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Hudson Canyon Expedition

Fishy Deep-sea Designs!

Focus

Adaptations of fishes living in the mesopelagic and bathypelagic zones of the deep ocean

Grade Level

7 - 9

Focus Questions

How do the characteristics of seawater at 200 meters differ from those at 1000 meters?

How might fishes living between 200 meters and 1000 meters of water differ from those living at depths greater than 1000 meters?

Learning Objectives

Students will be able to identify the basic characteristics of the mesopelagic and bathypelagic zones with regard to depth, temperature, pressure, light level and food availability.

Students will be able to explain several adaptive characteristics of fish living in mesopelagic and bathypelagic zones.

Students will learn that many fishes are bioluminescent.

Students will be able to explain some of the adaptive functions of bioluminescence.

Students will conduct independent research about the habitat requirements of a chosen species of deepwater fish.

Materials

- ❒ Bucket (with handle) of water
- ❒ Ice
- ❒ Thermometer
- ❒ Representative images of mesopelagic and bathypelagic fishes (can be accessed from multiple sources listed in Resources section)
- ❒ One blank and two completed "General Characteristics of Fish in Major Ocean Zones" charts for every team of 2-4 students
- ❒ 1 ziplock sandwich bag for every team of 2-4 students
- ❒ Optional: "Marine Bioluminescence: Secret Lights in the Sea" 26-minute video. Available by sending an e-mail to Ocean Research and Conservation Association at inquiries@oceanrecon.org or by direct order on their Web site at www.oceanrecon.org
- ❒ Optional: "The Bioluminescence Coloring Book," by Edith Widder, Ph.D., available from the Ocean Research and Conservation Association using the contact information above.
- ❒ Optional: "Night Life: Creatures of the Deep" 28-minute video created by the New England Aquarium and Bermuda Underwater Exploration Institute. To order, send an e-mail message to the New England Aquarium at wowfilms@neaq.org

Audio/Visual Materials

- ❒ Internet-connected computers, if possible, for student research
- ❒ Internet-connected computer with LCD projector, if possible, for showing images of fish

Teaching Time

2 45-minute class periods (more if videos are included)

One week for student independent research

Seating Arrangement

2-4 students per group

Maximum Number of Students

36

Key Words

Photic
Aphotic
Epipelagic zone
Mesopelagic zone
Bathypelagic zone
Twilight zone
Midnight zone
Bioluminescence
Counterillumination

Background Information

The ocean is divided into three zones based on depth. The upper 200 meters of the ocean is termed the photic zone. This zone is penetrated by sunlight and plants thrive. Food is relatively abundant. This region is also called the epipelagic zone and this term refers to the upper layer of the open ocean or "top pelagic" zone in the ocean.

The Mesopelagic Zone

Immediately below the epipelagic zone lies the mesopelagic zone and this zone extends from 200 meters to 1000 meters in depth. This zone is also called the middle pelagic zone. In the mesopelagic zone, dim light still exists but not at high enough levels to support plant growth. This zone has yet another name and has been coined the "twilight" zone which refers to the dissipation of light with increasing depth. At the lower depths of the twilight zone, light penetration becomes minimal and darkness abounds. Since the sunlight available to the depths of the mesopelagic zone is not sufficient enough to support plant growth, the availability of food, as compared to the epipelagic zone, is much reduced. Only about 20% of the food produced in the epipelagic zone makes its way to underlying waters of the mesopelagic zone.

It is in the mesopelagic zone that a transition between the warm surface waters of the epipelagic and the constant cold temperatures of the bathypelagic zones (see below) occurs. This transition in temperature is called a thermocline. At 200 meters, the temperature averages roughly 23 degrees Celsius and then declines linearly with depth to about 4°C at 1000 meters. Animals that migrate through the mesopelagic zone experience quite a bit of change in temperature, while animals that tend to stay at the same depths experience far fewer fluctuations.

Since pressure increases with depth (one atmosphere per 10 meters or 14.6 pounds per square inch per 10 meters), organisms living in the mesopelagic zone are under a quite a bit of pressure! The pressure at 200 meters is equivalent to 21 atmospheres or 307 pounds per square inch and at 1000 meters is equivalent to 101 atmospheres or 1475 pound per square inch.

Fishes of the Mesopelagic Zone

Many midwater fishes have light organs, or photophores, that produce light. The biological production of light is called bioluminescence. Bioluminescence has evolved in many different species and this suggests its importance to survival in the deep sea. There are several reasons why an organism may produce light. Some of these strategies are listed below, with an example of an organism that uses that strategy.

Counterillumination or "To Hide": Many animals that move up and down in the twilight zone have light producing organs on their ventral surfaces. They are able to increase the light level of their ventrally-located lights as they move into shallower, light-richer waters and dim them as they descend

into deeper waters. In this manner, they become somewhat invisible to predators swimming above or below them. A fish using counterillumination would have a ventral surface that blends in with the lighter waters above when viewed from a predator from below. This is very similar to countershading (animals with lighter ventral surfaces and darker backs, or dorsal surfaces) but uses light to achieve the same effect. Shining tubeshoulders and bristlemouths both have ventrally-located lights!

The use of photophores for counterillumination is a feature, in particular, which characterizes mesopelagic fishes. Therefore, if you observe a fish with photophores on its ventral surface, the fish is very likely to be a fish which migrates vertically and uses counterillumination as a survival strategy.

Attracting a Mate: Many organisms have species-specific light patterns and in some, specific to a certain sex. In a dark environment, this is a great way to get a date! Anglerfish and lantern fish both are thought to produce light to attract a mate. (For an anglerfish image, see http://oceanexplorer.noaa.gov/explorations/04deepscope/background/deeplight/media/fig3c.html)

Attracting Prey: Some organisms have lighted body parts that they use to attract prey. Gulper eels have a light at the end of their tail. It is thought that this animal might use the light to attract prey to its huge mouth.

Escape Tactic: Some organisms will use light to temporarily distract or divert predators. Some animals will shoot out "clouds" of light. The goal is for the light to confuse or distract a predator, while the "un-lighted" animal attempts to escape. The deep sea shrimp, *Acanthephyra purpurea*, is an example of animal which spews bioluminescence to blind or distract a predator. (For an image of this, see http://oceanexplorer.noaa.gov/explorations/04deepscope/background/deeplight/media/fig3c.html)

The common deep-sea jellyfish *Atolla wyvillei* exhibits a bioluminescent "burglar alarm" display meant to attract attention just as a burglar alarm does. If the jellyfish is caught in the clutches of a predator, its only chance of escape is to "call" for help with its eye-catching light display; i.e. to attract the attention of a bigger predator that may attack the jellyfish's attacker, thereby affording the jelly the chance of escape. (See http://www.oceanexplorer.noaa.gov/explorations/05deepscope/background/eyeinsea/eyeinsea.html)

Most mesopelagic fishes are quite small; food is scare and the limited resources available do not support large body sizes. Bristlemouths and lanternfish are the most abundant in this zone. Since food is scare, many midwater fishes have large mouths relative to their body size, unhingeable jaws that can be opened wide to swallow prey, and large teeth. If a rare meal swims by, a hungry midwater fish does not want to miss an opportunity to dine!

In the twilight zone, there are numerous fishes that are black or red. At depth, these fishes are not visible. The black animals absorb all colors of light available and the red animals appear black as well; there is no red light to reflect and their bodies absorb all other available wavelengths of light (see the 5th and 6th grade activity entitled "What's Bright Red and Invisible?" for more in-depth information). Thus red and black animals predominate. Since the color blue penetrates best in water, there simply are not that many blue animals in the midwater regions of the ocean; their entire bodies would reflect the blue light and they would be highly visible to predators. (See "All That Glitters" lesson plan, p. 100 http://oceanexplorer.noaa.gov/edu/curriculum/section5.pdf)

Fishes in the midwater zone can typically be grouped into two distinct categories; those that swim up to the epipelagic zone at night (vertical migrators) and those that remain at particular depths within the mesopelagic zone. Midwater fishes that make vertical migrations are typically

black or silver, have large eyes to capture available light, a large mouth, photophores and small body size. They also tend to have well-developed swim bladders, muscles and bones; all structures that aid in migration. Fishes that do not migrate tend to be black, red or silver, have large eyes, and have large mouths, photophores and small body size. They tend to lack a swim bladder, however, and they have weak bones and flabby muscles.

Bathypelagic Zone

Below depths of 1000 meters lies a world of perpetual darkness. The depths below 1000 meters comprise the bathypelagic or "deep pelagic" zone. Due to its constant darkness, this zone is also called the midnight zone. Only about 5% of the food produced in the epipelagic zone makes it way down to the bathypelagic zone. Food is a scarce commodity in the midnight zone.

The temperature in the bathypelagic zone, unlike that of the mesopelagic zone, is constant. The temperature in this zone never fluctuates far from a chilling 4°C.

The pressure in the bathypelagic zone is extreme and at depths of 4,000 meters, reaches over 5850 pounds per square inch! Though quite a harsh environment, the bathypelagic zone comprises the single largest habitat on Earth.

Fishes of the Bathypelagic Zone

In the bathypelagic zone, bioluminescence is as prevalent as in the mesopelagic zone. However, in the complete darkness of the bathypelagic zone, there is no need for countershading and bioluminescence is not used for this purpose. Bathypelagic fishes tend to have fewer photophores than mesopelagic fishes and the photophores tend to be on the head and sides of the fishes in bathypelagic fishes whereas mesopelagic fishes often have photophores on their ventral surfaces.

Fishes of the midnight zone usually have no need for large, sensitive eyes and the eyes of these fishes are often absent or reduced. Since food is so scarce, energy conservation is the name of the game! Most of the fishes are sluggish or tend to stay in one place. They have watery, flabby muscles, weak skeletons, no scales and poorly developed systems (nervous, respiratory and digestive). Almost all of the bathypelagic fishes lack a swimbladder. Most bathypelagic fishes have huge mouths, are small and have black bodies.

Learning Procedure

Step One:

1. Using a diagram, show students how the ocean has been divided into three zones (epipelagic, mesopelagic, and bathypelagic) based on depth.

2. Ask students what they think the temperature, pressure, light level and food availability in the mesopelagic and bathypelagic zones might be.

3. Describe the temperature, pressure, light level and food availability in the mesopelagic and bathypelagic zones.

4. Use a bucket of water to demonstrate pressure. Ask a student to lie down on his/her back at the front of the classroom. Ask the student to breathe in and out. Now gently place a bucket of water on the student's lung area. Hold onto the handle of the bucket to provide support. Ask the student to breathe and to tell the class if it was more or less difficult to inhale with a bucket of water sitting on top of their chest. Ask the entire class how it might feel to breathe with 50, 100 and 1000 buckets of water sitting on top of their lungs.

5. Remove about half of the water and fill the bucket with ice.

6. Use the bucket of ice water to convey temperature. Have a student come to the front of the class and submerge his/her hand in the ice water. Ask how it feels and whether they would like to take a bath in water just as cold.

7. Take a temperature reading of the ice water using a thermometer and convey reading to the class. Relate temperature reading to the temperature in mesopelagic and bathypelagic zones.

8. Ask students to describe the fishes they think would live in the mesopelagic and bathypelagic zones.

9. Brainstorm the characteristics of mesopelagic and bathypelagic fishes and record the characteristics on the board.

Step Two:

10. Prepare the "playing boards" for this portion of the activity:
    a. Copy one blank "General Characteristics of Fish in Major Ocean Zones" chart for every team of students. If you laminate these charts, you can use them repeatedly.
    b. Copy two completed "General Characteristics of Fish in Major Ocean Zones – Answer Key" charts for every team of students. Laminate one of each set of these completed charts.
    c. From the unlaminated completed chart, cut the "answers" apart into individual rectangles. Laminate and cut out each individual rectangle for repeated use. Place each set of rectangles in one ziplock sandwich bag for use by one student team. These are the "playing pieces."

11. Give each team of students one blank "General Characteristics of Fish in Major Ocean Zones" chart and one set of playing pieces. Tell the students to fill in the blanks with the playing piece answers. When they have completed their chart, give them a laminated completed chart with which to check their answers.

12. Once all teams have finished, discuss the results. Were there any answers which surprised the students? Ask students to offer suggestions about the functions of the various adaptations.

13. Show one or both of the recommended videos to students.

Step Three:

14. Provide students with the list of fishes from the mesopelagic and bathypelagic zone below. Allow them to select one fish and research the habitat requirements of the fish. Students should include the following in their report: a picture of the fish, the size of the fish, the depth(s) where the fish can be found, the general habitat requirements of the fish and special adaptations for survival. Also require that students include the genus and species of the fish they research and describe; many of the fishes listed below include several different species that will differ in habitat (i.e., some anglerfishes are found in the mesopelagic zone while others are found in the bathypelagic zone).
    Anglerfish
    Bristlemouth
    Lanternfish
    Hatchetfish
    Gulper eel
    Viperfish
    Fangtooth
    Dragonfish
    Barracudina
    Longnose lancefish
    Sabertooth fish

Note: Descriptions of some of these animals can be found on the Monterey Bay Aquarium's Web site http://www.mbayaq.org/efc/living_species/. Although this site provides distribution of animals in the Pacific, students can access great photographs and some good, basic information.

The BRIDGE Connection

Go to the BRIDGE Web site at http://www.vims.edu/bridge/

Under the Navigation side bar click on Human Activities to learn more about the technology used to study deep sea environments.

The "ME" Connection

If the bathypelagic zone of the ocean represents over 80% of all habitats on Earth, why might it

be important to study this habitat? How might discoveries in this deep sea habitat affect your life someday?

Connections to Other Subjects

Art

Using art materials, create a canyon habitat. Place fishes at the proper depths within the habitat. For information and canyon images, visit the Hudson Canyon expedition Ocean Explorer Web site at http://www.oceanexplorer.noaa.gov/explorations/02hudson/welcome.html Note: This builds on the evaluation tool listed below.

Mathematics

One atmosphere is equivalent to 14.7 pounds per square inch. At the surface of the ocean, one atmosphere of pressure exists due to the atmosphere above the water. Pressure in the ocean then increases one atmosphere with every increase in 10 meters of depth. How many pounds per square inch of pressure would exist at 200 meters? At 1000 meters?

Evaluation

Using art materials (construction paper, aluminum foil, glow-in-the dark paint, etc.), have students create a three-dimensional model, to scale, of the fish they researched.

Extensions

Have students visit the http://oceanexplorer.noaa.gov Web site to find out more about the Hudson Canyon and Mountains in the Sea expeditions.

Optional Extension

Have students paint the organisms featured in the "Bioluminescence Coloring Book" (listed in the Materials section). Display the completed paintings in a dark classroom; observe and discuss.

Multimedia Learning Objects

Click on the links to Lesson 6 for interactive multimedia presentations and activities on Deep Sea Benthos.

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 lesson plan's publication, but the linking sites may become outdated or non-operational over time.

Resources

Web sites for student research:

http://www.mbayaq.org/efc/living_species/
http://www.mbari.org/
http://www.biolum.org
http://www.lifesci.ucsb.edu/~biolum/
http://www.bioscience-explained.org/EN1.1/features.html
http://www.pbs.org/wgbh/nova/abyss/
http://oceanlink.island.net/oinfo/deepsea/deepsea.html
http://www.divediscover.whoi.edu
http://www.nationalgeographic.com
http://www.marine.whoi.edu/
http://www.oceanexplorer.noaa.gov/technology/technology.html
http://www.ocean.udel.edu/deepsea
http://www.pbs.org/wgbh/nova/abyss/
http://www.whoi.edu/WHOI/VideoGallery/vent.html

National Science Education Standards

Content Standard A: Science as Inquiry

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

Content Standard C: Life Science

- Structure and function in living systems
- Populations and ecosystems

Content Standard D: Earth and Space Science

- Structure of the Earth system

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 5.

The ocean supports a great diversity of life and ecosystems.

Fundamental Concept a. Ocean life ranges in size from the smallest virus to the largest animal that has lived on Earth, the blue whale.

Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms

(symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.

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.

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 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

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

For More Information

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Student Handout

General Characteristics of Fish in Major Ocean Zones

Note: These are general characteristics for fishes (not invertebrates or other marine organisms)	**Sunlight or Epipelagic Zone**	**Twilight or Mesopelagic Zone (vertical migrators)**	**Twilight or Mesopelagic Zone (non-migrators)**	**Midnight or Bathypelagic Zone**
Size				
Shape				
Musculature				
Eyes				
Coloration				
Bioluminescence				

General Characteristics of Fish in Major Ocean Zones – Answer Key

Note: These are general characteristics for fishes (not invertebrates or other marine organisms)	**Sunlight or Epipelagic Zone**	**Twilight or Mesopelagic Zone (vertical migrators)**	**Twilight or Mesopelagic Zone (non-migrators)**	**Midnight or Bathypelagic Zone**
Size	Wide size range	Small size	Small size	Small size
Shape	Streamlined shape	Elongated and/or laterally compressed	Elongated and/or laterally compressed	No streamlining, often globular shaped
Musculature	Strong muscles, fast swimming	Moderately strong muscles	Weak, flabby muscles	Weak, flabby muscles
Eyes	Large eyes	Very large, sensitive eyes	Very large, sensitive eyes; sometimes tubular	Eyes small or absent
Coloration	Typical countershading: dark back, white or silver belly	Black or black with silver sides & belly	Black or black with silver sides & belly	Black or white
Bioluminescence	Bioluminescence relatively uncommon	Bioluminescence common, often used for counter-illumination	Bioluminescence common, often used for counter-illumination	Bioluminescence common, often used to attract prey