# Dead Zones for Dinner

STUDENT READING

## DEAD ZONES AND EUTROPHICATION: 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).

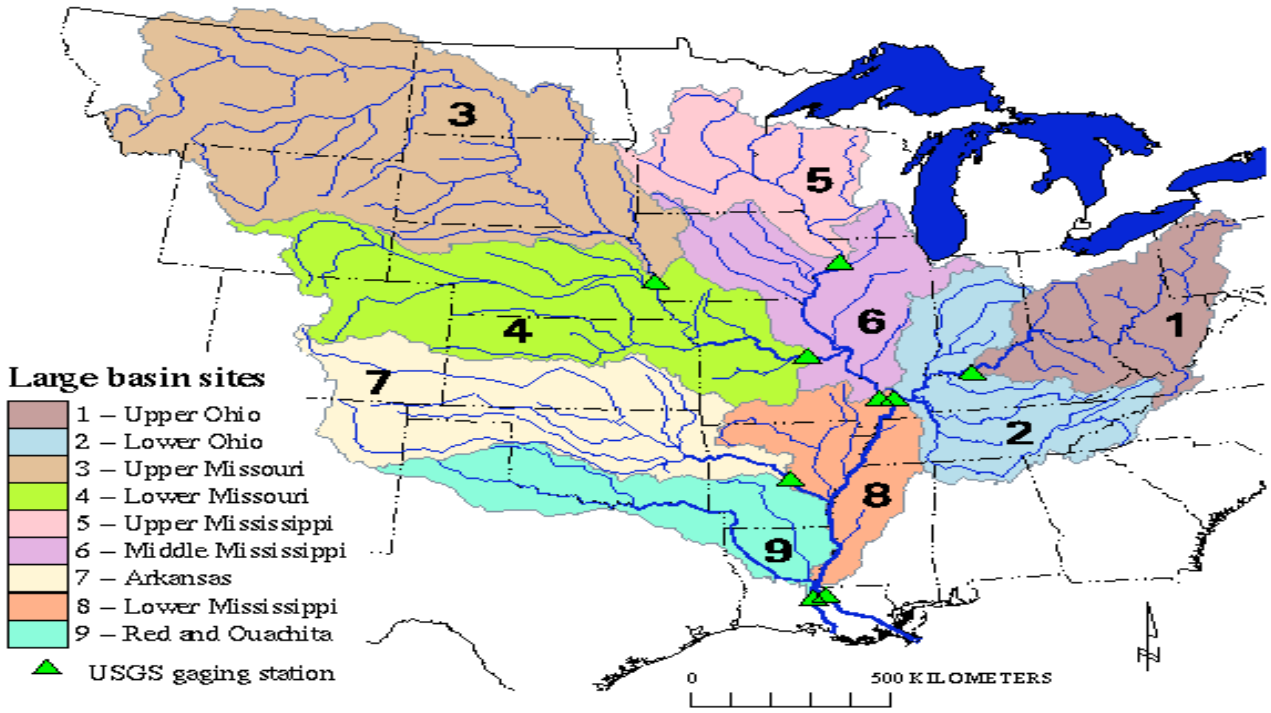


**FIGURE 1** The Mississippi watershed drains most of the United States. The area within this watershed is a major farming area, contributing nitrogen and phosphorus which is concentrated in the Gulf of Mexico dead zone. Source: http://toxics.usgs.gov/icons/hypoxiabig.gif

# Dead Zones for Dinner

STUDENT READING

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.

# 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 full squares | Number of 1/4 squares | Number of ½ squares | Number of ¾ squares | Number of all squares | Total Area in Miles$^2$ |
|---|---|---|---|---|---|---|
| DO ≤2ppm (Dead Zone) | | | | | | |
| DO 5≤ ppm but >2ppm (affected area outside dead zone) | | | | | | |
| Total Hypoxic Area | | | | | | |

## 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$^2$ |
|---|---|
| **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.

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.