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Guest Editorial

Ocean acidification in the freezer

Over a century after the Discovery Expedition (1901–04), our understanding of the environments and ecosystems in the Southern Ocean is still limited. Research efforts have focussed on warming and ice melt as the environment changes. Now a new challenge has emerged - ocean acidification - a concept that could not even have been comprehended 110 years ago as pH was only defined in 1909.

The ocean has absorbed about one third of the carbon dioxide released into the atmosphere through anthropogenic activities since the time of the Discovery Expedition. Associated with this has been an estimated global mean ~ 0.1 pH unit decrease in ocean surface chemistry, equivalent to a 30% increase in hydrogen ion concentrations. Model projections based on IPCC emission scenarios suggest further reductions of between 0.15 to 0.35 pH units are possible by the end of the 21st century, conditions that have probably not occurred for several million years. Moreover, the rate of change of ocean chemistry - 0.2 pH units/100 years - is fully two orders of magnitude faster than glacial/interglacial changes and possibly unprecedented in the last 65 Myrs.

The Southern Ocean is highly sensitized to these changes. The cold seawater temperatures mean that dissolved CO_2 concentrations were already elevated, while carbonate ion concentrations, which set the degree of saturation with respect to biogenic carbonates, are some $\sim 50\%$ lower than in the tropical ocean. The Southern Ocean will hence be one of the first regions to experience undersaturation occurring at the surface - by 2030 with respect to aragonite and by the end of the century for calcite. Despite monitoring stations elsewhere in the world the Southern Ocean has been neglected with respect to systematic monitoring of its carbonate chemistry, a situation that needs to change.

Changes in ocean chemistry have direct implications for a variety of physiological processes, such as photosynthesis, reproduction, and internal pH regulation. Declining saturation states will affect the biomineralisation of organisms living in shelf habitats - ecological hotspots which are amongst the most dynamic and diverse in the world. Benthic calcifiers stabilise the shelf ecosystem and greatly increase diversity by providing hard substrates for other organisms to settle on, implying a host of potential indirect impacts of ocean acidification.

Yet we often lack even basic knowledge of the physiology and biology of the keystone organisms in these settings. What is their life span and generation time, both of which probably influence their potential for acclimation or adaptation to rapid changes in the environment? What is the energy cost of maintaining mineralization rates and how will any loss of shell structural integrity influence interaction with predators, resistance to physical damage by waves or abrasion by ice? The balance between erosion and growth in these slow growing ecosystems will ultimately affect habitat diversity and ecosystem function. Understanding ecosystem-scale impacts is additionally challenging because other environmental changes such as temperature, water column stratification, sea ice limits, and nutrient runoff are predicted to change rapidly in the future and will induce a wide range of as-yet unpredictable synergies with the on-going stress of ocean acidification.

The complexity of future environmental change in the Southern Ocean, combined with the sparse sample coverage in this region and unknown physiology of many of the key organisms, currently prevents us from making societally-relevant projections of the impact of ocean acidification here. The rapidly approaching under-saturation of Antarctic surface waters adds considerable urgency to our efforts to analyse and reconstruct rates, magnitude and extent of the environmental changes occurring.

Daniela N. Schmidt - School of Earth Sciences
Andy Ridgwell - School of Geographical Sciences
University of Bristol