Ocean Acidification: How Carbon Threatens Coral… and What We Can Do About It

For 12,000 years, humans have enjoyed life on a planet perfectly balanced to meet our needs.

Earth's systems, across the land, atmosphere and oceans, have worked in tandem to create the stable conditions that allowed us to build civilisations.

However, over the past 200 years, our booming population has placed unprecedented pressure on the systems we rely on to support us. Today, many of those systems are flexing under the strain and some risk being pushed to breaking point.

Recent research conducted by Plymouth Marine Laboratories suggests that in recent years, we may have entered into a danger zone when it comes to ocean acidification. This could have consequences for our marine ecosystems and our lives on a fragile planet.

Planetary Boundaries act as an early alarm system

In 2009, Rockström et al. identified 9 key Earth systems, and set about quantifying the strain they could reasonably take on, whilst still keeping our planet healthy. They called these Planetary Boundaries.

Staying within a Planetary Boundary means we are exploiting a resource in a safe and sustainable way, where our planet will be able to counteract any fluctuations, and maintain the stable conditions we need to survive.

However, once a boundary is crossed, the future becomes more uncertain, and we risk doing irreparable damage to our carefully balanced life-support systems.

Crossing a boundary does not mean we are headed for immediate and irreversible collapse, but it does act as an early warning system, letting us know that it's time to take action to avoid widespread impact in the future.

Ocean acidification is the seventh of the nine planet boundaries to have been crossed.

What is ocean acidification?

Carbon dioxide doesn't just affect the atmosphere- it's dissolved in our oceans too.

Once there, it reacts with seawater to create a compound called carbonic acid. Carbonic acid is not very stable, so it quickly dissociates to form a new molecule, bicarbonate, and a hydrogen ion.

The hydrogen ions make the ocean more acidic…but that's not the only problem.

The hydrogen binds carbonate ions that would otherwise react with calcium to form calcium carbonate, which is vital to many marine organisms- corals use it to build their skeletons, molluscs like oysters and clams use it to build shells, crustaceans like crabs and lobsters use it to harden their exoskeletons, and echinoderms like starfish use it to build spines.

Ocean acidification is not only altering the pH of our oceans, but also removing a molecule which is vital to so many marine ecosystems.

Comparing today's oceans to the oceans of the past

You might imagine that measuring ocean acidification is as simple as checking the pH of sea water with a probe. This would give us some meaningful data, but ocean acidification is really about changes to carbon chemistry within the oceans.

The key thing scientists want to identify is how much carbon carbonate is available.

Aragonite is a form of calcium carbonate that many marine organisms rely on to build skeletons and shells. Higher levels of aragonite indicate that conditions are good for these calcifying organisms. As the ocean acidifies, the aragonite saturation of the water falls.

The scientists used global data sets to compare the aragonite saturation of the oceans today to pre-industrial levels, assessing how far human activity has pushed ocean acidification away from the conditions the organisms first evolved in.

They were also able to compare other parameters, such as pH, hydrogen ion concentration and carbonate ion concentration.

The team compared the levels of acidification seen today, to the known limits under which marine organisms can survive.

What did they discover?

By combining global observations, Earth system models, and biological thresholds, the researchers showed that large areas of the ocean, particularly polar regions and waters below the surface, have already dipped below the Planetary Boundary. In many cases, this had already happened by 2020.

Much of the global surface water remains safely within the boundary, but most ocean life doesn't live at the surface, and the majority of calcifying organisms live on the seafloor. With estimates showing that up to 60% of the global subsurface ocean has crossed the boundary, the increase in ocean acidification has major implications for the survival of these creatures.

Uncertainty, regional differences and biological complexity

Ocean acidification isn't happening uniformly, everywhere.

pH varies across seasonal cycles, locations and depth. This makes it very difficult to come up with one definitive measure of ocean acidification across the globe.

Cold polar waters naturally have lower aragonite saturation because colder water absorbs more CO_2, so recent fluctuations are hitting these ecosystems particularly hard. Meanwhile, in the tropics, aragonite has been historically more plentiful, but coral reef systems rely heavily on calcium carbonate availability, and so the effects are highly visible in these areas. The study suggests that there has been 43% reduction in the areas suitable for tropical and subtropical coral reefs since pre-industrial times.

Different species will respond differently, and there will be a delay between the changes in ocean chemistry and the visible response from marine organisms. Because much of the change is happening at depth, the impact is not seen by humans regularly, and quantifying change can be difficult.

It can also be hard to establish reliable estimates for carbon chemistry in the pre-industrial era.

The current system suggests that we should aim to keep aragonite saturation from dipping more than 20% below pre-industrial norm. The researchers suggest that this may not account for the uncertainty in the data, and for the first time, suggest attributing an uncertainty of +/-5.3% to the planetary boundary, and that more realistically, we should be aiming for no more than a 10% reduction in order to guarantee protection for marine organisms.

Consequences for ecosystems and society

It can be easy to feel that the oceans are out of sight and therefore out of mind, but the oceans play a key role in establishing the stable systems that have made Earth comfortably habitable for humans.

We rely on our oceans to provide us with food, medicine and coastal protection, as well as cycling nutrients, water and atmospheric gases.

The oceans also play a vital role in our economies. Fish and shellfish are major contributors to our global food supply chain, with fisheries accounting for a significant chunk of GDP across many countries. Coral reefs and their inhabitants also help to support national economies through bringing in valuable tourism to coastal nations.

Marine food webs are interconnected, meaning that this isn't simply a threat to calcifying organisms- it's a threat to the whole system. Removing one organism means removing predators and prey from food chains that depend on them. Losing coral reefs means the loss of a major nursing ground for young marine organisms that otherwise won't survive.

Allowing ocean acidification to continue is a gamble with biodiversity that stands to cost billions of dollars to the global economy if left unchecked.

What action can we take?

We can't return the oceans back to their previous state using chemical methods. The ocean is too large and complex.

The only viable solution is to take steps to reduce our CO_2 emissions.

The good news is, we already have many of the tools to do this. Getting behind low-carbon initiatives, scaling up our renewable energy sectors, and finding innovative ways to reduce atmospheric carbon will all contribute to a brighter future.

We can also give our oceans the best fighting chance, by maintaining healthy, resilient ecosystems. Reducing overfishing and destructive fishing practices and protecting important habitats like seagrass meadows, kelp forests and mangrove networks will go a long way to protecting biodiverse marine ecosystems capable of withstanding change.

Continued monitoring will also be vital in mitigating our impact on our oceans.

Governments and businesses have a large role to play in shaping policies and initiatives that will lead us towards a more stable future.

There is hope.

Crossing this Planetary Boundary does not mean we are headed for irrevocable collapse of our marine ecosystems. It simply means it's time to take notice of the damage we are doing and start taking steps to mitigate it.

Throughout the 1930s and into the 1970s, compounds known as CFCs were unknowingly leading to ozone depletion- another of our Planetary Boundaries. Campaigners brought this to the attention of the public and governments, and in 1987 the Montreal Protocol was adopted, promising to phase out the use of CFCs. Since then, the effects have been reversed and ozone depletion is now one of two Planetary Boundaries considered unbreached.

This success story is evidence that it is within our power to bring Planetary Boundaries under our control. We have the scientific tools to monitor our progress and the innovations in technology to lead our planet towards a safer future.

This recent study should be seen as a warning sign that it’s time to evaluate the risks we face, and make responsible decisions for the future of our planet and the people on it.