HARMFUL ALGAL BLOOMS LESSON PLAN

Bad Algae!

Theme

Human Health Hazards

Links to Overview Essays and Resources Needed for Student Research

http://oceanservice.noaa.gov/topics/coasts/hab
http://www.hab.nos.noaa.gov/
http://www.habhrca.noaa.gov/habfacts.html

Subject Area

Life Science

Grade Level

9-12

Focus Question

What are harmful algal blooms, and what can be done about them?

Learning Objectives

- Students will be able to define and describe harmful algal blooms.

- Students will be able to compare and contrast ways in which algal blooms may be harmful.

- Students will be able to describe actions that can be taken to reduce the impact of harmful algal blooms.

Materials Needed

- (optional) computers with internet access; if students do not have access to the internet, direct them to local library resources and/or print Harmful Algal Bloom information from *http://www.habhrca.noaa.gov/habfacts.html* and provide copies of these materials to each student or student group.

Audio/Visual Materials Needed

None

Teaching Time

One or two 45-minute class periods

Seating Arrangement

Groups of 3-4 students

Maximum Number of Students

32

Key Words

Harmful algal blooms
Paralytic shellfish poisoning
Ciguatera
Pfiesteria
Red tide
Brown tide
Amnesic shellfish poisoning
Diarrhetic shellfish poisoning
Neurotoxic shellfish poisoning
Harmful cyanobacterial blooms

Background Information

Algae are critical to life on Earth. Because they are able to convert solar energy into chemical energy through photosynthesis, algae are key primary producers in many marine food webs (that is, they provide the primary energy source for many other marine organisms). Oxygen is another product of photosynthesis, and single-cell algae (phytoplankton) living in the ocean are responsible for half of the oxygen produced on Earth. There are thousands of species of beneficial algae; but there are also a few dozen species that cause problems. These species become noticeable during periodic events known as "harmful algal blooms" (HABs). In the last two decades, HABs are estimated to have caused as much as $1 billion in losses to coastal resources and communities.

The specific events that accompany HABs vary depending upon the species of algae involved. In some cases, algae grow at unusually rapid rates and overgrow other species, alter habitats, or deplete oxygen (even though the algae produce oxygen while they are alive, large amounts of decaying algae can consume enough oxygen to cause a net depletion). Rapid growth of phytoplankton may produce enough cells to discolor the water. When discoloration occurs, the event is often called a "red tide," even though the actual discoloration may be green, yellow, or brown, as well as red; and the event has nothing to do with tides. Some algae are capable of producing powerful toxins that are harmful or deadly to other species. Observed impacts of HABs may include fish kills, injuries to marine invertebrates, and human illness or death.

The causes of HABs are not fully understood. In some cases, environmental changes such as alteration in water flow or water temperature have been observed to coincide with HABs. To live and grow, all plants need certain chemicals known as nutrients. Nitrates and phosphates are familiar examples. In many aquatic ecosystems, nutrients are scarce and this limits plant growth. When additional nutrients are added by various types of water pollution, this control is removed, often resulting in rapid growth of aquatic plants. When these plants die, the large mass of decaying vegetation depletes oxygen in the water and damages many other organisms in the system. Scientists suspect that increases in nutrients may also play a role in some HAB events.

HABs are becoming a global threat to living resources, fishing, tourism, and human health because the number and intensity of these events appear to be increasing in many countries. In 1987, the United Nations established a program focussed specifically on HABs and their impacts. In the United States, a research program on the Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) was launched in 1995 to develop methods for predicting where and when HABs are likely to occur, as well as techniques for preventing and controlling these events. The National Centers for Coastal Ocean Science (an office of the National Ocean Service) is the primary administrator of ECOHAB, and sponsors the program in partnership with the National Science Foundation, EPA, NASA, and the Office of Naval Research.

In this activity, students will investigate eight types of HABs, including an example of how scientific perspectives can change rapidly as a result of new research.

Learning Procedure

1. Briefly review the basic biology and consequences of harmful algal blooms.

2. Assign one of the following types of HABs to each student group:
   - Brown tide
   - Amnesic Shellfish Poisoning
   - Diarrhetic Shellfish Poisoning
   - Neurotoxic Shellfish Poisoning
   - Paralytic Shellfish Poisoning
   - Ciguatera fish poisoning
   - Harmful Cyanobacterial Blooms
   - *Pfiesteria piscicida*

   Tell students that their assignment is to prepare a written report on their assigned topic that includes the following information:
   - What type(s) of organisms are responsible?
   - What are the observed ecological, economic, and social impacts?
   - What species are affected?
   - What are possible causes?
   - What can be done to reduce, eliminate, or manage this type of HAB?

3. Have each student group summarize and discuss their research. Discussions should include the following points:
   - Brown tides are caused by golden-brown algae. *Aureococcus anophagefferens* and *Aureoumbra lanunensis* have been identified from these events. Microscopic drifting animals (zooplankton) that normally feed on phytoplankton seem to lose their appetite during brown tides. An algal bloom can significantly reduce the amount of sunlight that would normally reach plants growing beneath the water's surface, killing them. Widespread deaths among blue mussel and

bay scallop populations also have been associated with brown tides. Some brown tide events have coincided with changes in the flow of groundwater, suggesting that nutrient input may be involved.

- Amnesic Shellfish Poisoning (ASP) is caused by two species of diatoms (single-cell algae with glass-like shells). *Pseudo-nitzschia multiseries* and *P. australis* produce the toxin domoic acid, which can cause permanent loss of short-term memory, and may be fatal to some victims. Domoic acid has been detected in shellfish and in the organs of fish and crabs. In 1998, 70 California sea lions were fatally poisoned by domoic acid. Pelicans and cormorants have also been affected.

- Diarrhetic Shellfish Poisoning (DSP) is associated with a variety of phyoplankton species (including *Dinophysis acuminata*, *Dinophysis fortii*, and *Prorocentrum lima*) and a variety of toxins (including okadeic acids, pectenotoxins, yessotoxins, and dinophysistoxins). Affected species include mussels, oysters, scallops, and humans who consume contaminated shellfish. Symptoms in humans include nausea, vomiting, abdominal pain, and diarrhea.

- Neurotoxic Shellfish Poisoning (NSP) is caused by dinoflagellates (single-cell algae that have two whip-like flagellae that enable the algae to swim). The dinoflagellate species *Karenia brevis* produces brevetoxin, which affects manatees, bottlenose dolphins, oysters, fish, clams, and birds. Humans are exposed to the toxin by eating shellfish that have fed on toxic algae or by breathing seafoam containing the toxin. Symptoms include diarrhea, vomiting, neurologic symptoms such as tingling fingers or toes, and asthma-like symptoms if the toxin is inhaled. There is no known antidote, but most victims recover within a few days.

- Paralytic Shellfish Poisoning (PSP) is caused by a toxin, saxitoxin, produced by algae belonging to the genus *Alexandrium*. Affected species include mussels, clams, crabs, oysters, scallops, herring, sardines, marine mammals, and birds. Humans are exposed by eating contaminated shellfish. Symptoms include numbness, paralysis, and respiratory failure. There is no known antidote, and death from respiratory arrest may occur within 24 hours.

- Ciguatera fish poisoning (CFP) is caused by toxins (ciguatoxin and maitotoxin) produced by dinoflagellates that live in coral reef communities (particularly *Gambierdiscus toxicus*; other species implicated include *Amphidinium carterae*, *Coolia monotis*, and several others in the genera *Prorocentrum*, *Ostreopsis*, and *Thecadinum*). The toxins are transferred through the food chain and accumulate in the flesh of carnivorous fishes. If consumed by humans, CFP may causes nausea, vomiting, and neurologic symptoms such as tingling fingers or toes and sometimes reversal of heat and cold sensation (cold things feel hot, etc). There is no cure for CFP, and symptoms may last for years but are rarely fatal.

- Harmful Cyanobacterial Blooms (HCB) result from excessive growths of certain species of cyanobacteria (blue-green bacteria, formerly thought to be blue-green algae). Cyanobacteria are generally beneficial and are believed to have been responsible for producing the oxygen that changed the Earth's atmosphere more than 2,000 million years ago. A few species (including *Anabaena*, *Aphanizomenon*, and *Microcystis*), however, produce toxins that affect nerves, liver tissues, and other cells in a variety of mammals, birds, fishes, and invertebrates. These toxins are stored in the cells of the cyanobacteria and can be released into the surrounding water when the bacterial cells rupture or die. Humans can be exposed to cyanobacterial toxins by drinking or swimming in water containing the bacterial cells and/or toxins, as well as by breathing mists containing the toxins or cells. For example, such mists can be produced by waves breaking on shore, or by watering a lawn with contaminated water. Symptoms of cyanobacterial poisoning include nausea, diarrhea, stomach pain, difficulty breathing, allergic reactions, skin irritation, liver damage, and neurologic symptoms such as tingling fingers and toes. HCBs can also cause increased turbidity and reduced light penetration. This type of shading has been associated with destruction of underwater plants (especially "seagrasses" which are actually flowering plants that grow on the sea bottom), sponge beds and coral reefs.

- Some HABs cause fish kills through mechanisms other than toxicity. The diatom, *Chaetoceros convolutus* has long bristle-like structures called setae and secondary spines that cause the cells to become lodged in fish gills where they cause excessive mucous production that suffocates the fish.

- At present, control strategies center primarily upon predicting HAB events and providing adequate and timely public warning to allow people to avoid contaminated waters. This strategy has been particularly effective in reducing incidences of human exposure to toxins produced by HCB in Australia, and of NSP in Florida through the use of satellite imagery to detect algal blooms (visit *http://www.nccos.noaa.gov/news/june02.html* for more information).

- *Pfiesteria piscicida* is a dinoflagellate that is often included in discussions of HABs, because it has been linked to several well-publicized fish kills. Moreover, a number of commercial fishermen have reported health effects including flu-like symptoms, skin rashes, and memory loss. Since *Pfiesteria* was only discovered in 1988, relatively little was known about this organism at the time of the fish kills. Early studies reported that *Pfiesteria* had a highly complex life-cycle with 24 reported forms, a few of which (the amoeboid phases) were capable of producing toxins. Because the fish kills had significant economic impact and no one really knew how serious the threat from *Pfiesteria* might be, federal and state agencies gave high priority to learning more about this alga and the risks it might pose to public health.

  One problem with these studies was that it was not always possible to be certain which organisms in water samples were actually *Pfiesteria*; remember that researchers thought there were 24 possible forms of this one species. This problem was solved with a new molecular research technique using a fluorescent chemical that would bind only to a sequence of genes unique to *Pfiesteria piscicida*. Organisms containing this chemical glow brightly under infrared light. Since only *Pfiesteria* organisms can contain the chemical, it was easy to distinguish these organisms from other species.

Using this tool, researchers discovered that many of the forms thought to be part of *Pfiesteria's* complex life-cycle were actually other species. The researchers concluded that *Pfiesteria* has a simple seven-stage life cycle typical of other dinoflagellates found in coastal waters. No amoeboid phases were observed. Moreover, amoebae were isolated from a tank containing *Pfiesteria* and in which fish kills had been observed. During a two-year study, none of the amoebae transformed to *Pfiesteria*. Since the amoeboid life cycle stages were the ones that were supposed to be toxic, it is now much less certain that *Pfiesteria* forms HABs. Visit *http://www.nccos.noaa.gov/news/pfiesteria_press.html* for more details.

The case of *Pfiesteria* is a good example of how new techniques can provide new evidence that can quickly alter scientific perspectives. Ask students whether they think it was reasonable to undertake an accelerated research program to learn more about *Pfiesteria*. Be sure students understand that the case is not yet closed; there is still the question of what caused the fish kills and human symptoms. Additional research may reveal that *Pfiesteria* can indeed produce harmful toxins under the appropriate environmental conditions.

The BRIDGE Connection

http://www.vims.edu/bridge/ – Type "HABs" in the Search box to retrieve links about harmful algal blooms.

The Me Connection

Have students list three actions they could take to avoid being a victim of HABs.

Extensions

1.
Visit *http://www.nccos.noaa.gov/news/june04.html* for information on how autonomous underwater vehicles are being developed to detect and monitor HABs.

2.
Visit *http://www.bigelow.org/edhab/index.html* for additional educational activities involving HABs.

Resources

http://www.habhrca.noaa.gov/habfacts.html – Fact sheet on HABs from the National Centers for Coastal Ocean Science

http://oceanservice.noaa.gov/websites/retiredsites/sotc_pdf/hab.pdf – "State of the Coastal Environment" essay on HABs

http://www.cdc.gov/nceh/hsb/algal.htm – *Pfiesteria piscicida* and other harmful algae information from the Health Studies Branch of the Centers for Disease Control and Prevention

http://www.whoi.edu/redtide/ – The Harmful Algae Page of the National Office for Marine Biotoxins and Harmful Algal Blooms at Woods Hole Oceanographic Institution

http://www.bigelow.org/hab/organism.html – Web site provided by the Bigelow Laboratory for Ocean Sciences on toxic and harmful algal blooms

http://www.nccos.noaa.gov/news/pfiesteria_press.html – New NOAA Research Sheds Light on *Pfiesteria* Life Cycle (National Centers for Coastal Ocean Science)

http://www.hab.nos.noaa.gov/pfiesteriafacts.html – What about *Pfiesteria*? (National Centers for Coastal Ocean Science)

National Science Education Standards

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard C: Life Science

- Interdependence of organisms
- Behavior of organisms

Content Standard E: Science and Technology

- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Personal and community health
- Environmental quality

- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Content Standard G: History and Nature of Science
- Nature of scientific knowledge

Links to AAAS "Oceans Map" (aka benchmarks)

5D/H1
Ecosystems can be reasonably stable over hundreds or thousands of years. As any population of organisms grows, it is held in check by one or more environmental factors: depletion of food or nesting sites, increased loss to increased numbers of predators, or parasites. If a disaster such as flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually result in a system similar to the original one.

5D/H3
Human beings are part of the earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems.