Cradle of the Earthquake:
Exploring the Underwater San Andreas Fault 2010 Expedition

The Robot Fisherman

Image captions/credits on Page 2.

lesson plan

Focus
Underwater robotic vehicles for fish surveys

Grade Level
5-6 (Physical Science/Life Science)

Focus Question
Can underwater robotic vehicles be used to survey bottom fishes?

Learning Objectives
- Students will discuss advantages and disadvantages of using underwater robots in scientific explorations
- Students will identify key design requirements for a robotic vehicle that is capable of observing bottom-dwelling fishes
- Students will interpret results from a robot-based fish survey

Materials
- ❑ Copies of the *SeaBED Autonomous Underwater Vehicle Inquiry Guide*, one copy for each student group

Audio-Visual Materials
- ❑ None

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Groups of 3-4 students

Maximum Number of Students
32

Key Words
San Andreas Fault
Underwater robot
Autonomous underwater vehicle
AUV

Images from Page 1 top to bottom:
San Francisco, California, Earthquake April 18, 1906. Downtown San Francisco showing residents watching fire after the 1906 earthquake. Photo by Ralph O. Hotz. April 1906. Image courtesy USGS.
/htmllib/btch476/btch476j/btch476z/btch476/hpe00104.jpg

A small bush of tubeworms. When tubeworm bushes are young, only endemic species of animals can colonize them. The presence of the mussels (*Bathymodiolis childressi*) in the center of the bush means that methane is seeping just below. Image courtesy Gulf of Mexico 2002, NOAA/OER.
http://oceanexplorer.noaa.gov/explorations/02mexico/background/communities/media/2tubesmussels.html

San Francisco, California, Earthquake April 18, 1906. Fault trace 2 miles north of the Skinner Ranch at Olema. View is north. 1906. Plate 10, U.S. Geological Survey Folio 193; Plate 3-A, U.S. Geological Survey Bulletin 324. Image courtesy USGS.
/htmllib/btch126/btch126j/btch126z/btch126/ggk02933.jpg

Iceworms (*Hesiocaeca methanicola*) infest a piece of orange methane hydrate at 540 m depth in the Gulf of Mexico. During the Paleocene epoch, lower sea levels could have led to huge releases of methane from frozen hydrates and contributed to global warming. Today, methane hydrates may be growing unstable due to warmer ocean temperatures. Image courtesy Ian MacDonald.
http://oceanexplorer.noaa.gov/explorations/06mexico/background/plan/media/iceworms_600.jpg

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.

At 5:12 am on April 18, 1906, Ernest Adams was thrown violently from his bed and watched in disbelief as the side of his San Francisco home crumbled to the ground. "I fell and crawled down the stairs amid flying glass and timber and plaster. When the dust cleared away I saw nothing but a ruin of a house and home that it had taken twenty years to build. I saw the fires from the city arising in great clouds and it was no time to mourn my loss so getting into what clothing I could find, I started on a run for Kearny St., five miles away... " (Adams, 1906).

In 1906, modern plate tectonic theory was several decades in the future, so no one who lived through the Great San Francisco Earthquake could know that their terrifying experience resulted from interaction between two large pieces of Earth's crust now known as the Pacific and North America Plates. These tectonic plates are portions of the Earth's outer crust (the lithosphere) about 5 km thick, as well as the upper 60 - 75 km of the underlying mantle. They move on a hot flowing mantle layer called the asthenosphere, which is several hundred kilometers thick. Heat within the asthenosphere creates convection currents (similar to the currents that can be seen if food coloring is added to a heated container of water). Movement of convection currents causes tectonic plates to move several centimeters per year relative to each other.

Where tectonic plates slide horizontally past each other, the boundary between the plates is known as a transform plate boundary. As the plates rub together, huge stresses are set up that can cause portions of the rock to break, resulting in earthquakes. Places where these breaks occur are called faults. The San Andreas fault exists along the transform plate boundary between the Pacific and North America Plates in California. The 1906 San Francisco Earthquake was caused by a 296 mile-long rupture along the San Andreas fault from the Mendocino Triple Junction to San Juan Bautista. A triple junction is a place where three of Earth's tectonic plates intersect. At the Mendocino Triple Junction, the Pacific Plate and North American Plate intersect with the Juan de Fuca Plate. Other types of plate boundaries include convergent boundaries, which are formed when tectonic plates collide more or less head-on; and divergent boundaries, which occur where plates are moving apart. View animations of different types of plate boundaries at: http://www.seed.slb.com/flash/science/features/earth/livingplanet/plate_boundaries/en/index.html.

Understanding that the 1906 quake resulted from the movement of tectonic plates leads quickly to the realization that these plates are still in motion; in fact, the San Andreas fault is the fastest moving fault in western North America. This realization inevitably leads to the question, “When will a major earthquake like the 1906 quake strike again?”

To help answer this question, geologists study the history of past earthquakes along the San Andreas fault system. These studies, as well as thousands of years of historical records from China and Japan, tell us that giant earthquakes on faults like the San Andreas tend to occur every few hundred years. This interval is thought to be the time required for motion between tectonic plates to build stresses to levels that produce large quakes. In general, this evidence suggests that a 1906-size earthquake is not likely to strike Northern California for at least 100 years. Still, studies also show that stress has built up again along the San Andreas Fault system. For 70 years following the 1906 earthquake, there were only low levels of seismic activity in Northern California. Then, between 1979 and 1984, there were three quakes with magnitudes of about 6; and in 1989 a major (Loma Prieta) earthquake with a magnitude of 6.9. A similar pattern of earthquake activity took place during the 70 years prior to the 1906 quake.

The Cradle of the Earthquake: Exploring the Underwater San Andreas Fault 2010 Expedition will improve our understanding of the history of great earthquakes and how they are interrelated by investigating portions of the great plate boundary fault that lie offshore; areas that have virtually never been observed or explored. The first step in this exploration is to prepare detailed maps of the entire offshore fault using multibeam and side-scan sonar. These maps, in turn, will help scientists identify areas within the fault to be investigated in greater detail using an autonomous underwater vehicle (AUV) and a remotely operated vehicle to obtain high resolution photographs as well as samples of sediments and hard corals.

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 San Andreas Fault in much greater detail than has been possible with surveys that relied on other methods. An additional benefit of AUVs is that they are much less expensive to operate than manned submersibles.

In this activity, students will explore design requirements for a robotic vehicle that is capable of observing bottom-dwelling fishes, and will interpret results from a pilot survey using an autonomous underwater vehicle.

Learning Procedure

1. To prepare for this lesson:
(a) Review background essays for the Cradle of the Earthquake: Exploring the Underwater San Andreas Fault 2010 expedition http://oceanexplorer.noaa.gov/explorations/10sanandreas
(b) Review about the SeaBED AUV at http://www.whoi.edu/page.do?pid=11400; you may also want to download one or more images of SeaBED from this location; and
(c) Review question on the *SeaBED Autonomous Underwater Vehicle Inquiry Guide*.

2. Lead an introductory discussion of the Cradle of the Earthquake: Exploring the Underwater San Andreas Fault 2010 expedition. You may want to show students some images from the U.S. Geological Survey's Photographic Library (http://libraryphoto.cr.usgs.gov/; click on "Earthquakes" in the left column). Discuss the importance of studying the timing and impacts of past earthquakes to help prepare for similar events in the future. Briefly discuss the advantages and disadvantages of underwater robots compared to free divers or manned submersibles.You may want to show students some images of various robots from the Ocean Explorer Gallery (http://oceanexplorer.noaa.gov/gallery/technology/technology_collection.html). Briefly describe and/or show an image of the SeaBED AUV, but do not discuss this robot in detail at this point.

3. Provide each student group with a copy of the *SeaBED Autonomous Underwater Vehicle Inquiry Guide*. Explain that their assignment is to investigate the SeaBED AUV, and how it can be used to survey bottom-dwelling animals. You may want to provide this link as a starting point: http://www.whoi.edu/page.do?pid=11400.

4. Review students' answers to question on the *Inquiry Guide*. The following points should be included:

- During a typical mission, the SeaBED AUV travels slowly to allow it to obtain high quality photographic coverage of the sea floor.
- SeaBED normally flies about 2.5 m (8 ft) above the sea floor.
- Currently, SeaBED is rated for a maximum depth of 2,000 m.
- During a typical survey mission, SeaBED takes a digital photograph about every three seconds.
- Scientists wanted to use SeaBED for rockfish surveys because the rocky habitat of these fishes makes it difficult to use traditional trawl survey methods.

- A photomosaic is a series of overlapping photographs that provide a detailed picture of a survey area.

- SeaBED photomosaics provide information about the relationships and associations between geological formations, individual fish species, and other organisms such as invertebrates.

- A typical SeaBED dive is about six hours long.

- SeaBED can photograph 5 to 10 km (3 to 6 mi) during a typical dive.

- A laptop computer is used to control SeaBED.

- Once SeaBED is launched from a research vessel, the vessel doesn't have to do anything and can carry out other activities while SeaBED completes its mission.

- Hanumant Singh is the scientist at Woods Hole Oceanographic Institution who is primarily responsible for developing SeaBED.

- Rockfish appear to prefer rocky habitats (ask students if this finding is surprising).

- The most common size of rockfish seen in the survey was from 700 to 1200 grams.

- Rockfish in "Soft Edge" habitats are most likely to be large individuals.

5. Briefly discuss some advantages and disadvantages of using SeaBED for this type of survey.

   Advantages include:
   - The AUV can be easily operated from small vessels;
   - SeaBED is much less expensive to operate than larger robots or manned submersibles;
   - Photographic coverage combined with data from other sensors means that information from SeaBED surveys can be used to address a wide range of ecological questions; and
   - Once launched, SeaBED is autonomous, so the research vessel and crew can carry out other investigations while SeaBED completes its survey.

   Disadvantages include:
   - Identification of individual organisms depends upon a single photograph (video or diver observations allow more than one view);

- Considerable time is required to analyze photomosaics, but this is a problem with most photographic survey techniques (improved methods of image analysis are being worked on to reduce this problem).

The BRIDGE Connection

www.vims.edu/bridge/ - Click on "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

Assessment

Answers to *Inquiry Guide* questions and class discussions provide opportunities for assessment.

Extensions

1. See the Cradle of the Earthquake: Exploring the Underwater San Andreas Fault 2010 Expedition Education Module for additional information, activities, and media resources about deepwater ecosystems and earthquakes associated with the San Andreas Fault.
2. See books by Harry Bohm ("Other Resources") for additional projects involving underwater robots.

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html - Click on the link to Lessons 1, 2, and 4 for interactive multimedia presentations and Learning Activities on Plate Tectonics, Mid-Ocean Ridges, and Subduction Zones.

Other Relevant Lesson Plans from NOAA's Office of Ocean Exploration and Research

Call to Arms (PDF, 756 Kb)
(from the Bermuda: Search for Deep Water Caves 2009 Expedition)
http://oceanexplorer.noaa.gov/explorations/09bermuda/background/edu/media/09call.pdf (paste into your browser)

Focus: Buoyancy (Physical Science)

In this activity, students will describe the types of motion found in the human arm, and describe four common robotic arm designs that mimic some or all of these functions.

The Robot Ranger (PDF, 964 kb)
(from the *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks Expedition)
http://oceanexplorer.noaa.gov/explorations/09lophelia/background/edu/media/09ranger.pdf (paste into your browser)

Focus: Robotic Analogues for Human Structures (Distance Estimation) (Life Science/Physical Science)

In this activity, students will describe how humans are able to estimate the distance to visible objects, and describe a robotic system with a similar capability.

Entering the Twilight Zone (PDF, 468 kb)
(from the 2002 Gulf of Mexico Expedition)
http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_twilight.pdf

Focus: Deep-sea habitats (Life Science)

Students will be able to describe major features of cold seep communities, and list at least five organisms typical of these communities and will infer probable trophic relationships within and between major deep-sea habitats. Students will also be able to describe in the process of chemosynthesis in general terms, contrast chemosynthesis and photosynthesis, and describe major deep-sea habitats and list at least three organisms typical of each habitat.

InVENT a Deep-Sea Invertebrate (PDF, 460 kb)
(from the 2002 Galapagos Rift expedition)
http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr5_6_l3.pdf

Focus: Galapagos Rift Ecosystem (Structure and Function in Living Systems)

In this activity, students will design an invertebrate capable of living near deep-sea hydrothermal vents, and in doing so, will learn about the unique adaptations that organisms must have in order to survive in the extreme environments of the deep sea.

Let's Make a Tubeworm! (PDF, 464 kb)
(from the 2002 Gulf of Mexico Expedition)
http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_tube_gr56.pdf

Focus: Symbiotic relationships in cold seep communities (Life Science)

In this activity, students will be able to describe the process of chemosynthesis in general terms, contrast chemosynthesis and photosynthesis, describe major features of cold seep communities, and list at least five organisms typical of these communities. Students will also be able to define symbiosis, describe two examples of symbiosis in cold seep communities, describe the anatomy of vestimentiferans, and explain how these organisms obtain their food.

Animals of the Fire Ice (PDF, 364 kb)
(from the 2003 Windows to the Deep Expedition)
http://oceanexplorer.noaa.gov/explorations/03windows/background/education/media/03win_fireice.pdf

Focus: Methane hydrate ice worms and hydrate shrimp (Life Science)

Students will be able to define and describe methane hydrate ice worms and hydrate shrimp, infer how methane hydrate ice worms and hydrate shrimp obtain their food, and infer how methane hydrate ice worms and hydrate shrimp may interact with other species in the biological communities of which they are part.

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/explorations/10sanandreas – Web site for the Cradle of the Earthquake: Exploring the Underwater San Andreas Fault 2010 Expedition

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://earthquake.usgs.gov/regional/nca/1906/18april/index.php – U.S. Geological Survey Web page about the 1906 San Francisco earthquake

Adams, E. 1906. Letter to Reed and Barton. The Virtual Museum of the City of San Francisco; http://www.sfmuseum.net/1906/ew3.html

http://www.ess.washington.edu/SEIS/PNSN/HAZARDS/CASCADIA/cascadia_event.html – Web page about the January, 1700 Cascadia Subduction Zone earthquake and tsunami from the Pacific Northwest

Seismic Network; includes discussion of various lines of evidence that help pinpoint the date of past earthquakes

http://www.sciencecourseware.com/eec/Earthquake/ – Web site for Virtual Earthquake, an interactive activity designed to introduce concepts of how an earthquake epicenter is located and how the magnitude of an earthquake is determined

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.

Tolimieri, N., Clarke, M.E., Singh, H. and Goldfinger, C., 2008, Exploring the SeaBED AUV for monitoring groundfish in untrawlable habitat. In Reynolds, J.R., and H.G. Greene, eds. 2008. Marine habitat mapping technology for Alaska. Alaska Sea Grant College Program, University of Alaska Fairbanks, doi:10.4027/mhmta.2008.09; the technical article upon which this lesson is based; available online at http://doc.nprb.org/web/research/research%20pubs/615_habitat_mapping_workshop/Individual%20Chapters%20High-Res/Ch9%20Tolimieri%20et%20al.pdf

National Science Education Standards

Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science
- Properties and changes of properties in matter
- Motions and forces
- Transfer of energy

Content Standard C: Life Science
- Populations and ecosystems

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 and technology

Content Standard F: Science in Personal and Social Perspectives
- Natural hazards
- Science and technology in society

Ocean Literacy Essential Principles and Fundamental Concepts

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 2.
The ocean and life in the ocean shape the features of the Earth.
Fundamental Concept e. Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.
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 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

We value your feedback on this lesson.
Please send your comments to:
oceanexeducation@noaa.gov

For More Information

Paula Keener, Director, Education Programs
NOAA's Office of Ocean Exploration and Research
Hollings Marine Laboratory
331 Fort Johnson Road, Charleston SC 29412
843.762.8818   843.762.8737 (fax)
paula.keener-chavis@noaa.gov

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Student Handout

SeaBED Autonomous Underwater Vehicle Inquiry Guide

1. During a typical mission, does the SeaBED AUV travel quickly or slowly? Why?

2. How far above the sea floor does SeaBED normally fly?

3. How deep can SeaBED dive?

4. During a typical survey mission, how often does SeaBED take a digital photograph of the bottom?

5. Why did scientists from the National Marine Fisheries Service want to use SeaBED for surveying populations of rockfish?

6. What is a photomosaic?

7. What information do SeaBED photomosaics provide that could not be obtained with trawl surveys?

8. How long is a typical SeaBED dive?

9. How much territory can SeaBED photograph during a typical dive?

10. What kind of computer is used to control SeaBED?

11. Once SeaBED is launched from a research vessel, what does the vessel have to do while SeaBED completes its mission?

12. Who is Hanumant Singh?

Figure 1: An area called Daisy Bank off the Oregon coast where scientists conducted a field test to decide whether SeaBED could be used to survey populations of rockfish. The blue lines show the path that was covered by SeaBED during this test. The black arrows show the location of two active faults near Daisy Bank.

Figure 1

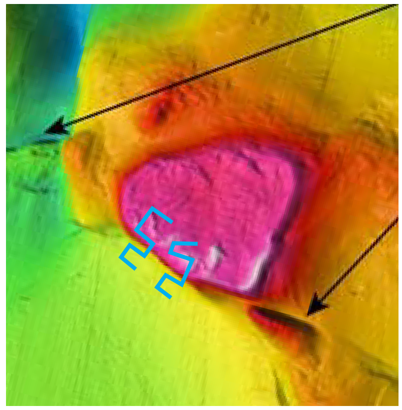
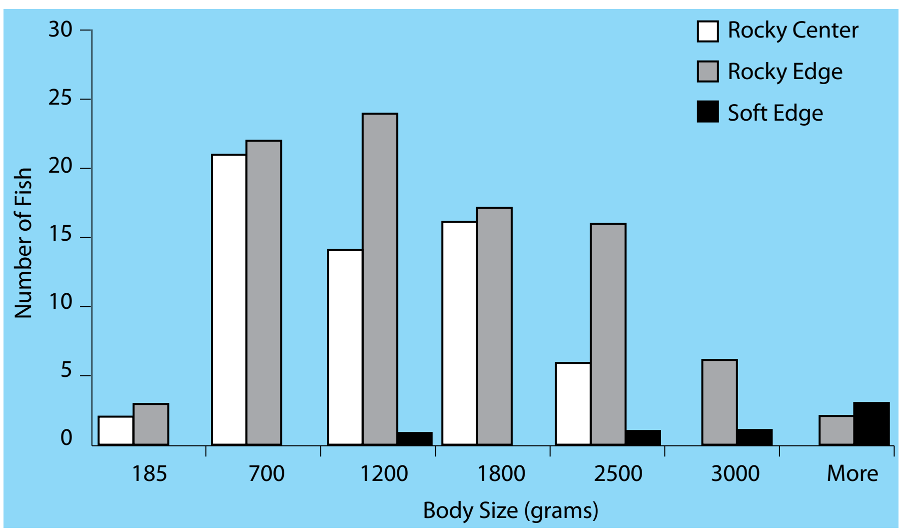


Image courtesy Lewis and Clark Legacy Expedition, NOAA-OER
http://oceanexplorer.noaa.gov/projects/02lewis/midcruise/media/daisyfaults_600.jpg

Figure 2: Size and number of rockfish in different habitats on Daisy Bank, as determined from SeaBED photomosaics. "Rocky Center" habitats are surrounded by rocks and pebbles on all sides; "Rocky Edge" habitats are on the boundary between rocks and soft mud; "Soft Edge" habitats have few or no rocks. "More" indicates body size greater than 3,000 grams.

Figure 2



Adapted from Tolimieri *et al.*, 2008.

Use Figure 2 to answer the following questions:

13. What habitats do rockfish appear to prefer?

14. What was the most common size of rockfish seen in the survey?

15. What size rockfish are most likely to be seen in Soft Edge habitats?