Ocean **acidification**

The other carbon dioxide problem

The oceans are helping to protect the planet from the worst effects of global warming by soaking up carbon dioxide from the air. This is part of the natural carbon cycle, where carbon moves between the atmosphere, oceans, living creatures and rocks (see 'What controls the acidity of the oceans').

Until recently, scientists believed that the oceans could cope with the extra carbon dioxide caused by human activities. Despite fluctuations in carbon dioxide levels in the atmosphere over the past 25 million years, the acidity of our oceans has been pretty much constant. So no one was expecting to see a big change now, even though about half of all released carbon dioxide ends up in the oceans. In the past 200 years, that amounts to over 500 billion tons.

But in 2003, researchers Ken Caldeira and Michael Wickett from the Lawrence Livermore National Laboratory, USA, published a paper in *Nature* which suggested that the extra atmospheric carbon dioxide has actually increased the acidity of the oceans by 0.1 of a pH unit over 200 years. This may sound trivial, but according to a Royal Society report*: 'This pH is probably lower than has been experienced for hundreds of millennia and, critically, at a rate of change probably 100 times greater than at any time over this period.'

But worse is to come. Even if we stopped all emissions today, acidification would continue. The carbon dioxide already in the air will be taken up by the oceans, leading to a predicted increase in acidity of another 0.5 pH units.

The revelation that the chemistry of our oceans was changing came as a shock to the scientific community. During its scientific review of ocean acidification in 2005*, it became apparent to the Royal Society working group that no one actually knew what to expect. The assumption that seawater acidity was constant had been so strong that little or no work had been done to see how this might affect marine systems.

The threat of too much acid

Why should we worry about ocean acidification? Animals such as corals, molluscs and plankton—which use calcium carbonate to make their chalky skeletons and shells—could suffer greatly from changes in pH. Given the importance of plankton to global productivity and as a food source for commercial fisheries, ocean acidification could have big socio-economic as well as environmental implications.

To investigate this important issue, we received a NERC grant to assess the impact of seawater acidification on marine sediments and the nutrients they provide.

The oceans harbour tremendous biological diversity. Most of this diversity is made up of animals living in or on the seafloor. Seafloor sediments and the organisms that live in them also play a crucial role in maintaining a healthy marine ecosystem. For example, 80 per cent of the nitrogen required by phytoplankton in coastal seas is processed through the seabed. As these tiny floating plants produce the food upon which the whole marine food chain depends, the supply of nutrients for their growth is essential for the productivity of our seas. So one of our projects focused on a burrowing heart sea urchin, one of a group of animals whose digging releases important quantities of nutrients from the mud for other sea creatures.

We found that one sea urchin, *Brissopsis lyrifera*, significantly decreases the rate at which the seafloor takes up nitrate and transforms mud from a source of phosphate to a sink. Nitrate and phospate are key nutrients for phytoplankton. Changes in the supply or availability of these nutrients could alter levels of primary productivity and change the composition of plankton communities.

Working with John Spicer (University of Plymouth) and John Arthur Berge (Norwegian Institute for Water Research), we found out just how vulnerable sea urchins are to changes in seawater acidity. A predictable effect was damage to their calcium carbonate skeleton, but perhaps of greater concern was the effect on the urchins' internal organs. Looking at their digestive system, we saw clear evidence that increased seawater acidity caused considerable damage and disruption to the cells making up the lining of the gut wall. Such effects could have serious implications for the urchins' ability to feed.

We also saw changes in the timing of the reproductive cycle of the sea urchins, with accelerated maturation of their sperm and eggs—a response not unlike that of other aquatic and land animals when exposed to a number of pollutants.

Carbon dioxide occurs all around us in the natural environment, so it is perhaps difficult to think of it as a pollutant. But it is clear from our work at Plymouth Marine Laboratory that carbon dioxide pollution is a considerable threat to the future health of our oceans.

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The chemistry of our oceans is changing, and carbon dioxide is to blame. **Steve Widdicombe** and **Dave Lowe** have been exploring what this change could mean for some very important marine animals.

What controls the acidity of the oceans?

The acidity of our oceans has been almost unchanged for the past 25 million years. This acidity, measured in pH units, was stabilised at around pH 8.2 by a chemical equilibrium between carbon dioxide, carbonic acid, bicarbonate and carbonate ions dissolved in the seawater.

Extra carbon dioxide is ultimately removed from the system by biological and geological processes such as the formation of the chalky skeletons of marine creatures such as corals and plankton. Over geological time, much of this calcium carbonate may become limestone. Until recently, it was believed the oceans contained so much dissolved carbonate and bicarbonate ions that any extra carbon dioxide absorbed from the atmosphere would have little effect.

Atmospheric concentrations of carbon dioxide are actually lower today than at some periods in Earth's history. Ocean acidity didn't change then, so why is it changing now? The big difference is that carbon dioxide is increasing 100 times faster now than natural fluctuations in the past. The geological processes that balance the carbon cycle can't react quickly enough and something has to give – ocean pH.

Former government minister Elliot Morley (centre) and Plymouth MP Linda Gilroy talk to Steve Widdicombe in his lab about the effects of acidification on sea urchins.

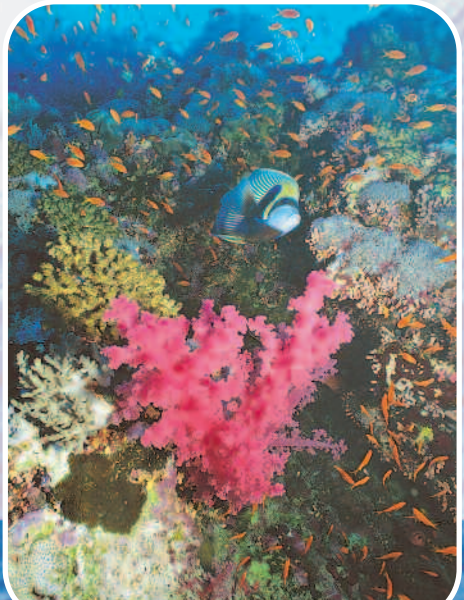
How our research informs policy

PML's research is already proving useful to government ministers as they develop climate policy. Elliot Morley, former minister for environment and climate change, visited us in 2005 to hear about our work on ocean acidification. PML scientists supplied information and evidence to Defra for the G8 summit and for a parliamentary question on the sustainability of ocean ecosystems in the face of acidification. Dr Carol Turley of PML was a member of the Royal Society working group on ocean acidification. Hazel Needham recently presented results from the sea urchin project at an event for young scientists in the House of Commons. Steve Widdicombe has given evidence to English Nature's council.

At PML we have developed the only lab in the UK for experiments with large quantities of seawater at predetermined and consistent pH.

Other research

Plymouth Marine Laboratory is leading on another major programme looking at ocean acidification (see page 4). The project, part of a £2.4 million NERC consortium grant for the Post-Genomics and Proteomics directed programme, is using an array of state-of-the-art molecular biology tools to see how plant and bacterial communities respond to a more acidic ocean.



Want to know more?

*Royal Society report (2005) on ocean acidification:
www.royalsoc.ac.uk/news.asp?year=&id=3250

For an explanation of ocean acidification, see
http://en.wikipedia.org/wiki/Ocean_acidification

Caldeira and Wickett (2003) *Nature* **425**, 365. Abstract at
www.nature.com/nature/journal/v425/n6956/abs/425365a.html