Investigating Aquatic Dead Zones

A series of activities designed to explore areas of low oxygen in aquatic systems

Objective

To explore the interdisciplinary factors involved with the onset of dead zones in aquatic systems.

National Science Education Standards:

K-12 Unifying Concepts and Processes

- Evidence, models, and explanation
- Constancy, change, and measurement

9-12 A. Science as Inquiry

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

9-12 C. Life Science

- Interdependence of organisms
- Matter, energy, and organization in living systems
- Behavior of organisms

9-12 F. Science in Personal and Social Perspectives

- Natural resources
- Environmental quality
- Natural and human-induced hazards

Investigating Aquatic Dead Zones

Background

In coastal marine environments, "Dead Zones" are regions where oxygen concentrations are very low. This condition of oxygen deficiency, known as hypoxia, is caused by an interaction between biological, chemical and physical factors. In the absence of sufficient oxygen, animals and plants either die or leave the dead zone. Although these affected waters are called dead zones, many bacteria can thrive in this region, feeding on the abundant food produced in the overlying waters. Hypoxia is a natural phenomenon that occurs periodically in coastal waters around the world. During the last 50 years, however, increases in key pollutants derived from human activities on land have thrown many coastal ecosystems out of balance, resulting in expanded dead zone regions.

This activity includes a series of experiments that demonstrate how dead zones are formed, what affects dead zones, and what are the effects of dead zones on aquatic organisms.

Part A. Draw a Dead Zone

Objective

Students will become engaged in the topic and begin to visually organize the complex factors that contribute to an ecological phenomenon.

Materials

- Blank paper
- Colored pencils/markers
- Tacks/tape for hanging up student work

Procedure

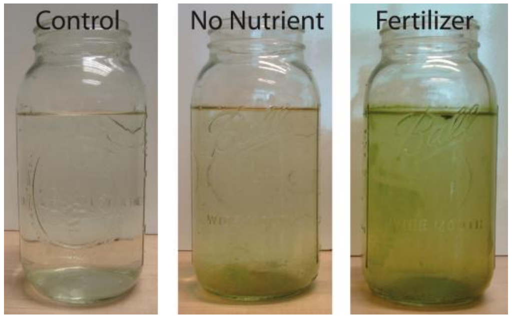
1. Hand out paper/drawing supplies and have the students work either individually or in groups to draw what they know about dead zones.
2. Hang up the drawings and lead a "gallery walk," having the artists share what they drew. Instructor can begin to introduce key vocabulary and concepts through discussion of drawings.
3. Save the drawings to revisit at the end of the unit.

Part B. How Does a Dead Zone Form?

1. Biology of Dead Zones

Objective
Students will understand the biological processes associated with dead zones, as well as how human activities impact the severity of dead zones.

Materials
Three clear 2 liter soda bottles or liter mason jars per group
Scissors
Vernier Dissolved Oxygen Sensor (http://www.vernier.com/probes/do-bta.html)
Tape to label bottles, plastic wrap, rubber bands
Pond, lake, stream, or estuary water
Tap water
Sunlit windowsill
Over the counter fertilizer (we used Bonide® Nitrate of soda (15-0-0) and Plant Starter Concentrate (3-10-3)). Use a fertilizer that contains only nitrate, ammonia, and phosphate (potash is ok) and avoid urea.
A dark place to set bottles
Student Data Sheet (download below)



Procedure
Place students in groups of 3 or 4 and assign them to bring in three bottles or jars (per group) for the lab experiment; review the concepts of photosynthesis, respiration, and decomposition.

1. Cut the top off each bottle (if using 2-liter bottles) where the bottle tapers and remove plastic/paper covering.
2. Fill one bottle with tap water and let sit overnight. Label the bottle "control."
3. Fill the other two bottles with pond, lake, etc. water.
4. Add 100 mg of each fertilizer to one of the remaining bottles and mix thoroughly to dissolve. Label this bottle "dead zone." Label the remaining bottle "no nutrient." Place each bottle in a sunlit window for 5-7 days. Have the students record daily observations of the bottles, including sight and smell descriptions as well as an oxygen reading using the Vernier lab probe. The best time of day to record oxygen is in the afternoon when the algae growing reach peak net photosynthesis (see manual for how to use Vernier lab probe – do not submerge the entire probe in water). The idea is to simulate an algal bloom, or eutrophication, in which excess phytoplankton grow in response to excess nutrient input. As the microscopic algae grow, you should observe increased oxygen

levels due to increased photosynthesis. Eventually you will be able to physically see increased algae as the water turns green. You should observe significantly more algae growing in the fertilized bottle, and significantly higher oxygen levels.

5. Plot the dissolved oxygen reading each day using a spreadsheet or by hand as in Fig. 1a.
6. After 5-7 days (when an algal bloom has grown in the bottle), remove the dead zone bottle from the sunlight and cover with plastic wrap (if a 2-liter bottle) or the mason jar cap. Secure the plastic wrap with a rubber band and leave them in a dark place. This is meant to simulate what happens when phytoplankton in a coastal system die, sink to the bottom, and decompose, consuming oxygen. Have students continue to record data each day. Oxygen levels should fall to a dead zone (<2 milligram per liter) as algae die from lack of sunlight and start to decompose.

Hints

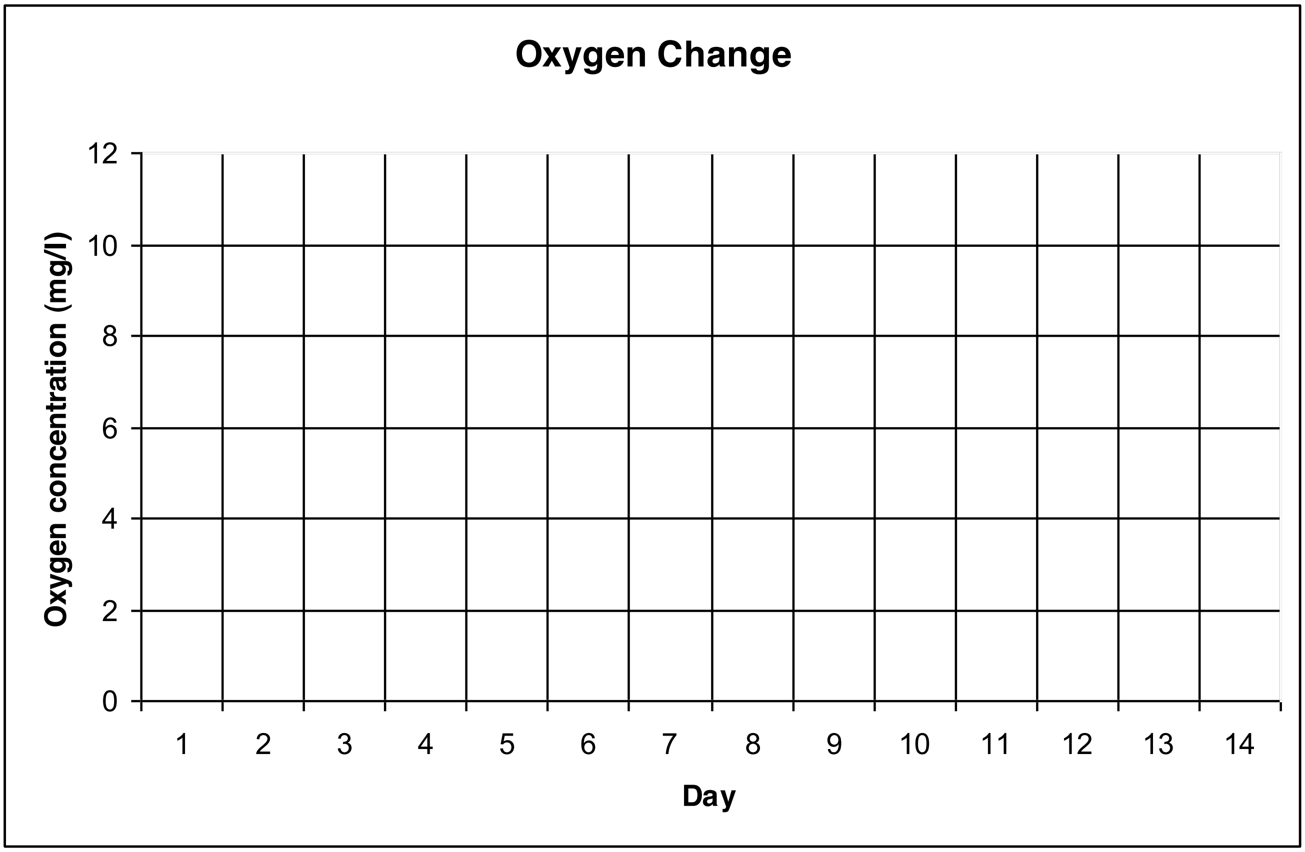
- This experiment is suited from non-winter months, when sunlight, phytoplankton biomass, and temperature are at high levels.
- Reagent grade nitrate and phosphate can be purchased or obtained from a chemistry lab and used instead of fertilizer.
- Take oxygen readings at the same time each day, ideally in the afternoon as this is the peak of daily phytoplankton oxygen production.
- You may need to leave the bottles in the sun for a few more days if you do not observe a marked difference between bottles, especially if you experience several cloudy days during the experiment.
- Students may need to be carefully supervised when using the oxygen probe, especially younger students.

Biology of Dead Zones: DATA SHEET

Data table for observations and dissolved oxygen measurements

Day	Dead Zone Observations		Control Observations	
	Qualitative (visual, odor)	Dissolved Oxygen (DO) mg/l	Qualitative (visual, odor)	Dissolved Oxygen (DO) mg/l
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				

Graph your oxygen data for both the dead zone bottle and control bottle. Be sure to label each line in your graph either “dead zone” or “control.”



Questions and Conclusions

1. Describe in one sentence what happened in each bottle when it was in the sun (summarize your visual observations and DO data).

Dead zone:

Control:

2. Describe in one sentence what happened in each bottle when it was in the dark (summarize your visual observations and DO data).

Dead zone:

Control:

3. What color did the water in the dead zone bottle turn? What caused the water to become this color? How do you know (hint: what types of living things are this color and what process do they undergo to make their food)?

4. When you placed the dead zone bottle in the dark, why did the oxygen change?

5. What type of organism caused the oxygen to change and what process did these organisms undergo to result in an oxygen change?

6. What did adding fertilizer to one bottle cause to happen?

7. What do you think would happen if you added a fish to the dead zone bottle after it has been in the dark for a while?

8. A farmer decides to use fertilizer on his corn this year. In the spring, he notices the pond next to his cornfield looks very green. In the past he has caught many fish in the pond, but this year catches nothing. What probably happened?

2. Physics of Dead Zones

Objective
To demonstrate density differences in ocean and coastal waters, and how these differences drive currents.

Background
Circulation in estuaries and oceans depends in part on differences in density of the waters. Water with more salt is heavier and sinks while fresher water is lighter and “floats” on the surface. These buoyancy differences result in the separation of water into layers (stratification) within an estuary or coastal ocean. Stratification can be disrupted by heating and cooling of surface waters and/or by wind-generated water movement like waves and currents. The primary source of fresh water in estuaries and coastal oceans is from rivers coming from land with a rating of 0-5 practical salinity units (PSU), while salt water is from the open oceans and has a rating of 32-35 PSU. In this simulation we will observe what happens when simulated river water (clear) is mixed with simulated ocean water (dyed blue).

Materials
Glass or clear plastic tank (example 10 gallon aquaria) (see instructions for constructing density tank in appendix)
Blue food coloring
Water
Salt (kosher salt works best)
Straw
Worksheet

Procedure:
Part 1
1. Measure 1 liter of tap water (to simulate river water) into a beaker or similar vessel.
2. Repeat this step, except to this second beaker, add blue dye (to simulate ocean water) and add 10 grams of table salt.
3. Set up tank with a divider in the middle (see below for instructions). The divider should be cut to fit the width of the aquarium. Use ¼ inch durable plastic or glass.
4. Slowly pour the “river” water into one side of the demonstration tank and the ocean water (blue) to the other side. Fill tank about half full and remove the divider. Observe.
5. Record observations on the worksheet.

Part 2

1. Blow on the surface of the water through a straw.

Questions and Conclusions

Part 1

1) Which water had a higher density?

2) What happened to the two water masses?

Part 2

After blowing on the surface of the water through a straw:

3) What happens to the two layers of water?

4) What happens when the wind stops?

5) How does this apply to the real world in coastal waters?

Part C. What Affects Dead Zones?

Objective

Students will be able to determine how wind and nutrient loading affect the size of a "dead zone" from a series of Data Cards containing graphs and maps of dead zones in the Chesapeake Bay.

Materials

Dead Zone Cards or
Computers with Internet Access
http://www1.coseecoastaltrends.net/modules/dead_zones/access_classroom_activities/#

Procedure

1. Using the data cards from above, observe the relationship between nutrients and wind and their effects on the duration and amount of dead zone area.

2. Answer the following questions:

a. Under which conditions is the size of dead zones smallest and the duration the shortest?

b. Under which conditions is the size of dead zones greatest and the duration the longest?

c. Which factor, wind or nutrients, has a greater effect on the dead zone?

d. How would the following weather events impact stratification in the Chesapeake Bay?

Light summer breeze:

Hurricane:

Part D. What are the Effects of Dead Zones on Aquatic Organisms? Habitat Squeeze

Objective

Students will understand how physical factors influence where an organism can live. Students will understand how dead zones can lead to a decrease in suitable habitat available to aquatic organisms.

Materials

Big open space (gym, field/courtyard)
Length(s) of rope or tarp(s)

Procedure

1. Lay out your tarp or make your rope into a large circle on the ground. Use additional tarps/ropes if you have a big group. You should make the space inside the tarp/rope big enough for everyone to fit inside with room to move around.
2. Start out by explaining that each student is a rockfish/striped bass. Rockfish need dissolved oxygen in the water in order to "breathe" (respire) and they also prefer relatively cool water. The area inside the tarp/rope is cool oxygenated water. Any area outside the rope/tarp is too hot or too low in oxygen for the rockfish to survive.
3. Have all the students stand behind a designated boundary. When you say go, have them all find a spot inside the rope/tarp. For each round, everyone must get inside the rope/tarp, no exceptions! Everyone will easily find a spot the first round.
4. Have students return to the boundary. Now start introducing various scenarios that can affect rockfish habitat conditions. Repeat rounds, each time decreasing the size of the rope or folding your tarp over some to make it harder to "squeeze" into suitable habitat. Ask the students each time how easy it was to find good habitat and how they feel crammed next to each other.

Scenarios:

a. First Round: Winter; the Bay is well mixed so no low oxygen areas and cold throughout. Plenty of room for everyone
b. Second Round: Late spring: Some phytoplankton from the spring bloom start to die and decompose; some areas of low oxygen form.
c. Third Round: Summer, dry spring: Surface waters and shallows heat up and some parts of the deeper cool waters experience hypoxia as the moderate spring bloom decomposes and consumes oxygen, but not too bad.
d. Fourth Round: Summer, wet spring: Surface waters and shallows heat up and a huge portion of the deeper cold water becomes hypoxic and even anoxic as massive spring blooms decompose, consuming lots of oxygen (make the tarp almost impossibly small, but remember everyone must fit.
e. Fifth Round: Tropical storm mixes the bay, re-oxygenating bottom waters. Increase the habitat size.

*Note: this is also a great team-building exercise. This activity requires working together in close physical proximity in order to solve a practical, physical problem. It tends to emphasize group communication, cooperation, patience and problem solving strategy, as well as issues related to physical self and physical proximity.