Caution: Do Not Bleach!

Coral Reef Bleaching / Grades 9-12 / Life Science

Focus Question

Why are coral reefs important, and what are possible explanations for the phenomenon known as "coral bleaching?"

Learning Objectives

- Students will be able to identify and explain five ways that coral reefs benefit human beings.
- Students will be able to identify and explain three major threats to coral reefs.
- Students will be able to describe major components of the Coral Reef Early Warning System.
- Students will be able to identify and discuss actions that can be undertaken to reduce or eliminate threats to coral reefs.
- Students will be able to discuss at least one hypothesis that explains why corals under stress may expel their zooxanthellae.

Links to Overview Essays and Resources Useful for Student Research

http://oceanservice.noaa.gov/topics/oceans/coralreefs/welcome.html
http://www.coris.noaa.gov/about/biology
http://www.coris.noaa.gov/about/hazards/
http://oceanservice.noaa.gov/education/kits/corals/coral01_intro.html
http://oceanservice.noaa.gov/education/kits/corals/coral08_naturalthreats.html

Materials

- Copies of either "Coral Reef Subject Review" *(fill-in-the-blank version, with or without word bank)* or "Coral Reef Subject Review Crossword Puzzle," one copy for each student or student group (from the Corals Tutorial at *http://oceanservice.noaa.gov/education/kits/corals*)
- Computers (optional) with Internet access; if students do not have access to the Internet, you can download copies of materials cited under "Learning Procedure," and provide copies of these materials to each student or student group

Audio/Visual Materials

None, unless students require A-V equipment for their public education programs

Teaching Time

One or two 45-minute class periods

Seating Arrangement

Classroom style or groups of 4-6 students

Maximum Number of Students

30

Key Words

Coral reefs
Aquarium
Symbiosis
Zooxanthellae
Broadcast spawning

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Background Information

Coral reefs are one of the most biologically productive ecosystems on Earth. Most people have seen images of brightly colored fishes and other reef-dwelling organisms, yet many do not understand why these systems are personally important. Programs and articles about coral reefs typically point out benefits that include protecting shorelines from erosion and storm damage, supplying foods that are important to many coastal communities, and providing recreational and economic opportunities. These benefits are obviously important to people who live near reefs, but there is another aspect of coral reefs that can benefit everyone: the highly diverse biological communities are new sources of powerful antibiotic, anti-cancer and anti-inflammatory drugs.

The idea of coral reefs as a source of important new drugs is new to many people; but in fact, most drugs in use today come from nature. Aspirin, for example, was first isolated from the willow tree. Morphine is extracted from the opium poppy. Penicillin was discovered from common bread mold. Although almost all of the drugs derived from natural sources come from terrestrial organisms, recent systematic searches for new drugs have shown that marine invertebrates produce more antibiotic, anti-cancer, and anti-inflammatory substances than any group of terrestrial organisms. Particularly promising invertebrate groups include sponges, tunicates, ascidians, bryozoans, octocorals, and some molluscs, annelids, and echinoderms. For more information on drugs from the sea, visit *http://oceanexplorer.noaa.gov/explorations/03bio/background/medicines/medicines.html*.

Despite their numerous benefits to humans, many coral reefs are threatened by human activities. Sewage and chemical pollution can cause overgrowth of algae, oxygen depletion, and poisoning. Fishing with heavy trawls and explosives damages the physical structure of reefs as well as the coral animals that build them. Careless tourists and boat anchors also cause mechanical damage. Thermal pollution from power plants and global warming cause physiological stress that kills coral animals and leaves the reef structure vulnerable to erosion. Many of these impacts are the result of ignorance; people simply aren't aware of the importance of coral reefs or the consequences of their actions, but the damage and threats to reefs continues to increase on a global scale.

Some of the most severe damage appears to be caused by thermal stress. Shallow-water reef-building corals live primarily in tropical latitudes (less than 30° north or south of the equator). These corals live near the upper limit of their thermal tolerance. Abnormally high temperatures result in thermal stress, and many corals respond by expelling the symbiotic algae (zooxanthellae) that live in the corals' tissues. Since the zooxanthellae are responsible for most of the corals' color, corals that have expelled their algal symbionts appear to be bleached. Because zooxanthellae provide a significant portion of the corals' food and are involved with growth processes, expelling these symbionts can have significant impacts on the corals' health. In some cases, corals are able to survive a "bleaching" event and eventually recover. When the level of environmental stress is high and sustained, however, the corals may die.

Prior to the 1980s, coral bleaching events were isolated and appeared to be the result of short-term events such as major storms, severe tidal exposures, sedimentation, pollution, or thermal shock. Over the past twenty years, though, these events have become more widespread, and many laboratory studies have shown a direct relationship between bleaching and water temperature stress. In general, coral bleaching often occur in areas where the sea surface temperature 1°C or more above the normal maximum temperature.

In 1998, the President of the United States established the Coral Reef Task Force (CRTF) to protect and conserve coral reefs. Activities of the CRTF include mapping and monitoring coral reefs in U.S. waters, funding research on coral reef degradation, and working with governments, scientific and environmental organizations, and business to reduce coral reef destruction and restore damaged coral reefs.

As co-chair of the CRTF, and as directed by the Coral Reef Conservation Act of 2000, NOAA has the responsibility to conserve coral reef ecosystems. NOAA's coral reef conservation efforts are carried out primarily through its Coral Reef Conservation Program (CRCP). Under this program, NOAA works with scientific, private, government, and nongovernmental organizations at the local, federal, and international levels to address conservation actions. Among other actions, the CRCP undertakes a variety of mapping and monitoring activities to understand:

- locations of coral reef ecosystems;
- how they function;
- how human activities impact reef processes; and
- how managers and the public can reduce or eliminate these impacts.

The first part of this lesson is intended to:

- introduce students to coral reefs and improve their understanding of why these systems are important, how they are threatened, and what can be done to protect and restore these unique and valuable ecosystems; and to

- introduce students to hypotheses that explain why corals under stress may expel their zooxanthellae.

In the second part of this lesson, students design and prepare educational programs to improve public awareness of the importance of coral reefs and what needs to be done to reduce or eliminate harmful impacts from human activities. This activity offers many opportunities for cross-curricular activities, and may be extended over several weeks or months. If time is limited, you may choose to use the first part alone.

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Learning Procedure

Part 1

1. Direct students to the Corals Tutorial at: http://oceanservice.noaa.gov/education/kits/corals. You may want to assign different tutorial sections to each student group. Have each student or student group complete one version of the Subject Review (downloadable), and lead a discussion to review the answers. Be sure that students understand the relationship between coral animals and their symbiotic algae (zooxanthellae), and that under thermal stress many corals will expel their zooxanthellae.

   Briefly explain the purpose and activities of the U. S. Coral Reef Task Force (CRTF) and the NOAA Coral Reef Conservation Program (CRCP), and highlight the monitoring functions that are intended to identify reef areas threatened by thermal stress or algal blooms (visit *http://www.coralreef.gov* for more information on the CRTF and *http://coralreef.noaa.gov* for more information on the CRCP).

2. Tell students that their assignment is to investigate possible explanations for zooxanthellae expulsion by corals under stress, and prepare a written report outlining at least one hypothesis that explains this behavior. The report should explain:

- the symbiotic relationship between corals and their zooxanthellae;
- how corals obtain their zooxanthellae; and
- how environmental stress may alter the symbiosis.

If you want to provide a starting point for this research, the following resources will be useful:

http://www.coralreefwatch.noaa.gov/ (NOAA Coral Reef Watch Program and Satellite Monitoring of Coral Bleaching)

http://oceanservice.noaa.gov/education/kits/corals/supp_coral_roadmap.html (Roadmap to Resources: Corals)

http://www.oneocean.org/overseas/200009/coral_bleaching_the_hows_and_whys_and_whats_next.html (article: Coral Bleaching: the Whys, the Hows and What Next?)

http://ioc.unesco.org/coralbleaching/Hughes%20et%20al.pdf (article: Climate Change, Human Impacts, and the Resilience of Coral Reefs)

http://www.crc.uri.edu/download/COR_0011.PDF (article: Coral Bleaching: Causes, Consequences and Response)

3. Lead a discussion of students' research results. Written reports should include some of the following points:

- Zooxanthellae are single-celled motile algae (dinoflagellates).
- Many marine invertebrates in addition to corals have symbiotic algae.
- Photosynthesis by zooxanthellae provides a significant source of nutrition for many host symbionts; as much as 90% of the total energy requirement in some coral and giant clam species.
- Zooxanthellae are also involved in calcium carbonate deposition (skeletal growth) in some corals.
- Some zooxanthellae produce an ultraviolet-absorbing pigment that may act as a sort of "sunscreen" for host corals.
- The mechanism by which corals obtain zooxanthellae (or, from a slightly different perspective, become infected with zooxanthellae) is not known, but sea anemone larvae have been reported to indiscriminantly ingest zooxanthellae along with other particulate materials. The algal cells become incorporated into the larvae's endodermal cells, while other particulate materials are either digested or expelled.
- "Bleaching" has been observed in most marine organisms that host zooxanthellae.
- It is not known whether bleaching happens because the algae leave their host animal or because the host expels the algae.
- Bleaching can also occur when algae expel their pigments.
- Bleaching appears to be the result of various types of environmental stress, including high temperature, exposure to excessive irradiance, lowered salinity, and pollution.
- Combinations of different stresses may result in bleaching, even though corals might be tolerant of the individual conditions (for example, if corals are near their upper thermal limit, even small increase in irradiance can result in bleaching)
- Elevated temperatures reduce the photosynthetic ability of zooxanthellae.
- Increased atmospheric carbon dioxide may lead to increased dissolved carbon dioxide in seawater, which will increase the solubility of calcium and reduce calcification.

- While there is no absolute proof that bleaching events are the result of climate change, most scientists consider the link to be incontrovertible.
- Different species of corals have different tolerance levels for various environmental factors. Similarly, different strains of zooxanthellae have different tolerance levels.
- Different strains of zooxanthellae are found within and among coral species.
- Coral genera with fast growth rates and high metabolic rates are most susceptible to bleaching.
- The “adaptive bleaching hypothesis” proposes that corals expel their zooxanthellae under stress so that they can be replaced with other strains that are better suited to the stress conditions. There is no evidence, however, that corals can simply take up more tolerant strains of algae. In addition, high mortality, reduced growth rates, and decreased fecundity in bleached corals do not suggest an effective adaptation to stress conditions.
- If the stress conditions that cause bleaching persist for more than about six weeks, corals may die. The duration of the stress conditions and the intensity of high temperatures determine the severity of bleaching and the ability of corals to survive.
- Some scientists have predicted that persistent temperature increases coupled with other stresses will lead to widespread loss of coral reefs, which may require 500 years or more to recover.
- Marine protected areas are currently the most effective management tool for protecting coral reefs and other marine resources, but they cannot stop temperature increases or other adverse climate changes.

Ask students to discuss why coral reefs are at risk, and what they think can or should be done to reduce or eliminate the negative impacts of human activity on coral reefs. There is a strong possibility that a significant part of the current risk to coral reef systems is the result of human activity, particularly as it relates to climate change. Meaningful actions to address this type of issue depend upon widespread understanding of the problem and commitment to workable solutions. Public education is an important step toward building this sort of understanding and commitment. Have students brainstorm what “key messages” might form part of a public education program about coral reefs, what audiences should be targeted to receive these messages, and how these messages might be most effectively delivered to these audiences.

Part 2

Have students or student groups prepare one or more public education programs about coral reefs, based on the results of their brainstorming sessions in Step 3. Encourage students to consider various media, including publications, visual presentations, drama, music, etc. You may want to have an entire class work on a single program, or have smaller groups work on multiple programs using the medium (or media) or their choice. There are many possibilities, depending upon the target audiences. These presentations also offer cross-curricular opportunities, particularly with social studies, English language arts, and fine arts. Whatever media students choose to work with, their final presentation should be accompanied by a list of sources for the information they present. A good starting point for this activity is the Roadmap to Resources: Corals (*http://oceanservice.noaa.gov/education/kits/corals/supp_coral_roadmap.html*), which provides links to many other sources of coral reef data and information.

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The Bridge Connection

The Bridge is a growing collection online marine education resources. It provides educators with a convenient source of useful information on global, national, and regional marine science topics. Educators and scientists review sites selected for the Bridge to insure that they are accurate and

current.

http://www.vims.edu/bridge/reef.html

The "Me" Connection

Have students write a short essay on why coral reefs are personally important, what personal actions may contribute to human-caused threats to coral reefs, and what they could do to reduce these threats.

Extensions

1. The symbiotic relationship between zooxanthellae and coral polyps can be a springboard for discussing other types of cellular symbionts. Many biology students tend to overlook microbial associations in natural communities, but there is mounting evidence that eukaryotic organisms were (and are) the result of symbiotic associations between prokaryotic organisms. At some point in these associations, one (or more) species (called endosymbionts) entered the cells of another species, and performed useful functions. Each species had its own DNA, and when these organisms reproduced, both were replicated. Eventually, the individual identities of the species disappeared, resulting in a new type of organism. This sort of transformation has actually been seen in the laboratory, and is described in Margulis and Sagan (1986). For more information and a lesson plan devoted to this topic, visit http://oceanexplorer.noaa.gov/explorations/03bio/background/edu/media/Meds_CellMates.pdf

2. Have students or student groups prepare a report on a specific aspect of coral biology, ecology, or management. Some possible topics include:

   - coral diseases
   - natural and anthropogenic hazards
   - oil spills on coral reefs
   - coral reef restoration
   - species diversity on coral reefs
   - benthic habitats associated with coral reefs
   - relationships between coral reefs and seagrass or mangrove ecosystems

   See Roadmap to Resources: Corals (http://oceanservice.noaa.gov/education/kits/corals/supp_coral_roadmap.html) for links to information on these and other relevant topics.

3. For more lesson plans and activities related to coral reefs, visit the education web pages for NOAA's Ocean Explorer Cayman Islands Twilight Zone 2007 Expedition at http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/edu.html.

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Resources

http://oceanservice.noaa.gov/education/kits/corals/supp_coral_roadmap.html – *The National Ocean Service education Web site's Roadmap to Resources about corals, with links to many other sources of coral reef data, background information, and reports*

http://www.oneocean.org/overseas/200009/coral_bleaching_the_hows_and_whys_and_whats_next.html

Diamante-Fabunan, D. 2000. Coral Bleaching: the Whys, the Hows and What Next? OverSeas, The Online Magazine for Sustainable Seas.

http://www.crc.uri.edu/download/COR_0011.PDF – "Coral Bleaching: Causes, consequences and response;" a collection of papers from the ninth international coral reef symposium.

http://www.nmfs.noaa.gov/habitat/habitatconservation/publications/Separate%20Chapters

/Cover%20and%20Table%20of%20Contents.pdf – "The State of Deep Coral Ecosystems of the United States," 2007 report from NOAA providing new insight into the complex and biologically rich habitats found in deeper waters off the U.S. and elsewhere around the world.

http://www.latimes.com/news/local/oceans/la-oceans-series,0,7842752.special – "Altered Oceans," five-part series from the Los Angeles Times on the condition of Earth's ocean; published July 30 – August 3, 2006

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

- The cell
- 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
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

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Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1. The Earth has one big ocean with many features.

- Fundamental Concept h. Although the ocean is large, it is finite and resources are limited.

Essential Principle 5. The ocean supports a great diversity of life and ecosystems.

- Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.

Essential Principle 6. The ocean and humans are inextricably interconnected.

- Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.

- Fundamental Concept e. Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.

- Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7. The ocean is largely unexplored.

- Fundamental Concept c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.

- Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

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