Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition

Easy as Pi

[adapted from the 2003 Charleston Bump Expedition]

Focus
Structural complexity in coral reef communities

Grade Level
5-6 (Life Science/Mathematics)

Focus Question
How do living and non-living structures affect coral reef habitats?

Learning Objectives
Students will be able to describe the importance of structural features that increase surface area in coral reef habitats.

Students will be able to quantify the relative impact of various structural modifications on surface area in model habitats.

Students will be able to give examples of organisms that increase the structural complexity of their communities.

Materials
❐ Modeling clay
❐ Marbles, golf balls, or other spherical objects
❐ Wooden dowels, matchsticks, or similar objects; diameter approximately 6 mm or less

Audio/Visual Materials
❐ Chalkboard, marker board, or overhead projector with transparencies for brainstorming sessions

Teaching Time
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
Structural complexity

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 virtu-

ally 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.

One of the most conspicuous features of coral reef habitats is spatial variety. Reef "rock" formations (they are actually the limestone skeletons of corals) include flat pavements, boulders, caves and overhangs. On top of this foundation, living corals, sponges, and other animals add to the variety, creating countless "microhabitats" in many sizes, making it possible for many different kinds of organisms to live in close proximity. In this activity, student will create models that illustrate this spatial variety, and will calculate the effect of various structures on the total surface area of their model habitats.

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 http://oceanservice.noaa.gov/education/tutorial_corals/welcome.html, 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 habitats. Have students brainstorm what functions or benefits an organism receives from its habitat. The students, list should include food, shelter (protection), and appropriate nursery areas. Lead an introductory discussion of the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition. You may want to show students some images from the Ocean Explorer Web sites (oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html).

   Explain the concept of "microhabitat." Be sure students understand how the combination of various coral "rock" formations and organisms with complex physical forms (like branching corals and sponges) can offer many different types of habitat and as a result can provide food, shelter, and nursery places for many different kinds of organisms.

   Discuss how a benthic community might benefit from structural modifications that increase available surface area. Depending upon the type of modification, these benefits could include increased shelter for different species, increased availability of food for surface grazers, more sites for larvae to attach, and more places upon which non-motile organisms may attach.

3. Tell student groups that they are to find out what sorts of habitats explorers on the 2008: Exploring Coral Reef Sustainability with New Technologies Expedition might find. Have students read relevant trip logs from the 2007 Cayman Island Twilight Zone Expedition (http://oceanexplorer.noaa.gov/explorations/07twilightzone/welcome.html). Have students pay particular attention to organisms that modify or enhance habitats by increasing surface area (such as branching corals and sponges), and find pictures or illustrations of typical organisms. In addition to printed reference books, the Ocean Explorer Gallery (oceanexplorer.noaa.gov, click on "Gallery") and http://biodidac.bio.uottawa.ca have lots of images suitable for downloading.

4. Tell student groups that their assignment is to "engineer" a model benthic habitat site to increase the available surface area and habitat variety, based on living and non-living features typical of the habitats they have researched. Have each group begin with a flat surface of modeling clay, approximately 20 cm x 20 cm. Students will then modify this surface by adding various shapes (dowels, spheres and partial spheres, hollowed out shapes representing caves and overhangs, circular depressions in the clay surface representing scours, etc.), keeping track of the total surface area available in their model habitat. Potential features include boulders, caves, overhangs, scours (curved depressions in the clay surface), and cylindrical corals. You may want to add more complex shapes such as sponges with holes in their surface or branched corals depending upon available time and students' ambition.

Prior to beginning the modeling assignment, you may want to review formulas for calculating the surface area of various geometric shapes:

Area of a rectangle = Length • Width
Area of a circle = π • (radius)^2
Area of a cylinder = height • π • (radius)^2
Area of a sphere = 4 • π • (radius)^2

Each group will begin with roughly the same area (20 cm • 20 cm = 400 cm^2). As they add features to increase surface area, be sure students remember to subtract the surface area that is lost due to the "footprint" of their object. If they add a half sphere to represent a boulder, for example, they have to subtract the area of the circle occupied by the "footprint" of the boulder. Groups should prepare a written summary of their modifications to the initial flat surface, including calculations of the surface area increase produced by each modification. Tell students that their models will be judged according to the following formula:

Score = (Percent Area Added to the Beginning Surface) • (Number of Different Shapes)

5. Have each group present and discuss their model habitats, explaining what natural features (actually found in deep-water communities) are represented by each shape in the model. Lead a discussion of which organisms and shapes add the most variety to a benthic community. Branched shapes can greatly increase total surface area without occupying very much "footprint" space. Highly folded surfaces can multiply available surface area by orders of magnitude, and are an important feature of many biological structures (such as lungs, gills, and other surfaces where diffusion takes place). Porous structures such as sponges, gravel, or loose sediment also greatly multiply available surface and provide different-sized shelter spaces as well as increase surface area. Based on this discussion, have students describe the features of the most diverse benthic habitat they can imagine, and compare this hypothetical vision to what scientists actually find during the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition.

The Bridge Connection

http://www.vims.edu/bridge/ - Scroll over "Ocean Science Topics" in the menu on the left, then "Habitats", then "Coastal", tehn "Coral Reefs"

The "Me" Connection

Have students write a short essay describing structures in their own bodies that increase available surface area, and why these structures are important.

Connections to Other Subjects

English/Language Arts, Physical Science

Assessment

Models and written reports prepared in Step 4 provide opportunities 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 http://oceanservice.noaa.gov/education/tutorial_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://coralreef.noaa.gov/getinvolved/whatyoucando/ 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

A Piece of Cake

http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/cake.pdf (7 pages; 282kb PDF) (from the 2007 Cayman Island Twilight Zone Expedition)

Focus: Spatial heterogeneity in deep-water coral communities (Life Science)

In this activity, students will be able to explain what a habitat is, describe at least three functions or benefits that habitats provide, and describe some habitats that are typical of deep-water hard bottom communities. Students will also be able to explain how organisms, such as deep-water corals and sponges, add to the variety of habitats in areas such as the Charleston Bump.

Deep Gardens

http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/deepgardens.pdf (11 pages; 331kb PDF) (from the 2007 Cayman Island Twilight Zone Expedition)

Focus: Comparison of deep-sea and shallow-water tropical coral communities (Life Science)

In this activity, students will compare and contrast deep-sea coral communities with their shallow-water counterparts, describe three types of coral associated with deep-sea coral communities, and explain three benefits associated with deep-sea coral communities. Students will explain why many scientists are concerned about the future of deep-sea coral communities.

Friend, Foe, or...

http://oceanexplorer.noaa.gov/explorations/05stepstones/background/education/ss_2005_friendfoe.pdf (5 pages, 331k) (from the North Atlantic Stepping Stones 2005 Expedition)

Focus (Life Science) - Symbiotic relationships with corals

In this activity, students will be able to define and describe symbiotic, mutualistic, commensal, parasitic, facultative and obligatory relationships between organisms; describe at least three species that have symbiotic relationships with corals; and discuss whether these relationships are mutualistic, commensal, or parasitic.

Architects of the Deep Reef

http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_architects.pdf (5 pages, 388k) (from the Gulf of Mexico Deep Sea Habitats 2003 Expedition)

Focus: Reproduction in Cnidaria (Life Science)

In this activity, students will be able to identify and describe at least five characteristics of Cnidaria coral, compare and contrast the four classes of Cnidaria, and describe typical reproductive strategies used by Cnidaria. Students will also be able to infer which of these strategies are likely to be used by the deep-sea coral *Lophelia pertusa*, and will be able to describe the advantages of these strategies.

Chemists Without Backbones

http://oceanexplorer.noaa.gov/explorations/03bio/background/edu/media/meds_chemnobackbones.pdf (4 pages, 356k) (from the 2003 Deep Sea Medicines Expedition)

Focus: Benthic invertebrates that produce pharmacologically-active substances (Life Science)

In this activity, students will be able to identify at least three groups of benthic invertebrates that are known to produce pharmacologically-active compounds and will describe why pharmacologically-active compounds derived from benthic invertebrates may be important in treating human diseases. Students will also be able to infer why sessile marine invertebrates appear to be promising sources of new drugs.

Keep Away

http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_keepaway.pdf (5 pages, 424k) (from the 2003 Gulf of Mexico Deep Sea Habitats Expedition)

Focus: Effects of pollution on diversity in benthic communities (Life Science)

In this activity, students will discuss the meaning of 'biological diversity' and compare and contrast the concepts of 'variety' and 'relative abundance' as they relate to biological diversity. Given information on the number of individuals, number of species, and biological diversity at a series of sites, students will make inferences about the possible effects of oil drilling operations on benthic communities.

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://coralreef.noaa.gov/getinvolved/whatyoucando/ – "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/page1.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://spo.nmfs.noaa.gov/olo6thedition/09–Feature%20Article%203.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/la-oceans-series,0,7783938.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 C: Life Science
- Structure and function in living systems
- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard D: Earth and Space Science
- Structure of the Earth system

Content Standard F: Science in Personal & 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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