OCEAN EXPLORATION & RESEARCH

Section 5: Underwater Robots for Volume 2: How Do We Explore?

NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image credit: NOAA. For more information, see the following Web site: http://oceanexplorer.noaa.gov/okeanos/welcome.html

What *Little Herc* Saw

Focus
Use of robotics for ocean exploration

Grade Level
7-8 (Physical Science/Technology)

Focus Question
How are remotely operated vehicles used aboard *Okeanos Explorer* to help explore Earth's deep ocean?

Learning Objectives
- Students will discuss the importance of robotic vehicle technology to the ocean exploration strategy used aboard the *Okeanos Explorer*.
- Students will discuss how information from underwater robots about biological and geological features is relevant to the concept of biodiversity.
- Students will demonstrate a process for analyzing video data from the *Okeanos Explorer*'s underwater robot.

Materials
- Copies of *Some Things Little Herc Saw*; one for each student group
- Digital or print copies of still imagery (see Learning Procedure Step 1e)

Audio Visual Materials
- (Optional) Video projector or other equipment to display downloaded images (see Learning Procedure, Step 1c)

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Groups of two to four students

Maximum Number of Students
30

Key Words and Concepts
Ocean Exploration
Okeanos Explorer
Robot

Imagery
Video

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

On August 13, 2008, the NOAA Ship *Okeanos Explorer* was commissioned as "America's Ship for Ocean Exploration;" the only U.S. ship whose sole assignment is to systematically explore Earth's largely unknown ocean. The strategy for accomplishing this mission is to use state-of-the-art technologies to search the ocean for anomalies; things that are unusual and unexpected. When an anomaly is found, the exploration strategy shifts to obtaining more detailed information about the anomaly and the surrounding area. An important concept underlying this strategy is the distinction between exploration and research. As a ship of discovery, the role of *Okeanos Explorer* is to locate new features in the deep ocean, and conduct preliminary investigations that provide enough data to justify follow-up by future expeditions.

The *Okeanos Explorer* strategy involves three major activities:

- Underway reconnaissance;
- Water column exploration; and
- Site characterization.

Underway reconnaissance involves mapping the ocean floor and water column while the ship is underway, and using other sensors to measure chemical and physical properties of seawater. Water column exploration involves making measurements of chemical and physical properties "from top to bottom" while the ship is stopped. In some cases these measurements may be made routinely at pre-selected locations, while in other cases they may be made to decide whether an area with suspected anomalies should be more thoroughly investigated. Site characterization involves more detailed exploration of a specific region, including obtaining high quality imagery, making measurements of chemical and physical seawater properties, and obtaining appropriate samples.

In addition to state-of-the-art navigation and ship operation equipment, this strategy depends upon four types of technology:

- Telepresence;
- Multibeam sonar mapping;
- CTD (an instrument that measures conductivity, temperature, and depth) and other electronic sensors to measure chemical and physical seawater properties; and
- A Remotely Operated Vehicle (ROV) capable of obtaining high-quality imagery and samples in depths as great as 4,000 meters.

In the summer of 2010, years of planning, field trials, and state-of-the-art technology came together for the first time on the ship's maiden voyage as part of the INDEX-SATAL 2010 Expedition. This expedition was an international collaboration between scientists from the United States and Indonesia to explore the deep ocean in the Sangihe Talaud Region. This region is located in the 'Coral Triangle', which is the

NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image credit: NOAA. For more information, see the following Web site: *http://oceanexplorer.noaa.gov/okeanos/welcome.html*

Okeanos Explorer Vital Statistics:

Commissioned: August 13, 2008; Seattle, Washington
Length: 224 feet
Breadth: 43 feet
Draft: 15 feet
Displacement: 2,298.3 metric tons
Berthing: 46, including crew and mission support
Operations: Ship crewed by NOAA Commissioned Officer Corps and civilians through NOAA's Office of Marine and Aviation Operations (OMAO); Mission equipment operated by NOAA's Office of Ocean Exploration and Research

For more information, visit *http://oceanexplorer.noaa.gov/okeanos/welcome.html*.
Follow voyages of America's ship for ocean exploration with the *Okeanos Explorer* Atlas at *http://www.ncddc.noaa.gov/website/google_maps/OkeanosExplorer/mapsOkeanos.htm*

global heart of shallow-water marine biodiversity. A major objective of the INDEX-SATAL 2010 Expedition was to locate submarine volcanoes, hydrothermal vents, chemosynthetic ecosystems, and seamounts associated with active geologic processes in Indonesia's deep sea. A key component in the expedition's quest for anomalies was to look for changes in chemical properties of seawater that can indicate the presence of these features. For more information about the INDEX-SATAL 2010 Expedition, see *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html*.

Map showing the Coral Triangle region – the most diverse and biologically complex marine ecosystem on the planet. The Coral Triangle covers 5.7 million square km, and matches the species richness and diversity of the Amazon rainforest. Although much of the diversity within the Coral Triangle is known, most still remains unknown and undocumented. Image courtesy of *www.reefbase.org*. *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/hires/coral_triangle_hires.jpg*

The site characterization component of the *Okeanos Explorer* exploration strategy depends heavily upon remotely operated vehicles (ROVs). These are unoccupied robots usually linked to an operator aboard a surface ship by a group of cables. Most ROVs are equipped with one or more video cameras and lights, and may also carry other equipment such as a manipulator or cutting arm, water samplers, equipment for collecting samples, and measuring instruments to expand the vehicle's capabilities for gathering data about the deep-ocean environment.

For the INDEX-SATAL 2010 Expedition, the NOAA Ship *Okeanos Explorer* carried *Little Hercules*, an ROV originally developed by a team of engineers at Dr. Robert Ballard's Institute for Exploration (IFE) at the University of Rhode Island for the primary purpose of gathering high quality video imagery. Nicknamed "*Little Herc*," the ROV proved to be well-suited to this purpose on a variety of successful missions for IFE, including providing the first and only images of John Kennedy's PT Boat, *PT-109*. Eventually, a much larger ROV named "*Hercules*" took over these tasks, and *Little Herc* became part of an exhibit at the Mystic Aquarium. This shore duty came to an end, however, when it became clear that *Okeanos Explorer*'s primary ROV would not be ready in time for the INDEX-SATAL 2010 Expedition. Through a collaboration between IFE and NOAA's Office of Ocean Exploration and Research, *Little Herc* was brought out of retirement and refitted specifically to meet the expedition's needs.

Little Herc is operated in tandem with a camera platform that carries 2,400 watts of lighting provided by HMI (hydrargyrum medium-arc iodide) arc lamps. This lighting illuminates the total darkness of the deep ocean, helps guide *Little Hercules*, and provides lighting for the high-definition video images of the ROV at work. The camera platform is named *Seirios*, after the name of the brightest star in the night sky (also called the Dog Star, sometimes spelled "Sirius"). *Little Herc* is attached to *Seirios* by a 30-m cable called the Remotely Operated Vehicle Tether, while the camera platform is attached to the *Okeanos Explorer*'s traction winch by a 17 mm Oceanographic Instrumentation and Control Cable which has an armored outer jacket with 3 power conductors and 3 optical fibers for transmitting data and control signals.

A variety of sensors are aboard the ROV for navigation and data collection. These include depth and altitude sensors, an Ultra Short Baseline Tracking System, full color imaging sonar, and a Seabird SBE 49 FastCAT CTD. Video equipment includes two Insite Pacific single CCD (charge-coupled device) high-resolution miniature color video cameras, one Insite Pacific triple CCD high-definition Zeus Plus video camera, two Deep Sea Power and Light 250-watt LED matrix lights, and two Deep Sea Power and Light 400-watt HMI arc lamps. For additional details about *Little Herc*, see the sidebar, The *Little Hercules* Remotely Operated Vehicle. For more information about other ROVs, visit *http://oceanexplorer.noaa.gov/technology/subs/rov/rov.html*.

This lesson introduces students to remotely operated vehicles and video imagery as they are used for ocean exploration aboard the *Okeanos Explorer*. In the future, students will have access to additional video imagery collected by ROVs as the *Okeanos Explorer* continues its voyages of discovery in Earth's deep ocean.

Learning Procedure

1. To prepare for this lesson:
   a) Review:
      - Introductory essays for the INDEX-SATAL 2010 Expedition (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html*); including *Little Hercules* ROV (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/rov/rov.html*);
      - Daily log entries for
        July 7 (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july07/july07.html*);
        July 24 (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july24/july24.html*); and
        August 6 (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/aug06/aug06.html*).

   You may want to assign one or more of these essays as background reading prior to beginning the rest of the lesson.
   (b) Review background information about the *Okeanos Explorer* exploration strategy and technologies.
   (c) Review procedures for analyzing ROV imagery beginning with Step 4. Depending upon available time, you may decide to have individual student groups analyze fewer images, then pool their results.
   (d) Make copies of *Some Things Little Herc Saw*; one copy for each student group.
   (e) Download the following image and video files from the INDEX-SATAL 2010 Expedition by going to: *http://oceanexplorer.noaa.gov/okeanos/edu/resources/media/movies/0711_site_k_transit_video.html*:
      20100711_01h56m25s04_ROVHD_TRANSIT.jpg
      20100711_01h56m44s04_ROVHD_TRANSIT.jpg
      20100711_01h57m05s04_ROVHD_TRANSIT.jpg
      20100711_01h57m25s04_ROVHD_TRANSIT.jpg
      20100711_01h57m49s04_ROVHD_TRANSIT.jpg

The *Little Hercules* Remotely Operated Vehicle

Little Hercules was developed by a team of engineers at Dr. Robert Ballard's Institute for Exploration (IFE) at the University of Rhode Island. Its primary purpose is to gather high quality video imagery in support of scientific research and ocean exploration. Major systems include:

- **Power** – 2,800 volts (AC) supplied from the surface; stepped down to 120 VAC by a transformer aboard *Little Herc;* further converted in the electronics pressure housing to 24 VDC (8A maximum load) and 12 VDC (0.6A maximum load)
- **Propulsion** – Four Technadyne 1020 electric thrusters; two oriented horizontally to provide forward, backward, and rotational motion, and two mounted to form a V when viewed from the front (vertran configuration) which provides up, down, and lateral movement
- **Onboard Control** – PC104 computer
- **Imaging** – Main Camera: One Insite Pacific triple CCD high-definition Zeus Plus HDTV camera with zoom and macro; Utility Cameras: Two Insite Pacific single CCD high-resolution miniature color video cameras
- **Lighting** – Two Deep Sea Power and Light 250-watt-equivalent LED matrix lights; Two Deep Sea Power and Light 400-watt HMI arc lamps
- **Navigation** – Ultrashort Baseline acoustic transponder (works in concert with ship-based system that calculates the ROV's underwater position)
- **Sensors** – Paroscientific 8B7000 pressure/depth sensor; Seabird SBE 49 FastCAT CTD; Tritech PA500 altimeter; Tritech Super SeaKing scanning sonar

These components are integrated within an aluminum frame that is supported in water by a flotation package of syntactic foam, which provides slightly positive buoyancy that is trimmed to neutral by the ROV's vertical thrusters. Most electronics are contained in a 10-inch diameter titanium pressure housing. The ROV is rated to a depth of 4,000 meters, and in air weighs 1,200 pounds.

Little Hercules is operated in tandem with a camera platform named *Seirios* that is equipped with a HD video camera identical to that on the ROV, as well as six HMI (hydrargyrum medium-arc iodide) arc lamps that provide a total of 2,400 watts of lighting. *Seirios* has no buoyancy module, and is intentionally much heavier than water to provide a buffer between the ROV and surface motion of the ship. *Little Hercules* is attached to *Seirios* by a 30-m cable called the Remotely Operated Vehicle Tether. *Seirios* is attached to the *Okeanos Explorer*'s traction winch by a 17 mm Oceanographic Instrumentation and Control Cable which has an armored outer jacket with 3 power conductors and 3 optical fibers for transmitting data and control signals. A traction winch has large diameter grooved drums that are designed to protect cables from excessive friction and bending under heavy load conditions.

Prior to every dive, the ROV crew reviews multibeam sonar maps of the proposed dive area, and develops a track-line that is the initial path that the ROV will follow. During a dive, the ROV pilots may modify the track-line as they receive requests from scientists aboard the ship and in Exploration Command Centers to obtain video images of certain features and organisms that the ROV encounters during its exploration.

20100711_01h58m11s04_ROVHD_TRANSIT.jpg
20100711_01h58m30s04_ROVHD_TRANSIT.jpg
20100711_01h58m39s04_ROVHD_TRANSIT.jpg
20100711_01h56m16s04_ROVHD_TRANSIT-300kb.mov

You may want to print the still images, but if possible it is preferable to have students work with these on classroom computers or their own computers. If students will not be using classroom computers, ensure that they will have access to the still image (.jpg) files.

(f) (Optional) You may also want to download images referenced in Steps 2 and 3, and/or additional examples of imagery from underwater robots (*http://oceanexplorer.noaa.gov/okeanos/media/slideshow/flash_slideshow.html* and *http://oceanexplorer.noaa.gov/okeanos/media/slideshow/video_playlist.html*).

(g) (Optional) Review the *Hands-On Activity Guides* included with the *Through Robot Eyes* lesson and decide whether you wish to have students complete one or more of these in addition to the image analysis activity described below. *Hands-On Activity Guides* are provided to introduce some basic systems used in many underwater robots to gather information for ocean exploration:

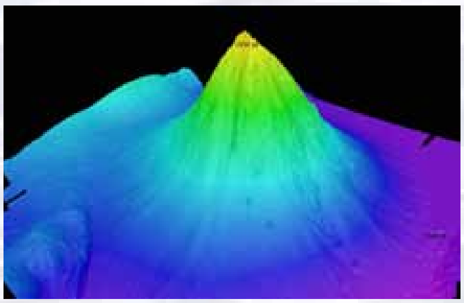
- *Getting Control with Microcontrollers*;
- *Making Things Happen with Servos*; and
- *Exploring with Sensors*.

The purpose of these activities is to introduce students and educators to materials, methods, and technologies that they can use for a wide variety of inquiries, activities, and projects that integrate skills in science, technology, engineering, and mathematics. These activities may be used at any grade level, depending upon available resources, curriculum content, and individual student needs. Unless students are already familiar with microcontrollers, the *Getting Control with Microcontrollers* activity should precede the other two.

2. Briefly introduce the NOAA Ship *Okeanos Explorer* and the INDEX-SATAL 2010 Expedition, and discuss why this kind of exploration is important (for background information, please see the lesson, *Earth's Ocean is 95% Unexplored: So What?*; *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/so_what.pdf*). Highlight the overall exploration strategy used by *Okeanos Explorer*, including the following points:
   - The overall strategy is based on finding anomalies;
   - This strategy involves
     - Underway reconnaissance;
     - Water column exploration; and
     - Site characterization;
   - This strategy relies on four key technologies:
     - Telepresence technologies that allow people to observe and interact with events at a remote location;
     - Multibeam sonar mapping system;
     - CTD and other electronic sensors to measure chemical and physical seawater properties; and
     - A Remotely Operated Vehicle (ROV) capable of obtaining high-quality imagery and samples in depths as great as 4,000 meters.

   You may want to show some or all of the images in the adjacent sidebar to accompany this review.

The ROV *Little Hercules* descends through deep water to an undersea volcano in the Celebes Sea to search for hydrothermal vents and associated ecosystems. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/1june29_hires.jpg



Okeanos Explorer's EM302 multibeam sonar mapping system produced this detailed image of the Kawio Barat seamount, which rises around 3800 meters from the seafloor. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/june26fig1_hires.jpg

Scientists in the Exploration Command Center at NOAA's Pacific Marine Environmental Laboratory in Seattle view live video from the *Okeanos Explorer's* ROV. Image courtesy NOAA
http://www.pmel.noaa.gov/images/headlines/ecc.jpg

Senior Survey Technician Elaine Stuart holds onto the CTD as it comes aboard the *Okeanos Explorer*. Image courtesy NOAA
http://www.moc.noaa.gov/oe/visitor/photos/photospage-b/CAP%20015.jpg

3. Briefly describe the capabilities of typical ROVs (you may want to show some images from *http://oceanexplorer.noaa.gov/technology/subs/rov/rov.html*). Conclude with the *Little Hercules* ROV, and explain that the primary purpose of this underwater robot is to gather high quality video imagery as part of site characterization activities. At this point you may want to show the video clip compilation referenced in Step 1f. Lead a discussion of how ocean explorers might use this imagery. Students should realize that in many cases this imagery provides the only indication of living organisms in sites being characterized. In addition, this imagery can provide data about geological formations and other environmental conditions that cannot be obtained with other data gathering instruments. Students should also realize that video imagery also has limitations, including:
   - coverage is limited to a relatively small area;
   - mobile organisms may avoid the moving ROV and/or lights used for video imaging; and
   - many organisms cannot be accurately identified from photographs alone.

   Show one of the still images downloaded in Step 1e, call students' attention to the red dots near the center of the image and ask for ideas about why these dots are present. Students should realize (possibly with your help) that these dots provide a scale that makes it possible to estimate the size of objects in the image. Explain that *Little Hercules*' video system has two lasers whose beams are parallel and are 10 cm apart. This places two bright dots on each image that establish the scale of the image.

4. Show students the video clip **20100711_01h56m16s04_ROVHD_TRANSIT-300kb.mov**. Say that this video was made by the ROV *Little Hercules* on July 11, 2010, during a dive to a volcanic cone-shaped seamount that turned out to be one of the most diverse sites visited by the INDEX-SATAL 2010 Expedition.

   Tell students that their assignment is to analyze eight still frames from this video, and estimate the number of different organisms in each frame, and the abundance of each organism. Provide each student group with one or more frames (either printed or on a computer), and a copy of *Some Things Little Herc Saw*. You may want to review the general biology of some of the organisms depicted on the handout, or assign each student group to provide this background for one or more organisms.

   Provide each student group with one or more of the images downloaded in Step 1e. It is easiest to examine these images on a computer since zoom functions are available, but printed copies may be used if adequate computer resources are not available.

   Instruct students to identify organisms as completely as possible. Students may protest that they have never seen most of the things in the video clip; and this is exactly the point! Deep-ocean explorers often encounter organisms that no one has seen before. All they can do is obtain good descriptions (which is why images are so valuable) and consult with experts who are familiar with organisms that appear similar. Having the ability to make these consultations at sea is one of the great benefits of telepresence. Tell students that during ROV dives, an Internet-based intercom system allows all participants, regardless of location, to easily

Table 1. Some Eventlog abbreviations for various groups of animals

ACN	Actinaria
APH	Amphipod
ART	Arthropod
ASR	Asteroid
BAR	Barnacle
BIO	Biology (Unspecified)
BIV	Bivalve
BRY	Bryozoan
CHI	Chiton
CHN	Chondrichthyes
CNI	Cnidarian
COR	Coral
CRA	Crab
CRI	Crinoid
ECN	Echiuran
EGG	Egg case
FEC	Fecal matter
FSH	Fish
GAS	Gastropod
GRO	Gromiid
HOL	Holothurian
HYD	Hydroid
ISO	Isopod
JFH	Jellyfish
LOB	Lobster
MAT	Bacterial Mat
MOL	Mollusk
NUD	Nudibranch
OCT	Octopus
OPH	Ophiuroid
PAG	Pagurid (hermit)
PEN	Pennatulacean
POL	Polychaete
SCA	Scale worm
SHI	Shrimp
SPO	Sponge
SQA	Squat lobster
SQD	Squid
STY	Stylasterid
TUN	Tunicate
URC	Urchin
USO	Unidentified sessile object
WOD	Wood
WOR	Worm
XEN	Xenophyophoran
ZOA	Zoanthid

Figure 1. Excerpt from Eventlog for July 11, 2010

2010-07-11	01:56:29	jonathanrose	FSH
2010-07-11	01:56:57	okeanosexplorer	we'll try to get a few for him
2010-07-11	01:57:10	okeanosexplorer	depth is 48m, heading is 57
2010-07-11	01:57:16	okeanosexplorer	458m
2010-07-11	01:57:18	cherissedupreez	SQA
2010-07-11	01:57:40	davebutterfield	the light-colored material around the base of the rocks is primarily coral debris.
2010-07-11	01:58:14	okeanosexplorer	large stalked CRI
2010-07-11	01:58:23	okeanosexplorer	SQA
2010-07-11	01:58:25	okeanosexplorer	SHI
2010-07-11	01:58:30	okeanosexplorer	STY's
2010-07-11	01:58:35	okeanosexplorer	with OPH's
2010-07-11	01:58:49	okeanosexplorer	very neat SPO's
2010-07-11	01:58:58	jonathanrose	FSH
2010-07-11	01:59:00	okeanosexplorer	purple COR
2010-07-11	01:59:13	dustinschomagel	ROV Depth 452 Hdg 62 deg
2010-07-11	01:59:34	okeanosexplorer	URC

communicate with all other participants. This real-time voice communication is supplemented by a real-time text-based tool called "the Eventlog," which allows each participant to write their personal observations to a common log. Log entries made by individuals can immediately be seen by all other users in real-time. The Eventlog software automatically records the date, time of entry, and author of each text observation.

Figure 1 shows the Eventlog entries during the time that the video clip was made. Table 1 lists some of the abbreviations that are used in Eventlog entries to name various organisms.

5. Have each student group present the results of their analyses. There is considerable variety of organisms in the video clip, and among the eight still frames.

Briefly discuss the concept of biodiversity. This concept is usually understood to include variety at several levels:

- **variety of ecosystems**: high biodiversity suggests many different ecosystems in a given area;
- **variety of species**: high biodiversity suggests many different species in a given area;
- **variety of interactions between species**; and
- **variety within species (genetic diversity)**: high biodiversity suggests a relatively high level of genetic variety among individuals of the same species.

The concept of biodiversity generally combines two measurements:

- the number of species in a given area; and
- how evenly individuals are distributed among these species.

Evenness is greatest when species are equally abundant. The simplest measure of species diversity is the number of species present in an environment. This is

So many images, so little time!

During the INDEX-SATAL 2010 Expedition, the *Okeanos Explorer*'s ROV team saved about 3,400 high-resolution still images. To make the images useful for later analyses (including the analyses done in this lesson), each image must be accompanied by certain information, including the geographic location and depth.

Each video file has a unique name that includes the date and time of the first frame as well as the camera source and a brief description. Individual frames from video files are selected by the ROV video team and saved as high-resolution JPEG images. The image filenames match the original video filename, but the date and time portions of the filenames are corrected to correspond with the actual time that the individual video frame was recorded.

Knowing the time that a specific frame was recorded makes it possible to retrieve information from other data files, including geographic location and depth. This information is included with each JPEG image, similar to the way that date and time are included with images from most digital cameras. For more details, see Pinner (2010).

called species richness. But there is more to diversity than just the number of species in an environment. A community that has more or less equal numbers of individuals within the species present is usually thought of as more diverse than a community that is dominated by one species.

Discuss these measurements as they apply to students' analyses of the eight still frames. There are many different species represented among the eight frames, but only a few are abundant in all of the frames. Many are only represented by one or two individuals in all eight frames. This is typical of biological communities that have relatively high biodiversity. If we did similar analyses of frames from video clips made in other locations, we could compare numbers of species and number of individuals within each species to get an idea about the relative diversity between the various locations.

Lead a discussion on the significance of biodiversity. The fact that diversity often decreases in stressed environments suggests that high diversity may be "good." On the other hand, it is important to realize that diversity can also be increased by changed or variable conditions (such as those at the boundary of two different types of habitat) or following a major change in a mature ecosystem (such as a forest fire). Encourage pro and con discussions of these questions, but be sure to challenge students to defend their positions. At some point in this discussion, ask students whether "unknown" is the same as "unimportant." You may want to cite examples in which obscure species proved to be directly important to humans, such as the Madagascar periwinkle that now provides a powerful cancer treatment; or the *Forcepia* sponges from deep-ocean habitats that have similar anti-cancer properties (for more information, see *http://oceanexplorer.noaa.gov/explorations/03bio/welcome.html*).

6. **Some Math Connections** – When scientists discuss biodiversity and populations of organisms, they often like to estimate the abundance of various species. One way to do this with video data is to navigate an underwater robot along a series of transects (a transect is a path along which data are collected) while recording video from a forward-looking camera. When the transects are completed, the video recording is reviewed and imaged organisms are identified and counted. The total counts for each species are divided by the total area of the transect to obtain an estimate of the density of each species. For example, if 50 corals belonging to a single species were counted in a video transect that covered 100 square meters, the density of that species would be

   50 corals / 100 square meters = 0.5 coral/square meter.

   Ask students how we might estimate the area covered during the video clip. Students should realize that we need to know the width of the area covered by each frame, and the total length of the transect. The width of the frames can be estimated using the laser dots (which are 10 cm apart). The spacing of these dots is similar on each of the eight still frames, and the width of the area covered is about 3.6 m.

   To find the length of the transect, we first need to know whether the ROV was headed in a straight line (more or less) during the time of the video clip. Checking the heading recorded for each of the eight frames, we find that the ROV's heading varied between 48.5 and 80.0 degrees. This is not exactly a straight line, but is OK for an approximation. Since we know the geographic location of each frame, we can find the distance between the location of the first frame (2° 50.84217' N, 125° 3..47277' E) and the location of the last frame (2° 50.84815' N, 125° 3.48355' E) using the spherical law of cosines formula:

$$d = \text{acos}\,(\sin(\text{lat1}) \bullet \sin(\text{lat2}) + \cos(\text{lat1}) \bullet \cos(\text{lat2}) \bullet \cos(\text{long2} - \text{long1})) \bullet R$$

where lat1, long1, lat2, and long2 are the latitude and longitude of points 1 and 2, respectively in radians, d is the distance between the points in km, and R is Earth's mean radius (6,371 km); latitude and longitude measurements in degrees may be converted to radians by dividing by 180 (or we can use an online calculator) which gives a distance between the locations of the first and last frame equal to 0.02282 km.

So, our estimate of the area covered during the video clip is

$$3.6 \text{ m} \bullet 22.8 \text{ m} = 82.1 \text{ m}^2$$

To calculate the density of the various types of organisms seen in the video clip, we would need to analyze the entire clip, counting each individual of each organism, then dividing the totals by the area of the video transect.

7. Discussion of underwater robots and image technology may also include the following components of technological literacy (ITEA, 2007):
   - **Core concepts of technology:** Underwater robots are composed of closely inter-related systems designed to meet specific requirements and constraints, which often involve trade-offs.
   - **Relationships between technologies and other fields of study**: Underwater robotics technology is closely linked to advancements in science and mathematics, and specific information requirements in these fields drive further innovation and invention.
   - **Effects of technology on the environment:** Underwater robotics technology provides new ways to monitor various aspects of the environment to provide information for decision-making.

8. If desired, have students complete the *Exploring with Sensors* activity (Step 1g). This activity addresses additional components of technological literacy, including:
   - Attributes of design;
   - Understanding of engineering design;
   - Problem-solving approaches;
   - Abilities to apply design processes; and
   - Abilities to use and maintain technological products.

The BRIDGE Connection

www.vims.edu/bridge/ – Scroll over "Ocean Science Topics" in the menu on the left side of the page, then "Human Activities," then "Technology" for links to resources about submersibles, ROVs, and other technologies used in underwater exploration.

The "Me" Connection

Have students write a brief essay about how the ability to use robotic imagery to compare biological communities could be personally beneficial.

Connections to Other Subjects

English/Language Arts, Life Science, Mathematics, Physics

STEM Connections

Ocean exploration aboard the *Okeanos Explorer* is a real-world example of STEM concepts in action:

Science provides the overall objective – to better understand Earth's ocean – as well as a methodology for systematically acquiring this understanding;

Technology includes the tools, systems and processes that have been made to make deep-ocean exploration possible;

Engineering designs the technologies that can function in the deep-ocean environment;

Mathematics provides the basis for measurements, data analysis, and engineering design.

With increasing attention to developing integrated approaches to STEM education and technological literacy, the *How Do We Explore?* theme offers an exciting context for educators who wish to bring more STEM content to their classrooms.

To assist with such efforts, most lessons developed for the *How Do We Explore?* theme identify opportunities to include specific benchmarks and standards for technological literacy that have been developed by the International Technology and Engineering Education Association (ITEA, 2007). While these standards have not been widely adopted, they provide useful guidance for efforts to enhance STEM content in advance of its inclusion in formal curricula.

In addition, the *How Do We Explore?* suite of lessons includes activities that are intended to provide opportunities to apply design processes, build technological devices, and develop some of the hands-on abilities that are an integral part of most concepts about STEM education. These activities are directly tied to the technologies and scientific methodologies used for ocean exploration aboard the *Okeanos Explorer*.

For more information, see: *http://www.iteaconnect.org/TAA/Publications/TAA_Publications.html*

Assessment

Students' analyses of video images and class discussions provide opportunities for assessment.

Extensions

1. Visit the *Okeanos Explorer* Digital Atlas (*http://www.ncddc.noaa.gov/website/google_maps/OkeanosExplorer/mapsOkeanos.htm*) and Web page (*http://oceanexplorer.noaa.gov/okeanos/welcome.html*) for reports, images, and other products from *Okeanos Explorer* cruises.
2. For additional techniques for analyzing video images, see the *Through Robot Eyes* lesson.
3. Visit *http://www.marinetech.org/rov_competition/rov_video_2007.php* for a video from the Marine Technology Society's student ROV competition, and links to other sites about underwater robots.
4. For ideas about building your own underwater robots, see Bohm and Jensen (1998), Bohm (1997), and the Sea Perch Program (see Other Resources).

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html – Click on the links to Lessons 1, 5, and 6 for interactive multimedia presentations and Learning Activities on Plate Tectonics, Chemosynthesis and Hydrothermal Vent Life, and Deep-Sea Benthos.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

I, Robot, Can Do That!

(from the Lost City 2005 Expedition)

http://oceanexplorer.noaa.gov/explorations/05lostcity/background/edu/media/lostcity05_i_robot.pdf

Focus: Underwater robotic vehicles for scientific exploration (Physical Science/Life Science)

In this activity, students will be able to describe and contrast at least three types of underwater robots used for scientific explorations, discuss the advantages and disadvantages of using underwater robots in scientific explorations, and identify robotic vehicles best suited to carry out certain tasks.

Let's Hit the Slopes!

(from the *Lophelia* II 2010: Cold Seeps and Deep Reefs Expedition)

http://oceanexplorer.noaa.gov/explorations/10lophelia/background/edu/media/loph10_hitslopes78.pdf

Focus: Benthic communities on continental slopes in the Gulf of Mexico (Grades 7-8; Life Science)

Students describe benthic communities found at selected sites on continental slopes in the Gulf of Mexico, explain the possible ecological role of at least three species that are characteristic of these communities, and calculate an index of similarity between two biological communities given species occurrence data.

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.

Anonymous. 2010. Web site for the INDEX-SATAL 2010 Expedition [Internet]. Office of Ocean Exploration and Research, NOAA [cited January 7, 2011]. Available from *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html* – Includes links to lesson plans, career connections, and other resources

Anonymous. Ocean Explorer [Internet]. NOAA Office of Ocean Exploration and Research [cited January 4, 2011]. Available from: *http://oceanexplorer.noaa.gov*.

Anonymous. 2011. *Okeanos Explorer* Education Materials Collection [Internet]. NOAA Office of Ocean Exploration and Research [cited January 4, 2011]. Available from: *http://oceanexplorer.noaa.gov*

Anonymous. *Okeanos Explorer* America's Ship For Ocean Exploration [Internet]. NOAA Office of Ocean Exploration and Research [cited January 24, 2011]. Available from: *http://explore.noaa.gov/special-projects/indonesia-u-s-scientific-and-technical-cooperation-in-ocean-exploration/files/Okeanos_Explorer_for_WOC_-_FINAL.pdf*; NOAA Fact Sheet about *Okeanos Explorer*

Anonymous. Sea Perch Program [Internet]. Massachusetts Institute of Technology Sea Grant Program. [cited January 12, 2011]. Available from *http://seaperch.mit.edu/* – Includes detailed instructions for building a simple remotely operated underwater vehicle; based on designs from "Build Your Own Under Water Robot and Other Wet Projects" by Harry Bohm and Vickie Jensen

Bohm, H. and V. Jensen. 1998. Build Your Own Programmable Lego Submersible: Project: Sea Angel AUV (Autonomous Underwater Vehicle). Westcoast Words. 39 pages.

Bohm, H. 1997. Build Your Own Underwater Robot and Other Wet Projects. Westcoast Words. 148 pages.

International Technology Education Association. 2007. Standards for Technological Literacy: Content for the Study of Technology. Reston, VA. 260 pages.

Pinner, W. 2010. Bulk Geo-Tagging of Images Using SCS Timestamped NMEA GGA, HDT and ROV Data [Internet]. OceanDataRat.org. [cited February 2, 2011]. Available from *http://www.oceandatarat.org/*

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard C: Life Science

- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard E: Science and Technology

- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Science and technology in local, national, and global challenges

Content Standard G: History and Nature of Science

- Science as a human endeavor
- Nature of scientific knowledge

Ocean Literacy Essential Principles and Fundamental Concepts

Because most Fundamental Concepts are broad in scope, some aspects of some Concepts may not be explicitly addressed in this lesson. Such aspects, however, can be easily included at the discretion of the individual educator.

Essential Principle 1.
The Earth has one big ocean with many features.

Fundamental Concept b. An ocean basin's size, shape and features (such as islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithospheric plates. Earth's highest peaks, deepest valleys and flattest vast plains are all in the ocean.

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 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 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, including how you use it in your formal/informal education settings.
Please send your comments to:
oceanexeducation@noaa.gov

For More Information

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Some Things *Little Herc* Saw

Anglerfish. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010

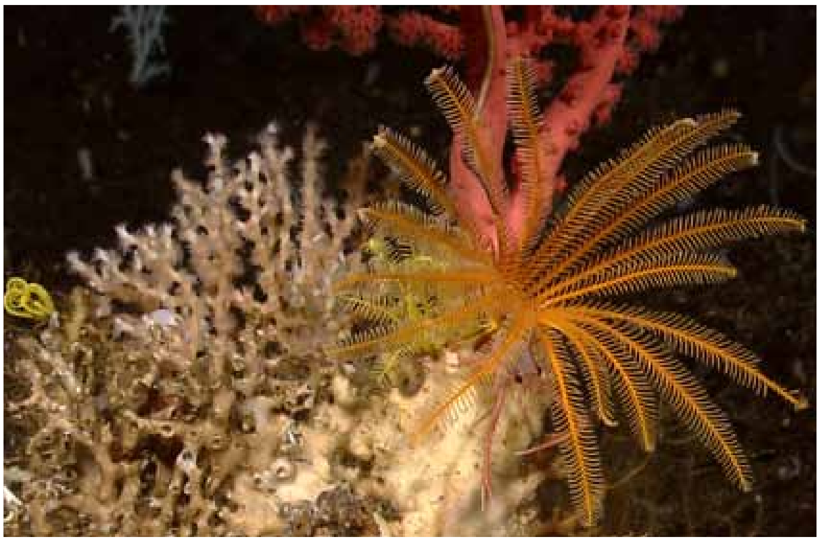
An anemone (Cnidaria) on the branches of a bamboo coral. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010

Cnidarian. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010

Sea anemone (Cnidaria); white stylasterid coral in background. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010

Brittle star (Echinodermata; Ophiuroidea) on reddish bubblegum coral (Cnidaria); yellow sea lily (Echinodermata; Crinoidea) at base of coral; another soft coral (Cnidaria) to the right. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010

Cnidarian; brittle star (Echinodermata; Ophiuroidea) on white stylasterid coral to the right. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010



Yellow sea lily (Echinodermata; Crinoidea); bubblegum coral (Cnidaria) in background. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010

Cup coral (Cnidaria). Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010

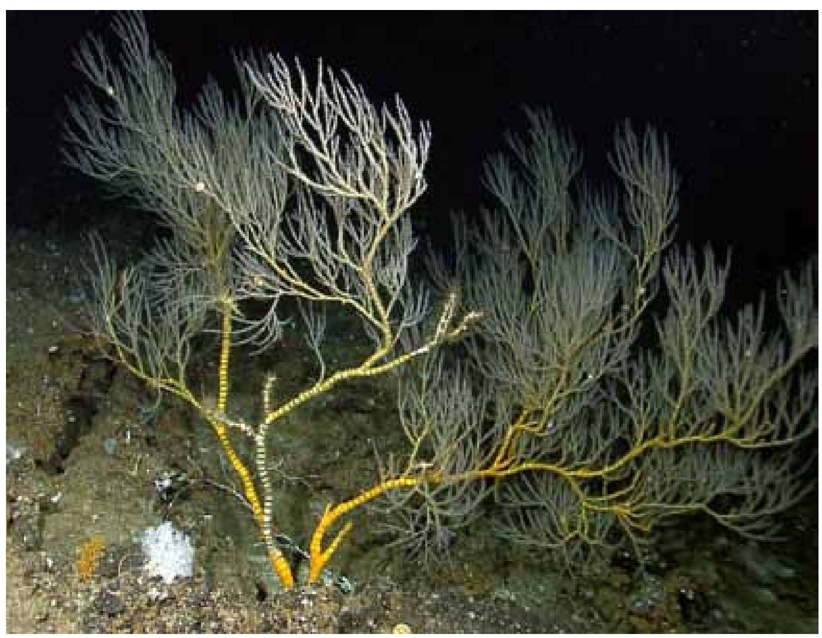
Gray-brown encrusting sponge (Porifera) on rock; white soft corals (Cnidaria) to the left. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010

Flatfish. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010

Gastropod snail. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010

Sea cucumber (Holothuria). Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010

Hermit crab (Arthropoda). Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010



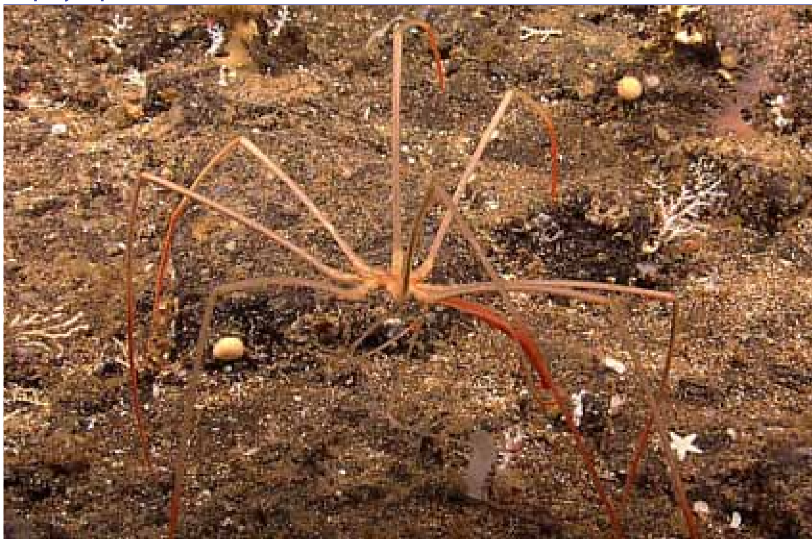
Bamboo coral (Cnidaria; Isididae). Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010

Octopus (Mollusca; Cephalopoda). Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010

Purple soft coral (Cnidaria) with brittle star (Echinodermata; Ophiuroidea). Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010

Brittle star (Echinodermata; Ophiuroidea). Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010

Purple sponge (Porifera). Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010


Sea spider (Pycnogonida). Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010


Soft coral (Cnidaria). Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010


Soft coral (Cnidaria) and sponges (Porifera); squat lobsters (Arthropoda) in right foreground. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010


Stalked sea lily (Echinodermata; Crinoidea), left; sea urchin (Echinodermata; Echinodea). Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010


Yellow encrusting sponge (Porifera). Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010