Ocean acidification; what is it and what can we do?

Message 1: Ocean acidification is a global threat with local consequences. Through human activities atmospheric carbon dioxide (CO_2) levels are increasing and are currently around 425ppm (May 2023), up from 280ppm at the start of the industrial revolution. This increase would have been even greater were it not for the ocean, which has absorbed around a third of the estimated 1.5 trillion tons of CO_2 we have generated so far. As CO_2 enters the ocean it reacts with the seawater to create carbonic acid which reduces the pH (a measure of acidity) [Figure 1, top panel]. Many years of taking up human-derived CO_2 has made our ocean around 40% more acidic than pre-industrial levels [Figure 1, bottom panel]. The CO_2 also reacts with other chemical elements to alter the availability of carbonate, a key component in the shells and skeletons of marine organisms, such as shellfish and corals. The rate of ocean acidification is accelerating globally but is experienced most strongly in coastal areas, where other processes exacerbate the phenomenon.

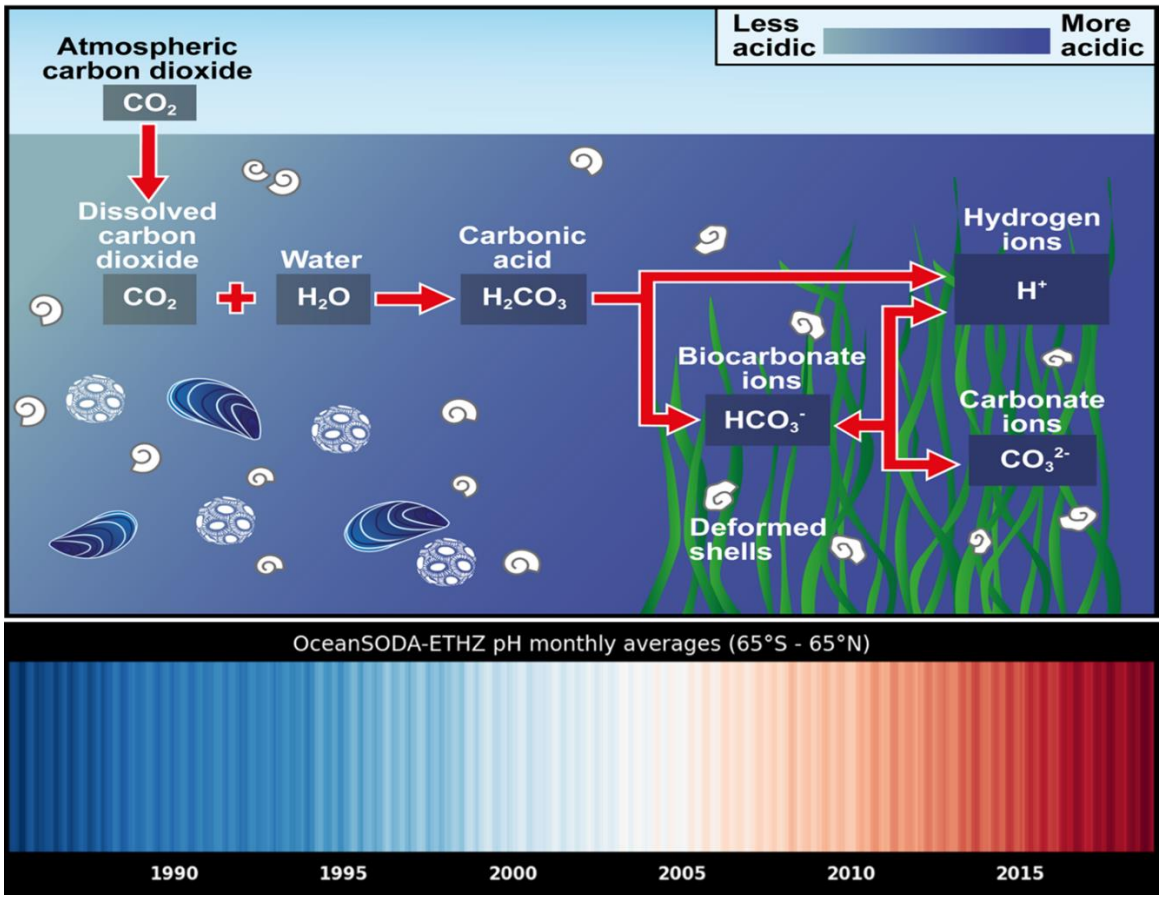

***Figure 1: Top panel**, a simplified description of the chemical reactions which occur when carbon dioxide (CO_2) dissolves in seawater. Collectively these reactions represent the phenomenon known as Ocean Acidification. **Bottom panel**, "pH stripes" illustrating the relative change in global pH levels over the past 35 years with red colours representing higher pH levels (low acidity) and blue colours representing lower pH levels (higher acidity). SOCAT pCO_2 data and ML salinity-derived alkalinity data from satellites were used to calculate pH. Stripes were created by Luke Gregor, ETHZ. ESA OceanHealth -Ocean Acidification project. Data: https://doi.org/10.5194/essd-13-777-2021*

Message 2: The threat ocean acidification poses to marine ecosystems, biodiversity, and ecosystem services is recognised at the highest level. The recent IPCC report on climate change stated with high confidence that *"Ocean warming and ocean acidification have adversely affected food production from fisheries and shellfish aquaculture in some oceanic regions"* (IPCC, Summary for Policymakers, AR6, 2023, https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf). Seeking to protect biodiversity, the UN's Global Biodiversity Framework (December 2022) committed all member states to minimizing the impact of ocean acidification on biodiversity and to increasing biodiversity resilience through mitigation, adaptation, and disaster risk reduction actions. In the North Atlantic and adjacent Arctic waters, the OSPAR Quality Status Report highlighted ocean acidification as a present and growing threat to marine ecosystems, and highlighted grave concern for important commercial species as well as those habitats and species with high conservation status. The impacts of ocean acidification on the marine environment are also at the heart of the 2030 Agenda for Sustainable Development, with the Intergovernmental Oceanographic Commission of UNESCO acting as custodian for the SDG indicator 14.3.1 "*Average marine acidity (pH) measured at agreed suite of representative sampling stations"* which aims to track progress made towards the SDG target 14.*3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels*. In response to the ocean acidification problem the ocean science community has come together to speed up the collection and sharing of knowledge.

Message 3: Combatting ocean acidification requires rapid and significant decarbonisation. As it is for climate change, the single most important thing we can do to halt ocean acidification is to significantly reduce CO_2 emissions as quickly as possible. However, even if we managed to achieve this overnight, the amount of CO_2 already in the system will take hundreds of years to remove and will continue to drive ocean acidification for many years to come. But it is not too late to make a difference, the quicker we act to reduce emissions, the less severe and long-lasting future acidification will be, avoiding irreversible regime shifts and leaving marine organisms and coastal communities time to adapt.

Message 4: Protecting and restoring nature will increase resilience to the impacts of ocean acidification. Healthy marine ecosystems, with high levels of biodiversity, will be better able to resist the worst effects of ocean acidification. We must take actions that successfully reduce the myriad of those other environmental impacts that threaten our ocean (e.g. overfishing, habitat destruction, resource extraction and pollution, including chemicals, human sewage, nutrients, light and noise). In doing so we will give natural systems the best chance to keep functioning, as climate change and ocean acidification pressures increase. This is not solely an altruistic pursuit. If we risk ecosystem collapse then we also risk losing the goods and services we humans derive from our ocean; food, medicines, coastal protection, climate regulation and leisure, not to mention cultural and spiritual well-being.

Message 5: Nature is our ally in the war against climate change and ocean acidification. The ocean, and the marine ecosystems it contains, is a natural part of the global carbon cycle. 'Coastal Blue Carbon' habitats, such as mangroves, saltmarshes, seagrasses, and kelp beds capture large amounts of CO_2, storing that carbon in sediments on the seafloor. However, this should not be seen as an overnight climate solution as these habitats take many years to build up their carbon stocks. Blue carbon should be seen as our 'Climate Pension'. In addition to their important role in climate action,

these habitats also support high numbers of species, and their protection is an effective weapon in the fight against the current global crisis of biodiversity loss and species extinctions.

Message 6: We cannot rely solely on new marine Carbon Dioxide Removal (mCDR) technologies to solve the climate and ocean acidification crisis. Chemical and biological ocean processes can act to remove CO_2 from the atmosphere, storing it either as dissolved inorganic carbon in the water column or as organic carbon that is eventually transported to the deep ocean to be recycled or sequestered into the seafloor. There is currently much interest in the potential to manipulate natural systems in ways that will increase the scale or speed of these ocean processes as a way of reducing atmospheric CO_2 levels. Whilst these proposed mCDR technologies, if successful, would remove CO_2 from the atmosphere, some of them would result in even more CO_2 being present in ocean systems, exacerbating the problem of acidification. For mCDR to be beneficial to ocean life it must ensure that all the additional CO_2 captured from the atmosphere is safely sequestered deep beneath the ocean floor. Currently, the scientific evidence needed to judge the various risks and benefits associated with different mCDR techniques, as well as the practicality, scalability and affordability of proposed projects, is lacking. It should also be noted that, without significant reductions in CO_2 emissions, the application of widescale mCDR will do little to address the climate or acidification crisis in our ocean, in the short term. Our approach should be to continue to research potential mCDR technologies, their risks and benefits, but with the intention of using them to reduce the residual stock of atmospheric and oceanic CO_2, once we have reduced CO_2 emissions to as near to zero as possible.

Message 7: Everyone can join the battle against ocean acidification. The Global Ocean Acidification Observing Network (GOA-ON, http://www.goa-on.org) connects nearly a thousand scientist from over 100 countries. Their goals are to observe and predict the rates and impacts of ocean acidification. But it isn't just scientists that are required to combat the causes and impacts of ocean acidification. The 'Ocean Acidification Research for Sustainability' (OARS) programme (www.oars-un.org) is part of the United Nations' Decade of Ocean Science for Sustainability initiative. OARS provides a roadmap towards delivering 7 key outcomes (Figure 2) and will require engagement from a wide range of different ocean professionals and stakeholders. If you are interested in finding out more about how you could contribute to OARS, please contact the GOA-ON Secretariat via email, secretariat@goa-on.org.

Figure 2: *The 7 desired outcomes from the UN Ocean Decade programme "Ocean Acidification Research for Sustainability".*