You might not have heard of 'the other CO_2 problem' but it may already be affecting the seas around Britain. Kelvin Boot looks at a new research programme that aims to understand the possible impacts of ocean acidification on our precious coastal ecosystems.

Sea urchins.

Ocean acidification and life on the sea floor

Ocean acidification (OA) sounds like the stuff of nightmares but it's happening now – since the start of the Industrial Revolution, the hydrogen ion concentration of the surface ocean – the variable that determines how acidic it is – is estimated to have increased by nearly 30 per cent. How? The chemistry is straightforward. As human activities produce more CO_2, more of the gas enters the ocean and reacts with sea water. This releases negatively-charged (acidic) hydrogen ions and reduces pH. It's that simple.

What isn't simple is demonstrating the consequences; just how OA may affect marine organisms and ecosystems, including not only seaweed, sea urchins and fish, but also bacteria and plankton. There is growing evidence that some organisms, such as coral reefs, are being affected in some parts of the world, but what of the life around our own shores?

What we do know is that if we keep emitting CO_2 at today's rates, by 2100 average surface ocean pH will have fallen from 8.1 to around 7.8 – average levels the Earth has probably not experienced for more than 20 million years. This would have wide implications for ocean life, especially, but not exclusively, for organisms that need calcium carbonate to build shells or skeletons. Not only do increased hydrogen ion concentrations inhibit calcium carbonate formation, but they can slowly dissolve calcium carbonate structures, even if pH is greater than the 'neutral' value of 7.0.

Any change that affects our important marine ecosystems could have a big effect on the environment and human societies. Though not yet as widely reported as other effects of CO_2 emissions, OA has been dubbed 'the other CO_2 problem'. It is now the subject of a major national research programme, bringing together over 120 researchers from 26 of the UK's top scientific institutions; the UK Ocean Acidification Research Programme (UKOA).

One of the programme's largest consortia is examining the effects on benthic (seabed) ecosystems, communities, habitats and species. This involves 12 UK institutions and is led by Steve Widdicombe of Plymouth Marine Laboratory (PML).

'The really big thing about this work is that for the first time we are bringing together people from different disciplines to work on the same creatures in order to establish the whole organism effect and how that in turn might affect the ecosystems in which they live,' says Widdicombe. 'With benthic, sediment and behavioural ecologists, evolutionary biologists, geneticists, chemists and many other disciplines coming together, we should get the best possible picture of how atmospheric CO_2 is affecting our marine life.'

It's a great example of how the diversity of UK marine science can be marshalled to investigate a phenomenon of increasing global concern.

Forty per cent of the world's population lives within 100km of the coast, so coastal seas are important for food, prosperity and well-being around the world. They also harbour incredibly high levels of biodiversity.

Until now, studies of OA's effects have been largely restricted to short-term experiments, exposing single species to varying sea water pH according to projections of future atmospheric CO_2 levels. These experiments have produced apparently contradictory results, with some organisms seeming to thrive in lower ocean pH while others show apparently negative effects. We need to know much more about what these effects might be, when they might happen and how they might be balanced by the organisms.

Steve Widdicombe sums up the challenge: 'We need to understand how animals divide their energy between things like shell growth, reproduction and other activities when faced with environmental stresses like ocean acidification and rising temperatures. Different animals will do it differently – some might be able to access the energy they need to adapt; many more might not.'

The problem calls for longer-term studies that can overlap experiments on a number of generations of animals, and look across a whole community or habitat.

The consortium has developed a series of unique experimental environments which closely reflect conditions in three coastal seafloor habitats: soft sediments; calcareous biogenic habitats – areas like cold-water coral reefs and coral-like algae called maerl; and the rocky intertidal zone.

Whilst collecting material for most of the experiments was relatively straightforward, the cold water coral studies could not begin until the first UKOA research cruise in 2011, led by the National Oceanography Centre. One of its first tasks was to visit the cold-water coral reefs off north west Scotland.

The aim is to understand the impact of ocean acidification and warming on the biogeochemistry of benthic habitats, and on the health of their organisms, and to assess how much those organisms can adapt to change. Rather than look at isolated species, the results will help predict the impact of future CO_2 changes on whole communities, and on the biodiversity and functioning of coastal habitats.

Time and tide

For these experiments to be worth their salt, they must be consistent across the consortium. So, each institute observes its particular marine environment under the same variations in CO_2 levels – 380 parts per million (ppm), 750ppm and 1000ppm – and under the same changes in temperatures, which follow seasonal variation as well as simulating a possible future increase of 4°C, following IPCC projected scenarios.

They must also reproduce real-world conditions as closely as possible. So PML keeps rocky shore species – including dog whelk, top shell, barnacle, sea urchin and seaweed – in a temperature-controlled room where light levels parallel those of the outside world.

Because the tides are a major influence on the behaviour of rocky shore animals, the researchers have built large cantilevered tanks that gradually fill with water so their occupants emerge and submerge as the local tides fall and rise.

Attention to detail is crucial. Mirroring the real world as closely as possible makes it more likely that any changes seen in these experiments are down to the variations in CO_2 and temperature alone.

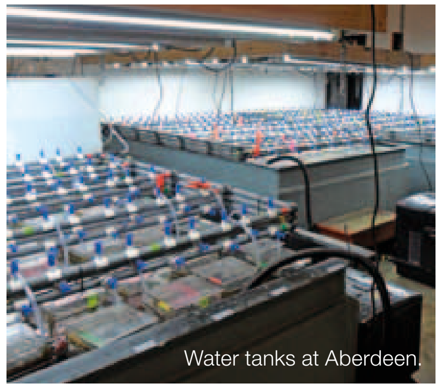
One experiment at Oceanlab at the University of Aberdeen will look for changes in the behaviour of cockles, brittlestars and ragworms by observing bioturbation – the way these creatures mix sediment (for example, by burrowing in or ingesting it) and how this affects the exchange of chemicals between sediment and water. By using brightly-coloured sediment particles and putting a bromide tracer in the sea water, the researchers can follow how the particles are being moved around, and measure the amount and rate of sea water moving through the creatures' burrows.

It's not just the range of experiments that is unusual. 'We are all using the same techniques for analysing the calcium-carbonate system in different environments, over a longer period – 18 months – than has been done before – this is a world first!' Widdecombe explains. 'Having a coordinated approach means other people can look at our data and relate our experimental responses to theirs.'

He expects the consortium's experiments to begin producing results within three months, but the real interest will come with longer-term observations of a year and beyond.

Ocean acidification is a relatively new field, and while it is beginning to gain attention from scientists, policy-makers and the public, we still have a great deal to learn. The UKOA programme will clear up many doubts about its consequences. It will begin providing the concrete evidence that we need to mitigate and adapt to the changes, before it's too late. ■

Near-empty tanks at simulated 'high tide', seabed submerged.



Water tanks at Aberdeen.

MORE INFORMATION

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The main partners in the benthic consortium include: Plymouth Marine Laboratory, Marine Biological Association of the UK, Scottish Association for Marine Science, Centre for Environment, Fisheries & Aquaculture Science, and the Universities of Aberdeen, St Andrews, Bangor, Heriot-Watt (with Glasgow), Hull, Plymouth and Southampton.