Our Marine Environment 2025

Tō Tātou Taiao Moana

New Zealand's Environmental Reporting Series
Te Kāhui Pūrongo Taiao o Aotearoa

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

Crown copyright ©

Unless otherwise stated, this copyright work is licensed for re-use under a Creative Commons Attribution 4.0 International licence. Except for any photographs, in essence, you are free to copy, distribute, and adapt the work, as long as you attribute the work to the New Zealand Government and abide by the other licence terms. To view a copy of this licence, visit Creative Commons Attribution 4.0 International licence. To re-use a photograph please seek permission by sending a request to the stated image owner.

Please note that neither the New Zealand Government emblem nor the New Zealand Government logo may be used in any way which infringes any provision of the Flags, Emblems, and Names Protection Act 1981 or would infringe such provision if the relevant use occurred within New Zealand. Attribution to the New Zealand Government should be in written form and not by reproduction of any emblem or the New Zealand Government logo.

If you publish, distribute, or otherwise disseminate this work (or any part of it) to the public without adapting it the following attribution statement should be used:

> Source: Ministry for the Environment, Stats NZ, and data providers, and licensed by the Ministry for the Environment and Stats NZ for re-use under the Creative Commons Attribution 4.0 International licence.

If you adapt this work in any way, or include it in a collection, and publish, distribute, or otherwise disseminate that adaptation or collection to the public, the following attribution statement should be used:

> This work uses material sourced from the Ministry for the Environment, Stats NZ, and data providers, which is licensed by the Ministry for the Environment and Stats NZ for re-use under the Creative Commons Attribution 4.0 International licence.

Where practicable, please hyperlink the name of the Ministry for the Environment or Stats NZ to the Ministry for the Environment or Stats NZ web page that contains, or links to, the source data.

Disclaimer

While all care and diligence has been used in processing, analysing and extracting data and information for this publication, the Ministry for the Environment, Stats NZ and the data providers give no warranty in relation to the report or data used in the report – including its accuracy, reliability and suitability – and accept no liability whatsoever in relation to any loss, damage, or other costs relating to the use of any part of the report (including any data) or any compilations, derivative works, or modifications of the report (including any data).

Citation

Ministry for the Environment & Stats NZ. (2025). *New Zealand's Environmental Reporting Series: Our Marine Environment 2025 | Tō Tātou Taiao Moana*. https://environment.govt.nz

Published in October 2025 by
Ministry for the Environment and Stats NZ

Publication number: ME 1920
ISSN: 2382-0179
ISBN: 978-1-991404-08-4

Cover: Okahu Bay Beach, Auckland
Photo: James Rua, truestock

Contents

Figures

Message to readers

Tēnā koutou katoa

Aotearoa New Zealand's position as an island nation shapes many aspects of our environment and our way of life. This geographic isolation has given rise to our unique flora and fauna, and our famously changeable weather is driven by the ocean that surrounds us. Our history, culture and identity are deeply intertwined with the marine environment and the isolation and protection it offers us.

The coast and ocean provide us with sustenance, recreation and economic opportunities. They also connect us to the rest of the world. But things are changing. Global climate disruption, resulting from humanity's greenhouse gas emissions, is reshaping oceanic processes. Increasing sea temperature and acidity, decreasing oxygen levels and changes to ocean currents affect us here in New Zealand.

As a result, our native species and ecosystems are increasingly under threat. Warming waters bring more invasive species, while rising sea levels and more intense storms reshape our coasts. These changes have profound impacts, not only on biodiversity and natural habitats, but also on people and communities. Our marine economy, the natural infrastructure that protects our coastlines and the deep cultural connections that tie us to these environments are all at risk.

While we know more than ever about pressures on our marine environment, significant blind spots remain. Filling these gaps is essential to reduce risk, support a sustainable marine economy and strengthen climate resilience. Expanding our knowledge is also essential if we are to build our nation's resilience and prepare for the changes to come. *Our Marine Environment 2025* brings together the most recent available data and insights to help New Zealanders understand the impacts of climate change on our coasts and ocean.

This report is part of a series produced in partnership with Stats NZ. Our teams of analysts and scientists work independently of the government to organise this evidence and provide New Zealand with a benchmark for reporting that is factual, reliable and robust.

This information enables better decisions as communities work together to build our nation's resilience and to hold on to the economic, cultural and environmental benefits we gain from our marine environment.

James Palmer
Secretary for the Environment

Mary Craig
Acting Government Statistician

Introduction

The health of our marine environment underpins our lives and livelihoods

Aotearoa New Zealand has more than 15,000 kilometres of varied coastline – as an island nation, we are never far away from the coast. For many of us, our connections to beaches and the ocean are fundamental to who we are as New Zealanders.

The ocean and coasts of New Zealand are more than part of our identity – they support the homes, livelihoods and cultural practices of communities across the country. For Māori, the moana (ocean) is a taonga, central to whakapapa (ancestral ties) and tikanga (customs and protocols), and it has long been a pathway of connection across Te Moananui-a-Kiwa (the Pacific Ocean). Whether we are gathering kaimoana (seafood), surfing or simply walking along the beach, the marine environment shapes our way of life and anchors us.

New Zealand's marine and coastal environments also play vital roles in supporting our economy. Industries such as aquaculture rely on clean, healthy waters to sustainably farm species such as mussels, oysters and salmon. Coastal tourism attracts both domestic and international visitors to experience our beaches, marine wildlife and water-based recreation.

Our activities on land and at sea are changing our climate, oceans and coasts

Human activities both on land and at sea continue to place pressure on the marine environment. Land-based impacts such as pollution, sedimentation, coastal habitat squeeze and nutrient run-off degrade coastal and marine ecosystems. Ocean-based activities like bycatch, bottom trawling and overfishing further threaten biodiversity and ecological resilience. Many of these pressures interact with and are compounded by human-driven changes in the climate.

The burning of fossil fuels, land-use change and industrial processes have all contributed to an increase in greenhouse gas concentrations in the atmosphere. This increase is warming the planet and altering the global climate system, with intersecting consequences for the world's oceans. Rising sea temperatures, ocean acidification, disrupted currents, and changing frequency and severity of extreme events are all symptoms of a climate system under pressure that is reshaping New Zealand's marine environments.

Our Marine Environment 2025 – the latest report in our three-yearly updates on the state of our coasts and ocean – focuses on the impacts of climate change on global oceans, and the consequences for New Zealand's coasts, marine ecosystems and communities. Previous reports have explored broader human and ecological systems in more detail, with the latest information available in *Our environment 2025* and *Our marine environment 2022*.

Our actions have significant consequences for the marine environment, which shows that we also have control over decisions that can improve environmental outcomes for both ecosystems and people. For examples of how people are adapting to changes in marine and coastal environments, see *Our Marine Environment: The Stories Behind the Numbers*.

The marine environment and our climate are intertwined

The global climate shapes the condition of New Zealand's marine environment. Oceans absorb approximately 25 percent of global carbon dioxide emissions and more than 90 percent of the excess heat generated by those emissions, making them critical in stabilising Earth's climate (UN, nd). However, absorbing all this heat and carbon dioxide makes the ocean warmer and more acidic, and the impacts of this are felt across New Zealand's marine ecosystems. Climate change is altering where species are able to live, disrupting food webs and increasing the vulnerability of habitats such as kelp forests, shellfish beds and coral communities, with some regions experiencing more severe changes than others. The ocean around New Zealand is also warming faster than the global average, with more intense, longer and more frequent marine heatwaves.

Sea levels are rising, driven by water expanding as it warms along with melting polar and glacial ice. Vertical land movements are also a factor in some areas. Sea-level rise is already affecting low-lying coastal areas, increasing the frequency and severity of coastal flooding and erosion. These changes pose growing risks to infrastructure, housing, livelihoods and culturally significant sites. Shifts in ocean currents and temperature are beginning to influence marine plants and animals. This affects our unique native species and key commercial fish stocks, with implications for fisheries management and food security.

New Zealand's isolation does not shield us from the far-reaching effects of global climate change. Instead, the changes to our oceans highlight the importance of understanding how climate, ocean health and human health are connected.

New Zealand's coasts and oceans are natural assets that help in adapting to a changing climate

New Zealand's coastlines and ocean are vital natural assets that protect and sustain our communities. Coastal wetlands and estuaries provide critical habitat for plants, insects, fish and shellfish, supporting biodiversity. They also act as natural buffers against coastal flooding, storms, wave inundation and erosion – reducing the impact of extreme weather events, storm surges and tsunamis. These natural features can function as protective infrastructure, reducing exposure to some climate-related hazards.

Beyond providing physical protection against the effects of climate change, marine ecosystems can help to maintain a stable climate by storing carbon in living organisms and sediments. Phytoplankton, kelp forests, seagrass meadows, saltmarsh, sediments and mangroves all play a role in capturing or storing carbon, helping to slow the increase of atmospheric greenhouse gas concentrations.

These ecosystems support New Zealand's marine economy – providing the foundation for fisheries, aquaculture, transport, energy and tourism – and they contribute to cultural and recreational wellbeing.

Understanding the full value of these natural systems helps us appreciate how closely environmental health is tied to social and economic resilience. As climate pressures intensify, recognising the role of coastal and marine ecosystems in supporting life and livelihoods will help us to respond effectively.

About *Our Marine Environment 2025*

Our Marine Environment 2025 is the latest in a series of environmental reports produced by the Ministry for the Environment and Stats NZ. It is the fourth report in the series dedicated to the marine environment, following the 2016, 2019 and 2022 reports, and is part of the fourth cycle of reports released under the Environmental Reporting Act 2015.

Evaluating specific policies and advice on responses to environmental issues is out of scope for environmental reports under the Environmental Reporting Act 2015, so these are not discussed in this report.

The indicator data used in this report came from many sources, including public research organisations and central and local government. Further supporting information was provided using a ‘body of evidence’ approach, which draws on and integrates findings from multiple sources to produce conclusions that are more robust and reliable than those based on a single study. This body of evidence includes peer-reviewed, published literature, grey literature such as government reports, and mātauranga Māori (Māori knowledge) and observational tools used to identify changes in the ecosystem.

All data used in this report, including references to scientific literature, were corroborated, and checked for consistency with the original source. The report was reviewed by a panel of independent scientists. The indicators related to the marine environment and the date they were last updated are available on the Stats NZ indicators web pages. Reports released under the Environmental Reporting Act 2015 are produced independently of government ministers.

Report structure

This report’s focus is on how climate change drives change in our marine and coastal environments, and how these changes in turn affect people. It begins with the changes to global climate and ocean systems, then explains what this means for New Zealand’s environment, and ends with impacts for all of us.

Section 1 explores the role and impacts of the ocean in relation to our rapidly changing climate. It outlines the large-scale drivers of change, including rising sea temperatures, ocean acidification, decreasing oxygen levels and changes in ocean currents. These global processes set the stage for the changes we observe closer to home.

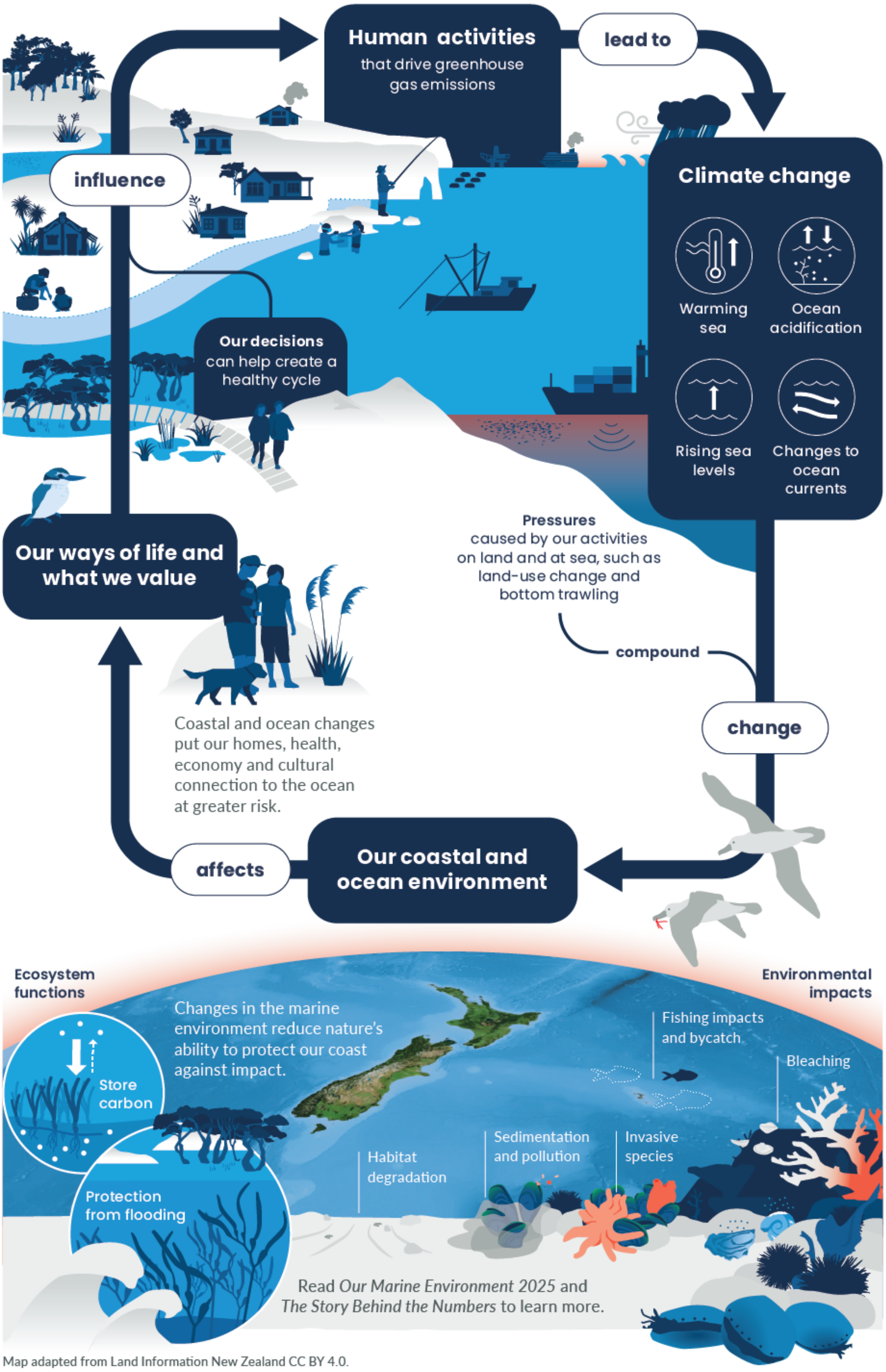
Section 2 moves the focus to New Zealand’s coasts. It examines how global ocean changes manifest in our marine and coastal environments – including through shifts in sea level, storm patterns, ocean chemistry and marine ecosystems. This section highlights the physical and ecological consequences of a changing ocean for our coastal waters, habitats and species.

Section 3 turns to people, exploring how changes in our marine and coastal environments affect communities, economies and cultural connections. This includes effects on coastal infrastructure, fisheries and customary practices, and on the wellbeing of people who live near or depend on the marine environment.

Section 4 outlines knowledge gaps and areas where more data, research and monitoring are needed to better understand the links between climate change and changes to the marine environment.

Our marine environment

Aotearoa New Zealand is an island country. We affect the ocean, and changes to the ocean affect all of us.



Map adapted from Land Information New Zealand CC BY 4.0.

1. Effects of climate change on the ocean around New Zealand

Section themes

- Climate change is driving significant changes in our oceans.
- Ocean temperatures are increasing, and marine heatwaves are becoming more frequent, intense and longer-lasting.
- Sea-level rise is accelerating at many locations.
- Natural cycles like the El Niño Southern Oscillation can interact with climate change to amplify warming and extreme events.
- These changes put stress on marine ecosystems and increase the risk of coastal flooding and erosion.

1. Effects of climate change on the ocean around New Zealand

Introduction

The ocean surrounding Aotearoa New Zealand is deeply connected to the global climate system. As the climate warms, sea-surface temperatures are rising, storms and marine heatwaves are intensifying, and ocean acidification is increasing. These changes are already reshaping the marine environment around New Zealand – and they are happening faster here than in many other parts of the world.

Natural climate oscillations such as the El Niño Southern Oscillation and the Southern Annular Mode continue to influence ocean conditions, and their interactions with climate trends are amplifying impacts. Together, these forces are altering ocean circulation, productivity and species distributions, with cascading effects on ecosystems and fisheries.

This section explores the physical changes occurring in our oceans — warming, acidification, shifting currents and rising sea levels — and what they mean for marine ecosystems.

How climate change is affecting different parts of the ocean

New Zealand's oceans are warming faster than the global average

- Human activities have driven rapid increases in atmospheric greenhouse gas concentrations, causing Earth to warm. Globally, oceans have captured 90 percent of the excess heat from greenhouse gas emissions, increasing ocean temperatures (Venegas et al, 2023).
- Average sea-surface temperatures have risen across New Zealand's four oceanic regions between 1982 and 2023. Their warmest year was recorded in either 2022 or 2023, depending on the region (see indicator: Sea-surface temperature: Data to 2023).
- Between 1982 and 2023, sea-surface temperature in the country's four oceanic regions increased, on average, 0.16 to 0.26 degrees Celsius per decade (see indicator: Sea-surface temperature: Data to 2023).
- The rate of warming in ocean waters around New Zealand is increasing and is now 34 percent faster than the global average warming rate (Pinkerton et al, 2024). New Zealand's oceans are warming faster than the global average due to changes in atmospheric circulation and corresponding changes in ocean currents (Trenberth et al, 2025).
- Projections indicate sea-surface temperatures in New Zealand's oceanic regions will warm 1.0 to 1.5 degrees Celsius by 2050 and 1.0 to 3.0 degrees Celsius by 2100 (relative to 1982–2022), with stronger warming in subtropical waters than subantarctic waters (Behrens et al, 2025).

Temperatures of coastal waters are increasing

- Coastal waters around New Zealand are warming faster than the global average, with rates of increase in the country's nine coastal regions ranging from 0.19 to 0.34 degrees Celsius per decade (Pinkerton et al, 2024; see indicator: Sea-surface temperature: Data to 2023 and figure 1). Remote sensing shows this warming is most pronounced around the South Island and occurs year-round in most regions, highlighting New Zealand's heightened sensitivity to ocean change (Pinkerton et al, 2024).
- Studies of long-term records of water temperatures in Pelorus Sound (Marlborough Sounds) and at Leigh (Northland) have shown annual warming trends, but the patterns of seasonal timing of warming varies between these regions. In Pelorus Sound, the warming is less rapid in winter and spring, and Leigh showed warming in autumn and winter, but not in summer and spring (Broekhuizen et al, 2021; Shears et al, 2024).
- Warming ocean trends affect the structure and functioning of marine ecosystems (see section 2).

Figure 1: Trends in coastal sea-surface temperature, 1982–2023

Data source: Stats NZ

Ocean stratification is increasing, and ocean oxygen content is reducing

- Ocean stratification is the separation of ocean waters into horizontal layers. As the upper ocean warms, ocean waters separate into more distinct layers, which reduces vertical mixing of heat and nutrients. This also reduces the ability of the ocean to take up carbon dioxide (Holt et al, 2022; Jo et al, 2022; Riebesell et al, 2009; see *Our marine environment 2019*).
- Ocean stratification reduces the amount of oxygen absorbed by the ocean from the atmosphere and so contributes to deoxygenation, which is increasingly recognised as a major stressor for marine ecosystems (Hollitzer et al, 2024). This will affect ecosystems, biodiversity and fisheries, although individual responses to these changes will vary widely (Breitburg et al, 2018). For example, sponges have made adaptive changes to survive in reduced- or low-oxygen water (Micaroni et al, 2022), but the size of some fish populations that are sensitive to these changes may decrease (Gong et al, 2021).

Ocean acidification is increasing globally and around New Zealand

- Oceans have captured about 26 percent of total human carbon emissions since industrialisation (Friedlingstein et al, 2025). This is making the ocean more acidic (Law et al, 2018). Surface ocean acidity is estimated to have increased almost 30 percent from 1750 to 2000 (Jiang et al, 2023). Ocean acidity increased 8.6 percent in subantarctic surface waters off the coast of Otago between 1998 and 2020 (see indicator: Ocean acidification).

The first shift in the large-scale ocean circulation and state around New Zealand has been observed

- The Subtropical Front is the boundary between cold subantarctic water from the south and warmer subtropical water from the north. It is an important area of biological and economic productivity (NIWA, nd-b).
- The region south of the Chatham Islands has shown strong, full-depth ocean warming since 2006, with surface warming around five times the global rate. The warming is a result of the Subtropical Frontal Zone unexpectedly shifting 120 kilometres west, with additional southward displacement further east (Sutton et al, 2024). These shifts have been driven by reduced Southern Ocean currents, likely arising from changes in the ocean heat content gradient between mid and high latitudes, and from changes in wind.
- This is the first time a shift in large-scale ocean circulation and state around New Zealand has been observed. Global climate models project these same changes will continue, suggesting that this warming will persist and strengthen through to the modelling horizon of 2100 (Fox-Kemper et al, 2023). Changes to other global ocean circulation systems, such as the Atlantic Meridional Overturning Circulation, could also accelerate warming trends in the Southern Hemisphere, potentially affecting New Zealand and the surrounding region (Boers, 2021).

Sea levels are rising at an accelerating rate in many locations

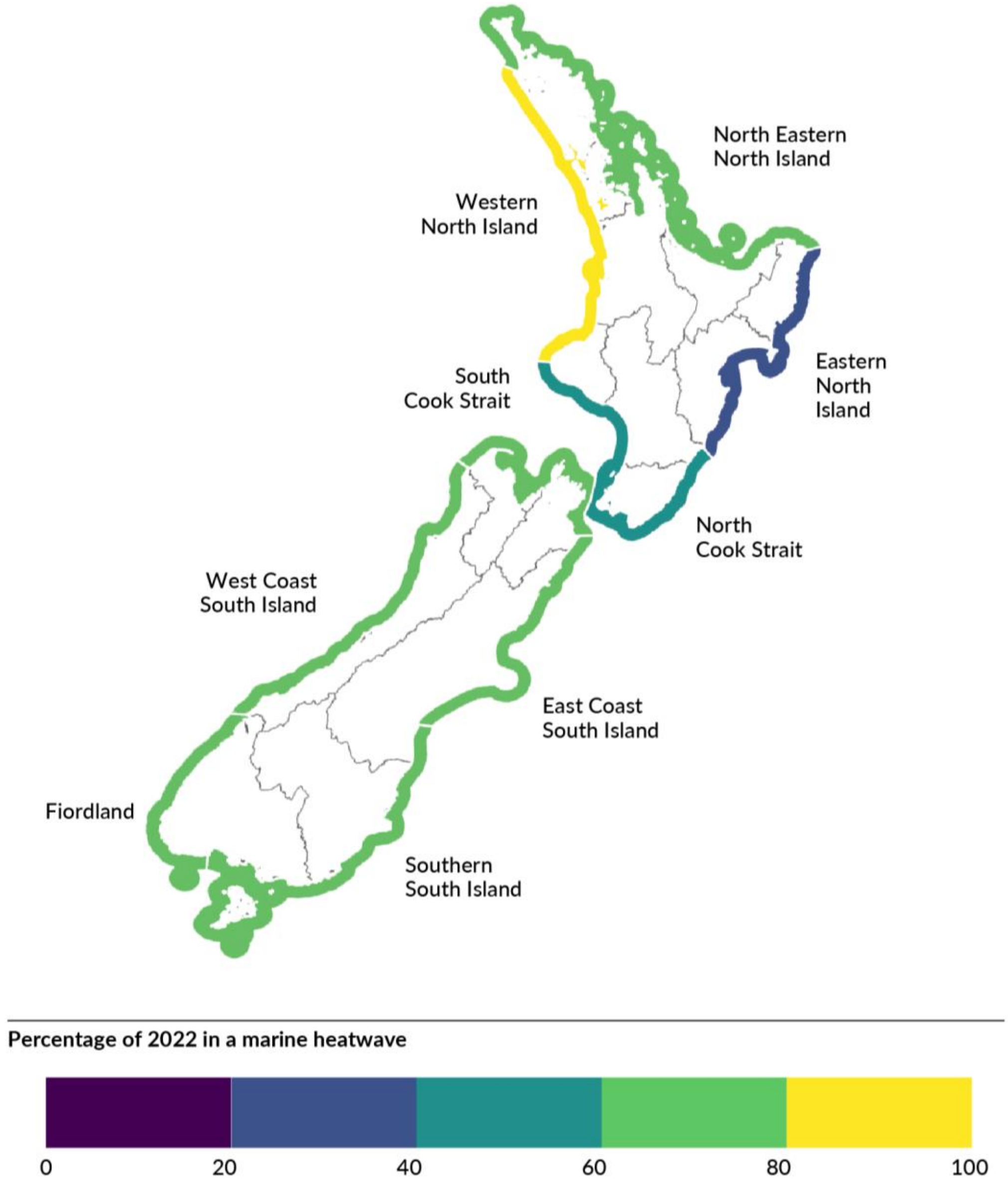
- Increasing ocean temperatures cause sea water to expand (Venegas et al, 2023). Combined with melting glaciers and ice sheets, this contributes to absolute sea-level rise (Lindsey & Dahlman, 2025; Venegas et al, 2023).
- The rate of annual mean coastal sea-level rise (relative to land) is accelerating. At four longer-term monitoring sites around New Zealand, annual mean coastal sea levels rose faster (relative to land) between 1961 and 2020 than during the period between 1901 and 1960. These sites are located at Auckland, Wellington, Lyttelton and Dunedin. Two additional monitoring sites with shorter monitoring terms (since 1961) are located at Moturiki (Mount Maunganui) and New Plymouth. At these sites, annual mean coastal sea levels are also rising (see indicator: Coastal sea-level rise).
- Although land uplift is slowing relative sea-level rise in some parts of New Zealand, land subsidence is accelerating it in others. Even without land movement, sea levels are expected to rise at least 20 to 30 centimetres by 2050, compared with 2005 levels (MfE, 2024). For parts of the country, a 30-centimetre rise is a threshold for coastal flooding – above this level, a coastal storm that previously had a 1 percent chance of occurring each year becomes an annual event (NZ SeaRise, nd).

The warming ocean results in longer, more intense and more frequent marine heatwaves

Marine heatwaves have become more frequent, more intense and longer-lasting

- Marine heatwaves are when the temperature of ocean water is abnormally high (in relation to a temperature threshold) for at least five consecutive days. They can have significant impacts on marine ecosystems and the services these ecosystems provide (Hobday et al, 2016; see indicator: Sea surface temperature: Data to 2023).
- Globally, marine heatwaves have become more frequent, more intense and longer-lasting (Montie et al, 2024; Sun et al, 2023).
- In 2022, New Zealand experienced a record number of marine heatwave days, including the two longest and most intense marine heatwaves on record (Salinger et al, 2023; Shears et al, 2024).
- In 2022, the Western North Island region spent an average of 88.5 percent of the year in marine heatwaves, which was the longest duration of the nine coastal regions (see figure 2). The Tasman Sea region spent an average of 61.1 percent of the year in marine heatwaves, which was the longest duration of the four oceanic regions (see indicator: Sea-surface temperature: Data to 2023).

Figure 2: Percentage of year spent in a marine heatwave, by coastal region, 2022



Data source: Stats NZ

Projections show marine heatwaves will continue to grow in frequency, intensity and duration

- The trends in increasing frequency, intensity and duration of heatwaves are expected to continue, but to varying degrees around New Zealand (Behrens et al, 2022, 2025; Bodeker et al, 2022; Montie et al, 2024; Sun et al, 2023).
- Marine heatwave intensities are projected to increase more strongly around the North Island, but the number of annual marine heatwave days will increase more around the South Island (ie, in Southland, South-East (Rise) and the Subantarctic) (Behrens et al, 2025). Under a high-emissions pathway (SSP3-7.0), marine heatwave conditions could become permanent year-round by the end of the century, relative to present-day conditions (Behrens et al, 2022).
- The New Zealand Earth System Model projects that marine heatwave intensity will increase more in subtropical waters than in subantarctic waters (Behrens et al, 2022).

- The largest changes in annual marine heatwave days are projected south of Australia and in the Tasman Sea within the Subtropical Frontal Zone, off the south-west coast of the South Island (Behrens et al, 2022).

Natural climate oscillations interact with climate change to affect ocean conditions

Climate oscillations influence natural climate variability

- Natural climate oscillations (cyclical variations in atmospheric and ocean conditions) influence weather and climate in New Zealand. These include the El Niño Southern Oscillation (ENSO), Interdecadal Pacific Oscillation and Southern Annular Mode (SAM) (see indicators: El Niño Southern Oscillation, Interdecadal Pacific Oscillation and Southern Annular Mode).
- ENSO affects our weather through changes in air pressure, sea temperature and wind direction. ENSO has three phases: neutral, El Niño and La Niña. It influences rainfall, temperature and wind patterns in New Zealand and globally. During La Niña, New Zealand may experience more north-easterly winds and wetter conditions in the north and east, and warmer-than-average air and sea temperatures. During an El Niño phase in summer, westerly winds increase, with more rain in the west and dryness in the east. In winter, El Niño can lead to more frequent, cooler southerly winds (Ummenhofer et al, 2009; see indicator: El Niño Southern Oscillation). However, understanding of how ENSO modulates the climate remains limited.
- The most recent El Niño phase was from July 2015 to April 2016. This was one of the two strongest El Niño phases between 1990 and 2022 – the other was during the period 1997 to 1998. The most recent La Niña phase was from April 2022 to December 2022 (see indicator: El Niño Southern Oscillation).

Climate change is affecting these oscillations, which in turn affect ocean conditions and extreme weather events

- Knowledge of the compounding impacts of climate oscillations and climate change is growing. Recent developments include new information on the occurrence of marine heatwaves, new methods for determining the significance of extreme weather conditions, growing knowledge of the role of climate change in amplifying large-scale circulation cycles such as ENSO, and new data on coastal erosion (Aldridge & Bell, 2025; Minobe et al, 2025; Oginni et al, 2025; Salinger et al, 2023, 2024). There is also new information on how climate oscillations influence the health and functioning of coastal ecosystems (Lam-Gordillo et al, 2023).
- Climate models indicate that ENSO variations have increased up to 10 percent since 1960, partly due to rising greenhouse gas concentrations in the atmosphere. One result is that El Niño and La Niña events could become stronger and more frequent (Cai et al, 2023).
- In its 'positive' phase, the SAM is associated with higher-than-normal air pressure in the New Zealand region, which tends to bring relatively light winds and tranquil weather conditions (NIWA, nd-a). Over recent decades, the SAM has shown a positive trend (Abram et al, 2014), creating conditions that are more favourable to marine heatwaves (Salinger et al, 2024).

- Evidence indicates that the positive trend in the SAM is partly an indirect response to stratospheric ozone depletion and climate change (Goyal et al, 2021; King et al, 2023; Morgenstern, 2021).
- If ENSO and SAM phases align (La Niña combined with positive SAM), this can have a compounding effect on ocean temperatures, and extreme heat conditions are a potential consequence (Salinger et al, 2024).

Changes in primary productivity may affect ecosystems

Most marine food webs depend on energy from primary producers

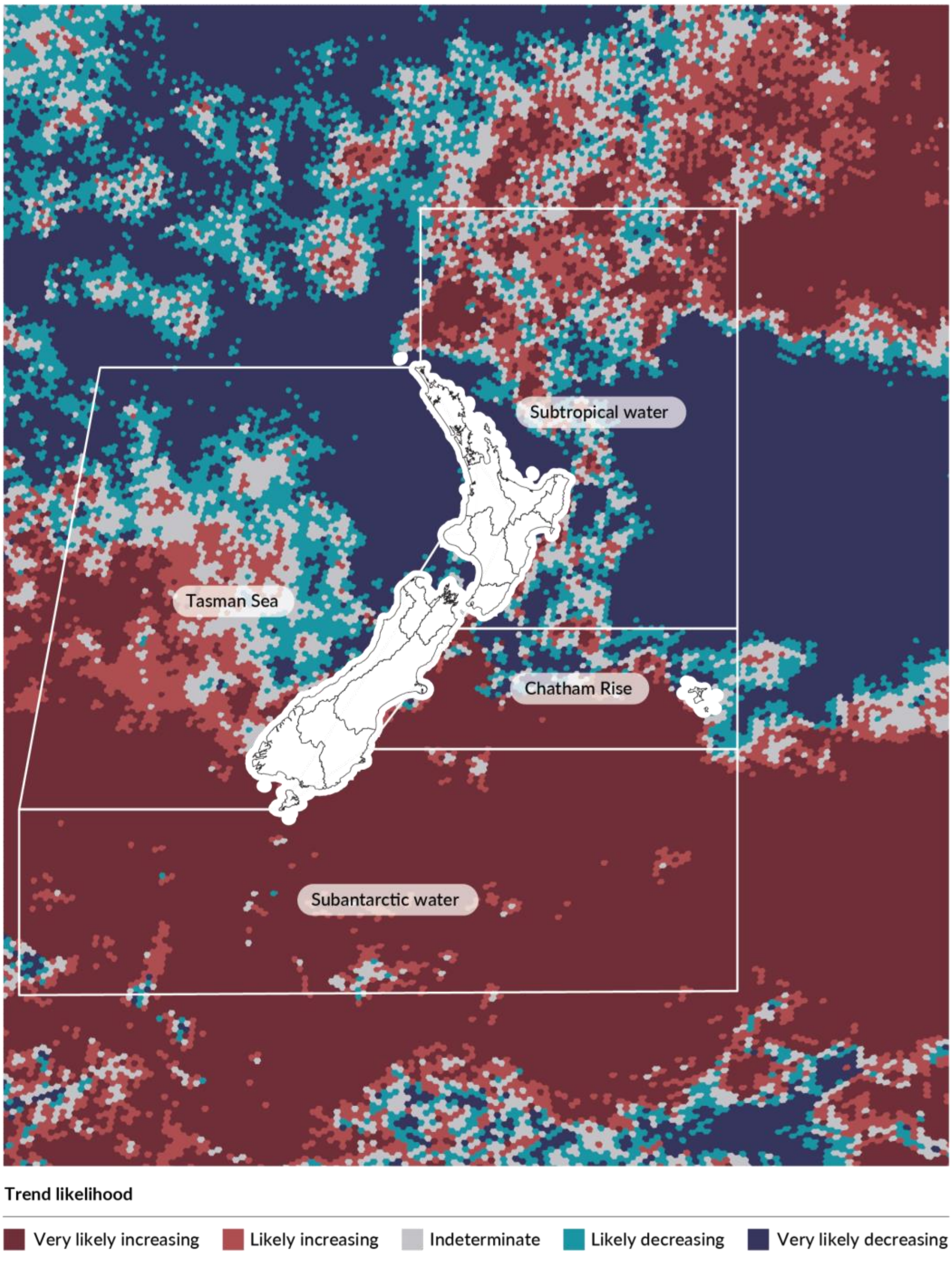
- Marine primary productivity describes the growth of primary producers in coastal and ocean waters, such as phytoplankton, seaweeds, seagrasses and periphyton. These organisms provide the energy that supports most marine food webs. Phytoplankton productivity is especially important, because it supports healthy marine ecosystems and sustains commercial fisheries for shellfish and finfish. In addition, phytoplankton play a key role in removing carbon dioxide from the atmosphere (MPI, 2021a; Pinkerton et al, 2023).
- Marine primary productivity is affected by nutrients, water temperature and the availability of light (see indicator: Marine primary productivity: Data to 2023). Large-scale changes to climate and ocean conditions can lead to changes in phytoplankton growth and primary productivity.
- In estuaries and coastal waters, unusually high primary productivity can indicate ecological stress. Excess nutrients from land run-off can result in harmful algal blooms, which reduce oxygen levels, disrupt food webs and pose risks to marine life and human health (Gall & Pinkerton, 2024; Pinkerton et al, 2023; Roberts & Hendriks, 2022).

Primary productivity is increasing in some areas and decreasing in others

- It is important to monitor changes in primary productivity to understand when conditions are generally beneficial for supporting marine ecosystems, but also when they are potentially harmful – such as when driven by excess nutrients (Nixon & Buckley, 2002; see indicator: Marine primary productivity: Data to 2023).
- Primary productivity is monitored by using satellites to measure chlorophyll-*a* (chl-*a*), which is an indicator of the amount of phytoplankton in ocean water. Greater chl-*a* concentrations indicate more phytoplankton and more primary production (see indicator: Marine primary productivity: Data to 2023).
- Most coastal regions saw very likely increasing primary productivity trends between 1998 and 2022, with average rates ranging from an increase of 5 to 13 percent a decade. Between 1998 and 2022, the highest average surface chl-*a* concentrations in coastal waters were around the West Coast and East Coast regions of the South Island. The North Eastern North Island coastal region had the lowest average chl-*a* concentration, and was the only coastal region to see a very likely decreasing trend between 1998 and 2022 (see indicator: Marine primary productivity: Data to 2023 and *Our environment 2025: Technical annex*).

- In ocean waters, mixed trends have been observed, with both increases and decreases in primary productivity (see indicator: Marine primary productivity: Data to 2023 and figure 3). Surface ocean chl-*a* concentrations across New Zealand's exclusive economic zone show a slight decreasing trend in the Subtropical ocean region, despite patterns of both increasing and decreasing trends in the northern Tasman Sea and southern Subtropical ocean regions (see indicator: Marine primary productivity: Data to 2023). At the exclusive economic zone scale, surface ocean chl-*a* concentrations in the Subantarctic region have generally been increasing over the period from 1997 to 2023, although a decline has occurred in the most recent years of the time series (Pinkerton et al, 2024).
- Primary productivity is expected to decrease around the North Island and the West Coast of the South Island, but it may increase in the Subantarctic region to the south of New Zealand, as habitable ranges shift in response to increasing sea temperatures (Law et al, 2018; Roberts & Hendriks, 2022). However, an unexpected and rapid decline in chl-*a* in all New Zealand ocean regions has been observed since mid-2019, which has continued to late 2023. This could potentially have significant ecological implications, but more analyses are needed to fully understand the risk (Pinkerton et al, 2024).
- Suspended solids can carry nutrients and block light in coastal and ocean environments. Total suspended solids showed more complex spatial and temporal patterns, but the trends observed off northern Coromandel Peninsula, the east coast of the North Island, Marlborough Sounds, Cloudy Bay (Cook Strait), the eastern South Island and Fiordland were virtually certain to be increasing. In contrast, virtually certain decreasing trends were observed around Kaipara Harbour over the period 2002 to 2023 (Pinkerton et al, 2023).
- Changes have been observed in the species that make up phytoplankton communities in the Firth of Thames, including increases in the abundance of toxic algae (*Pseudo-nitzschia*). These changes reflect nutrient enrichment over decades, driven by dissolved inorganic and organic nitrogen inputs from land run-off (Safi et al, 2022).

Figure 3: **Trends in oceanic marine primary productivity, 1998–2022**



Data source: Stats NZ

Note: See *Our environment 2025: Technical annex* for interpretation of Stats NZ trend likelihood.

2. Our coasts and estuaries are affected by a changing ocean

Section themes

- Our marine environment faces multiple pressures from climate change and human activities.
- Rising seas, storm surges and erosion threaten coastal ecosystems.
- Land-based impacts such as excess sedimentation, nutrient run-off and pollution degrade marine environments and the species that live there.
- Threats to our indigenous species include marine heatwaves, disease, bycatch and the spread of invasive species.
- Coastal habitats provide benefits like carbon storage and coastline protection, but many have been degraded.

2. Our coasts and estuaries are affected by a changing ocean

Introduction

Indigenous coastal, estuarine and marine species and ecosystems are valuable natural assets. They provide vital protection from coastal hazards, store carbon, support biodiversity, and underpin cultural and economic wellbeing. Yet these environments are increasingly at risk from the compounding impacts of climate change and human development. Critically, the effects of a changing climate and human activities on the ocean lead to changes in our coasts and estuaries as well.

This section examines how climate change compounds other pressures on coastal and marine species, habitats and ecosystems. Sea-level rise intensifies erosion and flooding risks in some areas and contributes to coastal squeeze, where natural habitats are trapped between rising seas and built infrastructure. The increasing frequency and severity of extreme weather events – including rain, winds and waves – add to these pressures, damaging ecosystems and infrastructure. Acidification is also more intense in coastal waters, due to increased carbon dioxide levels. Other pressures faced by coastal habitats and ecosystems include marine heatwaves, the increased mobility of invasive species, and marine diseases. All of these pressures are having devastating impacts on indigenous populations, and those impacts are predicted to continue.

These changes threaten the ability of coastal and estuarine systems to support the lifecycle of many species. They also undermine the ability of these systems to support cultural values and to deliver essential services such as carbon sequestration and natural coastal protection.

Climate change threatens coastal and marine systems

Sea-level rise threatens coastal ecosystems through inundation, flooding and erosion

- Sea-level rise is projected to lead to a cascade of negative impacts on low-lying coastal areas, including inundation, increased coastal erosion, saltwater intrusion into adjacent freshwater, and drainage issues. These effects can damage infrastructure, displace communities and disrupt ecosystems (MfE, 2024).
- Aotearoa New Zealand could begin to lose intertidal flats as early as this decade if rates of relative sea-level rise exceed about 5 millimetres a year in areas with limited sediment supply (Swales et al, 2020). In 14 estuaries, intertidal areas are predicted to decrease 27 to 94 percent by the end of the century in response to projected sea-level rise of 0.2 to 1.4 metres, if landward movement of the intertidal zones is restricted (eg, due to rapid rises in sea level, or the presence of flood and coastal defences) (Mangan et al, 2020).

- In the Hawke's Bay region in 2024, saltmarsh and seagrass ecosystems covered a total area of 1,476 hectares, of which 87 percent was saltmarsh habitat. Sea-level rise is estimated to reduce saltmarsh extent by 11 to 12 percent by 2050, and by 25 to 31 percent by 2100, depending on the sea-level rise scenario (Bulmer et al, 2024a).
- Predicted changes in tidal inundation and increased water depth due to sea-level rise will reduce light availability. This will negatively impact species such as seagrass (Capistrant-Fossa & Dunton, 2024; Lundquist et al, 2011), which plays an important role in supporting many fish species (Berthelsen, 2024).
- Rising sea levels increase the risk of erosion from waves, storm surges and high tides. This risk can be exacerbated by extreme weather events. For example, in February 2023, Cyclone Gabrielle caused 5 to 10 metres of erosion at certain beaches across parts of Northland, Auckland, Coromandel and Bay of Plenty (Coastal Change, nd).
- Coastal erosion – the wearing back of the land – is an important hazard for coastal communities and ecosystems (MfE, 2024). Shoreline mapping of open coast beaches and soft cliffs since about 1940 suggests that 40 percent of the coastline mapped is eroding, 42 percent is accreting (advancing seaward) and 18 percent is either stable or unresolved (Coastal Change, nd; Tuck et al, 2024). For example, Kaipara Harbour's North Head is one of the top hotspots of coastal erosion and accretion around the country, and it is eroding by around 6.4 metres a year (Coastal Change, nd). Coastal erosion also threatens people's property (see section 3).
- Sea-level rise and storm surges threaten coastal ecosystems and freshwater species by moving saltwater farther into coastal freshwater environments, altering their salinity (Lawrence et al, 2022; Neubauer et al, 2013; Schallenberg et al, 2003).
- Rising sea levels have led to a loss of nesting sites for various shorebirds and may put more species at risk (Keegan et al, 2022). For example, New Zealand's rarest indigenous breeding bird, the tara iti/fairy tern (*Sternula nereis davisae*), has an adult population of only 40 birds. This critically endangered species nests on beaches and is facing increasing threats from climate change impacts such as sea-level rise and intensifying storm surges (Brumby et al, 2025).

Changes in rainfall, storms, waves and winds threaten coastal health

- Climate change is leading to more frequent heavy rainfall events in some areas. This may cause landslides and soil erosion and intensify land degradation, especially in areas with exposed soils or non-native vegetation (Neverman et al, 2023). The resulting sediment run-off from degraded catchments flows into estuaries and coastal zones, reducing water quality and smothering sensitive habitats (see *Our environment 2025*).
- Storm surges and powerful wave forces can physically damage coastal habitats. For example, mussel beds can be dislodged or broken apart, especially when already thinned or loosely packed, with the result that mussels die if they cannot reattach (Hunt & Scheibling, 2001).
- Changes in wind and wave patterns are predicted to alter sediment movement and coastal upwelling of cooler nutrient-rich ocean waters in some places. These are important for coastal productivity, including fisheries (Bell et al, 2001; MPI, 2021a).

- Cyclone Gabrielle in 2023 highlighted the impacts that severe weather events can have on the marine environment. Excess sediment and resuspension of settled sediment during the event damaged seafloor habitats and ecosystems (Leduc et al, 2024). For example, pre- and post-cyclone imagery data show that populations of kelp, other macroalgae (seaweed) and sponges in the Wairoa Hard seabed area of Hawke's Bay were almost completely lost following Cyclone Gabrielle. It is highly likely that the loss was due to sediment impacts from the cyclone. Seafloor animals in Hawke's Bay and Gisborne also showed reduced abundance and diversity post-cyclone. Modelling suggests that recovery time may vary across types of organisms, and continued seabed trawling may slow down recovery time (Leduc et al, 2024).
- Storm-driven run-off can introduce pollutants, nutrients and organic matter into coastal waters. This can lead to harmful algal blooms and oxygen depletion, which threaten marine life and human health. These effects compound existing pressures from urbanisation, agriculture and infrastructure development (see *Our environment 2025*, section 1).

Human activities put pressure on marine and coastal environments

Land-based activities can degrade the marine environment via sediment and nutrient run-off, and litter

- Run-off and pollutants resulting from human activities on land enter streams and rivers, which then flow into the ocean. Impacts on coastal environments can spread out for kilometres beyond the initial river outflow areas, driven by tides, wind and currents (Jhugroo et al, 2025; Macdonald et al, 2023).
- Human activities on land – such as agriculture, horticulture, forest harvesting and urban expansion – can increase land erosion rates and the amount of fine sediment that reaches marine systems. Excess sedimentation in estuaries and coastal areas can: alter habitats; reduce foraging opportunities for fish like snapper; decrease light; smother sensitive species; and clog the gills of filter feeders such as cockles, pipi and scallops (Booth, 2020; Lowe et al, 2015; Morrison et al, 2009; PMCSA, 2021; Thrush et al, 2021).
- More frequent and severe extreme weather events due to climate change can exacerbate soil loss, increasing the amount of sediment flowing into coastal areas. For example, significantly higher levels of sediment erosion and deposition were detected in Hawke's Bay and Gisborne coastal marine areas immediately following Cyclone Gabrielle in 2023 (Leduc et al, 2024).
- Between 2006 and 2020, more coastal and estuarine sites had improving than worsening trends for suspended solids (66 of 84 sites) and for turbidity – a measure of how cloudy the water is – (54 of 87 sites). Monitoring sites were not distributed evenly around the coastline, and were often clustered around urban centres (see indicator: Coastal and estuarine water quality, *Our environment 2025,* section 4 and *Our environment 2025: Technical annex*).
- Land activities such as dairy farming, horticulture and urbanisation can also lead to elevated levels of nutrients such as nitrogen and phosphorus in estuaries and coastal areas. This can result in nutrient enrichment, algal blooms and depleted oxygen, causing harm to plants and animals (Dudley et al, 2020; Plew et al, 2020; Salmond & Wing, 2022). Between 2006 and 2020, more coastal and estuarine sites had improving than worsening trends for nitrogen and phosphorus measures (see indicator: Coastal and estuarine water quality).

- Pathogens such as faecal bacteria can enter estuaries and coastal waters from sources including animal excrement and wastewater discharges, and these can harm ecosystems and people (LAWA, 2023; see *Our environment 2025*, section 3). Between 2006 and 2020, faecal coliform levels were improving at 50 percent of coastal and estuarine monitoring sites (25 of 50 sites) and worsening at 26 percent (13 of 50 sites) (see indicator: Coastal and estuarine water quality).
- Sea lions (*Phocarctos hookeri*) and some dolphins are at risk when rainwater and run-off contaminated by cat faeces transport the parasite *Toxoplasma gondii* to the marine environment. High rates of infection and subsequent mortality from toxoplasmosis in Hector's (*Cephalorhynchus hectori*) and Māui (*Cephalorhynchus hectori maui*) dolphins are the suspected cause of approximately 25 percent of deaths between 2007 and 2018 (Roberts et al, 2019; Roe et al, 2013, 2017). Increased rainfall under a changing climate will likely elevate this risk.
- Litter (including plastics and microplastics) puts marine habitats at risk when it enters the marine environment. In 2023, 67 percent of items counted on beaches in litter surveys were plastic (Litter Intelligence, nd). Seabirds and other marine species are at risk from eating or getting tangled in plastics, which can result in injury or death (Buxton et al, 2013; Clark et al, 2023; PMCSA, 2019). For more information on plastics accumulating throughout the marine environment and the effects on marine species, see *Our environment 2025*, section 4.
- For more information on how land-based activities can affect coastal ecosystems, see *Our environment 2025*, sections 2 and 4, and *Our environment 2025: Technical annex*.

Commercial and recreational activities affect the marine environment

- Commercial fishing methods in New Zealand include trawling, dredging, potting, longlining and set netting. Trawling is the most common (MPI, nd-d; see *Our environment 2025* and *Our marine environment 2022*).
- Most scientifically evaluated fish stocks are meeting or exceeding specified performance measures, but some fish stocks continue to be overfished (MPI, nd-e).
- In 2024, 88 percent of assessed fish stocks in the New Zealand Quota Management System (128 of 146 stocks) were fished within specified limits. Among the 128 stocks where fishing complied with the limits, 105 were fished at or above their management goals (MPI, nd-e).
- However, 12 percent of assessed stocks (18 of 146) were overfished or depleted in 2024, such as some stocks of black cardinalfish, oysters, orange roughy, scallops and tarakihi. These overfished stocks are being managed so they will rebuild back towards target levels. Six stocks had collapsed (MPI, nd-e).
- The total estimated catch from recreational fishing in 2022/23 was 3.7 million fish and 1.6 million shellfish. Snapper, kahawai, blue cod and red gurnard together made up 80 percent of all fish harvested by recreational fishers (MPI, nd-b).
- Recreational fishing declined between 2017/18 and 2022/23 in terms of the number of fish harvested, particularly in the north of New Zealand. Contributing factors include extreme weather events in 2023, prolonged La Niña conditions and changes in fishing habits (MPI, nd-b).

Bycatch continues to contribute to population decline and extinction risk of some protected species

- 'Bycatch' refers to non-target species, including protected species, unintentionally captured during fishing (MPI, 2021b). Removing or killing important species through bycatch threatens biodiversity and puts pressure on marine ecosystems (Komoroske & Lewison, 2015).
- Since 2019/20, reported Hector's dolphin deaths due to commercial bycatch have ranged from 0 to 5 each year. After the roll-out of cameras in 2023/24, 15 deaths were reported for that year. All 15 of those reported deaths occurred on the east coast of the South Island, where an estimated 9,700 (65 percent) of the total estimated 14,849 Hector's dolphins reside (DOC, nd; FNZ, 2025; Roberts et al, 2019). Although the 2023/24 figure was above historical reporting levels, it was broadly in line with estimated captures predicted in fisheries risk assessment modelling. The increase is considered to reflect improved reporting of Hector's dolphin captures following the use of improved technology (FNZ, 2025).
- Other marine mammals, reptiles, large numbers of seabirds and some protected corals are also caught as commercial bycatch. In 2024/25, 477 fur seals (*Arctocephalus forsteri*) and sea lions and 2,225 seabirds were reported caught in trawling, longline and set-net fisheries (MPI, nd-f). In the 2022/23 fishing year, 6,704 kilograms of protected coral were reported as bycatch, compared with 2,073 kilograms reported in 2021/22 (McGovern, 2024; McGovern & Hewetson, 2025).
- Seabirds can be caught in fishing-net mesh or experience fatal interactions with trawl warps (cables). A significant number of seabirds killed by warp strikes may be unobserved, meaning that it is necessary to use cryptic mortality multipliers (a correction factor for estimated deaths based on observations) to more accurately estimate total deaths (Meyer, 2023). Large bycatch events, especially during the breeding season, can lead to chicks starving when foraging adults are caught.
- Between 2 and 34 captures of protected sea turtles during commercial fishing were reported each fishing year from 2007/08 until 2020/21, when 58 captures were reported (Dunn et al, 2022). In the first three-quarters of the 2024/25 fishing year, 53 sea turtle captures were reported (including 43 leatherback turtles (*Dermochelys coriacea*)), and all of these sea turtles were released alive (MPI, nd-f). The increase in captures in New Zealand waters may be occurring because warming sea-surface temperatures are bringing sea turtles further south.

The area trawled each year has been declining, but trawling still affects the seafloor and the animals that live there

- Commercial fish trawling and dredging have lasting impacts on the seabed and its habitats. Effects include altering seabed structure, damaging habitats and reducing marine populations (Clark et al, 2019, 2022a; MPI, nd-d).
- Between 1990 and 2024, about 11 percent of New Zealand's exclusive economic zone and territorial sea was trawled. The area trawled each year has been declining over time. In 2023/24, 68,048 square kilometres were trawled, which is a decrease of 7.5 percent from 73,567 square kilometres in 2022/23 (MPI, nd-d). Recent years have seen a reduction in bottom-contact trawling by both deepwater and inshore fisheries (MacGibbon et al, 2024).

- Underwater seamounts, knolls and hills can be highly productive and support rich biodiversity, including high densities of protected habitat-forming corals. They are also targeted by some deepwater fisheries (Clark et al, 2019, 2022b). Eleven percent of seamounts, knolls and hills in New Zealand's exclusive economic zone and territorial sea were trawled at least once between 1989 and 2019 (Clark et al, 2022b).
- Recovery of long-lived, slow-growing animals impacted by trawling, such as corals, is slow. For example, it took about two decades for the first signs of coral recovery to appear after trawling ceased on the Graveyard Knolls of the Chatham Rise (Clark et al, 2022a).

Aquaculture can have both positive and negative effects on marine ecosystems

- The growing aquaculture industry, which includes species like green-lipped mussels, Chinook salmon and Pacific oysters, can have both positive and negative impacts on marine ecosystems (Howarth & Major, 2023; MPI, 2013).
- Mussel farming, for example, can support seafloor communities and some wild fish. However, it can lead to local enrichment of the seabed and alter the composition of sediments (Howarth & Major, 2023; Underwood et al, 2023). Farm infrastructure can also disrupt currents, damage the seabed, shade the seafloor and put wildlife at risk of entanglement (Howarth & Major, 2023; MPI, 2013).

Our marine species are facing multiple threats

Many indigenous marine species are threatened or at risk

- The pressures from land-based and ocean-based activities outlined above combine to impact indigenous marine species. These pressures are often compounded by climate change, which directly impacts indigenous species through its effects on the temperature, acidity and circulation of global oceans.
- In 2021, 91 percent (82 of 90) of indigenous seabird species were threatened with extinction or at risk of becoming threatened, including 16 species identified as taonga. Estimated population trends show 27 percent of species have decreasing populations, while 18 percent are increasing, 12 percent are stable or increasing, and 43 percent are stable (see indicator: Extinction threat to indigenous species).
- In 2024, 35 percent (14 of 40) of indigenous marine mammal species were threatened with extinction or at risk of becoming threatened. Estimated population trends show 3 percent have increasing populations, 15 percent of species have decreasing populations, 27 percent have stable populations and 55 percent have no estimated trend (Lundquist et al, 2025; see *Our environment 2025: Technical annex*).
- In 2016, 9 percent (10 of 107) of shark, ray and chimaera species were threatened with extinction or at risk of becoming threatened, including one species identified as taonga. Estimated population trends show 2 percent of species have increasing populations, 1 percent have decreasing populations and 54 percent have no estimated trend (see indicator: Extinction threat to indigenous species and *Our environment 2025: Technical annex*). Since the introduction of the 2008 New Zealand threat classification system,

the only marine fishes assessed have been sharks, rays and chimaeras (see *Our marine environment 2022*).

- In 2021, 57 percent (449 of 786) of assessed indigenous marine invertebrate species were threatened with extinction or at risk of becoming threatened. Estimated population trends show 5 percent of assessed species have decreasing populations, 66 percent are stable and one species is increasing[1] (Funnell et al, 2023; see *Our environment 2025: Technical annex*).

Climate change exacerbates risks from invasive species and diseases

- Climate change increases the chance that established pests will spread further, reproduce faster and have more severe adverse impacts on biodiversity (Bollen et al, 2016; Spyksma et al, 2024). Higher water temperatures may also increase the risk of new invasive pests and diseases becoming established (Keegan et al, 2022; Rowley et al, 2024; Wesselmann et al, 2024).
- The occurrence of tropical fishes in temperate regions can be an indicator of climate change impacts. Tropical, subtropical and rare fishes have been documented in New Zealand's waters for more than a century, but the occurrence and diversity of warmer-water species have increased over the past 50 years. This may signal a climate-mediated shift in New Zealand's marine biodiversity (Middleton et al, 2023).
- Marine heatwaves can facilitate the spread of some invasive species. For example, the cover and abundance of sea squirt (*Symplegma brakenhielmi*) was observed to rapidly increase during a marine heatwave (which included growing over other invertebrate and seaweed species), and to decrease (but not disappear) as water temperatures reduced (Spyksma et al, 2024).
- The interactions between parasites and hosts can change due to global and local stressors, including warming waters and ocean acidification associated with climate change and marine pollution. An increase or decrease in disease can have effects at individual, population and community scales (Lane et al, 2022).

More non-native species are in our marine waters and are spreading to new locations

- Non-native marine species are being introduced continually to New Zealand waters, usually carried by ballast water or on the hulls of shipping and recreational vessels (Davis & Hepburn, 2020; see indicator: Marine non-indigenous species: Data to 2022).
- As of 2022, a total of 428 non-native marine species have been found in marine waters around New Zealand; 62 percent (266) of these have established populations here. Between 2010 and 2022, 73 new non-native species were found, 44 of which have become established (see indicator: Marine non-indigenous species: Data to 2022).
- Certain invasive species can change how coastal marine seafloor ecosystems function. The Mediterranean tubeworm (*Sabella spallanzanii*) is one example. Its behaviours of filter feeding and building tubes from sediment grains (eg, sand and shell fragments) may alter the flow of sediments and what they are made up of. This affects how nutrients

[1] Only some known species of marine invertebrates have been assessed for extinction threat status and estimated population trends.

are recycled, as well as how organic matter is distributed through the ecosystem (Tait et al, 2023).

- Non-native marine species can spread rapidly through New Zealand's marine environment. For example, the invasive crab *Charybdis japonica* has increased in distribution and abundance around the North Island since it was first detected in Waitematā Harbour in 2000. It is now found in Tauranga and Ōhiwa harbours, 200 kilometres further south than previously reported. It has also spread northwards as far as the Bay of Islands and to the west coast, in the Hokianga, Kaipara and Manukau harbours (Hilliam & Tuck, 2023).
- Two new *Caulerpa* seaweed species were recorded at Aotea Great Barrier Island in 2021 (see indicator: Marine non-indigenous species: Data to 2022). Globally, many *Caulerpa* species are considered highly invasive, having impacts on fish, invertebrates, native seaweeds and seagrass and affecting nutrient cycling. Preliminary New Zealand data suggested *Caulerpa* may have negatively affected two taonga species: tipa (scallops, *Pecten novaezelandiae*) and kina (sea urchins, *Evechinus chloroticus*) (Middleton, 2023). By August 2024, *Caulerpa* had spread to more than 1,500 hectares of the upper North Island seabed, competing with other species, disrupting local ecosystems and posing risks to recreational, cultural and commercial marine activities (MPI, nd-c).
- Existing and emerging bacteria and associated diseases have been identified as factors in the failure of toheroa (*Paphies ventricosa*) populations to recover from overfishing (Bennion et al, 2022) and skin infections in fish (Rudenko et al, 2025). Oysters in New Zealand are under threat from the parasite *Bonamia ostreae* and the ostreid herpesvirus type 1 (OsHV-1), both of which can cause oyster death. OsHV-1 may be transferred to new locations and species on the hulls of vessels (Fuhrmann et al, 2023).

Climate change is impacting many species and habitats already under pressure from other human activities

- Marine heatwave impacts have been documented (and predicted) for sponges, kelps, reef communities, fish, whales, turtles and penguins in New Zealand (Barlow et al, 2023; Behrens et al, 2025; Bell et al, 2023, 2024; Dunn et al, 2023; Montie & Thomsen 2023; Salinger et al, 2023).
- In years when sea-surface temperatures are warmer than usual, there is reduced survival of adult yellow-eyed penguins (Mattern et al, 2017). Marine heatwaves have contributed to local extinctions in southern bull kelp and may be linked to starvation of little penguins (Salinger et al, 2020). Marine heatwaves have led to severe bleaching and necrosis in sponges and a rapid expansion of invasive sea squirts (Bell et al, 2023, 2024; Salinger et al, 2023; Spyksma et al, 2024). Commercial fisheries and aquaculture have also been affected (see section 3).
- Impacts on one species can ripple across an entire ecosystem (Montie & Thomsen, 2023). For example, some areas where bull kelp (*Durvillaea* spp.) was completely lost during the 2017/18 heatwave were colonised by an invasive, non-native kelp (*Undaria pinnatifida*). This coincided with a decline in green-lipped mussels (kuku/kūtai) – an important mahinga kai (traditional food-gathering) species (Awatere et al, 2021; Thomsen et al, 2019).
- Warming ocean temperatures in northern New Zealand have coincided with areas of increased abundance of long-spined sea urchins – an indigenous species known to have large impacts on kelp forests (Balemi & Shears, 2023). Urchin barrens are areas where kelp forests are stripped due to overgrazing by sea urchins, often in the absence of predators like snapper and rock lobster. This results in reduced biodiversity, altered ecosystem

structure and diminished habitat for fish and invertebrates (Balemi & Shears, 2023; Kerr et al, 2024). There is a risk that urchin barrens could expand with further spread of long-spined sea urchins, in association with ocean warming (Kerr et al, 2024).

- Warmer temperatures and ocean acidification are expected to make it harder for species such as molluscs and corals to grow and maintain their shells and skeletons (Anderson et al, 2022; Böök et al, 2024; Law et al, 2018; McCullough et al, 2024).
- Exposure to changing ocean temperatures and acidification can exacerbate the negative impacts of other stressors that affect the survival of marine species. For example, in response to high temperature and low pH, the mottled brittle star (*Ophionereis fasciata*) – which is only found in New Zealand – demonstrates altered respiration, regeneration and growth, and survival (Márquez-Borrás & Sewell, 2024).

Coastal habitats provide key ecosystem and climate benefits, but are increasingly at risk

Coastal habitats protect against sea-level rise and coastal hazards, but many have been degraded

- Coastal habitats – including beaches, dunes, wetlands (eg, saltmarshes and mangroves), seagrasses, seaweed forests and shellfish reefs – provide a range of functions and services (Geange et al, 2019). These habitats play a role in stabilising sediments, recycling nutrients and supporting biodiversity, and they also provide great cultural, recreational and economic value (Anderson et al, 2019; Bulmer et al, 2024c; see *Our environment 2025*).
- Many of these habitats are found in estuaries, where seawater mixes with freshwater. Estuarine habitats support unique vegetation, invertebrates, fish, shellfish and bird species – enhancing biodiversity and supporting fisheries and ecosystem productivity (Rullens et al, 2022).
- These habitats buffer coastlines from hazards such as flooding and erosion. For example, mangroves have root systems that anchor soil and reduce coastal erosion, buffering coastlines from coastal and river flooding. They also trap sediments and filter pollutants from land-based sources (Shah & Ramesh, 2022).
- Alongside other benefits, native coastal vegetation, wetlands and dunes can help protect coastal ecosystems from excess sedimentation, nutrient pollution and coastal flooding (Allan et al, 2023; Thompson, 2022). Sand-trapping vegetation can also help increase the resilience of coastlines to erosion (Coastal Change, nd).
- Open coast habitats such as kelp forests are capable of dampening wave energy, which can reduce coastal erosion and sedimentation (Steneck et al, 2002).
- Despite their importance, many of these habitats are under pressure from coastal activities and development, altered freshwater inputs and excessive land-based contaminants, including sediments, nutrients and plastics (see *Our environment 2025*).
- Most coastal habitats have experienced loss or damage, with some exceptions such as mangroves (Anderson et al, 2019; Bennion et al, 2024; Morrison et al, 2014a; Suyadi et al, 2019).
- Between the 1950s and 2008, active sand dune extent decreased around 80 percent (see indicator: Active sand dune extent). Remaining active dunes are increasingly threatened

by introduced marram grass. Coupled with livestock grazing, land development, the effects of vehicles and erosion, and coastal squeeze, the expansion of marram grass degrades the integrity and function of dune ecosystems (Dune Restoration Trust of New Zealand, 2014; Thompson, 2022; see *Our land 2024*).

Coastal habitats store carbon, but their loss or degradation can release it back into the atmosphere

- The ocean holds the second-largest amount of carbon in the Earth system, second only to terrestrial carbon storage, and approximately 60 times more than the atmosphere (DeVries, 2022). 'Blue carbon' is the term used for carbon stored in ocean and coastal ecosystems.
- The seafloor in New Zealand's exclusive economic zone is estimated to contain about 1 percent of the global seabed organic carbon store (Nodder et al, 2023). An inventory of New Zealand marine carbon concluded that data are insufficient to reliably describe the marine carbon budget (accounting for how carbon is stored in, moves through and is released from marine systems) (Nodder et al, 2025).
- Coastal blue carbon refers to rooted vegetation in the coastal zone, such as seagrass meadows, mangroves and tidal marshes. These coastal ecosystems have high rates of carbon sequestration (10 to 45 gigatonnes of carbon globally) compared with terrestrial habitats, but store less carbon than the open ocean (37,000 gigatonnes in the form of dissolved inorganic carbon globally) (Friedlingstein et al, 2025; Friess et al, 2024; Warnell et al, 2022).
- Coastal blue carbon systems have potential to contribute to offsetting carbon emissions and climate change mitigation if they are protected or restored (Howard et al, 2023). These coastal ecosystems store carbon primarily in soils and sediments, where it can remain for long periods (Bulmer et al, 2024c). Protecting and restoring these habitats also supports biodiversity and ecological health.
- The types of coastal blue carbon habitat vary by region, as does land availability for restoration opportunities and potential carbon market benefits. The first national assessment of blue carbon habitats in New Zealand estimates estuaries and coastal areas contain 20,932 hectares of saltmarsh, 30,533 hectares of mangroves and 61,340 hectares of seagrass, which are estimated to collectively sequester 57,800 tonnes of carbon a year (Bulmer et al, 2024c).
- Unvegetated estuarine habitats, such as those dominated by shellfish and microscopic algae, also store significant amounts of carbon due to their large area, sequestering an estimated 164,483 tonnes of carbon a year in New Zealand (Bulmer et al, 2024c). There is potential to restore a further 56,482 hectares of saltmarsh, 17,291 hectares of mangroves and 14,087 hectares of seagrass. If all potential areas were restored, New Zealand would achieve a total sequestration potential of an estimated 91,680 tonnes of carbon a year (Bulmer et al, 2024c).
- Mangrove forests have expanded in many areas over at least the past 50 years, due to increased sedimentation (Anderson et al, 2019; Jones et al, 2022; Morrisey et al, 2010). For example, Auckland's mangrove area has increased an average of 3.2 percent annually from 1940 to 2014 (Suyadi et al, 2019).
- In New Zealand, seagrass area decreased during the past century, particularly in highly impacted harbours, where records showed reductions ranging from 40 percent (at

Whangamatā Harbour) to 90 percent (eastern Bay of Islands) (Morrison et al, 2014b). However, seagrass meadows have shown signs of recovery in some locations in recent decades. In the Waitematā Harbour, seagrass has increased exponentially since 2004 (Lundquist et al, 2018), and in Whangārei Harbour transplanting has been found to be an effective method for rehabilitation (Matheson et al, 2017). These systems still face threats from sea-level rise, rising temperatures, nutrient pollution, increased turbidity and disease (Turner & Schwarz, 2006).

- Salt marshes and other saline wetlands have shown small changes in extent over the past 20 years (Bulmer et al, 2024c). An estimated 90 percent of wetlands have been lost since pre-European settlement (Dymond et al, 2021). Between 1996 and 2018, saline wetland areas decreased by 180 hectares (see indicator: Wetland area).
- Degraded habitats have lower carbon sequestration (Thomson et al, 2025). Loss and degradation of coastal blue carbon ecosystems result in the release of large quantities of stored carbon back into the atmosphere (Bulmer et al, 2024c). Our remaining wetlands continue to degrade due to drainage, pollution, increased sedimentation, invasive weeds, animal pests and climate change (see *Our land 2024*).
- Bottom trawling can re-suspend carbon from the seabed into the water column, although the amount re-suspended is currently uncertain. This carbon may eventually be released into the atmosphere, contributing to greenhouse gas emissions. Areas such as Fiordland, the Chatham Rise and the Bounty Plateau are particularly rich in carbon but also vulnerable to disturbance (Nodder et al, 2023).

Rising seas and infrastructure limit the natural movement of coastal habitats

- In response to rising seas, coastal habitats such as dunes and wetlands would typically migrate landward. However, much of New Zealand's coastline features natural barriers such as cliffs, as well as built infrastructure such as seawalls, which protect our homes and communities from rising sea levels. Pasture and exotic vegetation can also act as barriers. These barriers block the movement of coastal habitats, leading to a phenomenon known as 'coastal squeeze'.
- Coastal squeeze may cause degradation and loss of important coastal habitats. It may also reduce the natural protection that these habitats can provide (Allan et al, 2023; Davis-Jones, 2025; Douglas et al, 2022; Stewart et al, 2020).
- Coastal squeeze will alter the distribution of intertidal habitats and the animals and plants within them, as well as altering coastal ecosystem functions and services (Rullens et al, 2022).
- In New Zealand, coastal hardening (building engineered structures such as seawalls for coastal protection) is expected to increase by 49 to 76 percent over 25 years, starting from 2018 (Floerl et al, 2021). Such structures will limit the ability of intertidal areas to shift landward with sea-level rise, resulting in coastal squeeze – and, in turn, leading to degradation and ultimately loss of habitat (Mangan et al, 2020).

3. Impacts of our changing ocean on people, society and the economy

Section themes

- Sea-level rise and extreme weather events are causing damage to housing, roads and infrastructure.
- Many marae, urupā (burial sites) and mahinga kai (traditional food gathering) sites are vulnerable to flooding and erosion, while recreation areas and walking tracks face risks from sea-level rise.
- Our health is put at risk through toxic algal blooms.
- Mātauranga Māori (Māori knowledge) and tikanga (customs and protocols) practices offer valuable insights for managing marine ecosystems and sustaining cultural identity and wellbeing.
- Pressures on key species threaten livelihoods, Māori fisheries settlements and the sustainability of marine industries.

3. Impacts of our changing ocean on people, society and the economy

Introduction

Aotearoa New Zealand’s coasts and oceans play a major role in how we live, work and connect with each other, and with the natural world. But as the climate changes, so does the marine environment, and we are increasingly feeling the consequences in our homes, communities and industries.

Rising sea levels and more frequent, intense storms are placing coastal communities at greater risk of inundation, infrastructure damage, and coastal flooding and erosion. Homes, roads and public spaces in low-lying areas are becoming more vulnerable. Some communities are already facing difficult decisions around long-term resilience.

Cultural and recreational connections to the coast are also under pressure. Beaches, estuaries and coastal tourism sites are places of gathering, identity and wellbeing. For Māori, many coastal sites are important wāhi taonga, with deep ancestral significance. As these places change or become less accessible, the impacts are felt not only in terms of land use, but also in the erosion of cultural heritage and community cohesion.

Climate change also presents both risks and opportunities for marine primary industries. Warmer waters, shifting species distributions and ocean acidification are affecting fisheries and aquaculture operations, with potential implications for productivity, biosecurity and market access. At the same time, innovation and adaptation in these sectors – such as low-emissions aquaculture and climate-resilient species – offer pathways to future resilience and economic sustainability.

Our homes and communities are at increasing risk from rising sea levels and storm damage

Changes in the ocean contribute to more extreme weather, flooding and inundation of coastal areas

- The environment provides the foundation for our homes, infrastructure and livelihoods. It offers the resources and stability needed for a thriving society. However, environmental change – in particular, climate change – poses serious threats to this foundation (see *Our environment 2025*).
- Extreme weather events like heavy rainfall and storms damage housing and infrastructure, particularly in flood-prone areas (see *Our environment 2025*).

- Sea levels in New Zealand are rising, and extreme weather events such as storms are projected to become more frequent and severe (see section 1). In low-lying coastal areas, higher storm surges are exacerbating the effects of flooding from heavy rainfall (NIWA, nd-c).
- Rising sea-surface temperatures in the Southern Pacific Ocean are providing more energy to drive extreme weather systems. La Niña climate episodes are associated with warmer sea-surface temperatures in the western Pacific and more rain in New Zealand, from subtropical sources of rainfall, ex-tropical cyclones and atmospheric rivers (see *Our atmosphere and climate 2023*). La Niña episodes are projected to become more extreme and may occur more frequently with climate change (Aldridge & Bell, 2025; see section 1). The future will potentially bring more intense tropical cyclones and heavier rainfall, increasing risks for vulnerable communities in New Zealand (Gibson et al, 2025).

Coastal homes, infrastructure and assets face an increasing risk of damage and loss due to sea-level rise

- Many New Zealand homes and critical assets are located on the coasts. These are already vulnerable to the increasing damage and loss due to the cascading risks arising from coastal erosion and flooding (Awatere et al, 2021; Lawrence et al, 2020). The compounding impacts of king tides combined with sea-level rise will result in regular small-scale surface flooding, and king tides coinciding with storm events will result in major tide-related flooding events (Stephens et al, 2020).
- Sea-level rise will increasingly affect our homes and properties in low-lying coastal communities. In 2023, approximately 219,000 residential properties were in coastal inundation and inland flood zones, representing $180 billion in assets. An estimated 1,300 residential properties in the coastal inundation zone (representing $900 million in assets at current property prices) will experience greater than 20 percent damage in one or more extreme events between 2026 and 2060 (Storey et al, 2025).
- Coastal erosion of approximately 5 to 30 metres has occurred along approximately 1,500 metres of the shore of the Waiau River estuarine lagoon in Southland, because of a storm event on 21 September 2023. This erosion has occurred in front of private properties along Bluecliffs Beach Road, causing a risk to these properties, with a potential loss of land, dwellings and outbuildings (Tonkin + Taylor, 2024).
- Sea-level rise also puts much of our coastal infrastructure at risk. In 2019, 2,273 kilometres of roads, 5,572 kilometres of water pipes, 2,457 square kilometres of land, and buildings with a combined replacement value of $26.18 billion (as of 2016) were assessed as vulnerable if sea levels rise by 0.6 metres (Paulik et al, 2019). Roads, including state highways and bridges, are essential for transporting goods and services, and for keeping communities connected. Transport hubs, like ports and airports, are also critical to our way of life and our industries, including fishing, imports and exports.
- Critical services for health and sanitation, such as stormwater and wastewater, will be affected (Feng et al, 2021; Kool et al, 2020; PCE, 2015). Sea-level rise, storm surges, and coastal erosion and flooding are just some of the effects of climate change that are expected to increasingly compromise wastewater infrastructure in New Zealand. This will exacerbate other challenges facing many of our wastewater networks due to ageing, under-design and deferred maintenance (Coxon, 2024; Hughes et al, 2021; Kirchoff & Watson, 2019).

- Landfills have been assessed nationally for their exposure to coastal erosion and coastal inundation. Under current climate conditions, 9 percent of landfills (288) are potentially exposed to coastal inundation; with a sea-level rise of 0.4 metres, this increases to 12 percent of landfills (379). Using coastal edge proximity as a proxy for coastal erosion, 3 percent of landfills (111) already lie within the average high-tide mark, with 8 percent (274) within 100 metres of the coast (Lindsey & Cartwright, 2024).
- Changes to climate cycles and weather, combined with sea-level rise, could increase the intensity and frequency of catastrophic storm and flooding events that cause widespread damage to coastal homes and infrastructure. For example, in 2023, Cyclone Gabrielle and the Auckland Anniversary Day floods each resulted in losses more than 10 times the value of previous insured losses. These increasing risks are likely to drive higher reinsurance costs for insurers, and higher insurance costs for households (Aldridge & Bell, 2025).
- Coastal storms and flooding events are predicted to grow more frequent and severe, placing pressure on natural systems and built infrastructure (Haasnoot et al, 2021; Lawrence et al, 2024). Nature-based solutions, like offshore reef and wetland restoration to reduce wave energy and store floodwaters, and hard engineering such as artificial reefs, seawalls and levees can mitigate the effects of sea-level rise, but are predicted to become increasingly difficult to maintain as sea levels continue to rise (Haasnoot et al, 2021; Lawrence et al, 2024).

The coastal places and activities many of us value are affected by climate change

Wāhi taonga and important coastal places for identity and connection are affected by climate change, rising seas and coastal erosion

- The natural beauty of our environment, including mountains, rivers and coasts, is central to New Zealand's culture and national identity. As individuals and communities, we connect to our local environment in different ways, including by walking along our estuaries and beaches, and swimming or fishing in the ocean. Tangata whenua are connected to various parts of the environment through whakapapa (ancestral ties). As the environment changes, these connections change – whether those changes are sudden and noticeable, or gradual and less obvious (see *Our environment 2025*).
- Many of our coastal ecosystems are changing or being lost due to climate change and other processes, including coastal hardening to protect coastal infrastructure from rising seas (see section 2). The loss of coastal ecosystems and the iconic species they support – especially in urban and rural areas, where these may already be rare – results in a permanent loss of connection to this part of the natural environment.
- Wāhi taonga (culturally important places and infrastructure), such as marae, kāinga (homesteads), urupā (burial sites) and sites of mahinga kai (traditional food-gathering), are vulnerable to damage from flooding, erosion, wildfires and other extreme weather events. Many of these sites are important for cultural activities. Damage to these sites reduces accessibility to place and cultural practices and can affect the Māori knowledge associated with them (Awatere et al, 2021; King et al, 2007). These impacts are exacerbated by climate change. Around the country, 191 marae are within 1 kilometre of the coast and, in the Bay of Plenty alone, 41 urupā are within 1 kilometre of the coast (Bailey-Winiata, 2021).

- Our ecosystems and the wildlife they support provide opportunities for recreation. For many New Zealanders, having access to nature is a major advantage of living here. Around half of the New Zealand population visited protected areas, including coastal reserves and beaches, each month over the 2023/24 summer (DOC, 2021, 2024).
- Many destinations for outdoor recreation and nature tourism are at risk from rising seas. In a 2019 assessment of public conservation sites and infrastructure, 50 amenity areas (eg, campgrounds and playgrounds), 127 buildings, 23 water systems and 126 structures (eg, boardwalks, bridges and jetties) were assessed as potentially vulnerable to flooding from the sea (Tait, 2019). Portions of four of New Zealand's 11 iconic Great Walks (the Abel Tasman Coast, Heaphy, Queen Charlotte and Rakiura tracks), along with 17 other walking and tramping tracks, were also assessed as moderately to highly vulnerable (Tait, 2019).
- Sea-level rise threatens many of New Zealand's archaeological sites. Of the 9,054 mapped sites in the coastal zone, 1,564 are vulnerable to flooding from the sea and 1,954 are highly vulnerable to erosion driven by sea-level rise. Erosion is a particularly serious threat because it permanently removes sites, erasing any evidence they could provide for archaeological investigation. The areas at greatest risk of erosion in the North Island are around Taranaki, Auckland, Coromandel and northern Hawke's Bay, and in the South Island are around Tasman and parts of Otago and Canterbury (Jones et al, 2024).

The effects of climate change, combined with other pressures on our coasts, can affect our health

- Many New Zealanders engage in outdoor recreation, and we get important cultural and health benefits from activities such as walking, swimming, waka ama (traditional Polynesian canoes), surfing, kayaking, fishing and gathering shellfish. Our communities' engagement and connection with the environment can be impaired if these activities cannot be enjoyed safely (see *Environment Aotearoa 2022*).
- Climate change, extreme weather events and degradation of the environment all pose threats to human health, increasing the risks of, for example, food, water and energy insecurity, poor air quality and contaminated water (see *Our environment 2025*). For information on water quality state and trends, see indicator: Coastal and estuarine water quality and *Our marine environment 2022*.
- Increasing sea-surface temperatures, ocean acidification and changing currents are likely to alter the occurrence, frequency, range and toxicity of some harmful algal blooms in New Zealand (Rhodes & Smith, 2022). Under future climate conditions, harmful algal species already detected in New Zealand waters may bloom, and new species may arrive (Rolton et al, 2022). Blooms of the algal species *Alexandrium pacificum* have already increased as a result of more frequent and intense marine heatwaves (Greenough et al, 2025). These blooms have implications for the behaviour, growth rates and mortality of juvenile mussels, impacting wild populations and aquaculture practices (Greenough et al, 2025).
- Some species of marine microalgae produce toxins when they bloom. These toxins can accumulate in fish and shellfish and make anyone who consumes them seriously ill. Contact with these toxins during swimming can also cause skin, eye and lung irritations. Many toxic algae species are present in New Zealand, and several large blooms have caused serious illness in people who consumed wild-gathered shellfish, and had the potential to cause illness in swimmers over the past several decades (Rhodes & Smith, 2022). To protect public health, the Ministry for Primary Industries monitors the main recreational shellfish harvesting areas for toxic blooms and imposes harvest bans when they are detected (MPI, nd-a).

- Increasing sea temperatures and nutrient pollution are expected to lead to increased frequency and severity of marine cyanobacterial blooms over the coming decades. A cyanotoxin produced by marine benthic cyanobacteria, lyngbyatoxin-a (LTA), has recently been detected for the first time in edible shellfish in New Zealand, originating from summer bloom events in 2022 and 2023 on Waiheke Island (Biessy et al, 2024). LTA accumulated in marine snails, rock oysters and cockles (Biessy et al, 2024).
- Nutrients and trace metals from land – which could increase, with more extreme rain and the inundation and erosion of coastal landfills due to sea-level rise – can increase the abundance and toxicity of blooms (Rhodes & Smith, 2022). Nutrient enrichment has led to increases in the toxic algae *Pseudo-nitzschia* in the Firth of Thames (Safi et al, 2022).
- Our wastewater networks are expected to experience more leaks, overflows and potential damage due to coastal erosion and flooding, exacerbated by climate change. This will contribute to the increasing contamination of coastal waters with faecal pathogens, heightening health risks for swimmers and shellfish gatherers and driving more frequent and extended closures of swimming and gathering sites (Coxon, 2024).

Te ao Māori and our marine environment

Impacts on Māori cultural connections and knowledge systems

- Our marine environments are where Māori first encountered this land, settled and became tangata whenua. From coasts to oceans, marine environments are central to te ao Māori (a Māori worldview), whakapapa (ancestral ties) and cultural identity. This is reflected in significant cultural practices and relationships with many parts of our marine natural environments.
- Te ao Māori encompasses our oceans as living systems to which we are connected by whakapapa. Our marine environments are central to mātauranga Māori (Māori knowledge) and tikanga Māori (customs and protocols), passed on between generations. This is held and passed on through language, pūrākau (ancient narratives), tikanga, atua (deities), tīpuna (ancestors) and cultural practices such as waka voyaging, ocean navigation, and caring for and gathering of resources such as kaimoana (seafood) (see *Our marine environment 2022*).
- Many marine environments are experiencing pollution and degradation, with estuaries and coastal areas suffering from recurring events of poor water quality. These pressures are felt at place among whānau, hapū (subtribes), hapori (community) and iwi (tribes), impacting identity and wellbeing at a range of spatial and temporal scales (Kainamu & Rolleston-Gabel, 2023). For example, in areas connected to the iwi Ngāti Porou, the decline of the moana (ocean) is affecting access to beaches and kaimoana stocks, and therefore connection to place, knowledge and practices (Sustainable Seas Challenge, 2024).
- The incorporation of mātauranga Māori and tikanga Māori into marine monitoring, mapping and management frameworks can improve access to up-to-date, evidence-based decision-making. Further, it can strengthen the knowledge of and response to the impacts of change on local ecosystems and communities (Paul-Burke et al, 2020).
- Cultural monitoring and management practices such as rāhui (temporary prohibition or restriction) play an important role in Māori environmental management of key taonga species – for example, enhancing mahinga kai and sustaining mātauranga Māori (Parsons et al, 2024).

- Management strategies between local knowledge-holders and central government can use both knowledge systems for effective environmental outcomes to address degradation of biological and cultural identity (Bennett-Jones et al, 2022). Management approaches based in te ao Māori are often focused on wellbeing and vitality of the environment, and te ao Māori perspectives can contribute to driving environmental change towards a healthier state (Awatere et al, 2023).
- Decision-making that includes te ao Māori perspectives has flow-on effects, enabling Māori to continue to maintain, develop and share environmental mātauranga Māori, tikanga and other cultural practices (Hale et al, 2024).

Tikanga and cultural wellbeing are connected to our coasts and seas

- Tikanga and other cultural practices are expressed through relationships with community, place and the natural environment. In coastal and marine environments, tikanga is grounded in whakapapa and through various practices such as karakia (incantations), pure (cultural ceremony), manaakitanga (showing of hospitality) and kaitiakitanga (stewardship). These practices are connected to Māori cultural wellbeing, and the health of marine environments affects the wellbeing of these communities (Jackson et al, 2017).
- The decline of kaimoana taonga species (treasured seafood species) and their environments impacts iwi, hapū and hapori and their ability to show manaakitanga to guests and share mātauranga Māori. The ability to practise manaakitanga is fundamental to the maintenance of mana (prestige, authority) (Parsons et al, 2024). These impacts are detailed in the mahinga kai section and highlighted where relevant indigenous biodiversity impacts are mentioned.

Impacts on Māori seasonal knowledge and tohu

- Traditional ocean navigation is a part of Māori migration histories, exploration and connection to marine environments. Navigational knowledge holds mātauranga Māori of environmental indicators – the sun, stars, planets, winds, clouds, ocean movement and ecological patterns. Alongside the practices of waka voyaging, modes of cultural transmission such as karakia, pūrākau whakataukī (proverbs) and mōteatea (traditional sung poetry) can be used to recover traditional Māori navigational knowledge and help a new generation of Māori voyagers reconnect with their tīpuna (Barclay-Kerr, 2016; Harris et al, 2013).
- Waka ama and waka hourua (double-hulled canoes) are used for voyaging and are connected to identity, cultural revitalisation, and the intergenerational sharing of mātauranga Māori. Climate change is altering ocean conditions, reducing safe voyaging windows and affecting taonga species used as tohu (environmental indicators) in non-instrument navigation. These changes impact the ability for Māori and communities to undertake waka voyages and the transmission of navigational mātauranga Māori (McDonald, 2022).
- Over time, Māori have built extensive knowledge about local weather and climate – vital to survival and incorporated into traditional and modern practices such as agriculture, fishing and conservation. The iwi Te Whānau-ā-Apanui has long held that there are six seasons and characterises their local climate in this way to assist in making decisions about timing, safety and viability of various activities (King & Skipper, 2006).

- Cultural monitoring of indigenous biodiversity uses tohu to inform harvesting activities. Changes in tohu are being tracked in marine environments to signal challenges such as development, environmental degradation and fish population decline. For example, rōpū (groups or organisations) in Whangārei-Te-Rerenga-Parāoa (Whangārei Harbour) are using 11 tohu to monitor the state of the harbour and explore how ecological and Māori knowledge systems and approaches can align to address complex scenarios involving multiple pressures and values in estuarine systems (Parsons et al, 2024).
- Changes in local climates are causing tohu to change. This affects planting, daily decision-making, and activities like resource gathering and hunting (Skipper, 2018). However, understanding and monitoring tohu as they change over time can help in managing and adapting activities sensitive to climate conditions (King et al, 2005). In Ōhiwa Harbour, overabundance of sea stars (a predator of mussels and shellfish) was considered a temporary tohu of degradation of mussel and shellfish populations. Trials were undertaken using quantitative methods to investigate predation pressure of sea stars on the mussel population, using mātauranga Māori alongside western science (Paul-Burke et al, 2022).
- The decline of taonga cultural keystone species such as pāua (*Haliotis iris*) will have intergenerational impacts. Pāua plays an important role in manaakitanga, and is of spiritual importance, with shells that have been used in ceremonies and toi Māori (Māori arts), and as items of trade and jewellery for generations. Indigenous use of pāua is at risk, due to declining populations as a result of years of overfishing, poaching and habitat degradation (Ryder et al, 2023). Many taonga species have been gathered over generations and are connected to traditional Māori practices, such as mahinga kai and rongoā (healing). They are central to the intergenerational transmission of knowledge – including knowledge about the sustainable use and protection of these taonga species and their associated ecosystems (Awatere et al, 2021; Harmsworth & Awatere, 2013; Smith, 2011).

Reduction in mahinga kai affects cultural identity and connections to the environment

- The harvesting of kaimoana such as pāua is culturally significant for Māori and is connected to many areas of cultural health. Degradation of habitats and populations of cultural keystone species has negative impacts on the ability of Māori to access and harvest kaimoana, resulting in a loss of cultural identity and connection to the environment (Ryder et al, 2023).
- Declines in kuku/kūtai (green-lipped mussels) in soft-bottomed harbours are due to sedimentation, predation, harvesting, climate change, pollution and legacy impacts (Paul-Burke et al, 2022).
- In coastal locations, such as in the rohe (territory/boundaries) of Heretaunga, Hawke's Bay region, increased sedimentation has been changing some areas from sandy to muddy. This affects kaimoana, including cockles, pipi, scallops, snapper, kina (sea urchins) and seaweeds, as well as people's ability to interact with these significant areas (Hayden et al, 2023).
- Human-driven pressure through harvesting by commercial, recreational and customary fishers is having an impact on waterways, with increased exposure to environmental degradation through land run-off and pollution. This is affecting the health of key taonga species including kina, kōura (crayfish), kūtai and pāua (Paul-Burke et al, 2020). For example, observation has shown significant declines in kūtai populations and traditional mahinga kai locations in Ōhiwa Harbour (Bulmer et al, 2024b).

- Non-indigenous species may threaten significant mahinga mātaitai (seafood-gathering) sites and pose a major threat to other ecologically and culturally valued marine environments. This has recently been observed with the incursions of seaweeds (*Caulerpa brachypus* and *Caulerpa parvifolia*) (von Ammon et al, 2023).

Climate change brings many risks and some opportunities for fisheries and aquaculture

Livelihoods from marine primary industries are at risk from a changing environment and climate

- Fisheries and aquaculture contribute to national and local economies. In 2023, fisheries and aquaculture employed 14,580 people and directly contributed an estimated $1.1 billion (0.3 percent) of New Zealand's gross domestic product (GDP) (Stats NZ, 2025a). Activity in the marine economy leads to further economic activity in non-marine industries. These indirect, or induced, estimates are also included in the marine economy account. For fisheries and aquaculture, this value is $1.1 billion (Stats NZ, 2025a).
- Climate change is already affecting some species and ecosystems that are important for aquaculture and wild-caught fisheries (see section 1 and section 2), and these changes affect their productivity. Marine heatwaves, for example, have caused substantial decreases in fish catch and large losses in farmed salmon and mussels (Ericson et al, 2023; Lacheheb et al, 2024; Muznebin et al, 2022; Salinger et al, 2019).
- The effects of climate change present risks to the sustainability of some adversely affected fisheries, as well as presenting opportunities for other fisheries that become more productive in warming waters. Warming sea temperatures and ocean acidification may reduce the growth rate of some species such as shellfish (including flat oysters, green-lipped mussels and pāua) and blue cod and other large fish species (Behrens et al, 2025; Brough et al, 2023; Cummings et al, 2021; Lavin et al, 2022; Lundquist et al, 2023). Conversely, ocean warming and marine heatwaves are likely to increase the abundance of some fish such as snapper and trevally – to a point, as these increases are likely to reverse if temperatures become too warm (Cook et al, 2025; Lacheheb et al, 2024; Mediodia et al, 2024).
- Changes in the migration and distribution of fish populations due to changing ocean temperatures will affect fisheries (Cummings et al, 2021; Datta et al, 2024). Quota ownership is limited to specific management areas, posing a challenge for quota management if fish populations shift. This would have implications for Māori commercial fisheries, which hold about one-third of the interests in New Zealand (Hudson, 2022). For example, warming south of the Chatham Islands since 2006 has placed the region in almost perpetual marine heatwave conditions, and could have implications for the orange roughy and hoki fisheries in the area (Sutton et al, 2024; see section 1).
- Diseases pose a major threat to the aquaculture industry. Further threats from human factors – like climate change, invasive species and pollution – add a layer of complexity (Lane et al, 2022). For example, experiments have shown indigenous green-lipped mussels are vulnerable to infections or other stressors such as harmful algal blooms (Ericson et al, 2023; Greenough et al, 2025), and they have poorer health at warmer temperatures (Azizan et al, 2023; Ericson et al, 2023; Kozal et al, 2024).

- Direct economic losses from two invasive fanworm species (*Sabella spallanzanii* and *Styela clava*) on green-lipped mussel aquaculture are estimated to be $26.4 million over a 24-year period. The related social costs are estimated at $10.7 million over the same period (Soliman & Inglis, 2018). Slowing the spread of the pests, reducing densities and enhancing the premium market position of green-lipped mussels could significantly mitigate these potential impacts.
- 'Milky white flesh syndrome' in New Zealand snapper is expected to become more frequent with warming seas. This syndrome was first documented in the Hauraki Gulf in 2019 and has since become markedly more common off the north-eastern coast of the North Island. It describes snapper that are chronically malnourished and have pale flesh with a 'mushy' texture. It has already affected commercial fisheries, with caught fish securing lower prices or being rejected entirely, and could significantly disrupt New Zealand's largest snapper fishery (Johnson et al, 2024).
- Important commercial and customary fishing species, such as kōura, hoki and pāua, are at risk from warming seas, invasive species, diseases and sedimentation (Awatere et al, 2021; Johnson et al, 2024; King et al, 2010; PMCSA, 2021).
- The transmission of ostreid herpesvirus type 1 (a virus affecting oyster feeding, swimming and survival) in New Zealand had a dramatic impact on Pacific oyster farming, causing up to 100 percent mortality in spat and a 70 percent drop in market-sized oyster production between 2010 and 2012. The outbreak led to bankruptcies of some businesses, farm closures and job losses – particularly affecting rural communities. In Northland, the industry had supported 336 full-time equivalent jobs and contributed $19 million to the regional economy. The closure of one processing facility alone resulted in 66 redundancies, with smaller businesses suffering the most due to their limited resources and inability to adapt quickly (Fuhrmann et al, 2019). After entering a waterway, the virus can become endemic, resulting in seasonally recurrent outbreaks of disease (Fuhrmann et al, 2023).
- Shellfish parasites *Bonamia exitiosa* and *Bonamia ostreae* have both had impacts on flat oyster (*Ostrea chilensis*) populations. *Bonamia exitiosa* has caused significant long-term declines in wild flat oyster populations in Foveaux Strait. Commercial harvests dropped sharply following major mortality events in the late 1980s and early 1990s, resulting in fishery closures in this area to allow the oyster population to rebuild. This resulted in reduced income for quota holders, processors and associated businesses (Cranfield et al, 2005). After *Bonamia ostreae* was detected in Marlborough Sounds in 2015, national restrictions were placed on flat oyster movements. Subsequently, in 2017, all flat oyster farms in New Zealand were de-populated and farming was stopped (Hilton et al, 2025).

Environmental pressures impact the Māori economy and Māori fisheries settlements

- Marine environmental degradation linked to human pressures is resulting in the depletion of fish stocks, which directly affects Māori fisheries and the wider Māori economy (Rout et al, 2019). These environmental pressures also directly affect customary and commercial fishing practices, reducing the health of key taonga species and disrupting mahinga kai and kaitiakitanga practices (see *Our marine environment 2022*).
- Māori fisheries settlements, customary rights and participation in the commercial seafood sector are established through the Treaty of Waitangi. The future of customary fishing is at risk due to degradation of marine environments, impacting iwi Māori involved in fisheries settlements. Current pressures on fisheries impact customary fishing rights, as they limit opportunities for food gathering, weaken community ties, destabilise traditions and diminish connection to the environment (Bennett-Jones et al, 2022).

Tourism is at risk from a changing environment and climate

- Tourism contributes to our national and local economies. In 2023, marine tourism and recreation employed an estimated 1,605 people and directly contributed an estimated $120 million to New Zealand's GDP. These are only partial estimates, due to limited data availability (Stats NZ, 2025a).
- Activity in the marine economy leads to wider economic activity in non-marine industries, which amounted to an estimated $93 million in 2023 (Stats NZ, 2025a).
- In the year to March 2024, tourism was New Zealand's second-largest export earner, with only selected primary exports having a higher value. International tourists contributed $16.9 billion of the total tourism expenditure of $44.4 billion, and the tourism sector employed 303,420 people – with 182,727 of those people directly employed in tourism (Stats NZ, 2025b).
- The natural environments that have supported the tourism industry, and the infrastructure that allows us to access and enjoy them, are at increasing risk. For example, under one tourism climate change scenario, in which there is a disorderly reaction to climate change, with little policy action until 2030, projected risks include some coastal roads and popular visitor journeys being damaged intermittently. This scenario could result in unreliable visitor experiences, total loss of some experiences, and increased health and safety concerns for operators (The Aotearoa Circle, nd).

4. Towards a better understanding of our marine environment

Aotearoa New Zealand's coastline and ocean are changing faster than ever because of climate change and human activity. These changes affect ecosystems, communities and the economy. To respond effectively, we need knowledge that connects global drivers to local impacts. This can help us to make decisions that anticipate change, protect what matters and make the most of opportunities for resilience and restoration.

New Zealand has a rich and growing base of knowledge about the marine environment, built through the efforts of iwi, local and central government, public research organisations, industry and community groups. This collective effort has already delivered valuable insights into the state of our coasts and ocean. However, this knowledge is uneven, and some critical areas remain poorly understood. Closing these gaps is about not just developing better science, but enabling smarter choices, reducing risk, and creating opportunities for climate resilience, a sustainable marine economy and cultural wellbeing.

Planning for the future

Building on what we know

Our understanding of the marine environment is growing, supported by long-term monitoring and modelling, and by bringing in mātauranga Māori (Māori knowledge) alongside other scientific approaches to offer a more inclusive and localised understanding of the marine environment (O'Callaghan et al, 2019). Emerging technologies such as automation, artificial intelligence and remote sensing are opening up new possibilities for collecting and analysing data.

To make the most of these opportunities, we need a reporting system that is:

- streamlined – focused on the most pressing issues, and tailored towards the needs of decision-makers
- efficient – using automation and digital tools to improve data capture and quality
- strategic – building climate and ocean literacy across organisations so risks and opportunities are recognised early
- connected and inclusive – sharing data across agencies and regions and embedding mātauranga Māori in ways that respect tikanga Māori (customs and protocols) and protect sensitive knowledge.

International collaboration and learning from global best practice will help ensure our approaches remain fit for purpose.

Where to focus effort first

Closing every gap is neither possible nor necessary. Instead, we should take a strategic approach and prioritise areas where better knowledge will make the biggest difference to decisions and outcomes. Some of these areas are outlined below.

Understanding compounding pressures

Climate change does not function alone – it amplifies other stressors like overfishing, pollution and habitat loss. Without an integrated view, cumulative impacts are underestimated, leading to delayed responses and higher long-term costs.

We need to:

- combine data on climate variables and local stressors with ecosystem indicators, to track cumulative impacts
- develop linked models that show how climate, land-based pressures, ocean circulation and biodiversity interact – and use scenarios to test future risks and management options
- improve early detection of emerging threats such as invasive species, harmful algal blooms and ocean acidification hotspots, so we can act before problems escalate.

Managing the front line – coastlines and blue carbon

The effects of climate change are most visible in coastal areas, where the impacts on people are also the most immediate. At the same time, these areas hold opportunities for carbon storage (blue carbon) and natural protection from storms and erosion.

We need to:

- assess the extent and condition of key coastal habitats such as seagrass beds, kelp forests, and wetlands, and restore them where this provides multiple benefits
- understand the potential for blue carbon sequestration and the conditions that support it
- bring mātauranga Māori and tohu (environmental indicators) into coastal monitoring and management.

Connecting global drivers to local impacts

Environmental decision-makers need confidence that global signals such as warming oceans or shifting currents translate into practical, place-based implications for policy and investment.

We need to:

- downscale climate and ocean projections to regional and local decision points
- use indicators that link environmental change to consequences for people, as well as for places and species of value
- make data open and accessible so local partners can act on the same evidence base as central agencies.

Strengthening data, monitoring and knowledge for action

Good decisions depend on what we measure, how often we measure it and how quickly we can use it. Priority improvements include:

- core inventories and baselines – expanding national coverage for biodiversity, habitats and pressures so we know what is where
- monitoring frequency and coverage – establishing long-term measurements to detect trends and sudden shifts, complemented by real-time data where risk is high
- emerging technologies – using remote sensing, autonomous platforms and artificial intelligence to improve coverage and reduce costs
- integrated knowledge – supporting mātauranga Māori and community-led monitoring alongside instrumented networks
- open access and interoperability – investing in platforms and standards so data can be shared and reused across agencies and regions.

Better data and models will improve forecasts of species shifts, ocean circulation changes, and coastal flooding. This, in turn, will enable proactive planning for infrastructure, fisheries, conservation and livelihoods.

Closing knowledge gaps enables action. With better knowledge, we can have more informed engagement with decision-makers to:

- plan adaptively – creating flexible, long-term plans that adjust as new information emerges, with clear early-warning thresholds for intervention
- protect and restore habitats – expanding marine protected areas, restoring degraded ecosystems, and prioritising areas less affected by warming or acidification
- manage fisheries sustainably – reducing overfishing and bycatch, and adopting harvest strategies that respond to changing productivity
- use climate-informed spatial planning – guiding zoning and activity restrictions based on projections and species distribution models, and adjusting as conditions change
- deploy early-warning systems – monitoring for marine heatwaves, acidification and low-oxygen events (hypoxia), and acting quickly when risks rise
- strengthen genetic and population resilience – maintaining breeding habitats and connectivity, and considering tools such as assisted migration for aquaculture species where appropriate.

Moving towards a better understanding of our marine environment means more than filling data gaps. It is about creating the knowledge systems we need to act with confidence. By connecting global drivers to local realities, bringing mātauranga Māori alongside western science and using new technologies to make information accessible and timely, we can move from reactive responses to proactive planning. This will help us protect what matters most, restore what has been lost and build resilience for the future.

Additional information

Environmental indicators

Listed below are the environmental indicators incorporated in this report, none of which was updated for this release. Three indicators updated since the release of *Our marine environment 2022* are in bold.

- Active sand dune extent
- Coastal and estuarine water quality
- Coastal sea-level rise
- El Niño Southern Oscillation
- Extinction threat to indigenous species
- Interdecadal Pacific Oscillation
- **Marine non-indigenous species: Data to 2022**
- **Marine primary productivity: Data to 2023**
- Ocean acidification
- **Sea-surface temperature: Data to 2023**
- Southern Annular Mode
- Wetland area

Acknowledgements

This report was compiled by the Ministry for the Environment and Stats NZ's Environmental Reporting team.

Data providers

We would like to thank the following for providing data and advice in the development of indicators used in this report.

- CPC (National Weather Service Climate Prediction Center)
- DOC (Department of Conservation)
- GEOMAR Helmholtz Centre for Ocean Research Kiel
- Land Information New Zealand (New Zealand Hydrographic Authority)
- Manaaki Whenua – Landcare Research
- Met Office Hadley Centre for Climate Science and Services
- MPI (Ministry for Primary Industries)
- NASA (National Aeronautics and Space Administration)
- NIWA (National Institute of Water and Atmospheric Research)
- NZOA-ON (New Zealand Ocean Acidification Observing Network)
- Regional councils and unitary authorities

Senior science and mātauranga advisors

We would like to thank the following people and organisations for providing advice and helping to shape this report.

- Carolyn Lundquist – Earth Sciences New Zealand and University of Auckland
- Linda Faulkner – Earth Sciences New Zealand
- Pete Wilson – SLR Consulting
- Shane Geange – Department of Conservation
- Stephen Hunt – Waikato Regional Council

External peer reviewers

We would like to thank the following people and organisations for providing advice and critical review of this report.

- Cliff Law – Earth Sciences New Zealand and Department of Marine Sciences, University of Otago
- Craig Stevens – Earth Sciences New Zealand and University of Auckland
- Jean Davis – Fisheries New Zealand, Ministry for Primary Industries
- Shari Gallop – PDP (Pattle Delamore Partners Ltd) and University of Waikato

Infographic

The infographic (page 9) was created by Dumpark Information Design.

References

Abram NJ, Mulvaney R, Vimeux F, Phipps SJ, Turner J, & England MH. (2014). Evolution of the Southern Annular Mode during the past millennium. *Nature Climate Change*, *4*(7), 564–569. https://doi.org/10.1038/nclimate2235

Aldridge J, & Bell R. (2025). Climate change impacts to extreme weather events associated with insured losses in New Zealand: A review. *Environmental Research: Climate, 4*(1), e012001. https://doi.org/10.1088/2752-5295/ada1f0

Allan S, Bell RG, & Forkink A. (2023). Coastal realignment: Another coastal challenge. *Policy Quarterly, 19*(1), 50–57. https://doi.org/10.26686/pq.v19i1.8105

Anderson OF, Stephenson F, Behrens E, & Rowden AA. (2022). Predicting the effects of climate change on deep-water coral distribution around New Zealand: Will there be suitable refuges for protection at the end of the 21st century? *Global Change Biology*, *28*(22), 6556–6576. https://doi.org/10.1111/gcb.16389

Anderson TJ, Morrison M, MacDiarmid A, Clark M, D'Archino R, Nelson W, ... & Wadhwa S. (2019). *Review of New Zealand's Key Biogenic Habitats*. NIWA Client report no. 2018139WN, prepared for the Ministry for the Environment. https://environment.govt.nz/assets/Publications/Files/NZ-biogenic-habitat-review.pdf

The Aotearoa Circle. (nd). *Tourism Sector Climate Change Scenarios*. Retrieved 15 September 2025. https://www.theaotearoacircle.nz/focus-areas/climate/climate-scenarios

Awatere S, King DN, Reid J, Williams L, Masters-Awatere B, Harris P, … & Jackson AM. (2021). *He Huringa Āhuarangi, he Huringa Ao: A Changing Climate, a Changing World.* Manaaki Whenua Landcare Research Contract Report LC3948, prepared for Ngā Pae o te Māramatanga. https://www.landcareresearch.co.nz/assets/researchpubs/He-huringa-ahuarangi-he-huringa-ao-a-changing-climate-a-changing-world.pdf

Awatere S, Harmsworth G, Harcourt N, Taura Y, Taylor L, Wilcox M, & Hyslop J. (2023). Whakamana te tangata – ka whai oranga te taiao: Indigenous led approaches for catchment health in Aotearoa-New Zealand. *PLOS Water*, *2*(12), e0000170. https://doi.org/10.1371/journal.pwat.0000170

Azizan A, Venter L, Jansen van Rensburg PJ, Ericson JA, Ragg NLC, & Alfaro AC. (2023). Metabolite changes of *Perna canaliculus* following a laboratory marine heatwave exposure: Insights from metabolomic analyses. *Metabolites, 13*(7), 815. https://doi.org/10.3390/metabo13070815

Bailey-Winiata APS. (2021). *Understanding the Potential Exposure of Coastal Marae and Urupā in Aotearoa New Zealand to Sea-level Rise.* [Master's thesis, University of Waikato – Te Whare Wānanga o Waikato.] http://api.digitalnz.org/records/49827757/source

Balemi CA, & Shears NT. (2023). Emergence of the subtropical sea urchin *Centrostephanus rodgersii* as a threat to kelp forest ecosystems in northern New Zealand. *Frontiers in Marine Science, 10*, 1224067. https://doi.org/10.3389/fmars.2023.1224067

Barclay-Kerr H. (2016). From myth and legend to reality: Voyages of rediscovery and knowledge. In E Emerald, RE Rinehart, & A Garcia (Eds), *Global South Ethnographies: Minding the Senses* (pp 85–91). Sense Publishers. https://doi.org/10.1007/978-94-6300-494-7_6

Barlow DR, Klinck H, Ponirakis D, Branch TA, & Torres LG. (2023). Environmental conditions and marine heatwaves influence blue whale foraging and reproductive effort. *Ecology and Evolution 13*(2), e9770. http://dx.doi.org/10.1002/ece3.9770

Behrens E, Rickard G, Rosier S, Williams J, Morgenstern O, & Stone D. (2022). Projections of future marine heatwaves for the oceans around New Zealand using New Zealand's Earth System Model. *Frontiers in Climate, 4*, 798287. https://doi.org/10.3389/fclim.2022.798287

Behrens E, Dunn MR, Holmes SJ, & Cummings VJ. (2025). *Marine Heatwaves and Fisheries in Aotearoa New Zealand: Observed and Projected Temperature Anomalies and Potential Impacts by Fisheries Management Area*. New Zealand Aquatic Environment and Biodiversity Report No. 351. Fisheries New Zealand. https://fs.fish.govt.nz/Doc/25860/AEBR-351-2025-Marine-heatwaves-and-fisheries-in-Aotearoa-New-Zealand.pdf.ashx

Bell JJ, Smith RO, Micaroni V, Strano F, Balemi CA, Caiger PE, … & Shears NT. (2023). Marine heat waves drive bleaching and necrosis of temperate sponges. *Current Biology, 33*(1), 158–163. https://doi.org/10.1016/j.cub.2022.11.013

Bell JJ, Micaroni V, Strano F, Ryan KG, Mitchell K, Mitchell P, … & Smith RO. (2024). Marine heatwave-driven mass mortality and microbial community reorganisation in an ecologically important temperate sponge. *Global Change Biology, 30*(8), e17417. http://dx.doi.org/10.1111/gcb.17417

Bell RG, Hume TM, & Hicks DM. (2001). *Planning for Climate Change Effects on Coastal Margins.* New Zealand Climate Change Programme report, prepared for the Ministry for the Environment. https://environment.govt.nz/assets/Publications/Files/effect-coastal-sep01.pdf

Bennett-Jones L, Gnanalingam G, Flack B, Scott NJ, Chambers P, & Hepburn, C. (2022). Constraints to effective comanagement of New Zealand's customary fisheries: Experiences of the East Otago Taiāpure. *Ecology and Society, 27*(4), 38. https://doi.org/10.5751/ES-13576-270438

Bennion M, Ross PM, Lane HS, & McDonald IR. (2022). Bacterial composition in the toheroa (*Paphies ventricosa*), a threatened surf clam from Aotearoa (New Zealand). *Marine Biology, 169*, 39. http://dx.doi.org/10.1007/s00227-022-04025-y

Bennion M, Brough T, Leunissen E, Morrison M, Hillman JR, Rowden AA, … & Lundquist CJ. (2024). Modelling spatial distributions of biogenic habitat-forming taxa to inform marine spatial planning. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *34*(3), e4079. https://doi.org/10.1002/aqc.4079

Berthelsen A. (2024). Seagrass quality and extent. In D Lohrer, A Alder, P Bellingham, A Berthelsen, L Biessy, E Biggs, … & J Zeldis, *Information Stocktakes of Fifty-five Environmental Attributes across Air, Soil, Terrestrial, Freshwater, Estuaries and Coastal Waters Domains*. NIWA, Manaaki Whenua Landcare Research, Cawthron Institute and Environet Limited. Report No. 2024216HN, prepared for the Ministry for the Environment. https://environment.govt.nz/publications/information-stocktakes-of-fifty-five-environmental-attributes

Biessy L, Puddick J, Wood SA, Selwood AI, Carbines M, & Smith KF. (2024). First report of accumulation of lyngbyatoxin-a in edible shellfish in Aotearoa New Zealand from marine benthic cyanobacteria. *Toxins, 16*(12), 522. http://dx.doi.org/10.3390/toxins16120522

Bodeker G, Cullen N, Katurji M, McDonald A, Morgenstern O, Noone D, … & Tait A. (2022). *Aotearoa New Zealand climate Change Projections Guidance: Interpreting the Latest IPCC WG1 Report Findings*. Report number CR 501, prepared for the Ministry for the Environment. https://environment.govt.nz/publications/aotearoa-new-zealand-climate-change-projections-guidance/

Boers N. (2021). Observation-based early-warning signals for a collapse of the Atlantic Meridional Overturning Circulation. *Nature Climate Change, 11*, 680–688. https://doi.org/10.1038/s41558-021-01097-4

Bollen M, Pilditch CA, Battershill CN, & Bischof K. (2016). Salinity and temperature tolerance of the invasive alga *Undaria pinnatifida* and native New Zealand kelps: Implications for competition. *Marine Biology, 163*, 194. https://doi.org/10.1007/s00227-016-2954-3

Böök IM, Krieger EC, Phillips NE, Michael KP, Bell JJ, Dillon WDN, & Cornwall CE. (2024). Effects of ocean acidification on the interaction between calcifying oysters (*Ostrea chilensis*) and bioeroding sponges (*Cliona* sp.). *Frontiers in Marine Science, 11*, 1444863. http://dx.doi.org/10.3389/fmars.2024.1444863

Booth JD. (2020). Reviewing the far-reaching ecological impacts of human-induced terrigenous sedimentation on shallow marine ecosystems in a northern-New Zealand embayment. *New Zealand Journal of Marine and Freshwater Research, 54*(4), 593–613. https://doi.org/10.1080/00288330.2020.1738505

Breitburg D, Levin LA, Oschlies A, Grégoire M, Chavez FP, Conley DJ, … & Zhang, J. (2018). Declining oxygen in the global ocean and coastal waters. *Science, 359*(6371). https://doi.org/10.1126/science.aam7240

Broekhuizen N, Plew DR, Pinkerton MH, & Gall MG. (2021). Sea temperature rise over the period 2002–2020 in Pelorus Sound, New Zealand – with possible implications for the aquaculture industry. *New Zealand Journal of Marine and Freshwater Research, 55*(1), 46–64. https://doi.org/10.1080/00288330.2020.1868539

Brough TE, Leunissen EM, & Beentjes M. (2023). *Habitat Use and the Impact of Multiple Stressors on Blue Cod Populations off Canterbury and in the Marlborough Sounds*. New Zealand Aquatic Environment and Biodiversity Report No. 323. Fisheries New Zealand. https://fs.fish.govt.nz/Doc/25581/AEBR-323-Habitat-Use-And-Impact-Of-Stressors-On-Blue-Cod-4425-2023.pdf.ashx

Brumby A, Marshall J, Murray T, O'Donnell C, & Richards R. (2025). *Trait-based Climate Change Vulnerability Assessments of Terrestrial Taxa in Aotearoa New Zealand*. Science for Conservation Report 343. Department of Conservation. https://www.doc.govt.nz/globalassets/documents/science-and-technical/science-for-conservation/343-climate-change-taxa/sfc343.pdf

Bulmer R, Flowers G, Lam-Gordillo O, Shao Z, & Stewart-Sinclair P. (2024a). *Assessing the Impact of Sea level Rise on Blue Carbon Habitats and Restoration Opportunity in the Hawke's Bay Region.* Technical Report No. 5671, prepared for the Hawke's Bay Regional Council. http://dx.doi.org/10.13140/RG.2.2.21062.38725

Bulmer R, Paul-Burke K, Ranapia M, Ellis J, Bluett C, O'Brien T, … & Stephenson F. (2024b). Weaving indigenous and western ecological knowledge to enhance environmental sustainability. *Ocean & Coastal Management, 258*, e107402. https://doi.org/10.1016/j.ocecoaman.2024.107402

Bulmer RH, Stewart-Sinclair PJ, Lam-Gordillo O, Mangan S, Schwendenmann L, & Lundquist CJ. (2024c). Blue carbon habitats in Aotearoa New Zealand – opportunities for conservation, restoration, and carbon sequestration. *Restoration Ecology, 32*(7), e14225. https://doi.org/10.1111/rec.14225

Buxton RT, Currey CA, Lyver PO'B, & Jones CJ. (2013). Incidence of plastic fragments among burrow-nesting seabird colonies on offshore islands in northern New Zealand. *Marine Pollution Bulletin, 74*(1), 420–424. https://doi.org/10.1016/j.marpolbul.2013.07.011

Cai W, Ng B, Geng T, Jia F, Wu L, Wang G, … & McPhaden MJ. (2023). Anthropogenic impacts on twentieth-century ENSO variability changes. *Nature Reviews Earth & Environment, 4*, 407–418. https://doi.org/10.1038/s43017-023-00427-8

Capistrant-Fossa KA, & Dunton KH. (2024). Rapid sea level rise causes loss of seagrass meadows. *Communications Earth & Environment, 5*, 87. https://doi.org/10.1038/s43247-024-01236-7

Clark BL, Carneiro APB, Pearmain EJ, Rouyer MM, Clay TA, Cowger W, ... & Quillfeldt P. (2023). Global assessment of marine plastic exposure risk for oceanic birds. *Nature Communications, 14*(1), 3665. https://doi.org/10.1038/s41467-023-38900-z

Clark MR, Bowden DA, Rowden AA, & Stewart R. (2019). Little evidence of benthic community resilience to bottom trawling on seamounts after 15 years. *Frontiers in Marine Science, 6*(63), 1–16. https://doi.org/10.3389/fmars.2019.00063

Clark MR, Bowden DA, Stewart R, Rowden AA, & Goode SL. (2022a). *Seamount Recovery: Analysis of 20 Years of Time-series Seafloor Image Data from the Graveyard Knolls, Chatham Rise, New Zealand*. New Zealand Aquatic Environment and Biodiversity Report No. 292. Fisheries New Zealand. https://webstatic.niwa.co.nz/library/NZAEBR-292.pdf

Clark MR, Wood B, Mackay K, Anderson OF, Hart A, Rickard G, & Rowden AA. (2022b). *Underwater Topographic Features in the New Zealand Region: Development of an Updated 'SEAMOUNT' Database and Information on the Extent and Intensity of Deep-sea Trawl Fisheries on Them*. New Zealand Aquatic Environment and Biodiversity Report No. 291. Fisheries New Zealand. https://www.mpi.govt.nz/dmsdocument/53304-AEBR-291-Underwater-Topographic-Features-in-the-New-Zealand-region-development-of-an-updated-SEAMOUNT-database-and-information-on-the-extent-and-intensity-of-deep-sea-trawl-fisheries-on-them/

Coastal Change. (nd). *Coastal Vegetation*. Retrieved 15 September 2025. https://coastalchange.nz/the-science/coastal-vegetation/

Cook KM, Dunn MR, Behrens E, Pinkerton MH, Law C, & Cummings VJ. (2025). *Marine Heatwaves and Fisheries in Aotearoa New Zealand: Review of Potential Effects on Marine Ecosystems and Fishstocks*. New Zealand Aquatic Environment and Biodiversity Report No. 352. Fisheries New Zealand. https://www.mpi.govt.nz/dmsdocument/68616-AEBR-352-Marine-heatwaves-and-fisheries-in-Aotearoa-New-Zealand-review-of-potential-effects-on-marine-ecosystems-and-fishstocks/

Coxon S. (2024). *Review of the Potential Impacts of Climate Change on Wastewater Networks and Treatment Plants in Aotearoa New Zealand, and Implications for Public Health*. Science for Communities Report No. FW24020, prepared for Health New Zealand | Te Whatu Ora. https://www.phfscience.nz/media/j0tg4qmu/esr-review-health-impacts-climate-change-wastewater-networks-new-zealand.pdf

Cranfield HJ, Dunn A, Doonan IJ, & Michael KP. (2005). *Bonamia exitiosa* epizootic in *Ostrea chilensis* from Foveaux Strait, southern New Zealand between 1986 and 1992. *ICES Journal of Marine Science, 62*(1), 3–13. https://doi.org/10.1016/j.icesjms.2004.06.021

Cummings VJ, Lundquist CJ, Dunn MR, Francis M, Horn P, Law C, … & Mielbrecht E. (2021). *Assessment of Potential Effects of Climate-related Changes in Coastal and Offshore Waters on New Zealand's Seafood Sector*. New Zealand Aquatic Environment and Biodiversity Report No. 261. Fisheries New Zealand. https://www.cakex.org/sites/default/files/documents/45265-AEBR-261-Assessment-Of-Potential-Effects-Of-Climate-Change-On-Seafood-Sector-3389.pdf

Datta S, Beran H, & Rogers A. (2024). The impacts of warming on shallow and deep-water fisheries in New Zealand. *Earth's Future, 12*(12), e2024EF004857. https://doi.org/10.1029/2024EF004857

Davis JP, & Hepburn CD. (2020). *Southland Regional Marine Invasive Species Surveillance and Compliance Plan.* Department of Marine Science, University of Otago report, prepared for Environment Southland. https://www.envirolink.govt.nz/assets/Envirolink/2027-ESRC292-Southland-Regional-Marine-Invasive-Species-Surveillance-and-Compliance-Plan.pdf

Davis-Jones C. (2025). *Climate Change Effects on Marine Habitats: Literature Review and Guidance Document.* SLR Project No. 810.031203.00001, prepared for the Bay of Plenty Regional Council. https://atlas.boprc.govt.nz/api/v1/edms/document/BOPRC-1864443702-56484/content

DeVries T. (2022). The ocean carbon cycle. *Annual Review of Environment and Resources, 47*, 317–341. http://dx.doi.org/10.1146/annurev-environ-120920-111307

DOC (Department of Conservation). (2021). *New Zealanders and the Environment. Domestic Customer Segmentation Research: New Zealanders Engaging with the Environment, Biodiversity and Conservation*. https://www.doc.govt.nz/globalassets/documents/about-doc/role/visitor-research/nzers-and-the-environment.pdf

DOC. (2024). *Understanding Summer Activity: Making Sense of What People Did in the Outdoors over the 2023/24 Summer*. https://www.doc.govt.nz/globalassets/documents/about-doc/role/visitor-research/understanding-2023-2024-summer-activity.pdf

DOC. (nd). *Hector's and Māui Dolphin Incident Database*. Retrieved 15 September 2025. https://www.doc.govt.nz/our-work/hectors-and-maui-dolphin-incident-database/

Douglas EJ, Bulmer RH, MacDonald IT, & Lohrer AM. (2022). Estuaries as coastal reactors: Importance of shallow seafloor habitats for primary productivity and nutrient transformation, and impacts of sea level rise. *New Zealand Journal of Marine and Freshwater Research, 56*(3), 553–569. http://dx.doi.org/10.1080/00288330.2022.2107027

Dudley BD, Burge OR, Plew D, & Zeldis J. (2020). Effects of agricultural and urban land cover on New Zealand's estuarine water quality. *New Zealand Journal of Marine and Freshwater Research, 54*(3), 372–392. https://doi.org/10.1080/00288330.2020.1729819

Dune Restoration Trust of New Zealand. (2014). Effects of vehicles on sand dunes. Technical Article No. 10.2. https://www.coastalrestorationtrust.org.nz/site/assets/files/1185/10.2_effects_of_vehicles.pdf

Dunn MR, Finucci B, Pinkerton MH, & Sutton P. (2022). *Review of Commercial Fishing Interactions with Marine Reptiles*. NIWA Client Report No. 2022147WN, prepared for the Department of Conservation. https://www.doc.govt.nz/globalassets/documents/conservation/marine-and-coastal/marine-conservation-services/reports/202122-annual-plan/int2021-03-review-of-commercial-fishing-interactions-with-marine-reptiles-final-report.pdf

Dunn MR, Finucci B, Pinkerton MH, Sutton P, & Duffy CAJ. (2023). Increased captures of the critically endangered leatherback turtle (*Dermochelys coriacea*) around New Zealand: The contribution of warming seas and fisher behavior. *Frontiers in Marine Science, 10*, e1170632. http://doi.org/10.3389/fmars.2023.1170632

Dymond JR, Sabetizade M, Newsome PF, Harmsworth GR, & Ausseil A-G. (2021). Revised extent of wetlands in New Zealand. *New Zealand Journal of Ecology*, *45*(2), 1–8. https://www.jstor.org/stable/48621882

Ericson JA, Venter L, Copedo JS, Nguyen VT, Alfaro AC, & Ragg NLC. (2023). Chronic heat stress as a predisposing factor in summer mortality of mussels, *Perna canaliculus*. *Aquaculture, 564*, e738986. https://doi.org/10.1016/j.aquaculture.2022.738986

Feng B, Zhang Y, & Bourke R. (2021). Urbanization impacts on flood risks based on urban growth data and coupled flood models. *Natural Hazards*, *106*(1), 613–627. https://doi.org/10.1007/s11069-020-04480-0

Floerl O, Atalah J, Bugnot AB, Chandler M, Dafforn KA, Floerl L, … & Major, R. (2021). A global model to forecast coastal hardening and mitigate associated socioecological risks. *Nature Sustainability, 4*, 1060–1067. http://dx.doi.org/10.1038/s41893-021-00780-w

FNZ (Fisheries New Zealand). (2025). *South Island Hector's Dolphin Bycatch Reduction Plan: Annual Report 2023/24*. https://www.mpi.govt.nz/dmsdocument/68775-South-Island-Hectors-Dolphin-Bycatch-Reduction-Plan-Annual-Report-202324/

Fox-Kemper B, Hewitt HT, Xiao C, Aðalgeirsdóttir G, Drijfhout SS, Edwards TL, … & Yu Y. (2023). Ocean, cryosphere and sea level change. In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp 1211–1362). Cambridge University Press. https://doi.org/10.1017/9781009157896.011

Friedlingstein P, O'Sullivan M, Jones MW, Andrew RM, Hauck J, Landschützer P, … & Zeng J. (2025). Global Carbon Budget 2024. *Earth System Science Data, 17*(3), 965–1039. https://doi.org/10.5194/essd-17-965-2025

Friess DA, Shribman ZI, Stankovic M, Iram N, Baustian MM, & Ewers Lewis CJ. (2024). Restoring blue carbon ecosystems. *Cambridge Prisms: Coastal Futures*, *2*, e9. https://doi.org/10.1017/cft.2024.9

Fuhrmann M, Castinel A, Cheslett DL, Furones Nozal D, & Whittington RJ. (2019). The impacts of ostreid herpesvirus 1 microvariants on Pacific oyster aquaculture in the Northern and

Southern Hemispheres since 2008. *Revue Scientifique et Technique de l'OIE*, *38*(2), 491–509. https://doi.org/10.20506/rst.38.2.3000

Fuhrmann M, Hick PM, Bestbier M, & Georgiades E. (2023). Pilot study: Investigating the role of biofouling in transmission of *ostreid herpesvirus 1* (OsHV-1). *Management of Biological Invasions, 14*(1), 133–155. https://www.reabic.net/journals/mbi/2023/1/MBI_2023_Fuhrman_etal.pdf

Funnell GA, Gordon DP, Leduc D, Makan T, Marshall BA, Mills S, … & Wing S. (2023). *Conservation Status of Indigenous Marine Invertebrates in Aotearoa New Zealand, 2021.* New Zealand Threat Classification Series Report No. 1077. Department of Conservation. https://www.doc.govt.nz/globalassets/documents/science-and-technical/nztcs40entire.pdf

Gall M, & Pinkerton M. (2024). Phytoplankton/chlorophyll a in estuary/coastal water (trophic state). In D Lohrer, A Alder, P Bellingham, A Berthelsen, L Biessy, E Biggs, … & J Zeldis, *Information Stocktakes of Fifty-five Environmental Attributes across Air, Soil, Terrestrial, Freshwater, Estuaries and Coastal Waters Domains*. NIWA, Manaaki Whenua Landcare Research, Cawthron Institute and Environet Limited Report No. 2024216HN, prepared for the Ministry for the Environment. https://environment.govt.nz/publications/information-stocktakes-of-fifty-five-environmental-attributes

Geange S, Townsend M, Clark D, Ellis JI, & Lohrer, AM. (2019). Communicating the value of marine conservation using an ecosystem service matrix approach. *Ecosystem Services, 35*, 150–163. https://doi.org/10.1016/j.ecoser.2018.12.004

Gibson PB, Lewis H, Campbell I, Rampal N, Fauchereau N, & Harrington LJ. (2025). Downscaled climate projections of tropical and ex-tropical cyclones over the southwest Pacific. *Journal of Geophysical Research: Atmospheres, 130*(14), e2025JD043833. https://doi.org/10.1029/2025JD043833

Gong H, Li C, & Zhou Y. (2021). Emerging global ocean deoxygenation across the 21st century. *Geophysical Research Letters, 48*(23), e2021GL095370. https://doi.org/10.1029/2021GL095370

Goyal R, Sen Gupta A, Jucker M, & England MH. (2021). Historical and projected changes in the Southern Hemisphere surface westerlies. *Geophysical Research Letters, 48*(4), e2020GL090849. https://doi.org/10.1029/2020GL090849

Greenough H, Vignier J, Smith KF, Brown CM, Kenny NJ, & Rolton A. (2025). Multi-stressor dynamics: Effects of marine heatwave stress and harmful algal blooms on juvenile mussel (*Perna canaliculus*) survival and physiology. *Science of The Total Environment*, *964*, e 178590. https://doi.org/10.1016/j.scitotenv.2025.178590

Haasnoot M, Lawrence J, & Magnan AK. (2021). Pathways to coastal retreat. *Science*, *372*(6548), 1287–1290. www.science.org/doi/10.1126/science.abi6594

Hale R, Thompson D, Brough T, Kregting L, Hayden M, Parsons D, … & Stevens C. (2024). Environmental implications of future offshore renewable energy development in Aotearoa New Zealand. *Journal of the Royal Society of New Zealand, 55*(4), 912–945. https://doi.org/10.1080/03036758.2024.2406829

Harmsworth G, & Awatere S. (2013). Indigenous Māori knowledge and perspectives of ecosystems. In JR Dymond (Ed), *Ecosystem Services in New Zealand: Conditions and Trends* (pp 274–286). Manaaki Whenua Press. https://www.landcareresearch.co.nz/uploads/public/Publications/Ecosystem-servicesin-New-Zealand/2_1_Harmsworth.pdf

Harris P, Matamua R, Smith T, Kerr H, & Waaka T. (2013). A review of Māori astronomy in Aotearoa-New Zealand. *Journal of Astronomical History and Heritage*, *16*(3), 325–336. https://doi.org/10.3724/SP.J.1440-2807.2013.03.08

Hayden M, Lundquist C, & Kainamu A. (2023). *Hapū and Iwi Perceptions of Cumulative Effects: Towards Supporting Kaitiakitanga*. Report for the Sustainable Seas National Science Challenge. https://www.sustainableseaschallenge.co.nz/assets/dms/Reports/Hapu-and-iwi-perceptions-of-cumulative-effects/Hapu-and-iwi-perceptions-of-CE.pdf

Hilliam K, & Tuck ID. (2023). Range expansion of the invasive portunid crab *Charybdis japonica* in New Zealand. *New Zealand Journal of Marine and Freshwater Research, 57*(4), 518–534. http://dx.doi.org/10.1080/00288330.2022.2071301

Hilton Z, Rolton A, Muznebin F, Webb SC, Fidler A, Elliot A, … & Hutson KS. (2025). Reduced farming density of New Zealand flat oyster *Ostrea chilensis* is associated with decreased infection by *Bonamia ostreae* and other parasites. *Aquaculture, 607*, e742683. https://doi.org/10.1016/j.aquaculture.2025.742683

Hobday AJ, Alexander LV, Perkins SE, Smale D, Straub SC, Oliver ECJ, … & Wernberg, T. (2016). A hierarchical approach to defining marine heatwaves. *Progress in Oceanography*, *141*, 227–238. https://doi.org/10.1016/j.pocean.2015.12.014

Hollitzer HAL, Patara L, Terhaar J, & Oschlies A. (2024). Competing effects of wind and buoyancy forcing on ocean oxygen trends in recent decades. *Nature Communications 15*, 9264. https://doi.org/10.1038/s41467-024-53557-y

Holt J, Harle J, Wakelin S, Jardine J, & Hopkins J. (2022). Why is seasonal density stratification in shelf seas expected to increase under future climate change? *Geophysical Research Letters*, *49*(23), e2022GL100448. https://doi.org/10.1029/2022GL100448

Howard J, Sutton-Grier AE, Smart LS, Lopes CC, Hamilton J, Kleypas J, … & Landis E. (2023). Blue carbon pathways for climate mitigation: Known, emerging and unlikely. *Marine Policy, 156*, e105788. https://doi.org/10.1016/j.marpol.2023.105788

Howarth L, & Major R. (2023). *Key Environmental Considerations for Seaweed Aquaculture in Aotearoa New Zealand*. Report for the Sustainable Seas National Science Challenge. https://www.sustainableseaschallenge.co.nz/assets/dms/Reports/Key-environmental-considerations-for-seaweed-aquaculture/Key-environmental-considerations-for-seaweed-aquaculture-in-Aotearoa-New-Zealand.pdf

Hudson M. (2022). Māori hold a third of NZ's fishing interests, but as the ocean warms and fish migrate, these rights don't move with them. *The Conversation*. https://www.waikato.ac.nz/news-events/news/maori-hold-a-third-of-nzs-fishing-interests-but-as-the-ocean-warms-and-fish-migrate-these-rights-dont-move-with-them/

Hughes J, Cowper-Heays K, Olesson E, Bell R, & Stroombergen A. (2021). Impacts and implications of climate change on wastewater systems: A New Zealand perspective. *Climate Risk Management*, *31*, e100262. https://doi.org/10.1016/J.CRM.2020.100262

Hunt HL, & Scheibling RE. (2001). Predicting wave dislodgment of mussels: Variation in attachment strength with body size, habitat, and season. *Marine Ecology Progress Series, 213*, 157–164. https://doi.org/10.3354/meps213157

Jackson AM, Mita N, & Hakopa H. (2017). *Hui-te-ana-nui: Understanding Kaitiakitanga in Our Marine Environment*. Report to Sustainable Seas National Science Challenge. https://www.sustainableseaschallenge.co.nz/assets/dms/Reports/Hui-te-ana-nui-Understanding-kaitiakitanga-in-our-marine-environment/HTAN-report-2017.pdf

Jhugroo K, O'Callaghan JM, & Stevens CL. (2025). The impact of high rainfall events on the submesoscale salinity field in a coastal sea: Greater Cook Strait, New Zealand. *New Zealand Journal of Marine and Freshwater Research, 59*(4), 735–761. https://doi.org/10.1080/00288330.2024.2368853

Jiang LQ, Dunne J, Carter BR, Tjiputra JF, Terhaar J, Sharp JD, … & Ziehn T. (2023). Global surface ocean acidification indicators from 1750 to 2100. *Journal of Advances in Modeling Earth Systems*, *15*(3), e2022MS003563. https://doi.org/10.1029/2022MS003563

Jo AR, Lee J-Y, Timmermann A, Jin F-F, Yamaguchi R, & Gallego A. (2022). Future amplification of sea surface temperature seasonality due to enhanced ocean stratification. *Geophysical Research Letters*, *49*(9), e2022GL098607. https://doi.org/10.1029/2022GL098607

Johnson KS, Gadd J, Bian R, Noll B, Pinkerton MH, Taylor R, … & Parsons DM. (2024). *Distribution and Potential Causes of Milky Fleshed Snapper in SNA 1*. New Zealand Fisheries Assessment Report 2024/25. Fisheries New Zealand. https://www.mpi.govt.nz/dmsdocument/62775/direct

Jones BD, Dickson ME, Ford M, Hikuroa D, & Ryan EJ. (2024). Aotearoa New Zealand's coastal archaeological heritage: A geostatistical overview of threatened sites. *Journal of Island and Coastal Archaeology, 19*(4), 657–677. https://doi.org/10.1080/15564894.2023.2207493

Jones HFE, Hunt S, Kamke J, & Townsend M. (2022). Historical data provides context for recent monitoring and demonstrates 100 years of declining estuarine health. *New Zealand Journal of Marine and Freshwater Research, 56*(3), 371–388. https://doi.org/10.1080/00288330.2022.2086588

Kainamu A, & Rolleston-Gabel T. (2023). *A Review of Te Ao Māori Perspectives of Marine Scales and Where These Are Impeded by Contemporary Management.* Report for the Sustainable Seas National Science Challenge. https://www.sustainableseaschallenge.co.nz/assets/dms/Reports/te-ao-Maori-perspectives-of-marine-scales/Te-ao-Maori-perspectives-of-marine-scales.pdf

Keegan LJ, White RSA, & Macinnis-Ng C. (2022). Current knowledge and potential impacts of climate change on New Zealand's biological heritage. *New Zealand Journal of Ecology, 46*(1), 3467. https://doi.org/10.20417/nzjecol.46.10

Kerr VC, Grace RV, & Shears NT. (2024). Estimating the extent of urchin barrens and kelp forest loss in northeastern Aotearoa, New Zealand. *New Zealand Journal of Marine and Freshwater Research, 59*(2), 441–462. https://doi.org/10.1080/00288330.2024.2336081

King D, Tawhai W, Skipper A, & Iti W. (2005). *Anticipating Local Weather and Climate Outcomes Using Māori Environmental Indicators*. NIWA. https://niwa.co.nz/sites/niwa.co.nz/files/niwa_report_akl2005-129.pdf

King D, & Skipper A. (2006). Understanding local weather and climate using Māori environmental knowledge. *NIWA Water & Atmosphere, 14*(2). https://niwa.co.nz/water-atmosphere/vol14-no2-june-2006/understanding-local-weather-and-climate-using-maori-environmental-knowledge

King DN, Penny G, & Severne C. (2010). The climate change matrix facing Māori society. In RAC Nottage, DS Wratt, JF Bornman, & K Jones (Eds), *Climate Change Adaptation in New Zealand: Future Scenarios and Some Sectoral Perspectives* (pp 100–111). New Zealand Climate Change Centre. https://www.researchgate.net/publication/273737386_The_climate_change_matrix_facing_Maori_society

King DNT, Goff J, & Skipper A. (2007). Māori environmental knowledge and natural hazards in Aotearoa-New Zealand. *Journal of the Royal Society of New Zealand*, *37*(2), 59–73. https://doi.org/10.1080/03014220709510536

King J, Anchukaitis KJ, Allen K, Vance T, & Hessl A. (2023). Trends and variability in the Southern Annular Mode over the Common Era. *Nature Communications, 14*, 2324. https://doi.org/10.1038/s41467-023-37643-1

Kirchoff CJ, & Watson PL. (2019). Are wastewater systems adapting to climate change? *Journal of the American Water Resources Association, 55*(4), 869–880. https://doi.org/10.1111/1752-1688.12748

Komoroske LM, & Lewison RL. (2015). Addressing fisheries bycatch in a changing world. *Frontiers in Marine Science, 2*, 83. https://doi.org/10.3389/fmars.2015.00083

Kool R, Lawrence J, Drews M, & Bell R. (2020). Preparing for sea-level rise through adaptive managed retreat of a New Zealand stormwater and wastewater network. *Infrastructures*, *5*(11), 92. https://doi.org/10.3390/infrastructures5110092

Kozal LC, Hofmann GE, Hawes NA, & Ragg NLC. (2024). Paternal heat exposure affects larval development in green-lipped mussels *Perna canaliculus*. *Aquaculture Environment Interactions, 16,* 43–57. https://doi.org/10.3354/aei00472

Lacheheb M, Noy I, & Kahui V. (2024). Marine heatwaves and commercial fishing in New Zealand. *Science of The Total Environment*, *954*, e176558. https://doi.org/10.1016/j.scitotenv.2024.176558

Lam-Gordillo O, Lohrer AM, Douglas E, Hailes S, Carter K, & Greenfield B. (2023). Scale-dependent influence of multiple environmental drivers on estuarine macrobenthic crustaceans. *Frontiers in Marine Science*, *10*, 1292849. https://doi.org/10.3389/fmars.2023.1292849

Lane HS, Brosnahan CL, & Poulin R. (2022). Aquatic disease in New Zealand: Synthesis and future directions. *New Zealand Journal of Marine and Freshwater Research, 56*(1), 1–42. https://doi.org/10.1080/00288330.2020.1848887

Lavin CP, Gordó-Vilaseca C, Stephenson F, Shi Z, & Costello MJ. (2022). Warmer temperature decreases the maximum length of six species of marine fishes, crustacean, and squid in New Zealand. *Environmental Biology of Fishes*, *105*, 1431–1446. https://doi.org/10.1007/s10641-022-01251-7

Law CS, Bell JJ, Bostock HC, Cornwall CE, Cummings VJ, Currie K, … & Tracey DM. (2018). Ocean acidification in New Zealand waters: Trends and impacts. *New Zealand Journal of Marine and Freshwater Research, 52*(2), 155–195. https://doi.org/10.1080/00288330.2017.1374983

LAWA (Land Air Water Aotearoa). (2023). *Factsheet: Faecal Indicators*. https://www.lawa.org.nz/learn/factsheets/faecal-indicators/

Lawrence J, Blackett P, & Cradock-Henry NA. (2020). Cascading climate change impacts and implications. *Climate Risk Management*, *29*, e100234. https://doi.org/10.1016/j.crm.2020.100234

Lawrence J, Mackey B, Chiew F, Costello MJ, Hennessy K, Lansbury N, … & Wreford A. (2022). Australasia. In *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp 1581–1688). Cambridge University Press. https://doi.org/10.1017/9781009325844.013

Lawrence J, Wreford A, Blackett P, Hall D, Woodward A, Awatere S, … & Milfont TL. (2024). Climate change adaptation through an integrative lens in Aotearoa New Zealand. *Journal of the Royal Society of New Zealand*, *54*(4), 491–522. https://doi.org/10.1080/03036758.2023.2236033

Leduc D, Collins C, Gall M, Lundquist C, Macdonald H, Mackay K, … & Toataua N. (2024). *Cyclone Impacts on Fisheries*. New Zealand Aquatic Environment and Biodiversity Report No. 326. Fisheries New Zealand. https://fs.fish.govt.nz/Doc/25605/AEBR-326-Cyclone-Impacts-On-Fisheries-2024-4461.pdf.ashx

Lindsey M, & Cartwright A. (2024). *National Landfill Climate Change Exposure Assessment*. Tonkin + Taylor report, prepared for the Ministry for the Environment. https://environment.govt.nz/publications/national-landfill-climate-change-exposure-assessment/

Lindsey R, & Dahlman L. (2025). *Climate Change: Ocean Heat Content*. NOAA Climate.gov. https://www.climate.gov/news-features/understanding-climate/climate-change-ocean-heat-content#

Litter Intelligence. (nd). *Data, Insights and Action for a Litter-free World*. Retrieved 22 September 2025. https://litterintelligence.org/

Lowe M, Morrison MA, & Taylor RB. (2015). Harmful effects of sediment-induced turbidity on juvenile fish in estuaries. *Marine Ecology Progress Series, 539*, 241–254. https://doi.org/10.3354/meps11496

Lundquist C, Cummings V, Hansen L, & Mielbrecht E. (2023). *State of Knowledge: Climate Change and New Zealand's Seafood Sector*. Synthesis report to support technical report, prepared for Fisheries New Zealand. https://www.mpi.govt.nz/dmsdocument/56242-Climate-change-andNZs-seafood-sector-2023

Lundquist CJ, Ramsay D, Bell R, Swales A, & Kerr S. (2011). Predicted impacts of climate change on New Zealand's biodiversity. *Pacific Conservation Biology, 17*(3), 179–191. https://www.motu.nz/our-research/environment-and-resources/climate-change-impacts/predicted-impacts-of-climate-change-on-new-zealands-biodiversity

Lundquist CJ, Jones TC, Parkes SM, & Bulmer RH. (2018). Changes in benthic community structure and sediment characteristics after natural recolonisation of the seagrass *Zostera muelleri*. *Scientific Reports, 8*, 13250. https://doi.org/10.1038/s41598-018-31398-2

Lundquist D, Boren L, Childerhouse S, Constantine R, van Helden A, Hitchmough R, … & Baker CS. (2025). *Conservation Status of Marine Mammals in Aotearoa New Zealand, 2024.* New Zealand Threat Classification System Report 1165, prepared for the Department of Conservation. https://nztcs.org.nz/reports/1165

Macdonald H, Collins C, Plew D, Zeldis J, & Broekhuizen N. (2023). Modelling the biogeochemical footprint of rivers in the Hauraki Gulf, New Zealand. *Frontiers in Marine Science, 10*, e1117794. https://doi.org/10.3389/fmars.2023.1117794

MacGibbon DJ, Mules R, & Goode S. (2024). *Extent and Intensity of Bottom Contact by Commercial Trawling in New Zealand Waters, 1990–2022*. New Zealand Aquatic Environment and Biodiversity Report No. 344. Fisheries New Zealand. https://fs.fish.govt.nz/Doc/25805/AEBR-344-2024-Extent-and-intensity-of-bottom-contact-by-commercial-trawling-in-New-Zealand-waters-1990-2022.pdf.ashx

Mangan S, Bryan KR, Thrush SF, Gladstone-Gallagher RV, Lohrer AM, & Pilditch CA. (2020). Shady business: The darkening of estuaries constrains benthic ecosystem function. *Marine Ecology Progress Series*, *647*, 33–48. https://doi.org/10.3354/meps13410

Márquez-Borrás F, & Sewell MA. (2024). Long-term study of the combined effects of ocean acidification and warming on the mottled brittle star, *Ophionereis fasciata*. *Journal of Experimental Biology, 227*(21), e249426. http://dx.doi.org/10.1242/jeb.249426

Matheson FE, Reed J, Dos Santos VM, Mackay G, & Cummings VJ. (2017). Seagrass rehabilitation: Successful transplants and evaluation of methods at different spatial scales. *New Zealand Journal of Marine and Freshwater Research, 51*(1), 96–109. https://doi.org/10.1080/00288330.2016.1265993

Mattern T, Meyer S, Ellenberg U, Houston DM, Darby JT, Young M, … & Seddon PJ. (2017). Quantifying climate change impacts emphasises the importance of managing regional threats in the endangered yellow-eyed penguin. *PeerJ, 5*, e3272. https://doi.org/10.7717/peerj.3272

McCullough A, Strano F, Micaroni V, Woods L, & Bell JJ. (2024). Responses of the temperate calcareous sponge *Grantia* sp. to ocean acidification. *Journal of the Marine Biological Association of the United Kingdom, 104*, e54. http://dx.doi.org/10.1017/S0025315424000419

McDonald RA. (2022). *He Moana Pukepuke e Ekengia e te Waka: Navigating a Changing Climate: A Waka Voyaging Perspective.* [Master's thesis, University of Waikato.] https://hdl.handle.net/10289/15749

McGovern H. (2024). *Conservation Services Programme Annual Research Summary 2021–22*. Conservation Services Programme report, prepared for the Department of Conservation. https://www.doc.govt.nz/globalassets/documents/conservation/marine-and-coastal/marine-conservation-services/reports/202122-annual-plan/csp-annual-research-summary-2021-22.pdf

McGovern H, & Hewetson E. (2025). *Conservation Services Programme Annual Research Summary 2022–23*. Conservation Services Programme report, prepared for the Department of Conservation. https://www.doc.govt.nz/globalassets/documents/conservation/marine-and-coastal/marine-conservation-services/reports/202223-annual-plan/csp-annual-research-summary-2022-23.pdf

Mediodia HJ, Noy I, & Kahui V. (2024). The impact of ocean warming on selected commercial fisheries in New Zealand. *The Australian Journal of Agricultural and Resource Economics*, *68*(3), 587–607. https://doi.org/10.1111/1467-8489.12564

Meyer S. (2023). *Desktop Update of Estimation of Seabird Cryptic Mortality in Trawls, via Warp and Net Captures in the New Zealand Domestic Fleet Using Standard Mitigation*. New Zealand Aquatic and Biodiversity Report No. 322. Fisheries New Zealand. https://www.mpi.govt.nz/dmsdocument/59485-AEBR-322-Desktop-update-of-estimation-of-seabird-cryptic-mortality-in-trawls-via-warp-and-net-captures-in-the-New-Zealand-domestic-fleet-using-standard-mitigation/

MfE (Ministry for the Environment). (2024). *Coastal Hazards and Climate Change Guidance*. https://environment.govt.nz/assets/publications/Coastal-hazards-and-climate-change-guidance-2024-ME-1805.pdf

Micaroni V, Strano F, McAllen R, Woods L, Turner J, Harman L, & Bell JJ. (2022). Adaptive strategies of sponges to deoxygenated oceans. *Global Change Biology, 28*(6), 1972–1989.

Middleton I. (2023). *Impact of Exotic Caulerpa on Native Species at Aotea/Great Barrier Island – Field report (Trip 2).* NIWA Client Report No. 2023358AK, prepared for Biosecurity New Zealand. https://www.mpi.govt.nz/dmsdocument/61714-Impact-of-exotic-Caulerpa-on-native-species-at-AoteaGreat-Barrier-Island-Field-report-Trip-2/

Middleton I, Francis M, Aguirre JD, Struthers C, Trnski T, Duffy C, … & Liggins L. (2023). Occurrences of tropical, subtropical and rare marine fishes in Aotearoa New Zealand indicate biodiversity change. *Journal of Biogeography*, *50*(9), 1490–1504. https://doi.org/10.1111/jbi.14677

Minobe S, Behrens E, Findell KL, Loeb, NG, Meyssignac B, & Sutton R. (2025). Global and regional drivers for exceptional climate extremes in 2023–2024: Beyond the new normal. *Npj Climate and Atmospheric Science, 8*, 138. https://doi.org/10.1038/s41612-025-00996-z

Montie S, & Thomsen MS. (2023). Long-term community shifts driven by local extinction of an iconic foundation species following an extreme marine heatwave. *Ecology and Evolution, 13*(6), e10235. https://doi.org/10.1002/ece3.10235

Montie S, Thoral F, Smith RO, Cook F, Tait LW, Pinkerton MH, … & Thomsen MS. (2024). Seasonal trends in marine heatwaves highlight vulnerable coastal ecoregions and historic change points in New Zealand. *New Zealand Journal of Marine and Freshwater Research, 58*(2), 274–299. https://doi.org/10.1080/00288330.2023.2218102

Morgenstern O. (2021). The Southern Annular Mode in 6th Coupled Model Intercomparison Project Models. *Journal of Geophysical Research: Atmospheres*, *126*(5), e2020JD034161. https://doi.org/10.1029/2020JD034161

Morrisey DJ, Swales A, Dittmann S, Morrison MA, Lovelock CE, & Beard CM. (2010). The ecology and management of temperate mangroves (pp 43–160). In RN Gibson, RJA Atkinson, & JDM Gordon (Eds), *Oceanography and Marine Biology: An Annual Review.* Volume 48. https://www.taylorfrancis.com/chapters/edit/10.1201/EBK1439821169-2/ecology-management-temperate-mangroves-donald-morrisey-andrew-swales-sabine-dittmann-mark-morrison-catherine-lovelock-catherine-beard

Morrison MA, Lowe ML, Parsons DM, Usmar NR, & McLeod IM. (2009). *A Review of Land-based Effects on Coastal Fisheries and Supporting Biodiversity in New Zealand*. New Zealand Aquatic Environment and Biodiversity Report No. 37. Ministry of Fisheries. https://healthyharbour.org.nz/wp-content/uploads/2016/08/Morrison-et-al-2009-Land-based-effects-on-coastal-fisheries.pdf

Morrison MA, Jones EG, Consalvey M, & Berkenbusch K. (2014a). *Linking Marine Fisheries Species to Biogenic Habitats in New Zealand: A Review and Synthesis of Knowledge.* New Zealand Aquatic Environment and Biodiversity Report No. 130. Ministry for Primary Industries. https://deepwatergroup.org/wp-content/uploads/2015/11/GEN2015A19-7516259-AEBR-130-Linking-marine-fisheries-species-to-biogenic-habitats-in-New-Zealand.pdf

Morrison MA, Lowe ML, Grant CM, Smith PJ, Carbines G, Reed J, & Brown J. (2014b). *Seagrass Meadows as Biodiversity and Productivity Hotspots.* New Zealand Aquatic Environment and Biodiversity Report No. 137. Ministry for Primary Industries. https://webstatic.niwa.co.nz/library/NZAEBR-137.pdf

MPI (Ministry for Primary Industries). (2013). *Overview of Ecological Effects of Aquaculture*. https://www.mpi.govt.nz/dmsdocument/4300-Overview-of-ecological-effects-of-Aquaculture

MPI. (2021a). AEBAR 2019–20: Ecosystem effects: NZ climate and oceanic setting. In *New Zealand Climate and Ocean, Aquatic Environment and Biodiversity Annual Review* (Chapter 12). https://www.mpi.govt.nz/dmsdocument/42141-Chapter-12-NZ-Climate-and-Ocean-Aquatic-environment-and-biodiversity-annual-review-AEBAR-201920

MPI. (2021b). AEBAR 2019–20: Non-target fish and invertebrate catch – technical summary. In *New Zealand Climate and Ocean, Aquatic Environment and Biodiversity Annual Review*. (Chapter 9). https://www.mpi.govt.nz/dmsdocument/51676-Chapter-9-Non-target-fish-and-invertebrate-catch

MPI. (nd-a). *What Are Toxic Algal Blooms?* Retrieved 15 September 2025. https://www.mpi.govt.nz/fishing-aquaculture/recreational-fishing/where-unsafe-to-collect-shellfish/what-are-toxic-algal-blooms/

MPI. (nd-b). *National Survey of Recreational Fishers*. Retrieved 15 September 2025. https://www.mpi.govt.nz/fishing-aquaculture/recreational-fishing/national-survey-of-recreational-fishers

MPI. (nd-c). *About Exotic Caulerpa and Where It’s Been Found in NZ.* Retrieved 15 September 2025. https://www.mpi.govt.nz/biosecurity/exotic-pests-and-diseases-in-new-zealand/long-term-biosecurity-management-programmes/exotic-caulerpa-seaweeds-caulerpa-brachypus-and-caulerpa-parvifolia-in-new-zealand/about-exotic-caulerpa-and-where-its-been-found-in-nz/

MPI. (nd-d). *Bottom Trawling*. Retrieved 15 September 2025. https://www.mpi.govt.nz/fishing-aquaculture/sustainable-fisheries/strengthening-fisheries-management/bottom-trawling/

MPI. (nd-e). *Fish Stock Status*. Retrieved 15 September 2025. https://www.mpi.govt.nz/fishing-aquaculture/fisheries-management/fish-stock-status/

MPI. (nd-f). *Accidental Captures of Seabirds and Protected Marine Species by Commercial Fishers from 1 April to 30 June 2025*. Retrieved 15 September 2025. https://www.mpi.govt.nz/fishing-aquaculture/sustainable-fisheries/managing-the-impact-of-fishing-on-protected-species/seabirds-and-protected-marine-species-caught-by-commercial-fishers-quarterly-report/

Muznebin F, Alfaro AC, Venter L, & Young T. (2022). Acute thermal stress and endotoxin exposure modulate metabolism and immunity in marine mussels (*Perna canaliculus*). *Journal of Thermal Biology 110*, e103327. https://doi.org/10.1016/j.jtherbio.2022.103327

Neubauer SC, Franklin RB, & Berrier DJ. (2013). Saltwater intrusion into tidal freshwater marshes alters the biogeochemical processing of organic carbon. *Biogeosciences, 10*(12), 8171–8183. https://doi.org/10.5194/bg-10-8171-2013

Neverman AJ, Donovan M, Smith HG, Ausseil A-G, & Zammit C. (2023). Climate change impacts on erosion and suspended sediment loads in New Zealand. *Geomorphology*, *427*, e108607. https://doi.org/10.1016/j.geomorph.2023.108607

NIWA. (nd-a). *The Southern Annular Mode and New Zealand Climate*. Retrieved 15 September 2025. https://niwa.co.nz/climate-and-weather/southern-annular-mode

NIWA. (nd-b). *The Stormy Seas Project*. Retrieved 15 September 2025. https://niwa.co.nz/climate-and-weather/stormy-seas-project

NIWA. (nd-c). *Coastal Storm Inundation*. Retrieved 15 September 2025. https://niwa.co.nz/hazards/coastal-storm-inundation

Nixon SW, & Buckley BA. (2002). 'A strikingly rich zone': Nutrient enrichment and secondary production in coastal marine ecosystems. *Estuaries*, *25*, 782–796. https://doi.org/10.1007/BF02804905

Nodder S, Watson S, Davidson S, Frontin-Rollet G, & Woelz S. (2023). *Organic Carbon Stocks and Potential Vulnerability in Marine Sediments around Aotearoa New Zealand*. NIWA Client Report No. 2023162WN, prepared for the Parliamentary Commissioner for the Environment. https://pce.parliament.nz/media/cdoodc0l/niwa-organic-carbon-stocks-and-potential-vulnerability-in-marine-sediments-around-aotearoa-new-zealand.pdf

Nodder SD, Law CS, Behrens E, Bury SJ, Cristi A, Collins C, … & Zeldis, JR. (2025). Aotearoa New Zealand's marine carbon cycle in a changing climate: Current understanding and future directions. *New Zealand Journal of Marine and Freshwater Research, 59*(5), 913–956. https://doi.org/10.1080/00288330.2025.2461289

NZ SeaRise. (nd). *NZ SeaRise | Our Changing Coast*. Retrieved 15 September 2025. https://www.searise.nz/

O'Callaghan J, Stevens C, Roughan M, Cornelisen C, Sutton PJH, Garrett S, … & Macdonald H. (2019). Developing an integrated ocean observing system for New Zealand. *Frontiers in Marine Science, 6*(143), 1–7. https://doi.org/10.3389/fmars.2019.00143

Oginni TE, Renwick J, & Behrens E. (2025). Influence of the El Niño-Southern Oscillation on tropical cyclone genesis in the southwest Pacific. *International Journal of Climatology*, *45*(10), e8899. https://doi.org/10.1002/joc.8899

Parsons DM, Shirkey T, Chetham J, Milner D, & Bulmer, RH. (2024). Exploring the impact of multiple stressors on cultural and ecological values: A case study from Te Rerenga Parāoa (Whangārei Harbour), Aotearoa New Zealand. *Ocean & Coastal Management, 258*, e107422. https://doi.org/10.1016/j.ocecoaman.2024.107422

Paul-Burke K, O'Brien T, Burke J, & Bluett C. (2020). Mapping Māori knowledge from the past to inform marine management futures. *New Zealand Science Review, 76*(1–2), 32–41. https://hdl.handle.net/10289/14324

Paul-Burke K, Ngarimu-Cameron R, Burke J, Bulmer R, Cameron K, O'Brien T, … & Ranapia M. (2022). Taura kuku: Prioritising Māori knowledge and resources to create biodegradable mussel spat settlement lines for shellfish restoration in Ōhiwa harbour. *New Zealand Journal of Marine and Freshwater Research, 56*(3), 570–584. https://doi.org/10.1080/00288330.2022.2111447

Paulik R, Stephens S, Wadhwa S, Bell R, Popovich B, & Robinson B. (2019). *Coastal Flooding Exposure under Future Sea-level Rise for New Zealand*. NIWA Client Report No. 2019119WN prepared for The Deep South Challenge. https://deepsouthchallenge.co.nz/wp-content/uploads/2021/01/Exposure-to-Coastal-Flooding-Final-Report.pdf

PCE (Parliamentary Commissioner for the Environment). (2015). *Preparing New Zealand for Rising Seas: Certainty and Uncertainty*. https://pce.parliament.nz/publications/preparing-new-zealand-for-rising-seas-certainty-and-uncertainty/

Pinkerton M, Gall M, Throal F, Sutton P, & Wood S. (2023). *Monitoring Ocean Health: 2023 Update on Satellite Indicators for Surface Temperature, Productivity and Suspended Solids*. NIWA Client Report No. 2023217WN_rev1, prepared for the Ministry for the Environment. https://environment.govt.nz/assets/publications/monitoring-ocean-health.pdf

Pinkerton MH, Gall M, Thoral F, Sutton P, & Wood S. (2024). *Monitoring Ocean Health: Satellite Indicators for Surface Temperature, Productivity and Suspended Solids*. NIWA Client Report No. 2023217WN_rev2, prepared for the Ministry for the Environment. http://dx.doi.org/10.13140/RG.2.2.29646.27208

Plew DR, Zeldis JR, Dudley BD, Whitehead AL, Stevens LM, Robertson BM, & Robertson BP. (2020). Assessing the eutrophic susceptibility of New Zealand estuaries. *Estuaries and Coasts, 43*, 2015–2033. https://doi.org/10.1007/s12237-020-00729-w

PMCSA (Office of the Prime Minister's Chief Science Advisor). (2019). *Rethinking Plastics in Aotearoa New Zealand*. https://www.pmcsa.ac.nz/topics/rethinking-plastics/

PMCSA. (2021). *The Future of Commercial Fishing in Aotearoa New Zealand*. https://bpb-ap-se2.wpmucdn.com/blogs.auckland.ac.nz/dist/f/688/files/2020/01/Fish-report-Full-report-11March21.pdf

Rhodes LL, & Smith KF. (2022). *Review of the Potential Effects of Climate Change on Marine Harmful Algal Blooms (HABs): Implications for Public Health in Aotearoa New Zealand*. Cawthron Report No. 3758, prepared for the New Zealand Ministry of Health. https://www.phfscience.nz/media/jjldikd0/esr-environmental-health-report-climate-change-toxic-freshwater-cyanobacteria-review.pdf

Riebesell U, Körtzinger A, & Oschlies A. (2009). Sensitivities of marine carbon fluxes to ocean change. *Proceedings of the National Academy of Sciences of the United States of America*, *106*(49), 20602–20609. https://doi.org/10.1073/pnas.0813291106

Roberts JO, Webber DN, Roe WD, Edwards CTT, & Doonan IJ. (2019). *Spatial Risk Assessment of Threats to Hector's and Māui Dolphins* (Cephalorhynchus hectori). New Zealand Aquatic Environment and Biodiversity Report No. 214. Fisheries New Zealand. https://www.mpi.govt.nz/dmsdocument/35007-AEBR-214-Spatial-risk-assessment-of-threats-to-HectorsMaui-dolphins-Cephalorhynchus-hectori

Roberts JO, & Hendriks HR. (2022). *Potential Climate Change Effects on New Zealand Marine Mammals: A Review*. DOC Research and Development Series 366. Department of Conservation. https://www.doc.govt.nz/globalassets/documents/science-and-technical/drds366entire.pdf

Roe WD, Howe L, Baker EJ, Burrows L, & Hunter SA. (2013). An atypical genotype of *Toxoplasma gondii* as a cause of mortality in Hector's dolphins (*Cephalorhynchus hectori*). *Veterinary Parasitology, 192*(1–3), 67–74. https://doi.org/10.1016/j.vetpar.2012.11.001

Roe WD, Michael S, Fyfe J, Burrows E, Hunter SA, & Howe L. (2017). First report of systemic toxoplasmosis in a New Zealand sea lion (*Phocarctos hookeri*). *New Zealand Veterinary Journal, 65*(1), 46–50. https://doi.org/10.1080/00480169.2016.1230526

Rolton A, Rhodes L, Hutson KS, Biessy L, Bui T, MacKenzie L, … & Smith KF. (2022). Effects of harmful algal blooms on fish and shellfish species: A case study of New Zealand in a changing environment. *Toxins*, *14*(5), 341. https://doi.org/10.3390/toxins14050341

Rout M, Reid J, Bodwitch H, Gillies A, Lythberg B, Hikuroa D, … & Davies K. (2019). *Māori Marine Economy: A Review of Literature Concerning the Historical and Contemporary Structure of the Māori Marine Economy*. University of Canterbury report for Sustainable Seas. https://www.canterbury.ac.nz/content/dam/uoc-main-site/documents/pdfs/reports/ntrc-contemporary-research-division/M%C3%84_ori-marine-economy---Lit-Review.pdf

Rowley AF, Baker-Austin C, Boerlage AS, Caillon C, Davies CE, Duperret L, … & Coates CJ. (2024). Diseases of marine fish and shellfish in an age of rapid climate change. *iScience*, *27*(9), e110838. https://doi.org/10.1016/j.isci.2024.110838

Rudenko O, Angelucci C, Kumanan K, Delisle L, Carson J, Morrison RN, … & Barnes AC. (2025). Genomics and serotyping of *Tenacibaculum maritimum* outbreak isolates from Australia and New Zealand for guided vaccine development and stewardship. *Aquaculture*, *603*, e742418. https://doi.org/10.1016/j.aquaculture.2025.742418

Rullens V, Mangan S, Stephenson F, Clark DE, Bulmer RH, Berthelsen A, … & Pilditch CA. (2022). Understanding the consequences of sea level rise: The ecological implications of losing intertidal habitat. *New Zealand Journal of Marine and Freshwater Research*, *56*(3): 353–370. https://doi.org/10.1080/00288330.2022.2086587

Ryder FJ, Gnanalingam G, Pritchard DW, Rayment WJ, Scott NJ, & Hepburn CD. (2023). Drivers of fishery status for the cultural keystone pāua (*Haliotis iris*) in customary fishery protection areas in Aotearoa New Zealand. *Fisheries Research*, *261*, e106613. https://doi.org/10.1016/j.fishres.2023.106613

Safi K, Zeldis J, Tait L, Robinson K, Gall M, & Thompson K. (2022). Microplankton interactions with decadal-scale nutrient enrichment in a deep estuary, with implications for eutrophication

– related ecosystem stressors. *Estuaries and Coasts*, *45*, 2472–2491. https://doi.org/10.1007/s12237-022-01099-1

Salinger MJ, Renwick J, Behrens E, Mullan AB, Diamond HJ, Sirguey P, … & Sutton PJ. (2019). The unprecedented coupled ocean-atmosphere summer heatwave in the New Zealand region 2017/18: Drivers, mechanisms and impacts. *Environmental Research Letters, 14*(4), e044023. https://doi.org/10.1088/1748-9326/ab012a

Salinger MJ, Diamond HJ, Behrens E, Fernandez D, Fitzharris BB, Herold N, … & Trought MCT. (2020). Unparalleled coupled ocean-atmosphere summer heatwaves in the New Zealand region: Drivers, mechanisms and impacts. *Climatic Change, 162*, 485–506. https://doi.org/10.1007/s10584-020-02730-5

Salinger MJ, Diamond HJ, Bell J, Behrens E, Fitzharris BB, Herold N, … & Trought MCT. (2023) Coupled ocean-atmosphere summer heatwaves in the New Zealand region: An update. *Weather and Climate*, *42*(1), 18–41. https://doi.org/10.2307/27226713

Salinger MJ, Trenberth KE, Diamond HJ, Behrens E, Fitzharris BB, Herold N, … & Trought MCT. (2024). Climate extremes in the New Zealand region: Mechanisms, impacts and attribution. *International Journal of Climatology, 44*(16), 5809–5824. http://dx.doi.org/10.1002/joc.8667

Salmond NH, & Wing SR. (2022). Sub-lethal and lethal effects of chronic and extreme multiple stressors on a critical New Zealand bivalve under hypoxia. *Marine Ecology Progress Series, 703*, 81–93. http://dx.doi.org/10.3354/meps14215

Schallenberg M, Hall CJ, & Burns CW. (2003). Consequences of climate-induced salinity increases on zooplankton abundance and diversity in coastal lakes. *Marine Ecology Progress Series, 251*, 181–189. https://doi.org/10.3354/meps251181

Shah H, & Ramesh R. (2022). Development-aligned mangrove conservation strategy for enhanced blue economy: A successful model from Gujarat, India. *Estuarine, Coastal and Shelf Science, 274*, e107929. https://doi.org/10.1016/j.ecss.2022.107929

Shears NT, Bowen MM, & Thoral F. (2024). Long-term warming and record-breaking marine heatwaves in the Hauraki Gulf, northern New Zealand. *New Zealand Journal of Marine and Freshwater Research, 59*(5), 1678–1689. https://doi.org/10.1080/00288330.2024.2319100

Skipper A. (2018). Ka taki mai te māuru: When the nor'wester howls. *Te Karaka*, *78*. https://deepsouthchallenge.co.nz/research-project/forecasting-weather-and-climate-extremes/

Smith T. (2011). Traditional Māori Growing Practices: A Literature Review. Te Atawhai o te Ao.

Soliman T, & Inglis GJ. (2018). Forecasting the economic impacts of two biofouling invaders on aquaculture production of green-lipped mussels *Perna canaliculus* in New Zealand. *Aquaculture Environment Interactions*, *10*, 1–12. https://doi.org/10.3354/aei00249

Spyksma AJP, Miller KI, & Shears NT. (2024). Marine heatwave promotes population expansion of the invasive ascidian *Symplegma brakenhielmi*. *Biological Invasions, 26*, 1987–1995. http://dx.doi.org/10.1007/s10530-024-03296-4

Stats NZ. (2025a). *Environmental-economic Accounts: Data to 2023.* https://www.stats.govt.nz/information-releases/environmental-economic-accounts-data-to-2023/

Stats NZ. (2025b). *Tourism Satellite Account: Year ended March 2024.* https://www.stats.govt.nz/information-releases/tourism-satellite-account-year-ended-march-2024/

Steneck RS, Graham MH, Bourque BJ, Corbett D, Erlandson JM, & Estes JA. (2002). Kelp forest ecosystems: Biodiversity, stability, resilience and future. *Environmental Conservation, 29*(4), 436–459. https://doi.org/10.1017/S0376892902000322

Stephens SA, Bell RG, & Haigh ID. (2020). Spatial and temporal analysis of extreme storm-tide and skew-surge events around the coastline of New Zealand. *Natural Hazards and Earth System Sciences, 20*(3), 783–796. https://doi.org/10.5194/nhess-20-783-2020

Stewart M, Coe I, Taylor L, Watchorn C, & Simmons W. (2020). *Quick Pass Dune Vulnerability Assessment*. University of Canterbury report prepared for Christchurch City Council and Environment Canterbury. https://www.canterbury.ac.nz/content/dam/uoc-main-site/documents/pdfs/see-2023-geography-engagement-/Quick%20Pass%20Dune%20Vulnerability%20Assessment.pdf

Storey B, Kloppenburg N, Knox D, & Zammit C. (2025). *Estimated Number and Valuation of Residential Properties within Inundation/Flood Zones Impacted by Climate Change*. Climate Sigma report, prepared for the Ministry for the Environment. https://environment.govt.nz/assets/publications/5.-CLIMATE-SIGMA-FINAL-REPORT_16-JAN-2025.pdf

Sun D, Li F, Jing Z, Hu S, & Zhang B. (2023). Frequent marine heatwaves hidden below the surface of the global ocean. *Nature Geoscience, 16*, 1099–1104. https://doi.org/10.1038/s41561-023-01325-w

Sustainable Seas Challenge. (2024). *Te Pā o Tangaroa*: *Asserting Mana Moana in Customary Fisheries Management*. Report for Sustainable Seas National Science Challenge project, Huataukina o hapū e! https://www.sustainableseaschallenge.co.nz/tools-and-resources/te-p%C4%81-o-tangaroa/

Sutton PJH, Rickard GJ, & Roemmich DH. (2024). Southwest Pacific Ocean warming driven by circulation changes. *Geophysical Research Letters*, *51*(13), e2024GL109174. https://doi.org/10.1029/2024GL109174

Suyadi, Gao J, Lundquist CJ, & Schwendenmann L. (2019). Land-based and climatic stressors of mangrove cover change in the Auckland Region, New Zealand. *Aquatic Conservation: Marine and Freshwater Ecosystems, 29*(9), 1466–1483. https://doi.org/10.1002/aqc.3146

Swales A, Bell R, & Lohrer D. (2020). Estuaries and lowland brackish habitats. In C Hendtlass, S Morgan, & D Neale (Eds), *Coastal Systems & Sea Level Rise: What to Look for in the Future* (pp 55–64). New Zealand Coastal Society. https://ref.coastalrestorationtrust.org.nz/site/assets/files/9412/nz_coastal_society_special_publication_on_estuaries.pdf

Tait A. (2019). *Risk-exposure Assessment of Department of Conservation (DOC) Coastal Locations to Flooding from the Sea*. Science for Conservation Report 332. Department of Conservation. https://www.doc.govt.nz/globalassets/documents/science-and-technical/sfc332entire.pdf

Tait LW, Lam-Gordillo O, Lohrer AM, Townsend M, Douglas EJ, & Inglis GJ. (2023). Ecosystem function modified by an invasive species: Density and distance dependent changes in sediment characteristics, fluxes, and benthic communities. *Estuarine, Coastal and Shelf Science, 293*, e108526. https://doi.org/10.1016/j.ecss.2023.108526

Thompson K. (2022). *Valuing Coastal Blue-green Infrastructure: Development of a Dune System Assessment Methodology, Ōtautahi Christchurch, New Zealand*. [Master's thesis, University of Canterbury.] http://dx.doi.org/10.26021/14266

Thomsen MS, Mondardini L, Alestra T, Gerrity S, Tait L, South PM, … & Schiel DR. (2019). Local extinction of bull kelp (*Durvillaea* spp.) due to a marine heatwave. *Frontiers in Marine Science, 6*, e00084. https://doi.org/10.3389/fmars.2019.00084

Thomson T, Pilditch CA, Fusi M, Prinz N, Lundquist CJ, & Ellis JI. (2025). Vulnerability of labile organic matter to eutrophication and warming in temperate mangrove ecosystems. *Global Change Biology, 31*(2), e70087. https://doi.org/10.1111/gcb.70087

Thrush SF, Hewitt JE, Gladstone-Gallagher RV, Savage C, Lundquist C, O'Meara T, … & Pilditch C. (2021). Cumulative stressors reduce the self-regulating capacity of coastal ecosystems. *Ecological Applications, 31*(1), e02223. https://doi.org/10.1002/eap.2223

Tonkin + Taylor. (2024). *Bluecliffs Beach Road Papatotara, Southland: Preliminary Hazard and Geotechnical Assessment – October 2023*. Tonkin + Taylor report, prepared for Southland District Council. https://www.cdsouthland.nz/media/dqtnjwvq/2024-02-08-bluecliffs-report-tonkin-taylor.pdf

Trenberth KE, Cheng L, Pan Y, Fasullo J, & Mayer M. (2025). Distinctive pattern of global warming in ocean heat content. *Journal of Climate, 38*(9), 2155–2168. https://doi.org/10.1175/JCLI-D-24-0609.1

Tuck M, Dickson M, Ryan E, Ford M, & Konlechner T. (2024). A national scale coastal change dataset for Aotearoa New Zealand. *Data in Brief, 57*, e111104. https://doi.org/10.1016/j.dib.2024.111104

Turner S, & Schwarz A-M. (2006). *Management and Conservation of Seagrass in New Zealand: An Introduction*. Science for Conservation Report 264. Department of Conservation. https://www.doc.govt.nz/documents/science-and-technical/sfc264.pdf

Ummenhofer CC, Sen Gupta A, & England MH. (2009). Causes of late twentieth-century trends in New Zealand precipitation. *Journal of Climate*, *22*(1), 3–19. https://doi.org/10.1175/2008JCLI2323.1

UN (United Nations). (nd). *The Ocean – the World's Greatest Ally against Climate Change.* Retrieved 15 September 2025. https://www.un.org/en/climatechange/science/climate-issues/ocean

Underwood LH, van der Reis A, & Jeffs AG. (2023). Diet of snapper (*Chrysophrys auratus*) in green-lipped mussel farms and adjacent soft-sediment habitats. *Aquaculture, Fish and Fisheries, 3*(3), 268–286. https://doi.org/10.1002/aff2.113

Venegas RM, Acevedo J, & Treml EA. (2023). Three decades of ocean warming impacts on marine ecosystems: A review and perspective. *Deep-Sea Research Part II: Topical Studies in Oceanography, 212*, e105318. https://doi.org/10.1016/j.dsr2.2023.105318

von Ammon U, Casanovas P, Pochon X, Zirngibl M, Leonard K, Smith A, … & Zaiko, A. (2023). Harnessing environmental DNA to reveal biogeographical patterns of non-indigenous species for improved co-governance of the marine environment in Aotearoa New Zealand. *Scientific Reports, 13*, 17061. https://doi.org/10.1038/s41598-023-44258-5

Warnell K, Olander L, & Currin C. (2022). Sea level rise drives carbon and habitat loss in the U.S. mid-Atlantic coastal zone. *PLOS Climate, 1*(6), e0000044. https://doi.org/10.1371/journal.pclm.0000044

Wesselmann M, Apostolaki ET, & Anton A. (2024). Species range shifts, biological invasions and ocean warming. *Marine Ecology Progress Series, 728*, 81–83. https://doi.org/10.3354/meps14544