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OCEAN ACIDIFICATION

The global heating being driven by rising levels of atmospheric carbon dioxide (CO_2) and other greenhouse gases is a planetary emergency. For the ocean, the most serious impacts – recently referred to by International Programme on the State of the Ocean (IPSO) experts as the 'four horsemen of the apocalypse' – are:

- sea surface warming
- ocean heating
- deoxygenation
- acidification.

All four are unprecedented, pervasive and accelerating. They are also interconnected, and the direct consequence of the ocean absorbing our CO_2 emissions and the resulting additional heat. Since 1750, the ocean has absorbed 28% of all man-made CO_2 emissions (Gattuso et al., 2015) and since 1970 it has stored over 90% of the excess heat trapped by greenhouse gases (IPCC, 2019).

CAUSES

Burning fossil fuels, deforestation, cement production and other activities have released massive quantities of CO_2 into the atmosphere over the last 200 years. Today, the ocean absorbs over one million tonnes/1 billion kg of CO_2 from the atmosphere every hour (IGBP, IOC, SCOR, 2013). When CO_2 dissolves in seawater, it forms carbonic acid and decreases the pH of the ocean, driving the water towards acidity. The massive increase in our carbon emissions means that this chemical process is happening on an unprecedented scale, causing what is collectively known as ocean acidification.

Between 20% and 30% of all human-induced emissions have been absorbed by the ocean since the 1980s, causing ocean acidification (IPCC, 2019) – and ocean acidification is now occurring about ten times faster than anything experienced over the last 300 million years (IUCN, 2017).

Without the ocean absorbing 24 million tonnes /24 billion kg of our CO_2 every day, the rate and severity of climate change would be far greater (Ocean-acidification.net, 2019). But this valuable service to humanity comes at great cost. Ocean acidity has already increased by 26% since the industrial revolution (IPCC, 2019), and is expected to increase by 170% by 2100 if things continue as they are (IGBP et al., 2013), causing sweeping changes in the chemistry of seawater and threatening marine life.

IMPACTS

Ocean acidification has already caused observable impacts on important ocean species and has the potential to change entire marine ecosystems and threaten vital services including coastal protection and the food and incomes provided by fishing.

Many sea creatures – including mussels, clams, coral, oysters and certain phytoplankton and zooplankton species – require calcium carbonate to build their shells and skeletons (NRDC, 2009). But carbonate levels drop when acidity rises, threatening the ability of these animals to develop and reproduce. As these species are at the bottom of marine food webs, the effects ripple up to fish, seabirds and marine mammals. Declining harvests attributed to ocean acidification are already being reported, for example in the US Pacific Northwest's oyster industry (NRDC, 2016).

A new study found that the world's coral reefs, already under existential threat from ocean heating, are also severely impacted by ocean acidification, with many corals and calcifying algae unable to

adapt to changing conditions (Comeau et al., 2019). The International Union for Conservation of Nature (IUCN) warns that the ability of corals to recover from devastating climate-related bleaching is also hampered by declining calcification rates caused by acidification (IUCN, 2017).

Changes in the growth, migration and reproduction of key species**,** combined with structural alterations in ecosystems like coral reefs**,** could undermine food security, threaten fishing industries and decrease natural coastal protection – increasing the risks from storm surges and erosion for low-lying communities.

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