

Understanding and acting on ocean acidification

Most people are now aware of the phenomenon of climate change, caused by the addition of large quantities of CO₂, resulting from human (anthropogenic) activities, accumulating in the atmosphere. This prevents heat leaving our planet so increasing global temperatures, with impacts already being felt around the world. Less familiar but equally worrying is ocean acidification, often called climate change's 'evil twin' or the other 'CO₂ problem'.



© Nelson A. Lagos

Same cause, different process

Climate change is the result of a suite of greenhouse gases (GHGs) acting together to trap heat from the Earth (greenhouse effect), causing the atmosphere to absorb more heat so raising temperatures (global warming). The effects are widespread and variable but its longer-term impacts, although beginning to be felt are still difficult to predict with certainty. Ocean acidification on the other hand, caused by CO_2 entering the ocean, results in chemical changes that are more certain and predictable, and its impacts are becoming clearer. In one sense the

ocean has done the planet a favour by absorbing some of the CO_2 that would otherwise have remained in the atmosphere and accelerated global warming even further, but this has its limits. As the ocean 'sucks up' more CO_2 and its temperature continues to rise, its ability to absorb CO_2 will decline and so the short-term gain of slowing climate change will be lost; global temperatures will rise more quickly, at the same time seawater pH is dropping and acidity rising.

The 'Evil Twin' at work



Oceanographic cruises are providing wider scale in situ measurements of how ocean pH is changing. © Nelson A. Lagos

In the ocean the addition of CO_2 leads to the release of hydrogen ions with accompanying lowering of pH, a move towards acidity and a reduction in available carbonate. Since ocean acidification was first intensively studied, just a decade or so ago, scientists have been carrying out laboratory-based experiments in efforts to understand the process of ocean acidification and how it might affect organisms. These early experiments and

observations were simple and concentrated on effects on single species, in artificial conditions over short time durations. To gain a better appreciation of the ocean acidification process larger and longer experiments have since been carried out in carefully created marine environments (mesocosms), both in the laboratory and at sea, which mimic near-natural conditions. Increasingly observations have been continued at community and ecosystem levels, not least at localised natural sites where CO_2 is seeping from the sea bed. Oceanographic research cruises, tethered and floating buoys, and satellite observations are providing wider scale information.

Powerful computer modelling techniques based on real scientific data enable scientists to make projections of how ocean acidification might progress and how impacts might cascade through ecosystems. The message coming through loud and clear is that despite some regional and seasonal variation, especially in coastal waters, the trend is following a path of declining pH, hence increasing acidity. While some species may actually benefit from this it is likely to have negative impacts on a wide range of species and their communities. We may still have gaps in the detail but overall the science of ocean acidification and its implications are clear.

A scale not seen for tens of millions of years

Over the last 200 years or so 500 billion tonnes of anthropogenic CO_2 have been released to the atmosphere, around half of that in the last 30 years, from burning fossil fuels, industrial processes, cement production and land use changes. Twenty-seven percent of this has entered the ocean where it forms carbonic acid, gradually shifting ocean chemistry from alkaline towards acidity. Over this period the ocean has acidified by about 30%, and if we carry on as we are, 'business as usual', it is predicted that in just a few

decades seawater acidity may increase by 120%! It's not just the amount of change but also the rate that is alarming, scientists are confident that this is 10 times faster than anything previously experienced in the last 55 million years, a point in geological time when the ancestor of the horse was still the size of a dog, and 53 million years before the first humans appeared. No one is suggesting that the ocean will ever turn 'acid' but the rate of 'acidification' now being observed could result in huge changes in the marine environment.

Marine life in harmony

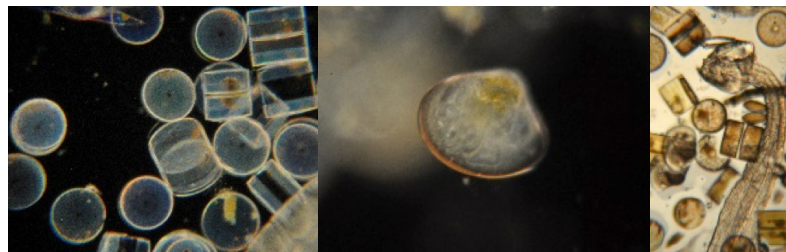
Every marine species has evolved over millions of years to survive within specific physical, chemical, climatic and biological conditions, but the delicate balance between



Shell-bearing organisms may have difficulty under more acidic conditions. © Nelson A. Lagos, Kelvin Boot

marine organisms and their watery environment is easily tipped. In the face of changes, including reduction of available carbonate wrought by ocean acidification, some organisms may have difficulty building their shells or growing their skeletons: shellfish (molluscs, crustaceans), echinoderms (starfish and sea urchins), corals and coralline algae are likely to be adversely affected. Others such as planktonic organisms including

fish eggs and larvae may not be able to cope with the changing conditions brought about by being bathed in water that does not suit their internal chemical balance.



Planktonic organisms including fish larvae and eggs, are likely to be affected by ocean acidification. © Kelvin Boot

The impacts of ocean acidification are now known to be complex affecting reproduction, physiology, growth, movement, food capture and predator avoidance, and while organisms may have some ability to 'trade off' between these essential life functions, there will be a 'cost'. Scientists have come to recognise that different species and even different individuals within a species or at different life stages may be affected differently.

One great big uncontrolled experiment

This is the first time that humans have dramatically altered the ocean's fundamental chemistry and are, in effect, carrying out a huge uncontrolled experiment. While we still cannot predict the final outcomes it is obvious that the ocean is and will continue to change. Studies from sites where CO₂ naturally vents into the ocean show that some plants may actually benefit from more of the gas, which is an essential component of photosynthesis, animals with calcareous skeletons and shells on the other hand are obvious victims as the balance towards acidity interferes with shell and bone growth. However, the fact remains that even where there are so-called 'winners', things are likely to change, cascading up food chains and putting even human food security at risk for billions of people globally – at the moment we don't know how serious that might be.

Ocean acidification has happened before in geological time and the fossil records can provide some pointers and the prognosis is not good, furthermore the current 'experiment' appears to be proceeding much faster. It is true that marine organisms can adopt a number of strategies to overcome such changes: but adaptation and evolution are unlikely to



Some marine plants may be 'winners' but ecosystem balances will still be affected. © Nelson A. Lagos

be able to keep pace with the rate of change of today's 'rapid ocean acidification'. Migration is an option but such mobile species, including the drifting eggs and larvae of sedentary organisms may not find the necessary conditions for settlement and survival in a future ocean. The danger is that any new communities that develop may not continue to provide the goods and services that support us and the rest of marine life. Ocean acidification is an uncontrolled experiment that is also a very risky gamble.

Impacts global, impacts now

Without reductions in CO₂ emissions, ocean acidification will eventually occur everywhere, but its intensity and impacts will vary due to local conditions

such as currents and sea temperature. It is the degree of calcium carbonate saturation that allows organisms to build skeletons and develop shells. Areas of the

ocean that encourage such calcification are said to be oversaturated. In undersaturated conditions the shells and skeletons fail to develop or, if present, may begin to dissolve; colder waters are likely to be affected first as they absorb more CO₂. Scientists predict, based on real observations and powerful computer models, that by the end of 2018 10% of the Arctic Ocean will have crossed this threshold to the undersaturated state. By 2050 this will rise to 50% and by the end of the 21st century the entire Arctic Ocean will be in a state where any unprotected calcium carbonate structures will dissolve. This is already happening in the Antarctic; the shells of some pteropods, known as sea butterflies, small swimming snails of immense

importance as food for fish, birds and whales, are already being dissolved.

While polar regions may be the first to be affected they are not alone. As ocean acidification progresses, the layer of oversaturated water along coastal and continental shelf areas grows shallower by the year, so exposing these areas to further inundation of CO₂ rich waters, brought from the deep sea during upwelling events. This will produce conditions that organisms living in these zones are not used to and shell-bearing animals are likely to be adversely affected. Upwelling along the west coast of North America already occurs with negative impacts on shellfisheries.

From evil twins to troublesome triplets

Ocean acidification does not work alone: in addition to other anthropogenic stressors, such as over-fishing and pollution there are the overriding, CO₂ related phenomena of climate change and deoxygenation. Deoxygenated zones arise for a number of reasons including oxygen-hungry plankton blooms driven by nutrient rich



Plastics and other pollution can be controlled, so relieving some of the pressure the ocean faces. © Kelvin Boot

agricultural run-off, but warming sea water holds less oxygen and stratification effectively caps off whatever oxygen is found near the surface from deeper layers. Existing deoxygenated zones are expanding and new ones are forming:

most life cannot survive without oxygen. So, the oceans face multiple stressors, and understanding their combined effects in any region is key to mitigating their threats and adapting to change. Some stressors should be immediately manageable - for example over fishing can be regulated, littering can be discouraged through education while pollution is the subject of international legislation. The wider, larger scale CO₂-related stressors are more difficult as they require a coordinated approach involving every country of Earth. Top down approaches through legislation and regulations are required if we are to achieve the targets set internationally for reducing nations' CO₂ emissions. But we can all make a difference: raising awareness through spreading the word, sharing concerns, arranging or taking part in community activities can all influence policy formers.

Face the problem, be part of the solution

Ocean acidification is happening on a global scale and requires urgent, concerted action across nations **to reduce the CO₂ emissions** that cause it and the related threats of climate change and deoxygenation. It may seem too big a challenge for any one person to make a difference but each of us can contribute to combating the threat that ocean acidification presents. These individual actions might seem like drops in the ocean but together they will influence others and they will make a difference.

Spread the word, tell everyone you know about ocean acidification so that more people become concerned and take action. Write to newspapers, ensure your MPs and local councillors know about ocean acidification.

The ocean faces many pressures and needs protecting over large areas. Support and **encourage the protection of the ocean** to minimise the combined effects.

Cars and planes produce large amounts of CO₂. Avoid them if possible and **use other forms of transport**.

Many products, including foodstuffs, come from far off sources, getting them to where they are used is expensive and results in yet more CO₂. Think before you buy, and **purchase local and seasonally** to avoid unnecessary transport.

Livestock (mainly cattle) not only produce large amounts of the GHG methane, but also around 5% of anthropogenic CO₂ emissions – recent studies indicate that livestock and associated land use change accounts for almost a fifth of global warming. **Eating less meat** (especially red meat) is a simple change that can make a difference.

Manufacturing is a CO₂ producer, so **redesigning products to avoid waste or reducing, reusing and recycling** can shrink your own carbon footprint. Making the change from consumer to producer can be as simple as growing some of your own food, and it's easy to compost food waste.

If you have the opportunity, choose **eco-friendly materials** and locally sourced materials in building projects to make an immediate reduction on your carbon footprint. Adding **renewable energy** technologies will also make a difference and should save you money in the long term.