

## OCEAN DEAD ZONES - INTERACTION AMONG EARTH'S SUB- SYSTEMS

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***Note:** This Investigation is the same as AMS Ocean Studies' Current Ocean Studies 1 from Preview Week. Participants only need to complete the Current Ocean Studies once.*

### **Do Now:**

1. Print this file, if directed by your instructor.
2. Read the *Weekly Ocean News* file, print if directed to do so by your instructor.  
(**Note:** Check the AMS Ocean Studies website during the week as breaking ocean news stories may have been added.)

Welcome to *AMS Ocean Studies*. This is the first of weekly Current Ocean Studies which supplement and build upon the corresponding chapter investigations of the *AMS Ocean Studies Investigations Manual*. We hope your use of current environmental information will become an engaging experience. We encourage your exploration of the AMS Ocean Studies website products.

### **To Do Investigation:**

1. Reference: Chapter 1 in the *AMS Ocean Studies* text.
  2. Complete Investigations 1A and 1B in the *AMS Ocean Studies Investigations Manual* as directed by your instructor.
  3. Complete this online-delivered *Current Ocean Studies* activity if directed by your instructor.
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Welcome to the first online *Current Ocean Studies* component of this course. *Current Ocean Studies* components accompany every chapter of study and typically are brief case studies of real-world recent, current, or ongoing oceanic situations.

### **Introduction:**

In December 2008, the National Research Council (NRC) published a report urging the U.S. Environmental Protection Agency and the U.S. Department of Agriculture to jointly establish an initiative leading to the mitigation (reduction) of nutrient pollution in the Mississippi River basin and the northern Gulf of Mexico. The NRC report called for immediate government action to reduce urban and Midwest farmland runoff blamed for feeding a broad and expanding lifeless swath of water, called a **dead zone**, which forms off both the Louisiana and northeastern Texas coasts every summer.

**A prime example of the interconnectedness of ocean, land, and impacts of human activity in the Earth system is the increase in number and intensity of such dead**

**zones.** Dead zones are ocean areas where dissolved oxygen in bottom and near-bottom waters declines to deadly proportions. Such areas of the seafloor, with too little oxygen for most marine life, are produced when excess nutrients, especially nitrogen and phosphorus compounds, enter coastal surface waters and spur algal blooms. When the algae die, they sink to the seafloor. Their decomposition consumes the dissolved oxygen, leaving a “hypoxic” (low oxygen) or “anoxic” (no oxygen) environment lethal to many marine species.

Ocean dead zones are primarily coastal and estuarine phenomena. The first to be identified was reported in the 1930s in the Chesapeake Bay estuary system. (Chesapeake Bay’s late July 2011 dead zone covered a third of the Bay and is expected to become the bay’s largest.) It has been estimated that there are nearly 500 dead zones existing worldwide (see [http://www.eurekalert.org/pub\\_releases/2008-08/viom-ssc081108.php](http://www.eurekalert.org/pub_releases/2008-08/viom-ssc081108.php) and <http://www.wri.org/project/eutrophication/map>). Most are seasonal, as exemplified by the largest dead zone in the United States which expands off the coast of Louisiana and Texas in late spring and summer. It results from huge quantities of nutrients originating as farm fertilizers and organic wastes carried by the Mississippi River system to the Gulf of Mexico. **Figure 1** displays the drainage system of the Mississippi River, including its tributaries and major distributary (Louisiana’s Atchafalaya River). This system is the 3<sup>rd</sup> largest in the world, after the Amazon and Congo, and drains about 40% of the contiguous U.S. Parts or all of 31 states, and two Canadian provinces, drain into the Mississippi River.



Figure 1. The Mississippi-Atchafalaya River Basin and general position of a typical summer’s Gulf of Mexico “dead zone” (in red). [EPA]

1. It can be seen in Figure 1 that Iowa farmers fertilizing their land to increase corn crop yield are contributing to a key stressor on marine ecosystems over a thousand miles away. This demonstrates clearly that human activity far from the ocean [(can)(cannot)] have dramatic effects on the ocean.
2. **Figure 2** depicts how the Gulf of Mexico dead zone forms. During spring, warm Mississippi River water flows into the Gulf and [(floats over)(sinks under)] the more dense seawater. The resulting surface water layer prevents convection and replenishment of dissolved oxygen in seawater at greater depths from the overlying atmosphere.

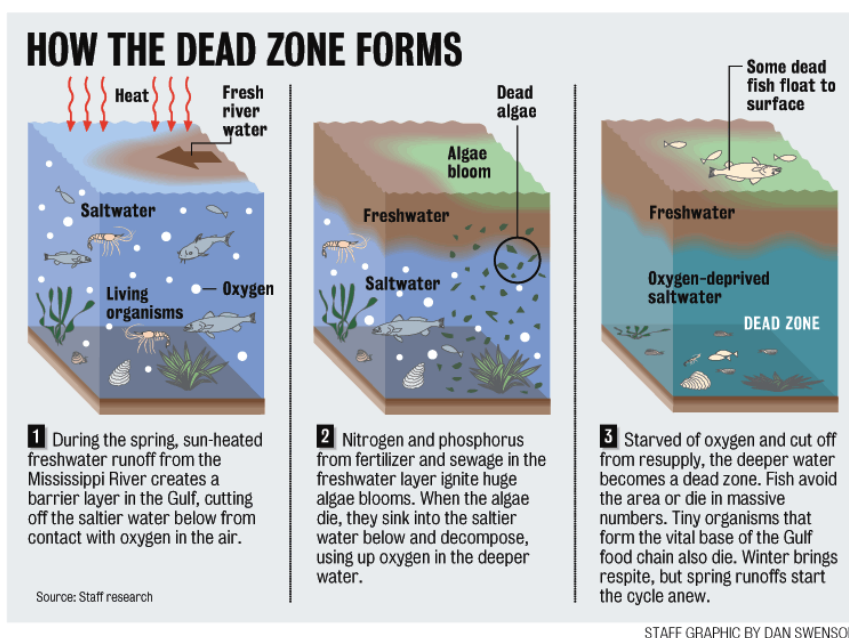


Figure 2. How the Dead Zone Forms. [*The Times-Picayune*, [http://blog.nola.com/graphics/deadzone\\_how061007.gif](http://blog.nola.com/graphics/deadzone_how061007.gif)]

View an animation, entitled “The Dead Zone: Nutrient Runoff Creates Hypoxia in the Gulf of Mexico”, by NOAA’s Environmental Visualization Laboratory, at <http://www.nnvl.noaa.gov/MediaDetail.php?MediaID=84&MediaTypeID=2> that describes the formation of a dead zone.

3. The animation of satellite imagery shows evidence that nutrients delivered by the Mississippi River into the Gulf of Mexico are generally carried by coastal currents [(eastward towards Florida)(westward towards Texas)]. The nutrients then produce algae (phytoplankton) blooms.

Another Flash animation describing the nutrient process that leads to hypoxia in the northern waters of the Gulf of Mexico can be found at: [http://www.gulphypoxia.net/Overview/hypoxia\\_flash.asp](http://www.gulphypoxia.net/Overview/hypoxia_flash.asp).

- The nutrients from the Mississippi River system, including those from fertilizer runoff and from sewage discharges, ignite algal blooms in the surface water warmed by the increasingly intense sunlight during spring that remains strong into summer. The dead algae then sink, settle to the ocean bottom, and decompose. The decomposition process results in the [(loss)(gain)] of dissolved oxygen in the deeper seawater.

Dissolved oxygen is an essential ingredient for sustaining life in the marine food chain. With little or no oxygen, commercially important fish and shellfish (e.g., crabs and oysters) as well as non-commercially important organisms die or are driven from their habitat. The result is the creation of a dead zone in bottom and near-bottom waters. The Gulf of Mexico dead zone typically persists until late summer or early autumn when passing storms (including hurricanes) and cooler temperatures act to stir and break up the density-layered water structure.

- The summer 2011 low-oxygen Gulf of Mexico dead zone was measured from the Louisiana Universities Marine Consortium's research vessel *Pelican* by a group of scientists led by Dr. Nancy Rabalais. **Figure 3** depicts their results showing the bottom-water dissolved oxygen (DO) concentration in milligrams per liter (mg/L) along the Gulf of Mexico coast extending from Louisiana to eastern Texas as observed 24-30 July 2011. Areas shaded yellow to red essentially show where bottom-water dissolved oxygen values were measured, with the dots indicating sample stations where casts were made to acquire data. The darker the shading, the lower the dissolved oxygen concentration. The black isoline (line of constant value) in the figure surrounding the darker red shadings has a value of 2 mg/L. Dead zones are generally defined as places where the dissolved oxygen concentration falls below 2 mg/L. Based on this criterion and locations where a 2 mg/L isoline encloses two or more sample stations, the figure reveals [(1)(2)(3)(4)] multi-station dead zone(s) in the sample area.

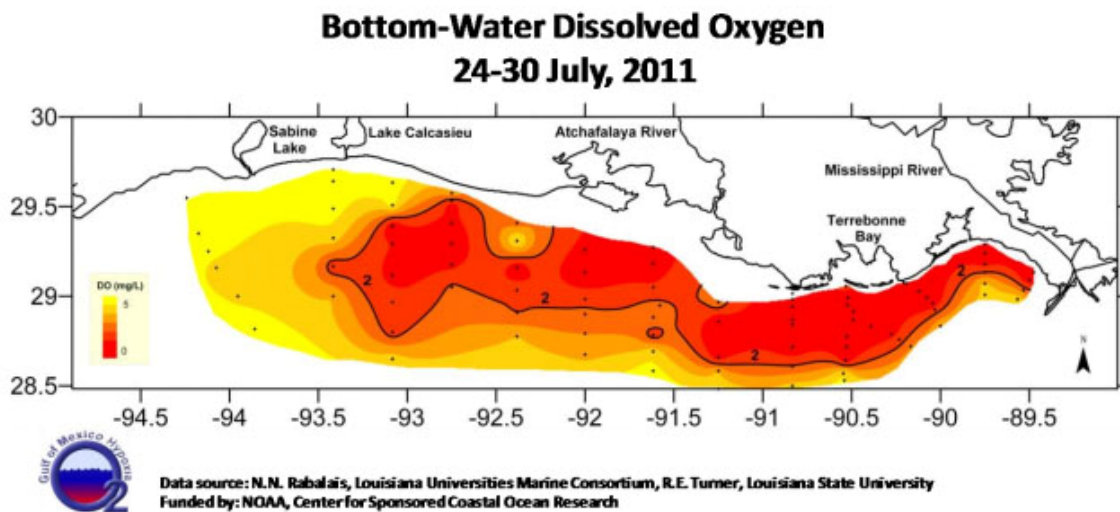


Figure 3. Gulf of Mexico Dead Zone Bottom Dissolved Oxygen (mg/L), 24-30 July 2011. [N.N. Rabalais, Louisiana Universities Marine Consortium, R.E. Turner, Louisiana State University. Funded by NOAA]

The size of the 2011 low-oxygen Gulf of Mexico dead zone extended over 17,520 square kilometers, or 6765 square miles. Although forecast to rank the highest or among highest since mapping was begun in 1985 because of the record-breaking flow of the Mississippi River this spring and summer, it did not happen. It ranked 11<sup>th</sup> largest over the 26 years of record. Dr. Nancy Rabalais, chief scientist for the mapping project, reported that the major disruptor of the predicted size was Tropical Storm Don, which whipped up the winds and waves during the sampling cruise. The agitation caused mixing of the water column, re-supplying oxygen to greater depths and reducing the area of low oxygen concentration, at least temporarily. This is another example of the interconnectedness of the ocean with other Earth system subsystems, this time with the atmosphere.

**Figure 4** shows the history of the size of the Gulf of Mexico dead zone through 2010. Included on the graph are horizontal dashed red lines indicating the average size over the period of record, the 5-year running average for the most recent five years ending in 2010, and the goal size sought by some attempting to reduce the human impact on the Gulf.

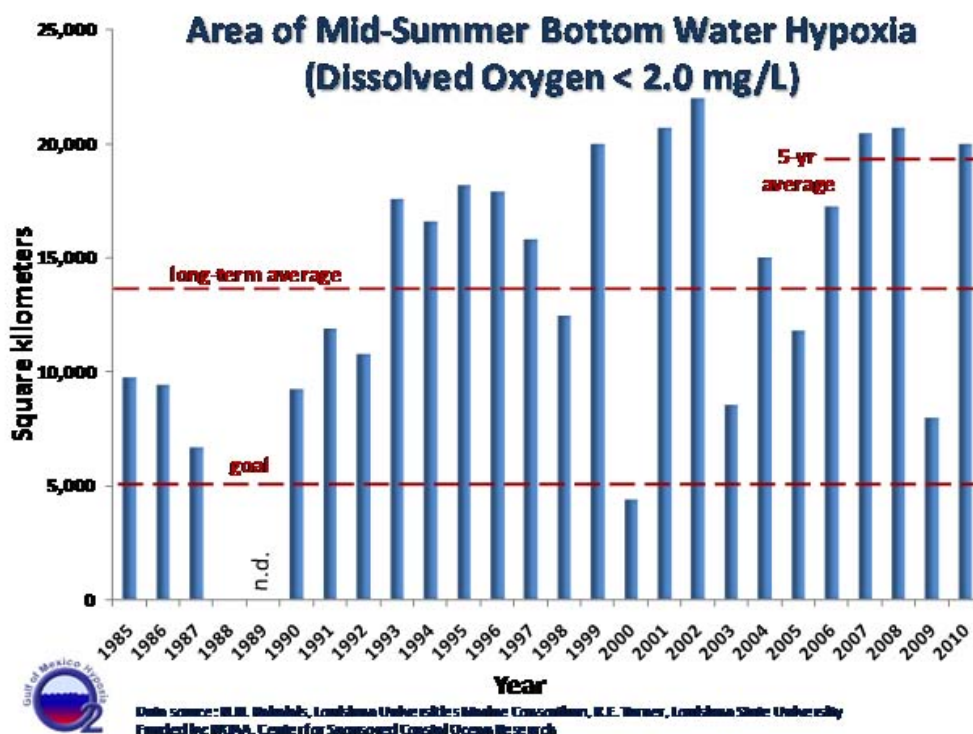


Figure 4. Annual maximum areas of mid-summer Gulf of Mexico dead zone, [Data source: N.N. Rabalais, Louisiana Universities Marine Consortium, R.E. Turner, Louisiana State University]

- To update Figure 4, add a vertical bar in the 2011 position in the graph to represent the 17,520 square-kilometer area of 2011's Gulf of Mexico dead zone. Compare the size of the 2011 dead zone with the long-term average dashed red line shown in Figure 4. The 2011 value was [*(about half)(nearly the same as)(somewhat higher than)*] the long-term average through 2010.

7. Figure 4 shows that over the entire period of record, there has been considerable variability in the size of the mid-summer Gulf of Mexico dead zone. At the same time, it suggests a general long-term trend toward [(lower)](steady) [(higher)] annual maximum areas of mid-summer Gulf of Mexico dead zones.
8. The Mississippi River/Gulf of Mexico Nutrient Management Task Force, composed of state and Federal agencies including the U.S. Department of Agriculture, supports the goal of reducing the size of the dead zone to less than 5000 square kilometers (1900 square miles) by 2015. Note the dashed red line in Figure 4 representing this goal. Achieving the goal in most years will require substantial reductions in nitrogen and phosphorus reaching the Gulf. Including the 2010 dead-zone area estimate, the most recent 5-year average of 17,300 square kilometers (6680 square miles) is [(far greater than)](close to) [(already less than)] the goal being sought by the Nutrient Management Task Force.

### Summary:

The phenomenon of dead zones, an example of *cultural eutrophication* (accelerated process of nutrient and sediment concentration in an aquatic system due to human activity), is clear evidence that humans are impacting the ocean environment. It, along with other observational evidence, demonstrates that we live in and are part of an Earth system. It shows that no matter where we live, our actions can impact all of the sub-systems of the Earth, including the ocean. Also, it demonstrates that understanding the underlying science of the phenomenon enables us to develop and implement mitigation strategies (if we have the will and choose to do so).

To learn more about the National Research Council report, *Nutrient Control Actions for Improving Water Quality in the Mississippi River Basin and Northern Gulf of Mexico*, go to: <http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=12544>.

To learn more about the 2011 Gulf of Mexico dead zone, go to:

<http://www.gulfhypoxia.net> or to

[http://www.eenews.net/assets/2011/08/01/document\\_gw\\_05.pdf](http://www.eenews.net/assets/2011/08/01/document_gw_05.pdf). If you would like to read a comprehensive report on hypoxia in U.S. waters, you can go to:

[http://www.vims.edu/newsandevents/docs/final\\_report.pdf](http://www.vims.edu/newsandevents/docs/final_report.pdf).

If directed by your instructor, place the answers to this Current Ocean Studies on the **Current Ocean Studies Answer Form** linked from the *AMS Ocean Studies website*.

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