What is a “Dead Zone”? and, is it really “dead”?

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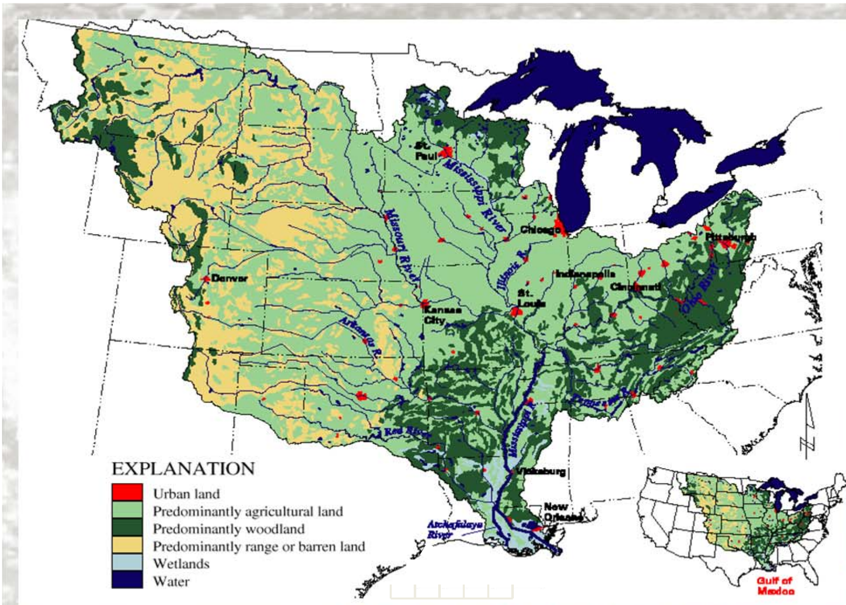
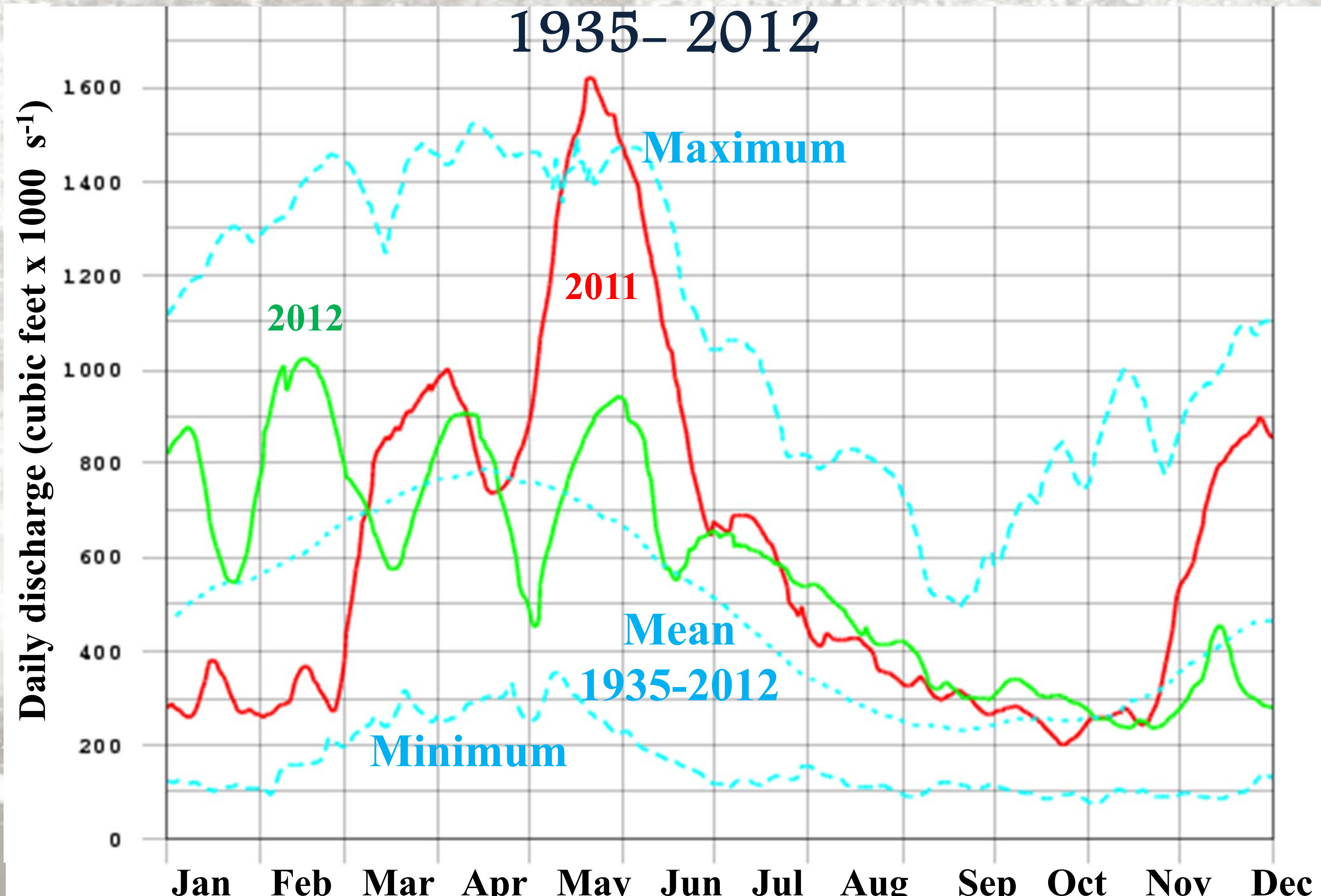
http://www.gulfhypoxia.net
http://cwc.lumcon.edu

Linked Land, River, Ocean Ecosystem

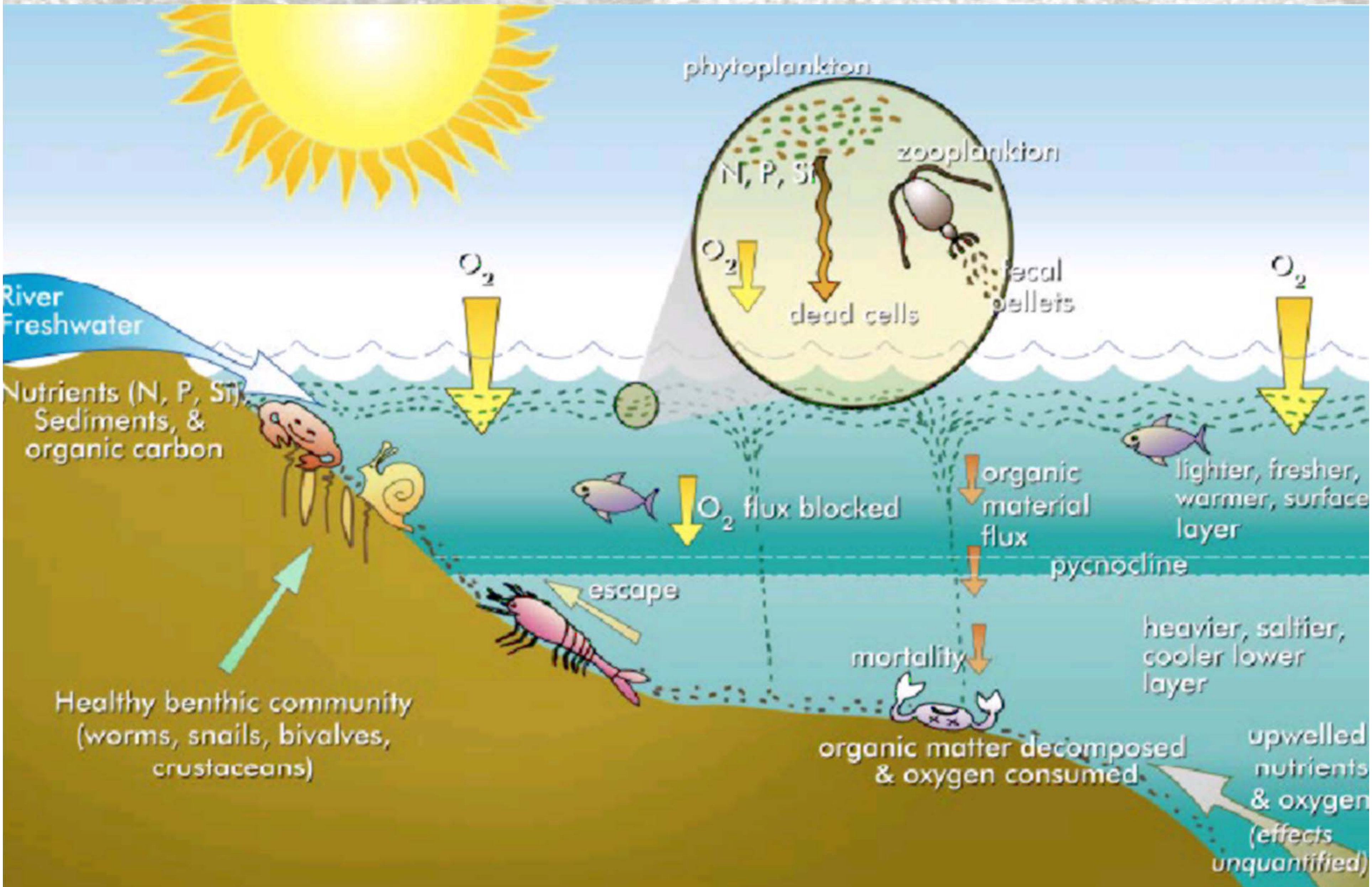


Mississippi River Discharge, Tarbert Landing, MS

1935- 2012



Nutrients, Increased Growth, Low Oxygen

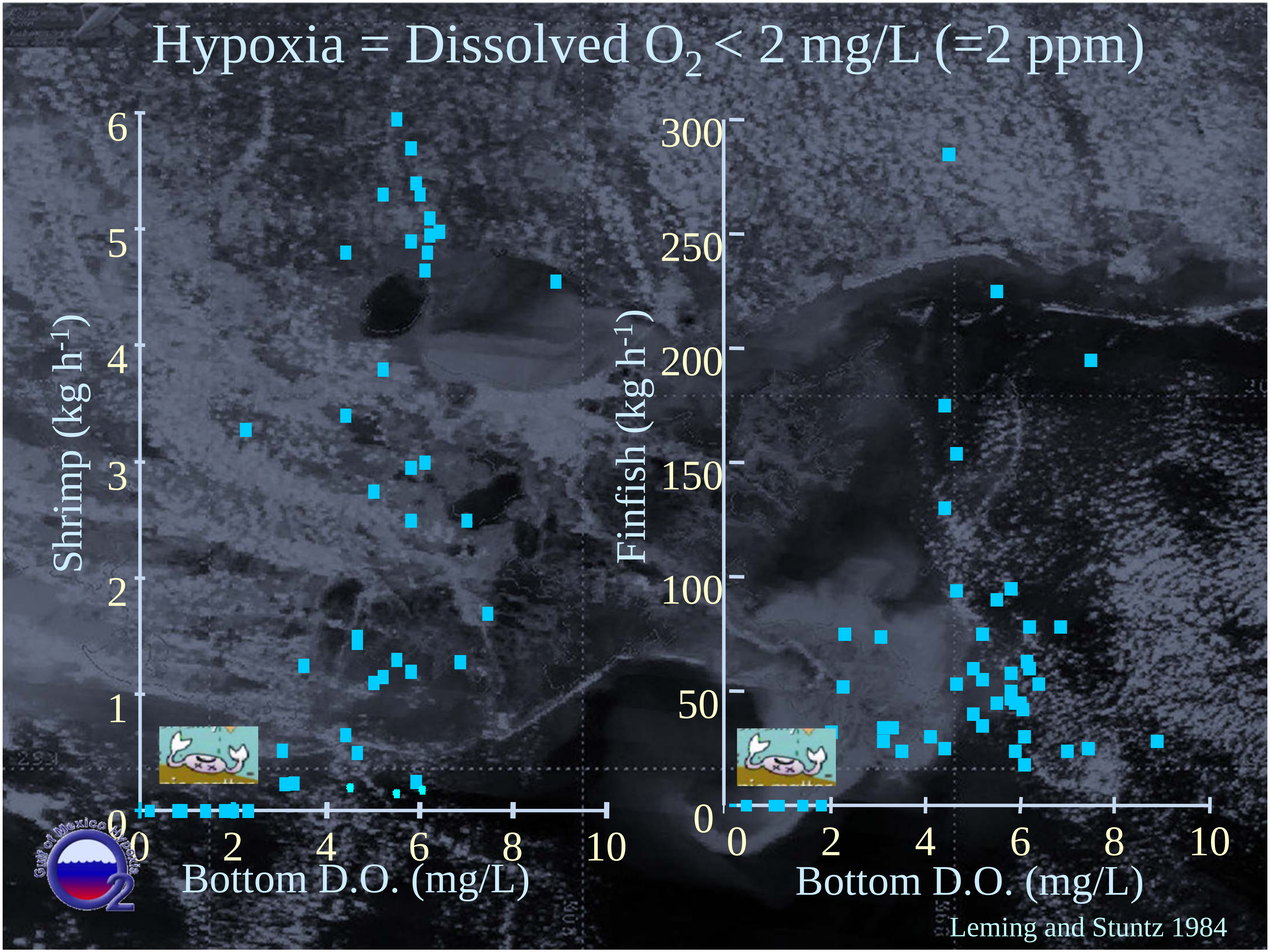


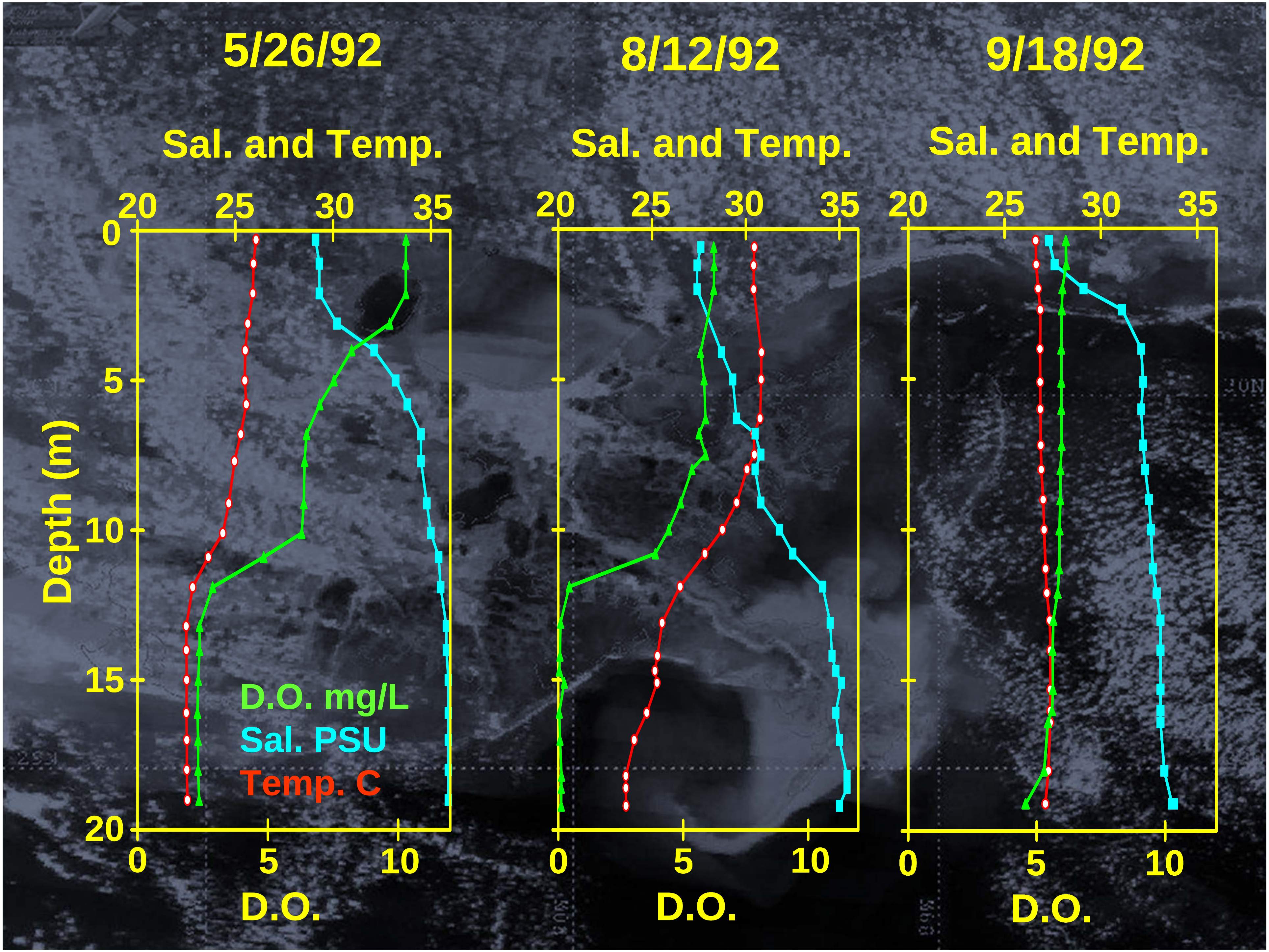
CENR 2001

Effects are more far reaching than suspended sediment plume, esp. N & somewhat P

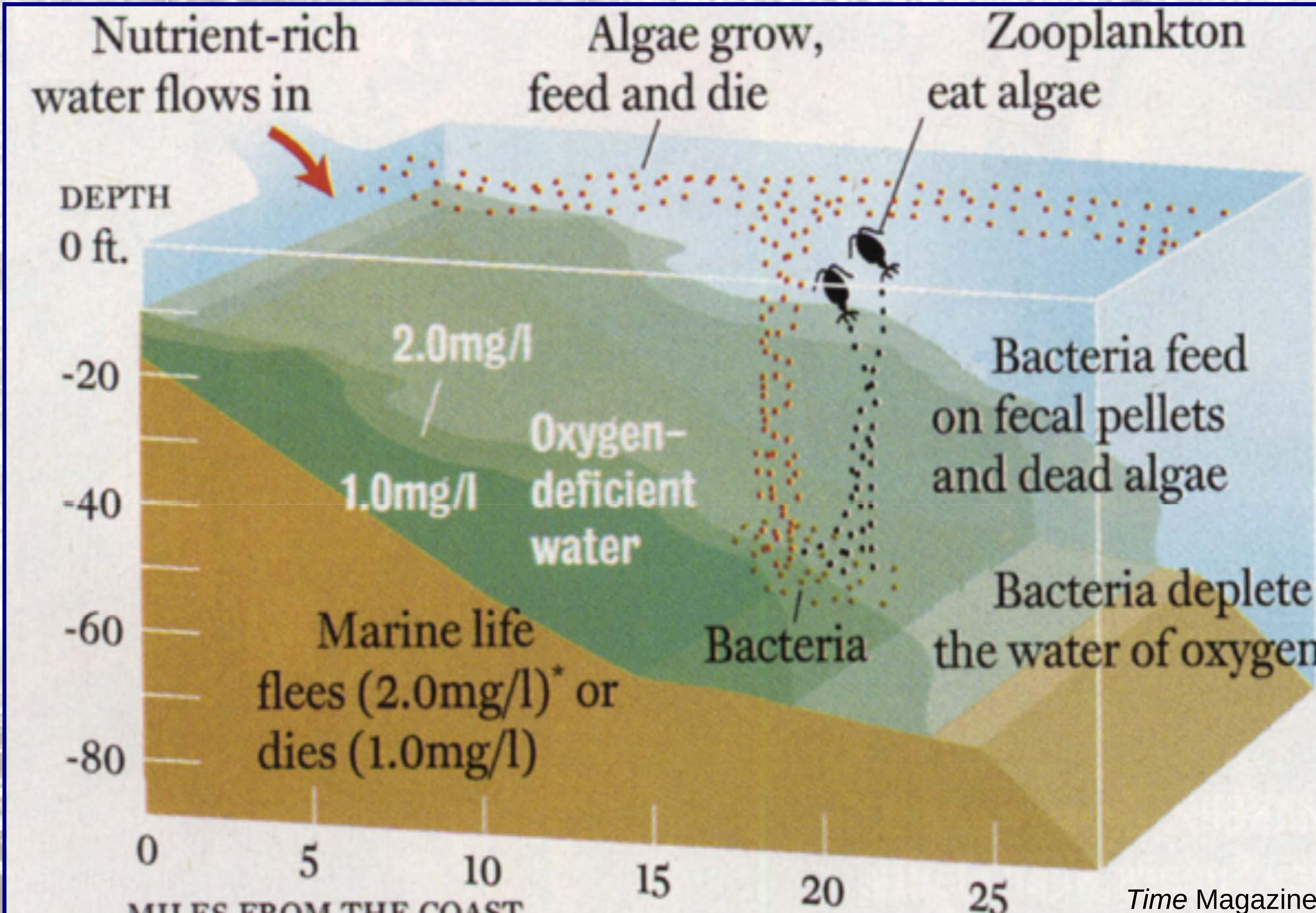
dominant wind direction

Source: N. Rabalais, LUMCON


Hypoxia = Dissolved O2 < 2 mg/L (=2 ppm)
Shrimp (kg h-1)
0
1
2
3
4
5
6
0
2
4
6
8
10
Bottom D.O. (mg/L)
Finfish (kg h-1)
0
50
100
150
200
250
300
0
2
4
6
8
10
Bottom D.O. (mg/L)
Leming and Stuntz 1984

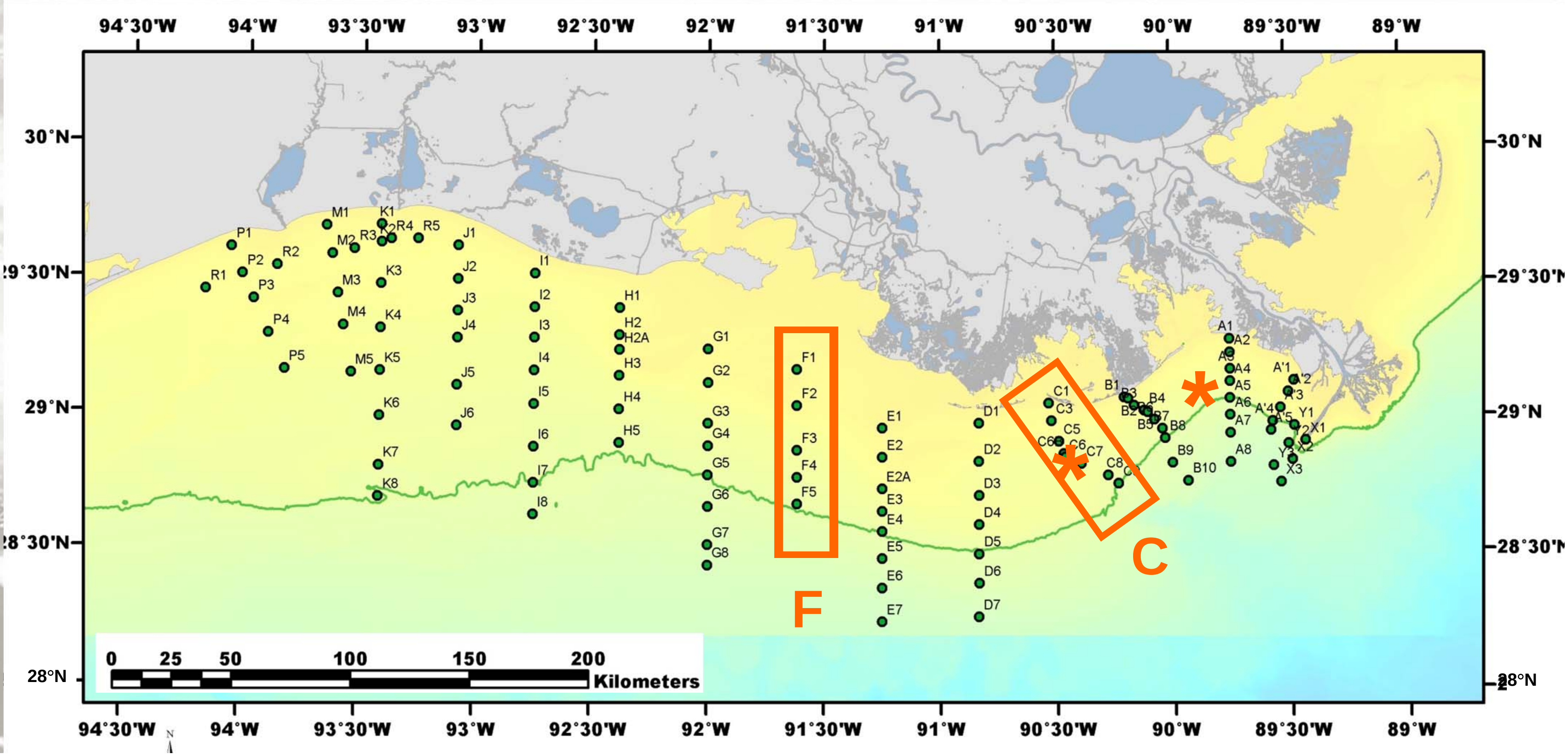

5/26/92
8/12/92
9/18/92
Sal. and Temp.
Sal. and Temp.
Sal. and Temp.
20
25
30
35
Depth (m)
0
5
10
15
20
D.O. mg/L
Sal. PSU
Temp. C
0
5
10
D.O.
D.O.
D.O.

Nutrients, Increased Growth, Low Oxygen

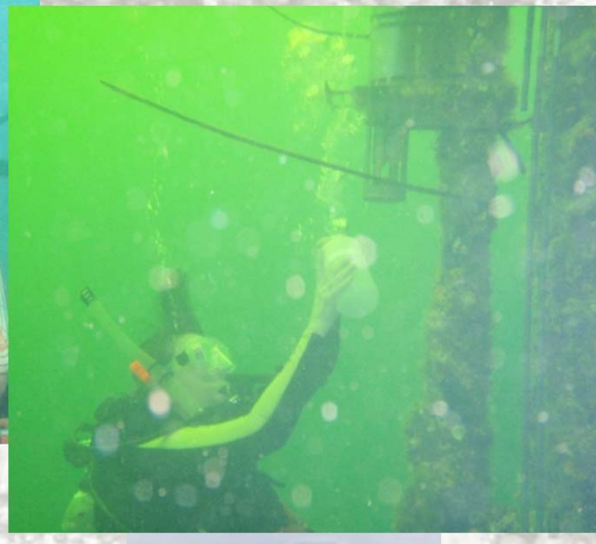


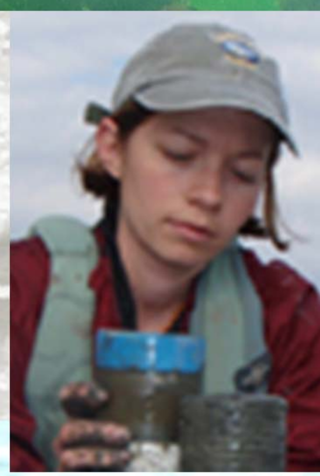
Time Magazine

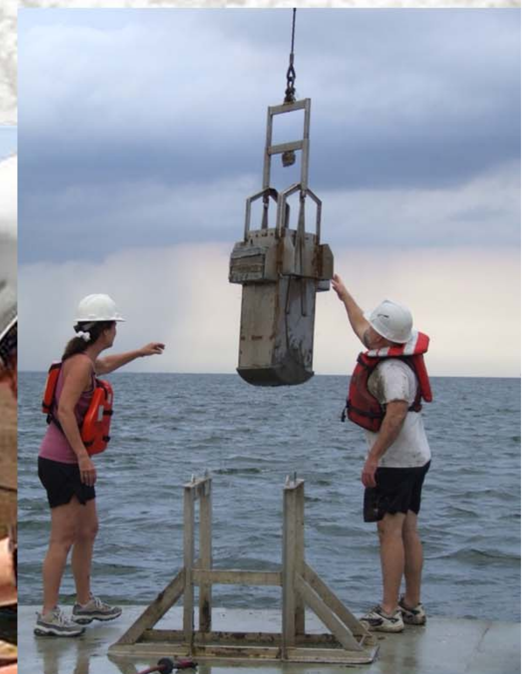
•Mid-summer shelfwide cruise
•Monthly/bimonthly samples along transects C & F
•Deployed oxygen meters

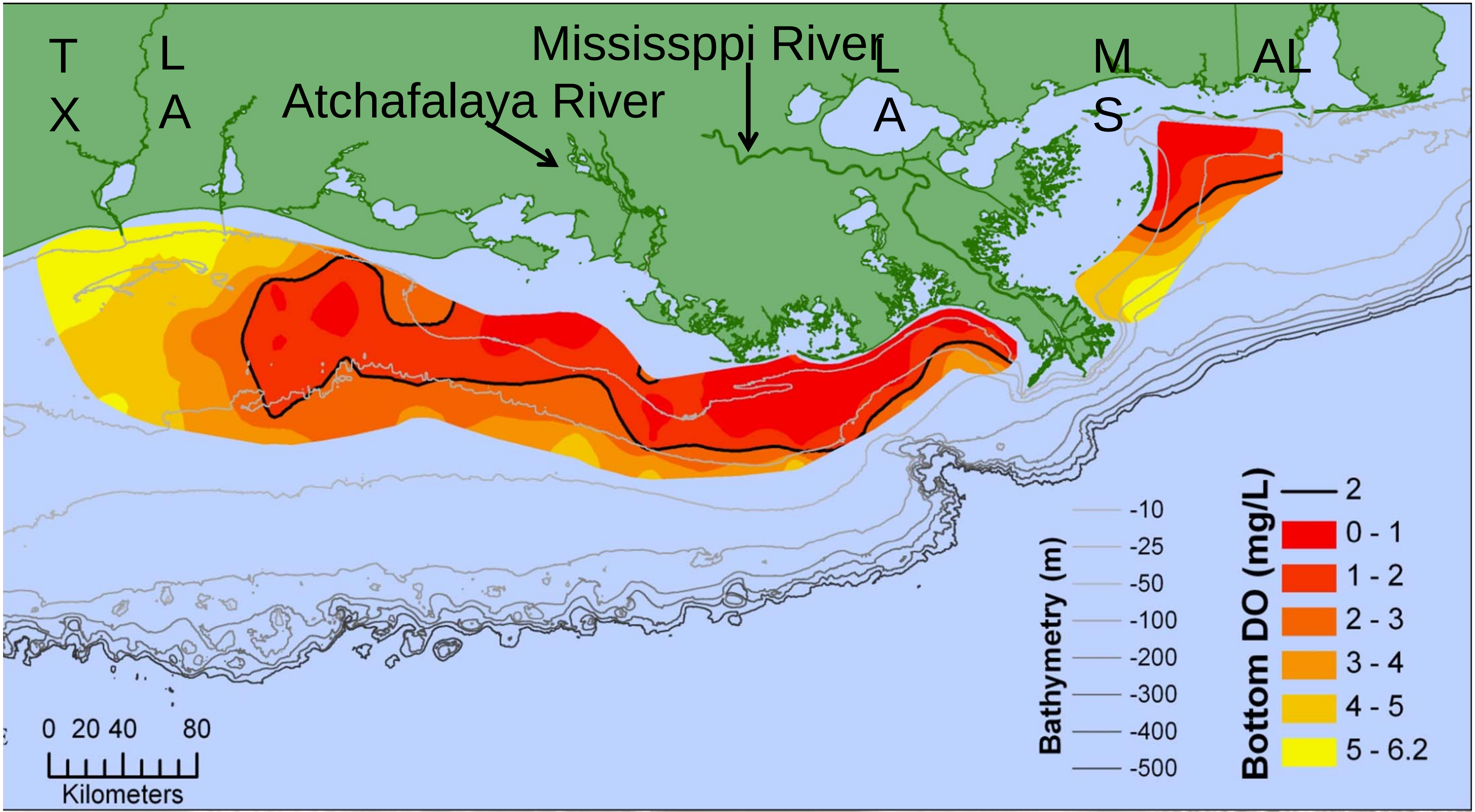


Extensive Field Measurements & Experiments

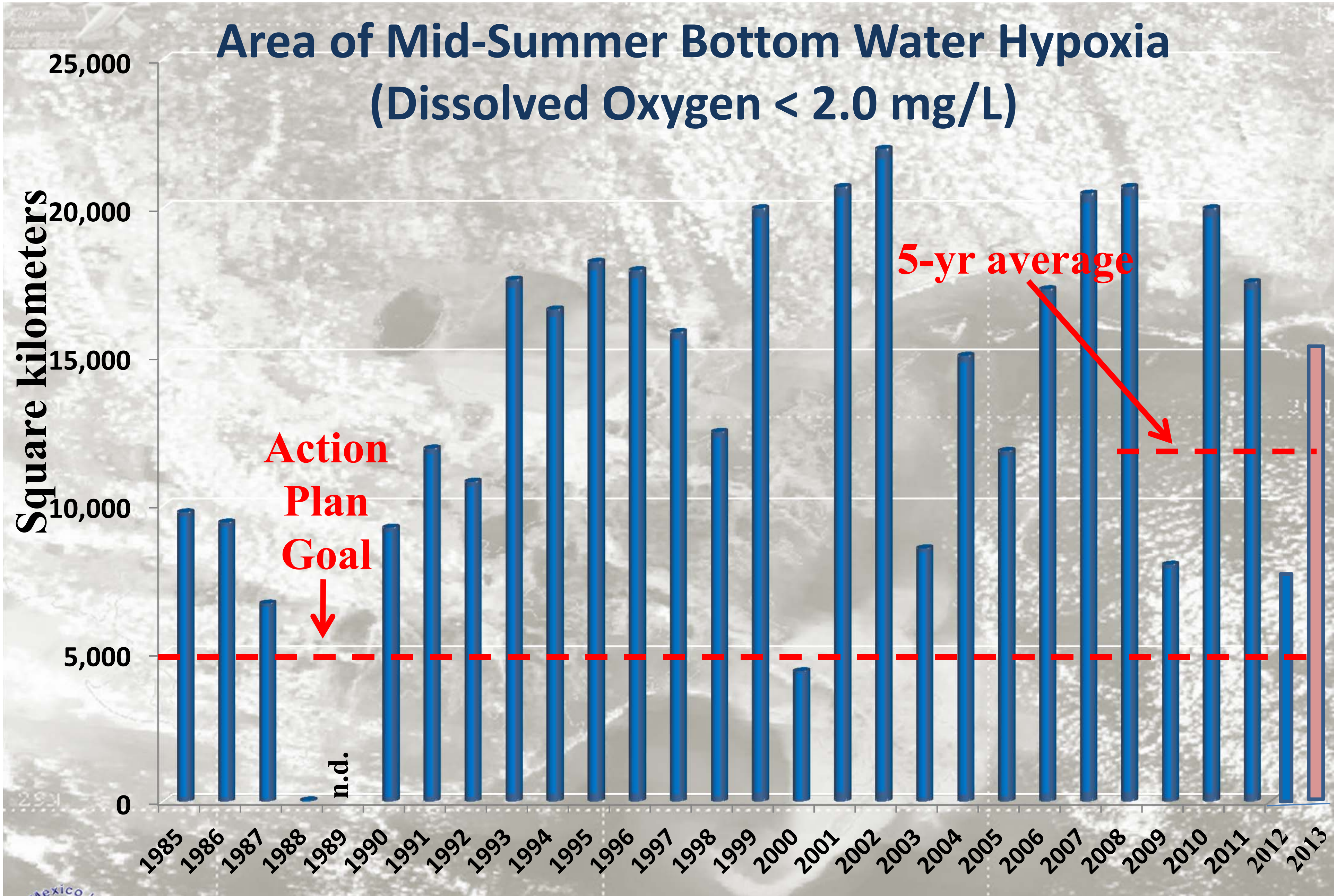





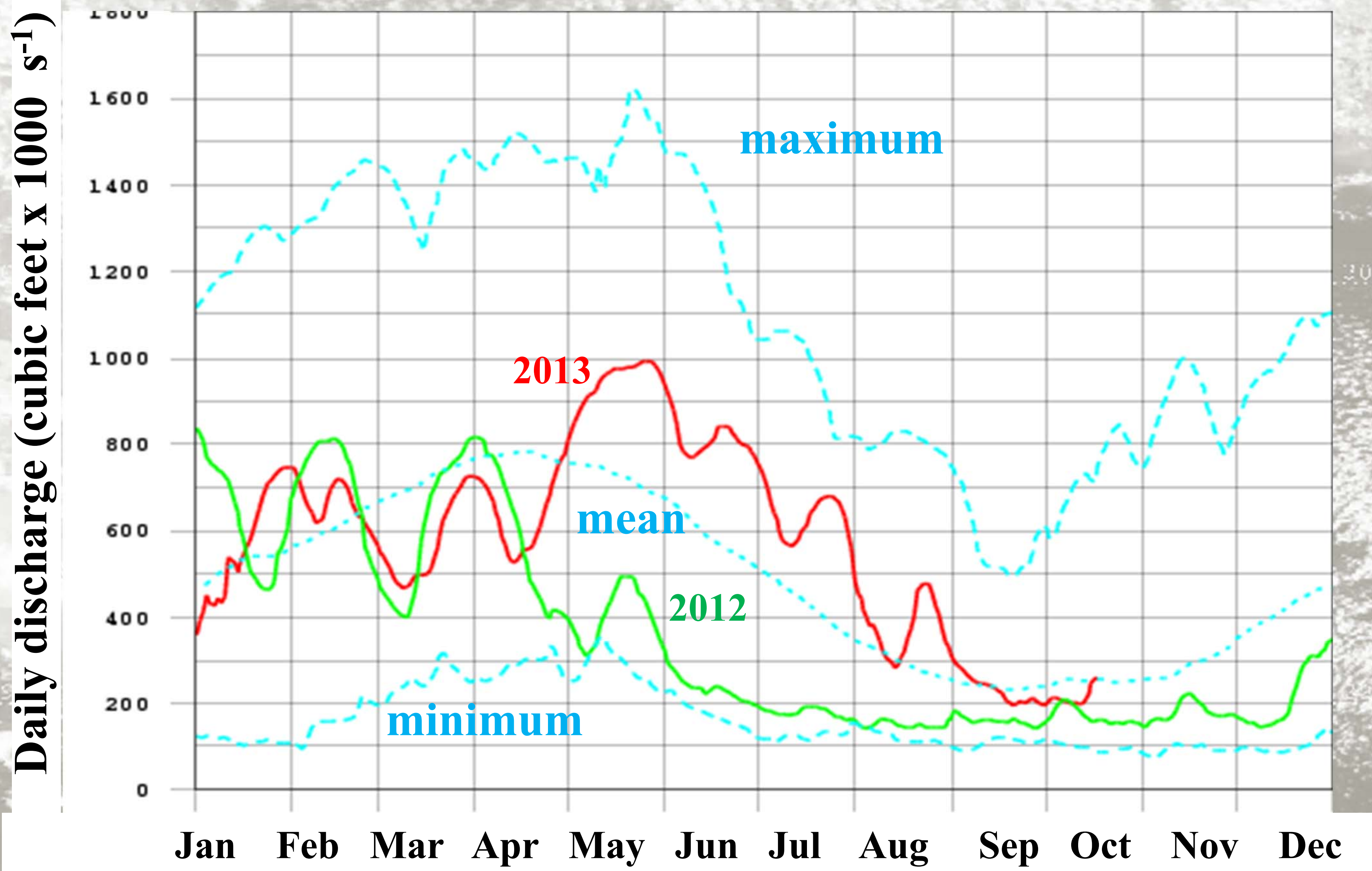



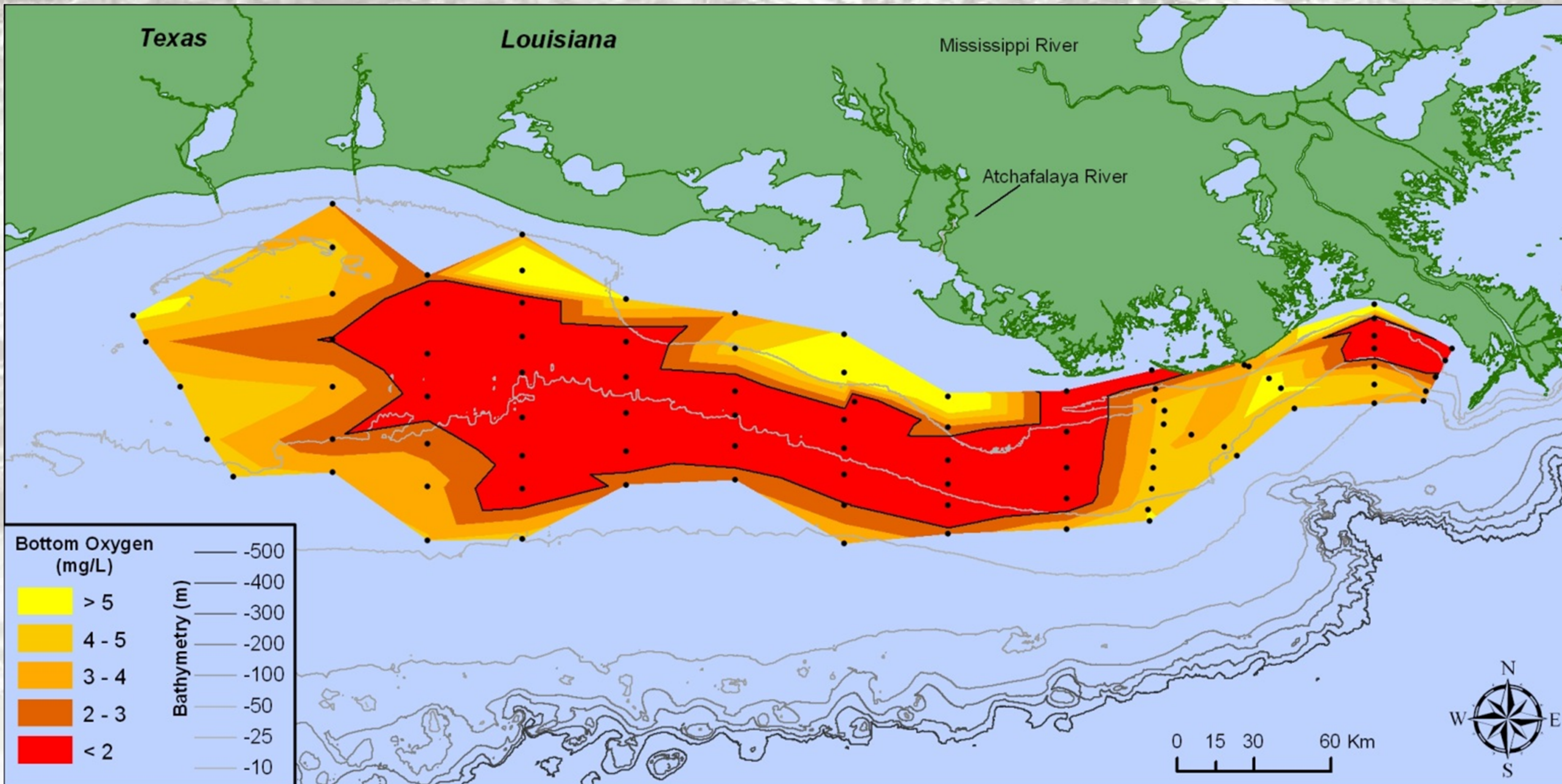
Distribution of bottom-water dissolved oxygen July 18-21 (east of the Mississippi River delta) and July 24-30 (west of the Mississippi River delta), 2011. Black line indicates dissolved oxygen level of 2 mg/L. Data source: Nancy N. Rabalais, LUMCON, and R. Eugene Turner, LSU. http://www.gulfhypoxia.net



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

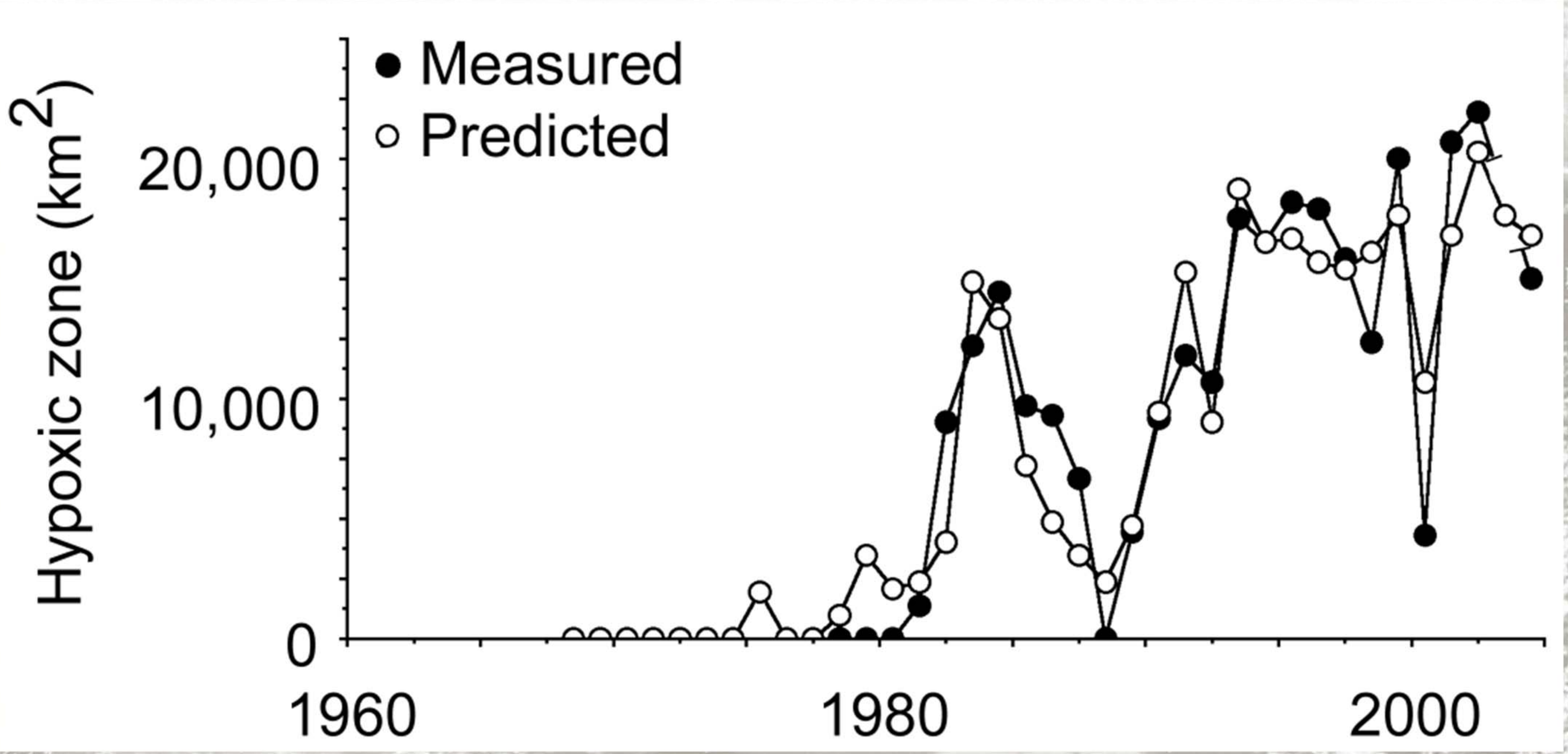
Mississippi River Discharge, Tarbert Landing, MS 1935- 2013





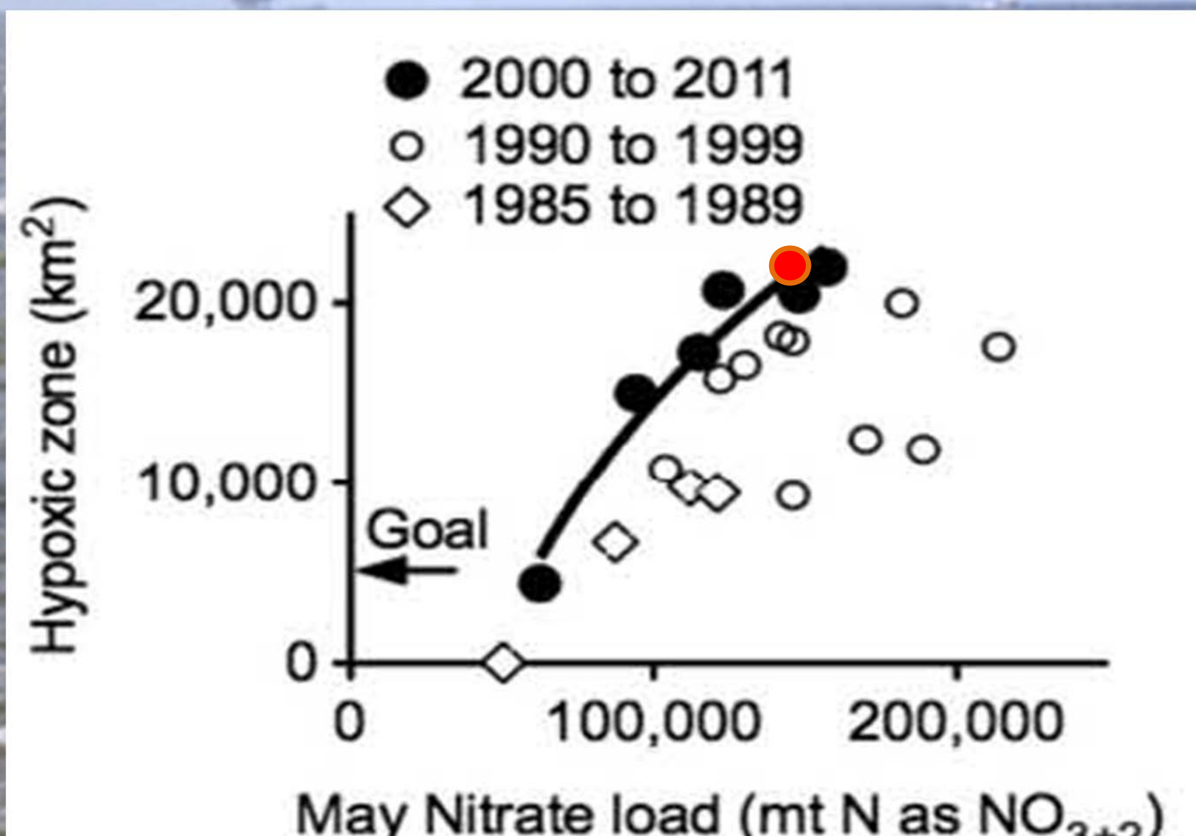
Distribution of bottom-water dissolved oxygen July 24-30, 2014. Black line indicates dissolved oxygen level of 2 mg/L.
Data source: Nancy N. Rabalais, LUMCON, and R. Eugene Turner, LSU.
http://www.gulfhypoxia.net

Predicting Hypoxia in summer (nitrate flux in the spring, Apr-Jun, year)



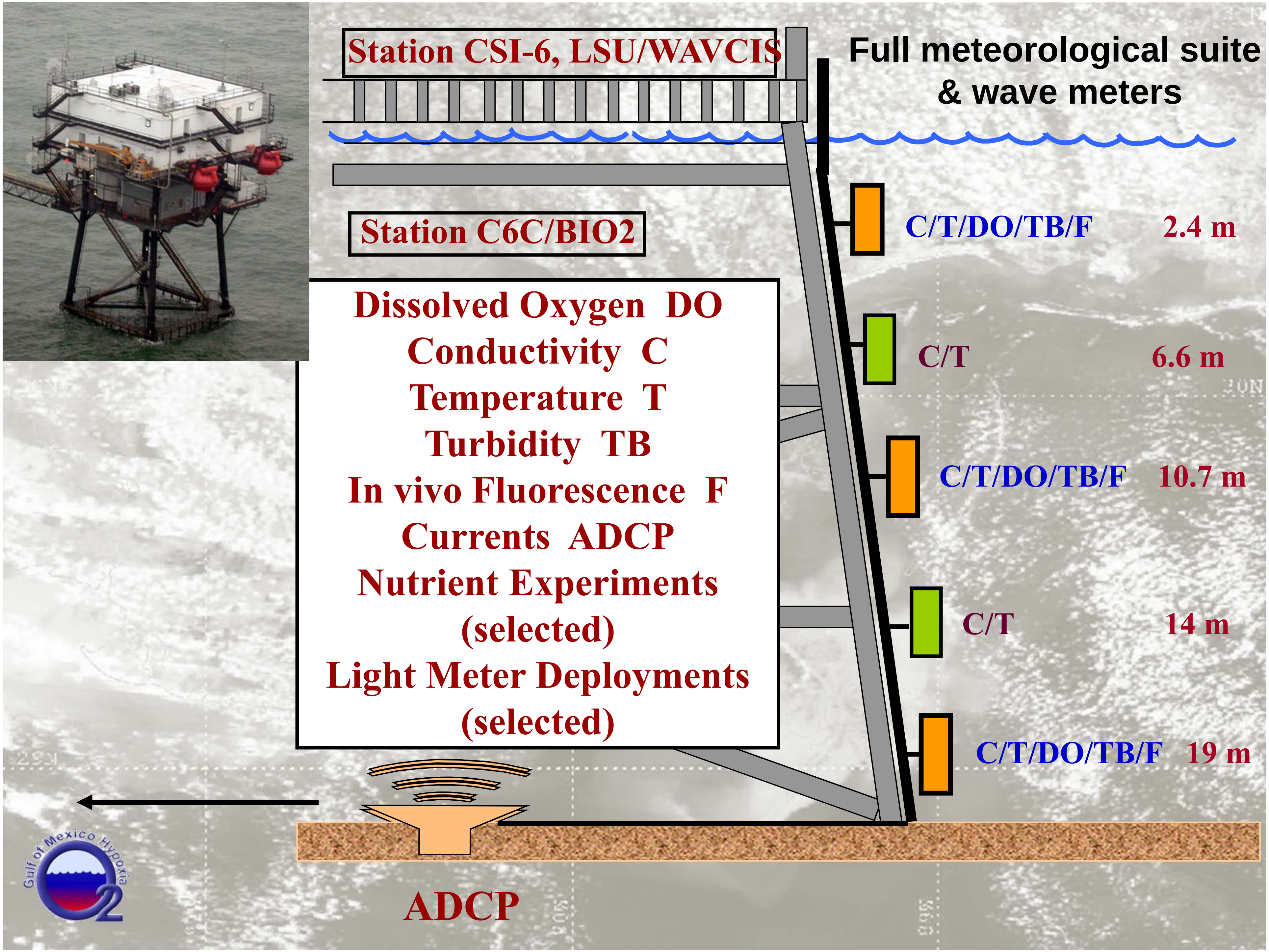
Similar analyses with PO4, TP, TN, Si, various Si:N:P ratios indicate that N, in the form of NO3+NO2, is the major driving factor influencing the size of hypoxia on the Louisiana shelf.

More Nutrients >>>
More Phytoplankton >>>
More Carbon Reaches the Bottom >>>
More Oxygen Consumed >>>
More Hypoxia
Verified by Paleoindicators

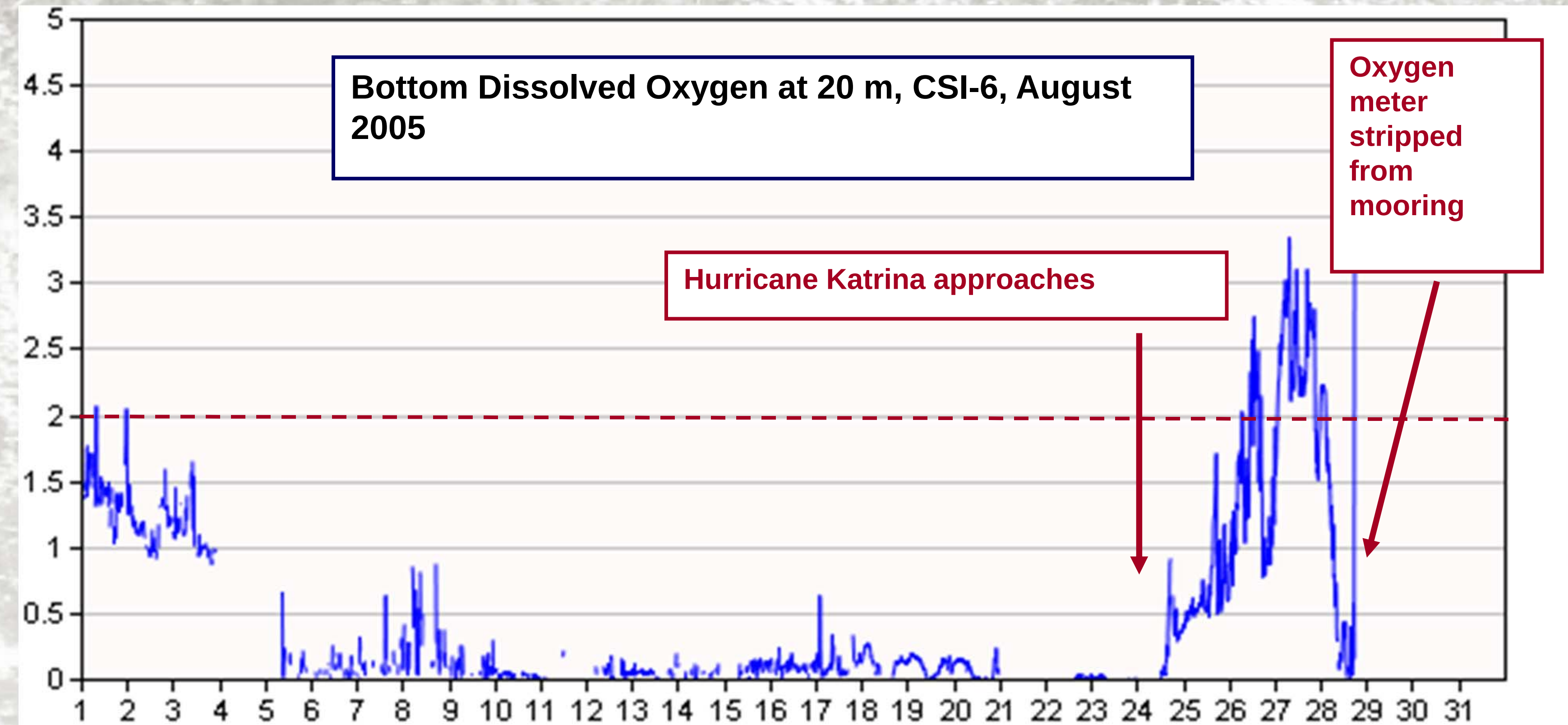


Turner et al. 2012

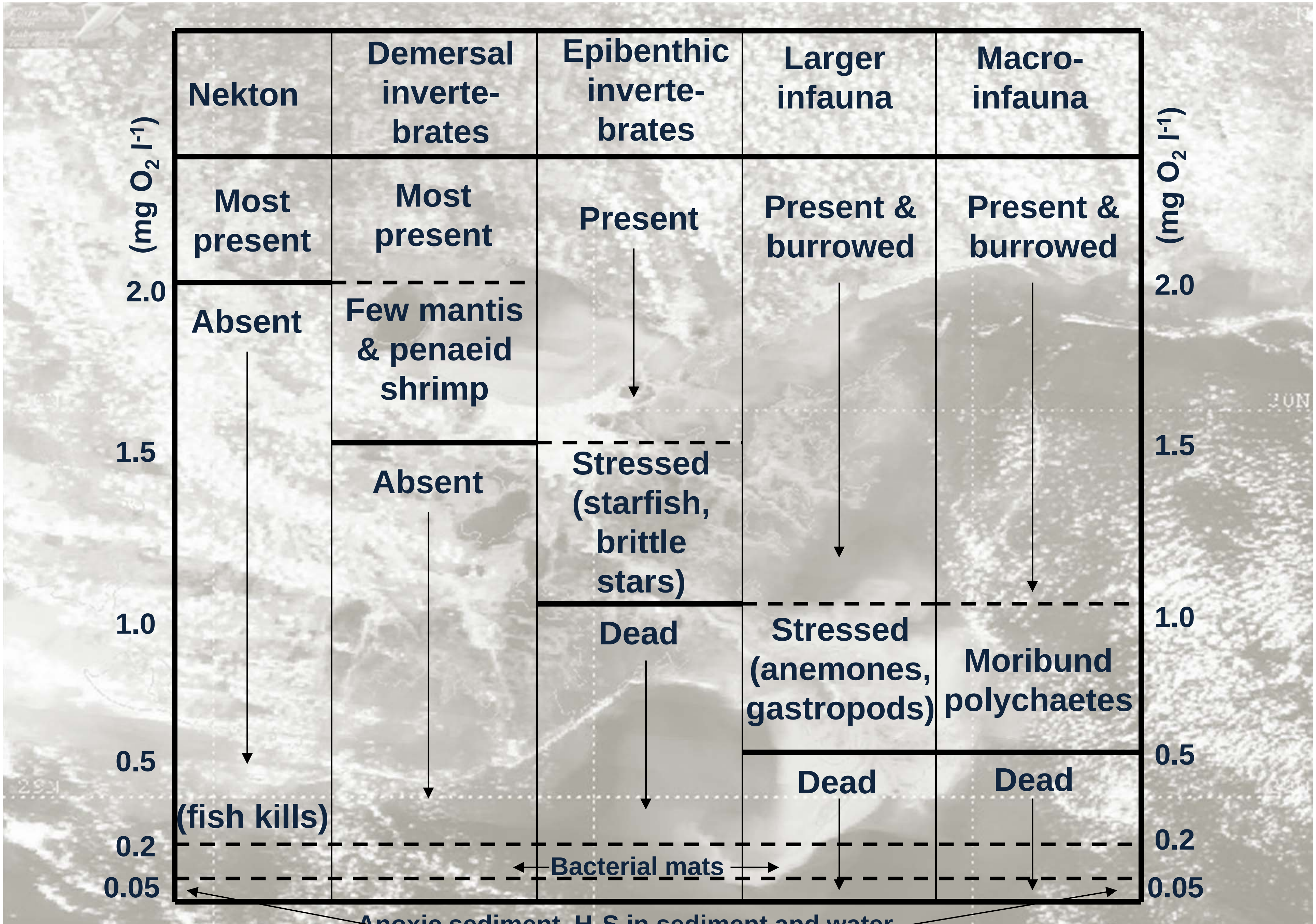
Photo: N. Rabalais, LUMCON



Station CSI-6, LSU/WAVCIS
Full meteorological suite & wave meters
Station C6C/BIO2
Dissolved Oxygen DO
Conductivity C
Temperature T
Turbidity TB
In vivo Fluorescence F
Currents ADCP
Nutrient Experiments (selected)
Light Meter Deployments (selected)
C/T/DO/TB/F 2.4 m
C/T 6.6 m
C/T/DO/TB/F 10.7 m
C/T 14 m
C/T/DO/TB/F 19 m
ADCP
Gulf of Mexico Hypoxia


Bottom Dissolved Oxygen at 20 m, CSI-6, August 2005
Hurricane Katrina approaches
Oxygen meter stripped from mooring
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


00:45 29-AUG-2005 GMT ©Copyright WSI Corporation http://www.wsi.com
LIGHT HEAVY
RAIN
LIGHT HEAVY
MIXED
LIGHT HEAVY
SNOW

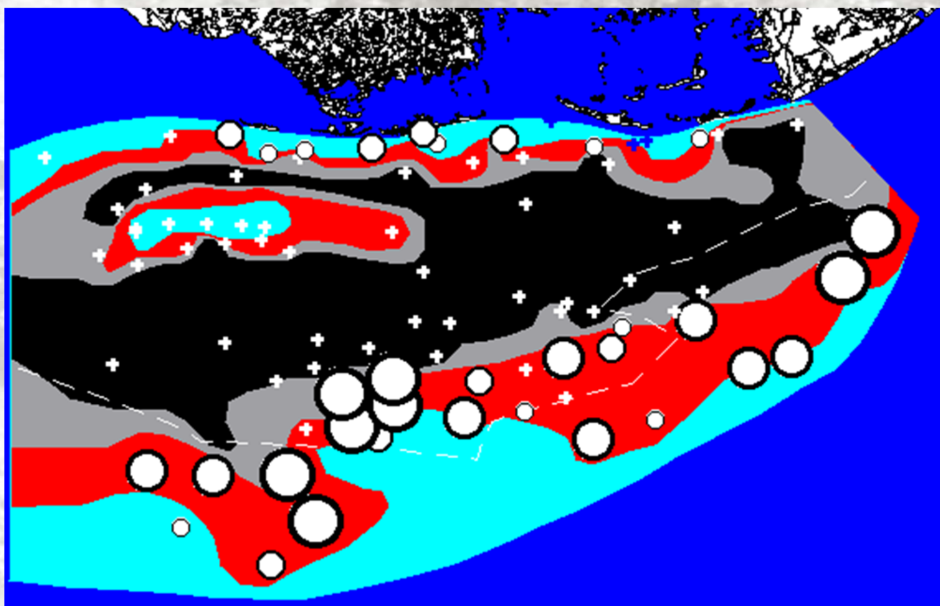


Rabalais et al. 2001

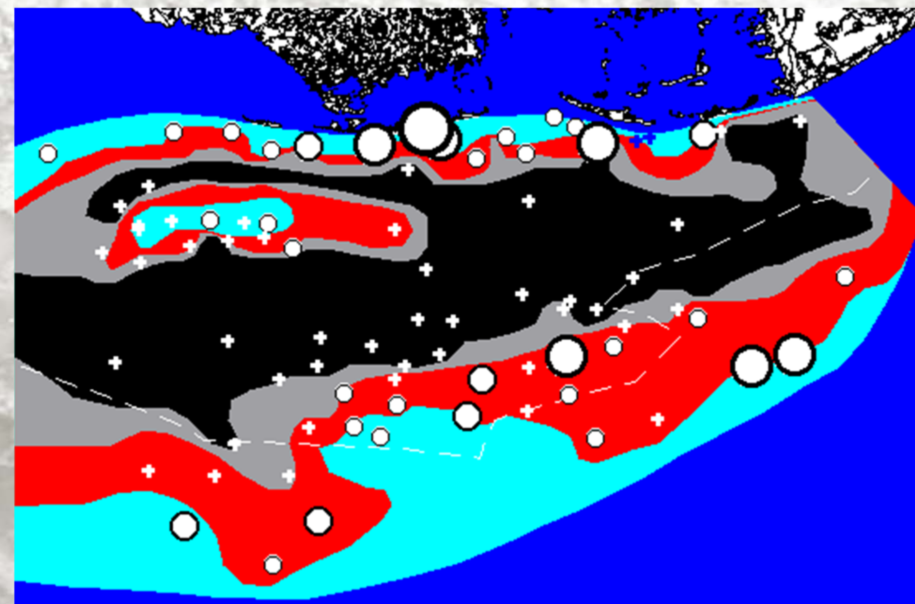
(Photo: Kevin Craig)

NGOMEX02 Cruise

Atlantic croaker



Brown shrimp



Dissolved oxygen (mg/l)

- 0-1
- 1-2
- 2-4
- >4

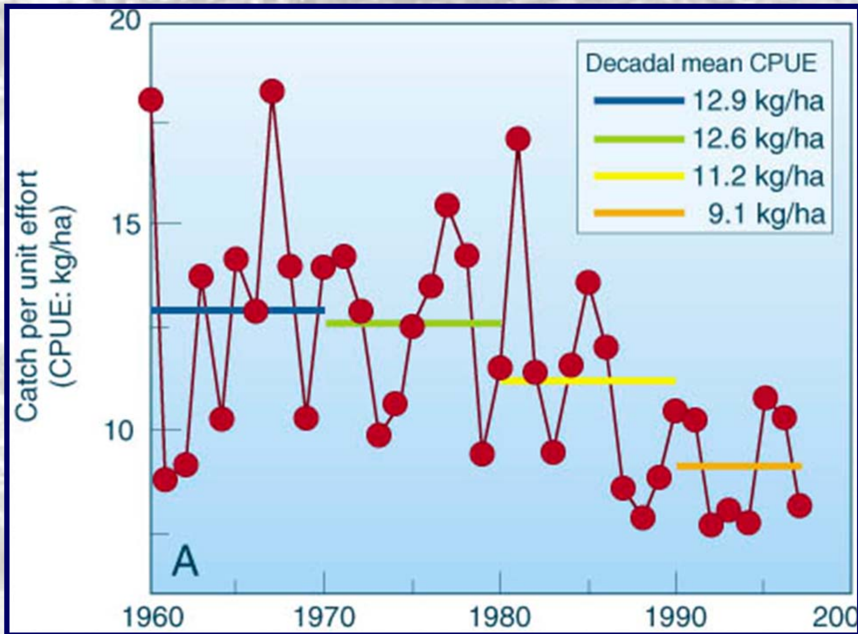
Catch percentiles

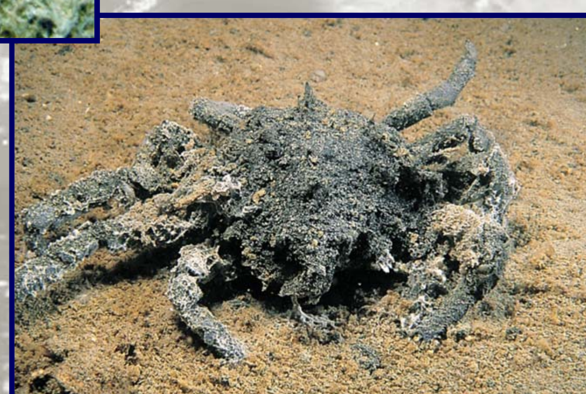
- + 0
- 1-25%
- 25-50%
- 50-75%
- 75-100%

(Kevin Craig, unpubl. data)

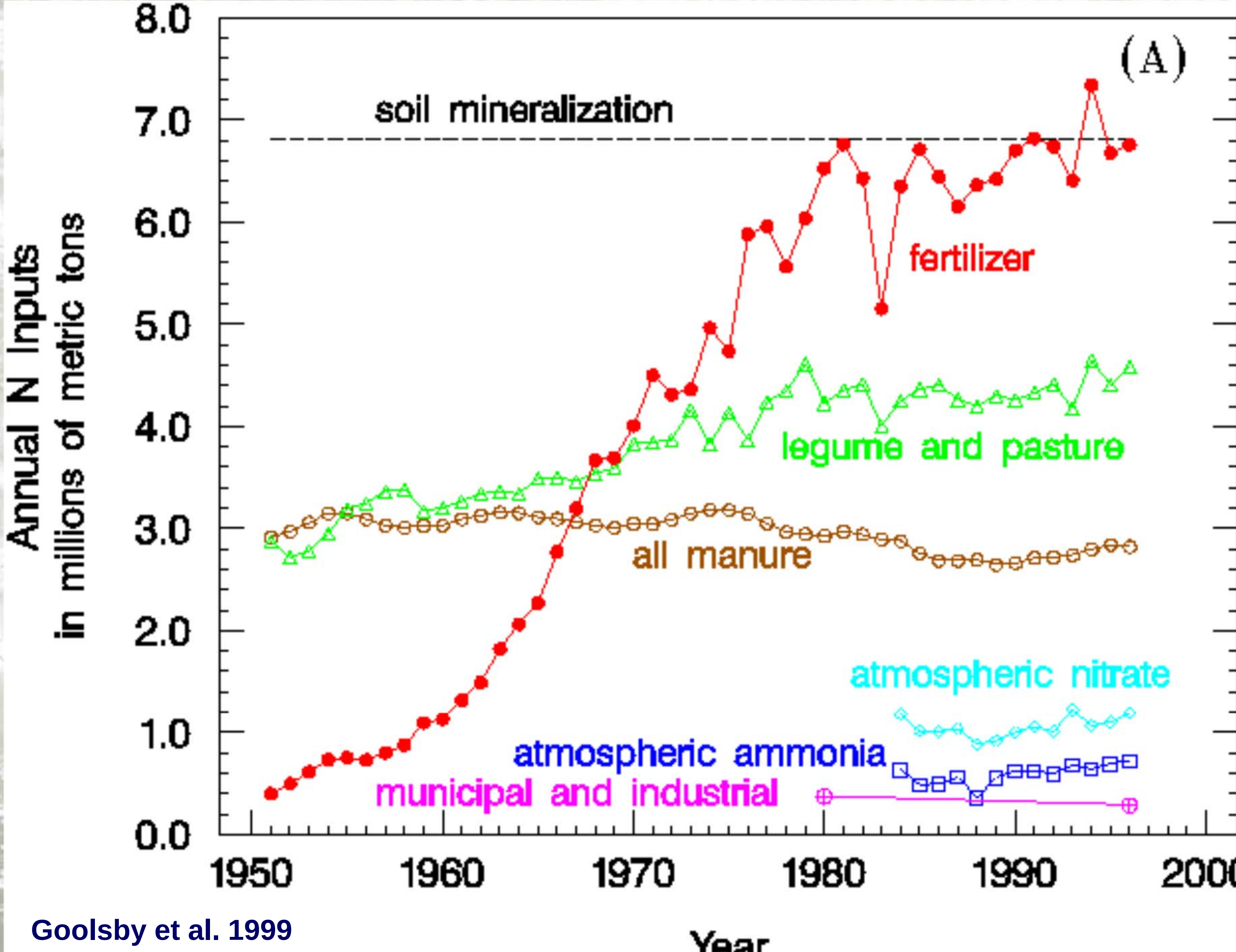
The Consequences

- Fisheries resources at risk
- Altered migration
- Reduced habitat
- Changes in food resources
- Susceptibility of early life stages
- Growth & reproduction



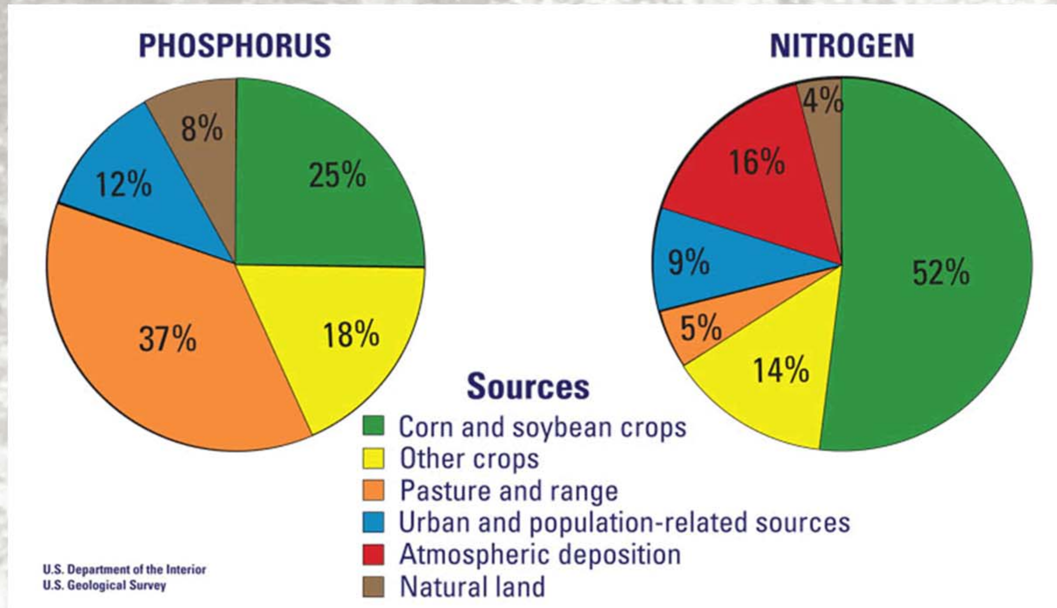


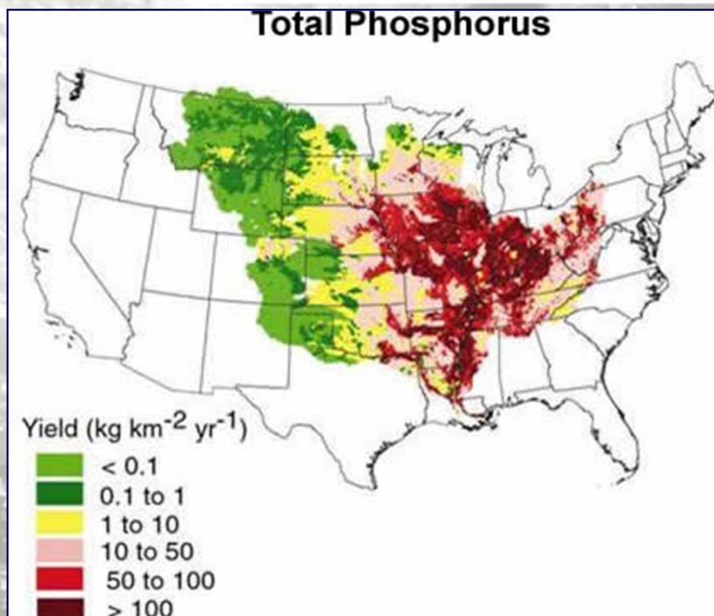
Nitrogen Inputs to the Mississippi Watershed

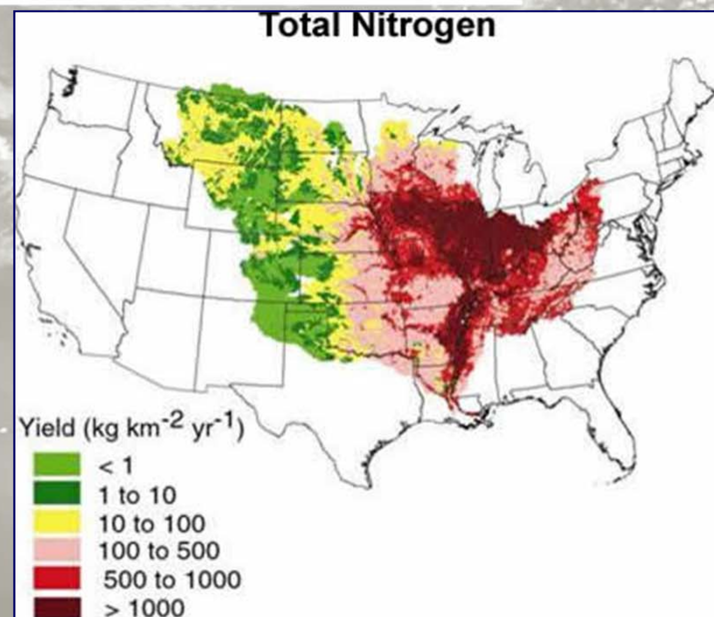


Goolsby et al. 1999

Nutrients Delivered to GoMx





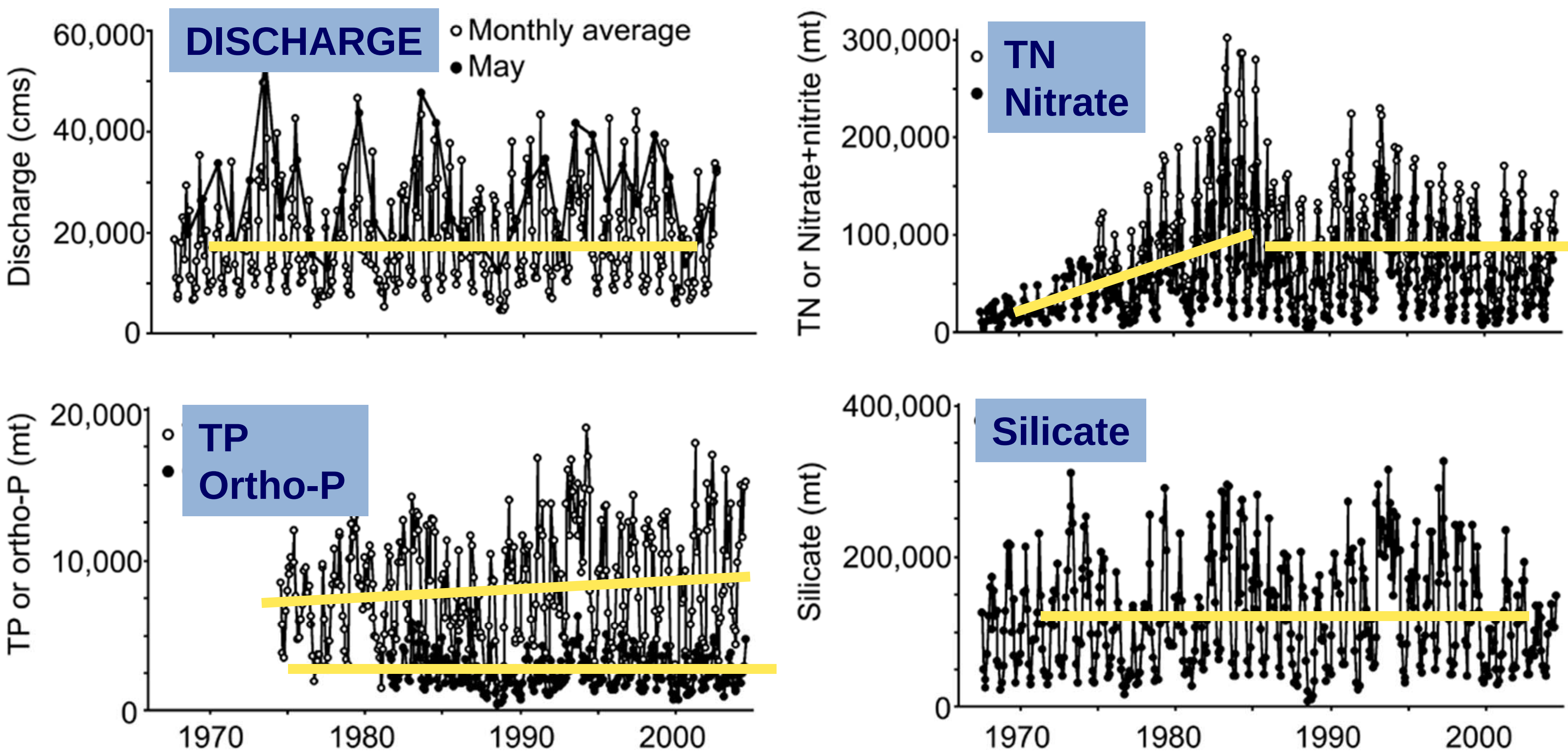


Alexander et al. 2008 & http://water.usgs.gov/nawqa/sparrow/gulf_findings/

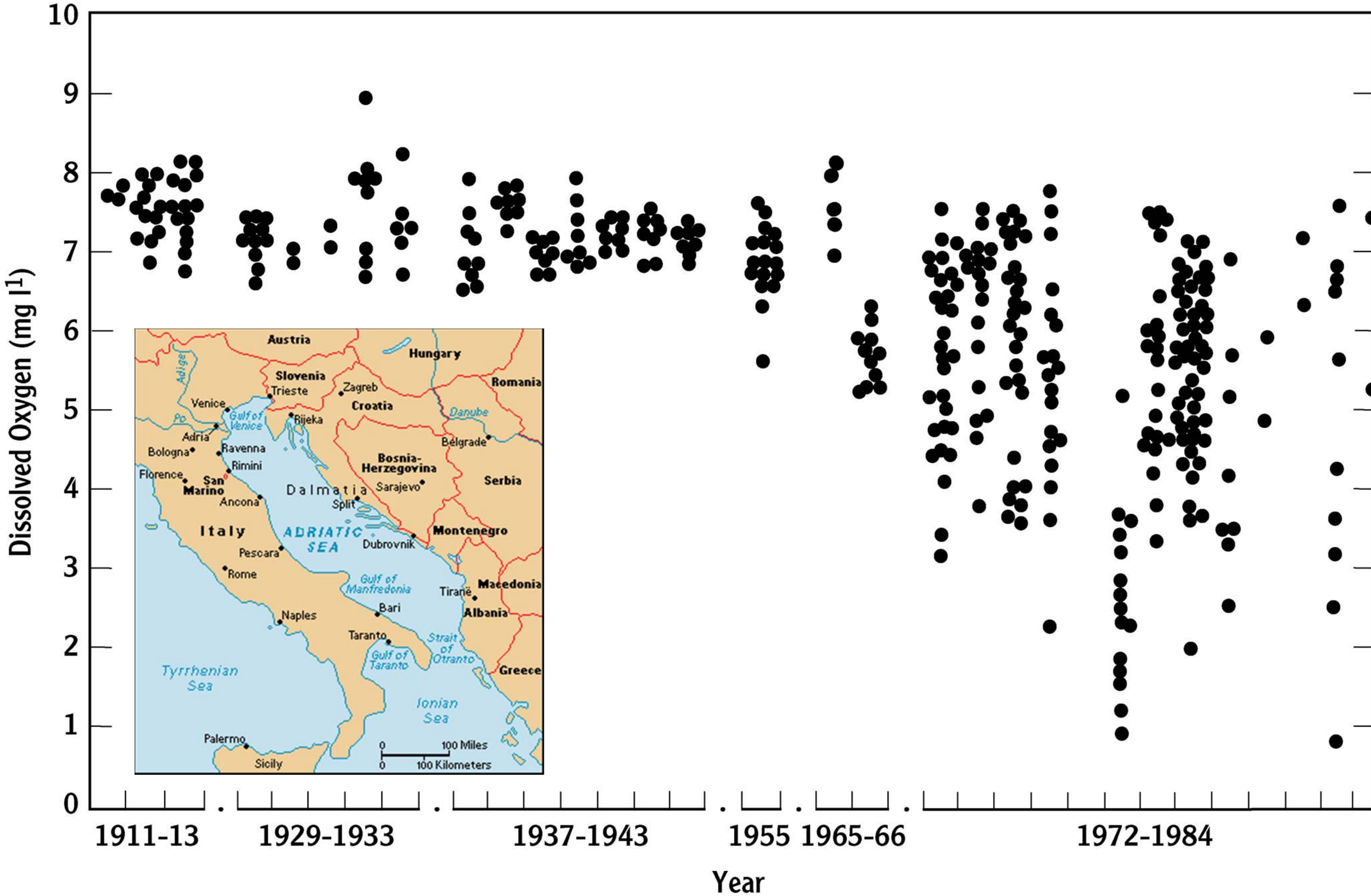
300% increase in N load

80% due to NO_3^- concentration ↑

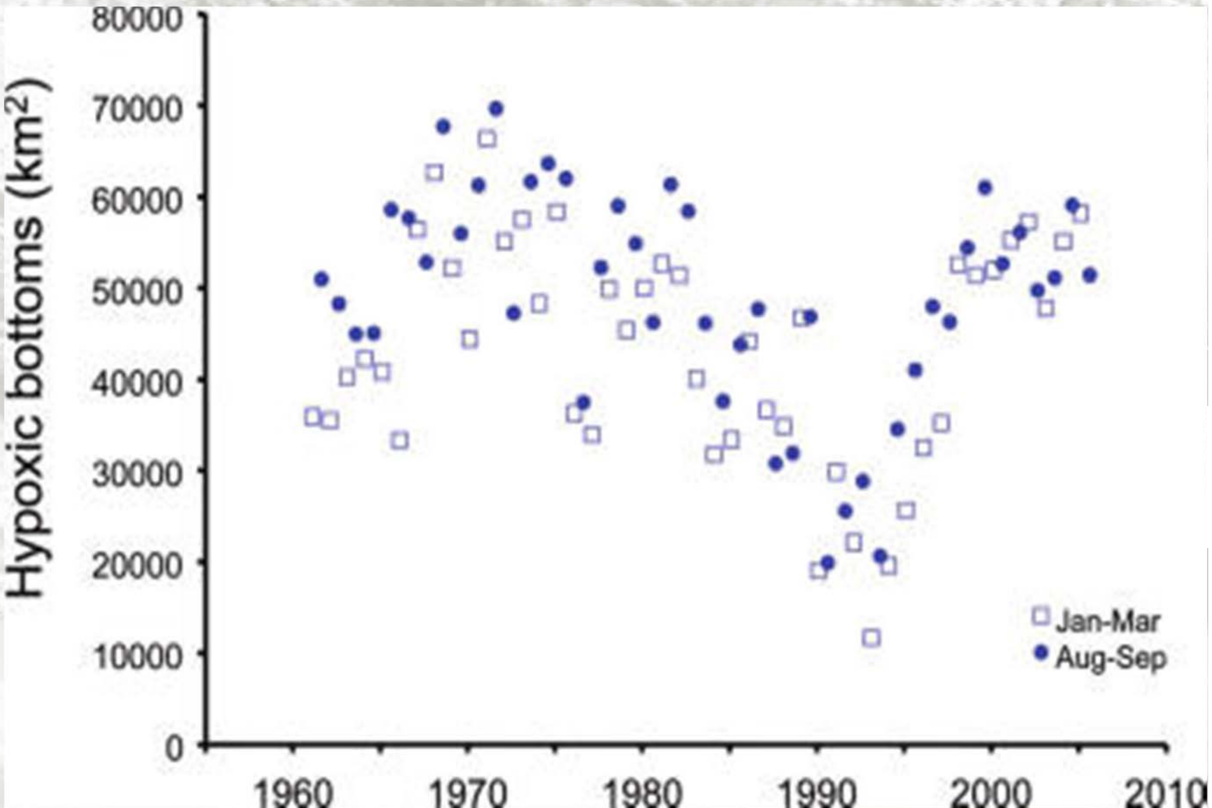
20% due to discharge ↑



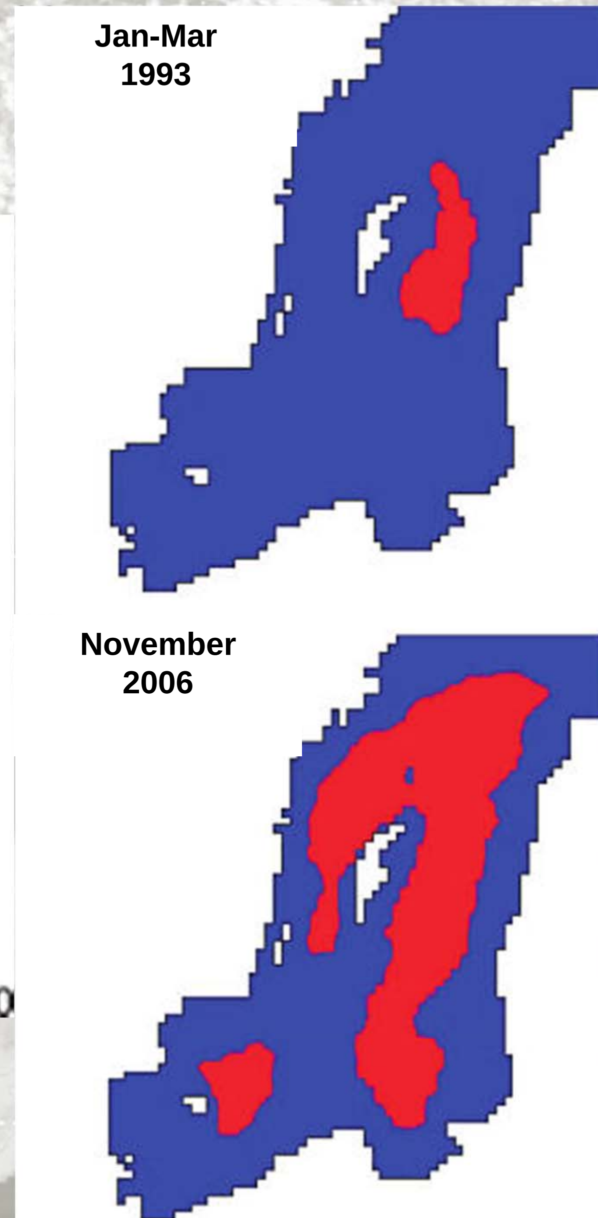
Turner et al. 2007



Oxygen content 2 m above the bottom during August-September in the northern Adriatic Sea from 1911 to 1984 for the periods indicated. Redrawn from Justić (1991) with permission.



Conley et al., 2009



Baltic Sea and Coastal Waters

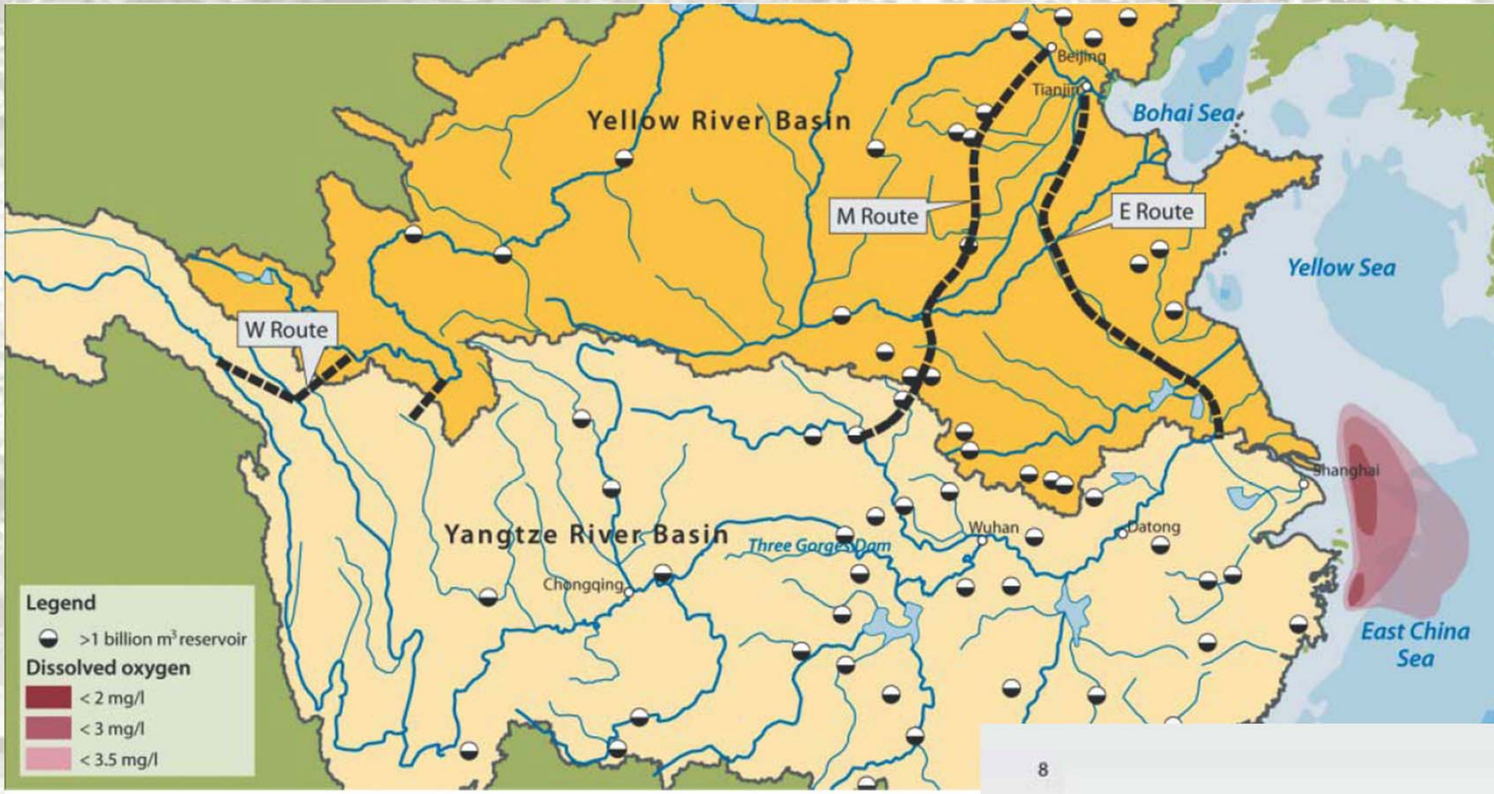


Figure 3. The Yangtze River drainage basin and the estimated hypoxy areas in the ECS (3

Li and Daler 2004

East China Sea

14,000 km^2
Annual Hypoxia

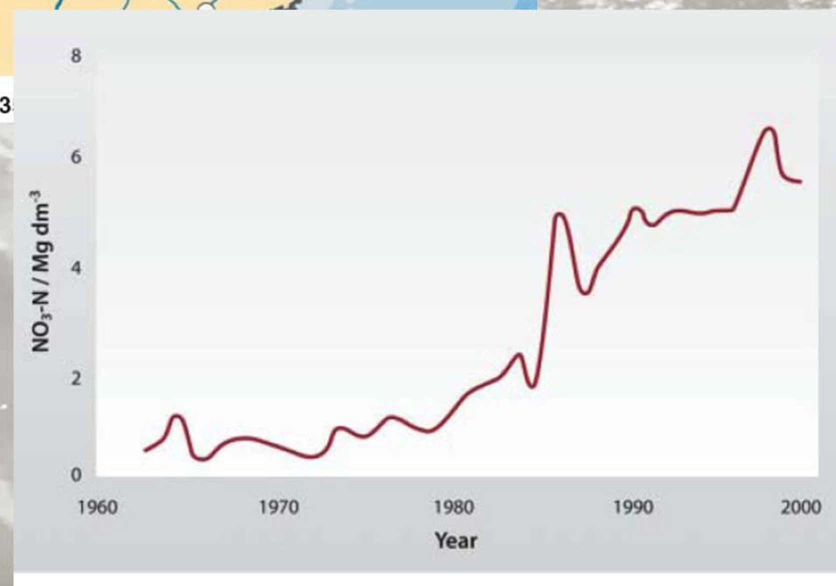
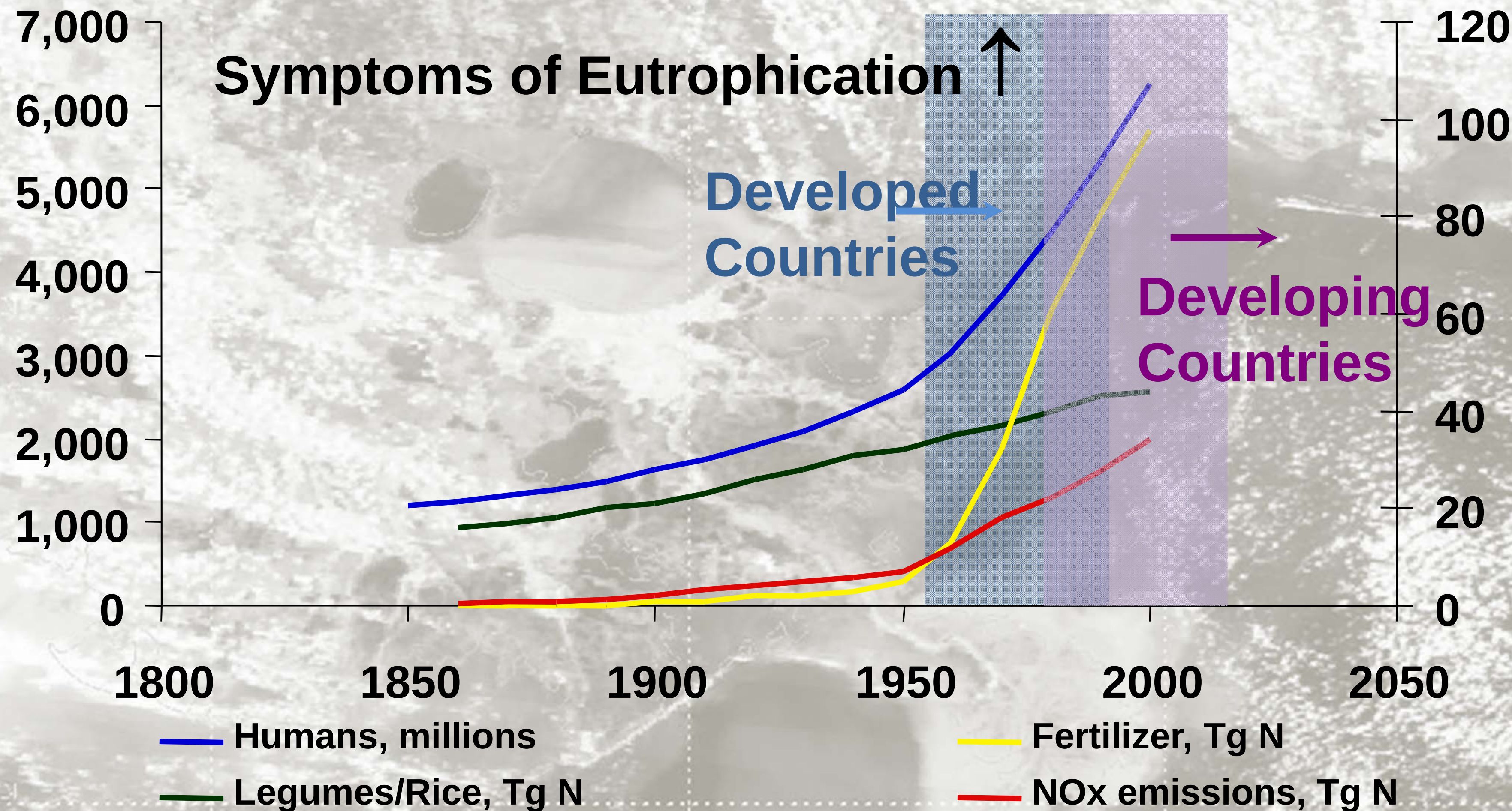


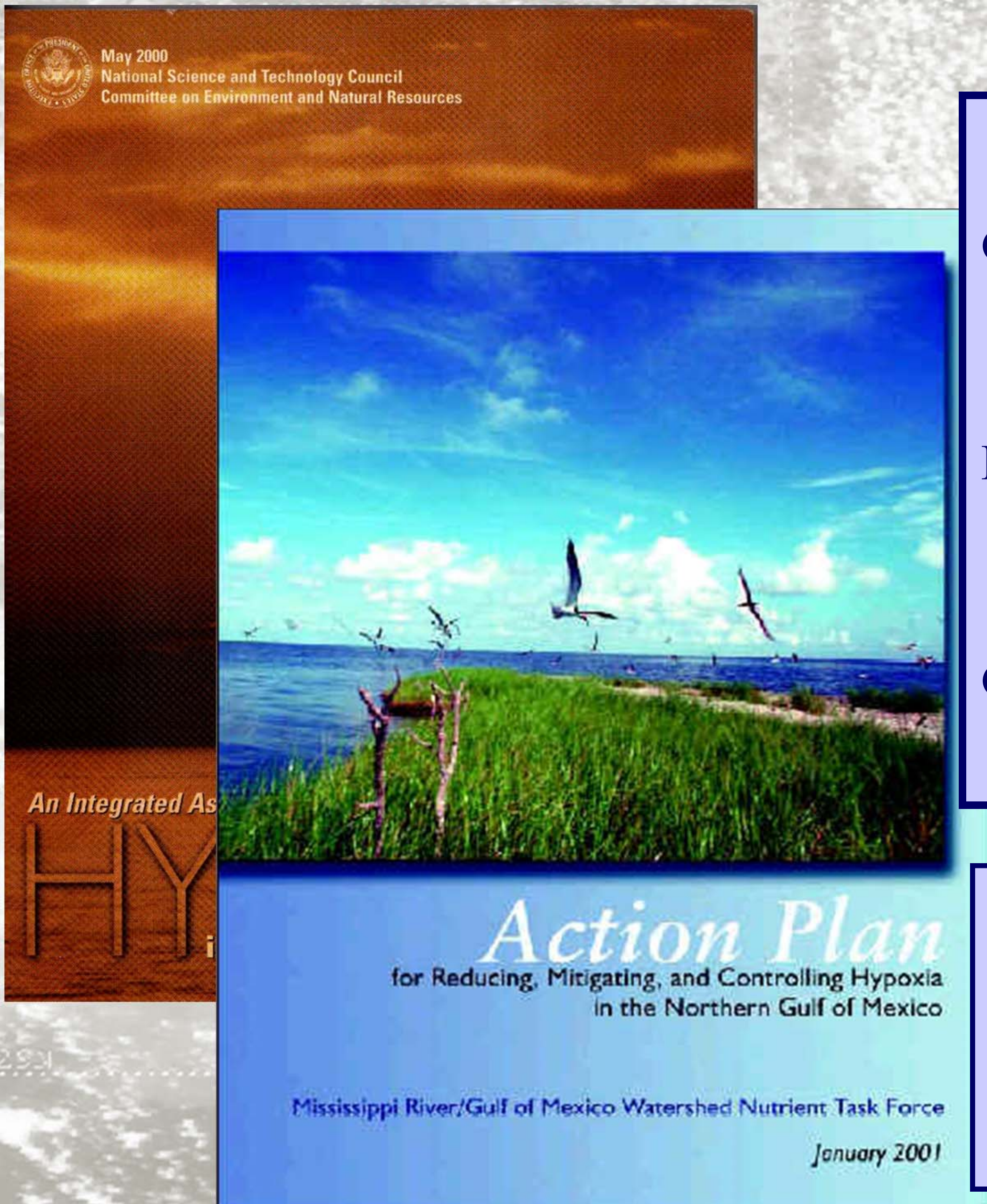
Figure 5. Historical variations of nitrate concentrations at Datong station (33).

“Our rivers are too large to have nutrient problems and dead zones”

Land-Ocean Interactions in the Coastal Zone (LOICZ/IGBP) Open Science Meeting, Bahia Blanca, Argentina, November 1999



(Rabalais et al., 2009; modified from Galloway and Cowling 2002; Boesch 2002)



GOALS

Coastal. By 2015, reduce hypoxia below 5,000 km^2 (over a 5-yr running average).

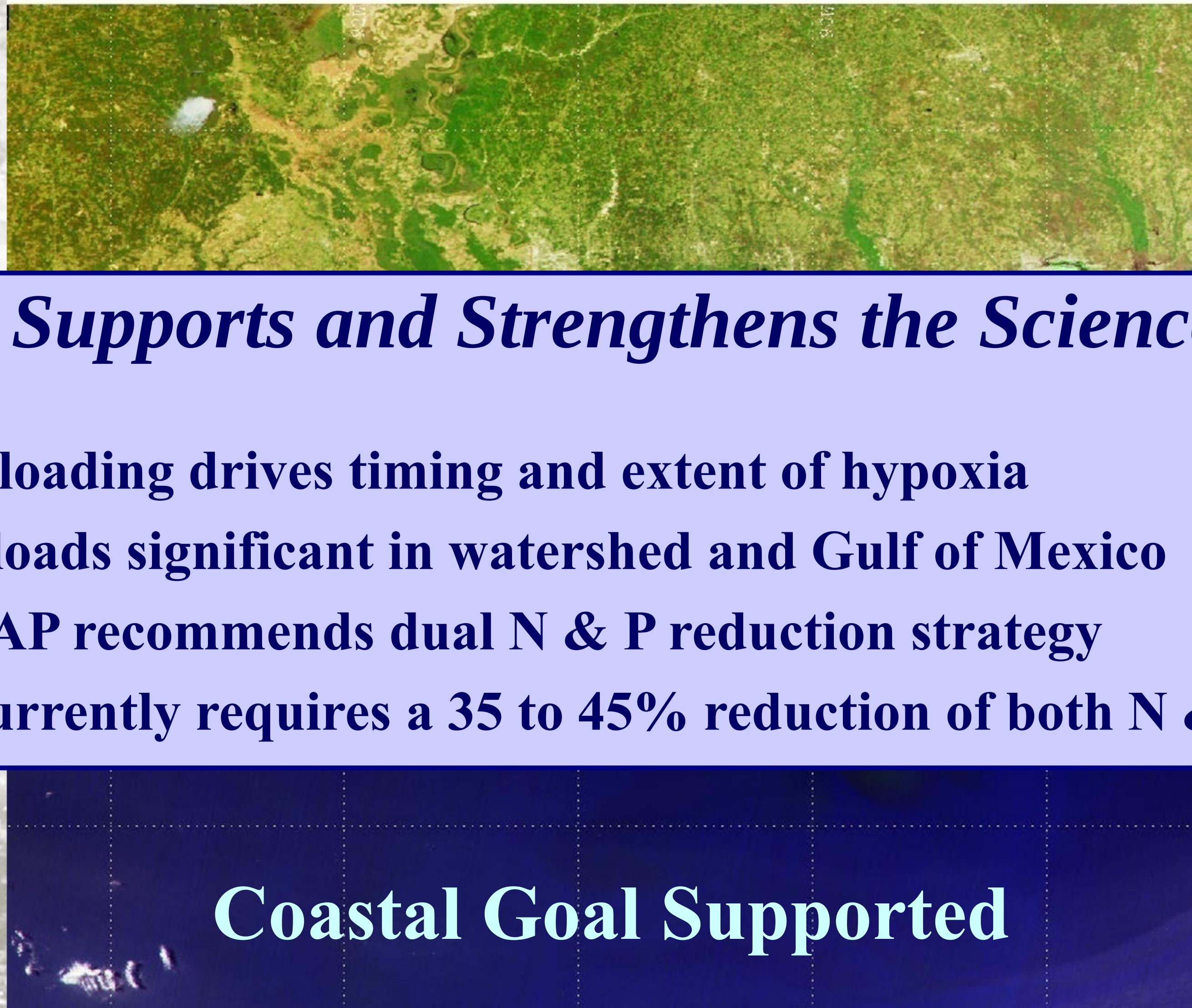
Basin. Restore and protect the waters of Basin States and Tribes.

Communities. Improve social and economic conditions in the Basin.

- Estimated N reduction required:
- 30% at time of Action Plan
- Voluntary actions, incentives, education

Hypoxia in the Northern Gulf of Mexico

An Update by the EPA Science Advisory Board



Supports and Strengthens the Science

- **N loading drives timing and extent of hypoxia**
- **P loads significant in watershed and Gulf of Mexico**
- **HAP recommends dual N & P reduction strategy**
- **Currently requires a 35 to 45% reduction of both N & P**

Coastal Goal Supported

Reduce Nitrogen (1000 MT/yr)

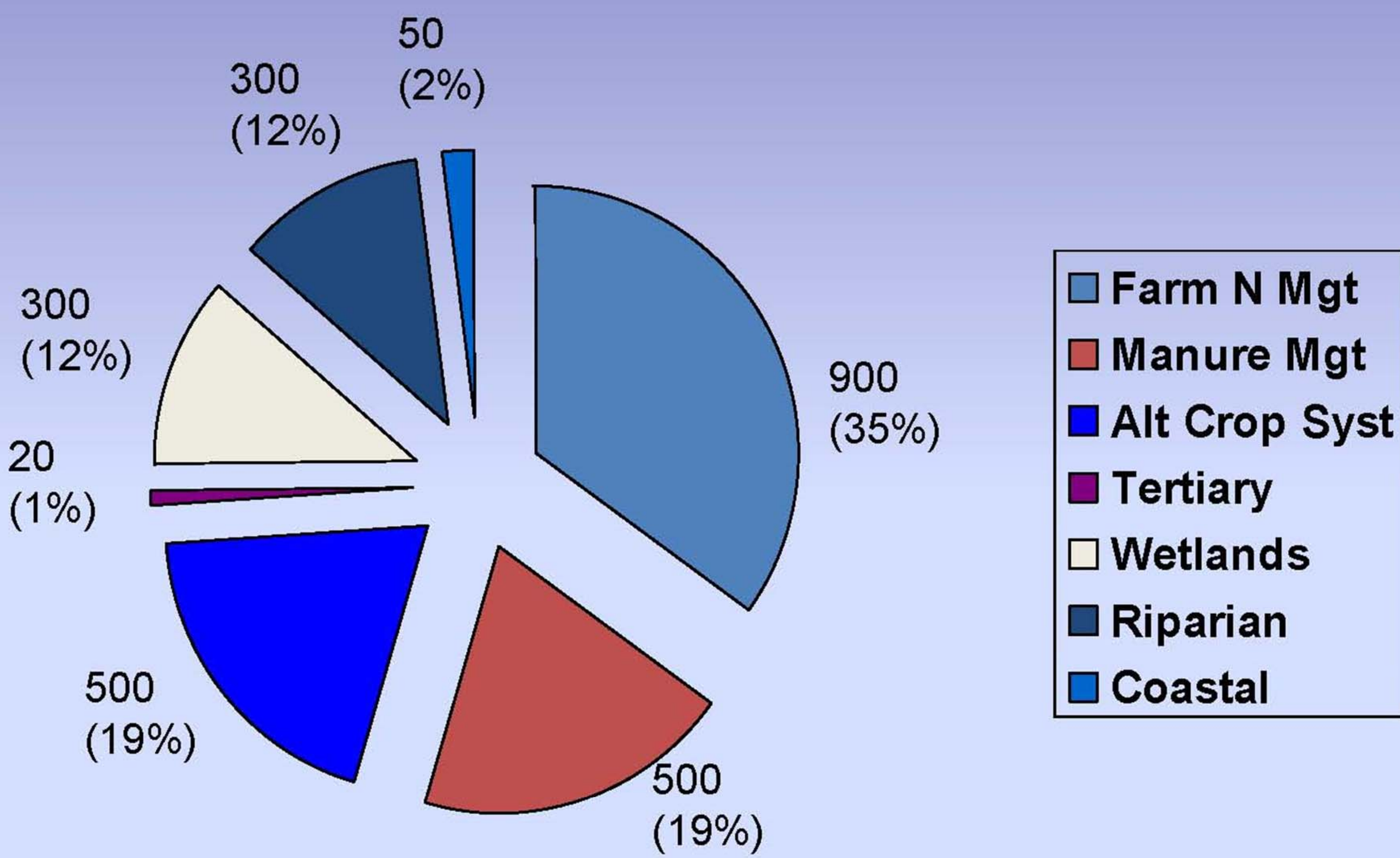
Farm N management
1,400 - 1,900
Alt. crop systems
500

Wetlands
300
Riparian Buffers
300

Tertiary treatment
(point sources)
20

Coastal Diversion
50

Potential N Reduction (1000 mt N/yr)

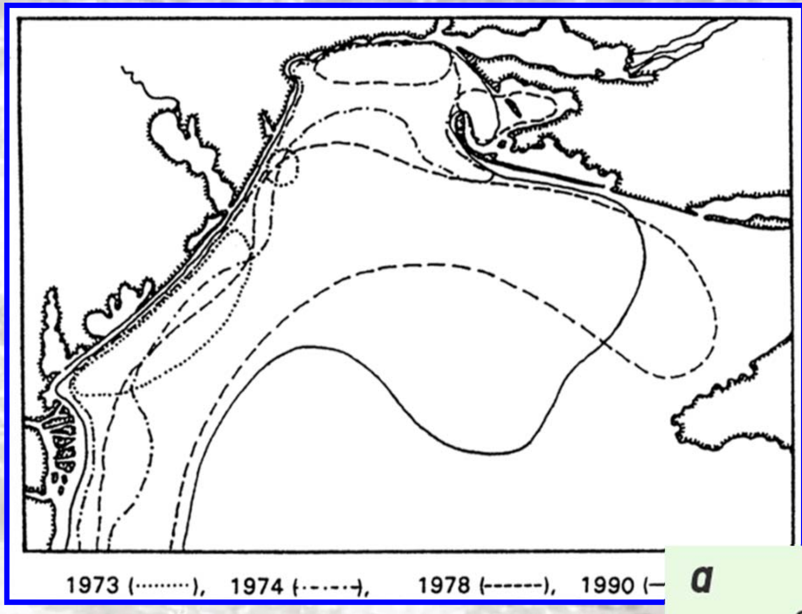


Data Source: Mitsch et al. 1999, 2001; CENR 2000

1960 1970 1980 1990 2000 2010 2020 2030

Coastal Hypoxia and Eutrophication

Reduce Nutrients, Reduce Hypoxia

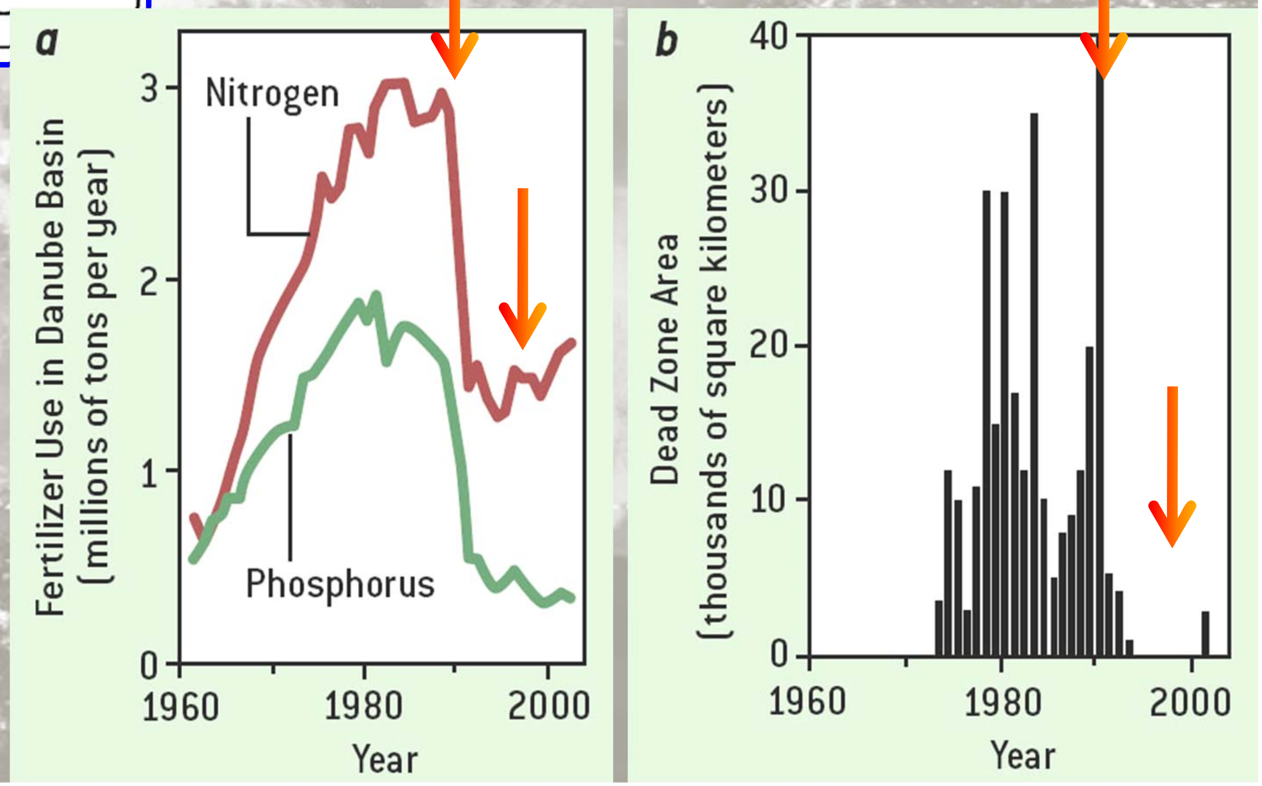


Zaitsev 1992

Northwestern Shelf
Black Sea

Hypoxic Area Up to 40,000 km^2
Currently, non-existent or minimal

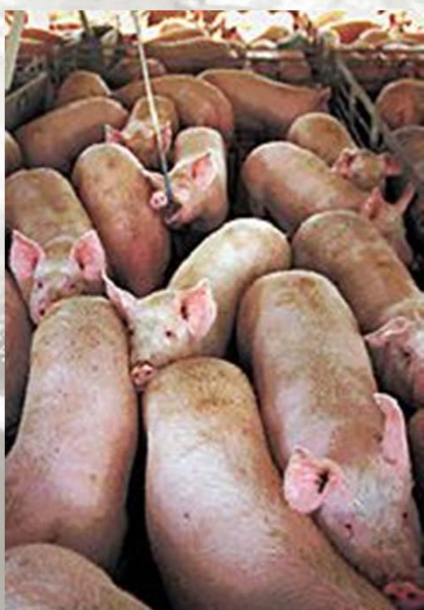
N and P Loads Correspond to Fertilizer Use

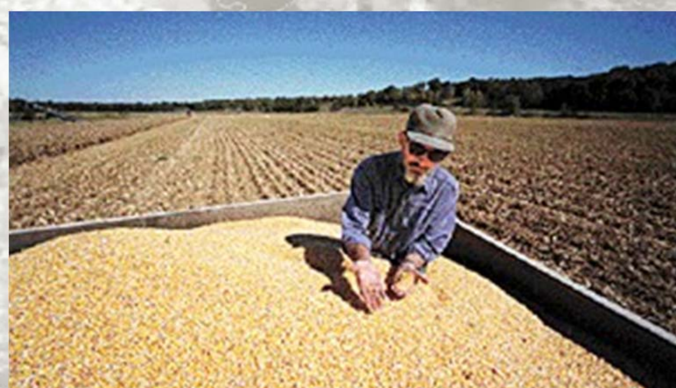


Mee 2006

The Future

Climate Change
Biofuels
Increased Population
Increased Agribusiness
Increased Atmospheric Deposition






Questions?
LOUISIANA UNIVERSITIES MARINE CONSORTIUM
LUMCON
LSU
Gulf of Mexico Hypoxia
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE
NSF