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Rising Acidity in the Ocean: The *Other* CO2 Problem

Emissions are making the oceans more acidic, threatening sea life

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Climate change caused by rising levels of atmospheric carbon dioxide (CO2) is now widely recognized. But the other side of the equation—the massive absorption of CO2 by the ocean—has received far less attention. The planet’s seas quickly absorb 25 to 30 percent of humankind’s CO2emissions and about 85 percent in the long run, as water and air mix at the ocean’s surface. We have “disposed” of 530 billion tons of the gas in this way, and the rate worldwide is now one million tons per hour, faster than experienced on earth for tens of millions of years. We are acidifying the ocean and fundamentally changing its remarkably delicate geochemical balance. Scientists are only beginning to investigate the consequences, but comparable natural changes in our geologic history have caused several mass extinctions throughout the earth’s waters.

That careful balance has survived over time because of a near equilibrium among the acids emitted by volcanoes and the bases liberated by the weathering of rock. The pH of seawater has remained steady for millions of years. Before the industrial era began, the average pH at the ocean surface was about 8.2 (slightly basic; 7.0 is neutral). Today it is about 8.1.

Although the change may seem small, similar natural shifts have taken 5,000 to 10,000 years. We have done it in 50 to 80 years. Ocean life survived the long, gradual change, but the current speed of acidification is very worrisome. Emissions could reduce surface pH by another 0.4 unit in this century alone and by as much as 0.7 unit beyond 2100. We are hurtling toward an ocean different than the earth has known for more than 25 million years.

About 89 percent of the carbon dioxide dissolved in seawater takes the form of bicarbonate ion, about 10 percent as carbonate ion, and 1 percent as dissolved gas. Modern marine life has evolved to live in this chemistry. A wide variety of organisms use carbonate ion to manufacture their skeletons: snails, urchins, clams, crabs and lobsters. And notably, it forms the calcified plates of microscopic phytoplankton that are so abundant and crucial to the entire marine food chain. Meanwhile carbon dioxide levels influence the physiology of water-breathing organisms of all kinds, which for most creatures has been optimized to operate in a narrow range of dissolved CO2 and ocean pH.

We are now carrying out an extraordinary chemical experiment on a global scale. Our fossil-fuel emissions raise the dissolved CO2 levels in the ocean, which reduces carbonate ion concentrations and lowers pH. The ocean’s sunlit surface layer (the top 100 yards or so) could easily lose 50 percent of its carbonate ion by the end of this century unless we reduce emissions dramatically. Marine animals will find it harder to build skeletons, construct reefs, or simply to grow and breathe. Compared with past geologic events, the speed and scale of this conversion is astonishing.

We therefore have a dilemma. The ocean’s absorption of CO2 helps to keep atmospheric change in check. For decades, climate scientists described the uptake as a blessing for society, and ocean chemists hoped that calcium carbonate sediments on the seafloor would dissolve in sufficient quantities to offset a drop in pH. But research has shown that the rate at which sediments dissolve cannot possibly keep pace with the far faster rate of acidification. Society can continue to depend on the ocean for help, but the cost is a rising threat to all marine life.

Although our understanding remains murky, the fossil record shows that ocean life has suffered massive extinctions during periods of rapidly rising carbon dioxide levels. Marine animals’ metabolic functions are typically tuned to narrow, internal pH ranges. In addition to reducing the calcification of skeletons, more acidic water will acidify body fluids, likely raising respiratory stress and depressing metabolism.

Some organisms may tolerate a certain amount of change, but thinner shells will make others more vulnerable to damage or predators. Some organisms might also tolerate acidification of internal fluids to a point, yet even so many will expend more energy to maintain their optimal acid-base balance or will struggle to supply their body with oxygen and to sustain cellular functions vital to life. The extra expense of coping with acidification may make them more prone to dying. These stresses will be particularly severe for deep-sea animals, which have adapted to an extremely stable environment. And even if animals survive, the stresses will sap energy they would otherwise use for growth and reproduction.

We would probably see the effects of ocean acidification first in animal groups that have finely tuned environmental ranges, particularly those already “living on the edge” such as coral reefs, which have already suffered widespread bleaching and death from warming ocean temperatures. Less appreciated are effects on massive communities of tiny animals that live in the ocean’s mid-levels. These creatures migrate en-masse to the surface layer at night to feed yet sink to deep water during the daytime to avoid predators. In so doing, they form a critical link between the warm, oxygenated surface layer and the cold, oxygen-depleted waters of the deep, as well as a critical link in the ocean-wide food chain.

Increased acidity and expanding zones of low oxygen in some regions may force these mid-water organisms into shallower waters where they would be more exposed to predators. And if, as expected, the zones of low oxygen expand and intensify, many of these migrators could die. Together these effects could slice through this daily, migratory lifeline between shallow and deep waters—an outcome that could impact society’s ocean fisheries.

How well marine life can adapt to rapid acidification remains an open question, but there is real reason for concern. Ocean life has weathered large environmental perturbations during the earth’s history, just barely; some 250 million years ago massive volcanism is thought to have caused ocean acidification and other factors that left 90 percent of marine species dead.

Although man-made climate change will be much milder, strong and immediate action to stabilize CO2 levels is essential to minimize our disruption of ocean chemistry and ecosystems. We can no longer deny our role in global climate change. Now is the time for serious discussion among science, business and political leaders about ways to minimize our impact on our air and water, to set limits on the effects of our fossil-fuel use, and to plan how to adapt to coming change.

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