CORAL REEF CONSERVATION LESSON PLAN

A Reef of Your Own

Theme
Coral Reef Biology

Links to Overview Essays and Resources Needed for Student Research
http://oceanservice.noaa.gov/topics/ocean/coralreefs
http://www.coris.noaa.gov/about/biology
http://oceanservice.noaa.gov/education/kits/corals/coral01_intro.html

Subject Area
Life Science

Grade Level
9-12

Focus Question
What physiological, ecological, and behavioral strategies contribute to the success of reef-building corals?

Learning Objectives
- Students will be able to describe and explain the importance of asexual and sexual reproductive strategies to reef-building corals.

- Students will be able to explain why is it important that reef-building corals have a nutritional strategy that includes both photosynthesis and carnivory.

- Students will be able to describe two behaviors that reef-building corals use to compete for living space with other species.

- Students will be able to explain how coral reefs can produce high levels of biological material when the waters surrounding these reefs contain relatively small amounts of the nutrients normally needed to support biological production.

Materials Needed

- Copies of either "Coral Reef Self-Test" (fill-in-the-blank version, with or without word bank) or "Coral Reef Self-Test Crossword Puzzle," one copy for each student or student group, available at: *http://oceanservice.noaa.gov/education/kits/corals/lessons/coral_bleach.pdf*
- (optional) Computers with internet access; if students do not have access to the internet, direct them to local library resources, and/or download copies of materials cited under "Learning Procedure" and provide copies of these materials to each student or student group

Audio/Visual Materials Needed

None

Teaching Time

Two or three 45-minute class periods, plus time for student research; additional time will be needed if you decide to set up a model coral reef ecosystem

Seating Arrangement

Groups of 3-4 students

Maximum Number of Students

30

Key Words

Coral reefs
Aquarium
Symbiosis
Zooxanthellae
Broadcast spawning

Background Information

Coral reefs are among the most biologically diverse and productive ecosystems on Earth. Coral reefs protect shorelines from erosion and storm damage, supply foods that are important to many coastal communities, and provide recreational and economic opportunities. In addition, the highly diverse biological communities associated with coral reefs are new sources of powerful antibiotic, anti-cancer and anti-inflammatory drugs that have the potential to benefit the entire human race (for more information on drugs from coral reefs, visit *http://oceanservice.noaa.gov/education/corals/lessons/coral_bleach.pdf* and *http://oceanexplorer.noaa.gov/explorations/03bio/background/edu/edu.html*).

Unfortunately, coral reefs are regularly damaged by a variety of natural stresses. Hurricanes and cyclones can break corals loose and scatter them into areas where they cannot survive. Storm damage to coastal areas can increase the inflow of sediments that can smother living reefs and reduce light needed by many shallow-water corals. Freshwater runoff may cause additional stress by lowering the salinity of water surrounding reefs. Unusually low tides can leave corals exposed to high temperatures, solar radiation, and the risk of drying out. High temperatures associated with phenomena such as El Nino and prolonged periods of unusual warmth cause severe damage through thermal stress and may be lethal. Corals are also subject to predation and disease. Coral reefs have survived these types of threats for millions of years. Some reefs have become extinct, but others have flourished.

Corals are also threatened by human activities. These stresses may have a much greater impact than natural stresses. Sewage and chemical pollution can cause overgrowths of algae, oxygen depletion, and poisoning. Poor land management and deforestation can lead to excessive runoff and sedimentation. Fishing with heavy trawls, poisons, and explosives damages the physical structure of reefs as well as the coral animals that build them. Careless tourists, boat anchors, and collection for the aquarium trade also cause mechanical damage. Thermal pollution from power plants and other human activities that raise water temperatures cause physiological stress that kills coral animals and leaves the reef structure vulnerable to erosion. Oil spills, fuel discharges, and anti-fouling chemicals from boats add additional stress. 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. There is also evidence that impacts caused by humans may be increasing the severity of natural threats. Many researchers have noticed an increase in coral diseases and believe that at least part of the reason is that the corals have been weakened by other stress factors.

One of the most striking responses to thermal stress is known as "bleaching." Most reef-building corals have single-cell algae called zooxanthellae living within their tissues. These algae play an important role in the corals' nutrition and growth. Pigments in the algae are also responsible for most of the corals' color. Under thermal stress, some corals may expel these algae, causing the corals to appear bleached. Some corals may recover and acquire replacement algae, but many others die.

In 1998, the President of the United States established the Coral Reef Task Force (CRTF) to protect and conserve coral reefs. The CRTF has identified six problem areas for priority action:

- Land-based sources of pollution;
- Overfishing;
- Lack of public awareness;
- Recreational overuse and misuse;
- Climate change and coral bleaching; and
- Disease.

All of these areas can benefit from broad public involvement, even from people who live thousands of miles from a living reef. The first step toward effective action to protect and manage coral reefs is to understand the biology of the organisms that create the reef structure.

In this activity, students will explore biology of reef-building corals, and use this knowledge to design a miniature coral reef system. If time permits, students may implement their design with live corals and other reef organisms.

Learning Procedure

1.

Direct students to the coral reef tutorials at *http://oceanservice.noaa.gov/education/kits/corals/coral01_intro.html*. You may want to assign different tutorial sections to each student group. Have each student or student group complete one version of the Self-Test, and lead a discussion to review the answers. Be sure students grasp the following points.
Almost all reef building corals are sessile (they remain in one place and do not move), and are adapted to their environment through specific physiological and behavioral characteristics.

Particularly important are:

- Reproductive strategies (both sexual and asexual modes, including mass spawning events);
- A combination of photosynthetic and carnivorous nutrition; and
- Behavioral interactions with other species that allow corals to successfully compete for living space.

2.

Tell students that they are going to design a functioning model of a coral reef ecosystem that could be put together in your classroom. To prepare for this task, their assignment is to research relevant aspects of

- Nutritional strategies used by corals;
- How corals compete with other species for space;
- How corals reproduce;
- How coral reefs can support large numbers of plants and animals when the waters surrounding these reefs contain so little of the nutrients needed to support biological production that these waters are often called "biological deserts"; and
- Key physical factors (temperature, water movement, etc.) required by corals.

You may want to brainstorm some of these functions to get things started. Students may recognize the need for a source of energy (which implies one or more food chains), some means for disposing of wastes, a source of oxygen, etc. In addition to the coral reef tutorials, you may want to direct students to the Roadmap to NOAA Resources: Corals at *http://www.oceanservice.noaa.gov/education/kits/corals/supp_coral_roadmap.html*.

3.

Lead a discussion of students' research results in the context of designing a model coral reef ecosystem. Students should recognize photosynthesis as the primary source of energy in coral reef systems and the role of the algae living within the coral tissues (zooxanthellae). Ask students to identify organisms that could provide an energy source for their miniature coral reef ecosystem. Corals with their associated zooxanthellae are one possibility. Algae (both microscopic and macroscopic) are another possibility, and on natural reefs compete directly with corals for space. Since the algae can grow more quickly than corals, they could overrun a reef ecosystem unless there was a way to keep the algae in check. On natural reefs, grazing fishes and invertebrates fill this niche. You may want to point out that coralline algae have hard surfaces similar to the surfaces of corals. Coralline algae are very important to reef growth, since the larvae of many corals can only settle on surfaces that have been previously colonized by coralline algae.

Be sure to discuss the food chains (or webs) that will exist in the model system, and how many steps in the chain (trophic levels) might reasonably be included in the system. You may need to remind students that it takes at least 10 grams of primary producers to support 1 gram of herbivores, and 1 gram of herbivores can support less than 0.1 gram of primary carnivores, and so forth (i.e., energy transfer efficiency between trophic levels is less than 10%). This means that the number of trophic levels in your model ecosystem will be quite limited unless an external source of energy (i.e., supplemental feeding) is provided. Similarly, large or highly active organisms (including many fishes) will probably require supplemental feeding, and leftover artificial food is a major cause of pollution in small aquaria.

Students should understand that while zooxanthellae supply a major part of corals' energy needs through photosynthesis, most corals must feed on other animals as well. When feeding, the individual coral animals (polyps) extend their tentacles, sting living prey with toxic microscopic darts produced by cells called nematocysts, then draw the victims into their mouths. Most corals also produce strands of mucous that extend from the mouth. Floating particles of dead plants and animals stick to the mucous strands, which are periodically drawn back into the mouth. Some species feed entirely on these particles. Carnivory is essential to most corals, because food from animal sources provides nitrogen to corals and their zooxanthellae. This element is essential to both organisms, and is cycled back and forth between them.

This cycling process is a key to why coral reefs are often called "oases of productivity in biological deserts." The tropical ocean waters that surround coral reefs are generally nutrient-poor, and consequently support much less biological production than most temperate waters. The relationship between corals and zooxanthellae is a classic example of a mutualistic symbiosis (a symbiosis is a relationship between two organisms; a mutualistic symbiosis benefits both). This relationship overcomes the problem of limited nutrients by cycling key nutrients between the symbionts, and provides the basis for a highly productive and biologically diverse ecosystem. Similar cycling is involved with various metabolic by-products. In human societies we often call these by-products "waste," but in nature they are raw materials for other organisms. The resulting linkages are the basis for many material cycles. Since much of this work is done by microorganisms, these also need to be present in the model system.

Another consideration is the reproductive strategy used by coral species that are candidates for the model system. Students should recognize that most (about 75%) stony coral species form hermaphroditic colonies that produce both male and female gametes, while the remainder are gonochoristic (the colonies produce either male or female gametes, but not both). In many coral species (and other sessile organisms such as sponges), neighboring individuals of the same species release their gametes almost simultaneously, a process known as "broadcast spawning." Discuss the advantages of broadcast spawning, which is found in about 75% of reef-building coral species. In nature, spawning time is correlated with lunar cycles. The exact moment at which gametes are simultaneously released by hundreds of individual corals appears to be triggered by the time of sunset. The gametes fuse in the water column to form floating larvae (planulae). Planulae usually swim toward the surface, then settle within two days, although the larval stage of some species may last several weeks or even months. The time between planulae formation and settlement is typically a period of very high mortality (mortality is lower in some coral species that brood the planulae within their bodies after internal fertilization).

This is also a good context in which to discuss competition. Remind students that corals require hard substrates (often coralline algae) for settlement and growth. Fast-growing corals compete for space using a strategy known as "overtopping," in which the faster-growing species shades its competition from light and currents bearing food particles, so the slower-growing species eventually starves. But the slow-growers have their own strategies. Nematocysts can be used for defense as well as feeding, and some corals are able to directly attack and kill nearby polyps of other species by extending tentacles and parts of their digestive system onto the polyps. Obviously, it would not be a good idea to locate an aggressive species near another species in the model system, unless one wants to see what happens.

Students should identify at least four key physical factors. Because most shallow-water corals are tropical, they need water temperatures between 18°C and 32°C. Salinity should be that of normal seawater (about 35 parts per thousand). Zooxanthellae obviously require light for photosynthesis, and students should recognize that the wavelengths present should resemble those of natural sunlight filtered through one to two meters of water. Water movement is essential to the transport of food particles to sessile organisms, as well as for the removal of byproducts of metabolism that will be toxic if allowed to accumulate.

4.
Have each student group prepare a written report describing how they would set up a miniature coral reef ecosystem, including a description of the key system functions, and how these functions will be provided. Students should compare and contrast the processes for providing these functions in their model system with the processes that provide these functions in natural coral reef systems. A typical model system would probably include a thermostat-controlled heater, a full-spectrum light with a time switch, and a circulating water pump capable of providing good flow rates (usually 5 to 10 times the volume of the aquarium per hour). Supplemental aeration may also be needed, depending upon the configuration of the water pump (a water circulating system that includes a fountain-like device will provide aeration as well as flow). Have each group present their designs, and lead a discussion to select the best features for an "optimum" model coral reef.

If you want to actually set up a model coral system, turnkey kits are commercially available (e.g., from Carolina Biological

Supply Company *http://www.carolina.com*). It is important to remember that a significant amount of damage is done to reefs by collectors who supply (often illegally) unscrupulous aquarium dealers. So be certain to verify the sources of any corals and other reef species brought into the classroom.

The Bridge Connection

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

The Me Connection

Have students write a brief essay describing what an individual could do to protect and/or restore coral reefs, and why this sort of action is important. If they don't think this is important, have them justify their opinion.

Extensions

Review and discuss "Things You Can Do to Protect Coral Reefs" at *http://coralreef.noaa.gov/outreach/thingsyoucando.html*. Even if you don't live near a reef, you can help protect coral reefs in the U.S.A. and around the world.

Resources

http://coralreef.noaa.gov/ – Home page for NOAA's Coral Reef Conservation Program

http://www.oceanservice.noaa.gov/education/kits/corals/supp_coral_roadmap.html – Roadmap to NOAA Resources: Corals; a guide for educators and students to specific online coral data offerings within the NOS and NOAA family of products

http://www.coris.noaa.gov/activities/actionstrategy – National Coral Reef Action Strategy

http://coralreef.noaa.gov/outreach/thingsyoucando.html – Things you can do to help protect coral reefs

http://www.coris.noaa.gov – NOAA's Coral Reef Information System (CoRIS) designed to be a single point of access to NOAA coral reef information and data products

http://www.coralreef.gov/taskforce/las.html – Coral Reef Local Action Strategies

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
- Matter, energy, and organization in living systems
- Behavior of organisms

Content Standard F: Science in Personal and Social Perspectives

- Natural resources
- Environmental quality
- Science and technology in local, national, and global challenges

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 results in a system similar to the original one.

5D/H2

Like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium. In the long run, however, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution.

5D/H3

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