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Tatauranga Aotearoa

>> New Zealand's Environmental Reporting Series

Environment Aotearoa 2015

DATA TO 2013

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Message from the Secretary for the Environment and the Government Statistician

Ko te taiao he taonga tukuiho mo apopo
Our environment is a treasured gift
that we inherit for the benefit of tomorrow

New Zealand's environment is a taonga of paramount importance. It sustains everything we depend on for healthy and prosperous lives: our economy, culture, and well-being. As New Zealanders, we need robust and reliable information to make good decisions about environmental matters that affect us. In 2013, Statistics New Zealand and the Ministry for the Environment started developing a better way to do environmental reporting. The framework, set out in the Environmental Reporting Act 2015, aims to ensure New Zealanders have environmental information that is reliable, relevant, and regular.

Under the framework, we developed New Zealand's Environmental Reporting Series. *Environment Aotearoa 2015* follows the *2014 Air domain report* under this new series. *Environment Aotearoa 2015* provides information on the state of New Zealand's environment across five 'domains' – air, atmosphere and climate, fresh water, land, and marine. It presents the human and natural pressures that cause changes to the state of these domains, and the impacts these changes have on our environment, economy, and way of life. The report does not include discussion of response – this is a process distinct from environmental reporting, which will involve all New Zealanders as part of an ongoing national conversation.

The *Environmental indicators Te taiao Aotearoa* website supports this report with maps, graphs, tables, and additional technical information. The report and indicators website present environmental information in a way that is intended to be accessible to a diverse audience – from students, to scientists and policymakers.

Some domains have more information and supporting data than others. This reflects the current state of information about our environment. Over time, we will have a more comprehensive range of environmental statistics and supporting information in each report. To achieve this, we will continue to work with data providers, local and central government, and iwi and hapū, to further improve the consistency, relevance, and representativeness of our environmental information.

Environment Aotearoa 2015 is part of an ongoing effort to improve our environmental reporting, by providing high-quality information on our environment. We hope this, and future reports produced using the new environmental reporting framework, enable New Zealanders to have an informed debate around ways to address the environmental issues raised by these reports.

Vicky Robertson
Secretary for the Environment

Liz MacPherson
Government Statistician

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New Zealand’s environment at a glance

New Zealand’s Environmental Reporting Series: Environment Aotearoa 2015 presents information on five environmental domains: air, atmosphere and climate, fresh water, land, and marine. Biodiversity is also included as a cross-domain theme.

The framework for the series is set out in the Environmental Reporting Act 2015. Reports will present information on the state of the environment and how it is changing over time, the natural or human pressures that influence this state, and the ecological, economic, social, and cultural consequences of changes in the state of the environment.

The reports do not include possible responses to the issues raised, to ensure separation between environmental reporting and policy decisions. Instead, environmental reporting provides the basis for discussions at both the national and local levels about how to best respond to the environmental issues New Zealand faces.

Here is an overview of each domain.

Air

Most New Zealanders enjoy good air quality most of the time. When air quality reaches levels considered unhealthy, this usually happens for limited periods in specific locations. The air pollutant of most concern from a health perspective is particulate matter – the tiny airborne particles that affect respiratory and cardiovascular health. Damage to respiratory and cardiovascular systems can lead to hospital admissions, days of work lost, and shorter lives for some New Zealanders.

Key findings:

- Burning wood and coal for home heating is the primary source of pollutants that cause most concern. It contributes 58 percent to annual emissions of human-made particulate matter in our air. This is a problem mainly in winter, in places where households use wood or coal to keep their homes warm.
- Air quality showed a significant improvement since 2006, driven mainly by the shift to cleaner home heating.
- Between 2001 and 2013, estimated emissions for five key pollutants from road vehicles fell between 26 and 52 percent, due to improvements to fuel, and stricter emission limits on new vehicles.
- In 2012, an estimated 1,000 premature deaths were associated with particulate matter in our air, 14 percent fewer than in 2006.

Atmosphere and climate

New Zealand’s temperate climate shapes and supports our natural environment, economy, and way of life. Our climate is naturally variable because of our location in the South Pacific Ocean and our small, but mountainous, land area. However, our climate is changing, and this has the potential to affect our economy, and marine and other ecosystems.

Key findings:

- The biggest driver of change is the increase in global greenhouse gases in the atmosphere. Global net emissions of greenhouse gases rose 33 percent since 1990. Between 1990 and 2011, New Zealand emitted around 0.1 percent of global emissions. New Zealand's greenhouse gas emissions increased 42 percent between 1990 and 2013.
- Carbon dioxide is the greenhouse gas that has the greatest impact over the long term. Over New Zealand, carbon dioxide concentrations increased 21 percent since 1972.
- New Zealand's temperature increased around 0.9 degrees Celsius in the past 100 years, almost certainly due to the increase in greenhouse gases in the atmosphere.
- We have high ultraviolet light levels in New Zealand. Our rates of skin cancer (melanoma) incidence are one of the highest in the world partly because of our high level of exposure to ultraviolet light.

Fresh water

The condition of our lakes, rivers, streams, wetlands, and groundwater is important for a number of reasons. For Māori, fresh water is a taonga and essential to life and identity. Our economy depends on having plentiful water – agriculture, tourism, and hydroelectricity generation particularly rely on water. New Zealanders and tourists enjoy many forms of recreation that use our lakes and rivers, such as swimming, kayaking, and fishing. Our waterways also support many indigenous animals, plants, and ecosystems. Fresh water is primarily taken for hydroelectricity generation and irrigation for farms, and our fresh water quality depends mainly on the dominant land use in a catchment.

Key findings:

- Water quality is very good in areas with indigenous vegetation and less intensive use of land. Rivers in agricultural and urban areas have reduced water clarity and aquatic insect life, and higher levels of nutrients and *Escherichia coli* (*E.coli*) bacteria.
- The greatest impact of excessive nutrients in New Zealand rivers is nuisance slime and algae (periphyton) growth. This growth can impede river flows, block irrigation and water supply intakes, and smother riverbed habitats. Poor water clarity and elevated *E.coli* levels also affect our ability to use fresh water for recreation.
- Between 1990 and 2012, the estimated amount of nitrogen that leached into soil from agriculture increased 29 percent. This increase was mainly due to increases in dairy cattle numbers and nitrogen fertiliser. Once in the soil, excess nitrogen travels through soil and rock layers, ending up in groundwater, rivers, and lakes.
- Between 1989 and 2013, total nitrogen levels in rivers increased 12 percent, with 60 percent of monitored sites showing statistically significant increases. About 49 percent of monitored river sites have enough nitrogen to trigger nuisance periphyton growth, as long as there is enough sunlight, phosphorus, and a lack of flood events for periphyton to bloom. Phosphorus also triggers nuisance periphyton growth. About 32 percent of monitored sites have enough phosphorus to trigger this growth.

- High levels of nitrogen can also be harmful to fish; however, less than 1 percent of monitored river sites have nitrogen levels high enough to affect the growth of multiple fish species.
- Water clarity improved at two-thirds of monitored sites between 1989 and 2013. *E.coli* levels are higher in urban and pastoral areas, but meet acceptable standards for wading and boating at 98 percent of monitored sites.

Land

Our land has undergone extensive change since human occupation 700 to 800 years ago, and particularly since European settlement in the 19th century. Today, agricultural and horticultural land occupies nearly 42 percent of New Zealand, while plantation forestry covers a further 7.5 percent. Indigenous forest covers about one-quarter of the country, concentrated mainly in upland and mountainous areas. Wetlands are reduced to about 10 percent of their original extent. The condition of our land affects its productivity for agriculture and other land-based industries. It also influences the health of our indigenous biodiversity and ecosystems.

Key findings:

- The extent of agricultural land has not changed substantially since 1996, but its use has become more intensive in a number of regions.
- The most critical issue affecting our land is erosion caused by human activity, particularly in the north and east of the North Island. Erosion reduces the productivity of the land and affects water quality, because it adds sediment and nutrients to waterways.
- A significant issue affecting our land is compaction. This is when soil is compressed, reducing the air pockets between soil particles, and making it harder for plants to grow. Over half the soils measured under dry stock (animals farmed for dairy, meat, wool, and velvet) and nearly 80 percent of soils under dairy farming are affected by compaction, which reduces the productivity of land.
- Pests are a serious threat to our indigenous animals, plants, and habitats. Possums, rats, and stoats are the most widespread of our pests – they are found across at least 94 percent of the country.

Marine

New Zealand has one of the most diverse marine environments in the world, because it encompasses subantarctic and subtropical waters. Our oceans support a wide range of habitats and sea life. Commercial harvesting is managed to ensure the sustainability of fisheries, but fishing methods that are damaging to the marine environment and bycatch (when an animal is caught unintentionally in fishing gear) are ongoing pressures on marine animals. The condition of our marine environment affects its productivity, as well as its ability to support marine life. Our marine environment is also important to New Zealanders from a recreational perspective, and for Māori, for whom it has long been a source of food and other resources.

Key findings:

- The most serious long-term pressures on our marine environment are likely to be caused by climate change. Coastal sea levels and long-term sea-surface temperatures around New Zealand have risen over the last century, and our oceans are more acidic than when measurements were first taken in 1998.
- Eight of our 30 indigenous marine mammal species are threatened with extinction. The extinction risk of one of these – the New Zealand sea lion – has increased in recent years. Māui’s dolphin is now one of the rarest marine mammals in the world, with an estimated 55 individuals over a year old remaining.
- Of the 92 indigenous seabird species and subspecies that breed in New Zealand, 35 percent are threatened with extinction. A further 55 percent are at risk of extinction. The risk of extinction has increased for seven seabird species in recent years.
- Between 2009 and 2014, the proportion of fish stocks subject to overfishing decreased from 25 percent to 14 percent. In 2014, more than 95 percent of fish caught were from stocks that are not overfished.

About *Environment Aotearoa 2015*

This section outlines the purpose and scope of *Environment Aotearoa 2015*, and provides some background about environmental monitoring in New Zealand.

Purpose of the report

New Zealand's Environmental Reporting Series: Environment Aotearoa 2015 presents information about our air, atmosphere and climate, fresh water, land, and marine environment (referred to as 'domains'). Biodiversity is included as a cross-domain theme.

This report provides:

- accurate and reliable information to encourage discussion and inform decision-making on issues that affect the environment
- the information New Zealanders need to understand the condition of our environment, why it is like that, and what it means for our economy, ecosystems, health, and society.

Environment Aotearoa 2015 is a source of information for all New Zealanders whose day-to-day decisions affect our environment – not just those responsible for environmental decision-making at a national or regional level. It is intended to form the basis of a national conversation about how to address the issues raised in the report. While much of the information is technical, we have made every effort to make this report accessible to a wide audience, from school students to policymakers and scientists.

Scope of *Environment Aotearoa 2015*

Environment Aotearoa 2015 and *Environmental indicators Te taiao Aotearoa* present data that fall in one of three categories: either a national indicator, a case study, or supporting information. These categories reflect the quality of the available data, measured against the Principles and protocols for producers of Tier 1 statistics (Statistics NZ, 2007). We assessed the data against six criteria: relevance, accuracy, timeliness, accessibility, coherence, and interpretability. Relevance and accuracy are the core criteria.

Data used in:

- **national indicators**: rates strongly on relevance and accuracy, and meets at least three of the four other criteria
- **case studies**: rates moderately on relevance and accuracy, and meets at least two of the four other criteria. A case study is used when it can further illustrate a national indicator, or explain an area of interest that is not measured nationally
- **supporting information**: rates moderately on relevance and accuracy, and provides useful information about a particular aspect of the environment or a domain.

We report on the environment only where reliable and accurate data are available. Because of this, there are gaps in our information. Because of the time it takes to collect, assess, and prepare data for publication, most data are to 2013 – except in a few cases where we could include 2014 data.

For an explanation of these gaps and areas for improvement see: Data needs and improvements chapter.

To understand how aspects of the environment have changed over time, we have done 'trend assessments' on most data with sufficient time series and accuracy. These assessments show 'statistically significant' decreases or increases at the 95 percent confidence level. When we refer to a decrease or increase being 'statistically significant' in *Environment Aotearoa 2015*, this means that we assessed it as showing a statistically significant trend.

Environmental monitoring in New Zealand

In New Zealand, environmental monitoring is a legislative responsibility shared across central government agencies, Crown research institutes, and local government. Regional and unitary councils are obliged to monitor our land, air, coastal, and freshwater environments under the Resource Management Act 1991. The Department of Conservation, the Ministry for Primary Industries, NIWA, and regional councils share responsibility for monitoring the marine environment. MetService, NIWA, and the Ministry for the Environment share responsibility for monitoring the atmosphere and climate, including greenhouse gas emissions.

Much of the information in this report comes from the data regional councils and other agencies collect to fulfil their obligations. Therefore, there is a strong connection between legislative requirements for environmental monitoring and the type of environmental data available to report on.

For more information see: Data needs and improvements chapter.

Our new reporting approach

This section explains our new reporting approach: the pressure-state-impact framework, environmental domains, and reflecting the Māori relationship with the environment.

Reporting on pressure, state, and impact

In the past, environmental reporting focused mainly on the state of the environment, often using a 'snapshot' approach. Our new approach is different – in addition to reporting on the state of the environment, we also report on the pressures that have created that state, and how this state influences other spheres of the environment and our life – such as our economy, health, social well-being, and the culture and heritage of tāngata whenua. By using this approach, we can better understand the environment as an interconnected and dynamic system that influences and is influenced by many aspects of the human world.

New Zealand's Environmental Reporting Series reports on three types of information:

- **Pressure**: the natural or human pressures that influence the state of the environment. Pressures explain why the domains are in the condition they are in.
- **State**: the physical, chemical, and biological characteristics of each aspect of the environment, and how these aspects are changing over time.
- **Impact**: the ecological, economic, social, and cultural consequences of changes in the state of the environment. Environmental impacts that have particular significance for Māori are covered under te ao Māori (Māori world view).

The chapters for each domain in this report present information on the impacts first, by asking why the condition of that domain matters. This is followed by a section on the pressures influencing the state of the domain. Finally, the last section presents information on the state of the domain.

We designed *Environment Aotearoa 2015* to be read with *Environmental indicators Te taiao Aotearoa*, which presents more detailed information on the national indicators, case studies, and supporting information for each domain. You can find the raw data we used on the Ministry for the Environment data service.

Why we do not cover how environmental issues will be addressed

New Zealand's Environmental Reporting Series does not cover how the environmental issues identified may be addressed. This separation from environmental reporting is an important principle of the environmental reporting framework, and is set out in the Environmental Reporting Act 2015.

Environmental reporting is an objective exercise in which we present information on our environment. In contrast, developing ways to address environmental issues is subjective and open to debate – even though it might be informed by environmental reporting. This process focuses on the question, 'What is New Zealand doing about it?' Responding to this question involves government, stakeholders, and society making value judgements – for instance, about what New Zealanders value most, and what trade-offs are acceptable.

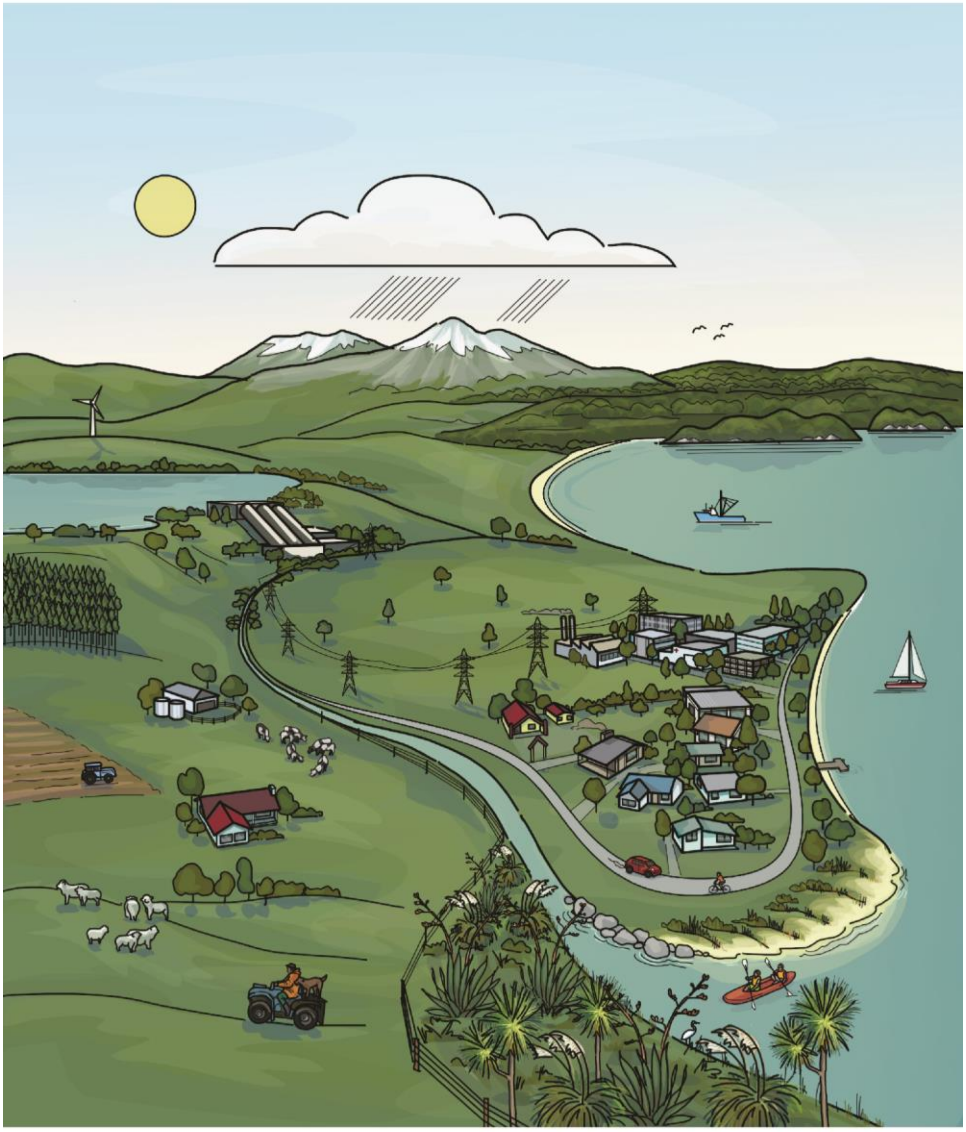
This separation is critical to ensuring environmental reporting is independent of other decision-making processes, and is therefore trusted and credible.

Environmental domains

Under New Zealand's environmental reporting framework, the environment is divided into five domains. We report on each of these separately, although strong links exist between each domain.

Figure 1

The five domains of our environment:
air, atmosphere and climate, fresh water, land, and marine



Source: Ministry for the Environment

- The **air domain** comprises the shallow gas layer that surrounds Earth. It is made up mainly of nitrogen and oxygen, which are essential to life. Our air also includes other gases and small quantities of vapour and particles. Many of these are pollutants produced by human activities and can be harmful to our heath and the environment.

  This domain does not include stratospheric ozone or the effects of greenhouse gases on Earth's climate – these aspects are included in the atmosphere and climate domain.
- The **atmosphere** is the layer of gases that surrounds Earth. **Climate** is the pattern in variables such as temperature, humidity, wind, and precipitation. Industrial, agricultural, and other human activities emit gases that affect the atmosphere and climate.
- The **freshwater domain** comprises fresh water in all its physical forms. This includes fresh water in rivers, lakes, streams, wetlands, and aquifers. Fresh water is vital to our economy. The way we use it affects its biodiversity and suitability for recreation, and other uses such as drinking. The way we use land also affects water quality.

  This domain does not include atmospheric water, or water in the marine domain.
- The **land domain** comprises the soil, the underlying rock, and what is on the land surface, such as vegetation and human-made structures. The way we use our land influences its productivity, and affects our indigenous biodiversity and ecosystems.
- The **marine domain** extends from the seashore to the outer limits of New Zealand's exclusive economic zone, and includes the continental shelf. Our marine environment supports biodiversity, fishing, oil and gas and minerals extraction, tourism, and recreation. The long-term condition of our oceans is affected by climate change.

We report on biodiversity in the freshwater, land, and marine domains. This report also includes a chapter presenting the impacts on biodiversity – an example of a cross-domain reporting approach that future reporting may take.

Māori relationship with the environment

Ko te whakapapa tēnei
Mō ngā taonga tuku iho a Io Matua Kore
Kā moe a Papatūānuku ki a Ranginui
Kā puta ko Tānemahuta, ko Tangaroa
Kō Tāwhirimatea, kō Tūmatauenga
Kō Haumie-tiketike, ko Rongomātāne
Kō ēnei ngā taonga tuku iho ō rātou mā
Kō mātou ngā kaitiaki mō ēnei taonga.

This genealogy recites for us our divine inheritance
Through the union of Earth Mother and Sky Father
Who gave birth to our resources
And entrusted their care into our hands
The land and the sea
The weather and the conflicts between the elements
The forests and the birds
The animals and plants
All these treasures, given to us from the past
Are for us to manage for generations to come.

This statement represents the Māori perspective on the importance of the environment, which links Māori to Papatūānuku (the Earth Mother) and Ranginui (the Sky Father) through genealogy (whakapapa).

Te ao Māori – a holistic understanding of our environment

We recognise the importance of te ao Māori (Māori world view) – a holistic understanding of our environment that benefits all New Zealanders – and our obligation to provide information that contributes to Māori decision-making and well-being.

The environment is integral to Māori identity and culture. Māori see the environment as an interconnected whole, and assess its health in the same way. For Māori, all parts of the environment – animate and inanimate – are infused with mauri (life force) and are connected by whakapapa – the descent of all living things from the original creators of life, and the genealogical relationships between all life. Māori express this relationship by identifying with their environment, often with awa or moana (river or lake) or a landform such as maunga (mountain).

Māori gain a sense of identity and belonging from their connection with the natural environment, while iwi (tribes), hapū (subtribes), and whānau (family groups) derive their sense of mana (authority and prestige) through this connection. The degradation of the natural environment can weaken this connection, with profound consequences for individual and social well-being.

Te Tiriti o Waitangi (Treaty of Waitangi) is the foundation of the Crown-Māori relationship on natural resources. Government is increasingly aware of the relationship between Māori and the environment, and the Māori world view. For example, the Tūhoe Deed of Settlement and Whanganui River Deed of Settlement clearly articulate a te ao Māori view of the relationship between humans and the environment, with Te Urewera and Whanganui River (Te Awa Tupua) becoming legal entities. As legal entities, Te Urewera and Te Awa Tupua are recognised in statute as holistic conceptions of the environment, with rights of their own, and distinct relationships to the tāngata whenua.

The National Policy Statement for Freshwater Management 2014 also recognises te mana o te wai (which can be understood as 'the quality and vitality of water') alongside the national significance of fresh water. These developments highlight both the increasing recognition of Māori environmental values in environmental management, and the significance of fresh water to Māori.

Kaitiakitanga – maintaining the environment for future generations

The environment has supported the economy and provided resources for Māori. Māori recognise that along with the privileges the environment provides come the responsibility to care for the environment and maintain it for future generations. This commitment is expressed as kaitiakitanga – the practice of guardianship and environmental management grounded in a Māori world view.

Kaitiakitanga is based on mātauranga Māori (Māori knowledge), a body of knowledge founded on Māori cultural practice, rather than western scientific frameworks. Customary rights and use of the environment represent the permanent and unique relationship Māori have with the environment.

There is increasing recognition of the value of mātauranga Māori to all New Zealanders, and researchers have devised tools to bridge the gap between mātauranga Māori and western science. For example, researchers have developed the cultural health index to assess the health of waterways from both a biophysical and cultural perspective. This assessment takes a holistic approach and combined with other methods, provides a more comprehensive understanding of the health of our waterways.

For examples of how the cultural health index has been used see: Fresh water chapter.

Iwi and hapū groups are the main sources of environmental information relevant to Māori. These groups are involved in monitoring the health of the streams, wetlands, and other environments over which they have mana whenua. Crown research institutes such as NIWA and Landcare Research collect data on aspects of the environment significant to Māori, including data on taonga species (animals and plants).

Currently, we do not have any indicator-level data gathered using Māori frameworks. We will work with data providers to explore ways to improve te ao Māori information in future reports (see: Data needs and improvements chapter). However, most of the data in New Zealand's Environmental Reporting Series will be relevant to Māori as it is to other New Zealanders. Some government initiatives involve iwi and iwi leaders – these explore how to reflect Māori aspirations and priorities in environmental reporting. In part, the *National Policy Statement for Freshwater Management 2014* and *He kai hei aku Ringa: The Crown-Māori Economic Growth Partnership* drive these initiatives.

Our environment and people

This section provides background information on New Zealand’s environment and people: geography, flora, and fauna; rivers and lakes; coasts and oceans; climate; human settlement and population; and the value of the environment to the economy.

Geography, flora, and fauna

New Zealand is an archipelago of more than 700 islands, with over 15,000 kilometres of coastline. Our land area is about 270,000 square kilometres – similar to that of Japan or the United Kingdom.

New Zealand’s location on the boundary of the Pacific and Indo-Australian tectonic plates has shaped – and continues to shape – our landforms. The resulting earth movements have produced hilly and mountainous terrain over two-thirds of our islands. We experience frequent earthquakes in most parts of the country, and have a zone of volcanic and geothermal activity in the central North Island.

Our terrain, climate, rock types, and vegetation have together produced more than 100 different soil types. Despite this diversity, New Zealand’s soils are generally low in nutrients because the rocks they come from are geologically young.

New Zealand is known for its biodiversity, with more than 52,500 species of indigenous animals, plants, and fungi. Our indigenous plants and animals developed in isolation for 60–80 million years, so many of them are unique. About 90 percent of our land-based animals (including insects), nearly 80 percent of our plants, and 26 percent of our fungi are found only in New Zealand. Thirty-eight percent of our marine animals live only in New Zealand waters (Gordon, 2013).

Rivers and lakes

Our landscape is relatively narrow (450 kilometres at its widest point) and dominated by mountains, in which many of our rivers originate. Our rivers are relatively short, steep, and fast-flowing, and generally open to a meandering course over lowland floodplains before reaching the sea.

Rivers also feed many lakes – New Zealand has 3,820 lakes larger than one hectare in area. Most lakes were formed through volcanic or glacial activity, or after land barriers were formed, blocking the outlets of waterways. The South Island has 360 glaciers, which carry snow and ice from the many peaks of the Southern Alps (Ministry for the Environment, 2007).

Coasts and oceans

Compared with its land area, New Zealand has one of the longest coastlines of any country in the world (Ministry for the Environment, 2007).

New Zealand’s exclusive economic zone extends from 12 nautical miles off the coast to 200 nautical miles offshore, an area of 4 million square kilometres, 15 times bigger than New Zealand’s land area.

Climate

New Zealand's climate is influenced strongly by geographic factors, including:

- its location between the latitudes of 40 and 50 degrees with prevailing westerly winds (known as the 'roaring forties')
- a large area of surrounding ocean
- mountain chains modifying weather systems that move eastward
- tropical weather patterns (ie storms that begin as tropical cyclones elsewhere and redevelop in the region, bringing warm moisture-laden tropical air that interacts with colder polar air).

Because of these factors, New Zealand's weather is more variable than that of larger, continental countries.

The average rainfall in most urban areas is between 600 millimetres and 1,500 millimetres a year (Ministry for the Environment, 2007). However, in the mountain ranges, annual rainfall often exceeds 4,000 millimetres a year (Ministry for the Environment, 2007).

Regions exposed to weather from the west and southwest experience a lot of precipitation – rain falls in these areas on about half of the days of the year. The rest of the country experiences much lower rainfall, particularly in eastern areas.

For more information see: Atmosphere and climate chapter.

Human settlement and population

New Zealand has a shorter human history than any other country. Archaeological evidence suggests that the first humans arrived from Polynesia in the 13th century (Wilson, 2013). It was not until the late 18th century that the first Europeans settled in New Zealand.

In March 2013, New Zealand's population was 4,242,048. It grew 35 percent in the 32 years between 1981 and 2013 (Statistics NZ, 2013a). Most New Zealanders (87 percent) live in urban areas. New Zealand has 138 towns and cities, most of which are located close to the coast. About three-quarters of New Zealanders live in the North Island. In comparison, only about 14 percent live in rural areas (Statistics NZ, 2013b). In 2013, the most highly populated regions were Auckland (1,415,550), Canterbury (539,436), and Wellington (471,315) (Statistics NZ, 2013a).

For more information on New Zealand's population see Statistics NZ Population statistics.

Value of the environment to the economy

New Zealand's economic wealth and well-being are reliant on our natural environment. A large proportion of our export income comes from primary products – goods produced from the land, fresh water, or ocean.

For more information on New Zealand economic indicators see Statistics NZ Economic indicators.

In 2013, the combined contribution of agricultural, horticultural, forestry, and seafood products to our exports was nearly 46 percent of the value of all exports. Dairy products are our single biggest export, contributing 20 percent. Tourism contributed just over 8 percent (Ministry of Business, Innovation and Employment, 2013).

Other sectors of the economy, such as energy generation and mineral extraction, also depend on our environment.

Air

The air domain comprises the shallow gas layer that surrounds Earth. It is made up mainly of nitrogen and oxygen, which are essential to life. Our air also includes other gases and small quantities of vapour and particles. Many of these are pollutants produced by human activities and can be harmful to our health and the environment.

Overview

This chapter sets out why good air quality is important, and presents information about the pressures on air quality in New Zealand, and its state and trends.

Air quality in New Zealand – a summary

Most New Zealanders enjoy good air quality most of the time. When air quality does reach levels considered unhealthy, this usually happens for limited periods in certain locations. In this way, New Zealand differs from many countries, where air pollution can be a year-round issue in cities and towns.

In New Zealand, home heating is the primary source of pollutants that cause most concern. This is a problem mainly in winter, in places where households use wood or coal to keep their homes warm. Transport is another major source of pollutants that can harm our health, usually in urban areas near busy roads. For both home heating and transport emissions, pollutants are most likely to become a problem on still, cold days, when particles are less likely to disperse.

Many factors contribute to our comparatively good air quality. New Zealand has a relatively small population and has low reliance on heavy industry compared with other developed countries. However, geographic and climatic factors are also important. New Zealand is an island surrounded by ocean, and some distance from other land masses. Therefore, unlike many parts of the world, pollution from other countries rarely affects us. Climatic factors also relate to our geography. New Zealand is a long, narrow country that sits in the path of the 'roaring forties', strong winds that blow to the east across the Pacific Ocean. These winds help to disperse pollutants.

The limited historical data we have for Auckland, New Zealand's biggest city, indicates that its air quality has improved over the past 50 years. This improvement is expected to be linked to longer-term improvements due to stricter controls on industrial and other emissions from the early 1970s, a gradual but consistent shift to 'cleaner' forms of home heating, improvements to fuel, and stricter emission limits on new vehicles. A pollutant of particular concern, lead in petrol, was phased out in 1996, and has resulted in a reduction in lead in our air.

Since monitoring became more extensive across the country in 2006, we have seen a significant improvement in air quality overall. These improvements in air quality were driven mainly by the shift to cleaner home heating. From 2006 to 2013, estimated annual emissions of particulate matter (PM_{10} and $PM_{2.5}$) from home heating decreased (24 percent and 23 percent, respectively).

Modelling showed a decrease in vehicle emissions, and these decreases were likely to have contributed to improved air quality. Between 2001 and 2013, estimated emissions for five key pollutants from road vehicles fell between 26 and 52 percent.

Poor air quality for even short periods can have serious health impacts. The air pollutant of most concern in New Zealand is particulate matter – the tiny airborne particles that affect respiratory and cardiovascular health. Damage to respiratory and cardiovascular systems can lead to hospital admissions, days of work lost, and shorter lives for some New Zealanders. In 2012, an estimated 1,000 premature deaths were associated with particulate matter in our air.

How we measure air quality

In New Zealand, regional and unitary councils monitor our air for a range of pollutants at sites around the country. These are usually in areas where high levels of pollutants are expected, or have been found historically, such as in towns or cities, and near busy roads.

Reporting against long-term guidelines gives a good indication of general air quality conditions. It also best represents the typical and long-term exposure at a particular location. Reporting on the short-term guidelines focuses on peak exposure events.

We report on our air quality by comparing long-term (annual) and short-term (daily and hourly) pollutant concentrations against:

- World Health Organization (WHO) 2006 long-term (annual) guideline
- Ministry for the Environment's *Ambient Air Quality Guidelines 2002*, where WHO long-term (annual) guidelines do not exist (eg for arsenic and benzo(a)pyrene)
- New Zealand's National Environmental Standards for Air Quality 2004 (daily and hourly standards).

In some cases, where WHO guidelines and national environmental standards differ (eg for sulphur dioxide), we report against both.

For some pollutants, such as nitrogen dioxide, information is collected using a screening method. The method gives good indications of concentrations, but the results cannot be directly compared with guidelines. In these cases, we state that concentrations are 'likely' to meet or exceed guidelines.

Types of pollutants

Air pollutants can be grouped into three broad categories: airborne particles, gases, and 'other pollutants'.

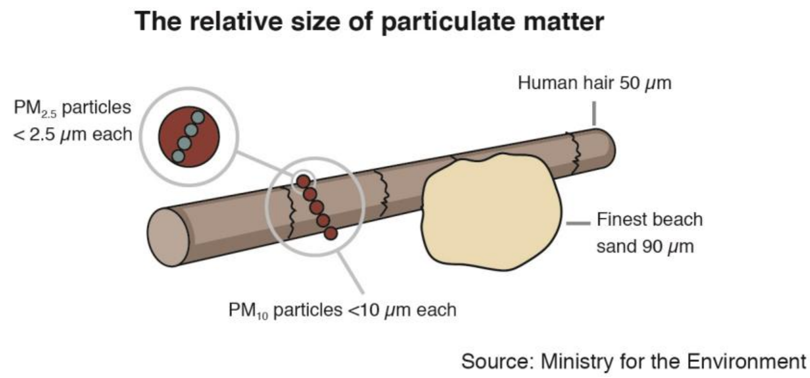
Airborne particles

In New Zealand, airborne particle pollutants are of most concern because of their high concentrations in some locations and their potential to cause a range of health problems, from relatively minor to severe. When larger airborne particles are inhaled, they are trapped in the nose, mouth, and nasal passages and can cause irritation. Smaller particles can travel to the lungs, where they can cause injury or be absorbed into the bloodstream, resulting in respiratory diseases, heart attacks, and lung cancer.

Particulate matter (PM) are commonly measured in two size ranges (see figure 2):

- PM_{10} have a diameter 10 or less micrometres
- $PM_{2.5,}$ a subset of PM_{10}, have a diameter of 2.5 micrometres or less.

Figure 2



Note: µm – micrometre, a unit of length equal to one thousandth of a millimetre.

Airborne particles can be generated by human activities or natural sources. Burning wood and coal for home heating, transport, burning garden and other household waste outdoors, and industrial processes are examples of human activities that cause pollution.

Sea salt, pollen, airborne soil, and volcanic ash are examples of natural forms of particulates. Generally, they are bigger particles and are therefore considered to be less harmful to human health. Because particles from natural sources are larger, we do not often find them in $PM_{2.5}$ concentrations. $PM_{2.5}$ is therefore more indicative of airborne particles from human activities.

The smaller airborne particles are, the greater the harm they pose to human health. Smaller particles can penetrate deep into the lungs and even into the bloodstream. The WHO guideline for both daily and annual average exposure to $PM_{2.5}$ is half that for PM_{10}.

Monitoring PM_{10} has been mandatory in New Zealand since 2004, while monitoring $PM_{2.5}$ is not mandatory. For this reason, we have more data about PM_{10} than $PM_{2.5}$. While we have PM_{10} data covering most of the country, $PM_{2.5}$ monitoring is limited only to Auckland, Canterbury, and Wellington.

Gases

Gases can also adversely affect our air quality and people's health. We have good information on nitrogen dioxide concentrations in New Zealand. WHO recognises nitrogen dioxide concentrations as an indicator of air pollution from road motor vehicles. It is linked to an increase in asthma symptoms and reduced lung function. Other gases, such as carbon monoxide, sulphur dioxide, and ozone, are also monitored at some sites in New Zealand.

Other pollutants

Other air pollutants include heavy metals and volatile organic compounds. For example, arsenic is emitted when treated timber is burnt. Benzene is a volatile organic compound emitted when vehicles burn petrol. Arsenic is associated with heart conditions and cancer, while benzene is associated with cancer, and adverse effects on the nervous system.

Why the condition of our air quality is important

Health effects are the primary reason we are concerned with air quality in New Zealand. Exposure to pollutants in the air is associated with a range of health problems, from respiratory irritation to some forms of cancer.

Based on modelled data, in 2012 there were about 1,000 premature deaths in New Zealand associated with exposure to human-made PM_{10}, such as emissions from home heating, industry, and transport. In these cases, exposure to PM_{10} was not the only cause of premature deaths, as other factors may be involved. These estimates are made by considering the concentrations of PM_{10} New Zealanders are exposed to and anticipated health risk (from national and international studies) associated with this level of exposure. This equates to about 3 percent of total deaths that year. However, an estimated 14 percent decrease in premature deaths associated with exposure to human-made PM_{10} occurred between 2006 and 2012. This decrease is linked to a decrease in PM_{10} over the same period.

For more information see: The state of our air section.

Air quality can also indirectly affect our economy through its impact on people's health, for instance, in the form of medical costs and lost productivity through absence from work. It also affects the environment. When air pollutants settle on land or waterways, or wash into waterways, they can pollute these environments. Certain air pollutants can also affect our climate. Some have a warming effect while others have a cooling effect. We do not report on these effects because of limited information on them.

For more detail see *Environmental indicators Te taiao Aotearoa*: Health effects from exposure to PM_{10}.

The pressures on our air quality

Human activities and natural pressures affect the quality of our air. This section describes these pressures, and the changes we are seeing in air quality over time.

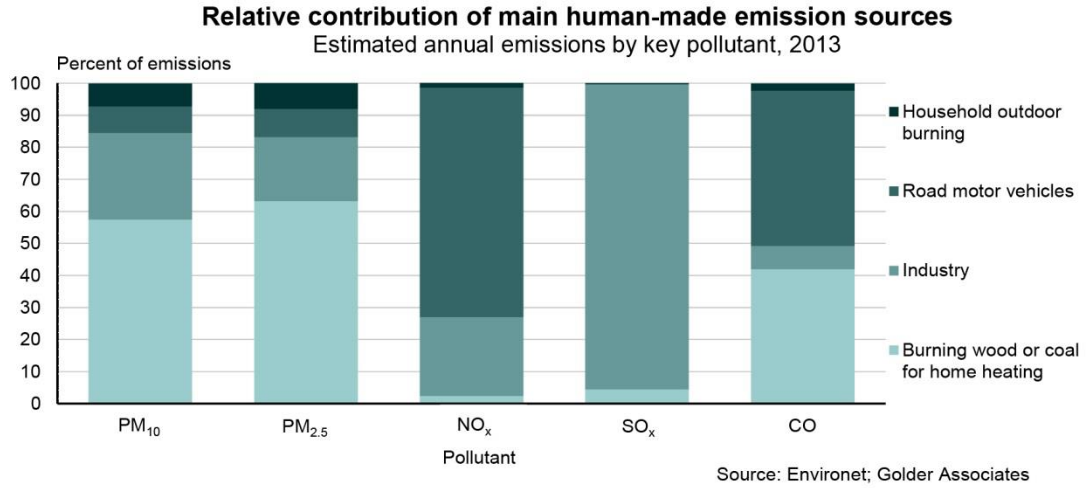
Human pressures

This section sets out the main human sources of air pollution and their relative contribution: home heating, industry, and road motor vehicle emissions.

Main human-made sources of air pollution and their relative contribution

Burning wood or coal for home heating, emissions from road motor vehicles, combustion of fossil fuels by industry, and outdoor burning of garden and other waste by households are the main human-made sources of air pollution in New Zealand (see figure 3).

Figure 3



Note: Industry emissions data use data from 2008 to 2013. Estimates of other sources use data from 2013. PM_{10} – particulate matter 10 micrometres or less in diameter; $PM_{2.5}$ – particulate matter 2.5 micrometres or less in diameter; NO_x – nitrogen oxides; SO_x – sulphur oxides; CO – carbon monoxide. Sulphur oxide emissions are not estimated for road motor vehicles. These emissions are expected to be low.

Emissions from home heating were the main source of PM_{10} and $PM_{2.5}$ nationwide. Road vehicles (passenger vehicles and heavy commercial vehicles) were the major source of nitrogen oxides and carbon monoxide emissions. Industry was the source of 95 percent of sulphur oxides emissions.

We do not have information on the estimated emissions for other sources at a national level. Limited local studies show that emissions from other sources (shipping, aviation, rail, and off-road machinery) are generally minor.

For more detail see *Environmental indicators Te taiao Aotearoa*: Relative contribution of key human-made emission sources.

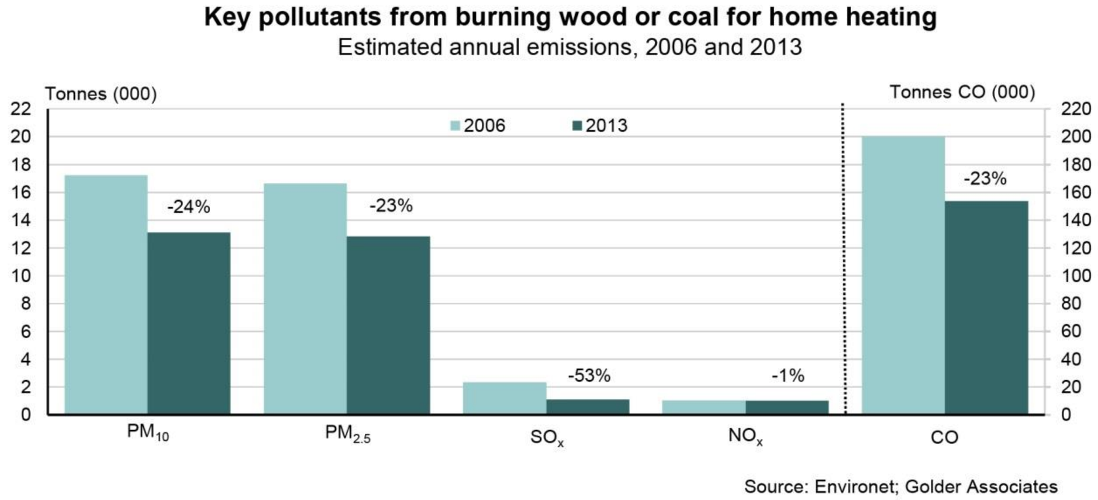
Home heating is the biggest contributor to particulate matter in our air

In New Zealand, 37 percent of households use wood for home heating and 4 percent use coal. A higher proportion of households use wood or coal for home heating in the South Island than the North Island. Illustrating this pattern, the highest proportion is in the West Coast (72 percent use wood, 56 percent use coal). In contrast, the proportion in Auckland is much lower (23 percent use wood and 2 percent use coal).

Burning wood or coal for home heating is the main human-made source of PM_{10} and the main source of $PM_{2.5}$ emissions. In 2013, 96 percent of PM_{10} and $PM_{2.5}$ exceedances of the short-term (daily) standard/guideline occurred during winter. These exceedances are linked to emissions from home heating, exacerbated by calmer winter conditions that slow the dispersal of pollutants.

From 2006 to 2013, estimated annual emissions of PM_{10} and $PM_{2.5}$ from home heating decreased (24 percent and 23 percent, respectively) (see figure 4). This decrease was due to fewer households burning wood and coal for home heating and lower emission requirements for new burners. These requirements were introduced nationally in 2004 as part of the National Environmental Standards for Air Quality, but some regional and unitary councils implemented wood burner requirements before 2004, or have tougher requirements than the national standard.

Figure 4



Note: The left axis shows the estimated annual emissions for particulate matter 10 micrometres or less in diameter (PM_{10}), particulate matter 2.5 micrometres or less in diameter ($PM_{2.5}$), sulphur oxides (SOx), and nitrogen oxides (NOx). The right axis shows the estimated annual emissions for carbon monoxide (CO). Percentage changes show the change in emissions from 2006.

As well as a decrease in particulate matter, estimated annual sulphur oxides emissions also decreased (53 percent) from 2006 to 2013. This was due to a decrease in the use of coal for home heating.

Despite these reductions, home heating still causes levels of PM_{10} and $PM_{2.5}$ that exceed standards and guidelines in some locations. Home heating also causes levels of arsenic (produced by burning treated-timber) and benzo(a)pyrene that exceed (or are 'likely' to exceed when screening methods are used) standards and guidelines in some locations. These pollutants are associated with adverse health effects ranging from respiratory irritation to cancer.

For more information see: The state of our air section.

For more detail see *Environmental indicators Te taiao Aotearoa*: Home-heating emissions.

Industry emissions are the biggest contributor of sulphur oxides

Nationally, industry is the main human-made source of sulphur oxides, and a smaller, but still significant contributor of nitrogen oxides and particulate matter.

For more detail see *Environmental indicators Te taiao Aotearoa*: Industrial emissions.

We cannot report on changes in emissions from industry at the national level, as this information is not currently available. We have identified this data gap as an area for improvement.

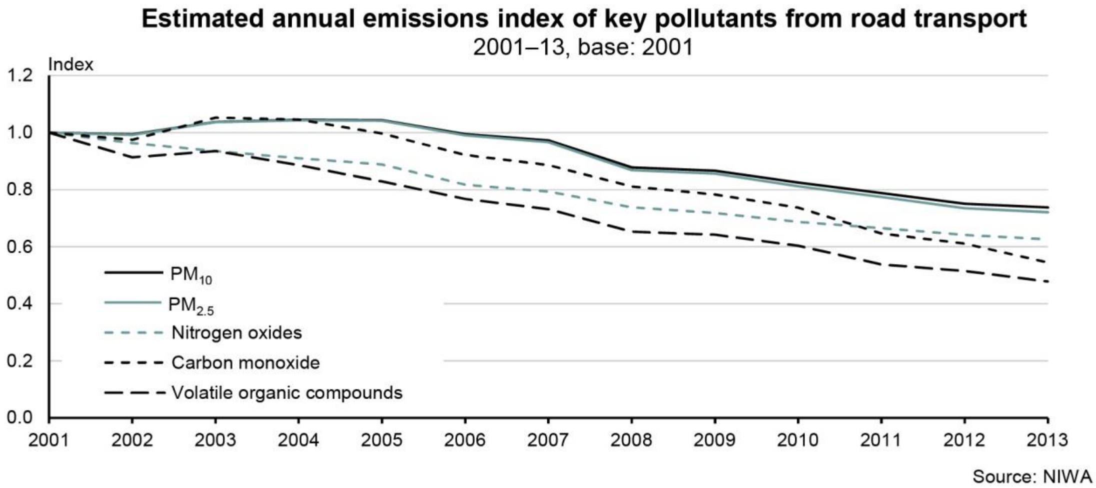
For more information see: Data needs and improvements chapter.

Road motor vehicle emissions are a major source of some air pollutants

Nationally, road vehicles are the main source of nitrogen oxides (of which nitrogen dioxide is a component) and carbon monoxide emissions. Road vehicles are those used on public roads, and include passenger vehicles through to heavy commercial vehicles. Compared with petrol vehicles, diesel vehicles contribute more air pollutants (especially nitrogen oxides and particulate matter) (Parliamentary Commissioner for the Environment, 2015). This is despite making up only 27 percent of total vehicle kilometres travelled (compared with 73 percent for petrol vehicles) (NIWA, 2015).

Pollutant emissions from road vehicles are estimated to have decreased between 2001 and 2013, despite a 12 percent increase in vehicle kilometres travelled (see figure 5) (Ministry of Transport, 2015). This change represents a statistically significant decreasing trend, and is due to improvements in our vehicle fleet and fuel quality. Emission requirements for vehicles imported into New Zealand took effect in 2004 and later amendments were more stringent. Improvements in fuel quality have reduced sulphur and other pollutants in our fuel.

Figure 5



Note: This index reflects changes in estimated road vehicle emissions relative to a 2001 base-year value.

Despite these decreases, road vehicle emissions still cause levels of nitrogen dioxide (a form of nitrogen oxides) and benzene that exceed (or are 'likely to', when screening methods are used) standards and guidelines in some busy transport sites at major urban centres (Auckland, Hamilton, Wellington, and Christchurch).

For more detail see *Environmental indicators Te taiao Aotearoa*: Road motor vehicle emissions.

Natural pressures

This section sets out the natural pressures on our air quality: natural sources, and weather and topography.

Natural sources can contribute significantly to airborne particulates

Sea salt, pollen, airborne soil, and volcanic ash are natural particulates that can influence our air quality.

Limited monitoring studies have shown that natural PM_{10} (sea salt and soil) contributes from 28 percent to 55 percent of annual PM_{10} concentrations at some urban locations. However, some of the airborne soil that makes up PM_{10} at some of these sites may be the direct result of soil disturbance caused by human activities such as construction or earthmoving (and therefore are not 'natural' sources).

Research on the health effects of natural particulate matter is inconclusive. However, for sea salt specifically, WHO (2013) concluded that there is little evidence that it poses a risk to health. Furthermore, the larger the size of particulate matter, the less harm it is likely to pose. Particulate matter from natural sources, such as sea salt and airborne soil, is generally large, and therefore less likely to be harmful to health.

For more detail see *Environmental indicators Te taiao Aotearoa*: Natural PM_{10}.

Weather and topography can influence air quality

Weather conditions also influence air quality because they can determine how pollutants are dispersed and removed from the air. Weather conditions and topography play a key role in patterns and rates of dispersal and removal (by rain). High wind speeds can quickly disperse pollutants, preventing them from accumulating. Low wind speeds can slow the dispersion of pollutants, allowing them to build up.

Meteorological conditions, influenced by topography, can create 'temperature inversions', where a layer of warm air traps cooler air, and any pollution, underneath. This weather pattern explains why some small towns can report higher concentrations of pollutants, despite emitting lower quantities of pollutants than larger towns.

The state of our air

New Zealand's air quality is generally considered good most of the time. Particulate pollutants are of most concern in New Zealand, because of their high concentrations in some locations and their potential to cause serious health problems.

The following section looks at the data relating to pollutants in our air, how we compare with other countries, and what changes we are seeing over time.

Airborne particles – the pollutants of most concern in New Zealand

Our PM_{10} concentrations are low compared with other countries. In 2011, our annual average PM_{10} concentration was the seventh-lowest of 34 Organisation for Economic Co-operation and Development (OECD) countries (a group of countries with similar levels of economic development to New Zealand). This comparison is indicative only, as some countries have a different monitoring approach. However, it shows that air quality in New Zealand is on average 'good' compared with most developed countries.

New Zealand's relatively small population and limited level of heavy industry contribute to our comparatively good air quality. However, climatic and geographical factors are also important. New Zealand is relatively windy, which helps to disperse pollutants. Our isolation from other countries means we are insulated from all but the more major sources of pollution from other countries (such as large forest fires in Australia) and so most of the air quality issues we experience are from local activities.

For more detail see *Environmental indicators Te taiao Aotearoa*: Annual average PM_{10} concentrations in OECD countries (urban areas).

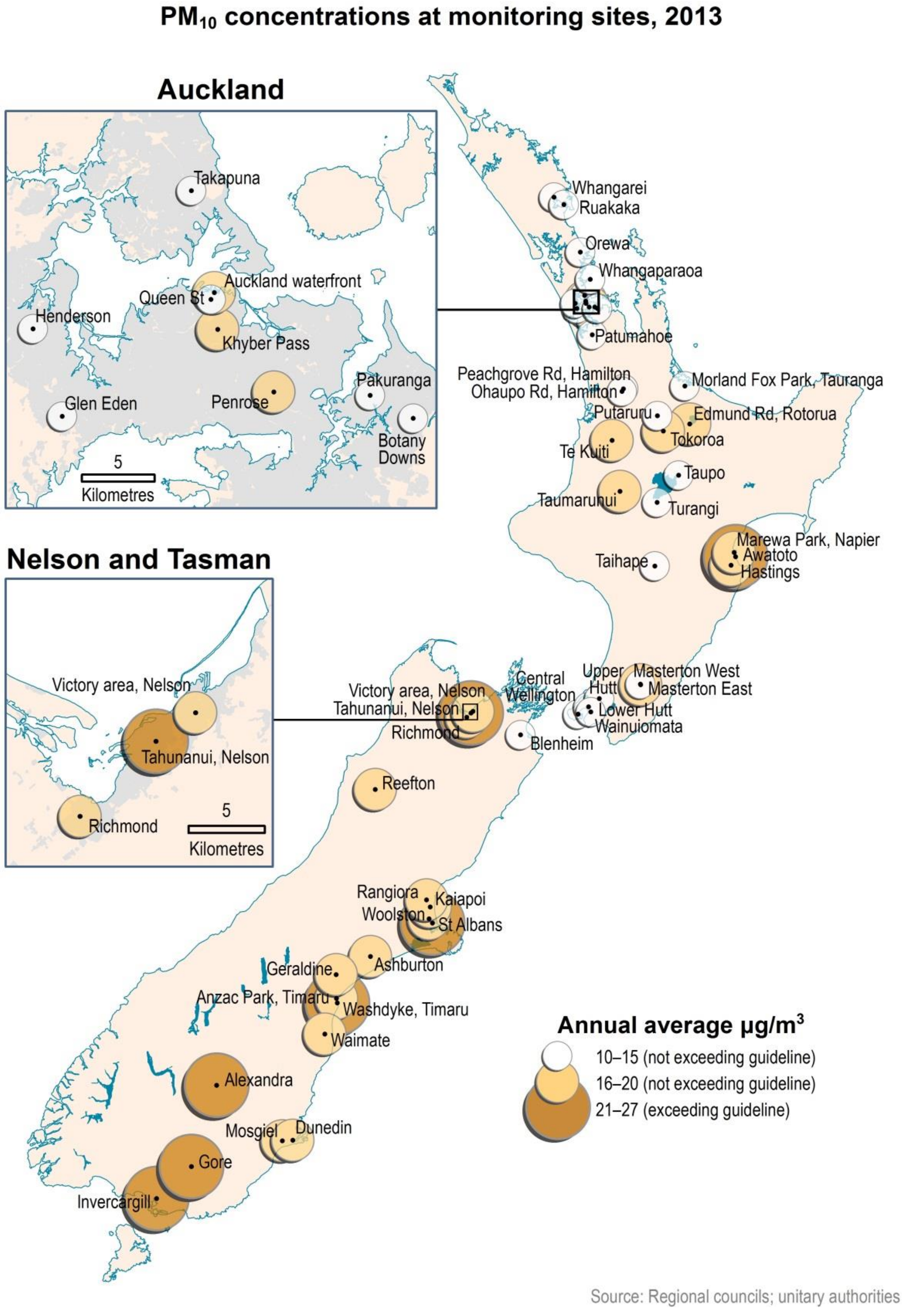
Our towns and cities rate well against WHO long-term guideline but not against short-term guideline

Our towns and cities generally measure up well against the WHO long-term guideline for average particulate concentrations (PM_{10}), but not as well against the WHO short-term guideline.

In 2013, 45 (85 percent) of the 53 sites monitored met the WHO long-term (annual) guideline (see figure 6). Of the eight sites that exceeded the guideline, six were in towns and cities in the South Island, and home heating was the likely cause of these high concentrations. Of the two remaining sites, one was a busy urban road in Auckland (Khyber Pass Road), while the other was an industrial area in Hawke's Bay, where the air has a high level of airborne sea salt (a natural source of PM_{10}).

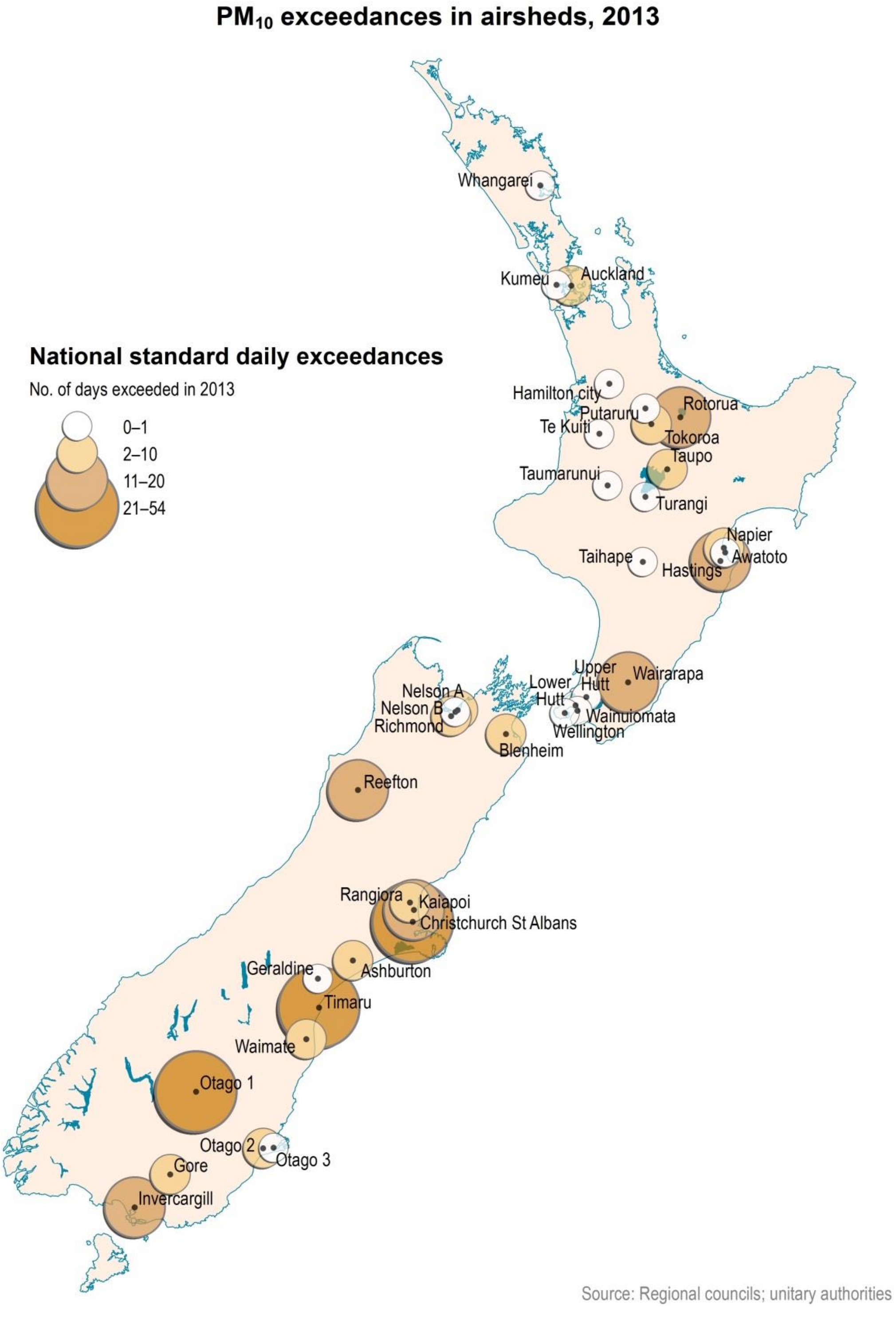
In contrast, more than half (21) of the 37 monitored airsheds (an area managed for air quality) exceeded the national short-term standard (which is based on the WHO short-term guideline) on two or more days in 2013 (see figure 7). When comparing against this standard, air quality is measured over a 24-hour period.

Figure 6



Note: Results at these monitoring sites do not necessarily represent the whole location. PM_{10} – particulate matter 10 micrometres or less in diameter. PM_{10} concentrations are in micrograms per cubic metre of air (µg/m^3). The WHO guideline is exceeded when concentrations are above 20 µg/m^3. Data from regional councils of Northland, Bay of Plenty, Waikato, Hawke's Bay, Manawatu-Wanganui, Wellington, Canterbury, West Coast, Otago, Southland; district councils of Marlborough and Tasman; Nelson City Council; Auckland Council.

Figure 7

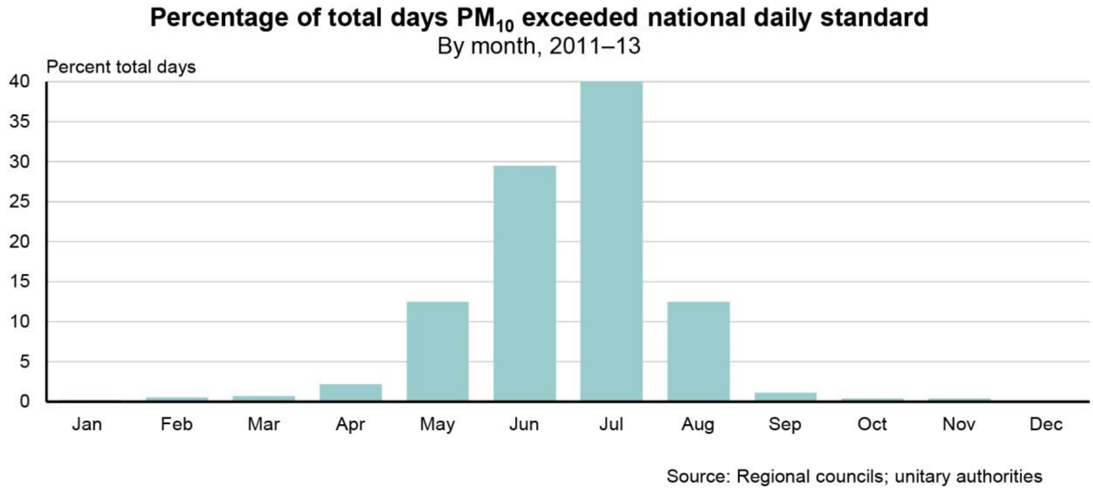


Note: Results shown for an airshed are not always the same for the whole airshed. An airshed is a defined area managed for air quality. An airshed can include a number of monitoring sites. PM_{10} – particulate matter 10 micrometres or less in diameter. Data from regional councils of Northland, Bay of Plenty, Waikato, Hawke's Bay, Manawatu-Wanganui, Wellington, Canterbury, West Coast, Otago, Southland; district councils of Marlborough and Tasman; Nelson City Council; Auckland Council.

When we measure concentrations against the long-term guideline, we measure air quality throughout the year – including times of high and low air pollution – with results showing the long-term (average) exposure at a particular location. When we measure against the short-term standard, this identifies times when air pollution is high.

The difference between long- and short-term results reflects the nature of air quality issues in New Zealand, as outlined in the Overview. Exceedances of the short-term standard are primarily a winter issue: 95 percent of all exceedances occurred in winter (see figure 8). This can be attributed to higher emissions from burning wood or coal for home heating, and calmer weather conditions that slow the dispersal of pollutants.

Figure 8



Note: PM_{10} – particulate matter 10 micrometres or less in diameter. Data from regional councils of Northland, Bay of Plenty, Waikato, Hawke's Bay, Manawatu-Wanganui, Wellington, Canterbury, West Coast, Otago, Southland; district councils of Marlborough and Tasman; Nelson City Council; Auckland Council.

Overall, the South Island had higher PM_{10} annual concentrations and more airsheds that exceeded the national short-term standard (ie 14 of the 20 exceeding airsheds in 2013). This is due to the greater use of wood and coal for home heating. Meteorological conditions (influenced by topography) can be a factor in some locations. For instance, Christchurch is sometimes affected by an inversion layer, where a layer of warm air traps cooler air and any pollution underneath.

For more detail visit *Environmental indicators Te taiao Aotearoa*: Annual average PM_{10} concentrations in towns and cities, Seasonality of PM_{10} exceedances, and PM_{10} daily concentrations.

Most sites exceeding guidelines for $PM_{2.5}$ are in urban areas

In 2013, 4 of the 10 sites monitored for $PM_{2.5}$ exceeded the WHO long-term guideline, while seven exceeded the daily guideline.

The seven sites that exceeded the daily guideline did so for between 1 and 55 days. Of these exceedances, 96 percent occurred during winter. Like PM_{10}, we can attribute these exceedances largely to home-heating emissions and calm weather conditions.

$PM_{2.5}$ monitoring is not mandatory, so we cannot report on it at a national level. It is monitored only at 10 sites in the Auckland, Wellington, and Canterbury regions.

Because $PM_{2.5}$ is a subset of PM_{10}, when high concentrations of PM_{10} occur at a site (usually urban sites), high $PM_{2.5}$ concentrations are also likely to occur.

For more detail visit *Environmental indicators Te taiao Aotearoa*: $PM_{2.5}$ concentrations.

Particulate pollutants in our air are decreasing over time

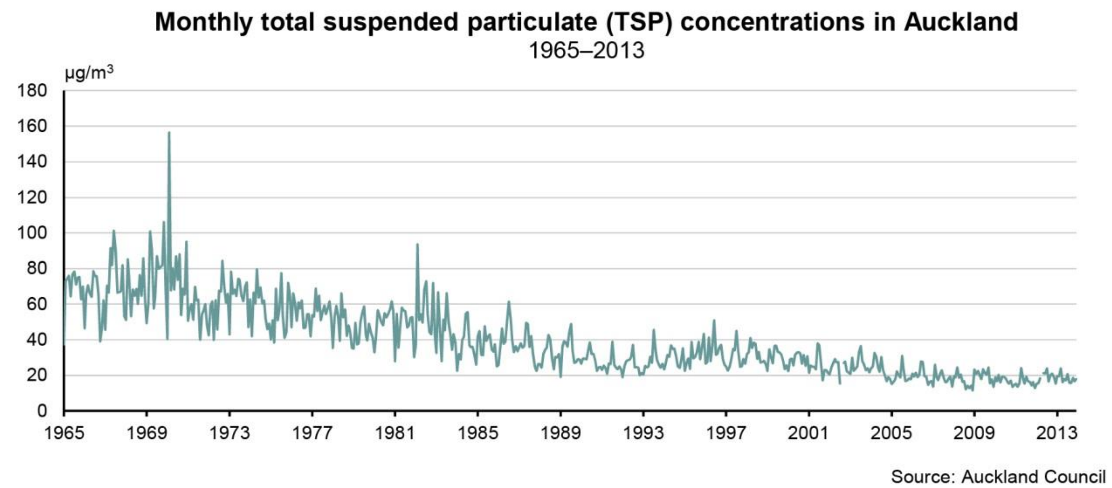
Concentrations of particulate matter in our air have been decreasing over time.

Nationally, we only have comprehensive data from 2006. From 2006 to 2013, New Zealand's annual average PM_{10} concentration decreased 8 percent – a statistically significant decrease. Just under one-third of the monitored sites (14 of 44) showed a statistically significant decrease in annual concentrations over this period.

For more detail see *Environmental indicators Te taiao Aotearoa*: PM_{10} annual average concentrations.

Local data from Auckland indicate a decrease in concentrations of particulate matter over a longer time-scale (from 1965). Until 1999, total suspended particles (TSP) rather than PM_{10} was measured in Auckland, and only TSP is shown in figure 9. This is a measure of all airborne particulate matter up to 100 microns, of which PM_{10} is a subset.

Figure 9



Note: Concentrations are in micrograms per cubic metre of air ($\mu g/m^3$).

This decrease in particulate matter is likely due to stricter controls and monitoring of industrial and other emissions from the 1970s, a steady shift from open fires to 'cleaner' forms of home heating, improvements to vehicle fuel, and stricter emission limits for new vehicles.

For more detail see *Environmental indicators Te taiao Aotearoa*: Total suspended particulate concentrations in Auckland.

Nitrogen dioxide and other pollutants in our air

Nitrogen dioxide generally meets the WHO guideline

The main source of nitrogen oxides (including nitrogen dioxide) is motor vehicles.

In 2013, 97 percent of 122 monitored sites likely met the WHO long-term guideline (measured using screening methods) for nitrogen dioxide. Between 2010 and 2013, 3 to 6 sites (about 2–5 percent of sites) 'likely' exceeded this guideline in each of these four years.

The 'likely' exceedances occurred close to busy local roads and state highways in major urban centres (Auckland, Hamilton, Wellington, and Christchurch). No 'likely' exceedances occurred at monitored urban areas away from busy roads, and concentrations were much lower than those at busy local roads and state highways.

For more detail see *Environmental indicators: Te taiao Aotearoa*: Nitrogen dioxide concentrations.

Other pollutants exceed health guidelines at some locations

We have only limited data on other pollutants. In some urban locations, concentrations of arsenic and benzo(a)pyrene (associated with cancer and irritation of the ear, nose, and throat) 'likely' exceeded Ministry for the Environment's long-term guidelines. These 'likely' exceedances are probably due to emissions from burning wood or coal for home heating.

Other pollutants exceeded guideline levels at certain locations. Sulphur dioxide (associated with respiratory problems) exceeded the short-term guideline at 4 of the 8 monitored locations in 2013. The four sites exceeded the guideline between 1 and 65 days of the year. The four sites were three industrial locations (Mount Maunganui, Woolston in Christchurch, and Timaru) and one port location (Auckland waterfront).

In 2013, no exceedances of the Ministry for the Environment's long-term guideline occurred at the eight sites monitoring benzene. However, one of these sites (Khyber Pass Road, Auckland) exceeded in 2012.

For more detail see *Environmental indicators Te taiao Aotearoa*: Other air pollutants that affect air quality and Sulphur dioxide concentrations.

Carbon monoxide, lead, and ground-level ozone generally meet health guidelines

Limited monitoring of other pollutants between 2007 and 2013 indicate that concentrations met the guidelines or standards for these pollutants:

- carbon monoxide (can aggravate heart conditions)
- lead (can affect the nervous system and impair mental development in children)
- ground-level ozone (associated with increased respiratory and cardiovascular conditions)
- busy transport locations for carbon monoxide and lead (of greater concern historically, before leaded petrol was phased out in 1996)
- locations at a distance from busy transport sites (because it takes time for the chemical reactions that create ozone to occur, and for chemicals to disperse away from their source).

These results suggest that concentrations of these pollutants at other sites would be unlikely to exceed health guidelines.

For more detail see *Environmental indicators Te taiao Aotearoa*: Carbon monoxide concentrations, Lead concentrations, and Ground-level ozone concentrations.

Atmosphere and climate

The atmosphere is the layer of gases that surrounds Earth. Climate is the pattern in variables such as temperature, humidity, wind, and precipitation. Industrial, agricultural, and other human activities emit gases that affect the atmosphere and climate.

Overview

This chapter sets out why we care about the condition of our atmosphere and climate, and presents information on the pressures, state, and trends of the atmosphere and climate in New Zealand.

Our atmosphere and climate – a summary

New Zealand has a temperate climate that supports our natural environment, economy, and way of life. Our climate is naturally variable because of our location in the South Pacific Ocean and our small but mountainous land area. These factors contribute to the extreme weather, such as heavy rainfall and droughts, which often lead to significant economic and social losses.

Although naturally variable, our climate is also changing. The biggest driver of change is the increase in greenhouse gases from human activities, which is causing temperatures to rise. Global net emissions of greenhouse gases have risen 33 percent since 1990. Between 1990 and 2011, New Zealand emitted around 0.1 percent of global emissions. Carbon dioxide is the greenhouse gas that has the greatest impact over the long term with concentrations over New Zealand rising about 21 percent since 1972. Some changes in our climate, glaciers, and oceans are linked to increasing concentrations of greenhouse gases in our atmosphere. New Zealand's temperature increased around 0.9 degrees Celsius in the past 100 years. Glacier mass in New Zealand decreased about 36 percent since 1978, while sea levels around New Zealand rose between 1.3 and 2.1 millimetres on average annually over the last century.

Rainfall and wind patterns are also expected to change as a result of the ongoing increase in greenhouse gases. However, because our weather is highly variable year-to-year, it is difficult to detect these effects on our climate. So far, we see no clear trends in the data we have analysed for rainfall and extreme weather patterns (eg lightning strikes and three-day rainfall).

A major feature of our atmosphere and climate is our relatively high levels of ultraviolet (UV) light for our latitude. New Zealand has one of the highest rates of skin cancer (melanoma) incidence in the world partly because of our exposure to high levels of UV light. There has been no discernible trend in the total incidence rate of melanoma since 1996.

Why the condition of our atmosphere and climate is important

The condition of our atmosphere and climate is important for many reasons. The following section provides information on economic effects, water availability, changes in glacier extent, and health effects.

Economic effects

Our dependence on our climate means that extreme weather has a significant impact on our economy – especially our agricultural sector, which is reliant on a temperate climate. Although extreme weather events have always occurred, these are expected to become more frequent due to climate change (NIWA, 2009).

Extreme weather events can cause millions of dollars of damage (Insurance Council of New Zealand (ICNZ), 2014) and lead to injury or the loss of life. Extreme weather includes storms that cause flooding or wind damage, droughts, and snowstorms.

In 2014, the ICNZ identified eight extreme weather events – mainly storms and floods – that caused over $150 million in insurance costs for damage to homes, businesses, and farms (ICNZ, 2014) – though the total costs are likely to be much higher. For example, the North Island floods of 2004 cost more than $140 million in insurance payouts, but the full cost of damage was an estimated $355 million. About half (around $185 million) was for damage to agriculture (Horizons Regional Council, 2004).

Droughts are costly to the agricultural sector. The 2013 drought contributed to an estimated 4.4 percent decrease in milk production per cow (DairyNZ, 2014). Rising temperatures and changes in rainfall patterns are expected to make drought more frequent and more intense, especially in the east and north of the country (Reisinger et al, 2014).

Changes in climate affect the tourism industry. For example, rising average temperatures could reduce snowfall, and in turn the number of days that ski fields operate.

Our cultural sites are vulnerable to climate change. Many sites significant to Māori are in low-lying or coastal areas, which may be affected by sea-level rise or increased coastal-storm activity (Reisinger et al, 2014).

For more detail see *Environmental indicators Te taiao Aotearoa*: Insurance losses for extreme weather events and Ski-field operating days.

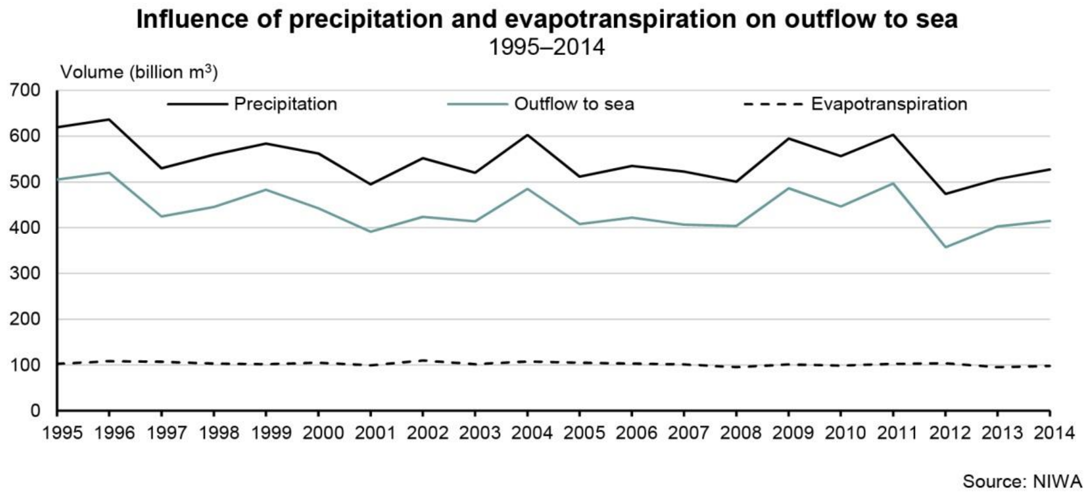
Water availability

Climate influences the amount of water in our lakes, rivers, streams, and aquifers, and therefore how much water is available for our use.

Climate affects rainfall and other forms of precipitation. The average annual outflow to sea is around 80 percent of the volume of precipitation. Evapotranspiration, or the loss of water to the atmosphere by evaporation, and from plants by transpiration, accounts for most of the remaining water from precipitation.

As well as the water that flows out to sea through New Zealand's rivers and streams (see figure 10), a large amount of water is stored in the ground (in aquifers). An estimated total of 711 billion cubic metres is held in aquifers, about three-quarters of this in Canterbury.

Figure 10



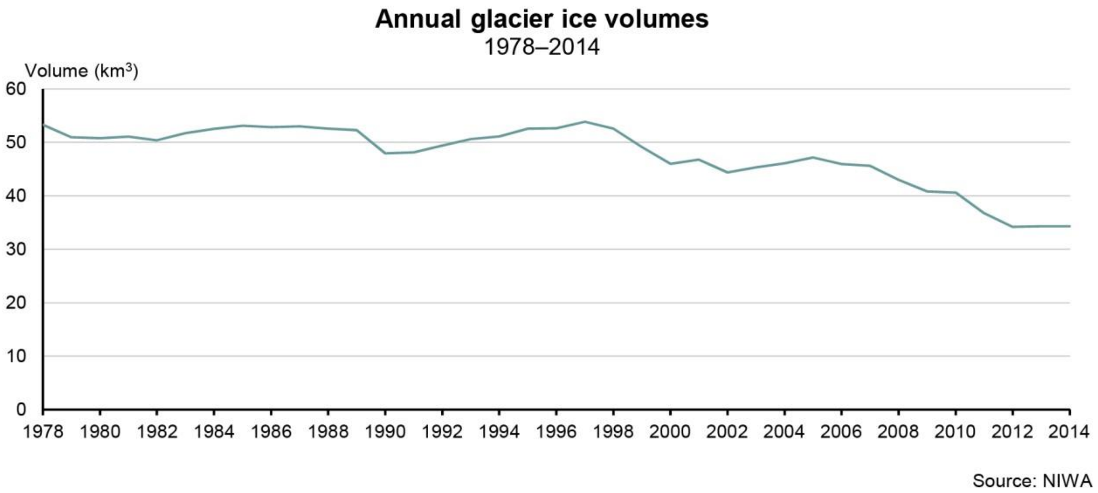
From current data, we cannot determine whether climate change has had an effect on surface or groundwater.

For more detail see *Environmental indicators Te taiao Aotearoa*: Water physical stocks: precipitation and evapotranspiration.

Glacier extent

The volume of glacier ice decreased 36 percent since 1978 (see figure 11). Increased temperatures over the last century have caused glaciers to melt. If temperatures continue to rise, it is likely that the extent of glaciers will shrink further.

Figure 11



For more detail see *Environmental indicators Te taiao Aotearoa*: Change in glacier ice volume.

Health effects

Climate, and change in climate, can affect our health. This section provides information on the incidence of melanoma (skin cancer), and the impact climate change may have on the incidence of some food- and water-borne illnesses.

High ultraviolet levels affect our health

New Zealand has one of the highest rates of skin cancer (melanoma) in the world (Ministry of Health, 2015). This is linked to the high ultraviolet (UV) light in our atmosphere, with peak intensities 40 percent greater than comparable latitudes in Europe. This is partly due to Earth's orbit bringing the Southern Hemisphere closer to the sun in summer. Air clarity or the effects of cloud also affect our UV levels (NIWA, 2015).

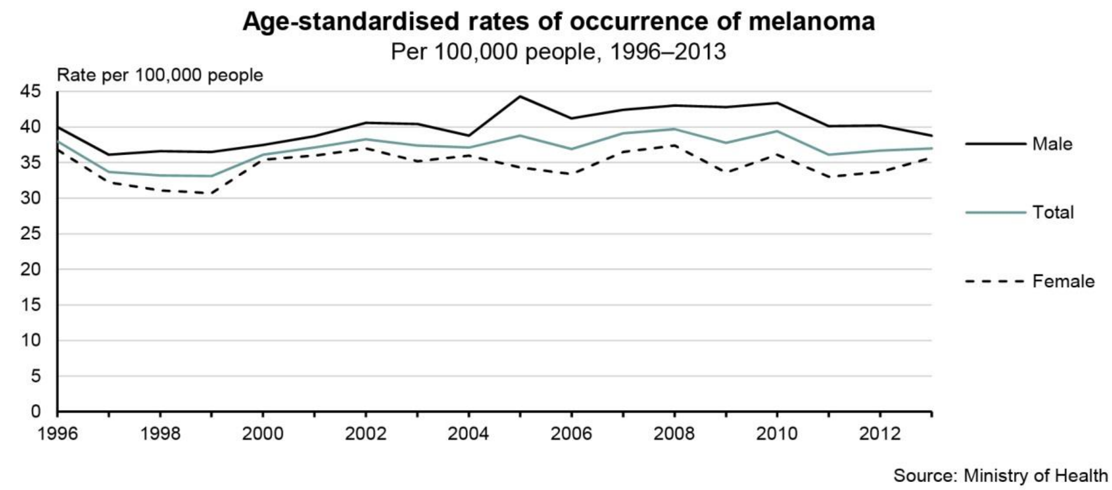
The 'ozone hole' does not have a significant impact on UV levels in our atmosphere as it occurs south of New Zealand. While ozone levels over New Zealand decreased slightly since 1978, our UV levels have not shown a consistent trend across monitoring sites.

There has been no discernible trend in the overall incidence of skin cancer since 1996, but there has been a statistically significant increasing trend for males. Long lag effects between exposure to UV light and the occurrence of skin cancer means any recent changes in exposure are not evident in our current skin cancer data.

Our high rates of melanoma are also linked to the relatively high level of exposure New Zealanders have to the sun, and the large number of fair-skinned people in New Zealand. Relative to population, New Zealand is estimated to have the highest incidence and death rate from melanoma in the world (Ferlay et al, nd). In 2011, 2,204 people were reported as having melanoma, while 359 died from it (Ministry of Health, 2014).

The incidence of cancer is strongly influenced by age. New Zealand has an increasing proportion of people in the older age groups so we can expect an increase in the incidence of melanoma. For this reason, we use 'age-standardised' data to compare data over time periods and between countries. The age-standardised incidence of melanoma in New Zealand between 1996 and 2013 showed no clear trend (see figure 12).

Figure 12



For more detail see *Environmental indicators Te taiao Aotearoa*: Occurrence of skin cancer.

Rising temperatures may affect our health

International research suggests rising temperatures increase the incidence of some diseases, such as food-borne diseases caused by *Campylobacter* and *Salmonella*, and water-borne diseases caused by *Cryptosporidium* (Health Analysis and Information for Action, 2015; Lal et al, 2013). However, the incidence of other illnesses more common in colder months, such as influenza, may decrease as a result of rising temperatures (Tompkins et al, 2012).

For more detail see *Environmental indicators Te taiao Aotearoa*: Food- and water-borne diseases and Influenza.

The pressures on our atmosphere and climate

Many factors affect the atmosphere and climate – both human-caused and natural. This section presents our latest findings on human-caused pressures (global emissions of greenhouse gases and ozone-depleting substances) and natural pressures (ocean conditions and climate oscillations).

Human-caused pressures

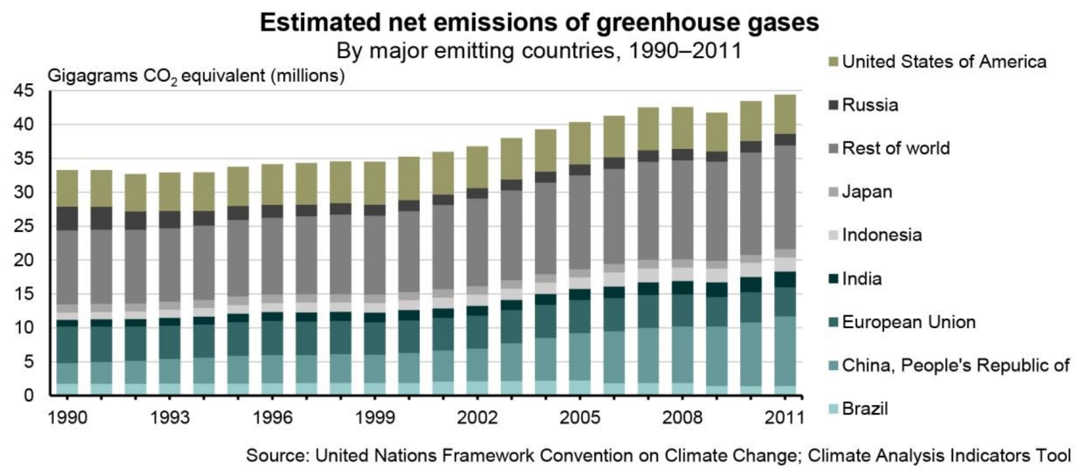
This section sets out the main human-caused pressures on the atmosphere: emissions of greenhouse gases and ozone-depleting substances.

Global emissions of greenhouse gases are still increasing

Human activities – mainly the burning of fossil fuels – have led to increased concentrations of greenhouse gases in the atmosphere. Between 1990 and 2011, global net emissions rose 33 percent (see figure 13).

Over this period, New Zealand emitted around 0.1 percent of global emissions. By comparison, the United States contributed an average of 16 percent, and China 15 percent.

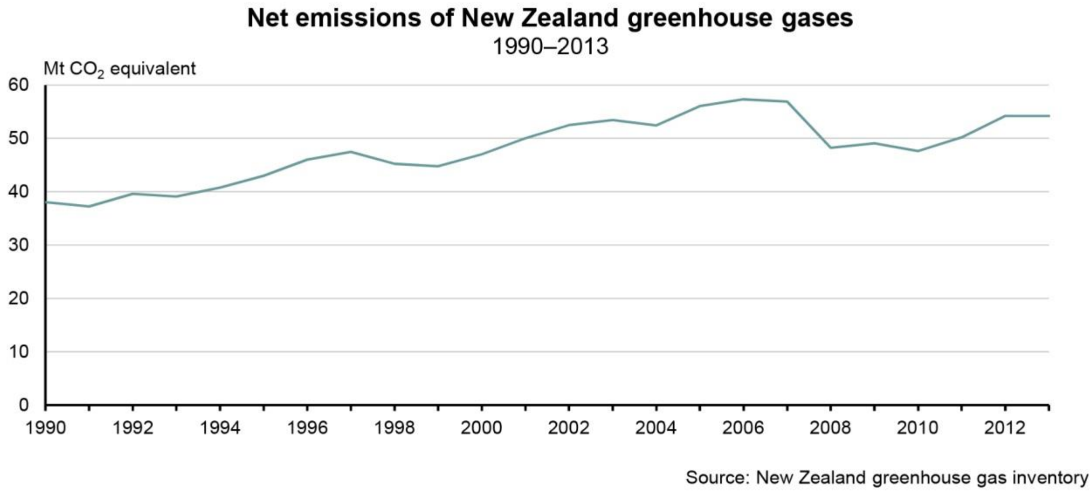
Figure 13



Note: The United Nations Framework Convention on Climate Change is the preferred data source, but because some countries do not report on all years since 1990, the data are supplemented with Climate Analysis Indicators Tool data. The effect of the various greenhouse gases are combined into one indicator, known as CO_2 (carbon dioxide) equivalent.

New Zealand's net greenhouse gas emissions increased 42 percent between 1990 and 2013 (see figure 14). Emissions from agriculture was the largest contributor at 48 percent (mainly methane emissions from cattle and sheep), followed by emissions from energy production, at 39 percent.

Figure 14



Note: Mt CO_2 equivalent – megatonnes equivalent carbon dioxide.

For more detail see *Environmental indicators Te taiao Aotearoa*: Global greenhouse gas emissions and New Zealand's greenhouse gas emissions.

Ozone-depleting substances drop to 2 percent of 1986 values

Globally, the production of ozone-depleting substances has decreased to 2 percent of their 1986 values. Atmospheric ozone is important as it absorbs harmful ultraviolet rays from the sun. Emissions from chlorofluorocarbons and other ozone-depleting substances have caused a hole to open in the ozone layer above Antarctica. While this 'ozone hole' has little effect on UV levels in our atmosphere, filaments of ozone-poor air can sometimes pass overhead when the ozone hole breaks up in spring.

The Montreal Protocol on Substances that Deplete the Ozone Layer, agreed in 1987, led to a decrease in the production of ozone-depleting substances. This decrease is expected to reduce the size of the ozone hole to pre-1980 levels by around the middle of this century (United Nations Environment Programme Ozone Secretariat, nd).

For more detail see *Environmental indicators Te taiao Aotearoa*: Global emissions of ozone-depleting substances.

Natural pressures

This section presents information on two natural pressures on our climate: oceans and climate oscillations.

Oceans influence our climate

The oceans influence our climate through the exchange of heat and moisture between the ocean and the atmosphere. For example, the oceans provide much of the heat that drives tropical cyclones, which are a significant influence on New Zealand's weather.

The oceans also moderate the effects of climate change by absorbing carbon dioxide and heat from the atmosphere. However, absorbing carbon dioxide makes oceans more acidic (Ciais et al, 2013).

For more information see: Marine chapter.

For more detail see *Environmental indicators Te taiao Aotearoa*: Coastal sea-surface temperature, Oceanic sea-surface temperature, and Ocean acidification.

Climate oscillations can affect our climate

Climate oscillations are natural variations in the world's climate patterns. Three of these have a particular influence on New Zealand's weather patterns – the El Niño Southern Oscillation, the Interdecadal Pacific Oscillation, and the Southern Annular Mode.

The El Niño and La Niña phases of the El Niño Southern Oscillation influence New Zealand's temperature and rainfall. El Niño can lead to droughts in the east of New Zealand, while La Niña can lead to flooding in the north (NIWA, 2007).

For more detail see *Environmental indicators Te taiao Aotearoa*: Climate oscillations.

The state of our atmosphere and climate

This section sets out the state of our atmosphere and climate. It presents information on greenhouse gases, ozone and ultraviolet intensity, temperature, rainfall, and extreme weather.

Greenhouse gases, ozone, and ultraviolet intensity

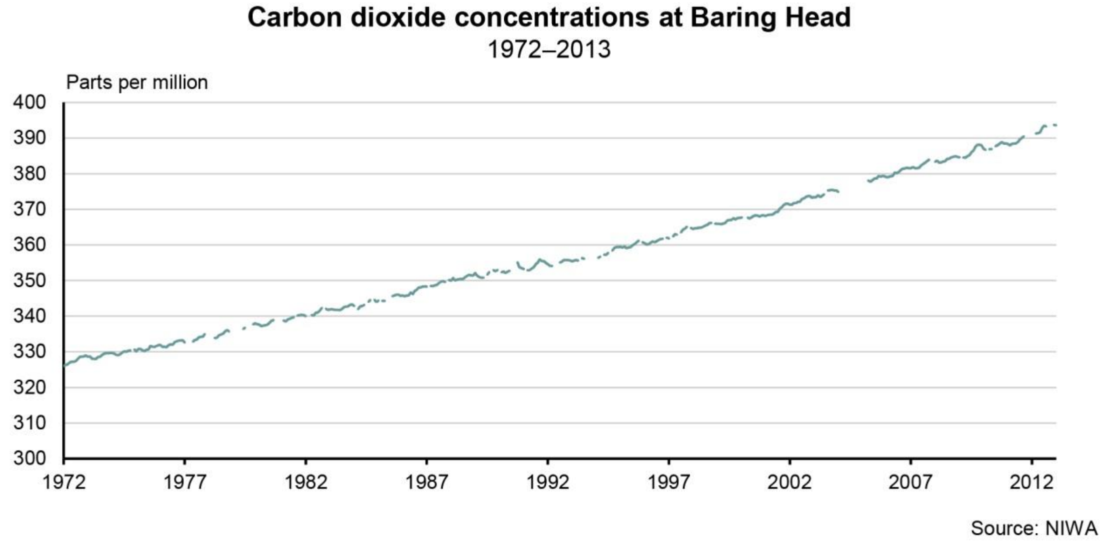
This section presents information on greenhouse gases, ozone concentrations, and ultraviolet (UV) intensity in our atmosphere.

Greenhouse gases are increasing

Greenhouse gases in the atmosphere absorb heat radiating from the Earth's surface causing warmer temperatures. The main greenhouse gases generated by human activities are carbon dioxide, methane, nitrous oxide, and carbon monoxide. Concentrations of these gases are measured by NIWA at Baring Head near Wellington. Carbon dioxide has the greatest impact over the long term because it persists in the atmosphere longer than the other greenhouse gases. However, the other greenhouse gases have a significant impact in the short term, because they absorb much more heat per kilogram than carbon dioxide.

Carbon dioxide concentrations measured over New Zealand increased 21 percent since measurements began in 1972 (see figure 15). This is an increase of about 1.6 parts per million a year (0.5 percent).

Figure 15



Note: Baring Head is near Wellington. It is a site that is less likely to be influenced by local sources of pollution. These observations are made only when the wind is blowing from the south and away from any likely local sources of gas emissions. This gives a measure representative of the concentrations over the Southern Ocean. Data are unavailable for some periods.

Methane and nitrous oxide concentrations also increased significantly since they were first measured in 1989 and 1996, respectively. On the other hand, carbon monoxide concentrations decreased significantly since first measured in 2000. Globally, technological improvements and stricter controls on vehicle and industrial emissions are leading to lower emissions of carbon monoxide (Mikaloff-Fletcher & Nichol, 2014).

The measurements taken in New Zealand are consistent with other observations around the globe. This is expected, because these gases get mixed around the globe by weather systems (Mikaloff-Fletcher & Nichol, 2014).

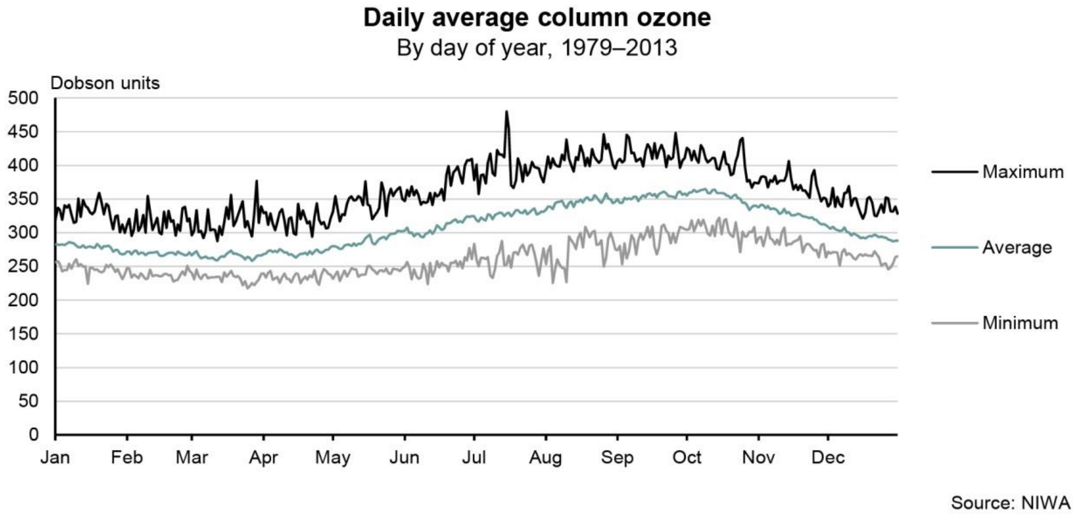
For more detail see *Environmental indicators Te taiao Aotearoa*: Greenhouse gas concentrations.

Ozone concentrations over New Zealand are comparable to countries of similar latitudes

The thickness of the ozone layer is significant because ozone absorbs UV light from the sun and acts as a filter against sunburn and other damage (eg to plastic and fabric). Changes in ozone concentrations can also influence the risk of skin cancer.

The amount of ozone in an atmospheric column is measured in Dobson units, where 1 Dobson unit corresponds to the amount of ozone required to form a 0.01 millimetre layer of pure ozone. The global average ozone is 300 Dobson units (Liley & McKenzie, 2007), slightly lower than the average ozone over New Zealand (307 Dobson units). Over New Zealand, the ozone layer ranges from about 275 Dobson units in autumn to 345 Dobson units in spring (see figure 16). Ozone varies by around 15 Dobson units from day to day (around 5 percent). Ozone concentrations over New Zealand are similar to other places around the world at similar latitudes.

Figure 16



Note: Maximum, minimum, and average ozone concentrations are shown.

A small but discernible downward trend is evident in ozone concentrations over New Zealand. However, this may only have had a small impact on our UV levels.

For more detail see *Environmental indicators Te taiao Aotearoa*: Ozone concentrations.

The ozone hole only affects New Zealand's ozone and UV levels when it breaks up in spring – when it can send plumes of air with lower ozone concentrations over the country. Even then, the ozone above New Zealand drops only about 5 percent, which is within the normal daily variation.

For more detail see *Environmental indicators Te taiao Aotearoa*: Ozone hole.

New Zealand's UV intensity is relatively high

Peak UV intensities in New Zealand are about 40 percent greater than at comparable latitudes in the Northern Hemisphere. The strength of UV light is measured using a solar UV index (UVI) or sun index. A UVI above 11 is extreme.

In New Zealand, UV indexes vary day to day, and showed no consistent trend across the five monitored sites between 1981 and 2014. In summer, the UVI often exceeds 11. For example, the northernmost site, Leigh, had an average of 73 days with a UVI greater than 11. In winter, the UVI can be as low as 1 even on clear days, mainly because the sun is low in the sky.

For more detail see *Environmental indicators Te taiao Aotearoa*: UV intensity.

Temperature, rainfall, and extreme weather

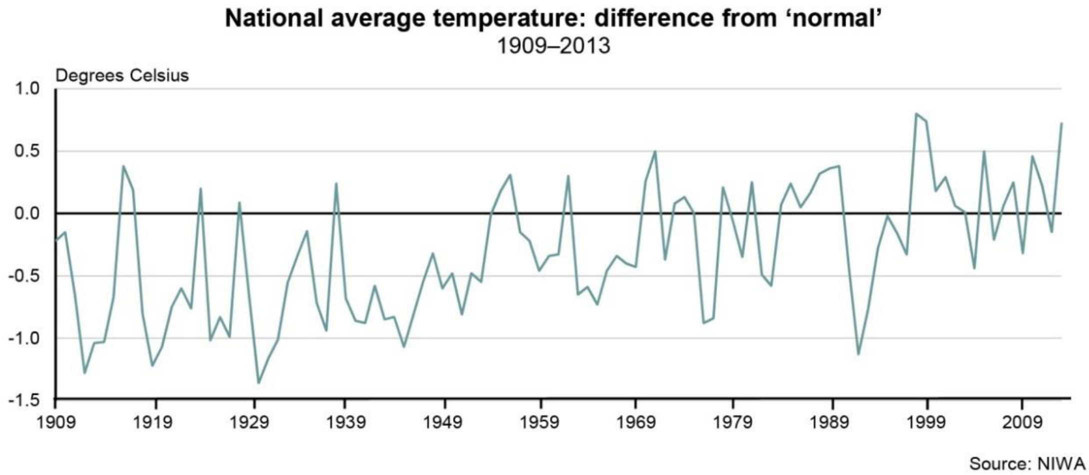
This section presents information on average temperatures, rainfall, and extreme weather. We also collect data on sunshine hours, but that is not discussed here (for information on sunshine hours see *Environmental indicators Te taiao Aotearoa*: Sunshine hours).

Average temperatures have risen

The average annual temperature in New Zealand increased by about 0.9 degrees Celsius over the last century (a statistically significant trend), slightly lower than the global average land-based temperature increase of around 1–1.2 degrees Celsius (NIWA, 2015) (see figure 17).

The Intergovernmental Panel on Climate Change concluded that global warming is beyond doubt, and it is extremely likely that human-caused pressures such as the burning of fossil fuels has been the primary cause since 1950 (IPCC, 2013).

Figure 17



Note: Data from seven sites around the country, adjusted for changes in site location. The plot shows the difference from the 1981–2010 average (known as 'normal'). Climatologists use the term 'normal' to refer to an average of the weather across a 30-year period.

New Zealand's average temperature, as estimated from seven monitored sites, fluctuates by about 0.4 degrees Celsius from year to year. This is a natural variation not directly linked to human-caused pressures. These year-to-year changes can be linked in part to climate oscillations such as the El Niño Southern Oscillation.

The increase in temperature is also reflected in 'growing degree days'. Growing degree days is the total days over a year in which the mean daily temperature is higher than a base value (10 degrees Celsius).

Of the 29 sites assessed, 18 showed upward trends, with a median increase across all sites of 0.22 growing degree days per year.

For more detail see *Environmental indicators Te taiao Aotearoa*: National temperature time series and Growing degree days.

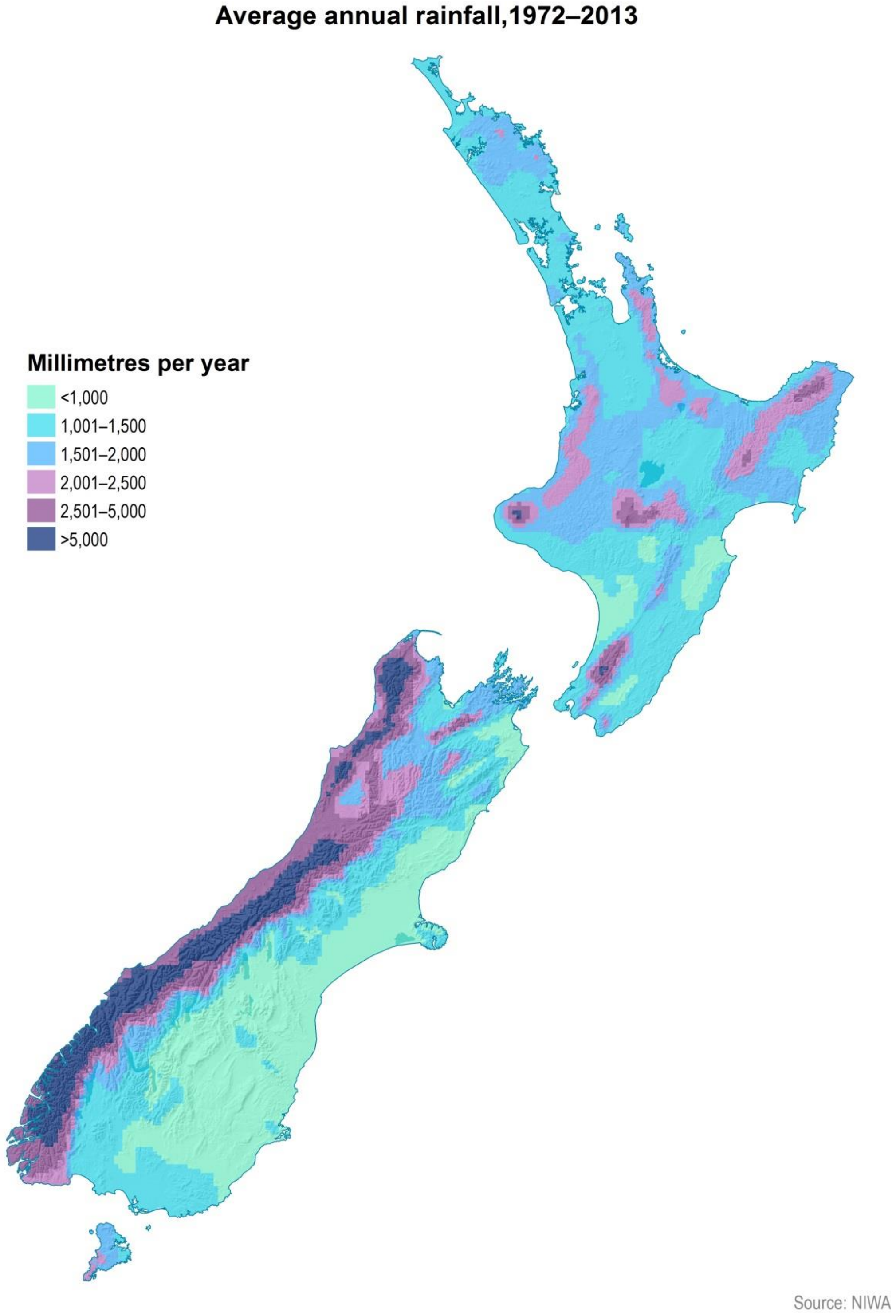
Rainfall is highly variable with no clear trend

Rainfall is highly variable both geographically and from year to year, so we have been unable to determine any long-term trends. However, it is expected that climate change will influence rainfall (and other forms of precipitation) over the longer term.

Geographically, annual average rainfall varies from less than 500 millimetres in dry years in places like Central Otago, to over 4,000 millimetres in mountainous areas such as the Tararua Range, and even more in the Southern Alps (see figure 18).

For more detail see *Environmental indicators Te taiao Aotearoa*: Annual rainfall.

Figure 18

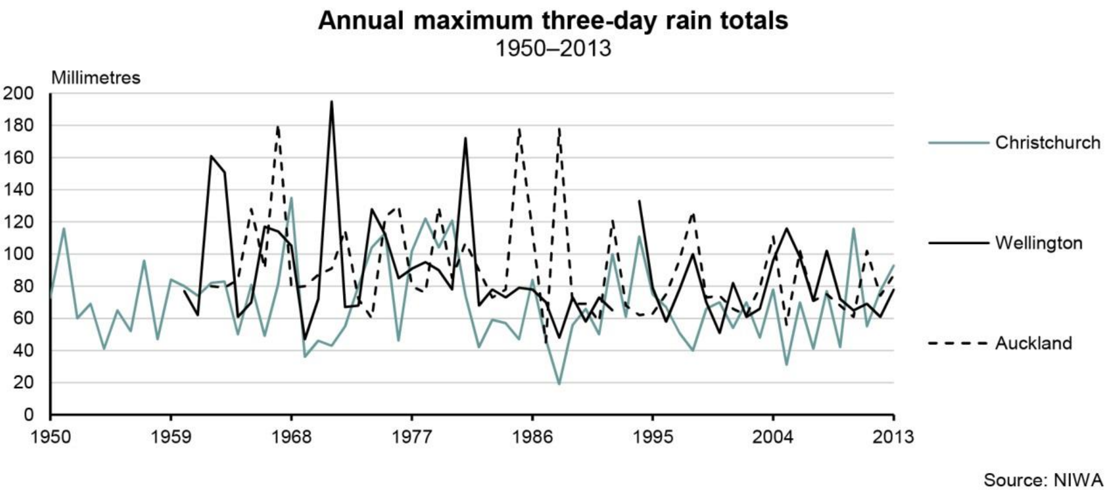

Average annual rainfall,1972–2013
Millimetres per year
<1,000
1,001–1,500
1,501–2,000
2,001–2,500
2,501–5,000
>5,000
Source: NIWA

Fewer days with gale-force winds but no clear trends in other extreme weather

This section presents information about three common elements of severe weather events: annual three-day rainfall maximums, the number of days with wind gusts above gale force, and lightning frequency.

Three-day rainfall data capture rainfall events likely to cause widespread flooding in affected areas. These data show the greatest rainfall total over any three-day period for each year, at each site. The data vary from year to year, so we cannot identify any statistically significant trends. While these data (see figure 19) show the maximum three-day rain totals for each year, they do not show the frequency of heavy rainfall events in a year.

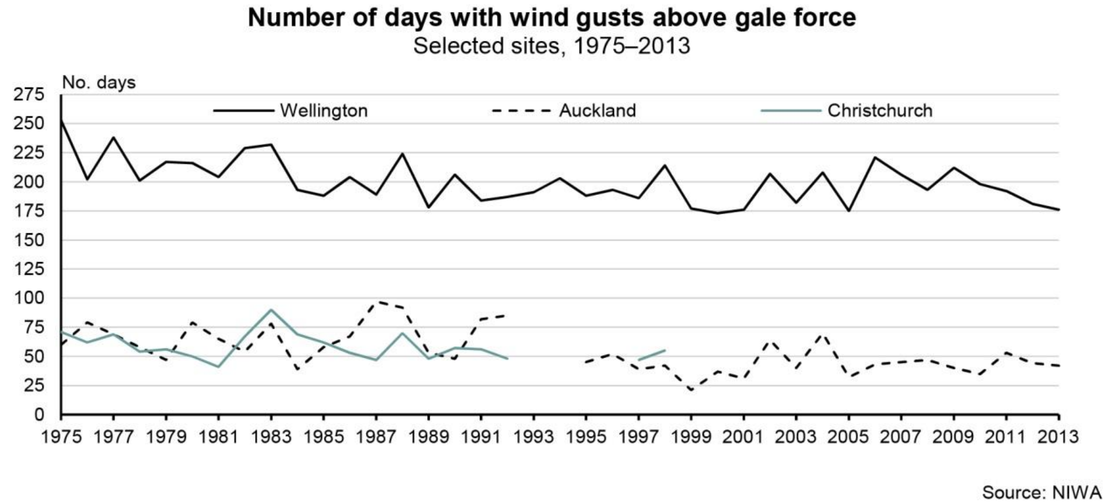
Figure 19



Note: Data was unavailable for Wellington in 1993.

We estimate damaging wind by the number of days a year wind gusts exceed gale force (61 kilometres an hour). The data show that Auckland, Wellington, and Christchurch regularly experience gale-force gusts, but Wellington is particularly prone to gale-force winds. Since 1975, the occurrence of potentially damaging wind has decreased in Wellington. Monthly (but incomplete) data for Christchurch and Auckland also suggest a smaller decrease (see figure 20). It is not clear whether this decrease is part of a natural cycle or is influenced by climate change. Studies predict global climate change may increase the frequency of damaging wind events in winter in almost all areas in New Zealand, and decrease the frequency in summer (Mullan et al, 2011).

Figure 20

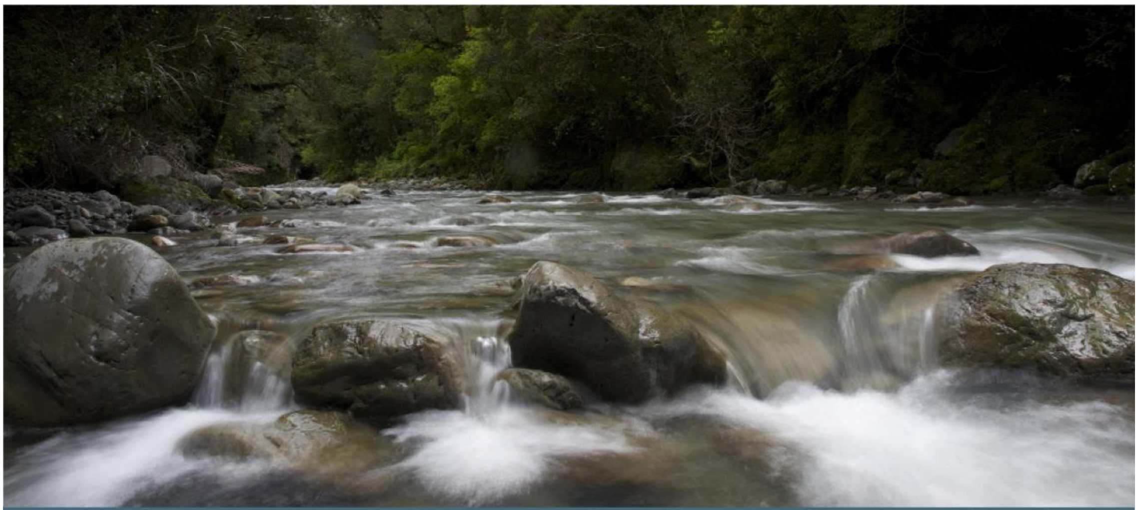


Note: Two of the three selected sites have missing data for some years. Gusts above gale force – above 33 knots, approximately 61 km/h.

Annually, there are about 190,000 lightning strikes on the New Zealand land mass and over coastal seas. This is not frequent by international standards. Lightning strikes are most frequent on the West Coast of the South Island. The data show a high degree of variability over the 14-year period from September 2000 to December 2014. However, thunderstorms, and therefore lightning, are expected to increase in frequency and intensity as a result of climate change (Mullan et al, 2011).

For more detail see *Environmental indicators Te taiao Aotearoa*: Annual maximum three-day rainfall, Occurrence of potentially damaging wind, and Lightning.

Fresh water



The freshwater domain comprises fresh water in all its physical forms. This includes fresh water in rivers, lakes, streams, wetlands, and aquifers. Fresh water is vital to our economy. The way we use it affects its biodiversity and suitability for recreation, and other uses such as drinking. The way we use land also affects water quality.

Overview

This chapter explains why the condition of our freshwater environment is important, and presents information about the pressures on New Zealand's fresh water and how its state is changing over time.

Our freshwater environment – a summary

Fresh water is important to New Zealand's way of life and economy. Our rivers, lakes, wetlands, and groundwater support the creation of wealth through agriculture, horticulture, hydroelectricity generation, and tourism. New Zealanders enjoy many forms of recreation in our lakes and rivers, including swimming, boating, and fishing. For Māori, fresh water is a taonga and essential to life and identity. Access to fresh water for food, materials, and customary practices is important to Māori. New Zealand's fresh water supports a range of aquatic animals including crayfish and more than 50 fish species, 39 of which are indigenous to New Zealand.

The quality of water in New Zealand's lakes, rivers, streams, and aquifers is variable, and depends mainly on the dominant land use in the catchment. Water quality is very good in areas with indigenous vegetation and less intensive use of land, and poorer where there are pressures from urban and agricultural land use. Rivers in these areas have reduced water clarity and aquatic insect life, and higher levels of nutrients and *Escherichia coli* (*E.coli)* bacteria.

Land use and population growth have placed increasing pressure on waterways. This is more evident with agricultural land because it surrounds 46 percent of New Zealand's rivers. Between 1990 and 2012, the estimated amount of nitrogen that leached into soil from agriculture increased 29 percent. This increase was mainly due to increases in dairy cattle numbers (and therefore urine which contains nitrogen) and nitrogen fertiliser use. Once in the soil, excess nitrogen travels through soil and rock layers, ending up in groundwater, rivers, and lakes.

Between 1989 and 2013, total nitrogen levels in rivers increased 12 percent, with 60 percent of the 77 monitored sites showing statistically significant increases. The greatest impact of excessive nitrogen levels in New Zealand rivers is nuisance slime and algae (periphyton) growth. This growth can reduce oxygen levels in the water, impede river flows, and smother the riverbed and plant life, which fish and other aquatic animals depend on for food and habitat. About 49 percent of monitored river sites currently have enough nitrogen to trigger nuisance periphyton growth, as long as there is enough sunlight, phosphorus, and a lack of flood events for periphyton to bloom.

High levels of nitrogen can also be harmful to fish; however, less than 1 percent of monitored river sites have nitrogen levels high enough to affect the growth of multiple fish species.

Like nitrogen, excessive phosphorus also promotes the growth of nuisance periphyton. Most phosphorus enters rivers on eroded soil and settles on riverbeds. Dissolved phosphorus levels increased (worsened) in the large rivers sampled by NIWA between 1989 and 2013, with 51 percent of the 77 monitored sites showing statistically significant increases. In contrast, dissolved phosphorus levels decreased (improved) in a broader collection of rivers sampled by regional councils between 1994 and 2013, with 48 percent of the 132 monitored sites showing statistically significant decreases. About 32 percent of monitored river sites currently have enough dissolved phosphorus to trigger nuisance periphyton growth.

Water clarity is a measure of underwater visibility and affects our ability to use rivers for recreational activities such as swimming and fishing. Water clarity is lower (worse) in urban and pastoral (agricultural) areas, but improved at two-thirds of monitored sites between 1989 and 2013.

Improved phosphorus levels and water clarity in rivers over the past 20 to 25 years were likely to be due to several factors. These include the management of erosion along river banks and surroundings, tree planting near waterways, reduced effluent discharges from industry, and a decrease in phosphorus fertiliser from 2004 to 2014.

The primary risk to human health from poor water quality comes from faecal contamination. This is indicated by the presence of *E.coli* bacteria in rivers or lakes. *E.coli* levels are highest in urban and pastoral areas, which are usually within 20 kilometres of where people live, and where people like to swim during summer. Higher *E.coli* levels are indicative of higher risks of infection for swimmers, particularly from stomach bugs like *Campylobacter*.

E.coli levels in New Zealand rivers meet acceptable standards for wading and boating at 98 percent of monitored sites. The acceptable levels for swimming are more stringent and require more intensive management. This is because *E.coli* can spike to high levels in rivers and streams for 2–3 days after heavy rainfall or during low river flows, particularly in lowland areas. Regional councils frequently monitor popular swimming spots for health reasons. Information about these sites, and their suitability for swimming on a given day, can be found on the Land, Air, Water Aotearoa website.

New Zealand has plentiful fresh water but not always where demand is greatest. Total average annual rainfall is high enough to fill Lake Taupō nine times over, but less rain falls in the north and on the east coasts of the North and South islands. Fresh water is mainly taken from rivers, lakes, and groundwater for hydroelectricity generation and irrigation for intensive farming. The remainder is used for industry, town supply, and stock water. Water use varies by region, with about half of the national consumption occurring in Canterbury, and one-quarter in Otago.

How we measure freshwater quality

New Zealand's lakes, rivers, and groundwater are monitored regularly by regional councils, NIWA, GNS Science, iwi, and community interest groups.

New Zealand's river network has a total river length of 199,641 kilometres. Regional councils monitor river water quality to manage environmental impacts. These sites tend to be in catchments dominated by agricultural land use. For this report, we included up to 708 comparable regional council river sites in our assessment. Of these sites, about 65 percent are in pastoral areas, 27 percent in indigenous landscapes, 4 percent in urban areas, and 4 percent in exotic forest. Rivers in most areas, particularly low-lying and hilly areas in the North and South islands, are well represented, while mountainous areas in the South Island and parts of the central North Island are not well represented.

NIWA also monitors water quality at 77 other sites on 35 major river systems (see figure 21). Together, these 77 sites drain about half of New Zealand's land and were selected to represent water quality in larger rivers (ie main-stem rivers) across New Zealand (Davies-Colley et al, 2011). The sites are located in the lower and upper reaches of each river, with 52 percent of the sites in pastoral areas, 44 percent in indigenous landscapes, and 4 percent in exotic forest. The NIWA sites were established to monitor changing trends in water quality in larger rivers over time. The sites are mainly located in cooler wetter locations (eg Southland and the Manawatu). Rivers in cooler climates that experience dry or extremely wet conditions are not well represented (eg Fiordland and the Central Plateau). No measurements are taken in urban areas. As the same sites have been measured consistently since 1989, the data is particularly useful for tracking changes in water quality over time (Ballantine & Davies-Colley, 2014).

Regional councils and NIWA measure a range of parameters at each of the sites they monitor. The parameters include water clarity; levels of nitrogen, phosphorus, and *E.coli*; and the number and type of macroinvertebrates present (aquatic animals such as insects, freshwater crayfish, snails, and worms). Some macroinvertebrates are sensitive to pollution, and their presence or absence is a good indicator of the overall health of a river or stream.

We used the NIWA river sites to assess trends in water quality for the 25-year period from 1989 to 2013. As the median dissolved phosphorus concentrations were significantly higher at regional council sites, we also used these sites to assess dissolved phosphorus trends for the 20-year period from 1994 to 2013.

We assessed the current state of New Zealand's rivers using the combined NIWA and regional council sites. When combined, these sites provide the broadest national coverage of river water quality.

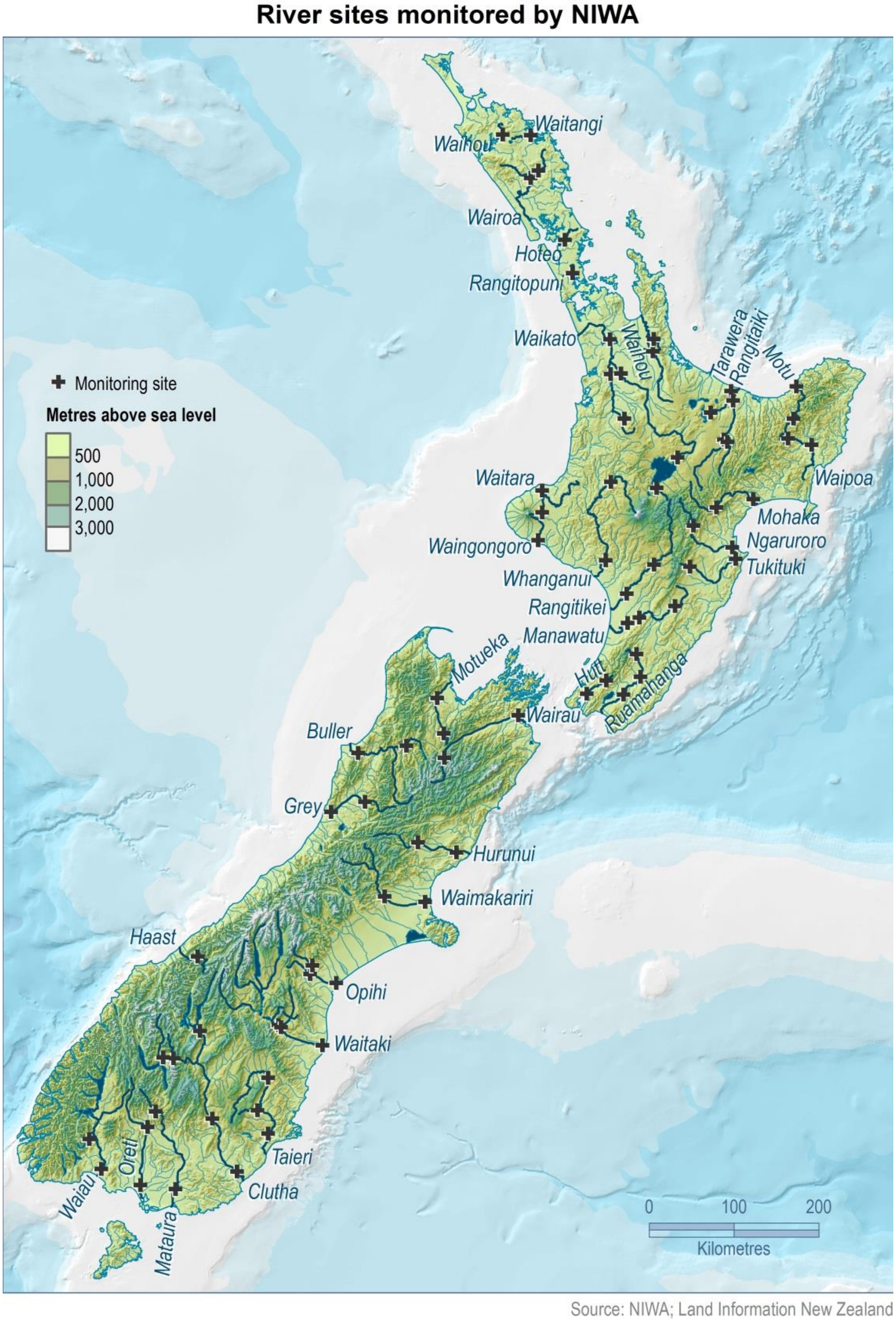
Regional councils and NIWA also monitor lakes. Four percent of lakes are currently monitored, but this proportion includes many of the largest and popular lakes close to urban areas. Lake water quality is assessed using the trophic level index (TLI), which combines a number of water-quality parameters. TLI scores rise with increasing eutrophication (elevated nutrient levels that can promote excessive algae growth and reduce oxygen levels in the lake). For this report, 65 lakes are assessed.

GNS Science monitors groundwater at about 100 sites that are fairly evenly distributed throughout the country. The current state of groundwater and trends in groundwater quality (for the 15-year period from 1998 to 2013), were assessed using the GNS Science sites.

Iwi and hapū groups are the main sources of environmental information relevant to Māori. Some Māori communities monitor rivers, streams, lakes, and wetlands in their rohe (area). To measure the health of waterways, they use the cultural health index or other methods (such as the mauri compass) that have a mātauranga Māori perspective. Crown research institutes such as NIWA and Landcare Research also collect data of significance to Māori, including data on taonga fish species.

For more information see: Fresh water supports Māori well-being and identity section.

Figure 21



Note: National River Water Quality Network sites. Rivers are labelled where they enter the sea.

Why the condition of our fresh water is important

The condition of our lakes, rivers, streams, wetlands, and groundwater is important for a number of reasons. Our economy depends on having plentiful water – agriculture, tourism, and hydroelectricity generation particularly rely on water. Having clean and plentiful water to drink is also important for our health and well-being. New Zealanders and visitors from overseas enjoy many forms of recreation that use our lakes and rivers, such as swimming, kayaking, and fishing. Our rivers, lakes, and wetlands also support many indigenous animals, plants, and ecosystems.

For Māori, rivers, lakes, and wetlands are a traditional source of sustenance and resources, as well as identity. Historically, many Māori settlements were located near rivers and lakes, reflecting the importance of waterways for food and resources, and also as transport routes. Māori regard fresh water as a taonga and essential to life and identity. Freshwater quality and flows affect the mauri (life force) of fresh water, and the availability and abundance of indigenous freshwater species for customary food gathering (mahinga kai).

Fresh water supports our economy

Rivers, lakes, and groundwater resources support our economy, particularly primary production such as agriculture, horticulture, forestry, and aquaculture (see Land chapter).

In 2014, dairy and meat exports accounted for 41 percent of the total value of merchandise exports. The relative contribution of the dairy sector to our gross domestic product (GDP) has been increasing, overtaking sheep, beef, and grain farming combined. Agriculture provides employment, particularly in rural areas. In 2013, agriculture employed more than 105,500 people, making the sector the second-largest 'employer' in New Zealand. Many businesses and industries in New Zealand exist because they provide products or services to the agricultural sector.

We generate much of our power from rivers and lakes, with hydroelectric generation accounting for 54.5 percent of New Zealand's electricity generation in 2013.

Our rivers and lakes are also a major attraction for international tourists engaging in activities such as fishing, white-water rafting, and jet boating. Tourism also makes an important contribution to our economy, accounting for more than 8 percent of GDP (Ministry of Business, Innovation and Employment, 2013).

For more detail see *Environmental indicators Te taiao Aotearoa*: Economic performance of the agricultural industry and Contribution of hydroelectricity to total electricity generation.

Fresh water supports recreation

New Zealanders enjoy a variety of recreational activities using our rivers and lakes, including fishing, swimming, and boating. We also enjoy the scenic beauty of our waterways, and the ecology they support. We want to know that our rivers and lakes are safe to swim in, and have adequate flows to support our recreational pursuits.

Water quality affects our ability to use rivers and lakes for recreational purposes. The primary risk to human health from poor water quality comes from faecal contamination of fresh water. The presence of *E.coli* bacteria in rivers or lakes indicates that the water is contaminated by animal or human faeces, posing a risk to infection from pathogens like *Campylobacter*. People are more likely to be infected while swimming than when they are engaged in activities that involve less frequent immersion (eg wading or boating). The likelihood of infection is greater because the risk of ingesting contaminated water increases when people submerge their head.

E.coli levels are highest in urban and pastoral areas, which are generally within 20 kilometres of where people live, and where people like to swim during summer. High *E.coli* levels are indicative of higher risks of infection for swimmers, particularly from stomach bugs like *Campylobacter*.

To meet acceptable guidelines for swimming during summer, *E.coli* levels must be below 540 *E.coli* per millilitre. To ensure these levels are not exceeded, the guidelines require that 19 of 20 sampling events are below this value. *E.coli* can spike to high levels in rivers and streams for 2–3 days after heavy rainfall or during low river flows (Davies-Colley, 2013), particularly in lowland areas. For this reason, regional councils frequently monitor popular swimming sites to assess the level of risk for recreational activities such as swimming. However, some inconsistencies in monitoring methodologies mean the data are neither representative nor comparable across all sites, and so do not meet our data quality standards for inclusion in this report as a national statistic. We are working with councils to develop more consistent monitoring and reporting of the suitability of a site for swimming at a national level. In the meantime, you can look for information about your local swimming spot on the Land, Air, Water Aotearoa website.

For more information see: *E.coli* levels are higher in urban and agricultural catchments section.

For more detail see *Environmental indicators Te taiao Aotearoa*: Participation in recreational fishing.

Fresh water supports Māori well-being and identity

The physical, ecological, and cultural health of waterways is vitally important to Māori. Waterways and wetlands continue to be used for mahinga kai (a source of food and resources).

We have little data on how the state of waterways impacts on the economic, social, and cultural well-being of Māori. However, waterway health can also be assessed using a holistic approach. A range of tools are being used that take into account te ao Māori (the Māori world view) and include concepts such as mauri (life force) and ki uta ki tai ('from the mountains to the sea').

The National Policy Statement for Freshwater Management 2014 recognises te mana o te wai (which can be understood as 'the quality and vitality of water') alongside the national significance of fresh water. These developments highlight both the increasing recognition of Māori environmental values in environmental management and the significance of fresh water to Māori.

There is increasing recognition of the value of mātauranga Māori (traditional knowledge) to all New Zealanders, and researchers have devised tools to bridge the gap between mātauranga Māori and western science. For example, researchers have developed the cultural health index to assess the health of waterways from both a biophysical and cultural perspective. This assessment takes a holistic approach and combined with other methods, provides a more comprehensive understanding of the health of our waterways. The following two examples show how the cultural health index can help us understand the freshwater environment.

Using cultural perspectives to assess freshwater health

The cultural health index (CHI) assesses the health of waterways from a cultural perspective, as well as in terms of the waterway's physical and biological characteristics. The CHI draws on information about a site's water quality, and the experience and observations of people from iwi and hapū who have had a relationship with the waterway over generations. It assesses people's ability to gather food or other resources (mahinga kai) from the site, and whether people from the hapū or iwi are likely to return to the site in future.

A Bay of Plenty Regional Council study (2014) of streams in the Te Arawa/Rotorua Lakes region highlighted the importance of evaluating the freshwater environment from a Māori cultural perspective. The study compared results from 31 sites that had been assessed using both scientific and cultural measures. Generally, it found a strong correlation between the measures, but it also highlighted differences. For example, the scientific view is that the effect of a contaminant will decrease as it is diluted, whereas the Māori view is that its impact will persist throughout the catchment, regardless of how much it is diluted.

In North Otago, the tribal committee Te Rūnanga o Moeraki uses the CHI to assess the condition of the Kakanui (or Kakaunui) River and its main tributaries. Over recent decades, land in the Kakanui catchment has been more intensively farmed, and the rūnanga is concerned about the water quality deteriorating. The rūnanga's assessments of water quality in the Kakanui catchment revealed that about a third of the 16 sites were in a state that did not sustain cultural values, such as the ability to gather food and other resources. The health of one tributary, Waiareka Stream, was particularly concerning because none of the sites in its catchment sustained cultural values (Tipa, 2015).

Fresh water supports aquatic biodiversity

A number of factors affect the capacity of our rivers, streams, lakes, and wetlands to support indigenous fish and other aquatic life. The factors include flows being changed by removing or diverting water from rivers for irrigation, hydroelectricity generation, and other uses; increases in pollutants and sediment, invasive species, dams and other barriers to fish migration; and loss of vegetation around waterways.

New Zealand has 39 indigenous freshwater fish species (Goodman et al, 2014). Our indigenous fish are generally small and nocturnal, spending daylight hours under stones, logs, or overhanging branches. More than half the species migrate between the sea and fresh water to complete their life cycles. This means that barriers in rivers, streams, and lakes can have a significant impact on the abundance of fish in affected lakes and rivers. Indigenous fish are generally most abundant in streams in hilly or mountainous country, rather than large rivers in lowland areas. This is probably because these areas are less affected by human activities (Brown et al, 2015).

Seventy-two percent of our indigenous freshwater fish species are classified as at risk or threatened with extinction (Goodman et al, 2014). The risk of extinction worsened for eight species between 2005 and 2011. The Parliamentary Commissioner for the Environment (2013) concluded that our largest freshwater fish, the longfin eel, was in a steady state of decline. An independent review recommended by the Parliamentary Commissioner's report found that, while eel numbers had generally declined between 1990 and 2000, there is evidence to suggest that the rate of decline may have slowed through the 2000's (Haro et al, 2013).

Observations of freshwater fish communities between 1970 and 2007 indicate an overall decline in the diversity of species at the sites where observations were made.

For more detail see *Environmental indicators Te taiao Aotearoa*: Freshwater fish communities, Freshwater plants and animals, Freshwater pests, and Changes in the conservation status of indigenous species.

The pressures on our fresh water

Our rivers, lakes, wetlands, and aquifers are affected by natural and human-caused pressures. Terrain and climate can influence the way rivers form, the way water flows, and how much water is in a waterway or aquifer. Natural erosion, especially from alpine areas, continually changes the shape of many New Zealand rivers. Rain, and snow and ice melt influence the amount of water carried by waterways. Most of these 'natural' pressures remain relatively constant over time (although climate change is expected to influence aspects such as rainfall).

Human-caused pressures include discharges of pollutants from agriculture, industry, and urban areas into waterways; human-caused erosion; and the taking of water for irrigation and hydroelectric power generation.

This section outlines some key pressures on our waterways and aquifers from land use and the taking of water for irrigation and other uses.

How we use land affects freshwater quality

Our land has dramatically changed since humans first settled in New Zealand 700–800 years ago (see Land chapter). This change accelerated with the spread of pastoral farming during the 19th century. Agriculture remains the dominant land use, and farming practices have further intensified over recent decades. Between 2002 and 2014, sheep numbers decreased 25 percent but dairy cattle numbers increased 30 percent.

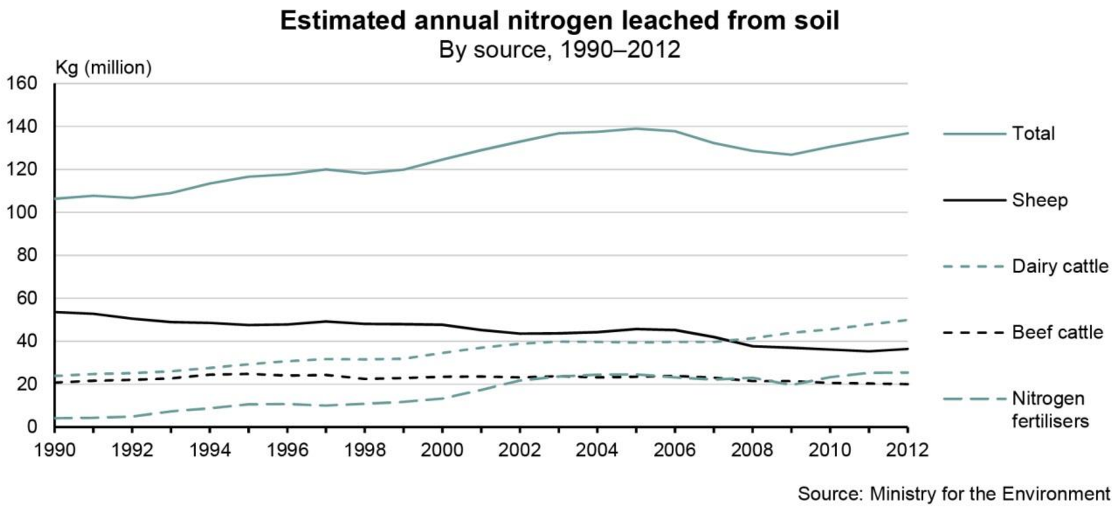
Land use and population growth have placed increasing pressure on waterways. This is more evident with agricultural land because it surrounds 46 percent of New Zealand's rivers. The main pressures from intensive agriculture are the taking of fresh water for irrigation, and an increase in the flow of nutrients and *E.coli* into waterways.

New Zealand's population grew 35 percent in the 32-year period from 1981 to 2013 (Statistics NZ, 2013a), with most of the increase in the Auckland region. Population growth has increased pressure on urban water infrastructure and increased the level of run-off and pollutants entering urban rivers and streams.

The nutrients of most concern in New Zealand are nitrogen and phosphorus. These nutrients occur naturally in relatively low quantities in rivers, streams, and lakes, and are essential for plants to grow. However, an excess of these nutrients can lead to excessive growth of slime and algae (periphyton). This excessive growth can increase daily fluctuations in dissolved oxygen and acidity (pH), impede river flows, and smother the riverbed, which fish and other aquatic animals depend on for food and habitat. High levels of nitrogen can also be harmful to fish and other aquatic animals.

In catchments dominated by agriculture, nitrogen in rivers comes mainly from livestock urine, and from nitrogen-based fertiliser. Between 1990 and 2012, the estimated amount of nitrogen that leached into soil from agriculture increased 29 percent (about 1.5 million kilograms a year). This increase was mainly due to increases in dairy cattle numbers (and therefore urine which contains nitrogen) and nitrogen fertiliser use (see figure 22). Once in the soil, excess nitrogen travels through soil and rock layers, and eventually ends up in groundwater, rivers, and lakes.

Figure 22



In catchments dominated by agriculture, phosphorus mostly enters waterways as part of eroded sediment. It can also come from phosphorus-based fertiliser.

Urban land use also affects waterways. Run-off from roads and other human-made surfaces can wash heavy metals and other pollutants into drains, streams, and rivers. Untreated wastewater also carries pollutants into streams and rivers. We currently have insufficient data to assess the effect of urban and industrial discharges on the freshwater environment and how these pressures have changed over time. We will include this information in future reports.

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

Most water taken from waterways is used for irrigation

Irrigation is the biggest consumptive user of water in New Zealand (consumptive use is when water is taken from a waterway but not returned). Based on resource consent information (which governs the amount of water a user is allowed to take), irrigation accounts for about three-quarters of consumptive water use. The remainder is used for industry, town water supply, and stock water (Aqualinc Research, 2010). There is strong regional variation in water use: about half the water allocated for consumption nationally is in Canterbury, and one-quarter is in Otago.

Hydroelectric power generation is a major user of fresh water, but most of this water is returned to the river or lake it was taken from and so is not included in the breakdown of consumptive use. The exception is the Manapouri power station, where water is diverted from the Waiau River into the sea.

We are currently collecting new data to enable more in-depth and accurate reporting on freshwater flows. The data includes information on the total irrigated area, actual water use from water meters, the reliability of supply, restrictions on water use to manage over-allocation or seasonal low river flows, and the impact of water use on instream flows, river width, and fish habitat.

The state of our fresh water

In this section, we present information on the quality and quantity of our fresh water, and how it is changing over time.

The quality of water in New Zealand's lakes, rivers, streams, and aquifers is variable, and depends mainly on the dominant land use in the catchment. Water quality is very good in areas with indigenous vegetation and less intensive use of land. Water quality is poorer where there are pressures from urban and agricultural land use. Rivers in these areas have reduced water clarity and aquatic insect life, and higher levels of nutrients (ie nitrogen and phosphorus) and *E.coli* bacteria.

Water clarity and nutrient levels

Some nutrient levels are higher but water clarity has improved overall

We report on three measures of nitrogen: total nitrogen, nitrate-nitrogen, and ammonia-nitrogen. Total nitrogen is all nitrogen forms found in waterways. Nitrate-nitrogen is highly soluble (dissolves in water) and can readily be used by plants and algae to help them grow. It can also leach through soils easily, particularly where the soils are sandy or porous, or after heavy rainfall (McDowell et al, 2008). In agricultural catchments, nitrate-nitrogen generally comes from nitrogen fertiliser and livestock urine.

At elevated concentrations, ammonia-nitrogen (ammonia in water) can be harmful to fish and other aquatic animals. Ammonia is commonly found in household bleach and is also a waste product from industry, humans, and animals. In the environment, it generally comes from point-source discharges of pollutants (rather than run-off), such as discharges from sewerage treatment plants, dairy sheds, and industrial operations.

Water clarity is a measure of underwater visibility, and is reduced by fine particles in the water like silt, mud, or organic material, mainly from soil erosion. Water clarity affects the suitability of waterways for recreational activities such as swimming and fishing, as well as affecting the habitat of fish and birds.

Between 1989 and 2013, water clarity improved overall. Total nitrogen and, to a lesser extent, nitrate-nitrogen increased (worsened) overall, while ammonia-nitrogen (ammoniacal nitrogen) decreased (improved) overall (see table 1). A trend could not be determined for total phosphorus, while dissolved reactive phosphorus (dissolved phosphorus) increased (worsened) overall. We could not determine a trend for the macroinvertebrate community index (MCI) at most sites.

Table 1: Trends for water clarity, nutrients, and macroinvertebrate community index at NIWA sites, 1989–2013

Variable	Trend	Sites showing a statistically significant increase (%)	Sites showing a statistically significant decrease (%)	Sites showing an indeterminate trend (%)
Clarity	↗	64	9	27
Total nitrogen	↗	60	14	26
Nitrate-nitrogen	~	52	27	21
Ammonia-nitrogen	↘	4	78	18
Total phosphorus	~	38	30	32
Dissolved phosphorus	↗	51	14	35
Macroinvertebrate community index (MCI)	~	5	13	83

Source: Larned et al (2015)

Note: Trends for NIWA's National River Water Quality Network (77 sites). Data are for the period 1989–2013, except for the MCI (covering 462 NIWA and regional council sites) which are for the period 2004–13. Green arrows indicate improving water quality; red arrows indicate declining water quality. No trends could be determined for nitrate-nitrogen, total phosphorus, and the MCI. Percentages may not add to 100 percent due to rounding.

The increases in total nitrogen levels are likely to be due to an increase in nitrate leaching through soils, as a result of more intensive agriculture – especially from dairy farming expanding and intensifying in many regions. The improvement in concentrations of ammonia-nitrogen is likely to be due to improvements in the way discharges from sewage treatment plants, dairy sheds, and industrial operations are treated.

We report on two measures of phosphorus: total phosphorus and dissolved phosphorus. Total phosphorus in water is a measure of the phosphorus bound to sediment and phosphorus dissolved in the water itself. Elevated phosphorus levels in rivers promote the growth of slime and algae (periphyton), as long as there is enough sunlight, nitrogen, and a lack of flood events for periphyton to bloom (see figure 25).

Dissolved phosphorus levels increased (worsened) in the large rivers sampled by NIWA between 1989 and 2013, with 51 percent of the 77 monitored sites showing statistically significant increases. These sites contain low to moderate levels of phosphorus (median of 5.0 milligrams per cubic metre).

As dissolved phosphorus levels were significantly higher at regional council sites that are concentrated in pastoral areas (median of 13.6 milligrams per cubic metre), we also used these sites to assess phosphorus trends. Compared with the rivers sampled by NIWA, dissolved phosphorus levels decreased (improved) at the regional council sites between 1994 and 2013, with 48 percent of the 132 monitored sites showing statistically significant decreases.

There has been no clear trend for total phosphorus over the 25-year period, although levels decreased (improved) from 2004 to 2013.

Phosphorus mostly enters waterways as part of eroded sediment. Improvements in phosphorus levels and water clarity in rivers over the past 20 to 25 years were likely due to a number of factors. These include the management of erosion along river banks and surroundings, tree planting near waterways, reduced effluent discharges from industry, and a decrease in phosphorus fertiliser use from 2004 to 2014. We are currently collecting further information about these factors to inform future reports.

For more detail see *Environmental indicators Te taiao Aotearoa*: River water quality trends: clarity, River water quality trends: nitrogen, and River water quality trends: phosphorus.

Water quality and land use

Nitrogen is higher in urban and agricultural catchments

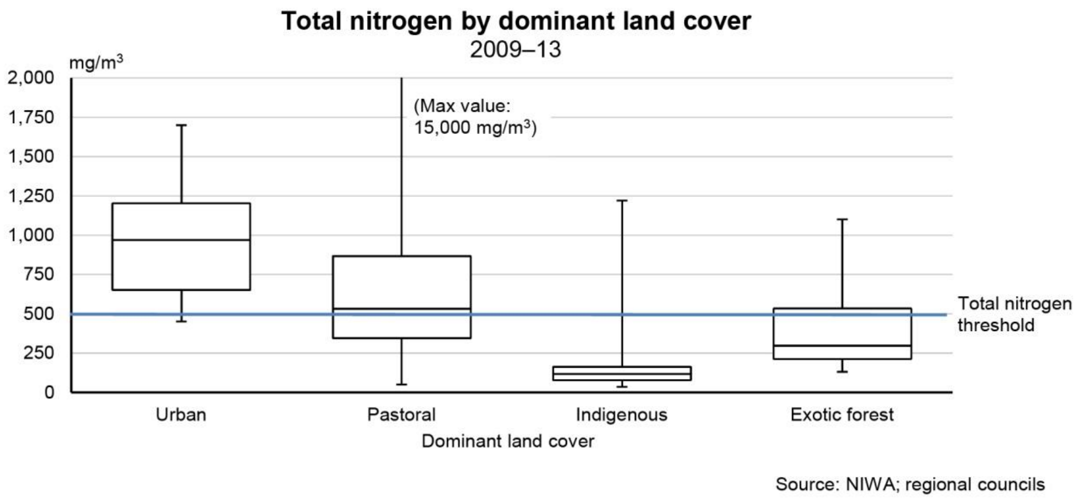
Nitrogen levels are higher in urban and pastoral lowland sites (see figures 23 and 24). The elevated levels of nitrogen are mainly due to an increase in nitrate-nitrogen from nitrogen fertiliser and untreated effluent. The contribution from ammonia-nitrogen from sewage treatment plants, dairy sheds, and industrial operations is relatively minor in comparison.

The greatest impact of excessive nitrogen in New Zealand rivers is nuisance slime and algae (periphyton) growth. This growth can reduce oxygen in the water, impede river flows, block irrigation and water supply intakes, and smother riverbed habitats. About 49 percent of monitored river sites currently have enough nitrogen to trigger nuisance periphyton growth (see figure 23), as long as there is enough sunlight, phosphorus, and a lack of flood events for periphyton to bloom.

High levels of nitrogen can also be harmful to fish, but less than 1 percent of monitored river sites in New Zealand have nitrate-nitrogen levels high enough (>6,900 milligrams per cubic metre) to affect the growth of multiple fish species (see figure 24).

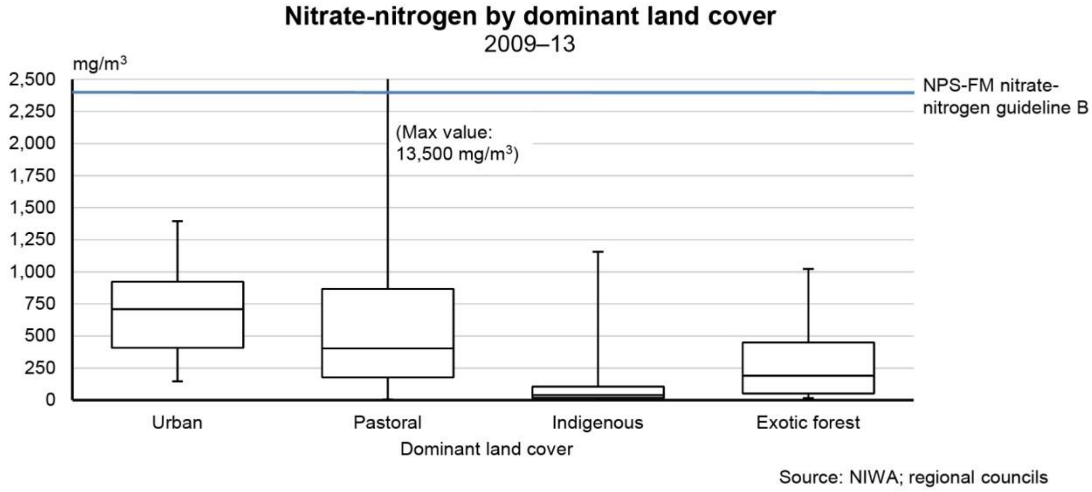
For more detail see *Environmental indicators Te taiao Aotearoa*: River water quality trends: nitrogen and Geographic pattern of nitrogen in river water.

Figure 23



Note: The ends of each 'box' in the box-plot are the upper and lower quartiles (25 percent of the sites are either higher or lower than these values). The top and bottom 'whiskers' represent the highest and lowest value. The middle line of the box represents the median (middle) data point (half the sites are above and half below this value). The maximum value for pastoral is 15,000 mg/m^3 (which is beyond the range of this figure). The blue line (at 496 mg/m^3) represents the median nitrogen threshold (Larned et al, 2015) required to meet the periphyton minimum standard in the National Policy Statement for Freshwater Management 2014. The threshold varies with climate and the source of flow (Larned et al, 2015). Nationally, the proportion of river length classified as predominantly urban is 0.8 percent; pastoral, 45.8 percent; indigenous forest, 47.7 percent; and exotic forest, 5.6 percent.

Figure 24



Note: The ends of each 'box' in the box-plot are the upper and lower quartiles (25 percent of the sites are either higher or lower than these values). The top and bottom 'whiskers' represent the highest and lowest value. The middle line of the box represents the median (middle) data point (half the sites are above and half below this value). The maximum value for pastoral is 13,500 mg/m^3 (which is beyond the range of this figure). The blue line (at 2,400 mg/m^3) represents the nitrate-nitrogen level that has some growth effects on up to 5 percent of fish species (National Policy Statement for Freshwater Management 2014). The maximum acceptable limit is 6,900 mg/m^3 – this is the level that has some growth effects on up to 20 percent of sensitive fish species. Nationally, the proportion of river length classified as predominantly urban is 0.8 percent; pastoral, 45.8 percent; indigenous forest, 47.7 percent; and exotic forest, 5.6 percent.

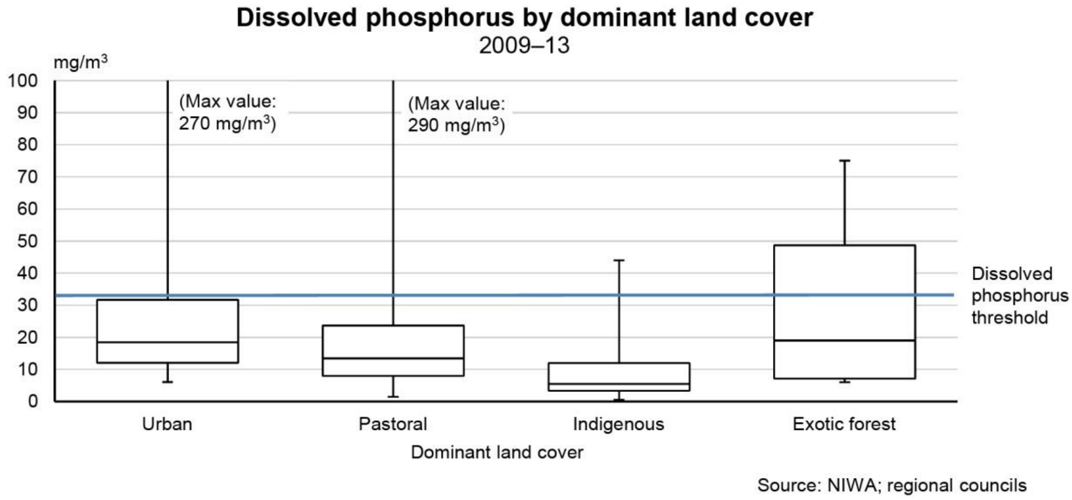
Phosphorus is higher in exotic forest, urban, and agricultural catchments

Phosphorus mostly enters waterways as part of eroded sediment and from phosphorus-based fertiliser. Phosphorus levels are higher in exotic forest, urban, and pastoral lowland sites (see figure 25). It is likely that the higher level of phosphorus in catchments dominated by exotic forest is connected with the geology of many of these sites. About half of the 14 exotic forest sites are in the Volcanic Plateau in the central North Island, where levels are naturally higher because the underlying rock is rich in phosphorus (Timperley, 1983).

Elevated phosphorus levels in rivers promote the growth of slime and algae (periphyton). About 32 percent of monitored river sites have enough phosphorus to trigger nuisance periphyton growth (see figure 25), as long as there is enough sunlight, nitrogen, and a lack of flood events for periphyton to bloom.

For more detail see *Environmental indicators Te taiao Aotearoa*: River water quality trends: phosphorus and Geographic pattern of phosphorus in river water.

Figure 25

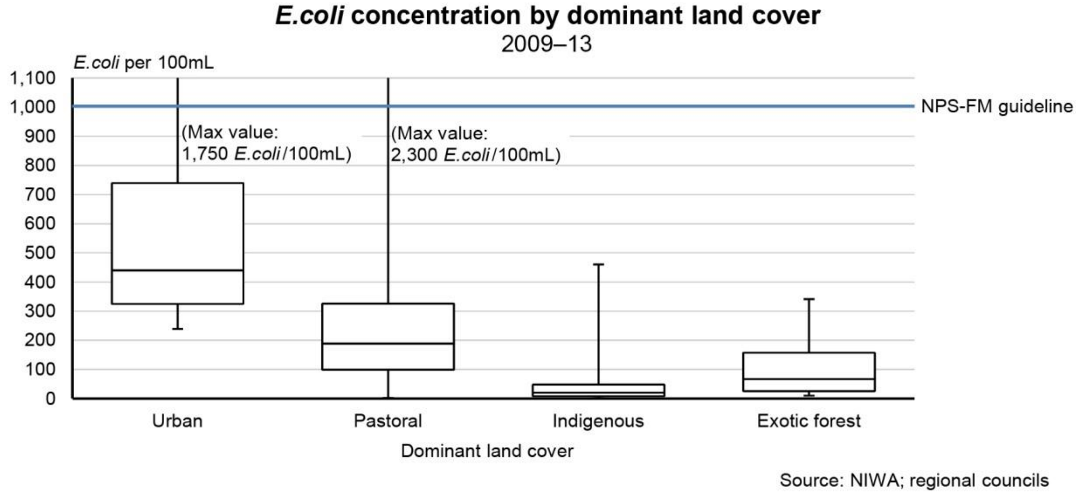


Note: The ends of each 'box' in the box-plot are the upper and lower quartiles (25 percent of the sites are either higher or lower than these values). The top and bottom 'whiskers' represent the highest and lowest value. The middle line of the box represents the median (middle) data point (half the sites are above and half below this value). The maximum values for urban and pastoral are 270 mg/m^3 and 290 mg/m^3, respectively (which are beyond the range of this figure). The blue line (at 33.2 mg/m^3) represents the median dissolved phosphate threshold (Larned et al, 2015) required to meet the periphyton minimum standard in the National Policy Statement for Freshwater Management 2014. The threshold varies with climate and the source of flow (Larned et al, 2015). Nationally, the proportion of river length classified as predominantly urban is 0.8 percent; pastoral, 45.8 percent; indigenous forest, 47.7 percent; and exotic forest, 5.6 percent.

E.coli levels are higher in urban and agricultural catchments

Like nutrients, levels of *E.coli* are higher in urban and pastoral lowland sites (see figure 26). *E.coli* in rivers or lakes comes from animal or human faeces. Higher levels of *E.coli* are indicative of higher risks of infection from pathogens like *Campylobacter* while swimming, wading, or boating. Median *E.coli* levels in New Zealand rivers meet acceptable standards for wading and boating at 98 percent of monitored sites (see figure 26). The 2 percent of sites that exceed acceptable levels for wading and boating (>1,000 *E.coli* per 100 millilitres) are in urban and pastoral areas in Auckland, Canterbury, Southland, and Wellington.

Figure 26



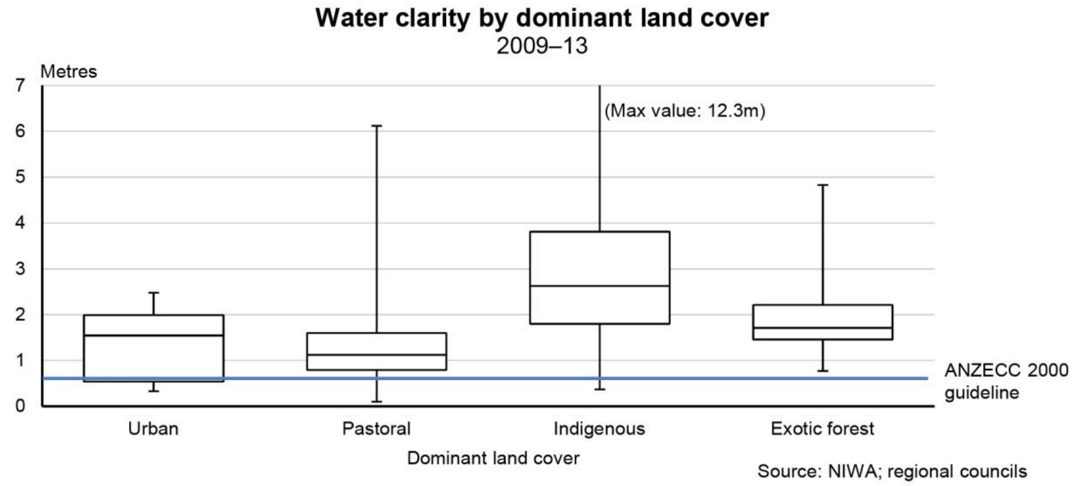
Note: The ends of each 'box' in the box-plot are the upper and lower quartiles (25 percent of the sites are either higher or lower than these values). The top and bottom 'whiskers' represent the highest and lowest value. The middle line of the box represents the median (middle) data point (half the sites are above and half below this value). The maximum values for pastoral and urban are 1,750 *E.coli*/100 mL and 2,300 *E.coli*/100 mL, respectively (which are beyond the range of this figure). The blue line (at 1,000 *E.coli* per 100mL) represents the maximum acceptable limit for wading or boating (National Policy Statement for Freshwater Management 2014). Nationally, the proportion of river length classified as predominantly urban is 0.8 percent; pastoral, 45.8 percent; indigenous forest, 47.7 percent; and exotic forest, 5.6 percent.

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

Water clarity is better in areas with indigenous land cover

Water clarity is mainly affected by land cover, and is lower (worse) in pastoral lowland sites and higher (better) in hilly or mountainous areas covered by indigenous vegetation (see figure 27). The Australian and New Zealand guidelines for fresh and marine water quality (ANZECC 2000 guidelines) recommend a trigger value of 0.6 metres for lowland rivers and 0.8 for upland rivers. The guidelines recommend that rivers with water clarity below this level be actively managed.

Figure 27



Note: The ends of each 'box' in the box-plot are the upper and lower quartiles (25 percent of the sites are either higher or lower than these values). The top and bottom 'whiskers' represent the highest and lowest value. The middle line of the box represents the median (middle) data point (half the sites are above and half below this value). The maximum value for indigenous is 12.3 metres (which is beyond the range of this figure).The ANZECC 2000 guidelines recommend a minimum trigger value of 0.6 metres for lowland rivers and 0.8 metres for upland rivers. The guidelines recommend that rivers with water clarity below these levels be actively managed. Nationally, the proportion of river length classified as predominantly urban is 0.8 percent; pastoral, 45.8 percent; indigenous forest, 47.7 percent; and exotic forest, 5.6 percent.

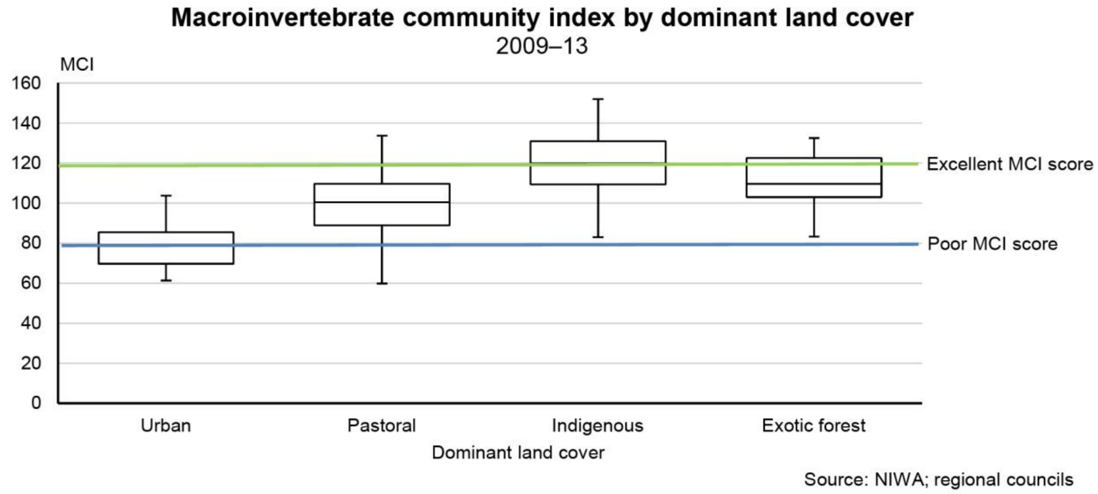
For more detail see *Environmental indicators Te taiao Aotearoa*: River water quality trends: clarity and Geographic pattern of river water clarity.

Macroinvertebrate levels are lowest in agricultural and urban catchments

The presence of macroinvertebrates (aquatic animals such as insects, freshwater crayfish, snails, and worms) in rivers is a good indication of stream health. Macroinvertebrates play an important role in stream ecosystems by feeding on plants and other aquatic life, and are a food source for fish. Rivers in New Zealand are scored based on the abundance of species sensitive to pollution using an index called the macroinvertebrate community index (MCI) (Stark & Maxted, 2007). A high index value (>100) generally indicates good river health.

Macroinvertebrates were assessed at 512 river sites between 2009 and 2013. The best MCI values were in catchments with predominantly indigenous vegetation in hilly areas. Most pastoral sites (in lowland and hilly areas) had MCI scores classed as fair to good. Fifty-five sites (about 11 percent) had a poor MCI value. All these sites were in urban and pastoral areas (see figure 28).

Figure 28



Note: The ends of each 'box' in the box-plot are the upper and lower quartiles (25 percent of the sites are either higher or lower than these values). The top and bottom 'whiskers' represent the highest and lowest value. The middle line of the box represents the median (middle) data point (half the sites are above and half below this value). A macroinvertebrate community index (MCI) greater than 119 indicates excellent river health, 100–119 indicates good health, 80–99 indicates fair health, and below 80 indicates poor river health (Stark & Maxted, 2007). Nationally, the proportion of river length classified as predominantly urban is 0.8 percent; pastoral, 45.8 percent; indigenous forest, 47.7 percent; and exotic forest, 5.6 percent.

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

Water quantity and availability

New Zealand has plentiful freshwater but not always where demand is greatest

New Zealand's average annual precipitation is about 550 billion cubic metres – enough to fill our largest lake (Taupō) nine times over. However, rain does not fall uniformly across the country, and this influences the amount of water flowing through our waterways.

The volume of water is generally lower in rivers and streams in the north and on the east coasts of the North and South islands (except for the larger rivers like Rakaia and Rangitata that flow from the Southern Alps).

For more detail see *Environmental indicators Te taiao Aotearoa*: Geographic pattern of natural river flows.

The largest volume of groundwater is stored in Canterbury aquifers

Aquifers are underground layers of water-bearing rock or sand from which groundwater can be extracted. They store water that can feed some lakes and rivers. Groundwater is also pumped directly from aquifers through wells and bores. Aquifers lie under 26.3 percent of New Zealand's land surface. About 200 aquifers have been identified nationally (see figure 29).

The volume of water stored in our aquifers is estimated to be about 711 billion cubic metres. Canterbury has an estimated 519 billion cubic metres of water in its aquifers (73 percent of New Zealand's total groundwater volume). Waikato has the next largest volume of groundwater (4.9 percent), followed by Bay of Plenty (4.4 percent), and Taranaki (3.5 percent).

Between 1994 and 2014, groundwater volumes varied by less than 2 percent, providing a relatively stable source of fresh water. About 20 percent of the water allocated for irrigation, drinking water, stock water, and hydroelectricity generation is estimated to be extracted from groundwater (Aqualinc Research, 2010).

Figure 29

Note: Identification of aquifers is limited by a number of factors, including different methods for identifying aquifer boundaries, and the scale at which mapping has been undertaken.

For more detail see *Environmental indicators Te taiao Aotearoa*: Location and extent of New Zealand's aquifers and Water physical stocks: precipitation and evapotranspiration.

Trends for groundwater quality are unclear

Groundwater and the water in rivers, lakes, and wetlands are part of a single hydrological system. However, it can sometimes take decades for water (and any contaminants it contains) to cycle from Earth's surface through the ground to aquifers, and then back into surface water systems.

From 2004 to 2013, there were no overall trends for groundwater quality. Over the 10-year period, 86 groundwater sites were analysed for nitrate trends. Nitrate concentrations increased at 22 of the sites (26 percent), but decreased at 13 sites, resulting in no overall trend. There was also no overall trend for dissolved phosphorus.

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

Lake water quality is lower in urban and agricultural catchments

Nutrients can accumulate in lakes and, above certain levels, cause them to become murky and green with algae. The lake trophic level index (TLI) indicates the health of a lake based on its concentration of nutrients. In general, a higher TLI means poorer water quality. Lakes with extremely poor water quality are rarely suitable for recreation and provide poor habitats for aquatic species. Four percent of lakes are currently monitored, but this proportion includes many of the largest and most popular lakes close to urban areas.

Between 2009 and 2013, the median TLI score for 65 monitored lakes was 3.6. This score reflects moderately nutrient-enriched conditions. The TLI is lower (better) in deep lakes in hilly country or mountainous areas dominated by indigenous vegetation. It is higher (worse) in lowland shallow lakes fed by urban or agricultural catchments. Trends were assessed for 30 lakes, mainly located in Northland and the Bay of Plenty. During 2004–13, the TLI significantly increased (worsened) for 11 lakes (37 percent) and significantly decreased for four lakes (13 percent). A trend could not be determined for 15 lakes (50 percent).

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

Wetlands occupy about 10 percent of their original extent

Wetlands perform a variety of functions, often described as 'ecosystem services'. They filter nutrients and sediment from water; absorb floodwaters; and provide habitat for plants, fish, and other animals.

In 2008, wetlands occupied approximately 250,000 hectares (or 1 percent) of New Zealand's land area – only about 10 percent of their original extent. The West Coast has the greatest extent of wetlands (84,000 hectares), followed by Southland (47,000 hectares), and Waikato (28,000 hectares).

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

Land

The land domain comprises the soil, the underlying rock, and what is on the land surface, such as vegetation and human-made structures. The way we use our land influences its productivity, and affects our indigenous biodiversity and ecosystems.

Overview

This chapter provides information on why the condition of our land is important, and presents information on the pressures and state of our land, and how this state is changing over time.

Our land – a summary

New Zealand has been occupied by humans for only 700–800 years, but in that time our land has gone through transformative change. When humans arrived, we think that forests covered all but the tops of mountains and the wettest parts of the lowlands. Wetlands covered extensive areas of both islands, particularly in lowland and coastal areas. Today, about one-third of this forest remains, concentrated mainly in upland and mountainous areas. Wetlands are reduced to about 10 percent of their original extent.

Farmland has taken the place of most of our forests and wetlands. Agricultural and horticultural land occupies about 42 percent of New Zealand, while plantation forestry covers a further 7.5 percent. The extent of agricultural land has not changed significantly since 1996, but its use has become more intensive in some regions. Agriculture is central to our economy, and along with other production from the land, it makes a major contribution to New Zealand's export earnings. The ongoing productivity of our land is therefore important, as it underpins our economic and social well-being.

The most critical issue affecting the productivity of land is erosion, which first became a major problem in the early 20th century. Large areas of steep terrain, unstable underlying rock, and high rainfall make our land prone to erosion. Natural erosion occurs particularly in alpine areas like the Southern Alps, where little vegetation exists and high rainfall occurs. When humans settled, they cleared forests and turned large areas into pasture, which expanded the area of the country vulnerable to erosion. From the 1940s, tree planting and other methods of soil conservation were successful in curbing soil erosion to some extent, especially in its most extreme forms. However, erosion remains a problem in New Zealand, particularly in the north and east of the North Island. Erosion affects productivity because topsoil, which has built up over millennia, contains most of the nutrients in the soil. When topsoil is washed into waterways, the underlying soil's fertility is degraded. Erosion also affects water quality because it adds sediment and nutrients to waterways.

Compacted soils also affect land productivity. Soil compaction is evident on land used for farming animals for dairy, meat, wool, and velvet, and is made worse by higher stocking rates and heavier stock. Over half of the land used for dry stock and nearly 80 percent of soils under dairy farming are affected by compaction. This can adversely affect productivity because compacted soils can impede pasture growth and the capacity of the soil to hold water, resulting in greater run-off.

The leaching of nutrients from farmland is an issue affecting our rivers, lakes, and estuaries. This happens when we apply more nutrients to the land than grass and other plants can use. When an excess of nutrients flow into waterways, they cause unwanted plants to grow, affecting water quality. Nitrate leaching has been an issue for some decades, but has grown in significance as farming intensified in many parts of the country.

We are also interested in the ability of the land to support indigenous animals and plants. The decrease in the extent of indigenous forests, wetlands, and other habitats since human settlement has reduced the area where indigenous plants and animals can live. In addition, humans brought with them numerous animals and plants from other parts of the world. Some of these animals prey on indigenous species or compete with them for food or habitat, while many introduced plants invade indigenous habitats. These pressures have led to a significant number of species becoming extinct, and many species continue to face this risk.

While the loss of indigenous habitats has slowed, pests continue to pose a serious threat to our indigenous animals, plants, and habitats. Today, possums, rats, and stoats are the most widespread of our pests – they are found across at least 94 percent of the country.

Why the condition of our land is important

Our agricultural, horticultural, and forestry industries, which all make a major contribution to our economy and support our way of life, depend largely on land. Our land environment also provides the habitat for many of our indigenous plants and animals – many of which exist nowhere else on Earth. Land provides food and materials, such as timber, and supports ecosystem services, such as the filtering of water.

For Māori, the whenua (land) is a source of identity, food, and other resources that have sustained people for hundreds of years. In Māori mythology, the whenua is Papatūānuku, the Earth Mother. All gods – and ultimately people, are descended from her and Ranginui, the Sky Father. The landscape therefore represents ancestors from whom people are descended. Land is also the site of wāhi tapu (sacred sites) and wāhi taonga (historical sites and other places of significance to Māori), such as urupā (cemeteries), battlegrounds, and locations for gathering precious resources.

Land supports our economic well-being

Agriculture, forestry, and horticulture made an important contribution to our economy. In 2014, dairy and meat exports alone accounted for 41 percent of the total value of merchandise exports. The relative contribution of the dairy sector to our gross domestic product (GDP) has been increasing, overtaking sheep, beef, and grain farming combined.

For more detail see *Environmental indicators Te taiao Aotearoa*: Economic performance of the agricultural industry.

Tourism also makes an important contribution to our economy – our national parks and open spaces are a major attraction for overseas visitors (Statistics NZ, 2014). In 2012, mining contributed 1.9 percent to GDP (Statistics NZ, 2012), about one-quarter of which is land-based, with the rest marine-based, such as oil and gas.

Agriculture provides employment, particularly in rural areas. In 2013, agriculture employed more than 105,500 people, making the sector the second-largest 'employer' in New Zealand. Many businesses and industries in New Zealand exist because they provide products or services to the agricultural sector.

Land supports our indigenous biodiversity

Our land environment is habitat to over 200 bird, 57 reptile, four bat, three frog, and around 2,380 plant species (excluding non-vascular plants such as mosses and algae). Of these, 78 percent of vascular plants and 91 percent of animal species exist nowhere else on Earth (ie they are 'endemic') (Gordon, 2013). The habitats many of them occupy are also unique, and require specific conditions to be sustained. The continued survival of our plants, animals, and their habitats depends on the ability of the land environment to support them.

Since our arrival in New Zealand, humans have modified the land to support our economy and way of life. This began with the arrival of Polynesians seven or eight centuries ago. Following their arrival, about half the forest in the South Island and about one-quarter of the forest in the North Island were destroyed by fire (Ministry for the Environment, 1997). All nine moa species and many other animals became extinct. Polynesians brought with them animals and plants to support their survival, some of which had an impact on indigenous animals.

After European settlement in the 19th century, milling and burning further reduced forest to about one-third of its original extent, while farming and settlements drained about 90 percent of wetlands. Natural dune lands reduced by 80 percent, as people stabilised and developed them for farming, settlement, and forestry. Europeans also brought animals and plants, a significant number of which have become pests.

The loss of indigenous habitats has slowed, but not stopped. Pest animals and plants now pose the greatest threat to the survival of many of our animals and plants.

For more information on pest species see: The pressures on our land section.

Benefits from land ecosystem

Land-based (terrestrial) ecosystems have many functions that benefit people. These functions, called ‘ecosystem services’, provide food and materials, regulate water flow, and maintain soil stability and fertility. However, the degradation of ecosystems can affect their capability to provide these services, which in turn can affect our economic, social, and cultural well-being. For example, wetlands filter (clean) water, act as a buffer for floodwaters, and are a rich source of freshwater fish. Wetlands remain central to the well-being of Māori, who depend heavily on them for tuna (eels) and other freshwater fish, and for harakeke (flax), raupō (bulrush), and kiekie (a climbing plant used for weaving).

The pressures on our land

New Zealand lies on two tectonic plates with edges that rub against each other. The resulting earth movements produced hilly and mountainous terrain over two-thirds of the land, with frequent earthquakes in most parts of the country and a zone of volcanic and geothermal activity. Much of the rock beneath our soils is relatively unstable, making the land prone to erosion. This instability is exacerbated by heavy rainfall in many regions, especially where the original forest was cleared and replaced with pasture. This is because grass is shallow-rooted and does not have the stabilising capability of deeply rooted trees. Our soils, which mostly evolved under forests, tend to be acidic with low levels of nutrients such as nitrogen and phosphorus.

Our mountainous terrain created fast-flowing rivers, which in times of heavy rain can breach their normal course and cause widespread damage to land. Climate change is also likely to bring more extreme weather in the future, leading to more flooding and erosion.

These natural pressures influence everything we do on our land – for example, agriculture and other primary production, urban and infrastructural development, and mining.

Humans have created additional pressures that affect land productivity and its ability to support biodiversity. These pressures will be discussed in this section.

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

Land use

This section describes two of the key pressures on our land: land use and pests.

Agriculture is the main land use with farming intensifying in some regions

Agriculture is a major contributor to our economy, but it has a considerable effect on the condition of our land and fresh water in New Zealand.

The area of pastoral farming (grazing of livestock) in New Zealand remained relatively stable between 1996 and 2012, but in some regions the nature of farming and its intensity have changed. These changes have put more pressure on land, and on our freshwater and marine environments.

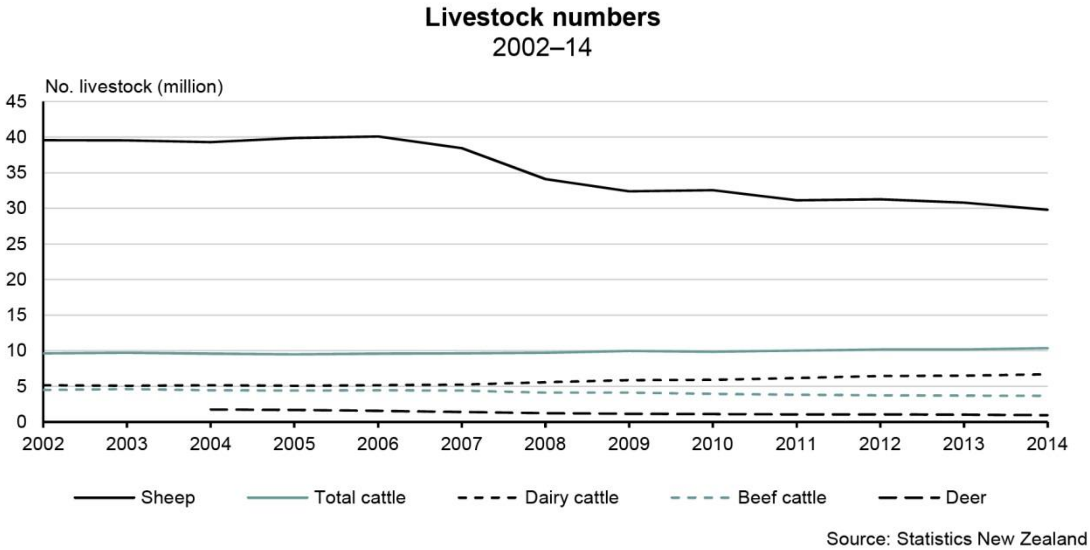
Intensive farming is characterised by higher stocking rates, repeated cultivation, and increased inputs to produce more food from the same area of land. These inputs include fertilisers, supplementary feed, water for irrigation and livestock, pesticides, herbicides, and energy.

Dairy farming is the main driver of recent farming intensification. Between 2002 and 2012, the area of dairy farming in New Zealand increased 28 percent. Most of this expansion was made by converting sheep and beef farms, which decreased in area by almost 11 percent. (Note that sheep and beef farming covers a significantly greater area than dairy farming, so this percentage change translates into a larger area relative to dairy farming.) In some regions this change was more pronounced – dairy farm areas in Canterbury, Otago, and Southland doubled between 2002 and 2012.

For more detail see *Environmental indicators Te taiao Aotearoa*: Farm size.

As the area of dairy farming increased, stock numbers also rose. From 2002 to 2014, the number of dairy cattle (including bobby calves) increased 30 percent, to about 6.7 million stock (see figure 30).

Figure 30



Note: All livestock numbers calculated as of June each year. Dairy cattle figures include bobby calves. Deer figures for 2002 and 2003 are not included – they are not comparable with those from 2004 onwards due to a change in survey design.

Farming intensification also affects land productivity. The treading of cattle, especially in wet conditions, can compact surface soil, which reduces pasture growth and the capacity of the soil to hold water, resulting in greater run-off. The potential for compaction is higher when stocking rates increase or a shift to heavier stock is made.

While increased use of nitrogen fertilisers and higher stocking rates can increase production, nutrient leaching and run-off can degrade the ecological health of fresh water.

For information about these pressures on fresh water, including the extent and impact of changes in nitrogen fertiliser use, see: The pressures on our fresh water section.

Other land-use pressures

Urban expansion also affects the productivity of land and its ability to support biodiversity. Between 1996 and 2012, New Zealand's area of urban settlement increased 10 percent. In the same period, our total population increased 18 percent, with most of that increase being in the Auckland region (53 percent), followed by Canterbury (11 percent), and Waikato (9 percent) (Statistics NZ, nd). Population growth and urban expansion, particularly when concentrated in specific areas, put pressure on our air, freshwater, land, and marine environments.

Expanding residential or rural residential areas (or lifestyle blocks) also affects land productivity – for example, by building on highly productive areas well-suited to producing vegetables, fruit, and grains.

For more detail see *Environmental indicators Te taiao Aotearoa*: High-class land for food production.

Pests

Animal and plant pests are the greatest threats to indigenous biodiversity and habitats in New Zealand. They also affect the productivity of agricultural and other productive land.

Of all animal pest species, possums, rats, and stoats are the most widespread in New Zealand. They are found across at least 94 percent of New Zealand, absent only from the tops of mountains and a few predator-free sanctuaries and offshore islands. Rats and stoats prey on indigenous birds, while possums eat large quantities of indigenous vegetation and prey on indigenous birds. Possums also pose a threat to the health of cattle and deer because they carry bovine tuberculosis.

From the available data we have for this report, we cannot draw any definitive conclusions about how their numbers and distribution have changed over time. However, we know that population 'explosions' of rats and stoats are associated with 'mast' events (ie when beech and other indigenous trees produce large amounts of fruit and seed). Rat and stoat populations can increase to up to five times their normal peak numbers in these masting seasons.

Feral goats and red deer are present in more than 30 percent and 57 percent of the country, respectively, mainly in forested and alpine regions. They do not pose as great a threat as the 'big three' (possums, rats, and stoats).

New Zealand has more species of exotic plants than indigenous ones. Many have become invasive in forests, tussock grasslands, wetlands, and other indigenous environments. Wilding pines (primarily Lodgepole pine and Douglas fir) have become one of our major plant pests in New Zealand. They can rapidly colonise tussock grassland or shrubland, become dominant, and make it less suitable as habitat for indigenous species. They are a specific problem in farmland and tussock grasslands in Canterbury and Otago.

Many introduced plants are also a nuisance on farms and forest plantations – they can poison or harm animals, clog irrigation channels, and smother crops.

For more detail see *Environmental indicators Te taiao Aotearoa*: Land pests and Modelled rat and stoat population responses to mast-seeding events.

The state of our land

In this section, we provide information on the condition of the land environment and how it is changing over time. We measure this condition through indicators such as land cover, extent of erosion, soil health, the conservation status of indigenous animals and plants, threatened land environments, and the distribution of indigenous trees.

Land cover

Nearly 40 percent of New Zealand is exotic grassland (primarily pasture used to graze stock). This percentage remained relatively stable between 1996 and 2012 (see figure 31).

Mature indigenous forest and regenerating forest ('broadleaved indigenous hardwoods' in table 2) cover 26 percent of the country. Most of this forest and regenerating forest is concentrated in hill and mountain areas, with little lowland forest remaining. Tussock grassland covers 8.7 percent of the country, mostly in the high country of Canterbury and Otago.

Plantation forest covers 7.5 percent of total land area, while crop lands, orchards, and vineyards account for 1.8 percent. Urban settlements cover 0.8 percent of total land area.

The first New Zealand-wide assessment of land cover using satellite imagery was in 1996. Between 1996 and 2012, three areas increased:

- exotic forests (up 11.5 percent or 208,000 hectares)
- urban areas (up 10.1 percent or 21,000 hectares)
- cropping/horticulture (up 9.6 percent or 41,000 hectares).

A decrease of more than 10,000 hectares in indigenous forest and regenerating forest (broadleaved indigenous hardwoods in table 2) occurred during this period. While this represents a small change (0.26 percent) in statistical terms, it is ecologically significant because any loss in forest also leads to a loss in ecosystems and the plants and animals that inhabit these ecosystems. Once indigenous forest is lost, it is difficult to restore.

Table 2: Area of land cover by main land-cover classes

Class	Area (hectares) 2012	Percent of total land area 2012	Percent change 1996–2012
Indigenous forest	6,390,000	23.8	–0.2
Broadleaved indigenous hardwoods	587,000	2.2	–1.2
Scrub	1,538,000	5.7	–3.1
Tussock grassland	2,338,000	8.7	–1.3
Alpine vegetation	653,000	2.4	0.1
Other indigenous vegetation	335,000	1.2	–1.3
Exotic forest	2,020,000	7.5	11.5
Exotic grassland (pasture)	10,675,000	39.8	–1.6
Cropping/horticulture	473,000	1.8	9.6
Urban	227,000	0.8	10.1
Bare ground	957,000	3.6	0.2
Snow and ice	111,000	0.4	..
Water	537,000	2.0	0.5

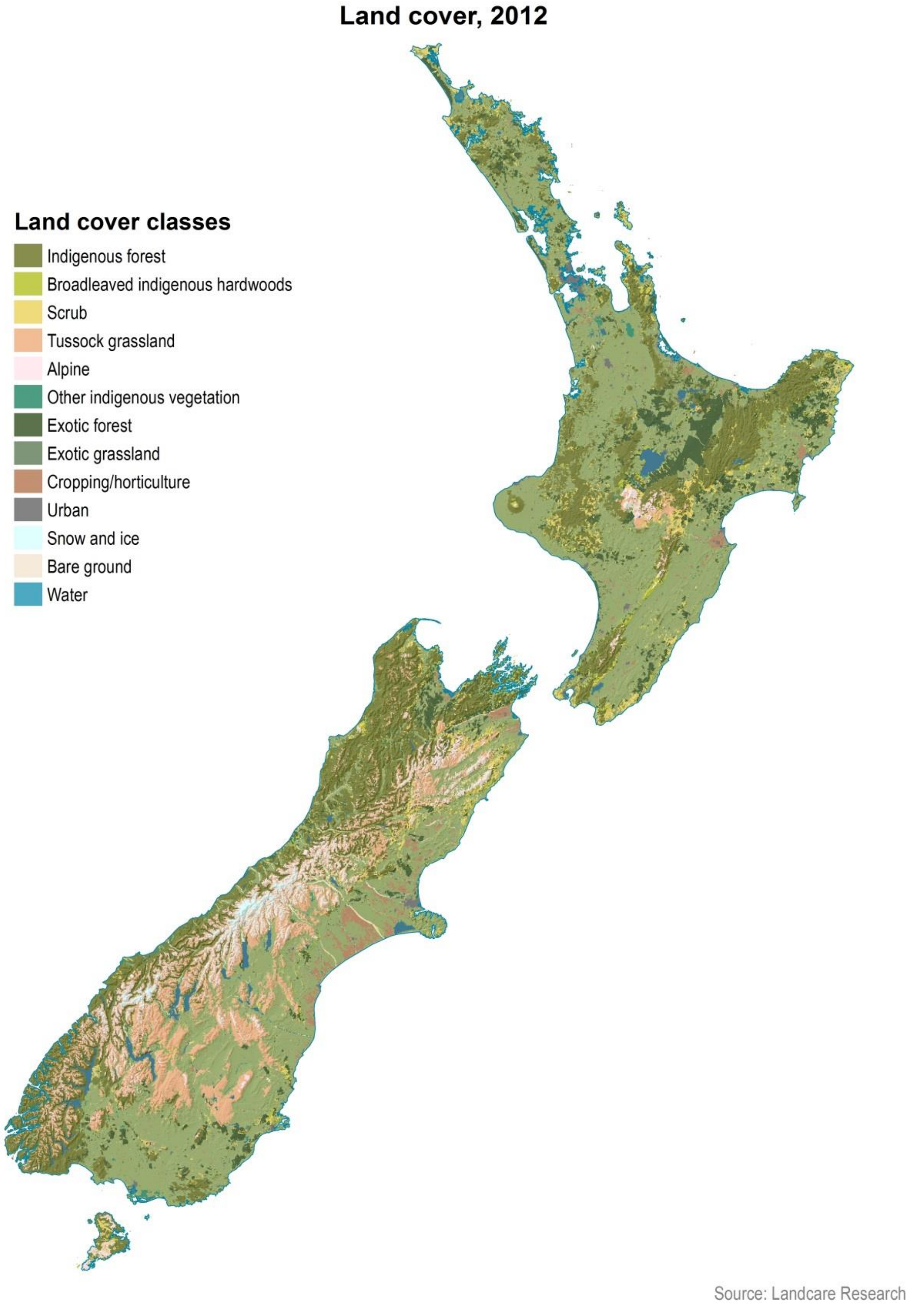
Source: Landcare Research

Note: 'Scrub' includes both indigenous (eg kānuka and mānuka) and exotic species (eg gorse and blackberry). 'Broadleaved indigenous hardwoods' is regenerating forest that has not yet recovered its tall dominant (typically conifer) species.

Total area of New Zealand calculated to 26,842,403 hectares. All areas rounded to nearest 1,000. Percentages are calculated using unrounded figures.

Symbol: .. figure not available. The area of snow and ice was calculated in 1996 and was not recalculated for land cover. For more information on glacier extent see: Atmosphere and climate chapter.

Figure 31



Note: Data is from the reclassified New Zealand Land Cover Database version 4.0.

Land stability and soil health

The condition of soils underpins the productivity of our land. This section examines three aspects of land and soil health – long-term soil erosion, the extent of land at risk of severe erosion, and soil health.

Human-caused soil erosion is higher in the North Island's north and east

Soil erosion reduces the productivity of land and limits future land uses. It also affects fresh water, as most eroded soil eventually washes into waterways and then out to sea. This affects water quality and the ecological health of rivers, streams, lakes, estuaries, and coastal environments. For more information see: The pressures on our fresh water section.

New Zealand loses around 190 million tonnes of soil into waterways and the ocean every year. This is estimated to contribute about 1.5 percent to global sediment loss, despite New Zealand making up only 0.2 percent of the global land area (Syvitski et al, 2005; Walling, 2008).

Gisborne has the highest rate of erosion in New Zealand, at about 4,800 tonnes per square kilometre annually, followed by the West Coast and Northland (2,100 and 1,160 tonnes per square kilometre, respectively) (see figure 32).

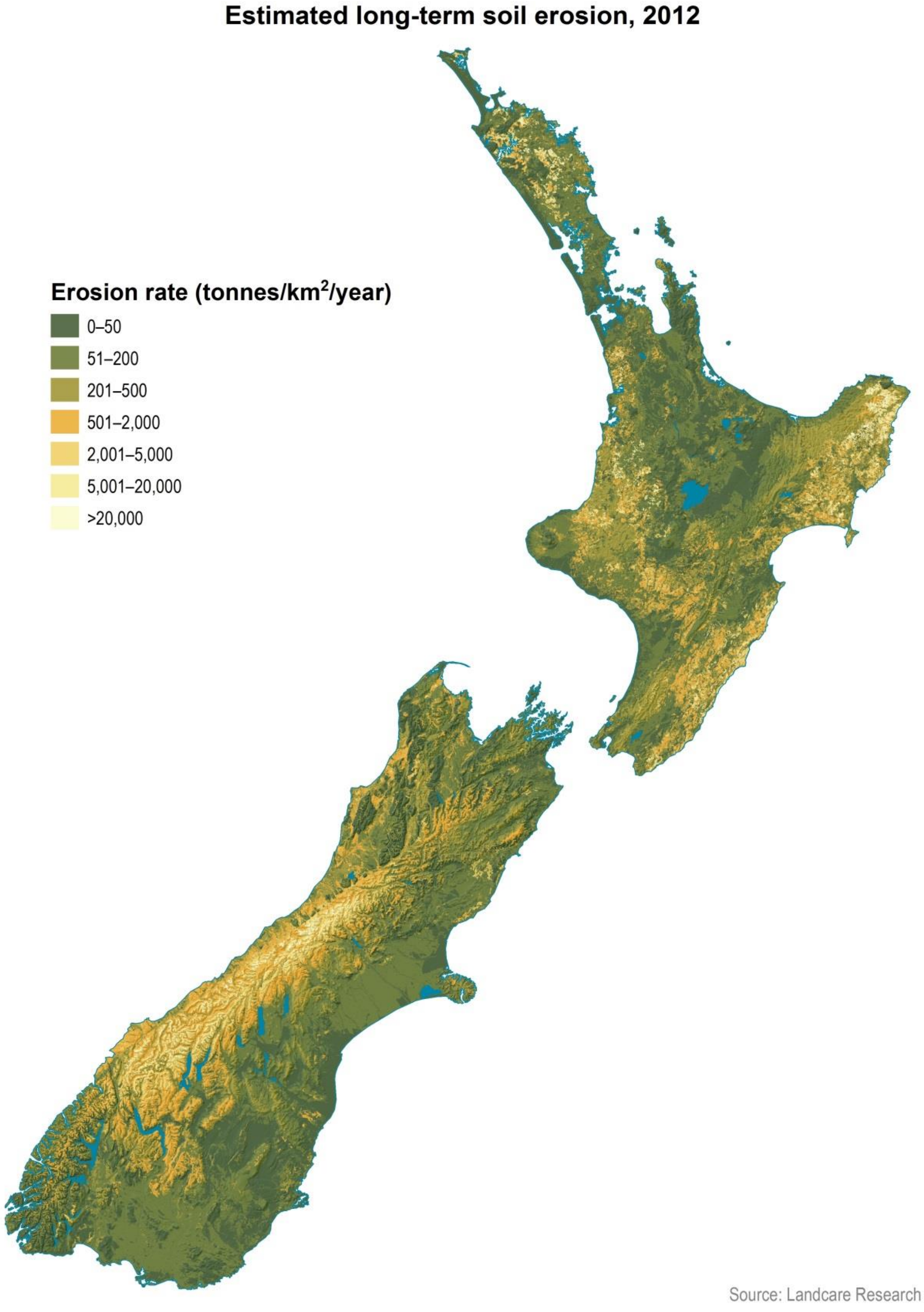
The North and South islands have high rates of soil erosion, but what causes this is different for each island. Soil erosion in the North Island occurs mainly in areas of hill country cleared of forest, often triggered by heavy rainfall. This also happens in the South Island but to a much lesser extent. In the South Island, serious erosion is due mainly to natural processes, such as rain and natural erosion, especially along the Southern Alps. Much of this land is in the public conservation estate or is extensively farmed land of low productive value, so the impact of such erosion on productivity is generally of less concern.

Nationally, we have no historical data for the average rates of erosion, and therefore cannot conclude whether erosion is increasing or decreasing. However, modelled data from Dymond et al (2010) suggest a downward trend in the extent of soil erosion since the early 1980s. They attribute this to an increase in plantation forestry and scrubland on land formerly used for agriculture.

Besides areas of actual erosion, 840,000 hectares of land have been identified in the North Island as being at risk of severe erosion. This assessment is based on land gradient, the presence of woody vegetation, and rainfall in the area. The extent of potentially erodible land was mapped only for the North Island because it has the greater risk from human-caused erosion. While this happens also in the South Island, it is not considered to be a widespread problem compared with the North Island. Regional councils and the Ministry for Primary Industries use this information to prevent erosion on susceptible land before it occurs.

For more detail see *Environmental indicators Te taiao Aotearoa*: Estimated long-term soil erosion and Estimated highly erodible land in the North Island.

Figure 32



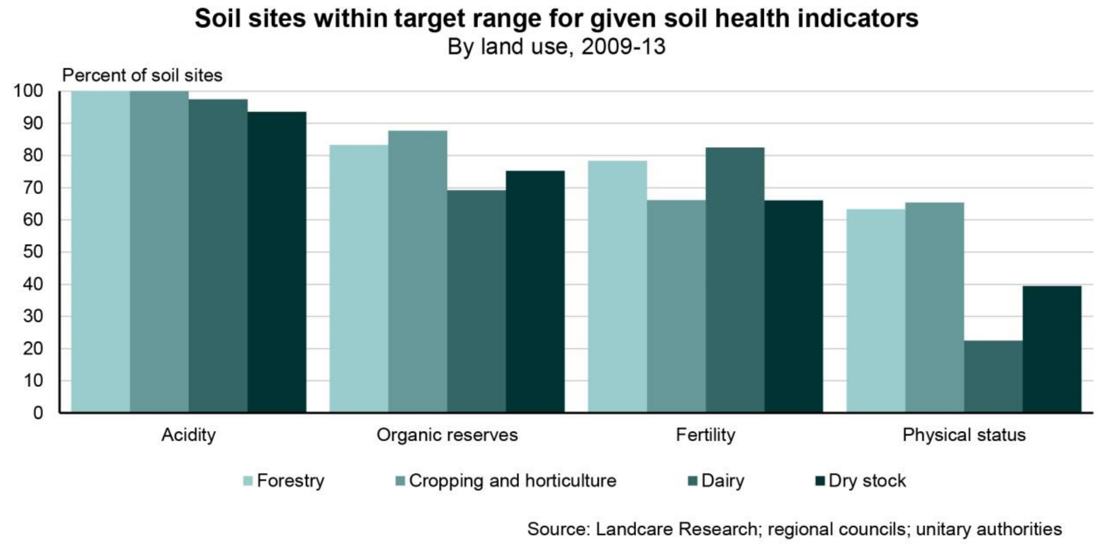
Note: Stewart Island is not mapped for erosion.

Most soil is in good condition but compaction is a problem on many dairy and dry-stock farms

Most of the soil surveyed by regional councils between 2009 and 2013 was in good condition overall, but compaction is a problem on many dairy and dry-stock sites. Councils measured 420 sites under four types of land use (cropping/horticulture, dairy, dry stock, and forestry) against soil health targets for acidity, fertility (phosphate available to plants), organic reserves (carbon, nitrogen, and mineralisable nitrogen), and physical status (how compacted the soil is).

More than 90 percent of sites met the targets for acidity, while the majority of sites met the targets for organic reserves and fertility (see figure 33). However, only 23 percent of dairy sites and 39 percent of dry-stock sites met the target for physical status (meaning they had high levels of compaction).

Figure 33



A high degree of compaction affects productivity because plant roots need spaces between soil particles to grow, while soil organisms need this space to 'breathe'. Compacted soils are often slow-draining, becoming water-logged when wet. This can lead to run-off and soil erosion (Mackay, 2008).

Compaction is generally caused by machinery or trampling by stock. The extent of compaction depends on many factors – the size and number of stock, the amount of organic matter (which makes soil more resilient to compaction), and moisture in soil (wetter soils are more prone to compaction).

Of all soil health problems, compaction is the hardest to remedy. High acidity can be addressed by adding lime; low fertility levels can be supplemented by adding phosphate fertilisers; and low organic reserves by applying nitrogen fertilisers. In contrast, the best way to address compaction is to 'rest' the soil, which takes time.

For more detail see *Environmental indicators Te taiao Aotearoa*: Soil health and land use.

Indigenous ecosystems and species

This section presents information on the state of our indigenous ecosystems – the threat status of indigenous plants and animals, the condition of our indigenous environments, and the populations of common forest trees.

Many indigenous plants and animals are at risk of extinction

Despite conservation efforts, many indigenous plants and animals are at risk of extinction, and for a substantial number of these, the risk is increasing.

Of 2,378 indigenous vascular plants, 235 are threatened with extinction and 683 are at risk (ie they are not currently threatened with extinction, but risk becoming so). Combined, this represents nearly 40 percent of our indigenous vascular plant species (de Lange et al, 2013). Seventy-two percent of our indigenous freshwater fish are at risk or threatened (Goodman et al, 2014). Freshwater habitats are directly affected by the way we use land – through discharges of effluent from industrial and urban sources; run-off from farmland; dams and other barriers to migration; and clearance of vegetation along waterways. Of our 203 living bird species, more than 80 percent are now threatened or at risk. Many are marine birds, but all birds roost and breed on land where they are prey to rats and mice (Robertson et al, 2013). Our lizard species are also decreasing – nearly 90 percent are threatened or at risk (Hitchmough et al, 2013).

The extinction risk for a number of land species worsened between 2005 and 2011, including 30 plant, 11 bird, and one bat species. The extinction risk for eight species of birds, three species of weta, and one bat species improved.

For more detail see *Environmental indicators Te taiao Aotearoa*: Changes in the conservation status of indigenous species.

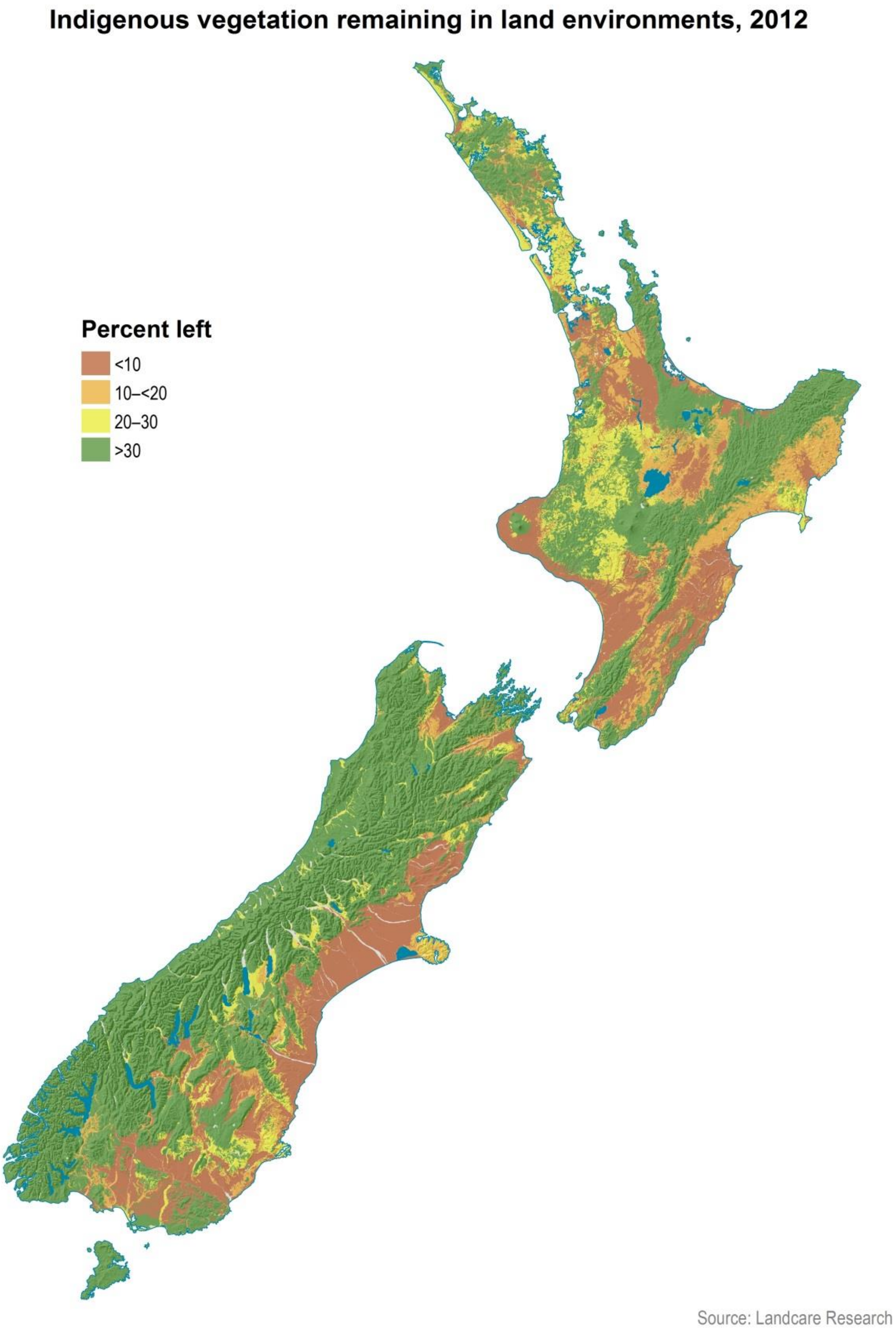
Remaining indigenous environments are not representative of original extent

Nearly one-third of our land environments have less than 10 percent of their indigenous cover, while 46 percent have less than 20 percent remaining. Scientists have identified 500 land environments, representative of all of New Zealand, based on their landforms (terrain and topography), soils, and the climates that influence them. Land environments help us understand the unique characteristics that shape localised environments, producing distinctive ecosystems and habitats for plants and animals.

Our most threatened indigenous environments are in coastal and lowland areas, particularly in the east of the South Island and most of the North Island (see figure 34). While New Zealand has relatively large areas of beech forest in mountainous areas of both islands, it has only small proportions of its coastal, wetland, and lowland forests remaining. These forests, often referred to as podocarp/broadleaf forests, are characterised by podocarp species such as rimu, tōtara, and kahikatea, and broadleaf species such as pukatea and rātā. In the north of the North Island, only a few kauri forests remain.

This measure of vegetation cover (also known as 'threatened environments') does not distinguish between forms of indigenous vegetation. This means that any form of indigenous vegetation is included in the assessment – not just the vegetation originally associated with the environment. For example, kānuka/mānuka scrub is considered indigenous vegetation, even if it is in environments where lowland mixed podocarp forest once grew. Therefore, the vegetation and ecosystems associated with some environments may be more at risk than this measure indicates.

Figure 34



For more detail see *Environmental indicators Te taiao Aotearoa*: Indigenous cover and protection in land environments and Rare ecosystems.

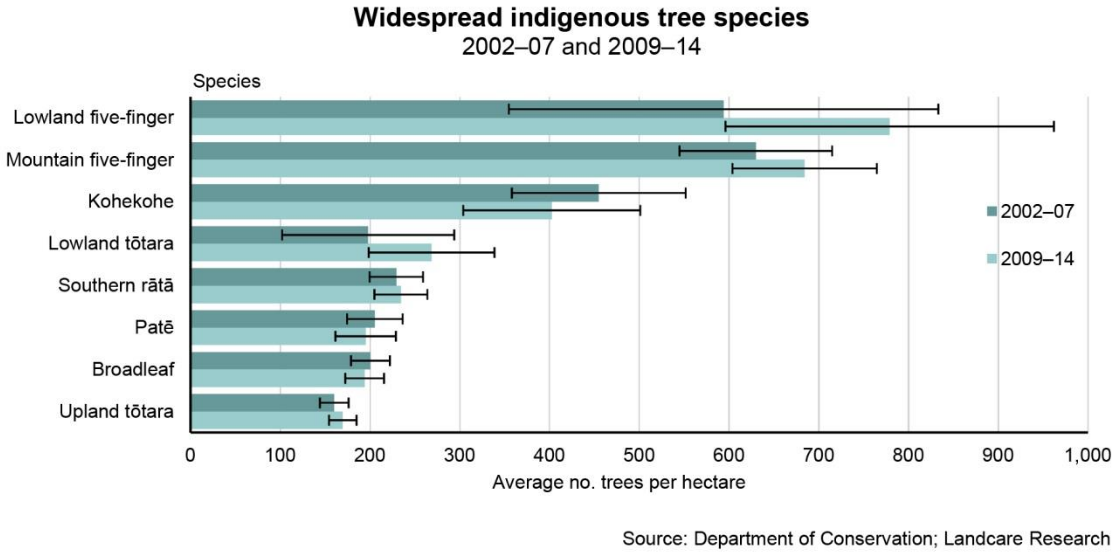
Common indigenous tree populations are stable

The populations of common indigenous forest trees have been stable for about 10 years. The presence of a widespread species is an indicator of general forest health across the country. A species' age structure is one factor that helps us understand the overall health of indigenous forests. Just like the human population, an imbalance in birth and death rates may indicate that something is disturbing the normal cycle of growth.

Forests are surveyed across New Zealand to monitor the carbon they capture and store. Data about biodiversity is also gathered as part of this work. The population structure of eight common tree species was assessed in two survey periods – in 2002–07 and 2009–14 (see figure 35). The information came from 869 sampling plots across public conservation land and private land. Because deer, goats, and possums eat these eight species, their population structure tells us about the extent of damage caused by these pests and the effect on the rate of regeneration of each species.

Nationally, the population structure of the indigenous forest trees surveyed was stable between the surveys. No significant changes occurred in the number of trees per hectare for the eight tree species investigated in the two surveys (see figure 35).

Figure 35



Note: Error bars represent standard error. Surveys with overlapping error bars are unlikely to be significantly different.

These results suggest that, for the eight tree species surveyed, just as many trees are becoming established as are dying, and therefore, on a national scale, indigenous forests are maintaining their ability to regenerate. However, some tree species are more vulnerable to pests than others. Deer, goats, and possums prefer to eat certain tree species, which may cause the tree to die. In the long term, this affects populations of these tree species, and can lead to them becoming locally extinct. This can affect the forest overall, adversely affecting its suitability as a habitat for some animal species.

For more detail see *Environmental indicators Te taiao Aotearoa*: Status of widespread indigenous trees and Pest impacts on indigenous trees.

Ecosystem function

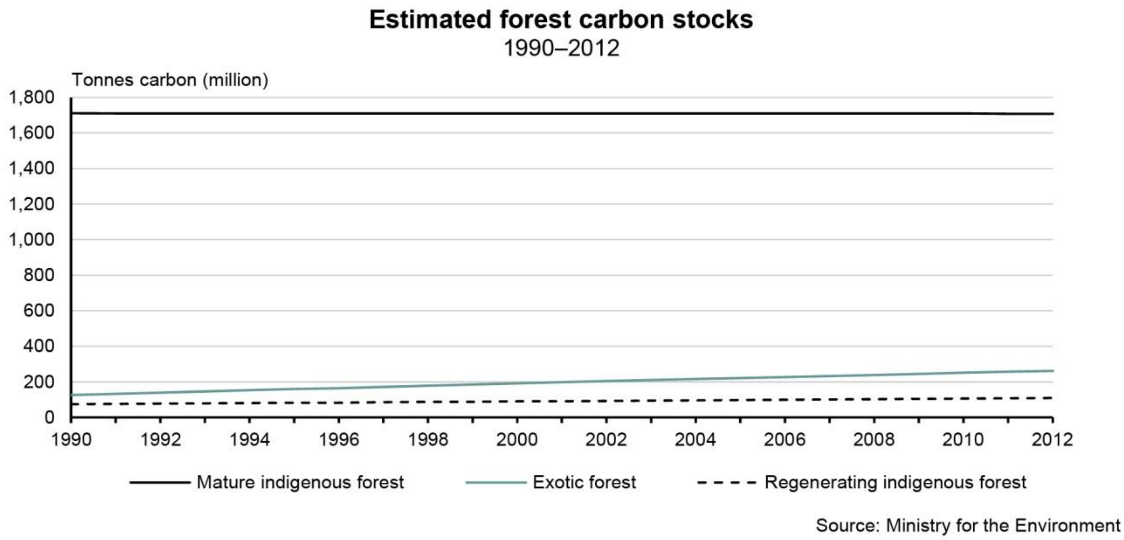
We have limited data on how well our forests and other land environments function from an ecological perspective, but have information about the carbon captured by our forests. Plants capture carbon through photosynthesis, so the ability of forests to capture and store carbon provides an indication of how well forests function as ecosystems. Carbon capture (or carbon sequestration) is an ecosystem service because it removes carbon dioxide (a greenhouse gas linked to climate change) from the atmosphere. We gather this data to report on greenhouse gas emissions as required by the Kyoto Protocol.

For more information see: Atmosphere and climate chapter.

Forests absorb carbon from the atmosphere

Our mature indigenous forests store an estimated 1,708 million tonnes of carbon – this amount changes little from year to year owing to the limited growth of these forests. Exotic and regenerating indigenous forests capture additional carbon, adding an estimated average of 8.2 million tonnes each year (calculated between 1990 and 2012; see figure 36). Because plantation forests and regenerating forests grow faster than mature forests, they capture more carbon than mature indigenous forests. When forests grow, their stocks of carbon increase.

Figure 36



This sequestering function can have economic value when it is used to offset the cost of greenhouse gas emissions from other sectors such as transport, energy, and agriculture.

For more detail see *Environmental indicators Te taiao Aotearoa*: Estimated forest carbon stocks.

Marine

The marine domain extends from the seashore to the outer limits of New Zealand's exclusive economic zone, and includes the continental shelf. Our marine environment supports biodiversity, fishing, oil and gas and minerals extraction, tourism, and recreation. The long-term condition of our oceans is affected by climate change.

Overview

This chapter explains why the condition of our marine environment is important. It presents information about the pressures and state of New Zealand's marine environment, and how its state is changing over time.

Our marine environment – a summary

The marine domain extends from the coast to the outer limits of New Zealand's exclusive economic zone (EEZ, the 200 nautical mile limit) and includes the extended continental shelf (see figure 37). Together, our territorial sea (extending to the 12 nautical mile limit) and our EEZ cover 4 million square kilometres, which is 15 times bigger than our land area. When the extended continental shelf is included, our marine environment is 21 times larger than our land area.

New Zealand has one of the world's most diverse marine environments because it encompasses subantarctic and subtropical waters. Our marine environment supports a wide range of habitats and sea life.

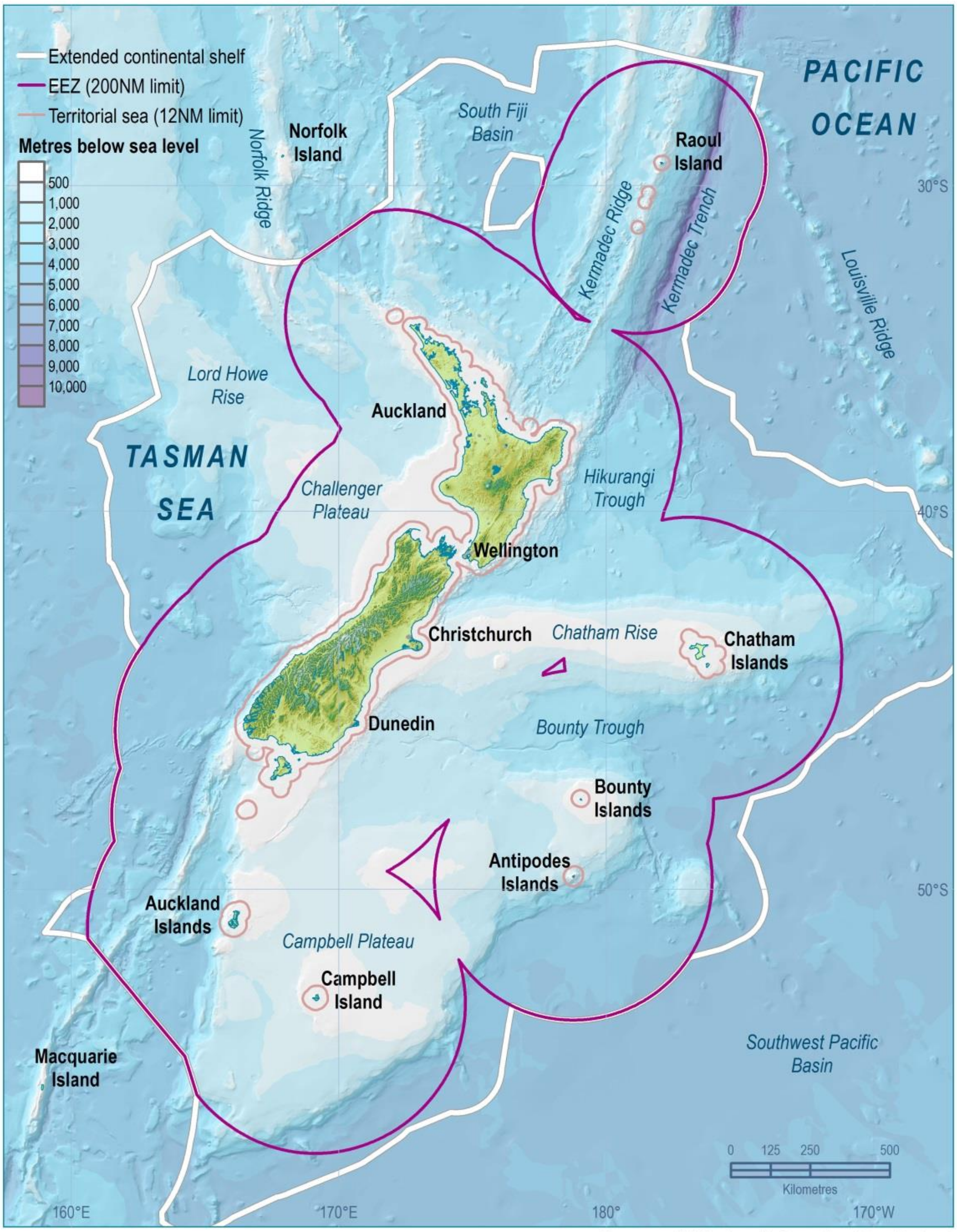
The oceans have played an important part in the lives of New Zealanders and our economy since Polynesian settlers arrived 700–800 years ago. Hunting and harvesting depleted some sea life, particularly larger animals such as seals, sea lions, and whales. Commercial harvesting is carefully managed now to ensure it is economically sustainable, but fishing methods such as trawling that damage the marine environment, as well as overfishing and bycatch (when fish and other animals are unintentionally caught in fishing gear) are ongoing pressures on sea life. While overfishing and trawling have decreased, many of our marine species and seabirds are still at risk from fishing activities. Aquaculture, the extraction of oil and minerals, waste, exotic species, and run-off from urban and agricultural land are also pressures on our marine environment, but we have little information on their impact on New Zealand's marine environment.

The most serious long-term pressures on our marine environment are likely to be caused by climate change. Coastal sea levels and long-term sea-surface temperatures around New Zealand have risen over the last century, and our oceans are more acidic than when measurements were first taken in 1998.

More than one-quarter of our indigenous marine mammal species are threatened with extinction, and the extinction risk of one mammal species, the New Zealand sea lion, has increased since 2005. Māui's dolphin is now one of the rarest marine mammals in the world, with an estimated 55 individuals more than a year old remaining. Ninety percent of indigenous seabird species and subspecies that breed in New Zealand are threatened or at risk of extinction. The risk of extinction has increased for seven of the 92 seabird species since 2005.

Figure 37

New Zealand's marine environment



Sources: NIWA; Land Information New Zealand

Note: Data from the satellite ocean colour sensors SeaWiFS and MODIS-Aqua. EEZ – exclusive economic zone; NM – nautical miles.

How our marine environment is monitored

From economic and ecological perspectives, the health of our fisheries (fish stocks that are harvested) and marine ecosystems is critical. Three government agencies monitor aspects of our marine environment. The Ministry for Primary Industries monitors fish stocks to ensure fishing is kept within sustainable limits under the quota management system for commercial catch. The Environmental Protection Authority is responsible for monitoring economic activities in our marine environment, such as aquaculture and exploration for oil and gas. The Department of Conservation monitors the marine environment to understand the state of its biodiversity and ecosystems.

Satellites now allow us to remotely monitor aspects of the marine environment such as sea-surface temperature, sea levels, and primary productivity (the amount of organic matter produced by plants and some microorganisms).

Regional councils monitor the quality of coastal water to check whether it is suitable for swimming and other recreational activities. Some iwi and hapū also monitor the health of the coastal marine environment in their rohe (area), using both scientific methods and mātauranga Māori (traditional knowledge).

The Government has designated marine reserves to help protect areas of the marine environment from fishing and disturbance from other activities. There are 44 marine reserves around our coast, all within the territorial sea. Collectively, these reserves cover 17,430 square kilometres, or about 10 percent of our territorial sea. They cover 0.4 percent of the territorial sea and EEZ combined. The Convention on Biological Diversity, of which we are a signatory, has a target of 10 percent of territorial sea and EEZ combined for marine conservation areas (Secretariat of the Convention on Biological Diversity, 2015).

Why the condition of our marine environment is important

The marine environment supports a diverse range of sea life that is important for global biodiversity. A healthy marine environment supports our cultural and social well-being, and the ocean's resources contribute to our economy.

The marine and coastal environment also plays a significant role in the Māori economy and way of life. A source of food and other resources since Māori first settled in New Zealand, the moana (ocean) is also spiritually and culturally important. Māori mythology and cosmology feature the sea god Tangaroa, son of the Earth Mother Papatūānuku and the Sky Father Ranginui.

Traditionally, the sea provided transport and a way to trade with other tribes. Kaimoana (seafood) was served to show hospitality at hui (meetings), tangi (funerals), and other gatherings. The marine environment remains important to Māori, from both customary and commercial perspectives.

The marine environment supports our economy

In 2014, the value of exports from New Zealand's ocean fisheries was $1,419 million, or about 3 percent of our total merchandise export earnings (from exported physical goods). From 2002 to 2014, the value of seafood exports grew 31 percent (Statistics NZ, 2014).

In addition to open-sea fisheries, fish farming (aquaculture) is a fast-growing industry. From 1989 to 2011, the value of aquaculture exports increased 500 percent, to $298 million (Aquaculture New Zealand, 2012).

Marine fisheries are also economically significant for Māori, who own about 40 percent of our commercial fisheries (Aotearoa Fisheries, 2014).

Oil and gas are significant contributors to our economy. About 80 percent of New Zealand's oil and gas production comes from marine fields, mainly in the Taranaki region. Oil and gas generate about $400 million a year in royalties (New Zealand Petroleum and Minerals, 2015). In 2014, the value of crude oil exports was $1,400 million (Statistics NZ, 2014). The petroleum and minerals industry directly employed 6,410 people in New Zealand in 2012.

The marine environment also supports our tourism industry. Numerous fishing, boating, and other enterprises such as whale-watching operations support the economies of communities in locations like Kaikoura, Marlborough Sounds, and Bay of Islands.

For more detail see *Environmental indicators Te taiao Aotearoa*: Oil and gas and minerals extraction and Value of fisheries and aquaculture.

The marine environment supports our indigenous biodiversity

New Zealand's marine environment is both complex and varied, and supports a diverse range of sea life. A primary reason for this is our geographical location: the New Zealand archipelago lies on an active tectonic plate boundary, at the confluence of subtropical and subantarctic water masses and ocean current systems. This means that New Zealand's marine environment includes a wide range of habitats and ecosystems, from rocky coastal reefs to deep trenches and seamounts (see figure 37).

Some of these marine habitats and ecosystems are especially important for biodiversity. For example, the Chatham Rise has our most ecologically productive offshore waters, and the Kaikoura Canyon provides a habitat for sperm whales close to the shore, which is a rare phenomenon anywhere in the world (Department of Conservation, 2015b).

Nearly one-quarter of the world's seabird species breed in New Zealand, and almost 10 percent breed only in our marine environment (Taylor, 2000). Nearly half of the world's whale, dolphin, and porpoise species are found in our waters, including threatened endemic species (found only in New Zealand) such as Māui's dolphin (Gordon et al, 2010; Taylor, 2000).

Only a fraction of New Zealand's vast marine environment has been explored, and there is still a lot that is not known about it. For example, we have only limited knowledge of the seafloor (the 'benthic environment'). While we have identified more than 17,000 marine species in our waters, experts estimate that between 17,000 and 65,000 species are yet to be identified (Gordon et al, 2010; Department of Conservation, 2015a).

For more detail see *Environmental indicators Te taiao Aotearoa*: Coastal habitats, Marine environments, and Changes in the conservation status of indigenous species.

Our coastal and marine environment supports recreation and culture

Many New Zealanders and overseas visitors enjoy recreational activities such as swimming, fishing, diving, and boating in our coastal beaches and oceans. The marine environment is also important to Māori for customary and spiritual reasons. Fish and shellfish, seaweed, and other resources from the sea remain an important part of the Māori economy and lifestyle.

New Zealanders want to know that their coastal waters are healthy and safe for recreational and customary use. The main health risk from swimming, diving, surfing, and other activities involving immersion in water is from ingesting pathogens (disease-causing microorganisms). Pathogens generally enter waterways through contaminated animal or human faecal matter.

Regional councils monitor popular swimming sites to assess the level of risk for recreational activities such as swimming. However, some inconsistencies in monitoring methodologies mean the data are neither representative nor comparable across all sites, and so do not meet our data quality standards for inclusion in this report. We are working with councils to develop more consistent monitoring and reporting, at a national level, of the suitability of coastal waters for swimming. In the meantime, you can look for information about your local swimming spot on the Land, Air, Water Aotearoa website.

The pressures on our marine environment

In this section, we describe the key pressures on our marine environment. We provide information about long-term climate change, and marine- and land-based activities that affect the marine environment.

Changes associated with greenhouse gas emissions are likely to have the greatest long-term impact on the marine environment (MacDiarmid et al, 2012b). Commercial fishing is an ongoing pressure on marine life. In particular, bycatch injures or kills marine animals, and trawling damages the seafloor. Land use can also affect the marine environment, particularly in coastal waters.

Long-term climate change

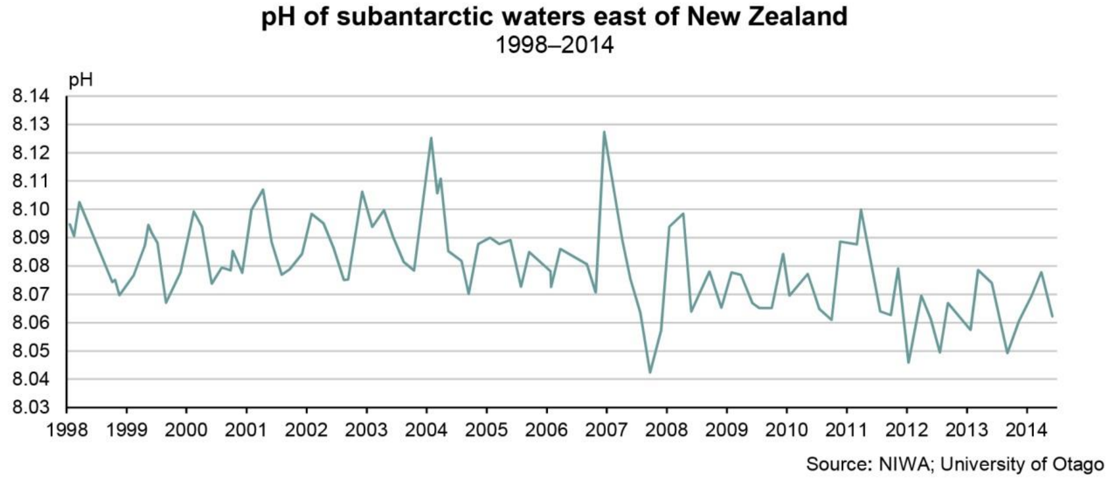
Global increases in greenhouse gases in the atmosphere have led to changes in the climate. In New Zealand, the concentration of carbon dioxide (one of the main greenhouse gases) has increased 21 percent since observations began in 1972 (see also Atmosphere and climate chapter). The increase in greenhouse gases, and especially carbon dioxide, in our atmosphere is changing our marine environment in three ways: it is leading to increased ocean acidification, rising sea levels, and increased sea temperatures over the long term.

Our oceans are becoming more acidic

The subantarctic waters east of New Zealand have become more acidic. Ocean acidification poses the greatest threat to our marine habitats, by directly affecting marine species and ecosystem processes (MacDiarmid et al, 2012b).

The acidity of New Zealand's oceans is measured in the subantarctic ocean off the Otago coast. Since 1998, the acidity has increased by a statistically significantly amount – an average decrease of 0.0015 units a year in the seawater's pH (a measure of acidity and alkalinity) (see figure 38). The increase in acidity measured at this site is consistent with changes measured elsewhere in the world (Bates et al, 2014). Acidity in our oceans is predicted to continue to rise as a result of carbon dioxide emissions (Ciais et al, 2013).

Figure 38



Ocean acidification directly affects marine species as well as ecosystem processes. With increasing acidification, plants and animals with calcareous shells (composed of or containing calcium or calcium carbonate), such as some plankton, snails, and corals, will find it harder to extract calcium carbonate from the ocean to build their shells (Secretariat of the Convention on Biological Diversity, 2014). Increased ocean acidity may slow the development of plankton species that have calcareous shells and reduce their survival rate. Plankton forms the base of the food chain and is a direct or indirect source of food for almost all marine animals. For this reason, acidification has potential to have widespread effects on marine ecosystems (Fabry et al, 2008).

Increased acidification may also affect our economic and social well-being, because it is likely to affect some of the species we harvest for customary, commercial, or recreational purposes, such as pāua, mussels, and oysters.

For more detail see *Environmental indicators Te taiao Aotearoa*: Ocean acidification.

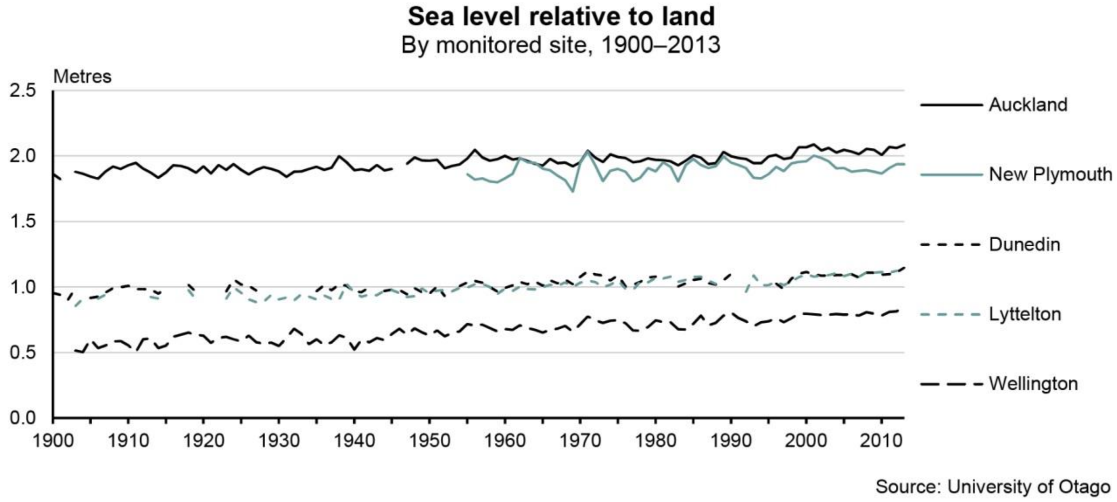
Our coastal sea levels are rising

Increased greenhouse gas concentrations in our atmosphere are also causing coastal sea levels to rise. This is probably due to the expansion of warming waters, and ice sheets or glaciers melting as sea temperatures rise and release water. Rising sea levels increase the likelihood of coastal erosion, a potential risk for New Zealand's cities, coastal communities, and infrastructure. Sea-level rise can lead to the loss of coastal habitats and species.

Between 1900 and 2013, sea levels rose (relative to land) between 1.31 millimetres and 2.14 millimetres annually at observation sites around New Zealand (see figure 39). These changes are consistent with the sea-level rise observed worldwide (Church & White, 2011).

For more detail see *Environmental indicators Te taiao Aotearoa*: Coastal sea-level rise.

Figure 39



Note: Data were not available for some periods.

Sea temperature and natural climatic variations also affect the marine environment

Other climatic pressures with potential to change the marine environment are rising sea temperatures and natural cyclical changes known as climate oscillations. Sea temperatures are expected to continue to rise as a result of climate change, while climate oscillations are part of a natural climatic cycle.

New Zealand's annual average sea surface temperatures measured by satellite do not show a significant trend over the past 20 years. However, long-term surface temperature measurements taken using ships, buoys, and satellites indicate an increase of about 0.71 degrees Celsius over the period 1909–2009 (Mullan et al, 2010). In comparison, global sea temperatures in the upper 75 metres have increased about 0.1 degrees Celsius every decade since 1971 (Rhein et al, 2013).

Change and variability in ocean temperatures can affect marine processes, habitats, and species. Depending on their tolerance for changing environmental conditions, some species may find it hard to survive in areas where waters are warming.

The oceans around New Zealand are influenced by natural cyclical changes (climate oscillations). During certain phases, these oscillations can lead to warmer seas or more stormy weather.

For more detail see *Environmental indicators Te taiao Aotearoa*: Oceanic sea-surface temperature, Coastal sea-surface temperature, and Climate oscillations.

Marine-based activities

Many of the activities people undertake in our marine environment can affect its productivity and biodiversity, and our ability to enjoy it in other ways, such as for recreation or customary purposes. A quota management system is used to control commercial fishing in New Zealand, to ensure our fisheries are sustainable. However, some aspects of commercial fishing continue to put pressure on marine life and habitats. The most significant of these are bycatch and trawling.

This section covers the impacts of commercial fishing (bycatch and trawling), aquaculture, and extraction of oil, gas, and minerals. It also covers exotic species introduced through shipping, and other human activities in the marine environment.

Bycatch of protected species is decreasing but still a threat

'Bycatch' occurs when fish or other animals are unintentionally caught and injured, or killed, during fishing operations. This is particularly concerning when it involves species that are threatened or at risk of extinction. Seabirds, sea lions, fur seals, and dolphins are the main protected species caught as bycatch. Protected sharks, such as basking sharks, are also caught as bycatch.

Fishing bycatch is the main pressure on seabirds. An estimated 55,000 seabirds were caught in fishing gear between 2001/02 and 2013/14. Over this period, the estimated number of seabirds caught each year fell, from 7,280 to 4,380. This decrease may be partly due to the fishing industry using bird-scaring devices and other measures to prevent bycatch.

Bycatch is a factor leading to the decline in the sea lion population in New Zealand waters (Baker et al, 2010; Robertson & Chilvers, 2011). The sea lion population is small (estimated at fewer than 3,000 mature individuals) and estimated to have decreased about 70 percent over three generations (about 32 years). The species is listed by the New Zealand Threat Classification System as nationally critical, meaning it has the highest risk of extinction (Baker et al, 2010). The number of sea lions estimated to have been caught as bycatch decreased from 59 in 2003/04 to 33 in 2012/13. This decrease may be partly due to the use of devices that help sea lions escape from nets, making them less likely to drown.

An estimated 508 fur seals were caught in 2012/13, a substantial decrease from the estimated 1,509 caught in 2004/05. Fur seal populations are now considered to be healthy, although they remain a protected species.

Hector's dolphins have an estimated population of between 7,000 and 9,000, while the population of Māui's dolphins aged over one year is estimated to be 55 (Baker et al, 2010; Hamner et al, 2012). The most common cause of unnatural death for Hector's and Māui's dolphins is entanglement in nets and other fishing gear (Currey et al, 2012). Of the deaths for which a cause could be determined, 42 percent are attributed to entanglement in fishing gear (Department of Conservation, 2013).

Bycatch of species that are not protected occurs in most of our commercial fisheries. From 2001/02 to 2011/12, the estimated bycatch of fish and invertebrates such as sponges, crustaceans, and cold-water corals fell 72 percent, to 32,098 tonnes. This decrease may be partly due to a decrease in overall catch.

For more detail see *Environmental indicators Te taiao Aotearoa*: Bycatch of protected species: sea lion and fur seal, Bycatch of protected species: seabirds, and Bycatch of fish and invertebrates.

Seabed trawling is decreasing

Seabed trawling has a major impact on seafloor habitats and species. When trawls are dragged along the seabed, they disturb sediment, damage corals, and scoop up seabed species such as crustaceans and brittle stars.

The number of trawl tows and dredge tows in New Zealand waters has fallen (Ministry for Primary Industries, 2014; Black & Tilney, 2015). From 1997 to 2014, the number of trawl tows reported each year decreased more than 50 percent. From 1996 to 2014, the number of dredge tows reported in New Zealand waters decreased 83 percent.

In 2010/11, deepwater fishing operators trawled 1.3 percent (53,031 square kilometres) of the territorial sea and EEZ. Trawling mainly occurs in the same areas each year, which limits the extent of newly affected habitat and species (Black & Tilney, 2015).

The extent of seabed trawled for the first time, where the potential for damage is greatest, has been decreasing each year since 2007. Similarly, the overall area trawled each year has been decreasing since 2002/03, except in 2010/11 when a larger area was trawled than in the previous year (Black & Tilney, 2015).

For more detail see *Environmental indicators Te taiao Aotearoa*: Commercial seabed trawling and dredging and Commercial coastal seabed trawling.

Aquaculture is increasing

Aquaculture is an expanding industry, and there is limited information about how aquaculture affects the marine environment. Operations are concentrated in particular areas (mainly around the top of the North and South islands), and the potential impacts from aquaculture are also likely to be concentrated in those environments.

Shellfish farms contain a high density of animals that filter the water to feed, and this can reduce the amount of phytoplankton (the base of the marine food chain) available for other species. Aquaculture operations can also increase nutrient enrichment of the surrounding seabed, which affects nearby habitats. They can deposit live animals, shells, and faeces (from shellfish farms), or uneaten food and faeces (from finfish farms), which can smother seabed species and habitats. Marine mammals and seabirds can also be displaced by aquaculture, and some species become entangled in the fish-farm structures. In addition, aquaculture may increase the risk of pests and diseases spreading or becoming established (Ministry for Primary Industries, 2013).

Extraction of oil and gas and minerals poses risks

About 197 offshore oil and gas wells have been drilled in New Zealand waters, most of them (176) in the Taranaki region (Petroleum Exploration and Production Association New Zealand, 2015). While there is no mineral extraction in New Zealand waters, possible sites are currently being surveyed and explored.

Oil and gas extraction can adversely affect the marine environment. Extraction operations directly affect seafloor habitats and species, although the effects are localised. Sediment plumes produced by the extraction process can have effects over an extensive area, as the suspended sediment spreads. They reduce food availability for some species and smother seafloor species such as corals. Discharge of tailings (residues from extraction) and effluent can have a wide range of impacts on plankton and fish species, including reducing primary productivity where suspended sediment shades phytoplankton (Chung et al, 2002; MacDiarmid et al, 2012a).

As seen in the Gulf of Mexico in 2010, the risk of an oil spill may be low, but the consequences for the marine environment can be catastrophic.

For more detail see *Environmental indicators Te taiao Aotearoa*: Oil and gas and minerals extraction.

Exotic species can affect indigenous biodiversity

Once exotic species become established, they can adversely affect indigenous species by competing for food and habitat. Examples of exotic species that have become pests in New Zealand's marine environment are the Asian paddle crab and didemnum (Whangamata sea squirt).

The Asian paddle crab is native to South-East Asia and was first reported in Auckland in late 2000. It is now widespread in the Waitematā Harbour and wider Hauraki Gulf. This aggressive species could compete with indigenous crabs for space and food. It is a potential threat to marine farming because it preys on shellfish and other aquaculture species. Didemnum has become a problem in Marlborough. It is a threat to marine farming because it can smother human-made structures such as mussel lines (Ministry for Primary Industries, 2010).

Of the 339 exotic species recorded as being present in New Zealand waters, 182 have established populations. The remainder have been found on boats or floating structures (Graeme Inglis, NIWA, personal communication, 2015), and have not become established. We do not have adequate information about the impact of exotic species on indigenous species in our marine environment.

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

Land-based activities

The marine environment is also affected by activities on land. For example, excess nutrients and sediment from farmland can flow into waterways and eventually out to sea. Stormwater discharges and pollution also contribute to degrading our oceans.

Run-off from land affects the coastal and marine environment

The transfer of sediment from land into waterways, and ultimately out to sea, is a natural process. It brings sand to our beaches and sediment to estuaries, creating habitats for wildlife. However, this natural process is disrupted when excess sediment enters waterways from eroding land. New Zealand loses about 192 million tonnes of soil into waterways and the ocean every year. This is estimated to contribute about 1.5 percent to global sediment loss, despite New Zealand making up only 0.2 percent of the global land area (Syvitski et al, 2005; Walling, 2008). Erosion is a particular problem when erosion-prone hill country is farmed (see Land chapter).

Excess sediment in estuaries can smother habitats such as seagrass meadows and mussel beds. It can also have a detrimental effect on water clarity, reducing the ability of phytoplankton and plants to turn carbon dioxide into energy through photosynthesis.

Land-based activities, and agriculture in particular, can cause an excess of nutrients – especially nitrogen and phosphorus – to enter waterways, estuaries, and coastal waters. Having too many nutrients in the sea promotes the growth of algae and can lead to harmful algal blooms that can affect habitats and species.

In 2013, monitoring found the levels of nutrients and turbidity (murkiness) caused by sediment were higher in estuaries than in other coastal environments. This highlights the impact of run-off from land and sediment being washed down waterways. Levels of dissolved oxygen in estuaries were lower than in other coastal environments. Nutrients and organic matter reduce oxygen in water, which can affect fish and other marine animals that depend on dissolved oxygen to survive.

Run-off from roads and other human-made surfaces contains heavy metals such as lead, zinc, copper, and cadmium. Heavy metals are toxic to both animals and humans, even at low concentrations. They wash into waterways, estuaries, and harbours, especially at times of heavy rain. Cadmium is also a component of some fertilisers, and can be contained in run-off from farms.

Heavy metals from run-off accumulate in the sediments of estuaries and can be taken up by organisms living in the sediment. They also build up in higher concentrations in species further up the food chain (bio-accumulate).

For more detail see *Environmental indicators Te taiao Aotearoa*: Heavy metal load in sediment and Coastal and estuarine water quality.

Large amounts of waste go into our oceans

Waste, mainly from urban areas, is a further pressure on our marine environment. Large amounts of waste is carried along waterways and washed out to sea. While some of the waste collects on beaches, most remains in the ocean. Plastics are a particular problem because they break down over time into small particles and enter the food chain.

Although we have no data for waste in New Zealand's marine environment, globally it is estimated that more than 5 million tonnes of plastic waste entered the world's oceans in 2010 (Jambeck, 2015). An estimated 250,000 tonnes of plastic is afloat on the ocean surface (Eriksen et al, 2014), forming huge drifting patches such as the Great Pacific Garbage Patch in the North Pacific ocean.

The build-up of debris in the marine environment has a range of effects: marine animals and seabirds can become entangled in it and be injured or killed; seabirds and turtles can swallow plastic debris they mistake for food; and debris drifting in the ocean can damage fragile marine habitats (Baird et al, 2012; Derraik, 2002).

We have only limited information about the effects of marine debris in New Zealand, but one study identified that between 1995 and 2005, the incidence of fur seals and sea lions being entangled in plastic and other debris in Kaikoura was one of the highest rates reported in the world (Boren et al, 2006).

For more detail see *Environmental indicators Te taiao Aotearoa*: Effects of marine debris on marine life.

The state of our marine environment

In this section, we describe the state of our marine environment and how it is changing over time. We provide information about the sustainability of fisheries and biodiversity.

Sustainability of fisheries

Our commercial fisheries are sustainably managed, and overfishing is decreasing

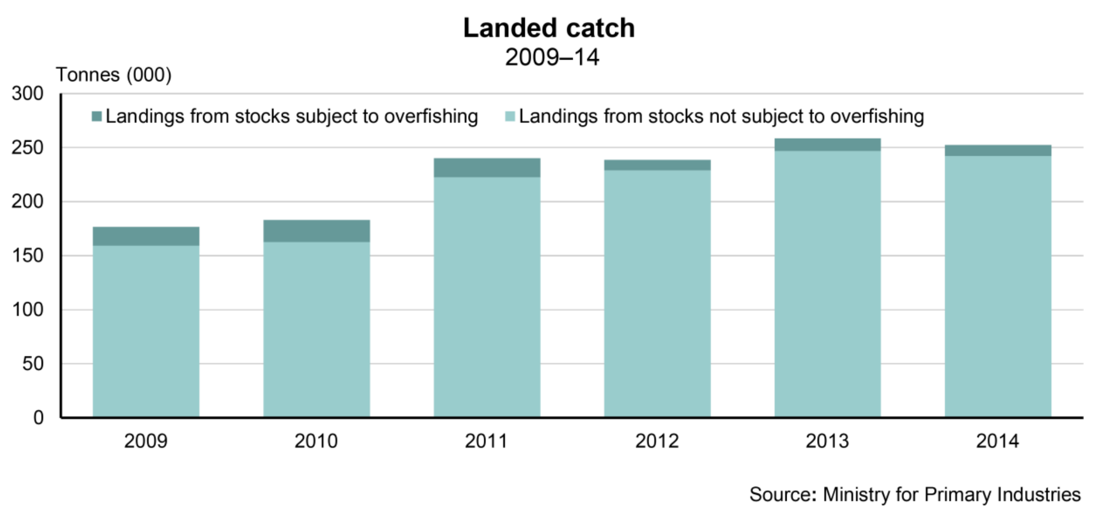
Overfishing occurs when the rate of harvesting a fish stock exceeds the rate at which it can naturally replenish. We can understand how sustainably our fish populations are being fished in two ways: first, by assessing the proportion of fish caught from stocks subject to overfishing; second, by assessing the proportion of stocks (ie fish populations) that are subject to overfishing.

In 2014, the proportion of fish caught (landings) from stocks subject to overfishing was less than 5 percent. This is a decrease from about 10 percent in 2009/10.

Between 2009 and 2014, the proportion of stocks subject to overfishing fell from 25 percent to 14 percent (from 19 of 76 assessed stocks, to 16 of 114 assessed stocks; see figure 40). This is partly due to a 20 percent reduction in the number of stocks subject to overfishing between 2013 and 2014. However, it is also due to more stocks being assessed each year, bringing the proportion of stocks subject to overfishing down.

Bycatch and trawling remain a pressure on our fisheries and other marine life.

Figure 40



For more information see: The pressures on our marine environment section.

For more detail see *Environmental indicators Te taiao Aotearoa*: State of fish stocks.

Marine biodiversity

This section presents information about the state of our marine biodiversity: seabirds, marine mammals, fish and reptiles, and invertebrates. The state of these species provides a good indication of the overall health of the marine environment.

For more detail see *Environmental indicators Te taiao Aotearoa*: Marine trophic index: Chatham Rise and Primary productivity.

Most indigenous seabird species are threatened with or at risk of extinction

New Zealand has 92 resident indigenous seabird species and subspecies, which is the highest number of endemic seabirds in the world (Croxall et al, 2012). ('Resident' refers to indigenous species that breed in New Zealand.)

Thirty-two (35 percent) of our indigenous resident seabird species or subspecies are threatened with extinction. Twelve (13 percent) of these are classified as nationally critical (meaning they face the highest risk of extinction). Another 51 species (55 percent) are at risk of extinction.

Between 2005 and 2011, the risk of extinction increased for seven species of seabird, while it improved for one species, the Chatham petrel.

Fishing bycatch is the main pressure on seabirds.

For more detail see *Environmental indicators Te taiao Aotearoa*: Conservation status of seabirds and shorebirds.

Some marine mammal species are threatened with extinction

New Zealand waters are home to 30 species and subspecies of resident indigenous marine mammals.

Eight of these species (27 percent) are threatened with extinction, and between 2005 and 2008–11, the extinction risk increased for one mammal species, the New Zealand sea lion.

The orca, Māui's dolphin, Bryde's whale, New Zealand sea lion, and southern elephant seal are considered nationally critical. The Māui's dolphin is estimated to have 55 individuals remaining that are over one year of age (those less than a year old are not monitored) (Hamner et al, 2012).

Nine species (30 percent) of marine mammals are considered to be not threatened. For one of these species, the New Zealand fur seal, the population is recovering.

For more detail see *Environmental indicators Te taiao Aotearoa*: Conservation status of marine mammals.

Conservation status of fish and reptiles is uncertain

We do not have recent information on the conservation status of marine fish. The Department of Conservation completed the last assessment of their conservation status in 2005. At that time, two of the 204 resident species assessed – the great white shark and basking shark – were classified as being in gradual decline, while 18 species were assessed as sparse. However, the system for assessing conservation status has changed since 2005 (Hitchmough et al, 2007).

Turtles and sea snakes also visit our waters and, while they are considered indigenous, their conservation status is not assessed because they do not breed in New Zealand's marine environment.

Many marine invertebrates are at risk of extinction

There is limited information available about the conservation status of marine invertebrates such as rock lobster, pāua, pipi, sponges, and corals. Of an estimated 12,000 species, 415 were assessed (Gordon et al, 2010; Freeman et al, 2014).

Of the assessed species, 11 (2.7 percent) were classified as threatened with extinction. A further 324 species (78 percent) were considered to be at risk of extinction, principally because they are naturally uncommon – that is, they are naturally restricted to certain habitats (Freeman et al, 2014).

Heavy metal levels in estuary sediment are generally low

The concentration of heavy metals in most estuary sites monitored between 2010 and 2014 was at levels considered unlikely to have adverse ecological effects on species living on the estuary seafloor. Heavy metals accumulate on the seafloor and have the most direct impact on species that live there.

Lead levels at 94 percent of sites were unlikely to have adverse effects. Levels of zinc, cadmium, and copper were unlikely to have adverse effects at 92 percent, 95 percent, and 89 percent of sites, respectively.

Levels at 1 percent of monitored sites for both cadmium and zinc (four sites each) exceeded levels likely to cause adverse ecological effects on species living on the estuary seafloor.

For more detail see *Environmental indicators Te taiao Aotearoa*: Heavy metal load in sediment.

Biodiversity

Biodiversity is an area that crosses all domains. The previous chapters provided information on aspects of biodiversity relevant to the respective domains. Using a cross-domain approach, this chapter presents information about the impacts on biodiversity and an example of a form that future reports might take.

For more information see: Future reporting chapter.

Overview

We combined the information we have for the land, fresh water, and marine domains to show how a range of processes and human activities affect biodiversity.

Biological diversity, or 'biodiversity', is the variability among living organisms and the ecological systems of which they are a part. Biodiversity includes the diversity within species, between species, and of ecosystems.

New Zealand has a high number of species found nowhere else in the world (referred to as 'endemism'). Owing to New Zealand's long history of isolation from other land masses, our endemic plants, animals, and fungi have developed associations with the species and environment around them. Our indigenous plants and animals also evolved without predatory or browsing mammals, making them especially vulnerable to introduced mammals and other species.

Since humans settled New Zealand 700-800 years ago, we have changed the environment to produce food, materials, energy, and other resources. Our economy and way of life are dependent on farming, forestry, and many other productive activities. However, many of our activities have also had an impact on our indigenous plants and animals, and their habitats:

- our indigenous forests are reduced to about one-third of their pre-human extent
- wetlands are reduced by about 90 percent; other ecosystems, such as active sand dunes, are also substantially reduced
- many indigenous species face extinction, including 81 percent of bird species that breed in New Zealand (known as resident species), 72 percent of freshwater fish, 88 percent of reptile, 100 percent of frog, and 27 percent of our resident marine mammal species
- the risk of extinction is increasing for some species – since 2005, the threat increased for 7 percent of our threatened freshwater, land, and marine species.

Why biodiversity is important

Biodiversity is important for many reasons. All species and ecosystems have intrinsic value – that is, the value of existing, quite apart from any economic or other benefits that humans derive from them. The intrinsic value of biodiversity is recognised in our key environmental legislation, the Resource Management Act 1991. Māori have a responsibility as kaitiaki (guardians) to protect and preserve our animals, plants, and ecosystems – this responsibility is both to the natural environment itself, and future generations. Because 52 percent of New Zealand's indigenous species are found nowhere else on Earth, our indigenous biodiversity also has global importance (Gordon, 2013). Reflecting the importance of our indigenous biodiversity within the global environment, New Zealand is a signatory to the Convention on Biological Diversity, an agreement that aims to conserve and maintain biodiversity.

Humans are also dependent on biodiversity – it underpins our economy and way of life. The benefits that we get from biodiversity are called ‘ecosystem services’. These include the provision of food, materials, and ingredients for medicines; water purification and regulation; pollination; erosion regulation; social and cultural benefits, including recreation; and, perhaps most importantly, functions that support life, including the cycling of nutrients and the production of oxygen.

We also gain direct economic benefits from our unique indigenous biodiversity. Our reputation as a country with relatively unspoiled nature and unique animals such as the kiwi, kākāpō, and tuatara attracts visitors from all over the world.

What happens in our land, freshwater, and marine environments also affects biodiversity in other parts of the world. New Zealand provides habitat for many migratory species, including marine mammals, seabirds, and wading birds. In recognition of this, New Zealand is a signatory to the Convention on the Conservation of Migratory Species of Wild Animals (the Bonn Convention) and the Convention on Wetlands of International Importance (the Ramsar Convention).

Impacts on biodiversity

This section describes the key impacts on biodiversity in New Zealand: the impacts on habitats and ecosystems, the effects of pests and weeds on biodiversity, impacts on species diversity, and impacts across domains.

Impacts on habitats and ecosystems

We have already lost a large proportion of our forests and other indigenous vegetation

An estimated 80 percent of the country was forested before humans arrived in New Zealand. Since then, milling and fire have destroyed much of our indigenous forest. Today, indigenous forest covers less than one-quarter of the country, mainly in mountainous areas. In coastal and lowland areas, much of the remaining forests are in small and isolated fragments.

The remaining indigenous forests and other vegetation do not represent the full range of ecosystems. For example, the loss of forests and other indigenous vegetation in coastal and lowland areas has adversely affected biodiversity – an estimated 57 percent of our threatened plant species grow in these environments (de Lange et al, 2004).

Although the rate of loss of indigenous forests has slowed, it has not stopped. Between 1996 and 2012, we lost a further 10,000 hectares of indigenous forests. While this represents a small change (0.26 percent) in statistical terms, it is ecologically significant – any loss of forest leads to a loss in ecosystems, and the plants and animals that live there. Once forest is lost, it is difficult to restore.

For more detail see *Environmental indicators Te taiao Aotearoa*: Land cover and Predicted pre-human vegetation.

Ecosystems that were once widespread continue to decline

Wetlands and active sand dunes were once widespread, but are now significantly reduced. These ecosystems support unique communities of plants and animals, and provide ecosystem services.

Active sand dunes are dunelands shaped by wind-blown sand. They support unique species of plants and animals, some of which face extinction (eg the New Zealand iris and some snail, moth, and butterfly species). Active sand dunes are affected by weeds that stabilise the dunes, changing their natural character and reducing their suitability as habitat for some indigenous species. Coastal development and rising sea levels also put pressure on sand dunes. They now cover less than 20 percent of the area they covered in the 1950s, and their loss continued to the most recent measurement in 2008.

Wetlands are also greatly reduced from their historic extent, mainly as a result of drainage for farming and settlement. Only an estimated 10 percent of wetlands remain from before European settlement. Wetlands provide flood protection, and filter and clean fresh water. They provide important habitat for biodiversity. For example, the Whangamarino wetland (one of New Zealand's six wetlands of international importance) is habitat to about 400 different plant and animal species. Of these, 17 are classified as threatened, including one species of plant – the swamp helmet orchid (*Corybas carsei*) that lives only at Whangamarino.

For more detail see *Environmental indicators Te taiao Aotearoa*: Active sand dune extent and Wetland extent.

Many naturally uncommon ecosystems are threatened

New Zealand has 71 different rare ecosystems. These ecosystems are generally small (ranging from less than 1 hectare to 1,000 hectares), but each has distinct environmental conditions that support unique communities of plants and animals, many of which are rare and threatened. Therefore, they make a significant contribution to our national biodiversity. Almost two-thirds (45) of the rare ecosystems are classified as threatened under the red-list criteria of the International Union for Conservation of Nature (Holdaway et al, 2012). Of these, 18 (40 percent) are critically endangered, which means they are at the greatest risk of degradation and loss.

For more detail see *Environmental indicators Te taiao Aotearoa*: Rare ecosystems.

Impacts of pests and weeds on our indigenous plants, animals, and ecosystems

New Zealand's indigenous plants and animals evolved without predatory or browsing mammals. Humans introduced animals and plants that are now considered pests in the land, freshwater, and marine environments. Introduced pests have a major impact on indigenous biodiversity. They eat indigenous animals and plants, and compete with them for food or habitat.

Possums, rats, and stoats pose the greatest threat to our indigenous plants and animals (Parliamentary Commissioner for the Environment, 2011). These pests are present in at least 94 percent of New Zealand. Rats and stoats prey on indigenous birds, while possums eat large quantities of indigenous vegetation, and prey on birds.

Possums are the major cause of decreasing distributions of trees – such as pōhutukawa, Hall's tōtara, kāmahi, māhoe, tawa, and rātā; they can also change the composition and structure of native forests (Payton, 2000; Nugent et al, 2010; Parliamentary Commissioner for the Environment, 2011). Possums destroy the nests of kererū and the North Island kōkako (Innes et al, 1999; Powlesland et al, 2003; Campbell et al, 2008). Possums have also been recorded killing sooty shearwater (tītī or muttonbird), the brown kiwi, kōkako, saddleback, Australasian harrier, fantail, and Westland black petrel (Brown et al, 1993; Sadlier, 2000).

Rats and mice have caused the declines or extinctions of many of our insects and lizards, including wētā, beetles, skinks, and geckos (Towns et al, 2006; St Clair, 2011; Newman, 1994). Like possums, rats and mice also slow forest regeneration by eating seeds and seedlings. The impact of ship rats on indigenous birds is clearly seen on Big South Cape Island near Stewart Island, which ship rats invaded in 1962. Rat populations grew rapidly, and within three years, nine species of birds declined or disappeared from the island, including the South Island saddleback, Stead's bush wren, and the Stewart Island snipe. On the mainland, rats contributed to declines in populations of forest birds such as the North Island kōkako, kererū, kākāriki, yellow head (mōhua), and brown creeper (Innes et al, 2010).

The stoat is one the world's most effective predators. Stoats are very agile, and are adept swimmers and climbers. In their average one-year life span, stoats occupy large home ranges and travel up to 70 kilometres in a fortnight. They are the principal predator of the kiwi: up to 60 percent of young kiwi are eaten by stoats (McLennan et al, 1996; Brown et al, 2015). Researchers filming kiwi nests have observed stoats repeatedly visiting burrows while the eggs were being incubated, waiting for the chicks to hatch. Stoats are a factor in the decline of threatened species such as the rock wren, black stilt, kākāpō, and the kōkako. Kākāpō and stitchbird (hihi) are now found only on islands or sanctuaries completely free of predators – they cannot survive where stoats are present (Powlesland et al, 2006; Department of Conservation, 2005).

Other pests, such as feral goats, red deer, and Himalayan tahr, have a more limited distribution, but when concentrated in large numbers, they can have significant effects on forest and alpine ecosystems.

Many introduced plants have become pests. The 'wilding pine' is a plant pest that has had a significant impact on indigenous ecosystems. These are introduced conifer species that spread beyond plantations or deliberate plantings, infesting indigenous ecosystems or farmland. Wilding pines grow much taller than tussock and shrubs, and when present in high numbers can dramatically change the nature of tussocklands and shrublands.

In our waterways, identified pests – nine fish, 11 invertebrate, and 41 plant species – have a significant impact on our rivers, streams, and lakes through predation, competition, and by altering freshwater habitats. For example, the algae didymo is now in over 150 South Island rivers. Didymo smothers and excludes aquatic plants and insects, and can substantially change stream ecology.

For more detail see *Environmental indicators Te taiao Aotearoa*: Land pests, Freshwater pests, and Marine pests.

Impacts on species diversity

New Zealand is a biodiversity hotspot but many species face extinction

New Zealand has the second-highest level of endemism for vertebrates in the world, after the Madagascar and the Indian Ocean Islands region. Vertebrates are animals with backbones, including bird, mammal, and amphibian species. Because of our high level of endemism, New Zealand is a 'biodiversity hotspot' (Mittermeier et al, 2004). Worldwide, only 35 countries and regions qualify as hotspots. These hotspots represent just 2.3 percent of Earth's land surface but support 50 percent of the world's endemic plant species and nearly 43 percent of endemic vertebrate species.

Many of our endemic species face extinction. For example, all our endemic marine mammal, frog, and most endemic bat species are now threatened or at risk of extinction (Baker et al 2010; Newman et al 2013; O'Donnell et al 2013).

Extinction is an ongoing threat to many species

Many species face an ongoing threat of extinction. The extinction of one species can detrimentally affect other species or even entire ecosystems. Since humans arrived, hunting, habitat destruction, and introduced animals and plants have resulted in at least 40 species being confirmed extinct. However, the actual number of extinctions is likely to be substantially greater. For example, at least 70 New Zealand species or subspecies have not been seen for more than 20 years, but are still classified as 'data deficient' or 'nationally critical (data poor)', rather than 'extinct' (Hitchmough, 2013).

Table 3: Indigenous species that are threatened or at risk of extinction, by taxonomic group

Taxonomic group	Still living (number)	Threatened or at risk of extinction (number)	Threatened or at risk of extinction (%)
Bats	4	3	75
Birds	203	164	81
Earthworms	171	32	19
Freshwater fish	39	28	72
Freshwater invertebrates	580	148	26
Frogs	3	3	100
Marine invertebrates	307	233	76
Reptiles	57	50	88
Vascular plants	2378	918	39

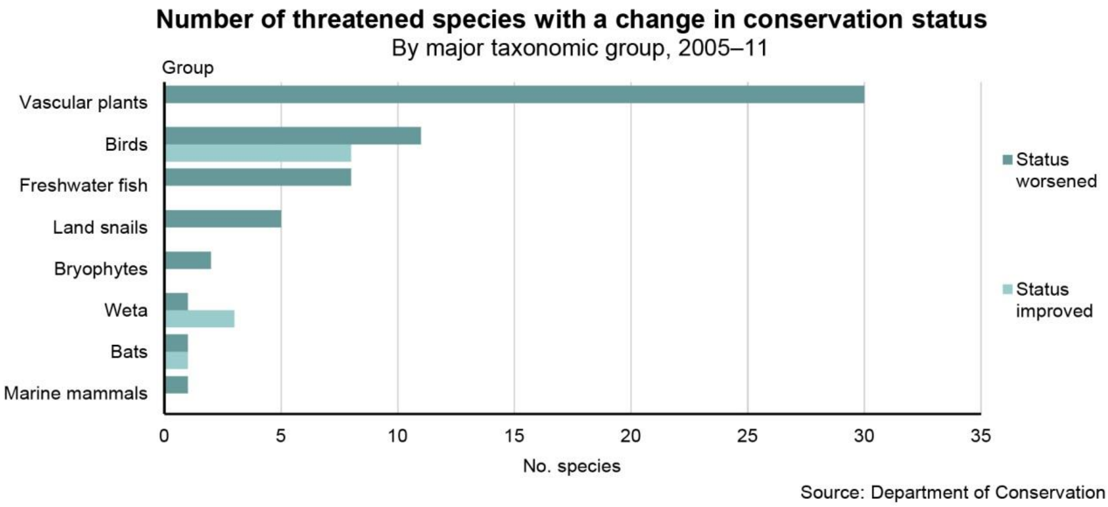
Source: Department of Conservation; Threat Classification System 2012–14; Hitchmough et al (2013); de Lange et al (2013); Robertson et al (2013); Newman et al (2013); O'Donnell et al (2013); Goodman et al (2014); Grainger et al (2014); Freeman et al (2014); Buckley et al (2015).

Note: Excludes taxonomically indeterminate taxa, species that do not breed in New Zealand, and groups for which a recent threat classification is not available. In addition to the above species, 40 species are confirmed extinct.

Risk of extinction for some species still rising

For some species, the risk of extinction is increasing (see figure 41). The risk for about 7 percent (59 of 799) of our indigenous species worsened between 2005 and 2011, including birds, plants, freshwater fish, and marine mammals. In contrast, the risk of extinction for 12 species (1.5 percent of all species) improved (eg brown teal, yellowhead, and the Little Barrier giant wētā). These findings are based on assessments by the Department of Conservation since 2002, which evaluate the extinction risk of our indigenous species. The assessment uses the New Zealand Threat Classification System, which is similar to the International Union for Conservation of Nature (IUCN) Red List.

Figure 41



For more detail see *Environmental indicators Te taiao Aotearoa*: Changes in the conservation status of indigenous species.

Impacts in one domain can affect biodiversity in others

Our environment is interconnected. Changes in the condition of one domain, such as land, can affect other domains, such as fresh water or marine.

Sedimentation of estuaries and coastal environments

The way we use our land affects freshwater and marine ecosystems. For instance, run-off from land can flow into waterways and into estuaries, affecting coastal ecosystems.

An example of this is the Kaipara Harbour catchment. Increased sediment in the rivers and streams flowing into Kaipara Harbour may affect snapper populations down the entire west coast of the North Island, from Cape Reinga to Wellington. Researchers analysed the chemistry of fish ear bones and found that almost all these snapper populations originated from the Kaipara Harbour (Morrison et al, 2009), where juvenile snapper live in horse-mussel beds and subtidal seagrass meadows. These habitats are affected by sediment flowing into the harbour from land in the wider catchment as a result of agriculture and other land uses (Morrison et al, 2014). Juvenile snapper are directly affected by sediment because it impedes their ability to find food and develop their gills (Lowe, 2013). This affects biodiversity, but also the ability to harvest these fish for recreational and commercial purposes.

Ocean acidity

What we do on land also affects the marine environment. Increased levels of carbon dioxide in the atmosphere, produced mainly by the burning of fossil fuels, is causing the acidity of our oceans to rise (Ciais et al, 2013). The ocean (and other water bodies) absorbs carbon dioxide from the atmosphere, which when dissolved, increases the acidity of water.

Ocean acidification will directly affect marine species and ecosystem processes. Plants and animals with calcareous shells (composed of or containing calcium or calcium carbonate), such as some plankton, snails, and corals, will find it harder to extract calcium carbonate from the ocean to build their shells (Secretariat of the Convention on Biological Diversity, 2014). Some plankton species have calcareous shells, and increased ocean acidity will slow their development and reduce their survival rate. This has the potential to have flow-on effects on the entire marine ecosystem. Plankton forms the base of the food chain and is a source of food (directly or indirectly) for almost all marine animals. Acidification has the potential to have widespread effects on marine ecosystems (Fabry et al, 2008).

Increased acidification may also affect our economic and social well-being. Some species that we harvest for customary, commercial, or recreational purposes, such as pāua, mussels, and oysters, will likely be affected by acidification.

For more information see: Marine chapter.

For more detail see *Environmental indicators Te taiao Aotearoa*: Ocean acidification.

Data needs and improvements

This chapter presents the limitations on the available national-level data, and outlines the initiatives underway to improve future reports.

Current reporting limitations

There are limitations in both the extent and quality of environmental data available to us for this report. We are working with data providers to reduce these limitations for future environmental reporting.

Some environmental monitoring networks are patchy, with some regions or sites well monitored but others less so. An example of this is air quality monitoring – especially of $PM_{2.5}$ (particulate matter 2.5 micrometres or less in diameter) – where we have a clear picture of the environment in some parts of New Zealand, but not a nationally representative view of the country.

There is a bias for monitoring to be in places with poor environmental health. Often, these sites are more carefully monitored, which may lead to an inaccurately negative picture of the state of the overall environment. An example of this is water quality – for public health reasons, regional councils monitor swimming spots with a higher risk of exceeding recommended health limits.

Data from monitoring sites may not be consistent, as different sites can use different methods and technologies to take measurements. Therefore, data from these sites may not be comparable, and cannot always be combined to create a national picture.

Where an issue is relevant and worthy of inclusion in New Zealand's Environmental Reporting Series, but data is of lower quality, we included it as supporting information in *Environmental indicators Te taiao Aotearoa*. In future, we plan to have better data available so that key supporting information can be improved to the quality of case studies or national indicators.

Incorporating the Māori perspective

An important objective of New Zealand's Environmental Reporting Series is to reflect te ao Māori (the Māori world view). *Environment Aotearoa 2015* contains only a limited amount of information from a Māori perspective. To add to this information, we will work with data providers to examine and measure aspects of the environment relevant to Māori. Examples of aspects to measure in future reports are the state of taonga species, mahinga kai (food-gathering sites), wāhi tapu, wāhi taonga, tikanga practices, customary use, land cover, and land-use change on Māori land.

Improving information on pressures and impacts

We have little information on environmental pressures and impacts – most of the information in *Environment Aotearoa 2015* relates to the state of the environment. However, we intend to build the body of information we have on both pressures and impacts (eg economy, public health, culture and recreation, ecological integrity, and te ao Māori).

To better understand the link between the environment and the economy, in the future we may include internationally developed measures on the interactions between them.

Improving data quality

Targeted improvements to environmental monitoring will result in higher-quality data. We are working with data collectors and government funding agencies to help improve national environmental data for future reporting.

Working with data collectors

The Environmental Monitoring and Reporting (EMaR) project is one of the cross-government initiatives aimed at improving the quality and consistency of data gathered. EMaR is led by local government in partnership with the Ministry for the Environment, with support from Statistics NZ and other agencies. The project aims to develop integrated regional and national environmental data collection networks, and to make environmental data accessible to the wider public. This is currently done through the Land, Air, Water Aotearoa (LAWA) website.

Regional councils are also developing standards and guidance for collecting data on the state of our environment, supported by the Ministry for the Environment. Standards will ensure consistency in monitoring techniques and methods between councils. An example of these is the national environmental monitoring standards.

Future data improvement projects will help data providers improve their current monitoring and reporting efforts. For example, projects may link with the current work of Crown research institutes and universities to develop their monitoring programmes. They could also use funds from Envirolink or the Ministry for Business, Innovation and Employment to help improve environmental monitoring and reporting.

Improving representativeness

We can make data more representative by installing monitoring devices in a wider range of locations. To address the bias for monitoring sites in poor environmental condition, more sites in comparatively good environmental condition may be included. For example, the Ministry for the Environment is working on improving the coverage of the water quality monitoring network.

Modelling will have an increasingly important role in producing a representative national picture, and in providing consistency across the regions and between indicators. Future modelling will include biophysical models as well as increasingly sophisticated statistical models.

For example, the Ministry for the Environment is developing a national freshwater flows model. When this model is complete, it will enable us to estimate the characteristic patterns of flow quantity, timing, and variability in rivers throughout New Zealand, the pressures on these characteristic flow patterns, and their impacts on our environment, economy, and society. We are also developing a water quality model – using data from the past 25 years – to understand freshwater quality throughout New Zealand and the pressures affecting it.

Improving specific datasets and creating new ones

The Ministry for the Environment has a limited amount of funding to target specific data improvement projects. Recent projects included funding a comprehensive home-heating inventory to better understand the sources of poor air quality, and commissioning an improved estimate of the amount of groundwater in New Zealand. We will continue to commission such projects, as resources and priorities allow, to improve our ability to understand New Zealand's environment.

Future reporting

Environment Aotearoa 2015 brings together information on New Zealand's air, atmosphere and climate, land, fresh water, and marine domains into one report. We will publish this 'whole of environment' report every three years, and a report on one domain every six months from mid-2016.

To make our reporting on the environment more relevant to New Zealanders, we are exploring different ways of presenting information in *Environment Aotearoa*. One objective is to strengthen the distinction between the individual domain reports and *Environment Aotearoa*. Another objective is to present findings using cross-domain themes – an example of this is in the Biodiversity chapter.

Using cross-domain themes to present information

Our aim is for the cross-domain themes to enhance our understanding of each domain and their interaction with each other, and the relationships between pressures, states, and impacts.

In future, we could present the cross-domain themes through one part of the reporting framework (ie pressure, state, or impact), or all three. Examples of cross-domain themes that focus on one component of the pressure-state-impact framework are climate effects (pressure), economic impacts, and impacts on biodiversity (impacts). Examples of aspects of the environment that cover more than one part of the reporting framework are climate change, biodiversity, and pests.

Currently, we do not have enough data to take a cross-themed approach for all aspects of the environment covered in this report. However, we have included an example of this approach in this report – see Biodiversity chapter.

Links to other reporting tools and frameworks

Environmental reporting is evolving as our understanding of the environment and its connections with human health, society, and the economy develops. The tools and frameworks for measuring the environment – both stand-alone and in relation to society and the economy – are being developed nationally and internationally.

New Zealand's Environmental Reporting Series will meet national and international reporting obligations to provide a richer, fuller picture of our environment and its interconnections with other aspects of society, such as the economy.

For more information about how environmental reporting links to other national and international tools and frameworks for reporting see: A framework for environmental reporting in New Zealand.

Give us your feedback

We welcome your feedback on how to present future reports in New Zealand's Environmental Reporting Series.

Complete the survey on the Ministry for the Environment's website to provide your feedback. The survey will ask for your comments on *Environment Aotearoa 2015* and *Environmental indicators Te taiao Aotearoa*. We will use the results from this survey to improve future reports.

The survey is open until 21 January 2016.

Glossary

Age-standardised rate	Rate adjusted to take into account how many old or young people are in a population. When rates are age-standardised, we know that differences in the rates over time or between geographical areas do not simply reflect variations in a population's age structure. This is important when looking at cancer rates because cancer is a disease that mainly affects the elderly. Without age standardisation, it would be unclear if differing rates were due to age or are a result of other factors.
Airshed	Area formally notified in the *New Zealand Gazette* that is likely or known to have unacceptable levels of pollutants, or may require air-quality management.
Ammonia-nitrogen	Form of nitrogen that can be toxic to freshwater organisms at high concentrations.
Annual average	The average of all values in a range of samples or measurements over a given year.
Anomaly	A temperature anomaly is the difference from an average, or baseline, temperature. Baseline temperature is typically computed by averaging 30 or more years of temperature data. Climate change studies generally use temperature anomalies, rather than absolute temperature.
Aquaculture	The practice of farming aquatic organisms such as fish, crustaceans, or molluscs in marine and freshwater environments.
Aquifer	An underground layer of water-bearing rock or sand from which groundwater can be extracted.
Archipelago	Group of islands.
Arsenic	A heavy metal, which in New Zealand comes mainly from burning timber treated with preservative copper-chromate-arsenic. Can be emitted into the air by burning offcuts of treated timber from building projects for home heating. Some industrial processes also emit arsenic.
At-risk species	Species assessed according to the New Zealand Threat Classification System as being at risk of extinction. Includes four subcategories: declining, recovering, relict, and naturally uncommon.
Benthic	Ecological region of the seafloor, including sediment surface and some sub-surface layers. Extends from the

	shoreline, seaward along the seafloor, to outer boundaries of New Zealand's marine environment.
Benzene	A volatile organic compound. Motor vehicles and home heating are the main sources, and some industrial activities.
Benzo(a)pyrene (BaP)	A polycyclic aromatic hydrocarbon largely emitted from the combustion of fuels (such as wood and coal from home heating), vehicle emissions, and some industrial processes.
Biodiversity	The variability among living organisms, and the ecological systems they are part of. Includes the diversity within species, between species, and of ecosystems.
Biodiversity hotspot	A biogeographic region with a significant proportion of biodiversity under threat of extinction. To qualify, a region must have at least 1,500 vascular endemic plants and have lost 70 percent or more of its original natural vegetation.
Biophysical models	Models that tell us about the physical aspects of the environment, such as how much water is flowing. Also provides information on biological aspects of the environment, such as the presence of *E.coli* – an important indicator of water quality.
Busy local road	Where the annual average daily traffic count is greater than 20,000 vehicles a day or is a known hotspot for traffic congestion.
Bycatch	Species not targeted by a fishery but caught incidentally during fishing operations. Once caught, they can be landed, discarded, or released.
Campylobacter	*Campylobacter* infection (Campylobacteriosis) is caused by bacteria found in the gut of birds and other animals. It is the most common bacteria causing food-borne illness, passed on in the faeces of infected animals and humans.
Carbon monoxide	Colourless and odourless gas produced by incomplete burning of carbon-containing fuels such as wood, coal, petrol, and diesel.
Catchment	Area of land in which rainfall drains toward a common stream, river, lake, or estuary.
Climate change	Change in global or regional climate patterns, evident over an extended period (typically decades or longer). May be due to natural factors or human activities.

Climate oscillations	Natural fluctuations in global or regional climates that produce recurring climate cycles or patterns. Cycles are generally defined by changes in air pressure, sea temperature, and wind direction over oceans. Climate oscillation periods can vary from a few months to several decades. Climate oscillations affecting New Zealand are the El Niño Southern Oscillation, Pacific Decadal Oscillation, the similar Interdecadal Pacific Oscillation, and Southern Annular Mode.
Concentration	Measure of the relative quantity of a given substance contained within a specified medium (eg the amount of pollution in the air). Stated as mass per unit volume of air.
Consumptive water use	When water is taken from a water body and not returned to a water body.
Continental shelf	Seabed and subsoil of submarine areas extending out to the continental margin (the zone of the ocean floor that separates the thin oceanic crust from the thick continental crust).
Cryptosporidium	Parasite found in the gut of animals and humans. It is passed on in the faeces of infected animals and humans. *Cryptosporidium* is widespread in New Zealand.
Dissolved phosphorus	Highly soluble form of phosphorus.
Dobson unit	Total column ozone is measured in Dobson units (DU). One DU represents the amount of ozone molecules needed to produce a 0.01 millimetre layer of pure ozone.
Dredge tow	Process of dragging a dredge along the seabed behind a fishing vessel (usually to harvest oysters or scallops).
Dry stock	Sheep, cattle, and deer grazed for meat, wool, and velvet.
***E.coli (Escherichia coli*)**	Bacteria normally found in the gut of warm-blooded animals and people. Some types can cause illness, such as *Campylobacter,* which can be transmitted through contaminated water or food, or through contact with infected animals or people.
Ecologically productive	Ecosystems that generate large amounts of biological material from solar energy.
Ecosystem	A community of plants, animals, and microorganisms in a particular place or area, interacting with the non-living components of their environment (like air, water, and mineral soil).

Emission	The release of a pollutant into the atmosphere; its concentration in the air will depend on how the pollutant disperses in the atmosphere.
Endemic	A plant or animal that occurs naturally only in one place or region.
Evapotranspiration	The transport of water into the atmosphere from surfaces, including soil (evaporation), and from vegetation (transpiration).
Exceedance	Where the concentration of a pollutant exceeds a standard or a guideline. A 'likely exceedance' is when screening methods are used and the results cannot be used to determine compliance with a standard or guideline.
Exclusive economic zone (EEZ)	Area of ocean extending from 12 to 200 nautical miles from shore, including the seabed and subsoil. New Zealand has jurisdiction over exploration and extraction of marine resources in its EEZ.
Exposure	Contact with a chemical, physical, or biological agent that can have either a harmful or beneficial effect.
Extended continental shelf	The part of the continental shelf beyond the EEZ.
Extinction	The loss of a species. The moment of extinction is generally considered to be marked by the death of the last individual of that species.
Fossil fuel	Coal, natural gas, liquefied petroleum gas (LPG), crude oil, or a fuel derived from crude oil (including petrol and diesel), so called because they have been formed from ancient organic matter over long periods of time.
Freshwater flow (rivers)	Volume and flow rate, measured by continuously monitoring the height of the river surface and converting it to a flow rate.
Glacier	A slow-moving mass of ice formed by accumulated and compacted snow on mountains or near the North or South poles.
Greenhouse gases	Carbon dioxide, nitrous oxide, methane, ozone, water vapour, and chlorofluorocarbons occurring naturally and resulting from human (production and consumption) activities, and contributing to the greenhouse effect (global warming).
Ground-level ozone	A colourless and odourless gas produced by other gases reacting in the presence of sunlight. Examples of pollutants that form ozone are oxides of nitrogen and volatile organic compounds caused by transport, home heating, and industrial processes.

Groundwater	Water located beneath Earth's surface in pore spaces (the spaces within a rock body that are not occupied by solid material) and fractures of rock formations.
Growing degree days	Total days over a year in which the mean daily temperature is higher than a base value (10 degrees Celsius).
Guidelines	Guidelines provide recommendations that outdoor air quality should meet. Unlike standards, they are not required by law to be met. We used national and international guidelines (the Ministry for the Environment's 2002 Ambient Air Quality Guidelines and the World Health Organization (WHO) guidelines in this report to compare long-term concentrations. We used the WHO guidelines to compare short-term concentrations where they differ from the national standards.
Heavy metal	Subset of elements that exhibit metallic properties and have relatively high atomic weight. Heavy metals can be emitted from human activities, such as vehicle tyre/brake wear and battery and steelmaking facilities, but some also occur naturally in the air.
Humidity	Amount of water vapour in the air. Water vapour is the gaseous state of water and indicates the likelihood of precipitation, dew, or fog.
Indigenous	Belonging naturally to a given region or ecosystem, as opposed to an animal or plant that is exotic or introduced. Also referred to as 'native'.
Influenza	Commonly known as 'the flu', influenza is a virus that spreads quickly from person to person, and in serious cases, can cause death. In temperate climates such as New Zealand's, people are more likely to get the flu in winter.
Invertebrate	An animal without a backbone or spinal column. Insects, spiders, worms, slaters, and many marine animals such as corals, sponges, and jellyfish are examples of invertebrates.
Macroinvertebrate	Small animal that has no backbone and can be seen with the naked eye (eg insects, freshwater crayfish, snails, and worms).
Macroinvertebrate community index (MCI)	An indicator of general river health: excellent >119; good 100–119; fair 80–99; poor <80.
Mātauranga Māori	The knowledge, comprehension, or understanding of everything visible and invisible existing in the universe, and often used to mean 'wisdom'. Often includes

	present-day, historic, local, and traditional knowledge; systems for transferring and storing knowledge; and goals, aspirations, and issues from an indigenous perspective.
Median	The midpoint of a series when the data are listed in ascending order. Half the numbers or values are above the midpoint, and half are below it.
Microgram per cubic metre (µg/m^3)	Unit of density used to measure volume in cubic millimetres to estimate weight or mass in micrograms.
Micrometres (µm)	A unit of length equal to one-thousandth of a millimetre. Also called a micron.
Monitoring site	Site where equipment is deployed to sample and/or measure the quality of air or water.
National standards	Standards set by the government to help maintain a clean, healthy environment. National standards for air quality set minimum requirements for outdoor air quality in New Zealand, with a maximum concentration that a pollutant can be experienced at and the allowable number of times this maximum concentration can be exceeded in a year. We used the national standards in this report to compare daily and hourly concentrations.
Naturally uncommon	Species whose distribution is naturally confined to specific habitats or geographic areas, or which naturally occur in small and widely scattered populations.
Nitrate-nitrogen	Highly soluble form of nitrogen that is both a nutrient and, in excess quantities, a toxic substance.
Nitrogen	Nutrient essential for plant and animal life. Too much can cause large amounts of weeds and algae to grow, harming river health. In some forms can be toxic to fish and other aquatic animals.
Nitrogen dioxide	Reddish-brown, pungent gas produced mainly from the combustion of fossil fuels (coal, gas, diesel, and oil) and some industrial processes. It can be emitted directly into the air but is most often formed when nitric oxide emissions react with other chemicals in the air. Collectively, nitrogen dioxide and nitric oxide are referred to as nitrogen oxides.
Nitrogen oxides	Collective term for nitrogen dioxide and nitric oxide. Nitric oxide often makes up the larger component, but is readily converted to nitrogen dioxide in the environment.
Nutrient enrichment	When sediment becomes enriched as a result of nutrients being leached or deposited.

Overfishing	Rate of fishing that exceeds the rate at which the stock is naturally replenished and will lead to a stock falling below management targets and/or limits.
Ozone	Pungent, colourless, toxic gas that occurs naturally at a concentration of about 0.01 parts per million of air. Levels of 0.1 parts per million are considered to be toxic. In the stratosphere, ozone provides a protective layer shielding Earth from the harmful effects of ultraviolet radiation. In the troposphere, it is a major component of photochemical smog, which seriously affects the human respiratory system.
Ozone-depleting substance	Substance that depletes the ozone layer, such as chlorofluorocarbon.
Particulate matter	Small airborne particles composed of solid and/or liquid matter.
pH	Measure of acidity/alkalinity, with measures below 7 being acid and above 7 being alkaline.
Phosphorus	Nutrient essential for plant and animal life. Too much can cause large amounts of weeds and algae to grow, harming river health.
Photosynthesis	Process where plants use light energy from the sun to convert carbon dioxide, water, and minerals to sugar, which they use as energy to grow and release oxygen.
PM_{10} particle	Airborne particle 10 micrometres or less in diameter (about one-fifth the thickness of a human hair). Produced by the combustion of wood and fossil fuels, as well as by various industrial and natural processes.
$PM_{2.5}$ particle	Airborne particle 2.5 micrometres or less in diameter and mostly come from combustion sources (see PM_{10} particles). Most particulate matter from natural sources is larger than 2.5µm in diameter.
Point-source discharge	Discharge from a fixed source such as an effluent pipe, as opposed to diffuse discharges such as agricultural run-off from land.
Pollutant	Any substance (including gases, odorous compounds, liquids, solids, and microorganisms) or energy, or heat, that causes an undesirable change to the physical, chemical, or biological environment.
Precipitation	Primary mechanism for transporting water from the atmosphere to Earth's surface. Includes rain, sleet, snow, and hail.
Primary productivity	The amount of organic matter produced by plants and some microorganisms.

Quota management system	System established in 1986 to control the total commercial catch for most of the main fish stocks in New Zealand's exclusive economic zone.
Resident	Species that breed in New Zealand.
Salmonella	Bacteria that causes the infection salmonellosis. It is the second most-common bacteria that causes food-borne illness in New Zealand. *Salmonella* bacteria live in the gut of many farm animals and can contaminate meat, eggs, poultry, milk, and other foods.
Screening method	Any non-standard method that provides indicative data for a particular contaminant. It uses low-resolution instruments and cannot be used to determine compliance with a standard or guideline.
Siltation	Pollution of water by fine suspended sediment and the accumulation of fine sediment on the bottom of a seafloor or estuary, where it can smother plants or animals.
Species	A basic unit of biological classification, comprising individual organisms that are very similar in appearance, anatomy, physiology, and genetics, due to having relatively recent common ancestors. Species can interbreed.
Standard method	Air-quality monitoring method recommended by a national or international body that can be used to determine compliance with a standard or guideline.
Statistically significant	When a finding is likely to be due to something other than random chance. A statistically significant finding is determined by tests based on the 95 percent confidence interval. This interval shows the range of values that would include the estimate 95 percent of the time if the test was repeated multiple times.
Stratosphere	Upper layer of the atmosphere, from about 10 to 50 kilometres above Earth's surface. The stratosphere is almost completely free of clouds or other forms of weather.
Subspecies	Geographically isolated population that interbreeds and is part of a species.
Sulphur dioxide	Colourless gas with a pungent smell, produced during the combustion of fuels containing sulphur, such as coal and diesel.
Temperature inversion	Occurs when a layer of warm air sits over a layer of cooler air near the ground. Because cool air is heavier than warm air, it often remains trapped close to the

	ground. Air pollution that gets trapped beneath the inversion layer can build up, increasing air pollution concentrations.
Territorial sea	Area of sea extending from the coast to the 12 nautical mile limit.
Threatened species	Species assessed according to the New Zealand Threat Classification System as being threatened with extinction. Includes three subcategories: nationally critical, nationally endangered, and nationally vulnerable.
Total column ozone	Total amount of ozone in a column from the surface of Earth to the edge of the atmosphere.
Trawl tow	Process of dragging a trawl net behind a fishing vessel, along or just above the seabed.
Trophic level index	An indication of the level of nutrient enrichment (excessive amounts of nutrients) of a lake, based on the growth of plants and algae.
Troposphere	Lowest layer of Earth's atmosphere, where almost all our weather develops. Extends about 10 kilometres upward from Earth's surface and contains 75 percent of the atmosphere's mass and most of its water vapour.
Ultraviolet (UV) rays	Light in the wavelength range between visible light and X-rays. The ozone layer prevents a large amount of UV light from reaching Earth's surface.
Vascular plants	Plants that have developed a system to transport water and nutrients. These include plants with flowers and cones, ferns, horsetails, and clubmosses. They exclude algae, hornworts, liverworts, and mosses.
Vertebrate	Animal with a backbone. Includes amphibians, reptiles, birds, mammals, and fish.
Volatile organic compound	Any compound of carbon (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate) that participates in atmospheric photochemical reactions.
Wading	Activity with a low risk of full immersion in fresh water (eg accidental immersion while walking (wading) through water for exercise, or standing in water while fishing).
Water clarity	Measure of the underwater range of vision in freshwater systems such as rivers and streams.

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