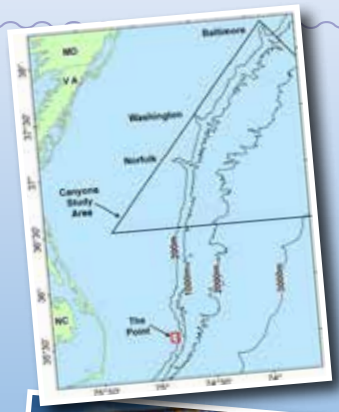
OCEAN EXPLORATION & RESEARCH



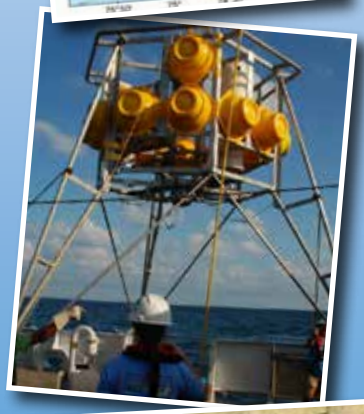


Image captions/credits on Page 2.

lesson plan

Deepwater Canyons 2013 - Pathways to the Abyss

Who Else is Feeding in the Flow?

(Supplemental Lesson to *Feeding in the Flow* from the Deepwater Canyons 2012 Expedition)

Focus

Effect of water currents on benthic communities

Grade Level

9-12 (Life Science)

Focus Question

How do water currents in deepwater canyons affect benthic communities?

Learning Objectives

- Students will construct explanations for observations about events and observations reported from investigations of deepwater ecosystems.
- Students will use evidence to support arguments about how the distribution of deepwater organisms is affected by environmental factors.

Materials

- ❑ Copies of Mission Logs listed in Learning Procedure, Step 1, one for each student group; or Internet access to these materials
- ❑ Copies of *Guidance for Mission Log Review*; one copy for each student group

Audio-Visual Materials

- ❑ (Optional) Interactive white board

Teaching Time

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

Seating Arrangement

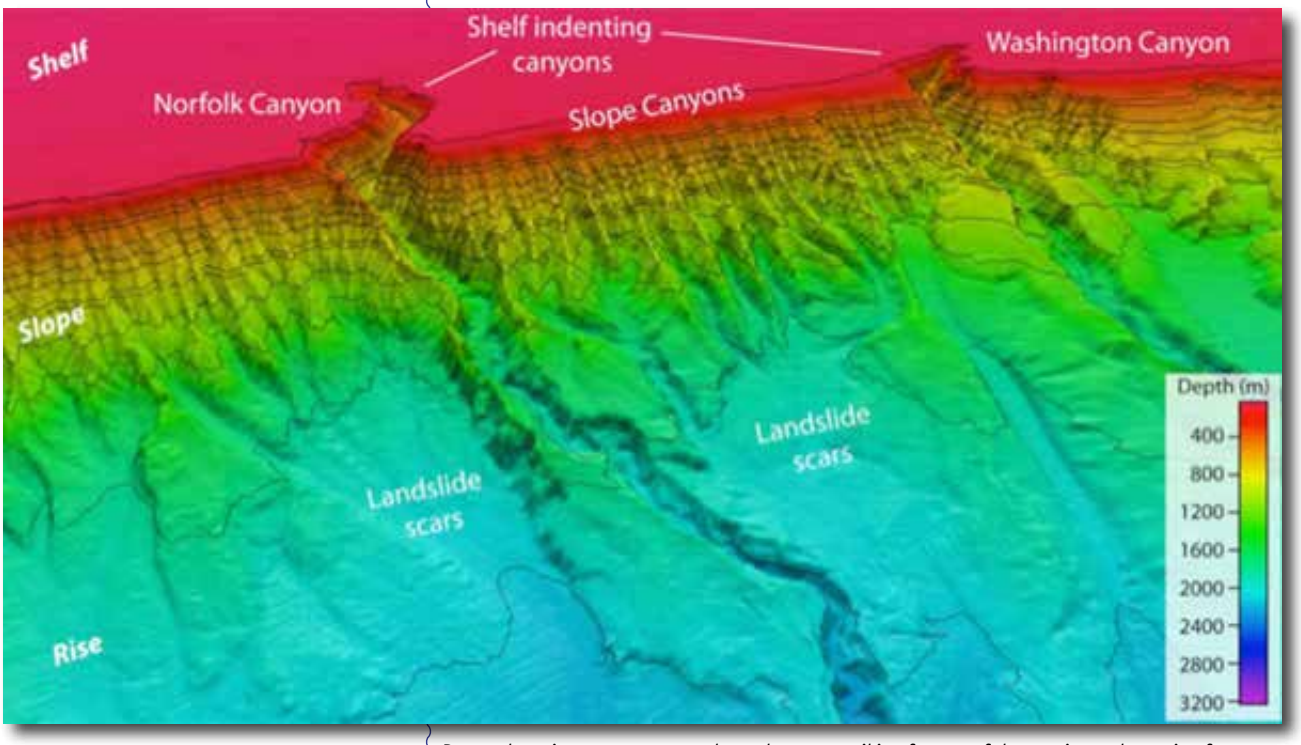
Groups of two or three students

Maximum Number of Students

30

Key Words

Atlantic canyon
Benthic community
Habitat
Deep-water coral
Microhabitat
Current



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

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.

Background information about deepwater canyons off the east coast of the United States is provided in the Expedition Education Module for the Deepwater Canyons 2012 – Pathways to the Abyss Expedition [http://oceanexplorer.noaa.gov/explorations/12midatlantic/background/edu/edu.html], and the *Feeding in the Flow* lesson plan [http://oceanexplorer.noaa.gov/explorations/12midatlantic/background/edu/media/dwc12_feeding912.pdf].

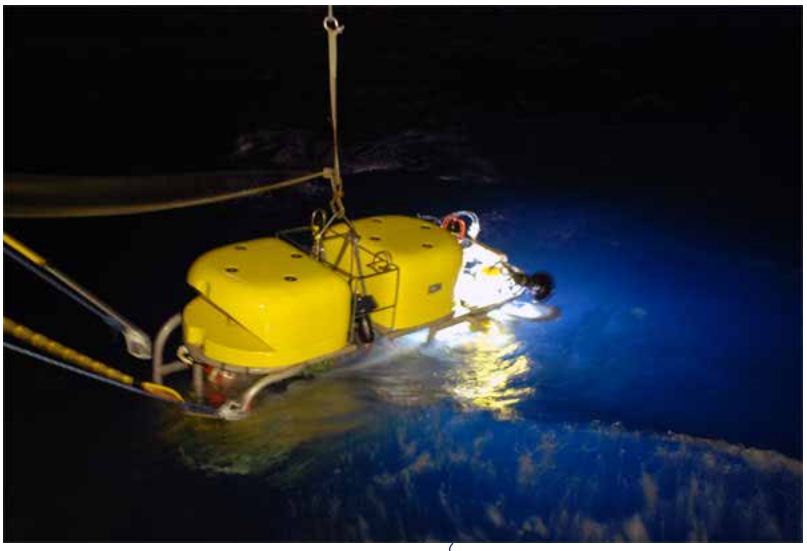
The purpose of the Deepwater Canyons 2013 - Pathways to the Abyss Expedition is to extend work begun in 2012 to explore and investigate deepwater coral and hard bottom communities and shipwreck sites on the continental slope off Virginia, Maryland, and Delaware. This work includes bathymetric mapping, collection of photographic imagery and samples using a remotely operated vehicle, and deploying long-term monitoring instruments to measure physical and chemical conditions including temperature, salinity, turbidity, dissolved oxygen, and

Images from Page 1 top to bottom:
Submarine canyons are dominant features of the outer continental shelf and slope of the U.S .East coast from Cape Hatteras to the Gulf of Maine. Image courtesy of Steve W. Ross, UNC-W. http://oceanexplorer.noaa.gov/explorations/12midatlantic/background/canyons/media/studyarea.html

Netherlands Inst. of Sea Research BOBO benthic lander that will be used in the Middle Atlantic deep-water canyons. Image courtesy of Steve Ross, UNC-W. http://oceanexplorer.noaa.gov/explorations/12midatlantic/background/benthiclanders/media/bobo.html

A goosefish is well camouflaged in any habitat. Image courtesy of Deepwater Canyons 2012 Expedition, NOAA-OER/BOEM. http://oceanexplorer.noaa.gov/explorations/12midatlantic/logs/aug27/media/goosefish.html

A *Lophelia* coral colony seen in Baltimore Canyon. Image courtesy of Deepwater Canyons 2012 Expedition, NOAA-OER/BOEM. http://oceanexplorer.noaa.gov/explorations/12midatlantic/logs/sept13/media/lophelia1-hires.jpg

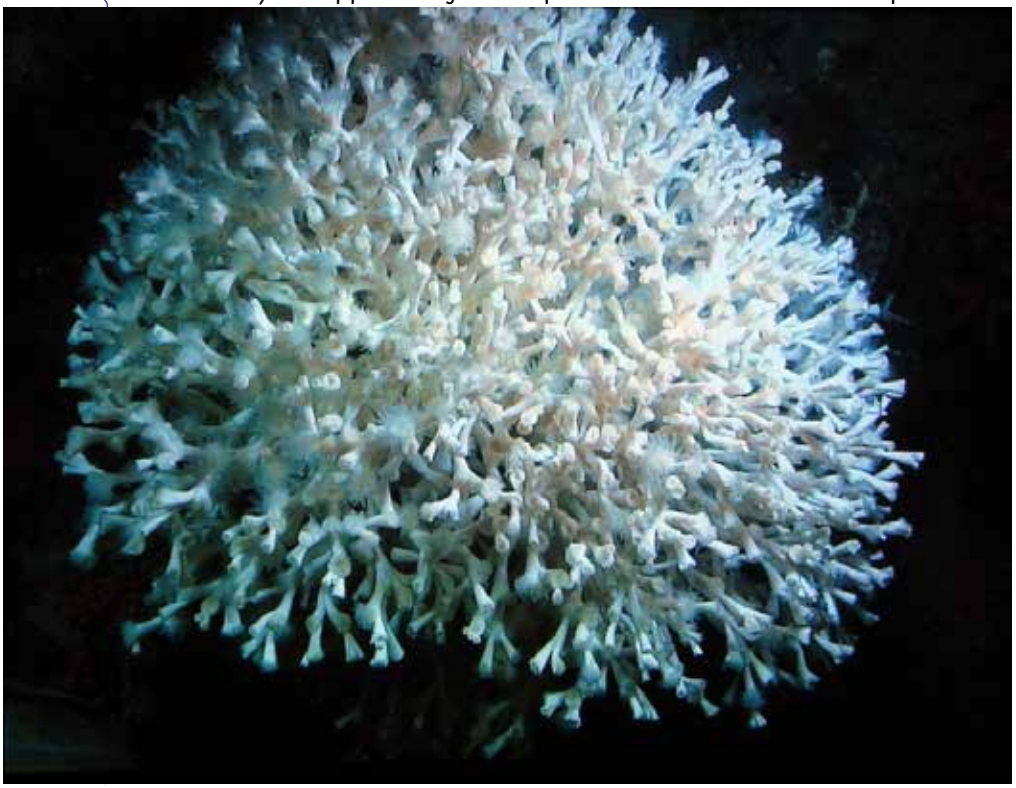


Lights, camera, action! The *Kraken II* remotely operated vehicle used for the 2012 expedition was built for science and was equipped with all the tools needed for collecting deepwater specimens. Image courtesy of the Deepwater Canyons 2012 Expedition, NOAA-OER/BOEM.
http://oceanexplorer.noaa.gov/explorations/12midatlantic/logs/sept30/media/kraken.html

bottom currents. In 2012, most of this effort was concentrated on Baltimore Canyon. In 2013, the focus will shift to Norfolk Canyon.

Deepwater corals form extensive structures in many parts of Earth's ocean, and often create habitats for many other species. *Lophelia pertusa* is the most abundant deepwater coral species found in the canyons and around shipwrecks off the eastern U.S coast, but until 2012 had not been found in Baltimore Canyon. That changed on September 13, when the 2012 Pathways to the Abyss Expedition found several colonies of *L. pertusa* among more extensive colonies of other coral species. On a later dive, expedition scientists attempted to use their observations about the topography surrounding *L. pertusa* colonies in Baltimore Canyon to predict locations in Norfolk Canyon that might also be inhabited by this coral species. This effort was successful, since one colony of *L. pertusa* was finally located in Norfolk Canyon; but scientists are confident that there are more colonies in this area and plan to continue their search in 2013.

The fact that the Pathways to the Abyss Expeditions take place over several subsequent years gives students (as well as expedition scientists) the opportunity to compare conditions in several deepwater



First *Lophelia* coral colony seen in Baltimore Canyon. Image courtesy of Deepwater Canyons 2012 Expedition, NOAA-OER/BOEM.
http://oceanexplorer.noaa.gov/explorations/12midatlantic/logs/sept13/media/lophelia1-hires.jpg

canyons, and to see how observations in one area can be used to guide explorations in other locations. In the 2012 *Feeding in the Flow* lesson, students analyzed data about water motion and feeding behavior of corals to make inferences about how water currents and external morphology affect particle-feeding organisms. In this lesson, students will use observations from the Deepwater Canyons 2012 - Pathways to the Abyss Expedition to make inferences that can help guide explorations in 2013. In addition, mission logs from the 2013 expedition will allow students to compare their inferences with actual discoveries as the 2013 expedition unfolds.

Learning Procedure

1. To prepare for this lesson:
   (a) Review the background essays for the Deepwater Canyons 2013 - Pathways to the Abyss Expedition [http://oceanexplorer.noaa.gov/explorations/13midatlantic/welcome.html]. If students have not completed the *Feeding In the Flow* lesson, you may also want to review background information for this lesson as well [http://oceanexplorer.noaa.gov/explorations/12midatlantic/background/edu/media/dwc12_feeding912.pdf].

   (b) Ensure that students will have access to the following Mission Logs from the 2012 expedition:

   "*Lophelia* in the Canyons!" (September 13, 2012) by Sandra Brooke and Steve W. Ross [http://oceanexplorer.noaa.gov/explorations/12midatlantic/logs/sept13/sept13.html]

   "Shark Attack!" (September 24, 2012) by Terry Connell [http://oceanexplorer.noaa.gov/explorations/12midatlantic/logs/sept24/sept24.html]

   "Benthic Community Ecology of Canyons" (September 25, 2012) by Amanda Demopoulos [http://oceanexplorer.noaa.gov/explorations/12midatlantic/logs/sept25/sept25.html]

   "Benthic Passion" (September 28, 2012) by Kirstin Meyer [http://oceanexplorer.noaa.gov/explorations/12midatlantic/logs/sept28/sept28.html]

   "Standing on the Roof " (September 30, 2012), by Esprit Heestand Saucier [http://oceanexplorer.noaa.gov/explorations/12midatlantic/logs/sept28/sept28.html]

2. Briefly describe deepwater canyon habitats. Mention some of the reasons for exploring these habitats, which include the facts that similar sites in other areas are known to support important fisheries and other biological resources, and that cold-seep communities may

White bacterial mats indicate cold-seep activity. Image courtesy of Deepwater Canyons 2012 Expedition, NOAA-OER/BOEM. http://oceanexplorer.noaa.gov/explorations/12midatlantic/logs/aug26/media/whitebacterialmats.html

exist in some locations. If students are not familiar with cold-seep habitats, briefly describe these (see the Expedition Education Module for the *Lophelia* II 2012: Deepwater Platform Corals Expedition, http://oceanexplorer.noaa.gov/explorations/12lophelia/background/edu/edu.html, for more details). Point out the significance of potential methane hydrate deposits, including their potential as a new energy source as well as their potential for triggering underwater landslides that can result in tsunamis.

Introduce the Deepwater Canyons 2013 - Pathways to the Abyss Expedition and tell students that this is a continuation of an expedition that began exploring this area in 2012. If students have not completed the *Feeding in the Flow* lesson, briefly discuss the possible significance of water motion to biological communities in bottom habitats. If students are not familiar with the basic morphology of corals, briefly review these features (see Background Information in the *Feeding in the Flow* lesson for more details). Students should understand that the corals we often see in pictures are colonies of individual animals called polyps, and that coral colonies may grow in a variety of shapes: branches, boulders, plates, fans, whips, etc.

3. Provide each student group with copies of the Mission Logs referenced in Step 1b or Internet access to these materials. Tell students that their assignment is to review these Logs, and prepare a short summary that addresses questions on the *Guidance for Mission Log Review* document.

4. When students have completed their reviews, lead a discussion of their results. The following points should be included:

(1) Gorgonians belong to the phylum Cnidaria, class Anthozoa, subclass Octocorallia, order Gorgonacea. They are commonly known as soft corals, sea whips, or sea fans. They do not form reefs, but are often abundant on hard bottoms and structures made by humans.

(2) Observations about the five colonies of *Lophelia pertusa* found in Baltimore Canyon and their surrounding locations suggest that sediment accumulation could be a factor that limits the distribution of this species, since the colonies were round and compact (a shape that accumulates less sediment than a flatter growth form) and were found in areas protected from sediment accumulation.

(3) When selecting a site in Norfolk Canyon where they hoped to find hard corals, expedition scientists looked for steep, craggy topography with large overhangs, in depths of 750 meters or more.

(4) Shipwrecks create a variety of habitat spaces, which provide shelter for a variety of species, some of which may be food for catsharks. Rough, rocky bottoms also provide more diverse habitats than smooth bottoms, which may account for catsharks' preference for rocky areas.

(5) The author suggests that the vertical thruster failure was caused by a catshark that attacked the ROV after it collected a tasty (to the catshark) spider crab. This idea is supported by the fact that the thruster failed soon after the crab was collected, and that a catshark was found lodged in the vertical thruster mechanism in such a way that it could have caused the thruster motor to burn out. Another catshark was found entangled with the lateral thruster mechanism, but there is no indication that anything involving a spider crab took place before this thruster failed. So, the physical evidence supports the idea that catsharks were involved with the failure of both thrusters, but whether either of these events had anything to do with spider crabs is not clear from the information provided.

(6) Expedition scientists used box corers, trawls, benthic landers and moorings to investigate the benthic community ecology of deepwater canyons because these devices sample different portions of the benthic food web (organisms that dwell within sediments, organisms that exist near the seafloor, and particulate material including nutritious algae). One or two of these sampler types could not have provided as complete a picture of benthic ecosystems.

(7) Organisms that live on the flat, muddy plains of the deep ocean often aggregate around any structure they can find, because structural variety increases the variety of available habitats. This attracts a more diverse group of organisms, increasing the variety of potential food sources.

(8) Samples collected with a trawl can be analyzed to calculate the number of animals in a given sample area, and this calculation can be compared to counts of organisms in video images captured as a remotely operated vehicle traverses a known area over a shipwreck. This comparison can be used to quantify the effects of shipwrecks on benthic biodiversity.

(9) The bottom environment of many parts of Earth's deep ocean is smooth mud or sand, but there are also areas with much more complex topography, such as seamounts, volcanoes, or canyons. The latter areas offer greater variety of habitats and tend to be inhabited by many more animals than are found in less structurally complex areas.

(10) The statement, "Much of deep sea is a broadly homogeneous environment that can be compared to vast African deserts in that it is relatively flat and covered in sediment," does not mean that there are no animals living in these areas. These sediments are often inhabited by extensive biological communities that are invisible at the surface of the sediments.

(11) A variety of topographical features in a certain area often means that there is a corresponding variety of habitats, which make it possible for a variety of biological organisms to live in that area. All of these organisms are potential food for other animals, so topographical variety tends to increase the amount of food available within a community or ecosystem.

(12) The observation that a species of coral found on one seamount is not found on another nearby seamount, but is found on a third seamount much farther away might be the result of water circulation patterns that carry larvae away from the first seamount in a direction that is away from the nearby seamount, but toward the more distant seamount.

(13) Microsatellites are regions on a strand of DNA in which there is a repeating sequence of nucleotides.

(14) If a scientist says, "There is very little gene flow between a population of coral in Baltimore Canyon and another population of the same species in Norfolk Canyon," it means that larvae from corals in the Baltimore Canyon population do not arrive in Norfolk

Canyon in numbers large enough to affect the genetic structure of corals in Norfolk Canyon. This means that evolutionary changes in the population of one canyon probably will not affect the population in the other canyon. Eventually, these two populations may change enough so that they become separate species (which means that individuals from one population could not successfully mate with individuals from the other population).

5. Have student groups take turns reviewing Mission Logs from the Deepwater Canyons 2013 - Pathways to the Abyss Expedition, and make brief (5 – 10 minute) oral reports about new discoveries, and how observations and events reported in these Logs compare to results from the 2012 expedition.

The BRIDGE Connection

www.vims.edu/bridge/ – Scroll over "Ocean Science Topics" in the navigation menu to the left, then "Habitats," then "Coastal," then "Coral" for resources on corals and coral reefs. Click on "Physics" for resources on ocean currents.

The "Me" Connection

Have students write a short essay about how discoveries in deepwater canyons might one day affect their own lives.

Connections to Other Subjects

English Language Arts, Mathematics, Earth Science

Assessment

Student reports and class discussions provide opportunities for assessment.

Extensions

Have students visit http://oceanexplorer.noaa.gov/explorations/13midatlantic/welcome.html to find out more about the Deepwater Canyons 2013 - 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

and

Other Resources

Please see the *Feeding in the Flow* lesson [http://oceanexplorer.noaa.gov/explorations/12midatlantic/background/edu/media/dwc12_feeding912.pdf].

Correlations to *Next Generation Science Standards (NGSS)*

The objectives of this lesson address the following Performance Expectations:

Objective: Students will construct explanations for observations about events and observations reported from investigations of deepwater ecosystems

HS-LS2-3. Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.

[*Clarification Statement:* Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.]

[*Assessment Boundary*: Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.]

HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

[*Clarification Statement:* Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and, extreme changes, such as volcanic eruption or sea level rise.]

Objective: Students will use evidence to support arguments about how the distribution of deepwater organisms is affected by environmental factors.

HS-LS2-3. Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.

[*Clarification Statement:* Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.]

[*Assessment Boundary*: Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.]

HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

[*Clarification Statement:* Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and, extreme changes, such as volcanic eruption or sea level rise.]

Correlations to Common Core State Standards for English Language Arts

RI.4 – Determine the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings

SL.1 – Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 9-12 topics, texts, and issues, building on others' ideas and expressing their own clearly.

L.4 – Determine or clarify the meaning of unknown and multiple-meaning words and phrases, choosing flexibly from a range of strategies.

L.6 – Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

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

Paula Keener, Director, Education Programs
NOAA 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

Acknowledgements

This lesson was developed and written for NOAA's Office of Ocean Exploration and Research (OER) by Dr. Mel Goodwin, PhD, Marine Biologist and Science Writer
Design/layout: Coastal Images Graphic Design, Mt. Pleasant, SC.

Credit

Guidance for Mission Log Review

"*Lophelia* in the Canyons!" (September 13, 2012) by Sandra Brooke and Steve W. Ross [http://oceanexplorer.noaa.gov/explorations/12midatlantic/logs/sept13/sept13.html]

1. What are gorgonians?

2. Only five colonies of *Lophelia pertusa* were found in Baltimore Canyon. Based on observations about these colonies and their locations, what environmental conditions may be preventing this species from becoming more widespread?

3. What characteristics did expedition scientists look for when they selected a site in Norfolk Canyon where they hoped to find hard corals?

"Shark Attack!" (September 24, 2012) by Terry Connell [http://oceanexplorer.noaa.gov/explorations/12midatlantic/logs/sept24/sept24.html]

4. Chain catsharks prefer rough, rocky bottoms in the deep waters of the outer continental shelf; yet scientists found thousands of these sharks on and around shipwrecks resting on a smooth, sandy bottom. What explanation could account for this observation?

5. The author of this mission log suggests a reason that a catshark may have caused the vertical thruster to fail. Could this explanation also account for the failure of the lateral thruster?

"Benthic Community Ecology of Canyons" (September 25, 2012) by Amanda Demopoulos [http://oceanexplorer.noaa.gov/explorations/12midatlantic/logs/sept25/sept25.html]

6. Why did expedition scientists use a box corer, trawl, benthic landers and moorings to investigate benthic community ecology of deepwater canyons? Wouldn't one or two of these devices be enough?

"Benthic Passion" (September 28, 2012) by Kirstin Meyer [http://oceanexplorer.noaa.gov/explorations/12midatlantic/logs/sept28/sept28.html]

7. Organisms that live on the flat, muddy plains of the deep ocean often aggregate around any structure they can find. Why?

8. How can samples collected with a trawl and other samples collected with a remotely operated vehicle be used to quantify the effects of shipwrecks on benthic biodiversity?

"Standing on the Roof " (September 30, 2012), by Esprit Heestand Saucier [http://oceanexplorer.noaa.gov/explorations/12midatlantic/logs/sept30/sept30.html]

9. Why are there many more animals in some areas of Earth's deep ocean than in other areas?

10. "Much of deep sea is a broadly homogeneous environment that can be compared to vast African deserts in that it is relatively flat and covered in sediment. " — Does this mean that there are no animals living in these sediment-covered areas?

11. How do topographical features affect the amount of food available to animals?

12. Suppose a species of coral found on one seamount is not found on another nearby seamount, but the same species is found on a third seamount much farther away. What could explain this observation?

13. What are microsatellites?

14. Suppose a scientist says, "There is very little gene flow between a population of coral in Baltimore Canyon and another population of the same species in Norfolk Canyon." What does this mean?