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Ocean acidification: how will marine life cope?

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Ocean acidification
How will marine life cope?

CO_2 emissions are making the oceans more acidic. We're still not sure what this will do to marine life, but in many places the result's unlikely to be good. Jason Hall-Spencer describes his efforts to understand the impact by investigating places where the gas bubbles naturally from the seabed.

David Liittschwager

Diver studying ocean acidification at CO_2 vents.

Giorgio Caramagna

Jellyfish thrive at high CO_2 sites.

Demetris Kletou

Carbon dioxide (CO_2) emissions are causing ocean acidification (OA), which certainly sounds bad. Yet the seas will not become acidic, in the sense of their pH falling below seven, even if we burn all of the wood, coal, gas and oil on Earth. So what's the problem?

On average the pH at the surface of the oceans has fallen by only 0.1 since burning coal for steam power became widespread in the 18th century, and if we keep on rapidly burning the planet's hydrocarbons this could fall as low as 7.4. So that's still alkaline. The pH of coastal waters can vary widely, by a whole unit between night and day, because plants and algae take up CO_2 during the day through photosynthesis, raising the water's pH. Yet just as we breathe out more CO_2 than we breathe in, marine organisms raise CO_2 levels through respiration so pH levels fall again at night.

Astonishingly productive fisheries occur in upwelling regions where CO_2 and nutrient-rich waters flowing up from below stimulate the growth of algae and provide abundant food. So we know marine life can thrive despite low or widely varying pH; so why have NERC, Defra and DECC just pumped £12 million of taxpayers' money into finding out more about OA?

One reason is that the small drop in pH that we have seen since the Industrial Revolution reflects enormous changes in the concentration of hydrogen ions which are already up 30 per cent in surface waters. They are increasing so rapidly that by 2100 their concentration is expected to be 130 per cent higher than at any point in human history.

This transforms the chemistry of seawater, reducing levels of dissolved carbonate and so making it corrosive to many marine plants and animals. It is the speed of this change that is causing most concern, since it is outstripping the rate of weathering of alkaline rocks which will eventually raise carbonate levels again. In the past year, 800km^2 of the seabed off Iceland was newly exposed to waters that are corrosive to the shells and skeletons of marine life. I haven't run the calculations for UK waters, but we have been similarly affected.

Another, less well-studied, reason to invest in OA research is that CO_2 is a resource for marine plants and algae. They capture carbon to survive, and this may help us mitigate the problem.

Since 2006, when I first heard about OA, I have been running expeditions to areas of the seabed that are already acidified, so that we can see which organisms thrive and which are vulnerable. We have focused on underwater volcanoes in the Mediterranean and Papua New Guinea where CO_2 bubbles up through the sea floor like a jacuzzi, acidifying large areas for centuries.

First we carefully monitored the chemistry of the study sites so we could home in on areas that had the daily variation in CO_2 found in natural coastal systems, but without the confounding effects of increased heat, alkalinity anomalies or toxic chemicals that are often found at volcanic seeps. These natural variations in CO_2 levels from place to place clearly show how habitats change as carbonate levels fall.

Learning from CO_2 seeps

We have found similar ecosystem shifts at all the seeps, so I am now convinced that OA will be a game-changer. How this plays out depends on location, with two major causes of change – the corrosive effects of CO_2, and the way plants and algae use it.

In the water around the seeps we have found that algae known as diatoms, whose shells are made of insoluble silica, do especially well, whereas plankton with calcium carbonate shells, such as coccolithophores, dissolve away. On the seabed, algae that attack coral reefs by boring into their hard skeletons proliferate – so do brown seaweeds, swamping slower-growing competitors such as coralline algae.

These calcified coral-like seaweeds have been a particular favourite of mine since I did my PhD on them – they can provide habitat for a rich mix of plants and animals, forming 'hotels' for invertebrates and juvenile fish. They emit chemicals that stimulate the metamorphosis and settlement of commercially-important shellfish, yet they are one of the most obvious groups to fare badly as CO_2 levels rise.

We see abundant life at CO_2 seeps, but only some of the species we have today can thrive. What worries me most is that biodiversity consistently falls as CO_2 levels rise, in both temperate and tropical waters. Seagrasses thrive – a good thing as they take up and store carbon – but the habitats they form are much less diverse at high CO_2.

Reefs formed by corals or molluscs are severely weakened as CO_2 rises, so deep-water reefs off the UK will suffer as our waters become more corrosive to their skeletons. In the tropics weakened reefs will likely worsen coastal erosion, which is already a problem due to rising sea levels, increased storminess and the loss of protective habitats such as mangrove swamps. Livelihoods are also at risk – reefs provide habitat for fish, and we have found that the breeding and territorial behaviour of fish is disrupted at CO_2 seeps.

Some organisms can adapt to the effects of long-term acidification – some can calcify even faster with more CO_2 – but the more acidic conditions mainly benefit non-calcified organisms. Jellyfish, anemones and soft corals do especially well, but when we transplant hard corals and the reefs formed by vermetid gastropods – known as 'worm snails' – into areas with an average pH of 7.8, they dissolve away. So acidified oceans could end up dominated by much fewer species with crumbling reefs and the rise of soft-bodied jellyfish and seaweed, for example.

A few species have an outer layer of protective tissue that allows them to grow in acidified seawater, such as *Porites* corals in the tropics and *Mytilus* mussels in temperate areas. But even these CO_2 tolerant organisms can only survive if they are not stressed by other factors. The combination of acidification and rising temperatures kills off corals and shellfish, and increasing CO_2 reduces biodiversity across the board, from simple organisms such as bacteria and microalgae, to bigger ones like corals and molluscs.

What does it mean for UK coastal habitats and fisheries? I'm not sure. Our highly productive waters may provide oysters, mussels and corals with enough food to cope with falling carbonate levels. Next year I hope to study natural analogues for future ocean conditions in the north Atlantic, as this will reveal organisms with more chance of coping. Acidification may benefit seagrasses, kelps and diatoms, depending on how it interacts with warming waters; these organisms' ability to counteract OA by absorbing CO_2 may help those who earn their living through shellfish aquaculture, or who depend on reefs for coastal protection and tourism.

The past five years' work shows OA is a serious issue with real financial costs, and that marine life is already affected. This evidence is helping galvanise change as governments get serious about cutting emissions. Investing in research is absolutely worth it – 'forewarned is forearmed'. We know that systems under less stress are more resilient – I hope this new knowledge helps improve coastal management and strengthen marine regeneration efforts.

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