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Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition

Sonar Simulation

(adapted from the Steamship Portland 2003 Expedition)

Focus
Side scan sonar

Grade Level
7-8 (Earth Science/Physical Science)

Focus Question
How can side-scan sonar be used to locate objects underwater?

Learning Objectives
Students will be able to describe side-scan sonar.

Students will be able to compare and contrast side-scan sonar with other methods used to search for underwater objects.

Students will be able to make inferences about the topography of an unknown and invisible landscape based on systematic discontinuous measurements of surface relief.

Materials
- ❒ Shoeboxes, one for each student group
- ❒ Plaster of Paris, 1 – 2 lb for each student group
- ❒ Woodworking awl or sharp nail, 3 – 4 mm diameter
- ❒ Masking tape
- ❒ Pingpong balls, 2 for each student group
- ❒ Wooden dowel, approximately 3 mm diameter, 30 cm long, one for each student group
- ❒ Colored pencils, five colors for each student group
- ❒ Ruler, one for each student group
- ❒ Graph paper
- ❒ Copies of "Sonar Simulation Activity," one copy for each student group

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

Teaching Time
One 45-minute class period

Seating Arrangement
Groups of 2-4 students

Maximum Number of Students
32

Key Words
Coral reef
Bonaire
Sonar
Side-scan sonar
Topography

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.

The technological centerpiece of the Bonaire Expedition is a collection of robots known as Autonomous Underwater Vehicles (AUVs). AUVs operate without a pilot or cable to a ship or submersible. This independence allows AUVs to cover large areas of the ocean floor, as well as to monitor a specific underwater area over a long period of time. AUVs used to map Bonaire coral reefs will provide scientists with video and sonar images that can be used to create maps of the reefs.

Sonar (which is short for SOund NAvigation and Ranging) systems are used to determine water depth, as well as to locate and identify underwater objects. In use, an acoustic signal or pulse of sound is transmitted into the water by a sort of underwater speaker known as a "transducer." The transducer may be mounted on the hull of a ship, or may be towed in a container called a "towfish." If the seafloor or other object is in the path of the sound pulse, the sound bounces off the object and returns an "echo" to the sonar transducer. The system measures the strength of the signal and the time elapsed between the emission of the sound pulse and the reception of the echo. This information is used to calculate the distance of the object, and an experienced operator can use the strength of the echo to make inferences about some of the object's characteristics. Hard objects, for example, produce stronger echoes that softer objects. This is a general description of "active sonar." "Passive sonar" systems do not transmit sound pulses. Instead, they "listen" to sounds emitted from marine animals, ships, and other sources. Subbottom profiler systems are another type of sonar system that emits low frequency sound waves that can penetrate up to 50 meters into the seafloor. Visit http://ocean.noaa.gov/technology/tools/sonar/sonar.html for more information about sonar systems.

Side-scan sonar systems use transducers housed in a towfish, usually dragged near the seafloor, to transmit sound pulses directed toward the side of the ship, rather than straight down. Return echoes are continuously recorded and analyzed by a processing computer. These data are used to construct images of the seafloor made up of dark and light areas. These images can be used to locate seafloor features and possible obstructions to navigators, including shipwrecks (visit http://oceanexplorer.noaa.gov/technology/tools/sonar/sonar.html for more information). Multibeam sonar system are used to make bathymetric maps and create three-dimensional images of the seafloor. Multibeam sonars send out multiple, simultaneous sonar beams in a fan-shaped pattern that is perpendicular to the ship's track. This allows the seafloor on either side of the ship to be mapped at the same time as well as the area directly below (visit http://oceanexplorer.noaa.gov/technology/tools/sonar/sonar.html for more information). Sonar technology is also capable of detecting objects that are in the water column, so it may also be possible to obtain information about how fishes are using Bonaire's coral habitats at the same time as the reefs are being mapped.

In this lesson, students will learn about side-scan sonar, and use mock sonar set-ups to experience some of the difficulties encountered when trying to locate objects or map the ocean floor.

Learning Procedure

[Note: This lesson is adapted from the "Shoebox Bathymetry" activity on the Ocean World Web site, http://oceanworld.tamu.edu/educators/props_of_ocean/activities/PO_systems.htm.]

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).

- Prepare "mystery bathymetry" shoeboxes. Mix plaster of Paris, and pour a 1 – 2 cm thick layer into the bottom of each shoebox. Make irregular mounds of plaster in one area to simulate rough topography. Embed one ping-pong ball somewhere in the rough topography, and another pingpong ball in a smoother area. Allow plaster to harden. Punch five rows of holes 3 – 4 mm in diameter in the lid of the shoebox with an awl or nail. Space the holes 2 cm apart over the surface of the lid. Temporarily fasten the lids to the boxes with masking tape.

2. 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). Discuss the importance of monitoring and the need for baselines as a means for recognizing changes in reef communities over time.

   Describe the role of underwater robots and side-scan sonar in surveying Bonaire coral reefs. Say that sonar is short for "sound navigation ranging," and uses sound waves to locate underwater objects by measuring the time it takes for a transmitted sound wave to be reflected back to its source. The sound wave is transmitted through a transducer, which is analogous to a speaker in a radio. Side-scan uses a transducer housed in a hollow container called a towfish that is towed through the water 10 to 20 feet above the bottom. The transducer emits sound waves to either side of the towfish, and measures the time it takes for the waves to be reflected back to the towfish. These measurements are processed into an image that resembles an aerial photograph, and can be viewed in real-time on a computer monitor aboard the towing vessel. A differentially corrected global positioning system (DGPS) is used to guide the towing vessel along predetermined search paths, as well as to identify points of interest on the side-scan image. This allows searchers to return to any point on the image for further investigation. Side-scan sonar does not depend upon light and can be used under conditions that would make searching by divers dangerous or impossible. Because it typically covers a swath of 60 to 120 feet at about 2 miles per hour, it is a very efficient way to search large areas. For these reasons, side-scan sonar has been used increasingly over the last few years to search for drowning victims.

3. Tell students that their assignment is to map an unexplored and invisible landscape. Distribute one copy of "Sonar Simulation Activity" to each student group. When students have completed their bathymetry graphs, have each group show their graphs to the entire class and report their conclusions about the mystery landscape. After each group has reported their conclusions, have them open their box, and compare the actual topography with their predictions.

4. When all groups have made their presentations, ask students how their investigations could be improved. Students should realize that this activity does not simulate side-scan sonar, or even conventional sonar; it is more like the centuries-old method used by mariners who lowered a lead weight attached to a measured line until the weight touched the bottom (or some object resting on the bottom). A conventional sonar system would provide a continuous record of depth directly beneath a ship. This would improve resolution along the search path, but there would still be gaps between the paths that are much greater than the area actually imaged. Side-scan sonar would fill in these gaps, and give an almost continuous picture of the search area. Students should also realize that rough topography can obscure other topo-

graphic features, so better resolution is especially important when there are boulders, reefs, or other irregular objects in a search area.

The Bridge Connection

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

The "Me" Connection

Ask students to imagine that they are asked to locate a small boat that has sunk in a nearby water body, and write a short essay describing the procedures and equipment they would use to complete this task.

Connections to Other Subjects

English/Language Arts, Earth Science

Assessment

Experimental notes and oral reports prepared in Step 3 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. The National Ocean Service Coral Reef Discovery Kit (http://oceanservice.noaa.gov/education/kits/corals/welcome.html) 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.

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 - Paleoclimatology (Physical Science)

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

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://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/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 D: Earth and Space Science

- Structure of the Earth system

Content Standard E: Science and Technology
- Abilities of technological design

Content Standard F: Science in Personal and Social Perspectives
- Natural hazards
- Risks and benefits

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 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

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Student Handout

Sonar Simulation Activity

1. Assign a different color to each of the five rows of holes on your shoebox.

2. Select one row (it doesn't matter which one). Insert the wooden dowel into each hole in the row and measure the depth from the surface (lid) by marking it with your finger, pulling the dowel out, and measuring the distance with your ruler. Record this measurement on your graph paper in the appropriate color. The x-axis of your graph paper should correspond to the numbers of the holes in each row (the first hole should correspond to number 1 on the x-axis, the second hole to number 2, etc.). The y-axis of your graph should correspond to the depth measurements.

3. Continue doing Step 2 until the depth through all holes in the first row has been measured. Connect the dots on your graph with the appropriate color.

4. Based on this one row of measurements, predict what the topography is like inside your shoebox. Record your predictions.

5. Repeat Step 2 on the next row of holes using a different color pencil. Record data on the same graph used for the first row, using the appropriate color.

6. Examine your data for the second row. Are they the same? What does this new information reveal? Record any changes in your predictions.

7. Repeat Steps 5 and 6 for the remaining three rows of holes. Now wait for further instructions from your teacher.