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Islands in the Stream 2002: Exploring Underwater Oases

All That Glitters...

Focus
Bioluminescence and deep-sea life

Grade Level
7th through 8th (Can easily be adapted for use in High School Biology)

Focus Questions
What colors, if any, are visible down in the deep sea? What is bioluminescence?

Learning Objectives
Students will learn that white light (visible light) is comprised of all colors of the spectrum.

Students will learn that the quantity of light decreases with increasing depth in the ocean.

Students will learn that the quality of light changes with increasing depth.

Students will earn that red light penetrates water the least and that blue light penetrates water the most.

Students will learn that many ocean organisms are bioluminescent.

Students will learn that bioluminescent light is usually blue.

Students will learn why organisms bioluminesce.

Students will learn about several bioluminescent animals through independent research.

Additional Information for Teachers of Deaf Students
In addition to the words listed as Key Words, the following words should be part of the vocabulary list.
Transparent
Translucent
Counterillumination
Ventral
Countershading
Pelagic

The key words are integral to the unit, but will be very difficult to introduce prior to the activity. They are really the material of the lesson. There are no formal signs in American Sign Language for any of these words and many are difficult to lipread. Having the vocabulary list on the board as a reference during the lesson will be extremely helpful. This activity may require a bit more time to complete. It would be very helpful to copy the Background Information and hand it out to the students to read at the start of the lesson. You can then cover the key elements prior to the activity.

Materials
For the teacher:
- ❒ Thin cardboard (from a food product box) cut to fit shape of projector light source with slit
- ❒ Prism
- ❒ One pair of scissors
- ❒ 36 blue report covers
- ❒ Paper cutter
- ❒ Stapler
- ❒ Staples

- ❒ One glowstick (available at dive shops)
- ❒ If your budget allows, one vial of Ostracods from Carolina Biological (Catalog number GR-20-3430; approximately 500 mg at $32.80)
- ❒ If you are able to collect them, one jar of fireflies

Per student pair:

- ❒ One pair of "deep sea glasses" (see Teacher Prep below)
- ❒ One red, orange, yellow, green, blue and black (dark brown) M&Ms or one small red, orange, yellow, green, blue and black circle, created using a hole punch
- ❒ One piece of black construction paper

Audio/Visual Equipment

- ❒ Slide projector
- ❒ Movie screen or white wall
- ❒ Internet access for students

Teaching Time

One hour

Seating Arrangement

In pairs of two

Maximum Number of Students

36

Key Words

Photic
Aphotic
Twilight zone
Midnight zone
Bioluminescence
Spectrum
Wavelength
Reflect
Absorb

Background Information

If you were able to combine all of the world's ocean basins and stir them together with a spoon, the average temperature of the water would be 4°C, the average depth would be about 14,000 feet, and the average light level would be zero. The bulk of our oceans are comprised of deep sea habitats that exist in very little to no light.

With regard to light level, the ocean has been divided into three zones based on depth and light level. The specific depths of these zones will vary based on a number of physical parameters, but the following three divisions can be used when teaching about light levels in ocean waters. The upper 200 meters of the ocean is termed the photic zone. This zone is penetrated by sunlight and plants thrive. The zone between 200 meters and 1000 meters is known as the "twilight" zone; in this zone the intensity of light dissipates as depth increases and at the lower depths, light penetration becomes minimal. The aphotic zone, or "midnight" zone, exists in depths below 1000 meters. Sunlight does not penetrate to these depths and the zone is bathed in darkness.

Since a bulk of the ocean contains vast regions where light levels are low to nonexistent, numerous species that inhabit these deeper waters produce their own light. This biological process is termed bioluminescence. We will revisit this concept later in this section.

As you travel from surface waters to deeper waters, the quantity of light changes; it decreases with depth. The quality of light also varies with depth. Sunlight contains all of the colors of the visible spectrum (red, orange, yellow, green, blue and violet). These colors combined together appear white. Red light has the longest wavelength and therefore the least amount of energy in the visible spectrum. Violet light has the shortest wavelength and therefore the highest amount of energy in the visible spectrum. The wavelength decreases and the energy increases as you move from red to violet light across the spectrum in the following order: red, orange, yellow, green, blue and violet; the energy of the light is inversely proportional to the wavelength. Middle school students do not need to know the formula below, but it has been included for teacher reference.

E = hc/wavelength where E = energy (in Joules), h = Planck's constant (6.6260755 X 10^{-34} Joules/second), c = the speed of light (2.99792458 X 108 meters/second) and wavelength is in meters

Red light is quickly filtered from water as depth increases. As the wavelength of light increases from red light to blue light, so does its ability to penetrate water; blue light penetrates best. Green light is second, yellow light is third followed by orange light and red light. The exception to the rule is violet light. Although it has the shortest wavelength and the highest energy, violet light is also quickly filtered from water; the small wavelength of light is easily scatted by particles in the water.

All objects that are not transparent or translucent either absorb or reflect nearly all of the light that strikes them. When struck by white light (containing all colors), a red fish reflects red light and absorbs all other colors. Likewise, grass reflects green light and absorbs all other colors. White objects appear white because they reflect all colors of light in the visible spectrum. Black objects appear black because they absorb all colors of light. On a hot sunny, summer day do you stay cooler wearing a white shirt or a black one? The answer is a white shirt! A white shirt reflects all wavelength of light, while a black shirt absorbs them. Now consider that red fish. If a red fish is swimming at the surface of the ocean, it appears red because it reflects red light. Can you see a red fish swimming at 100 meters? At this depth the red fish is difficult, if not impossible to see, and appears blackish because there is no red light to reflect at that depth and the fish absorbs all other wavelengths of color.

In the twilight zone, there are numerous animals that are black or red. At depth, these organisms 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. 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.

Animals that seek to produce something visible to other organisms have taken advantage of the penetration of blue light in water. Many ocean animals, especially those living in the twilight and midnight zones, are bioluminescent and can produce their own light. Most bioluminescence, although not all, produces blue light. This now makes sense. An animal producing red light in deep water would produce light that is not visible. Blue light, in the form of bioluminescence, is visible at depth. 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 underside, or ventral surface. They are able to increase the light level of their underside 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 an underside that blends in with the lighter waters above when viewed from a predator below. This is very similar to countershading (animals with lighter undersides and darker backs (upper or dorsal surfaces), but instead the organism has adapted to using light to achieve the same effect. Shining tubeshoulders and bristlemouths both have underside-lights!

Attracting a Mate: Many organisms have species-specific light patterns and in some, these patterns are 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.

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. Scientitsts believe that this animal might use the light to attract prey to its humongous mouth.

Escape Tactic: Some organisms will use light to temporarily distract or divert predators. Some animals will shoot out "clouds" of light. Others actually drop bioluminescent body parts! The goal is for the light to confuse or distract a predator, while the "unlighted" animal attempts to escape. Some deep-water shrimps "vomit" bioluminescent clouds, while some copepods shoot bioluminescent clouds from their other ends!

During the South Atlantic Bight Expedition, two scientists from the Harbor Brach Oceanographic Institution, Dr. Tamara Frank and Dr. Edith Widder, will be studying vision and bioluminescence in the deep sea. They are particularly curious about animals with large eyes that live on the bottom of the seafloor in the aphotic zone. Many animals that swim in the open water (pelagic) in the twilight zone have very large eyes relative to their body size. This makes sense. Just like an owl that hunts at night in minimal light conditions, these animals too have maximized eye size to capture available light. As depth increases in the twilight zone and into the midnight zone, eye size in many organisms becomes reduced. For example, there are two different species of bristlemouths, *Gonostoma denudatum*, a midwater fish, and *Gonostoma bathyphilum*, a deeper water fish. *Gonostoma denudatum* has a much larger eye as compared to *Gonostoma bathyphilum*. In the total absence of light, it makes sense that eyes would be reduced or altogether absent. However, an enigma exists. Many animals living along the benthos (along the sea floor) in deep, dark water have huge eyes!!! Dr. Frank and Dr. Widder want to know why! Are these animals looking for bioluminescence or do they use their eyes for some other purpose? They will be attempting to collect some of these large-eyed, benthic animals to study the physiology of their eyes and, thus, to determine their function.

Learning Procedure

Teacher Prep:

1. Cut out a piece of thin cardboard to fit over the projector light source.
2. Cut a thin slit, just a few millimeters wide and about an inch long, in the center of the cardboard.
3. Place cardboard over the light source to create a thin beam of white light.
4. Place prism in beam of light and practice rotating prism to best project the colors of the spectrum on the movie screen or white wall.
5. Cut each blue report cover lengthwise into four strips of roughly two-inch thickness. Because the report covers have a front and a back, you will end up with eight strips total.
6. Staple the eight strips together, using two staples, along the short edge. Each set of eight strips will serve as student "Deep Sea Dive Goggles."
7. Separate M&Ms by colors so that each student pair will have one of each of the following colors: black (dark brown), red, orange, yellow, green and blue to create an "M&M" set. Students love to play with candy, but you can also use a hole puncher to cut out dots from construction paper of each of the colors listed above for each student pair (use bright blue paper for the color blue).

The Day of the Lesson:

1. Begin with a discussion of what your students know about light.
2. Discuss the key elements presented in the Background Information.
3. Explain that a slide projector, like the sun, is a source of white light.
4. Explain that a prism breaks white light into all of the colors that comprise white light.
5. Dim the lights in the classroom.
6. Using the slide projector and prism, show students the colors of the visible spectrum.
7. Have students write down the colors they see

in order as they observe them.

8. Tape a small piece of a blue report cover over the light source.
9. Ask students to note what color is projected (blue).
10. Ensure that students understand that the blue report cover blocks part of the spectrum by absorbing some of the colors of light.
11. Turn off slide projector.
12. Pass out one piece of black construction paper, one set of Deep Sea Diving Goggles, and one "M&M set" to each pair of students.
13. Explain that the black piece of paper represents the darkness of the deep sea.
14. Ask students to spread their M&Ms out over the black piece of paper.
15. Have students place one of the eight layers of blue report covers over their eyes and while looking through the blue layer, observe which colors of M&Ms are readily visible. Allow enough time for each student in the pair to observe.
16. Have students add an additional report cover layer (total of two layers) and repeat their observations.
17. Continue to add layers and observe colors until all eight layers have been used. Note: Using the blue report covers allow students to see how colors appear in deeper water. The blue covers filter out other colors of the spectrum with increasing efficiency as additional layers are used. Water, likewise, with increasing depth selectively filters out all other colors of the spectrum with the exception of blue. Students should observe that the color black disappears first, followed by red, then orange, and yellow.
18. Ask students why they think there are so many red animals living in the twilight zone.
19. Introduce bioluminescence using fireflies or a glow stick. Explain that glow sticks often produce light that is not blue, but that most bioluminescence in the ocean produces blue light. Ask students why they think most bioluminescence produces blue light and not some other color.
20. Explain that most bioluminescence is produced when organisms mix two chemicals together in the presence of oxygen. The result of the chemical mixing is bioluminescence.
21. If you were able to purchase ostracods from Carolina Biological, place three to five in the palm of your hand. Add two drops of water to your palm. Crush the dried animals using a finger and show your palm to the students; a bright blue light is produced. When you crush the dried animals, two chemicals mix to create blue light.
22. Explain what scientists Widder and Frank will be studying during the upcoming South Atlantic Bight Expedition.
23. 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	Ratfish
Squat lobster	Snailfish
Midwater shrimp (*Sergestes sp.*)	

Note: descriptions of these animals can be found on the Monterey Bay Aquarium's website 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.

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

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.

Connections to Other Subjects

Art - Using glow in the dark paint and construction paper recreate a deep sea animal, in 3-D, that bioluminesces.
The Bioluminescence Coloring Book, by Edith Widder. Harbor Branch Oceanographic Institution. ISBN 0-9659686-0-X

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

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 offshore 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

Provide student pairs with a flashlight and a written specific pattern for turning their flashlight on and off (i.e. two second on, five seconds off, four seconds on, five seconds off). Provide the same pattern to one other student pair in the room. Provide different patterns to other student pairs in your classroom (ensuring that two student pairs have a matching pattern). Dim the classroom lights and ask students to begin their "flashlight patterns." To reduce chaos, have students remain seated. Ask students to find the other team in the room that is displaying the same pattern as they are. Explain that in the deep sea many animals use light patterns to recognize different species and, in some cases, to recognize one sex from the other.

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://people.whitman.edu
http://www.seasky.org/monsters
http://www.divediscover.whoi.edu
http://www.nationalgeographic.com
http://www.marine.whoi.edu/ships/alvin/alvin.htm
http://www.ocean.udel.edu/deepsea
http://www.pbs.org/wgbh/nova/abyss/life/extremes.html
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

For More Information

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