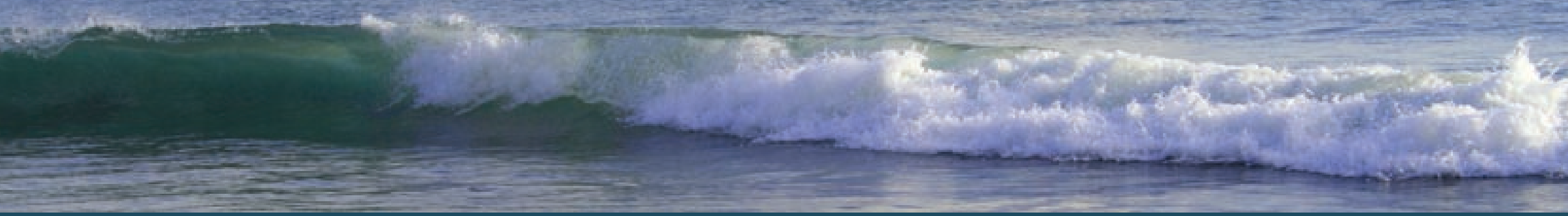


Ocean Acidification
– the other half of the CO_2 problem

Background

The World's oceans cover over 70% of the planet's surface, contribute half of its primary production and contain an enormous diversity of life. Thus it is not surprising that they provide invaluable resources to human society. They also play a vital role in the Earth's life support system through regulating climate and global biogeochemical cycles through their capacity to absorb atmospheric carbon dioxide (CO_2).

The oceans currently absorb half of the CO_2 produced by anthropogenic sources. Put simply, climate change would be far worse if it wasn't for the oceans. However, there is a cost to the oceans. The pH (a measure of acidity, the lower the pH the greater the acidity) of pristine seawater measures from 8 to 8.3, meaning oceans are in fact naturally slightly alkaline. When carbon dioxide dissolves in seawater it forms carbonic acid. As more CO_2 is taken up by the oceans surface, the pH decreases moving towards a less alkaline and therefore more acidic state. This is called "ocean acidification" and is happening at a rate that hasn't been experienced for at least 400,000 years and probably for the last 20 million years.

The effect of ocean acidification on marine ecosystems and organisms that inhabit them has only recently been recognized and is of serious concern to scientists and policy makers involved in climate change, biodiversity and the marine environment.

What happens when ocean pH decreases?

The world's oceans currently absorb on average about one metric tonne of CO_2 produced by each person every year. It is estimated that the surface waters of the oceans have taken up over 500 thousand million tonnes of CO_2 (500 Gt CO_2), about half of all that generated by human activities since 1800. This additional CO_2 is already reducing ocean pH and it is also affecting the carbonate chemistry through the reduction of the carbonate ions, aragonite and calcite, which are used by many marine organisms to build their external skeletons and shells.

If the current trends in CO_2 emissions continue to increase due to human activities, by the end of the century pH of surface seawater could decrease by about 0.45 units from pre-industrial times. This change in the chemistry of the oceans is quantifiable and predictable. The consequences of acidification on marine organisms are much less certain due to the complex mesh of effects and results from research are now just emerging. These studies suggest that acidification is a real threat for the survival of some important marine ecosystems and a number of key marine species.

Ocean acidification leads to the decrease in carbonate ion concentration, a crucial element in the construction of the external skeleton or shells of many marine calcifying organisms. By the end of this century, ocean acidification will affect the calcification process which allows organisms such as corals, molluscs and calcareous phytoplankton to build their external skeleton or shells. Further loss of coral reefs will threaten the stability and longevity of many organisms and impact the human populations that depend on them. Cold-water coral communities are also likely to be strongly affected before they have even been fully explored.

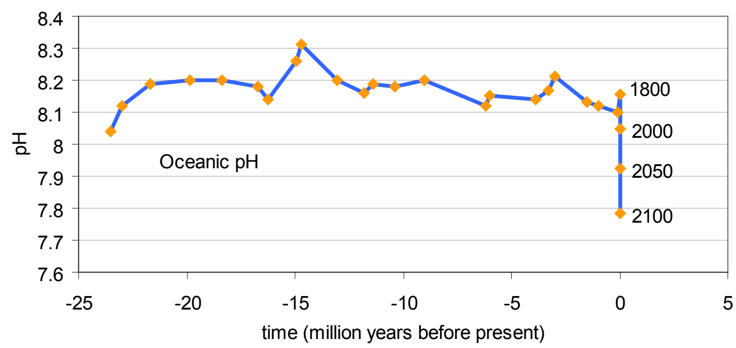
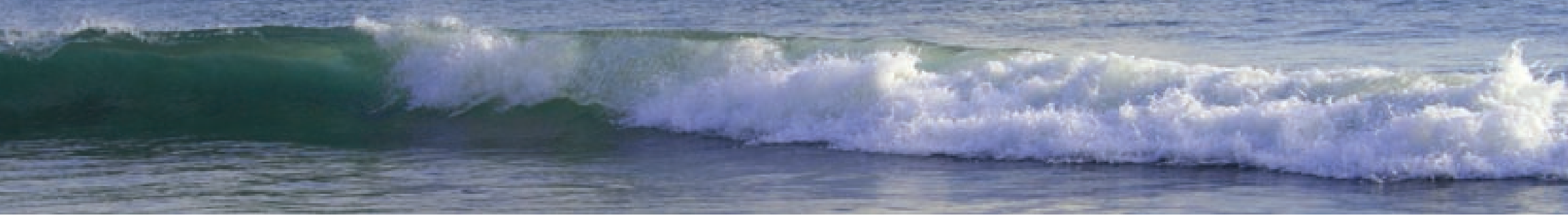


Figure 1. Past and contempory variability of marine pH. Future predictions are model derived values based on IPCC mean scenarios (from Turley *et al*, 2006. Cambridge University Press, 8, 65-70).

Predictions based on numerical models suggest that in 50 years, surface waters in the Southern and Arctic Oceans will be corrosive to aragonite, a crystalline calcium carbonate compound that pteropods secrete to form their shell. These small planktonic snails may therefore not be able to survive in polar waters. As they occur in high numbers and are an important food source for many species, from zooplankton to whales and commercial fishes such as salmon, their disappearance may have a substantial knock-on effect on the whole Southern Ocean ecosystem.

In addition to calcification, we know that CO_2 or pH affects nutrients, bacterial processes, primary production and trace elements. Thus many key regulatory cycles of the ocean may be disrupted. Acidification can also reduce the ability of marine creatures to grow, feed and reproduce. Of particular concern are those animals that have planktonic larvae. It is likely that changes in community structure will result and ecosystems will become less robust and even more vulnerable to changes in the future.

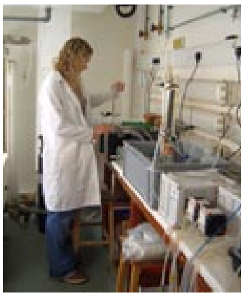


Ocean Acidification in the long term

Pterapod, *Limacina helicina* (Russ Hopcroft, NOAA – net tow)

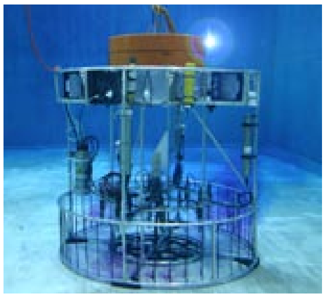
Simultaneously to ocean acidification, scientists predict that marine ecosystems will be affected by global warming with changes in temperature, currents, mixing, stratification and storminess. Surface ocean acidification is happening now and will continue as long as CO_2 is emitted into the atmosphere. The CO_2 in the atmosphere will continue to be absorbed by the sea causing acidification long after we stop producing CO_2. Organisms and ecosystems are going to have to deal with a number of major rapid global changes at once – unless we urgently introduce effective ways to reduce CO_2 emissions.

The long term consequences on marine organisms and their ecosystems are still difficult to predict. Further research is required to investigate the impact on a wide range of polar, temperate and tropical sea bed and seawater ecosystems, processes and organisms. Scientists employ a range of techniques to study ocean acidification including laboratory experiments, the use of mesocosms, and more recently, field experiments as seen in the images below. Scientists also need to investigate to what extent, and at what rate, species and ecosystems will be able to adapt to ocean chemistry changes, either physiologically, ecologically or by evolutionary processes. Socio-economical and environmental impacts also need to be evaluated.



Laboratory experiments at PML looking at larval development under future CO_2 scenarios

Mesocosom set up in Bergen (Norway) with different CO_2 concentrations



The Free Ocean Carbon Experiment (FOCE) apparatus on the floor of MBARI's test tank. This device maintains a lower pH state in the interior of the array to monitor the effects of increased CO_2 in the ocean. Image: Bill Kirkwood

The current scientific consensus is that ocean acidification, combined with affects from climate change poses a serious threat to the integrity of the marine ecosystem and its provision of goods and services to nation states. The chemical principles are well understood but we have almost no measurements of actual rates of change particularly when set against the relatively large variability in pH across oceans and seas. Moreover due to the complexity of the system and the breadth of processes vulnerable to acidification, the precise ecosystem response is currently unquantifiable. Policy makers will need to know what constitutes "dangerous ocean acidification" and what pH decreases the oceans and their ecosystems can withstand and how this might vary depending on geographical location and ecosystem type. It is imperative that this research is carried out so that policy makers and advisors can be informed, especially those concerned with negotiating international agreements on reducing CO_2 emissions.

Action Points

- The current rate of ocean acidification and its future magnitude will threaten some marine ecosystems in coming decades - so we need to increase our knowledge of what these are and when they will occur.
- Effects of and adaptations to ocean acidification will differ across different marine ecosystems and cannot be determined at present with certainty. It is therefore important to reduce our uncertainty through further interdisciplinary research.
- We need additional observational, experimental and modelling research to assess the consequences of ocean acidification, including better understanding of changes in ocean carbonate chemistry, responses of ocean biology and socio-economic consequences.
- Despite uncertainties, policymakers must begin to act immediately if they hope to reduce CO_2 emissions and thus stabilize atmospheric CO_2 at a level that will avoid large-scale consequences to ocean ecosystems.

Plymouth Marine Laboratory

This Fact Sheet was composed by scientists from the Plymouth Marine Laboratory in the UK as well as colleagues from Marine Environment Laboratories (IAEA) and Observatoire Océanologique, (CNRS). For further details please contact any of the scientists listed below: Jerry Blackford (JCB@pml.ac.uk), ecosystem modelling; Carol Turley (CT@pml.ac.uk), overview and policy issues; Steve Widdicombe (SWI@pml.ac.uk), impact on benthic organisms, biodiversity and ecosystem function; James Orr (James.Orr@cea.fr), global biogeochemical ocean modelling; and Jean-Pierre Gattuso (gattuso@obs-vlfr.fr), impacts on calcification and coral reefs. Download related papers from the Fact Sheet pages at www.eur-oceans.eu/KTU

Fact Sheet by: EUR-OCEANS Knowledge Transfer Unit, hosted by the GLOBEC IPO at Plymouth Marine Laboratory.
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