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Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition

My Wet Robot

[adapted from the PHAEDRA 2006 Expedition]

Focus
Underwater Robotic Vehicles

Grade Level
9-12 (Physical Science)

Focus Question
What are some workable solutions to typical problems involved with the design of practical underwater robots?

Learning Objectives
Students will be able to discuss the advantages and disadvantages of using underwater robots in scientific explorations.

Given a specific exploration task, students will be able to identify key design requirements for a robotic vehicle that is capable of carrying out this task.

Students will be able to describe practical approaches to meet identified design requirements.

(Optional) Students will be able to construct a robotic vehicle capable of carrying out an assigned task.

Materials
- ❒ (Optional, if students will be required to construct a robotic vehicle) Materials to build a robotic vehicle, such as PVC pipe, batteries, propellers for model boats, floats, Lego® Robotics components, and other materials identified by student groups
- ❒ (Optional, if students will be required to construct a robotic vehicle) A place to test students' robots, such as a swimming pool or child's wading pool filled with clear, fresh water

Audio/Visual Materials
- ❒ None

Teaching Time
Two or three 45-minute class periods, plus time for students to complete their projects

Seating Arrangement
Groups of 2-4 students

Maximum Number of Students
32

Key Words
Coral reef
Bonaire
Robot
AUV
ROV
Robotic vehicle

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 2008: Exploring Coral Reef Sustainability with New Technologies Expedition is a collection of underwater 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. Typical AUVs can follow the contours of underwater mountain ranges, fly around sheer pinnacles, dive into narrow trenches, take photographs, and collect data and samples. These capabilities will make it possible to map and study the coral reefs of Bonaire in much greater detail than has been possible with surveys that relied solely on the capabilities of human divers. An additional benefit of AUVs is that they are much less expensive to operate than manned submersibles.

Two kinds of AUVs will be used to map the reefs of Bonaire. The Fetch1 AUV was developed by Mark Patterson (Co-Principal Investigator of the Bonaire Expedition), and carries sensors to measure dissolved oxygen, pH, and chlorophyll, as well as an underwater video camera and side-scan sonar. The Gavia AUVs were developed by Hafmynd ehf, a company based in Iceland. The Gavia AUVs have similar sensors and also carry a type of sonar called multibeam. For more information and images of these AUVs, visit http://oceanexplorer.noaa.gov/explorations/08bonaire/welcome.html.

In this activity, students will design and, optionally, build an underwater robotic vehicle capable of performing specified tasks.

Learning Procedure

1. To prepare for this lesson, review the introductory essays for the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition at http://oceanexplorer.noaa.gov/explorations/08bonaire/welcome.html.

   If you are not already familiar with coral reefs, you may also want to review the coral reef tutorials at 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).

   Decide on the desired level of complexity for this lesson. The simplest, quickest, and least expensive approach is to simply have students design robotic vehicles that could be capable of performing prescribed tasks. A more involved approach would be to require the robotic vehicles to be capable of autonomous activity, so that students would have to incorporate programmable robotics such as Lego® Mindstorms components. The most involved (and also the most fun and rewarding) approach is to require students to actually construct the robots they design. If you plan to have students construct their robotic vehicles, you may also want to review the books by Harry Bohm listed under "Resources." If you opt for one of the more complex approaches, at least a month should be available for students to complete their assignment; more time would be better.

   If students do not have access to the internet, make copies of relevant materials on underwater robotic vehicles from the Web site referenced above.

2. Discuss the importance of coral reefs, and reasons that they are threatened. Discuss the importance of monitoring to identify threatened reef areas and to establish baselines for assessing changes in reef structure and functions.

   Lead an introductory discussion of the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition, and the role of underwater robots on the expedition. Briefly discuss the advantages and disadvantages of underwater robots compared to free divers or manned submersibles. You may want to show students some images from the Ocean Explorer Web sites (oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html).

3. Tell students that their assignment is to design an underwater robotic vehicle that they could construct and that would be capable of moving in a horizontal direction at a fixed depth. You may also want to include a requirement that the robot must collect some type of information about the surrounding environment such as temperature or visual images. If you want to require that the vehicles be capable of autonomous activity and/or actually constructed, add those instructions as well.

   To help students get started, lead a brainstorming session of key components or systems that would have to be included in this kind of vehicle, such as:
   - power system
   - propulsion system
   - communication system
   - buoyancy control system
   - information gathering system(s)

   Discuss specific requirements for each of these systems. Emphasize that the intention of this assignment is for students to design an underwater robotic vehicle that they could construct (whether you actually require them to do so or not), so students' solutions to these requirements should be practical and involve materials to which they have access. Assign "milestone" dates by which certain tasks should have been completed. Have each group present a periodic progress report, identifying problems that have been encountered and proposed solutions.

   There are numerous reports and case studies on the internet about underwater robotics projects, and students should be encouraged to locate these and learn from prior experience. Procedures for waterproofing motors and other components, programs for autonomous control of simple movements, and many other "lessons learned" are available. Tell students to be sure to document the sources for any "prior knowledge" that they use in designing their robots, and to keep a notebook in which they record the assigned requirements for their robot, their approaches to providing key systems, and (if their assignment includes constructing a robot) test procedures and results for each of these systems as well as for the assembled robotic vehicle.

   On the date assigned for project completion, each group should present a report of their design solutions and demonstrate their assembled robotic vehicle (if this was part of their assignment).

The Bridge Connection

www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click "Ocean Science Topics," 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 describing how robots are (or may be) of personal benefit.

Connections to Other Subjects

English/Language Arts, Mathematics

Assessment

Notebooks, project reports, and completed robots (if assigned) 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.

4. Discuss the "coral reef crisis" and what students might do to help protect and restore coral reefs. Visit http://www.coralreef.noaa.gov/outreach/thingsyoucando.html and http://www.publicaffairs.noaa.gov/25list.html for ideas. A key concept is that the current environmental conditions on Earth are not the result of a single event or human action; they are the result of countless individual decisions that collectively can have huge—and often unforeseen—impacts.

Multimedia Learning Objects

http://www.learningdemo.com/noaa/ – Click on the links to Lessons 3, 12, and 13 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Food, Water, and Medicine from the Sea, and Ocean Pollution.

Other Relevant Lesson Plans from the Ocean Exploration Program

The Benthic Drugstore

http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/drugstore.pdf (8 pages; 278kb PDF) (from the 2007 Cayman Island Twilight Zone Expedition)

Focus: Pharmacologically-active chemicals derived from marine invertebrates (Life Science/Chemistry)

Students will be able to identify at least three pharmacologically-active chemicals derived from marine invertebrates, describe the disease-fighting action of at least three pharmacologically-active chemicals derived from marine invertebrates, and infer why sessile marine invertebrates appear to be promising sources of new drugs.

Watch the Screen!

http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/watchscreen.pdf (8 pages; 278kb PDF) (from the 2007 Cayman Island Twilight Zone Expedition)

Focus: Screening natural products for biological activity (Life Science/Chemistry)

In this activity, students will be able to explain and carry out a simple process for screening natural products for biological activity, and will be able to infer why organisms such as sessile marine invertebrates appear to be promising sources of new drugs.

Now Take a Deep Breath

http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/breath.pdf (8 pages; 278kb PDF) (from the 2007 Cayman Island Twilight Zone Expedition)

Focus: Physics and physiology of SCUBA diving (Physical Science/Life Science)

In this activity, students will be able to define Henry's Law, Boyle's Law, and Dalton's Law of Partial Pressures, and explain their relevance to SCUBA diving; discuss the causes of air embolism, decompression sickness, nitrogen narcosis, and oxygen toxicity in SCUBA divers; and explain the advantages of gas mixtures such as Nitrox and Trimix and closed-circuit rebreather systems.

History's Thermometers
http://oceanexplorer.noaa.gov/explorations/02alaska/background/edu/media/thermo9_12.pdf (5 pages, 80k) (from the 2002 Alaska Seamount Expedition)

Focus: Use of deep-water corals to determine long-term patterns of climate change (Physics)

In this activity, students will be able to explain the concept of paleoclimatological proxies, learn how oxygen isotope ratios are related to water temperature, and interpret data on oxygen isotope ratios to make inferences about climate and climate change in the geologic past.

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

Focus: Gene sequencing and phylogenetic expressions (Life Science)

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

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

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

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

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

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

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

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

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

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

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

Focus: Molecular genetics of deepwater corals (Life Science)

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

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

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

In this activity, students will identify and briefly explain two methods for estimating the age of hard corals, learn how oxygen isotope ratios are related to water temperature, and interpret data on oxygen isotope ratios to make inferences about the growth rate of deep-sea corals.

Other Links and Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

oceanexplorer.noaa.gov – Web site for NOAA's Ocean Exploration program

oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html – Ocean Explorer photograph gallery

Bellwood, D.R., T.P. Hughes, C. Folke, and M. Nyström. 2004. Confronting the coral reef crisis. Nature 429:827-833 (http://www.eco.science.ru.nl/Organisme%20&%20Milieu/PGO/PG03/Bellwood.pdf)

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.

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.cees.iupui.edu/Education/Workshops/Project_Seam/Exercises/bird_biodiversity_exerciese.htm – Biodiversity exercises from the Center for Earth and Environmental Science, Indiana University – Purdue University, Indianapolis

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

http://www.ucmp.berkeley.edu/cnidaria/cnidaria.html – Introduction to Cnidaria from the University of California Museum of Paleontology

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
- Understandings about science & technology

Content Standard F: Science in Personal and Social Perspectives

- Natural hazards

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 f. Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).

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 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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