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Imagine standing on a boat in the Gulf of Mexico and looking down at the water. Instead of seeing blue as expected, it is oddly red (Figure 1). What could cause this? It may be a harmful algal bloom.

Figure 1. *Karenia brevis* bloom off Florida

Microalgae (also referred to as phytoplankton) are small, single celled organisms that grow in freshwater and oceans. When they grow rapidly, they can reach large numbers resulting in an algal bloom. Harmful algal blooms (HABs) are sometimes called red tides, but not all HABs discolor the water or turn it red. Sometimes, HABs are green, brown, or golden, depending on the algal species causing the bloom.

Harmful algae cause injury by producing toxins or disrupting aquatic food webs. HABs are not new, but they are getting more attention because of the increasing number of coastal residents. HABs are also being investigated by an increasing number of researchers from many fields. In the past, HABs were of concern primarily to taxonomists and shellfish growers; however, HABs are now studied by ecologists, oceanographers, molecular biologists, and remote sensing specialists, to name a few of the new disciplines that are now contributing to this field of study. Their efforts are being combined to try to predict and mitigate the effects of HABs.

From this increased attention, a number of new tools and techniques are being developed to detect HAB species and their toxins at low concentrations. Currently, scientists are developing monitoring techniques and models that emphasize remote sensing from buoys, autonomous underwater vehicles (unmanned free-moving craft; Figure 2), and satellites. Other new technologies, like molecular probes, are borrowed from medical science. These techniques help provide species identification when the HAB cells might be confused with other non-toxic cells. New toxin detection and quantification methods are also being developed to help provide early warning of harmful conditions in the oceans.

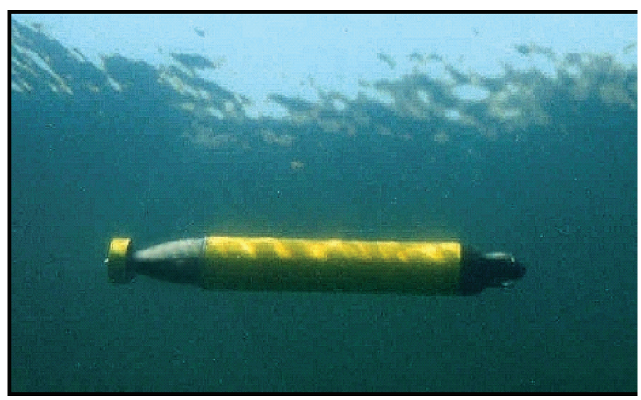

Figure 2. Autonomous underwater vehicles (AUVs) are used to monitor HABs.

There is a consensus in the field that HABs are happening more frequently and in places where they were not known to occur 10 or 20 years ago. Note that nearly every coastal area has reported HABs (Figure 3).

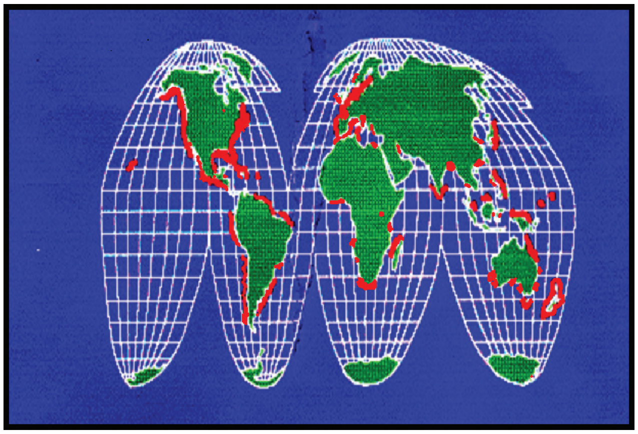

Figure 3. Reports of harmful algal blooms worldwide (in red).

Why Should We Care About HABs?

Effects of HABs include:

- Threat to human health
- Regional economic impacts
- Mass mortality of fish
- Loss of environmental quality
- Marine mammal deaths
- Effects on non-commercial species
- Water quality degradation

What is known about HABs and the toxins they produce?

HAB toxin production is a very active area of research because it affects human health, economics, and marine resources. The most significant public health problems caused by harmful algae are poisoning as a result of eating contaminated fish or shellfish. Here are a few examples of the types of poisoning that can occur from HAB toxin production.

Amnesic Shellfish Poisoning (ASP)

ASP was first recognized in 1987 on Prince Edward Island, Canada after locals consumed blue mussels. There were over 100 acute cases and 4 deaths. One of the organisms causing ASP is *Nitzschia pungens* f. multiseries, which produces the neurotoxin, domoic acid (Figure 4). A severe case of ASP includes symptoms of gastroenteritis, dizziness, headache, seizures, disorientation, short-term memory loss, and respiratory difficulty.

Figure 4. *Nitzschia pungens* f. *multiseries*, cell width ~3 μm (image by Rita Horner)

Ciguatera Fish Poisoning (CFP)

CFP was first recognized in the 1550s in the Caribbean, however, the causative organism was not identified until more recently. CFP has a pantropical distribution and is known from the Caribbean basin, Florida, the Hawaiian Islands, French Polynesia, and Australia. Higher trophic-level carnivores, such as fish, accumulate high levels of the toxin by feeding on herbivorous fish. The herbivorous fish feed on macroalgae, which serve as substrate for an assemblage of benthic dinoflagellates including *Gambierdiscus toxicus,* which is responsible for ciguatoxin production (Figure 5). These fish may be toxic for up to two years after becoming contaminated. In extreme cases, death from respiratory paralysis may occur. There is no antidote for CFP, which is now considered a major health and economic problem in many tropical islands, for locals and for uninformed tourists.

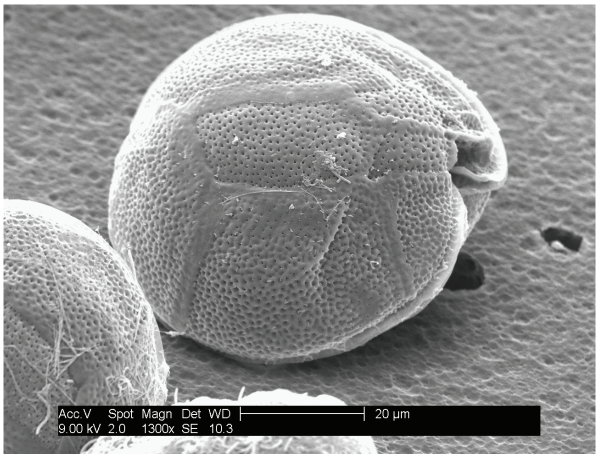

Figure 5. *Gamberdiscus* sp. (image by Maria Faust)

Neurotoxic Shellfish Poisoning (NSP)

NSP is similar to CFP in that it also produces gastrointestinal and neurological symptoms. The dinoflagellate *Karenia brevis* is responsible for NSP (Figure 6). Blooms of *K. brevis* are marked by large patches of discolored water and massive fish kills. *Karenia brevis* is an unarmored dinoflagellate and can be ruptured easily by wave action, causing its toxins to become aerosolized and produce asthma-like symptoms. *K. brevis* blooms were first recognized in the 1880s. *K. brevis* blooms are known through much of the Gulf of Mexico and are most common off the western Florida continental shelf; however, in the fall and winter of 1987–88, there was a large *K. brevis* bloom in the coastal waters of North Carolina. The local economy lost $24 million dollars when many shellfish harvesting areas were closed for the entire season, during which 48 cases of NSP were reported.

Figure 6. *Karenia brevis*, size ~20 µm

Diarrhetic Shellfish Poisoning (DSP)

DSP was first reported in Japan in 1976. The causative organisms are several species of the dinoflagellate, *Dinophysis,* which produces okadaic acid (Figure 7). DSP produces symptoms such as nausea and diarrhea, which are often mistaken for a bacterial infection. DSP is not fatal and recovery is generally within three days, even without medical treatment. DSP has been reported in Spain, Chile, Thailand, Japan, and New Zealand. DSP has also been reported in northeast U.S. waters. Some consider DSP to be the most serious and globally widespread phycotoxin-caused seafood illness.

Figure 7. *Dinophysis* sp., size ~50 µm (image by Rita Horner)

Paralytic Shellfish Poisoning (PSP)

PSP was recognized by Native Americans before the arrival of European explorers. PSP is caused by saxitoxin, which was first characterized in 1957 and is recognized in 21 different forms. These saxitoxins contaminate fish and shellfish. Food chain concentrations of saxitoxin in mackerel have resulted in marine mammal deaths. Saxitoxins act on the peripheral nervous system and the central nervous system by inhibiting nerve transmission to muscles. If contamination is severe enough, death may occur through respiratory failure. Other symptoms include gastrointestinal distress, tingling, numbness, and ataxia. These are symptoms common to most other algal toxin-related illness. Organisms containing saxitoxins include *Alexandrium catenella* and *Alexandrium tamarense* (Figure 8).

Figure 8. *Alexandrium* sp., size ~25 μm (Image by Rita Horner)

Cyanobacteria

Just as there are many saltwater species that cause HABs, there are freshwater species called cyanobacteria (blue-green) algae that cause similar problems. These can be recognized as green pond scum or algal mats. Common species are *Microcystis* and *Oscillatoria* (Figure 9). These freshwater HAB-causing organisms have the following characteristics:

- Worldwide distribution in fresh water,
- Respond to nutrient enrichment with rapid growth,
- Cyanotoxins bioaccumulate in the food chain, and
- Produce neurotoxins and cause acute liver toxicity and gastrointestinal effects.

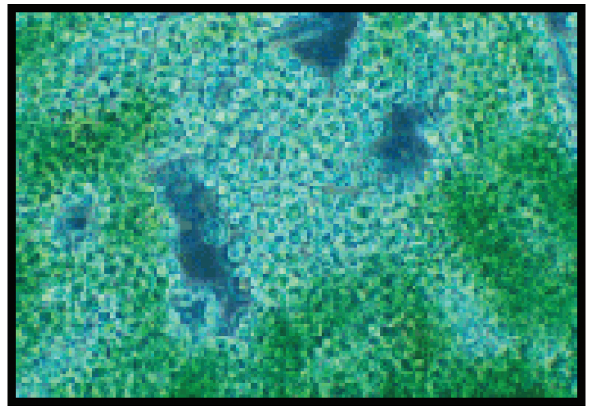

Figure 9. *Microcystis* sp., size ~2–3 μm (image by Hans Pearl)

Many questions are still unanswered regarding harmful algal blooms and the species that cause them; however, there are several actions that can be taken to reduce the effects of HABs. These actions include increased monitoring of environmental conditions, improving methods used to accurately identify the algal species that cause blooms, and ensuring safety of seafood by developing cost-effective methods for determining toxins in seafood.

Additional Reading

D.M. Anderson, "Red tides," *Scientific American,* vol. 271, pp. 62–68, 1994.

I. Amato, "Plankton planet," *Discover,* vol. 25, 2004.

W.W. Charmichael, "The toxins of Cyanobacteria," *Scientific American,* vol. 270, pp. 78–86, 1994.

Glossary

Aerosolized—in the form of ultramicroscopic solid or liquid particles dispersed or suspended in air or gas.

Ataxia—loss of the ability to coordinate muscular movement.

Autonomous underwater vehicles (AUV)—unmanned free-moving craft.

Bioaccumulate—the increase in concentration of a substance in an organism over time.

Dinoflagellates—any of numerous minute, chiefly marine protozoans of the order Dinoflagellata, characteristically having two flagella and a cellulose covering of theca.

Gastroenteritis—an irritation and inflammation of the digestive tract.

Microalgae—small, single celled plants that grow in freshwater and oceans

Pantropical—found and/or distributed in tropical regions around the world.

Phycotoxin—toxin produced by algae.

Trophic—pertaining to nutrition or to a position in a food web, food chain, or food pyramid.

Web Sites

www.noaa.gov

The National Oceanic and Atmospheric Administration homepage—This site provides access to a wealth of ocean-related data, from nautical maps to current ocean conditions.

http://www.whoi.edu/redtide/

The Harmful Algae Page—An overview of HABs, a description of HAB species, a discussion of possible effects, distribution maps of HABs, and current news are all provided on this Web site.

http://www.csc.noaa.gov/crs/habf/

NOAA's Harmful Algal Bloom Forecasting System Web Site—For the Gulf of Mexico, this Web site warns of possible HABs that are developing. The service was set up specifically to warn of potential *Karenia brevis* blooms and to help mitigate their impact

Pat Tester received her B.S. at California State University—Sonoma, and both her M.S. and Ph.D. degrees at the Oregon State University School of Oceanography. Her work has focused on harmful algal blooms and their effect on the food web. She even had the opportunity to brief the Senate and House staff on harmful algal blooms and their potential impacts. In addition to science, she also enjoys hand spinning, weaving, and swimming.