Environment Aotearoa 2022

New Zealand's Environmental Reporting Series

Ministry for the Environment
Manatū Mō Te Taiao
Stats NZ
Tatauranga Aotearoa

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Cover: Wenderholm Regional Park, Waiwera
*Photo: Spid Pye, **truestock***

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Message to our readers

We are proud to present *Environment Aotearoa 2022*, our triennial report on the state of the environment (te taiao) in Aotearoa New Zealand.

One of the greatest motivations for change that we hear from people is wanting to ensure Aotearoa New Zealand is a great place to be for our children and grandchildren.

Just three years on from the previous state of the environment report, our environmental indicators do not register much change. But the way in which we have approached and compiled this report has changed.

We have explored the evidence in a different way, starting with the importance that nature plays in our lives and to our livelihoods. We have pulled together a diverse set of evidence drawing on Māori knowledge (mātauranga Māori), environmental science, health science, and economics. In using a more diverse evidence base, we have consulted a wider network of scientists and experts, and put in place a broader independent peer review process.

To organise the evidence, we have used the Matariki star constellation. As a signal of the Māori new year, it commemorates loss and celebrates hope for the future. Bringing this Māori world view (te ao Māori) recognises the interconnectedness of all that is living, and speaks to something that connects us all to Aotearoa. It also supports our commitment as a public sector to build genuine partnerships with Māori for the benefit of all New Zealanders.

This report also helps to transition us towards a new system of reporting shaped by recommendations of the Parliamentary Commissioner for the Environment about how we can improve the environmental reporting system.

So, what comes next? Well, this is up to all of us.

We hope *Environment Aotearoa 2022* will help us reflect on our impact and the state of our environment. We believe the integrated approach and wellbeing focus of this report will urge and empower us to create the future we want, for ourselves and for future generations.

Vicky Robertson
Secretary for the Environment

Mark Sowden
Government Statistician

Ngā kupu tīmata (Opening words)*

Mānawa maiea te putanga o Matariki	Celebrate the rising of Matariki
mānawa maiea te ariki o te rangi	celebrate the lord of the sky
mānawa maiea te Mātahi o te tau.	celebrate the new year.
Ka eke Tiromahuta	Rise Tiromahuta
ka eke Rongorupe	rise Rongorupe
ka eke Rangitāhuahua	rise Rangitāhuahua
kei au te tauranga taku tū	come to rest at this place
te mauri tū	your power
te whiwhi a nuku tū,	to benefit everyone,
puritia mai i roto	maintain
te whiwhi a roto,	the bounty,
tēnei te mauri ka whakapiki	the vitality rises
te mauri ka whakakake	the vitality climbs
ko te mauri o te tau hou Māori e tū mai nei.	the essence of the new year.
Whano, whano,	Unite, unite,
haramai te toki!	and bring forth the dawn!
Haumi, e!	Together!
Hui, e!	In union!
Tāiki, e!	We are one!

*In te ao Māori, significant events are opened with tikanga, an acknowledgment of ancestral support and guidance. We open *Environment Aotearoa 2022*, a significant report, with these ngā kupu tīmata generously gifted by Professor Rangi Matamua.

He mihi

"Tērā ko Matariki e ārau ana ki te pae,
ko te tohu o te tau hou Māori."

Ko te kāhui o Matariki he huihuingā whetū ki te rangi. Ka tū ki te tahatū o te rangi i te hōtoke kia mōhio pai ai te tangata kua tīmata Te Mātahi o te Tau. E ai ki ētahi, e iwa ngā whetū kei te kāhui, ā, ka hāngai ia whetū ki tētahi wāhanga o te taiao Māori. Ko Matariki tonu te ingoa o te whetū nui e noho ana ki te poka pū o te rōpū, ko ia te whaea o ngā whetū e karapoti nei i a ia. Ko te wāhi ki a Matariki whetū ko te oranga o te tangata, ka whakanuia te tūhonotanga o te taiao ki te oranga o te tangata mā roto mai i a Matariki.

Kua tīpakohia a Matariki hei mahere ārahi i tēnei rīpoata. Ka kōrerohia ia whetū me tana hononga ki te taiao kei ngā upoko o te tuhinga nei. Ka tirohia anō hoki te hua o ngā wāhanga katoa o te taiao ki te oranga o te tangata, me te tūhonohonotanga o ngā tangata katoa ki tō tātau taiao.

Ki tā te Māori titiro ko te tangata ko te taiao, ko te taiao ko te tangata, tē taea te whakawehe. Koinei i tīkina ai ko Matariki hei tūāpapa mō tēnei rīpoata. Kia eke ai tātau ki te kōrero, Matariki hunga nui, Matariki ahunga nui, Matariki manako nui.

Professor Rangi Matamua
Massey University
Chief Advisor Matariki and Mātauranga Māori

PART A

About Environment Aotearoa 2022

This part of the report sets out the scope, context, and introduction to our approach. It describes a broadened focus to include the connections between our environment and people's wellbeing, as well as a more diverse evidence base and a narrative based on Matariki.

Mt Crichton Loop Track, Queenstown, Otago.
Photo: Clare Toia-Bailey, image-central.co.nz

Our changing world

Environment Aotearoa 2022 is a synthesis report – bringing together the regular six-monthly reports produced by the Ministry for the Environment and Stats NZ that cycle air, freshwater, marine, atmosphere and climate, and land domains. The report does not suggest any response as it is out of scope under the report's governing legislation.

In reviewing the evidence, it is hard to identify significant change in many of the environmental issues highlighted in the last synthesis report, ***Environment Aotearoa 2019***. The Parliamentary Commissioner for the Environment's report, ***Focusing Aotearoa New Zealand's environmental reporting system*** (2019) recognises that 'most of the key environmental issues that concern us have developed over lengthy time frames and are unlikely to be remedied in short order'.

But what has changed significantly since *Environment Aotearoa 2019* is our context. The current worldwide pandemic has heightened our focus on wellbeing and how we connect with each other and with the environment. Significant reforms are underway for the environmental reporting programme and the resource management system, challenging us to think about how we report on, and interact, with the environment.

Against this background we have produced *Environment Aotearoa 2022*. It takes a different focus to previous state of the environment reports, putting environmental change in the context of our lives as individuals, families (whānau), and communities. *Environment Aotearoa 2022* brings together evidence to explore how our values and choices place pressure on the environment, the impact of environmental change on the wellbeing of people and communities, and the state and condition of the environment.

As we prepare for a new system of reporting, this report takes a transitional format. This format reflects many of the recommendations of the Parliamentary Commissioner for the Environment's 2019 report, and the improvements we wish to make to the environmental reporting system. These include:

- expanding the reporting framework to include drivers and outlooks
- providing broader context to the environmental reporting indicators with evidence obtained from scientific papers, reports, and other forms (including Māori knowledge (mātauranga Māori), social science, health, and economics)
- the interweaving of Māori worldview (te ao Māori) to illustrate national-level issues, connect environmental issues with place, and make reports relevant to a wider audience, including Māori.

Connections between environment and wellbeing

In this report we take the view that people are inherently connected to the environment. When we view ourselves as being *a part* of the environment, we also see that our wellbeing is interdependent on the environment. Our health, our livelihoods, our leisure – our wellbeing – are dependent on a healthy environment, and that is why wellbeing is such a major focus of this report.

To explain the connection between environment and wellbeing, data and insights from our most recent domain reports on air, land, atmosphere and climate, freshwater, and the marine environment are supplemented with the findings from a wider body of peer-reviewed research.

This report also draws more on mātauranga Māori, the body of knowledge arising from the experiences of Māori living in the environment of Aotearoa New Zealand. This was something the Parliamentary Commissioner for the Environment identified in his 2019 report, stating 'mātauranga Māori represents the only human record [dating back more than 600 years] we have of the environment of these islands and their surrounding waters. For that reason alone, it is of immense importance. Given how much we do not know, we can ill afford to disregard this traditionally curated knowledge.'

While there is no single accepted definition of Mātauranga Māori, for the purposes of this report we've adopted one of the definitions from the Environmental Protection Authority's mātauranga guide (EPA, 2020). This definition is based on that of Ranginui Walker, who recognises that "Mātauranga has a strong oral tradition – it is transmitted in a variety of forms, including whakapapa, waiata, haka, whakataukī, pūrākau, kōrero tuku iho, and whakairo. Whakapapa is a central principle that connects and orders the universe, linking the physical and spiritual worlds, tracing the universe back to its origins" (Walker, 1993).

We also recognise that understanding how mātauranga Māori can enrich our understanding of the natural world has been traditionally under-resourced. There is greater potential in the future to use mātauranga Māori as a complementary form of knowledge on the environment (Hikuroa, 2017).

It is this interweaving that contributes to *Environment Aotearoa 2022* presenting an approach to environmental reporting that is unique to Aotearoa and distinctive from other approaches around the world. This report is a starting point that builds towards a more sophisticated understanding of how to bring different systems of knowledge together but we recognise there is still much to do, and much to learn.

A Matariki narrative

There are many analytical frameworks to describe the connections between the environment and people, and these have been used to interpret the evidence and inform this report. Through discussions with experts from the research community and our Science Advisory Panel, the need for a coherent narrative for the report that would talk to all New Zealanders was identified. We chose to adopt Te Kāhui o Matariki, the nine stars of the Matariki cluster (also known as Pleiades), as an organising structure for the report.[1]

The various stars in the cluster are associated with different domains of the natural world, particularly the earth, the forests, freshwater, salt water, wind, and rain. Matariki therefore helps us tell the story of the many facets of the environment, its connection and interaction with people (tāngata), and provides a link from the past to the present and into the future.

The guiding values associated with Matariki and the Māori new year are outlined in the advice from the Matariki Advisory Committee (Matamua, 2021). They include: remembrance – honouring those we have lost; celebrating the present – gathering to give thanks for what we have; and looking to the future – the promise of a new year. In all dimensions, this feels appropriate for *Environment Aotearoa 2022*.

Report structure

The structure of this report is framed on the nine stars of Te Kāhui o Matariki, each representing a different aspect of the environment and people's connection with it. Table 1 outlines the connection between each star, its domain, and the associated environmental reporting topics.

Following the Environmental Reporting Act 2015, we use the concepts of pressure, state, and impact to report on the environment. The logic of the framework is that *pressures* cause changes to the *state* of the environment, and these changes have *impacts*. Following the recommendations of the Parliamentary Commissioner for the Environment we have also reported on future *outlooks*. These are listed in table 1.

The report starts with the star Matariki, in which we further explore the connections between environmental health and human wellbeing. Pōhutukawa is connected to those we have lost, and this section gives an opportunity to reflect on the changes we have made to the environment and how we can learn from our past use of the environment. The next six sections focus on the parts of the environment associated with each star and their connections to individual and community wellbeing: land (Tupuānuku and Tupuārangi), freshwater (Waitī), marine (Waitā), and air and atmosphere and climate (Waipunarangi and Ururangi). The report finishes with the youngest star, Hiwa-i-te-rangi, where we outline impending challenges and aspirations and hopes for the future. (See the Matariki infographic on page 14 for a description of the stars.)

1 We acknowledge there are regional and iwi variations in how Matariki is observed. This report is based on the understanding provided to us by Māori astronomer researcher Rangi Matamua.

Table 1: Te Kāhui o Matariki (the Matariki cluster) and the *Environment Aotearoa 2022* report structure and framework

Star	Domain	Main topics		Pressure, state, impact, outlook framework
Matariki				
	People and wellbeing	• Health and vitality of living systems • People and wellbeing		Framework
Pōhutukawa				
	Loss and pressures	• Relationship to the environment and changes over time	• Pressures on the environment ▸ Land-use change ▸ Invasive species ▸ Pollution ▸ Natural resource use ▸ Climate change	Pressures
Tupuānuku				
	Land and soil	• Soil health and wellbeing of people • Benefits of healthy soil • Food and economy	• **State** ▸ Soil quality ▸ Soil loss	State and impact
Tupuārangi				
	Biodiversity and land ecosystems	• Customary harvesting • Economic benefits from the forest • Forests and cultural identity • Greenspace and wellbeing	• **State** ▸ Indigenous forest cover ▸ Rare ecosystems ▸ Threatened species	State and impact
Waitī				
	Freshwater	• Freshwater and health, culture, and identity • Freshwater recreation and wellbeing • Irrigation and hydroelectricity • Drinking water • Wetlands	• **State** ▸ Freshwater quality ▸ Wetland ecosystems	State and impact

Star	Domain	Main topics		Pressure, state, impact, outlook framework
Waitā				
	Marine	• Ocean and human health • Oceans and cultural identity • Marine economy • Marine tourism and communities	• **State** ▸ Sedimentation ▸ Nutrient pollution ▸ Plastic waste ▸ Water quality ▸ Climate change and oceans ▸ Fish stocks and seafood (kai moana) species ▸ Mātauranga Māori measures of state	State and impact
Waipunarangi				
	Rain and frosts	• Cultural knowledge and rain • Climate, biodiversity, and ecosystems • Rainfall and agriculture • Floods, droughts, and wellbeing	• **State** ▸ Average and extreme rainfall ▸ Drought ▸ Frost and warm days ▸ Glacial ice volumes	State and impact
Ururangi				
	Air, winds, and the sky	• Tikanga (customs/protocols) and observation of the sky • Engaging with the night sky • Connections to the sky and the winds	• **State** ▸ Air quality ▸ Airborne diseases ▸ Light pollution, health, ecosystems, and mātauranga ▸ Mātauranga and wind patterns ▸ Extreme winds	State and impact
Hiwa-i-te-rangi				
	Futures	• Future outlooks: ▸ Climate change ▸ Threats to native ecosystems ▸ Impact of global trends on Aotearoa ▸ Food and water security ▸ Infectious diseases	• Strengthening the value of environmental reporting • Looking ahead	Outlooks

PART B

Our environment, our wellbeing

Following the nine stars of the Matariki cluster, this part of the report discusses how our wellbeing is connected to the state of the environment in Aotearoa New Zealand.

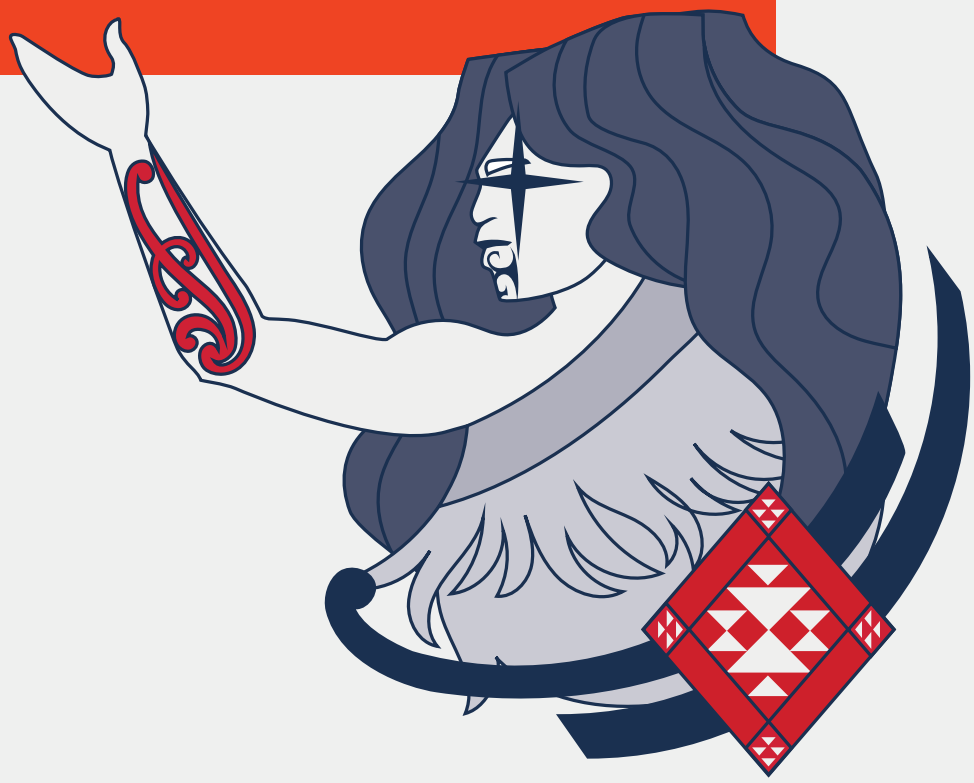
Whānau celebrating Matariki with hāngī (earth oven) at Taupiri, on the eastern bank of the Waikato River. Photo: Erica Sinclair, Erica Sinclair Photography

Matariki

The stars of the year (Ngā whetū o te tau)

MATARIKI ATUA KA EKE KI TE RANGI E
TE KAIWHAKAHAERE O TE KĀHUI
HARIA MAI RĀ TE ORANGA O TE TANGATA
E TŪ E, TE PAKI O MATARIKI

MATARIKI RISING IN THE SKY
THE CONDUCTOR OF THE CLUSTER
BESTOW HEALTH UPON ALL PEOPLE
STAND BRIGHT MATARIKI, A SIGN OF WELLBEING



Matariki is a herald of wellbeing

Matariki is the name given to the central star within the Matariki cluster, as well as the entire cluster itself. Matariki is the mother (whaea) star of the cluster. She ensures the stars of the cluster rise together in unison to mark a new year[2] and signal the health of the environment.

Matariki is linked to the wellbeing of people. The phrase 'te paki o Matariki' means 'the bright star of Matariki' and is a sign of wellbeing and peace. The appearance of the Matariki star is one of several signals used to determine how plentiful harvests will be over the coming year, which is of critical importance to the ongoing wellbeing of people.

In some iwi traditions, Matariki's husband is the atua[3] Rehua[4] , who is connected with healing (rongoā). The saying 'Matariki huarahi ki te oranga tangata' ('Matariki, pathway to the wellbeing of people') reaffirms this association with health (Riley, 2013).

Wellbeing is subjective

Wellbeing has different meanings for different people (Roberts et al, 2015). It encompasses a vast range of elements, and has been conceptualised differently according to culture, working concepts, and application. The way people define and understand their relationships with the rest of the living world is diverse and evolving. However, as the Parliamentary Commissioner for the Environment recently noted, it is broadly agreed that our economic and non-economic wellbeing are linked to the environment, now and in the future (PCE, 2021b).

In recent decades a growing body of research and scientific evidence has demonstrated the link between environment and wellbeing (Capaldi et al, 2015; Chan et al, 2016; Díaz et al, 2018; Harvey, 2021; Martin et al, 2020; McMahan & Estes, 2015; McMeeking et al, 2019; Richardson et al, 2021; Roberts et al, 2015; Twohig-Bennett & Jones, 2018).

There are also many conceptual frameworks to describe and visualise the connections between environment and wellbeing of today's and tomorrow's generations (Ausseil et al, 2021a; Naeem et al, 2016). One government perspective, for example, focuses on the things that matter for New Zealanders' wellbeing, now and into the future. The Treasury's Living Standards Framework characterises wellbeing in three levels (New Zealand Treasury – Te Tai Ōhanga, 2021). One level captures the resources and aspects of our lives that have been identified as important for our wellbeing as individuals, families (whānau), and communities. A second level captures the role our institutions and organisations play in facilitating the wellbeing of individuals and collectives, as well as safeguarding and building our national wealth. And a third level captures how wealthy we are overall, including aspects of wealth not fully captured in the system of national accounts such as human capability and the natural environment.

He Ara Waiora is another wellbeing framework, used by Treasury and He Pou a Rangi – Climate Change Commission (McMeeking et al, 2019) and informed by mātauranga Māori (Māori knowledge). For this framework, wellbeing has been described using the term 'waiora', a broad conception of human wellbeing, grounded in water (wai) as the source of life (ora). This view of wellbeing has spirit (wairua) at the centre to reflect that it is the foundation or source of wellbeing. The environment (te taiao) is paramount and inextricably linked with human wellbeing. Humans have responsibilities and obligations to sustain and maintain the wellbeing of te taiao. The human domain (te ira tangata) encapsulates human activities and relationships, including the relationships between generations. The concept of mana (power, authority) is key to wellbeing.

While Matariki is used to tell the story of the connection between environment and wellbeing, this report is informed by a range of perspectives and conceptual frameworks, including those described above.

2 Some iwi herald the new year with the rising of a star called Puanga (Rigel), found in the Orion constellation (Matamua 2017).
3 Atua is a uniquely Māori understanding and personified form of natural realms.
4 Rehua is sometimes associated with the star Antares, but is not part of the Matariki cluster.

Matariki, wellbeing, and mauri are connected

In the Māori worldview (te ao Māori), Matariki and wellbeing are intrinsically connected with mauri. Mauri is an important Māori concept that describes the health and vitality of living systems. It has been described as the spark of life and active component of that life (Mead, 2003), and the binding force that holds together the physical and spiritual components of a being or thing (Durie, 1998; Morgan, 2006). Mauri is found in water, land, and forests as well as mist, wind, soil, and rocks (Hikuroa et al, 2011). The essential bond between the physical and spiritual is weakened when actions negatively impact the mauri of something. Broken bonds can lead to the separation of the physical and spiritual elements causing the loss of capacity to support life. (Morgan, 2006).

The Parliamentary Commissioner for the Environment (2019), states that many 'non-Māori New Zealanders would also probably welcome a way to describe a more holistic account of ecological functioning that sits uneasily with whatever concepts – issues, themes, domains – have been used to simplify highly complex systems'. The idea of mauri, and the environment as an organic, living entity, has been difficult to include in past environmental reports. Yet mauri has been used by many scientists to describe the state and sustainability of a particular environment and measures have been created to assist this (Morgan, 2006). These cases provide good examples of how a Māori concept and science can work together to inform local environmental health.

Te Kāhui o Matariki

The cluster of stars that rise together in unison to mark a new year.

WAIPUNARANGI

URURANGI

HIWA-I-TE-RANGI

WAITĪ

TUPUĀRANGI

MATARIKI

is the central star and mother of the other stars. She ensures they rise together to mark the new year. Matariki is associated with wellbeing.

WAITĀ

PŌHUTUKAWA

TUPUĀNUKU

PŌHUTUKAWA
is connected to those who have passed since Matariki the previous year. Pōhutukawa prompts us to reflect on the past year.

TUPUĀNUKU AND TUPUĀRANGI
'Tupu' means 'new shoot' or 'grow'. Tupuānuku is connected to food grown in the ground. Tupuārangi is connected to everything that grows above the earth or from the sky such as birds and berries.

WAITĪ
is connected to freshwater and all living things that inhabit rivers, lakes, streams, and wetlands.

WAITĀ
is associated with the ocean and represents the many types of food we gather from the sea.

WAIPUNARANGI AND URURANGI
Waipunarangi is connected to rain. Her name means 'water that pools in the sky'. Ururangi is connected to the winds. His appearance predicts the winds for the year.

HIWA-I-TE-RANGI
signals the promise of the new season. She is the youngest (pōtiki) of the cluster.

Pōhutukawa

Loss, extinction, gratefulness to the environment (te taiao)

E TŪ PŌHUTUKAWA E
TE KAIKAWE I NGĀ MATE O TE TAU
HAERE RĀ KOUTOU KI TE UMA O RANGINUI
HAERE KI TE KETE NUI A TĀNE
KOIA RĀ! KUA WHETŪRANGITIA KOUTOU

BEHOLD PŌHUTUKAWA
WHO CARRIES THE DEAD OF THE YEAR
ONWARD THE DEPARTED TO THE CHEST OF THE SKY
ONWARD INTO THE MILKY WAY
INDEED! YOU HAVE BECOME STARS

An introduction to Pōhutukawa

Pōhutukawa (Sterope/Asterope) is the eldest child of Matariki and is the star that is connected to the dead. When Matariki rises in the new year, Māori honour the memories of all the people who have passed, and their spirits are released to become stars. Pōhutukawa encourages us to reflect on the past and to be thankful for those who have contributed to our lives.

Our connection to Pōhutukawa

REFLECTING ON WHAT WE HAVE LOST CAN GUIDE US INTO THE FUTURE

Pōhutukawa is connected to remembrance. A ceremony called 'whāngai i te hautapu' traditionally took place when Matariki had re-appeared in the mid-winter morning sky. The ceremony involved cooking and offering food to the different stars of Matariki, along with conducting karakia (incantations). Those who had died since the last rising of Matariki were honoured in the first part of the ceremony, when people would weep for their loved ones as their names were called out (Matamua, 2021).

For this report, Pōhutukawa represents the species and ecosystems we have lost and are at risk of losing, as well as the appreciation and duty of care we have for the environment (te taiao). When a species is gone its mauri extinguishes, and we are left with its memory and the lessons we can take from its departure (see the **Matariki section** for the definition of mauri used in this report). The loss of any part of the environment has a negative impact on our wellbeing when we recognise our connection to the environment. Furthermore, the loss is not just ours but a loss of opportunity and connection for future generations. Our gratefulness and duty of care is therefore to acknowledge the pressures we put on the environment and plan on how we can reduce them.

Photo: Erica Sinclair, Erica Sinclair Photography

Our values as drivers of landscape change

People's impact on the environment is a result of complex socio-cultural, economic, and technological factors. These, ultimately, are embedded in systems of values – how we treat the environment we live in comes down to what we collectively view as most important. In broad terms, environmental value systems can be categorised as instrumental, intrinsic, or relational (Chan et al, 2020; Pascual et al, 2017).

Instrumental values represent the value of ecosystems to support human needs and goals (Pascual et al, 2017). In this case, nature is viewed as a resource to fulfil the needs of an individual or a society and provide utilitarian benefits, such as ecosystem services. Intrinsic values refer to the value of ecosystems by their own right. From this perspective we should value nature for its own existence, independent of any benefits it may provide us (Connor & Kenter, 2019).

By contrast, relational values are starting to be recognised as another system of values. They refer to a view that people and nature are inseparable. This perspective sees us as embedded within our environment, and often implies moral duties to care – as the environment supports us we have a reciprocal responsibility to take care of it (Chan et al, 2016).

The notion of relational value systems aligns most closely with Māori understandings of the environment, in which humans are connected to ecosystems and all living beings through whakapapa (genealogy). Whakapapa understands the total environment or whole system and its lineage, allowing us to see the ways we are connected to te taiao (Harmsworth & Awatere, 2013).

These different value systems exist together in a society, and understanding which value sets are used in decision-making and how this changes over time is still an active area of research (Hill et al, 2021). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services gathered scientific evidence on the extent to which nature contributes to people in reciprocal ways and is vital for human existence. Their recent global assessment showed that by focusing on instrumental values, that is material supply of food, energy, and other tangible materials, human society has compromised many other contributions from nature (IPBES, 2019).

While the material benefits from the environment brought us economic gains, focusing entirely on instrumental values can result in loss of species and ecosystems, and the invisible or intangible benefits we receive from intact ecosystems. These include habitat for wildlife, flood and erosion control, and enhancement to our spiritual and psychological wellbeing (Powers et al, 2020; Tomscha et al, 2019).

Thinking differently about our relationship with the environment and recognising the full range of values can restore balance. To achieve this balance, we need to clarify how our actions are affecting the environment. The remainder of this section examines the pressures past generations have placed on te taiao, the legacy we are left with, and our own legacy for future generations.

Loss and extinction

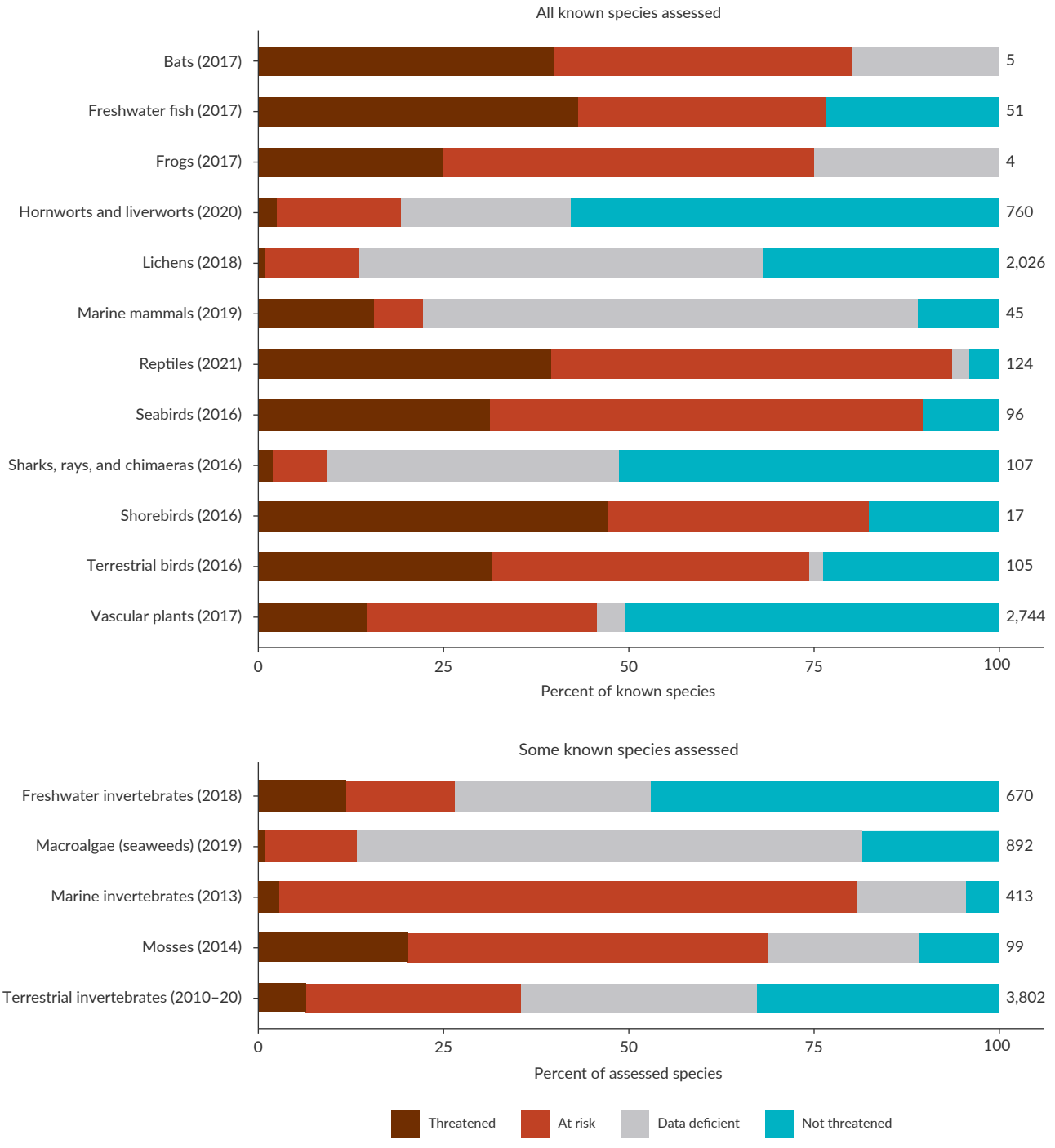
In Aotearoa New Zealand, a diversity of values and cultural backgrounds have shaped and continue to shape the landscape as we see it today. Each generation has left a legacy that we can trace back to the first landing of humans. How the land gets used and transformed is informed by values such as the ones outlined above (Journeaux et al, 2017). Farming first by Māori, then early European settlers, became the most significant human influence and soon became the backbone of economy of Aotearoa (Haggerty & Campbell, nd).

Before human arrival, more than 80 percent of the land was covered with native forest. (See indicator: **Predicted pre-human vegetation**.) This reduced to 27 percent by 2018. Recently, indigenous land cover area losses have continued. Between 2012 and 2018, indigenous land cover area decreased by 12,869 hectares, with Southland having the highest area net loss (3,944 hectares) (See indicator: **Indigenous land cover** and **Tupuārangi section**).

Humans also brought with them exotic species, either inadvertently or intentionally. Over 80 exotic species brought by humans became established, further contributing to the decline of original ecosystems in Aotearoa (Craig et al, 2000). Due to its geographic isolation, Aotearoa has a high number of endemic species (found nowhere else in the world). The changes brought by human settlement resulted in the extinction of at least 81 animal and plant species, including 62 bird species (DOC, nd-b; Robertson et al, 2021). These changes are continuing.

Figure 1 provides a summary of the state of our threatened land, marine, and freshwater species. Note that some groups have not had their extinction threat risk assessed for all species, so a comprehensive percentage of species in each extinction threat category is not available. (See indicators: **Extinction threat to indigenous land species**, **Extinction threat to indigenous marine species**, **Extinction threat to indigenous freshwater species**.)

Figure 1: Extinction threat to indigenous species



Data source: Department of Conservation

Note: For the all known species assessed figure, extinction threat percentages are derived from the total of all known species assessed. For the some known species assessed figure, extinction threat percentages are derived from the total number of species that have been assessed, not the total number of known species. Total species assessed are listed to the right of the bars.

Legacy effects

He hokinga whakamuri he kokiringa whakamua

I walk backwards into the future with my eyes fixed on my past

Drawing from previous reports in the environmental reporting series, this section synthesises the legacy of our past actions to understand what we leave for the future. The section reflects the broad themes we used in *Environment Aotearoa 2019*, and the five drivers of change known to have the biggest impacts on nature (land-use change, invasive species, pollution, natural resource use, and climate change) (IPBES, 2019). See the **previous reports** for a more comprehensive summary of pressures in each of the five environmental domains of our reporting system (marine environment, freshwater, atmosphere and climate, land, and air).

LAND-USE CHANGE AND INTENSIFICATION

We have intensified our use of agricultural land in recent years, particularly through dairy farming and horticulture. Intensification involves increasing the use of inputs such as fertiliser and irrigation, with the aim of increasing production – for example, having more animals per hectare of land or increasing the number or volume of harvests from crops (MfE & Stats NZ, 2021a).

Much of the intensification has been a result of a switch from sheep to dairy farming, driven by higher relative global market prices for dairy products (Wynyard, 2016). Overall, dairy cattle numbers increased by 21 percent between 2002 and 2019. (See indicator: **Livestock numbers**.) In Aotearoa, dairying accounted for around 40 percent of export revenue for primary industries in 2021, which is expected to reach $50.8 billion for the year ended June 2022 (MPI, 2021f).

The area of exotic forestry in 2018 was 12 percent higher (220,922 hectares higher) than in 1996. Of the land area that changed to exotic forestry, three quarters was from the conversion of land that was previously exotic grassland. (See indicator: **Exotic land cover**.)

The area of irrigated agricultural land almost doubled between 2002 and 2017 from 384,000 hectares to 747,000 hectares – a 94 percent increase in this period. Between 2017 and 2019, the area of irrigated land fell 11,666 hectares, a 1.6 percent decrease compared to 2017. (See indicator: **Irrigated land**.) Also, as of 2018, about 10 percent of Aotearoa land was estimated to be artificially drained (see ***Our freshwater 2020***).

The increase in fertiliser and irrigation use can deplete the health of our soils and pollute rivers and lakes. Clear felling of plantation forests, the harvest method used in Aotearoa, disturbs soils and increases sediment in waterways (MfE & Stats NZ, 2020b). These impacts and their implications for our wellbeing are discussed in the **Tupuānuku section**. See ***Our land 2021*** for more detail on land-use intensification.

Intensification is also being driven by urbanisation and land fragmentation. Often highly productive agricultural and horticultural land, land that is particularly good for food production, is on urban fringes. As urban areas expand, this land is fragmented by housing development. The area of highly productive land that was unavailable for agriculture (because it had a house on it) increased 54 percent between 2002 and 2019. (See indicator: **Land fragmentation**.) This pushes agriculture and horticulture on to less productive land, which means farmers use more fertiliser and irrigation to maintain productivity (MfE & Stats NZ, 2021a).

The area of urban land in Aotearoa increased by 15 percent from 1996 to 2018. (See indicator: **Urban land cover**.) Urbanisation can reduce access to green and open spaces. See **Tupuārangi section** for more on access to and benefits from greenspace.

Land-use change and intensification is putting pressure on the unique ecosystems and native species of Aotearoa. Change in land cover is driving fragmentation of habitats and allowing invasive species to spread, a process being exacerbated by climate change (Macinnis-Ng et al, 2021).

Wetlands are one example of a rare ecosystem with high biological, cultural, and disaster resilience values that are under threat. It is estimated that 90 percent of wetlands have been lost since pre-human settlement (Dymond et al, 2021) due to draining, ploughing, or burning, with approximately 60 percent of remaining wetlands in a moderately to severely degraded state (Ausseil et al, 2011). See **Waitī section** for more on recent changes to wetland extent.

INVASIVE SPECIES

The threat from introduced plants and animals is one of the greatest pressures our native species and ecosystems are facing. Aotearoa has the second-highest recorded number of invasive species in the world, excluding overseas territories (Turbelin et al, 2017). Introduced land mammals such as stoats, possums, and rats are responsible for most of an estimated 26.6 million egg and chick losses for native bird species every year (Russell et al, 2015). The pressures these invasives put on populations of treasured (taonga) species impact on customary practices for Māori (see **Tupuārangi section** for impacts on tikanga (customs/protocols) and Māori knowledge (mātauranga Māori)). The pressures from invasive species also have an economic effect, particularly on agriculture. (See indicator: **Land pests**.)

Invasive weeds are similarly a major threat, often out-competing native species (MfE & Stats NZ, 2021a). While control efforts have been underway for decades, we still lack comprehensive information about invasive weed distribution and rate of spread (PCE, 2021a). See **Tupuānuku** and **Tupuārangi** sections for how ecosystems are being affected by plant and animal land pests.

The aquatic ecosystems of Aotearoa are as unique as those on land, and pests in both the freshwater and marine environments pose a major threat. Introduced fish, invertebrate, and plant species reduce native biodiversity and lower water quality. Between 2015 and 2017, three additional non-native marine species were considered to be established in the waters of Aotearoa, bringing the total of non-native marine species that are established to 214 (MfE & Stats NZ, 2019). The impacts of pest species are compounded by climate change – for instance, marine heatwaves can reduce the population of native species in an area, potentially enhancing the likelihood that empty spaces are re-colonised by non-natives (MfE & Stats NZ, 2019; Thomsen et al, 2019). (See indicators: **Freshwater pests**, **Marine non-indigenous species**.)

POLLUTION

Our waterways are particularly vulnerable to pollution in various forms, as waste from the land is washed, pumped, or leached into the rivers and then to the sea. Plastic waste is a major problem: plastic takes centuries to break down, and large quantities continue to be produced. For example, in 2018 Aotearoa imported 575,000 tonnes of plastic material (PMCSA, 2019). A significant proportion of this accumulates in the environment, and plastics are found in the most remote areas and in the bodies of many animals. There is much we still do not know about quantities of plastics in the environment and the extent to which they affect ecosystems (MfE & Stats NZ, 2019; PMCSA, 2021). See **Waitā section** for what we are learning about how plastics impact the marine environment.

Land-use change and intensification increases pollution in our waterways. The amount of pollutants entering streams, rivers, and the ocean is linked to intensified agriculture and forestry, drained wetlands, industry, and urban development (McDowell et al, 2021; MfE & Stats NZ, 2020b). The environmental impacts we are seeing today are in many cases the result of decisions made in the past. For instance, fertilisation of agricultural land and urine from livestock impacts soil health and leaches nitrogen into waterways. However, water does not always move quickly through a catchment, and there are lag times between when the fertiliser was applied to the land and when the effects are evident in ecosystems. For a selection of river systems, the median lag time was estimated to be around five years, while in some catchments it can be many decades before the water completes its journey (McDowell et al, 2021; MfE & Stats NZ, 2020b). This has downstream effects on rivers, lakes, estuaries, and marine environments. Sediment accumulation has been identified as one of the main pressures on estuaries (see ***Our marine environment 2019***).

Air pollution from vehicles, wood burning, and manufacturing comes at a cost to human and environmental health. Despite having sites that register pollution levels above World Health Organization 2021 guidelines, especially during winter months, air quality in Aotearoa is slowly improving at monitored sites. This demonstrates that environmental pressures can be reduced through concerted effort (MfE & Stats NZ, 2021b). See **Ururangi section** for levels of air pollution and their effects.

NATURAL RESOURCE USE

Prioritising the productive capacity of the environment runs the risk of over-exploitation of many natural resources beyond the capacity of the environment to sustain us over the long term. Modelling shows that the quantity of water taken for irrigation had the most potential to affect and reduce river flows compared to other uses (Booker & Henderson, 2019). Furthermore, global warming has reduced the volume of ice in our glaciers and the water available for the rivers they feed. (See **Waipunarangi section** and the **Annual glacier ice volumes** indicator.)

Structures for diverting or controlling water such as dams, weirs, fords, and floodgates also put pressure on ecosystems. Blocking waterways and altering flow patterns alters the natural integrity of rivers and their ability to adjust, impacting their mauri. These barriers and changing water flows affect the migration and spawning of taonga species such as whitebait (īnanga) (MfE & Stats NZ, 2020b). See **Waitī section** for more on these impacts.

In the marine environment, some fish species are over-fished, and seabed trawling and dredging, although decreasing, can still damage habitat and alter the structure of the seabed (see ***Our marine environment 2019***). The **Waitā section** reports on the state of key fish stocks, the majority of which are considered to be fished within safe limits. The pressures which result from overfishing are still reducing the availability of important seafood (kai moana) species, and the tikanga and mātauranga Māori associated with collecting them. Many of these species face further stress from other pressures such as ocean acidification from carbon emissions.

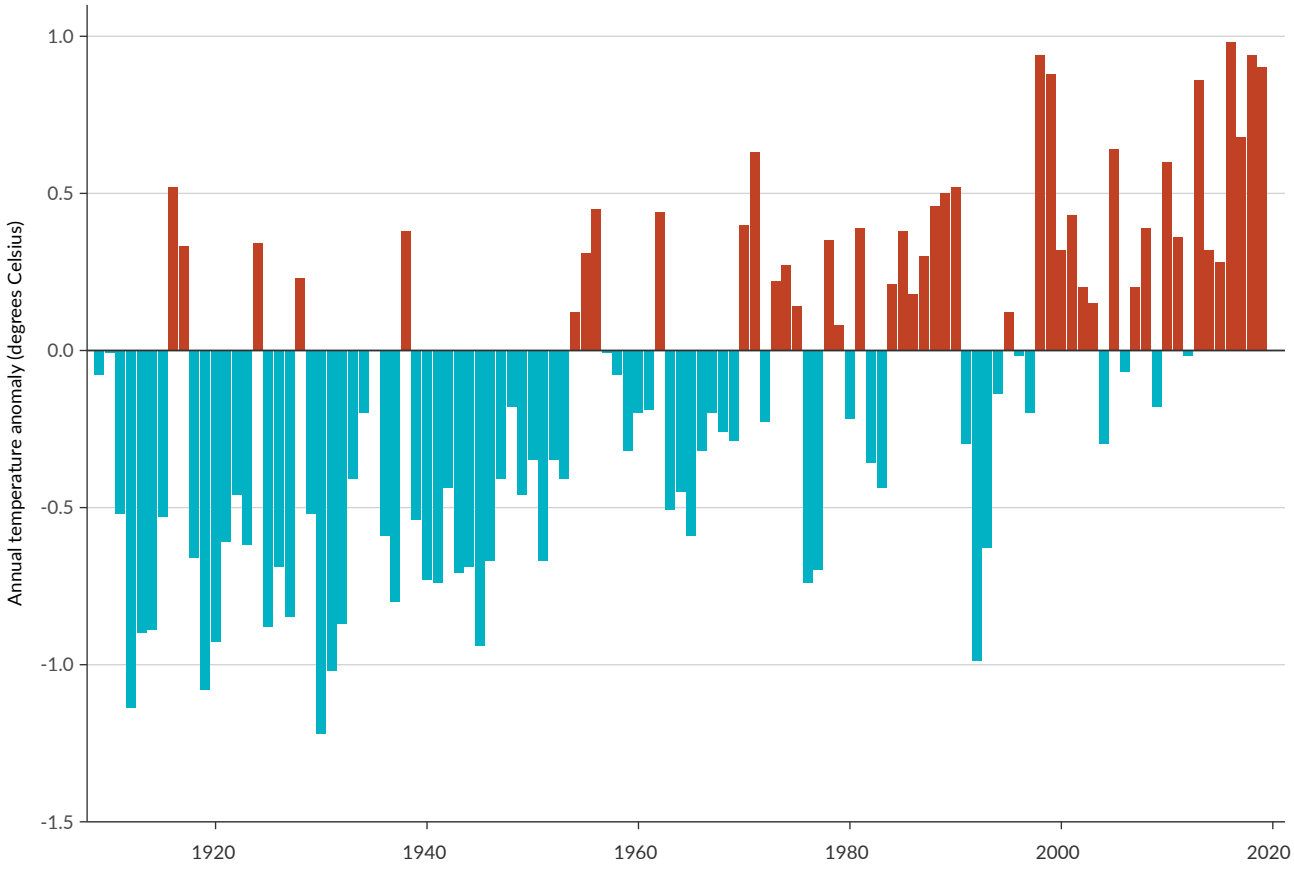
CLIMATE CHANGE

Our climate is changing, and this will continue to increase pressures on all parts of the environment (see ***Our atmosphere and climate 2020***). Greenhouse gas emissions have increased globally, and the concentration of carbon dioxide (CO_2) in the atmosphere continues to rise (Ritchie & Roser, 2020).

Aotearoa is also contributing to this issue. In 2020 Aotearoa's gross greenhouse gas emissions (or total emissions) were 21 percent higher than 1990 levels but have been relatively stable over the last decade despite increases in population and economic activity. For the same year, the country's net emissions (total emissions plus any emissions added or removed by the land use, land-use change and forestry sector) were 26 percent higher than 1990 levels (MfE, 2022). As long as our net emissions are greater than zero, we are still contributing to further climate change (MfE & Stats NZ, 2020a). In 2020, agriculture accounted for 50 percent of our total gross emissions, mainly from livestock (39 percent of gross emissions; 78 percent of the agriculture sector) and agricultural soils (10 percent of gross emissions; 20 percent of the agriculture sector). This was followed by energy at 40 percent, with energy for transport accounting for 17 percent of gross emissions; 42 percent of the energy sector (MfE, 2022).

The greenhouse gases we and the rest of the world emit are creating a warming effect in the climate. Overall, average temperatures are increasing (see figure 2). In Aotearoa, the annual average temperature increased by 1.13 (± 0.27) degrees Celsius over the period 1909 to 2019. In the 22 years to 2019, Aotearoa had its five warmest years on record: in 1998, 1999, 2016, 2018, and 2019. In the period from 1972 to 2019, 28 out of 30 monitored sites showed an increase in annual average temperature (the increasing trend was statistically very likely at 25 sites and likely at 3). (See indicator: **Temperature**.) The annual cumulative amount of warmth available has likely or very likely also increased at 27 of the 30 monitoring sites over the same period. (See indicator: **Growing degree days**.) For trend assessment detail, see relevant indicators.

Figure 2: New Zealand annual average temperature anomaly, 1909–2019



Data source: NIWA

Note: The baseline for temperature anomalies is the average annual temperature for the 30 years from 1961 to 1990.

A warming atmosphere also impacts weather patterns, including precipitation, seasonal temperature (frost and warm days), and wind patterns. The Waipunarangi and Ururangi sections cover the observed changes in climate and impacts of flooding and drought (Waipunarangi) and wind (Ururangi) on our wellbeing. The Tupuārangi, Waitī and Waitā sections cover the effects of changes in climate on some species in the land, freshwater, and marine domains.

In summary

The way we view nature, and the subsequent choices in the ways we live and make a living, result in pressures on the environment. These pressures can result in the loss of ecosystems and species, negatively impacting different aspects of our wellbeing. We explore the connections between environmental pressures and our wellbeing in the coming sections.

Many of these pressures will continue to have an impact, leaving a legacy effect on the wellbeing of future generations. Our duty of care is therefore to acknowledge the pressures we put on the environment and plan on how we can reduce them.

Pōhutukawa

Reflecting on what we have lost can guide us into the future.

More than 80%
of land was covered with native forest before human arrival. This was reduced to 27% in 2018.

At least 81
animal and plant species became extinct after human arrival.

62 bird species

Over 80
exotic species brought by humans became established, contributing to the decline of the original ecosystems of Aotearoa.

PŌHUTUKAWA
When Matariki rises, we honour the memories of all those who have passed. Pōhutukawa is the star that is connected to the dead. She encourages us to reflect on the past and to be thankful for those who have contributed to our lives.

Climate change

Loss of ecosystems and habitats

Urban development

Urban expansion on productive land pushes agriculture and horticulture on to less productive land.

Wetland drainage

Invasive species
Introduced species compete with and prey on our native biodiversity.

Erosion

Pollution
Pollution from our activities affects our air, waters, and land.

Run-off and leaching

Land-use change and intensification

Change of natural flow

Natural resource use and exploitation

Nutrient leaching

Aquifer

Cumulative impacts and legacy effects
The pressures combine with each other and compound over time. All parts of the environment (te taiao) are interconnected, and changes in one area can have flow on effects to others.

As we reflect on the changes we have brought to the environment and what we have lost, it presents an opportunity to consider how we give back to the environment and learn from the past.

Tupuānuku

Our soils and food grown in the earth

E TŪ TUPUĀNUKU E
TIRITIRIA TE ONEONE
KIA MATOMATO KI RARO
KA TĪNAKU, KA TUPU, KA TĀMAOTA NGĀ MĀRA E

BEHOLD TUPUĀNUKU
TILL THE SOIL
SO EVERYTHING BECOMES LUSH
GERMINATE, GROW, AND LET THE GARDENS BE ABUNDANT

An introduction to Tupuānuku

Tupuānuku (Pleione) is the star connected to anything within the soil. This star also represents geographical features such as mountains, plains, and valleys. She is associated with the food grown in the ground, both cultivated (ie grown in gardens) and uncultivated. Tupuānuku is comprised of two words: 'tupu' which can mean 'new shoot' or 'to grow', and 'nuku', an abbreviation of 'Papatūānuku' (Earth mother). Tupuānuku resides in the domain of Rongo-mā-Tāne, the atua of agriculture.

This section is about the health of our soils and the different ways in which this affects our wellbeing.

Our connection to Tupuānuku

CONNECTIONS BETWEEN SOIL AND PEOPLE

Tāne (atua of the forest) created the first woman, Hineahuone, from clay (her name means 'earth-formed woman') (Hutchings et al, 2018). Her source (clay) highlights the importance of soil and the connection between soil and people. This connection is also seen in Māori language (te reo Māori), where the word 'whenua' means both 'land' and 'placenta'. The whenua or placenta is often buried at a significant place such as a marae, acknowledging the intimate spiritual and physical connection between land and people (Harmsworth & Awatere, 2013).

For some Māori, soil health is reflected in its capacity as a living ecosystem to sustain and support all life, including microbes, plants, animals, and humans (Hutchings et al, 2018). Soil is the ancestor of our food (kai) and affects our wellbeing as consumers (Hutchings et al, 2020). This means soil requires special attention. Instead of viewing soil as a commodity, we can understand it as a living entity and enhance its mauri by protecting and growing its microbial diversity and structure (Hutchings et al, 2018) (see the **Matariki section** for the definition of mauri used in this report).

Acknowledging the soil as our ancestor

Dr Jessica Hutchings (Ngāi Tahu, Gujarati) is a Māori research leader and organic farmer who has helped shape a Māori framing of the soil. She notes that "When I hold soil or living compost in my hands, there's a feeling of intrigue, of mystery, about its creative potential for growth and for nurturing ngā kākano (seeds) into life. I have reverence for soil because she is my tupuna and there is no separation between me as a human being and the soil as my ancestor."

For Jessica, "Soil is the most precious thing we have. We come from soil and are the embodied form of Papatūānuku, so to assign personhood status and see soil as an ancestor would elevate her mana. Our soil is suffering, and time is running out – we need an intervention as bold as giving soils personhood status to change the way we think about soils and to restore their immeasurable value."

For further discussion of Jessica's work and her ideas for elevating the mana of soils, see ***Our land 2021***.

MĀTAURANGA AND SOIL HEALTH

Caring for the soils through land healing and regeneration practices contributes to restoring the biodiversity and mauri of whenua, ecosystems, and species (Hutchings et al, 2020). For some Māori, the indivisible connection between environmental and human health means the state of the soil affects our wellbeing (Harmsworth & Awatere, 2013).

From archaeology we have historic evidence that Māori gardeners adapted their practices to the specific features of the land and worked in harmony with environmental conditions (Furey, 2006). This reflects kaupapa Māori (a Māori way), so is similarly observed today in the whole-of-landscape Māori approach towards soil health which highlights the tikanga (customs/protocols) and associated gardening practices of growing food (kai) (Hutchings et al, 2018).

These practices seek to improve the mauri of the soil and include composting, using livestock to increase soil fertility, and reducing the use of mechanised equipment to limit soil compaction. Nitrogen-fixing crops are grown to add nutrients, help maintain soil structure, and prevent erosion. The whole-of-landscape Māori soil health approach also aims to maintain natural soil processes by avoiding the use of chemical fertilisers, pesticides, and herbicides (Hutchings et al, 2018). Long-established soil care practices that can adjust to natural variability continue to build knowledge and improve soil health, whilst also emphasising the whakapapa (genealogy) of the soils and encouraging resilient cultivation and sustainable use of soils in the future (Hutchings et al, 2018).

The greatest yields are when this knowledge is used together with the maramataka, which provides guidance on when to plant and harvest for the best results. Maramataka means 'the moon turning' and is the traditional Māori way by which time was marked by observing the phases of the moon. It is commonly held that Matariki and the maramataka both inform our understanding of how the various lunar nights affect the world and all its inhabitants. In turn, this understanding informs planning and day-to-day activities (Matamua, 2017). For example, according to horticulture and rongoā rākau (plant medicine) knowledge holder Joan Ropiha, planting kūmara during favourable phases of the moon means the crop will be resistant to decay once it is harvested and stored (Ropiha, 2010).

Some believe that if Tupuānuku appears dim and small when Matariki rises in the new year, it signals anticipation that the harvest from the gardens in the year to come would be less plentiful than previous harvests. If the star is bright in the sky, then storehouses would be full with a plentiful harvest (Matamua, 2017).

The connection between Tupuānuku and agriculture is reflected in the proverb (whakataukī) 'Hauhake tū, ka tō Matariki' (the harvest ends when Matariki sets). Traditionally, the harvesting of gardens is undertaken in autumn, during the month of Poutūterangi (around March and April). At this time of year Matariki sets in the western sky at dusk and does not appear again until winter, when it rises at dawn, marking the beginning of the Māori new year.

SOIL AND HEALTH

As we have seen, in the Māori worldview (te aō Māori), the state of the soil affects our wellbeing (Stronge et al, 2020). Initial international research also suggests soil health, food nutrition, and therefore human health, are linked – healthier soil means healthier food and so healthier people (Cirillo et al, 2016; Omondi et al, 2021; Ren et al, 2017). Many factors contribute to the uptake of nutrients from the soil by crops, and the relationship between soil quality and nutritional quality is not clearly understood. However, evidence shows that changes in soil fertility affect the nutrient content of fruits and vegetables (Meagy, 2014), and that crops grown with a focus on long-term soil management have greater nutritional value (Mitchell et al, 2007; Omondi et al, 2021; Ren et al, 2017).

Soil is the basis for our food production. Keeping soil healthy and productive ensures we can maintain its ability to produce food and fibre for our own use and export (MfE & Stats NZ, 2021a). Aotearoa soils also provide benefits beyond production, such as supplying building materials, the ability to filter nutrients and contaminants, the ability to store water and mitigate floods, decomposition of wastes, and maintaining biodiversity (Brevik et al, 2020; Dominati & Mackay, 2013). Healthy soils also support microorganisms that are important for human nutrition and developing our immune systems (Brevik et al, 2020). These benefits are lost if soils erode or are degraded.

Trade-offs are likely required as soils managed for agricultural benefit alone mean we lose some of the other benefits (Ng & Zhang, 2019). For example, the value of non-production benefits provided by soils decreases with higher stocking rates on a typical dairy farm in Aotearoa (Breure et al, 2012).

When measuring and managing soil health, a broad view of the benefits of healthy soil beyond increasing agricultural production can enhance our wellbeing in many ways: "A healthy soil determined purely on its ability to supply goods is equivalent to measuring human health based on a person's ability to do work or a person's economic value as a member of the society" (Ng & Zhang, 2019). Broadening the concept of soil health to wellbeing can help reflect the diverse societal and cultural values and help consider soil management in a more sustainable way (Stronge et al, 2020).

SOIL AND ECONOMIC BENEFITS

In addition to providing us with sustenance, food grown from the land, through agriculture and horticulture, contributes to the economy of Aotearoa. In the year ended March 2020, agriculture contributed 4.3 percent of GDP, equating to $14 billion. The respective contributions to this total were 50 percent from dairy, 28 percent from sheep and beef, and 17 percent from horticulture (Stats NZ, 2021a).

Agriculture comprises a significant share of export revenue: in 2020, agriculture and horticulture exports generated $40.7 billion in export revenue (MPI, 2021f). (Note, export revenue is not the same as economic benefit to Aotearoa.)

Māori own a significant proportion of assets in the primary sector: 30 percent of lamb production, 30 percent of sheep and beef production, 10 percent of dairy production, and 10 percent of kiwifruit production (MFAT, 2019). In 2012, about 6 percent of the total exports of Aotearoa came from the Māori economy, which encompasses all people, entities, and enterprises self-identifying as Māori. The main contributions to this were meat and dairy (Schulze & Reid, 2019).

The state of Tupuānuku

As outlined above, specific soils and topographies are best suited to growing certain crops, and we know that repeated cropping on the same soils depletes their fertility. However, today, there are numerous pressures on our land, affecting soil quality and the extent of land suitable for growing food crops. Here we provide a high-level overview of soil quality; for more detailed information see ***Our land 2021***. For more information on pressures on our land see the **Pōhutukawa section**.

SOIL QUALITY

Seven soil indicators are commonly used to monitor soil quality in Aotearoa. These are:

1. macroporosity (the proportion of large pore spaces in the soil and a measure of soil compaction)
2. total carbon (the amount of all organic and non-organic carbon forms in the soil)
3. Olsen phosphorus (the amount of phosphorus available to plants and a measure of soil fertility)
4. total nitrogen
5. mineralisable nitrogen (the quantity of organic nitrogen that microorganisms can process and make available to plants)
6. pH (soil acidity)
7. bulk density (density of the soil and a measure of soil compaction).

Intensive use of food-producing land can degrade soil health, which has flow-on effects on soil productivity. Heavy machinery and large numbers of livestock per hectare can cause damage by compacting the soil which has a negative effect on the macroporosity of the soil (Drewry et al, 2008; MfE & Stats NZ, 2021a). Pastures on degraded soils respond less to nitrogen fertilisers, while soil compaction can also increase nitrogen dioxide emissions (Douglas, 1994; Hu et al, 2021).

Soil compaction can also lower productivity. In Aotearoa, pasture production was estimated to decrease by an average of 2.5 percent for every 1 percent decrease in macroporosity within the first 10 centimetres of the soil layer (Hu et al, 2021).

The biodiversity of soil is not routinely monitored in Aotearoa, despite being an important measure of overall soil health. The concept of soil health is more holistic than soil quality, focusing on how soil functions as a living ecosystem. Soils are home to over 25 percent of the world's total biodiversity (FAO et al, 2020), and contain insects, worms, fungi, and microorganisms. These have an important role making nutrients available for plants to grow and protecting them from disease (MfE & Stats NZ, 2021a). Understanding soil biodiversity and its effects on the wider environment remains a large knowledge gap in Aotearoa and globally.

Diversity of microorganisms in the soil is lower at sites with a history of nitrogen fertilisation and this may limit future restoration of soil ecosystems and habitats (Addison et al, 2021). Intensive agricultural land use can reduce the microbial biodiversity in soils for decades. This means those soils could be best suited for agriculture or plantation forestry, and have limited capacity to be restored to native ecosystems or to adapt to climate change effects (Addison et al, 2021).

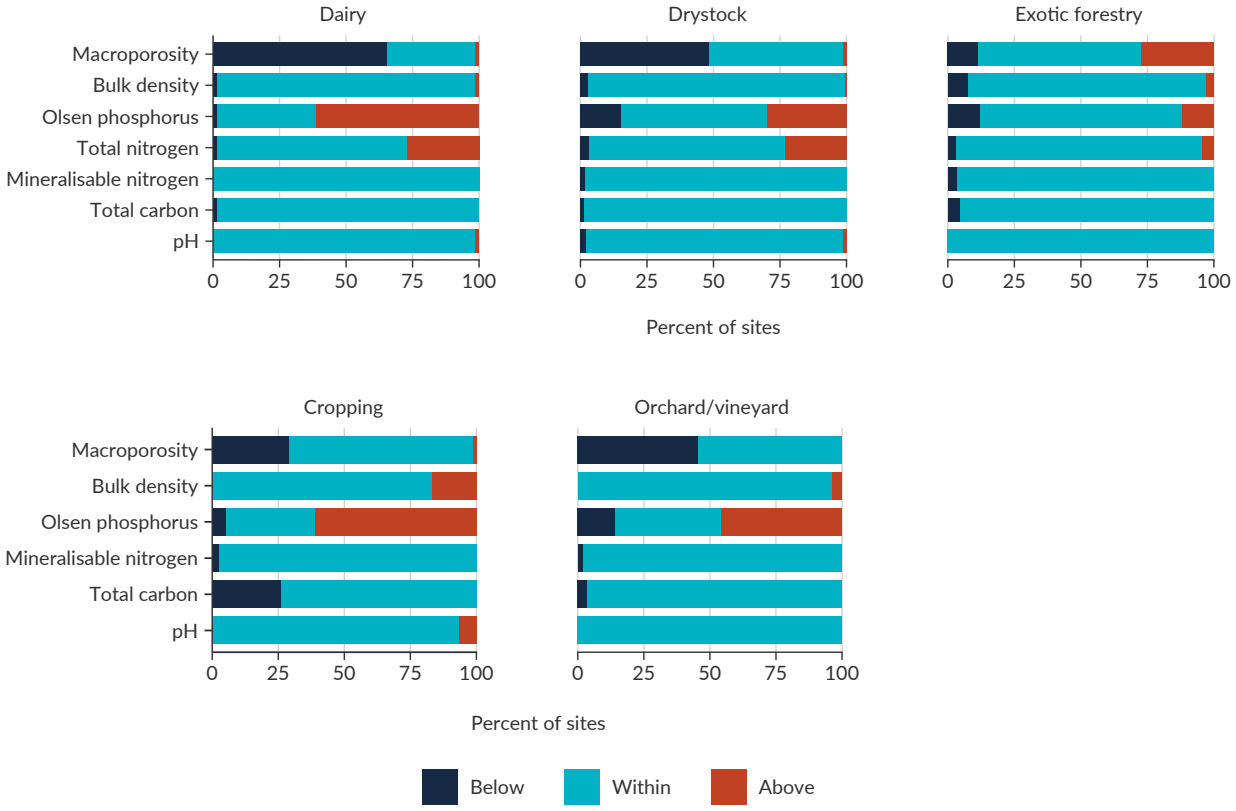
There was no overall improving trend in soil quality observed over the period 1994–2018 in Aotearoa (Stevenson & McNeill, 2020). Sites measured comprised a range of land uses, including farming (dairy and drystock), horticulture, forestry, and lifestyle.

Eighty percent of measured sites failed to meet the targets for at least one of the seven soil quality indicators for the period 2014–18. Of note, nearly half of all sites (275 of 602) were below the target range for macroporosity, which indicates whether roots can access air and whether water can flow through the soil. This was especially notable in:

- dairy sites, where 95 of 146 sites (65 percent) were below target ranges
- drystock, where 103 of 214 sites (48 percent) were below the target
- orchard/vineyard, where 25 out of 55 (46 percent), were below target
- cropping, where 22 of 76 sites (29 percent) were below target (see figure 3).

Over the period 2014–18, over 90 percent of measured sites met target ranges for the following soil quality indicators: bulk density, mineralisable nitrogen, total carbon, and pH (soil acidity). (See indicator: **Soil quality and land use**.)

Figure 3: Sites within target range of soil quality indicators by land use, 2014–18



Data source: Manaaki Whenua – Landcare Research

EROSION AND LAND FRAGMENTATION

Highly productive land (which makes up only 15 percent of our country's total land area) is increasingly under pressure from the demand for more housing, especially around our cities (MfE & Stats NZ, 2021a) (see **Pōhutukawa section**.) The area of highly productive land no longer available for crops and livestock increased by 54 percent in the period 2002–19. (See indicator: **Land fragmentation**.)

Erosion is a widespread natural process in Aotearoa mainly due to weak and highly erodible rocks and high rainfall events. However, human actions have made large areas of land more susceptible to erosion, especially the deforestation of hill country for pastoral farming. As reported in *Environment Aotearoa 2019*, there is a knowledge gap on monitoring erosion and we have limited understanding of where, how, and to what extent it is happening. Data from 2012 showed that an estimated 192 million tonnes of eroded soil entered our rivers each year. Forty-four percent of this (84 million tonnes) was estimated to have come from land with exotic grass cover (including pastoral farmland). In decreasing order, West Coast, Gisborne, Otago, Canterbury, Northland, and Manawatū/Whanganui were the regions with the highest levels of sediment movement into waterways. (See indicators: **Estimated long-term soil erosion**, **Highly erodible land**.)

Small forested catchments with native or exotic forest cover tend to yield 50 to 80 percent less sediment than pastoral catchments, with variation due to rainfall, topography, and geology (Basher, 2013). However, the harvesting of plantation forests can lead to soils becoming vulnerable to erosion, particularly on erodible steep land (Phillips et al, 2017).

Losing soil through erosion reduces the benefits that soils can provide (Dominati & Mackay, 2013). Shallow landslides are one of the most widespread types of erosion in Aotearoa. These landslides remove soil nutrients and reduce its depth and water holding capacity (Basher, 2013). Eroded soils often have limited biodiversity (Rey, 2021). Soil washed from the land can degrade freshwater habitats by filling in streambeds that fish and invertebrates use to hide and breed, while making it more difficult for them to find food (MfE & Stats NZ, 2020b). Fine sedimentation can also increase flooding, disrupt the functioning of hydroelectric power dams, and make rivers less suitable for recreation and traditional food gathering practices (mahinga kai) (Collier et al, 2017; Rey, 2021). (See indicator: **Deposited sediment in rivers**.)

Soil loss can be prevented. Vegetation on sloping land helps to slow run-off and reduce erosion, and vegetation on riverbanks helps control water currents, protecting banks from erosion (Rey, 2021). Low-density shrubland reforestation such as with mānuka can help reduce erosion in steep areas, especially where root structures reach beyond the depth where landslides occur. Increased planting density and improved weed management for seedling success could further mitigate erosion (Marden et al, 2020).

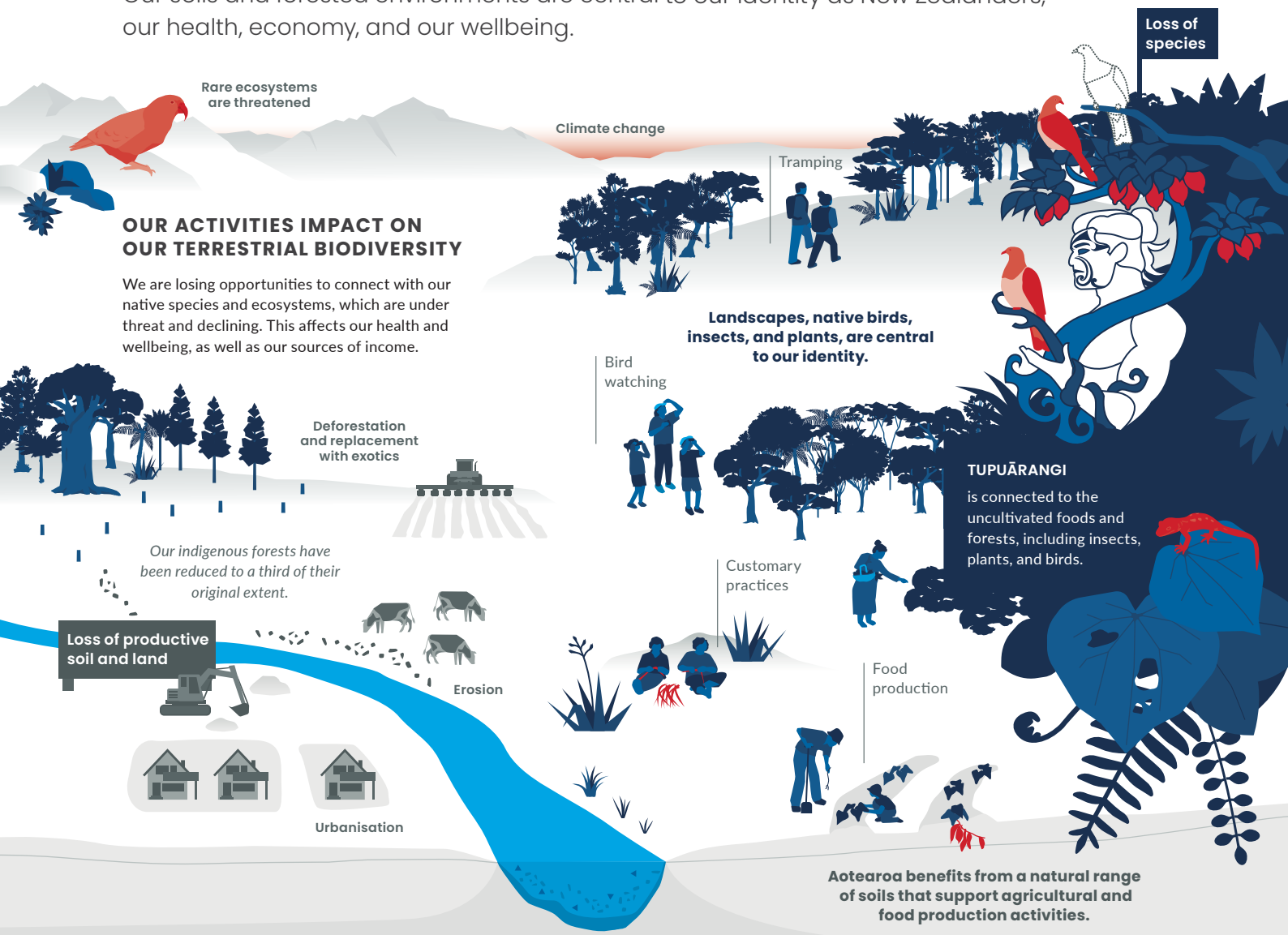
In summary

The quality of our soils is not always within target ranges. Eighty percent of measured sites did not meet soil quality targets for at least one indicator for 2014–18, with nearly half of all sites below the target range for macroporosity. We also continue to lose our productive soils to erosion, development, and land fragmentation.

If this continues we risk our current food production systems becoming unsustainable. The variety, quality, and amount of food we can grow could be limited, compromising the ability to access the food we need and reducing the economic benefits from our primary sector. How we look after our soil has wide-ranging consequences for both our health and the environment, including nutrients and sediment in rivers and estuaries. (See the **Waitī** and **Waitā** sections for more detail.)

Our land and biodiversity

Our soils and forested environments are central to our identity as New Zealanders, our health, economy, and our wellbeing.



OUR ACTIVITIES IMPACT ON OUR TERRESTRIAL BIODIVERSITY

We are losing opportunities to connect with our native species and ecosystems, which are under threat and declining. This affects our health and wellbeing, as well as our sources of income.

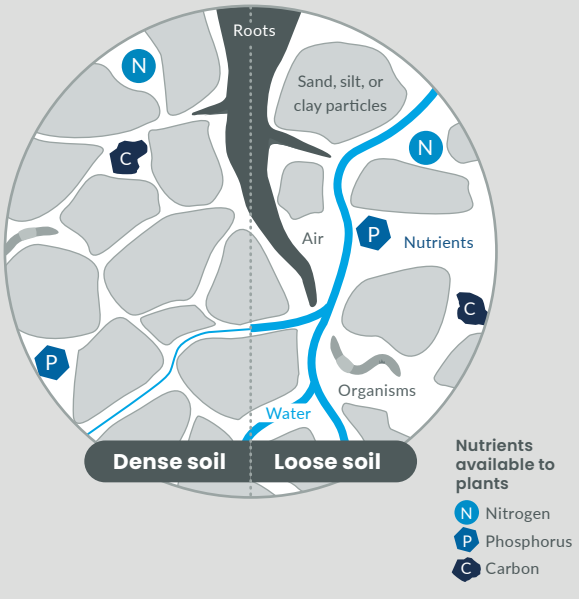
Excess soil, nutrients, and contaminants affect our freshwater and marine environments.

TUPUĀNUKU

is connected to anything associated with the soil, including cultivated and uncultivated foods grown in the ground.

THE WAY WE USE OUR LAND IMPACTS SOIL QUALITY AND AVAILABILITY

Intensive use of the land that produces our food has led to degraded macroporosity (the number of pore spaces in the soil), especially in areas of dairy and drystock farming. Macropores are important because they provide air for roots and allow water to flow through the soil.



Tupuārangi

Everything that grows above the earth

E TŪ TUPUĀRANGI E
KA PŌKAI TARA KI RUNGA
WHATITIRI NGĀ PARIRAU MANU
NAU MAI TE PUA NUI A TĀNE

BEHOLD TUPUĀRANGI
A GREAT FLOCK OF BIRDS ABOVE
WITH MANY WINGS LIKE THUNDER
WELCOME THE BOUNTY OF TĀNE

An introduction to Tupuārangi

Tupuārangi (Atlas) is the star linked to food and growth above the ground. Tupuārangi also has a strong connection with birds. Tupuārangi is comprised of two words: tupu which can mean 'new shoot' or 'to grow', and rangi (sky), an abbreviation of 'Ranginui' (sky father). Tupuārangi has influence over the domains of Tāne, the atua of the forest, Haumietiketike, the atua of uncultivated foods and insects, and Tūtewehiwehi, the father of reptiles, fern roots, nīkau, harakeke, and silver tree fern (ponga).

This section focuses on land-based ecosystems, in particular our forests. It looks closely at some key species which illustrate our connection to Tupuārangi, including kererū, flax (harakeke), and mānuka.

Our connection to Tupuārangi

CONNECTIONS BETWEEN NATURE AND PEOPLE

Mātauranga Māori tells us that shifts in the mauri of any part of an ecosystem eventually affect the whole system (see the **Matariki section** for the definition of mauri used in this report). The use or harvest of parts of the ecosystem such as birds and plants may cause such shifts in mauri. Any damage or contamination to the environment will therefore also cause loss of, or damage to, mauri (Harmsworth & Awatere, 2013).

Some believe that if the stars Tupuānuku and Tupuārangi shine brightly when Matariki rises in the new year, people can plan for a plentiful harvest of crops, as well as berries, fruits, and birds from the forest (Matamua, 2017). Reflecting the connection of Tupuārangi to birds, during the rising of Matariki, kererū (*Hemiphaga novaeseelandiae*) were harvested in large numbers and preserved for the months ahead. This is seen in the proverb 'Ka kitea a Matariki, kua maoka te hinu' ('When Matariki is seen the fat of the kererū is rendered so the birds can be preserved') (Matamua, 2017).

The connections some Māori have with Tupuārangi can be demonstrated with the kererū. Historically, Tūhoe Tuawhenua (an iwi located in the Ruatāhuna region in Te Urewera) harvested kererū only in a particular season as a food source and for special occasions. There were strict observances around who would harvest kererū, as well as the ways in which their meat and feathers would be used and prepared (Timoti et al, 2017).

More recently, Tūhoe Tuawhenua have also reflected on the loss of kererū from the Te Urewera Ranges, particularly after the 1950s. Given the close linkages between kererū and Tūhoe Tuawhenua, some iwi members believe their declining interactions with kererū have contributed to the decline of the birds' population (Lyver et al, 2008).

This loss of connection to Tupuārangi shows how the loss of access to ecosystems can diminish the sense of connection to place, identity (especially through whakapapa/geneology), and mana (power, authority). It also leads to the loss of Māori knowledge (mātauranga Māori) which comes from engaging with the environment (Lyver et al, 2008).

Practices concerning the harvesting of tītī (sooty shearwater or muttonbird) in the islands around Stewart Island (Rakiura) provide a further example of the inherent connections of humans to ecosystems – and the physical and spiritual worlds – in Māori worldviews. Tītī are an important source of food. Chicks are harvested by Rakiura Māori, who hold the manawhenua (territorial rights) on local breeding sites (King et al, 2013).

For Rakiura Māori, the harvesting of tītī (or 'muttonbirding') has not only food purposes but also significant social and cultural importance: in particular kinship links, the importance of keeping access rights to resources, and maintaining cultural knowledge (Wanhalla, 2009). Similar practices happen elsewhere in Aotearoa – for example, on islands off the Coromandel Peninsula iwi harvest small numbers of grey-faced petrel chicks (King et al, 2013).

Maintaining and rebuilding connections to customary harvesting of food (kai) reconnects people with land (whenua), wetlands (repo), and other ecosystems. Further, this supports the transmission of knowledge to the generations to come (Herse et al, 2021; Waitangi Tribunal, 2011).

Tupuārangi is also connected with plants and trees. Growing in our repo, harakeke has always been and continues to be an important resource in the Māori culture and economy. As well as being used for a wide range of medicinal applications, its leaves can be woven into baskets and other containers, mats, and clothing. The fibre (muka) can be twisted, plaited, and woven to make useful objects such as fishnets and traps, footwear, and ropes (DOC, 2022; Manaaki Whenua – Landcare Research, 2022).

FORESTS AND WELLBEING

Our forests and other wild places contribute to our wellbeing by giving us experiences, a sense of place, and enhancing our understanding of the environment. Sense of place is important when considering ecosystem values and environmental management (Dunball, 2020; Masterson et al, 2017). Recognising that people are part of ecosystems makes the management of ecosystems inseparable from their connections to human society (Ryfield et al, 2019).

Forests provide important economic benefits which support people's livelihoods and wellbeing. Timber from pine plantation forests is one of our major export revenue earners. For the year ending December 2020, almost all (99.97 percent) of the logs harvested in Aotearoa came from plantation forests, with the remaining percentage harvested from indigenous forests. Of these, 87 percent of the trees in our plantation forests were *Pinus radiata* and 7 percent Douglas fir (Forest Owners Association, 2021). For the same year nearly 33 million logs were harvested, of which 61 percent were exported non-processed and the remainder processed in Aotearoa. The contribution of forestry and logging to GDP was 0.5 percent in 2020 (Stats NZ, 2021a). The total value of all forestry exports in 2020 was $5.5 billion (MPI, 2021f).

Honey is another important product we obtain from forest ecosystems. Twenty-seven thousand tonnes of honey were produced in Aotearoa in 2020 from 9,585 bee-keeping enterprises, most of them in the North Island. Honey export volumes have increased by 28 percent (2,223 tonnes) in 2020 compared to 2019 (MPI, 2021a). Mānuka honey in particular is an important export earner, with monofloral mānuka honey making up over half of honey export volume and commanding a higher price than other varieties for the year ended March 2021 (MPI, 2021e).

Geographic features and landscapes, such as forests and mountains, contribute to New Zealanders' national identity (Blaschke, 2013; Chick & Laurence, 2016). When New Zealanders were asked what species and natural features they considered nationally iconic, species commonly mentioned were kiwi, ferns, kauri, pōhutukawa, tūī, kākāpō, kea, rimu, kōwhai, and tuatara (Premium Research, 2011).

Our forests and native ecosystems also provide opportunities for recreation, and to appreciate their wildlife and enjoy the scenic landscapes in which they occur. A survey of over 3,800 New Zealanders about their experiences in the outdoors found that 84 percent of respondents felt having access to the outdoor spaces of Aotearoa is a major advantage of living here (DOC, 2020b).

ACCESS TO NATURE AND GREENSPACE

Access to greenspace enhances our wellbeing in numerous ways. We can receive many of these benefits through spending time in urban parks in our towns and cities as well as by visiting our more remote native forests. Natural features such as forests and parks in towns and cities provide many benefits for our health and lifestyle quality, including reduced air and noise pollution and increased biodiversity (Meurk et al, 2013).

These benefits are not always available close to where people live. For people living in towns and cities, accessing and benefiting from greenspace becomes more challenging (MfE & Stats NZ, 2021a). These benefits are unevenly distributed: lower-income communities in general have less access to greenspace and the wellbeing benefits it provides (Regional Public Health, 2010). The area of publicly accessible greenspace in Aotearoa urban areas is low compared to Europe (Souter-Brown, 2020), yet in 2019, 84 percent of New Zealanders lived in towns and cities (Stats NZ, 2021b). The highest percentage of greenspace in Aotearoa towns and cities is 13 percent in New Plymouth, while the highest in Europe is 68 percent in Oslo, Norway (World Cities Culture Forum, 2018). This lack of access to greenspace is likely to disadvantage urban Māori, who disproportionately live in lower socio-economic areas and tend to have fewer opportunities to connect with nature (Walker et al, 2019).

Access to nature and greenspace has a range of wellbeing benefits (MfE & Stats NZ, 2021a). It is positively associated with physical activity, and both physical activity and greenspace exposure are associated with greater emotional wellbeing (Markevych et al, 2017; Ward et al, 2016). In adults, greenspace is strongly associated with life satisfaction (Cleary et al, 2017; Houlden et al, 2018), while recreational visits to green and blue spaces improve mental wellbeing (White et al, 2021). Exposure to greenspace has also been shown to help build social connections (Markevych et al, 2017). People who live in areas with more urban greenspace perceive their neighbourhoods to be more socially cohesive (Holtan et al, 2015) and are more likely to volunteer (Ng et al, 2019).

There are mental health benefits for younger people in access to greenspace. In children, it is shown to reduce stress and improve attention, cognitive function, memory, and behaviour (McCormick, 2017; Sobko et al, 2018). In adolescents, exposure to greenspace is associated with reductions in stress, depressive symptoms, and psychological distress and improvements in mood, emotional wellbeing, and behaviour (Mavoa et al, 2019; Zhang et al, 2020).

Under COVID-19 lockdown restrictions, we learnt that access to nature was important for people's wellbeing. During 2020 lockdowns in the UK, people reported better wellbeing and health if they had access to parks or gardens (Poortinga et al, 2021). In Aotearoa, people reported that connecting with nature during lockdown, such as listening to birdsong, brought a sense of calm and joy and eased anxieties (Greenaway, 2020).

The state of Tupuārangi

This section examines the state of terrestrial biodiversity in Aotearoa, with a focus on the ecosystems and some of the plant and animal species that are especially important to Māori in the realm of Tupuārangi.

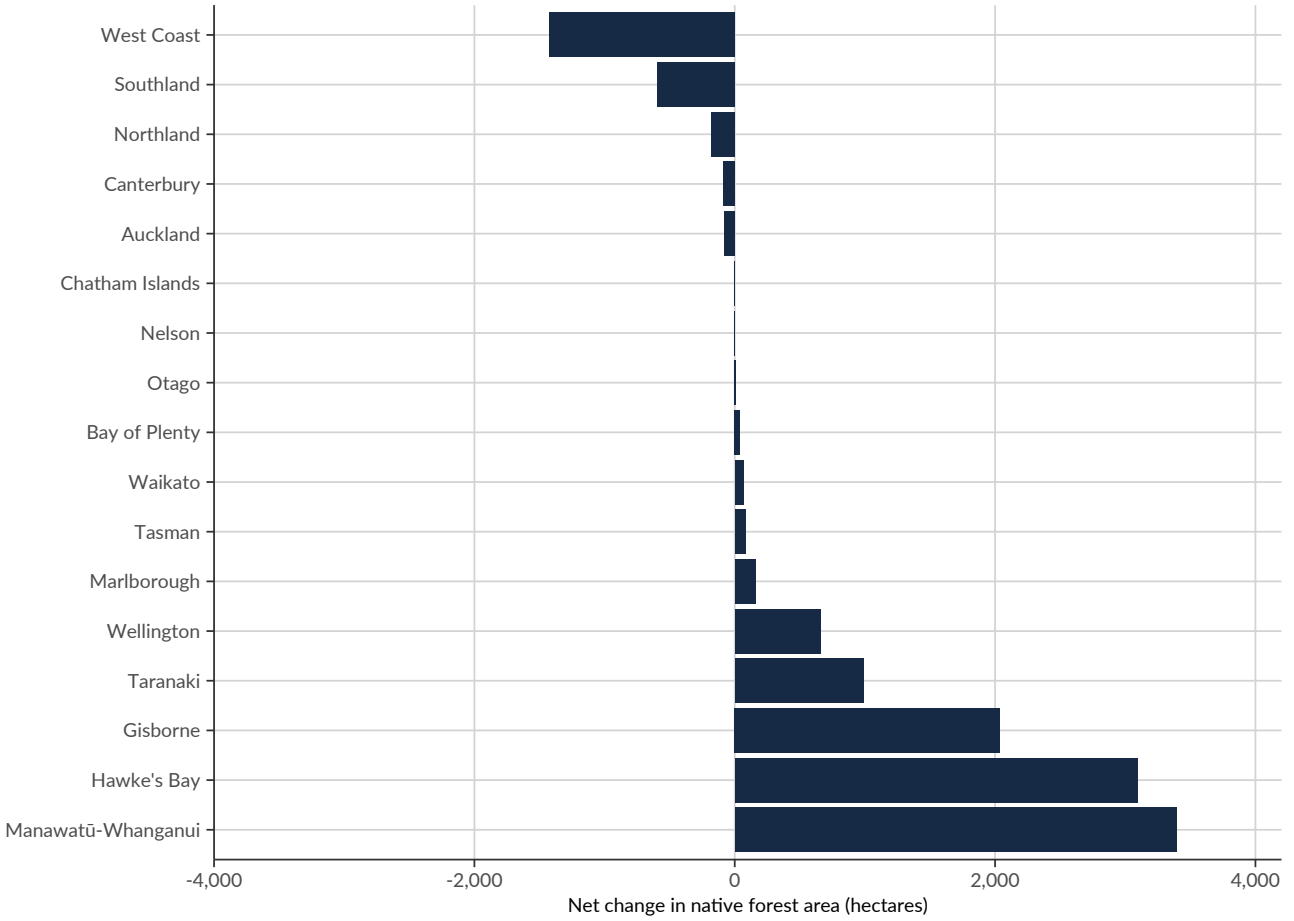
INDIGENOUS FORESTS

Native forests in Aotearoa have been steadily removed since human occupation, with less than one third of their original extent remaining (see **Pōhutukawa section**). Little of our lowland or coastal forests remain. In recent times, the area of native forest has remained fairly static. However, some regions have seen increases between 2012 and 2018 (in particular, Manawatū-Whanganui, Hawke's Bay, and Gisborne). Other regions, most notably the West Coast, continued to lose indigenous forest (1,423 hectares lost in this region over this period). (See figure 4 and indicator: **Indigenous land cover**.)

RARE ECOSYSTEMS

In 2014, 71 ecosystems were identified as rare ecosystems in Aotearoa because they represented less than 0.5 percent of the country's land area. Of these rare ecosystems, 45 were classified as threatened with collapse. Inland and alpine systems had the largest number of rare ecosystems (30), with just over half of these threatened (16). (See indicator: **Rare ecosystems**.)

Figure 4: Native forest area net change by region, 2012–18



Data source: Manaaki Whenua – Landcare Research

Restoration of urban ecosystems helps to protect native species and enhance recreation

As a consequence of topography and British planning tradition, cities such as Dunedin and Wellington have the benefit of an urban green belt (Meurk et al, 2013). Initiatives in other cities aim to increase the area of accessible greenspace. Urban forests enhance people's wellbeing by providing recreation areas, community involvement and connection with biological heritage.

Waiwhakareke Natural Heritage Park in Hamilton is an example of successful urban forest restoration (Wallace & Clarkson, 2019). The Avon Ōtākaro River park proposed for Eastern Christchurch aims to restore native habitats for birds and other species, while also creating access for recreation and citizen science projects (Orchard et al, 2017).

Large scale conservation projects near cities seek to revitalise the environment through restoring the ecology and protecting native species. Examples include Cape to City in Hawke's Bay (Predator Free Hawke's Bay, nd) and Taranaki Mounga in Taranaki (Taranaki Mounga Project, 2022), which involve planting natives and predator trapping to increase habitats for birds.

STATUS OF SPECIES DISCUSSED IN THIS SECTION

With the reduction of our forests and wetlands, habitats for the plants and animals that depend on these ecosystems have vanished. Habitat destruction, along with the introduction of mammalian predators, has severely reduced the populations of many of our unique birds, reptiles, and plants (see **Pōhutukawa section**).

In 2016, 74 percent of our terrestrial birds (78 of 105) were threatened with extinction or at risk of becoming threatened. For reptiles this proportion was far greater: 94 percent (116 of 124) were threatened or at risk in 2021, while for vascular plants it was 46 percent (1,253 of 2,744) in 2017. (See indicator: **Extinction threat to indigenous land species**.)

Looking at some of our treasured (taonga) species that were highlighted earlier in this section, kererū are classified as not threatened (population is stable) and have the qualifier 'conservation dependent'. This means they are dependent on ongoing conservation efforts such as pest control (Robertson et al, 2017; Townsend et al, 2008). However, declines have been noted in some parts of the country, especially the South Island. Besides controlling predation by introduced mammals within forests, kererū recovery needs to also address the availability of food and forest areas for these birds (Carpenter et al, 2021).

Mātauranga Māori indicators of kererū populations in Te Urewera suggest that kererū in the area are in decline. The cultural indicators Tūhoe Tuawhenua use as evidence of this decline include audible and visual cues (rustling and fumbling noises, size of flocks, and visits to toromiro trees). Traditionally, the ease of harvest was also an indicator of population trends. These indicators reflect the breadth of interactions and knowledge that is involved in the connection Tūhoe Tuawhenua have with kererū. The loss of mana by the iwi over the kererū and forest and the retraction of the mauri of the kererū by Tāne-mahuta are some of the mātauranga explanations for the decline. Biophysical explanations for the decline are predation, competition with introduced species, variability in food supply, and loss of habitat (Lyver et al, 2008).

Eight out of the nine species of tītī are classified 'at risk' (Robertson et al, 2017).

There are two recognised species of New Zealand flax: *Phormium tenax* (flax, harakeke), and *Phormium cookianum* (mountain flax, whaririki). These are both considered 'not threatened' (population is stable to increasing) (de Lange et al, 2017). Flax grows throughout Aotearoa, but it is likely that some special cultivars cultivated by Māori for weaving may have gone extinct (Harris & Woodcock-Sharp, 2000). Manaaki Whenua – Landcare Research holds national collections of remaining unique cultivars and distributes plants to weaving groups and marae throughout the country (Manaaki Whenua – Landcare Research, nd).

Mānuka is widespread throughout Aotearoa (DOC, nd-a), but between 2001 and 2018 the area has decreased and some variants are threatened (de Lange et al, 2017). (See indicator: **Indigenous land cover**.) The pathogen myrtle rust introduced in 2017 is posing an increasing risk on the mānuka honey industry and other species of the Myrtaceae family (Sutherland et al, 2020).

In summary

While native forest cover has remained fairly static in recent years, we still see losses in some regions. Habitat destruction, along with the introduction of mammalian predators, has severely reduced the populations of many of our unique birds, reptiles, and plants, with many remaining threatened with extinction or at risk of becoming threatened.

Even small changes to our environment can have important consequences for ecosystems and species, and hence our wellbeing. Forested landscapes and native species are a big part of our identity as New Zealanders. Simply spending time in greenspace enhances our wellbeing, and we receive many other cultural and economic benefits from our land ecosystems.

Waitī

Freshwater

E TŪ WAITĪ E
HE WAI WHAKAATA
HE WAI MĀORI
HE WAI ORANGA E

BEHOLD WAITĪ
REFLECTING WATER
FRESHWATER
WATER THAT BRINGS LIFE

An introduction to Waitī

Waitī (Maia) is connected to freshwater: springs, streams, rivers, lakes, wetlands, and the plants and animals that live in freshwater. Waitī is comprised of two words wai (water) and tī which means sweet. Waitī is linked to Parawhenuamea, atua of freshwater and Rakahore, the personification of the rocks.

This section focuses on our essential connection to freshwater, and how we are impacted by the degraded state of many of our freshwater environments.

Our connection to Waitī

CONNECTIONS BETWEEN PEOPLE AND FRESHWATER

The mauri concept for Waitī links the health of freshwater to everything that is connected to it. If the mauri of Waitī is low, the mauri of everything that lives with her is negatively impacted (see the **Matariki section** for the definition of mauri used in this report). If she is healthy and well (mauri ora) we will see an abundance of food supplies such as whitebait (īnanga), eels (tuna), and freshwater crayfish (kōura).

The mauri of Waitī is affected by how we, as humans, have altered the freshwater environment. A healthy mauri means that eels and fish are free to swim in unpolluted water upstream to live or spawn without the damaging effects of dams, weirs, and other barriers. We would also have water clean enough to drink and swim in.

For Māori, the human and non-human worlds are indivisible; there are kinship relationships and therefore responsibilities towards natural features, including freshwater. A healthy mauri is a sign that a river is expressing its mana, or spiritual power. Indigenous frameworks are a part of our approach to freshwater management. They provide a hierarchy of needs greater than human needs, first and foremost giving back to the water, a preservation of mauri. This is followed by the health needs of the people (eg drinking water), and then the ability of people and communities to provide for their social, economic, and cultural wellbeing (MfE & MPI, 2020).

In addition to this, some settlements now require recognition of interconnectedness between the mana of wai and the mana of the iwi. These include Te Awa Tupua (Whanganui River) which established in law Tupua te Kawa, the intrinsic values of the river, and Ngā Toka Tupua o Te Waiū o te Ika, which did the same for the Whangaehu River. These settlements enshrine in legislation the relationship between these iwi and their awa (river) (Nancy Tuaine, pers. comm., 2022).

FRESHWATER AND CULTURE

Our interaction with freshwater builds knowledge and, in turn, identity. According to Rangi Matamua, "where there are bodies of freshwater, people inhabit those areas. When people inhabit an area, knowledge is formed. So, identity is dependent on freshwater that is embedded in the land" (Rangi Matamua, pers. comm., 2021).

The natural beauty of our rivers, lakes, and estuaries is central to our national identity. Aotearoa is perceived as a healthy place to live and grow up, and a high value is placed on the ability to swim in our rivers and lakes (Roberts et al, 2015). For Māori, water is a treasure (taonga) that people share an intimate connection with. The flow of freshwater through the landscape connects people and places to each other and to other forms of life (Anderson et al, 2019).

One indicator of the health of the waters and the people, and the close links between them, is the ability to fish and harvest food. Mahinga kai refers to the traditional Māori practices of gathering food, across the realms of land (whenua) and marine and freshwater. A range of foods are gathered from freshwater environments, including eel (tuna), whitebait (īnanga), freshwater mussel (kākahi), freshwater crayfish (kōura), and watercress (wātakirihi) (Collier et al, 2017). Flax (harakeke) and bulrush (raupō), plants that grow near waterways or in wetlands, are also used for harvesting, carrying, and preparing food.

More than simply food gathering, the ability to collect these resources affects the mana of an iwi or hapū, as they contribute to their capacity for manaakitanga – offering food from their whenua and wai to invited guests, an important part of hospitality. The protection of taonga species important to mahinga kai is therefore also the protection and maintenance of Māori language (te reo Māori), tikanga (customs/protocols), and Māori knowledge (mātauranga Māori): the language, practices and knowledge that are associated with them. In this way the ability to harvest these species is an indicator of the health of both the waters and the people (Rainforth & Harmsworth, 2019).

FRESHWATER AND RECREATION

The Tupuārangi section noted the importance of access to greenspace for our mental and physical wellbeing. There is a growing body of evidence that spending time in or near 'blue space', such as rivers, lakes, and the sea, has similar benefits. These wellbeing benefits are evident when we spend this time actively (eg swimming, running, or walking) or passively (eg simply sitting by blue space). Benefits include reduced fatigue and stress, improved immune system function, and increased fitness (Gascon et al, 2017; Pasanen et al, 2019; White et al, 2020).

Many New Zealanders engage in freshwater recreation. A survey of almost 4,000 New Zealanders found that over 50 percent of adults participate in swimming outdoors at least once a year. Approximately a third of people engage in fishing at least once a year, and around 20 percent of people participate in kayaking or rafting at least once a year (DOC, 2020c).

Blue spaces also provide the opportunity for social connection. This is amplified through activities that involve collaboration with others, such as stream restoration (Meurk et al, 2013). These activities offer other mechanisms for increased wellbeing, including fostering a sense of belonging through enhanced connection with place, and a sense of contributing meaningfully towards creating a better environment (Morris et al, 2015).

FRESHWATER AND ENERGY

Freshwater is essential to agriculture and electricity generation. As outlined in the Pōhutukawa section, the amount of irrigated land almost doubled between 2002 and 2017, and then decreased by 1.6 percent from 2017 to 2019. Increased irrigation has enabled greater agricultural production but it does put pressure on other areas, changing river flows and altering the habitats of native species. It can also impact recreation and drinking water supply (MfE & Stats NZ, 2020b). (See indicator: **Irrigated land**.)

When compared to total energy consumption, Aotearoa has one of the highest proportions of renewable energy consumption in the world. Hydroelectric power is the biggest single contributor to electricity supply for Aotearoa, accounting for between 55 and 60 percent of generation each year (MBIE, 2020a). The artificial lakes created by dams are also used extensively for recreation (PCE, 2012).

However, dams also significantly alter the character of a river and the surrounding landscape. The mauri of the river is adversely impacted by it not being able to flow unobstructed from the mountains to the sea, and the spiritual significance to iwi rests in the river as a whole. Changes to flows and sediment transport negatively impact native plants and animals (PCE, 2012; Young et al, 2004). Dams also block the migrations of native fish and eels. The New Zealand longfin eel, endemic to Aotearoa, is particularly affected due to its migrations far inland. Some retrofitting of dams with devices to allow fish migration is currently being undertaken (Williams et al, 2017). For more on the impacts of dams see ***Our freshwater 2020***.

FRESHWATER AND HEALTH

Access to unpolluted water for drinking and recreation is vital for our health. Good quality water for hydration is essential for human digestion, improves our moods, energy levels, and alertness, and enhances physical and mental performance (Benton et al, 2015). During 2018–19, approximately a quarter of New Zealanders on registered drinking water supplies did not have access to water that met all the requirements of the Drinking-water Standards for New Zealand. These standards set acceptable levels of bacteria (such as *E. coli*), protozoa (such as *Cryptosporidium*), and chemicals (EHINZ, 2020).

Contamination of water used for drinking or preparing food is linked to a range of negative health outcomes. Contamination can come in a variety of forms, including the presence of illness-causing bacteria such as *Campylobacter* and *E. coli* or unsafe levels of contaminants such as nitrates (a form of nitrogen) or heavy metals. For instance, blue baby syndrome, also known as infant methaemoglobinaemia, is caused by excessive nitrates in drinking water (WHO, 2016).

WETLANDS (REPO) AND WELLBEING

Wetlands (repo) are an integral part of environmental and cultural landscapes. Repo act like giant filters, with the ability to remove nutrients and sediment from water. As well as protecting from extreme events like floods or storms, repo, especially peatlands, store large amounts of carbon that could be released if drained or disturbed (Ausseil et al, 2015; The Ramsar Convention on Wetlands, 2019).

The ability of wetlands and estuaries to trap sediment and filter out pollutants before they reach the ocean are among the many benefits of wetland protection and restoration (NIWA, 2007). See **Waitā section** for the impacts of pollutants and sediment on freshwater and marine ecosystems.

Repo cover less than one percent of the land area of Aotearoa, yet they provide a habitat for two thirds of our threatened freshwater and estuarine fish species and 13 percent of threatened plant species. Wetlands are also vital for the survival of many of our native bird species, including the Australasian bittern (matuku), brown teal, New Zealand fernbird (mātātā), marsh crake (koitareke), and white heron (kotuku), who rely entirely on remnant wetlands (Clarkson et al, 2013; DOC, nd-c). They are a crucial source of mahinga kai, as the breeding grounds for tuna, īnanga, and other culturally important fish species (Clarkson et al, 2013). Repo are also a source of plants for medicinal use (rongoā), plants for use in weaving (raranga), and construction materials for houses (whare) (Taura et al, 2017, see also **Tupuārangi section**).

More than simply a supplier of food and materials, repo are an important part of the cultural landscape. They are deeply embedded in cultural life, as reservoirs of mātauranga Māori and places of deep historical, economic, and spiritual significance (Taura et al, 2021). If repo continue to be lost, cultural indicators that have been founded on generations of mātauranga Māori, such as those relating to watercress (kōwhitiwhiti), the giant spike sedge (kuta), and harakeke, will also be lost, along with the ability to interact with these places.

The state of Waitī

WATER QUALITY IN OUR RIVERS, LAKES, AND GROUNDWATER

Many of our lakes and rivers have unnaturally high levels of nutrients due to leaching and run-off from urban or agricultural sources. We used both measured and modelled data to assess the water quality of our rivers and lakes. Computer models were used to estimate water quality for the period 2016–20 for all lakes and river segments, including those that do not have monitoring sites. Models are based on measured data, as well as variables such as climate, geology, topography, hydrology, and land cover. These models estimated that of 3,813 lakes in Aotearoa, 46 percent rated poor or very poor in terms of nutrient enrichment (as measured by Trophic Level Index) between 2016 and 2020.

Modelled data for 2016–20 indicated risk of environmental impairment (based on comparison with reference conditions) from at least one form of phosphorus (total phosphorus, or dissolved reactive phosphorus) in 64 percent of the river length of Aotearoa, and 69 percent for at least one form of nitrogen (total nitrogen, nitrate-nitrite-nitrogen, or ammoniacal nitrogen).

Water quality varies according to how much the catchment has been modified. Freshwater river quality tends to be poorest near areas with a high proportion of human modification and is highest quality in areas that have had the least modification. Monitored sites with higher proportions of human modified land cover in the upstream catchment area had higher concentrations of all forms of nitrogen and phosphorus, compared to sites with lower proportions of human modified land cover for 2016–20.

Between 2001 and 2020, trends were improving for nitrate-nitrite-nitrogen at 38 percent of monitoring sites, and for ammoniacal nitrogen at 61 percent of monitoring sites. (In this and the following section, improving and worsening trends include both likely and very likely statistical trends. See relevant indicators for trend assessment detail.) For the same period, 67 percent of sites had improving trends for dissolved reactive phosphorus. Freshwater systems are complex and nutrients can move at different speeds through catchments, so it is difficult to understand the causes of these trends (McDowell et al, 2021; MfE & Stats NZ, 2020b). For lake water quality there was insufficient data to determine 20-year trends across the network of monitored lakes. (See indicators: **Lake water quality**, **River water quality: phosphorus**, **River water quality: nitrogen**.)

Water clarity is a measure of underwater visibility in rivers and streams, while turbidity is a measure of how cloudy the water is. Excess sediment introduced to waterways by human activities such as forest clearing and urban development contributes to lowered clarity and increased turbidity. Computer models for 2016–20 estimated risk of environmental impairment (based on comparison with reference conditions) for turbidity in 37 percent of the river length of Aotearoa, and 9 percent for visual clarity. For the period 2001 to 2020, clarity and turbidity trends were improving at over half of monitoring sites and worsening at approximately one third. (See indicator: **River water quality: clarity and turbidity**.)

Macroinvertebrates – small animals without backbones such as insects and worms that live in the water – are used as an overall measure of river health. Macroinvertebrates play a central role in stream and river ecosystems by feeding on algae, aquatic plants, dead leaves, and wood, or on each other. In turn, they are an important food source for fish and birds. A high macroinvertebrate community index (MCI) score indicates a high level of river health.

Of the river length of Aotearoa, computer models estimated 17 percent had MCI scores that may indicate severe organic pollution or nutrient enrichment between 2016 and 2020. Only seven percent had modelled MCI scores indicative of pristine conditions with almost no organic pollution or nutrient enrichment. MCI scores worsened across 56 percent of monitoring sites between 2001 and 2020. (See indicator: **River water quality: macroinvertebrate community index**.)

The quality of our groundwater is mixed but improving in many places. For nutrients, between 2009 and 2018 more groundwater monitoring sites had improving trends than worsening. However, for *E. coli*, half of groundwater monitoring sites showed a worsening trend with only 18 percent improving over this period. For further discussion of groundwater see ***Our freshwater 2020*** and indicator: **Groundwater quality**.

WATER QUALITY AND HUMAN HEALTH

Polluted waters degrade the connections we have with Waitī. Water quality is especially important for drinking water and for recreational activities involving full immersion (eg swimming) or where water droplets may be inhaled (eg kayaking). *E. coli* is used as an indicator for the presence of other pathogens associated with animal or human faeces, including *Campylobacter*.

For the period 2016–20, computer models estimated 22 percent of river length in Aotearoa had an average *Campylobacter* infection risk of more than seven percent (the highest risk). Concentrations tended to be higher at monitored sites with higher proportions of human modified land cover in the upstream catchment area. Between 2001 and 2020 the number of monitoring sites with improving trends in *E. coli* (declining concentrations) was approximately equal to the number of sites with worsening trends (increasing concentrations). (See indicator: **River water quality: Escherichia coli**.)

Popular swimming spots in Aotearoa are monitored over the summer months for the presence of *E. coli* and the likelihood of cyanobacterial toxins. Toxic algae or cyanobacteria are also monitored at recreational sites as contact can be harmful to the health of both people and dogs. Toxic algal blooms generally occur as a result of high levels of nutrients (nitrogen and/or phosphorus) in warm, calm weather, forming thick mats on rocks or the riverbed. If water containing toxic algae is ingested, it can cause symptoms such as nausea, vomiting, and diarrhoea, and can be fatal to dogs. Skin contact can cause rashes and irritation of the eyes, nose, and mouth (Canterbury District Health Board, 2020).

FRESHWATER HEALTH

Properly assessing the health of freshwater requires a holistic view. Ki uta ki tai (from the mountains to the sea) is an approach to freshwater management based on Māori knowledge and practice. This approach recognises that the health and mauri of a river cannot be determined by looking just at the water. The whole catchment that is drained by a river must be examined, as an intact mauri depends on the status of all the interrelated components in the catchment. In this approach, the mauri of the water diminishes as it comes into contact with detrimental aspects of human activities (Tipa, 2009).

Ki uta ki tai methodologies to assess the overall health of a catchment are increasingly being used in freshwater management (Rainforth & Harmsworth, 2019). The mauri of the waterways is connected to the mauri of the people who live there, and the conditions of the water impact cultural wellbeing (Anderson et al, 2019). This means that ki uta ki tai approaches are intrinsically connected to particular places and the values of the people who live there. These values are not transferrable so it is not possible to understand the state of freshwater without also understanding the core values of the people in that place (Crow et al, 2018). The cultural health index is a national tool used to assess the health and mauri of a waterway and to monitor changes to it over time. It assesses a site's accessibility, its ability to undertake mahinga kai activities, and cultural stream health. Cultural health index scores for waterways were very good or good at 11 sites, moderate at 21 sites, and poor or very poor at 9 sites, of 41 sites tested between 2005 and 2016. (See indicator: **Cultural health index for freshwater bodies**.)

While the focus in this section is the quality of our freshwater, there are knowledge gaps around how much freshwater is removed from rivers and aquifers for human use. We know how much freshwater extraction regional councils have given consents for. These data show a legal maximum, but we do not know how much water is actually being used. See ***Our freshwater 2020*** for further discussion on water extraction.

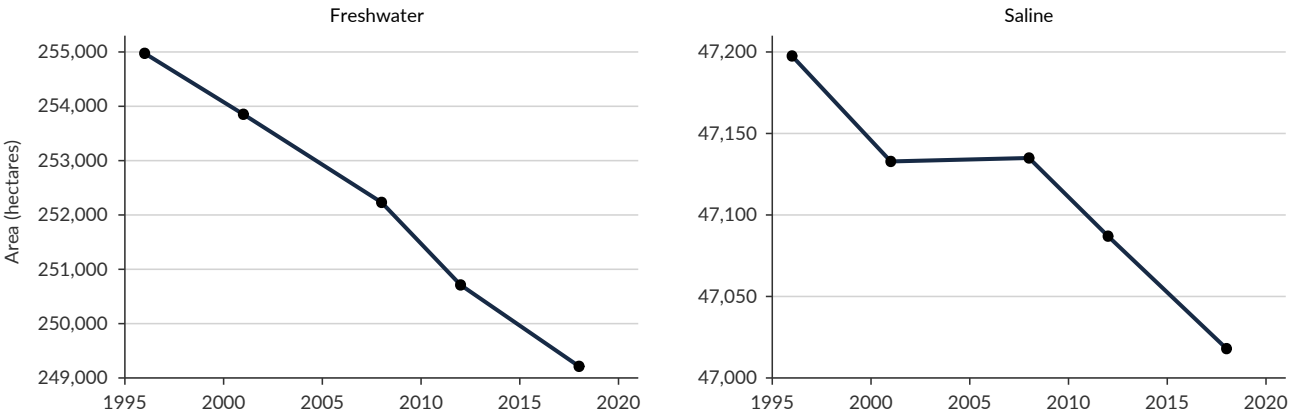
WETLAND ECOSYSTEMS

As outlined in the Pōhutukawa section, we have lost the majority of our historical wetland area (Dymond et al, 2021). The wetlands that remain still provide enormous benefits, but wetland loss is continuing, with freshwater wetland area decreasing by 1,498 hectares (0.6 percent) between 2012 and 2018, and saline wetland area decreasing by 69 hectares (0.1 percent) in the same period. (See figure 5 and indicator: **Wetland area**.)

In Southland, between 1996 and 2018, there was a net loss of 2,665 hectares of freshwater wetlands. Of the area of freshwater wetlands that were lost, 98 percent were because of conversion to land covers associated with farming and forestry. (See indicator: **Wetland area**.)

If wetlands continue to be lost, cultural indicators that have been founded on generations of mātauranga Māori will also be lost, along with the ability to interact with these places. The legacy of the drainage of organic soil wetlands is also having an effect, with a potential contribution to greenhouse gas emissions, in the order of 0.5 and 2 Mt CO_2 equivalent per year (Ausseil et al, 2015).

Figure 5: Wetland area in New Zealand, 1996–2018 (excluding Chatham Islands)



Data source: Manaaki Whenua – Landcare Research

We can enhance our wellbeing by restoring threatened freshwater ecosystems

The enormous importance of wetlands across so many domains means their protection and restoration has many benefits, to ecosystems and to people. Being involved in the active restoration of wetlands can enhance our wellbeing in many ways – from the individual-level physical and psychological benefits of engaging in blue and greenspaces, to building and maintaining cultural knowledge of environmental indicators, through to the large-scale societal and environmental benefits that wetlands provide. There are many examples of wetland restoration projects across Aotearoa.

An agreement has been reached to construct a nationally significant wetland next to Lake Horowhenua. The project is a collaboration between Muaūpoko, Lake Horowhenua Trust (representing the owners of the lake), Ngāti Raukawa ki te Tonga, Horizons Regional Council, Horowhenua District Council, dairy farmers, horticulturalists, and the wider Lake Horowhenua community. Currently a dairy farm, the land will be converted back to a wetland which is intended to improve the water quality of the lake and restore its ecosystem (New Zealand Government, 2021).

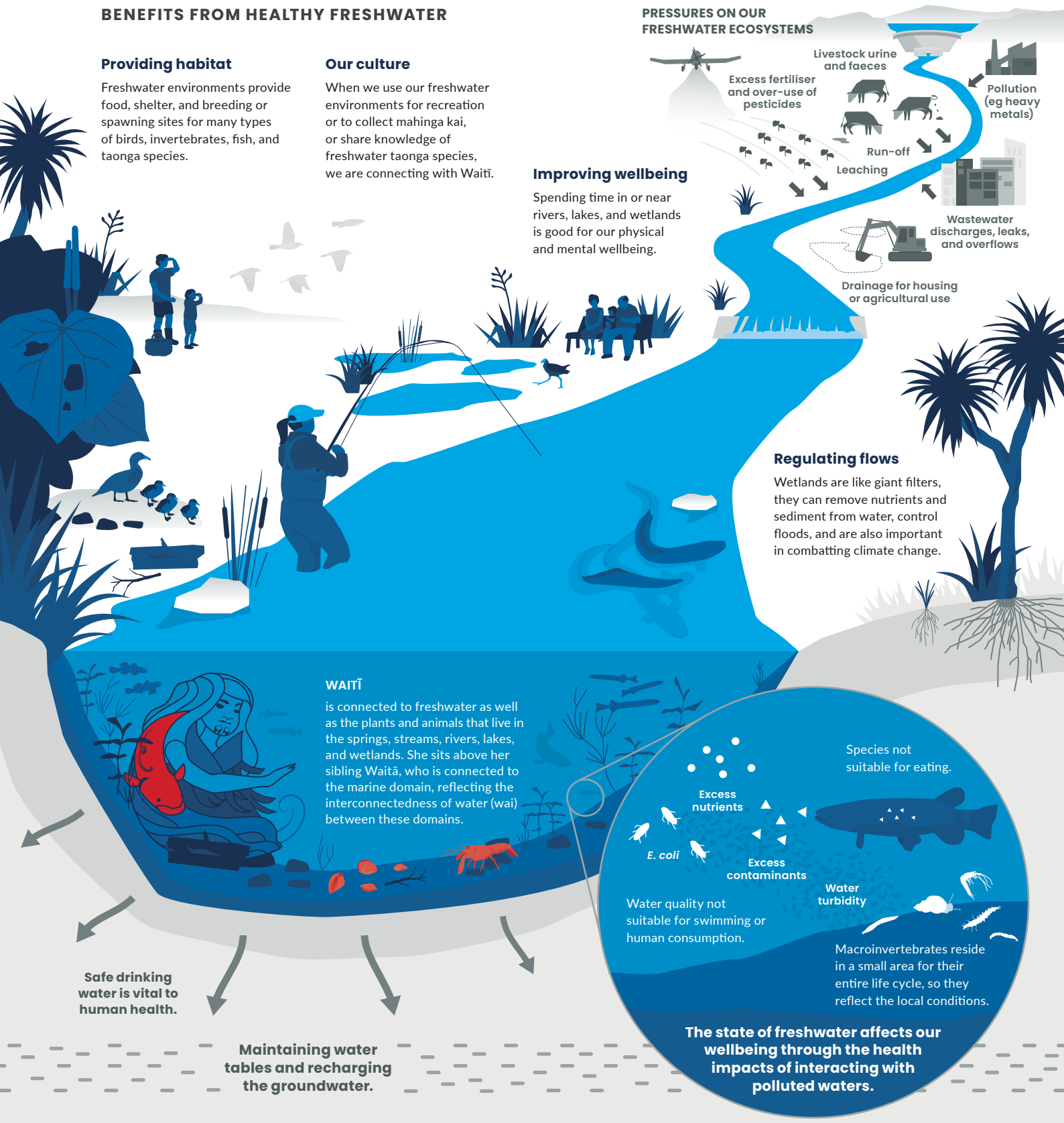
In summary

Human activities are degrading our rivers, lakes, and groundwater with many lake and river sites scoring poorly in terms of water quality. Pollutants in our waterways and habitat destruction put pressure on our native freshwater ecosystems and fish species.

If we are unable to swim, kayak, or fish in our rivers and lakes, this undermines the physical and psychological benefits of blue spaces. Unhealthy freshwater ecosystems prevent us from gathering mahinga kai. This lack of access to freshwater spaces undercuts important aspects of how we identify as New Zealanders.

Our freshwater environment

Our connections to freshwater are important to our identity. However, the state of our rivers, lakes, and groundwater is degraded in areas where land has been transformed by human activities.



Waitā

Ocean and marine conditions

E TŪ WAITĀ E
TE TAI TAMATĀNE
TE TAI TAMAWAHINE
TE TINI A TANGAROA

BEHOLD WAITĀ
FROM THE WEST COAST
TO THE EAST COAST
THE BOUNTY OF THE OCEAN

An introduction to Waitā

Waitā (Taygeta) is associated with the ocean and marine conditions and represents the many types of food gathered from the sea. Waitā is comprised of two words, wai (water) and tā (salt). Waitā is linked to three atua: Kiwa, controller of the ocean; Hinemoana, the mother of all marine sentient beings; and Tangaroa, the great atua of the ocean (Best, 2005; Matamua, 2017).

This section is about the ways we depend on the ocean for our livelihoods and wellbeing, and how these are being affected by pollution, climate change, and resource depletion.

Our connection to Waitā

CONNECTIONS BETWEEN OCEANS AND PEOPLE

For many Māori, the ability to gather seafood (kai moana) is an important indicator of the mauri of the ocean and is reflected in the extent to which traditional food gathering practices (mahinga kai) can be carried out (see the **Matariki section** for the definition of mauri used in this report). This in turn is linked to other aspects of life and tikanga Māori (customs/protocols).

These include manaakitanga, the ability to host guests (manuhiri) at marae, and oranga, sustaining the health and welfare of whānau. Many iwi have a system of pātaka, where kai moana are collected and distributed to iwi members for cultural purposes.

If our marine environment is unhealthy, traditional kai moana species are put at risk. Their disappearance, whether localised or across the country, can also mean the loss of Māori knowledge (mātauranga Māori) and traditional practices relating to these species and their collection. Mana moana, which includes the inherent right of iwi to harvest kai moana within their rohe (region), is unable to be exercised, and customary practices of harvesting at specific times of the seasons and maramataka fall out of use (see **Tupuānuku section**).

There are specific kai moana species found in each region that have significant cultural value to the iwi in those regions. If these species are not available – if their populations are reduced due to pollution or overfishing – this affects the mauri of the people and community.

Some species, such as pāua, are having to be translocated to new areas to help their survival (Fisheries New Zealand, 2021). However, translocation can affect local harvesting traditions and practices. If pāua are not available to be caught, passing on knowledge around this taonga (treasured) species becomes more difficult. It can also impact on the mauri of the mahinga kai system, as ecosystems are put out of balance by moving pāua from areas they would naturally live.

Gathering kai moana is an important activity for many New Zealanders. A national survey estimated that nearly 600,000 adult New Zealanders participated in recreational marine fishing between October 2011 and September 2012 (Wynne-Jones et al, 2014). As well as connecting us to our environment, international research has found that people who partake in recreational fishing report experiencing a range of important wellbeing benefits including social support and reductions in stress and anxiety (McManus et al, 2011).

Kina barrens: a sign of ecosystems out of balance

Kina are an important species for many iwi (Kawe, 2014). Historically, their numbers are controlled naturally by predators such as snapper and crayfish. As these predators grow larger, they eat more kina, but also become bigger targets for fishing. Fishing, combined with warmer sea temperatures and the effects of other human activities, has allowed kina numbers to explode in some places. This creates large areas knows as 'kina barrens,' where the kina graze all the seaweed and leave behind a bare reef where other species cannot establish (Gee, 2021; Heeringa, 2021). This removes the habitat for many kai moana species, and puts at risk the knowledge and practices associated with them. Kina growing in kina barrens are also of lower quality for food production (Warren-Meyers et al, 2020).

OCEANS, CULTURE, AND HEALTH

Beaches have a key place in Aotearoa national identity and are central to our leisure culture. Most major population centres are coastal, and beaches are popular holiday destinations. There are many physical, social, and psychological benefits to ocean recreation. People and families form deep attachments to particular coastal sites, and they are key places for connecting with nature and forming communities.

Recreational activities create strong bonds between people and the coastal places they visit, as well as providing stress relief and promoting mental and physical wellbeing. The strength of this connection was made evident during the lockdowns imposed as part of the COVID-19 pandemic response in 2020, when surfing was not allowed. Many surfers vented frustration, anxiety, and anger due to being unable to take part in a practice they saw as central to their identity and wellbeing (Wheaton et al, 2021).

Ocean recreational activities can also revive and maintain cultural practices, in addition to other wellbeing benefits. Waka ama, the sport of paddling traditional Polynesian outrigger canoes, has been growing rapidly in popularity in Aotearoa (Sport New Zealand – Ihi Aotearoa, nd). Waka ama encourages the revitalisation of te reo Māori (Māori language) through the use of karakia (incantations), waiata (song), and general terms used when paddling. Those who engage with this sport also connect with the natural environment, build community, and gain knowledge of waiora, the spiritual connections between health (hauora) and the environment.

Our ability to interact with the ocean through recreational activities is an indicator of its mauri. We get important wellbeing benefits from being able to swim and surf at the beach, kayak in an estuary, or gather shellfish along the coast. If the water is too polluted to do these activities safely, its mauri is degraded, and so too is the mauri of the communities who engage with it.

Water pollution is monitored through measurements of faecal indicator bacteria at many beaches and estuaries around the country. This monitoring indicates the presence of pathogens that can cause gastrointestinal illnesses and other infections, making water unsafe for swimming. These bacteria enter the water from animal excrement, stock effluent, wastewater discharge, and contaminated soil run-off (LAWA, 2021).

OCEANS AND ECONOMIC BENEFITS

We rely on the ocean (moana) to support the economy and provide jobs for people. Data for the year ended March 2017 show that around 33,000 people were employed in the marine economy in Aotearoa. The same data show that the total direct contribution of the marine economy to Aotearoa was $3.8 billion, equating to 1.4 percent of total GDP. Combined with a further $3.2 billion in indirect contributions, the total value of the marine economy in 2017 was $7 billion. Most of this comes through shipping, fishing and aquaculture, and mineral extraction. These economic valuations do not reflect the non-monetary value of the oceans, or account for the environmental harms that some of these activities contribute to. (See indicator: **Marine economy**.)

Māori are heavily involved in the marine economy, particularly the fishing sector. Māori own around 20 percent of the Aotearoa fishing quota by value, and are actively engaged in all different parts of the fishing industry. A survey of people involved in Māori fishing businesses found that maintaining the mauri of the ocean was equally as important as making a profit and that a majority saw mātauranga Māori as extremely important. However, a similar majority rated the ability for Māori to exercise kaitiakitanga (guardianship) as limited (Reid et al, 2018).

The state of Waitā

The quality of our coastal waters and marine environment is affected in different ways by human activities on land. Pollution and sediment flowing from rivers into estuaries and coastal waters reduces water quality in the coastal zone, which harms populations of kai moana species and the ecosystems they depend on. Water quality is usually worse in places with higher freshwater inflows. Estuaries generally have worse water quality than the open coast, and are more polluted where there is higher urban or agricultural land cover upstream (Dudley et al, 2020). The processes that affect freshwater and marine domains are closely linked (see **Waitī section** for detail on freshwater quality).

Rising sea levels also affect the land, increasing coastal erosion which affects coastal communities, damages cultural sites and infrastructure such as bridges and roads, and contributes to the loss of habitats and ecosystems (MfE & Stats NZ, 2019).

SEDIMENT

The amount of sediment entering the ocean from rivers has increased over decades, particularly in the North Island. The main reason for this is deforestation, as forest cover lowers erosion rates (see **Pōhutukawa section** for more detail). Before European drainage works and confinement of rivers between stopbanks, floodplains and wetlands would also have intercepted greater proportions of river sediment before it reached the ocean (NIWA, 2019).

The amount of sediment is highly variable by region, and depends on soil type, slope, climate, land cover, and activities within the catchment (Phillips et al, 2017). The New Zealand empirical erosion model estimated that the highest levels of sediment movement into waterways for the North Island was in the Gisborne region (40 million tonnes/year), and for the South Island, in the West Coast region (49 million tonnes/year). (See indicator: **Estimated long-term soil erosion**). *Environment Aotearoa 2019* noted, that in Gisborne, due to a combination of a lack of woody vegetation, steep slopes, and erodible rock types, soil erosion rates are high. On the west coast of the South Island, the highest sediment loads occur in South Westland due to the area's steep slopes, geology, and heavy rainfall. Sediment accumulation is increasing in many estuaries across Aotearoa, but the rates are highly variable between locations making comparisons difficult (MfE & Stats NZ, 2019).

Increased sediment in estuaries and along coasts directly affects the health of many species (Lowe et al, 2015; Booth 2020; PMCSA, 2021b). For example, cockles, pipi, and scallops feed by filtering food from the water. High sediment loads clog their gills and mean they cannot feed efficiently. Increased sediment can also be harmful for the larval and juvenile life stages of some fish species by reducing available nursery grounds and changing fish gill structure (PMCSA, 2021b).

NUTRIENT POLLUTION

Increased nutrients such as nitrogen and phosphorus can also reduce water quality in the coastal zone, potentially harming ecosystems that support our kai moana species. International research has shown that nutrients can increase the growth of some organisms and lead to algal blooms. This has a number of flow-on effects, including reducing biodiversity, amenity value, and potential for recreational activities (Larned et al, 2018; Dudley et al, 2020; Plew et al, 2020).

While these nutrients do occur naturally, levels have increased dramatically over time. Compared to modelled natural baseline levels, between 1977 and 2013, human influence led to an estimated 74 percent increase in total nitrogen loads into the ocean, 159 percent increase in nitrate-nitrogen loads, 48 percent increase in total phosphorus, and 18 percent increase in dissolved reactive phosphorus (Snelder et al, 2018).

High nutrient levels in estuaries or the sea can be toxic, or lead to algal blooms which can kill marine life by depleting oxygen levels. Estuaries, particularly those that are shallow or have large intertidal areas, are sensitive to nutrient pollution. Modelling estimates show that more than a quarter of estuaries in Aotearoa are highly or very highly susceptible to ecosystem harm resulting from an excess of nutrients (Plew et al, 2018).

Between 2008 and 2017, 72 percent of coastal and estuarine water quality monitoring sites showed an improving trend for total phosphorus. However, 35 percent of sites showed a worsening trend for total nitrogen over this period while only 18 percent showed an improvement. Across nine of 12 marine water quality variables measured, more sites showed an improving trend than a worsening trend. (See indicator: **Coastal and estuarine water quality** for details about the variables and trend assessment.) However, across the 12 variables, the trend direction could not be determined for between 25 and 64 percent of sites. Trends also vary by region and are affected by many factors including the complexity of the coastal environment, limited data, and insufficient information about freshwater inputs. (See indicator: **Coastal and estuarine water quality**.) For more detail see ***Our marine Environment 2019***.

PLASTIC WASTE

Plastic pollution in the ocean is an enormous problem globally. It is estimated that up to four million tonnes of plastic waste are washed into the oceans globally every year (Schmidt et al, 2017). Microplastics are pieces of plastic less than 5 mm long. They have large negative impacts on marine life and potentially have consequences for human health. Microplastics are widespread throughout the world's oceans, including in Aotearoa, where they have been found on the seafloor (Fisheries New Zealand, 2020; NIWA, 2021b).

Studies of sampled Aotearoa fish species have found they are commonly ingesting microplastics. Almost a quarter of samples from six species in the Hauraki Gulf had microplastics in their gut, as did 95 percent of hoki samples from the West Coast, Cook Strait, and the Chatham Rise. The studies also found that microplastic fragments can find their way from the gut into fish muscle tissue, potentially passing on the plastic to larger fish and humans who consume it (NIWA, 2021a).

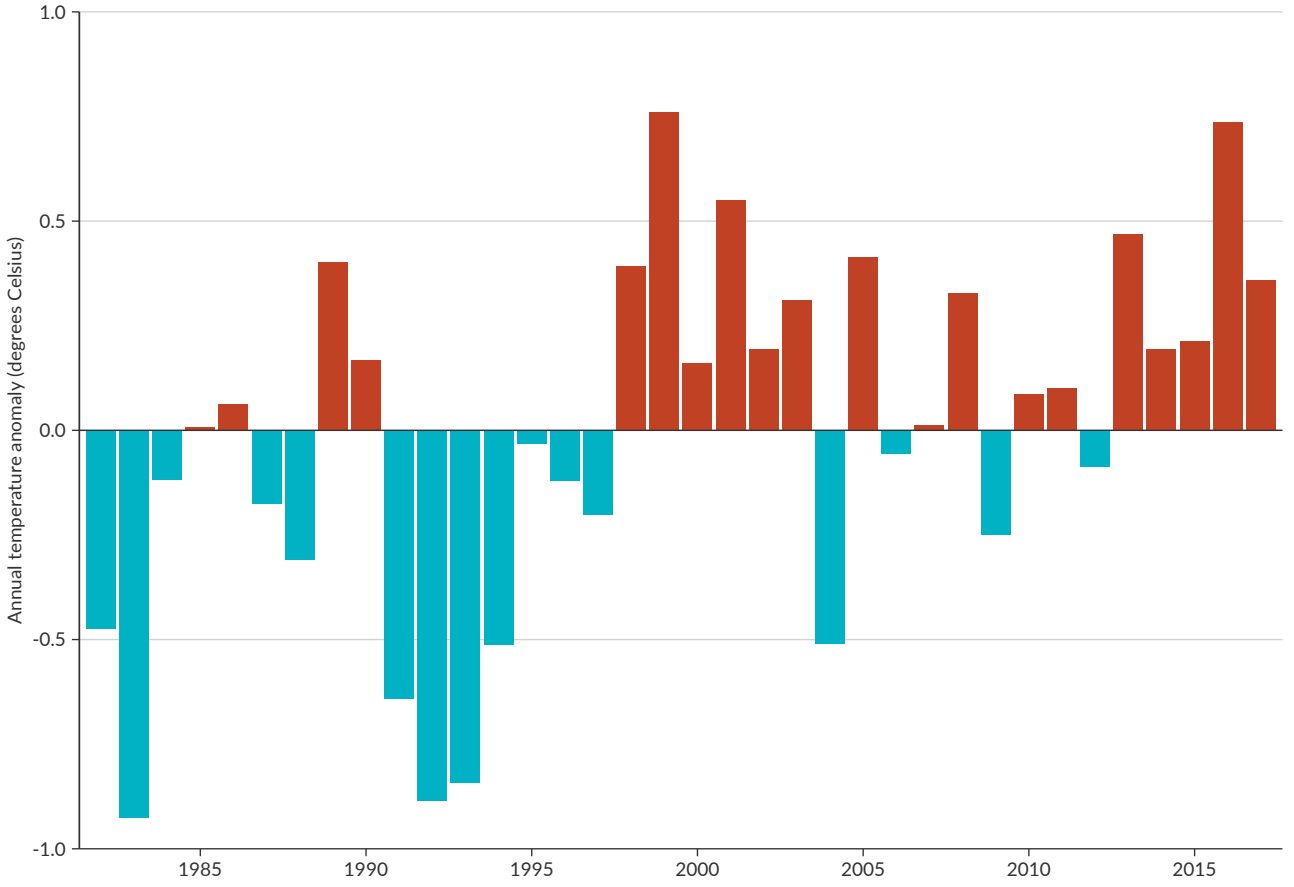
CLIMATE CHANGE AND OUR OCEANS

Climate change is having profound effects on our oceans, and reversing many of these changes will take thousands of years even if carbon emissions are reduced. Increased carbon dioxide in the atmosphere from the burning of fossil fuels is absorbed by seawater and makes it more acidic. Ocean acidity increased 7.1 percent between 2008 and 2017 at the monitoring site off the Otago coast which provides data for the longest-running record of ocean acidification in the Southern Hemisphere. (See indicator: **Ocean acidification**.) This rate of increase is similar to estimates for the world ocean, and ocean acidification is projected to accelerate in Aotearoa and global waters (Law et al, 2018a; Turley et al, 2006).

Sea-surface temperatures are rising due to climate change. On average, coastal waters have warmed by 0.2 degrees Celsius per decade between 1981 and 2018 (see figure 6 and indicator: **Sea-surface temperature**). Marine heatwaves are also becoming more common (MfE & Stats NZ, 2019).

These changes are affecting our ability to gather kai moana. Evidence suggests marine species will be affected by climate associated change, though quantifying these effects is difficult, due to a lack of data around both species responses and the challenges they may face (Cummings et al, 2021). Ocean acidification impacts key species in several ways. Higher acidity means that pāua larvae cannot establish themselves easily, and can suffer other negative effects including slower growth, lower survival rates, smaller sizes, and abnormal shapes. Some of these effects are also seen in oysters, sea urchins, and corals (Espinel-Velasco et al, 2021). Acidification also means shellfish cannot grow their shells properly, as the calcium in the shells dissolves more easily in more acidic waters (Law et al, 2018a).

Figure 6: New Zealand coastal sea-surface temperature annual average anomalies, 1982–2017



Data source: NIWA

Note: The baseline for anomalies is the average sea-surface tempertature across the entire date range, 1982–2017.

FISH STOCKS AND KEY KAI MOANA SPECIES

Of the fish stocks that are assessed under the Aotearoa quota management system for fisheries, 82 percent are considered to be in good condition in 2020 (MPI, 2020). This means the species can maintain itself while supporting a fishery. However, there are many fish stocks that are not assessed, representing 32 percent of catch (MfE & Stats NZ, 2019). Others are assessed infrequently. Fish stocks and the way we get an indication of seafood stocks aren't based on observations of local whānau who rely on these food sources for mahinga kai and manaakitanga. This leads to significant knowledge gaps in the assessment process, making the sustainability of fishing levels impossible to gauge (PMCSA, 2021).

Shellfish are important economically, and as recreational and kai moana species. Pāua are highly valued as a food source and play an important role for some Māori in caring for visitors (manaakitanga) (MPI, nd). Pāua management is divided into 11 areas, with different regulations depending on stock levels. Stocks are estimated to be good in the lower North Island and Canterbury areas, while in the upper South Island and Marlborough Sounds stocks have declined and are at risk. In the rest of the North Island, the west coast of the South Island, and the Chatham, Kermadec, and Subantarctic Islands, data are either unavailable, outdated or of poor quality (MPI, 2021b).

There are gaps in knowledge about stock levels for other important species. Green-lipped mussels (kuku) are distributed mainly in the central and northern parts of the country. They are the main mussel species harvested in Aotearoa, with the fishery valued at over $200 million in 2009 (Alfaro et al, 2011). They have been used extensively by Māori and are very important in customary fishing. Despite this, there are currently no stock assessments available. Localised assessments in Ōhiwa Harbour indicate a reduction of more than 99 percent in abundance between 2006 and 2015 due to sediment deposition (MPI, 2021c).

Once populations of shellfish have been depleted, they can take a long time to recover. Toheroa are a native surf clam considered a seafood delicacy. Populations were greatly reduced due to over-harvesting, and commercial and recreational fishing were banned by 1969 and 1980 respectively. Despite having protections in place for over 40 years, toheroa populations have not recovered, and some continue to decline. There are several factors behind this, including widespread illegal harvesting, driving vehicles on beaches, declines in water quality, and a lack of freshwater coming onto beaches from inland (Ross et al, 2018).

Fishing can have long-term and wide-ranging effects on the marine environment beyond depletion of target species. Seabed trawling is a fishing practice that damages the seabed and its habitats. Even after trawling stops, ecosystems can remain damaged and show few signs of recovery for long periods of time (Clark et al, 2019). Seabed trawling is more prevalent in shallow waters, with varying impacts depending on fishing intensity, gear type, and vulnerability of habitat (MfE & Stats NZ, 2019).

The incidental capture of seabirds and marine mammals is another consequence of fishing activity. Incidental captures are still a significant pressure on some populations (MfE & Stats NZ, 2019). Overall, the full ecological impact of fisheries remains a gap in our understanding (MfE & Stats NZ, 2019).

MĀTAURANGA MĀORI PROTOCOLS FOR DETERMINING AND MANAGING THE STATE OF WAITĀ

Assessments of fish stocks are done in isolation and do not account for the interactions between different stocks or interactions with the broader marine environment (MfE & Stats NZ, 2019). Marine management approaches and tools based on mātauranga Māori take a more holistic view of the environment, taking into account the health of ecosystems and the wellbeing of communities who are linked to them. Some Māori fishing companies use kaitiaki-based business models and mātauranga Māori to ensure the Māori marine economy is both profitable and sustainable over the long-term (Rout et al, 2019).

Mātaitai reserves are marine management tools which allow Māori to develop localised management regimes for traditional fishing areas. They generally allow for customary and recreational fishing but prohibit commercial fishing (Paul-Burke, 2020). Legislation empowers tangata whenua to establish fishing bylaws to restrict any activities that they consider will threaten the sustainability of the fisheries in a reserve, subject to consultation and ministerial approval. Iwi in any area can also establish similar bylaws through the Crown treaty settlement process (MPI, 2021d). About 17,430km^2 or about 10 percent of our territorial sea (out to the 12 nautical mile limit) is protected by marine reserves. Almost all this marine reserve area is in the Kermadec and Subantarctic Islands. (See indicator: **Protection in the marine environment**.)

In 2011, the container ship Rena ran around on Astrolabe Reef (Ōtāiti) near Tauranga, spilling approximately 350 tonnes of oil into the sea in one of the worst Aotearoa maritime environmental disasters. Research in the post-disaster period used the Mauri Model Decision Making Framework (Mauri Model) methodology which assessed the whole system including community, hapū, and whānau mauri alongside environmental impacts. The mauri of the local communities was negatively affected by the disaster, with measured declines in social and cultural wellbeing. The mauri of the environment increased as the recovery process progressed, showing the deep connections between the health of communities and ecosystems (Faaui et al, 2017).

In summary

Human activities including pollution, overfishing, and impacts from climate change are damaging the mauri of our marine environments and reducing our ability to connect with them. Sedimentation and coastal nutrient pollution have increased, though recently total phosphorus is improving in a majority of coastal and estuarine sites. Climate change continues to put pressure on coastal environments through acidifying our oceans and increasing sea-surface temperatures. These issues are important to us, as we rely on the ocean (moana) as a source of food, a space for recreation, and a place for identity formation and spiritual wellbeing.

Our marine environment

Our oceans contribute to our health, our cultural identity, and our livelihoods.
Some of our activities result in environmental harm, adding pressure on marine species.

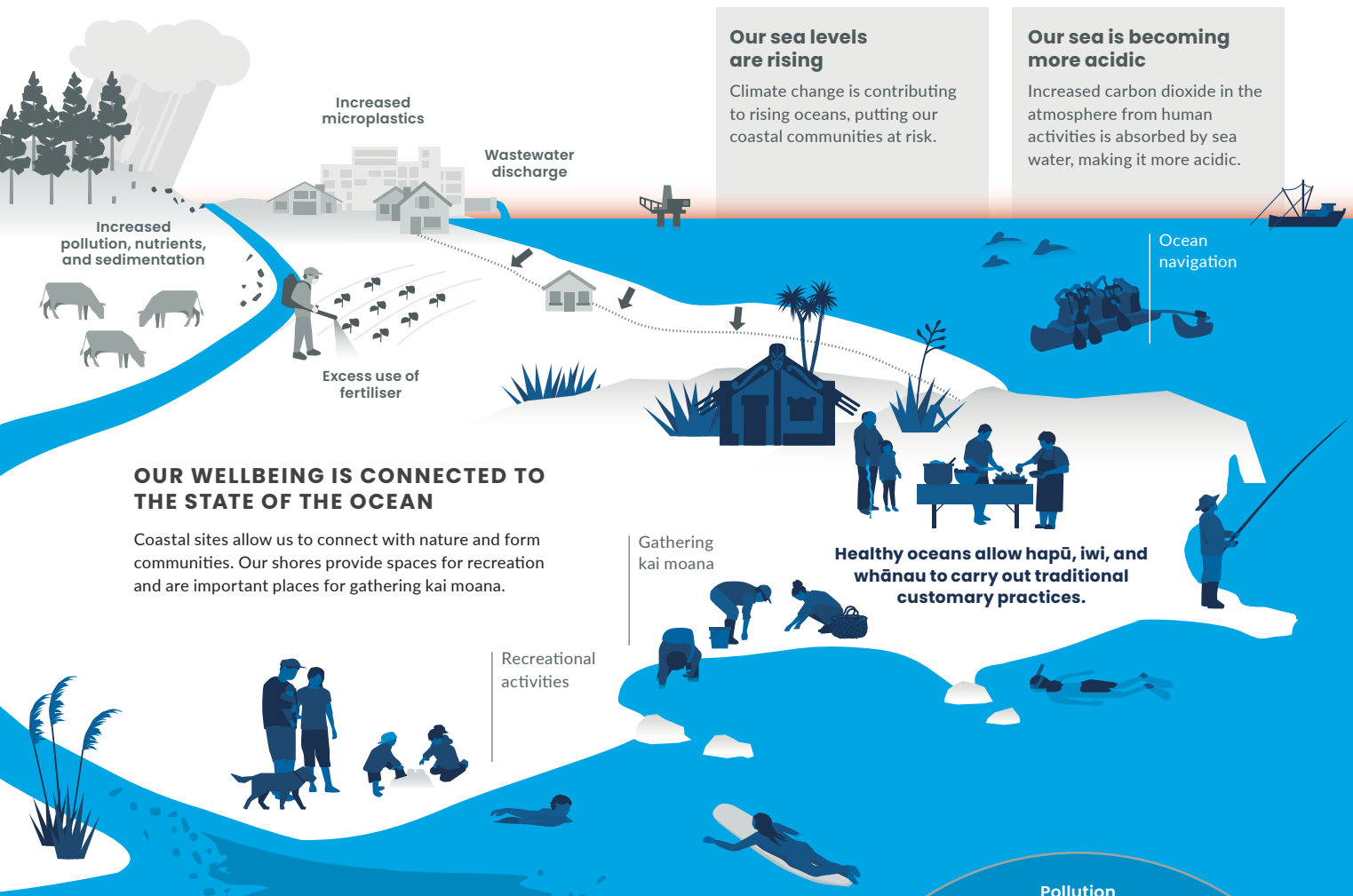
PRESSURES IMPACTING THE MARINE ENVIRONMENT

Our sea levels are rising

Climate change is contributing to rising oceans, putting our coastal communities at risk.

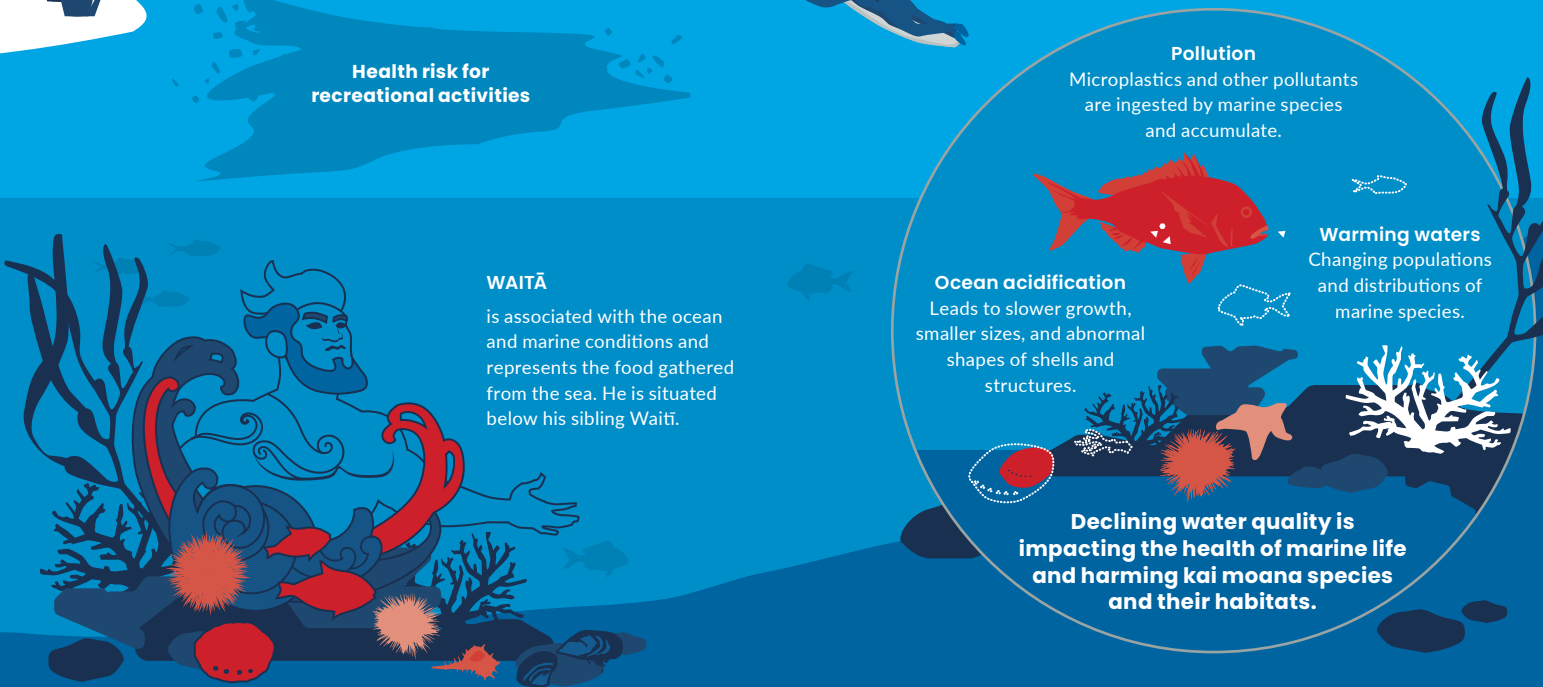
Our sea is becoming more acidic

Increased carbon dioxide in the atmosphere from human activities is absorbed by sea water, making it more acidic.



OUR WELLBEING IS CONNECTED TO THE STATE OF THE OCEAN

Coastal sites allow us to connect with nature and form communities. Our shores provide spaces for recreation and are important places for gathering kai moana.



WAITĀ

is associated with the ocean and marine conditions and represents the food gathered from the sea. He is situated below his sibling Waitī.

Waipunarangi

Rain and frosts

E TŪ WAIPUNARANGI E
HE UA KŌNEHUNEHU
HE UA KŌPATAPATA
HE UA HŪKERIKERI

BEHOLD WAIPUNARANGI
IT IS A DRIZZLE
IT IS A LIGHT SHOWER
IT IS A DELUGE

An introduction to Waipunarangi

Waipunarangi (Electra) is the star that is connected to the rains and other atmospheric conditions. The meaning of Waipunarangi is 'water that pools in the sky.' This aligns with what science tells us about the hydrological cycle, where water vapour is held in the atmosphere and then comes back to Earth's surface as precipitation. Waipunarangi is linked to Te Ihorangi, who is the personification of rain.

Our connection to Waipunarangi

CONNECTIONS BETWEEN CLIMATE, WEATHER, AND PEOPLE

The ability to forecast rain is an example of knowledge passed down through observation and oral tradition to selected custodians (Tawhai, 2013). Some believe that the projections of Waipunarangi during the rising of Matariki foretell the weather outcomes for the year ahead. If she is not visible, this signals heavy rains and possibly flooding. If she is brighter than the rest of the stars, this signals to people that rainwater should be conserved.

From a Māori perspective, the mauri of Waipunarangi is connected to the water that pools in the sky (Matamua, 2017) (see the **Matariki section** for the definition of mauri used in this report). As this water falls as rain, it connects Waipunarangi to the other stars of Matariki. The rains nourish Papatūānuku (Earth mother), enhancing the mauri of Tupuānuku and Tupuārangi, and flow through Waitī then into Waitā (Hakaraia, nd). A balance of water pools in the sky is important for supporting the balanced flow of mauri from Waipunarangi to the other stars. If there is too much, or too little rain, the effect of this imbalance is felt across the environment (te taiao). The mauri of each star is therefore intimately connected to the others through the waters of Waipunarangi.

The links between people and the environment can be jeopardised by a changing climate. Climate change is likely to affect tikanga Māori (customs/protocols) including the ability to practice mahinga kai (traditional food gathering practices) and rongoā (medicine), and transfer mātauranga Māori (Māori knowledge) across generations. These practices often require access to medicinal plants, and harvesting of harakeke and similar materials which are used for practical, artistic, or ceremonial purposes (Awatere et al, 2021). The availability and distribution of these species can be affected by changing climate patterns (Macinnis-Ng et al, 2021).

Climate change may also lead to the loss of customary harvesting grounds and the land used for food gardens (māra kai). For example, under warmer weather and prolonged periods of dryness we can expect an increased frequency of toxic algae blooms, which can potentially reduce the availability of key cultural species (eg kōura (freshwater crayfish)). This reduces the capability of iwi/hapū to practice manaakitanga (caring for visitors) for marae-based events and events such as funerals (tangihanga) (Awatere et al, 2021).

CLIMATE AND ECOSYSTEMS

In addition to our geographic isolation, climate played a major role in the evolution and ecological history of the native species and ecosystems of Aotearoa (DOC, 2020a; Park, 2000). Temperature and rainfall patterns are key drivers of ecosystem function and distribution, along with the life cycles and migrations of species. Plant species have naturally adapted to their preferred climate and soil, and this results in the different types of forest that we experience in Aotearoa (Singers & Rogers, 2014; Whitehead et al, 1992). Some plant communities and species are more adaptable than others and can tolerate a range of moisture, humidity, and rainfall patterns (Singers & Rogers, 2014). Shifting weather patterns as the climate changes will put pressure on species and ecosystems that cannot adapt, while creating more suitable conditions for different species.

Changing climatic conditions can have multiple effects on species and their interactions, and these depend on their tolerance to change, habitat shifts, and migration. Shifts in the timing and severity of frosts, as well as a reduction in snowfall, are likely to create a mismatch between when plants flower and when their insect pollinators are active. This could adversely impact some plant species and strongly affect some ecosystem functions (McGlone & Walker, 2011; Renwick et al, 2016). Droughts or altered rainfall patterns can have detrimental effects on mudfish, whitebait (īnanga), bird nesting habitat in braided rivers, and macroinvertebrate communities, while also affecting kauri tree functions (Keegan et al, 2022).

CLIMATE AND SPECIES' HABITATS

Species loss due to climate may affect our wellbeing through loss of culture, sense of place, and identity (see **Tupuārangi section**). An assessment of 10 freshwater treasured (taonga) species found that vulnerability to changing temperature, rainfall patterns, and extreme events varies across species. Highly vulnerable taonga species include whitebait (īnanga), shortfin eel (tuna), freshwater mussels (kākahi/kāeo), banded kōkopu, and kōaro (a native fish) (Egan et al, 2020). Tuatara have been shown to be affected by an imbalance of male offspring due to increased temperature (Mitchell et al, 2006). Moderately vulnerable species include freshwater crayfish (kōura/kēwai) and giant kōkopu (Egan et al, 2020). Of the assessed species, only yellow-eye mullet (aua/kātaha) is ranked at a low level of vulnerability to climate change (Egan et al, 2020).

The frequency of masting events (the intermittent and synchronous production of large seed crops) in forest and alpine environments have been linked to changes in temperature (Kelly et al, 2013; Monks et al, 2016). In the case of beech mast, this can lead to an outbreak of pests such as rats and mice, leading to stoats breeding prolifically on abundance of food. This increase in pest numbers poses an increased threat of predation to native forest birds (King, 1983).

Other indirect climate impacts include increased vulnerability to erosion, coastal habitat squeeze (the loss of intertidal habitat due to sea-level rise and structures such as sea walls), severe fires, and changes in ocean productivity and food webs (Keegan et al, 2022; Lundquist et al, 2011; Macinnis-Ng et al, 2021).

There are still a lot of unknown direct and indirect impacts of climate change on our native species and ecosystems that need to be addressed. Mātauranga Māori, including maramataka, holds centuries of observations to understand causal effects (Hikuroa, 2017) (see **Tupuānuku section**). For example, oral records of changes in timing and distributions due to environmental change have been used to identify negative relationships between the El Niño Southern Oscillation and abundance of sooty shearwater (Humphries & Möller, 2017).

CLIMATE AND ECONOMY

The agricultural sector relies heavily on rainfall and is particularly vulnerable to the extremes of both high and low rainfall. As farmland is often located on fertile floodplains it is particularly exposed to the risk of flooding (Craig et al, 2021), while water availability during drought events also poses a high risk.

Dairy farming is particularly vulnerable to flood events as it largely occurs on flat and low-lying land on floodplains, and requires regular transport of fresh milk to dairy factories. The likelihood of damages from floods is also higher for dairy farmers who rely on fixed assets, including vulnerable vegetation, farm machinery, and buildings (Craig et al, 2021). Climate change contributed to 12 extreme rainfall events in Aotearoa between 2007 and 2017, which resulted in $471 million in total insurance costs. The modelled portion of these costs attributable to human influence on climate change was estimated to be around $140 million (roughly 30 percent) (Frame et al, 2020).

Drought events can have even greater impacts on the primary sector than floods. Droughts cause the soil to dry out, and can lead to the loss of almost all of a farm's profits (Bell et al, 2021). The two major drought events of 2007–08 and 2012–13 have been estimated by the New Zealand Treasury to incur about $4.8 billion in costs, including indirect losses (including loss of income during and following events or emergency response costs). Human influence on climate change accounted for an estimated 15–20 percent of these costs, about $800 million. These costs will almost certainly increase over time, as the climate continues to change (Frame et al, 2018, 2020).

Agriculture is one of the highest risk sectors in relation to climate change impacts due to its direct reliance on the natural environment (Arent et al, 2014). In a recent survey, 52 percent of farmers believed that severe weather and a changing climate are having a moderate or major impact on their operation, and ensuring a future supply of water was a priority for many (MPI, 2019) (see **Hiwa-i-te-rangi section** for more details on food and water security).

FLOODS, DROUGHT, AND HEALTH

While we can estimate the likely financial impacts of floods and droughts events, it is much more difficult to assess how these events could affect mental wellbeing.

International studies have found that in the aftermath of floods, people often experience post-traumatic stress disorder (PTSD) (Cianconi et al, 2020). Floods bring mourning, displacement, and psychosocial stress due to loss of lives and belongings. A study in England found a higher incidence of depression, anxiety, and post-traumatic stress disorder in participants affected by floods (Waite et al, 2017). After the Bay of Plenty flooding in April 2017, farmers highlighted the importance of community resilience, social cohesion, and supporting others. However, respondents also reported suffering from mental health issues, in some cases necessitating time off the farm to help alleviate stress caused by the event (Paulik et al, 2021).

Throughout the world farmers are shown to be particularly susceptible to the mental health risks associated with drought (Cianconi et al, 2020). Following Australia's decade-long drought ending in 2012, studies found an increase in anxiety, depression, and potentially suicide in rural communities. These were related to financial and employment issues, combined with feelings of helplessness and lack of optimism for the future (Albrecht et al, 2007; Polain et al, 2011).

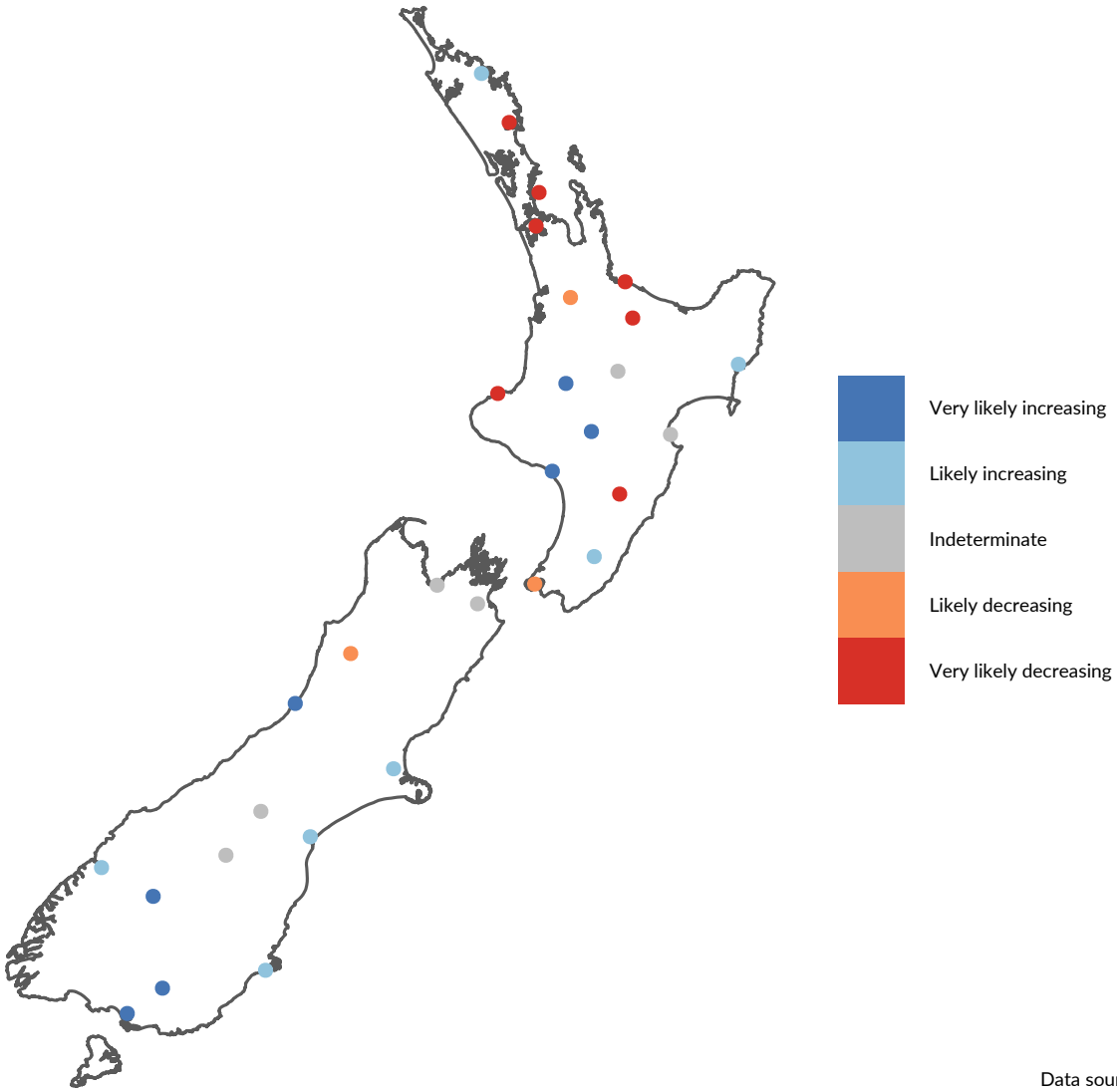
In Aotearoa, there are very few studies examining the impact of drought on people's wellbeing, even though it can affect mental health. This is particularly the case for those in rural areas who rely on rain for their livelihoods (EHINZ, 2021). Services are available to farmers to help with their wellbeing, such as Farmstrong (Farmstrong, nd).

The state of Waipunarangi

RAINFALL

Between 1960 and 2019, annual rainfall increased at 14 sites and decreased at 10 across 30 monitoring sites in Aotearoa (increases and decreases include both likely and very likely statistical trends; see indicator for trend assessment detail). Increased rainfall occurred in the southern South Island and the west coast. Many of the sites where rainfall decreased were in the northern half of the North Island (see figure 7). (See indicator: **Rainfall**.)

Figure 7: Annual total rainfall trends, 1960–2019



Data source: NIWA

EXTREME RAINFALL

As Earth warms, scientists expect that the frequency of extreme rainfall will increase (Glasser, 2020). We have information about extreme rainfall events at 30 sites across Aotearoa between 1960 and 2019. The indicator measures the proportion that very wet days contribute to total rainfall, and the maximum amount of rainfall that fell in a single day. (See indicator: **Extreme rainfall**.)

The annual maximum rainfall in a single day decreased at 10 sites (seven of which are in the northern half of the North Island), while it increased at 9 of 30 sites across Aotearoa (increases and decreases include both likely and very likely statistical trends; see indicator for trend assessment detail). Trend direction couldn't be determined for 11 sites. The proportion that very wet days contributed to total rainfall decreased at 11 sites and increased at 13. Trend direction couldn't be determined for six sites.

Heavy rain and floods have a significant impact on landscapes and places of cultural significance, affecting communities' ability to practice tikanga (Awatere et al, 2021). These impacts are likely to increase over time as climate change leads to increased frequency and magnitude of extreme events. Flood events impact connections and practices on, and between, marae, sites of significance (wāhi tapu), cultural infrastructure, and communities. Across Aotearoa, wāhi tapu are threatened by sea-level rise, and are being lost to flooding, storm surge, and coastal erosion.

For example, the course of the Wairoa River in Hawke's Bay (Te Wairoa Hōpūpū Hōnengenenge Mātangi Rau) has naturally moved closer to Mātiti Urupā (burial ground). This increases the risk of erosion to the urupā from around the riverbed, particularly during significant floods. Efforts to prevent the erosion include forums (wānanga) with experts, constructing a barrier in the river and planting along the banks, but the erosion has continued (MfE & Stats NZ, 2020a).

SHORT-TERM DROUGHT

We have information about drought at 30 selected sites across Aotearoa between 1972 and 2019. The frequency of short-term drought (those lasting three months) increased at 13 sites and decreased at 9 of 30 sites across Aotearoa over this period (increases and decreases include both likely and very likely statistical trends; see indicator for trend assessment detail). In the South Island, the majority of increasing trends in short-term drought frequency occurred in the north and east, while decreasing trends were focused in the west and south over this period of time. (See indicator: **Drought**.)

A study from NIWA found an overall increasing trend in low rainfall extremes, particularly on the east coast. This is consistent with a projected increase in westerly winds during winter and spring, producing drier conditions in the east (Srinivasan et al, 2021).

FROST AND WARM DAYS

We have information on the number of frost and warm days for 30 sites across Aotearoa from at least 1972 to 2019. A 'warm day' is when the daily maximum air temperature is above 25 degrees Celsius, and a 'frost day' is when the daily minimum air temperature is below 0 degrees Celsius. The number of frost and warm days changes from year to year in response to climate variation, such as the warming pattern induced by El Niño. Projections from climate models indicate we may experience more warm extremes and fewer cold extremes in the future. (See indicator: **Frost and warm days**.)

Between 1972 and 2019, warm days increased at 24 of the 30 measurement sites, while frost days decreased at 18 of the 30 sites (increases and decreases include both likely and very likely statistical trends; see indicator for trend assessment detail). The number of heatwave days for the same period increased at 18 of the 30 sites, with some of the fastest increases happening in inland locations of the South Island. A heatwave day is defined as three or more consecutive days with a maximum temperature greater than 5 degrees Celsius above the monthly average for 1981–2010. For more detail see ***Our atmosphere and climate***.

GLACIER VOLUMES

Glaciers are fed by snow, and hold large amounts of freshwater. Glaciers in Aotearoa decreased in volume by 35 percent between 1978 and 2020. Since our last synthesis report in 2019, annual glacier ice volumes have decreased from 40.7 cubic kilometres in 2016 to 34.6 cubic kilometres in 2020 (a loss of 6.1 cubic kilometres). (See indicator: **Annual glacier ice volumes**.) Glacier volume is influenced by increasing temperatures and changing rain patterns because of climate change. Changes to the ice volume in glaciers can affect river flows and ecological and hydropower resources, and cultural values.

In summary

As the planet warms, we are starting to observe changes in our rainfall patterns. Rainfall trends show decreases in the north of the North Island, and increases in the west and south of the South Island. At some locations, the frequency of short-term droughts has increased. Due to their reliance on the natural environment, our food production systems are particularly vulnerable to these changes. Changing rainfall and weather patterns add to and compound the existing pressures ecosystems are facing, having flow-on effects to all other parts of the environment and almost every aspect of our lives.

Our atmosphere and climate

The air we breathe, the skies we observe, and the weather we experience, can affect our wellbeing.

URURANGI

means 'winds of the sky' and is connected to atmospheric conditions, winds, and the sky.

WAIPUNARANGI

means 'water that pools in the sky' and is connected to the rains and other atmospheric conditions.

Navigation

Aotearoa has a strong connection to the winds through sailing and wayfinding using the stars.

Observing the sky

Some tikanga Māori practices rely on the observation of the sky to predict the correct times for planting and harvesting or hunting and fishing.

RAINFALL AND WEATHER PATTERNS ARE CHANGING

Changes in future temperature and precipitation will have impacts on people and ecosystems.

AIR QUALITY IMPACTS OUR HEALTH

At times, poor air quality is negatively impacting people's health. How we generate and use energy and transport affects air quality.

Our culture

The ability to practice mahinga kai is intertwined with the weather, along with access to plants used for medicinal, practical, artistic, or ceremonial purposes.

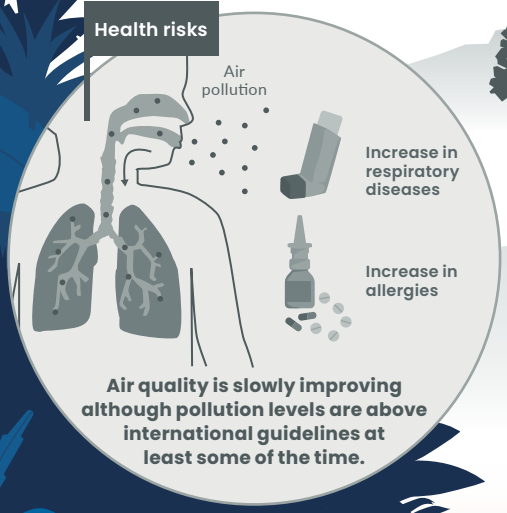
Increase in extreme events

- Damage to property and infrastructure
- Impact on food production
- Impact on mental wellbeing
- Floods
- Droughts
- Harm to people and the economy
- Extreme winds

Increasing temperatures

- Fewer frost days
- Melting glaciers

Health risks



Air quality is slowly improving although pollution levels are above international guidelines at least some of the time.

IMPACTS ON SPECIES

Changing temperature, rainfall patterns, and extreme events increase the vulnerability of taonga species by altering their distribution, life cycles, and migrations.

- Altered species distribution and life cycles

Ururangi

Atmospheric conditions, winds, and the sky

E TŪ URURANGI E
TUKUA MAI HE HAU KŌTENGITENGI
TUKUA MAI HE HAU PŪREKEREKE
HE HAU HEI MIRI I TE KIRI

BEHOLD URURANGI
SEND A GENTLE BREEZE
SEND A PUFF OF WIND
A WIND TO CARESS MY SKIN

An introduction to Ururangi

Ururangi (Merope) is the star linked to atmospheric conditions, winds, and the sky. Ururangi means 'winds of the sky', and is associated with the various types of winds and the weather patterns each brings. Ururangi resides in the domain of Tāwhirimātea, the atua of the winds and weather.

Our interactions with Ururangi can be seen in the quality of the air we breathe, the visibility of the night sky, and the winds that are used to fill the sails of our navigating ancestors and those who continue the practice of navigating the oceans. The wind can also be destructive.

Our connection to Ururangi

"We connect with Ururangi whenever we feel the winds connect to our bodies and the swaying of the trees. There are 500 distinct types of winds with different personalities and names. For example, te hau māngere is the lazy wind. Te haututū is the mischief wind which can also be referred to our children who are called haututū, mischievous but curious personalities" (Rereata Makiha, pers. comm., 2019).

The winds and atmosphere have life force (mauri), and our interactions with them affect our own mauri (see the **Matariki section** for the definition of mauri used in this report). They are a matangaro, an invisible phenomenon – we can detect them by the interactions they have with Earth, the sea, people, landscapes, ecosystems, and living beings (Rereata Makiha, pers. comm., 2021).

CONNECTIONS TO THE SKY

Observations of the sky have informed specific tikanga Māori (customs/protocols) and are essential for readings of Matariki, which provides predictions for the year ahead. The changing of the seasons is tracked through observing the appearance of certain stars and the changing path of the sun (Harris et al, 2013).

The maramataka (see **Tupuānuku section**) provides a framework for understanding the environment (te taiao) and informing cultural practices. The practice of observing particular signs (tohu) adds to and tests knowledge of the environment, and allows that knowledge to be shared and passed down through the generations (Hikuroa, 2017).

Being able to follow the maramataka and observe Matariki and other celestial tohu is reliant on sky visibility to optimise times for harvesting, planting, and growing food. The maramataka helps determine when to plant or harvest crops, and the appropriate times to hunt and fish for specific animals (Harris et al, 2013). Observing the maramataka is also crucial to preserving tikanga and cultural knowledge. Practices such as karakia (incantations), pūrākau (stories), and waiata (song) are often used in conjunction with planting and harvesting, and these are lost if tohu are not seen or practices decline (Smith, 2011; Tawhai, 2013).

Ururangi and observation of the winds and skies also provides linkages to the first peoples who arrived in Aotearoa. Navigation of the waka hourua (double hulled waka used for ocean migration), used to travel across the Pacific utilises wayfinding. The stars, moon, sun, wind, and birds, are used for navigation (Science Learning Hub, 2014). The path of the sun and the rising and setting of specific stars during a journey are used to steer the waka in the right direction. These locations shift over the course of a long voyage, so accurate understanding and observations are crucial to navigation (Harris et al, 2013).

The links to first peoples, such as Kupe, Māui, and Rata, and their achievements in relation to waka hourua connect many Māori to their ancestral practices and tūpuna (ancestors). Storytelling, songs, and poetry are used to remember the names of navigators, captains, canoes, and crew (Barclay-Kerr, 2016). These practices continue to be upheld today. Along with learning traditional navigational knowledge, participants are able to see the importance of their connection to the environment and the issues affecting the Pacific Ocean (Barclay-Kerr, 2016).

OBSERVING AND ENGAGING WITH THE SKIES

Connecting with the night sky is a universal human experience. People often have an emotional and spiritual attachment to observing the stars, and studies have found it has psychological benefits including improved mood and enhanced social connections (Blair, 2018; Kelly, 2003; Kelly & Daughtry, 2007; Kelly & Kelly, 2010). People who are constantly exposed to pristine night skies also report an increased sense of responsibility towards nature (Blair, 2018).

The Southern Cross constellation (Te Pae Māhutonga) is a distinctive feature of the night sky in Aotearoa, visible at any time of year. It is one of the first star patterns children learn to recognise and is associated with national and cultural identity. As well as appearing on our flag, the Southern Cross is part of several national memorials such as the Tomb of the Unknown Warrior. Planes, boats, newspapers, organisations, and companies have been named after the Southern Cross, including the first plane to cross the Tasman Sea in 1928, highlighting its importance as a national symbol (Wassilieff, 2006).

OUR CONNECTIONS TO URURANGI CAN BE SEEN IN MANY ASPECTS OF OUR LIVES

While the winds and atmosphere are invisible, their impacts can be seen in many different aspects of our lives. Good air quality allows us to live healthy, active lives, and many recreational, cultural, educational, and economic activities are directly related to the winds and the sky (Auckland University of Technology, nd; Tainio et al, 2021; UNESCO, nd).

Universities, observatories, and research institutions in Aotearoa conduct world-leading research in astronomy. This creates many scientific and educational opportunities, and through building international space agency partnerships inspires new generations of researchers.

An important aspect of this is the development of Māori astronomical research at our universities, building knowledge of the sky as a cultural resource. Māori-led and Māori-focused astronomical research is growing. More than just recording the historical practices of Māori, the research focuses on giving new life and purpose to the historical practices of Māori and revitalising various Māori practises and beliefs (Whaanga & Matamua, 2016).

The MacKenzie Basin has been designated an international dark sky reserve, the largest in the southern hemisphere and one of only eight globally. As well as enabling astronomical research, the reserve is a tourism drawcard. It has a layered design approach, where the natural, cultural, scientific, and astronomical heritage values of the site are interwoven (UNESCO, nd).

Ongoing connections to Māori astronomical practices can be seen more widely in the increasing celebrations of Matariki in recent years. Schools, communities, and marae around the country hold activities linked to Matariki, and from 2022 Matariki has been adopted as a national public holiday. Matariki traditions reflect the strong connection many Māori have with their surrounding environment, and how important the environment was for the survival of Māori. While our relationship to the world may have changed in a modern context, Matariki reminds us of the link between humanity and the environment that will always remain (Whaanga & Matamua, 2016).

WIND AND WELLBEING

Matariki celebrations connect us to the winds as well as the stars. Today many kite festivals happen around the country during Matariki. Often these are co-led by iwi groups and local councils. An example is the Ōrākei Manu Aute Kite Day, a community celebration of kite-flying organised by Auckland Council and Ngāti Whātua Ōrākei (Matariki Festival, nd).

Aotearoa has a strong connection to the winds through sailing. Sailing is a popular recreational activity, with around 125,000 New Zealanders taking part in sailing or windsurfing in 2020 (Dodd et al, 2020). It is also a strong source of national pride, with great success in many international events, including Olympic Games and the America's Cup. Along with this, sailing contributes to the economy through events such as the America's Cup (MBIE, 2017).

Wind power is an increasingly important part of energy generation in Aotearoa, making up around 5 percent of our electricity supply. Current wind generation capacity is 690 megawatts, with a goal of increasing this to 2,500 megawatts by 2030 and 8,000 megawatts by 2060 (MBIE, 2020b).

The state of Ururangi

The state of Ururangi can be observed through measuring the conditions of the air, the sky, and the wind.

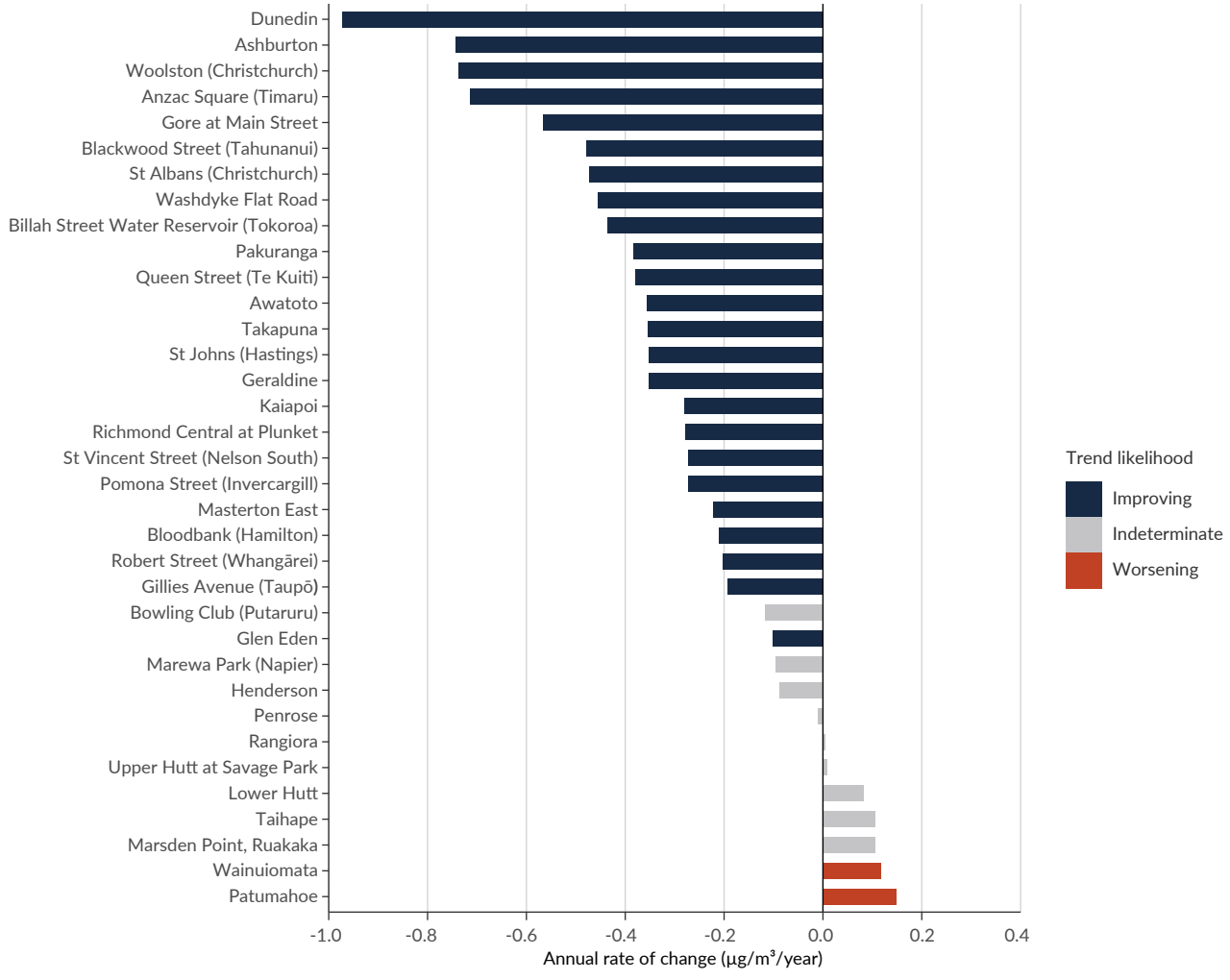
AIR QUALITY

Our activities affect the quality of the air we breathe. Air quality is measured through the levels of particulate matter (PM_{10} and $PM_{2.5}$) and the concentration of four gases – nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), and ground-level ozone (O_3).

Major sources for air pollutants include vehicle emissions ($PM_{2.5}$, NO_2, and CO), manufacturing and industry ($PM_{2.5}$), wood burning for home heating ($PM_{2.5}$), and dust from unsealed roads (PM_{10}).

In general terms, air quality is slowly improving at a majority of measurement sites in Aotearoa, although pollution levels are greater than the World Health Organization guidelines for most air pollutants some of the time (WHO, 2021) (see figure 8 for details for PM_{10}; see indicator for trend assessment detail). For more detail, see ***Our air 2021***. (See indicators: **PM_{10} concentrations**, **$PM_{2.5}$ concentrations**, **Sulphur dioxide concentrations**, **Nitrogen dioxide concentrations**, **Carbon monoxide concentrations**, **Ground-level ozone concentrations**.)

Figure 8: PM_{10} trends, 2011–20



Data source: Regional councils, unitary authorities

Despite the winds and atmosphere being invisible to the eye (matangaro), if the air is not healthy – if its mauri can be regarded to be in a poor state – this has major impacts on human health (see **Matariki section** for the definition of mauri used in this report).

In 2021, the World Health Organization lowered the safe exposure levels for most air pollutants in its guidelines, reflecting recent research which found that air pollution negatively affects human health even at very low concentrations (WHO, 2021).

Air pollution causes serious health effects, including premature deaths, heart and lung disease, and respiratory diseases (Huangfu & Atkinson, 2020; Lee et al, 2020; Orellano et al, 2020, 2021; Zheng et al, 2021). Modelling indicated that human-generated PM_{10} was linked to 27 premature deaths per 100,000 adults over 30 in 2016. More detail is available in ***Our air 2021***. (See indicator: **Health impacts of PM_{10}**.)

Between 2000 and 2019, hospitalisation rates for respiratory diseases have risen in Aotearoa. In 2017, the economic cost of respiratory disease (from all causes) was estimated at $6.7 billion per year. There are significant inequalities in respiratory health outcomes: in 2019, hospitalisation rates for Pacific peoples and for Māori were higher than average (2.6 and 2.2 times respectively), and hospitalisation rates in the most deprived households were 2.3 times higher than average (Barnard & Zhang, 2021).

Studies have found that restrictions associated with the COVID-19 pandemic in 2020 improved air quality and reduced respiratory disease rates in Aotearoa (Barnard & Zhang, 2021; Talbot et al, 2021b). The first COVID-19 lockdown (March to June 2020) resulted in a significant and sudden change to our lifestyles. Most car trips were not allowed during the most restrictive lockdown periods, leading to a large and immediate reduction in NO_2 in urban areas – between 38 percent and 66 percent below the long-term mean, adjusted for weather. In most places these levels rebounded to near pre-lockdown levels as restrictions eased and motor vehicle use increased again. This shows how much our behaviours affect the world around us, and how quickly we can see changes in the environment when we shift the way we live (Talbot et al, 2021a).

Changes to the places we live can also affect the health of Ururangi. Urban greenspaces have many benefits for the physical and mental wellbeing of people (see **Tupuārangi section**). Research has found that urban tree cover reduces NO_2 concentrations in the air and can result in fewer respiratory problems among residents (Rao et al, 2014).

AIRBORNE DISEASES AND ALLERGIES

Allergic rhinitis or hay fever is another common respiratory condition, affecting about 20 percent of people in Aotearoa, although this number has been increasing. Hay fever is commonly caused by an allergic reaction to wind-borne pollen. Environmental changes such as the spread of new invasive plants, land-use changes, and climate change have likely contributed to its increase (Newnham, 2022).

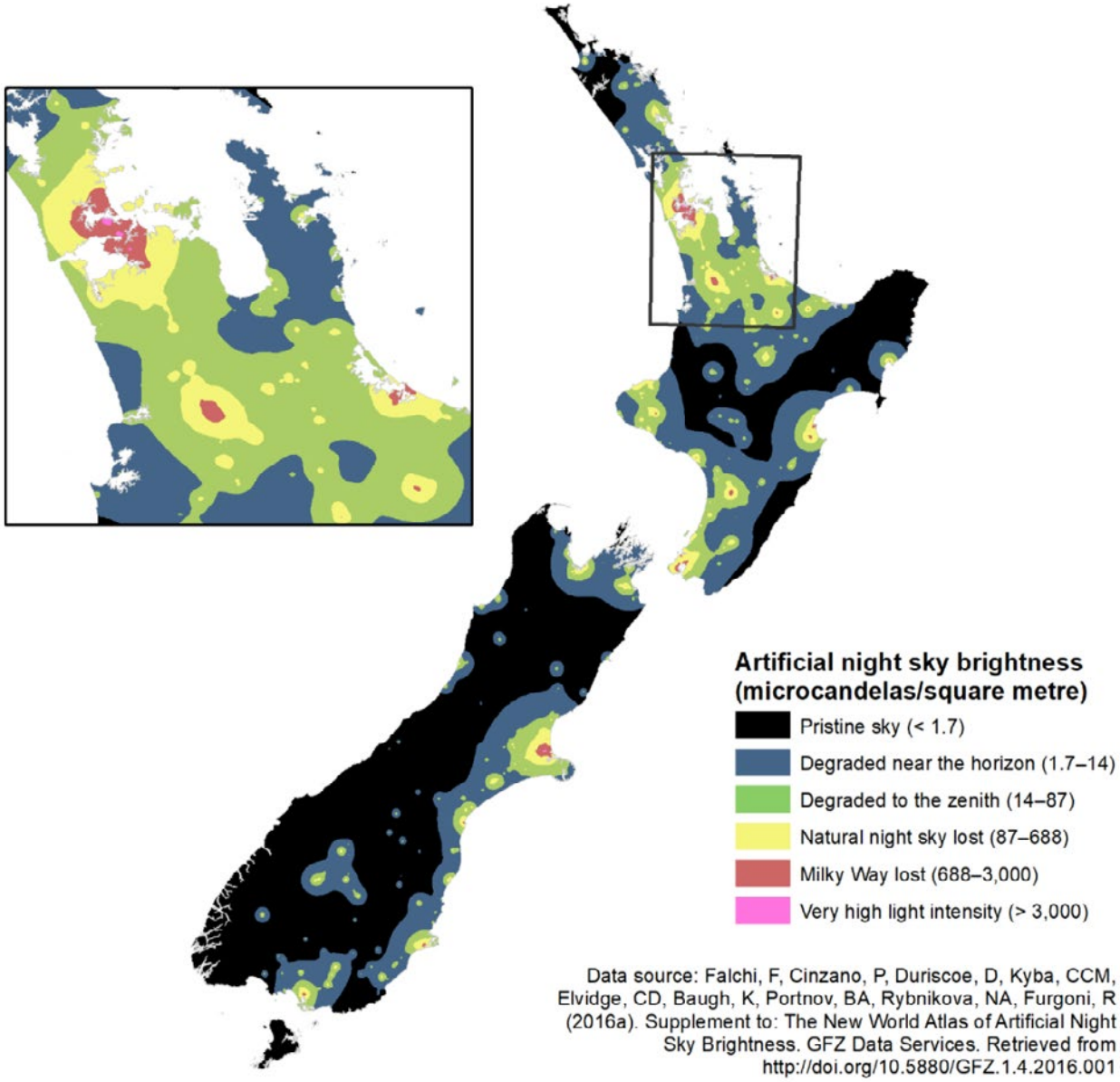
There are significant data gaps in our understanding of airborne pollen in Aotearoa, with very little reporting and forecasting compared to other countries. The last systematic nationwide study of airborne pollen was conducted in 1989. More accurate pollen monitoring and forecasting could help those with hay fever to better manage it and reduce the severity of impacts (Newnham, 2022).

LIGHT POLLUTION

The state of Ururangi can be measured by our ability to see the night sky. In data from 2014, 74 percent of the North Island and 93 percent of the South Island had night skies that were either pristine or degraded only near the horizon (see figure 9). Due to light pollution being concentrated in urban centres, an estimated 56 percent of the Aotearoa population live in areas where the Milky Way is not visible due to artificial brightness. (See indicator: **Artificial night sky brightness**.)

Not being able to see the night sky has negative impacts. As discussed earlier, being able to see the night sky has positive impacts on wellbeing. With 84 percent of the population of Aotearoa living in urban areas in 2019 (Stats NZ, 2021b), opportunities to see the sky in its fullness are significantly reduced. For some Māori, not being able to clearly see the night sky has implications for cultural connections and tikanga. Reading Matariki, observing tohu, traditional food gathering practices (gathering mahinga kai), and navigating by the stars are more difficult or impossible when the sky is not visible. The more general wellbeing effects that come from connecting with the night skies are also made more difficult with light pollution in urban areas.

Figure 9: Visual impact of light pollution over New Zealand, 2014



There is evidence that the increasing use of energy-efficient LED lights in urban areas is increasing light pollution. These blue-rich LED lights disrupt the circadian day-and-night rhythms of living organisms and have potential negative effects for humans, species, and whole ecosystems (Schulte-Römer et al, 2019). Light pollution affects many species, disrupting navigation and orientation, foraging activity, reproduction, communication, and community composition.

Measurements in Auckland city recorded night sky brightness 10 times higher than natural levels, which can partially mask even the moon (McNaughton et al, 2022). This has a particular impact on insects, with artificial light disrupting natural behaviours and contributing to the global decline in insect numbers (Owens et al, 2020). Studies of wētā have found they alter their behaviour near light sources, and that light significantly reduced the number of observations of both cave and tree wētā (Farnworth et al, 2018).

EXTREME WINDS AND SHIFTING WIND PATTERNS

Local knowledge developed by some iwi informs understanding of provincial weather and climate conditions. A range of tohu are used in preparation for activities that are sensitive to changes in weather and climate. For Ngāi Tahu, the nor'west arch (Te Māuru) is core to understanding weather patterns in the South Island. The height of the arch above the Southern Alps (Kā Tiritiri-o-te-Moana) during a warm nor'wester helps inform the intensity of the cold southerly (Skipper, 2018).

Exposed coastal locations in Aotearoa often experience strong winds due to being positioned in the direction of prevailing westerly winds (Macara, 2018). The indicator for extreme wind measures the daily maximum wind gust (a measure of windiness), annual maximum wind gust (a measure of wind strength), and the number of days where gusts were extreme for that location (potentially damaging). Fourteen sites around the country had sufficient data between 1980 and 2019 to allow trends in extreme wind to be determined. Two of the extreme wind measures likely or very likely decreased at 12 of the 14 measurement sites (daily maximum wind gust and number of days with a gust that is extreme for that location). The annual maximum wind gust likely or very likely decreased at 11 sites (see indicator for trend assessment detail). Only Gisborne and New Plymouth showed an increase across all three measures. (See indicator: **Extreme wind**.)

The recent declines in extreme wind magnitude and frequency may be related to the Southern Annular Mode (SAM) more often being in a positive phase which moves storm tracks further south, though the size of this effect is uncertain (NIWA, nd). For more details on the SAM and its impacts on Aotearoa, see ***Our atmosphere and climate 2020***. Climate models project that extreme wind will increase in the southern North Island and the South Island, especially east of the Southern Alps, in the coming years. (See indicator: **Extreme wind**.)

Extreme wind can cause significant harm to people and infrastructure. Natural disasters, such as the 2021 tornado which affected South Auckland in June of the same year, can cause fatalities, injuries, and harm to mental health (Insurance Council of New Zealand, 2021; Makwana, 2019). In February 2022 ex-cyclone Dovi caused treefall, power outages, road closures (including the Auckland Harbour Bridge), slips, flight and ferry cancelations, and damage to farming infrastructure and crops (RNZ, 2022a, 2022b). See **Waipunarangi section** for more on the impacts of natural disasters on mental wellbeing.

Economic impacts of extreme winds to infrastructure, forestry, and agriculture can also be high. A windstorm in the South Island in September 2021 caused an estimated $20 million in damage, with the South Auckland tornado resulting in $32 million in insurance claims (Insurance Council of New Zealand, 2021). Wind damage was responsible for 60,000 hectares of damage in planted forests between 1945 and 2010, a median of 90 hectares per extreme wind event (Moore et al, 2013). Strong winds can also increase the risk and spread of fire (Scion, 2015).

In summary

International air quality guidance has changed with the World Health Organization 2021 guideline update. Air quality in Aotearoa is improving slowly at a majority of measurement sites, but in many places pollution levels are above the new guidelines. Light pollution is concentrated around our cities, where most people live. Interacting with our pristine night skies requires visiting dark sky reserves or travelling away from urban centres. The damage human activity is causing to the air, winds, and sky has a range of negative consequences. While they do not touch us physically, changes to atmospheric conditions have an impact on many aspects of our wellbeing, including health and recreation.

Hiwa-i-te-rangi

Future aspirations and actions to sustain the environment (te taiao)

E TŪ HIWA-I-TE-RANGI E
TE KAUWAKA O TE MANAKO NUI
ANEI NGĀ TŌMINA O TE NGĀKAU
HEI WHAKATINANATANGA MAU

BEHOLD HIWA-I-TE-RANGI
THE MEDIUM OF MY DESIRES
YOU KNOW FOR WHAT I YEARN
MAKE MY DREAMS COME TRUE

An introduction to Hiwa-i-te-rangi

Hiwa-i-te-rangi is the youngest child of Rehua and Matariki. 'Hiwa' means 'vigorous of growth' and 'i te rangi' means 'in the sky'. Her role is distinct yet connected to those of her siblings in Te Kāhui o Matariki (the Matariki cluster). Her siblings are connected to specific environmental domains and provide signs (tohu) in relation to the environment (te taiao). The role of Hiwa-i-te-rangi is to shine (to pīata), and provide a light and motivation to step into the unknown. She helps us navigate these signs to move forward.

Hiwa-i-te-rangi represents our aspirations for a prosperous season ahead (Matamua, 2017). She is connected to looking forward: planning to succeed, hopes for future growth, and holding on to a prosperous vision of our future.

Future outlook

Our values and choices result in pressures on te taiao, including land-use change and intensification, invasive species, pollution, natural resource use, and climate change (see **Pōhutukawa section**). These pressures can result in the loss of ecosystems and species, and negatively impact on aspects of wellbeing, especially non-material aspects of wellbeing. These pressures can also leave a legacy, impacting the wellbeing of future generations.

In this section we look ahead to the complex and interconnected environmental challenges facing us and future generations, as well as our ability to adapt to and mitigate future risk.

A CHANGING CLIMATE

Future greenhouse gas emissions from Aotearoa and the rest of the world will continue to drive climate change. However, even if emissions were brought to a halt, the greenhouse gases that have already accumulated in the atmosphere will have major impacts. Globally, it is estimated that by the end of the century average global temperatures will very likely be between 1 degree and 5.7 degrees Celsius warmer than pre-industrial temperatures (ie those recorded during 1850–1900). A sustained global surface temperature at or above 2.5 degrees Celsius higher than pre-industrial level is estimated to have occurred over 3 million years ago. Exactly how much warming we experience depends on the trajectory of our future emissions (IPCC, 2021).

We are already observing changes in our climate and experiencing their impacts (see **Waipunarangi section**). For Aotearoa, it is expected that our future climate will include higher temperatures across the country and a consequent increase in the number of warm days (defined as days with a maximum temperature of 25 degrees Celsius or higher). Rainfall patterns are also projected to change, generally with wetter areas getting wetter, drier areas becoming drier, and extreme rainfall events becoming more common in many areas (MfE & Stats NZ, 2020a). The combination of warmer temperatures and rainfall changes are projected to bring more severe and frequent droughts. Hotter, drier, and windier conditions are also expected to increase the days with high or very high extreme fire danger. By 2100, sea-surface temperatures are projected to increase between 1.1 and 2.5 degrees Celsius above the mean sea-surface temperature observed between 1976 and 2005, with major impacts on the marine environment (Law et al, 2018b).

Sea level is also rising with warming temperatures. The rate at which this will progress depends on future emissions and how fast polar ice sheets will change with rising temperatures (MfE & Stats NZ, 2020a). As sea levels continue to rise, low-lying areas will continue to be at risk of coastal inundations, with impacts on housing, infrastructure, and coastal ecosystems (see **Waipunarangi section**).

THREATS TO NATIVE ECOSYSTEMS

Our indigenous fauna and flora face many pressures including invasive species, habitat fragmentation, and intensive land use. Climate change is likely to exacerbate these. For instance, exotic plant species could be advantaged by warmer temperatures and more suitable conditions, displacing and outcompeting native species (Macinnis-Ng et al, 2021; PCE, 2021a).

Plant diseases which harm our native flora could also be advantaged. For instance, myrtle rust arrived in Aotearoa in 2017. This fungal disease reproduces in conditions of high humidity and warm temperatures. While temperature is currently the limiting factor, future scenarios of climate change indicate an increase in optimal conditions for infection and spread of myrtle rust across the country (Campbell et al, 2020). Climate change may also alter the distribution of wildlife diseases (Alley & Gartrell, 2019).

Other indirect climate impacts on ecosystems include increased vulnerability to erosion, coastal habitat squeeze (the loss of intertidal habitat due to sea-level rise and structures such as sea walls), severe fires, and changes in ocean productivity and food webs (IPCC, 2022b; Keegan et al, 2022; Lundquist et al, 2011; Macinnis-Ng et al, 2021; Parsons et al, 2020). We have limited knowledge on the direct impacts of recent climate change on biodiversity. The lack of data and long-term studies limit our ability to understand how Aotearoa species will be affected in the future (IPCC, 2022a; Law et al, 2018b; Macinnis-Ng et al, 2021).

GLOBAL TRENDS, LOCAL IMPACTS

Displacement of human populations due to weather-related disasters or rising sea levels may drive population changes and migration patterns (International Organization for Migration, 2021; Ning et al, 2018). Globally, changes in dietary preferences (such as increased meat consumption) and unequal crop yield changes will also likely drive changes in commodity prices and trade policies, affecting our agricultural sector (Ning et al, 2018; Renwick et al, 2016; Ritchie & Roser, 2017).

Changes in demographics is known to be one of the drivers of change for land demand and urban expansion (see ***Our land 2021***). The population that resides in Aotearoa is expected to continue growing in the coming 50 years. However, projections indicate the speed of this growth will slow with time, and could eventually result in a population decline (Stats NZ, 2020). In addition, it is expected that the country will continue to move towards an ageing population structure where there is a growing proportion of the population in the older age brackets (Stats NZ, 2020).

FOOD AND WATER SECURITY

Climate change will have major impacts on agriculture through rising temperatures and shifting rainfall patterns. Modelling using climate projections shows optimal locations for pasture production may shift. Overall yields are projected to stay relatively constant or could even increase due to climate change (Keller et al, 2021). However, these yields are estimated to be increasingly variable and unpredictable. The increase in carbon dioxide in the atmosphere is expected to help plants grow, through stimulating photosynthesis and water-use efficiency for pasture and pine forest, although the magnitude of the effect is uncertain (Keller et al, 2021; Kirschbaum et al, 2012).

Warming temperatures may pose serious risks for the health of livestock. This can be directly through heat stress (Ausseil et al, 2019), and indirectly through potential increases in existing diseases (such as facial eczema), and through more severe microbial and parasite infections (Lake et al, 2018). Warmer temperatures may be favourable to insect pests, increasing damage to crops and plantation forestry (MPI, 2015). Fire risk may also increase (Watt et al, 2019). Climate change represents a particular risk for Māori forestry, farming, and horticulture, as Māori land is often on erosion prone hill country already vulnerable to extreme events (Awatere et al, 2021).

Some adaptation measures are showing promise to counteract the effects of a warming climate. For instance, earlier sowing dates for maize can compensate and even increase production, and provide opportunities for longer winter growing seasons (Ausseil et al, 2019; Teixeira et al, 2020). New areas of Aotearoa will likely become suitable for vineyards due to a decrease in frosts, and a shift to other grape cultivars adapted to warmer and drier climates could bring new opportunities (Ausseil et al, 2021b). Some crops such as kiwifruit may need to shift location or use chemicals to induce fruiting (Tait et al, 2017).

The unpredictability of rainfall patterns will lead crops to depend more on irrigation to cope with future droughts. Climate change will affect the water cycle and hydrology, although large uncertainties remain on how climate change will impact water availability in different regions (Collins et al, 2018; IPCC, 2022b; MfE, 2020). Drinking water availability will also need to be assessed in conjunction with future demands from a growing population (Kamish et al, 2020). All these changes and demands will likely increase pressure on our freshwater environments.

INFECTIOUS DISEASES

Pests and diseases that can establish or spread more easily due to climate change are a risk to human health. Three quarters of new and emerging human infectious diseases are caused by pathogens of animal origin (Taylor et al, 2001). The emergence of these diseases from wildlife has increased over the past 80 years (Jones, 2008). This is mainly due to human impacts on land-use change and the wildlife trade that have exacerbated the likelihood of spill-over of pathogens into humans (Lawler et al, 2021). COVID-19 provides a recent example of this.

In Aotearoa, the risk of wildlife diseases jumping to humans due to climate and land-use change needs to be investigated further (Lal et al, 2015). Climate change, the age structure of our population, and anti-microbial resistance may also increase the risk to our population. An integrated approach such as OneHealth is needed to understand the interconnectedness and magnitude of these effects (PMCSA, 2021b).

Strengthening the value of environmental reporting

The environmental challenges ahead are complex, interacting, and sometimes outside our direct control. Understanding how our wellbeing is interconnected with environmental change is necessary to ensure the health of the environment as well as that of future generations. It is therefore crucial to make sure we can measure and report on the changes happening in the environment.

Over the past three years the Parliamentary Commissioner for the Environment has released a series of reports that identify the need for systemic reform to better integrate the environment and intergenerational wellbeing into policy. These reports, viewed collectively, point to the fundamental role of **environmental reporting** and **environmental research** in building the **environment and wellbeing** into decision-making and public expenditure. The recommendations in all three reports are being reflected in the Ministry for the Environment and Stats NZ's work programmes, in particular the proposed amendments to the Environmental Reporting Act. *Environment Aotearoa 2022* builds on the advances made in the last domain reports and takes us closer towards an improved system of environmental reporting.

AREAS OF FOCUS

Alongside the work to reform the Environmental Reporting Act, focus needs to be placed on building a fit-for-purpose environmental monitoring and reporting system that is adaptable to a rapidly changing future. Particular areas of focus include:

- A shift from passive harvesting to active capturing of data. Unlike the economic and social sectors, we don't yet have a unified data architecture for environmental information. This will support reporting on environmental issues at a national level across both time and place.
- Implementing a national monitoring network. Our current monitoring system is fragmented, and reliant on monitoring systems designed at a regional level to support regional needs. A national monitoring network is needed to improve consistency while serving multiple users of environmental data.
- Exploring alternative monitoring technologies. Advances in technology are opening new pathways for monitoring and reporting, and have the potential to introduce new data and insights at a national scale.
- Improving the integration of Mātauranga Māori. Mātauranga Māori represents a valuable record of our environment that is unique to Aotearoa and that complements our existing science and evidence base. More work is needed to improve the resourcing, access, and integration of Mātauranga Māori within our environmental monitoring and reporting system.

The challenge

The purpose of environmental reporting is 'to enable the evidence-based analysis and decision making needed to achieve effective stewardship of the environment' (PCE, 2019). In *Environment Aotearoa 2019*, we summarised the purpose of the report as providing 'evidence to enable an open and honest conversation about what we have, what we are at risk of losing, and where we can make changes'. This report presents a commentary, supported by Māori knowledge (mātauranga Māori), science, and indicator data, with this purpose in mind.

But this report is only the start of the journey. Hiwa-i-te-rangi invites us to reflect on these insights and to engage in conversations about our aspirations for the future. *Environment Aotearoa 2022* will only serve its purpose if we as individuals, as whānau, and as communities think to the future and how we protect te taiao, our wellbeing, and the wellbeing of future generations.

Photo: Clare Toia-Bailey, image-central.co.nz

PART C

Environmental indicators, Acknowledgments, and References

Tree Planting at Polhill Reserve, Wellington.
Photo: Jeff McEwan, Capture Studios

Environmental indicators

The data used in Environment Aotearoa 2022 is drawn from the most recent domain reports (***Our air 2021***, ***Our land 2021***, ***Our atmosphere and climate 2020***, ***Our freshwater 2020***, and ***Our marine environment 2019***) and the Stats NZ indicators that featured in them. Data from 11 updated indicators have also been incorporated. Criteria to update these indicators focussed on their relevance to this report and whether there was a need to incorporate the most recent data.

Listed below are the indicators that have been published alongside the domain reports, and 11 indicators updated for this report (shown in bold).

- **Annual glacier ice volumes**
- Artificial night sky brightness
- Carbon monoxide concentrations
- Coastal and estuarine water quality
- Cultural health index for freshwater bodies
- Deposited sediment in rivers
- Drought
- Estimated long-term soil erosion
- Exotic land cover
- **Extinction threat to indigenous freshwater species**
- **Extinction threat to indigenous land species**
- **Extinction threat to indigenous marine species**
- Extreme rainfall
- Extreme wind
- Freshwater pests
- Frost and warm days
- Ground-level ozone concentrations
- Groundwater quality
- Growing degree days
- Health impacts of PM_{10}
- Highly erodible land
- Indigenous land cover
- Irrigated land
- **Lake water quality**
- Land fragmentation
- Land pests
- Livestock numbers
- Marine economy
- Marine non-indigenous species
- Nitrogen dioxide concentrations
- Ocean acidification
- $PM_{2.5}$ concentrations
- PM_{10} concentrations
- Predicted pre-human vegetation
- Protection in the marine environment
- Rainfall
- Rare ecosystems
- **River water quality: clarity and turbidity**
- **River water quality: Escherichia coli**
- **River water quality: macroinvertebrate community index**
- **River water quality: nitrogen**
- **River water quality: phosphorus**
- Sea-surface temperature
- Soil quality and land use
- Sulphur dioxide concentrations
- Temperature
- Urban land cover
- **Wetland area**

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STANDING ADVISORY PANEL

- Adrian McDonald, University of Canterbury
- Andrea Byrom, independent consultant, member of the Environmental Protection Authority Board
- Craig Stevens, NIWA; University of Auckland
- Jason Tylianakis, University of Canterbury
- Joanne Clapcott, Cawthron Institute
- Shaun Awatere, Manaaki Whenua – Landcare Research
- Simon Lambert, University of Saskatchewan, Canada.

STANDING ADVISORY PANEL WORKING GROUP

- Daniel Hikuroa, University of Auckland
- Isaac Warbrick, Auckland University of Technology
- Shaun Awatere, Manaaki Whenua – Landcare Research.

EXTERNAL PEER REVIEWERS

- Carolyn Lundquist, NIWA
- Hauiti Hākopa, Mātauranga Māori Researcher and Advisor
- Suzie Greenhalgh, Manaaki Whenua – Landcare Research
- Troy Baisden, Motu Economic & Public Policy Research.

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