Coral Reefs, Climate Change and Ocean Acidification

Faced with global environmental change and its effect on coral reefs, what can the average aquarium hobbyist do, if anything?

By Britt-Anne A. Parker and C. Mark Eakin, NOAA Coral Reef Watch. Photos by C. Mark Eakin.

Coral reefs are some of the most colorful, biologically diverse ecosystems on Earth. We treasure them for their beauty and even try to capture a bit of their grandeur in home aquaria. Reefs feed the imagination of young and old alike, from Disney's Finding Nemo to dream-dive-destination vacations. So, these transfixing environments should also inspire us to change some of our habits that are causing them serious harm.

Coral reefs not only serve as home to multitudes of fish, coral and invertebrate species. Perhaps more importantly, they serve as the livelihood for millions of people worldwide. Reefs are vitally important as sources of food, cultural heritage, tourism income, protection from storms and pharmaceuticals. The health of coral reefs has been in serious decline the last few decades due to poor water quality, increasing disease, overfishing and coastal development. Even as aquarists have sought to bring the beauty of coral reefs into their homes, some unscrupulous fish and coral collectors have damaged reefs. Now, warming seas are stressing corals, causing more frequent and larger bleaching events, while ocean acidification has slowed the growth of corals. The ever-growing impact of climate change has the potential to deal a devastating blow to those reefs that remain. The future of our reefs is not lost, but to protect the reefs, immediate action is required to reduce the negative impacts of both climate change and local threats.

2008 has been designated as the International Year of the Reef (IYOR) by the International Coral Reef Initiative, in an effort to raise awareness of the value and importance of coral reefs worldwide, as well as to motivate people to take action to protect reefs from threats to their sustainability. We will discuss the affects of climate change and ocean acidification on corals and what actions we all might take to protect reefs worldwide.

Climate Change and Ocean Acidification
In 2007 coral reef scientists from around the world, led by Ove Hoegh-Guldberg, published a paper entitled "Coral Reefs Under Rapid Climate Change and Ocean Acidification." The paper appeared in the journal Science and summarized our current knowledge about coral reefs and climate change. As humans burn fossil fuels, such as coal, gasoline and natural gas, carbon dioxide (CO_2) is released into the atmosphere.

Before the Industrial Revolution, natural levels of CO_2 in the atmosphere were around 280 parts per million (ppm). Today we are seeing levels that are about 30 percent higher — around 380 ppm — and those levels are increasing faster and faster. We now know that this increase in CO_2 has contributed to the warming we have seen in the oceans and in air temperatures worldwide. During the 20th century, this has corresponded to an average increase in ocean temperature of 1.4 degrees Fahrenheit, though this increase is not felt equally around the world. The northern latitudes are warming faster than other areas, which is contributing to ice melt around the Arctic and Greenland.

But there is another effect of adding CO_2 to the atmosphere that you may not have heard much about. Roughly one-third of the CO_2 added to the atmosphere each year is absorbed by the ocean, where it reacts with seawater to form carbonic acid. This process is changing the chemistry of the ocean, making the waters more acidic. The average pH of the global ocean has already dropped from around 8.2 to 8.1; this process is commonly referred to as ocean acidification.

How are these changes different from past climate fluctuations? Scientists can determine the past composition of the atmosphere by analyzing the gases trapped in bubbles in ancient Antarctic ice. As a result of burning fossil fuels, CO_2 levels are higher, oceans are warmer and pH is lower than at any time in at least 800,000 years and probably over 20 million years. Even more troubling is that all three are changing at a much faster rate than they have in the past. The Earth's climate has varied in the past, but the changes we are seeing today are so fast that natural systems, including coral reefs, are unable to adapt quickly enough to keep up!

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Fish are by no means immune to the impacts of rising temperatures and ocean acidification. This pink skunk clownfish hiding in its anemone at Eddie Reef, Australia, may feel safe, but anemones are subject to bleaching at high temperatures too.
A mix of hard and soft corals creates the beautiful structure at Eddie Reef, Australia. Rising temperatures and acidification

in our oceans threatens coral reefs and their diversity.Warming Ocean Temperatures and Coral Bleaching
Corals are animals that live in a mutualistic symbiotic relationship with single-celled plants, algae known as zooxanthellae. A mutualistic relationship is one in which both partners benefit. In this case, the coral provides a safe, protected place for the zooxanthellae to live. In turn, through photosynthesis, the zooxanthellae use solar energy to convert carbon dioxide and water into oxygen and carbohydrates. The corals then use these carbohydrates as their major food source. The algae also give the corals their characteristicly brilliant colors.

As with all organisms, both corals and zooxanthellae have optimal temperature ranges in which their systems function efficiently. But high temperatures stress both corals and zooxanthellae, much like our bodies can become stressed on hot, humid days.

Zooxanthellae become more sensitive to the bright tropical sunlight, which causes their photosynthetic process to break down. When this happens, they become toxic to the corals. To protect themselves, the corals expel the zooxanthellae. This process is called “coral bleaching” because the corals turn a pale white color when the zooxanthellae are gone.

Temperatures of only 1.8 to 3.6 degrees Fahrenheit above the hottest summertime temperatures that corals normally see can cause them to bleach. If bleaching continues for a month or more, the corals can starve and die. Even if the corals do survive, this stress increases their susceptibility to disease and reduces their ability to reproduce normally for years.

Large-scale bleaching events on coral reefs have become more common with just a 1.4 degree increase in average ocean temperature. Future temperature increases of 1.8 degrees are almost certainly coming within this century, and the temperatures may rise by as much as 7.2 degrees on average, which means coral bleaching events will likely increase in their frequency and severity. This will leave corals with less time to recover between bleaching episodes, and it will make them more susceptible to other stressors in their environment.

Ocean Acidification and Coral Growth
In addition to the stress of warming ocean temperatures, oceans are becoming more acidic, thus slowing coral growth and hindering the ability of corals to build their skeletons.

As the ocean takes up CO2 from the atmosphere, water becomes more acidic and the concentration of carbonate ions in the water decreases. Corals require these carbonate ions to form their calcium carbonate skeletons. As ocean acidification continues, some coral reefs may no longer be able to grow fast enough to keep up with the natural forces that break them down.

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Often referred to as "underwater rain forests," coral reef ecosystems like this one in Australia sustain a myriad of marine life forms. As coral reefs disappear so do many of the species that depend on them.There is evidence from the Great Barrier Reef in Australia that coral growth rates have already decreased by 15 percent in the last 15 years. The skeletons that the corals are currently building also may be weaker, making them more vulnerable to erosion, storm damage and predators. There is still a great deal to be learned about ocean acidification.

We used to think that the ocean could take up CO2 with little or no consequence. We believed it would be nearly impossible to change ocean pH — but it is apparent that we were wrong. Even though this process is not as well understood as warming waters and coral bleaching, it is important that we begin talking about the impact that ocean acidification can have on corals, as well as other calcium-building organisms such as foraminiferans and cocolithophores, which are at the base of the ocean food webs, and shellfish such as mussels and clams that we enjoy eating.

Threats Beyond Climate Change
Warming ocean waters and acidification are not the only threat to coral reefs. Localized stresses — poor water quality, overfishing, harmful fishing practices, recreational overuse, deforestation and nutrient runoff — also threaten reef health. The combination of these factors makes it tough for reefs to remain healthy.

If we continue along our current path, the future outlook for coral reefs is bleak. But there is good news! The future of coral reefs is up to us. And the actions we take during the next 10 years will be critical.

When natural systems are out of balance, as they are now, recovery takes time. More warming and acidification will happen before the Earth’s system comes back into balance, even if we stop adding CO2 to the atmosphere today. In fact, a 1.8 degree Fahrenheit rise in temperature is expected by the end of the century just from the CO2 we have already added to the atmosphere. That is more warming then we have already seen this century, so protecting the reefs is very

important.

Hundreds of millions of people around the world depend on healthy coral reefs for food, and the socioeconomic impacts of reef declines are huge. As reef habitat is lost, there will be less fish and other food species. Climate impacts will make reefs less attractive to tourists and to divers in particular, thereby taking away valuable tourism-based income from small communities that depend on it.

Degraded reefs offer less protection from waves and storms, and this issue will become more important if sea levels continue to rise and storms become stronger. Without the protection of reefs, waves and storms will cause beaches to erode faster. This will cause an additional headache for the tourism industry, as well as for turtles and sea birds that rely on beach habitat for survival.

The Future
Scientists, managers and conservationists continue to struggle to lessen the influence of climate change.

They are working to protect large predatory fish and herbivores (algae eaters of the reef community). By protecting fish that do many different jobs on the reefs, they hope that the reef system will be healthier and more resilient. They are working hard on new methods to “farm” corals that may make large-scale reef restoration a possibility.

Controlling some of the local stresses to reefs is also very important. Divers need to be conscientious to not touch or damage reefs, and fishing regulations can help to prevent overfishing. Better standards for waste water treatment, fertilizer use and application and industrial waste can improve water quality.

Here is the crux of the matter: we need to reduce the amount of CO2 going into the atmosphere.

You Can Make a Difference
Climate change can seem like an overwhelming issue — too big for individuals to have an impact on — but this is not true! Actions you take every day impact the total amount of carbon going into the atmosphere. Taking small steps to reduce your carbon footprint like switching to compact fluorescent light bulbs, using energy-efficient appliances and vehicles, unplugging electrical devices that are not in use, carpooling and eating locally produced foods do matter. If you have one or more saltwater aquariums in your home, make sure that the fish and corals you purchase are raised or harvested in a sustainable manner.

The International Year of the Reef is a great time to think about how we as individuals impact the environment and what we can do to bring about change. Even if you do not live near an ocean there are things that you can do to help protect coral reefs.

The website of the National Oceanic and Atmospheric Administration’s Coral Reef Conservation Program lists 20 things people can do to help (www.coralreef.noaa.gov/outreach/thingsyoucando.html). The IYOR website lists activities directly associated with IYOR that you can participate in (www.iyor.org/get_involved/whatyoucando.asp). The most important thing is to continue these activities and to educate one’s self even after the IYOR draws to an end. Re-member, every action counts!

The manuscript contents are solely the opinions of the authors and do not constitute a statement of policy, decision or position on behalf of NOAA or the United States government.

C. Mark Eakin, Ph.D., has spent more than 20 years working on the impacts of climate change on coral reefs and directs the National Oceanic and Atmospheric Administration Coral Reef Watch Program, which uses satellite data to provide current reef environmental conditions to quickly identify areas at risk for bleaching.

Britt Parker, M.S., coordinates communication and outreach for the National Oceanic and Atmospheric Administration Coral Reef Watch Program.