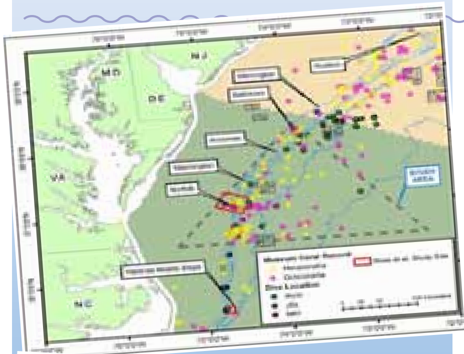
Deepwater Canyons 2012 - Pathways to the Abyss

Life is Weird

(adapted from the 2003 Windows to the Deep Expedition)



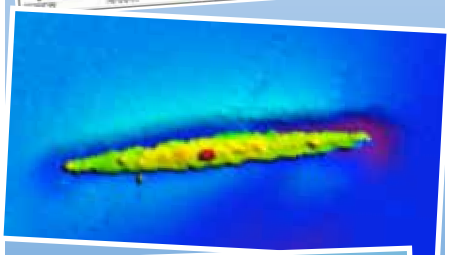


Image captions/credits on Page 2.

lesson plan

Focus

Biological organisms in cold-seep communities

Grade Level

7-8 (Life Science)

Focus Question

What organisms are typically found in cold-seep communities, and how do these organisms interact?

Learning Objectives

- Students will obtain, evaluate, and communicate information about flows and cycles of energy in cold-seep ecosystems.
- Students will develop a model that describes some of the interdependent relationships in cold-seep ecosystems.

Materials

- 5″ x 7″ index cards
- Drawing materials
- Corkboard, flip chart, or large poster board
- Colored yarn or string (see Learning Procedure Step 4)

Audio-Visual Materials

- (Optional) Interactive white board

Teaching Time

Two 45-minute class periods, plus time for student research

Seating Arrangement

Groups of two or three students

Maximum Number of Students

30

Key Words

Atlantic canyon
Cold seep
Methane hydrate
Chemosynthesis

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.

Deepwater canyons are among the most striking features of the continental slope off the east coast of the United States. There are more than 70 of these canyons in depths ranging from about 100 m to about 3,500 m, with steep, narrow walls that make exploration difficult. Research during the 1970's and 1980's (Hecker *et al.*, 1980; Hecker and Blechschmidt, 1979) showed that submarine canyons along the mid-Atlantic continental slope can contain unique hard bottom communities, many of which include high densities of deepwater corals.

Habitat complexity in submarine canyons results from a combination of geological and biological features. Steep canyon walls, rocky outcrops, hard clay formations, boulders, rock rubble, and soft sediments all provide surfaces upon and within which various benthic organisms may grow. Sessile (non-moving) species such as sponges and cnidarians increase the surface complexity and provide additional habitat for other species. Soft sediment is the major substrate type, and most mid-Atlantic canyons have extensive holes and tunnels produced by crabs, tilefish, burrowing anemones, and other animals that further extend the range of available habitats.

Mid-Atlantic canyons may also include chemosynthetic communities whose food webs are based on the energy of chemical compounds, in contrast to photosynthetic communities whose food webs are based on photosynthesis that uses energy from the sun. The first chemosynthetic communities were discovered in 1977 near the Galapagos Islands in the vicinity of underwater volcanic hot springs called hydrothermal vents, which usually occur along ridges separating the Earth's tectonic plates. Hydrogen sulfide is abundant in the water erupting from hydrothermal vents, and is used by chemosynthetic bacteria that are the base of the vent community food web. Another type of chemosynthetic community is found in areas where gases (such as methane) and liquid hydrocarbons seep out of sediments. These areas, known as cold seeps, are commonly found along continental margins, and (like hydrothermal vents) are home to many species of organisms that have not been found anywhere else on Earth.

Cold-seep communities have been found at two locations on the east coast continental slope. These communities may signal the presence of other unusual ecosystems, potentially important energy resources and areas that may be susceptible to submarine landslides that can trigger tsunamis. An historic example of this hazard was the 1929 Grand Banks

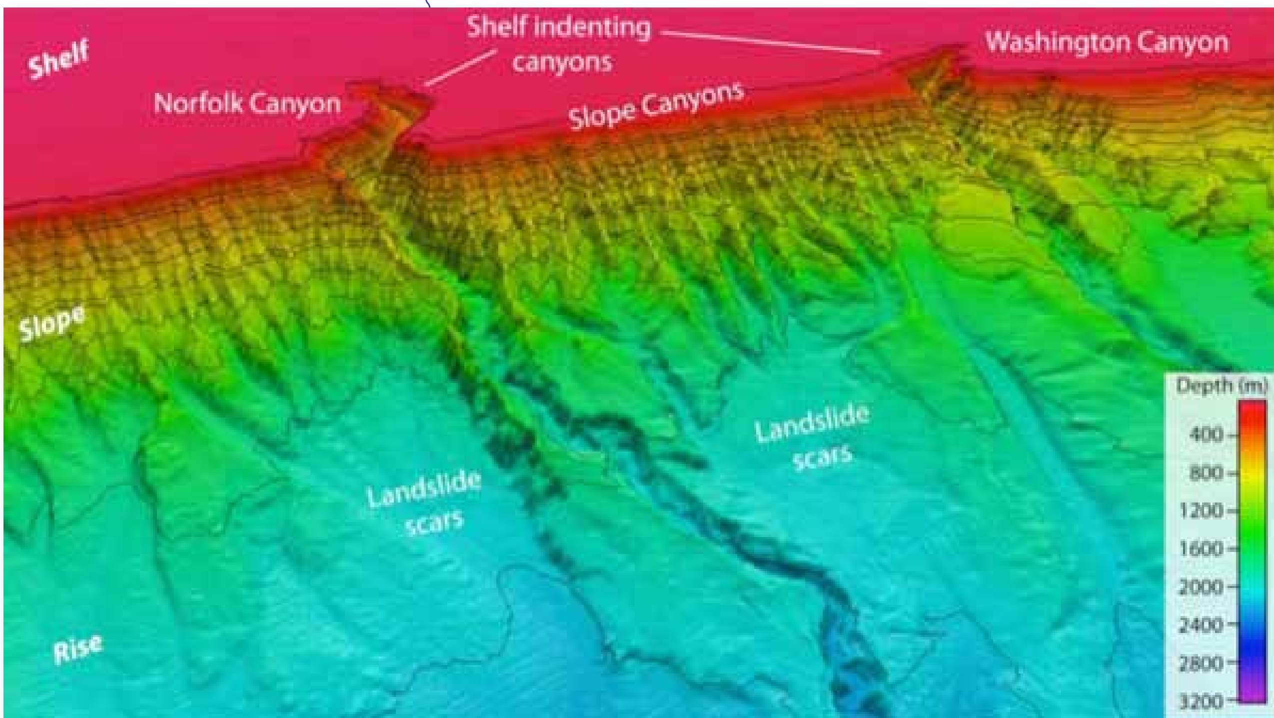
Images from Page 1 top to bottom:
The primary target areas for the Deepwater Mid-Atlantic Canyons Project are in and around the Norfolk, Washington, Accomac, and Baltimore Canyons. This map shows places where deep-sea corals were previously identified (indicated by yellow and pink stars) as well as locations of previous submersible dives (green, blue, and red circles). Image courtesy SW Ross, UNC-W.
http://oceanexplorer.noaa.gov/explorations/11midatlantic/hires/plan_fig0_hires.jpg

High-resolution multibeam sonar image of a shipwreck on the continental shelf near Norfolk Canyon. Image courtesy R Mather, URI.
http://oceanexplorer.noaa.gov/explorations/11midatlantic/hires/plan_fig1_hires.jpg

Benthic landers, designed at the University of North Carolina – Wilmington, will be used during the Deepwater Mid-Atlantic Canyons Project. They provide a way to deploy multiple instruments and experiments to the deep-sea floor and collect precise time-series data on environmental variability that is typically unattainable. Image courtesy SW Ross, UNC-W.
http://oceanexplorer.noaa.gov/explorations/11midatlantic/hires/plan_fig6_hires.jpg

3D rendering of a submarine canyon system just north of Cape Hattaras, NC which illustrates both the rugged canyon topography and the kind of detail that is possible to obtain from multibeam sonar mapping. Image courtesy SW Ross, UNC-W.
http://oceanexplorer.noaa.gov/explorations/11midatlantic/hires/plan_fig4_hires.jpg

submarine landslide, which produced a tsunami 3m to 8 m high. That tsunami killed 28 people along the Newfoundland coast, even though this area was sparsely populated at the time. A similar tsunami along the present-day Atlantic coast might be much more devastating.



Deep submarine canyons are perhaps the most striking feature of the continental margin of the eastern United States. Most of these canyons are relatively minor features, but several are incredibly extensive and cut quite deeply into the seafloor. This image shows the Norfolk and Washington Canyons along the continental margin offshore of Virginia. Image courtesy of USGS. http://oceanexplorer.noaa.gov/explorations/11midatlantic/background/seafloormapping/media/seafloormapping_fig3.html

Shipwrecks are another type of substrate known to be present in mid-Atlantic canyons, and have historical as well as ecological significance. The mid-Atlantic coast of the United States has a maritime history that spans more than 400 years, and is marked by numerous shipwrecks that are neither well-documented nor well-understood. Shipwrecks, like many other human artifacts, can provide hard surfaces that may be associated with a high biomass of biologically diverse organisms. Deterioration of shipwrecks can enhance the settlement of some organisms (e.g., corals; see “Corrosion to Corals.” http://oceanexplorer.noaa.gov/explorations/08lophelia/background/edu/media/corrosion.pdf), but the importance of artificial substrates to natural ecosystems is not clear. In areas with a low percentage of natural hard substrates (such as mid-Atlantic submarine canyons), shipwrecks may represent a significant habitat resource for benthic organisms.

The purpose of the Deepwater Canyons 2012 - Pathways to the Abyss expedition is to explore and investigate deepwater coral and hard bottom communities and shipwreck sites on the continental slope off of Virginia, Maryland, and Delaware. These studies are expected to discover new coral areas and other significant canyon habitats and provide information about processes that control their distribution, abundance, and ecological functions. Selected shipwreck sites will be studied to determine their historical significance and their ecological function as artificial substrates for deepwater organisms. For more information about exploration techniques, please see the Expedition Education Module for the Deepwater Canyons 2012 - Pathways to the Abyss expedition.

In this lesson, students will investigate some of the organisms that are typically found in cold seep communities, and how these organisms interact.

Learning Procedure

1. To prepare for this lesson:

   Review the background essays for the Deepwater Canyons 2012 - Pathways to the Abyss Expedition (http://oceanexplorer.noaa.gov/explorations/12midatlantic/welcome.html). You may also want to download images from one or more of the Web sites cited in Step 2.

2. Briefly introduce the Deepwater Canyons 2012 - Pathways to the Abyss expedition, including the general location of deepwater canyons on the continental slope off the east coast of the United States. If necessary, review the concept of habitats, and discuss how habitat complexity affects the variety of organisms found in specific habitats (more complex habitats tend to support a greater variety of organisms). Be sure students understand that habitat complexity can result from geological features (such as rocky outcrops, hard clay formations, boulders, rock rubble, or sediments), as well as from living organisms (such as sponges and corals). Point out that the activities of certain organisms can also increase the variety of habitats, such as the creation of tunnels in soft sediments by burrowing activities of crabs, fishes, worms, and burrowing anemones.

   Lead a discussion of chemosynthetic communities. Contrast chemosynthesis with photosynthesis. In both processes, organisms build sugars from carbon dioxide and water. This process requires energy; photosynthesizers obtain this energy from the sun, while chemosynthesizers obtain energy from chemical reactions. Review the concepts of food chains and food webs, including the concept of trophic levels (primary producer, primary consumer, secondary consumer, and tertiary consumer). Describe hydrothermal vents and cold seeps as examples of chemosynthetic communities (you may want to refer to http://www.pmel.noaa.gov/vents, http://www.divediscover.whoi.edu/vents/index.html, and/or https://homes.bio.psu.edu/people/faculty/fisher/dir2/intromom.html for images and more information).

Briefly describe methane hydrates, and point out that cold seep communities may signal the presence of methane hydrate deposits. Point out that if methane hydrates become unstable, they can trigger submarine landslides that can cause tsunamis. While we don't hear much about tsunamis on the U.S. east coast, you may want to mention the 1929 Grand Banks submarine landslide, which produced a tsunami 3m to 8 m high and killed 28 people along the Newfoundland coast.

3. Assign each student group one or more of the following groups to research:
   Methanotrophic bacteria
   Thiotrophic bacteria
   Xenophyophores (see also genus Syringammina)
   Anthozoa (sea anemones)
   Turbellaria (a flatworm of the genus Platyhelminthes)
   Nautiliniella (a genus of polychaetes)
   Maldanidae (a family of polychaetes)
   Chaetopteridae (a family of polychaetes)
   Capitellidae (a family of polychaetes)
   Sipunculida (peanut worms)
   Bathymodiolus heckerae (a species of mussel)
   Vesicomya (a genus of clams)
   Octopoda (octopus)
   Munidopsis (a genus of crustacean)
   Alvinocaris (a genus of crustacean)
   Nematoda (a round worm)
   Sarsiaster greigi (a species of sea urchin)
   Chiridota (a genus of sea cucumber)
   Ophioctenella (a genus of brittle star)
   Brisingia (a genus of sea star)

   In addition to written reference materials (encyclopedias, periodicals, and books on the deep sea), the following Web sites contain useful information:
   https://homes.bio.psu.edu/people/faculty/fisher/dir2/intromom.html
   http://biodidac.bio.uottawa.ca/
   http://eol.org

   Each student group should try to determine the energy (food) source(s) of their assigned organisms. It may not be possible to precisely determine specific foods for all groups, but students should be able to draw reasonable inferences from information about related organisms and anatomical features that may give clues about what the animals eat. Students should prepare a 5" x 7" index card for each organism with an illustration of the organism (photocopies from reference material, downloaded internet pictures, or their own sketches), notes on where the organism is found, approximate size of the organism, its trophic level (whether it is a primary producer, primary consumer, secondary consumer, or tertiary consumer), and whether it depends upon photosynthesis, chemosynthesis, or both.

4. Have each student group orally present their research results to the entire class. Temporarily attach the cards prepared by students to a corkboard, flip chart, or piece of poster board (painting tape, sticky notes, or thumbtacks can be used to temporarily anchor the cards). Tell students that their class assignment is to use the information on the cards to create a model that describes some of the interdependent relationships and energy flows in cold seep ecosystems.

   Allow student groups to study the cards for 15 minutes and develop their ideas about interdependent relationships and energy flows. Then have groups take turns moving the cards so that they are arranged to show which organisms inhabit cold-seep communities and which organisms are from deep-sea environments outside cold-seep communities. Students should also indicate trophic (feeding) relationships between organisms using pieces of colored yarn or string. Depending upon available time, you may require student groups to move only one card at a time and make only one trophic connection, or allow them to move several cards at a time and make multiple trophic connections.

5. Lead a discussion of the food web(s) the students have created. Which groups show the greatest variety of anatomical types and feeding strategies? Which groups are responsible for primary production? Be sure students understand that since the bacteria, tubeworms, and mussels of the cold seeps obtain their nutrition through chemosynthesis, they take on the role of primary producers in this type of ecosystem since the food they make can be eaten by many other kinds of animals. At the same time, some primary production from photosynthesis also enters the system as dead plants settle to the bottom from shallower portions of the ocean above. The focus of this discussion should be on students' analyzing information and arguing from evidence, rather than specific details about individual organisms.

   Ask students to make inferences about the relative abundance of each trophic level. In the simplest analysis, organisms at lower trophic levels (primary producers and primary consumers) must be more abundant than those on higher trophic levels. If this does not appear to be true, then there must be additional energy sources for the higher trophic levels.

The BRIDGE Connection

www.vims.edu/bridge/ – Click on "Ocean Science Topics," "Biology," "Plankton" in the navigation menu to the left for resources on ocean food webs. Click on "Ocean Science Topics," "Habitats," "Deep Sea" for resources on deep-sea communities.

The "Me" Connection

Have students write a short essay on their favorite deep-sea or cold-seep community organism, stating why they like it and at least three interesting facts about it. Have students discuss how deep-sea communities such as those found in Thunder Bay may someday affect their lives.

Connections to Other Subjects

English Language Arts, Mathematics

Assessment

Student presentations and class discussions provide opportunities for assessment.

Extensions

Have students visit http://oceanexplorer.noaa.gov/explorations/12midatlantic/welcome.html to find out more about the Deepwater Canyons 2012 - Pathways to the Abyss Expedition.

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html Click on the links to Lessons 3, 5, 6, and 8 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, Deep-Sea Benthos, and Ocean Currents.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

How Am I Supposed to Eat THAT?
(from the 2003 Charleston Bump Expedition)
http://oceanexplorer.noaa.gov/explorations/03bump/background/education/media/03cb_eatthat.pdf

Focus: Feeding adaptations among benthic organisms (Life Science)

Students describe at least three nutritional strategies used by benthic organisms typical of deep-water coral communities and describe physical adaptations associated with at least three nutritional strategies used by benthic organisms.

Mapping the Deep Ocean Floor
(from the NOAA Ship *Okeanos Explorer* Education Materials Collection - How Do We Explore?)
http://oceanexplorer.noaa.gov/okeanos/edu/lessonplans/media/hdwe_78_oceanfloor.pdf

Focus: Bathymetric mapping (Physical Science/Earth Science)

Students explain the advantages of multibeam sonar, and its role in the exploration strategy used aboard the *Okeanos Explorer*; and use data from the *Okeanos Explorer* to create a bathymetric map.

I, Robot, Can Do That!
(from the Lessons from the Deep: Exploring the Gulf of Mexico's Deep-Sea Ecosystems Education Materials Collection)
http://oceanexplorer.noaa.gov/edu/guide/media/gomdse14irobot78.pdf

Focus - Underwater robotic vehicles for scientific exploration (Physical Science)

Students 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 given a specific exploration task, identify robotic vehicles best suited to carry out this task.

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/12midatlantic/welcome.html – Web site for the Deepwater Canyons 2012 - Pathways to the Abyss expedition

De Leo, F. C., C. R. Smith, A. A. Rowden, D. A. Bowden, and M. R. Clark. 2010. Submarine canyons: hotspots of benthic biomass and productivity in the deep sea. Proc. Biol. Sci. 277(1695):2783-2792.

http://www.pmel.noaa.gov/vents – "Vents Program" Web page from NOAA's Pacific Marine Environmental Laboratory

http://www.divediscover.whoi.edu/vents/index.html for more information and activities on hydrothermal vent communities.

https://homes.bio.psu.edu/people/faculty/fisher/dir2/intromom.html – Web page about cold seep ecosystems

Relationship to *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*

The objectives of this lesson integrate the following Practices, Crosscutting Concepts, and Core Ideas:

Objective: Students will obtain, evaluate, and communicate information about flows and cycles of energy in cold seep ecosystems.

Science and Engineering Practices:

8. Obtaining, evaluating, and communicating information

Crosscutting Concepts:

5. Energy and matter: Flows, cycles, and conservation

Disciplinary Core Ideas:

PS3.D Energy in chemical processes and everyday life
LS2.B Cycles of matter and energy transfer in ecosystems

Objective: Students will develop a model that describes some of the interdependent relationships in cold seep ecosystems.

Science and Engineering Practices:

2. Developing and using models
7. Engaging in argument from evidence

Crosscutting Concepts:

4. Systems and system models

Disciplinary Core Ideas:

LS2.A Interdependent relationships in ecosystems

Correlations to Common Core State Standards for English Language Arts

SL.1 – Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 7-8 topics, texts, and issues, building on others' ideas and expressing their own clearly.

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 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 f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.
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 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.

Send Us Your Feedback

In addition to consultation with expedition scientists, the development of lesson plans and other education products is guided by comments and suggestions from educators and others who use these materials. Please send questions and comments about these materials to: oceanexeducation@noaa.gov.

For More Information

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Credit

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