Life in the Deep Sea

Answers to Worksheet Questions

Name _____ Period _____ Date _____

Now that Dr. Widder prepared you as a diver, it is time to investigate the unique properties of life in deep sea. You and your group will have 10 minutes to explore each station. We will rotate clockwise and the stations can be started in any order. Once you arrive, read the information on the station card and answer your questions below.

A necessary skill of an Ocean Scientist is to work collaboratively and build on each other's strengths. Therefore, we encourage you to work with each other to accomplish the goals of the station. Many of these stations are ones you've seen or used; however, note how when they are put into a real world context they stimulate investigative questions and interest into learning more about the deep sea. Bon Voyage!

Station A: The Wonders of Water

Background: *Water has unique properties that make life on Earth possible. We are going to focus on two of these:*

1. *The Water Molecule: We all talk about water made of hydrogen and oxygen molecules to our students. Here is a way to show the bubbles of gas as the water molecules are being separated.*
2. *Water Density: Water density increases with increasing salinity. As the density of a liquid increases, its molecules are closer together, which allow objects with less density to float. Liquid water, like most substances, becomes denser as it cools. So, cold saline water is denser than warm fresh water. As water continues to cool however, it expands and becomes ice. Ice is less dense than water, which is why it floats.*

A1 – The Water Molecule

Procedure

1. Hold the points of the pencils against the battery poles and immerse the other ends in the cup of salt water.

2. Observe bubbles rising from each of the pencil points and record the differences.

Analysis

1. What gases are produced by the electrodes?
   Hydrogen and Oxygen

2. Which electrode, positive or negative, has more bubbles touching it? Why?
   The pencil touching the negative pole of the battery will generate more bubbles because the positively charged hydrogen atoms are pulled to the pencil touching the negative pole of the battery and the negatively charged oxygen is pulled to the positive pole. There are 2 H atoms for every 1 oxygen atom.

A2 – Water Density and Salinity

Procedure

1. Fill the fresh and salt-water cups half-way with water. Try to add equal amounts of water to each glass.
2. Add an egg to each cup and observe.
3. We want to make the egg float. Predict the number of tablespoons your group will need to add before the egg will float.
4. Add salt to the salt-water cup and record the amount added below. It is ok if you add in slow increments to discover the approximate amount of salt needed.
5. Test your progress by placing 1 egg in each cup and observing.
6. Please pour out the salt water into the bucket, and clean up the station area following the activity.
7. Bonus: use the Refractometer to measure the salinity of the water.

Analysis

1. Predict the number of tablespoons it will take to make the egg float? _____ Tsp

2. Amount of salt added to make the egg float. _About 2_Tsp Salinity? _____

3. Why did the egg float in the salt water but not in the fresh water?
   The salt water is a denser than the overall density of the egg and therefore the egg floats. In the case of the fresh water, the density of the egg is less than the water and it sinks.

4. Write the relationship between salinity and density. As salinity increases…density…
   As salinity increases, density increases.

5. If you were given two water samples, one from the deep ocean and one from the surface, how might you be able to tell them apart?
   The deep ocean sample will be saltier and more dense than the surface sample, therefore you could test by floating an egg in samples of deep ocean and surface water. The egg should float higher in the deep ocean water and lower in the surface water.

A-3 Water Density and Temperature

Procedure

1. Place the blue ice cube in the cup of water.
2. Observe where the dye goes. Use the thermometer to measure the temperature of the water in the streams of dye compared to the temperature of the surrounding water.

Analysis

1. What is the temperature of the water? _____ of the melted blue water? ____

2. Where did the blue dye go as the ice melted?
   The blue water sinks to the bottom of the container because the colder water is denser.

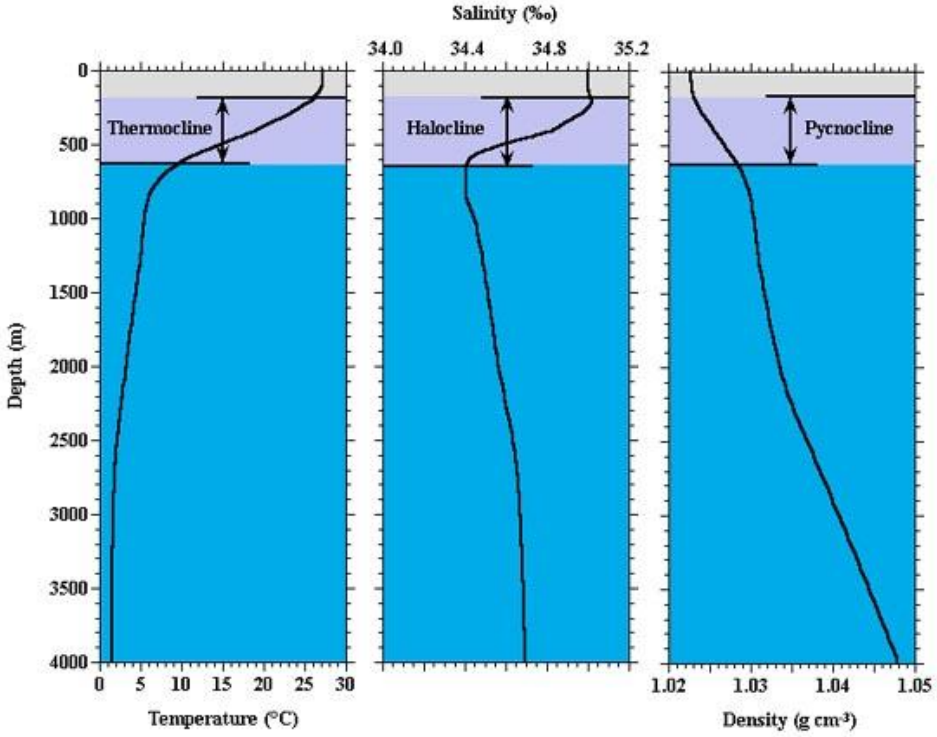
3. How does the action of the blue water explain how currents could be formed?
   As cold water sinks, the motion of it moving from the surface and replacing subsurface water creates deep water currents.

Conclusions

The zone in which temperature changes rapidly with depth is called a **thermocline**, the zone in which salinity changes rapidly with depth is called a **halocline** and the zone in which density changes rapidly with depth is called a **pycnocline**. These "clines" (from the Greek word meaning "to lean" like an incline) have a profound influence on where different animals live in the ocean.

1. Which of the previous experiments demonstrates how these clines can be formed? Explain.
   Station A-2 and A-3 demonstrate how a thermocline, pycnocline and halocline can be formed. Station A-2 shows us that the saltier the water, the more dense the water will become. The ocean is influenced by a variety of waters inputs and outputs that influence the salinity, like evaporation at the equator or fresh water inputs. These waters then stratify into a halocline. Station A-3 looks at the effect of the temperature on the density of the water. The colder the water, the more dense it is and this stratifies the ocean (with exception to the polar regions) with a distinct thermocline of warmer, less dense waters at the surface, and cooler, more dense waters at depth.

2. Look at the graphs of a thermocline, halocline and pycnocline below. What is life like in the deep sea (below 1000 or 1500 m) in terms of temperature, salinity and density?
   Very cold, moderately saline and dense water.



3. How do you think these different properties might influence where different animals live?
   Some organisms are better adapted for warmer water and live shallower, while some have adapted for the cold water environment and live deeper. Some are better adapted for saltier water and some have higher density tissues and so they live in deeper waters. Many animals maintain their depth in the water not by swimming but by the density of their bodies so like the eggs they will float at the depth that matches their density.

Station B: Animal Adaptations to Life in the Deep Sea – Using bioluminescence to survive
Background: Many animals spend most of their lives in near darkness and use bioluminescence to help them do all the things they need to do to survive: find food, attract mates and avoid being eaten. In fact most of the animals living in the open ocean – out away from shore – are bioluminescent.

Advantages of bioluminescence vary. Many fish, squid and shrimp use their bioluminescence for camouflage with a trick called c**ounterillumination**. Dim blue light filters down through the depths in the midwater or mesopelagic zone (200-1000 m). At these depths predators can locate prey by searching for the silhouettes of the animals swimming above them. To camouflage themselves, organisms have **photophores** (light organs) located on their bellies or ventral sides of their bodies. These photophores are used to produce light that matches the color and intensity of light coming from above. This makes the animal almost invisible to the predators below them. Animals can even adjust the light from their belly lights to match the light fluctuations from above.

Procedure
There are 10 deep-sea specimens for you to observe at this station. Investigate and explore the adaptations these organisms have to survive life in the deep sea. Then choose four of the organisms to focus on and answer the following questions.

1. Where are the bioluminescent organs located on the organism and how does the production of light in these specific areas benefit the organism? **On the ventral side (belly), sides of body and around the head. Deep-sea organisms use bioluminescence to hide, find food and find a mate. For example, lateral photophores are often used to counterilluminate the light above to help the organisms camouflage in the open ocean.**

2. What other adaptations enable this organism to reside in the deeper depths of the ocean? **Dentition, Color, Body shape, Eyes.**

3. *If you have time, sketch the organism and color in the photophores with highlighter.*

Analysis See Animal Adaptations Cards

1. Organism 1 _____
   a. Bioluminescent light

   b. Other Adaptations

2. Organism 2_____
   a. Bioluminescent light

   b. Other Adaptations

3. Organism 3_____
   a. Bioluminescent light

   b. Other Adaptations

4. Organism 4_____

a. Bioluminescent light

b. Other Adaptations

Conclusions

1. Name 3 ways animals use bioluminescence to survive.
Finding Food, Defense, Finding mates

2. Why do you think the majority of bioluminescence in the ocean is blue in color?
Blue light travels further through seawater than any other color so it is the best color for communicating over long distances

Station C: Changes with Depth – Pressure

Background: *The weight of the Earth's atmosphere at the surface of the ocean is equal to 1 atmosphere, 1 bar, or 14.7 pounds per square inch (psi). You are exposed to that amount of pressure every day. Water is much denser than air, and if you dive into the ocean you will experience an increase in pressure as you dive deeper. The deeper you go in the ocean, the greater the amount of water you have pressing in on you. The greatest impact is on animals with gas-filled spaces in their bodies – such as ear canals and fish swim bladders.*

C1 – Water Pressure Demonstration Tube

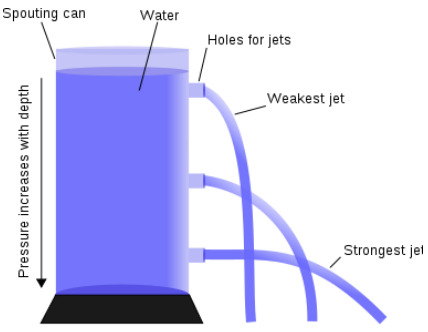
Procedure

1. Using the beaker or pitcher, fill the cylinder with water to approximately 1 cm from the top.
2. Using three hands, remove the blue corks from the demonstration cylinder at the same time.
3. Observe the spouts of water.
4. Repeat if necessary.

Analysis

1. What is the relationship between the distance of the holes from the top of the cylinder and the stream length:

The weight of water is heavy. The water on the bottom of the cylinder has more heavy water piled on top which influences the water pressure. With more weight and water pressure, the water from the bottom spout is pushed with more force and is the strongest and furthest jet.. Students should be able to explain that the weight of the water is greater at the 3rd hole and shows the increase in pressure with depth – see diagram below.



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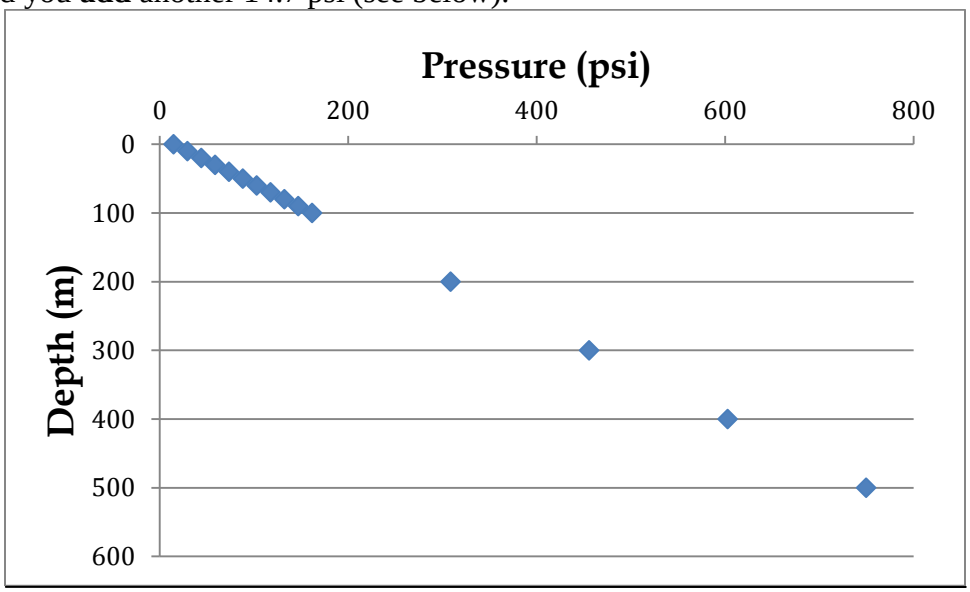
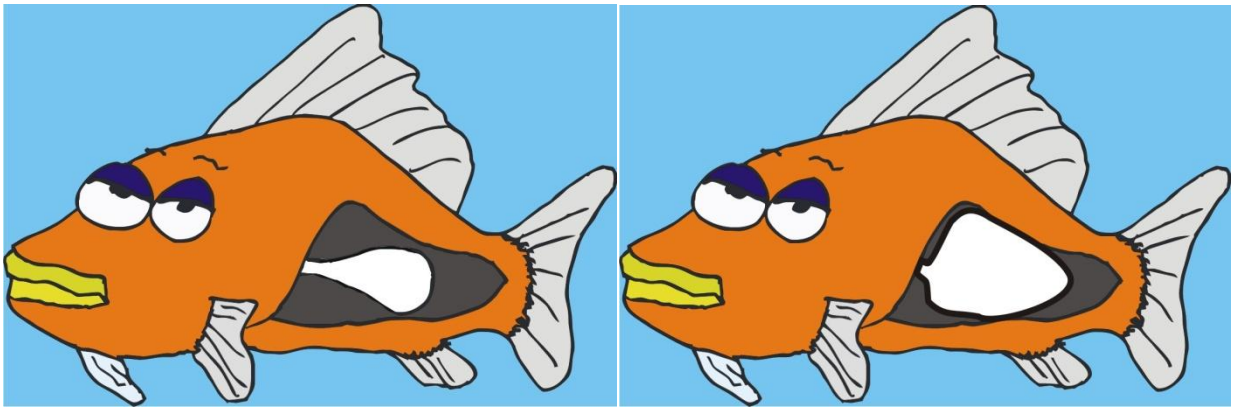
Conclusions –

Water is heavy, much heavier than air. The weight of the Earth's atmosphere at the surface of the ocean is equal to 1 atmosphere or 14.7 pounds per square inch (psi). If you dive into the ocean you feel the pressure build up very quickly because water is so heavy compared to air. At just 10 m the pressure doubles to 2 atmospheres or 29.4 psi. If you dive deeper the pressure **increases**. For every 10 m that you descend you **add** another 14.7 psi (see below).



1. Use the graph above to determine how much pressure a fish would feel that is living at 500 m? **764.4 psi**



A B E.Widder

2. Note the differences in the size of the swim bladder in these two fish, A and B. They are the same species and size of fish, however fish B has a noticeable increase of gasses in the swim bladder. Which fish would be swimming higher in the water column?

Fish B would be higher in the water column due to the increase in gasses and buoyancy. Many fishes regulate their buoyancy through the swim bladder, to remain neutrally buoyant. Gasses consist primarily of nitrogen, oxygen, and carbon dioxide. There are 2 types of swim bladder: open and closed. The open bladder is connected to the esophagus and air is gulped and stored in the swim bladder. The closed type of swim bladder is not connected to the esophagus and instead regulates the gasses in the swim bladder through gas exchange in the bloodstream.

Station D: Changes with Depth – What is Light?
Emitted light results from changes that occur in atoms when they absorb energy. Different types of light are distinguished by their different sources of energy. The two main forms of light are **incandescence** or hot light and **luminescence** or cold light.

In **incandescence** the energy to produce the light comes from heat so these sources generate both heat and light. Examples include the sun, a candle flame and an incandescent light bulb.

In **luminescence** the energy to produce the light is produced by some means other than heating. Four examples o f luminescence are:

- **Fluorescence** – The energy comes from light. Wavelengths of light are absorbed and the substance immediately re-emits the light at a lower intensity. The re-emitted light stops when you remove the light source. "Black Light" posters are fluorescent.
- **Phosphorescence** – The energy comes from light. Wavelengths of light are absorbed and the substance slowly re-emits the light at a lower intensity. The re-emitted light does not stop when you remove the light source. It may continue re-emitting light for a long time. Glow-In-The-Dark paint and toys are phosphorescent.
- **Chemiluminescence** – The energy comes from a chemical reaction and is generated by the release of energy created from the chemicals combining.
- **Bioluminescence** – The energy comes from a chemical reaction and is a form of chemiluminescence created by living organisms. Fireflies and lantern fish bioluminese.

Procedure/Analysis
D-1 Incandescence and Luminescence
Read the background information and then look at the real world examples of light. Dr. Widder may also provide insight as well.

Record the following observations:

	Incandescence	Fluorescence	Phosphorescence	Chemiluminescence	Bioluminescence
Hot or Cold?	**Hot**	**Cold**	**Cold**	**Cold**	**Cold**
Energy Source	**Electricity**	**Light**	**Light**	**Chemical**	**Chemical**
Colors?	**All Colors**	**All Colors**	**All Colors**	**All Colors**	**All Colors- mostly blue and green**

D-2 Fluorescence and Phosphorescence

1. Use the UV flashlight to shine on the fluorescent material (Fluorescent highlighter and clay). Turn the light off.
   Did the fluorescent material emit light after the flashlight was turned off?
   No, Fluorescence requires light to be emitted before it can be reemitted in the form of fluorescence.

2. Use the UV flashlight to shine on the phosphorescent material (Phosphorescent putty in petri dishes). Turn the light off.

Did the phosphorescent material emit light after the flashlight was turned off?
Yes, Phosphorescence will be emitted at a lower energy in the form of fluorescence, even after the radiant light energy has been removed.

3. Now try the flashlight with the red light.
   Record the difference in luminescence emitted using the red light and UV light.
   The UV light produced more reemitted phosphorescence than the red light.

4. After you removed the light source from the putty, which light produced the larger amount of luminescence in the putty? Explain.
   The UV light is a higher energy, shorter wavelength. The red light is a lower energy, longer wavelength. Therefore there is a higher amount of energy introduced by the UV light, and subsequently a larger amount of light reemitted by the phosphorescent material.

D-3 Chemiluminescence – Light Sticks

Observe the two light sticks: one is in hot water and one in cold water.

1. After an hour at these different temperatures- If you allow each light stick to come back to room temperature, do you think they will emit the same amount of light or will one be brighter than another?
   One brighter than the other. After an hour (or longer if a high quality light stick) the one in colder water will be brighter than the light stick in the hot water.

2. If the latter, which one will be brighter and why?
   The one in hot water because the chemicals are moving slower and bumping into each other less often. If you allow the light sticks to come to room temperature and then compare them you will find that the light stick that was in the cold is the brighter one. This is because while it was cold it was using up its light producing chemicals more slowly than the light stick in the hot water. So now the difference in brightness is due to different concentrations of the reacting chemicals, rather than to different speeds.

D-4 Bioluminescence

Gently stimulate the dinoflagellates.

1. What color is the light emitted and what happened to the flashes of light over time?
   Blue flash of light. Note that they flash when disturbed and each flash is dimmer than the last because just as with the light sticks the chemicals are used up. Given time and sunlight, so that they can photosynthesize, these dinoflagellates can produce new chemicals. Students should realize that animals need to produce cold light to keep from burning up.

2. Predict why this light may be beneficial for the dinoflagellate?
   And many animals use bioluminescence to avoid being eaten. Some can release their bioluminescent chemicals into the water to distract or temporarily blind a predator. Others use their bioluminescence once they are caught by a predator to attract the attention of a larger predator that will attack their attack and give them a chance to

escape. This display is called a *burglar alarm* and is the most commonly accepted reason dinoflagellates produce light.

Station E: Changes with Depth – Light in the Ocean

Background: *Visible l*ight can be **emitted**, **scattered** and **absorbed** and these properties play key roles in how light is transferred through ocean depths. The amount of sunlight in oceanic waters decreases with depth, and the color changes as the wavelengths of light become scattered and absorbed. Most of the visible light is absorbed in the top 10 meters of the surface with very little visible light penetrating below 150 meters depth. Wavelengths of light change are absorbed and scattered with depth as well. The longer wavelengths like red light are absorbed first where as the shorter wavelengths penetrate deeper.

The absence or presence of light defines where organisms live in the water column. Visible wavelengths of light from the sun allow photosynthesis to occur in plants inhabiting the surface layers of the ocean. Below these surface layers (between 100-1000 m) is a dimly lit area that does not support photosynthesis but animals live there. Sunlight is absent below 1000m.

Station E-1 Light Bottles
Procedure

1. Turn out lights and shine the flashlight into the top of each bottle. If the flashlight is waterproof, push the light against the surface of the water.
2. Record how the light looks as it shines through each bottle. Pay attention to the colors of light you see and the relative depths where they dissipate.

Bottle Number	Treatment	Observations with White Light	Observations with Blue Light stick	Observations with Red Light stick
1	Water only	Light goes through water.	Visible	Visible
2	Water + Coffee creamer	Light scattered throughout water and out of bottle.	Not visible, but the blue light is scattered throughout the water.	Red light scattered but diminished intensity.
3	Water + Blue dye	Light goes through water.	Visible	Diminished light and a different color.
4	Water + Coffee creamer + Blue Dye	Light scatters throughout the water.	Not visible, but the blue light is scattered throughout the water.	Very little light observed. Light stick disappears.

3. Activate blue and red light sticks
4. Lower the blue light stick into each bottle, one after the other

5. Observe and record the light you see in each bottle above
6. Lower the red light stick into each bottle, one after the other
7. Observe and record the light you see in each bottle above.

Analysis

1. Did the light decrease in intensity or retain the same intensity as it passed through the water? Explain.

Comparing the 1st and 2nd bottles demonstrates that you only see light that is scattered toward your eye. (Note that visible lasers seen in Hollywood movies like Oceans 12 are a myth. You can't see the laser unless there are particles in the air or the water to reflect the light toward your eye.) Comparing the 1st and 2nd bottles with the 3rd and 4th bottles shows what happens when light is absorbed – the intensity of light diminishes. Note that blue dye appears blue because it absorbs all colors except blue. Similarly seawater appears blue because it scatters blue light.

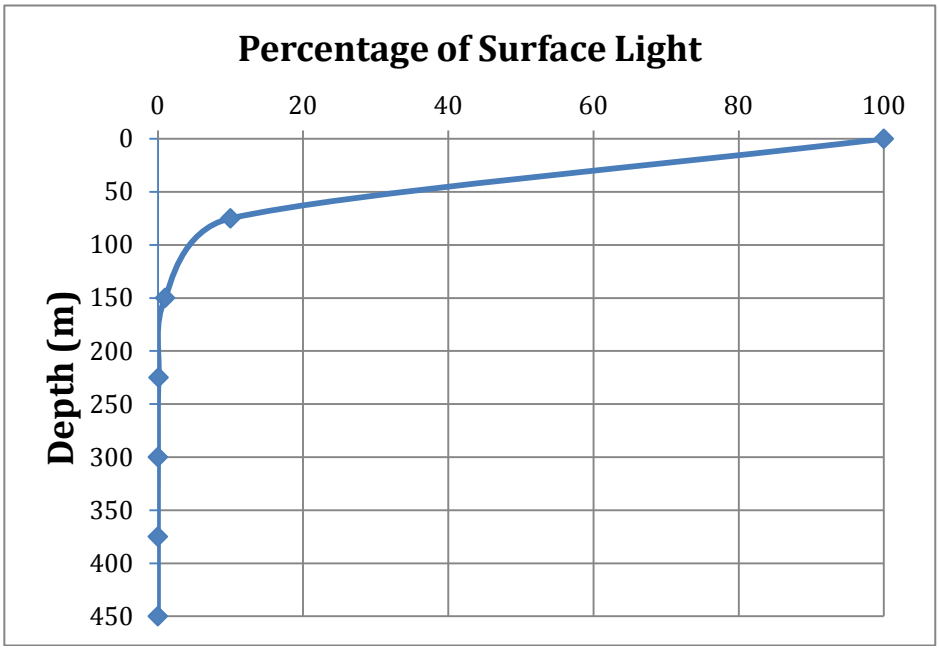
The 4th bottle demonstrates what happens over very long distances in the ocean – light is both scattered and absorbed. The more particles there are in the water - as occurs in coastal waters where sediment runs off the land – the more the light is redirected and the more opportunities it has to be absorbed, therefore the light doesn't penetrate as far as it does in very clear water away from shore.

In clear ocean water, visible light **decreases** approximately 10-fold for every 75 m that you descend. This means that at 75 m the light is 10% as bright as it was at the surface; and at just twice that depth, 150 m, it is another 10-fold dimmer, or 1% of surface light. Below this depth there is insufficient light for photosynthesis, but there is still plenty of light for seeing. This is because eyes are useful over an astonishing range of intensities. It is believed that the very sensitive eyes of some deep-sea fish can still detect sunlight at 1000 m.

To calculate the 10% decrease in light with each 75 m of increasing depth you simply **multiply** the light by 0.1, which is the same as 10%

Depth (m)	Percentage of surface light
0	100
75	10
150	1
225	0.1
300	0.01
375	0.001
450	0.0001

2. Plot these data on the graph below:



E-2 – Challenges of the Deep
Procedure: View the video clip from: Challenges of the Deep – Survival at Extreme Depths.

Analysis

1. List the colors from the color chart attached to the ROV, in the order they disappeared during the decent. **Red, Green and Yellow almost simultaneously, Blue**

Conclusions

1. What factors affected the light transmission in the bottle?
   The amount of particulate or creamer in the water scattering light. The color of the water that influences the visible light spectrum

2. Why is the red wavelength of light absorbed quickly in the water, and blue light penetrates further?
   Wavelengths of light are scattered at the ocean surface and absorbed as the water becomes deeper. The longer wavelengths with lower energy are red and orange. These wavelengths are quickly absorbed, leaving only the shorter, higher energy wavelengths of light availa-

ble. The shorter wavelengths, violet and blue, are higher in energy and penetrate further into the depths of the ocean. This blue light that remains is why the ocean looks blue.

3. Figure 2 below is a graph that shows light penetration in the open ocean vs. coastal waters. What are 2 factors that would affect light penetration in both the coastal waters and open ocean? **Explain to students that although when plotted on a graph like this it looks like there is no light below 150 m that, in fact, there is enough light for animals to see each other down to as deep as 1000 m.**

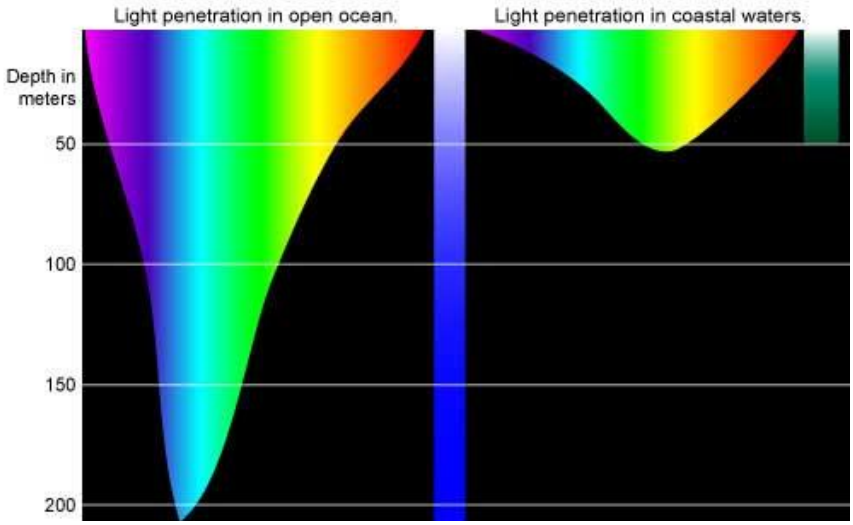


Figure 2. Light attenuation in open ocean vs. coastal waters. NOAA

Assessments

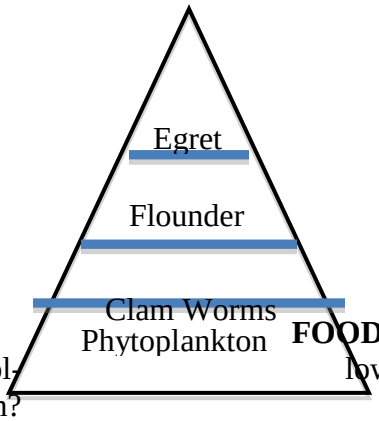
Multiple Choice Questions

8th Grade FCAT Question from the Florida Department of Education (2007):
The Indian River Lagoon

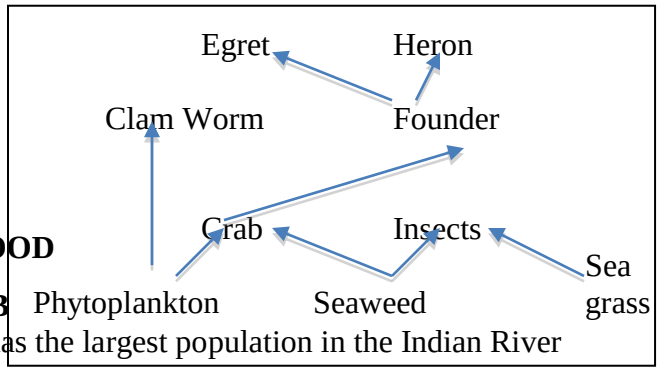
An estuary is a body of water in which fresh water draining from the land mixes with salt water from the ocean. The result of this mixture is an environment with abundant plant and animal life. The Indian River Lagoon is a 156-mile-long estuary on Florida's eastern coast. It is a diverse estuary, supporting thousands of species of plants and animals.

The food web and food pyramid shown below are examples of the relationships that exist in the Indian River Lagoon ecosystem.

not to scale



PYRAMID



FOOD WEB

1. Which of the following has the largest population in the Indian River Lagoon ecosystem?

A. crab
B. egret
C. flounder
D. Phytoplankton
Answer D Phytoplankton

2. In the Indian River Lagoon ecosystem, many organisms compete with one another for food sources. Which organism in the food web competes with egrets for food?

A. Clam worm
B. Crab
C. **F**lounder
D. Heron
Answer D Heron

3. Which of the following statements **most** accurately describes the energy transfer between the levels of the food pyramid in the Indian River Lagoon?

A. Energy travels up the pyramid.
B. Energy stays in the phytoplankton at the lowest level.
C. Energy is released into the environment only at the top level.
D. Energy moves from the flounder to both the clam worms and egret.
Answer A Energy travels up the pyramid.

Critical Thinking Questions (2-3)

1. How does both produced light, in the form of bioluminescence, and ambient light play a role in predator – prey relationships in the mid-water and deep sea?
   Bioluminescence is utilized by predators to find prey by means of a lure, or even emitted like a flashlight to help search for prey. Fortunately for the prey, bioluminescence is also used in counterillumination, to reduce their silhouette, and alleviate the chance of predators seeing them from below. This is much like countershading used by organisms nearer surface waters (lighter ventral coloration/darker dorsal coloration). Bioluminescence can also be used by prey as a burglar alarm, and also emitted as a blinding mechanism or to get the predator's attention to focus on the bioluminescent chemicals in the water, while the prey can move to safety undetected. The small amount of light in the mesopelagic zone may not be visible to humans, however many of the organisms in this region of the ocean have adapted to see this minimal light. Predators depend on this light to feed, and prey uses the light as well to illuminate predators. As the light diminishes in the evening, vertical migration is triggered and animals move up to the surface waters to feed in the dark waters. Even the small changes in ambient light in these deeper waters changes behavior and predator-prey strategies.

2. Although a great distance divides the surface waters from the deep sea; the productivity of the mid-water and deep sea is largely dependent upon energy produced in the surface waters. Describe 3 ways the surface waters provide energy to the mid-water and deep sea.
   Cold water sinking due to increased density brings a great deal of nutrients from the surface waters. Primary productivity in the photic zone moves through the food web to the deep-sea organisms. (Many of the larval stages of deep-sea organisms actually inhabit upper layers of the ocean until they move into juvenile stages and descend)

   Marine Snow is a primary source of food for many deep sea and benthic organisms- small bits of organic matter descend from surface waters. Vertical migration occurs when large masses of organisms move up in the water column to feed on abundant plankton in the surface waters. Deep-sea organisms ascend as well to feed.

3. Imagine you are diving down to 2000 meters deep and looking out your submersible window. What changes would you observe as you submerged and at what depths would you expect to find these changes occurring?
   Light will quickly diminish as we dive. Depending upon where we dive and the turbidity of the water, only 1% of the surface light will be available around 150 meters. Below that depth to 1000 meters, it will seem dark to our eyes and we will use the sub lights to navigate down. Organisms living in these mesopelagic zones are able to utilize the minimal rays of light to see. Below 1000 m, the waters outside the sub seem pitch dark with the lights on, yet fantastically illuminated by surrounding bioluminescence when the sub lights are turned off. Other observations will depend upon the depth of the thermocline. The bright upper waters are warm and as the waters get dark, they will also get cold. We are protected within the engineering of the sub that is bearing the increasing pressure with depth.