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Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition

What's Down There?

[adapted from the 2007 Cayman Island Twilight Zone Expedition]

Focus
Mapping Coral Reef Habitats

Grade Level
9-12 (Life Science/Earth Science)

Focus Question
What type of data do scientists collect to monitor coral reefs, and how are these data used?

Learning Objectives
Students will be able to access data on selected coral reefs and manipulate these data to characterize these reefs.

Students will be able to explain the need for baseline data in coral reef monitoring programs.

Students will be able to identify and explain five ways that coral reefs benefit human beings.

Students will be able to identify and explain three major threats to coral reefs.

Materials
- ❒ Copies of "Coral Habitat Data Worksheet," one copy for each student group
- ❒ Copies of "Habitat Analysis Grid" photocopied onto transparencies; one for each student group

Audio/Visual Materials
None

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

Seating Arrangement
Groups of 3-4 students

Maximum Number of Students
32

Key Words
Coral reef
Bonaire
Benthic habitat
Monitoring

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 lesson, students will learn about some sources of data on coral reefs, and will have hands-on experience with manipulating and interpreting some of these data.

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.

   Review instructions and Web site contents provided in the "Coral Habitat Data Worksheet"

   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. Discuss the importance of coral reefs, and reasons that they are threatened. You may want to mention the purpose and activities of the U. S. Coral Reef Task Force (visit http://coralreef.gov/ for more information). Discuss the importance of monitoring to identify threatened reef areas and to improve understanding of reef ecosystems.

   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).

3. Tell students that their assignment is to use online data tools to investigate nearshore coral reef habitats around Molokai Island, Hawaii. Assign one of the following habitat maps to each student group: 40, 43, 44, 46, 47. Provide each student group with a "Coral Habitat Data Worksheet." Have each student group complete the tasks described.

4. Lead a discussion of students' results. Students should realize that a primary purpose of habitat surveys is to establish baselines that can be compared with subsequent surveys to detect changes in coral reef systems. Discuss the variability of habitats around Molokai Island. Students should recognize that there often is considerable variability among habitats, even though the habitats are in the same geographic area.

   An important part of developing a comprehensive understanding of coral reef ecosystems is knowing how reefs change over time in response to various types of environmental change. Particularly striking is the difference between nearshore habitats on the southwestern end of the island compared to habitats on the northeastern end. Ask students to speculate on possible reasons for these differences. Images of adjacent land in the two areas show striking differences in topography; the northeastern coast is much more rugged and appears more heavily eroded than the southwestern coast.

   Remind students that heavy sediment loads are often detrimental to reef-building corals. Students may also speculate that volcanic activity may be involved, since some of the habitats on the northeastern coast are described as "Uncolonized Volcanic Rock" and "Uncolonized Pavements." Molokai was formed by two volcanoes: West Molokai (also called Mauna Loa) on the western half of the island and East Molokai (also known as Wailau) on the eastern two-thirds of Molokai. Much of the East Molokai volcano grew below sea level. In addition, parts of this volcano have collapsed in giant landslides, which contribute to the heavily eroded appearance as well as the influx of sediment to adjacent coastal waters. Some pieces of landslide debris are so large that they have been given individual names as seamounts.

The Bridge Connection

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

The "Me" Connection

Have students write a short essay on why coral reefs are personally important. They should include specific actions that individuals might take to reduce threats to coral reef systems.

Connections to Other Subjects

English/Language Arts, Mathematics

Assessment

Written reports and discussions in Steps 3 and 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. Online data and tools introduced in this activity can be used for a wide variety of additional activities related to coral reefs and coral reef management. Many of these data and tools can be accessed through "Discover NOAA's Data" at the CoRIS home page (http://coris.noaa.gov/) and the "Corals Roadmap to Resources" (http://oceanservice.noaa.gov/education/kits/corals/supp_coral_roadmap.html). The National Ocean Service Coral Reef Discovery Kit (http://oceanservice.noaa.gov/education/kits/corals/welcome.html) also contains a variety of other coral reef-related lessons, information, and activities.

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

Cut-off Genes

http://oceanexplorer.noaa.gov/explorations/04mountains/background/edu/media/MTS04.genes.pdf (12 pages, 648k) (from the Mountains in the Sea 2004 Expedition)

Focus: Gene sequencing and phylogenetic expressions (Life Science)

In this activity, students will be able to explain the concept of gene-sequence analysis; and, given gene sequence data, students will be able to draw inferences about phylogenetic similarities of different organisms.

Feeding in the Flow

http://oceanexplorer.noaa.gov/explorations/03bump/background/edu/media/03cbfeedflow.pdf (6 pages, 268k) (from the 2003 Charleston Bump Expedition)

Focus: Effect of water currents on feeding efficiency in corals (Life Science)

In this activity, students will be able to describe at least two ways in which current flow may affect the feeding efficiency of particle-feeding organisms and explain how interactions between current flow and the morphology of a particle-feeding organism may affect the organism's feeding efficiency. Students will also be able to identify at least two environmental factors in addition to current flow that may affect the morphology of reef-building corals.

Cool Corals

http://oceanexplorer.noaa.gov/explorations/03edge/background/edu/media/cool.pdf (7 pages, 476k) (from the 2003 Life on the Edge Expedition)

Focus: Biology and ecology of *Lophelia* corals (Life Science)

In this activity, students will describe the basic morphology of *Lophelia* corals and explain the significance of these organisms, interpret preliminary observations on the behavior of *Lophelia* polyps, and infer possible explanations for these observations. Students will also discuss why biological communities associated with *Lophelia* corals are the focus of major worldwide conservation efforts.

Keep It Complex!

http://oceanexplorer.noaa.gov/explorations/03bump/background/edu/media/03cb_complex.pdf (5 pages, 272k) (from The Charleston Bump 2003 Expedition)

Focus: Effects of habitat complexity on biological diversity (Life Science)

In this activity, students will be able to describe the significance of complexity in benthic habitats to organisms that live in these habitats and will describe at least three attributes of benthic habitats that can increase the physical complexity of these habitats. Students will also be able to give examples of organisms that increase the structural complexity of their communities and infer and explain relationships between species diversity and habitat complexity in benthic communities.

Are You Related?

http://oceanexplorer.noaa.gov/explorations/05deepcorals/background/edu/media/05deepcorals_related.pdf (11 pages, 465k) (from the Florida Coast Deep Corals 2005 Expedition)

Focus: Molecular genetics of deepwater corals (Life Science)

In this activity, students will define "microsatellite markers" and explain how they may be used to identify different populations and species, explain two definitions of "species," and describe processes that result in speciation. Students will also use microsatellite data to make inferences about populations of deep-sea corals.

How Does Your (Coral) Garden Grow?

http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_growth.pdf (6 pages, 456k) (from the Gulf of Mexico Deep Sea Habitats 2003 Expedition)

Focus: Growth rate estimates based on isotope ratios (Life Science/Chemistry)

In this activity, students will identify and briefly explain two methods for estimating the age of hard corals, learn 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.

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

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/PGO3/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 C: Life Science

- Interdependence of organisms

Content Standard D: Earth and Space Science
- Geochemical cycles

Content Standard E: Science and Technology
- Understandings about science & technology

Content Standard F: Science in Personal and Social Perspectives
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

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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For More Information

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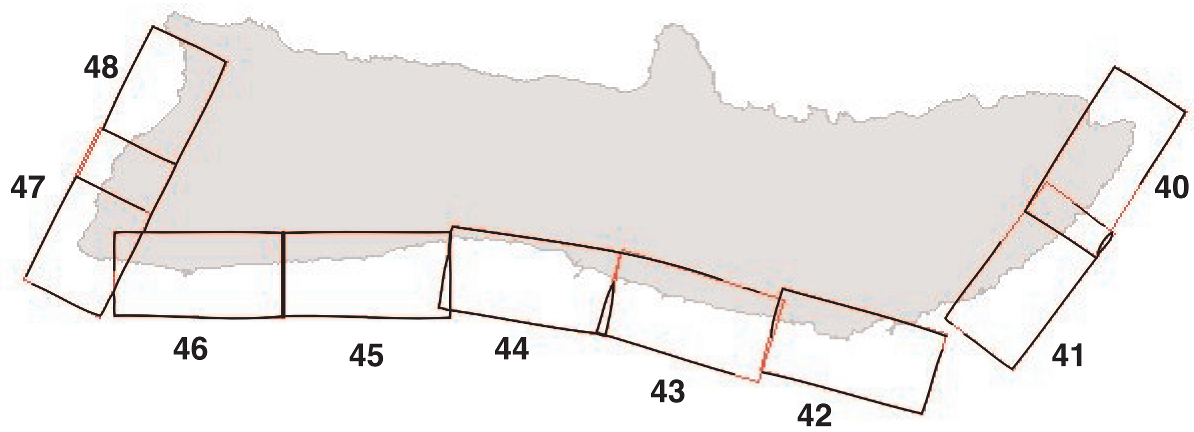
Student Handout

Coral Habitat Data Worksheet

1. Obtain a map of benthic habitats for your assigned area:

   a. Point your Web browser to http://ccma.nos.noaa.gov/products/biogeography/hawaii_cd/index.htm/. This is the home page for NOAA's Center for Coastal Monitoring and Assessment's "Benthic Habitats of the Main Hawaiian Islands" Web site.

   b. Click on "Maps," which opens an index page that shows a map of the main Hawaiian Islands. Click on "Molokai" to open a new index page showing areas around the island for which maps are available. The Molokai maps are numbered as follows:



   c. Click on your assigned number to open a map of the nearshore marine habitats in the corresponding area around Molokai. Habitat types on these maps have been outlined and coded as shown in the legend for each map. Maps 41, 42, and 45 have not been "classified," which means that habitat types have not been outlined and coded. Print the map on a color printer. You may also want to save this file for future reference.

2. Using the transparent "Habitat Analysis Grid," count the number of grid squares occupied by each habitat type. Each grid square corresponds to an area of 0.01 square kilometers.

   Make a table summarizing the total area of each type of habitat shown on your map.

3. Construct a pie chart showing the relative areas for each type of habitat.

Student Handout

Habitat Analysis Grid

(one square represents approximately 0.01 km^2)