

# Dead Zones for Dinner connections between foods we eat, water Pollution and Eutrophication

# OBJECTIVES

- 1. Understand the causes and processes of eutrophication and their relation to the occurrence of dead zones.
- Understand the methods for generating a map of dead zones in our oceans.
- 3. Determine the area of hypoxia, or low dissolved oxygen levels, off the coast of Louisiana, which is one of the most studied dead zones in the world.
- 4. Appreciate the scale of the dead zones. The area of the dead zone determined in Objective #3 will be compared to areas of states in order to better visualize the scale the dead zone represents.
- 5. Understand the limits of data and examine ways to improve the data sets.
- 6. Make predictions about the effects of other variables on the size of the dead zone.

## MATERIALS

- Photocopies of the student reading
- · Photocopies of the student activity handout
- Photocopies or transparencies of 0.5 cm graph paper
- · Colored pencils or markers in order to transfer the map area to the graph
- Calculators
- Computer with internet resources
- Library and/or classroom resources

# VOCABULARY

**Cellular Respiration** - A chemical process that all living cells undergo that converts oxygen to carbon dioxide and releases energy to the organism and the surrounding environment.

**Dead Zone** – A region of the ocean where most life is unable to survive because of inadequate dissolved oxygen, usually below 2 ppm O2.

**Dissolved Oxygen** – The amount of oxygen gas that is dissolved in a unit of water. This is a standard indicator of an aquatic ecosystem's health, and is measured in parts per million (ppm) or the equivalent unit of mg/l.

**Eutrophication** — A process whereby excessive nutrient enrichment of an aquatic system leads to the system becoming oxygen-depleted.

**Hypoxic** - When an aquatic system has less oxygen than that particular system requires to sustain itself, it is hypoxic or lacking in oxygen.

**Photosynthesis** – A process that transforms the sun's radiative energy into chemical energy and releases oxygen as a product.

**Phytoplankton** – Single-celled organisms in open water that undergo photosynthesis and release oxygen to their environment.

**ppm** or **mg/1**- Equivalent units used to indicate the concentration of dissolved oxygen or nutrients.

**Runoff** - Surface water that eventually flows into nearby rivers; it carries dissolved nutrients, sediments and other pollutants.

**Tributary** - Any smaller branch of a river that drains into that river.

Watershed - Total land area that a particular river system drains.



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# key questions

- What are dead zones and where are they located?
- · How are dead zones formed?
- Why should we care that dead zones exist?
- · How might what we eat be linked to the Gulf of Mexico?
- · What are the environmental consequences to the dead zones?
- · How can we prevent the formation of the dead zones?

## ENGAGE

- 1. Show a photo similar to the one found at <a href="http://news.nationalgeographic.com/news/2010/09/photogalleries/100916-fish-kill-louisiana-suffocated-oil-pictures/">http://news.nationalgeographic.com/news/2010/09/photogalleries/100916-fish-kill-louisiana-suffocated-oil-pictures/</a> and ask the students what they think it is and what they think might have caused it. (You may be able to find similar pictures from your own region by searching for "fish kill"+the name of your state or region.)
- 2. Show http://www.gulfhypoxia.net/Overview/hypoxia\_flash.asp, a 15-second looping Flash video that describes the basics behind the creation of a dead zone. (This is from http://www.gulfhypoxia.net/default.asp, a site that specializes in the Gulf of Mexico region that offers basic information regarding dead zones as well as links to information on other dead zones around the world)
- 3. Show the 5-minute video clip http://www1.coseecoastaltrends.net/modules/dead\_zones/ get\_started/
- 4. Add any discussion questions that would be relevant.

# LESSON ACTIVITY

- 1. Have students read "Dead Zones and Eutrophication: How Food We Eat Is Connected to Water Pollution" and complete the mapping activity on the Gulf of Mexico Dead zone.
- 2. Have students complete the analysis questions at the end of the mapping activity.
- 3. Discuss their results and brainstorm ways the students could become further involved and educated about their local watershed and its connection to oceans.



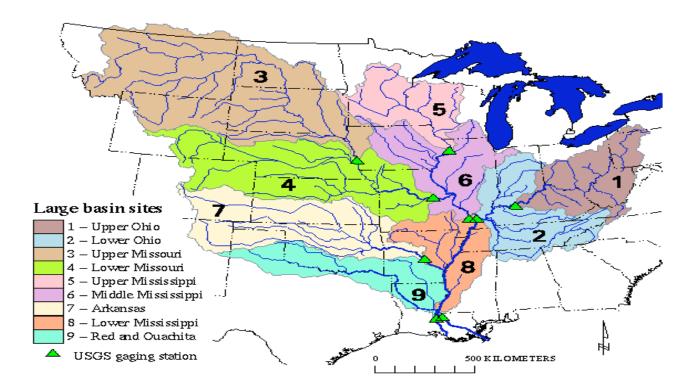
STUDENT PEADING

## DEAD ZONES AND ENTPOPHICATION: HOW FOOD WE EAT IS CONNECTED TO WATER POLLUTION

#### Introduction

Imagine scuba diving in an aquatic environment where life abounds—a place whose biological diversity includes small crabs, clams, fish, turtles and sharks. It is a beautiful place. Now imagine you are in a place where the amount of oxygen dissolved in the water is so low that most of the life is either dead or absent. These areas are known as DEAD ZONES and they are one of the most troubling consequences of water pollution. It is estimated that there are over 400 dead zones in the world. Some dead zones are as big as U.S. states.

Dead zones are formed as a result of an accumulation of nitrogen and phosphorus compounds which cause a process known as eutrophication (explained below). Nitrogen and phosphorus are present in manure, and are used on farms. These compounds are washed into rivers by irrigation or rainwater, and can be carried hundreds of miles from their source to areas such as deltas — where rivers meet the sea and their waters slow. In such areas, the nitrogen and phosphorus the river carried become concentrated and can cause a dead zone. The most famous dead zone in the United States lies just off the coast of Louisiana, in a portion of the Gulf of Mexico to the west of the outlet of the Mississippi River. The nitrogen and phosphorus which cause the dead zone come from the vast inland farming areas which drain into the Mississippi River (Figure 1).



**FIGURE 1** The Mississippi watershed drains most of the United States. The area within this watershed is a major farming area, contributing nitrogen and phosphorus which is concentrated in the Gulf of Mexico dead zone. Source: <a href="http://toxics.usgs.gov/icons/hypoxiabig.gif">http://toxics.usgs.gov/icons/hypoxiabig.gif</a>



STUDENT PEADING

Some of the largest sources contributing nitrogen and phosphorus to the Mississippi River are human sewage, manure from farms, and fertilizer which is spread on farm fields. When these materials runoff into rivers and creeks, the nitrogen and phosphorus they contain ultimately flow into the Mississippi River. The river then takes the dissolved nitrogen and phosphorus to the Gulf of Mexico where the dead zone is the result.

The Mississippi River watershed drains over 40% of the United States. There are many farms and cities in this area and therefore a lot of nitrogen and phosphorus is released into the river. The consequence is a very large dead zone in the Gulf of Mexico.

How do nitrogen and phosphorus cause a dead zone?

#### PROCESS OF EUTROPHICATION

#### STEP 1: NUTRIENTS

In order to solve the dead zone problem we must first understand eutrophication. It all starts with two critical nutrients, nitrogen and phosphorus. Three sources of these nutrients which enter the water are:

- Fertilizer spread on farm fields which runs off into a watershed
- Excess manure from farm animals which runs off into a watershed
- · Human sewage which is released into a watershed

#### STEP 2: ALGAE BLOOM

When excess nitrogen and phosphorus enter a water system the result is rapid growth of single-celled algae called phytoplankton. This is known as an algal bloom; in many cases, the bloom is visible as a colored film on the surface of the water.

#### STEP 3: ALGAE DIE OFF

Eventually, the algae reach a point where their population exceeds their resources. The population crashes. This is known as an algal die-off.

#### STEP 4: DECOMPOSER BLOOM

When algae die, they become food for decomposers. Very small microscopic decomposers reproduce rapidly and the algal die-off is followed by a bloom in microbes. However microbes, unlike algae, only consume oxygen to live.

#### STEP 5: THE DEAD ZONE

As the microbes grow, they rapidly remove the oxygen in the water. This causes the water to become hypoxic. Many fish and other animals which need oxygen can no longer live in a hypoxic area and they leave or die. Animals like clams die because they cannot leave the area. The area becomes a DEAD ZONE. Surrounding the dead zone are areas which have depleted oxygen. Some animals can still live in these areas, but many animals are absent.

Dead zones are not just ugly and smelly; they also cause a major disruption to the food chain and the economy. For example, birds will not fly in the air above a dead zone and migratory animals will avoid dead zones due to the lack of food. The loss of shrimp, fish and other organisms causes a reduction in the fishing, seafood and recreation industries. It is estimated that over 235,000 tons of marine life is lost each year in the Gulf of Mexico dead zone. An additional 75,000 tons of marine life is lost in the Chesapeake Bay dead zone each year. A smaller dead zone off the coast in New York in 1976 was estimated to cost more than 500 million dollars.



STUDENT WOPESHEET 1/3

# HOW BIG IS THE DEAD ZONE IN THE GULF OF MEXICO?

Use the map found at http://www.gulfhypoxia.net/Research/Shelfwide%20Cruises/2011/DOMaps/ to complete the following.

This map is assembled like a topographic map. It has individual data points of Dissolved Oxygen (DO) quantities that are recorded at documented locations. Then lines are drawn like elevation contours to enclose the area that contains the points with a given value. For example, the black line surrounds the entire region that contains a value of 2 mg/l or 2 ppm or less.

#### Determine the total area of the Dead Zone

- 1. Overlay the graph paper on the map. If you are using graph paper and colored pencils, you will first want to lay the graph paper over the map and tape both to a window for light to pass through. NOTE: A plastic copy of the graph paper could also be used
- 2. Work inside the black line to determine the area of the Dead Zone that has a Dissolved Oxygen (DO) amount of 2 ppm or less. Count the squares, using your marker or colored pencil to keep track of the squares counted. Record in the table below a tally of whole squares, as well as estimates of three quarter squares, half squares and quarter squares covered by the colored area. Add the total number of full and partial squares to determine the area inside the black line. Nearly all organisms important to the ecosystem perish within this boundary. This is the area where most of the animals are either dead or absent.
- 3. Repeat the procedure from step b, but this time count the total squares that lie in the colored portion of the map that is outside the black line. This is the area of affected water. Some organisms important to the ecosystem are unable to survive here.
- 4. Each square of graph paper is equal to 0.5 square centimeters and represents a land area of 75 square miles. Calculate the total square miles for the region of the map that is ≤2ppm DO by multiplying your total squares by 75. Repeat for the region of the map that is greater than 2 ppm DO but less than or equal to 5 ppm DO. Record your results in the table below.
- 5. Finally, to determine the total area affected by reduced dissolved oxygen, add the calculated area from the two regions. This represents the area we refer to as hypoxic. Record your results in the table below:

Map Region	Number of	Number of	Number of	Number of	Number of	Total Area in
	full squares	1/4	½ squares	¾ squares	all squares	Miles <sup>2</sup>
		squares				
DO ≤2ppm (Dead						
Zone)						
DO 5≤ ppm but						
>2ppm (affected						
area outside dead						
zone)						
Total Hypoxic						
Area						



Student worksheet 2/3

### **Analysis**

1. The value in the rightmost column of your table is in square miles. In order to better appreciate the scale of the dead zone, compare your value of the Total Hypoxic Zone to the areas of the states listed below. Which state is closest in area to the area you determined for the Total Hypoxic Zone?

State	Area in Miles <sup>2</sup>		
Maryland	12407		
Hawaii	10931		
Massachusetts	10555		
Vermont	9614		
New Hampshire	9350		
New Jersey	8721		
Connecticut	5543		
Delaware	2489		
Rhode Island	1545		

Data from: http://www.ipl.org/div/stateknow/popchart.html#statesbyland

- 2. If humans contributed to the destruction of life in an area of land the size of the state from question 1, most people would be aware of the problem. List and describe some of the reasons people are less aware of the vast dead zones in our oceans.
- 3. Look at your results for the affected area and refer back to the map. Do you expect that your calculated value is likely an overestimate of the total affected area or an underestimate? Defend your answer.
- 4. The size of dead zones is usually greatest during summer months. Describe two reasons why the summer dead zones might be larger.



Student worksheet 3/3

5. Describe how a hurricane over a dead zone could impact the dead zone. Describe how heavy rains in the watershed (for example in the middle U.S.) could impact the dead zone.
6. From the reading section, describe in your own words the process of eutrophication.
7. Do you live in an area drained by the Mississippi?
8. Explain how you might be connected to the Gulf of Mexico dead zone even though you might not live in the Mississippi River watershed.



ANSWER FEY, STUDENT WORKSHEET

## **Analysis**

- 1. The value in the rightmost column of your table is in square miles. In order to better appreciate the scale of the dead zone, compare your value of the Total Hypoxic Zone to the areas of the states listed below. Which state is closest in area to the area you determined for the Total Hypoxic Zone? **Connecticut or New Jersey**
- 2.If humans contributed to the destruction of life in an area of land the size of the state from question 1, most people would be aware of the problem. List and describe some of the reasons people are less aware of the vast dead zones in our oceans. Media does not cover the story; Dead zones are located off the coast in waters where there is less human activity; Dead zones do not have any visible indications from above (aerial or satellite photos do not show anything wrong).
- 3. Look at your results for the affected area and refer back to the map. Do you expect that your calculated value is likely an overestimate of the total affected area or an underestimate? Defend your answer. Probably an underestimate, because there seem to be areas of dead zone that are not shown on the map. The dead zone appears to run off the edge of the map.
- 4. The size of dead zones is usually greatest during summer months. Describe two reasons why the summer dead zones might be larger. More fertilizer is used during the growing season. Warm water holds less oxygen. More animals are raised in the summer. There is more precipitation in the spring and summer to wash runoff into the Mississippi. Summer sun aids algae growth.
- 5. Describe how a hurricane over a dead zone could impact the dead zone. Describe how heavy rains in the watershed (for example in the middle U.S.) could impact the dead zone. A direct hit by a hurricane might decrease the size of a dead zone by diluting the area with fresh rain water or winds. (In fact this has been observed with hurricanes in the Gulf!) Heavy rains or floods in the watershed increase the size of the dead zone, because they wash more runoff into the river, bringing more nutrients to the dead zone.
- 6. From the reading section, describe in your own words the process of eutrophication. **Answers will vary.**
- 7. Do you live in an area drained by the Mississippi? Correct answer depends on where you live.
- 8. Explain how you might be connected to the Gulf of Mexico dead zone even though you might not live in the Mississippi River watershed. If you eat meat which was raised in the Mississippi River watershed or eat produce which was grown using fertilizer in the watershed, you might contribute.



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### WEB PESOUPCES

#### Temperature

http://oceanservice.noaa.gov/education/tutorial\_estuaries/media/supp\_est10a\_temp.html **Dissolved Oxygen** 

http://oceanservice.noaa.gov/education/tutorial\_estuaries/media/supp\_est10d\_dis.html **Nutrients** 

http://oceanservice.noaa.gov/education/tutorial\_estuaries/media/supp\_est10g\_nutr.html

#### Monitoring Methodology

http://www.gulfhypoxia.net/Research/

#### Satellite Image with Superimposed Grid

http://www.gulfhypoxia.net/Research/Shelfwide%20Cruises/2011/SatelliteImage.pdf **How Stuff Works** 

http://science.howstuffworks.com/environmental/earth/oceanography/dead-zone1.htm

#### Learn about Dead Zones

http://www1.coseecoastaltrends.net/modules/dead zones/learn about/

#### **USGS Hypoxia Pages**

http://toxics.usgs.gov/definitions/hypoxia.html

http://toxics.usgs.gov/hypoxia/hypoxic zone.html

#### **Gulf Hypoxia Website**

http://www.gulfhypoxia.net/default.asp

# connections to national science content standards

#### Life Science Content Standard C

**The Interdependence of Organisms**: Students will understand through example the interrelationships and interdependencies of organisms in ecosystems and destruction that can ensue when humans also interact with these ecosystems.

**Matter, Energy, and Organization in Living Systems**: Without the continuous addition of energy to an ecosystem, the ecosystem could not sustain their chemical and physical organization. When our oceans experience a major disruption of their Chemical and Physical systems through input by humans, vast dead zones are the result.

## Environmental Quality in Personal and Social Perspectives Content Standard F

**Environmental Quality**: Ecosystems provide services for humans in the form of clean oxygenated air, nutrient rich soils and clean water. Students will have opportunities to study agricultural practices that are detrimental to ecosystems as well as practices that enhance the natural systems. They will appreciate the many factors that can be impacted positively or negatively.

Science and Technology in Local, National and Global Challenges: By understanding how use of land resources by humans impacts marine organism even though they may be more than a thousand miles downstream, students can be a part of the imagination and innovations that can lead to solutions to this unintended impact.