*Lophelia* II 2009:
Deepwater Coral Expedition: Reefs Rigs, and Wrecks

# Sound Pictures

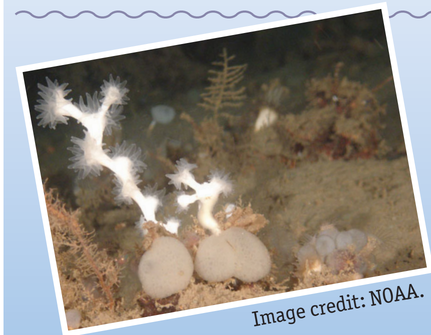
Image credit: NOAA.


Image credit: NOAA.

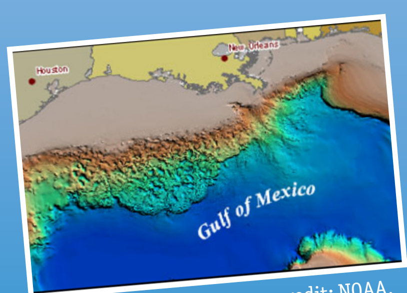

Image credit: NOAA.


Image credit: Chuck Fisher, NOAA.

Image captions on Page 2.

lesson plan

## Focus
Sonar

## Grade Level
9-12 (Physical Science)

## Focus Question
How can scientists obtain information about the bathymetry of the seafloor?

## Learning Objectives
- Students will be able to explain the concept of sonar.
- Students will be able to describe the major components of a sonar system.
- Students will be able to explain how multibeam and sidescan sonar systems are useful to ocean explorers.
- Students will be able to simulate sonar operation using a motion detector and a graphing calculator.

## Materials
- Copies of *Sonar Inquiry Guide*; one copy for each student group
- Graphing calculator, data logger, and motion sensor (e.g., Lego® NXT system with ultrasonic sensor; Vernier motion detector, logger, and graphing calculator); may be shared among several students groups [NOTE: an alternative method is also provided that does not require this equipment (see Learning Procedure, Step 1)]
- Graph paper
- Boxes, cans, and other objects to create a model seafloor
- String
- Meter stick
- Masking tape
- Felt tip marker for marking string

## Audio-Visual Materials
None

## Teaching Time

One or two 45-minute class periods, plus time for student inquiry

## Seating Arrangement

Groups of two to four students

## Maximum Number of Students

32

## Key Words

Deep-sea coral
Sonar
Sidescan sonar
Multibeam sonar
Bathymetry

## Background Information

[*NOTE: Explanations and procedures in this lesson, except for the Inquiry Guide, are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators usually will need to adapt the language and instructional approach to styles that are best suited to specific student groups.*]

Deepwater coral ecosystems on hard substrates in the Gulf of Mexico are often found in locations where hydrocarbons are seeping through the seafloor. Hydrocarbon seeps may indicate the presence of undiscovered petroleum deposits, and make these locations potential sites for exploratory drilling and possible development of offshore oil wells. Responsibility for managing exploration and development of mineral resources on the Nation's outer continental shelf is a central mission of the U.S. Department of the Interior's Minerals Management Service (MMS). Besides managing the revenues from mineral resources, an integral part of this mission is to protect unique and sensitive environments where these resources are found.

For the past three years, NOAA's Office of Ocean Exploration and Research (OER) has collaborated with MMS on a series of expeditions to locate and explore deep-sea chemosynthetic communities in the Gulf of Mexico. These communities not only indicate the potential presence of hydrocarbons, but are also unique ecosystems whose importance is presently unknown. To protect these ecosystems from negative impacts associated with exploration and extraction of fossil fuels, MMS has developed rules that require the oil and gas industry to avoid any areas where geophysical survey data show that high-density chemosynthetic communities are likely to occur. Similar rules have been adopted to protect archeological sites and historic shipwrecks.

**Images from Page 1 top to bottom:**
*Lophelia pertusa* colony with polyps extended.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept24/media/green_canyon_lophelia.html

The ROV from SeaView Systems, Inc., is prepared for launch.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept20/media/rov_prep.html

Multibeam bathymetry allows terrain models to be created for large areas of the seafloor.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept21/media/gomex_multibeam.html

*Lophelia pertusa* create habitat for a number of other species at a site in Green Canyon.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept24/media/green_canyon_lophelia.html

OER-sponsored expeditions in 2006, 2007, and 2008 were focused on discovering seafloor communities near seeping hydrocarbons on hard bottom in the deep Gulf of Mexico; detailed sampling and mapping at selected sites; studying relationships between coral communities on artificial and natural substrates; and gaining a better understanding of processes that control the occurrence and distribution of these communities. The *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks will take place aboard the NOAA Ship *Ronald H. Brown*, and is directed toward exploring deepwater natural and artificial hard bottom habitats in the northern Gulf of Mexico with emphasis on coral communities, as well as archaeological studies of selected shipwrecks in the same region. Expedition scientists will use the *Jason II* remotely operated vehicle (ROV) to:

- Make collections of *Lophelia*, other corals, and associated organisms from deepwater reefs;
- Collect quantitative digital imagery of characterization of deepwater reef sites and communities;
- Collect near-bottom oceanographic data;
- Deploy cameras, current meters, and samplers for microbes and larvae;
- Collect push cores; and
- Conduct archaeological/ biological investigations on deep water shipwrecks.

Before any of this work can begin, scientists need accurate and detailed information about seafloor topography. Previous expeditions have provided this information using multibeam sonar that can measure water depth, locate underwater objects, and provide detailed bathymetric maps and three-dimensional images.

This lesson guides a student inquiry into sonar technology and a simulation of sonar operation.

## Learning Procedure

NOTE: Portions of this lesson are adapted from the National Ocean Service lesson, "See That Sound," http://oceanservice.noaa.gov/education/classroom/lessons/23_hydrosurvey_see.pdf. A similar activity using a Calculator-Based Laboratory® system was developed by Steven Stevenoski of Lincoln High School, Wisconsin Rapids, WI as part of the Teachers Experiencing Antarctica and the Arctic Program (see http://tea.armadaproject.org/teainfo/TEA_flyer_0203AA.pdf for information on the TEA program, and http://tea.armadaproject.org/activity/stevenoski/seeingtheseafloorusingsoundmultibeamsidescansonar_main.html for Stevenoski's lesson)

1. Depending upon the length of your class period, at least two periods will probably be needed to complete this lesson. Part A of

the *Inquiry Guide* may be assigned as homework, or may be done in class if suitable library or Internet research resources are available. Introductory discussion and instructions may take place during part of a class period prior to the day on which students begin working on Part B of the *Inquiry Guide*. In this way, an entire period may be devoted to completing Part B. Wrap-up discussions can then take place during part of a subsequent class period.

To prepare for this lesson:
- Review introductory essays for the *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks at http://oceanexplorer.noaa.gov/explorations/09lophelia/welcome.html;
- Review procedures and questions on the *Sonar Inquiry Guide* and make copies for student groups;
- Collect materials needed for the sonar simulation activity;
- Identify locations (such as your classroom floor) where students will create their ocean floors, and mark two points two to four meters apart with masking tape (see *Inquiry Guide* Step B1); and
- Run through the sonar simulation activity with the equipment you plan to use and make notes of any additional directions needed for this specific equipment. If graphing calculators and motion sensors are not available, you can have your students do an alternative bathymetry simulation using the traditional (i.e., pre-sonar) technique for measuring depth with a lead line.

2. Briefly introduce the *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks and describe deepwater coral communities. You may want to show images from http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html. Point out the variety of organisms found in these communities, and briefly discuss their potential importance. Explain to students that while deepwater coral reefs were discovered in the Gulf of Mexico nearly 50 years ago, very little is known about the ecology of these communities or the basic biology of the corals that produce them. Mention some of the scientific activities planned for the *Lophelia* II 2009 expedition, and explain that the first step to this kind of exploration is to obtain detailed maps of the area to be studied. Since much of this area is unexplored, mapping has been a major objective for previous expeditions. Point out that the oldest scientific organization in the U.S., the Office of Coast Survey was created in 1807 to prepare a hydrographic survey of the entire U.S. coast by order of President Thomas Jefferson (the Office of Coast Survey is now part of NOAA's National Ocean Service).

   In Jefferson's day, depths were commonly measured using a "lead line", which was simply a rope marked at fixed intervals (usually fathoms; one fathom equals six feet) attached to a lead cylinder which was lowered to the bottom. When the line went slack, depth was estimated from the marks on the rope. Often, the bottom of the lead cylinder was hollowed out and filled with wax. When the lead was brought back on board the survey ship, bits of sand, shell, mud, etc. stuck in the wax gave the surveyors clues about the materials present on the seafloor.

3. Ask students how hydrographic data on deep ocean bottom topography are obtained by modern hydrographers. Some students will probably be familiar with the concept of sonar. If not, they may have heard about this technology in connection with submarine warfare. Give each student group a copy of the *Sonar Inquiry Guide*, and explain that their assignment is to learn about sonar and work with other groups to conduct a simulation of a bathymetric survey using sonar techniques (or lead line techniques if you plan to use the alternative simulation procedure). Assign Part A as homework, or have students complete this work during part of a class period.

   Provide any additional instructions needed for the simulation equipment, then have students begin Part B or C of the *Inquiry Guide*. When each group has collected depth soundings from their model ocean floor, have them exchange their data with another group. Instruct students NOT to look at other groups' models until they have plotted the depth data and recorded their predictions about the objects.

4. Lead a discussion of the results of students' background research.
   1) SONAR is an acronym for "SOund NAvigation and Ranging"

   2) The basic components of a sonar system are:
   - A transmitter capable of emitting an acoustic signal;
   - A receiver capable of detecting echoes from the transmitted signal; and
   - A processing unit to interpret the reflected signal.

   Students may also mention:
   - A cable to connect the processor with the transmitter and receiver;
   - A transducer (which is analogous to the antenna on a radio transmitter or receiver); and
   - A towfish to allow the transducer(s) to be towed behind the survey vessel.

   3) Transducers for sidescan sonar are often towed behind the survey vessel because:
   - Being able to tow the transducer at some depth below the surface means that there is less water through which the acoustic signal must travel, so there is less absorption and scattering of the acoustic energy, and consequently, the signal is stronger;

- The transducer is less affected by the surface motion of the survey vessel (particularly rolling motion); and
- The transducer can be towed beneath a thermocline (the boundary between two water masses of different temperature) which can interfere with the acoustic signal.

4) Higher frequencies give better image resolution (more detail) but travel shorter distances than lower frequencies.

5) Sidescan and multibeam sonars both transmit a fan-shaped pattern of acoustic signals. Sidescan systems continuously record the strength of the return echo caused by the transmitted signal bouncing off of the sea floor or other object. Multibeam systems, on the other hand, record depth by measuring the time elapsed between transmission of a sound signal and detection of the reflected signal by the sonar's receiver. Multibeam sonar transmitters are generally attached to a vessel, rather than being towed as is typical of sidescan systems.

The simulations illustrate the importance of sample intervals in obtaining an accurate depiction of the bottom, as well as the difficulty of drawing inferences about three-dimensional shapes from two-dimensional data. You may want to show one or two images produced by sidescan sonar, which provides three-dimensional bottom data (see http://ocean.noaa.gov/technology/tools/sonar/sonar.html for more information about sidescan sonar).

## The Bridge Connection

http://www.vims.edu/bridge/ – Scroll over "Ocean Science Topics," then click "Chemistry," or "Atmosphere" for links to resources about ocean chemistry or climate change.

## The "Me" Connection

Show students a description of the ultrasonic sensor used in the Lego® NXT system, or the Vernier motion detector. Explain that these devices are based on the same principle as sonar, but may be useful in ways that have nothing to do with detecting underwater objects. Have students write a brief essay describing one example of how sound ranging techniques might be of personal benefit. If they need a hint you may want to mention devices that warn backing vehicles of the presence of objects, or ultrasound medical imaging devices.

## Connections to Other Subjects

English/Language Arts, Mathematics

## Assessment

Students' *Inquiry Guide* reports and class discussions provide opportunities for assessment.

## Extensions

1. Have students visit http://oceanexplorer.noaa.gov/explorations/09lophelia/welcome.html to find out more about the *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks.

2. Visit http://www.ocean-institute.org/edu_programs/materials/P/PDF/PDF_SFE/A_SONAR.pdf and/or http://www.education-world.com/a_lesson/00-2/lp2083.shtml for other activities about sonar.

## Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html
Click on the links to Lessons 3, 5, and 6 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, and Deep-Sea Benthos.

## Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

(*All of the following Lesson Plans are targeted toward grades 9-12*)

**What's the Difference?**
(PDF, 300 kb) (from the Lophelia II 2008 Expedition)
http://oceanexplorer.noaa.gov/explorations/08lophelia/background/edu/media/difference.pdf

Focus: Identification of biological communities from survey data (Life Science)

In this activity, students will be able to calculate a simple similarity coefficient based upon data from biological surveys of different areas, describe similarities between groups of organisms using a dendrogram, and infer conditions that may influence biological communities given information about the groupings of organisms that are found in these communities.

**The Robot Archaeologist**
(17 pages, 518k) (from AUVfest 2008)
http://oceanexplorer.noaa.gov/explorations/08auvfest/background/edu/media/robot.pdf

Focus: Marine Archaeology/Marine Navigation (Earth Science/Mathematics)

In this activity, students will design an archaeological survey strategy for an autonomous underwater vehicle (AUV); calculate expected position of the AUV based on speed and direction of travel; and calculate course correction required to compensate for the set and drift of currents.

**My Wet Robot**
(300kb) (from the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition)
http://oceanexplorer.noaa.gov/explorations/08bonaire/background/edu/media/wetrobot.pdf

Focus: Underwater Robotic Vehicles (Physical Science)

In this activity, students will be able to discuss the advantages and disadvantages of using underwater robots in scientific explorations, identify key design requirements for a robotic vehicle that is capable of carrying out specific exploration tasks, describe practical approaches to meet identified design requirements, and (optionally) construct a robotic vehicle capable of carrying out an assigned task.

**Where Am I?**
(PDF, 4 pages, 344k) (from the 2003 Steamship Portland Expedition)
http://oceanexplorer.noaa.gov/explorations/03portland/background/edu/media/portlandwhereami.pdf

Focus: Marine navigation and position finding (Earth Science)

In this activity, students identify and explain at least seven different techniques used for marine navigation and position finding, explain the purpose of a marine sextant, and use an astrolabe to solve practical trigonometric problems.

**Where's My 'Bot?**
(492kb) (from the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition)
http://oceanexplorer.noaa.gov/explorations/08bonaire/background/edu/media/wheresbot.pdf

Focus: Marine Navigation (Earth Science/Mathematics)

In this activity, students will estimate geographic position based on speed and direction of travel and integrate these calculations with GPS data to estimate the set and drift of currents.

**Cool Corals**
(7 pages, 476k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/corals.pdf

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.

**This Old Tubeworm**
(10 pages, 484k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/old_worm.pdf

Focus: Growth rate and age of species in cold-seep communities (Life Science)

In this activity, students will be able to explain the process of chemosynthesis, explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps, and construct a graphic interpretation of age-specific growth, given data on incremental growth rates of different-sized individuals of the same species. Students will also be able to estimate the age of an individual of a specific size, given information on age-specific growth in individuals of the same species.

**What's Down There?**
(8 pages; 278kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/whatsdown.pdf

Focus: Mapping Coral Reef Habitats (Life Science/Earth Science)

Students will be able to access data on selected coral reefs and manipulate these data to characterize these reefs, and explain the need for baseline data in coral reef monitoring programs. Students also will be able to identify and explain five ways that coral reefs benefit human beings, and identify and explain three major threats to coral reefs.

**Submersible Designer**
(4 pages, 452k) (from the 2002 Galapagos Rift Expedition)
http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr9-12_l4.pdf

Focus: Deep Sea Submersibles (Physical Science)

In this activity, students will understand that the physical features of water can be restrictive to movement; understand the importance of design in underwater vehicles by designing their own submersible; and understand how submersibles such as *Alvin* and *Abe*, use energy, buoyancy, and gravity to enable them to move through the water.

**Living in Extreme Environments**
(12 pages, 1Mb) (from the 2003 Mountains in the Sea Expedition)
http://oceanexplorer.noaa.gov/explorations/03mountains/background/education/media/mts_extremeenv.pdf

Focus: Biological Sampling Methods (Biological Science)

In this activity, students will understand the use of four methods commonly used by scientists to sample populations; understand how to gather, record, and analyze data from a scientific investigation; begin to think about what organisms need in order to survive; and understand the concept of interdependence of organisms.

**What Was for Dinner?**
(5 pages, 400k) (from the 2003 Life on the Edge Expedition)
http://oceanexplorer.noaa.gov/explorations/03edge/background/edu/media/dinner.pdf

Focus: Use of isotopes to help define trophic relationships (Life Science)

In this activity, students will describe at least three energy-obtaining strategies used by organisms in deep-reef communities and interpret analyses of $^{15}N$, $^{13}C$, and $^{34}S$ isotope values.

**Chemosynthesis for the Classroom**
(9 pages, 276k) (from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Chemo.pdf

Focus: Chemosynthetic bacteria and succession in chemosynthetic communities (Chemistry/Biology)

In this activity, students will observe the development of chemosynthetic bacterial communities and will recognize that organisms modify their environment in ways that create opportunities for other organisms to thrive. Students will also be able to explain the process of chemosynthesis and the relevance of chemosynthesis to biological communities in the vicinity of cold seeps.

**This Life Stinks**
(9 pages, 280k) (from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Stinks.pdf

Focus: Methane-based chemosynthetic processes (Physical Science)

In this activity, students will be able to define the process of chemosynthesis and contrast this process with photosynthesis. Students will also explain the process of methane-based chemosynthesis and explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps.

## Other 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.*

http://oceanexplorer.noaa.gov – Web site for NOAA's Ocean Exploration Program

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book – A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focusing on the exploration, understanding, and protection of Earth as a whole system

http://oceanservice.noaa.gov/topics/navops/hydrosurvey – National Ocean Service hydrographic survey Web site

http://www.oceanexplorer.noaa.gov/technology/tools/sonar/sonar.html – NOAA's Ocean Explorer Web page about sonar

http://www.l-3klein.com/; http://www.geoacoustics.co.uk/df-sonar.htm; http://www.wesmar.com/ – Web sites for commercial sidescan sonar manufacturers

http://www.gomr.mms.gov/index_common.html - Minerals Management Service Web site

http://www.gomr.mms.gov/homepg/lagniapp/chemcomp.pdf (PDF) - *Chemosynthetic Communities in the Gulf of Mexico* teaching guide to accompany a poster with the same title, introducing the topic of chemosynthetic communities and other ecological concepts to middle and high school students http://www.coast-nopp.org/ - Resource Guide from the Consortium for Oceanographic Activities for Students and Teachers, containing modules, guides, and lesson plans covering topics related to oceanography and coastal processes

http://cosee-central-gom.org/ - Web site for The Center for Ocean Sciences Education Excellence: Central Gulf of Mexico collaborative

## National Science Education Standards

**Content Standard A: Science As Inquiry**

- Understandings about scientific inquiry

**Content Standard B: Physical Science**

- Structure and properties of matter

**Content Standard E: Science and Technology**

- Abilities of technological design
- Understandings about science and technology

**Content Standard F: Science in Personal and Social Perspectives**

- Natural resources
- 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 g.* The ocean is connected to major lakes, watersheds and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments and pollutants from watersheds to estuaries and to the ocean.
*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 d.* Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.
*Fundamental Concept g.* There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

**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 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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## Acknowledgements

This lesson plan was produced by Mel Goodwin, PhD, The Harmony Project, Charleston, SC for the National Oceanic and Atmospheric Administration. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: http://oceanexplorer.noaa.gov

## Sound Pictures

# Sonar Inquiry Guide

### A. Background Research

1. SONAR is an acronym. What does it mean?

2. What are the basic components of a sonar system?

3. Why are transducers for sidescan sonar often contained in a towfish that is towed behind the survey vessel?

4. What are the advantages and disadvantages of high frequency (500 kHz and up) sonar signals compared to lower frequency (50 kHz or 100 kHz) signals?

5. What is the difference between sidescan sonar and multibeam sonar?

## Sound Pictures

# Sonar Inquiry Guide - continued

### B. Sonar Simulation

1. **Create an Ocean Floor Model** – In the location identified by your teacher, arrange at least six objects of varying height and shape between two points two to four meters apart. Using chairs or stools for support, stretch a string between these points, 1.0 to 1.5 meters above the floor.

2. **Map an Ocean Floor Model** – Your assignment is to use sound waves to create images of objects on an Ocean Floor Model. Your teacher will explain specific instructions for the ultrasonic ranging system that you will use to complete this assignment. Here are the rest of the steps for creating your bathymetric map:

   a. Your ranging system should be set up to collect distance data as a function of time.

   b. Go to the Ocean Floor Model assigned by your teacher, and have one member of your group hold the ultrasonic sensor (or motion detector) at one end of the string.

   c. Trigger the system to begin data collection, and move the sensor smoothly along the string to the other end. It is important that the sensor is moved at a constant rate of speed, which should be slow enough to allow the system to collect enough data points to adequately map the objects. If the motion detector is moved slowly, more data points (distance measurements) will be collected and a more detailed image will be produced.

   d. Exchange depth data with another group, and graph the depth measurements as a function of time. Since the elapsed time is proportional to the linear distance along the string, the series of distance measurements should create a profile of the objects beneath the string. Actually, a reverse profile will be created, since taller objects will be closer to the string, so the distance to tall objects will be smaller than the distance to shorter objects. You can correct this distortion with a simple data transformation that calculates object height as the absolute value of the difference between the measured distance (from your ranging system) and the height of the string above the floor:

   object height = |(measured distance) – (height of string)|

   Write your predictions about these objects, then look at the Ocean Floor Model to see how accurate your predictions were.

## Sound Pictures

# Sonar Inquiry Guide - continued

### C. Alternative Bathymetric Simulation (optional)

1. Set up an Ocean Floor as described in Step B1 above, but mark the string at three-inch intervals before stretching it above the objects.

2. Mark a second string about 2 m long at one-inch intervals and attach a weight (fishing sinker, metal nut, etc) to one end of the string.

3. Using the Ocean Floor Model created in Step B1, use the weighted string to obtain depth measurements at three-inch intervals.

4. Exchange depth data with another group and graph the depth measurements as a function of position on the string. Since these are point measurements, you will have to guess about the actual shape of the objects on the simulated Ocean Floor. Write your predictions about these objects, then look at the Model to see how accurate your predictions were.