UK Ocean Acidification Research Programme

AVOID 2

Can we avoid dangerous climate change?

How can we minimise negative impacts on ocean health?

Rising temperatures and sea levels, acidification, and deoxygenation are carbon dioxide (CO_2)-driven stressors that are already affecting the ocean, as well as the life it supports and the benefits it provides. These effects are in addition to pollution, over-fishing and lost habitats and their combination is likely to be worse than the sum of the parts: threatening ecosystems, human well being and the ability of the ocean to absorb CO_2. Whilst damage is inevitable, actions can be taken to reduce its severity.

The ocean is a key source of food and livelihood for millions of people, and ocean habitats create a range of other benefits, such as recreation and flood protection. The ocean can also pose a threat to coastal communities through sea level rise, storm surges and coastal flooding. Although ocean waters absorb both CO_2 and heat, thus slowing climate change, those processes alter ocean physics and chemistry, with knock-on effects for ecosystems and food security.

What are the changing stresses on the marine environment?

Warming

The ocean surface is currently warming by about 0.1°C per decade. Such temperature changes affect ocean currents and mixing; they also alter the distribution (and abundance) of fish that prefer cooler or warmer conditions, such as cod and sardines respectively. Tropical regions are expected to lose the greatest amount (more than 50%) of their maximum potential fish catch under high greenhouse gas emission scenarios.

Sea level rise

Global sea level is presently rising on average by 3.2 cm per decade; faster in some areas and slower in others. Coastal ecosystems such as corals and mangroves are at particular risk; furthermore, their loss increases coastal erosion and societal vulnerability to future sea level rise – which in the long term, is likely to be at the scale of metres if climatic thresholds relating to ice-sheet stability are exceeded.

Acidification

Increased atmospheric CO_2 directly causes ocean acidification (lowering of pH) when gas dissolving at the surface changes the chemistry of the water. A wide range of marine organisms can be affected, with corals, molluscs and calcified (shelled) animals being most sensitive. Radical changes to the species balance may occur in fragile marine ecosystems (e.g. polar regions); although some species could benefit, many others would be adversely affected. Corals and molluscs seem most at risk (Figure 1).

Reduced gas uptake

Warmer seawater can hold a smaller capacity of dissolved gases, such as CO_2 and oxygen. This reduces the "ocean carbon sink", a natural process that has greatly slowed the increase of atmospheric CO_2 to date. Reduction of the ocean's oxygen capacity, or **deoxygenation**, can be highly damaging for active organisms such as fish. Low oxygen levels can, however, be well-tolerated by some microbes, overall this can change food webs and ocean productivity.

Other stressors

Marine ecosystems are subject to many other human impacts, including pollution (by nutrients, metals, hydrocarbons and plastics), over-fishing, and direct habitat damage. Global reduction of such stressors, and local reduction within marine protected areas, would increase resilience to impacts driven by climate change.

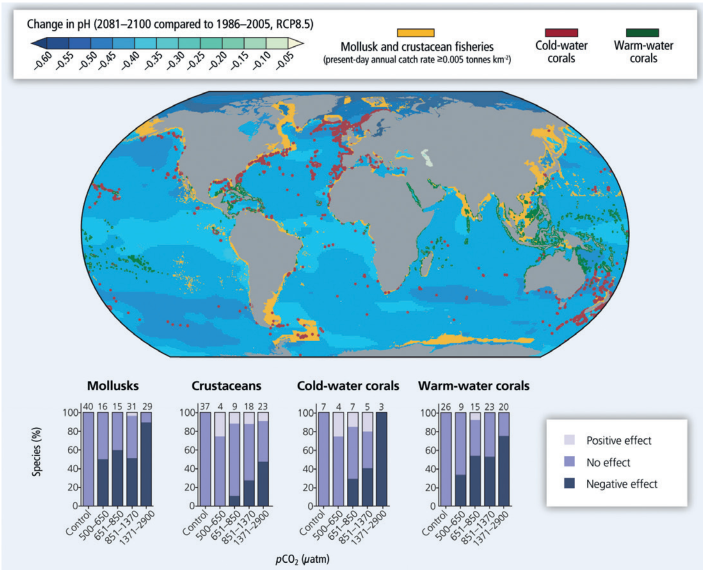


Figure 1: Vulnerability to ocean acidification. Marine mollusc and crustacean fisheries (present-day estimated annual catch rates ≥0.005 tonnes km^{-2}) and known locations of cold- and warm-water corals, depicted on a global map showing the projected distribution of ocean acidification under RCP8.5 (pH change from 1986-2005 to 2081-2100). The bottom panel compares sensitivity to ocean acidification across molluscs, crustaceans, and corals, vulnerable animal phyla with socioeconomic relevance (e.g., for coastal protection and fisheries). The number of species analysed across studies is given for each category of elevated CO_2.

Source: IPCC AR5, WGII; SPM Fig 6.

How can these impacts be minimised?

Reduction of human greenhouse gas emissions, particularly CO_2 will reduce the direct effects on temperature and pH and would also slow the rate of sea level rise. But even with a low emissions pathway (and net-zero emissions later this century, as agreed in Paris), some further effects on the marine environment are inevitable (Figure 2).

Nevertheless, some species may naturally adapt, if the rate of change is slow enough. This could involve:

- genetic selection for strains that tolerate low pH conditions;
- changes in distribution, such as coastal habitats gradually migrating inland in response to sea level rise;
- new coral reefs developing in waters that are currently too cool, in response to warming.

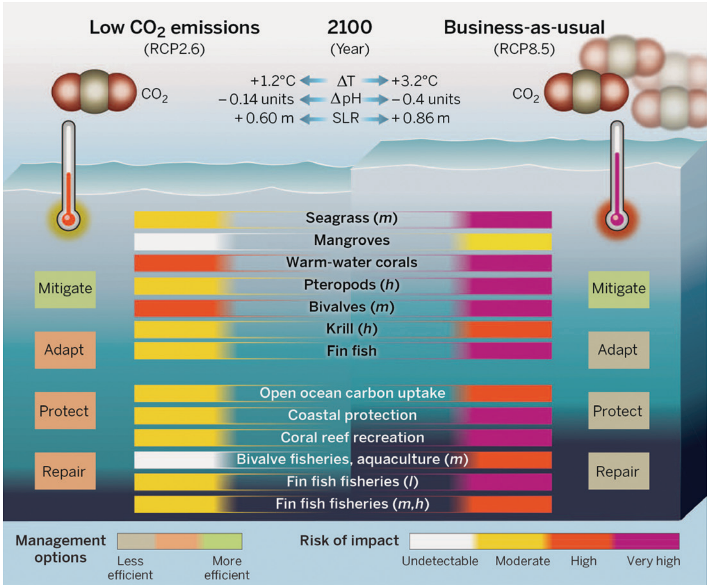


Figure 2: Contrasting the impacts of low- and high-emission IPCC scenarios on species, habitats and ecosystem services in the twenty-first century. Emission reduction is always the most efficient management option, with adaptation, protection and repair more challenging in a higher-emission pathway.

Source: Gattuso et al (2015).

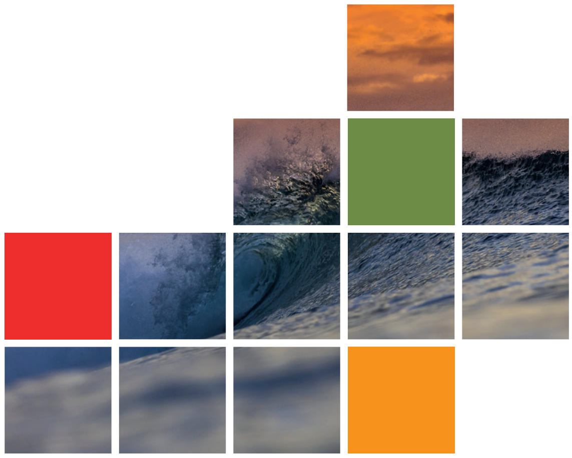
However, a faster rate of change, and numerous stressors, would mean many species are less likely to adapt successfully.

Local adaptation through changing management practices

Oyster hatcheries on the US Pacific coast have already experienced economic losses due to ocean acidification, since the seawater there already has a naturally low pH. However, a combination of careful monitoring and seawater treatment within the aquaculture facilities is now in operation – and has been successful in restoring hatchery survival rates.

Ultimately, business practices must adapt to limit exposure to damage. This will depend on favourable economic conditions, and cannot continue indefinitely in the face of rapid and ever-continuing change.

Larger-scale coastal and open ocean water treatment has also been proposed to 'neutralise' ocean acidification; for example, by adding finely-ground olivine rock. Such methods are untested; however, their economic cost seems likely to be high, and their public and political acceptability are low.



Read more

Turley C et al, WMO Bulletin **63** (1) (2014): Hot, sour and breathless – ocean under stress.

AVOID 2 policy card E1/E2: *How can land use management and "blue carbon" activities contribute to meeting mitigation targets?*

Gattuso et al, Science **349** (2015): *Contrasting futures for ocean and society from different anthropogenic CO_2 emissions scenarios*.