



Learning Ocean Science through Ocean Exploration

Section 5 Ocean Zones

Ocean Zones

The Ocean Geologic Features section introduced you to the bottom of the ocean—the benthic regions, examining sediments, vents, rocky reefs, seamounts and other features of the bottom. The majority of Ocean Exploration expeditions have a benthic focus—submersibles and ROVs are most useful where features concentrate geologic and biologic interest. But there are also different kinds of places with different physical characteristics within the water. ROVs and submersibles have to pass through these zones on their way down and up again, giving scientists access to direct observations of these zones as well. The vertical dimension of an aquatic system is called the water column. The most obvious physical characteristics that vary with location in the water column are:

- pressure
- light
- temperature
- oxygen
- mineral nutrients

If you combined all of the world's ocean basins and stirred them together, the average water temperature would be 4 degree Celsius, the average depth would be about 14,000 feet, and the average available light would be zero. But the oceans are not averaged. The distribution of oxygen and mineral nutrients varies greatly, also. The spatial variation in these physical characteristics determines which kinds of organisms live where and have selected for an interesting suite of adaptations.

Temperature

Surface temperatures may range from warm tropical water at 30°C to an ice-covered surface in the polar regions. Since cold water is most dense at 4 degrees C, it sinks in cold regions. Cold water at the poles drops to the bottom and moves across the ocean floor, forming layers of cold water in the deep ocean. Cold water has a high saturation value for oxygen, so the cold, deep water carries dissolved oxygen with it to the ocean floor.

Oxygen

Oxygen at the surface is frequently high in the ocean, and the deep sea has abundant oxygen in its cold water. A layer in between, in the mid-water or mesopelagic region, at around 500 m may be low in oxygen. This oxygen minimum layer creates interesting problems for mid-water species that are solved by both behavioral and biochemical adaptations to low oxygen.

Mineral Nutrients

Nitrogen is generally the limiting mineral nutrient for primary production in the oceans, although iron is also limiting in some oceans. When organisms die, they sink and take their minerals with them to the bottom where the minerals are released by decomposers. Consequently, cold deep ocean water is often much higher in essential mineral nutrients than surface waters where primary production depletes them. Where ocean currents, climate and geography force deep water to the surface, primary production increases dramatically with the introduction of higher levels of mineral nutrients. This production supports entire food chains. This upwelling is caused by both geographic and climatic factors. It produces areas in the ocean where the fisheries are particularly rich, and thus, are of high interest to humans.

Pressure

As organisms with gas-filled spaces upon which we depend—lungs—we tend to focus on pressure as a big deal for aquatic organisms. With each 10 m of seawater, another atmosphere of pressure is added. For example, at 100 m one would experience 1 atm of air pressure and 10 atm of water pressure for a total of 11 atm. At

deep-sea depths, the pressure is unimaginable, yet many creatures have no problem living there. Since most living things are largely water and water is incompressible, organisms lacking gas-filled spaces like lungs or swim bladders are less affected by pressure than we imagine. Some ocean species perform vertical migrations of 1,000 m each day, experiencing a 100 atm range of pressures with no harmful effects.

Most organisms with gas-filled spaces would be crushed by the same pressures. Humans do relatively shallow dives by breathing air at a pressure equivalent to the surrounding water pressure using SCUBA gear. Nitrogen and oxygen both cause cognitive problems for divers saturated at depth. Returning to the surface rapidly results in gases coming out of solution in the blood, causing crippling or death. Exotic mixes of gases allow deeper dives, but still expose humans to problems with blood gases because blood is saturated with these gases at the ambient levels. Instruments put into the ocean must be protected from seawater under great pressure. They are generally sealed in very strong containers. Humans also seal themselves in containers—submersibles that keep the internal pressure the same as on land—1 atm—so that they may go very deep and return to the surface without breathing air at increased pressures.

Deep-sea pressures do affect chemical reaction rates somewhat, speeding up reactions. Organisms adapted to these pressures may experience metabolic problems when brought to the surface for study.

The bulk of the oceans are deep-sea habitats with no light. The importance of light in the seas is reflected by the description of the ocean's vertical zones (zones of the water column) in terms of how much light they have. The ocean is generally divided into three named zones. The zones' depth ranges vary with location. The terms epipelagic, mesopelagic and bathypelagic are most com-

Light and the Zones

Photic or Epipelagic Zone

monly used when referring to organisms and their adaptations to vertical ocean zones.

The upper 200 m of the ocean is termed the photic zone. Sunlight penetrates sufficiently to support the growth of phytoplankton and/or macro algae. Limits to primary production are often low mineral nutrient levels since minerals are consumed by producers that die and sink, removing them from the surface waters. Minerals must be replaced by re-circulation of deeper ocean water or run-off from land. Ocean primary production is largely restricted to the epipelagic zone. Organisms in the zones below are dependent on what food drifts down from above, ranging from tiny clumps of bacteria and dead algae to occasional bonanzas like a dead whale.

Mid-water or Mesopelagic Zone

The area between 200 m and 1,000 m is also called the “twilight” zone in popular sources. Light intensity is severely reduced with increasing depth so light penetration is minimal. When one looks up toward the surface with dark adapted eyes, enough light can be seen so that organisms living here have adaptations that help obscure their outline against the surface. About 20% of the surface primary production is transferred to the mesopelagic zone. Consequently, the density or biomass of its occupants is lower than at the surface, and mesopelagic organisms have an interesting variety of mechanisms that help them find food as well as avoid being a meal for another species.

Bathypelagic or Aphotic Zone

Sunlight does not penetrate this eternal darkness. Popular sources sometimes refer to this as the midnight zone. About 5% of the primary production from the surface makes it to the bottom. Less food means lower biomass. Occasionally large items like dead sharks or whales arrive, but generally food is scarce.

Light In Water

As you travel from surface waters to deeper waters, the quality of light also varies with depth. Sunlight produc-

es a visible spectrum of the colors: red, orange, yellow, green, blue and violet. These colors combined together appear white. Red light is the longest wavelength and has the least energy in the visible spectrum. Violet light has the shortest wavelength with the highest energy. Wavelength decreases and energy increases from red to violet across the spectrum in the order listed above. The visible spectrum has two critical functions—it enables organisms to see and it provides the energy for most primary production.

Water absorbs light. It does so differentially. The longer the wavelength, the lower the energy and the faster that wavelength is absorbed. Thus red light disappears higher in the water column and blue penetrates deepest. The exception to the rule is violet light. Although it has the shortest wavelength and the highest energy, violet is scattered by particles in the water.

Objects that are not transparent or translucent either absorb or reflect most of the spectrum striking them. A red fish in white light reflects red wavelengths and absorbs other colors. Likewise, grass reflects green light and absorbs other colors. White objects are seen as white because they reflect all light in the visible spectrum. Black objects absorb all colors.

Organisms that live in water use light, colors and vision for many things: to find prey, to hide from predators, and to find mates. For example, a red fish swimming at the ocean surface looks red because there is red light in shallow water. In 100 m of water, that same fish is difficult to see, appearing black. There is no red light to reflect at that depth, and the fish absorbs all other wavelengths. In the mesopelagic zone, many species are black or red. At depth, these organisms are virtually invisible unless they are silhouetted against the distant surface viewed from below.

Seeing Things Clearly

Since blue travels best through water, there has been selection for blue among animals wishing to be seen. Since there is no ambient light, mid- and deepwater organisms for whom being seen is an advantage, tend to produce blue light in light organs. Done by biochemical means, bioluminescence is relatively common among deep-sea fishes and other organisms. Bioluminescence has evolved in many different species, suggesting its value to deep-sea species. Several OE expeditions included studies of bioluminescence. Some suggested adaptive values for bioluminescence include:

Counter-illumination Many animals that move up and down in the mesopelagic zone have light-producing organs on their underside. They increase the light level underneath themselves as they move up into shallower water where they are silhouetted against the sky and dim it as they descend to deeper water. A fish using counter-illumination blends in with the lighter waters above when viewed from a predator below. This is similar to counter-shading in which open water photic zone animals have light undersides and dark backs. Shining tubeshoulders and bristlemouths have ventral light organs.

Attracting a mate Many organisms have species-specific light patterns and in some, these patterns are specific by sex. This is a great way to get a date in the dark! Anglerfish and lanternfish both are thought to produce light to attract a mate.

Attracting prey Some organisms have lighted body parts that appear to attract prey. Gulper eels have a light at the end of their tail that is believed to attract prey to its humongous mouth.

Escape or startling tactic Some organisms appear to use light to temporarily distract or divert predators. Some produce shining clouds of light in the water. Others drop bioluminescent body parts that the predator may follow.

Some deepwater shrimp “vomit” bioluminescent clouds, while some copepods emit bioluminescent clouds from their posterior ends.

Lack of ambient light is an issue for ocean explorers. Humans have to take lights with them in order to see and to shoot film or video. Video data collection has proven very useful as video is highly adaptable to low light, and the recording systems are much less expensive than film. Look for evidence of use of underwater lights as you explore the OE CD expedition stories on the CD or web site.

The activities *All that Glitters...* and *Light at the Bottom of the Deep, Dark Ocean?* from the Ocean Exploration expedition Islands in the Stream 2002 follow.

Other OE education activities that coordinate with this section can be found on the OE CD. They are:

- *Fishy Deep-sea Designs* from the OE Hudson Canyon 2002
- *What’s Bright Red and Invisible?* also from the Hudson Canyon 2002 OE expedition
- *Blinded by the Light!* from 2002 OE Islands in the Stream expedition
- *Lights in the Deep* from the OE expedition to the Northwestern Hawaiian Islands

Lights for Ocean Exploration

Classroom Activities about Light in this Section

Where to Find More Activities about Ocean Zones and Light in the Ocean

Lesson Plan 13

All That Glitters...

Focus

Light in the deep sea

Focus Question

What happens to light in the ocean? How do deep-sea creatures compensate for lack of light?

Learning Objectives

Students will experiment with a model of what happens to light and colors as one descends into the ocean.

Students will describe at least two adaptations to low or no ambient light on the part of deep-sea organisms.

Materials

For the teacher:

- 3" x 5" card with 1-in slit cut in middle
- 35 mm slide projector
- Prism
- Glow stick (from dive shops, fishing tackle or sporting goods store)
- Optional: vial of ostracods from Carolina Biological Catalog: GR-20-3430; \$32.80

Per student pair:

- Deep Sea Dive Goggles (one blue transparent report cover per viewer)
- One red, orange, yellow, green, blue and black (dark brown) M&Ms per pair
- Sheet of black construction paper

Audio/Visual Equipment

- Slide projector
- Movie screen or white wall

- Internet access for students

Teaching Time

One 45-min period

Seating Arrangement

Pairs

Key Words

Photic
Aphotic
Mesopelagic
Bathypelagic
Twilight zone
Midnight zone
Bioluminescence
Spectrum
Wavelength
Reflect
Absorb

Background Information

This activity allows students to explore the nature of light, ask what happens to light as it passes through the ocean and speculate on how deep-sea animals deal with living in the dark.

During the 2002 South Atlantic Bight Expedition, Islands in the Stream, two scientists from the Harbor Branch Oceanographic Institution, Dr. Tamara Frank and Dr. Edith Widder, studied vision and bioluminescence in the deep sea. Of particular interest were animals with large eyes that live on the sea floor in the aphotic zone. Many animals that swim in open water (pelagic) in the mesopelagic or twilight zone have large eyes relative to their body

size. Large eyes capture what little light is available. As depth increases below the mesopelagic, eye size in many organisms decreases. For example, two species of bristlemouths, *Gonostoma denudatum*, a midwater fish, and *Gonostoma bathyphilum*, a deeper water fish, have different eye sizes. The midwater species has much larger eyes. The deep water species has much smaller eyes—the result you would expect if eyes had no value in the total absence of light. However, an enigma exists. Many animals living on the deep-sea floor sea have huge eyes! One possible value of vision where there is no ambient light is that some deep-sea organisms make their own light—they are bioluminescent.

LEARNING PROCEDURE

Teacher Prep

1. Cut a thin slit, just a few millimeters wide and about an inch long, in the card.
2. Place card over the light source, creating a thin beam of white light.
3. Place prism in beam of light and practice rotating prism to project the colors of the spectrum on the movie screen or white wall.
4. Cut each blue report cover lengthwise into four strips roughly two inches wide and 12 inches long, making 8 strips.
5. Staple the eight strips together, using two staples, along one short edge to make one set of Deep Sea Dive Goggles. Use a hole punch to make a hole through all the plastic on each end. The plastic will form a fan with one end stapled and the other loose.
6. Separate M&Ms by colors so that each student pair has one of each: black (dark brown), red, orange, yellow, green and blue.

Learning Procedure

1. Ask your students to tell you what they know

about light. Dim the lights and project a visible spectrum on the wall. Have the students write down the colors they observe in the order they see them in the spectrum. Review colors, absorption and reflection.

2. Tape a small piece of a blue report cover over the light source. Ask students to note what color is projected (blue). Make sure that students understand that the blue report cover blocks part of the spectrum by absorbing colors of light other than blue.
3. Challenge the students to observe what the underwater world looks like by using Deep Sea Dive Goggles. Pass out black construction paper, Deep Sea Diving Goggles, and M&M sets to each pair of students.
4. Explain that the black piece of paper represents the darkness of the deep sea. Spread the M&Ms on the black paper.
5. Bend 7 layers of report covers back and observe the colors of the M&Ms through one layer. Then add a layer and observe. Repeat with each layer, simulating what it looks like to go deeper into the ocean. What happened with each color? The blue report covers enable them to see how colors appear in deeper water. The blue covers filter out other colors just as water absorbs them. Students should observe that the color black disappears first, followed by red, then orange, and yellow.
6. If they were fish wishing to hide in the mesopelagic twilight zone, what colors would be the best camouflage? Black and then red.
7. Introduce bioluminescence using the glow stick. Demonstrate “turning it on”—shaking it makes it brighter as you are mixing the chemicals that produce light when they react. Ask the students for their experiences with bioluminescence: fireflies are the most common among eastern US students.

Black light posters are fluorescence—a very different process. Observe the glow stick with the goggles on. How might deep-sea species use the light they make? Discuss counter-illumination, finding a mate, finding prey, attracting prey and startling predators by blinding them. What color would be the most effective for bioluminescence—blue as it penetrates water most easily.

8. You may wish to go into detail about the chemical nature of bioluminescence if your students have sufficient foundation. If you have the ostracods, place three to five in your palm. Add two drops of water and crush the dried animals using a finger. Show your palm; a bright blue results. When you crush the dried animals, two chemicals mix to create blue light.
9. Visit the South Atlantic Bight OE expedition on the web or the OE CD and see what the scientists were studying about bioluminescence.

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 you were to become a SCUBA diver, what color wetsuit would wear to become less visible to fishes (like sharks)? Your wetsuit choices include yellow, orange, red, green and blue.

CONNECTION TO OTHER SUBJECTS

Chemistry, Physics

EVALUATION

Provide students with the following hypothetical newspaper article. Ask them to explain why the journalist’s hypothesis regarding the brown cloud was wrong.

“Yesterday I was SCUBA diving with a young woman in eighty feet of water just off the

coast of South Carolina. The woman was studying the abundance of fish on an off-shore rocky reef when she became tangled in some clear, nylon fishing line. Fortunately she was carrying a dive knife and was able to cut herself free. However, in the process she cut a five-inch gash across her left calf. I saw a brown cloud of something in the water around her leg. I thought it might be blood, but knew it couldn’t be since it wasn’t red. An octopus must have come by and released some ink or some other substance to camouflage itself.”

EXTENSIONS

Over the next week, have students conduct independent research on any of the following animals:

anglerfish
bristlemouth
fangtooth
filetail catshark
sixgill shark
giant ostracod
giant red mysid
gulper eel
hatchetfish
lanternfish
eelpout
blackdragon
hagfish
viperfish
shining tubeshoulder
snipe eel
spiny king crab
raffish
squat lobster
snailfish
midwater shrimp (*Sergestes* sp.)

Descriptions of these animals can be found on the Monterey Bay Aquarium’s web site http://www.mbayaq.org/efc/living_species/ Although this site displays animals in the Pacific, they share many characteristics with the Atlantic species. Students

should include a physical description of the animal, noting the animal's eye size relative to the overall size, whether or not the animal can bioluminescence, and at what depth(s) it lives.

For an art project, use glow in the dark paint and construction paper to recreate deep sea animals, in 3-D, that bioluminesce. Hang them from the classroom ceiling and shut off the lights. *The Bioluminescence Coloring Book*, by Edith Widder, Harbor Branch Oceanographic Institution. ISBN 0-9659686-0-X is a good source of information.

RESOURCES

http://www.mbayaq.org/efc/living_species/

<http://www.mbari.org/>

<http://www.biolum.org>

<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.marine.who.edu/ships/alvin/alvin.htm>

<http://www.ocean.udel.edu/deepsea>

<http://www.who.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

Activity developed by Stacia Fletcher, South Carolina Aquarium

Lesson Plan 14

Light at the Bottom of the Deep, Dark Ocean?

FOCUS

Feeding adaptations of some deepwater organisms

FOCUS QUESTION

What are some adaptations that might help deep-sea fishes to find food in the dark deep ocean?

LEARNING OBJECTIVES

Students will experience the impact of bioluminescence on finding food and becoming prey in the deep ocean.

Students will be able to describe the positive and negative values of being able to produce light.

MATERIALS

For the class:

- Long table in open space that can be made dark; push several tables together, pull down shades and turn off lights; cover table with black paper
- Bag or two of Skittles candy

For each student:

- Deep Sea Dive Goggles from All That Glitters; use hole punched at each end and tie 18-inch strings (or use paper clips and very long rubber bands) in holes so they may be worn hands free as a mask
- Flashlight
- Student worksheet
- Snack-size plastic bags

AUDIO/VISUAL EQUIPMENT

None

TEACHING TIME

Two 45-minute periods

SEATING ARRANGEMENT

Students take turns in large groups depending on size of the table and number of flashlights

KEY WORDS

Adaptation
Camouflage
Photic zone
Aphotic zone
Bioluminescence

BACKGROUND INFORMATION

This exercise should be preceded by *All that Glitters...* It uses some of the same equipment and assumes that the students have an understanding of light, light in the ocean and bioluminescence. The students should have already worked with colors in the ocean.

Deep-sea fish use color to help hide—they may be camouflaged. Red is good camouflage since red light disappears in shallow water. Black is also useful in the dark. In this exercise students will apply what they have learned about color.

Finding food in the deep sea may be aided by use of bioluminescence—fish may have light organs that illuminate the surrounding water, revealing prey. On the other hand, when a fish lights up looking for prey, it exposes itself to predation by a larger fish. Bioluminescence is an adaptation to life in the deep sea. It may be useful for communication among members of a species, for attracting a mate, it may illuminate prey or attract prey, and it is used for counter-illumination to obscure its outline against the lighter surface.

In this exercise, students will be deep-sea fish with light organs that are used to illuminate prey so that they can eat them. They may also eat what they can find in the dark. The teacher will be the large predatory gulper eel.

LEARNING PROCEDURE

1. The day before this exercise, remind the students of what they learned in *All that Glitters...* about light and color in the deep ocean. Suggest that they dress in clothing that would make good camouflage in the deep sea for the next class. Red or black would be best, with long sleeves and good coverage, but do not tell them this—leave it up to them. Students wishing to go to extremes might choose to bring a face covering ski mask. For this activity they will be modeling the behavior of deep-sea fish that feed using bioluminescence.
2. To do this exercise, select the first set of students, give them flashlights, plastic bags and goggles. Spread Skittles thinly on the black paper on the tabletop and tell them this is their food. They must find it in the dark, wearing the goggles. They are fish living in deep water where there is very little light. They may use the flashlight, their bioluminescent organ, to look for food, but whenever it is on, you may tag them because they are visible to a predator—you. When you tag them, a gulper eel has eaten them. They may only use one hand to collect food—using their thumbs and forefingers to pick up one item at a time and place it in their bag. Students not playing will watch to make sure the rules are followed. Anyone being rowdy loses.
3. With goggles in place, dim the lights and let the students begin feeding. If they can see the prey, they may feed without the light, but the light will illuminate almost invisible items. Play until you have tagged about 1/2 of the students. Repeat with another group. The students may keep their bags when tagged. They just have to stop eating.

4. Have the students evaluate the contents of their bags for colors selected. Add up all the Skittles eaten by color versus those left on the table by color.
5. Allow all students time for reflection by having each student fill out the Student Worksheet. Then have a class discussion about the questions.

THE BRIDGE CONNECTION

www.vims.edu/bridge/biology.html

THE "ME" CONNECTION

Research the characteristics of deep-sea fishes versus surface-water fishes with regard to vision and bioluminescence. Compare with human vision and eyes as well as our sources of illumination.

CONNECTION TO OTHER SUBJECTS

Physical Science, Chemistry

EVALUATION

Student Worksheets may be collected for assessment; classroom participation in activity and discussion.

EXTENSIONS

Have students visit <http://oceanexplorer.noaa.gov> to check out the 2002 Islands in the Stream Ocean Exploration.

Research the chemistry of bioluminescence and its distribution among different kinds of organisms. Which species make their own light and which have mutualistic symbionts that produce the light for them.

Write a paragraph about how you felt as a deep-sea animal that uses bioluminescence.

RESOURCES

www.biolum.org – Information about bioluminescence

<http://www.bioscience-explained.org/EN1.1/features.html> – An ar-

Article written by Dr. Edith A. Widder, Harbor Branch
Oceanographic Institution

<http://www.sciencegems.com/earth2.html>

<http://www.sci.lib.uci.edu/HSG/Ref.html>

NATIONAL SCIENCE EDUCATION STANDARDS

Content Standard A: Science as Inquiry

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

Content Standard B: Physical Science

- Chemical reactions
- Interactions of energy and matter

Content Standard C: Life Science

- Diversity and adaptations of organisms
- Interdependence of organisms
- Behavior of organisms

Content Standard D: Earth and Space Science

- Structure of the Earth system

*Activity developed by Margaret Spigner, West
Ashley High School, Charleston, SC*

Student Handout

1. What color clothing did you choose to wear to class? Why did you select these items? Were they effective? What evidence do you have for this conclusion?

2. Did you do anything special to cover your face, hair or other parts that might show up well? If so, what? Did it work well and why?

3. How well were you able to see the prey with your flashlight off? On? Did the colors make a difference in your ability to see a prey item?

4. When you used the flashlight, did you develop a strategy that decreased your chances of being eaten by the gulper eel? What did you do to avoid becoming prey?

5. Did you benefit from another's flash of light? How?

6. Did the colors of the prey influence those items eaten? If so, in what way?
