
the ROYAL SOCIETY of NEW ZEALAND
TE APĀRANGI

# OCEAN ACIDIFICATION
## Emerging Issues

**Summary**
One third of humanity's emissions of carbon dioxide are currently absorbed by the world's oceans. As a result, our oceans are becoming more acidic.

Our present knowledge of ocean behaviour and of ecosystem vulnerabilities suggests continuing ocean acidification would put important ocean ecosystems at substantial risk. These risks cannot yet be quantified, especially as ocean acidification is just one of many stressors on marine ecosystems.

Clarifying this risk requires information on the current state of the ocean, on which species and ecosystems are vulnerable, their distribution, likely changes to ecosystem function and services, the human impact of these changes, and how ecosystems, industries and communities may adapt. Research to develop this knowledge will also assist with quantifying the risks to aquaculture, fishing and other marine industries and with determining the broader impacts on the way we value our coasts and oceans. Reducing emissions of carbon dioxide is the only plausible way to slow ocean acidification.

**Increased atmospheric carbon dioxide causes oceans to become more acidic**
Since the industrial age began, the average pH of oceans has been inferred to decrease by around 0.1 units due to carbon dioxide absorption. This represents a 30% increase in hydrogen ion concentration. Excess carbon dioxide in the atmosphere will continue to be absorbed by the oceans. If unabated, continuing emissions are predicted to decrease pH by 0.5 units by 2100, although ocean acidity will continue to increase for centuries more. The increased acidity will be far beyond natural variations, as will be the rate of change of acidity. As carbon dioxide is more soluble in colder water, the changes will be more acute in colder waters.[1]

The chemical response of oceans additional carbon dioxide is well understood but the scientific community has only recently realised the biological impacts of this change. Concerns exist over acidification and its: "potential, within decades, to severely affect marine organisms, food webs, biodiversity, and fisheries."[2]

There is also feedback between ocean acidification and climate change – warmer, oceans with slower turnover and more acidic surface waters will slow the removal of carbon dioxide from the atmosphere, potentially increasing climate change.

**Responses of individual species to acidification is complex**
Many species use calcium carbonate to build and maintain shells and skeletons. Acidification decreases the availability of carbonate, thinning shells or retarding growth. Marine primary producers require carbon dioxide to photosynthesise and changes to carbon dioxide in water will affect productivity of microscopic and seaweed algae. Higher organisms, such as fin fish, could suffer early life cycle disruptions, interference with respiration, and other problems.

Increased acidity potentially affects all ocean organisms, either directly or through knock-on effects as food webs. Some vulnerable groups are foundation species (such as coral and temperate reefs, and shellfish beds) that provide shelter, settlement, and other functions within ecosystems. Additional system-level changes include the availability of nutrients and toxins and organic waste transfer from surface waters to the depths.

When ocean acidification was first identified as an issue, it was assumed that the species most strongly affected would be calcifying organisms in cold waters. However, species' responses are nuanced and may depend on: the type of calcium carbonate a species uses; how it builds and maintains carbonate structures; how it concentrates the chemical components; effects on larvae navigation and settling; influences of other environmental parameters such as temperature, light and nutrient availability; and as yet undiscovered factors. In addition, the effect on interactions with other species, either through a species' position in the food chain or as a habitat will play a role in the magnitude of the impact.

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[1] Royal Society of London, "Ocean acidification due to increasing atmospheric carbon dioxide", Policy Document 12/05, 2005

[2] Monaco Declaration, Second International Symposium on the Ocean in a High-$CO_2$ World, October 2008

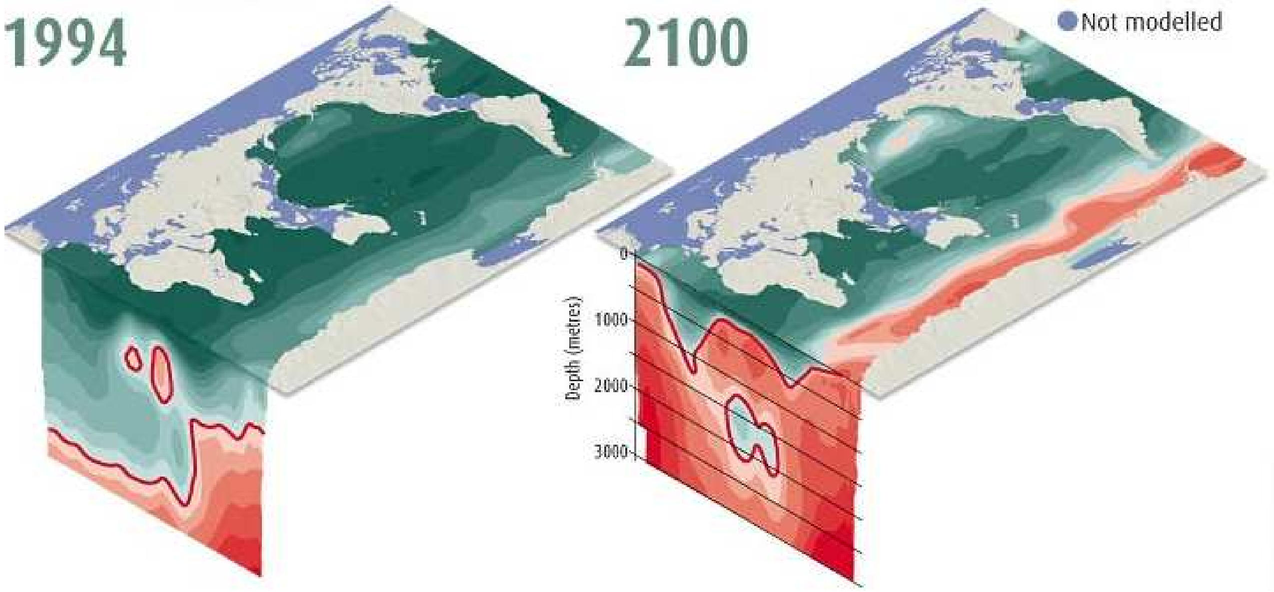


Figure 1: Predicted changes in saturation state of aragonite, a form of calcium carbonate used by corals and other marine calcifiers. Red areas are under-saturated, favouring dissolution of carbonate shells.
Antarctic Climate and Ecosystems Cooperative Research Centre, "$CO_2$ Emissions and Climate Change: Ocean Impacts and Adaptation Issues", 2008, after Orr et al. "Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms", 2005

Many of these effects have been observed in laboratory and semi-open water experiments. Monitoring acidification in the field is at an early stage. Given natural variation and other stresses on ecosystems, evidence for existing biological impacts of acidification is currently limited[3].

**Responses of ecosystems to acidification and other stressors is even more complex**

Ocean acidification is one of many challenges to ecosystems. Warming and altered weather from climate change, reduced ocean turnover due to surface warming, overfishing, pollution, sediment run-off, increased UV stress, and changed weather patterns may also affect our marine ecosystems.

Globally, the ecosystems most strongly affected by ocean acidification are anticipated to be the Antarctic coast, the Southern Ocean, Arctic Ocean, warm coral reefs such as the Great Barrier Reef, and cold, deep coral reefs. However, while these ocean ecosystems are expected to be disrupted, not enough is known to predict the overall net effects.

Given the range of stresses on ecosystems, it is difficult to predict which of New Zealand's ecosystems will be most strongly or rapidly affected by acidification. Our present understanding on how various ecosystems operate indicates the following systems may be vulnerable to increasing acidification: the Bluff oyster fisheries in Foveaux Strait; the calcifying algae that cover 80% of the Otago coast and provide the habitat for kina and paua larvae; the hundreds of species that rely on the reef-forming bryozoan communities found in coastal areas; cold, deep water corals; and the open ocean plankton that underpin the ocean food web.

Coastal ecosystems may be more vulnerable than the open ocean due to stresses beyond acidification. However they may instead have more resilience as coastal conditions naturally vary, chemically, more than the open ocean. Fjords in the south may be more vulnerable than other coastal regions due to colder water, but may have more naturally acidic water due to run-off from peaty land, so organisms there may already be adapted to acidic conditions. Antarctic ecosystems will be very vulnerable to combined warming and acidification, with their ability to adapt to rapidly changing conditions hindered by the lower speed of life in frigid conditions. The lack of data and limited research means that the effects on New Zealand and Antarctic ecosystems are unclear.

Cold, deep corals are slow-growing and cold, deep waters will be amongst the first to be affected by acidification. Our limited knowledge of these ecosystems means that detection of changes is not currently possible.

[3] Antarctic Climate & Ecosystems Cooperative Research Centre, "Position Analysis: $CO_2$ emissions and climate change: Ocean Impacts and Adaptation Issues", 2008

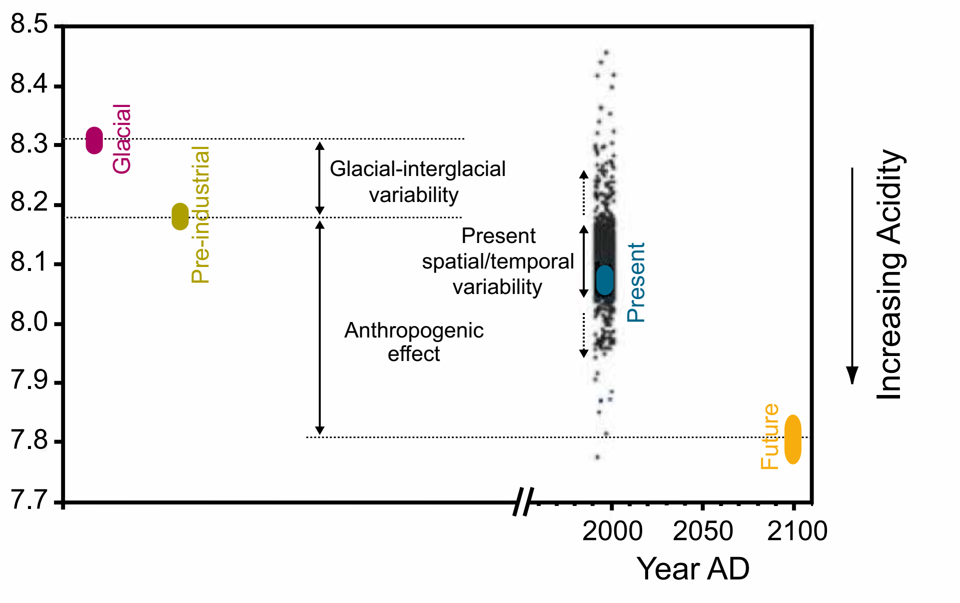


Figure 2: Increase in oceanic acidity from glacial and pre-industrial to present and future. Expected future pH is outside the range of natural variability.
Steffan, W. "Stronger Evidence but New Challenges: Climate Change Science 2001-2005", Australian Greenhouse Office, Department of the Environment and Heritage.

**Our knowledge of acidification in New Zealand oceans is poor**
Acidification is certain to occur in New Zealand waters. However, there is very little data available about the current chemical state of the waters in our Exclusive Economic Zone, nor is there much data about changes of state. Lack of data combined with natural variability, over timescales from hourly to decadal, make it so far impossible to unequivocally detect ocean acidification in these waters. Detecting the biological response, understanding ecosystem changes and apportioning them to acidification and/or other sources of ecosystem stress will be difficult without solid baseline data.

The Australian government has developed an ecosystem vulnerability index to prioritise policy, research and management strategies[4]. Strategies include recognising the value of long-term marine datasets as tools for monitoring and mapping acidification impacts. In New Zealand, marine data is being collected for various purposes and could inform an understanding of New Zealand waters. However, the data varies in quantity, quality, and accessibility and needs collation to maximise benefits and understand deficiencies.

[4] CSIRO Marine and Atmospheric Research, "Impacts of Climate Change on Australian Marine Life", report to the Australian Greenhouse Office, Department of the Environment and Heritage, 2006

**The impacts on New Zealand ecosystems and industries are unknown**
At present, risks to the aquaculture and fishing industries cannot be estimated. Mussels, Pacific and Bluff oysters, paua, and scallops make up a $300 million industry[5]. The future effect of ocean acidification on the aquaculture and fishing industries is unknown but suspected to be negative. The effect on taonga such as paua and kina is not known. Similarly, the future effect upon coastal and off-shore fisheries is also not known, nor is it known how rapidly any problem may occur. The overall effect on harvestable biomass is cannot be predicted.

**Research into the risks from ocean acidification is at an early stage**
Substantial international ocean acidification research programmes include the nine-nation European Project on Ocean Acidification (EPOCA). China, Japan, Korea and the USA have large national programmes. However, New Zealand-specific work is required to apply overseas learning to endemic species and ecosystems.

Assessing the risk from ocean acidification requires understanding of five factors: the current situation, the potential impacts, the likelihood of those impacts occurring, the expected timescale of those impacts, and the ability of affected eco- or economic systems to adapt. Currently, New Zealand (and global) researchers have a poor understanding of these factors.

[5] The New Zealand Aquaculture Strategy
Ministry of Fisheries, Export Earnings, 2007

Research needs would fit within this risk-assessment framework, aiming to establish baseline conditions, identify species and ecosystems at risk, their distribution, what wider impacts would arise from impacts on those species and ecosystems, and how adaptation to impacts could take place. With the chemical conditions that acidification causes now well understood, biological experiments should be able to produce meaningful results. Paleochemistry and paleoclimate records should also be able to inform on future changes.

Recent New Zealand research touching on ocean acidification has been supported by two FRST and two Marsden contracts[6]. One FRST postdoctoral fellowship has been awarded specifically to study ocean acidification. The Ministry of Fisheries provided funding during the International Polar Year (2007-8) and is now funding a five-year study of the impact of acidification on phytoplankton. Much of the research has been funded internally by universities and CRIs.

As a scientific problem, ocean acidification crosses several disciplinary boundaries. A key strength of New Zealand's research capability is the connection between geologists, marine chemists, and biologists. While our research community is small, it is diverse and well connected both internally and internationally, although without formal collaborations. Additionally, our location offers researchers easy access to a large latitudinal gradient and the confluence of differing water masses.

**Adapting to ocean acidification will be necessary**

Several responses have been proposed for aquaculture. These include breeding existing species for acidification resistance, changing water chemistry (especially for larval stages), reducing stocking density to avoid acidosis, and changing farmed species. The effectiveness and cost of these responses have not been investigated in New Zealand and are not well understood globally. The continued economic viability of aquaculture cannot be given a clear steer at this time.

Wild fisheries may face ecosystem changes resulting in substantial changes in the availability of harvestable species. Adaptation may mean accepting drastic changes in the economic viability of the industry and accepting of the potential extinction of many species.

**Mitigating ocean acidification requires reductions in carbon dioxide emissions**

There have been several mechanisms proposed to mitigate climate change and, more specifically, ocean acidification. However, the majority do not address the root cause of ocean acidification, namely the increase of atmospheric carbon dioxide. For those that do, the scale required is immense, the side effects unknown, and the economic cost uncertain but large.

The only plausible way to slow the rate of ocean acidification is to reduce emissions of carbon dioxide.

**Further reading**

Royal Society of London, "Ocean acidification due to increasing atmospheric carbon dioxide", Policy Document 12/05, 2005

Antarctic Climate & Ecosystems Cooperative Research Centre, "Position Analysis: $CO_2$ emissions and climate change: Ocean Impacts and Adaptation Issues", 2008

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[6] FRST contracts are HAYX0701 and C01X0707. Marsden contracts are UOA215 and UOO005.