Our marine environment 2019

New Zealand's Environmental Reporting Series

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

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Cover photo: Above and below the water at the Mokohinau Islands, Hauraki Gulf. Credit: Lorna Doogan, Experiencing Marine Reserves.

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Credit: Lorna Doogan, Experiencing Marine Reserves

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Message to our readers

Aotearoa New Zealand is an island nation, so te moana – our marine environment – is central to our identity, the activities we enjoy and our prosperity. It provides for us in so many other ways too, for example, regulating the climate and absorbing pollutants. We have one of the largest areas of ocean in the world, so how we look after it makes a difference.

This report marks the beginning of the second cycle of environmental reporting, building on previous reports including Our marine environment 2016 and Environment Aotearoa 2019. It shines a light on the pressures and changes in the marine environment so we are equipped to make decisions to better safeguard it into the future.

Our marine environment 2019 examines the most pressing issues in our oceans, seas, harbours, and coastlines. Four priority marine issues have been selected for this report: biodiversity loss, activities on land, activities at sea, and climate change. Evidence supports that these are the areas most in need of attention and action for our oceans and coasts.

What this report shows is that our marine environment continues to experience pressure from the combined effects of our activities – both on land and in our oceans. In some areas, we are seeing improvements, for example, some marine species are back from near extinction and seabed trawling and dredging have decreased in the last 20 years. But in others, the data shows some of the effects are worsening, and faster than first thought. This is especially true of the impacts of climate change and pollution on our marine environment.

Some of the impacts of individual activities are obvious – the number of marine species caught as bycatch, for example – but it is the cumulative effect of many pressures that could present the biggest issues, and there is so much we still don't know. We know less about our coasts and oceans than any other environmental domain.

However, we are building a more complete picture all the time. For the first time, we have broadened our body of evidence to include citizen science and are increasing our use of mātauranga Māori. And improved satellite monitoring, especially in near-coast areas, allows us to better understand the impacts of climate change in our oceans.

The challenges our oceans face are complex and there are many ways we could tackle them. In some areas, positive change is already occurring. Iwi, the science community, industry, coastal managers, and communities have already begun to take steps to improve the health of the marine environment. New technology offers the potential to better monitor the marine environment cost effectively and improve our understanding of, and ability to manage, cumulative pressures.

While we have expanded the range of data used in this report, it is an ongoing journey to build knowledge on what matters most for environmental outcomes in Aotearoa. We hope it provides a basis for an open and informed conversation about what we have, what we are at risk of losing, and where we can make changes.

Vicky Robertson
Secretary for the Environment

Liz MacPherson
Government Statistician

Our marine environment at a glance

Photo credit: *Photo New Zealand*

Te moana, the coast and oceans of Aotearoa New Zealand, are central to our identity and intertwined with our history – we are a maritime nation. For Māori, te moana is a source of whakapapa.

We have one of the largest areas of ocean in the world. Our marine landscapes and habitats are diverse, supporting complex ecosystems and many unique species.

Our oceans support us. The marine economy added $7 billion to our economy in 2017 and employed more than 30,000 people. Healthy marine ecosystems provide essential benefits like taking up carbon dioxide, removing pollutants and providing kaimoana. In te ao Māori (the Māori world and worldview) the mauri, or life force, of a healthy moana enhances the mauri of those who interact with it.

This report summarises four priority issues for the marine environment and these issues mirror those we are also grappling with on land.

OUR NATIVE MARINE SPECIES AND HABITATS ARE UNDER THREAT

An estimated 30 percent of Aotearoa New Zealand's biodiversity is in the sea but many species are in trouble: very few marine species are assessed, but of these 22 percent of marine mammals, 90 percent of seabirds and 80 percent of shorebirds are threatened with, or at risk of, extinction. The number of identified, non-native species established here is rising and now totals 214. Many non-native species can spread rapidly and some affect native species and habitats.

Estuaries and living habitats, like seagrass meadows and kelp forests, provide marine life with the food and shelter they need to thrive. Many biogenic habitats are decreasing or under threat. A decline in the number of kuku (green-lipped mussel), from over 100 million in 2007 to less than 500,000 in 2016, was observed in Ōhiwa Harbour. Declining marine health makes our coasts and oceans less resilient to disturbances, including climate change.

OUR ACTIVITIES ON LAND ARE POLLUTING OUR MARINE ENVIRONMENT

Our activities on land, especially agriculture and forestry, and growing cities, increase the amount of sediment, nutrients, chemicals, and plastics that enter our coasts and oceans.

Inter-tidal sedimentation rates have generally increased and become highly variable since European settlement. In estuaries and harbours across the Waikato region, historical sediment accumulation rates were less than 0.5 millimetres per year. After European settlement, rates became unstable, reaching almost 200 times historical rates. Thick deposits of sediment can smother animals and degrade habitats.

Coastal water quality is variable but generally improving nationally although very site dependent. Some pollutants, like pharmaceuticals and cleaning products, end up in the marine environment and the impacts of this are not well understood. Plastic is found throughout the ocean including inside shellfish, fish, and birds. Seabirds and other animals that eat plastic can get sick or die. Citizen science data collected at 44 sites showed more than 60 percent of beach litter was plastic. Pollution affects our ability to harvest kaimoana, swim, and fish in our favourite local places.

OUR ACTIVITIES AT SEA ARE AFFECTING THE MARINE ENVIRONMENT

Our activities on coasts and in oceans like fishing, aquaculture, shipping, and coastal development, provide value to our economy and support growth.

Since 2009, the total commercial catch has remained stable at less than 450,000 tonnes per year. In 2018, 84 percent of routinely assessed stocks were considered to be fished within safe limits, an improvement from 81 percent in 2009. Of the 16 percent that were considered overfished, 9 stocks were collapsed.

Fishing has long-term and wide-ranging effects on species and habitats. The accidental capture (bycatch) of seabirds and marine mammals is decreasing but remains a significant pressure on some populations. Seabird deaths in the 2016/17 fishing year were estimated at 4,186. Seabed trawling and dredging have decreased in the last 20 years. About 24 percent of the fishable area has been trawled since 1990. Shallow areas are trawled more extensively than deeper areas, with varying impacts depending on fishing intensity, gear type, and vulnerability of habitat.

As an island nation, 99.5 percent of our imports and exports move by sea, and shipping traffic and vessel size has increased. Boat traffic is associated with the spread of non-native species and pollution and requires further construction of wharves and coastal infrastructure.

Most of our activities in the marine environment tend to increase in intensity towards the coast and, on top of the pressure from coastal development, this results in coastal environments being most impacted. Coastal waters tend to hold the greatest diversity of species.

CLIMATE CHANGE IS AFFECTING MARINE ECOSYSTEMS, TAONGA SPECIES, AND US

Global concentrations of atmospheric greenhouse gas are increasing because of activities like burning fossil fuels for heat, transport, and electricity generation. This is causing unprecedented change in our oceans.

The rate of sea-level rise has increased: the average rate in the past 60 years (2.44 millimetres per year) was more than double the rate of the previous 60 years (1.22 millimetres per year). Recent data suggests an even faster rate of sea-level rise. Extreme wave events may be becoming more frequent. Roads, bridges, coastal communities, and habitats are at risk from flooding and sea-level rise.

Our seas are warming. Satellite data recorded an average increase of 0.2° Celsius per decade since 1981. Years with an average temperature above the long-term average are more frequent. An unprecedented marine heatwave occurred in the Tasman Sea and near the Chatham Islands from November 2017 to February 2018 during our hottest summer on record.

Warmer seas affect the growth of even the smallest things in the ocean like plankton which can impact the whole food web. Some temperature-related changes in individual species and fish communities have been observed and tohu (environmental indicators that identify trends in the natural world) have changed.

Long-term measurements off the Otago coast show an increase of 7.1 percent in ocean acidity in the past 20 years. Oceans will continue to become more acidic as more carbon dioxide is absorbed. Shellfish, including oysters, pāua and mussels, are vulnerable to increasing ocean acidity and this poses a risk for the shellfish-farming industry.

ISSUES ARE NOT ISOLATED, BUT BUILD ON EACH OTHER AND CAUSE MORE HARM

The pressures associated with biodiversity loss, activities on land, our activities at sea, and climate change have many effects on coasts and oceans. These can interact and lead to cumulative effects. This is one of the most urgent problems we face in our oceans. Given the complexity of the marine environment and lack of long-term data, the nature of cumulative effects is difficult to predict.

This report looks at the individual and cumulative pressures on kuku (green-lipped mussel). This is illustrative only and helps to build a picture of what the messages in this report mean within the context of a single species. The ability to report on the impacts of changes in the marine environment on species and habitats is often limited by a lack of baseline data, understanding of tipping points, and connections between domains.

Working together across mātauranga Māori and other science disciplines is improving our holistic place-based knowledge that is crucial in understanding cumulative effects. For Māori the whenua and moana are inextricably linked and there is a complement or balance for everything on land in the oceans.

The complexity of our marine environment

Our marine environment is vast, diverse, and complex. It is impacted by our activities both on land and at sea. Here are some examples of the impacts from our activities.

Issue 1: Our native marine species and habitats are under threat

Marine species threatened with or at risk of extinction

Shorebirds (2016)
80%

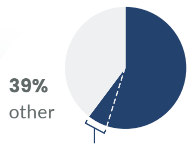
Seabirds (2016)
90%

Marine mammals (2019)
22%

An increasing number of non-native species detected, 2010–2017

Issue 2: Our activities on land are polluting our marine environment

Beach litter in New Zealand



Up to 200x

Increase of average annual sedimentation rates and variability in Waikato since Europeans arrived.

Issues interact and have cumulative effects on our marine environment

Issue 4: Climate change is affecting marine ecosystems, taonga species, and us

+2.44 mm

Average rate of sea-level rise per year between 1961 and 2018.

+0.2 °C

Average temperature increase per decade in New Zealand's coastal waters.

Issue 3: Our activities at sea are affecting the marine environment

>99%

The amount of New Zealand imports and exports transported by sea.

335,812 km²

The total trawled area in deepwater fisheries (1990–2016).

Follow the kuku story through the issues identified in the report.

Map data from NIWA (NODL 1.0), LINZ (CC BY 4.0), Ollivier & Co (CC BY 3.0)

What the marine environment means to New Zealanders

Photo credit: Photo New Zealand

Te moana is deeply embedded in our culture, identity, and history.* As an island nation, many of our ancestors arrived by waka and by boat. We are drawn to the coasts and approximately 65 percent of New Zealanders live within 5 kilometres of the sea. Much of our major infrastructure is close to the coast (OECD, 2019).

The Māori relationship with te moana is based on whakapapa and a long history of people who were astronomers, scientists, ocean navigators, fishers, and regulators. Before colonisation, the Māori economy was based on fishing and a comprehensive trading system. Advanced fishing methods were used – some nets used at Maketu in the Bay of Plenty were up to 1,900 metres long. In addition, the people of Muriwhenua in the Far North identified and named hundreds of fishing grounds within 25 miles offshore, including seasonal descriptions and the species present (Waitangi Tribunal, 1988).

As treaty partners, Māori have a role as kaitiaki of te moana and mātaitai (fish or food obtained from the sea). Kaitiaki are guardians who carry out the act of tiaki and look after, protect, and conserve the resource or taonga; kaitiaki can be a human, animal, or a spiritual being. This role and the close relationships that Māori have with the moana are acknowledged by the Crown and reflected in Treaty settlements and post-settlement agreements.

* In this report 'moana' describes a holistic view of our coasts and oceans, although it can have wider and narrower definitions.

OUR MARINE ENVIRONMENT IS VAST, DIVERSE, AND UNIQUE

New Zealand's exclusive economic zone (EEZ) extends from 12 to 200 nautical miles from the coast. It is one of the biggest in the world and 15 times larger than our land area. The coastline is estimated at 15,000 kilometres – one of the longest in the OECD – while our population is one of the smallest (LINZ, 2019; OECD, 2019).

As a long, narrow and isolated island nation, our marine environment has a high level of local variation. Ocean currents and diverse undersea landscapes also allow different communities to flourish. Local uniqueness and an extensive Pacific history is reflected in mātauranga Māori (the body of knowledge passed down from Māori ancestors, which includes worldviews, perspectives, and practices). Mātauranga Māori provides knowledge about changes in the environment across generations, and is strongly associated with a place. This pursuit and application of knowledge is continually adapted and incorporated into people's lives (Ataria et al, 2018; Hikuroa, 2017).

More than 17,000 species have been recorded in our EEZ and the marine environment accounts for up to 30 percent of Aotearoa New Zealand's biodiversity (Gordon et al, 2010). There is still much to learn about our marine biodiversity and its ecosystems. More than 4,000 currently known species have not yet been studied in detail and new species are discovered regularly. The number of known fish species increases by about 20 species per year and about half of these are new to science (Gordon et al, 2010).

OUR MARINE ENVIRONMENT SUPPORTS OUR MAURI AND WELLBEING

When the mauri (life force and essential quality and vitality of living things) of the moana is healthy it enhances the mauri of humans who are in contact with it. In te ao Māori (the Māori world and worldview) people are spiritually connected with the oceans, waitai (water from the sea), and with species and elements of the moana. Waitai also spiritually cleanses and heals wairua (the spirit or soul of a person).

Conversely, an unhealthy mauri has a destructive effect on our mauri. An unhealthy marine environment affects our physical, mental, and spiritual health. It also impacts Māori ability to manaaki tangata (provide hospitality and generosity to others), including providing food for people and guests. This can affect the mana of both giver and receiver of manaaki.

Healthy marine ecosystems provide other essential benefits (or ecosystem services) that are not easy to measure. Some benefits include climate regulation, as oceans take up carbon dioxide, and seagrasses or mussel beds providing shelter for young fish (Geange et al, 2019).

Our marine environment supports our economy and provides jobs, especially in shipping, fishing and aquaculture, and offshore minerals. In 2017, New Zealand's marine environment was estimated to add at least $7 billion to our economy (Stats NZ, 2019a). This estimate does not cover some sectors of the marine economy like research or education.

Current estimates of the value of the marine economy do not take into account the non-market value of the marine environment, or count the cost of environmental degradation caused by our activities.

Purpose of *Our marine environment 2019*

REPORTING UNDER THE ENVIRONMENTAL REPORTING ACT 2015

Under the Environmental Reporting Act 2015 (the Act), the Secretary for the Environment and the Government Statistician must produce regular reports on the state of our environment.

Under the Act, a report on a domain (marine, freshwater, land, air, and atmosphere and climate) must be produced every six months and a whole-of-environment (or synthesis) report every three years. Each domain report has now been published once (see Environmental reporting series for the full list). The most recent synthesis report, Environment Aotearoa 2019, was published in April 2019. The previous marine report was Our marine environment 2016.

Our marine environment 2019 begins the second cycle of domain reporting. It updates Environment Aotearoa 2019 and Our marine environment 2016 by presenting new data and insights.

As required by the Act, state, pressure, and impact are used to report on the environment. The logic of the framework is that **pressures** cause changes to the **state** of the environment and these changes have **impacts**. The report describes impacts on ecological integrity, public health, economy, te ao Māori, culture, and recreation to the extent that is possible with the available data.

Suggesting or evaluating any responses to environmental impacts is out of scope under the Act. Therefore, this report does not cover the work that organisations and communities are doing to mitigate the issues. It does provide an update on the most recent data about the state of the marine environment. The evidence in this report is a basis for an open and informed conversation about what we have, what we are at risk of losing, and where we can make changes.

A FOCUS ON WHAT MATTERS

When reviewing *Environment Aotearoa 2015*, the Parliamentary Commissioner for the Environment suggested structuring future synthesis reports according to issues, where an issue is defined as:

> *...a change in the state of the environment that is (at least partly) caused by human activities (pressures) and has consequences (impacts).*

Taking a whole system approach, *Environment Aotearoa 2019* identified nine priority environmental issues facing New Zealand (table 1).

Four criteria were established to identify and help describe the sense of significance and urgency of the issue:

Spatial extent and scale – how much of New Zealand is affected by the issue?

Departure from natural conditions – is the issue increasing in scale and/or distribution or accelerating?

Irreversibilty and lasting effects of change – how hard is it to fix?

Scale of effect on culture, recreation, health, and economy – how much does it affect the things we value?

This report provides more in-depth information about how the issues in *Environment Aotearoa 2019* relate to the marine environment. It focuses on four priority issues identified using the criteria described above.

Table 1 (overleaf) has more detail about each issue.

This is not an exhaustive list of all the issues our marine environment faces. Some issues have an impact on the marine environment but are not featured as they do not rank as highly against the criteria as other issues.

For each issue, this report addresses four questions:

- Why does this issue matter?
- What is the current state of this issue and what has changed?
- What has contributed to this issue?
- What are the consequences of this issue?

The final section describes how the effects associated with the four issues overlap and interact in local environments, resulting in cumulative effects. This can sometimes offset impacts but more often results in new or increased impacts. To demonstrate this we have woven the story of kuku (or kūtai), the New Zealand green-lipped mussel, through each issue. Kuku are an important traditional food source for Māori and considered a significant taonga (treasured object, resource, idea, or technique).

Our marine environment 2019 also describes significant gaps in our knowledge that, if filled, would improve our ability to respond to the issues identified in this report.

Table 1: How issues covered in this report relate to the themes and issues identified in Environment Aotearoa 2019

THEMES FROM EA2019	*Environment Aotearoa 2019* (EA2019) identified nine priority environmental issues across all domains. ISSUE	*Our marine environment 2019* (this report) discusses four priority environmental issues in the marine domain. ISSUE	NEW DATA AND INSIGHTS SINCE EA2019
Our ecosystems and biodiversity	1. Our native plants, animals and ecosystems are under threat	1. Our native marine species and habitats are under threat	New data on: ▸ first review of the state of key biogenic habitats using nationally-available data ▸ conservation status of marine mammals ▸ non-native species
How we use our land	2. Changes to the vegetation on our land are degrading the soil and water 3. Urban growth is reducing versatile land and native biodiversity	2. Our activities on land are polluting our marine environment	New data on: ▸ beach litter ▸ broadened body of evidence for water quality and sediment
Pollution from our activities	4. Our waterways are polluted in farming areas 5. Our environment is polluted in urban areas		
How we use our freshwater and marine resources	6. Taking water ecosystems changes flows which affects our freshwater 7. The way we fish is affecting the health of our ocean environment	3. Our activities at sea are affecting the marine environment	New data on: ▸ fish stocks ▸ bycatch ▸ marine economy
Our changing climate	8. New Zealand has high greenhouse gas emissions per person 9. Climate change is already affecting Aotearoa New Zealand	4. Climate change is affecting marine ecosystems, taonga species, and us	New data on: ▸ sea-level rise ▸ ocean and coastal sea-surface temperature ▸ ocean acidification ▸ ocean and coastal extreme waves ▸ primary productivity
		All our activities put cumulative stress on the marine environment	

INFORMATION FOR THIS REPORT COMES FROM MANY SOURCES

Data, upon which this report is based, came from many sources including Crown research institutes, central government, and regional councils. Further supporting information was provided using a 'body of evidence' approach. This is defined as peer reviewed, published literature, and data from reputable sources. This also includes mātauranga Māori and observational tools used to identify changes in an ecosystem.

These signs and signals of the natural world, ngā tohu o te taiao or tohu, are often referred to as environmental indicators. Māori environmental practitioners use them to identify trends or changes in the state or health of marine environments, for example stingrays as an indicator of seabed health (Faulkner & Faulkner, 2017). Data related to the sustainability of fisheries was sourced from recently published literature like the *2018 Aquatic Environment and Biodiversity Annual Review* (Ministry for Primary Industries, 2019).

All the data used in this report, including references to scientific literature, was corroborated and checked for consistency. The report was reviewed by a panel of independent scientists. The indicators related to the marine environment and the date they were last updated is available in the Environmental reporting series.

SUPPORTING INFORMATION IS AVAILABLE

This report is supported by other products that are published by the Ministry for the Environment and Stats NZ:

- Environmental Indicators: Marine – summaries, graphs, interactive maps, and data that are relevant to the state, pressures, and impacts on the marine environment.
- Data tables are available on the Ministry for the Environment's data server, and technical reports on the Ministry for the Environment's website.

ISSUE 1

Our native marine species and habitats are under threat

Photo credit: Lorna Doogan

A diverse range of species and complex, healthy habitat can help ecosystems be more resilient to climate change and other disturbances. Many of our marine species are considered taonga – of cultural significance and importance to Māori.

Report focus: marine mammals, seabirds, shorebirds, non-native species (non-indigenous), and biogenic habitats.

Why does this issue matter?

SPATIAL EXTENT

All of New Zealand's marine environments are affected. Many species face an increased risk of extinction and a reduced extent of habitats. Climate change will alter where many species are found.

DEPARTURE FROM NATURAL CONDITIONS

There are major declines in habitat condition since European settlement. Some species are no longer found in the areas where they once lived.

IRREVERSIBILITY

Many changes are slow to reverse and some are irreversible. Only some habitats and species recover quickly from disturbance or depletion.

IMPACTS ON WHAT WE VALUE

It can have significant impacts on our wellbeing, identity, and cultural values. Iwi relationships with rohe moana will be affected.

What is the current state of this issue and what has changed?

Updated or new in *Our marine environment 2019*

Review of New Zealand's key biogenic habitats.

Conservation status of indigenous marine species.

Marine non-indigenous (non-native) species indicator updated.

MOST ASSESSED NATIVE MARINE SPECIES ARE THREATENED

The conservation status of 675 native marine species has been established (figure 1), although this is only a fraction of the total number of species thought to exist in our marine environment (see indicator: Conservation status of indigenous marine species).

Nearly half of the world's cetacean species (whales, dolphins, and porpoises) have been recorded in New Zealand waters (Gordon et al, 2010).

Based on the 2019 New Zealand assessment, 10 out of 45 (22.2 percent) assessed species of marine mammals are threatened with, or at risk of, extinction. The most threatened species are Māui dolphin, Bryde's whale, southern elephant seal, and orca.

The conservation status of marine mammals was previously assessed in 2013. Since then, the status of southern right whale and the New Zealand sea lion have improved (table 2). For other marine mammals, there is insufficient data to determine with certainty whether the conservation status changed between 2013 and 2019.

Thirty assessed species of marine mammals are classified as data deficient (Baker et al, 2019). Knowledge about some species is growing, for example a new population of blue whale was recently identified in the Taranaki Bight (Barlow et al, 2018).

Seabirds are ranked the world's most threatened birds by the International Union for Conservation of Nature (IUCN). Nearly a quarter of all seabird species breed in New Zealand and 10 percent only breed here (Croxall et al, 2012; Taylor, 2000). However, little information is available about their population numbers and breeding sites (Whitehead et al, 2019).

The most recent New Zealand conservation status assessment in 2016 found that 90 percent of seabirds and 80 percent of shorebirds were threatened with, or at risk of, extinction. Since 2012, two seabirds (Campbell Island mollymawk and yellow-eyed penguin/hoiho) declined in status, while two shorebirds (northern New Zealand dotterel and pied stilt/poaka) improved.

Assessing the risk of species extinction

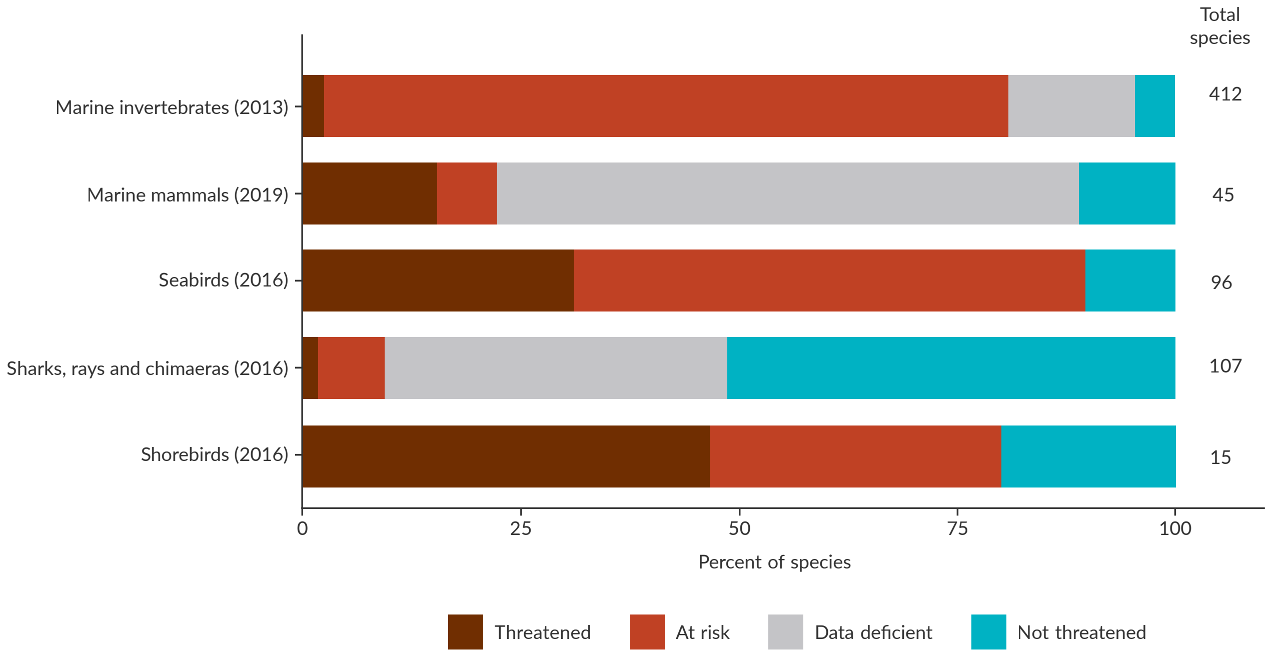
The New Zealand Threat Classification System (NZTCS) is used to assess the risk of extinction of New Zealand species. Not all native species are assessed because the available data is limited.

Expert panels determine the conservation threat status using population factors, including the number of breeding pairs, past and predicted changes in population, and pressure from human-induced effects.

Species can be:

- **threatened:** high risk of extinction in the immediate to medium term
- **at risk:** not considered to be threatened but could quickly become so if declines continue or a new threat arises
- **not threatened:** no current threat
- **data deficient:** not enough information about the populations in New Zealand to determine the conservation status.

Figure 1: Conservation status of native marine species



Note: Total species in the figure refers to the total number assessed. For marine invertebrates, the 412 species assessed are likely to represent less than 5 percent of the total number of existing species.

Table 2: Change in conservation status of marine mammals

Species	2013 assessment	2019 assessment	Reason for change
Change in conservation status within the same threat category			
New Zealand sea lion	Threatened (nationally critical)	Threatened (nationally vulnerable)	Actual improvement
Hector's dolphin	Threatened (nationally endangered)	Threatened (nationally vulnerable)	More knowledge
Change in threat category			
Leopard seal	Non-resident native (vagrant)	At risk (naturally uncommon)	More knowledge – now known to live here
False killer whale	Not threatened	At risk (naturally uncommon)	More knowledge – now known to live here
Southern right whale	Threatened (nationally vulnerable)	At risk (recovering)	Actual improvement

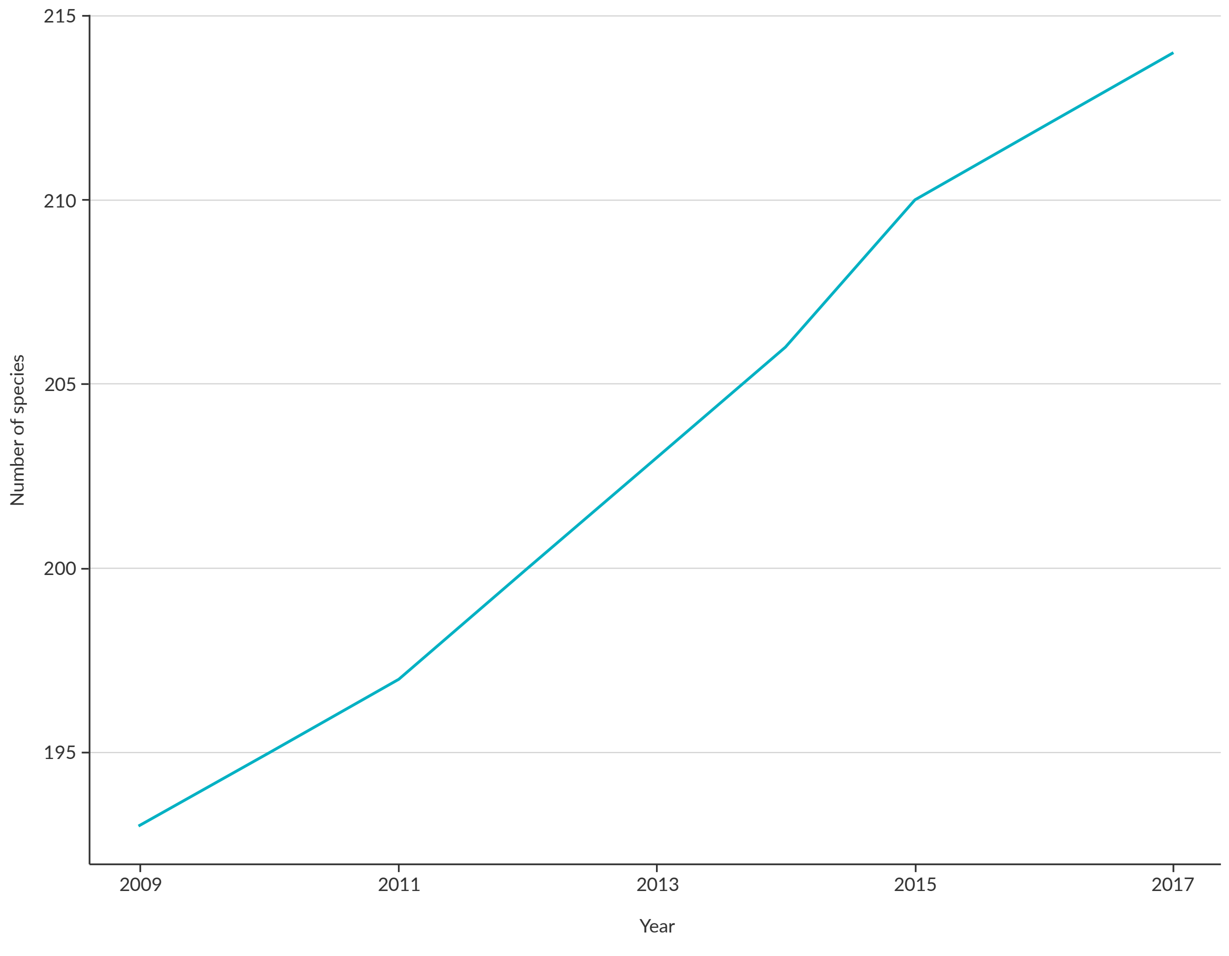
Note: A group of 18 taxa that had previously been assessed (5 Not Threatened, 6 Migrant and 7 Vagrant) are now listed as data deficient because the assessment panel agreed there was insufficient data to support the previous assessments.

MORE NON-NATIVE SPECIES ARE FOUND IN NEW ZEALAND WATERS

Non-native, marine species are being introduced to New Zealand continually, usually carried by ballast water or on the hulls of ships (see Our marine environment 2016). Between 2010 and 2017, 43 percent of the non-native, marine species detected in New Zealand had established populations here and were living on permanent surfaces like rocks and piers (figure 2).

The number of established non-native, marine species has increased at a generally consistent rate since baseline surveys and a national review were completed in 2009. We now have 214 non-native, marine species living (and considered to be established) in our waters (see indicator: Marine non-indigenous species). Three more non-native marine species have established in New Zealand since *Our marine environment 2016* was published.

Figure 2: Cumulative number of non-indigenous species established since the 2009 baseline



Data source: (Seaward & Inglis, 2018)

Note: At the 2009 baseline, 193 non-native species were already established.

Once established, some non-native, marine species can spread very quickly due to their tolerance to changing environmental conditions, fast growth rates, or other factors. For example:

- *Undaria pinnatafida* (a brown seaweed) has continued to spread even in areas from where it is being actively removed. Efforts to eradicate a small infestation in Fiordland failed in 2017 when it was discovered to have spread further (South et al, 2017). *Undaria* is now so well established it has been approved for commercial harvesting for fertiliser and food to help manage its abundance (Ministry for Primary Industries, 2011).
- The ascidian (sea squirt) *Puyra doppelgangera* recently arrived in New Zealand, where it outcompetes the green-lipped mussel for space. This has consequences for species that are dependent on mussel beds, and for cultural and recreational harvests. *P. doppelgangera* is well established in Northland and spreading southwards (Davis et al, 2018).
- The Indo-Pacific acidian was first detected in Whāngārei Harbour in 2015. By 2016, it had spread to Waitematā Harbour and, by 2017, it was found extensively from Beach Haven in the northwest to Hobson Point in the southeast. This species spreads rapidly, particularly in summer (see indicator: Marine non-indigenous species).

THE AREA OF BIOGENIC HABITAT HAS DECLINED

In contrast to non-living habitats like rocks and sand, biogenic habitats are created by plants and animals. Biogenic habitats play a crucial role in enhancing biodiversity by providing ecosystem services. Examples of their benefits include a mussel bed providing shelter to juvenile fish or seagrass meadows removing and storing carbon dioxide from the atmosphere. Biogenic habitats, however, are vulnerable because they protrude from the seabed and are fragile.

The available data shows that, although some biogenic habitats are increasing in extent (mangroves for example), most are declining (table 3).

Figure 3: Spread of the non-native Indo-Pacific ascidian in Waitematā Harbour between 2016 and 2017. Observations from 2016 are coloured green and from 2017 are orange. (Marine Biosecurity Porthole, nd)

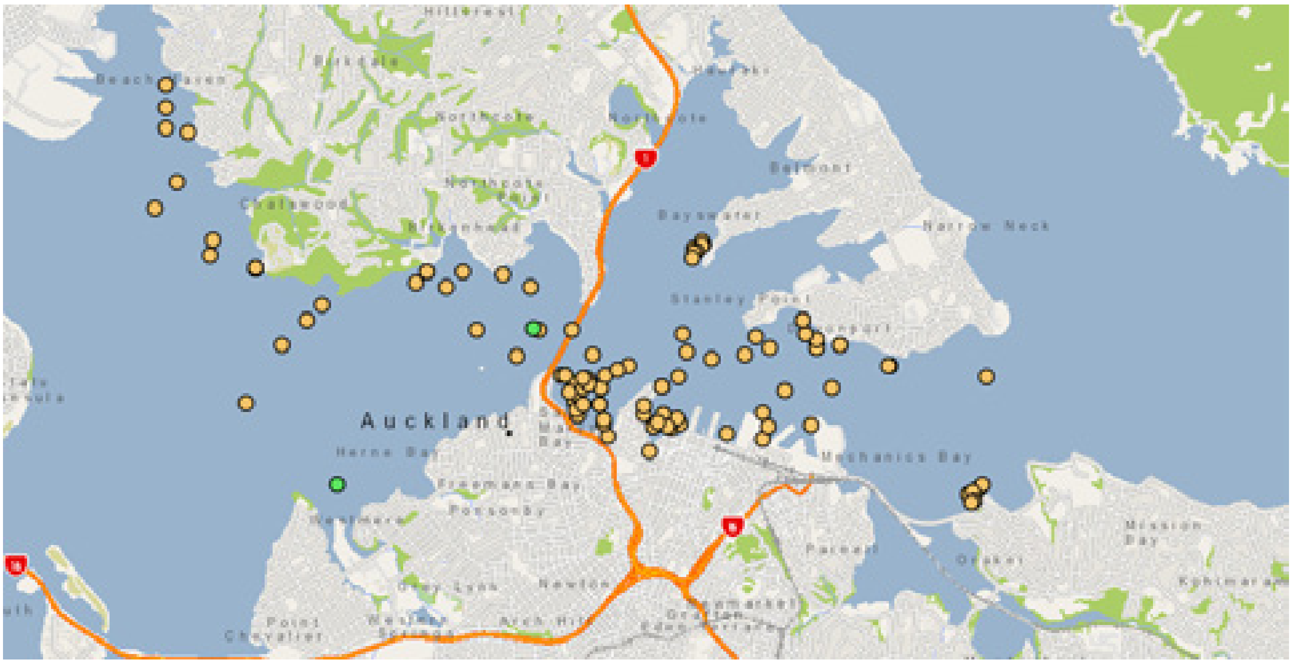


Table 3: Summary of the state of seven key biogenic habitats based on a synthesis of the best available data. For more information see (Anderson et al, 2019).

Key: Arrow direction represents national extent increasing ⬆, decreasing ⬇, stable ~.

Biogenic habitat	Examples of services provided	Distribution in New Zealand	Change in national extent	Confidence in data	Future prediction for national extent
Seagrass meadows	High primary productivity, nutrient cycling, nursery habitat provision	Widespread, particularly in estuaries and harbours	⬇	Good to moderate	~ **or** ⬆
Mangrove forests	Sediment trapping, erosion protection, wave buffering, habitat provision	Upper half of the North Island	⬆	Good	⬆
Kelp forests	Primary production, carbon sequestration, buffering waves, habitat provision, food, and refuges	Widespread, including offshore islands	~	Good	~ **vulnerable**
Bryozoan thickets	Carbon sequestration Habitat provision	Widely dispersed	⬇	Moderate to low	⬇
Stony coral	Biodiversity hotspots in the deep ocean, habitat provision, nursery areas, and refuges for species	Widespread, particularly in deeper ocean and around offshore islands and seamounts	~ **or** ⬇	Good to moderate	~ **or** ⬇
Beds of large shellfish	Filtration, sediment management, nutrient processing, hard habitat provision (on otherwise soft sediments), nursery habitat provision	Widespread on coastline	**Generally** ⬇	Good to moderate	**Generally** ⬇
Calcareous tubeworm mounds	Biodiversity hotspots, habitat provision	As far north as the Hauraki Gulf to Stewart Island	~	Good	~ **or** ⬇

The scale of change and amount of habitat loss is a significant knowledge gap, due mainly to the cost of monitoring habitats (especially those that are under water). However, many organisations are mapping these habitats and the services they provide. A recent collaboration between Marlborough District Council, NIWA, and Land Information New Zealand found extensive but previously unknown kelp forests in Tory Channel (Marlborough District Council, nd).

Te Rūnanga o Ngāti Awa initiated repeated surveys of sub-tidal kuku reefs in Ōhiwa Harbour. It used data from mātauranga Māori interviews as the baseline for establishing their historical distribution and for further surveys. Two of the three traditional kuku beds on the eastern side of the harbour had gone. On the western side, a decline was observed from an estimated 112 million kuku in 2007 to 485,000 in 2016, representing an 88 percent decline in area. In 2009, 1.2 million pātangaroa (eleven-armed seastar), a significant predator of kuku, were also observed for the first time (Paul-Burke et al, 2018). The causes of these changes are not known.

An appreciation for the value that estuaries provide (see box Estuaries: sensitive spaces that link land and sea) and our understanding of estuarine health is growing.

What has contributed to this issue?

The changes and declines in our native species and habitats are not due to a single pressure and its effects, but the combination of:

- what we do on land (see Our activities on land are polluting our marine environment)
- what we do in the sea (see Our activities at sea are affecting the marine environment)
- the pervasive pressure from climate change (see Climate change is affecting marine ecosystems, taonga species, and us).

These interactions can accelerate the degradation and loss of our native species and habitats (see All our activities put cumulative stress on the marine environment).

Further impacts on marine biodiversity and habitats are the result of historical activities, like the first conversions of land from native forest, early exploitation and localised depletion of coastal kaimoana, and the industrialisation of fishing. Many of these legacy impacts remain apparent today.

Estuaries: sensitive spaces that link land and sea

The mixing of fresh and salty water where rivers meet the sea makes estuaries dynamic ecosystems. They contain species that thrive in these challenging conditions and can survive the changes wrought by tides, floods, and storms. Throughout history, these productive environments have been valued as sources of food.

Estuaries receive water, nutrients, and sediment from a whole catchment. In a healthy estuary, nutrients from the land are beneficial and enrich the environment for birds, fish, and other species. They also act as buffer zones and protect coastal areas from floods and storms.

Many activities take place around estuaries such as the provision of food (eg, fish and shellfish), recreation, and cultural practices (Thrush et al, 2013).

All the activities that take place upstream, including farming, forestry, and urban development, influence an estuary. Estuaries are able to trap and filter out pollutants in freshwater before it enters the ocean. However, if an estuary is overloaded with nutrients, sediment and pollutants, its health as well as its benefit to us, can be compromised (Thrush et al, 2013).

Mahinga kai (places where food is extracted or produced) is an important cultural health indicator for many hapū and iwi. A study of four estuaries in Canterbury (including Avon-Heathcote and Rakahuri-Saltwater Creek) found experienced shellfish harvesters changed their cultural practices when they noticed poorer environmental conditions (Kainamu-Murchie et al, (Ngāi Tahu), 2018).

A recent assessment of 48 lower North Island estuaries found some sites contained rare ecosystems and many supported high numbers of threatened and at-risk species. The 21 sites that were identified as having high restoration potential were less modified or had existing populations or fragments of habitat to build on (Todd et al, 2016).

New Zealand has more than 400 estuaries that are very different in their size, shape, and exposure to the sea (Hume et al, 2007). While some are overlooked or in a poor state, there are opportunities to maintain and enhance their health and value.

What are the consequences of this issue?

ECOSYSTEMS ARE WIDELY AFFECTED BY CHANGES IN SPECIES

Lower levels of biodiversity can reduce an ecosystem's resilience to pressures, including climate change (Oliver et al, 2015; Thrush et al, 2011). The decline of one species can also change interactions in food webs and cause cascading effects through an ecosystem.

One example is the relationship between kelp, kina, and snapper. Snapper eat kina, and kina eat kelp. Therefore, areas with low numbers of snapper can have more kina and less kelp, or be devoid of kelp (called kina barrens). This, in turn, affects the many species that depend on kelp for food and habitat (Shears & Babcock, 2002).

HABITAT DEGRADATION HAS FAR-REACHING CONSEQUENCES FOR ECOSYSTEMS

Healthy habitats are essential for healthy ecosystems. They provide food, refuge (especially for juveniles), and take up contaminants. If habitats are lost or degraded, the feeding, breeding, and migration behaviours of species are threatened. As well as direct impacts on species, the loss of biogenic habitats also results in the loss of wider ecosystem benefits (Sunday et al, 2017). Not all the consequences that habitat degradation can have on ecosystems are known.

Dense beds of shellfish filter water and hold sediment, contributing to improved water quality and providing habitat for other species. Kuku (green-lipped mussel) are common on coastal reefs, rocky shores, and mussel farms. Historically, they were also once a dominant habitat growing on soft sediments in areas like the Firth of Thames, Hauraki Gulf, and the Kaipara Harbour. By the end of the 1970s, they were considered mostly ecologically extinct from soft sediment environments and do not provide the same ecosystem benefits (Anderson et al, 2019). For example, an estimated 107 million mussels were lost in less than 10 years from a prized taonga bed in Okiwa Harbour in the Marlborough Sounds. About 500 square kilometres of kuku beds in the Firth of Thames were also lost (Anderson et al, 2019).

It has been estimated that with the historic coverage of mussel beds, the volume of the Firth could have been filtered in a single day. Current estimates are that remnant mussel beds take nearly two years to filter the same amount of water. Patches of kuku beds in the Bay of Plenty and the Hauraki Gulf supported invertebrate densities two to eight times higher than bare seabed and showed higher diversity of species (Mcleod, 2009).

LOSS OF HABITATS AND BIODIVERSITY CHANGE OUR RELATIONSHIP WITH THE MARINE ENVIRONMENT

Many species that are classified as threatened or at risk, are culturally significant to New Zealand and especially Māori (Ataria et al, 2018; Department of Conservation, nd).

Changes in marine biodiversity can affect how we value the ocean, and compromise the marine activities we enjoy like boating, fishing, and swimming (United Nations, 2016). The loss or decline of our iconic and taonga species can negatively affect traditional harvesting practices (mahinga kai) and the intergenerational transfer of mātauranga Māori and kaitiakitanga (Faulkner & Faulkner, 2017). In an analysis of 3,421 whakataukī (short phrases or proverbs that share intergenerational knowledge), 57 marine species were named. Koura (lobster), parāoa (sperm whale), ururoa (great white shark), and pipi were mentioned the most frequently (Whaanga et al, 2018). This illustrates an in-depth knowledge and connection with the marine environment.

Traditional ways of managing and protecting marine species and places for present and future generations could also be lost. This jeopardises the ability of communities to harvest species of traditional value and the ability to manaaki tangata.

Globally, traditional knowledge accumulated over tens of thousands of years and held by indigenous cultures is being forgotten. This includes important knowledge related to fishing methods, the uses of particular species like medicinal plants, and a vast array of spiritual and religious beliefs (United Nations Economic and Social Council, 2019).

Changes can also be costly. District councils, central government, industry, and tangata whenua spent more than $310,000 on managing the non-native Mediterranean fanworm at the top of the South Island alone during 2017 and 2018 (The Lawless Edge Ltd, 2018). Other non-native species could pose a threat to Marlborough's aquaculture industry. Studies have estimated the potential economic impacts from the spread of the sea squirt *Styela clava* could reach $47.8 million per year (Goldson et al, 2015).

Loss or degradation of habitats can decrease the benefits we receive from marine habitats in our estuaries and oceans (Anderson et al, 2019; Diaz & Rosenberg, 2008; Thrush et al, 2001).

The benefits we receive from marine habitats are many and diverse but include:

- Mitigating the effects of climate change: Habitats like mangroves, seagrass meadows, and kelp capture and sequester carbon. They can also act as buffers to more extreme weather events (Duarte, 2017; Duarte & Krause-Jensen, 2017; Fourqurean et al, 2012; Mcleod et al, 2011).
- Removing sediment and pollutants: Mangrove forests hold sediment and reduce coastal erosion. This reduces nutrient inputs into estuaries and the ocean and improves water quality for harvesting food, diving, and swimming.
- Providing nursery habitat: Seagrass meadows are important nursery habitats for taonga species such as snapper, and a food source for many species. Seagrass health is linked to juvenile fish abundance (Morrison et al, 2014; Parsons et al, 2013).

There is insufficient data to quantify how much these benefits have changed over time.

Habitats provide services that go some way to mitigating the impacts of our activities, but this is finite. The interactions between species, and the interactions between species and the environment, are complex and cumulative. For example, mussels that are stressed by accumulated sediment may be more susceptible to competition from other species.

How ecosystem pressures affect kuku

Kuku beds significantly declined in soft sediment environments due to legacy pressures, especially prior to the 1980s.

Decline of species

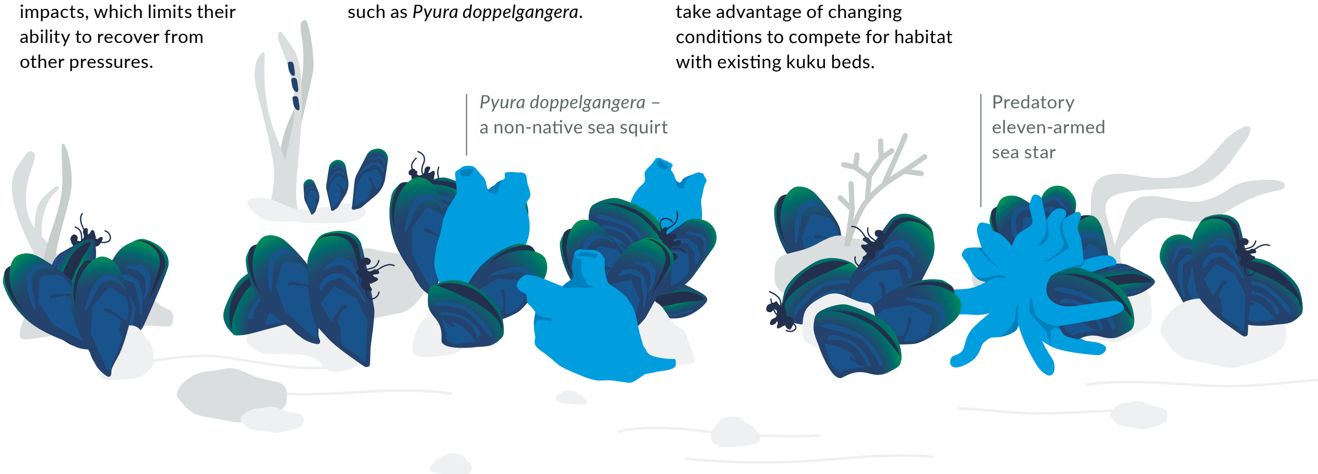
Kuku beds have significantly declined in area due to legacy impacts, which limits their ability to recover from other pressures.

Pressure from non-native species

Kuku beds are vulnerable to some competitive non-native species, such as *Pyura doppelgangera*.

Changing communities

Other native species, like the eleven-armed sea star, can also take advantage of changing conditions to compete for habitat with existing kuku beds.



ISSUE 2

Our activities on land are polluting our marine environment

Photo credit: Rob Suisted

Our everyday activities in cities and towns, and our use of rural areas, have altered the state of many of our coastal ecosystems.

Coasts and oceans also receive and process pollutants from the land. Most of the changes that have compromised the ecological health of coasts and estuaries occurred after European settlement. Our connection to the marine environment through mahinga kai and recreation has also been affected.

Report focus: coastal water quality, sediment accumulation, emerging contaminants, plastics.

Why does this issue matter?

SPATIAL EXTENT

It affects most of our coastal waters. Pollutants are found in marine environments from estuaries to deep ocean trenches.

DEPARTURE FROM NATURAL CONDITIONS

The concentration of pollutants is variable and some are much higher than in natural conditions. New contaminants are being discovered and their effects are unknown.

IRREVERSIBILITY

Remediating marine pollution is challenging and costly because it occurs widely over a long time, is difficult to get to, and has legacy effects.

IMPACTS ON WHAT WE VALUE

Cultural connections with the environment are undermined, and human health and recreation are affected.

What is the current state of this issue and what has changed?

Updated or new in *Our marine environment 2019*

Beach litter data collected using citizen science. Broadened body of evidence for water quality and sediment.

SEDIMENT ACCUMULATION HAS INCREASED SINCE EUROPEAN SETTLEMENT

Human settlement (and European settlement in particular) has brought large shifts in the nature of sediments in most coastal environments. These include changes in the rate of accumulation, increase in muddiness, and the type and amount of contaminants that are bound to sediments (Robertson & Stevens, 2015). Sediment accumulation is variable (see box below High natural variations complicate assessments). In this section, we focus on accumulation rate.

High natural variations complicate assessments

Rain and wind move soils and other material from land to the sea. The rate of this movement depends on factors in the catchment like the slope, underlying rock and soil type, vegetation, and volume and intensity of rainfall. When the amount of material (sediment) arriving in the marine environment is greater than its ecosystems can process, sediment becomes a pollutant.

Once in the sea, how sediment moves and settles is determined by waves and tides. Waves can erode and prevent sedimentation, and tidal flows can redistribute sediment (Hunt, 2016). These local factors make it difficult to compare sediment accumulation rates between regions or locations without long-term monitoring.

Sediment accumulation in estuaries is increasing in many parts of New Zealand but the accumulation rates are highly variable. The proposed guidelines for *The Australia and New Zealand Guidelines for Fresh and Marine Water Quality* (previously known as ANZECC) regard the health of estuaries as being affected when sedimentation rates exceed natural rates by two millimetres per year in an estuary or part of an estuary (Townsend & Lohrer, 2015). The effort required to achieve this guideline and keep our estuaries healthy will vary throughout New Zealand.

In the Pauatahanui and Onepoto arms of Te Awarua-o-Porirua Harbour, the average sedimentation rates were 9.1 millimetres per year and 5.7 millimetres per year respectively for the 35 years from 1974 to 2009 (Gibb & Cox, 2009). The largest proportion of sediment in the harbour came from pasture, followed by earthworks. Earthworks accounted for 24 percent of all sediment from the Te Awarua-o-Porirua Harbour catchment, despite accounting for just 1 percent of the land area (Greater Wellington Regional Council et al, 2015). Sediment accumulation rates across Waikato estuaries have become unstable (see Sediment accumulation rates in Waikato).

COASTAL WATER QUALITY IS VARIABLE

The water quality variables commonly used to assess ecological health are nutrients (phosphorus and nitrogen), phytoplankton, oxygen, water clarity, and pH. Faecal bacteria, an indicator of the presence of pathogens, is used to assess water quality for human health.

It is difficult to assess the overall state of coastal water quality as the state is defined by the combination of different variables, and the natural capacity to process pollutants differs between places. This means for many variables there are no national guidelines that would allow for consistent assessment of the state of a particular coastal water body or the coastal waters of New Zealand overall.

Coastal water quality around Aotearoa New Zealand is variable, as shown by median concentrations and changes over time (trends) for all monitored sites (see figure 5 and indicator: Coastal and estuarine water quality). It is difficult to measure the ecological importance of these trends for organisms without established thresholds for ecosystem health. However, further context is provided below for chlorophyll-a, dissolved oxygen, and the presence of enterococci.

Sediment accumulation rates in Waikato

To find out how sediment accumulation rates have changed in Waikato, 61 sediment cores were taken from the intertidal areas of 7 estuaries – the cores tracked sedimentation back to 10,000 years ago.

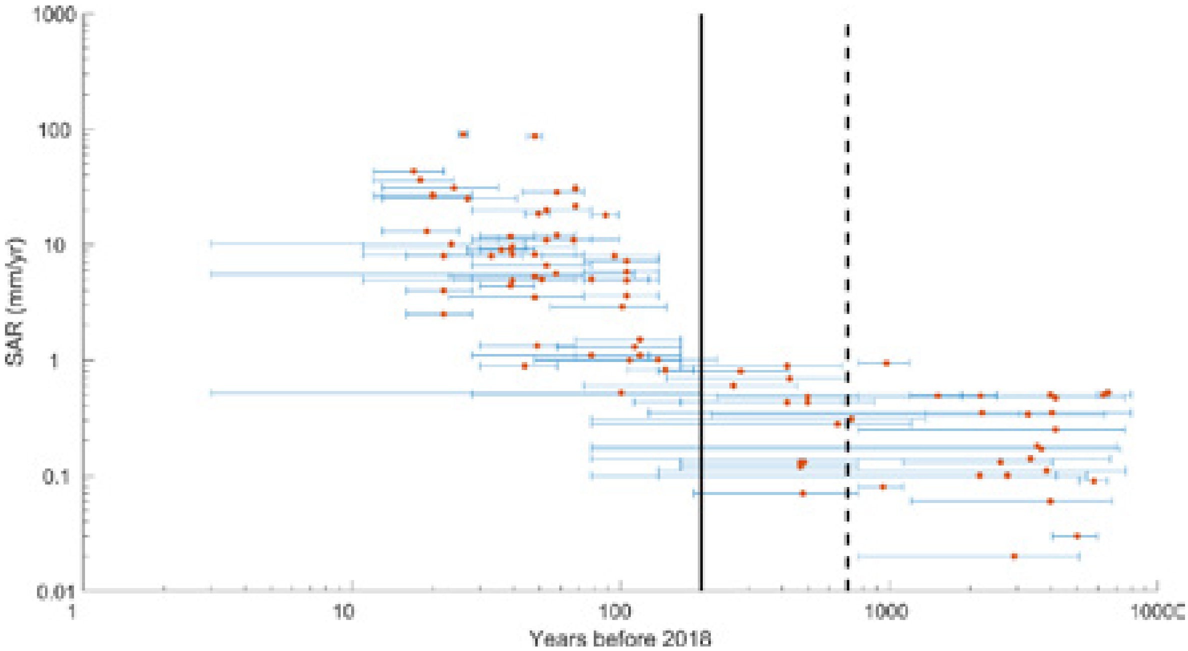
Before the arrival of Europeans, intertidal sediment accumulation rates were 0.02–0.5 millimetres per year. In the last 100 years, sedimentation rates in Waikato have become unstable, reaching almost 200 times those of the previous 10,000 years (see figure 4) (Hunt, 2019).

Changes in the sedimentation rate corresponded with changes in the types of pollen found in sediment cores. This shows widespread changes in the vegetation in catchments.

There is high variation between estuaries. For example, compared to sedimentation rates before mid-1800s, sedimentation in the southern Firth has been increasing at rates higher than many other North Island estuaries, sometimes up to 10 times higher (Swales et al, 2016).

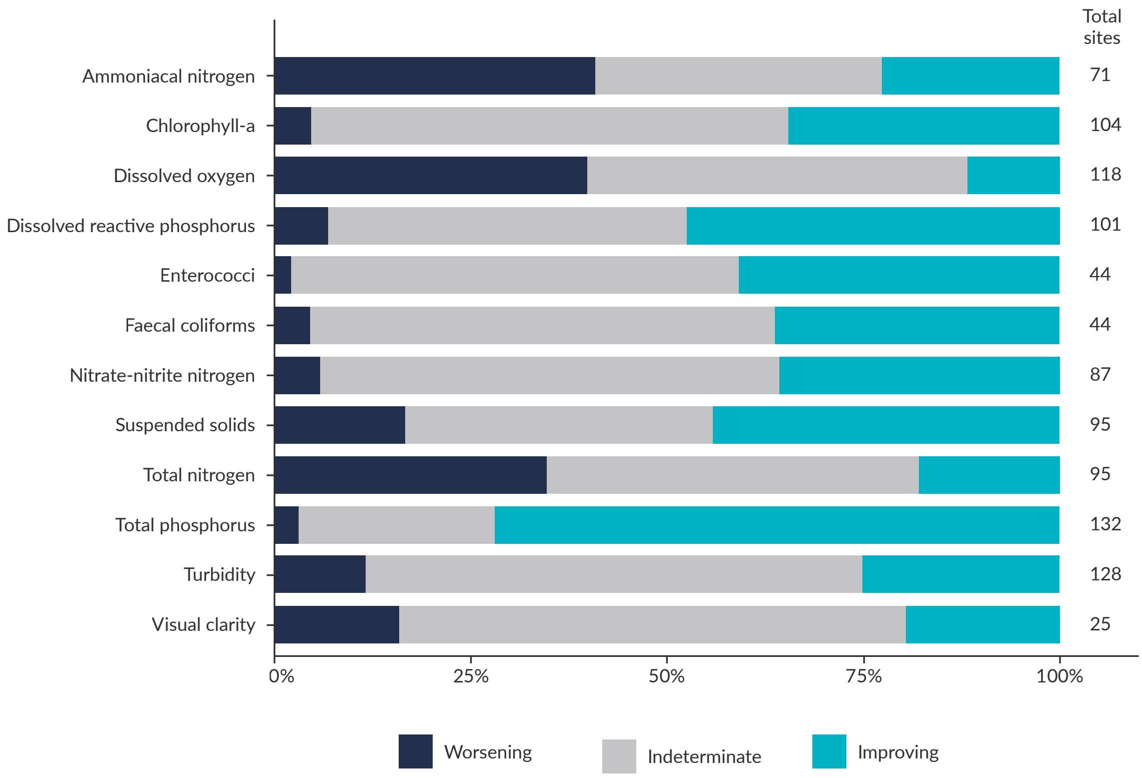
The sampled estuaries were in Raglan (Whaingaroa Harbour), Coromandel (Whangapoua, Whitianga, Wharekawa, Whangamata, and Coromandel harbours) and the Firth of Thames.

Figure 4: Historic sediment accumulation rates from core taken in intertidal estuarine areas in the Waikato region.



Note: The error bars show the date range over which results are calculated and the dots show the average date. The solid black vertical line is the approximate date of European settlement and the dashed black vertical line is the approximate date of Polynesian settlement. Both axes are logarithmic, figure adapted with permission from (Hunt, 2019).

Figure 5: Coastal and estuarine water quality trends measured at monitoring sites, 2008—2017



Chlorophyll-a can be used as an indicator of coastal ecosystem health and is a proxy for the amount of phytoplankton present. Trends in chlorophyll-a concentrations are shown in Figure 6. Chlorophyll-a is sensitive to nutrient and sediment inputs. High pollution loads can lead to eutrophication: an overload of nutrients that can cause algal blooms, depleted oxygen levels, and subsequent harmful effects on marine life. At 84 percent of all monitored sites across New Zealand, the median concentration of chlorophyll-a was less than 0.003 mg/L (see indicator: Coastal and estuarine water quality). At these low concentrations, the effects of pollution are considered to be minimal and ecological communities are healthy and resilient (Robertson et al, 2016).

Dissolved oxygen is essential for aquatic organisms and is an indicator of ecosystem health. At all but one monitored site, the median, dissolved oxygen concentration from 1973 to 2018 (the time period varied between sites) was greater than 6 mg/L. Long-term thresholds for oxygen concentration have not been defined. In the shorter term (weekly), mean concentrations below 6 mg/L are known to cause stress in estuarine organisms (Robertson et al, 2016).

The presence of a faecal indicator organism, enterococci, is most commonly used to assess whether coastal waters are safe for recreation. The median concentrations at monitored sites ranged from 0.85 to 210 enterococci per 100 millilitres (see indicator: Coastal and estuarine water quality). Frequent sampling for enterococci helps to assess whether coastal waters are safe for recreation: regional councils monitor popular coastal beaches over summer to manage this health risk. Under the New Zealand microbial water quality guidelines, caution is advised if a single coastal water sample has more than 140 enterococci per 100 millilitres. A second consecutive exceedance triggers a management action or red mode. The Land, Air, Water Aotearoa (LAWA) website has the most up-to-date information on local water quality.

Trends in coastal and estuarine water quality between 2008 and 2017 are shown in figure 5. For 9 out of 12 variables, more sites had an improving trend than those that were worsening (figure 5). Particularly notable is that 72 percent of sites showed an improving trend for total phosphorus. This may reflect the improvements observed in river phosphorus levels (see indicator: River water quality: phosphorus). More sites showed worsening trends for total nitrogen (35 percent), ammoniacal nitrogen (41 percent), and dissolved oxygen (40 percent). Across the 12 variables, the trend was stated as indeterminate at 25 to 64 percent of sites.

Reasons for these trends are not clear. Factors that may affect these trends include the complexity of the coastal environment, limited data, and insufficient information about freshwater inputs (especially nutrient and sediment loads).

Coastal sites with large river inflows had the highest nitrogen concentrations and high levels of faecal bacteria – these areas are particularly affected by pollutants from land-based activities (Dudley et al, 2017). Deep estuaries and open coast sites had the best water quality. This may be due to mixing with ocean water where dilution makes them less susceptible to the adverse effects of pollutants (Larned et al, 2018). The effects of natural climatic variations compared with the effects of human activities on coastal water quality are also poorly understood.

Figure 6: Chlorophyll-a monitoring results shown as trends calculated from data collected between 2008 and 2017 at a subset of monitoring sites

LITTER AND PLASTIC DEBRIS IS PERVASIVE

Plastic debris is now found throughout the ocean, including the bottom of the Mariana Trench (Chiba et al, 2018). Sources of marine plastic are waste from industry and landfills and the waste we throw away. Over time, plastic debris is broken down into smaller and smaller pieces.

Plastic pellets have been recorded on New Zealand beaches since 1972 (Gregory, 1978). Plastic is the most common type of litter on our beaches. At six out of seven selected survey areas, hard plastics were in the top two types of plastic litter by item count (see Litter on our beaches infographic overleaf).

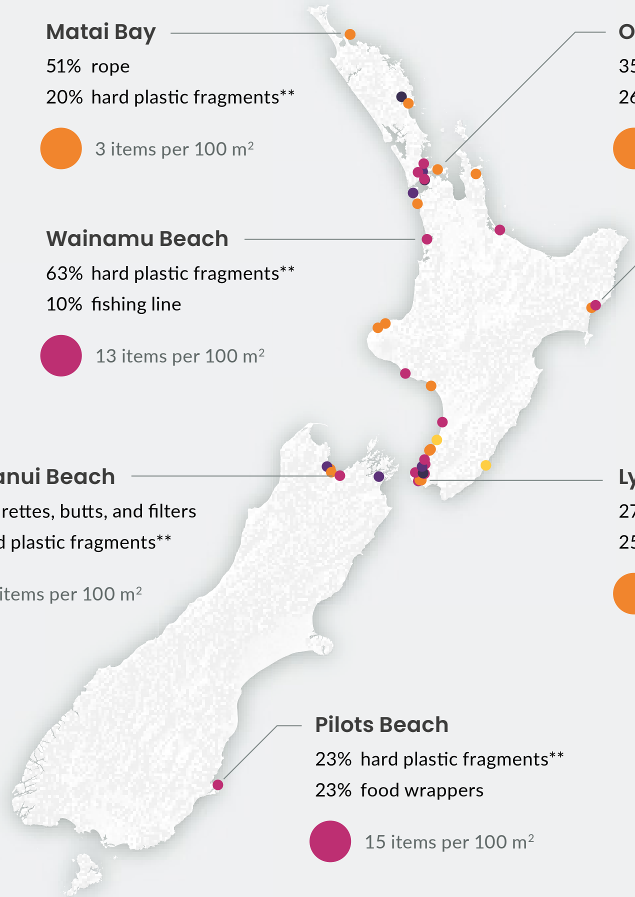
Plastics are found throughout the food web. In New Zealand, plastics have been reported in fish, shellfish, and seabirds (Forrest & Hindell, 2018; Markic et al, 2018). Plastic was found in the stomachs of New Zealand prions as early as 1960. A global review of published diet data for 135 seabird species between 1962 and 2012 found 59 percent of species had eaten plastic. Furthermore, an increasing proportion of individuals had eaten plastic over time. A strong relationship between eating plastic and exposure to it was observed, indicating the potential for greater numbers of seabirds to eat plastic if its concentrations in oceans continues to increase (Wilcox et al, 2015).

Litter on our beaches

44 survey areas in the Sustainable Coastlines Litter Intelligence programme* data snapshot: April 2019. Type and amount of waste in coastal marine habitats.

LITTER DENSITY AND TOP 2 TYPES OF PLASTIC FOR SELECTED SURVEY AREAS

Plastic is the most commonly found beach litter in New Zealand.



Matai Bay
51% rope
20% hard plastic fragments**
3 items per 100 m²

Oneroa Beach
35% hard plastic fragments**
26% rope
5 items per 100 m²

Wainamu Beach
63% hard plastic fragments**
10% fishing line
13 items per 100 m²

Waikanae Beach
34% hard plastic fragments**
28% lollipop sticks and cotton buds
18 items per 100 m²

Tahunanui Beach
73% cigarettes, butts, and filters
17% hard plastic fragments**
34 items per 100 m²

Lyall Bay
27% lollipop sticks and cotton buds
25% cigarettes, butts, and filters
9 items per 100 m²

Pilots Beach
23% hard plastic fragments**
23% food wrappers
15 items per 100 m²

Litter density for 44 survey areas
- > 100 items per 100 m²
- > 50
- > 10
- > 1
- < 1

Cigarettes, butts, and filters make up about 11% of all plastic items collected and 6% of all items overall.

*CITIZEN SCIENCE

The **Litter Intelligence programme** is a citizen science project that collates the results of litter surveys around New Zealand. It is run by Sustainable Coastlines and funded by the Waste Minimisation Fund.

**Unidentified hard plastic fragments

LITTER BY CATEGORY, ALL SURVEYS

Type	Item count	Weight
Plastic	60.9%	9.8%
Glass and ceramic	21.7%	59.2%
Foamed plastic	6.2%	0.3%
Metal	5.3%	6.3%
Wood	2.1%	16.0%
Cloth	1.3%	3.6%
Rubber	1.3%	3.4%
Paper and cardboard	0.9%	0.3%
Other	0.4%	1.0%

Although plastic litter accounts for 60.9% of all items found, it only makes up about 9.8% of total weight

Glass and ceramic fragments made up the greatest weight

OUR UNDERSTANDING OF NEW CONTAMINANTS IS IMPROVING

Rainwater can pick up contaminants as it passes over roads, moves through drains, and enters the wastewater network. Although our understanding of the adverse impacts and sources of various contaminants is improving, many contaminants are persistent in the environment and managing them can be problematic. The contaminants can be natural or human-made and include pharmaceuticals, personal care product additives, cleaning products, and industrial compounds (like flame retardants).

New Zealand does not have a national strategy for managing new or emerging contaminants, and monitoring is limited and inconsistent. Our understanding of the sources, ranges, and effects of pollutants on our marine environment and on people lags behind their introduction. This is the case in New Zealand and worldwide. Regional councils, however, are working together to develop appropriate monitoring systems.

What has contributed to this issue?

Our activities on land – agriculture, forestry, transport, and the growth of cities and towns – create pollutants. More pollutants, like plastics and synthetic materials, are also being generated.

The amount and type of pollutants depends on the mix of land uses in a catchment as well as factors like the soil type, slope, climate, and how land is used and managed. Pollutant loads can be increased by land intensification (more livestock per hectare), creating more impenetrable surfaces (urban development), and by draining wetlands. Pollutant transport can be reduced by keeping livestock out of streams and by improving wastewater and stormwater treatment systems in urban areas.

The concentrations of nitrogen, phosphorus, fine sediment, and *Escherichia coli (E. coli)* in rivers increase as the area of farmland upstream increases (Larned et al, 2018). From 2013 to 2017, rivers with pastoral land cover had modelled *E. coli* levels that were 14.6 times higher than rivers with native land cover (see indicator: River water quality: *Escherichia coli*). Urban rivers can contain even higher levels of these contaminants: modelled levels of *E. coli* in urban rivers for 2013 to 2017 were up to 30 times higher than those with native land cover (see Environment Aotearoa 2019) (see indicator: Urban stream water quality). Urban waterways can also contain heavy metals.

What are the consequences of this issue?

POLLUTANTS CAUSE ECOLOGICAL HARM

Pollutants from land – such as sediments, nutrients, and chemicals – have known effects on marine species, but the scale at which these effects occur is not well understood (Larned et al, 2018; Morrison et al, 2009). Species in shallow estuaries are usually more vulnerable than those in open coastal environments (Dudley et al, 2017). The potential for harm also depends on a species' behaviour (like feeding), habitat, and its proximity to human settlements. Broad-scale information about these impacts is not available but some local examples are presented below.

- Thick deposits of sediment adversely affect most animals buried beneath them (Norkko et al, 2002; Thrush et al, 2004).
- Suspended sediments are harmful to aquatic life and can reduce fish spawning and juvenile survival. Excess sedimentation and eutrophication can reduce diversity (Morrison et al, 2009).
- Exposure to pharmaceuticals can reduce feeding rates and survival in shellfish. Mussels bind less successfully to rock surfaces, and changes in immune responses and biochemical markers were also observed (Gaw et al, 2014).

INGESTING PLASTICS HAS MANY EFFECTS ON MARINE ANIMALS

The scale of the effect that plastics have in the ocean is unknown. Much of it is microplastic (less than 5 millimetres in length).

When birds eat plastic, it can reduce their intake of nutrients, decrease reproduction, cause poisoning and internal and external wounds, and block their digestive tracts (Gregory, 2009; Wilcox et al, 2015). Fish can accumulate plastic by eating smaller fish or plankton that have ingested it (Boerger et al, 2010).

Plastics have been found in many other species and cause a variety of effects including:

- zooplankton – international studies show decreases in nutritional intake and survival (Botterel et al, 2019; Cole et al, 2013)
- mussels – international studies have shown blue mussel stress response and feeding behaviour can be affected (Von Moos et al, 2012; Wegner et al, 2012). In New Zealand, mussels have been found to ingest microplastics but the effects of ingestion in the species are still unknown (Webb, 2017)
- oysters – feeding and reproductive behaviour can be affected (Sussarellu et al, 2016).

POLLUTANTS CAN REDUCE HARVESTING AND COASTAL RECREATION

Pollutants change the way we use our coastal environments for gathering kaimoana, fishing, and recreation. The presence of harmful bacteria closes beaches and reduces our enjoyment of them. We can become sick if we come into contact with contaminated seawater or kaimoana. Increased concentrations of toxins in shellfish have posed health risks for recreational harvests (Mackenzie, 2014; Malham et al, 2014). Degraded coastal environments disconnect us from these places and disempower people (Faulkner and Faulkner, 2017) (see Toxic sediment).

From a Māori perspective, sewage systems and food gathering should occur in completely separate domains. The increasing overlap of urban areas and places from where food is harvested results in a loss of integrity of mahinga kai. Interviews with kaumātua from Ngāti Awa revealed that tohu for pipi in the mouth of the Whakatāne River showed a decline in abundance and quality. Before effluent was discharged into the river, pipi had white shells and were a regular source of food. The first signs of decline in pipi mauri were the discolouration of the shells and reduced numbers. Pipi were then considered too polluted to eat (pers comms, K Paul-Burke, 2019).

Toxic sediment

Ahuriri Estuary/Te Whanganui a Orutū is a nationally significant estuary that is recognised for its wildlife and fish habitat (Hawke's Bay Regional Council, 2012). It supported many settlements on the east coast of the North Island and was a coveted natural resource. The estuary has cultural significance for seven hapū and many people enjoy recreational activities in the area.

Industrial, urban, and rural land uses upstream have degraded the estuary and caused a disconnection of tangata whenua with the place. Even at levels within food safety limits, pollution is unacceptable to most of the Māori community who have placed an unofficial rāhui (restriction of access) upon the estuary. Such restrictions reduce social cohesiveness, customary practices, and language use. Other subtle impacts affect hapū, who have a sense of whakamā (shame and regret) that they have been unable to carry out their kaitiaki duties and protect this taonga. An inability to manaaki (host) manuhiri (guests) with food from Ahuriri estuary also brings whakamā.

Scientists (including those from Hawke's Bay Regional Council) have been working with hapū to find out how contaminants are affecting Ahuriri estuary. Most sediment contaminants were associated with urban and industrial stormwater and some were above guideline threshold values (this included galaxolide, a synthetic musk found in cleaning and personal care products).

Evidence of acute toxicity was also found, as well as effects on the reproduction of copepods (a type of zooplankton). Copepods are a source of food for other marine species (Charry et al, 2018).

How land-based pressures affect kuku

Our activities on land can have a range of impacts on kuku. A lack of established thresholds for ecosystem health and understanding of response makes these impacts difficult to predict.

Discharge of toxins and bacteria

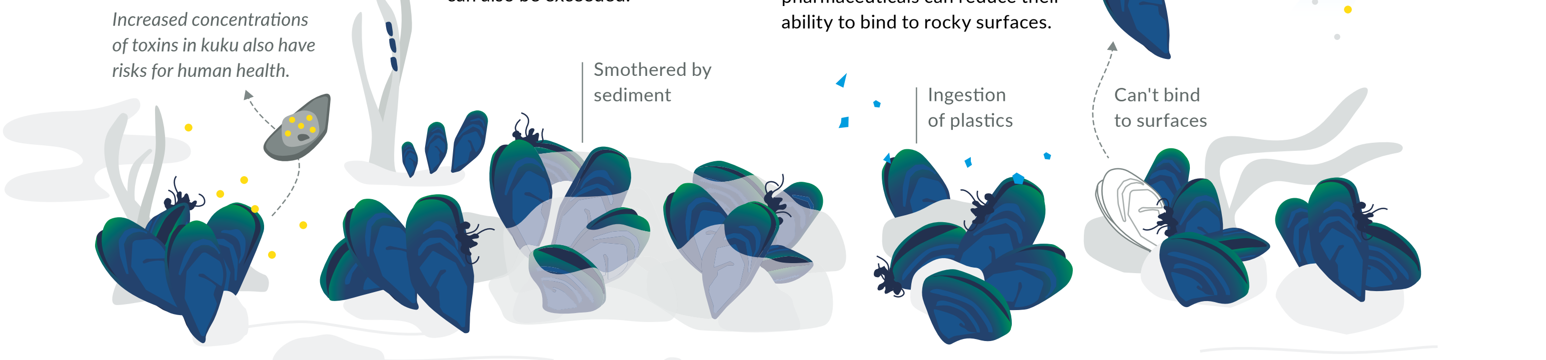
Increased eutrophication* and algal blooms can deplete oxygen and kill kuku.

Excess sedimentation

Sediment accumulates and smothers kuku beds.
Their capacity to filter sediment can also be exceeded.

Other contaminants

Ingested plastics can leach harmful chemicals and affect how kuku cope with stress. Exposure to pharmaceuticals can reduce their ability to bind to rocky surfaces.



* Nitrogen and phosphorus build up, which lead to more algae and deplete oxygen, and can kill aquatic organisms

ISSUE 3

Our activities at sea are affecting the marine environment

Photo credit: istock

Many of our activities at sea affect the health of marine ecosystems and its social, cultural, and economic value to us. Understanding the effects of these activities is crucial for managing our activities and minimising their effects.

Report focus: fishing, shipping, coastal development. (See *Environment Aotearoa 2019* for more detail on fishing and the impacts from fishing).

Why does this issue matter?

SPATIAL EXTENT

Almost all of the marine environment. Coastal areas are most affected because of the intensity of overlapping activities.

DEPARTURE FROM NATURAL CONDITIONS

Marine biodiversity is reduced and parts of the seabed and coastline are profoundly modified since European settlement.

IRREVERSIBILITY

Long-lived species may recover slowly from fishing, mining, and dredging. Trawled seabeds are slow to recover.

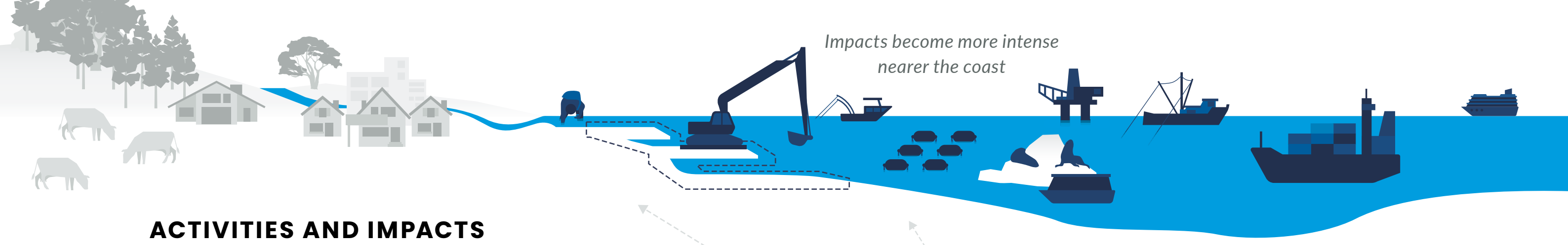
IMPACTS ON WHAT WE VALUE

Activities threaten protected species and can degrade ecosystems. They affect social and economic values, iwi relationships with rohe moana, and cultural practices.

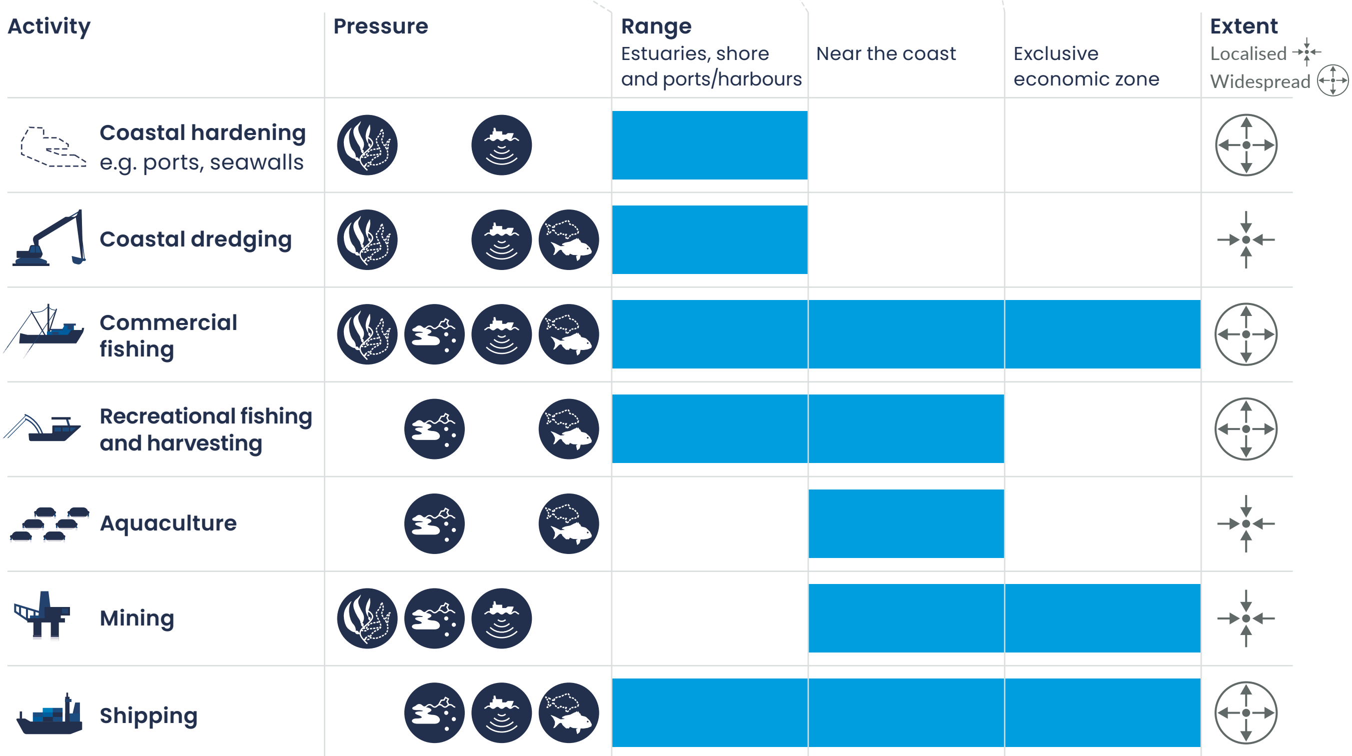
Our activities in the marine environment

What we do in and on our beaches, estuaries, and oceans provides benefits, but our activities affect our marine environment.

Our activities have risks and impacts on the marine environment. The scale depends on the intensity and extent of the activities. An improved understanding of the risks and impacts is crucial for better management of our activities.



ACTIVITIES AND IMPACTS



PRESSURES

Habitat degradation

Coastal development such as ports, sea defences, and wharves alter and destroy coastal habitats. Commercial fishing activities like seabed dredging and trawling cause significant seabed disturbance and damage.

Pollution

Pollution such as pathogens, plastics, and increased nutrient levels affect marine ecosystem health.

Noise

Noise disturbs natural systems and increases stress levels in marine species, masking natural sounds and altering behaviours and responses.

Pressure on species

Bycatch* and invasive species are ongoing issues.

* Non-target species captured by commercial fisheries

What is the current state of this issue and what has changed?

Updated or new in *Our marine environment 2019*

Updated data on fish stocks and impacts of fishing from the *Aquatic Environment and Biodiversity Annual Review*, updated indicators for bycatch of protected species: Hector's and Māui dolphins, and the marine economy.

FISHING PRESSURE HAS EASED BUT SOME STOCKS ARE OVERFISHED

New Zealand's total marine catch peaked at nearly 650,000 tonnes in 1997 and 1998. Since 2009, the catch has remained stable at less than 450,000 tonnes per year (FAO, 2018, 2019).

Fish stocks are managed under Aotearoa New Zealand's quota management system where a stock is defined as a species of fish, shellfish, or seaweed in a particular area. In 2018, the quota management system included 642 stocks (685 including substocks) of which 169 were scientifically evaluated (representing 68 percent of catch) and 219 were not assessed (representing 32 percent of catch). The remaining stocks are regarded as nominal (representing less than 1 percent of catch) (Fisheries New Zealand, 2019a, 2019b).

In 2018, 84 percent of routinely assessed stocks were considered to be fished within safe limits, an improvement from 81 percent in 2009 (Fisheries New Zealand, 2019a). Of the 16 percent that are considered overfished, 9 stocks were collapsed, meaning that closure should be considered to rebuild the stock as quickly as possible (Fisheries New Zealand, 2019b).

Stock assessments apply to individual fish stocks so they do not account for interactions between different stocks or interactions with the broader marine environment.

BYCATCH OF MOST PROTECTED SPECIES IS DECREASING

During fishing, protected species like seabirds, marine mammals, and some sharks and rays, and other non-commercial fish and invertebrates are caught unintentionally. Deaths caused by fishing can have consequences for a population (Carrier et al, 2010; Robertson & Chilvers, 2011; Schreiber & Burger, 2001). Bycatch can have a particular impact on our protected species because they generally have long life spans, mature at a late age, and have low fertility.

Bycatch is decreasing but remains a serious pressure on some populations (table 4). It is the main threat to seabirds, especially albatrosses and petrels (Ministry for Primary Industries, 2013).

Table 4: Summary of latest protected species bycatch data

What is affected	What is changing?	Latest figures
Seabirds	Decrease in bycatch in the last 20 years but not for all species	4,186 estimated seabird deaths in the 2016/17 fishing year compared to 8,192 in the 2002/03 fishing year
Sea lions	Decrease in observed captures in trawl fisheries since 2003, but variable between years	3 observed captures of sea lions in the 2016/17 fishing year compared to 12 in the 2002/03 fishing year
Fur seals	Observed captures are variable but there is a decrease in overall estimated captures between the 2002/03 and the 2016/17 fishing years	111 observed captures across trawl and longline fisheries in the 2016/17 fishing year compared to 125 in the 2002/03 fishing year
Māui and Hector's dolphins	Decrease in bycatch of Māui and Hector's dolphin in the last 20 years (see indicator: Bycatch of protected species: Hector's and Māui dolphins)	1 Māui and 29 Hector's dolphins were reported as entangled or potentially entangled in 2009–2018, compared to 4 and 60 respectively for 1999–2008

Note: Numbers for seabirds, sea lion and fur seal are from Protected species bycatch in New Zealand fisheries, Ministry for Primary Industries Dragonfly data science. Numbers for Māui and Hector's dolphin bycatch are from the Department of Conservation's Hector's and Māui dolphin incident database (see indicator: Bycatch of protected species: Hector's and Māui dolphins).

Bycatch also affects non-protected species but those without commercial value are discarded and the number caught is not usually recorded. Bycatch of dolphins (other than Māui and Hector's), turtles, and protected sharks also occurs (see *Environment Aotearoa 2019).*

In addition to fishing, Hector's and Māui dolphin deaths can have other causes like boat strikes, maternal separation, or disease. Toxoplasmosis has been identified as a potentially serious threat, particularly to female Māui and Hector's dolphins. The disease has negative consequences for reproduction, behaviour, and mortality, and has been confirmed in nine dolphins that died between 2007 and 2018. The infection is caused by the parasite *Toxoplasma gondii*, which reproduces in cats, is emitted in their faeces, and carried to the sea (Roberts et al, 2019).

SEABED TRAWLING AND DREDGING HAVE DECREASED

The number of commercial trawl and dredge tows has decreased in the past two decades, and the area that is trawled is decreasing (Ministry for Primary Industries, 2019). The total trawled area in deepwater fisheries for 1990–2016 was estimated as 335,812 square kilometres. This corresponds to 24 percent of the fishable area (Baird & Wood, 2018). Fishable area represents seabed that is shallower than 1,600 metres, the current maximum depth that trawlers can reach, where there are no seabed trawling restrictions like benthic protection areas.

The shallow seabed is trawled more extensively than deeper areas. Between 1990 and 2016, trawling occurred over approximately 28 percent of the seabed where the water depth was less than 200 metres, 40 percent of the seabed where water depth was 200–400 metres, and 35 percent of the seabed where water depth was 400–600 metres (Baird & Wood, 2018).

SHIPPING AND CRUISE SHIP TRAFFIC HAS INCREASED

Almost all (99.5 percent) of our imports and exports are transported by sea. The volume of exports grew steadily from 2004 to 2014 then levelled off. Imports and exports in containers continue to grow (Deloitte, 2016, 2018).

Vessel traffic data from July 2014 to June 2015 recorded the highest shipping traffic densities off the east coast of New Zealand, especially off Canterbury and the north-east coast of the North Island (Riding et al, 2016) (see figure 7).

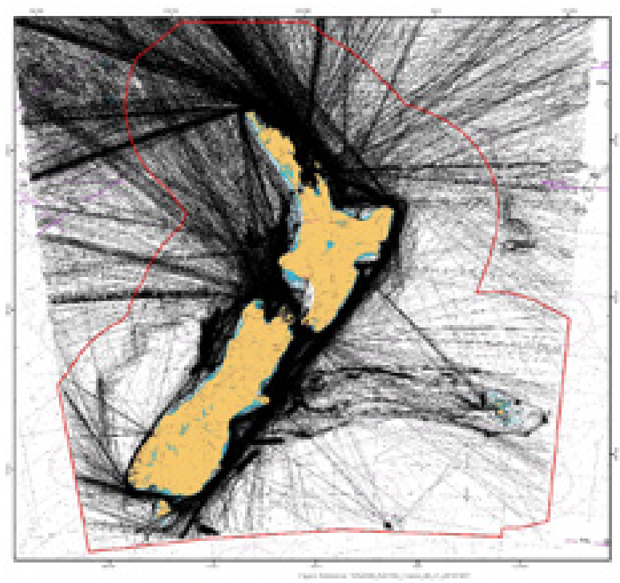
The number of cruise ships coming to New Zealand and the number of passengers per ship grew five-fold between 2004 and 2015 (Ministry of Business Innovation and Employment, 2016). Annual reports from Maritime New Zealand show a general increase in New Zealand port visits by cruise ships since 2005. The average number of passengers and consequently the size of cruise ship has also grown.

COASTAL DEVELOPMENT HAS INCREASED

Coastal development around the world has increased and involves physically altering coastal habitats and coastal hardening (the replacement of natural coastal environments with hard surfaces). Developments include engineering for coastal protection works, dredging, building ports, wharfs and jetties, residential development, and reclaiming land from the sea (GESAMP, 2001). Before humans arrived in New Zealand, forests grew to the water's edge. After settlement, and European settlement in particular, much of this vegetation was removed (Brake & Peart, 2013).

Understanding the extent of coastal development is limited by a lack of data and analysis.

Figure 7: Combined vessel traffic in the New Zealand EEZ based on AIS transponders from July 2014 to June 2015. Fishing vessel records from VMS data are not included.



Note: Figure courtesy of LINZ (Land Information New Zealand)

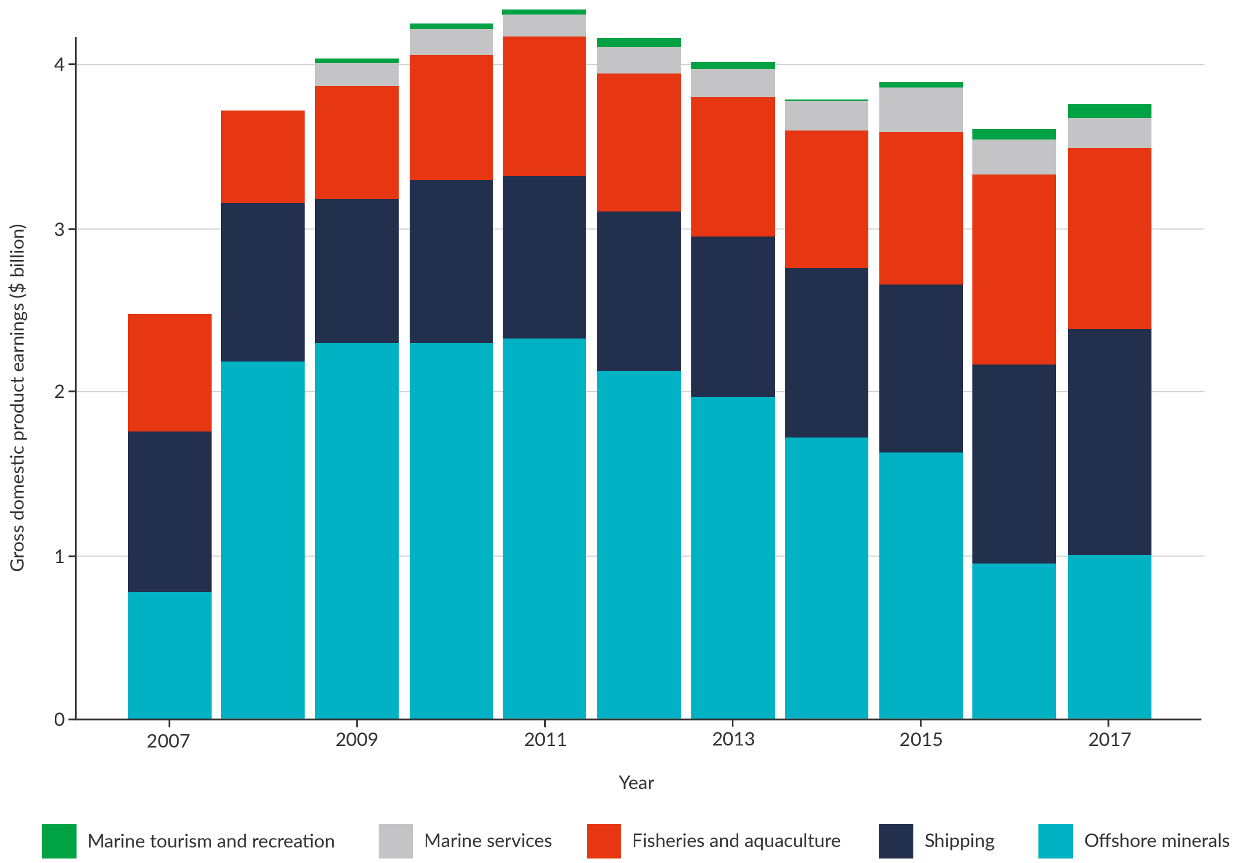
What has contributed to this issue?

Our activities at sea support economic and population growth. In the year ended March 2017, the marine economy was estimated to contribute $3.8 billion directly to New Zealand's economy and a further $3.2 billon indirectly (Stats NZ, 2019b).

At 37 percent, shipping is now the biggest contributor to our marine economy, surpassing offshore minerals as the highest-earning economic activity (see indicator: Marine economy). Shipping includes ship and boat building and repair services, water freight and water passenger transport, and port and water transport terminal operations (see indicator: Marine economy and figure 8).

For comparison, in 2017, fisheries and aquaculture contributed 29 percent and offshore minerals contributed 27 percent to the marine economy. The value of cruise ship activity has increased by 13 percent per year since 2010. However, this is not measured as a contribution to our marine economy as vessels are operated by overseas companies. An estimated $411.8 million was generated during the 2011/12 season from port visits, of which about 63 percent remained in the New Zealand economy (Worley, 2012).

Figure 8: Contribution of activity category to the marine economy, 2007—2017



Data source: Stats NZ

Commercial fishing has become more industrialised. Fishing vessels are now larger and more powerful than when trawling began more than 100 years ago – this change is occurring worldwide. A small number of vessels today can have the same impact as a larger fleet would have had in previous decades (See Environment Aotearoa 2019).

In many parts of New Zealand, an increasing population and demand for new houses close to the sea is driving coastal development and encroachment of coastal habitat. Structures like seawalls and groynes are built to protect property and infrastructure from storms and waves (Brake and Peart, 2013). Ultimately, this results in an increased area of hard surfaces.

What are the consequences of this issue?

FISHING HAS LONG-TERM EFFECTS ON ECOSYSTEMS

Fishing changes the population structure of a species as well as reducing the overall number of fish. Fishing changes behaviour, leads to different size or sex ratios, and can affect population genetics (See Environment Aotearoa 2019). Population changes can have cascading effects through the food web by affecting the dynamics of predation, food availability, and competition for food and habitat.

The way we fish matters too. Seabed trawling and dredging alter the structure of the seabed, damage habitats, and re-suspend sediment. Some ecosystems show few signs of recovery and may remain damaged for long periods of time after the activities stop (Clark et al, 2019). For example, reef-forming bryozoans are found in areas of our continental shelf where fishing occurs. Bryozoans are fragile and activities like dredging and bottom trawling have caused loss of bryozoan habitat in some areas. Benthic fishing is a significant threat to bryozoans, especially where fishing activity is high (Anderson et al, 2019).

VESSELS SPREAD NON-NATIVE SPECIES AND DISCHARGE POLLUTANTS

Shipping and boat traffic have direct and indirect effects on the marine environment. Indirect effects include shipping-related activities such as development of supporting coastal infrastructure that is associated with impacts from dredging, and construction of piers and other hard structures (GESAMP 2001).

Most non-native, marine species in New Zealand arrived via visiting vessels. Increased shipping and boating enables them to spread more readily throughout the marine environment (Clarke Murray et al, 2011; Darling et al, 2012; Seebens et al, 2016).

Pollution, like oil spills and accidental cargo release from ships, also has environmental impacts. For example, the wrecking of *MV Rena* in 2011 released cargo, ship debris, and oil that covered seabirds and little blue penguins (Schiel et al, 2016). Shipping is also a significant source of noise pollution (Walker et al, 2018) and air pollution, with sulphur dioxide, nitrogen oxides, carbon monoxide, and particulate matter being released (see Our air 2018).

Bryde's whales in the Hauraki Gulf

Hauraki Gulf is home to a small, semi-resident population of Bryde's whales and has the highest number of reported sightings of the species in New Zealand. Bryde's whale has a threatened – nationally critical conservation status.

The gulf is also a major shipping route for freight, cruises, and recreational boat traffic. Increased boat traffic is associated with an increased risk of collision with marine mammals (Behrens & Constantine, 2008).

Shipping can affect the whale's communication (Putland et al, 2018). Vessel strike was identified as a major threat to the population (Baker et al, 2010; Constantine et al, 2015). Between 1996 and 2014, an average of two Bryde's whales were killed per year as a result of vessel strike (Constantine et al, 2015). In recent years, fewer deaths have been reported after management measures, including reducing vessel speed, were introduced (Baker et al, 2019).

COASTAL DEVELOPMENT MODIFIES HABITAT

Physical changes to coastal habitats can affect local coastal water flow and wave action. This causes localised erosion and the deposit of sediments, and can alter the shape of beaches and estuaries (GESAMP, 2001; Larned et al, 2018). Changes to the coastline alter the way waves and sediment move and can result in intertidal habitats being lost (Gittman et al, 2016). Coastal environments will also be affected by sea-level rise (see issue 4).

Most of our activities in the marine environment tend to increase in intensity towards the coast and these pressures, on top of coastal development, result in coastal environments being most impacted. This is significant as shallower coastal environments hold the greatest diversity and turnover of species (Zintzen et al, 2017). Coastal development also affects the breeding habitats of birds and continues to put pressure on seabird and shorebird populations (see Our marine environment 2016).

OUR QUALITY OF LIFE AND ECONOMY CAN BE COMPROMISED

Our reliance on the marine environment for food, tourism, transport, recreation, cultural activities, and to make a living, may be compromised if our activities continue to degrade marine ecosystems.

Our ability to fish and harvest seafood could be affected by the degradation of the marine environment and the impacts of climate change. In 2017, commercial fishing and aquaculture provided employment for more than 14,000 people and earned $2.0 billion in seafood exports, leading to a direct contribution to GDP from this sector of $1.1 billion (0.4 percent) (Stats NZ, 2019b). About 700,000 people in New Zealand fish in the sea every year and recreational fishing also contributes to economic activity (Holdsworth et al, 2016).

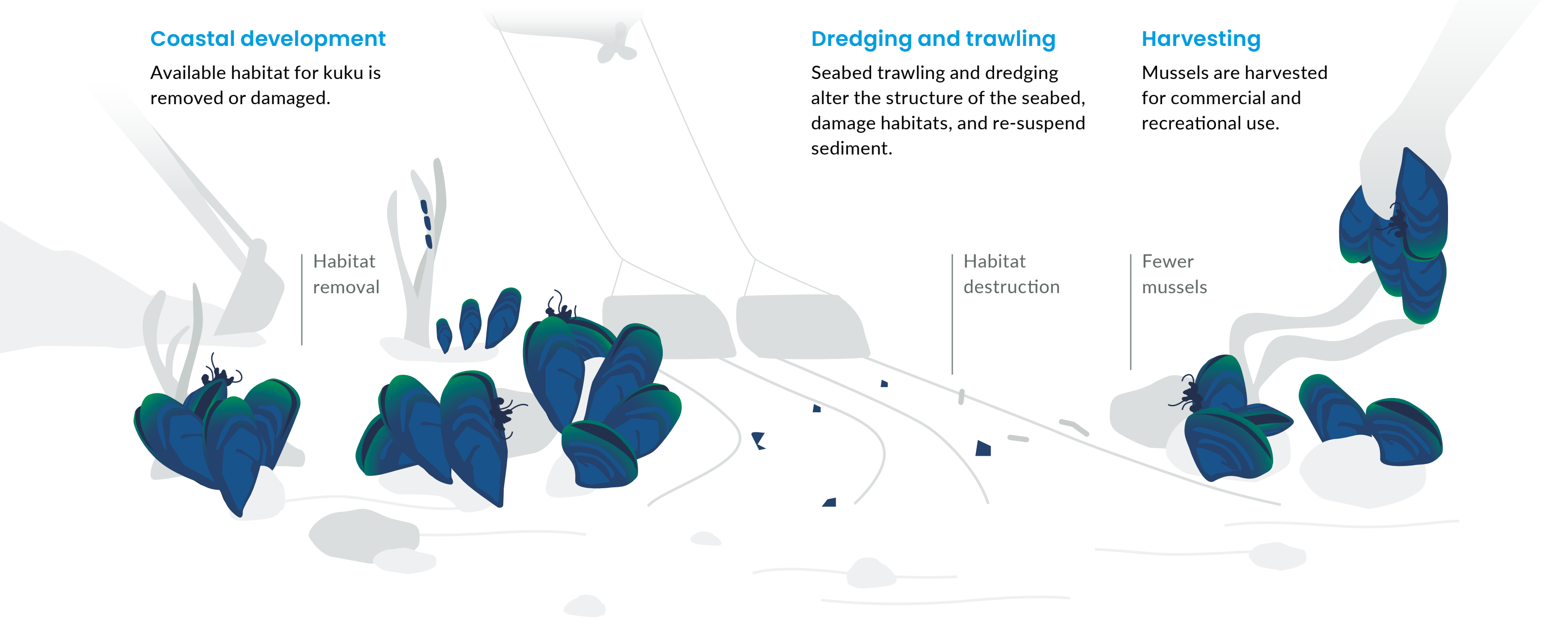
The activities that generate this significant revenue also put pressure on the marine environment. The cost of their impacts is not accounted for, which makes it difficult to weigh up the true cost and value of these activities. The decline of the endemic toheroa (New Zealand's largest shellfish) at many New Zealand sites in the second half of last century was due to commercial and recreational harvesting in equal measure. Climate, disease, changes in land use, and driving on beaches have also contributed to toheroa populations failing to recover (Ross et al, 2018).

Changes in commercial and customary activities in the marine environment also damage connections between tangata whenua (local or indigenous people from the land) and the sea. A loss of biodiversity erodes mauri and restricts opportunities to express kaitiakitanga. Although kaitiakitanga is often used to mean guardianship, it can also mean conservation and protecting. Most importantly, it refers to active, collective, and knowledge-based decision-making that fits local conditions (Rout et al, 2018).

Damage to the marine environment transgresses the basic concepts of te ao Māori in ways that undermine cultural, community, and individual identity. The Māori customary knowledge that exists today is highly valued, and in some cases, is a direct result of a scarcity and loss of knowledge. Customary knowledge is considered taonga tuku iho (treasures handed down by the ancestors) (Forster, 2012).

How marine-based pressures affect kuku

Activities in the marine environment have resulted in impacts on kuku, both directly through harvesting and indirectly by trawling and altering of habitats.



ISSUE 4

Climate change is affecting marine ecosystems, taonga species, and us

Photo credit: T Whittaker

Climate change is already causing unprecedented and enduring change in our oceans. The consequences of climate change on the marine environment are not fully understood. For example, we benefit from the role oceans have in regulating our climate and storing carbon but these benefits may be compromised by climate change.

Report focus: sea-surface temperatures, marine heatwaves, sea-level rise, extreme wave events, ocean acidification, and primary productivity.

Why does this issue matter?

SPATIAL EXTENT

Marine species and people experience the effects of climate change across New Zealand, but effects vary by region.

DEPARTURE FROM NATURAL CONDITIONS

Some changes are not well understood. Others show unprecedented rates of change and differ significantly from pre-industrial conditions.

IRREVERSIBILITY

Many impacts are irreversible on a human timescale.

IMPACTS ON WHAT WE VALUE

Our culture, environment, and economy are already being affected. We can expect these effects to continue.

What is the current state of this issue and what has changed?

Updated or new in *Our marine environment 2019*

Satellite monitoring for coastal sea-surface temperatures, and coastal primary productivity.

Updated data on relative sea-level rise, coastal and ocean acidification, ocean primary productivity, and extreme waves.

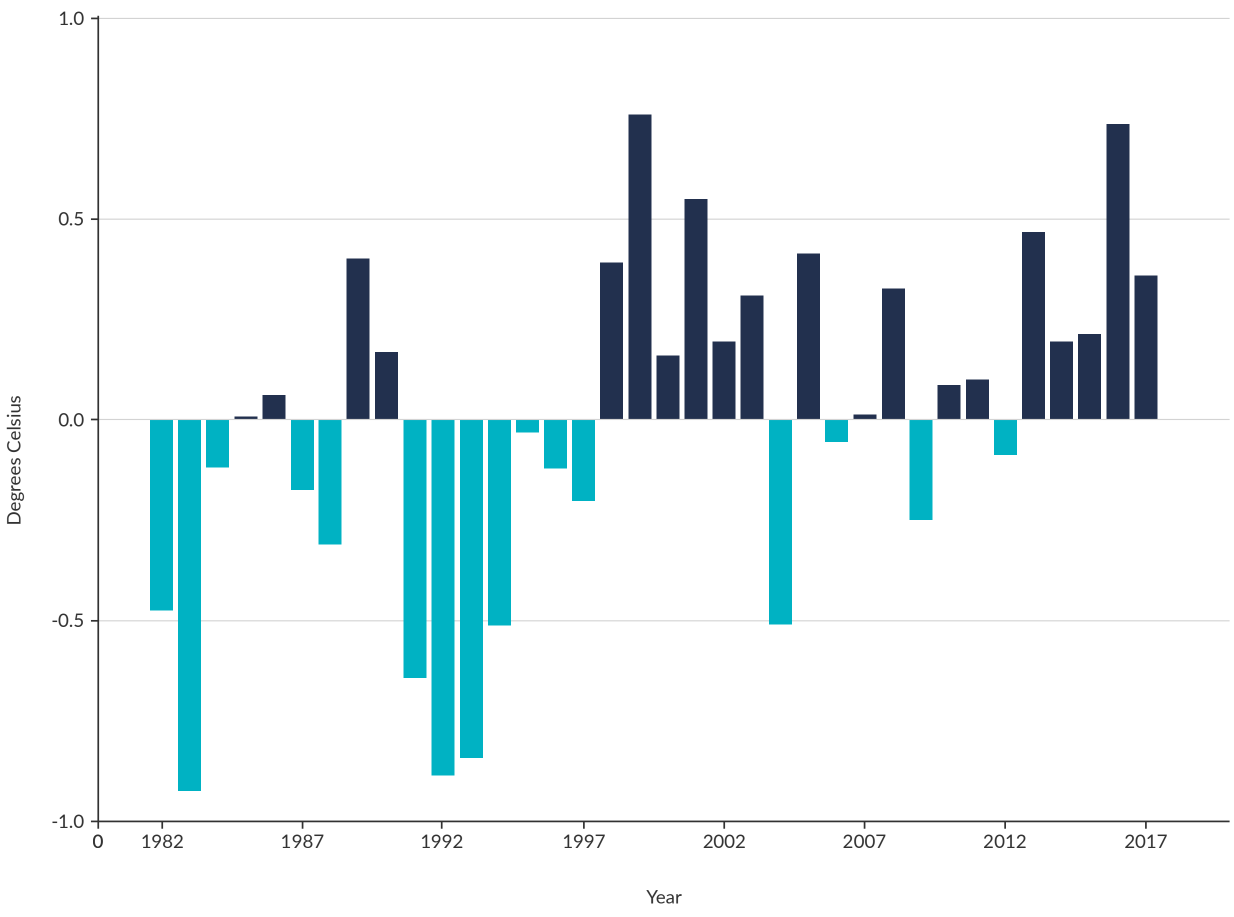
OUR SEAS ARE WARMING

Measurements of the sea-surface temperatures in New Zealand's coastal and ocean areas have been recorded by satellite from 1981 to 2018. This data provides a comprehensive record of change.

On average, coastal waters have warmed by 0.2 degrees Celsius per decade. Also, there are now more years when the average temperature of the sea around New Zealand was greater than the long-term average temperature (see annual deviation from average temperature 1981–2018) (figure 9). Ocean waters throughout our EEZ showed significant warming between 1981 and 2018 (see indicator: Sea-surface temperature).

The rate of warming varies but higher rates have been observed off the South Island's west coast between 2002 and 2018 (Chiswell & Grant, 2018) and east of the Wairarapa coast since 1981 (Sutton & Bowen, 2019).

Figure 9: Annual average anomalies in coastal sea-surface temperature, 1982–2017



Data source: NIWA

Not only are average temperatures increasing, but marine heatwaves are becoming more frequent because of human-induced warming. Marine heatwaves are periods of extremely high sea-surface temperatures that last for days to months and occur in areas of up to thousands of kilometres (Frölicher et al, 2018).

A marine heatwave occurred in the Tasman Sea and south of the Chatham Rise from November 2017 to February 2018 during New Zealand's hottest summer on record (Pinkerton et al, 2019). Short-term changes in sea-surface temperature occur naturally, but this event was unprecedented (based on the satellite data recorded since 1981) (see indicator: Sea-surface temperature).

Sea-surface warming trends in New Zealand were consistent with global averages between 1981 and 2015 (Pinkerton et al, 2019).

Climate projections suggest that sea-surface temperatures will increase 0.8–2.5 degrees Celsius by 2100 (Law et al, 2018a). The ocean has an important role in removing carbon dioxide from the atmosphere, but as oceans warm, they lose their capacity to absorb as much carbon dioxide, which may result in further increases in atmospheric carbon dioxide concentrations.

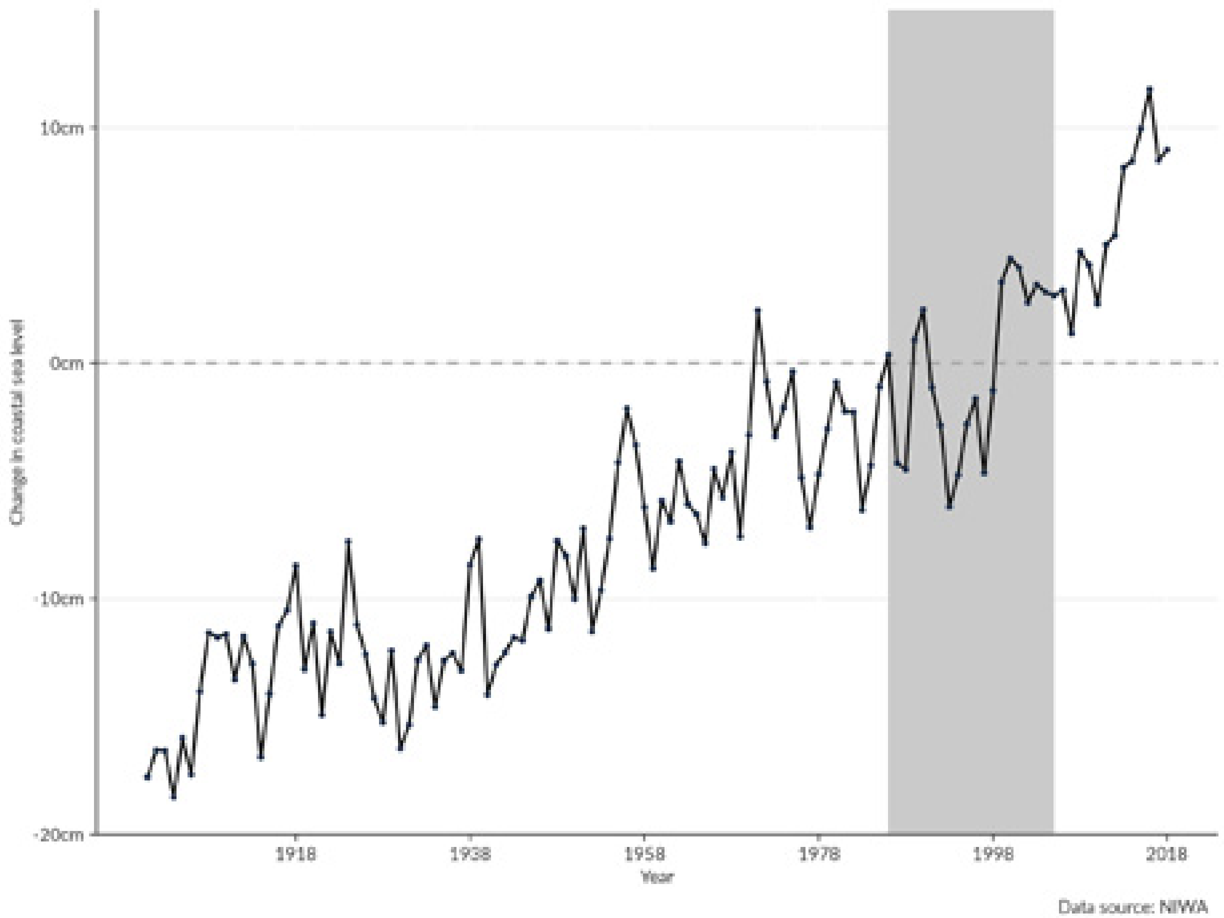
RELATIVE SEA LEVELS ARE RISING

Coastal sea levels are rising as ice melts, and because water expands when it warms (see Our marine environment 2016).

The mean sea-level has increased relative to the baseline (figure 10). The 1986–2005 baseline is used by the Intergovernmental Panel on Climate Change (IPCC) as a reference period to compare future change against. It is long enough to cover the range of tidal combinations and longer-term climate variability. New Zealand's mean relative sea-level has risen by 1.81 (±0.05) millimetres per year on average since records began. The national mean and trends in annual sea-level rise are based on four long-term monitoring sites (Auckland, Wellington, Lyttelton, and Dunedin). Regional measurements show consistent patterns but the increasing trend is most pronounced in Wellington due partly to land subsidence as well as rising seas (see indicator: Coastal sea-level rise).

Relative sea-level rise is a measure of the absolute change in sea level combined with local uplift, subsidence, or vertical land movement caused by tectonic activity. This measure is more useful for understanding local and regional implications than the absolute change in sea level (which does not account for land movement).

Figure 10: Annual mean coastal sea-level rise relative to the 1986–2005 baseline



Not only are sea levels rising, but they are rising faster than before. Between 1961 and 2018, the average rate of sea-level rise across 4 long-term monitoring sites was 2.44 (±0.10) millimetres per year. This is twice the average rate that occurred between the start of New Zealand records and 1960 (1.22 (±0.12) millimetres per year).

In addition, trend calculations that incorporate data from 2016 to 2018 show even faster rates of relative sea-level rise than those reported in Our marine environment 2016. This indicates an increased rate in relative sea-level rise, but it is too early to separate this trend from shorter-term oceanic cycles (Bell & Hannah, 2019) (see indicator: Coastal sea-level rise).

Global satellite data has recorded a rise in global mean sea level of more than 7 centimetres in the last 25 years. Global sea-level estimates may also indicate an acceleration in sea-level rise (Dangendorf et al, 2019).

Climate projections suggest that on average globally, we can expect a rise of 0.2–0.4 metres by 2060 and 0.3–1.0 metres by 2100, depending on global greenhouse gas emissions (Climate Change Adaptation Technical Working Group, 2017).

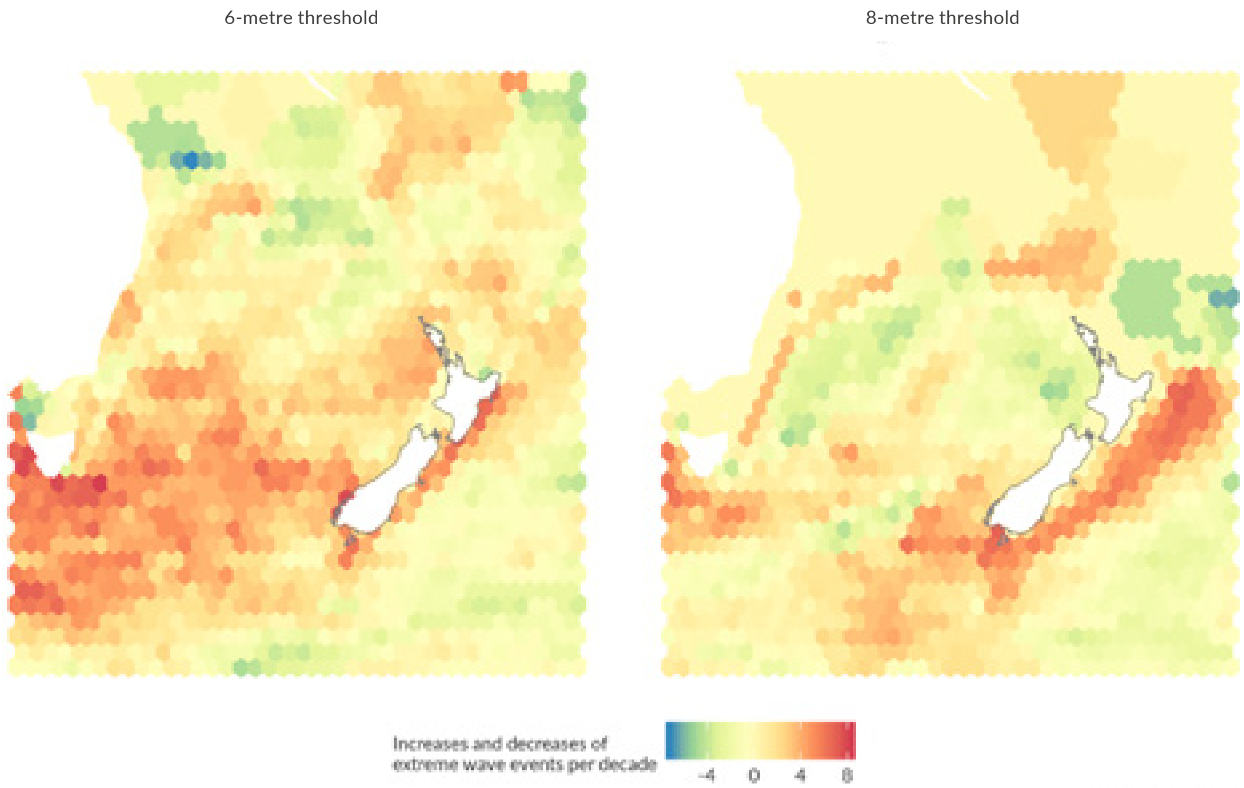
EARLY INDICATIONS SHOW EXTREME WAVE EVENTS ARE BECOMING MORE FREQUENT

Changes in ocean wave patterns are occurring, and these affect our coastal environment. Extreme wave events can disturb marine ecosystems and affect coastal infrastructure, ocean-based industries, and other human activities (see Our marine environment 2016). An extreme wave event is defined as a continuous 12-hour period when the wave height equals or exceeds 1 of 3 thresholds: 4, 6, or 8 metres (see indicator: Oceanic and coastal extreme waves for more detailed definitions).

In 2017, 17 extreme wave events exceeded the 8-metre threshold in coastal regions – 15 of these were around the South Island. In oceanic regions in the same year, 16 extreme wave events exceeded the 8-metre threshold.

Preliminary trends indicate the frequency of extreme wave events is increasing to the east and south of New Zealand, and decreasing on the North Island's west coast and to the north of the Bay of Plenty (figure 11). The short time period for which data is available makes it too early to definitively separate this trend from longer-term climate cycles, such as the Interdecadal Pacific Oscillation (see indicator: Oceanic and coastal extreme waves).

Figure 11: Trends in extreme wave events at the 6-metre and 8-metre threshold, 2008–2017



Data source: NIWA

OCEAN ACIDITY IS INCREASING

Oceans absorbed about 30 percent of global human-emitted carbon dioxide between 1994 and 2007 (Gruber et al, 2019). When carbon dioxide from the atmosphere is absorbed by seawater, chemical reactions occur, producing hydrogen ions that acidify the water and decrease seawater pH. This is called ocean acidification.

Subantarctic waters off the coast of Otago show an increase in acidity of 7.1 percent in the past 20 years (figure 12). This the longest-standing ocean acidification record in the southern hemisphere and is based on samples taken from the Munida Transect.

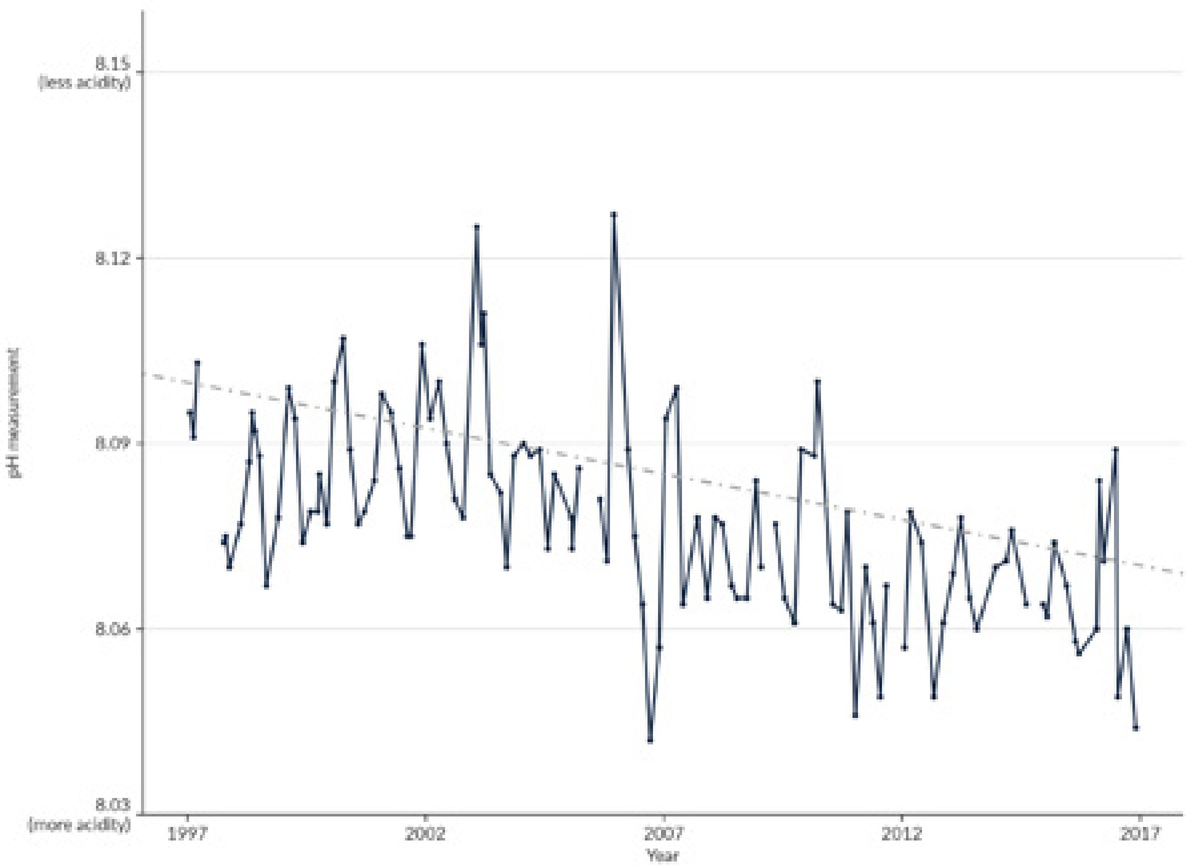
Very small changes in pH represent substantial differences in acidity: pH 4 is 10 times more acidic than pH 5 and 100 times more acidic than pH 6.

A new dataset for coastal water pH is used in this report, using the same method for nine sites across New Zealand. Fresh and coastal waters tend to be more naturally acidic than open ocean water. The highest acidity was observed at the Auckland monitoring site (Chelsea Point). More data is needed before the role of climate change can be separated from other factors that may be affecting the acidity of coastal waters (see indicator: Ocean acidification).

Since the beginning of the industrial era, the pH of ocean surface water has decreased by 0.1 pH units, which represents a 26 percent increase in acidity (IPCC, 2013).

Climate projections suggest the pH of waters around New Zealand will decrease by 0.3 to 0.4 pH units by the end of this century (Orr et al, 2005). Oceans will continue to become more acidic as they absorb more carbon dioxide, and reversing this profound change will take tens of thousands of years (IPCC, 2014).

Figure 12: The pH of New Zealand subantarctic surface waters along from the Munida Transect, 1998–2017



Data source: NIWA (Kim Currie)

OCEAN PRODUCTIVITY IS CHANGING

Phytoplankton abundance indicates ocean primary productivity at broad scales. Primary productivity is the creation of energy by living organisms, and it provides the energy that supports most marine food webs. Satellite data is used to measure the abundance of phytoplankton in the surface waters.

The abundance of phytoplankton has increased and decreased in different New Zealand waters in the past 20 years (see indicator: **Primary productivity**). Offshore ocean phytoplankton abundance has:

- decreased in northern (subtropical) waters
- increased in southern (subantarctic) waters and in the subtropical front (west of Fiordland and over the Chatham Rise) (**figure 13**).

In inshore waters (territorial sea), patterns of coastal phytoplankton abundance are affected by climate variation and changes to land use (for example, the levels of nutrients in rivers). Decreasing phytoplankton abundance was observed around:

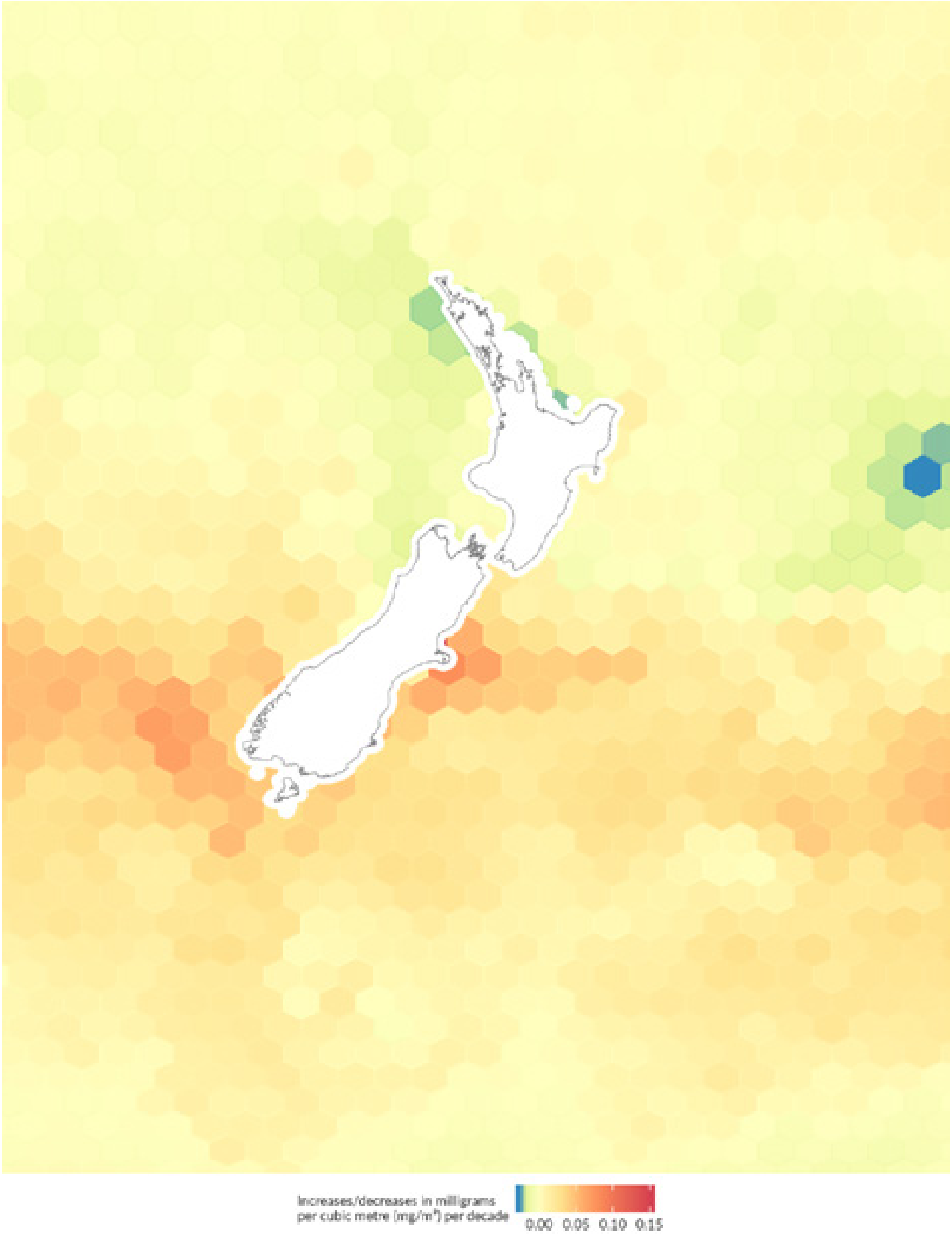
- Northland
- Coromandel and Bay of Plenty
- Tasman and Golden Bay
- off the west coast of the South Island.

Increasing phytoplankton abundance was observed:

- in the Firth of Thames (Hauraki Gulf), between Kaipara and New Plymouth
- in Hawke's Bay
- around Kaikoura and Oamaru
- around Stewart Island (Pinkerton et al, 2019).

The power to determine whether these trends are statistically significant is limited by the length of the dataset. The consequences of changing oceanic productivity is specific to the location in which it occurs; an increase or decrease in one area may not have the same impacts as the same increase or decrease in another area. Net primary production is projected to decrease globally. Primary production in New Zealand is projected to follow these patterns but in a less pronounced way (see indicator: **Primary productivity**) (Law et al, 2018a).

Figure 13: Trends of measured abundance of phytoplankton (measured as chlorophyll-a) near the sea surface, 1997–2018



Data source: NIWA

Note: Shades of green to blue show decreasing trends in the abundance of phytoplankton. Shades of orange to red show increasing trends in phytoplankton abundance.

What has contributed to this issue?

Natural variations

Changes in the ocean are hard to track because of the high natural variation and long-term cycles in the marine environment. Long-term time series and observations are needed to be able to separate signals from climate change from natural variations.

Natural variations include:

- Plate tectonics that deform Earth's crust resulting in increased or reduced relative sea levels (Bell & Hannah, 2019). This can occur quickly, like after the 2016 Kaikōura earthquake when land rose out of the sea, or gradually, like subsidence that is occurring in the Wellington region.
- Large-scale climatic fluctuations (such as El Niño and La Niña) can affect sea-surface temperature and sea-level rise. Under La Niña, sea-surface temperatures in New Zealand tend to be naturally higher (Salinger & Mullan, 1999).
- Biological activity can cause short-term and localised variations. For example, photosynthesis from primary producers can cause significant changes in water chemistry between day and night time (Cornwall et al, 2013).

HUMAN-GENERATED EMISSIONS ARE CAUSING CHANGES

Atmospheric greenhouse gas concentrations are increasing because of activities like burning fossil fuels for heat, transport, and electricity generation. Globally, the rate of emissions is increasing (Ministry for the Environment, 2018). This rise in atmospheric carbon dioxide has caused the observed changes in ocean acidity (Law et al, 2018a).

New Zealand's greenhouse gas emissions are high per capita but contribute a small proportion to the total global emissions. The sources of our greenhouse emissions and changes over time were reported in Environment Aotearoa 2019 and Our atmosphere and climate 2017. Agricultural industries make the highest contribution (49.7 percent) to New Zealand's total emissions, but household emissions increased 19.3 percent between 2007 and 2017 (Stats NZ, 2019a).

THE OCEAN'S ABILITY TO TAKE UP CARBON IS DECLINING

Oceans play an important role in regulating Earth's climate and help mitigate the consequences of global emissions. The Southern Ocean and the tropics both take up more human-emitted carbon than any other ocean region (Mikaloff Fletcher et al, 2006).

New Zealand's oceans may take up more carbon dioxide than our forests (MacDiarmid et al, 2013). Coastal marine habitats including mangroves, sea-grass meadows, and kelp forests also capture and store carbon. As sea temperatures increase, gases like carbon dioxide dissolve in the ocean less easily. This will reduce the oceans ability to take up carbon dioxide – estimates are for a 9–15 percent reduction by 2100 (Riebesell et al, 2009; Wang et al, 2014). An increase in stratification, or layering, will further reduce the ability of the ocean to take up carbon dioxide (Riebesell et al, 2009).

What are the consequences of this issue?

SPECIES DISTRIBUTION AND POPULATIONS WILL CHANGE

Warmer sea-surface temperatures affect phytoplankton abundance and therefore primary production of oceans. Near-surface stratification is a natural phenomenon, but ocean warming from climate change is expected to strengthen this effect (Capotondi et al, 2012). Stratification may reduce the supply of nutrients needed for phytoplankton growth in subtropical waters in the northern parts of New Zealand. The effect may be smaller in the south, where primary production is more limited by other factors such as light intensity (Pinkerton et al, 2019).

Changes to primary productivity have implications for the whole food web, including fish species and top predators like seabirds, marine mammals, and commercially valuable fish. Increasing abundances of phytoplankton in parts of the Chatham Rise may be positive for fisheries in this region (Pinkerton et al, 2019). Increased primary productivity can also have negative impacts on fisheries when phytoplankton blooms die off, potentially causing oxygen depletion in the water column (Morrison et al, 2009).

New species are being observed in our waters as climate change brings warmer water inshore. *Gambierdiscus*, the small plankton responsible for ciguatera fish poisoning, was recently observed for the first time in the subtropical northern region of New Zealand (Rhodes et al, 2017). Eating fish contaminated by this toxin triggers neurological, gastrointestinal, and cardiovascular symptoms (Armstrong et al, 2016).

Marine heatwaves can reduce the range of some species or cause others to disappear locally. During the 2017/18 marine heatwaves in the South Island, bull kelp suffered losses in Kaikōura and was completely lost from some reefs in Lyttelton (Thomsen et al, 2019). Following these losses, the empty spaces were rapidly colonised by *Undaria*, an introduced non-native species (Thomsen et al, 2019). Bull kelp acts as a carbon sink, dampens the effects of waves on the coastline, and provides structure and shelter for many species.

Warming waters in summer are already affecting fish. The reproduction of some fish species (like snapper and hoki) appears to be affected by sea-surface temperature. Warming and other changes to the marine environment could affect other species, and increases and decreases in stocks are possible (Ministry for Primary Industries, 2017).

Past approaches to fisheries management and catch levels may no longer work for some species and stocks. As coastal and ocean temperatures increase, wild fisheries can expect to see greater numbers, dominance, and distribution of warmer water species. Temperature-sensitive species may move south to cooler waters (Law et al, 2018a). In aquaculture, heatwaves can lead to increased mortality and an associated loss of revenue (New Zealand King Salmon, 2018; Sanford Limited, 2018).

Increased erosion and wave exposure associated with sea-level rise can impact seaweeds and animals living on exposed rocky reefs. Seaweeds may be particularly vulnerable to increased movement of sediment and reduced light levels. Local losses of large seaweeds can reduce protection from flow and reduce settlement of young seaweeds (Willis et al, 2007). Large wave forces can break or remove mussels, resulting in death if they cannot reattach. Mussel beds that are already thinned or less tightly packed are even more vulnerable (Hunt & Scheibling, 2001).

OCEAN ACIDIFICATION INCREASES STRESS ON OUR TAONGA SPECIES

The western United States provides an example of increased ocean acidity with a natural upwelling of cold, nutrient-dense water. The incident shows what could happen as New Zealand waters increase in acidity. This observation found that periods of increased acidity limited the growth of carbonate shells in settling oyster larvae, and caused high mortalities (Clements & Chopin, 2017). Although this upwelling does not occur in New Zealand to the same extent, the acidity observed could happen here under current projections.

In 2017, the aquaculture industry's estimated total revenue was $557 million, with 62 percent of this from mussels (Aquaculture New Zealand, 2018). Pāua, cockles, kuku, and kina are taonga species with carbonate shells that are valued for recreational and cultural reasons. All are vulnerable to increased ocean acidity.

Improving our understanding of how ocean acidification affects species

Previous environmental reports noted gaps in our knowledge about the impacts of ocean acidification on organisms. Recent research has focused on New Zealand species and is helping to define the risks, and shows that sensitivity to higher acidity varies between species (Law et al, 2018b).

Some recent research is summarised below:

- Experiments on shell-forming phytoplankton found a decrease in their carbonate content when acidity increased (Feng et al, 2017).
- The early and juvenile life stages of carbonate-forming species are particularly susceptible to ocean acidification, which may act as a bottleneck for survival to the adult stage in the future (Cunningham et al, 2016; Lamare et al, 2013; Pecorino et al, 2014). Adult pāua are more resilient to acidification but divert more energy to maintaining their shells in more acidic water. This may affect their condition (Law et al, 2018b).
- Some fish larvae, like New Zealand kingfish, appear to be relatively resilient to acidification (Munday et al, 2016; Watson et al, 2018). The larvae of other species, like reef fish, had altered responses to risk and predators (for example, a reduced response to the scent of predatory species) that could affect their survival (Baumann et al, 2012; Munday et al, 2010).

Our understanding of the indirect effects of ocean acidification, for example on primary production and food webs, remains limited.

MĀTAURANGA MĀORI AND KAITIAKITANGA MAY BE LOST

Māori marine knowledge and practices that are passed from one generation to the next, are unique to Aotearoa New Zealand. They are deeply ingrained in our identity as a people and as a country. These long histories in kaitiakitanga may help us recognise the impacts of long-term environmental changes, although climate change may be creating a situation with no precedent.

Some traditional Māori tohu or marine indicators can no longer be used in the same way. Māori scientific knowledge is based on observation and is evolving in response to current changing seasonal patterns. This includes observations of seasonal change used to indicate harvest periods. For example, traditionally when pōhutukawa bloomed, it was time to harvest kina. Today, the reproductive period of kina occurs at a different time due to changes in sea temperatures. Kaitiakitanga and traditional management methods and commercial practices are changing because of the different environmental conditions.

OUR INFRASTRUCTURE AND COASTAL COMMUNITIES ARE AT RISK

Rising sea levels and extreme wave events are affecting some coastal communities, infrastructure (bridges, road, and rail), environments, and biodiversity. It is very likely that increases in sea level will result in more frequent and extreme coastal flooding by 2050 and cause the loss of habitat in coastal regions (Ministry for the Environment, 2017).

If sea level rises by 1.5 metres, as is projected to occur by 2100, more than 6,000 kilometres of drinking water, wastewater and stormwater pipes and 2,000 kilometres of roads are at risk (Simonson & Hall, 2019). The total replacement value of all of New Zealand's potentially affected buildings could exceed $19 billion (data for the West Coast, Southland, Taranaki, Manawatu-Wanganui, and Marlborough was not included). The costs could be even higher if sea levels exceed these projections (Bell et al, 2015).

Our recreation and heritage could also be affected. A recent report estimated that 331 Department of Conservation assets (2 percent) and 119 visitor sites are potentially at risk from coastal inundation due to sea-level rise. Similarly 4,149 New Zealand Archaeological Association archaeological sites (6 percent) are considered to be at risk (Tait, 2019). Many coastal iwi and hapū have marae and other sites (like urupā) in vulnerable areas, which are important to their identity and the wellbeing of their people (see Environment Aotearoa 2019). More than half of Māori assets are in industries, including fishing, that are vulnerable to climate change impacts (Jones, 2013).

The infographic opposite shows the ways that warming oceans, increasing ocean acidity, and increasing storm frequency and intensity affect kuku – the green-lipped mussel.

How climate change pressures affect kuku

The pressures associated with climate change have impacts on kuku at difference life stages.

Warming seas

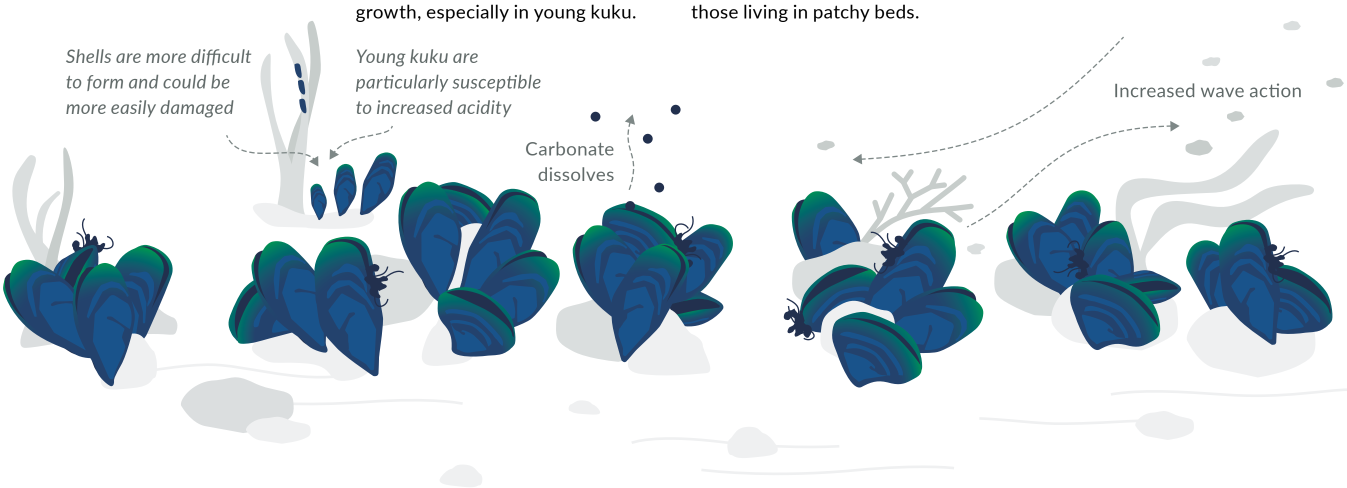
Could affect timing of reproduction and development of larvae.

Increasing ocean acidity

Shell development requires more energy and can lead to reduced growth, especially in young kuku.

Coastal extreme waves are more frequent

Wave events may damage or remove mussels, especially those living in patchy beds.



All our activities put cumulative stress on the marine environment

Photo credit: Alamy

Cumulative effects are one of the most urgent and complex problems facing our marine environment. In some instances, when effects overlap they can offset each other and reduce the overall impact, but more often effects compound, or result in unexpected impacts (Davies et al, 2018).

This report covers four priority issues to give a deeper understanding of the complexity within each issue. However, in reality, the effects of our activities and natural stressors overlap. Issues therefore need to be considered together rather than in isolation.

Effects overlap and build over time

The consequences of cumulative effects are highly variable. They are determined by:

- the range and type of pressures in a place
  - for example, pressures from excess sediment and nutrient inputs are most relevant in estuaries but pressures from climate change occur everywhere
- the intensity and extent of effects over time
  - for example, effects could be seasonal or localised, like from finfish aquaculture, or small incremental changes over time, like rising sea-surface temperature
- historical pressures on the local environment
  - for example, places that have been trawled or have accumulated sediment from modified catchments, may be more vulnerable to the adverse effects of sedimentation even after the activity has stopped
- current and past national or local protection and restoration efforts
  - for example, marine protection (like marine-protected areas and areas over which rāhui have been established) can provide refuge for species and potentially increase their resilience to future pressures.

Data on cumulative effects is limited but increasing

The complexity of our environment and patchy, long-term observations of parts of the system mean a full understanding of the impacts of cumulative effects is lacking (Larned et al, 2018). National data on the impacts from cumulative effects is scarce.

Understanding the scale and characteristics of these effects is complicated by the natural capacity of a species or habitat to respond – for example, they may respond or recover at different rates or be impacted by cumulative effects (Davies et al, 2018). Measuring the impact of cumulative effects requires an ability to detect change and understand tipping points.

New Zealand is making progress in understanding cumulative effects. Models are being developed that allow the effects of several pressures (such as catchment changes and fishing pressure) to be considered together. New technology, including continuous fixed-monitoring buoys, drones and cameras, along with coordinated national monitoring, have the potential to monitor the marine environment more cost effectively.

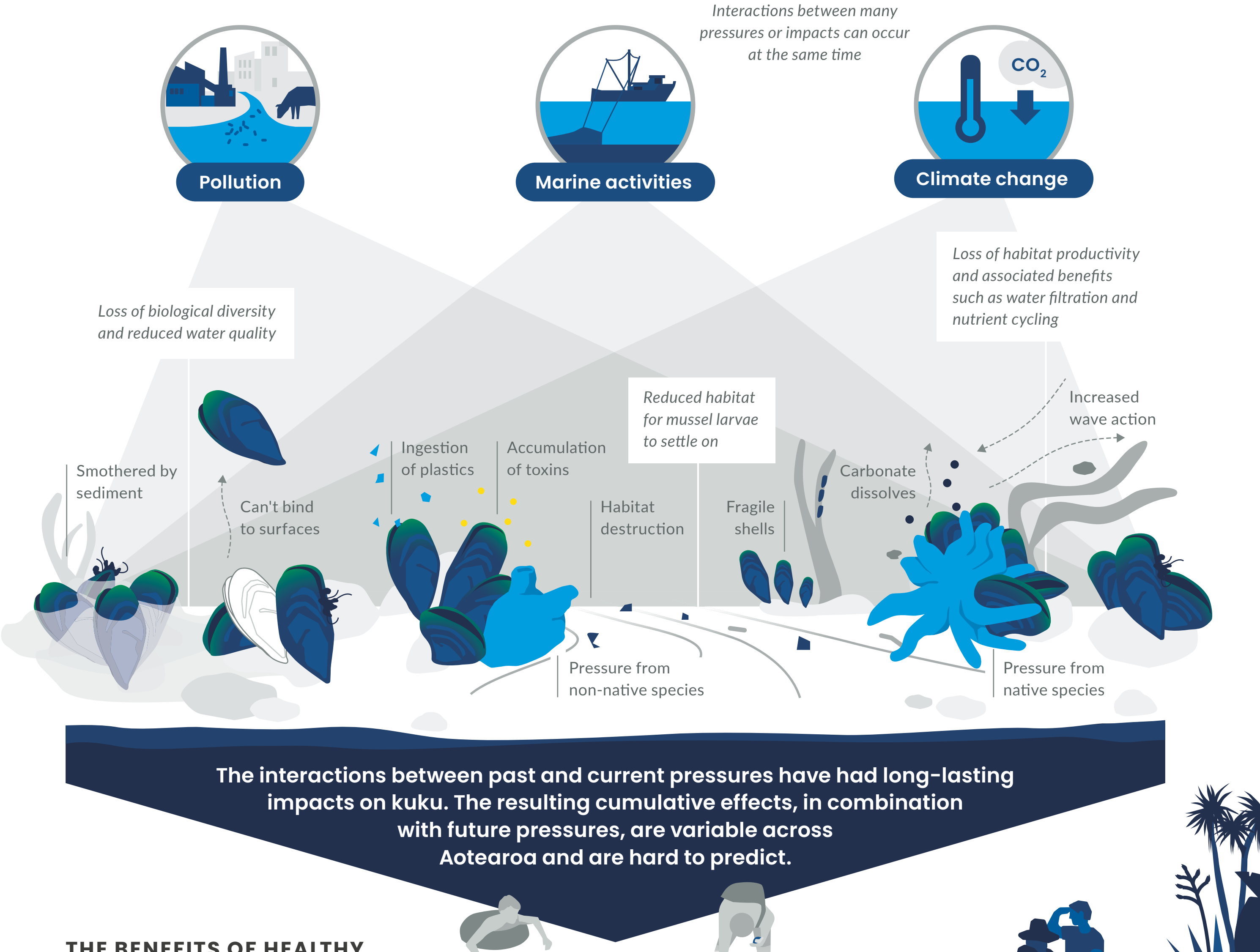
Integrating this data with local information and mātauranga Māori can provide holistic, place-based knowledge that is crucial to understanding cumulative effects. Connections between pressures are not new from a te ao Māori perspective, where even small shifts in the mauri of any part of the environment would cause shifts in the mauri of related parts of the environment, and eventually the wider environmental system (Environs Holdings Ltd, 2011).

The final image (opposite) in the story of kuku, the green-lipped mussel, shows that while we can measure individual effects, an understanding of cumulative effects when pressures overlap is limited. This considerable knowledge gap constrains our understanding of further impacts and where thresholds and tipping points for kuku may occur. The example from this single species illustrates the complexity of cumulative effects that occur more widely in our marine environment.

All pressures that affect kuku

Most of our impacts in the sea and many on land have impacts on kuku that overlap and interact, resulting in cumulative effects.

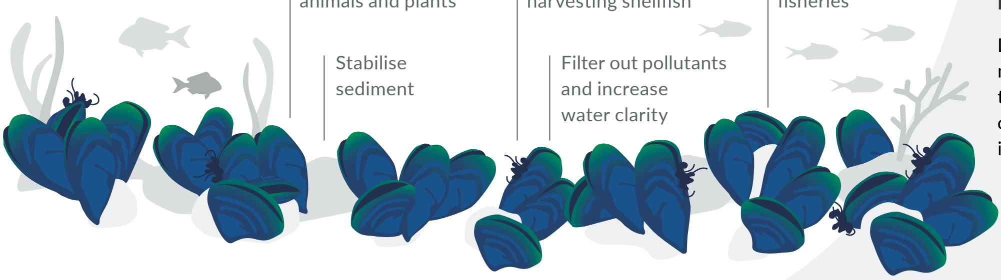
PRESSURES ON KUKU



THE BENEFITS OF HEALTHY, DENSE KUKU BEDS ARE BEING DEGRADED OR LOST

Dense kuku beds:

- Provide economic and income gain
- Provide homes and food for other marine animals and plants
- Stabilise sediment
- Improve water quality for swimming and harvesting shellfish
- Filter out pollutants and increase water clarity
- Support fish population and fisheries



IMPACT ON OUR VALUES

Loss of benefits and biodiversity erodes mauri and takes away opportunities to express kaitiakitanga, put kai moana on the table, and share intergenerational knowledge.

Towards a better understanding of our environment

Photo credit: Dave Allen, NIWA

We face important choices about how to manage and respond to the combined impacts of our activities on land and in the marine environment – including the consequences of climate change. When we understand our environment, we can manage it better by making decisions, adjusting our actions to stop further declines, and responding to unanticipated changes.

Making informed decisions despite complexity

Our coasts and oceans do not function in isolation, but are part of a wider environmental system that has high local variation and operates at different scales. This complexity means it is difficult to be certain about how our actions in one place affect other parts of the marine system.

Making informed decisions depends on being equipped with relevant data and accurate knowledge. Yet because of the size of the marine environment and the difficulties in measuring it, decisions will inevitably have to be made using the best available information at the time.

Smart decisions about what information to collect also have to be made. Choosing to gather data that shows the effects of our activities, and developing more responsive management systems, should be a priority.

Strengthening our knowledge and reporting systems

Many organisations are involved in building knowledge about the environment. These include local and central government, Crown research institutes, iwi, Māori trusts, universities, National Science Challenges, industry, businesses, and community groups.

Although good progress has been made to better understand our marine environment, gaps in data coverage and consistency remain. This limits some understanding and reporting. These gaps present opportunities: to develop a national picture through coordinated monitoring, and to grow our knowledge about specific places. This could include what people who live in that place do, what they value and want to achieve, as well as understanding the state of the environment in that place.

Much could be done to improve our understanding of how the environment works. With limited resources and an extensive marine environment, we will need innovation and focus to act where impact is likely to be the greatest. This includes aligning, coordinating, and building on efforts across knowledge and reporting systems, and across sectors.

Joint mātauranga Māori and other scientific approaches to data collection are becoming increasingly common (O'Callaghan et al, 2019). Together, they can provide a broader and more inclusive knowledge of the environment system. Environmental indicators can be used to show changes over time in ways that are meaningful for communities. Indicators for marine environments include mahinga kai, changes in the taste or smell of water, and litter (Environs Holdings Ltd, 2011; Faulkner and Faulkner, 2017). Another indicator is the mauri of the moana and the mauri of the people, which are usually interconnected. Sharing of data between organisations is still limited by a lack of centralised access to data and consistent data-collection methodologies.

Many elements of mātauranga Māori are culturally sensitive and managing this sensitive information appropriately is important. Reporting on indicators to the public versus their own iwi, hapū and whānau must therefore consider cultural and intellectual property rights (Environs Holdings Ltd, 2011). Reassurance that Māori knowledge will be respected, valued, and properly acknowledged is not always provided. The divergence between Māori and European scientific knowledge around spiritual or metaphysical indicators is also a barrier to sharing knowledge.

Priorities for improving understanding

Understanding the effects of cumulative pressures and how our actions affect the marine environment are significant knowledge gaps. The priority areas below are put forward as opportunities where the greatest value could be added.

Investigating how mātauranga Māori can be incorporated into coastal and marine monitoring and management frameworks, in accordance with tikanga Māori.

This would broaden Aotearoa New Zealand's knowledge of the impacts of change on local communities.

Examples:

- Using tohu and knowledge gathered over generations for coordinated national monitoring systems.
- Supporting or empowering Māori environmental practices.

Improving our understanding of the ways impacts on estuaries, coasts, and oceans interact and intensify in places and over time.

This would allow for the management of cumulative effects by managing activities in relation to one another rather than as single pressures.

Examples:

- How atmospheric carbon and inputs from land contribute to ocean acidity.
- How climate extremes and sea-level rise affect coastal systems and communities.
- How ecosystem function is affected by recreational, customary, and commercial fisheries in combination with other pressures like climate change.

Characterising connections between the health of the marine environment and past, current, and future land use in the short and long term.

This would inform better management of land-based activities and their effects on the receiving environments because many pressures in coastal waters can only be addressed on land.

Examples:

- Identify estuarine, coastal, and oceanic thresholds and tipping points, especially if cumulative pressures are operating.
- Understand sources of pollutants and how they move in land, freshwater, and marine environments by developing more consistent monitoring methods.

Assessing the extent, condition, and ecological integrity of marine habitats.

This would improve management of current and new activities on coasts and in oceans.

Example:

- Continue to improve mapping of habitat location and extent. This would improve our knowledge of the condition of marine habitats (and their changes) to better quantify their resilience to short- and long-term pressures.

Quantifying the benefits that New Zealand's marine ecosystems provide, beyond the income gained from using their resources.

This would better inform management trade-offs between use and conservation.

Examples:

- Develop, test, and adopt a national framework to account for the benefits derived from marine ecosystems.
- Update monitoring programmes to collect data in line with the framework.

Environmental reporting series and References

Photo credit: Photo New Zealand

Environmental reporting series

PREVIOUS REPORTS

- Our marine environment 2016
- Our fresh water 2017
- Our atmosphere and climate 2017
- Our land 2018
- Our air 2018
- Environment Aotearoa 2019.

ENVIRONMENTAL INDICATORS

New and updated for 2019

- Coastal sea-level rise
- Conservation status of indigenous marine species
- Sea-surface temperature
- Primary productivity
- Marine non-indigenous species
- Oceanic and coastal extreme waves
- Ocean acidification
- Bycatch of protected species: Hector's and Māui dolphins
- Marine economy.

This report includes new data on marine litter, though it does not have a separate indicator page.

INDICATORS UPDATED FOR ENVIRONMENT AOTEAROA 2019

- Coastal and estuarine water quality
- Heavy metal load in coastal and estuarine sediment
- Conservation status of indigenous marine species.

INDICATORS LAST UPDATED FOR OUR MARINE ENVIRONMENT 2016

- State of fish stocks
- Commercial catch: sharks and rays
- Bycatch of fish and invertebrates
- Protected species bycatch: sea lion and fur seal
- Bycatch of protected species: seabirds
- Commercial coastal seabed trawling and dredging
- Commercial seabed trawling and dredging
- Ocean storms
- Marine-protected areas.

OTHER INDICATORS REFERRED TO IN THIS REPORT

- River water quality: phosphorus
- Urban stream water quality.

References

Anderson TJ, Morrison M, Macdiarmid A, Clark M, Archino RD, Tracey D, … Wadhwa S (2019). *Review of New Zealand's Key Biogenic Habitats*. NIWA client report no. 2018139WN. Prepared for the Ministry for the Environment. Wellington, New Zealand.

Aquaculture New Zealand (2018). *New Zealand Aquaculture. A sector overview with key facts and statistics*. Nelson, New Zealand.

Armstrong P, Murray P, Nesdale A & Peckler B (2016). Ciguatera fish poisoning. *The Journal of the American Medical Association*, *129*(1444), 111-. https://doi.org/10.4103/1995-705X.90904

Ataria J, Mark-Shadbolt M, Mead ATP, Prime K, Doherty J, Waiwai J, … Garner GO (2018). Whakamanahia Te mātauranga o te Māori: empowering Māori knowledge to support Aotearoa's aquatic biological heritage. *New Zealand Journal of Marine and Freshwater Research*, *52*(4), 467–486. https://doi.org/10.1080/00288330.2018.1517097

Baird SJ & Wood BA (2018). *Extent of bottom contact by New Zealand commercial trawl fishing for deepwater Tier 1 and Tier 2 target fishstocks, 1989–90 to 2015–16*. New Zealand Aquatic Environment and Biodiversity Report No. 193. Prepared for the Ministry for Primary Industries. Wellington, New Zealand.

Baker CS, Chilvers BL, Constantine R, DuFresne S, Mattline RH, van Helden A & Hitchmough RA (2010). *Conservation status of New Zealand marine mammals, 2009. New Zealand Journal of Marine and Freshwater Research*, *44*(2), 101–115. https://doi.org/10.1080/00288330.2010.482970

Baker CS, Boren LJ, Childerhouse S, Constantine R, Van Helden A, Lundquist D, … Rolfe JR (2019). *Conservation status of New Zealand marine mammals, 2019*. New Zealand Threat Classification Series 29. Wellington, New Zealand. Retrieved from https://www.doc.govt.nz/globalassets/documents/science-and-technical/nztcs29entire.pdf

Barlow DR, Torres LG, Hodge KB, Steel D, Baker CS, Chandler TE, … Klinck H (2018). Documentation of a New Zealand blue whale population based on multiple lines of evidence. *Endangered Species Research*, *36*, 27–40. https://doi.org/10.3354/esr00891

Baumann H, Talmage S & Gobler C (2012). Reduced early life growth and survival in a fish in direct response to increased carbon dioxide. *Nature Climate Change*, *2*(1), 38–41. https://doi.org/10.1038/nclimate1291

Behrens S & Constantine R (2008). *Large Whale and Vessel Collisions in Northern New Zealand*. Paper SC/60/BC9 to the International Whaling Commission Scientific Committee. Cambridge, United Kingdom.

Bell RG, Paulik R & Wadwha S (2015). *National and regional risk exposure in low-lying coastal areas. Areal extent, population, buildings and infrastructure*. NIWA client report no. HAM2015-006. Prepared for the Parliamentary Commissioner for the Environment. Hamilton, New Zealand.

Bell RG & Hannah J (2019). *Update to 2018 of the annual MSL series and trends around New Zealand*. NIWA client report 2019263WN. Prepared for the Ministry for the Environment. Hamilton, New Zealand.

Boerger CM, Lattin GL, Moore SL & Moore CJ (2010). Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre. *Marine Pollution Bulletin*, *60*(12), 2275–2278. https://doi.org/10.1016/j.marpolbul.2010.08.007

Botterell ZLR, Beaumont N, Dorrington T, Steinke M, Thompson RC & Lindeque PK (2019). Bioavailability and effects of microplastics on marine zooplankton: A review. *Environmental Pollution Journal*, *245*, 98–110. https://doi.org/10.1016/j.envpol.2018.10.065

Brake L & Peart R (2013). *Caring for our coast: An EDS Guide to managing coastal development*. Auckland, New Zealand: Environment Defence Society.

Capotondi A, Alexander MA, Bond NA, Curchitser EN & Scott JD (2012). Enhanced upper ocean stratification with climate change in the CMIP3 models. *Journal of Geophysical Research: Oceans*, *117*, 1–23. https://doi.org/10.1029/2011JC007409

Carrier J, Musick J & Heithaus M (2010). *Sharks and their relative II: Biodiversity, adaptive physiology and conservation*. Boca Raton, Florida, USA: CRC Press.

Charry MP, Keesing V, Costello M & Tremblay LA (2018). Assessment of the ecotoxicity of urban estuarine sediment using benthic and pelagic copepod bioassays. *PeerJ*, *6*, 19. https://doi.org/10.7717/peerj.4936

Chiba S, Saito H, Fletcher R, Yogi T, Kayo M, Miyagi S, … Fujikura K (2018). Human footprint in the abyss: 30 year records of deep-sea plastic debris. *Marine Policy*, *96*(April), 204–212. https://doi.org/10.1016/j.marpol.2018.03.022

Chiswell S & Grant B (2018). *New Zealand Coastal Sea Surface Temperature*. NIWA client report no. 2018295WN. Prepared for the Ministry for the Environment. Wellington, New Zealand.

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*, 1–16. https://doi.org/10.3389/fmars.2019.00063

Clarke Murray C, Pakhomov EA & Therriault TW (2011). Recreational boating: A large unregulated vector transporting marine invasive species. *Diversity and Distributions*, *17*(6), 1161–1172. https://doi.org/10.1111/j.1472-4642.2011.00798.x

Clements JC & Chopin T (2017). Ocean acidification and marine aquaculture in North America: potential impacts and mitigation strategies. *Reviews in Aquaculture*, *9*(4), 326–341. https://doi.org/10.1111/raq.12140

Climate Change Adaptation Technical Working Group (2017). *Adapting to Climate Change in New Zealand.* Wellington, New Zealand. Retrieved from http://www.ccadaptation.org.cn

Cole M, Lindeque P, Fileman E, Halsband C, Goodhead R, Moger J & Galloway TS (2013). Microplastic ingestion by zooplankton. *Environmental Science and Technology*, *47*(12), 6646–6655. https://doi.org/10.1021/es400663f

Constantine R, Johnson M, Riekkola L, Jervis S, Kozmian-Ledward L, Dennis T, … Aguilar de Soto, N (2015). Mitigation of vessel-strike mortality of endangered Bryde's whales in the Hauraki Gulf, New Zealand. *Biological Conservation*, *186*, 149–157. https://doi.org/10.1016/j.biocon.2015.03.008

Cornwall CE, Hepburn CD, Mcgraw CM, Currie KI, Pilditch CA, Hunter KA, … Hurd CL (2013). Diurnal fluctuations in seawater pH influence the response of a calcifying macroalga to ocean acidification. *Proceedings of the Royal Society B: Biological Sciences*, *280*. https://doi.org/10.1098/rspb.2013.2201

Croxall JP, Butchart SHM, Lascelles BG, Stattersfield AJ, Sullivan B, Symes A & Taylor PD (2012). Seabird conservation status, threats and priority actions: a global assessment. *Bird Conservation International*, *22*(1), 1–34. https://doi.org/10.1017/S0959270912000020

Cunningham SC, Smith AM & Lamare MD (2016). The effects of elevated pCO_2 on growth, shell production and metabolism of cultured juvenile abalone, Haliotis iris. *Aquaculture Research*, *47*(8), 2375–2392. https://doi.org/10.1111/are.12684

Dangendorf S, Hay C, Calafat FM, Marcos M, Piecuch CG, Berk K & Jensen J (2019). Persistent acceleration in global sea-level rise since the 1960s. *Nature Climate Change*, *9*. https://doi.org/10.1038/s41558-019-0531-8

Darling JA, Herborg LM & Davidson IC (2012). Intracoastal shipping drives patterns of regional population expansion by an invasive marine invertebrate. *Ecology and Evolution*, *2*(10), 2557–2566. https://doi.org/10.1002/ece3.362

Davies K, Fisher K, Foley M, Greenaway A, Hewitt J, Le Heron R, … Lundquist C (2018). Navigating collaborative networks and cumulative effects for Sustainable Seas. *Environmental Science & Policy*, *83*, 22–32. https://doi.org/https://doi.org/10.1016/j.envsci.2018.01.013

Davis AR, Walls K & Jeffs A (2018). Biotic consequences of a shift in invertebrate ecosystem engineers: Invasion of New Zealand rocky shores by a zone-forming ascidian. *Marine Ecology*, *39*(3), 10. https://doi.org/10.1111/maec.12502

Deloitte (2016). *New Zealand ports and freight yearbook 2016*. Retrieved from https://www2.deloitte.com/content/dam/Deloitte/nz/Documents/finance/New-Zealand-ports-and-freight-report-2017.pdf

Deloitte (2018). *Industry insight New Zealand ports and freight yearbook 2018*. Retrieved frrom https://www2.deloitte.com/content/dam/Deloitte/nz/Documents/finance/nz-2018-ports-and-freight-report-final.pdf

Department of Conservation (nd). Māori and New Zealand sea lion. Retrieved September 5, 2019, from https://www.doc.govt.nz/nature/native-animals/marine-mammals/seals/new-zealand-sea-lion/maori/

Diaz RJ & Rosenberg R (2008). Spreading dead zones and consequences for marine ecosystems. *Science*, *321*(5891), 926–929. https://doi.org/10.1126/science.1156401

Duarte CM (2017). Reviews and syntheses: Hidden forests, the role of vegetated coastal habitats in the ocean carbon budget. *Biogeosciences*, *14*(2), 301–310. https://doi.org/10.5194/bg-14-301-2017

Duarte CM & Krause-Jensen D (2017). Export from Seagrass Meadows Contributes to Marine Carbon Sequestration. *Frontiers in Marine Science*, *4*, 13. https://doi.org/10.3389/fmars.2017.00013

Dudley B, Zeldis JR & Burge O (2017). *New Zealand Coastal Water Quality Assessment*. NIWA Client Report no. 2016093CH. Prepared for the Ministry for the Environment. Christchurch, New Zealand. Retrieved from https://www.mfe.govt.nz/publications/environmental-reporting/new-zealand-coastal-water-quality-assessment

Environs Holdings Ltd, (2011). *Assessing the mauri of the Kaipara. Science*. Contract No. C09X1003. Prepared for Manaaki Whenua Landcare Research. Whangarei, New Zealand. Retrieved from https://www.landcareresearch.co.nz/publications/researchpubs/Te_Uri_o_Hau_2011_Assessing_mauri_Kaipara.pdf

FAO (2018). FAO Fisheries & Aquaculture – Fishery Statistical Collections – Global Capture Production. Retrieved November 20, 2018, from http://www.fao.org/fishery/statistics/global-capture-production/query/en

FAO (2019). *FAO yearbook. Fishery and Aquaculture Statistics 2017.* Rome, Italy. Retrieved from http://www.fao.org/documents/card/en/c/ca5495t

Faulkner L & Faulkner R (2017). *Marine Cultural Health Indicators Report*. Retrieved from http://www.ngatitoa.iwi.nz/sitecontent/images/Folders/Blog/Ngati-Toa-MCHI-report-final-2017.pdf

Feng Y, Roleda MY, Armstrong E, Boyd PW & Hurd CL (2017). Environmental controls on the growth, photosynthetic and calcification rates of a Southern Hemisphere strain of the coccolithophore *Emiliania huxleyi*. *Limnology and Oceanography*, *62*(2), 519–540. https://doi.org/10.1002/lno.10442

Fisheries New Zealand (2019a). *Status of New Zealand's fish stocks 2018*. Wellington, New Zealand. Retrieved from https://www.mpi.govt.nz/dmsdocument/11950-the-status-of-new-zealands-fisheries-2018

Fisheries New Zealand (2019b). *The Status of New Zealand's Fisheries 2018*. Wellington, New Zealand. Retrieved from https://www.mpi.govt.nz/dmsdocument/34419-the-status-of-new-zealand-fisheries-report-2018-final

Forrest AK & Hindell M (2018). Ingestion of plastic by fish destined for human consumption in remote South Pacific Islands. *Australian Journal of Maritime & Ocean Affairs*, *10*(2), 81–97. https://doi.org/10.1080/18366503.2018.1460945

Forster ME (2012). *Hei whenua papatipu : kaitiakitanga and the politics of enhancing the mauri of wetlands : a thesis presented for the degree of Doctor of Philosophy, Māori Studies, Massey University, Palmerston North, New Zealand.* Retrieved from https://mro.massey.ac.nz/handle/10179/3336

Fourqurean JW, Duarte CM, Kennedy H, Marbà N, Holmer M, Mateo MA, … Serrano O (2012). Seagrass ecosystems as a globally significant carbon stock. *Nature Geoscience*, *5*(7), 505–509. https://doi.org/10.1038/ngeo1477

Frölicher T, Fischer E & Gruber N (2018). Marine heatwaves under global warming. *Nature*, *560*(7718), 360–364. https://doi.org/10.1038/s41586-018-0383-9

Gaw S, Thomas KV & Hutchinson TH (2014). Sources, impacts and trends of pharmaceuticals in the marine and coastal environment. *Philosophical Transactions of the Royal Society B*, *369*. https://doi.org/10.1098/rstb.2013.0572

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

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection) and Advisory Committee on Protection of the Sea. (2001). *Protecting the oceans from land-based activities. Land-based sources and activities affecting the quality and uses of the marine, coastal and associated freshwater environment.* GESAMP Reports and Studies No. 71. The Hague, Netherlands. Retrieved from http://wedocs.unep.org/bitstream/handle/20.500.11822/9169/protecting_oceans.pdf

Gibb J & Cox G (2009). *Patterns and rates of sedimentation within Porirua.* Consultancy Report 2009/1. Prepared for Porirua City Council. Keri Keri, New Zealand. Retrieved from file://mfeprodfps01/TellierP$/downloads/Porirua_Harbour_Patterns_and_Rates_of_Sedimentation_Report.pdf

Gittman RK, Scyphers SB, Smith CS, Neylan IP & Grabowski JH (2016). Ecological consequences of shoreline hardening: A meta-analysis. *BioScience*, *66*(9), 763–773. https://doi.org/10.1093/biosci/biw091

Goldson SL, Bourdôt GW, Brockerhoff EG, Byrom AE, Clout MN, McGlone MS, … Templeton MD (2015). New Zealand pest management: Current and future challenges. *Journal of the Royal Society of New Zealand*, *45*(1), 31–58. https://doi.org/10.1080/03036758.2014.1000343

Gordon DP, Beaumont J, MacDiarmid AB, Robertson DA & Ahyong ST (2010). Marine biodiversity of Aotearoa New Zealand. *PLoS ONE*, *5*(8), e10905. https://doi.org/10.1371/journal.pone.0010905

Greater Wellington Regional Council, Porirua City Council, Wellington City Council & Te Rūnanga o Toa Rangātira (2015). *Te Awarua-o-Porirua Harbour and Catchment Sediment Reduction Plan.* Welington, New Zealand. Retrieved from http://www.gw.govt.nz/assets/Uploads/Te-Awarua-o-Porirua-harbour-and-catchment-sediment-reduction-plan.pdf

Gregory MR (1978). Accumulation and distribution of virgin plastic granules on New Zealand beaches. *New Zealand Journal of Marine and Freshwater Research*, *12*(4), 399–414. https://doi.org/10.1080/00288330.1978.9515768

Gregory MR (2009). Environmental implications of plastic debris in marine settings – entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*, 2013–2025. https://doi.org/10.1098/rstb.2008.0265

Gruber N, Clement D, Carter BR, Feely RA, van Heuven S, Hoppema M, … Wanninkhof R (2019). The oceanic sink for anthropogenic CO_2 from 1994 to 2007. *Science*, *363*(6432), 1193–1199. https://doi.org/10.1126/science.aau5153

Hawke's Bay Regional Council (2012). *Te Whanganui a Orotū (Ahuriri Estuary).* Napier, New Zealand. Retrieved from https://www.hbrc.govt.nz/assets/Document-Library/Outstanding-Water-Bodies/Secondary-Assessments/Te-Whanganui-a-Orotu-Ahuriri-Estuary.pdf

Hikuroa D (2017). Mātauranga Māori—the ūkaipō of knowledge in New Zealand. *Journal of the Royal Society of New Zealand*, *47*(1), 5–10. https://doi.org/10.1080/03036758.2016.1252407

Holdsworth J, Rea T & Southwick R (2016). *Recreational Fishing in New Zealand: A Billion Dollar Industry.* Hunua, New Zealand. Retrieved from http://www.nzmrf.org.nz/files/New-Zealand-Fishing-Economic-Report.pdf

Hume TM, Snelder T, Weatherhead M & Liefting R (2007). A controlling factor approach to estuary classification. *Ocean & Coastal Management*, *50*, 905–929. https://doi.org/10.1016/j.ocecoaman.2007.05.009

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://www.jstor.org/stable/24864209

Hunt S (2016). Regional Estuary Monitoring Programme (REMP) intertidal sedimentation measurements, results and review of methodologies. *Waikato Regional Council Technical Report 2019/04* (June). Hamilton, New Zealand. Retrieved from https://www.waikatoregion.govt.nz/assets/WRC/Services/publications/technical-reports/2019/TR201904.pdf

Hunt S (2019). *Summary of historic estuarine sedimentation measurements in the Waikato region and formulation of a historic baseline sedimentation rate*. Waikato Regional Council Technical Report 2019/08. Hamilton, New Zealand. Retrieved from http://www.waikatoregion.govt.nz/assets/WRC/Services/publications/technical-reports/2019/TR201908.pdf

IPCC (2013). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. (TF Stocker, D Qin, G-K Plattner, MMB Tignor, SK Allen, J Boschung, … PM Midgley, Eds). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. Retrieved from www.cambridge.org

IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. (V R Barros, CB Field, DJ Dokken, MD Mastrandrea, KJ Mach, TE Bilir, … LL White, Eds).Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. https://doi.org/10.1017/CBO9781107415324.004

Jones, R (2013). Climate change and Māori health. In M Katene, Selwyn; Mulholland (Ed), *Future challenges for Māori*. Wellington, New Zealand: Huia Publishers.

Kainamu-Murchie AA, Marsden ID, Tau RTM, Gaw S & Pirker (Ngāi Tahu) J (2018). Indigenous and local peoples' values of estuarine shellfisheries: moving towards holistic-based catchment management. *New Zealand Journal of Marine and Freshwater Research*. https://doi.org/10.1080/00288330.2018.1523200

Lamare M, Uthicke S, Dworjanyn SA, Winter D & Byrne M (2013). The stunting effect of a high CO_2 ocean on calcification and development in sea urchin larvae, a synthesis from the tropics to the poles. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *368*(1627), 20120439–20120439. https://doi.org/10.1098/rstb.2012.0439

Larned S, Booker D, Dudley B, Moores J, Monaghan R, Baillie B, … Short K (2018). *Land-use impacts on freshwater and marine environments in New Zealand*. Christchurch, New Zealand.

Law CS, Bell JJ, Bostock HC, Cornwall CE, Cummings VJ, Currie KI, … Tracey DM (2018b). 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

Law CS, Rickard GJ, Mikaloff-Fletcher SE, Pinkerton MH, Behrens E, Chiswell SM & Currie K (2018a). Climate change projections for the surface ocean around New Zealand. *New Zealand Journal of Marine and Freshwater Research*, *52*, 309–335. https://doi.org/10.1080/00288330.2017.1390772

LINZ (2019). NZ Coastlines. Retrieved from https://data.linz.govt.nz/layer/50258-nz-coastlines-topo-150k/

MacDiarmid AB, Law CS, Pinkerton MH & Zeldis J (2013). New Zealand Marine Ecosystem Services. In JR Dymond (Ed), *Ecosystem services in New Zealand: conditions and trends* (p. 539). Lincoln: Manaaki Whenua Press.

Mackenzie AL (2014). The risk to New Zealand shellfish aquaculture from paralytic shellfish poisoning (PSP) toxins. *New Zealand Journal of Marine and Freshwater Research*, *48*(3), 430–465. https://doi.org/10.1080/00288330.2014.911191

Malham SK, Rajko-Nenow P, Howlett E, Tuson KE, Perkins TL, Pallett DW, … McDonald JE (2014). The interaction of human microbial pathogens, particulate material and nutrients in estuarine environments and their impacts on recreational and shellfish waters. *Environmental Sciences: Processes and Impacts*, *16*(9), 2145–2155. https://doi.org/10.1039/c4em00031e

Marine Biosecurity Porthole (nd). Marine Biosecurity in New Zealand. Retrieved from https://www.marinebiosecurity.org.nz/new-page-11/

Markic A, Niemand C, Bridson JH, Mazouni-Gaertner N, Gaertner JC, Eriksen M & Bowen M (2018). Double trouble in the South Pacific subtropical gyre: Increased plastic ingestion by fish in the oceanic accumulation zone. *Marine Pollution Bulletin*, *136*, 547–564. https://doi.org/10.1016/j.marpolbul.2018.09.031

Marlborough District Council (nd). Seabed habitat maps. Retrieved from https://marlborough.maps.arcgis.com/apps/MapSeries/index.html?appid=155a89b0beb74035bd1c4c71f6f36646

Mcleod E, Chmura GL, Bouillon S, Salm R, Björk M, Duarte CM, … Silliman BR (2011). A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO_2. *Frontiers in Ecology and the Environment*, *9*(10), 552–560. https://doi.org/10.1890/110004

Mcleod IM (2009). *Green-lipped mussels,* Perna canaliculus, *in soft-sediment systems in northeastern New Zealand*. University of Auckland. Auckland, New Zealand. https://doi.org/10.13140/2.1.2822.3046

Mikaloff Fletcher SE, Gruber N, Jacobson AR, Doney SC, Dutkiewicz S, Gerber M, … Sarmiento JL (2006). Inverse estimates of anthropogenic CO_2 uptake, transport, and storage by the ocean. *Global Biogeochemical Cycles*, *20*(2). https://doi.org/10.1029/2005GB002530

Ministry for Primary Industries (2011). *Rules on marine farming Undaria in New Zealand*. Wellington, New Zealand.

Ministry for Primary Industries (2013). *National Plan of action to reduce the incidental catch of seabirds in New Zealand fisheries 2013*. Wellington, New Zealand.

Ministry for Primary Industries (2017). *Aquatic Environment and Biodiversity Annual Review 2017. A summary of environmental interactions between the seafood sector and the aquatic environment. Aquatic Environment and Biodiversity Annual Review*. Wellington, New Zealand.

Ministry for Primary Industries (2019). *Aquatic Environment and Biodiversity Annual Review 2018. A summary of environmental interactions between the seafood sector and the aquatic environment*. Wellington, New Zealand.

Ministry for the Environment (2017). *Coastal Hazards and Climate Change: guidance for local government*. Ministry for the Environment. Wellington, New Zealand. Retrieved from http://www.mfe.govt.nz/sites/default/files/media/Climate Change/coastal-hazards-guide-final.pdf

Ministry for the Environment (2018). *Climate change projections for New Zealand: atmosphere projections based on simulations from the IPCC fifth assessment, 2nd edition*. Wellington, New Zealand. Retrieved from http://www.mfe.govt.nz/sites/default/files/media/Climate Change/climate-projections-snapshot.pdf

Ministry of Business, Innovation and Employment (2016). *Tourism infrastructure*. Tourism insights series. Wellington, New Zealand. Retrieved from https://www.mbie.govt.nz/assets/780c75be7c/tis-1-tourism-infrastructure.pdf

Morrison MA, Jones EG, Consalvey M & Berkenbusch K (2014). *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. Wellington, New Zealand. Retrieved from https://fs.fish.govt.nz/Doc/23651/AEBR_130_2514_HAB2007-01%20(obj%201,%202,%20RR3).pdf.ashx

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. Wellington, New Zealand. Retrieved from https://fs.fish.govt.nz/Doc/22003/AEBR_37.pdf.ashx

Munday P, Dixson D, Mccormick M, Meekan M, Ferrari M & Chivers D (2010). Replenishment of fish populations is threatened by ocean acidification. *Proceedings of the National Academy of Sciences*, *107*(29), 12930–12934. https://doi.org/10.1073/pnas.1004519107

Munday P, Watson S, Parsons D, King A, Barr N, Mcleod I, … Pether S (2016). Effects of elevated CO_2 on early life history development of the yellowtail kingfish, *Seriola lalandi*, a large pelagic fish. *ICES Journal of Marine Science: Journal Du Conseil*, *73*(3), 641–649. https://doi.org/10.1093/icesjms/fsv210

New Zealand King Salmon (2018). NZK Annual Report 2018. Nelson, New Zealand. Retrieved from https://www.kingsalmon.co.nz/kingsalmon/wp-content/uploads/2018/10/NKS23278-Annual-Report-2018-03.10.18.pdf

Norkko A, Thrush SF, Hewitt JE, Cummings VJ, Norkko J, Ellis JI, … MacDonald I (2002). Smothering of estuarine sandflats by terrigenous clay: The role of wind-wave disturbance and bioturbation in site-dependent macrofaunal recovery. *Marine Ecology Progress Series*, *234*, 23–41. https://doi.org/10.3354/meps234023

O'Callaghan J, Stevens C, Roughan M, Cornelisen C, Sutton PJH, Garrett S, … Fishwick JR (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

OECD (2019). *Responding to Rising Seas: OECD Country Approaches to Tackling Coastal Risks*. Paris, France. https://doi.org/https://doi.org/10.1787/9789264312487-en

Oliver T, Heard M, Isaac N, Roy D, Procter D, Eigenbrod F, … Bullock J (2015). Biodiversity and Resilience of Ecosystem Functions. *Trends in Ecology and Evolution*, *30*(11), 673–684. https://doi.org/10.1016/j.tree.2015.08.009

Orr JC, Fabry VJ, Aumont O, Bopp L, Doney SC, Feely RA, … Yool A (2005). Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature*, *437*(7059), 681–686. https://doi.org/10.1038/nature04095

Parsons DM, Morrison MA, Thrush SF, Middleton C, Smith M, Spong KT & Buckthought D (2013). The influence of habitat structure on juvenile fish in a New Zealand estuary. *Marine Ecology*, *34*(4), 492–500. https://doi.org/10.1111/maec.12050

Paul-Burke K, Burke J, Te Ūpokorehe Resource Management Team, Bluett C & Senior T (2018). Using Māori knowledge to assist understandings and management of shellfish populations in Ōhiwa harbour, Aotearoa New Zealand. *New Zealand Journal of Marine and Freshwater Research*, *52*(4), 542–556. https://doi.org/10.1080/00288330.2018.1506487

Pecorino D, Barker M, Dworjanyn S, Byrne M & Lamare M (2014). Impacts of near future sea surface pH and temperature conditions on fertilisation and embryonic development in Centrostephanus rodgersii from northern New Zealand and northern New South Wales, Australia. *Marine Biology*, *161*(1), 101–110. https://doi.org/10.1007/s00227-013-2318-1

Pinkerton MH, Sutton PJH & Wood S (2019). Satellite indicators of phytoplankton and ocean surface temperature for New Zealand. NIWA Client Report 2018180WN. Prepared for the Ministry for the Environment. Wellington, New Zealand.

Putland RL, Merchant ND, Farcas A & Radford CA (2018). Vessel noise cuts down communication space for vocalizing fish and marine mammals. *Global Change Biology*, *24*(4), 1708–1721. https://doi.org/10.1111/gcb.13996

Rhodes LL, Smith KF, Murray S, Harwood DT, Trnski T & Munday R (2017). The Epiphytic Genus Gambierdiscus (Dinophyceae) in the Kermadec Islands and Zealandia Regions of the Southwestern Pacific and the Associated Risk of Ciguatera Fish Poisoning. *Marine Drugs*, *15*(7), 219. https://doi.org/10.3390/md15070219

Riding J, Roberts J & Priovolos G (2016). *New Zealand Hydrographic Risk Assessment. National Overview*. Report No.15NZ326-A. Prepared for Land Information New Zealand. Wellington, New Zealand. Retrieved from https://www.linz.govt.nz/sea/charts/annual-work-programme/new-zealand-hydrographic-risk-assessment

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. Prepared for the Ministry for Primary Industries. Wellington, New Zealand. Retrieved from http://fs.fish.govt.nz

Robertson BM, Stevens L, Robertson B, Zeldis J, Green M, Madarasz-Smith A, Plew D, Storey R, Oliver M (2016) *NZ Estuary Trophic Index Screening Tool 2. Determining Monitoring Indicators and Assessing Estuary Trophic State*. Prepared for Envirolink Tools Project: Estuarine Trophic Index, MBIE/NIWA Contract No: C01X1420.

Robertson BC & Chilvers BL (2011). The population decline of the New Zealand sea lion Phocarctos hookeri: A review of possible causes. *Mammal Review*, *41*(4), 253–275. https://doi.org/10.1111/j.1365-2907.2011.00186.x

Robertson B & Stevens L (2015). *Porirua Harbour Fine Scale Monitoring 2014/15*. Prepared for Greater Wellington Regional Council. Nelson, New Zealand. Retrieved from http://www.gw.govt.nz/assets/council-publications/Porirua-FS2015WEB.pdf

Ross PM, Beentjes MP, Cope J, de Lange WP, McFadgen BG, Redfearn P, … Williams JR (2018). The biology, ecology and history of toheroa (*Paphies ventricosa*): a review of scientific, local and customary knowledge. *New Zealand Journal of Marine and Freshwater Research*, *52*(2), 196–231. https://doi.org/10.1080/00288330.2017.1383279

Rout M, Reid J, Bodwitch H, Gillies A, Lythberg B, Hikuroa D, … Davies K (2018). *Māori Marine Economy: A review of literature concerning the historical and contemporary structure of the Māori marine economy.* Sustainable Seas National Science Challenge.

Salinger MJ & Mullan AB (1999). New Zealand climate: temperature and precipitation variations and their links with atmospheric circulation 1930–1994. *International Journal of Climatology*, *19* (October 2014), 1049–1071. https://doi.org/10.1002/(SICI)1097-0088(199908)19

Sanford Limited (2018). *2018 Annual Report*. Auckland, New Zealand. Retrieved from https://www.sanford.co.nz/investors/reports-1/company-reports/2018/2018-annual-report/

Schiel DR, Ross PM & Battershill CN (2016). Environmental effects of the MV Rena shipwreck: cross-disciplinary investigations of oil and debris impacts on a coastal ecosystem. *New Zealand Journal of Marine and Freshwater Research*, *50*(1), 1–9. https://doi.org/10.1080/00288330.2015.1133665

Schreiber E & Burger J (2001). *Biology of marine birds*. Boca Raton, FL, USA: CRC Press.

Seaward K & Inglis G (2018). *Long-term indicators for non–indigenous species (NIS) in marine systems*. NIWA Client Report 2018310CH. Prepared for the Ministry for the Environment. Christchurch, New Zealand.

Seebens H, Schwartz N, Schupp PJ & Blasius B (2016). Predicting the spread of marine species introduced by global shipping. *Proceedings of the National Academy of Sciences of the United States of America*, *113*(20), 5646–5651. https://doi.org/10.1073/pnas.1524427113

Shears NT & Babcock RC (2002). Marine Reserves Demonstrate Top-down Control of Community Structure on Temperate Reefs. *Oecologia*, *132*(1), 131–142. https://doi.org/https://doi.org/10.1007/s00442-002-0920-x

Simonson T & Hall G (2019). *Vulnerable: the quantum of local government infrastructure exposed to sea level rise*. Wellington, New Zealand. Retrieved from http://www.lgnz.co.nz/assets/Uploads/d566cc5291/47716-LGNZ-Sea-Level-Rise-Report-3-Proof-FINAL-compressed.pdf

South PM, Floerl O, Forrest BM & Thomsen MS (2017). A review of three decades of research on the invasive kelp Undaria pinnatifida in Australasia: An assessment of its success, impacts and status as one of the world's worst invaders. *Marine Environmental Research*, *131*, 243–257. https://doi.org/10.1016/j.marenvres.2017.09.015

Stats NZ (2018). *Environmental-economic accounts: 2018 (corrected)*. Wellington, New Zealand. Retrieved from www.stats.govt.nz

Stats NZ (2019a). Environmental-economic accounts: Data to 2017. Wellington, New Zealand. Retrieved from www.stats.govt.nz

Stats NZ (2019b). Environmental-economic accounts: 2019 – tables. Retrieved September 5, 2019, from https://www.stats.govt.nz/information-releases/environmental-economic-accounts-2019-tables

Sunday JM, Fabricius KE, Kroeker KJ, Anderson KM, Brown NE, Barry JP, … Harley CDG (2017). Ocean acidification can mediate biodiversity shifts by changing biogenic habitat. *Nature Climate Change*, *7*(1), 81–85. https://doi.org/10.1038/nclimate3161

Sussarellu R, Suquet M, Thomas Y, Lambert C, Fabioux C, Pernet MEJ, … Huvet A (2016). Oyster reproduction is affected by exposure to polystyrene microplastics. *Proceedings of the National Academy of Sciences*, *113*(9), 2430–2435. https://doi.org/10.1073/pnas.1519019113

Sutton PJH & Bowen M (2019). Ocean temperature change around New Zealand over the last 36 years. *New Zealand Journal of Marine and Freshwater Research*, *53*, 1–22. https://doi.org/10.1080/00288330.2018.1562945

Swales A, Gibbs M, Olsen G, Ovenden R, Costley K & Stephens T (2016). Sources of eroded soils and their contribution to long-term sedimentation in the Firth of Thames. Waikato Regional Council Technical Report 2016/32. Hamilton, New Zealand. Retrieved from https://www.waikatoregion.govt.nz/services/publications/technical-reports/2016/tr201632/

Tait A (2019). *Risk-exposure assessment of Department of Conservation (DOC) coastal locations to flooding from the sea.* Science for Conservation No. 332. Wellington, New Zealand. Retrieved from https://www.doc.govt.nz/globalassets/documents/science-and-technical/sfc332entire.pdf

Taylor GA (2000). *Action plan for seabird conservation in New Zealand part A: threatened seabirds*. Threatened Species Occasional Publication No. 16. Wellington, New Zealand. Retrieved from https://www.doc.govt.nz/documents/science-and-technical/tsop16.pdf

The Lawless Edge Ltd (2018). Top of the South Councils' Marine Biosecurity Operational Plan. Actual work completed in 2017/2018. Prepared for Top of the South Marine Biosecurity Partnership. Nelson, New Zealand. Retrieved from http://www.marinebiosecurity.co.nz/downloads/4802370/Final+Marine+Biosecurity+Operational+Plan+2017-2018+Report+on+actuals+-+...-1.pdf

Thomsen MS, Mondardini L, Alestra T, Gerrity S, Tait L, South PM, … Marzinelli EM (2019). Local Extinction of Bull Kelp (Durvillaea spp.) Due to a Marine Heatwave. *Frontiers in Marine Science*, *6* (March), 1–10. https://doi.org/10.3389/fmars.2019.00084

Thrush SF, Hewitt JE, Cummings VJ, Ellis JI, Hatton C, Lohrer A & Norkko A (2004). Muddy Waters: Elevating Sediment Input to Coastal and Estuarine Habitats. *Frontiers in Ecology and the Environment*, *2*(6), 299–306. https://doi.org/10.2307/3868405

Thrush SF, Hewitt JE, Lundquist C, Townsend M & Lohrer AM (2011). *A strategy to assess trends in the ecological integrity of New Zealand's marine ecosystems*. NIWA Client Report No: HAM2011-140. Prepared for the Department of Conservation. Hamilton, New Zealand. Retrieved from https://www.doc.govt.nz/Documents/conservation/marine-and-coastal/marine-protected-areas/ecological-integrity-marine-ecosystems.pdf

Thrush SF, Hewitt JE, Funnell GA, Cummings VJ, Ellis J, Schultz D, … Norkko A (2001). Fishing disturbance and marine biodiversity: The role of habitat structure in simple soft-sediment systems. *Marine Ecology Progress Series*, *223*, 277–286. https://doi.org/10.3354/meps223277

Thrush SF, Townsend M, Hewitt JE, Davies K, Lohrer AM, Lundquist C & Cartner K (2013). The many uses and values of estuarine ecosystems. In J R Dymond (Ed), *Ecosystem services in New Zealand – Conditions and Trends* (pp. 226–237). Lincoln, New Zealand: Manaaki Whenua Press.

Todd M, Kettles H, Graeme C, Sawyer J, Mcewan A & Adams L (2016). *Estuarine systems in the lower North Island/Te Ika-a-Māui. Ranking of significance, current status and future management options*. Wellington, New Zealand. Retrieved from https://www.doc.govt.nz/globalassets/documents/conservation/estuaries/lower-north-island-estuaries-report.pdf

Townsend M & Lohrer D (2015). *ANZECC guidance for estuary sedimentation*. NIWA Client Report No. HAM2015-096. Prepared for Ministry for the Environment. Hamilton, New Zealand. Retrieved from http://www.mfe.govt.nz/publications/fresh-water/anzecc-guidance-estuary-sedimentation

United Nations (2016). *First Global Integrated Marine Assessment. World Ocean Assessment I*. Prepared by the Group of Experts of the Regular Process. New York, NY, USA.

United Nations Economic and Social Council (2019). *Traditional knowledge: generation, transmission and protection. Permanent Forum on Indigenous Issues, Eighteenth session (22 April–3 May 2019)*. New York, NY, USA. Retrieved from https://undocs.org/en/E/2019/43

Von Moos N, Burkhardt-Holm P & Köhler A (2012). Uptake and effects of microplastics on cells and tissue of the blue mussel Mytilus edulis L. after an experimental exposure. *Environmental Science and Technology*, *46*(20), 11327–11335. https://doi.org/10.1021/es302332w

Waitangi Tribunal (1988). *Report of the Waitangi Tribunal on the Muriwhenua fishing claim, Wai 22*. Waitangi Tribunal report. Wellington, New Zealand. Retrieved from https://forms.justice.govt.nz/search/Documents/WT/wt_DOC_68478237/Muriwhenua%20Fishing%20Report%201988.compressed.pdf

Walker TR, Adebambo O, Del Aguila Feijoo MC, Elhaimer E, Hossain T, Edwards SJ, … Zomorodi S (2018). Environmental Effects of Marine Transportation. *World Seas: An Environmental Evaluation*, (February), 505–530. https://doi.org/10.1016/b978-0-12-805052-1.00030-9

Wang SJ, Cao L & Li N (2014). Responses of the ocean carbon cycle to climate change: Results from an Earth System Climate Model simulation. *Advances in Climate Change Research*, *5*(3), 123–130. https://doi.org/10.1016/j.accre.2014.11.004

Watson S, Allan B, McQueen D, Nicol S, Parsons D, Pether S, … Munday P (2018). Ocean warming has a greater effect than acidification on the early life history development and swimming performance of a large circumglobal pelagic fish. *Global Change Biology*, *24*(9), 4368–4385. https://doi.org/10.1111/gcb.14290

Webb S (2017). *Microplastic accumulation in New Zealand green-lipped mussels* Perna canaliculus *and the role of microplastics in the uptake of triclosan. Masters thesis*. University of Canterbury. Christchurch, New Zealand. Retrieved from https://ir.canterbury.ac.nz/bitstream/handle/10092/13604/Masters thesis – Samantha Webb.pdf

Wegner A, Besseling E, Foekema EM, Kamermans P & Koelmans AA (2012). Effects of nanopolystyrene on the feeding behavior of the blue mussel (Mytilus edulis L.). *Environmental Toxicology and Chemistry*, *31*(11), 2490–2497. https://doi.org/10.1002/etc.1984

Whaanga H, Wehi P, Cox M, Roa T & Kusabs I (2018). Māori oral traditions record and convey indigenous knowledge of marine and freshwater resources. *New Zealand Journal of Marine and Freshwater Research*. https://doi.org/10.1080/00288330.2018.1488749

Whitehead E, Adams N, Baird K, Bell B, Borrelle S, Dunphy B, … Russell J (2019). *Threats to Seabirds of Northern Aotearoa New Zealand*. Auckland, New Zealand.

Wilcox C, Van Sebille E & Hardesty BD (2015). Threat of plastic pollution to seabirds is global, pervasive, and increasing. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(38), 11899–11904. https://doi.org/10.1073/pnas.1502108112

Willis T, Handley S, Chang F, Law C, Morrisey D, Mullan A, … Tait A (2007). Climate change and the New Zealand marine environment. NIWA Client Report NEL2007-025, (October), 88.

Worley T (2012). *Economic Impact Assessment of the New Zealand Cruise Sector*. Prepared for Cruise New Zealand. Auckland, New Zealand.

Zintzen V, Anderson MJ, Roberts CD, Harvey ES & Stewart AL (2017). Effects of latitude and depth on the beta diversity of New Zealand fish communities. *Scientific Reports*, *7*(1), 1–10. https://doi.org/10.1038/s41598-017-08427-7