Defenders of Wildlife

Carbon Dioxide & Ocean Acidification

Ocean Acidification

The world's oceans play a tremendously important role in the global dynamics of the carbon dioxide (CO_2) that is released by the burning of fossil fuels, the clearing of forests, and industrial processes. Through biological and chemical processes, oceans take up nearly 22 million metric tons of CO_2 every day-- roughly a quarter of the carbon dioxide emitted every year, and without them, the atmospheric concentration would stand at roughly 442 parts per million (ppm), rather than the 387 ppm where it stands today. While these changes have helped to buffer the terrestrial world from the impacts of climate change, they are not without impact to the marine realm.

Photo: NOAA

Some of the CO_2 ends up being used by algae and other marine plants, just as CO_2 in the air is taken up by land plants as they photosynthesize. Much of this CO_2 is fairly rapidly recycled through the food chain, as these plants themselves, and the organisms that feed on them, utilize the stored energy and release the carbon dioxide. A portion of this carbon ends up in plants or animals that sink to the bottom of the ocean and get buried, sequestering the carbon for the long term, but this a relatively small fraction.

A large amount of CO_2 simply dissolves into the surface seawater. When CO_2 combines with water (H_2O), it forms a chemical called carbonic acid (written with the chemical formula H_2CO_3). The defining feature of an acid is that hydrogen (H^+) atoms can easily escape from it, in this case leaving behind bicarbonate (HCO_3^-) ion. The measure of hydrogen ions in a solution is called pH, which is measured on a scale of 1 to 14. Lower pH means more hydrogen ions, because the numbers in the scale refer to the number of places after the decimal point. This is exactly what is happening in our oceans. In fact, over the past 250 years, the pH of the ocean has decreased by 0.1 units. That may not sound like a lot, but because of how the pH scale works, it corresponds to a 30% increase in hydrogen ion concentration; hydrogen ion concentration is projected to continue to increase at a rate of 0.5% to 1.0% per year.

Many organisms in the ocean form external skeletons by secreting layer of calcium carbonate that hardens into a shell, best known to most in the form of seashells, pearls and chalk. Calcium carbonate—usually called calcite or aragonite depending on its structure-- readily dissolves when it comes into contact with a strong acid; in fact, limestone, type of rock made up predominantly of ancient pieces of shell or coral, will fizz when touched with a drop of vinegar or lemon juice. However, even weak acid concentrations can make it harder for organisms to produce their crystal skeletons, because the bicarbonate ion formed in the acid reaction is useless to these animals, and the more bicarbonate there is, the less carbonate is available.

Photo: NOAA

Marine Creatures Impacted by Acidification

Coral Reefs

Coral reefs only account for about one-tenth of one percent of the world's area, but harbor at least five percent of its known species. Australia's Great Barrier Reef, for instance, contains 350 species of hard corals and 1500 species of fish; huge numbers of sponges, anemones and other invertebrates also live in association with reefs. These remarkable systems depend on a symbiotic relationship between a tiny animal and an even tinier alga. The coral itself is a primitive animal related to jellyfish, consisting mostly of a stomach topped with tentacles they use to sting and eat plankton. In addition, each coral polyp can ingest tiny photosynthetic algae called zooxanthellae and harbor them in its stomach cavity without digesting them. In this symbiotic relationship, the coral provides the algae with carbon dioxide, the essential building block of photosynthesis, important nutrients like nitrogen and phosphorus, as well as a protected place to live and reproduce. In turn, the photosynthetic action of the zooxanthellae provides the coral with up to 90% of its energetic requirements, as well as oxygen, a by-product of photosynthesis.

Protecting each coral is an external skeleton of calcium carbonate, which is secreted by each individual coral polyp. Over long time frames, the action of thousands of identical polyps living colonially together, builds the structure of the reef, around which vast numbers of organisms feed, shelter or live. Because their skeletons are made from calcium carbonate, the corals cannot form if too much of the carbonate in the ocean gets converted to bicarbonate by the action of hydrogen ions. It is estimated that at current rates, corals will no longer be able to lay down skeletons by 2150.

Plankton

Plankton form the basis of the food chain, and calcium carbonate-forming plankton are a large and important group of plankton found worldwide. Many of these have been found to slow down their rate of growth, and to show increases in deformities of their calcium carbonate plates, in the presence of higher levels of dissolved CO_2. The loss of carbonate plankton could have tremendous repercussions up the food chain, as well as possibly hindering the ocean's role in the biological uptake of atmospheric CO_2.

Photo: NOAA

Shellfish

Common shellfish species, like clams, mussels and oysters, as well as other creatures like sea urchins and starfish, share an important feature: they all form exoskeletons from calcium carbonate. These creatures too will face increasing difficulty forming their shells as the ocean becomes more acidic. In addition to their hugely important economic value, these species are also a vital food source for wildlife ranging from sea otters to walruses.

References

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