ECOLOGICAL FORECASTING LESSON PLAN

The Dead Zone

Theme

Ecological Forecasting

Links to Overview Essays and Resources Needed for Student Research

http://oceanservice.noaa.gov/topics/coasts/ecoforecasting/
http://www.cop.noaa.gov/stressors/pollution/current/gomex-factsheet.html
http://www.cop.noaa.gov/stressors/

Subject Area

Life Science/Earth Science

Grade Level

9-12

Focus Question

What causes hypoxic (low oxygen) conditions that produce the "Dead Zone" in the Gulf of Mexico?

Learning Objectives

- Students will explain how nutrient enrichment in aquatic habitats can result in hypoxic or anoxic (no oxygen) conditions.
- Students will develop a plausible hypothesis that explains the existence of the "Dead Zone" in the northeastern Gulf of Mexico.
- Students will design an experiment to test their hypothesis.

Materials Needed

- (optional) Computers with internet access; if students do not have access to the internet, download copies of materials cited under "Learning Procedure" and provide copies of these materials to each student or student group

Audio/Visual Materials Needed

- (optional) overhead projector or computer projection equipment (see Learning Procedure, Step 3)

Teaching Time

One or two 45-minute class periods, plus time for student research

Seating Arrangement

Groups of 3-4 students

Maximum Number of Students

30

Key Words

Gulf of Mexico Dead Zone
Hypoxia
Anoxia
Eutrophication
Watershed
Mississippi River
Nutrient enrichment

Background Information

In August 1972, scientists participating in the Offshore Ecology Investigation in the Gulf of Mexico found severe oxygen depletion in bottom waters of the southeastern Louisiana shelf at depths of 10 – 20 meters (33 – 66 feet). Since then, numerous studies have found large areas in the northwestern Gulf of Mexico where summertime dissolved oxygen levels drop from normal values of about 7 parts per million (ppm, or mg oxygen per kilogram water) to 2 ppm or less. In 1985, annual surveys were begun to map the extent of this seasonally hypoxic (oxygen-depleted) region. Because dissolved oxygen levels below 2 ppm cause suffocation in many fish species, this region has come to be known as the "Gulf of Mexico Dead Zone."

Not surprisingly, discovery of the Dead Zone immediately led scientists to seek the cause of hypoxic conditions. Investigators soon agreed that the most probable cause of these conditions was the influx of fertilizer and animal waste from the

Mississippi River watershed, coupled with seasonal stratification of Gulf waters. Subsequent investigations confirmed this conclusion. While there is evidence that hypoxic conditions occasionally occurred in the same area before modern agriculture, such conditions were much less common than they have been since the 1970's.

Fertilizer and animal waste include nutrients, such as nitrogen and phosphorus, that are essential for the growth of algae normally found in healthy marine and freshwater ecosystems. But an overabundance of nutrients can cause excessive algal growth, so that more algae grow than can be consumed by other organisms in the system. Excess algae can reduce sunlight, crowd out other organisms, and lead to oxygen depletion when the algae die and begin to decompose.

Stratification occurs when surface waters are heated during warmer months, and consequently become less dense than colder, deeper waters. This is a relatively stable condition (warm, less dense water on top of colder, more dense water), and tends to suppress the exchange of water between the surface and deeper waters. Without vertical mixing, it is much more difficult for oxygen from the atmosphere to replenish oxygen consumed in deeper water. When decomposing algae increase the rate of oxygen consumption in deeper waters, unusually low oxygen concentrations can result.

The Mississippi River watershed (the area of land that drains into a particular water body) encompasses more than 1.2 million square miles and drains 41% of the continental United States. Thirty-one states and two Canadian provinces are included in the watershed, along with some of the major U.S. agricultural regions including those involving grain, soybean, and livestock production. Excess fertilizer and animal waste from agricultural activities are washed into the Mississippi River, and are eventually carried into the Gulf of Mexico.

NOAA's National Centers for Coastal Ocean Science (NCCOS) supports on-going research projects to improve our understanding of the causes of the Dead Zone, how seasonal hypoxia affects Gulf of Mexico ecosystems, and how the future extent and impacts of these occurrences can be predicted. The Gulf of Mexico Hypoxia Watch is a cooperative project of NCCOS, the National Marine Fisheries Service, the National Coastal Data Development Center, and the CoastWatch Gulf of Mexico Regional Node.

In this lesson, students will investigate some Hypoxia Watch activities, as well as some of the causes of seasonal hypoxia and what can be done to reduce the resulting impacts.

Learning Procedure

1.

To prepare for this lesson, make overhead transparencies of Figures 1, 2, 3, and 4 (found at the end of this lesson); or load these files onto a computer for projection; or make paper copies for each student or student group. If students will not have access to the internet for research, you may also want to make copies of one or more of the articles cited in Step 5, below.

Teachers should also consider whether or not to place constraints on proposed student investigations (e.g., are laboratory simulations acceptable, or should investigations be confined to field measurements), as well as whether students will be required to actually carry out their proposed investigations.

2.

If necessary, briefly review the significance of dissolved oxygen in aquatic environments. Be sure students understand the customary units for reporting dissolved oxygen concentration in water (mg/L or parts-per-million), and the normal values for dissolved oxygen in water (freshwater at 25°C is saturated with dissolved oxygen at a concentration of about 8.3 mg/L; seawater at 25°C is saturated with dissolved oxygen at a concentration of about 6.9 mg/L). You may also want to point out that the solubility of oxygen decreases as temperature increases, and also decreases as salinity increases. Portions of the National Ocean Service Estuary Discovery Kit (*http://oceanservice.noaa.gov/education/kits/estuaries*) dealing with temperature and dissolved oxygen provide a useful overview of these topics (see *oceanservice.noaa.gov/education/kits/estuaries/media/supp_estuar10a_temp.html*, and *oceanservice.noaa.gov/education/kits/estuaries/media/supp_estuar10a_dissolvedox.html*).

3.
Show students Figures 1 and 2. Tell them that Figure 1 shows the location where dissolved oxygen concentration has been monitored for many years, and that Figure 2 is a graph of dissolved oxygen concentration near the bottom of this location for the months between April and November of 1993. Ask students to identify the approximate location of this sampling station, and to interpret the data in Figure 2. Students should recognize that the sampling location is in the Gulf of Mexico near the coast of Louisiana, and that the data in Figure 2 show periods of severe oxygen depletion, particularly during the months of August and September. If students are not already familiar with the terms "hypoxic" (low oxygen concentrations) and "anoxic" (absence of oxygen), weave these terms into the discussion.

4.
Tell students that the conditions documented in Figure 2 were not an isolated event, but have been an annual occurrence for more than 30 years. Show Figure 3, and say that these diagrams show the extent of hypoxic (low oxygen) conditions in the northwest Gulf of Mexico for the last week in July of 1993. Ask students why they think this area is known as the "Gulf of Mexico Dead Zone." Students should infer that these conditions would probably be lethal for most aerobic organisms. While some species might be able to tolerate brief periods of low (or no) oxygen such as those experienced during April and May, prolonged absence of oxygen for more than a month during August and September would be too much for most species.

5.
Tell students that their assignment is to research the Gulf of Mexico Dead Zone, develop an hypothesis for the probable cause, and design an experiment to test this hypothesis. You may want to provide one or more of the following references:

- *http://www.ncddc.noaa.gov/ecosystems/hypoxia*;
- *http://toxics.usgs.gov/hypoxia/*;
- *http://www.smm.org/deadzone/*;
- *http://www.epa.gov/msbasin/*;
- *http://www.ducks.org/news/deadzone.asp*;
- *http://www.nwrc.usgs.gov/climate/hypoxia.pdf* (2 pages, 184 kb); and/or
- *http://www.seaweb.org/background/book/dead_zone.html*

Alternatively, you may wish to have students discover these (or other resources) on their own.

6.
Lead a discussion of the results of students' research. Based on their research, students should identify nutrient enrichment (eutrophication) as the most probable cause, though alternative hypotheses should be allowed if they are supported by a plausible line of reasoning. You may want to use the Mississippi River watershed map in Figure 4 to supplement this discussion (from the Mississippi National River and Recreation Area Web site, *http://www.nps.gov/miss/features/factoids/watershed.html*). Fertilizers and animal wastes should be recognized as potential sources of excess nutrients. Be sure students recognize that eutrophication occurs naturally as part of the process of succession in many freshwater systems. The key difference in the case of hypoxic areas like the Gulf of Mexico Dead Zone is that excess nutrient inputs from human activities cause the eutrophication to be much more rapid and extensive than the normal process.

Have each student group present their hypothesis and describe their planned experiment. Key points that should be included are:

- The hypothesis should relate to potential causes of oxygen depletion that are substantiated by students' literature research.
- If the hypothesis involves fertilizers and/or animal wastes from agricultural activities, the experimental test should use fertilizers or waste that might actually be involved with such activities.
- There should be appropriate controls for each different factor being tested.
- There should be at least two replicates of each test and control.

You may also want to have students describe the statistical tests that will be used to analyze their experimental data, since the intended statistical approach is a key consideration in experimental design.

7.
If you plan to have students actually conduct their experiments, refer to the following examples for equipment ideas and safety considerations:

- *http://ei.cornell.edu/watersheds/Eutrophication_Experiments.pdf* (6 pages, 32KB) – Eutrophication experiments from Cornell University's Institute on Science and the Environment for Teachers
- *http://www.zoo.utoronto.ca/able/volumes/vol-23/13-bennett.pdf* (16 pages, 64KB) – Eutrophication - A Project Lab for Multi-Section Lab Courses by Virginia Bennett, Department of Biology, Georgia Southern University
- *http://www.stormwatercoalition.org/pdf/Lesson%20Plans/lesson_11.pdf* (5 pages 108KB) – Eutrophication activity from Salt Lake County Storm Water Quality Education Lesson and Activity Plans

The Bridge Connection

http://www.vims.edu/bridge/archive1099.html/ – "The Dead Zone: A Marine Horror Story;" includes information on the causes and implications of the dead zone. Includes maps and data and invites students to find ways to fix the problem.

The Me Connection

The Gulf of Mexico Dead Zone is a dramatic example of how activities in one locale can have far-reaching impacts elsewhere. Have students write a brief essay describing how one or more activities with which they are personally involved could have an effect (positive or negative) on ecosystems in others locations.

Extensions

http://lamer.lsu.edu/classroom/deadzone/index.htm – "On Again, Off Again —The Dead Zone;" Louisiana Sea Grant Dead Zone Mapping Activity

http://www.lpb.org/education/classroom/ntti/cdpdf2003/6jmHyp.pdf (8 pages, 80KB) – "Hypoxia and the Dead Zone in the Gulf of Mexico: Is It the Mississippi River's Fault?" activity by Janiece Mistich, from the National Teacher Training Institute *http://www.epa.gov/msbasin/index.htm* – EPA Web page on the Mississippi River Basin and Hypoxia in the Gulf of Mexico, including information on subbasins, hypoxia, culture and history of the area, strategies for reducing the frequency of hypoxic events, and links to other resources

http://www.epa.gov/gmpo/ – "The Gulf of Mexico Watershed" provided by the U.S. Environmental Protection Agency, Gulf of Mexico Program; follow links from "Educator and Student Resources" to "Kid's Stuff" for facts, figures and maps of the Gulf watershed.

Resources

Rabalais, N. N., R. E. Turner, D. Justic, Q Dortch, and W J. Wiseman, Jr.1999. Characterization of Hypoxia – Topic 1 Report for the Integrated Assessment on Hypoxia in the Gulf of Mexico. NOAA Coastal Ocean Program Decision Analysis Series No. 15

http://www.ncddc.noaa.gov/ecosystems/hypoxia – Hypoxia Watch System for the Gulf of Mexico

http://www.aoml.noaa.gov/ocd/necop/ – Web site for NOAA's Atlantic Oceanographic and Meteorological Laboratory's Nutrient Enhanced Coastal Ocean Productivity (NECOP) Program; scroll down to "NECOP Projects by Year" to access data from Gulf of Mexico research cruises

http://toxics.usgs.gov/hypoxia/ – Web site on hypoxia in the Gulf of Mexico and related activities of the US Geological Survey

http://www.nps.gov/miss/features/factoids/ – General information and "factoids" about the Mississippi River and its watershed from the Mississippi National River and Recreation Area Web site

Mississippi River/Gulf of Mexico Watershed Nutrient Task Force. 2001. Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico. Washington, DC; available online at *http://www.epa.gov/msbasin/taskforce/pdf/actionplan.pdf* (36 pages, 6.4MB) *http://www.nwrc.usgs.gov/climate/hypoxia.pdf* (2 pages, 184 kb) – Fact sheet from the U.S. Geological Survey, National Wetlands Research Center

http://www.epa.gov/msbasin/ – Web page from the U.S. Environmental Protection Agency with information on hypoxia, the relationship between the Mississippi River Basin and the Gulf of Mexico , and links to scientific reports

Osterman, L. E., R. Z. Poore, P. W. Swarzenski, and R. E. Turner. 2005. Reconstructing a 180 yr record of natural and anthropogenic induced low-oxygen conditions from Louisiana continental shelf sediments. Geology 33(4):329–332; available online at *http://www.cosee-ma.net/newsletter/pdfs/MS-Dead-Zone-180-yr-article.pdf* (5 pages, 304K)

http://www.smm.org/deadzone/ – Web site from the Science Museum of Minnesota about the Gulf of Mexico Dead Zone with interactive activities, links, maps and video in English and Spanish

http://www.ducks.org/news/deadzone.asp – Ducks Unlimited News Web site; several articles provide an overview of the hypoxia problem and discuss nonpoint source pollution in the Mississippi River with an interactive map

http://www.seaweb.org/background/book/dead_zone.html – SeaWeb briefing book, including a recommended reading list

http://www.osu.edu/units/research/archive/hypoxia.htm – "Potential solutions for Gulf of Mexico's 'dead zone' explored;" News from Ohio State University about recent research into controlling nutrient and pesticide pollution in the Mississippi River watershed

Diaz, R. J. 2001. Overview of Hypoxia around the world. Journal of Environmental Quality. 30:275-281; available online at *http://jeq.scijournals.org/cgi/content/abstract/30/2/275* (7 pages, 369K)

National Science Education Standards

Content Standard A: Science as Inquiry

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

Content Standard C: Life Science

- Interdependence of organisms

Content Standard D: Earth and Space Science

- Geochemical cycles

Content Standard F: Science in Personal and Social Perspectives

- Personal and community health
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Links to AAAS "Oceans Map" (aka benchmarks)

5D/H2 – Like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium. In the long run, however, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution.

5D/H3 – Human beings are part of the Earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems.

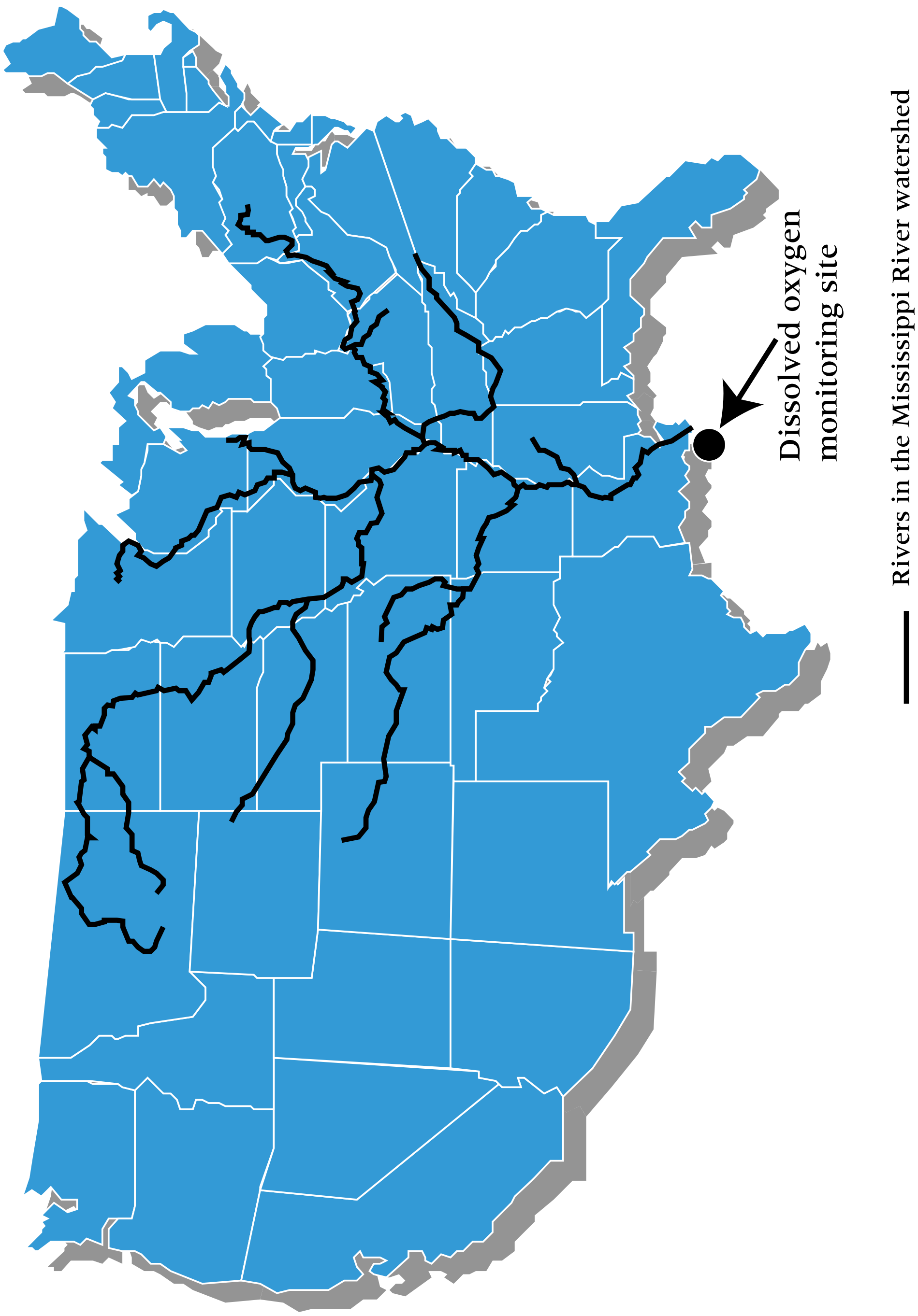
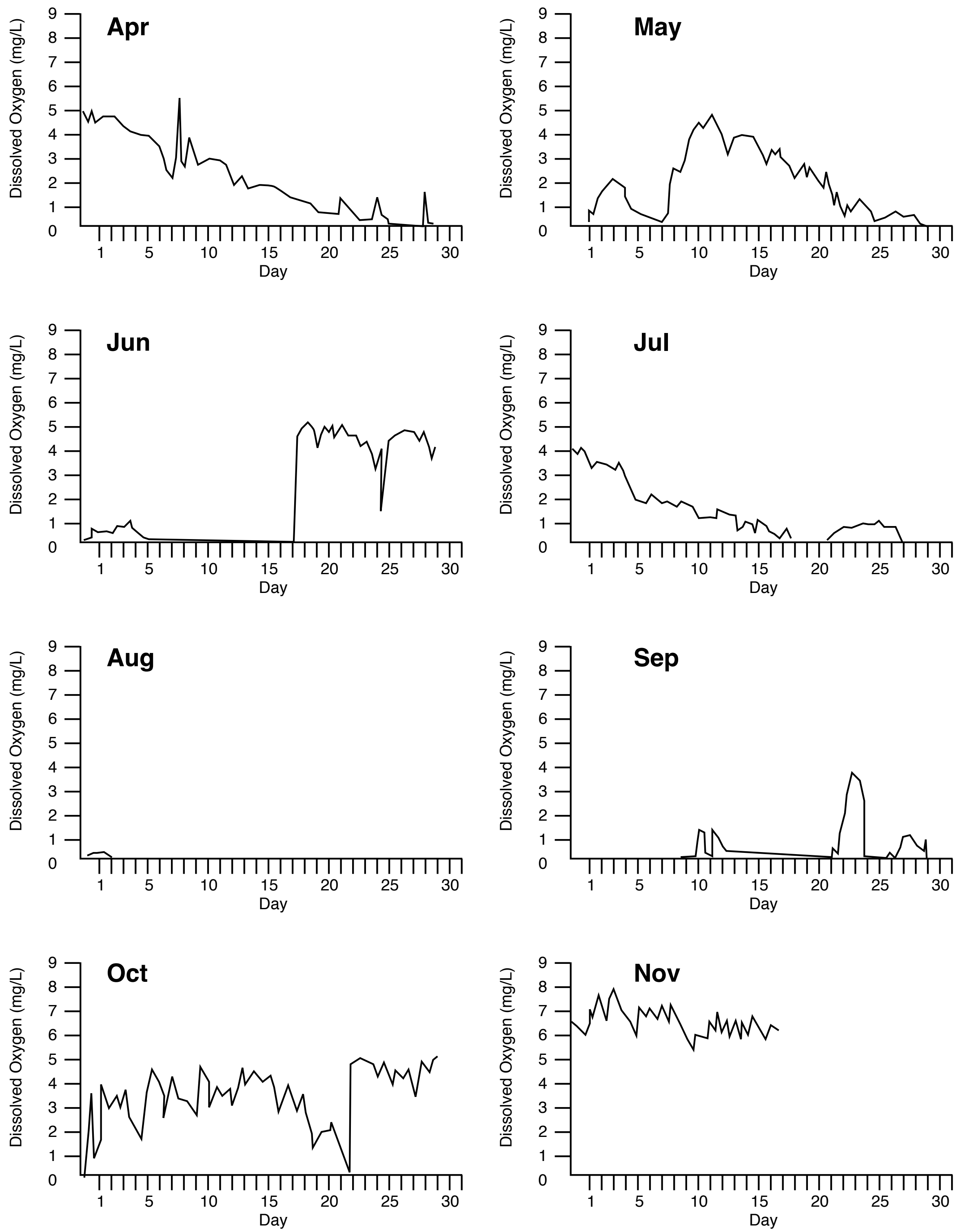

Dissolved oxygen monitoring site
Rivers in the Mississippi River watershed

Figure 1

Figure 2

Station C6B 1993 Bottom Dissolved Oxygen (mg/L)



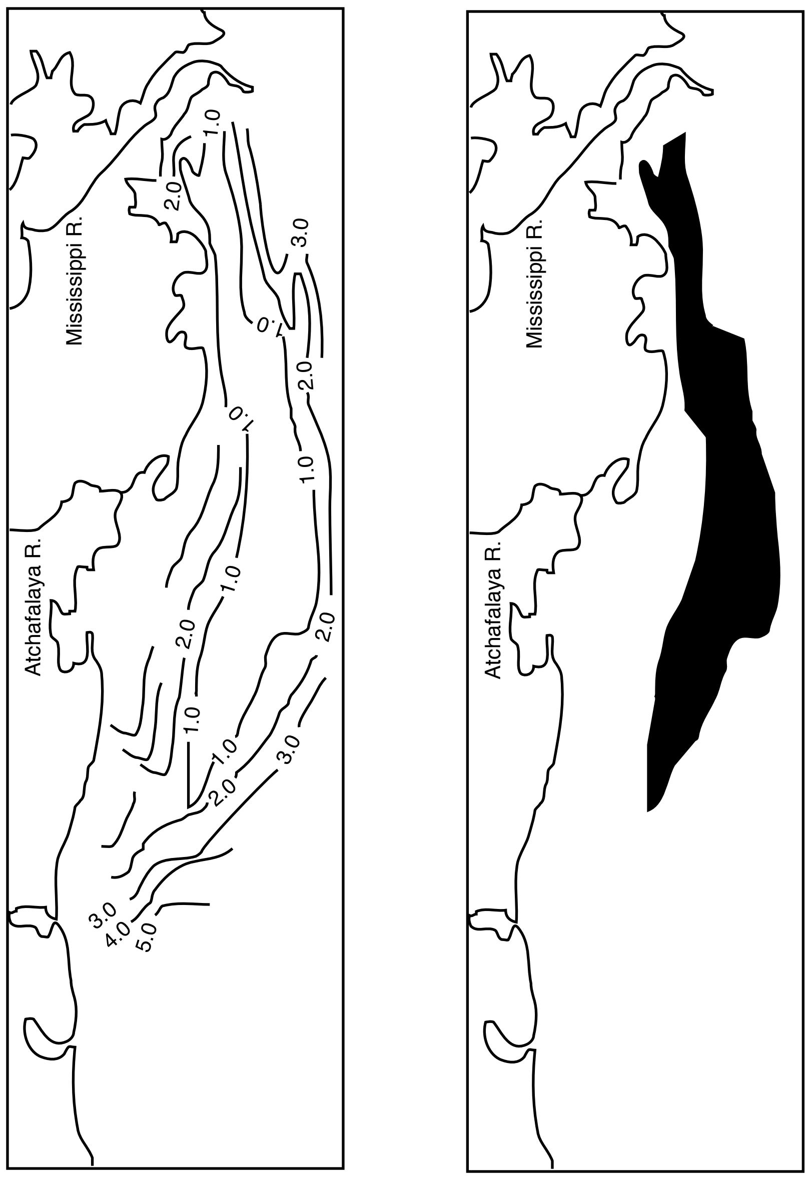
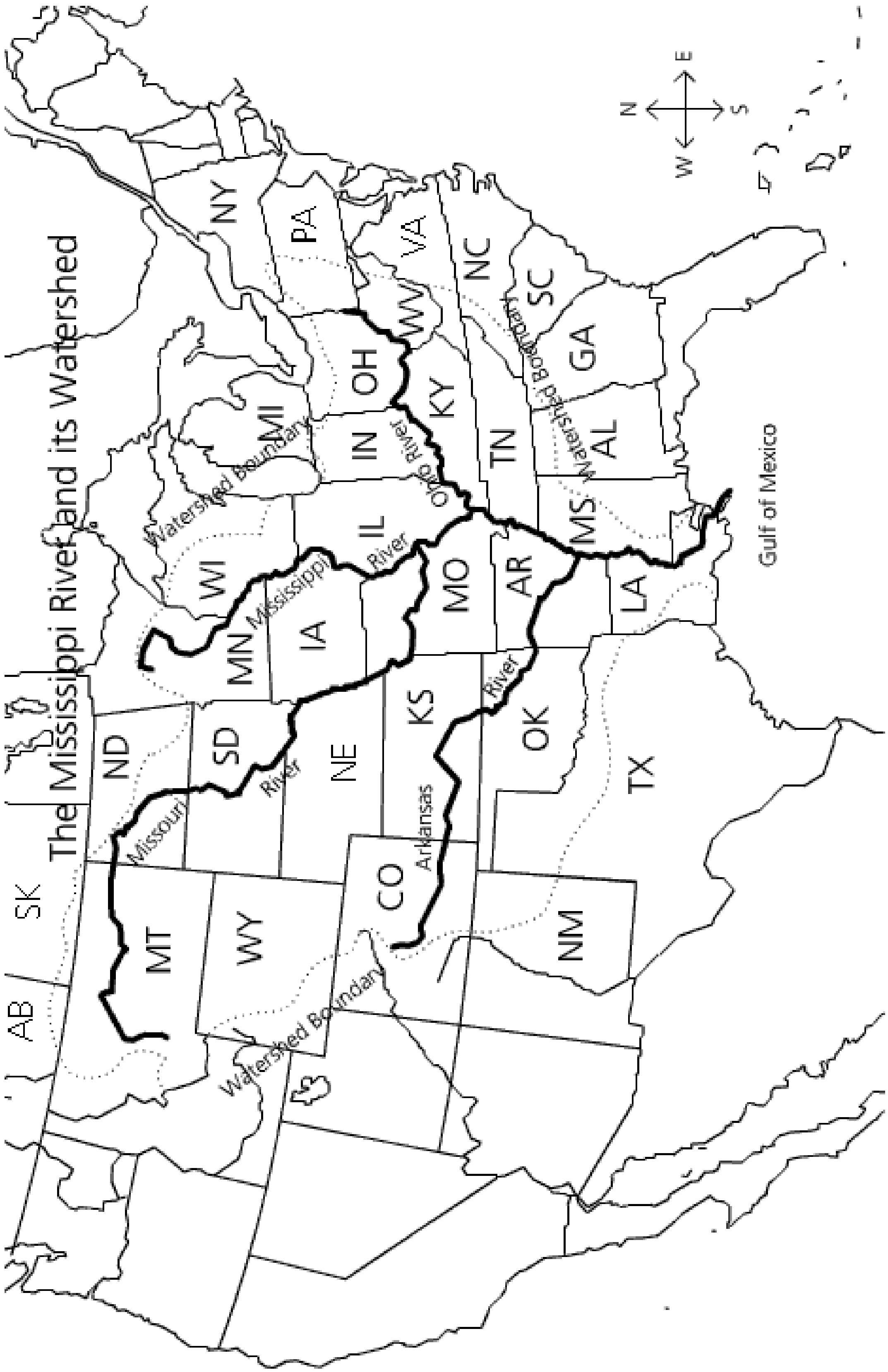

Mississippi R.
Atchafalaya R.
1.0
2.0
3.0
4.0
5.0
Mississippi R.
Atchafalaya R.

Figure 3


The Mississippi River and its Watershed
Watershed Boundary
Mississippi River
Missouri River
Ohio River
Arkansas River
Gulf of Mexico
N
E
S
W
AB
SK
MT
WY
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SD
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CO
KS
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KY
TN
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OH
WV
VA
NC
SC
GA
NY
PA

Figure 4