

U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Marine Fisheries Service

Lesson 5: The Dead Zone

Overview

Lesson 5 explains the effects of nutrients and eutrophication in the ocean. The lecture describes ways that human activities can cause excess nitrogen to enter the water. The formation of “dead zones,” large areas with little to no dissolved oxygen and a virtual absence of marine life, is described. In the activity, students evaluate data to determine when dead zones are forming.

Lesson Objectives

Students will:

1. Define dissolved oxygen (DO) and its units of measurement
2. Describe how human activities affect the amount of nitrogen in the ocean
3. Explain why excess nitrogen reduces DO and contributes to “dead zone” formation

Lesson Contents

1. Teaching Lesson 5
 - a. Introduction
 - b. Lecture Notes
 - c. Additional Resources
2. Teacher’s Edition: Who Will Survive the Dead Zone?
3. Student Activity: Who Will Survive the Dead Zone?
4. Student Handout
5. Mock Bowl Quiz

Standards Addressed

National Science Education Standards, Grades 9-12

Unifying concepts and processes

Life science

Earth and space science

Science in personal and social perspectives

Ocean Literacy Principles

The ocean and humans are inextricably interconnected

DCPS, High School

Environmental Science

E.2.1. Understand and explain that human beings are part of Earth’s ecosystems, and that human activities can, deliberately or inadvertently, alter ecosystems

E.8.2 Describe sources of air and water pollution and explain how air and water quality impact wildlife, vegetation, and human health

Lesson Outline¹

I. Introduction

Ask students to recall the preceding lesson on biogeochemical cycles, or give students a brief explanation if you did not complete this lesson. Tell students that nutrients are elements and compounds that are essential to life and many of these nutrients move through Earth's major systems: the land, air, water and living organisms. This movement occurs through natural processes and humans can influence these processes.

Give students two minutes to list all the ways they can think of that humans could influence the amount of nutrients that enter the ocean. Allow students to share the ideas they thought of and lead a brief discussion of these mechanisms. For instance, you may want to discuss: rain washing materials into rivers and into the ocean; direct dumping of waste into the ocean; accidental spills that contain nutrients or contaminants; or release of nutrients into the atmosphere (like gases from factories) that then move into the ocean through dissolution of gases or atmospheric deposition (rain).

II. Lecture Notes

Use the PowerPoint for Lesson 5 to present the following information. Distribute the Student Handout before you begin for students to take notes on key information.

What is a dead zone? (slide 5)

1. A **dead zone** is an area of an ocean, estuary, river, lake or other water body with low DO (hypoxic conditions) or no DO (anoxic conditions) that cannot support most marine life.
2. Dead zones can occur anywhere in the world. The second largest dead zone in the world occurs in the US in the northern Gulf of Mexico.

Human activities and water pollution (slide 6)

1. Human activities can increase the supply of nutrients like nitrogen directly into the ocean or into rivers that wash into the ocean.
2. These activities include agriculture, waste deposition, wastewater treatment and pollution from factories.

Causes of dead zones (slides 7 and 8)

1. Dead zones are one result of eutrophication, an ecological imbalance that occurs because of excess nutrients like nitrogen and phosphorus.

¹ Unless otherwise indicated, all websites provided or referenced in this guide were last accessed in November 2010.

2. Nitrogen is used by phytoplankton, small, passively drifting marine plants (often microscopic) for reproduction. When there is an excess of nitrogen a period of rapid population growth can occur (known as a plankton bloom).
3. When organisms in the plankton bloom die, they sink through the ocean and are decomposed by bacteria. The decomposition process consumes DO and depletes the supply available to other marine life. When there is little or no DO left, organisms like fish, crab, shrimp and jellyfish must leave the area in order to survive.

III. Additional Web Resources

1. Background information:
http://www.classzone.com/books/earth_science/terc/navigation/home.cfm
http://www.palomar.edu/oceanography/salty_ocean.htm

Who Will Survive *The Dead Zone*?

Overview

In this activity, students read data of dissolved oxygen (DO) readings to decide whether hypoxic or anoxic conditions exist at different times of year in the Gulf of Mexico.

Background

A dead zone is an area that has little or no oxygen and cannot support marine life. One large dead zone (about the size of New Jersey) exists off the Gulf of Mexico. Similar dead zones exist in marine and fresh waters around the world, though the one in the Gulf of Mexico is particularly significant due to its large size. A dead zone is one example of **eutrophication**, which means an ecological imbalance that occurs as a result of excess nutrients.

It was in August 1972 that scientists began investigating the dead zone in the Gulf of Mexico, finding severe oxygen depletion at shelf depths of 10-20 meters. Many studies since then have revealed dissolved oxygen (DO) levels lower than the normal seawater level of about 6 milligrams per liter (mg/L) (See Figure 2). Marine life needs DO to live. When conditions become **hypoxic** (this means DO is less than 2mg/L) shrimp, crabs, fish and other marine life suffocate and die. In some cases, there is no DO (0mg/L). When there is no DO, conditions are known as **anoxic**. As DO drops very low, large fish and marine mammals will quickly swim out of the area.

Several factors can cause a dead zone. Excess nutrient input to rivers and the ocean is a primary factor. Nutrients, such as nitrogen and phosphorus, are found in sources including fertilizers, animal wastes (pets and farms) and wastewater treatment. When it rains, these nutrients are flushed into rivers and the ocean. In the Gulf of Mexico, the Mississippi River is the primary source of freshwater and nutrient input. These nutrient sources can trigger and feed large algae or phytoplankton blooms. As the algae die from these blooms and fall to the bottom, bacteria begin to decompose them. Decomposition requires large amounts of DO. The more phytoplankton that bloom, the greater the number of phytoplankton that will die, and the more bacteria will use DO to decompose them. The end result after a bloom is water with little to no oxygen. Hypoxic and anoxic conditions can result in massive fish die-offs and long-lasting dead zones as we've seen in the Gulf of Mexico.

Other physical factors can influence dead zone formation. DO content is related to water temperature: the cooler the water, the higher the solubility of DO (more O₂ dissolves into the water). Thus warmer water temperatures reduce the availability of DO. Also, water circulation influences dead zone formation. During the summer, water circulation tends to be lower which means that DO doesn't disperse very much.

Procedure

Break your students into groups and distribute the activity. Assist your students with the questions as needed. Try to leave enough time before the bowl quiz to go over the answers as a class.

Answer Key

1. Refer to Figure 2 for questions a-d.
 - a. Which month has the longest period of anoxic conditions?
August.
 - b. Are there any months during which anoxic or hypoxic conditions don't exist?
November.
 - c. Based on the graphs, when are low oxygen conditions (either hypoxic or anoxic) worse:
 - i. **Summer (July-September).**
 - d. Explain why you think the season you chose for (c) is likely to have the low oxygen conditions?
Temperatures are highest in summer (higher water temp, lower solubility of DO) and water circulation is lower. These conditions favor Dead Zone formation.
2. What does DO stand for? What are the common units for measurement of DO?
Dissolved Oxygen; mg/L.
3. How are hypoxic conditions defined? Anoxic conditions?
Hypoxic: <2mg/L DO.
Anoxic: DO=0mg/L.
4. What is a significant cause of Dead Zones?
Excess nutrients (nitrogen, phosphorus).
5. What do you think are some economic impacts that could occur when Dead Zones occur, not only in the Gulf but in other locations around the world?
Reduced fishing revenues because fish have moved away or died; reduced tourism.
6. A shark, a crab and a shrimp find themselves in hypoxic conditions. Who do you think is most likely to survive a dead zone? Why?
A shark could swim the fastest and is most likely to make it out of the dead zone alive.

Who Will Survive *The Dead Zone*?

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Several factors can cause a dead zone. Excess nutrient input to rivers and the ocean is a primary factor. Nutrients, such as nitrogen and phosphorus, are found in sources including fertilizers, animal wastes (pets and farms) and wastewater treatment. When it rains, these nutrients are flushed into rivers and the ocean. In the Gulf of Mexico, the Mississippi River is the primary source of freshwater and nutrient input. These nutrient sources can trigger and feed large algae or phytoplankton blooms. As the algae die from these blooms and fall to the bottom, bacteria begin to decompose them. Decomposition requires large amounts of DO. The more phytoplankton that bloom, the greater the number of phytoplankton that will die, and the more bacteria will use DO to decompose them. The end result after a bloom is water with little to no oxygen. Hypoxic and anoxic conditions can result in massive fish die-offs and long-lasting dead zones as we've seen in the Gulf of Mexico.

Phytoplankton blooms are sometimes visible in satellite imagery as swaths of blue and green. Blooms like those pictured below off the coast of Namibia (Africa, Nov 8, 2007) have caused dead zones in the Atlantic Ocean.

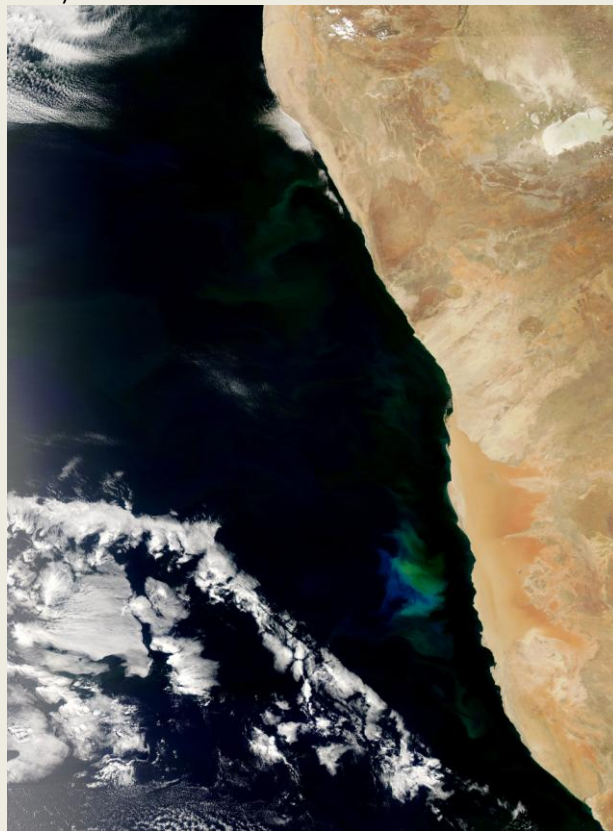


Photo: NOAA

Other physical factors can influence dead zone formation. DO content is related to water temperature: the cooler the water, the higher the solubility of DO (more O₂ dissolves into the water). Thus warmer water temperatures reduce the availability of DO. Also, water circulation influences dead zone formation. During the summer, water circulation tends to be lower which means that DO doesn't disperse very much.

Figure 1 shows the location of a DO monitoring site in the Gulf of Mexico and Figure 2 shows DO content readings from this station. Use these data to answer the questions below.

Questions:

1. Refer to Figure 2 for questions a-d:
 - a. Which month has the longest period of anoxic conditions?
 - b. Are there any months during which anoxic or hypoxic conditions don't exist?
 - c. Based on the graphs, when are low oxygen conditions (either hypoxic or anoxic) worse:
 - i. Spring (April-June)
 - ii. Summer (July-September)
 - iii. Fall (October-November)
 - d. Explain why you think the season you chose for (c) is likely to have the low oxygen conditions?
2. What does DO stand for? What are the common units for measurement of DO?
3. How are hypoxic conditions defined? Anoxic conditions?
4. What is a significant cause of dead zones?
5. What do you think are some economic impacts that could occur when dead zones occur, not only in the Gulf but in other locations around the world?
6. A shark, a crab and a shrimp find themselves in hypoxic conditions. Who do you think is most likely to survive a dead zone? Why?

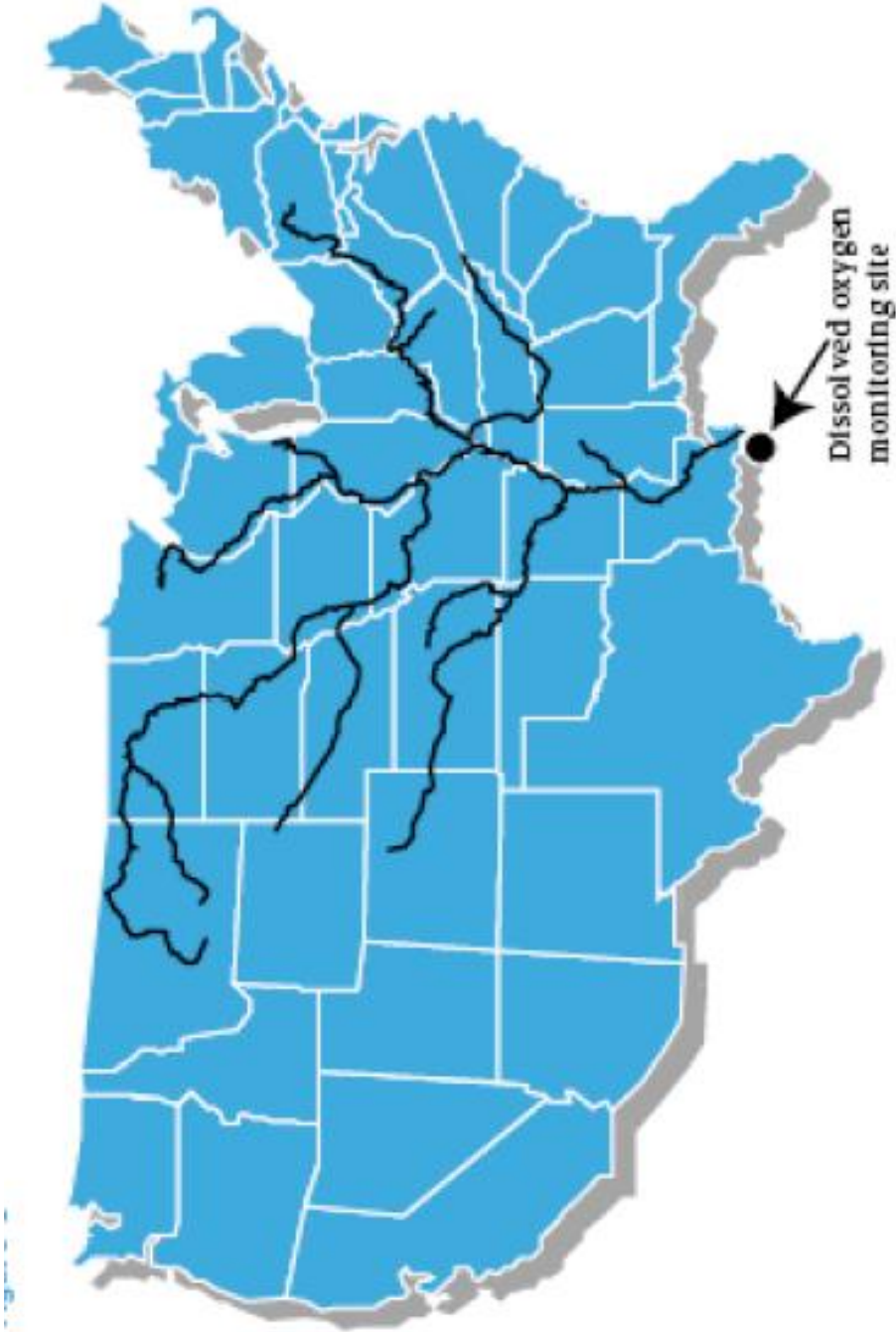


Figure 1. The location of the Gulf of Mexico dead zone DO monitoring site that collected samples in Figure 2.

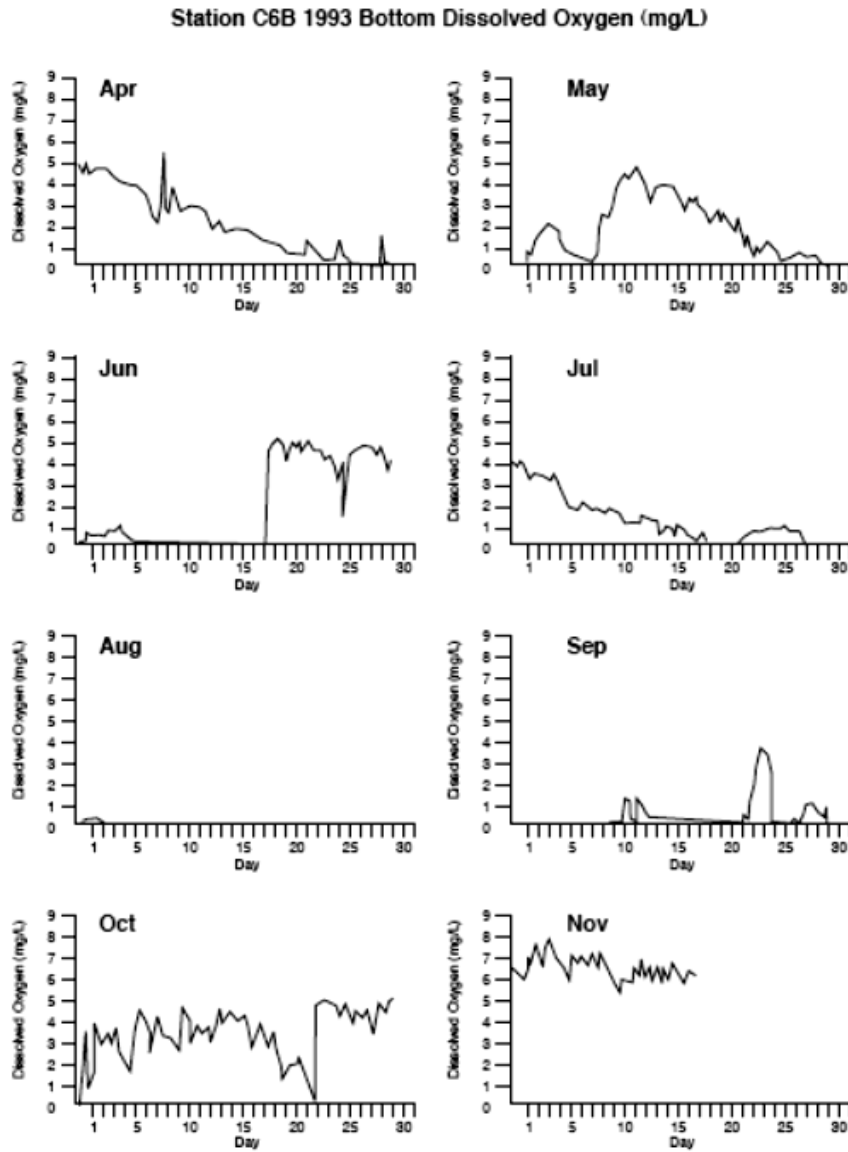


Figure 2. Station DO content readings (mg/L) in 1993 Aug-Nov.

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² Source: NOAA/NOS Lesson Plan on dead zones:
http://oceanservice.noaa.gov/education/classroom/lessons/13_ecoforecasting_deadzone.pdf

Tips for the Bowl - Nitrogen and Eutrophication

Definitions

Write definitions and key concepts for these terms – you will see them during your teacher’s presentation and during the activity. You may see them again at the Bowl!

Plankton Bloom:

Anoxic:

Hypoxic:

Eutrophication:

Nitrogen: (Note that the symbol for nitrogen is N)

Make the connections!

Make sure you understand the following relationships from this section.

1. Nitrogen, like carbon, is part of the biogeochemical cycle. Marine life needs some nitrogen to survive. Phytoplankton require it for survival.
2. When excess nitrogen is put into the water, phytoplankton can reproduce very quickly. Excess material causes eutrophication, a disruption in the balance of the normal nitrogen cycle.
3. When phytoplankton die, decomposition occurs and can reduce the dissolved oxygen (DO) in the water. Low levels of DO can lead to dead zone formation.

Why does it matter?

Here are just a few of the human-ocean interactions from this lesson. Can you think of others?

- Human activities can increase the flow of nutrients such as nitrogen into a water body. Excess nutrients are one type of factor that can lead to dead zone formation.
- When dead zones occur, human resources use can be negatively impacted. For example, fish may be scarce and fisheries could lose money. Tourist activities could lose money too if there is no ocean life for people to see.

Visit this link! If you have Adobe Flash, you can play this walk-through video of the N cycle. It will help you prepare for the Bowl.

<http://bcs.whfreeman.com/thelifewire/content/chp58/5802004.html>

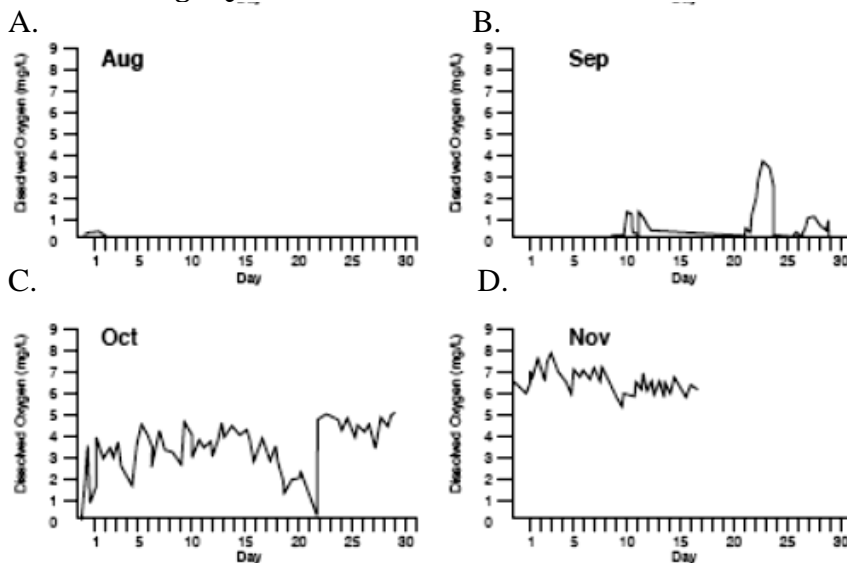
The Dead Zone

1. An excess of which of the following would most likely be associated with formation of a dead zone?
 - w. Carbon
 - x. Oxygen
 - y. **Nitrogen**
 - z. Iron
2. The term hypoxic means...
 - w. **DO content is less than 2-3mg/L, but still above zero**
 - x. DO content is 0mg/L
 - y. DO content is greater than 2-3mg/L
 - z. DO content is 6mg/L
3. This term refers to an ecological imbalance caused by excess nutrients.
 - w. **Eutrophication**
 - x. Nitrification
 - y. Decomposition
 - z. Photosynthesis
4. Typically dissolved oxygen is expressed as...
 - w. Milligrams per milliliter
 - x. Pounds per liter
 - y. Grams per liter
 - z. **Milligrams per liter**
5. Which of the following correctly expresses the relationship between decomposition and dissolved oxygen?
 - w. **Decomposition uses dissolved oxygen, removing it from the water**
 - x. Decomposition releases dissolved oxygen into the water
 - y. Decomposition does not require dissolved oxygen
 - z. Decomposition creates dissolved oxygen
6. Which of the following DO content would be considered “normal” and supportive of marine life?
 - w. 0mg/L
 - x. 1mg/L
 - y. **6mg/L**
 - z. 2mg/L
7. Short answer: The term anoxic refers to an absence of what molecule?
Answer: Oxygen gas or O₂ gas

8. Reminder question: The primary process by which carbon is returned to the surface waters from the deep ocean is:
- w. **Upwelling of deep ocean currents**
 - x. Photosynthesis by phytoplankton
 - y. Erosion at the coastline
 - z. Heating of subsurface waters

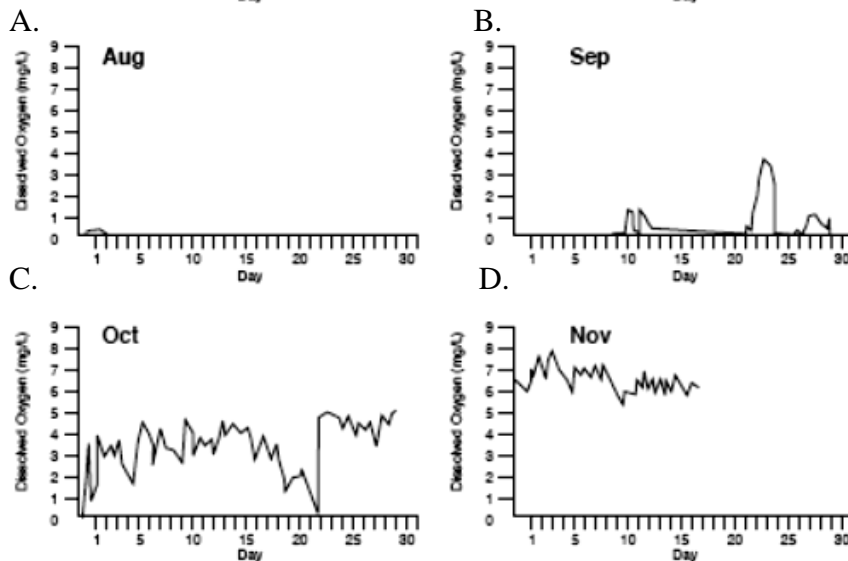
9. Short answer: DO refers to what ocean chemistry term:
Answer: Dissolved Oxygen

10. Team Challenge Question



1. The graphs above are Dissolved Oxygen content readings in the Gulf of Mexico Aug-Nov 1993. Which graph depicts mostly anoxic conditions? (1pt)
2. Which graph depicts mostly hypoxic conditions? (1pt)
3. In which month do you think eutrophication was not occurring? (1pt)
4. What is a phytoplankton bloom? Based on the graphs, in which months do you think these are occurring in the Gulf? (5pt)
5. Name 3 human activities that could lead to phytoplankton blooms. (3pt)

ANSWER



- The graphs above are Dissolved Oxygen content readings in the Gulf of Mexico Aug-Nov 1993. Which graph depicts mostly anoxic conditions? (1pt)
Graph A
- Which graph depicts mostly hypoxic conditions? (1pt)
Graph B
- In which month do you think eutrophication was not occurring? (1pt)
November because DO levels remain normal throughout all observations
- What is a phytoplankton bloom? Based on the graphs, in which months do you think these are occurring in the Gulf? (5pt)
A phytoplankton bloom is a rapid population growth of phytoplankton populations, sometimes caused by excess nutrients in water (2pt). Aug, Sep and Oct (1pt each).
- Name 3 human activities that could lead to phytoplankton blooms. (3pt)
Answers vary but can include agriculture (fertilizer use), factory emissions, wastewater treatment or run-off (1pt each).