A Cacophony in the Deep Blue Sea: How Ocean Acidification May Be Deafening Whales

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Rising atmospheric concentration of carbon dioxide caused by increasing human activities has posed a threat to the balance of the natural carbon cycle. It is well known that the increasing atmospheric concentration of greenhouse gases endangers our living environment through global warming. Inevitably, as the atmospheric CO2 rises, more is absorbed in the oceans and seawater gets progressively more acidic through the formation of carbonic acid, H2CO3.

Burning of fossil fuels, deforestation, industrialization, cement production, and other land-use changes all expedite this process. Excessive uptake of anthropogenic carbon dioxide from the atmosphere induces an increase in the oceanic concentration of carbonic acid. This in turn brings about an accumulation of hydrogen ions, a decrease in the pH of the oceans and a reduction in the number of available carbonate ions (CO_3^{2-}), a phenomenon known as ocean acidification. (1)

Evidence suggests that these changes will have significant consequences for marine taxa, particularly those that build skeletons and shells of biogenic calcium carbonate (2). Under normal conditions, calcite and aragonite are stable in surface waters since the carbonate ion is at supersaturating concentrations. However, as ocean pH falls, so does the concentration of this ion, and when carbonate becomes undersaturated, structures made of calcium carbonate are vulnerable to dissolution.

Scientists have determined that the rate of current and projected increases in atmospheric CO2 is approximately 100 times faster than has occurred in at least 650,000 years. Evidence from species of marine taxa tested to date indicates that the calcification rates of tropical reef-building corals will be reduced by 20–60 percent at double pre-industrial CO2 concentrations. (2)

Since the marine calcifiers such as Acropora eurystoma, Porites lutea, Galaxea fascicularis, and Turbinaria reniformis, and calcifying macroalgae such as Coralline Algae and Halimeda are all sensitive to changes in carbonate saturation state, it has become increasingly difficult for marine calcifying organisms to form biogenic calcium carbonate. Recent research efforts suggest that ocean acidification is the primary inducing agent in the extinction of numerous reef species and the decreasing diversity in reef communities (1, 2).

Even more destructive to the ecosystem are the heavy impacts on higher trophic-level organisms that rely on these calcifiers to survive. For example, crustose coralline algae (CCA) are a critical player in the ecology of coral-reef systems as they provide the “cement” that helps stabilize reefs, make significant sediment contributions to these systems, and are important food sources for sea urchins, parrotfish, and several species of mollusks. Experiments exposing CCA to higher concentrations of CO2 indicate up to a 40 percent reduction in growth rates, 78 percent decrease in recruitment, 92 percent reduction in total area covered by CCA, and a 52 percent increase in non-calcifying algae (2). Thus, higher concentrations of CO2 will clearly affect the living environment of CCA and other marine organisms.

Excessive concentration of greenhouse gases also induces other side effects, such as climate change and increase in water temperature that indirectly expedite this destructive process.

Among the numerous detrimental side effects of ocean acidification, the hardest one to imagine would be deafening the whales by altering the ambient noisiness of the ocean. Lately, this seemingly bizarre theory is backed up by numerous scientific endeavors.

Two recently published articles offered convincing, although somewhat convoluted explanations for this trickle effect. Peter Brewer and his team at the Monterey Bay Aquarium Research Institute, in California published an article in Geophysical Research Letters suggesting that the ocean has become noisier as a result of increased acidity (3). In the same journal, Alexander Pazur and Michael Winklhofer stated that geomagnetic field variations could further amplify sounds through the ocean (4).

But how could ocean acidification affect the hearing of whales? One possibility is the increased sound transmission through the acidified water (3). Brewer and his colleagues proposed that increased concentrations of CO_2 invoke an imbalance in dissolved ions that absorb vibrations at acoustic frequencies, resulting in significant reduction in ocean sound absorption for frequencies lower than 10 kHz, the frequency at which most whales communicate. This consequently amplifies the ambient low-frequency ocean noise level.

In his paper, Brewer also pointed out another less evident, but equally crucial factor: increased heat flux induced by growing atmospheric CO_2 heats the ocean, further contributing to the decreased sound absorption in the lower frequency range. CO_2 is not the only greenhouse gas contributing to the ocean noise level. Another factor that is worth noticing is the deposition of sulfur and nitrogen from the combustion of fossil fuels. These atmosphere additions of strong acids change ocean alkalinity and pH.

Solid statistics are even obtained to back up their theory: the ocean absorbs at least 12 percent less sound now than it did in pre-industrial times. And what's more frightening is that by calculation, it is surmised that this number might rise to 70 percent in 2050. The increasing noisiness of the ocean poses an impending threat for the whales. (3)

Scary as it sounds, this potential ecological hazard cannot be solely attributed to human activities. More surprisingly, it has also been suggested by Pazur that there are strong correlations between geomagnetic field and climate parameters. According to Pazur, reduction in magnetic field strength releases up to ten times more carbon dioxide from the surface of the ocean. (4)

Furthermore, rotational acceleration or deceleration due to waxing or waning ice sheets might trigger instabilities in the geodynamic and promote geomagnetic events of large magnitude, which further affects to CO_2 solubility and absorption rate. (4)

The magnetic field effect on gas solubility presents a physical link between geomagnetic field and climate. The small-scale laboratory experiments indicate lower solubility of CO_2 in seawater under reduced magnetic field intensity. The extra amount of CO_2 not dissolved due to reduced solubility would not only add to greenhouse effect but also acidify the water and endanger the living environment for whales and other marine creatures.

Although we may cast shadows on the credibility of some of the explanations offered, the result is solid and observable. From this, we can see that the damage brought about by greenhouse gases is endless and far beyond global warming. The possibilities of discovering and resolving the domino effects are endless.

References

1. J. M. Guinotte, V. J. Fabry, Ann. NY Acad. Sci. 1134, 320 (2008).

2. D. P. Manzello et al., Proc. Natl. Acad. Sci. 105, 10450 (2008).

3. K. C. Hester, E. T. Peltzer, W. J. Kirkwood, P. G. Brewer, Geophys. Res. Letters 35, L19601 (2008).

4. A. Pazir, M. Winklhofer, Geophys. Res. Letters 35, L16710 (2008).