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Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition

Design a Reef!

[adapted from the Gulf of Mexico Deep Sea Habitats 2003 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, or overhead projector with transparencies for group discussions.

TEACHING TIME
One or two 45-minute class periods, plus time for student research

SEATING ARRANGEMENT
Groups of 4-6 students

MAXIMUM NUMBER OF STUDENTS
30

KEY WORDS
Coral reef
Bonaire
Habitat
Niche

BACKGROUND INFORMATION
Coral reefs provide habitats for some of the most diverse biological communities on Earth. Most people have seen photographs and video images of shallow-water coral reefs, and many have visited these reefs in person. Historically, scientists have believed that reef-building corals were confined to relatively shallow depths because many of these corals have microscopic algae called zooxanthellae (pronounced "zoh-zan-THEL-ee") living inside their soft tissues. These algae are often important for the corals' nutrition and growth, but require sunlight for photosynthesis. The maximum depth for reef-building corals was assumed to be about 150 m, since light levels below this

depth are not adequate to support photosynthesis. Recently, though, ocean explorers have discovered extensive mounds of living coral in depths from 400 m to 700 m—depths at which there is virtually no light at all! These deep-water corals do not contain zooxanthellae, and do not build the same types of reef that are produced by shallow-water corals. But recent studies indicate that the diversity of species in deep-water coral ecosystems may be comparable to that of coral reefs in shallow waters, and that there are just as many species of deep-water corals (slightly more, in fact) as there are species of shallow-water corals.

Coral reefs provide a variety of benefits including value for recreation and tourism industries, protecting shorelines from erosion and storm damage, supplying foods that are important to many coastal communities, and providing promising sources of powerful new antibiotic, anti-cancer and anti-inflammatory drugs (for more information about drugs from the sea, visit the Ocean Explorer Web site for the 2003 Deep Sea Medicines Expedition (http://oceanexplorer.noaa.gov/explorations/03bio/welcome.html). Despite their importance, many of Earth's coral reefs appear to be in serious trouble due to causes that include over-harvesting, pollution, disease, and climate change (Bellwood et al., 2004). In the Caribbean, surveys of 302 sites between 1998 and 2000 show widespread recent mortality among shallow- (≤ 5 m depth) and deep-water (> 5 m depth) corals. Remote reefs showed as much degradation as reefs close to human coastal development, suggesting that the decline has probably resulted from multiple sources of long-term as well as short-term stress (Kramer, 2003; for additional information about threats to coral reefs, see "More About the Coral Reef Crisis" in the introduction to this Expedition Education Module).

Despite these kinds of data and growing concern among marine scientists, visitors continue to be thrilled by the "abundance and diversity of life on coral reefs." This paradox is an example of "shifting baselines," a term first used by fishery biologist Daniel Pauly. A baseline is a reference point that allows us to recognize and measure change. It's how certain things are at some point in time. Depending upon the reference point (baseline), a given change can be interpreted in radically different ways. For example, the number of salmon in the Columbia River in 2007 was about twice what it was in the 1930s, but only about 20% of what is was in the 1800s. Things look pretty good for the salmon if 1930 is the baseline; but not nearly as good compared to the 1800's. The idea is that some changes happen very gradually, so that we come to regard a changed condition as "normal." When this happens, the baseline has shifted. Shifting baselines are a serious problem, because they can lead us to accept a degraded ecosystem as normal—or even as an improvement (Olson, 2002). So, people who have never seen a coral reef before may still find it to be spectacular, even though many species have disappeared and the corals are severely stressed.

One of the few coral systems that seems to have escaped the recent coral reef crisis is found in the coastal waters of Bonaire (part of the Netherlands Antilles in the southwestern Caribbean). A 2005 survey of the state of Bonaire's reefs (Steneck and McClanahan, 2005) found that they were among the healthiest reefs in the Caribbean, even though dramatic changes have occurred among corals and other reef species. This means that Bonaire's reefs have unique importance as baselines for comparison with other Caribbean coral reef ecosystems. Detailed mapping of Bonaire's shallow- and deep-water coral reefs is a top priority for protecting these ecosystems, as well as for defining a baseline for investigating and possibly restoring other coral reef systems. This mapping is the focus of the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition.

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, review the introductory essays for the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition at http://oceanexplorer.noaa.gov/explorations/08bonaire/welcome.html.

   If you are not already familiar with coral reefs, you may also want to review the coral reef tutorials at nos.noaa.gov/education/kits/corals/, as well as essays and trip logs from the 2007 Cayman Island Twilight Zone Expedition (http://oceanexplorer.noaa.gov/explorations/07twilightzone/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: such as, where, when and on what it feeds; where it lives; who its enemies are. Have students brainstorm the characteristics they would use to describe the niche.

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. To get the thought processes started, brainstorm some of these roles. Students may recognize the need for a source of energy (which implies one or more food webs), including some means for disposing of wastes, and a source of oxygen.

   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.

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 are very important to reef growth, and 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 web for our model reef system. Ask students how many more links could reasonably be added to the food web 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). 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

ASSESSMENT

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

EXTENSIONS

1. Visit oceanexplorer.noaa.gov to keep up to date with the latest Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition discoveries.

2. For more information, activities, and lessons about coral reefs, visit the National Ocean Service Coral Reef Discovery Kit at oceanservice.noaa.gov/education/kits/corals/welcome.html.

3. Discuss the concept of "shifting baselines," and why this is relevant to environmental and conservation issues. Brainstorm examples of shifting baselines from students' own experience. You may also want to visit http://www.shiftingbaselines.org/index.php for more information about this concept and its relevance to ocean conservation.

4. Discuss the "coral reef crisis" and what students might do to help protect and restore coral reefs. Visit http://www.coralreef.noaa.gov/outreach/thingsyoucando.html and http://www.publicaffairs.noaa.gov/25list.html for ideas. A key concept is that the current environmental conditions on Earth are not the result of a single event or human action; they are the result of countless individual decisions that collectively can have huge—and often unforeseen—impacts.

MULTIMEDIA LEARNING OBJECTS

http://www.learningdemo.com/noaa/ – Click on the links to Lessons 3, 12, and 13 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Food, Water, and Medicine from the Sea, and Ocean Pollution.

OTHER RELEVANT LESSON PLANS FROM THE OCEAN EXPLORATION PROGRAM

Let's Go to the Video Tape!

http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/videotape.pdf (11 pages; 327kb PDF) (from the 2007 Cayman Island Twilight Zone Expedition)

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

In this activity, students will recognize and identify some of the fauna groups found in deep-sea coral communities, infer possible reasons for observed distribution of groups of animals in deep-sea coral 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.

Treasures in Jeopardy

http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/treasures.pdf (8 pages; 278kb PDF) (from the 2007 Cayman Island Twilight Zone Expedition)

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

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

Big Fleas Have Little Fleas

[http://oceanexplorer.noaa.gov/explorations/03mountains/background/education/media/mts_fleas.pdf] (7 pages, 1Mb) (from the 2003 Mountains in the Sea Expedition)

Focus: Physical structure in benthic habitats (Life Science)

In this activity, students will recognize that natural structures and systems often display recurrent complexity over many scales of measurement, infer the importance of structural complexity to species diversity and abundance in benthic habitats, and discuss ways that octocorals may modify seamount habitats to make these habitats more suitable for other species.

Climate, Corals, and Change

http://oceanexplorer.noaa.gov/explorations/06davidson/background/edu/climate.pdf (14 pages, 441k) (from the 2006 Exploring Ancient Coral Gardens 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.

Biodiversity of Deep-Sea Corals

http://oceanexplorer.noaa.gov/explorations/03mountains/background/education/media/mts_deepseacoral.pdf (3 pages, 1Mb) (from the Mountains in the Sea 2003 Expedition)

Focus: Deep-sea corals

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; students will compare the diversity and adaptations of tropical corals to deep-sea corals.

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 LINKS AND RESOURCES

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

oceanexplorer.noaa.gov – Web site for NOAA's Ocean Exploration program

oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html – Ocean Explorer photograph gallery

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/library/weekly/aa031399.htm – Background article on coral reef aquaria

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

http://www.coralreef.noaa.gov/outreach/thingsyoucando.html – "Things You Can Do to Protect Coral Reefs" from NOAA's Coral Reef Conservation Program

http://www.publicaffairs.noaa.gov/25list.html – "25 Things You Can Do To Save Coral Reefs," also from NOAA

Bellwood, D.R., T.P. Hughes, C. Folke, and M. Nyström. 2004. Confronting the coral reef crisis. Nature 429:827-833 (http://www.eco.science.ru.nl/Organisme%20&%20Milieu/PGO/PG03/Bellwood.pdf)

Kramer, P. 2003. Synthesis of coral reef health indicators for the Western Atlantic: Results of the AGRRA program (1997-2000). In Lang, J.C. (ed.) 2003. Status of coral reefs in the Western Atlantic: results of initial surveys, Atlantic and Gulf Rapid Reef Assessment (AGRRA) program. Atoll Research Bulletin 496. 639 pp. Washington, DC. (http://www.botany.hawaii.edu/faculty/duffy/arb/496/Synthesis.pdf)

Olson, R. 2002. Slow-motion disaster below the waves. Los Angeles Times, November 17, 2002, pp. M.2 (http://www.actionbioscience.org/environment/olson.html)

Steneck, R.S., S.N. Arnold, and J.B. Brown, eds. 2005. A report on the status of the coral reefs of Bonaire in 2005 with advice on the establishment of fish protection areas. Pew Charitable Trust Report, 64 pp. (http://www.bmp.org/pdfs/Status-of-coral-reef-2005.pdf)

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 Web site; includes explanations of the major classes, a glossary of terms and diagrams and photos

http://www.calacademy.org/research/izg/calwildfall2000.pdf – 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://www.mcbi.org/publications/pub_pdfs/Deep-Sea%20Coral%20issue%20of%20Current.pdf – A special issue of *Current: the Journal of Marine Education* on deep-sea corals.

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

Diamante-Fabunan, D. 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.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
- Understanding 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 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 f. Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).

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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FOR MORE INFORMATION

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