Ocean Acidification: A Fundamental Problem for the Future of Recreational Diving

By: Adrienne Sutton, PhD, NAUI 42005

The oceans, like our lungs, exchange gases with the air around them. It's as if the oceans also breathe. Rainforests usually get the credit, but the oceans actually provide most of the oxygen that makes life on earth possible. As a diver, you've likely had the pleasure of being surrounded by a sea of tiny specks of light during a night dive safety stop—these are the ocean plants that provide us with that critical molecule, oxygen. Divers are intimately connected with the undersea world, but every human being is directly connected to the oceans via the air we all breathe.

Just as our lives depend on that air-sea connection, the health of the ocean also depends on that connection. Over the past two and a half centuries, the oceans have absorbed at least a quarter of the carbon dioxide humans have emitted through fossil fuel burning and deforestation. Initially, many scientists thought this was a good thing: a service provided by the sea with little consequence. But like we've learned with sewage sludge, the oceans are not a limitless buffer of human waste.

In a series of well-understood chemical reactions, carbon dioxide reacts with seawater resulting in a reduction of pH. This chemical response to carbon dioxide emissions is called "ocean acidification" and is measured and predicted with a high degree of certainty and scientific accuracy. At the beginning of the industrial revolution, the average pH of the ocean was about 8.2, but today the average is closer to 8.1. This may not seem like much – but the pH scale, like the Richter scale, is logarithmic so this change represents about a 30 percent increase in acidity.

Additional carbon dioxide in seawater also decreases the availability of dissolved calcium and carbonate, the chemical building blocks for the skeletons and shells of many marine organisms including coral reefs. In areas where most life now congregates in the oceans, the seawater is *supersaturated* with respect to calcium carbonate minerals. This means there are abundant building blocks for the organisms to build their skeletons and shells. However, continued ocean acidification is causing many parts of the ocean to become *undersaturated* with these minerals, making it harder for them to grow. And in some areas of the ocean, their mineral structures may begin to dissolve.

Not all organisms will lose as the ocean absorbs more carbon dioxide. For example, photosynthetic algae and seagrasses may benefit from higher carbon dioxide conditions in the ocean, as they require carbon dioxide to live just like plants on land. Yet we still have ample reason to be concerned for the losers. Marine organisms that form calcium carbonate shells and skeletons are not only ecologically important, but they are economically important, too. Consider the pteropods: tiny planktonic snails that account for approximately half of the diet of many first-year North Pacific pink salmon while living in the ocean. Consider shellfish, such as clams and oysters, popular among seafood lovers that in turn support a robust aquaculture industry. And consider the free-floating plants and animals at the bottom of the food chain (including those tiny bioluminescent creatures you observe during your night dives) that support the most productive and biologically-diverse regions of the ocean.

Ocean acidification is an emerging global problem. While the basic theory behind ocean acidification has existed for decades, there was not enough field data gathered until the late 1990s to prove these changes were actually happening. Over the last decade, there has been much focus in the ocean science community on studying the potential impacts of ocean acidification. I will focus the remainder of this article on one of the ecosystems that scientists believe will be the most vulnerable to ocean acidification, and one that brings joy and awe to divers all over the world: coral reefs.

Tropical coastlines are blessed with prodigious coral reefs. These reefs exist because the tiny sea anemone-like creatures that build reef structures are able to produce calcium carbonate minerals faster than is lost through other biological and physical processes. Over millions of years, countless generations of these coral polyps have built carbonate skeletons on top of the carbonate skeletons of their ancestors to form the massive reefs of today. Scientists estimate that building this carbonate skeleton expends up to 30 percent of a coral polyp's energy. The remainder is used for other physiological demands such as foraging for food, cell maintenance, and reproduction.

So how does acidification affect coral polyps and the reef structures they build? Most experimental studies to date have demonstrated that coral calcification—the building of those skeletons—is highly sensitive to the decrease in concentration of carbonate associated with ocean acidification. It is estimated that coral calcification will decrease 10 to 50 percent by 2050 compared to rates prior to the industrial revolution (Kleypas and Yates, 2009). A study on 69 coral colonies in the Great Barrier Reef has shown that coral calcification has already decreased 14 percent between 1990 and 2005, likely due to a combination of increased ocean temperature and ocean acidification (De'ath et al., 2009). Not only could the skeleton building of some corals decline, but the reef structure could actually begin to dissolve.

A shore reef, Bonaire. Credit: John Meyer.

Goose barnacles and blue mussels. Credit: John Meyer.

Mussels, barnacles, anemones, and urchins that cover the Oregon coast. Credit: John Meyer.

Since we understand how ocean chemistry changes as carbon dioxide increases and since we are beginning to understand the impacts on coral reefs, we can now project how corals may be affected in the future. When atmospheric carbon dioxide concentrations double (560 parts per million [ppm]) relative to pre-industrial levels (280 ppm), all tropical reef-building coral may be in a state of dissolution (Silverman et al., 2009). The current concentration of carbon dioxide in the atmosphere is 390 ppm and, if we continue our current trajectory of emissions, is projected to reach 560 ppm by 2050.

There is no precedent in Earth's history for the type of disruption we might expect from the current rate of carbon dioxide release. There have been periods in Earth's history in which carbon dioxide concentrations have been higher and pH in the ocean has been lower than today's levels, but it is the current *rate of change* that is so geologically unusual. Historical changes occurred over millions of years, giving many organisms a chance to adapt. In periods when coral reefs were unable to adapt, leading to a disappearance of large reef structures and their associated ecosystems, it likely took them millions of years to emerge again. We have whittled down a several million year timeframe of change into just hundreds of years. Little is known about which marine species will successfully adapt to this rapid change, but recent evidence suggests that coral reefs may not fare well.

Losing corals has a ripple effect. The three dimensional structures reefs provide are home to an estimated one million types of organisms, 25 percent of the world's species. Such diversity provides seafood for human consumption, especially important for the livelihood of small island nations that have limited alternatives to subsistence fishing. The large structures of coral reefs also provide our coastal communities the valuable service of shoreline protection from hurricanes and tsunamis. As divers, we know that coral reefs attract vacationers from all over the world, which subsequently supports an extensive recreation and tourism industry. The rich beauty of coral reefs has immense aesthetic value, and although this is difficult to explain in ecological or economic terms, we know it is critical to many coastal and island cultures and is certainly critical to "scuba culture."

Ocean acidification is not the only threat to coral reefs and the services they provide: overfishing and destructive fishing practices, warming ocean water, coral diseases, and coastal pollution also affect the productivity and survival of these systems. Coral reefs are already struggling to survive in many areas. For those of you that dive in the Caribbean, you've seen firsthand the decline of many reefs in that region over the last few decades. The combined effects of coral bleaching and ocean acidification may push struggling corals in other parts of the ocean past a similar tipping point. Ocean acidification is an added stress that will be felt by every reef on the planet, even the remote reefs that have escaped other human impacts thus far.

Since the advent of scuba, coral reefs have been a Mecca for divers. How will the continued decline of coral reef health impact the recreational diving community? Great dive spots will always exist in other underwater ecosystems that are more resilient to the impacts of human activities, but the opportunity to experience colorful and diverse tropical coral reefs up close and in person may be at risk. The prospect of having this experience is often the motivation behind getting scuba certified and/or snorkeling on vacation. If our current understanding of the impact of ocean acidification on coral reefs is correct, the future of recreational diving and the industries that depend on the sport (training organizations, dive retailers, equipment manufacturers, and dive resorts) could also be in jeopardy.

There are solutions to the problem of ocean acidification, but because this global-scale problem is a consequence of increasing carbon dioxide, reducing fossil fuel emissions and transitioning to sustainable sources of energy are essential components of any solution. Locally, managing other stressors, such as coastal pollution and destructive fishing practices may make ecosystems more resilient to the global pressures of warming ocean waters and acidification.

What can you do? As a diver, you are a steward of the ocean. Learn more about our current understanding of ocean acidification and educate your family, friends, and neighbors. As a diving instructor, you have the ability to impact the lives of many future ocean stewards. Incorporate a description of ocean acidification into your classroom discussions on the marine environment.

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Living on the Edge of Extinction

By LeRoy French, NAUI A50

When you hear about a species becoming extinct, this means it is gone forever. It does not exist in our ecosystem any longer. This is an extremely sad and serious situation for mankind. We have all read in the news media and seen on television many stories regarding the polar bears' problem. My story is to explain in common terminology their ongoing struggle.

This is the largest carnivore on land, measuring up to 10 feet and weighing around 1700 pounds. This enormous animal is losing the battle with climate change.

There are many ongoing research projects worldwide that are trying to help the polar bear fight this battle. Scientists have many theories on what to do, but the basic problem is the melting of ice caps due to global warming.

Temperatures in the Canadian Arctic have risen over 7° Fahrenheit (4° Celsius) in the past 50 years. The Arctic Circle temperatures have increased at twice the rate of the rest of the world's climate. The Arctic ice is melting and this is bad news for the polar bears.

With sea ice melting at a record pace, polar bears face an inability to access prey. The distances between sea ice and land has increased to the point that the polar bear can no longer swim between the two, and as a result in some instances they drown in the attempt. Polar Bears are not supposed to drown! This animal is capable of swimming over 100 miles at a time and mainly hunts on land. Its main diet is seals, and it hunts the seals on land. It cannot hunt in the water as the seal will out-swim the bear. This means that with the increase in distances, the bear is forced to stay on land for extended periods and cannot travel from ice cap to ice cap, meaning it cannot hunt and without food their bodies start to shrink. As a result this makes them slower and not as able to catch their prey. The polar bears habitat is about as cold as it gets, with temperatures dropping to minus 49° Fahrenheit (-45° Celsius), however this amazing animal has evolved to thrive in these conditions.

A polar Bear on flat ice flow. Photo courtesy of: dailygreen.org.

The polar bears need all the help they can get. After all, planet Earth has been their home for quite a few years.

Now along with the polar bears plight there exists another one, and that is the arctic seal. What's happening here is that it is estimated that 1,500 newborn seals in the Arctic Circle are unlikely to survive their first few months. When born the seal cub will remain burrowed in the ice for about a month until their bodies develop layers of fat and fur so that they can survive in the frigid waters. So with the ice melting too quickly, the cubs find themselves in the water before they are ready. The arctic seal population in the last century has gone from 180,000 to 8,500. This is a very disturbing statistic!

It has been noted that by mid-century it is likely that polar bears will be eliminated

Close up of a polar bear on an elevated ice cap. Photo courtesy of: thelmagazine.com

from the southern end of the polar basin, where sea ice is moving further from land. This area is home to about two thirds of the polar bear population. Various studies indicate this population could disappear by 2050 if global warming continues.

So having said all this, what is the solution? Note: Humans were responsible for the extinction of the Caribbean Monk Seal. Do we want to be responsible for another species becoming extinct? Scientists believe that the "sea bear" evolved about 200,000 years ago from brown bears. 200,000 years of evolution....WOW! To lose that would be unthinkable.

This is something we can correct. Studies seem to indicate that ice melting is "very likely" caused by human emissions of greenhouse gases. Global warming is our problem; don't make it the polar bears demise. There is so much written nowadays about global warming and how we can each help, that its not necessary for me to go into detail. Go online and access some of the material written on global warming. Most of these articles offer many ways that the normal person can get involved.

The polar bears need all the help they can get. After all, planet Earth has been their home for quite a few years.

I just learned today that thousands of Harp seals will die this year due to ice melting. Kind of a sad situation.

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As a concerned citizen, you can support political and business leaders to expand the use of clean and renewable energy sources. Recreational divers are passionate about the ocean, and sharing that passion with your neighbors, students, and elected officials can help to gain support to preserve a healthy ocean for the generations of divers to come.

For more information on ocean acidification:

- www.pmel.noaa.gov/co2/OA
- www.tos.org/oceanography/issues/issue_archive/22_4.html
- www.whoi.edu/OCB-OA
- www.epoca-project.eu
- www.nrdc.org/oceans/acidification/aboutthefilm.asp (Acid Test documentary)
- www.aseachange.net

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Silverman, J., B. Lazar, L. Cao, K. Caldeira, and J. Erez. 2009. Coral reefs may start dissolving when atmospheric CO2 doubles. *Geophysical Research Letters* 36, L05606, doi:10.1029/2008GL036282.