2006 Laser Line Scan Expedition

Design a Reef!
(adapted from the 2003 Gulf of Mexico Deep Sea Habitats Expedition)

Focus
Niches in coral reef ecosystems

Grade Level
7-8 (Life Science)

Focus Question
What are the major functions that organisms must perform in a coral reef ecosystem?

Learning Objectives
Students will be able compare and contrast coral reefs in shallow water and deep water.

Students will be able to describe the major functions that organisms must perform in a coral reef ecosystem.

Students will be able to explain how these functions might be provided in a miniature coral reef ecosystem.

Students will be able to explain the importance of three physical factors in coral reef ecosystems.

Students will be able to infer the fundamental source of energy in a deep-water coral reef ecosystem.

Materials
- ❒ (Optional) Turn-key miniature coral reef aquarium kit, or student-designed components (see Learning Procedure, Step 5)

Audio/Visual Materials
- ❒ Chalkboard, marker board with markers, or overhead transparencies for group discussions

Teaching Time
One 45-minute class period, plus time for student research

Seating Arrangement
Groups of 4-6 students

Maximum Number of Students
30

Key Words
Ahermatypic
Hermatypic
Niche
Zooxanthellae
Chemosynthetic
Photosynthesis

Background Information
Coral reefs are one of the most biologically productive ecosystems on Earth, and benefit humans in a variety of ways that include protecting shorelines from erosion and storm damage, supplying foods that are important to many coastal communities, and providing recreational and economic opportunities. In addition, these highly diverse biological communities are proving to be very promising sources of powerful new antibiotic, anti-cancer and anti-inflammatory drugs. Most drugs in use today come from nature. While almost all of these drugs are derived from terrestrial plants and microbes, 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 about drugs from the sea, see "More About Drugs from the Sea" below. You may also want to visit the Ocean Explorer Web site for the 2003 Deep Sea Medicines Expedition (http://oceanexplorer.noaa.gov/explorations/03bio/welcome.html).

Even though they provide 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 damage the physical structure of reefs as well as the coral animals that build them. Careless tourists and boat anchors also cause mechanical damage. 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 20 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 events often occur in areas where the sea surface temperature rises 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. NOAA monitors reefs using a system of specially designed buoys that measure air temperature, wind speed and direction, barometric pressure, sea temperature, salinity and tidal level, and transmit these data every hour to scientists. Satellites are also used to monitor changes in sea surface temperatures and algal blooms that can damage reefs. Research and restoration projects on selected coral reefs are conducted by NOAA's National Undersea Research Program (NURP). Using high-resolution satellite imagery and Global Positioning Satellite (GPS) technology, NOAA has made comprehensive maps of reefs in Puerto Rico, the U.S. Virgin Islands, the eight main Hawaiian Islands and the Northwestern Hawaiian Islands. Maps of all shallow U.S. coral reefs are expected to be completed by 2009.

While these maps show where various reef habitats are located, they are unable to provide detailed information needed for effective management of complex coral reef systems. Side-scan sonar techniques are able to cover large areas, but cannot distinguish individual organisms in communities of fish, algae, and invertebrates. Video and photographic data can be collected by divers in areas shallower than 20 to 30 meters, and by towed cameras, remotely operated vehicles, and manned submersibles in deeper waters. None of these methods, though, are able to collect the large amounts of visual data needed to make detailed maps of coral reef habitats.

A new technology called laser line scan (LLS) may provide a bridge between broad-scale approaches such as side-scan sonar and fine-scale video and still photography. LLS systems can detect objects as small as about one centimeter. This is much better resolution than is possible with side-scan sonar, but not quite as good as video. While LLS systems are unable to cover as much area as side-scan sonar, these systems provide two to five times the coverage of video. One of the most publicized uses of LLS was in the search for wreckage from TWA Flight 800, which went down off Long Island in 1996. In 2001, the Ocean Explorer program and NURP co-sponsored a field test of a commercial LLS system for imaging seafloor habitats. Results from this test confirmed the potential of LLS technology for mapping benthic habitats. The laser images revealed details of low relief sediments such as sand waves and ripples, and showed a variety of fishes, salp chains, sea anemones, sea pens, kelp and other macro-algae. These images allowed scientists to identify fish and invertebrate species within a given habitat, and to observe the relationships of these animals to their habitats. The purpose of the 2006 Laser Line Scan Expedition is to test the ability of LLS technology to provide detailed information about a variety of coral reef habitats in the Hawaiian Archipelago.

This activity is designed to acquaint students with some of the ecological roles that are typical of coral reefs, and to provide a basis for student inferences about the ecology of deep-water reef communities.

Learning Procedure

1. To prepare for this lesson:
   - Read the introductory essays for the 2006 Laser Line Scan Expedition at http://oceanexplorer.noaa.gov/explorations/06laserline/.

   If you are not already familiar with coral reefs, you may also want to review the coral reef tutorials at http://www.nos.noaa.gov/education/welcome.html.

2. Review the concept of "niche." A simple way to explain this idea is to think of an organism's niche as its occupation: that is, where, when and on what it feeds; where it lives; who its enemies are, etc. Have students brainstorm the characteristics they would use to describe the niche of an organism living on a coral reef.

3. 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 the various occupations (niches) that need to be filled to make a coral reef ecosystem work, and what kinds of organisms fill these roles in a shallow water coral reef. You may want to get the thought processes started by brainstorming some of these roles. 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.

   You may want to direct your students to http://www.vims.edu/bridge/reef.html for background information on coral reef ecosystems.

4. Lead a discussion of students' research results in the context of designing a miniature coral reef ecosystem. Students should recognize that the primary source of energy in coral reef systems is sunlight which is converted to chemical energy by green plants through photosynthesis. Many shallow-water corals contain single-celled algae called zooxanthellae (pronounced zoh-

zan-THEL-ee) within their tissues. Chemicals produced by the algae through photosynthesis are transferred to the coral tissues, and the pigments of the algae cause the corals to appear brightly colored. Students should also have discovered that corals also have tentacles equipped with stinging cells (nematocysts) capable of feeding on particulate materials and plankton. Ask students to infer what energy sources might be used by corals living in very deep water where sunlight does not penetrate. Many organisms in deep-sea reef communities are particle feeders and obtain energy from plankton and/or the remains of dead organisms that settle from shallower waters. Be sure students realize that the availability of these materials also depends upon photosynthesis in shallower water, so sunlight is still the fundamental source of energy for these particle-feeding organisms.

Ask students if there is another energy source that does not involve sunlight. Some students may identify chemosynthesis as an alternative to photosynthesis. Organisms that use sulfur as an energy source (e.g., those found in the vicinity of hydrothermal vents; visit http://www.pmel.noaa.gov/vents for more information) are not dependent on sunlight, and may resemble some of the earliest forms of life on Earth. Other organisms use organic chemicals such as methane or other hydrocarbons as a source of energy (visit http://www.bio.psu.edu/cold_seeps for more information).

But since these hydrocarbons come from the remains of once-living plants and animals that were dependent upon photosynthesis, sunlight is still the fundamental energy source for these organisms even though they are chemosynthetic. Mention that Norwegian scientists have found large *Lophelia* banks at sites where relatively high levels of light hydrocarbons are present in the sediments.

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. Some species of algae that produce hard limestone deposits are very important to reef growth. These algae are called "coralline algae," and the larvae of many corals can only settle on surfaces that have been previously colonized by coralline algae.

So now we have the beginnings of a food chain for our model reef system. Ask students how many more links could reasonably be added to the food chain in the model system. You may need to remind them that energy transfer efficiency between trophic levels is less than 10% (i.e., 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, etc.). This means that the number of trophic levels in your model ecosystem may be limited. This also calls attention to the issue of size and types of organisms that should be included in the miniature reef ecosystem. Highly active organisms (such as fishes) will probably require supplemental feeding, and leftover artificial food is a major cause of pollution in small aquaria.

This leads to the issue of waste disposal. Be sure they understand that the concept of "waste" is a human invention: in nature, byproducts from one organism are "raw materials" for other organisms. This process is essential to natural recycling. Much of this work is done by microorganisms, which need to be present for a model system to work well.

Discuss key physical factors. These include temperature (most shallow-water corals are tropical and need water temperatures between 18°C and 32°C); light (natural sunlight contains substantially more blue wavelengths than most artificial lights); and water movement (very important for the transport of food particles to sessile organisms, as well as for the removal of metabolic byproducts that would be toxic if allowed to accumulate). So, the miniature coral reef ecosystem may need a thermostat-controlled heater, a full-spectrum light with a time switch, and a pump capable of providing good flow rates (usually 5 to 10 times the volume of the aquarium per hour).

5. Now have students explore some practical options for setting up their miniature coral reef ecosystem. Even if it isn't possible to actually do so, students can still learn a great deal from this process. Turnkey kits are commercially available (e.g., from Carolina Biological Supply Company), or they might create their own using information available from the Geothermal Aquaculture Research Foundation at www.garf.org.

6. Have each student group prepare a written report describing how they would set up a miniature coral reef ecosystem, including a description of the niches that would be included in their system.

The Bridge Connection

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

The "Me" Connection

Have students write a short essay describing their niche in the ecosystem of which they are part, and what other niches are important to their own lives.

Connections to Other Subjects

English/Language Arts, Chemistry, Earth Science

Evaluation

Written reports prepared in Step 6 provide an opportunity for assessment.

Extensions

Log on to http://oceanexplorer.noaa.gov to keep up to date with the latest 2006 Laser Line Scan Expedition discoveries, and to find out what researchers are learning about coral communities in the Hawaiian Archipelago.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

Treasures in Jeopardy

http://oceanexplorer.noaa.gov/explorations/05deepcorals/background/edu/media/05deepcorals_treasures.pdf

(6 pages, 299k) (from the Florida Coast Deep Corals 2005 Expedition)

Focus: Conservation of deep-sea coral reefs (Life Science)

In this activity, students will compare and contrast deep-sea coral reefs with their shallow-water counterparts and explain at least three benefits associated with deep-sea coral reefs. Students will also describe human activities that threaten deep-sea coral reefs and describe actions that should be taken to protect deep-sea coral reef resources.

Let's Go to the Video Tape!

http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_letsgo.pdf

(7 pages, 552k) (from the 2003 Gulf of Mexico Deep Sea Habitats Expedition)

Focus: Characteristics of biological communities on deep-water reef habitats (Life Science)

In this activity, students will recognize and identify some of the fauna groups found in deep-sea coral reef communities, infer possible reasons for observed distribution of groups of animals in deep-sea coral reef communities, and discuss the meaning of "biological diversity." Students will compare and contrast the concepts of "variety" and "relative abundance" as they relate to biological diversity, and given abundance and distribution data of species, will be able to calculate an appropriate numeric indicator that describes the biological diversity of a community.

Mapping Deep-sea Habitats in the Northwestern Hawaiian Islands

http://oceanexplorer.noaa.gov/explorations/02hawaii/background/education/media/nwhi_mapping.pdf
(7 pages, 80kb) (from the 2002 Northwestern Hawaiian Islands Expedition)

Focus: Bathymetric mapping of deep-sea habitats (Earth Science - This activity can be easily modified for Grades 5-6)

In this activity, students will be able to create a two-dimensional topographic map given bathymetric survey data, will create a three-dimensional model of landforms from a two-dimensional topographic map, and will be able to interpret two- and three-dimensional topographic data.

Climate, Corals, and Change

http://oceanexplorer.noaa.gov/explorations/05stepstones/background/education/ss_2005_climate.pdf
(14 pages, 441k) (from the North Atlantic Stepping Stones 2005 Expedition)

Focus (Physical Science) - Paleoclimatology

In this activity, students will be able to explain the concept of "paleoclimatological proxies" and describe at least two examples, describe how oxygen isotope ratios are related to water temperature, and interpret data on oxygen isotope ratios to make inferences about the growth rate of deep-sea corals. Students will also be able to define "forcing factor" and will be able to describe at least three forcing factors for climate change and discuss at least three potential consequences of a warmer world climate.

Deep Sea Coral Biodiversity

http://oceanexplorer.noaa.gov/explorations/deepeast01/background/education/media/deepseacorals.pdf
(3 pages, 152k) (from the 2001 Deep East Expedition)

Focus: George's Bank

In this activity, students will research life found on tropical coral reefs to develop an understanding of the biodiversity of the ecosystem; students will research life found in deep-sea coral beds to develop an understanding of the biodiversity of the ecosystem; and students will compare the diversity and adaptations of tropical corals to deep-sea corals.

Other Resources

http://oceanservice.noaa.gov/education/kits/corals/welcome.html – The National Ocean Service Coral Reef Discovery Kit, with a variety of coral reef-related lessons, information, and activities.

http://www.coris.noaa.gov/ – NOAA's Coral Reef Information System

http://www.csc.noaa.gov/benthic/mapping/techniques/sensors/laserline.htm – Information about laser line scan technology

http://response.restoration.noaa.gov/kids/kids.html – Click on "Coral Reefs and Oil Spills: A Guided Tour" for a basic overview of coral ecology, types of things that can harm coral, and see how resource managers go about response and restoration efforts; from the National Ocean Service Office of Response and Restoration

http://www.carolina.com/tips/02pdfs/march_tips_high.pdf — Article on miniature coral reef aquaria, focussing on a turnkey system

http://saltaquarium.about.com/gi/dynamic/offsite.htm?site=http://www2.hawaii.edu/%7Edelbeek/homerf1.html — Article

on "Your First Reef Aquarium: How to Create a Miniature Coral Reef System at Home"

http://saltaquarium.about.com/od/startinganaquarium/ — Web page with lots of articles and information on starting salt water aquaria

http://www.garf.org/ — Web site for the Geothermal Aquaculture Research Foundation with lots of information about corals in aquaria

Roberts, S. and M. Hirshfield. Deep Sea Corals: Out of sight but no longer out of mind. http://www.oceana.org/index.php?id=699 — Background on deep-water coral reefs

Ariadne, D. and D. Diamante-Fabunan. 2000. Coral Bleaching: the Whys, the Hows and What Next? OverSeas, The Online Magazine for Sustainable Seas. http://www.oneocean.org/overseas/200009/coral_bleaching_the_hows_and_whys_and_whats_next.html

http://www.coral.noaa.gov/ – Web site for NOAA's Coral Health and Monitoring Program

http://www.mesa.edu.au/friends/seashores/index.html – "Life on Australian Seashores" by Keith Davey on the Marine Education Society of Australasia website, with an easy introduction to Cnidaria, including their method of reproduction.

http://www-biol.paisley.ac.uk/courses/Tatner/biomedia/units/cnid1.htm – Phylum Cnidaria on Biomedia of the Glasgow University Zoological Museum on the Biological Sciences, University of Paisley, Scotland website; includes explanations of the major classes, a glossary of terms and diagrams and photos.

http://www.calacademy.org/calwild/2000fall/stories/seavenoms.html – Article from California Wild: "Stinging Seas - Tread Softly In Tropical Waters" by Gary C. Williams; an introduction to the venomous nature of tropical cnidarians, why and how they do it

http://oceanica.cofc.edu/activities.htm – Project Oceanica Web site, with a variety of resources on ocean exploration topics

National Science Education Standards

Content Standard A: Science As Inquiry

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

Content Standard B: Physical Science

- Transfer of energy

Content Standard C: Life Science

- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard F: Science in Personal and Social Perspectives

- Populations, resources, and environments

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 e.* The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.
- *Fundamental Concept f.* Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy." Some regions of the

ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

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 c.* The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.
- *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 a.* The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.
- *Fundamental Concept b.* Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
- *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 d.* New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
- *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.

Send Us Your Feedback

We value your feedback on this lesson.
Please send your comments to:
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