FACTSHEET

Ocean acidification

This factsheet provides essential information on ocean acidification.

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As carbon dioxide (CO_2) concentrations increase in the atmosphere (see Emission Scenarios factsheet) more CO_2 is available for oceanic uptake, dissolving in the seawater and changing ocean chemistry [1]. This process, termed 'ocean acidification' (OA) [2], results in fewer carbonate ions and more hydrogen ions, therefore increasing acidity (reducing the pH) (Figure 1).

In the ocean, carbonate is used (together with calcium) by corals in the form of aragonite to form hard reef structures. Aragonite is also used by other invertebrate organisms to make their skeletons and hard shells [3]. The reduction of aragonite (strongly correlated to changes in pH) in the ocean means that it will be more difficult for these creatures to make their shells and for corals to build and repair reef structures [4].

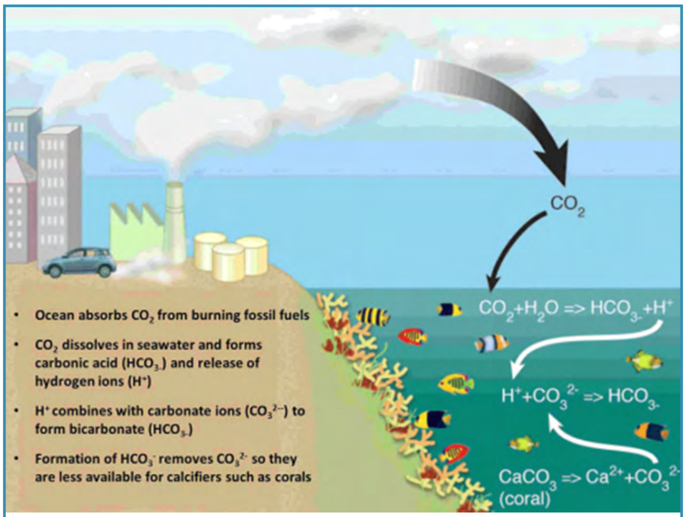

Figure 1 The process of ocean acidification.
Source: modified from Hoegh-Guldberg et al. 2007 [5].

This poses a significant threat to the long-term viability of corals, shellfish and fish (through impacts on growth, survival of juveniles, recruitment, and food web relationships), coral reefs and associated marine ecosystems, and to coastal communities that rely on them for their livelihood and wellbeing.

Observed changes in aragonite saturation and pH

Atmospheric CO_2 concentrations have increased 47 % since the pre-industrial era (1850–1900) [6] and 24–33 % of the excess CO_2 is being absorbed by oceans globally [7]. In the western tropical Pacific Warm Pool, trends during the 1985–2016 period show a change on average of −0.0013 per year for pH and −0.0083 per year for the aragonite saturation state [8]. Since the pre-industrial era, pH of the tropical Pacific Ocean has decreased by 0.06 pH units, with average ocean pH now 8.1 [7]. While the projected changes in pH seem small, it is important to remember that the pH scale is logarithmic, so the reduction in pH in surface ocean waters that we have already seen actually represents a 30 % increase in acidity.

Projected aragonite saturation and pH for Vanuatu

Projections of future OA conditions under a changing climate are crucial for guiding society's mitigation and adaptation efforts [9]. Under all global emission scenarios a net decrease in pH and aragonite saturation state occurs, with the largest changes associated with the highest atmospheric CO_2 levels [10] clearly indicating that it will be harder for corals and other marine organisms to form their hard skeletons and shells in the future [11, 12]. Global climate projections suggest that if atmospheric CO_2 emissions follow a high scenario (RCP8.5), by 2050 coral reefs in the western tropical Pacific, including Vanuatu, may not only stop growing but start to get smaller, as they dissolve faster than they are built [11]. However, if emissions follow a low scenario (RCP2.6), consistent with the Paris Agreement target of keeping global warming below 2°C, then the aragonite saturation state may start to recover after 2060 (Figure 2, top).

For a high emissions scenario (RCP8.5), a drop of 0.4 units in pH represents more than a doubling (an almost 150 % increase) in the acidity of the ocean (Figure 2, bottom). However, if emissions follow a low scenario (RCP2.6), the drop is only 0.05 pH units.

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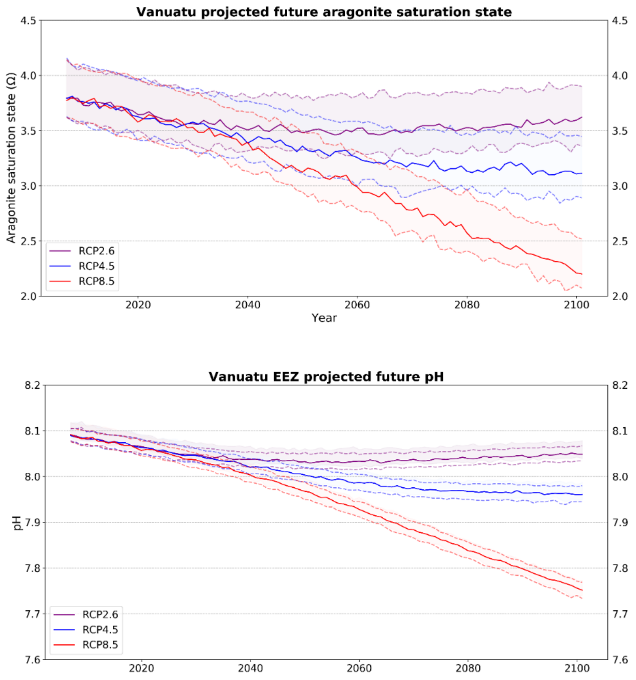


Figure 2 Projected decreases in aragonite saturation state (top) and pH (bottom) for the Vanuatu Exclusive Economic Zone (EEZ) from six CMIP5 climate models under three emissions scenarios: RCP2.6, RCP4.5, and RCP8.5. Shown are the median values (bold lines), and the 10th and 90th percentiles (dashed lines and shading) (see Appendix for methods).

There is very high confidence that the ocean will become more acidic, with a net reduction in pH. There is also high confidence that the rate of OA is, and will continue to be, proportional to the CO_2 emissions. There is medium confidence that long-term viability of corals will be impacted under RCP8.5 and RCP4.5, and that there will be harm to marine ecosystems from the large reduction in pH under RCP8.5 [10].

Impacts of ocean acidification

The combined impacts of OA with other stressors, such as ocean warming (see Marine Heatwave factsheet), have implications for the health, including biodiversity, productivity and physical integrity, and overall longer term sustainability of reef ecosystems [13, 14]. Marine life (including calcifying plankton and algae, shellfish) will find it more challenging to build their skeletons and shells. This will lead to a reduction in growth for many of these species and ecosystems, which could jeopardise the ocean's role as a nutrition provider. For example, OA has been shown to lower the temperatures at which corals bleach [15], potentially reducing the resilience of these environments to natural climate variability (e.g. as driven by ENSO) and long-term climate change. Increasing OA has the potential to impact fin and shellfish fisheries, aquaculture and overall marine biodiversity and productivity, as well as tourism and coastal protection (as inshore reefs physically deteriorate, including from the combined effects of climate change from coral bleaching and tropical cyclones in some locations) [16].

Fish provide 50–90 % of animal protein in the diet of coastal communities across a broad spectrum of Pacific islands, and national fish consumption per person in many Pacific islands is more than 3–4 times the global average. A loss of fisheries productivity would threaten national economies dependent on fisheries resources [17]. Aquaculture commodities in the tropical Pacific that are expected to be most vulnerable to acidification are pearl oysters, shrimp, and marine ornamentals [7].

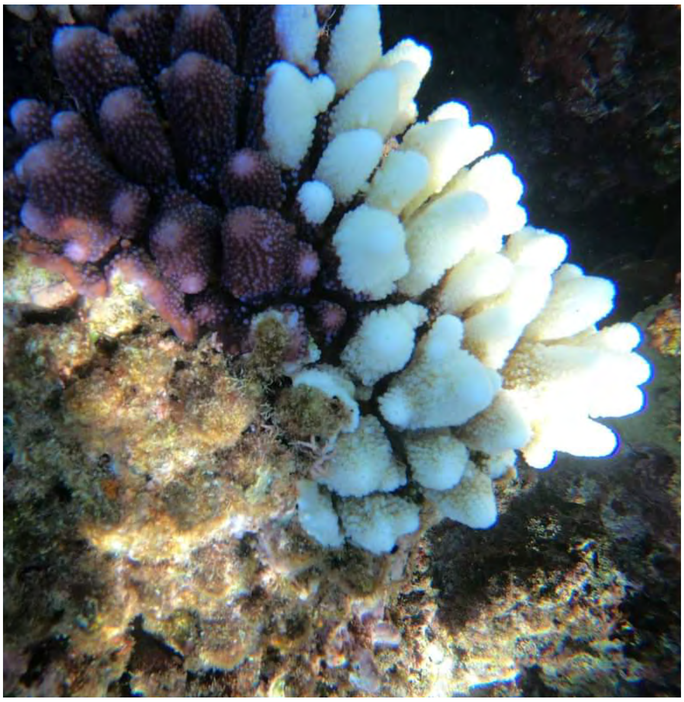
The key implications of OA for governance and management focus on the extent to which declines in fisheries and aquaculture productivity are likely to affect the regional and national plans and policies to maximise the sustainable benefits for economic development, food security, and livelihoods [7].

That said, it is difficult to generalise actual responses across organisms and ecosystems to changing ocean chemistry for several reasons. Projected changes in aragonite saturation and pH are surface open ocean projections, and do not account for numerous local processes that modify ocean chemistry, especially on reefs. Closely related species can respond differently; most experiments have been conducted under relatively short-term laboratory conditions (although field-based experiments are becoming more widespread); and research has shown greater adaptive capacity in some species, but not others [18]. Studies suggest aragonite saturation states between 3.5–4.0 are adequate (but not optimal) for coral growth, and values between 3.0–3.5 are marginal [19]. Coral reef ecosystems are not found at aragonite saturation states less than 3 and these conditions are classified as extremely marginal for supporting coral growth, at least in assessing the global average conditions [11, 19].

Importance of Pacific ocean acidification monitoring network

Local OA observations are vital to improve our understanding of natural variability in ocean chemistry at the scale of reefs and coastal communities, and associated responses in a wide range of organisms and ecosystems. The Global Ocean Acidification Observing Network (GOA-ON The Global Ocean Acidification Observing Network), an international collaborative network, provides a framework for the international coordination of methods and resources for making local-scale OA observations.

A series of Sofar Spotter buoys has recently been deployed by the Van-KIRAP project across the Vanuatu archipelago (see Ocean Monitoring factsheet). With the importance of understanding the vulnerability of ocean organisms to changes in OA, together with the need to enhance the availability of reliable, finer spatial scale OA observational data records in Vanuatu, there is an opportunity for integration of ocean chemistry monitoring instruments into the existing Sofar Spotter buoy coastal network efficiently and cost-effectively.



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Data sources and biases

The baseline for the CMIP5 ocean chemistry projections is 1986–2005. The pH and aragonite data are all sourced from the 2014 PACSSAP report [11]. The six climate models considered were:

- CanESM2
- GFDL-ESM2M
- HadGEM2-ES
- IPSL-CM5A-LR
- IPSL-CM5A-MR
- MPI-ESM-MR

Projections from coupled climate-carbon models that include an active carbon cycle under three of the RCPs (2.6, 4.5 and 8.5) are used, which allow the changes in the ocean carbon cycle to be projected, and their impact on ocean acidification quantified. Coupled climate-carbon models presently simulate a larger range of values compared to the observed aragonite saturation state in the western tropical Pacific. These biases were removed by scaling the mean value of aragonite in the year 2000 to match the observed values [20].

Van-KIRAP Resources

Vanuatu Climate Futures Portal
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