Ocean acidification, a threat to life

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Healthy oceans are essential to our existence. And not only human beings suffer from the deteriorating state of the world's oceans; biodiversity is also critically at risk. Oceans cover 70 percent of our planet. Seafood, both caught in the wild and farmed, forms the main source of protein of some three billion people (WWF, undated), while it is a staple for nearly a billion, mainly in the developing world (FAO, 2005). Seas and oceans are playing an important role in sequestering carbon dioxide: over 30 percent is taken up by our oceans, which are still continuing to absorb about a million tons per hour (Kolbert, 2011: 200). As expressed on the 'Oceans Day' (4 Dec. 2015) website of the UNFCCC COP21:

> "Oceans and climate are intertwined, with oceans driving climate and climate change affecting ocean health and coastal and island peoples. Oceans cycle over 93% of carbon dioxide in the atmosphere, produce 50% of the oxygen we breathe, store 50% of all naturally sequestered carbon, and absorb 90% of the heat added to the global system in the past 200 years"

There is a constant exchange of CO_2 between the atmosphere and oceans. While there are many diverse habitats in the world's oceans, I will only mention three where the impact of acidification is very different:

1) *The open ocean and coral reef seas***:** some of the carbon that goes into the top ocean layers is taken up by phytoplankton, the tiniest algae that drift close to the surface. There sufficient sunlight penetrates to allow plants to make sugars from CO_2 by photosynthesis - and incidentally provide the animal world including ourselves with some more breathable oxygen. These tiny plantlets get consumed by all kinds of sea creatures, above all the multi-trillions of roaming zooplankton who migrate up from the seafloor to feed at night, returning to their bottom dwelling place by day. At their death, the tiny bodies gradually sink to the seafloor with the CO_2 safely deposited in the form of organic carbon which can be recycled into nutrients by bacteria, to be consumed again by other creatures. But the bulk of this massive ocean life – estimated to amount to some 90 percent of all marine biomass - is eaten during their migration by larger and stronger sealife: by sea butterflies, by krill, but also by blue whales, shrimps and jellyfish. The two last ones are again eaten by other, larger creatures of the sea, such as fish and at the top of the chain there are the sharks, sea otters, seals, sea birds, and not to forget human beings. Unfortunately, much of the CO_2 absorbed by the oceans does not go down with the zooplankton; instead it dissolves and combines with seawater. This may rise back up into the much warmer atmosphere in places of major upwelling. as for instance at the Chilean coast, where the cold, nutrient rich Antarctic water (McClintock, 2012: 132) from the Humboldt Current emerges, delivering a bounty of fish, but also a cargo of CO_2.The remaining unsequestered CO_2 has the unfortunate effect of changing ocean chemistry for the worse. Whereas ocean water is slightly more alkaline than tapwater, the dissolved CO_2 combines with seawater to form carbonic acid – no more than a fairly weak acid, it is true, but still sufficiently so to affect shell-forming organisms. These include life forms at the bottom of the food chain as well as many higher up such as sea butterflies, shellfish and corals. Coral reefs suffer a double whammy from climate change: warmer water leads to coral bleaching (NOAA, 2015), in effect robbing the coralline seaweeds which serve as glue to keep corals together, of their brilliant colours, while the loss of alkalinity attacks the very fabric of the reefs. As these support a scarcely imaginable variety of life – their demise would be a catastrophe for organisms dependent on marine food webs.

2) *Ice-covered polar seas*: in this case diatoms, a kind of phytoplankton, grows suspended from the drifting ice McClintock, 2012: 70, 172), which still lets a small quantity of sunlight through, such as the shelf ice of the Antarctic Peninsula. Otherwise the food chain is roughly similar to the one described above, but with very different sea food customers. Unfortunately, weakening of the alkaline character of seawater is strongest at high latitudes, (*Ibid*: 39) while warming there too is climbing much faster than elsewhere. In consequence, arctic sea life is likely also to be attacked

by predators migrating poleward, such as king crabs, observed climbing the Antarctic slopes, to hoover up much of the bottom layer of the Antarctic food chain (*Ibid*: 119, 141-161)

3) *Volcanic Deep Sea Vents*, which tend to be highly acidic and may be up to 400° C. They are characterised by the absence of calcifying shellfish. Studies at a much shallower volcanic vent near Castello Aragonese, west of Naples, which is continually subjected to CO_2 bubbling up from the depths, give a good idea of the effects of low alkalinity on ocean life (Kolbert, 2014: 111-124). While there may be diatoms, phytoplankton sporting a silica shell in surface waters close to shallow vents, the sea water is too acidic to permit the forming of aragonite or calcium carbonate shells or of corals. In fact, subjecting Antarctic sea butterflies, tiny pteropod shellfish to seawater of pH 7.8 (still more alkaline than tapwater) led to buckling and deformation of their hair thin shells (McClintock, 2012:119). Low alkalinity even affects non-calcifying organisms, such as the semen of lugworms, common near British coasts, when in combination with copper pollution (Waldbusser *et al*., 2013).

If business-as-usual continues, scientists expect the alkalinity of the oceans to decrease to pH 7.8, the figure of the sea butterfly test, by the end of the century, i.e. less basic by 150 percent (the pH scale is logarithmic). The fact that the sea water is warming is not good news for other oceanic creatures either. Most people will have read about coral bleaching. This refers to the dying of a range of algae, which live in symbiosis with corals; even a slight warming is fatal for many species. As to the effect of a high CO_2 environment on reefs, this is how the Intergovernmental Panel on Climate Change puts it:

> Ocean acidification poses substantial risks to marine ecosystems, especially polar ecosystems and coral reefs, associated with impacts on the physiology, behavior, and population dynamics of individual species from phytoplankton to animals. Calcified molluscs, echinoderms, and reef-building corals are more sensitive than crustaceans (high confidence) and fishes (low confidence), with potentially detrimental consequences for fisheries and livelihoods (March 2014: 17)

Can something be done to mitigate the consequences of ocean acidification? There have been attempts to sow the ocean with iron filings or crushed olivine to boost diatom growth. Before resorting to technofixes, we should protect what Roman and McCarthy call ‘the whale pump’: cetaceans feed near the seafloor, bringing nutrient-rich matter back to the surface in their excrement, which tends to remain in suspension near the surface in the form of a faecal plume (2010)..

These nutrients are consumed by phytoplankton, allowing them to thrive. In addition, the huge whale skeletons, sunk to the ocean floor, store impressive amounts of carbon and nutrients, while providing shelter. Although the decline of baleen and sperm whales is well over 66 percent, Roman and McCarthy think recovery is still possible and would be of huge benefit for the oceanic ecosystem: “Dozens, possibly hundreds, of species depend on these whale falls in the deep sea,” The more whales are valued and protected, the greater the gain for biodiversity. Roman et al. even speak of whales as “Marine ecosystem engineers” in their latest paper (2014). If we want to preserve ocean health, the world needs more whale sanctuaries in addition to the two existing ones as well as a permanent ban on commercial whaling and a firm commitment to limit greenhouse emissions.

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