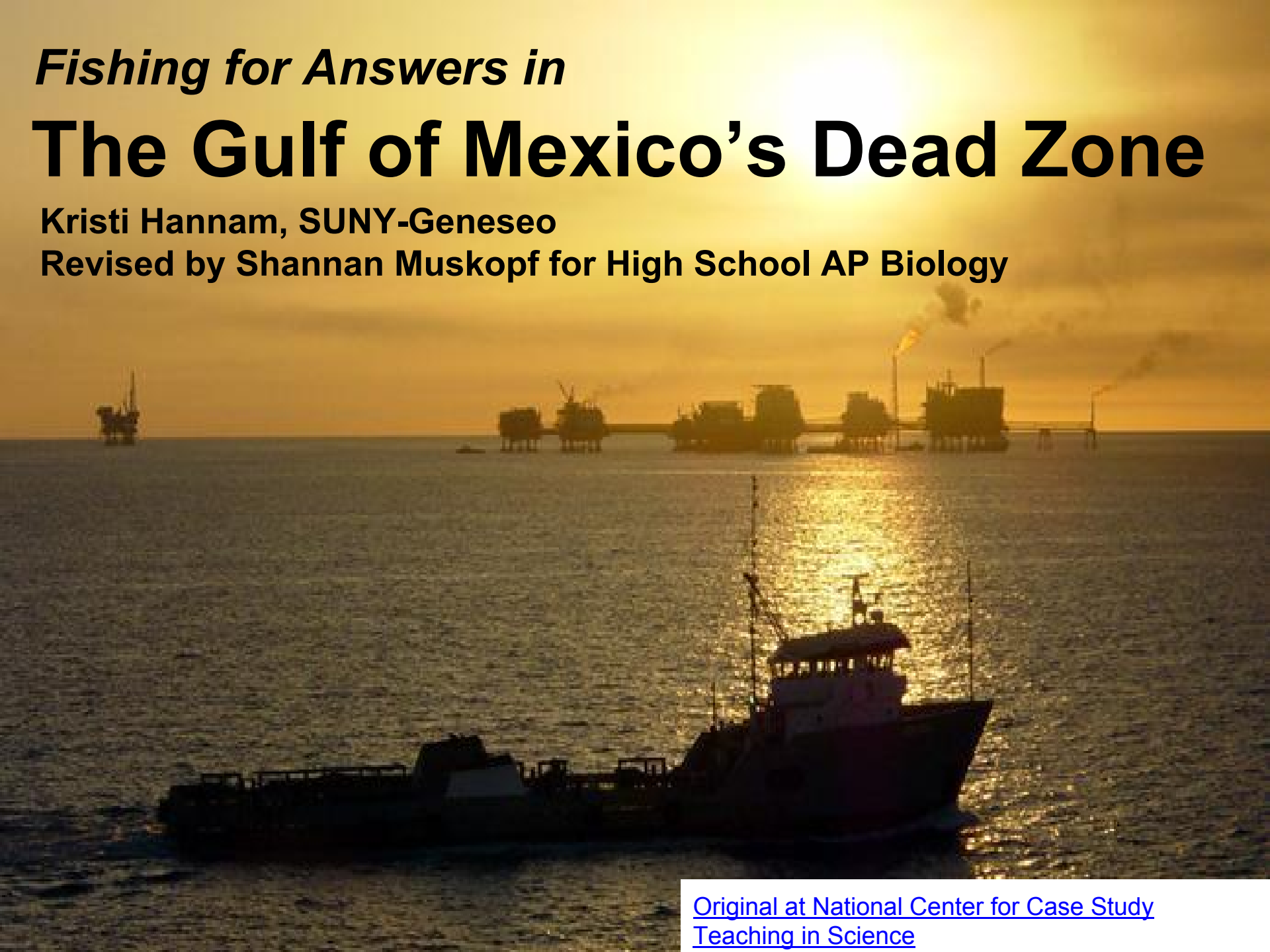
Fishing for Answers in

The Gulf of Mexico's Dead Zone

Kristi Hannam, SUNY-Geneseo
Revised by Shannan Muskopf for High School AP Biology



Original at National Center for Case Study Teaching in Science

Summer at the Seafood Shack

Susan had moved in with Aunt Janet in Louisiana for the summer. She wanted to enjoy the sun and the beach, and save some money for college next fall. A week ago, she found a job as a waitress at Captain Joe's Seafood Shack.

At lunch, a businessman asked: "Where's the shrimp from anyway?"

She'd been asked this twice before already, so she knew the answer. "From Thailand."

*

Next Morning

The next morning, Susan and Aunt Janet were eating breakfast while watching boats on the Gulf.

Aunt Janet pointed. “See that boat with the funny stuff sticking out the back? That’s George. He’s a shrimper.”

“A shrimper? Then why does Captain Joe buy shrimp from Thailand?”

“I don’t know, why don’t you ask him!”

*

Business Decision

Captain Joe was busily setting up lunchtime plates when Susan found him.

“If there are shrimp in the Gulf, why do you buy shrimp from Thailand, Captain Joe?”

He stared at her, annoyed by the interruption. “Too expensive!” he grunted.

Quick Discussion:

In your group, find out what the favorite kind of shrimp is?

(fried, scampi, shrimp cocktail, popcorn…)

*

Your poll will show here

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Why is it so expensive?

Susan wondered why shrimp in the gulf are more expensive than fish caught in Thailand or even shrimp grown in artificial ponds. Turns out, shrimp farms in the U.S. sell shrimp to restaurants, even restaurants on the coast!

1. a) Describe the set-up that an Illinois shrimp farmer uses to grow shrimp.

b) How long does it take to grow a full size shrimp?

c) How much per pound are these farm raised shrimp? Use the internet to find how this cost compares to Gulf shrimp costs.

d) Would you rather eat farm-raised shrimp or gulf shrimp?

Watch this news report on shrimp farms in Illinois.

http://wqad.com/2015/04/30/shrimp-farms-becoming-a-big-deal-in-illinois/

Dead Zone

George continued: “People around here have a lot of different ideas about why shrimp are going away. Some think hurricanes like Katrina are to blame, others think overfishing, pollution, or climate change are the cause. I don’t know for sure, but something has definitely happened – people are calling our part of the Gulf a ***Dead Zone*** – and it seems to be growing every year.”

*

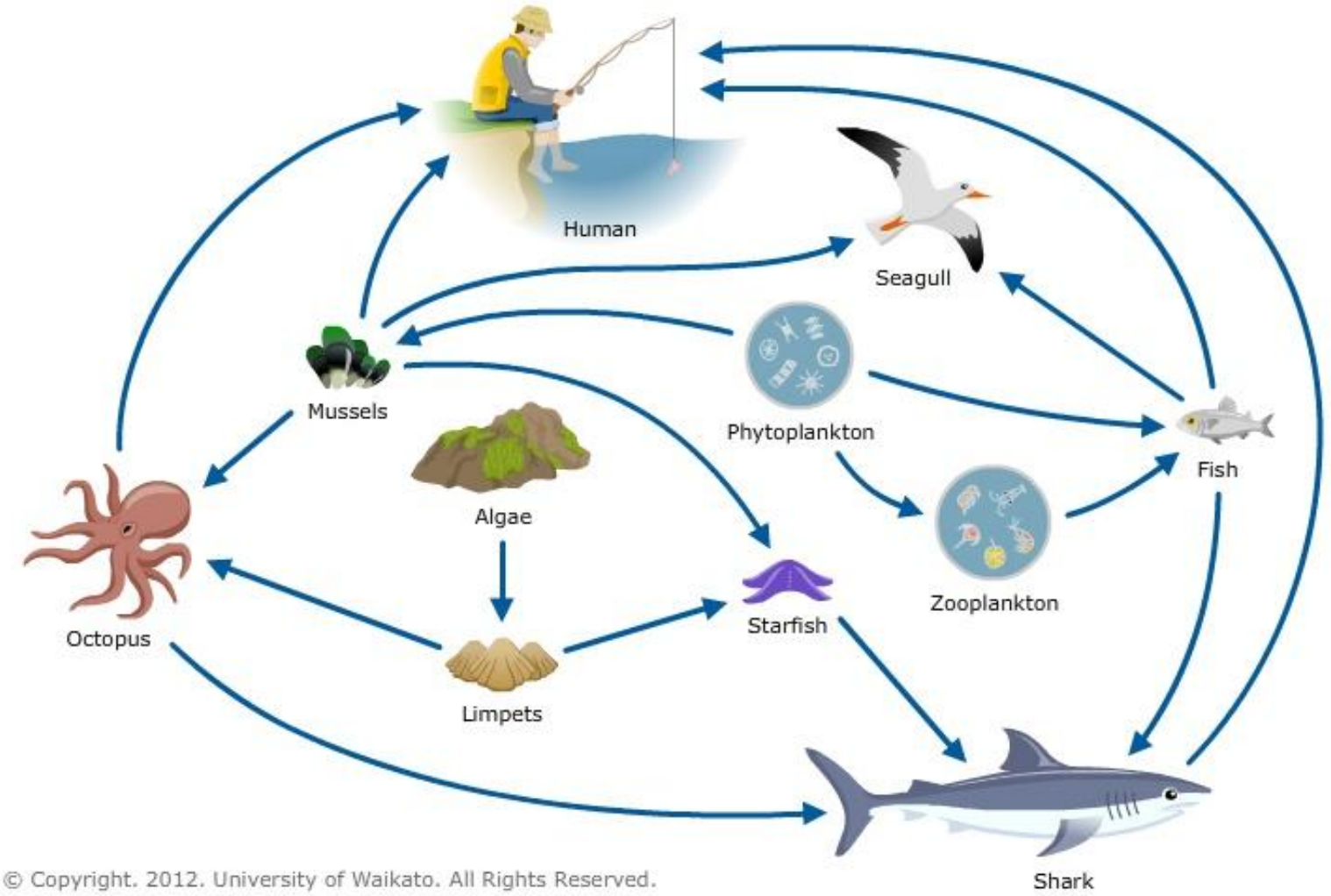
Question 2: What is the dead zone and what are the economic impacts it is having on the Gulf?

Dory: "Hey, it's krill!"

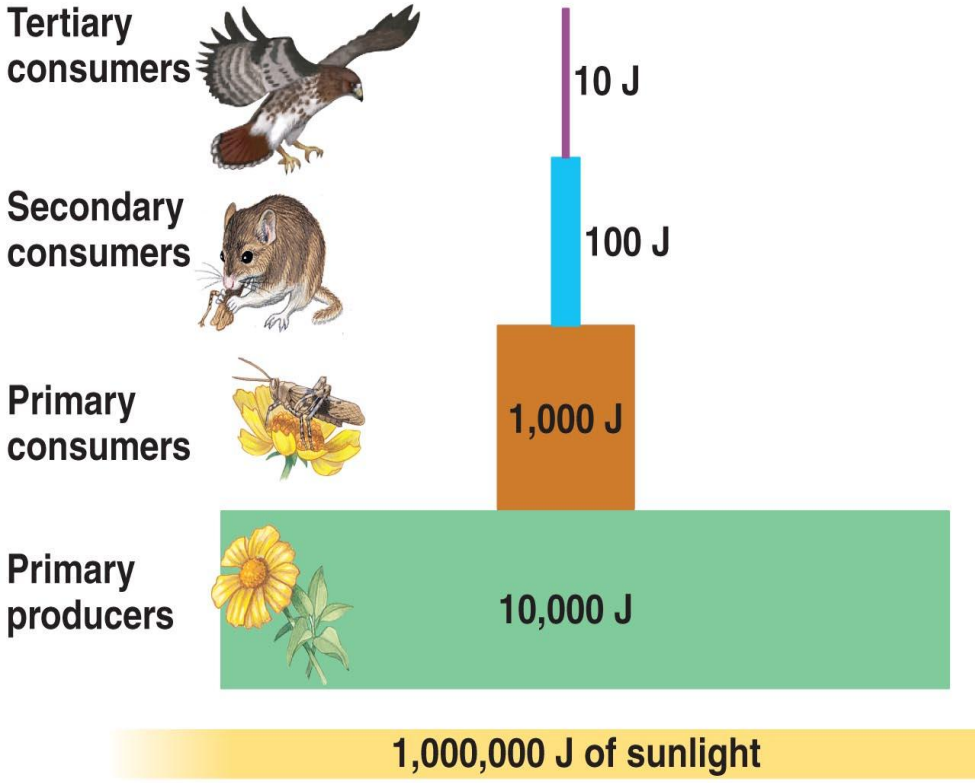
Question 3: Consider the food web shown below.

a) Where would you put shrimp? (Create a food chain.)

b) How will decreased amounts of shrimp affect other species?



Based on food webs, ecologists can create a pyramid of energy that shows energy flow in community. The different levels represent different groups of organisms that might compose a food chain



4. Shown here is a grassland biome energy pyramid.

a) Construct one that would apply to an ocean biome.

b) What should they both have in common?

c) What happens when a primary consumer (like shrimp) is removed?

3: Based on information from the locals, 5 hypotheses have been proposed. Which one do YOU think is correct?

A. Overfishing has depleted shrimp populations.

B. Water pollution/toxins have killed off shrimp populations.

C. Rising water temperatures caused by climate change have made the habitat inhospitable to shrimp.

D. Hurricane Katrina (2005) destroyed all the shrimp and their habitat.

E. BP Oil Spill (2010)

*

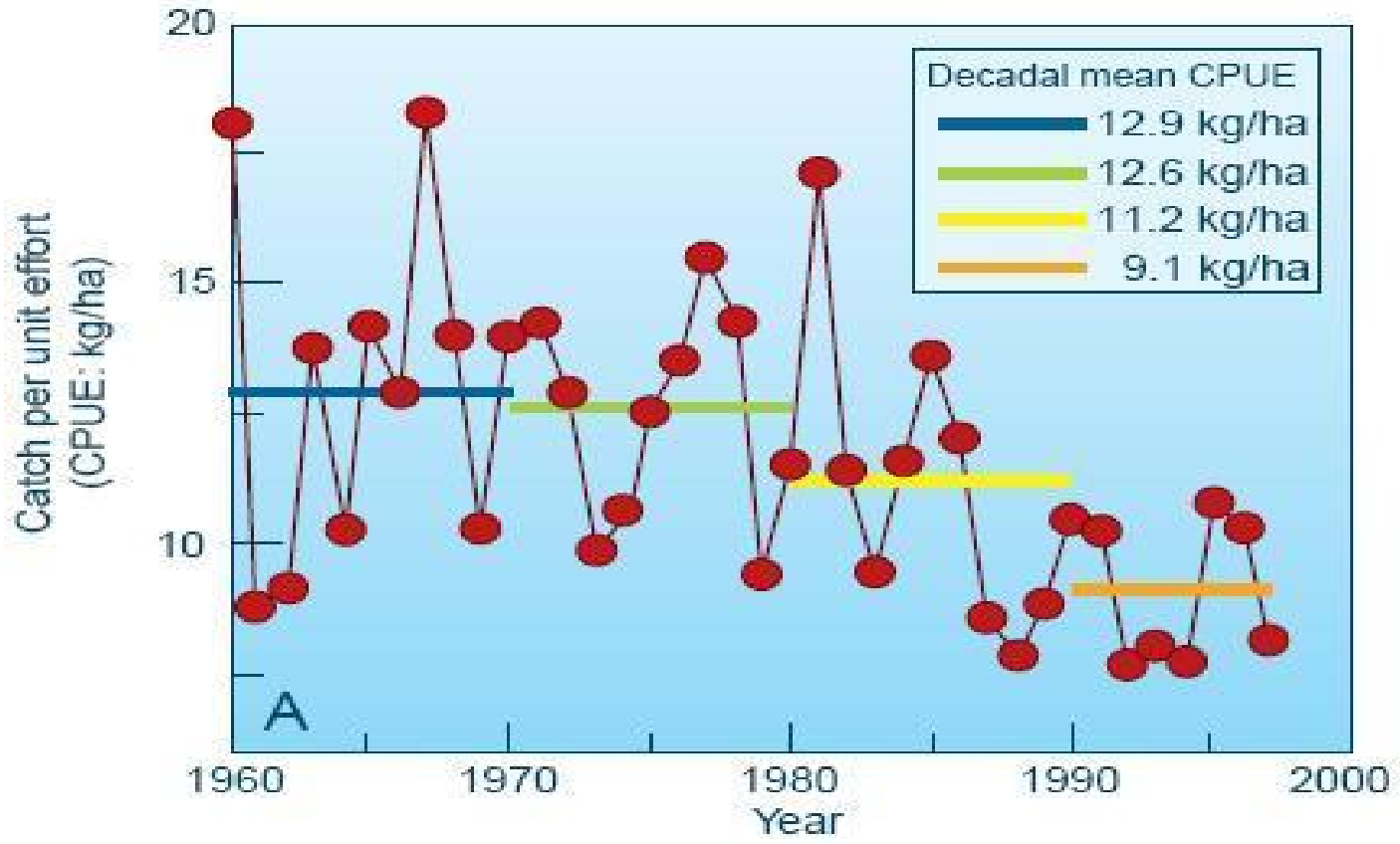
The five working hypotheses for the Dead Zone are:

- Hurricane Katrina (2005)
- Pollution
- Climate change
- Overfishing
- Oil Spill (2010)

Jot down your choice so that you can reference it throughout the case.

Question 4: What data would you need to collect to support or reject the hypothesis that overfishing has resulted in the dead zone?

5. Summarize the data of this graph , what does it tell you about average shrimp catch over time?

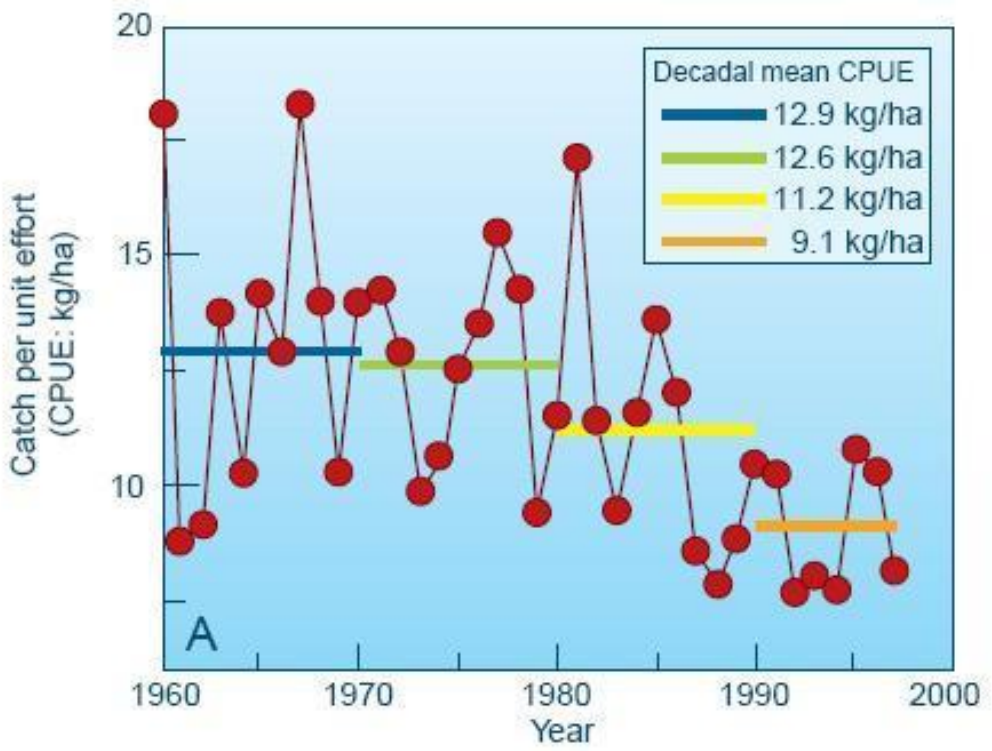


The graph shows annual changes of CPUE for brown shrimp in areas of the Gulf of Mexico. The colored bars are “decadal means.” They show the average CPUE for a span of ten years (CPUE = catch per unit effort). Data: James Nance, National Marine Fisheries Service.

*

6: Which hypotheses does this graph NOT support?

A. Hurricane Katrina
B. Pollution
C. Climate Change
D. Overfishing
E. Oil Spill



Explain your reasoning.

(Hint: Consider dates)

*

Watching the local news that night, Susan saw an image of the Gulf Coast at the mouth of the Mississippi River that caught her attention:

7. What do you think the arrow is pointing to?

8: Which hypothesis does the evidence in this image support?

A. Hurricane Katrina
B. Pollution
C. Climate Change
D. Overfishing

*

Of her original hypotheses, Susan decided the evidence suggests she should explore the pollution hypothesis:

- Hurricane Katrina
- Pollution
- Climate Change
- Overfishing
- BP Oil Spill

Susan decided to investigate the sediment plume to see if there was a link to the disappearing shrimp in the Dead Zone.

Her research revealed the following map:

Watersheds of the Mississippi River Basin

Source: USGS Fact Sheet 016-00

[Take the watershed poll.](#)

What is your favorite (water) vacation spot?

*

Your poll will show here

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Susan realized that runoff from an enormous area could be causing the sediment plume.

BUT:

- The SIZE of the Mississippi River watershed probably hasn't changed in thousands of years.
- People have been shrimping and fishing in the Gulf for over 100 years.

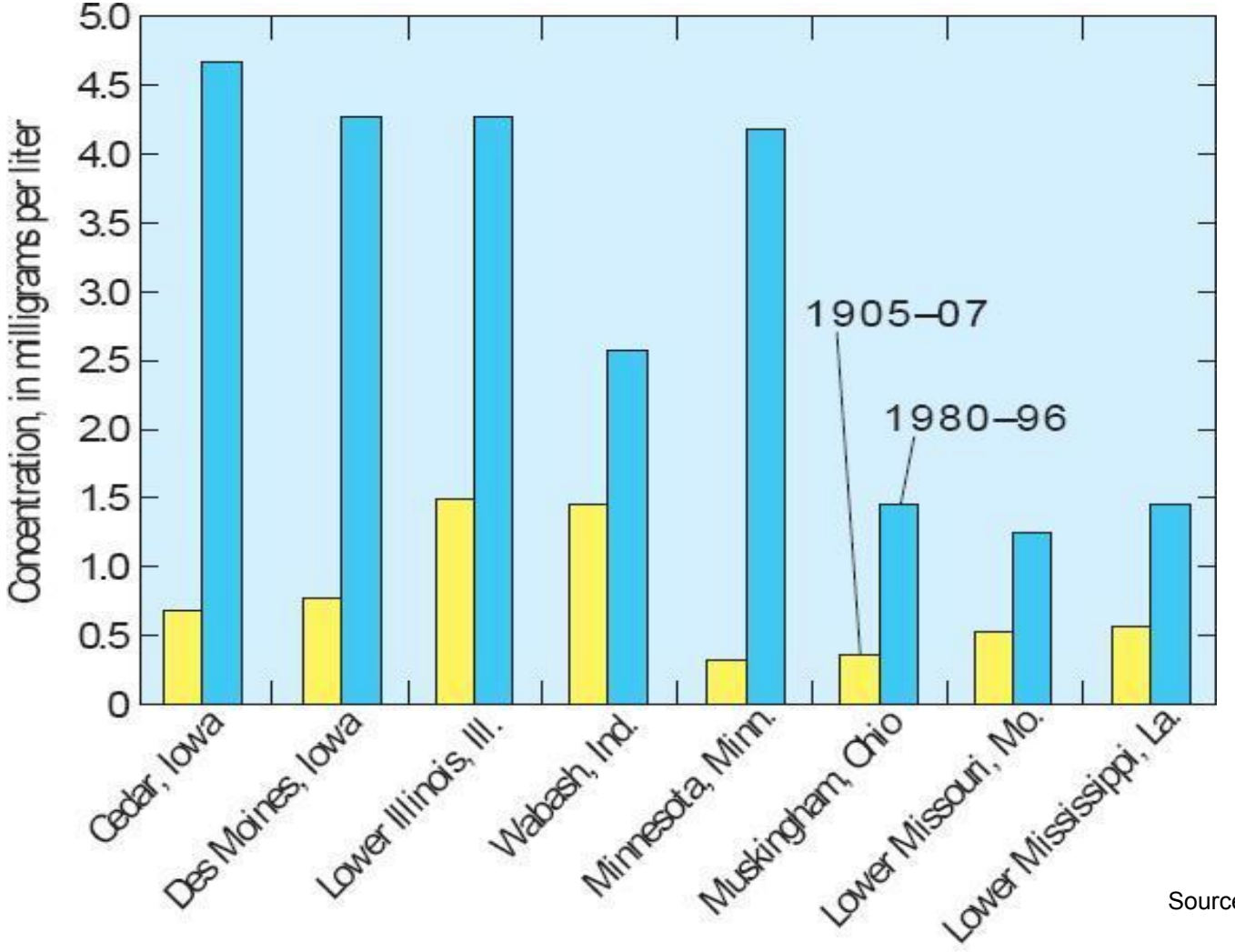
Source: USGS Fact Sheet 016-00

9. So WHAT could be causing the problem *now*? What <u>has</u> changed in the last 100 years?

Use poll to brainstorm ideas. Submit at least one from your group.

Vote on others' submissions.

10. What does this figure tell you about the runoff to the Mississippi River basin over time?



Source: USGS Fact Sheet 135–00

Figure 3. Average annual nitrate concentrations in selected rivers during 1905–07 and 1980–96.

11. What is the relationship between streamflow and nitrate flux?

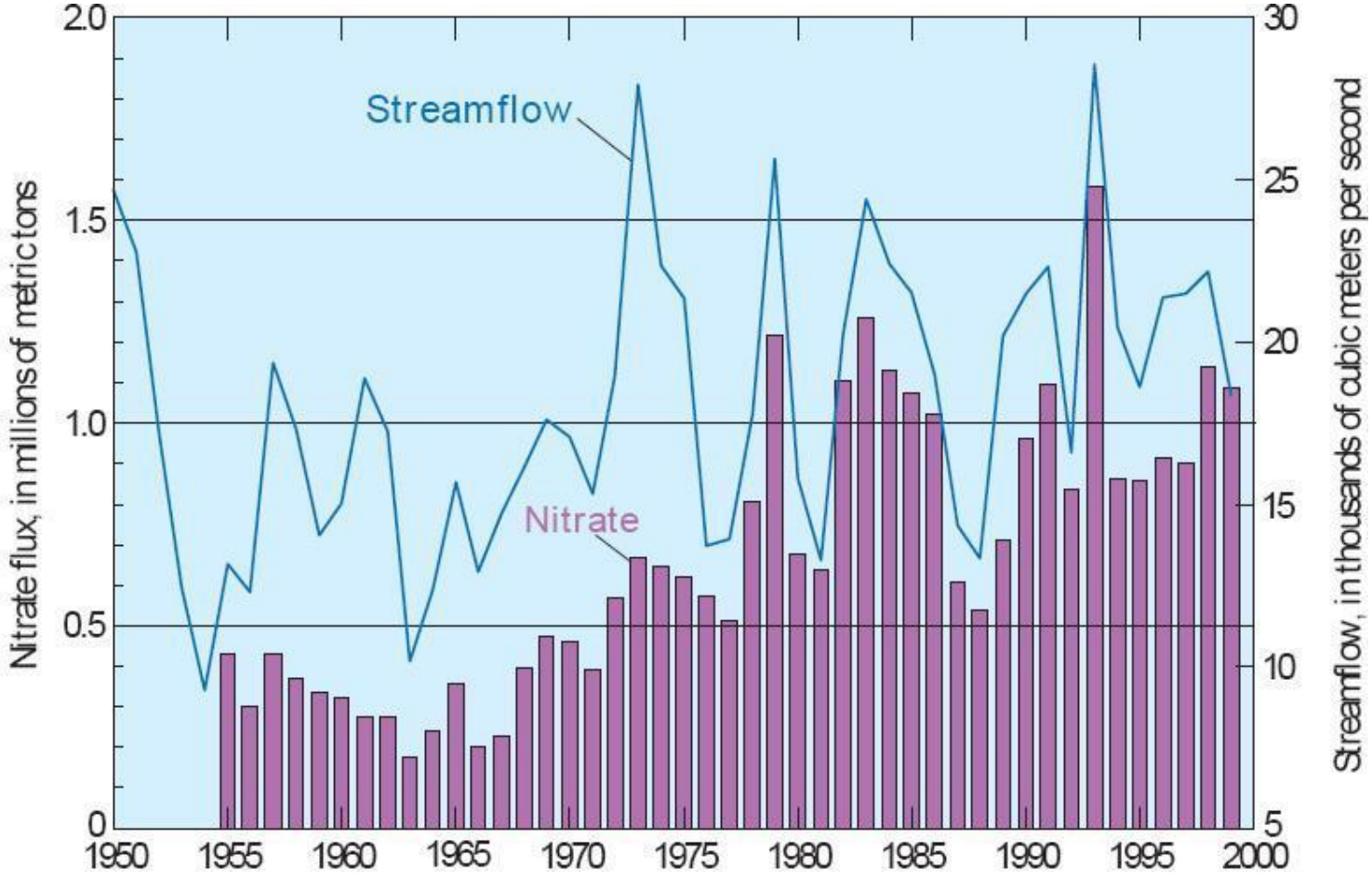
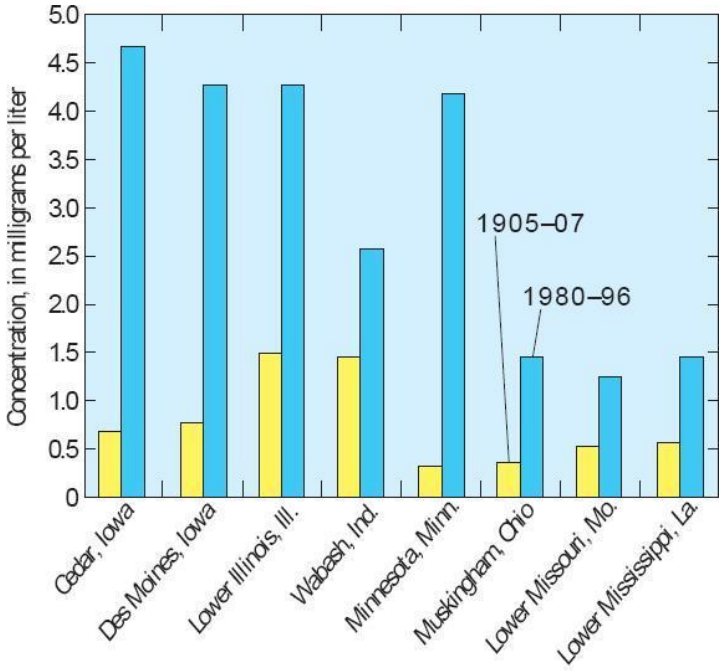


Figure 4. Annual nitrate flux and mean annual streamflow from the Mississippi River Basin to the Gulf of Mexico.

Source: USGS Fact Sheet 135–00

*

12: What do these figures tell you about the runoff to the Mississippi River basin over time?



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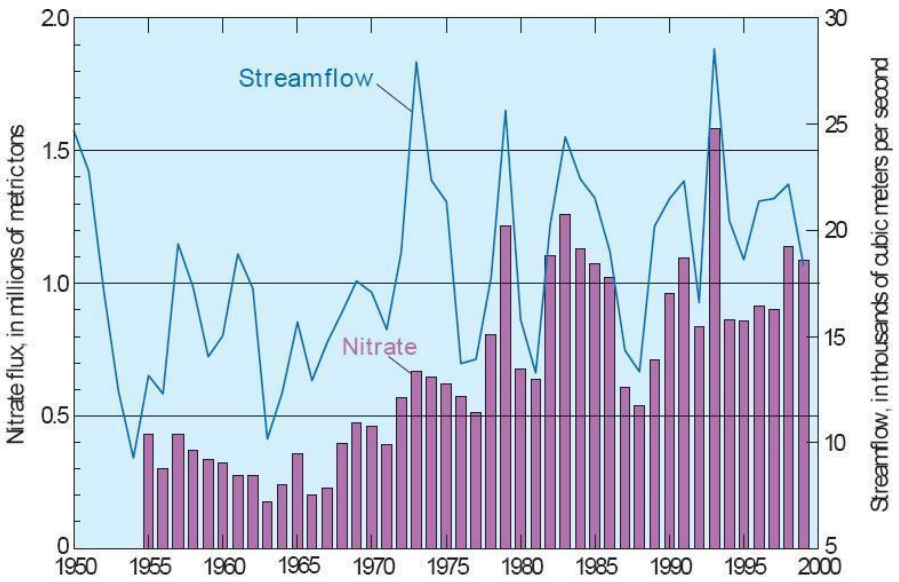
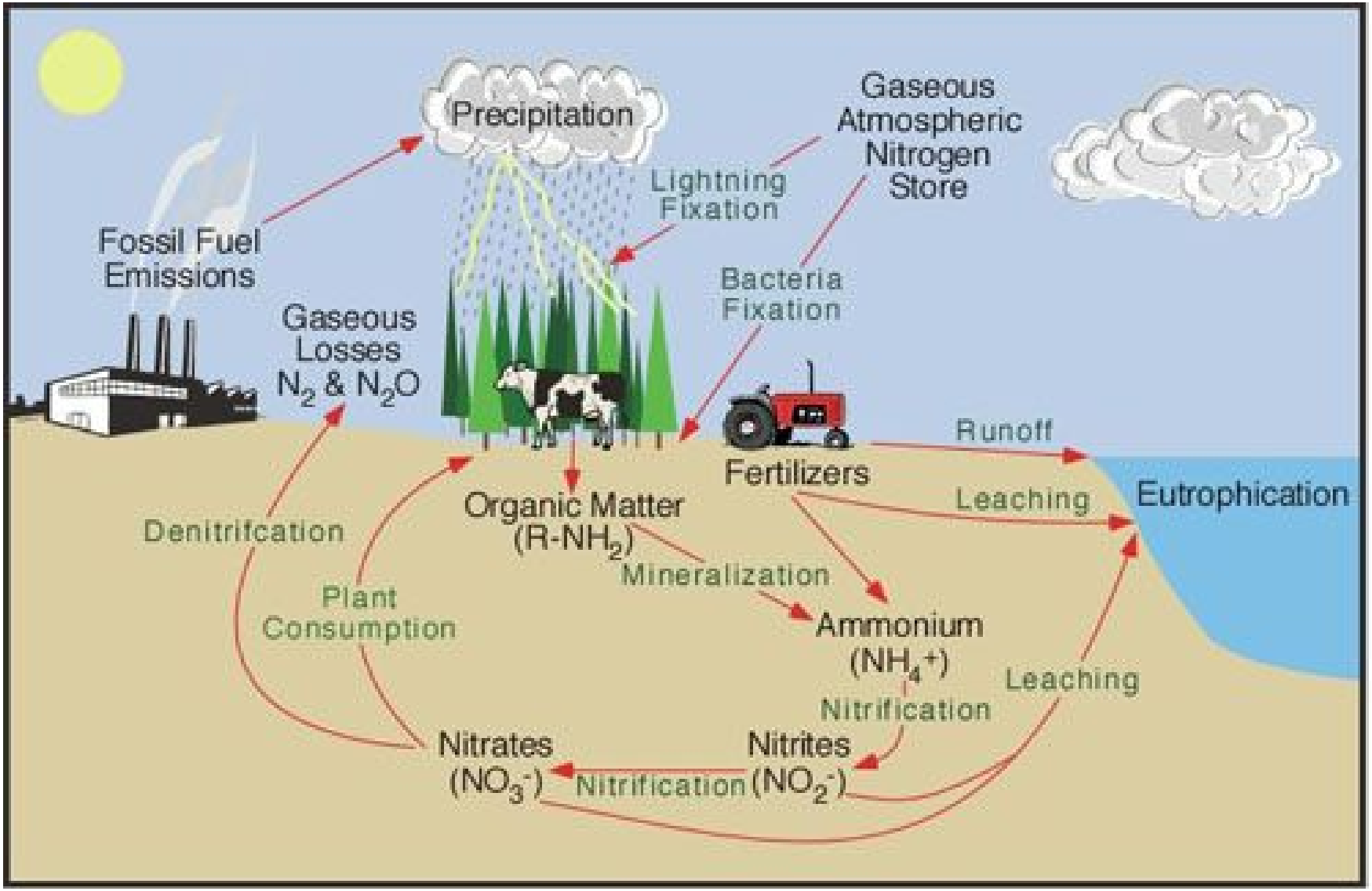


Figure 4. Annual nitrate flux and mean annual streamflow from the Mississippi River Basin to the Gulf of Mexico.

A. Annual nitrate concentrations have increased over time.
B. Stream flow has remained constant over time.
C. The biggest source of nitrates is the area farthest from the Gulf of Mexico.
D. Only A and C.
E. A, B, and C are true.

*

Susan recalled a figure from her biology course

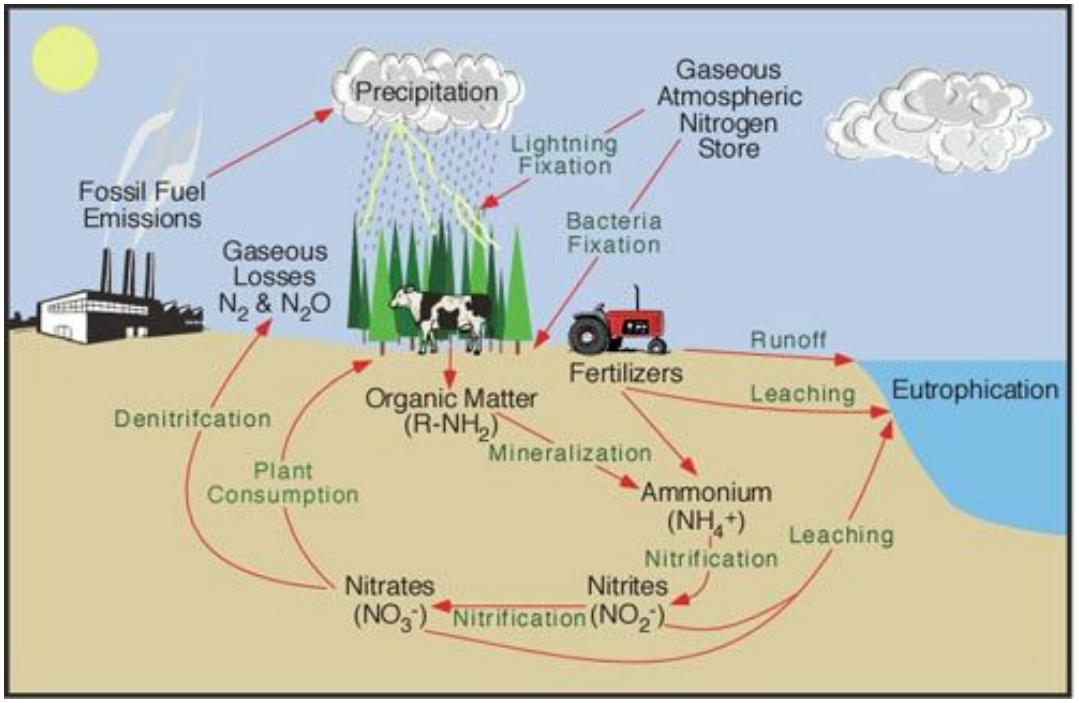


http://serc.carleton.edu/images/microbelife/microbservatories/northinlet/Nitrogen_Cycle

*

13: What is the most likely source of nitrogen in runoff?

A. Fossil fuel emissions.
B. Organic matter.
C. Leaching of nitrates from nitrification.
D. Fertilizer runoff.



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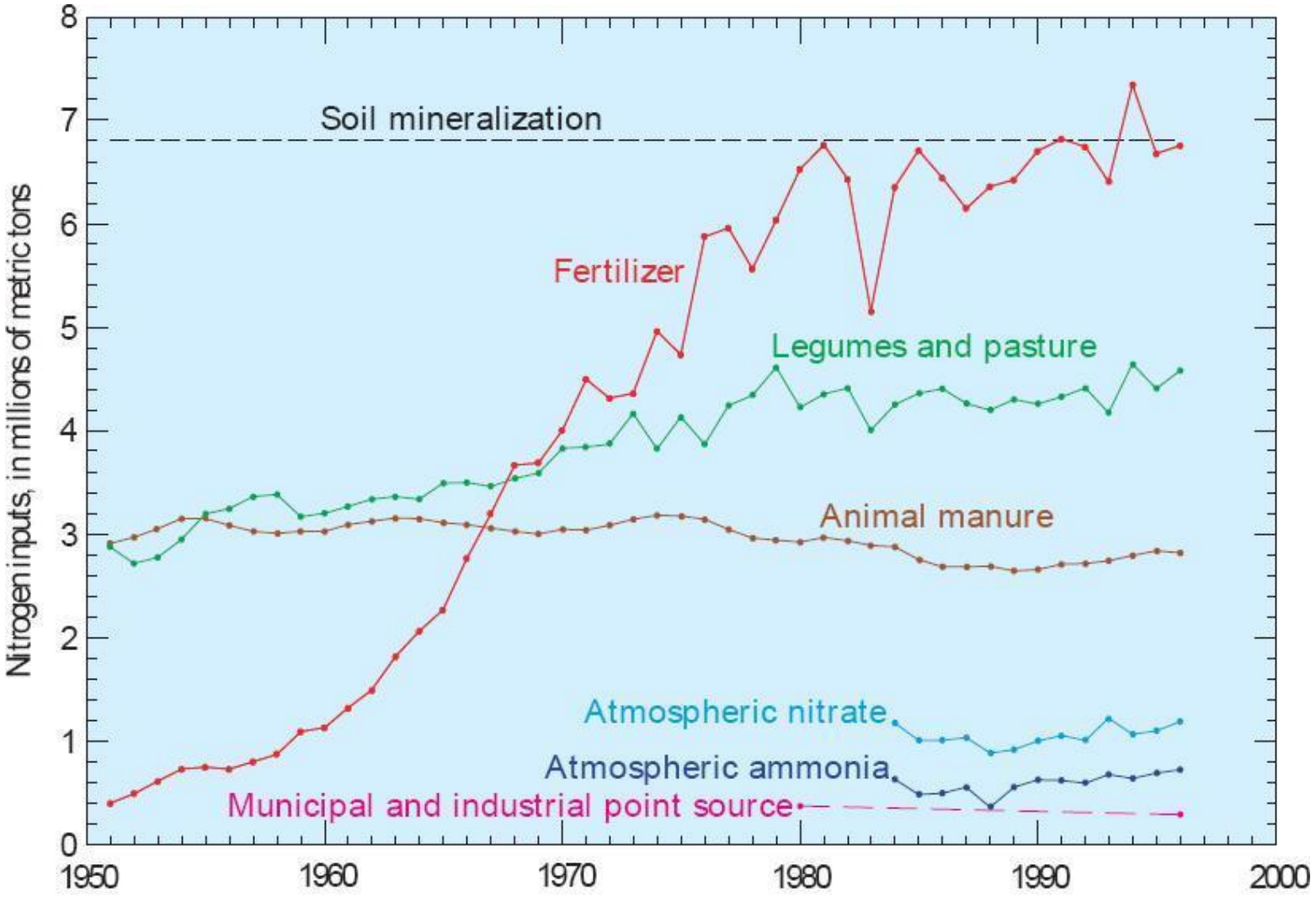


Figure 5. Annual nitrogen inputs to the Mississippi Basin from major sources.
USGS Fact Sheet 135-00

14. a) Which source(s) of nitrates has increased?
    b) Which has remained relatively constant?

*

Susan's Question

Susan realized that her Internet research had distracted her from her original question about shrimp. How could increased nitrates be connected to decreased fish and shrimp populations?

She had figured out this much:

a) Nitrates flow into the Gulf of Mexico from the Mississippi River watershed (especially states further north).

b) The nitrates are carried by the freshwater river into the saltwater Gulf of Mexico.

Interior Watersheds of the Mississippi River Basin

Largest river basin in North America.

Third largest basin in the world.
Includes 70 million people, 30 states.

One of the most productive farming regions in the world:

~60% of the basin is cropland (corn, soybeans, wheat)
~20% woodland,
~20% barren land,
~2% wetland, and
~ 0.6% urban land

(*Goolsby and Battaglin, 2000*)

Source: USGS Fact Sheet 016-00

*

15: When the freshwater river flows into the saltwater Gulf, what do you predict will happen?

A. The freshwater and the saltwater will mix, lowering the overall salinity of the Gulf.
B. The warmer freshwater will sink to the bottom of the Gulf, and the colder saltwater will float above.
C. The less dense freshwater will float on top of the more dense saltwater.
D. The amount of freshwater entering the Gulf is so small compared to the total volume of the Gulf that there will be no noticeable effect of the freshwater input.

*

Temperature & Salinity Layering

- Video of temp & salinity experiments

  http://www.smm.org/deadzone/activities/top.html

  *** or https://youtu.be/AasKk3HRyOI

- Video of what happens in the Gulf

  http://www.smm.org/deadzone/causes/dead-zone.html

16. Describe what happens when warm water meets cold water.

*

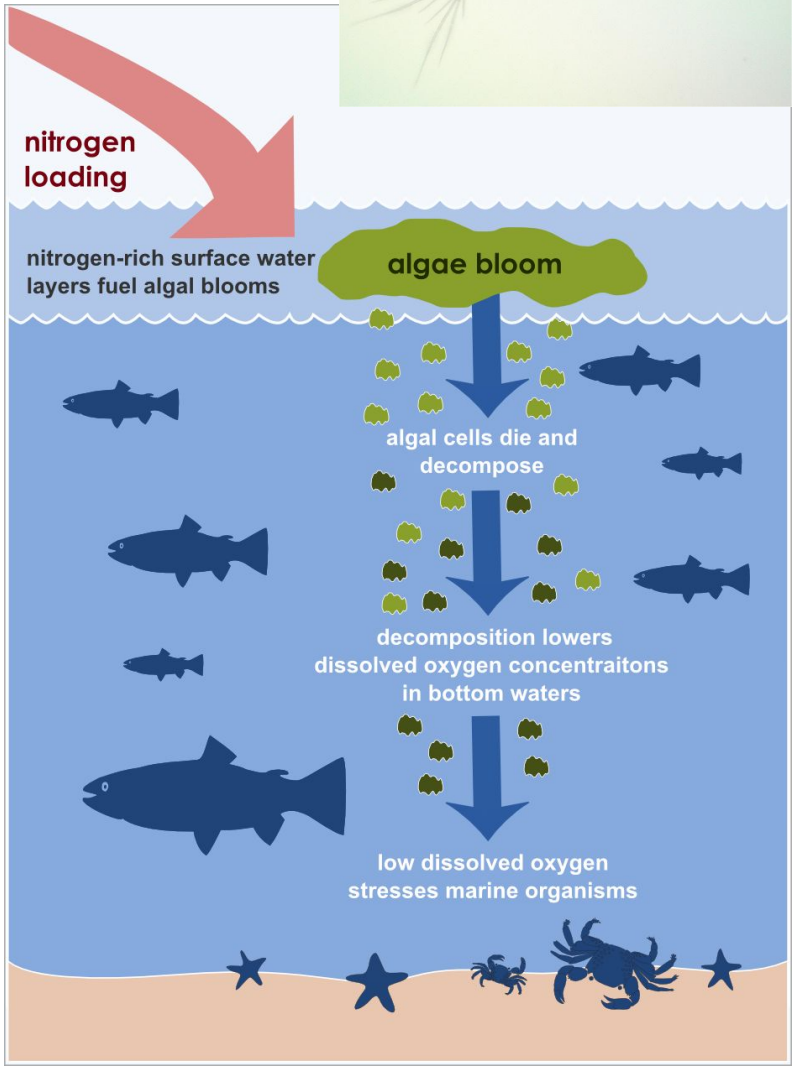
What Happens Next?

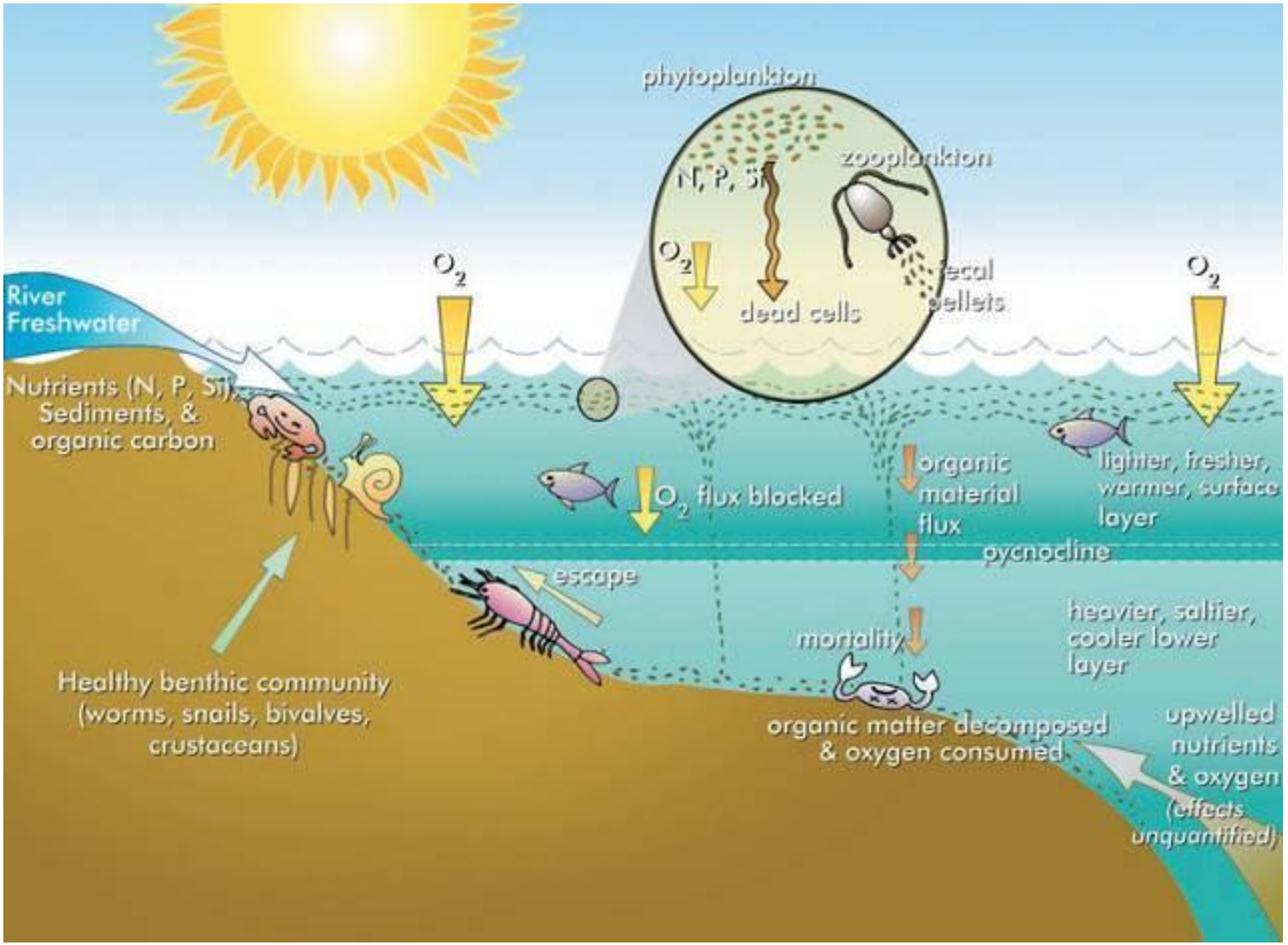
Excess nitrogen and more sunlight in surface waters leads to algae blooms.

The algae bloom provides food for zooplankton such as copepods.

Copepod wastes and dead algae sink to the bottom of the Gulf and decomposition lowers oxygen levels.

Continuing decomposition by bacteria lowers oxygen levels even more.





17. Algae are producers at the base of the food chain. Explain why the algae bloom here is actually BAD for shrimp and other organisms that live in the bottom layer of the gulf.

Eutrophication leads to hypoxia in the benthic waters of the Gulf

- Normal oxygen levels: ~ 4.8 mg/L
- Hypoxia: < 2-3 mg/L
- Anoxia: 0 mg/L

18. Define the terms used in this case study

(in your own words, google if necessary)

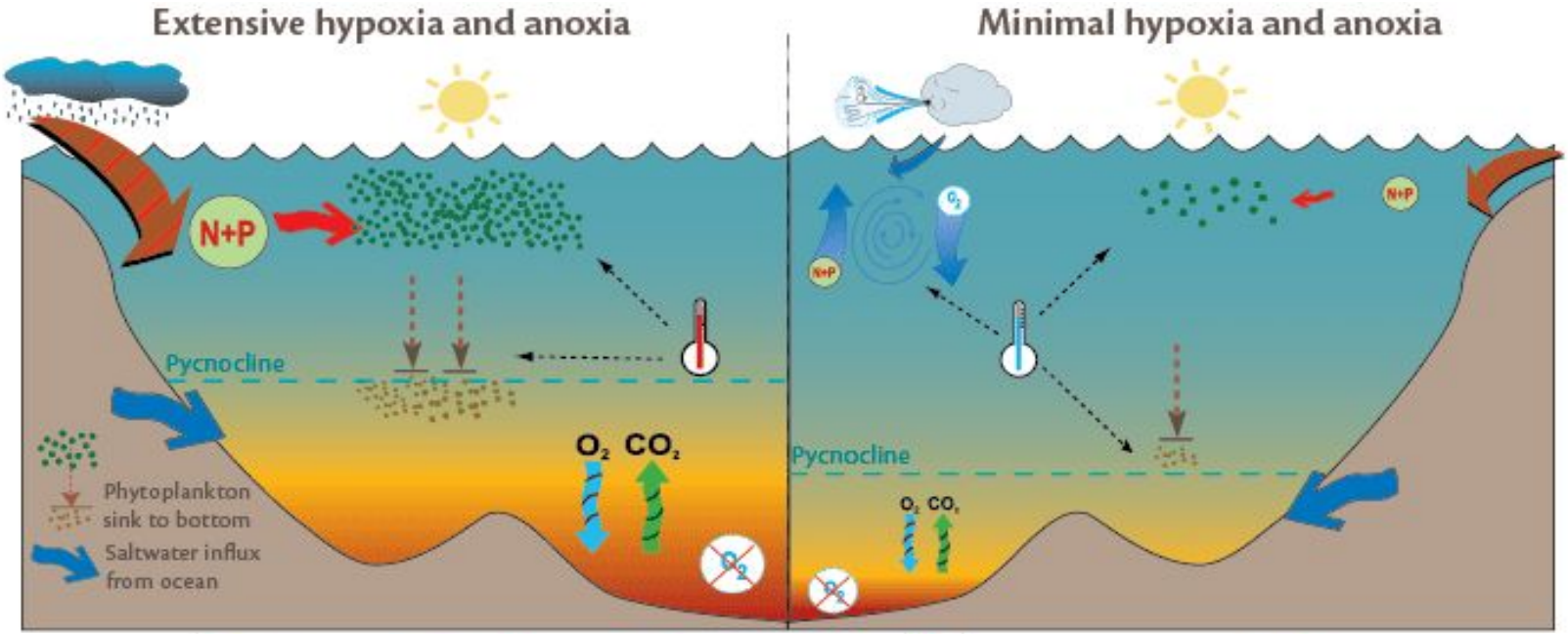
a) Benthic

b) Eutrophication

c) Hypoxia

Pause and check out this gallery on algae blooms:
https://www.flickr.com/photos/40964293@N07/galleries/72157650043401513/

Stratification and Hypoxia



	Loads	Phytoplankton	Decomposition	Temperature	Wind event
Large amount of low dissolved oxygen	Large nitrogen and phosphorus loads	Elevated nutrients cause large phytoplankton blooms	High oxygen consumption by decaying phytoplankton	Warm water a) Stimulates decomposition b) Stratifies water column c) Stimulates phytoplankton	No wind event: water column remains stratified
Little amount of low dissolved oxygen	Small nitrogen and phosphorus loads	Less nutrients lead to small phytoplankton blooms	Low oxygen consumption by decaying phytoplankton	Cool water: a) Slow decomposition b) Mixed water column c) Slow phytoplankton growth	Wind events destratifies water column: a) Bottom water aerated b) Nutrients move to surface

Conceptual diagram detailing the factors that determine the dissolved oxygen content of the tidal waters of Chesapeake Bay

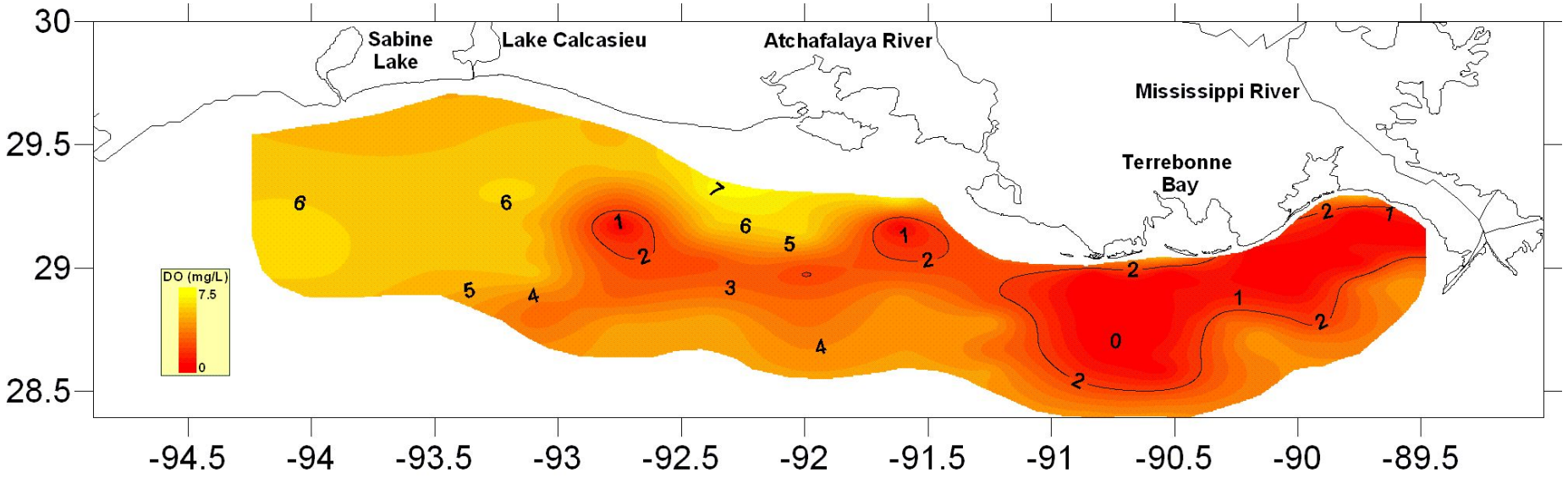
Source: http://www.eco-check.org/forecast/chesapeake/methods/

*

Is there evidence of hypoxia in the Gulf of Mexico?

Bottom-Water Dissolved Oxygen

18-23 July 2009 Data



Data source: N.N. Rabalais, Louisiana Universities Marine Consortium, R.E. Turner, Louisiana State University Funded by: NOAA, Center for Sponsored Coastal Ocean Research

19. In what area(s) are the most severe cases of hypoxia? How do you know?

20. a) Does the evidence you've seen so far mean that climate change and overfishing are NOT to blame for the decline of the shrimp fishery?

A. Yes

B. No

b) What data would you need to gather to provide evidence for the climate change hypothesis?

Responsibility

Upon figuring this all out, Susan was quite upset.

She was amazed that farmers in the Midwest might be to blame for the lack of shrimp in the water off the Louisiana coast.

Read Article: Voluntary Plan to Reduce….

Suppose you are on a government panel studying the Dead Zone problem.

21. a) What recommendations would you make for solving the problem of the Dead Zone?

22. Consider all of the ideas for solving the problem. Why might it be difficult to enact any of these solutions?

- Make a watershed-wide plan.
- Restore wetlands and forests
- Establish a nitrogen credit system with incentives for the agricultural industry to reduce nitrogen-based fertilizers.
- Develop (GM) crops that need less fertilizer

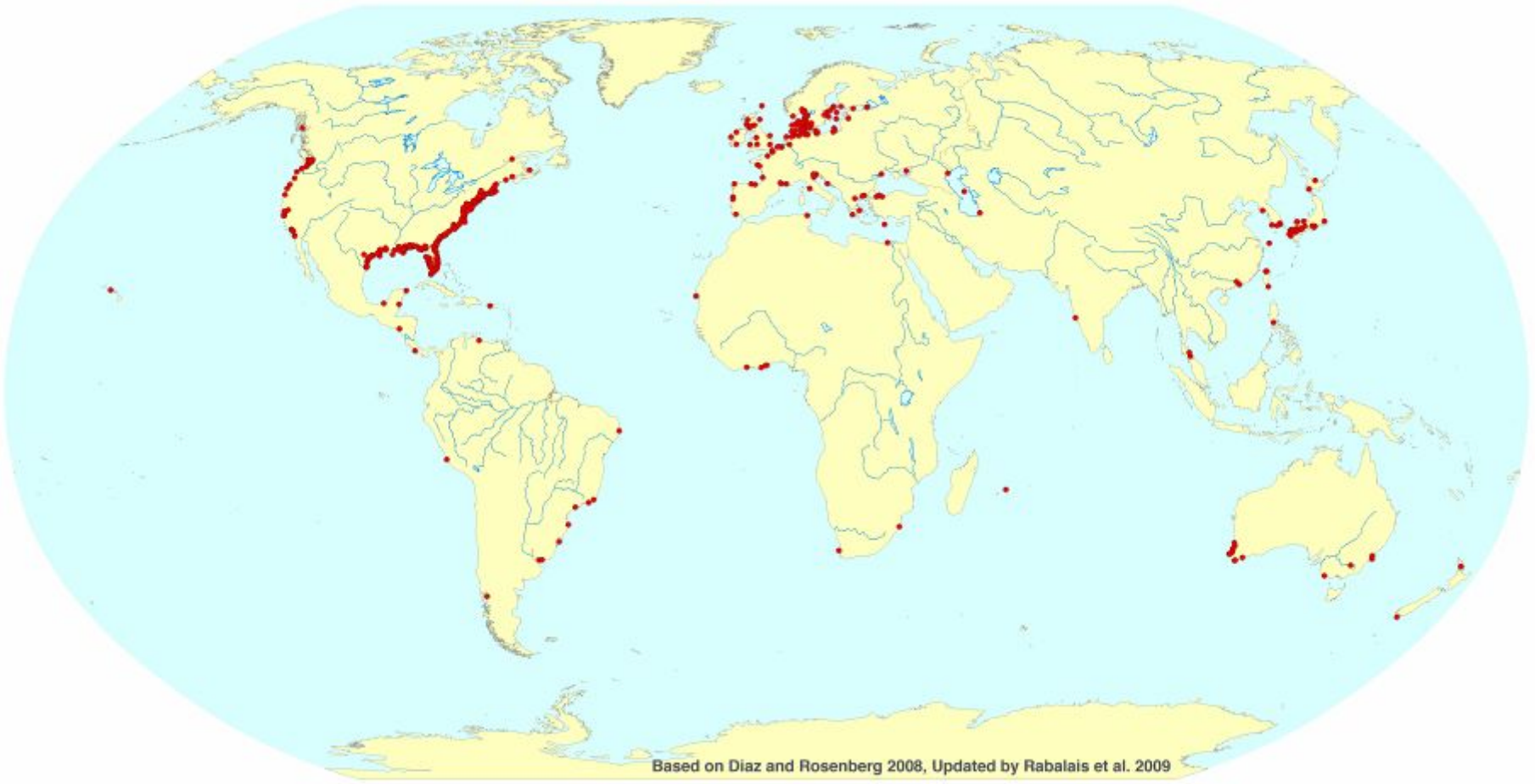
2008 Plan by EPA

*

The four hypotheses for the Dead Zone:

- ~~Hurricane Katrina~~
- Pollution & *Eutrophication*
- Climate Change
- Overfishing
- Oil Spill

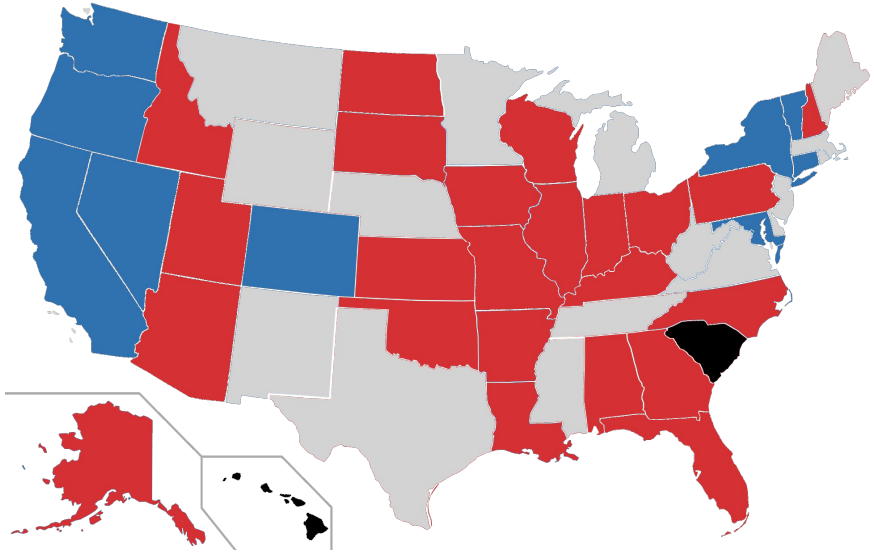
Sites of Eutrophication Worldwide



23. Suggest reasons why eutrophication is not a problem in S. America and Africa.

Consider that a relevant political theme for this time period is state rights and federal rights. The federal government creates policies that affect all states, and some states feel that federal rights should not supersede the rights of states.

22. Which governing body should monitor and protect the waterways: state governments or federal governments. Why?



23. This case study has attempted to simulate how ecologists go about solving a problem. In this case, the problem was the Dead Zone in the Gulf of Mexico. Now is the time to summarize what you have learned.

Create a descriptive essay OR a concept map OR and infographic that:

1) Explains the problem using relevant/appropriate vocabulary

2) Discusses how ecologists determined the actual cause(s) of the problem (include evidence)

3) Proposes steps to solve the problem

WHAT HAPPENED

HOW DO WE KNOW

WHAT DO WE DO ABOUT IT?

Slide Credits

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Description: Photo of Gulf of Mexico with ship.
Author: Chad Teer
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Description: A hatchery on a shrimp farm in South Korea.
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Description: Photo of old fishing boat.
Author: Gabriel Nardelli Araujo
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Slide 10 and Slide 11
Description: Brown Shrimp catch graph.
Source: Left panel of Figure 3.6 in: Council for Agricultural Science and Technology (CAST). 1999. *Gulf of Mexico Hypoxia: Land and Sea Interactions*. Task Force Report 134. CAST, Ames, Iowa.
Link: http://www.public.iastate.edu/~downing/tier%202/jadpdfs/1999%20Gulf%20of%20Mexico.pdf
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Slide 13 , Slide 14 , and Slide 15
Description: Mississippi River sediment plume in Gulf of Mexico.
Author: Liam Gumley, Space Science and Engineering Center, University of Wisconsin—Madison and the MODIS science team.
Source: NASA Earth Observatory website, http://earthobservatory.nasa.gov/IOTD/view.php?id=1257
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Slide 17 , Slide 18 , and Slide 26
Description: Interior watersheds of the Mississippi River Basin.
Source: USGS Fact Sheet 016-00—Restoring Life to the Dead Zone: Addressing Gulf Hypoxia, a National Problem
Link: http://www.nwrc.usgs.gov/factshts/016-00/016-00.htm
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Slide19 and Slide 21 —Left
Description: Average annual nitrate concentrations in selected rivers during 1905–07 and 1980–96.
Source: Figure 3 in "Nitrogen in the Mississippi Basin-Estimating Sources and Predicting Flux to the Gulf of Mexico" by Donald A. Goolsby and William A. Battaglin. USGS Fact Sheet 135-00, December 2000.
Link: http://ks.water.usgs.gov/pubs/fact-sheets/fs.135-00.pdf
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Slide 20 and Slide 21 —Right
Description: Annual nitrate flux and mean annual streamflow from the Mississippi River Basin to the Gulf of Mexico.
Source: Figure 4 in “Nitrogen in the Mississippi Basin-Estimating Sources and Predicting Flux to the Gulf of Mexico” by Donald A. Goolsby and William A. Battaglin. USGS Fact Sheet 135-00, December 2000.
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Slide 22 and Slide 24
Description: Illustration of the nitrogen cycle.
Author: Michael Pidwirny
Source: Pidwirny, M. (2006). Figure 9s-1, “The Nitrogen Cycle,” *Fundamentals of Physical Geography, 2nd Edition*.
Link: http://www.physicalgeography.net/fundamentals/9s.html
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Slide 23
Description: Annual nitrogen inputs to the Mississippi Basin from major sources.
Source: Figure 5 in “Nitrogen in the Mississippi Basin-Estimating Sources and Predicting Flux to the Gulf of Mexico” by Donald A. Goolsby and William A. Battaglin. USGS Fact Sheet 135-00, December 2000.
Link: http://ks.water.usgs.gov/pubs/fact-sheets/fs.135-00.pdf
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Slide 29
Description: How marine hypoxia & eutrophication happens.
Source: Hypoxia 101, What is hypoxia and what causes it? EPA, OW, Office of Wetlands, Oceans, and Watersheds.
Link: http://www.epa.gov/msbasin/hypoxia101.htm
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Slide 31
Description: Environmental factors that affect dissolved oxygen.
Source: EcoCheck, a partnership program between NOAA Chesapeake Bay Program Office and the Integration and Application Network (IAN) at the University of Maryland Center for Environmental Sciences (UMCES).
Link: http://www.eco-check.org/forecast/chesapeake/2009/methods/#_DO_-_anoxia
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Slide 32
Description: Map of hypoxic zone in Gulf of Mexico.
Source: Gulf of Mexico Dead Zone Surprisingly Small in Area, but Severe. July 24, 2009. N.N. Rabalais, Louisiana Universities Marine Consortium, R.E. Turner, Louisiana State University Funded by: NOAA, Center for Sponsored Coastal Ocean Research.
Link: http://www.gulfhypoxia.net/Research/Shelfwide%20Cruises/2009/Files/Press_Release.pdf
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Slide 33
Description: Graph of extent of hypoxia in Gulf of Mexico.
Source: Gulf of Mexico Dead Zone Surprisingly Small in Area, but Severe. July 24, 2009. N.N. Rabalais, Louisiana Universities Marine Consortium, R.E. Turner, Louisiana State University Funded by: NOAA, Center for Sponsored Coastal Ocean Research.
Link: http://www.gulfhypoxia.net/Research/Shelfwide%20Cruises/2009/Files/Press_Release.pdf
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Slide 35
Description: Photo of cows.
Author: Andy Wright from Sheffield, UK
Source: Wikimedia Commons, although originally posted to Flickr.
Link: http://commons.wikimedia.org/wiki/File:Cows.jpg
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Slide 39
Description: Global map showing sites of marine hypoxia.
Source: Louisiana Universities Marine Consortium
Link: http://www.gulfhypoxia.net/Overview/
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