Eutrophication, Coastal Hypoxia, Carbon & Climate

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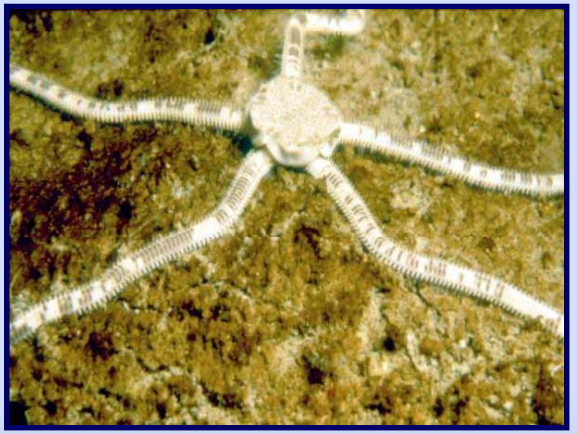
http://www.gulfhypoxia.net

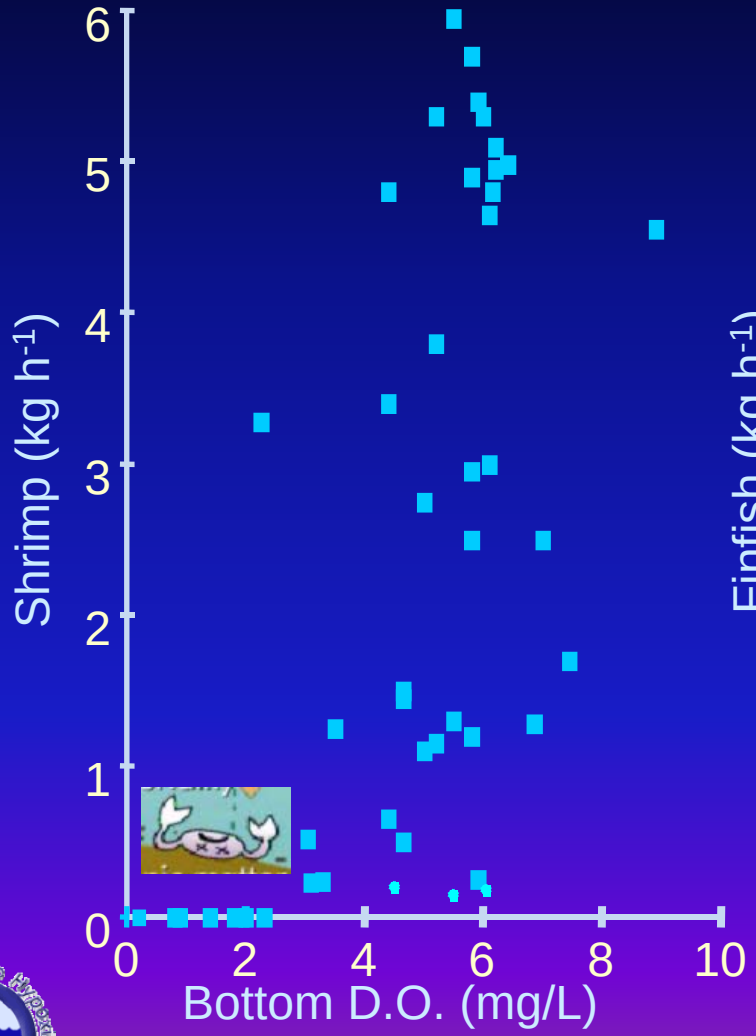
“Charismatically stressed and dead benthic fauna” Downing 2002

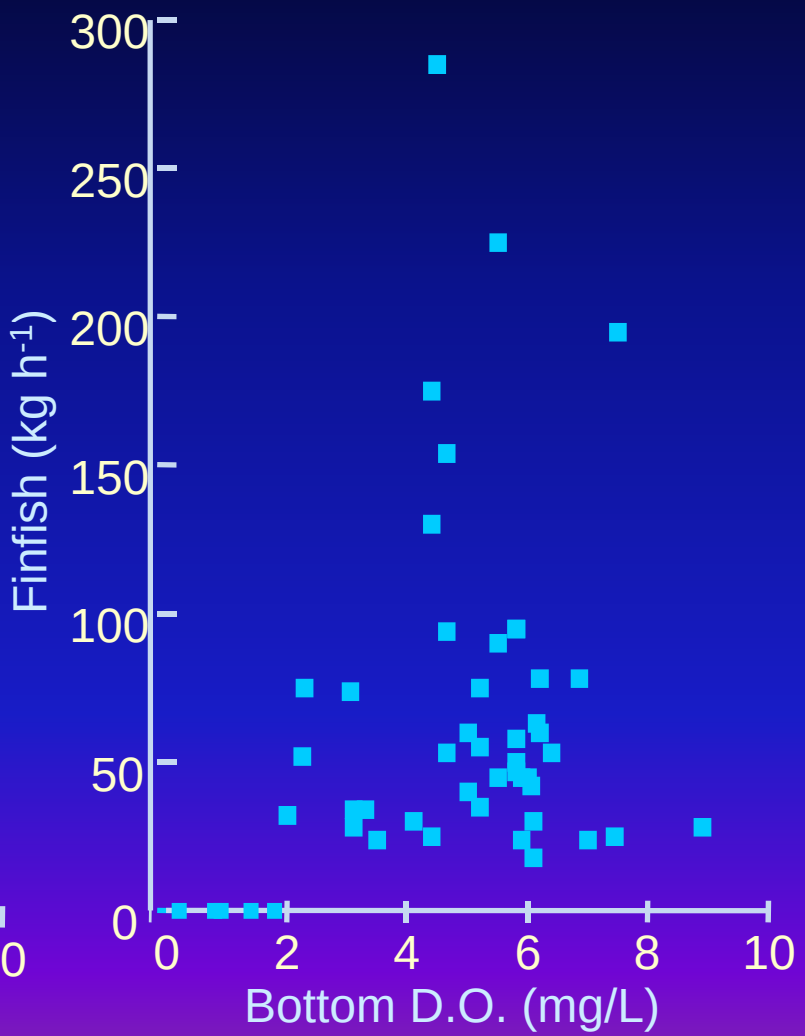
- Significant fisheries resources at risk
- Altered migration
- Reduced habitat
- Loss of biomass
- Changes in food resources
- Susceptibility of early life stages
- Growth & reproduction



No trawlable fish, shrimp, crabs

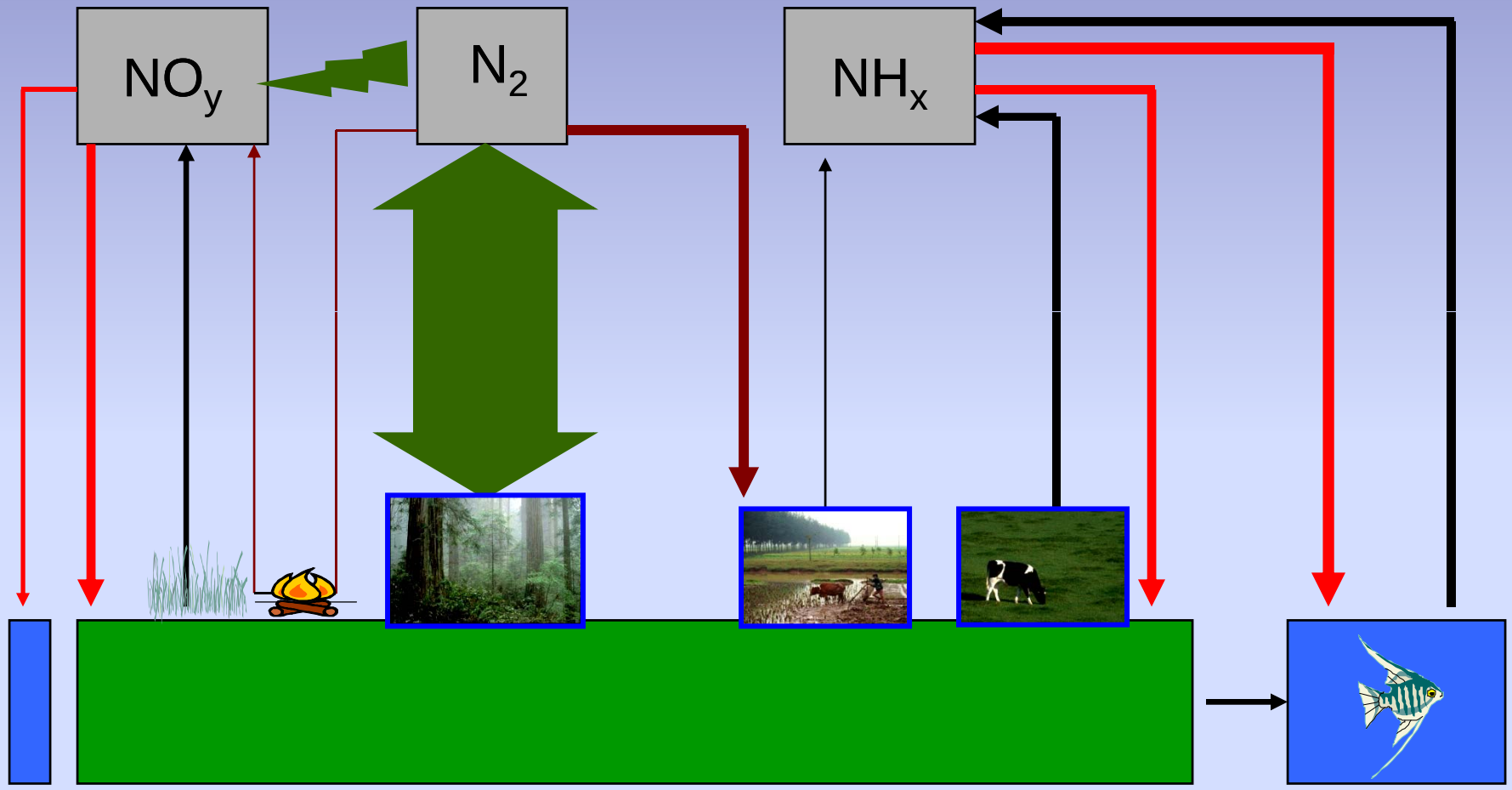
Hypoxia = Dissolved O_2 < 2 mg/L (=2 ppm)





Leming and Stuntz 1984

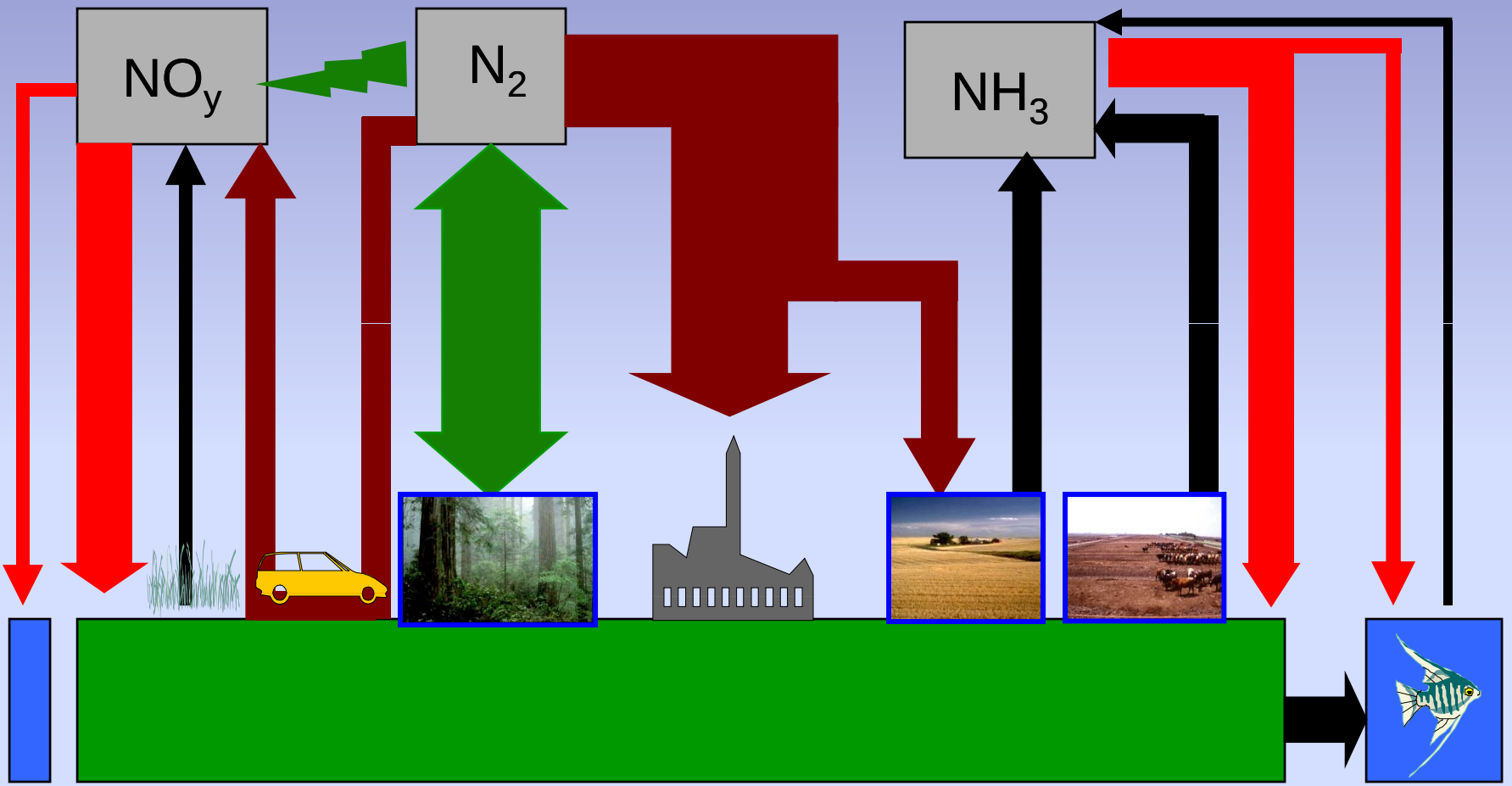
Global N Budget: ~1860 (Tg N/yr)



N Fixation, natural | N Fixation, human | N Transfer | N Deposition

Galloway and Cowling 2002

Global N Budget: Present (Tg N/yr)

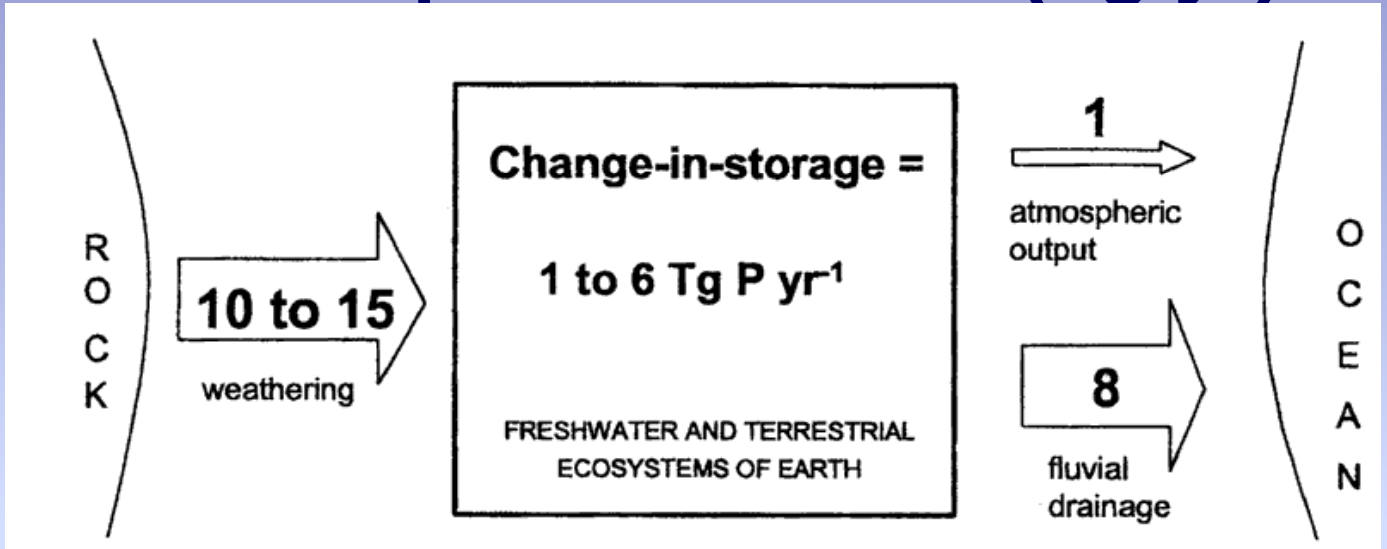


N Fixation, natural | N Fixation, human | N Transfer | N Deposition

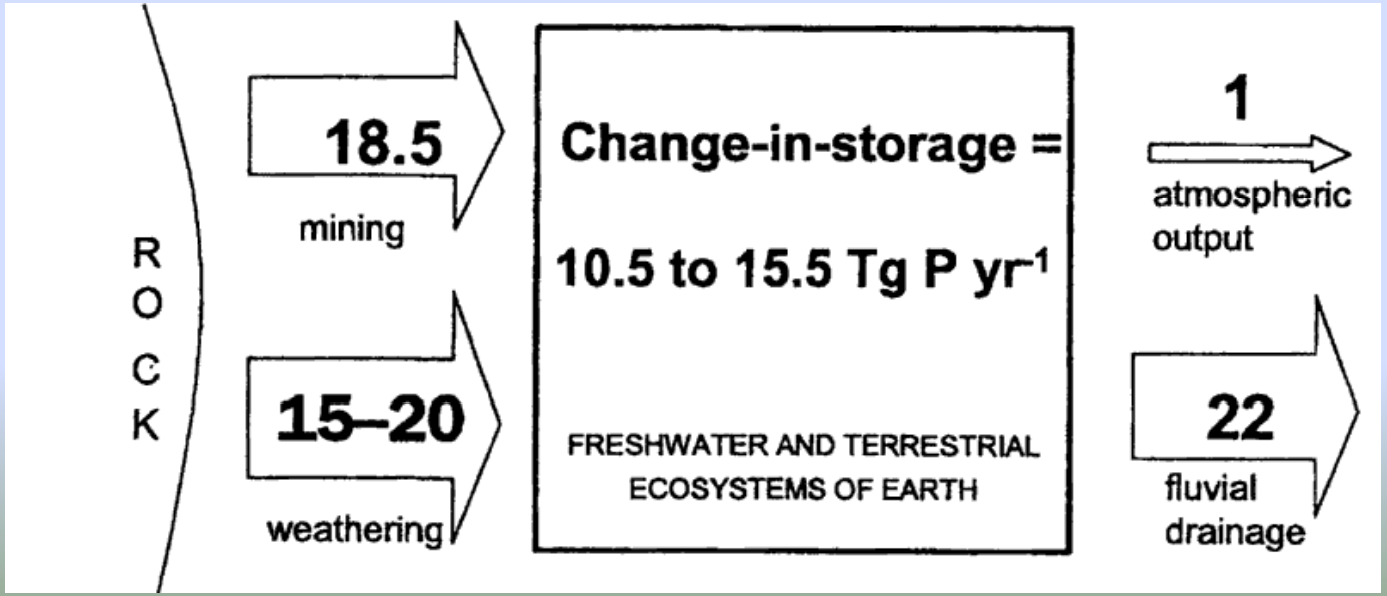
Galloway and Cowling 2002

Don't forget phosphorus!
Terrestrial Phosphorus Fluxes (Tg/yr)

Pre-Industrial

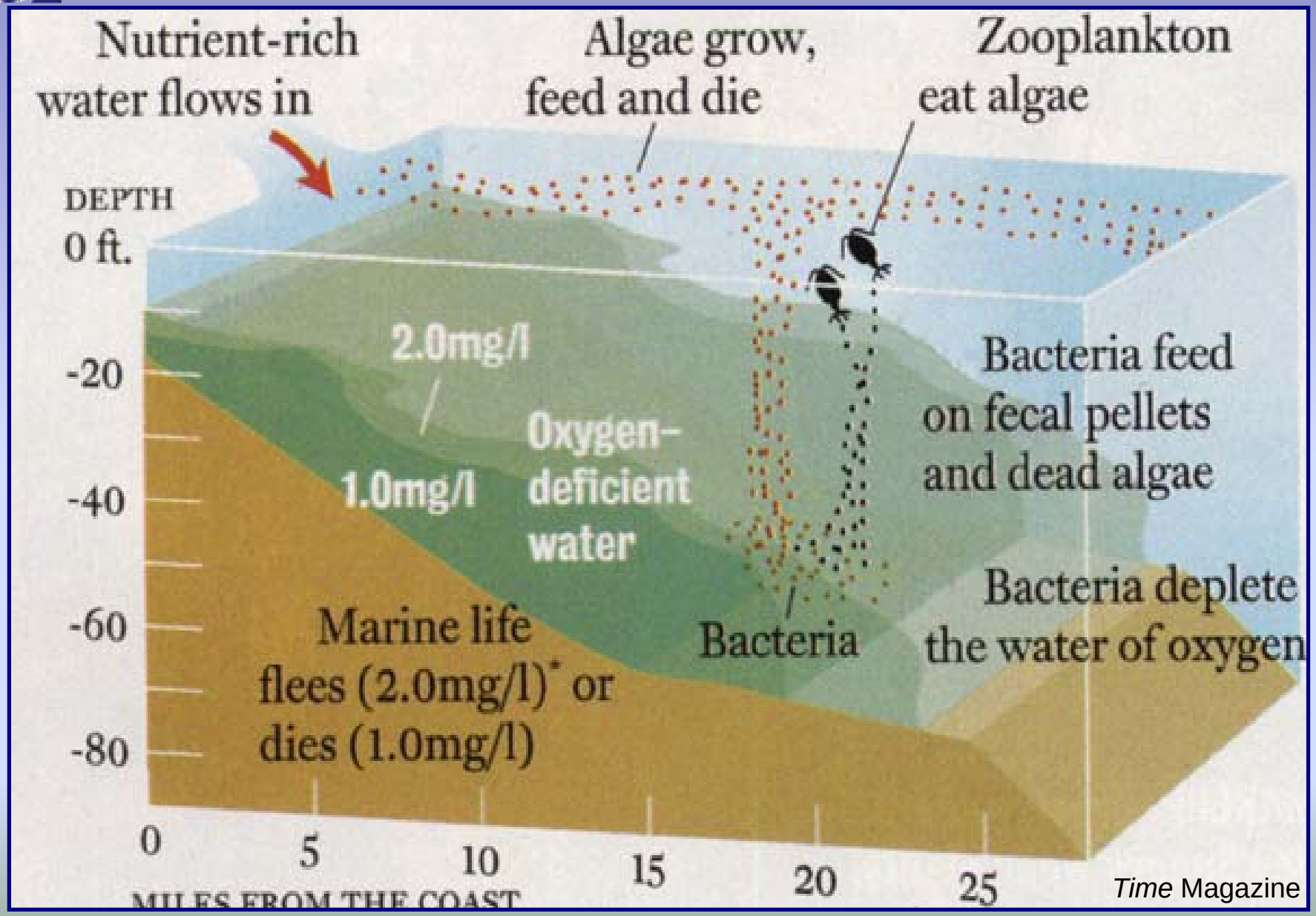


Current



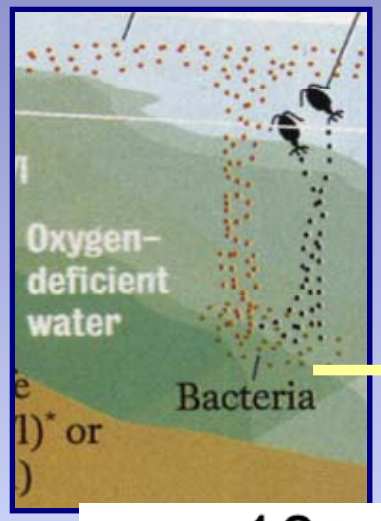
Bennett et al., 2001

Nutrients, Increased Growth, Low Oxygen

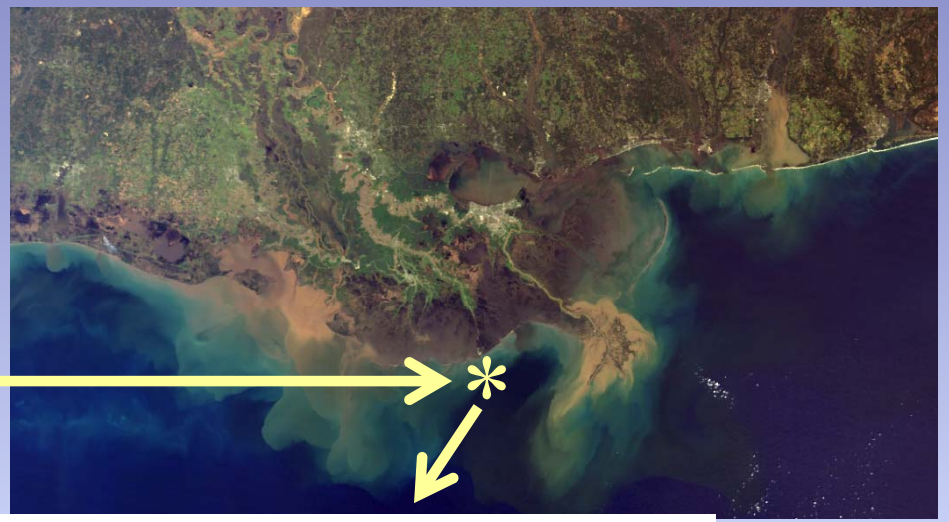


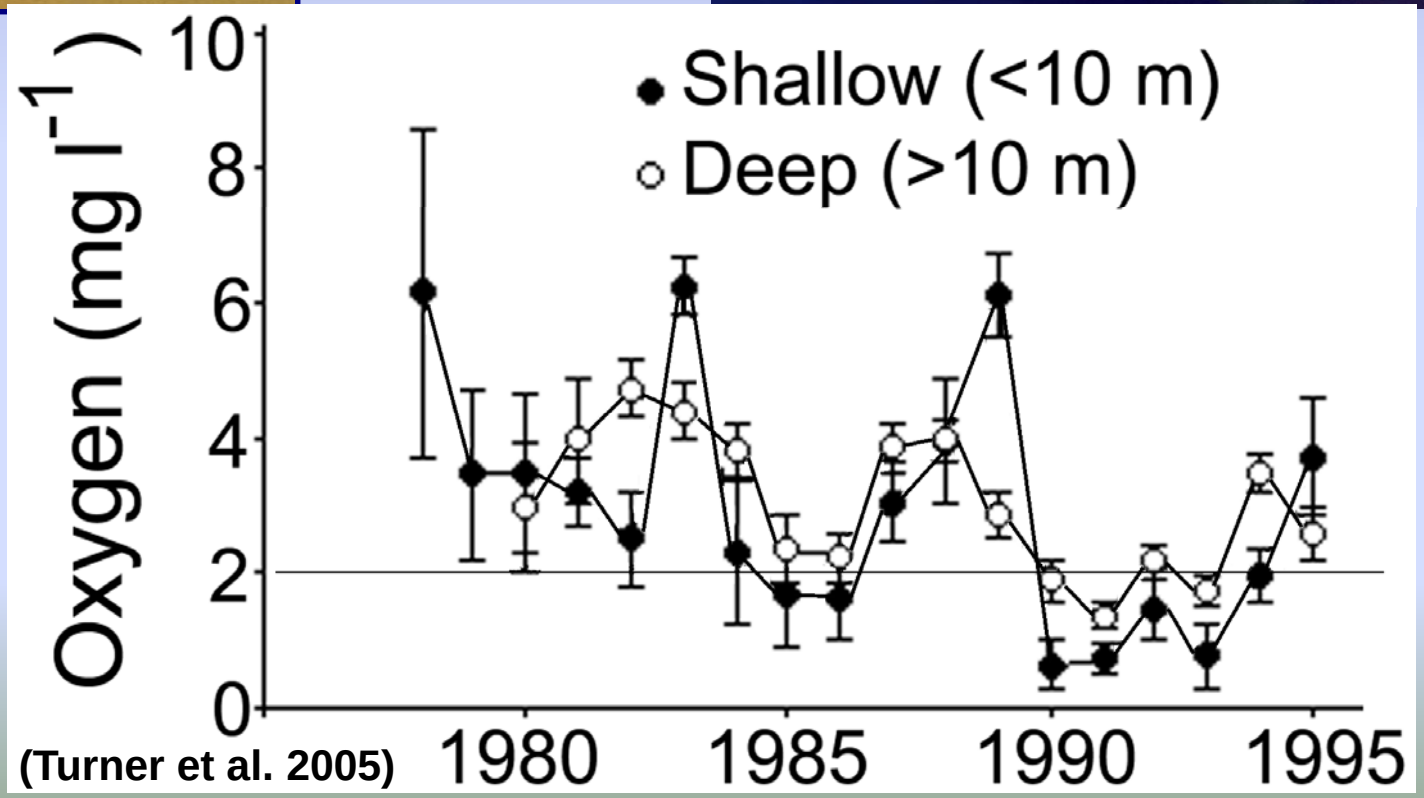
Time Magazine

Nutrients, Increased Growth, Low Oxygen

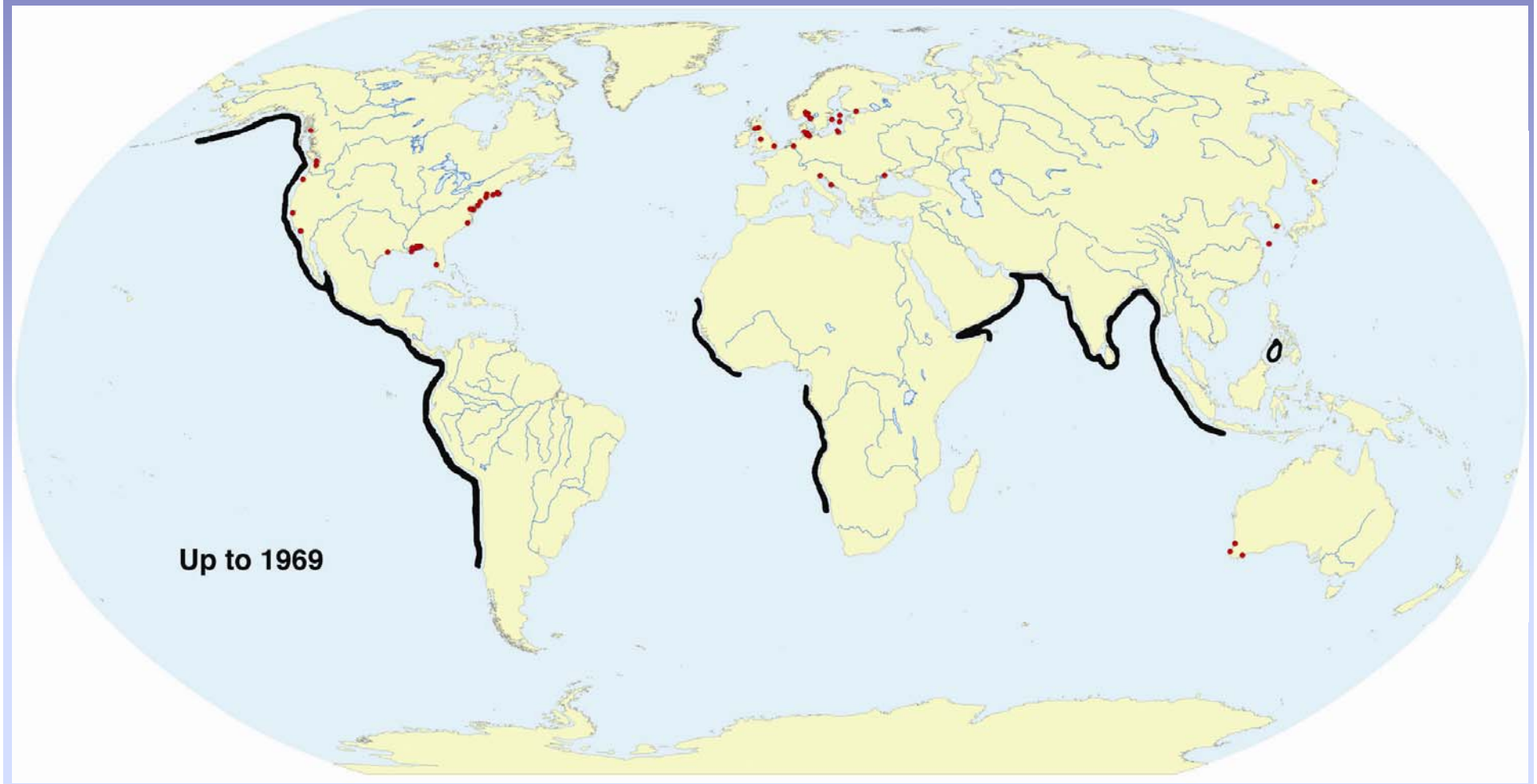


50% C↓



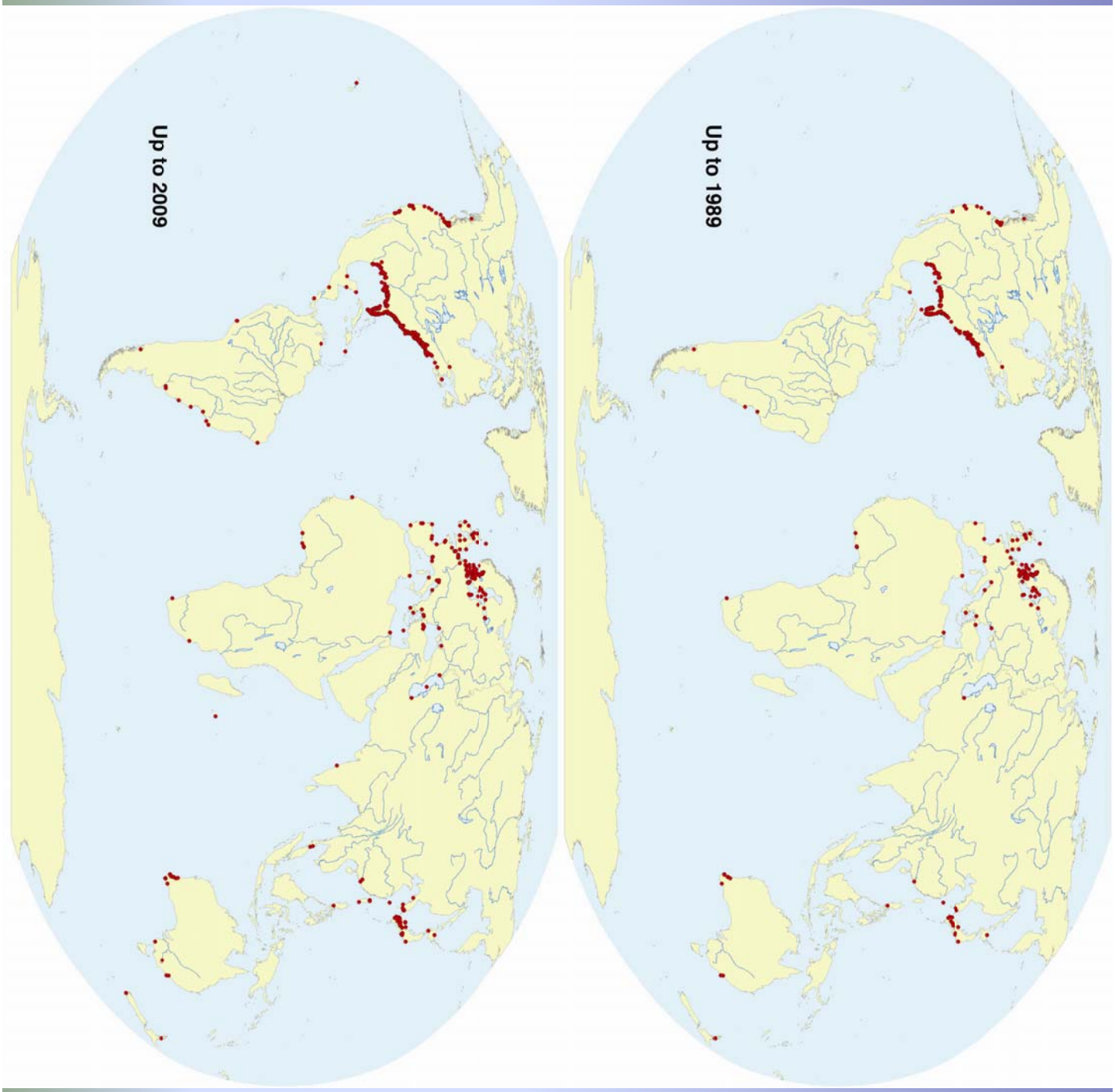


(Turner et al. 2005)

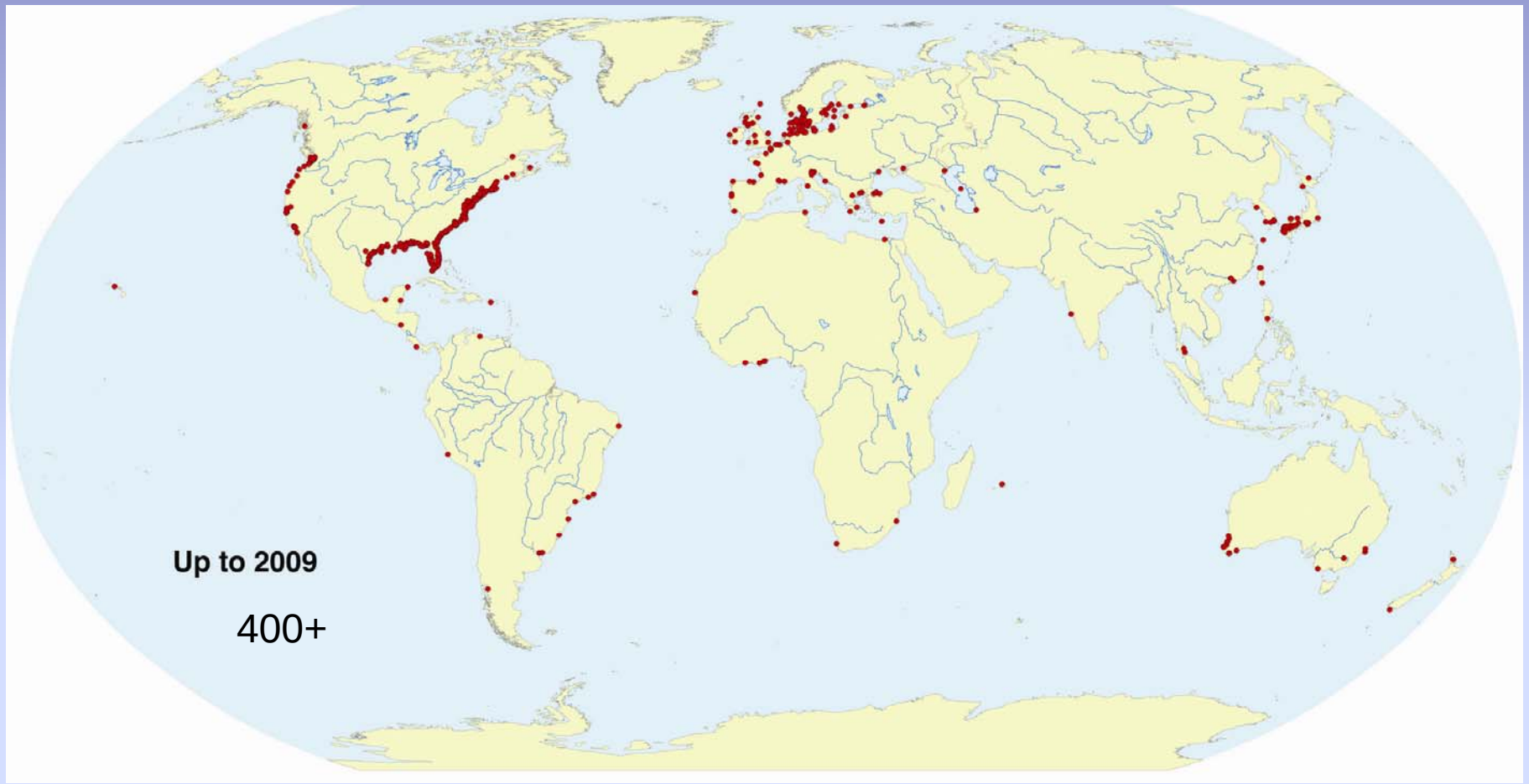


Global pattern in the development of coastal hypoxia. Black lines represent continental shelf areas threatened with hypoxia from expansion of OMZ and upwelling. Rabalais et al. 2010; modified from Díaz and Rosenberg 2008 and Levin et al. 2009.

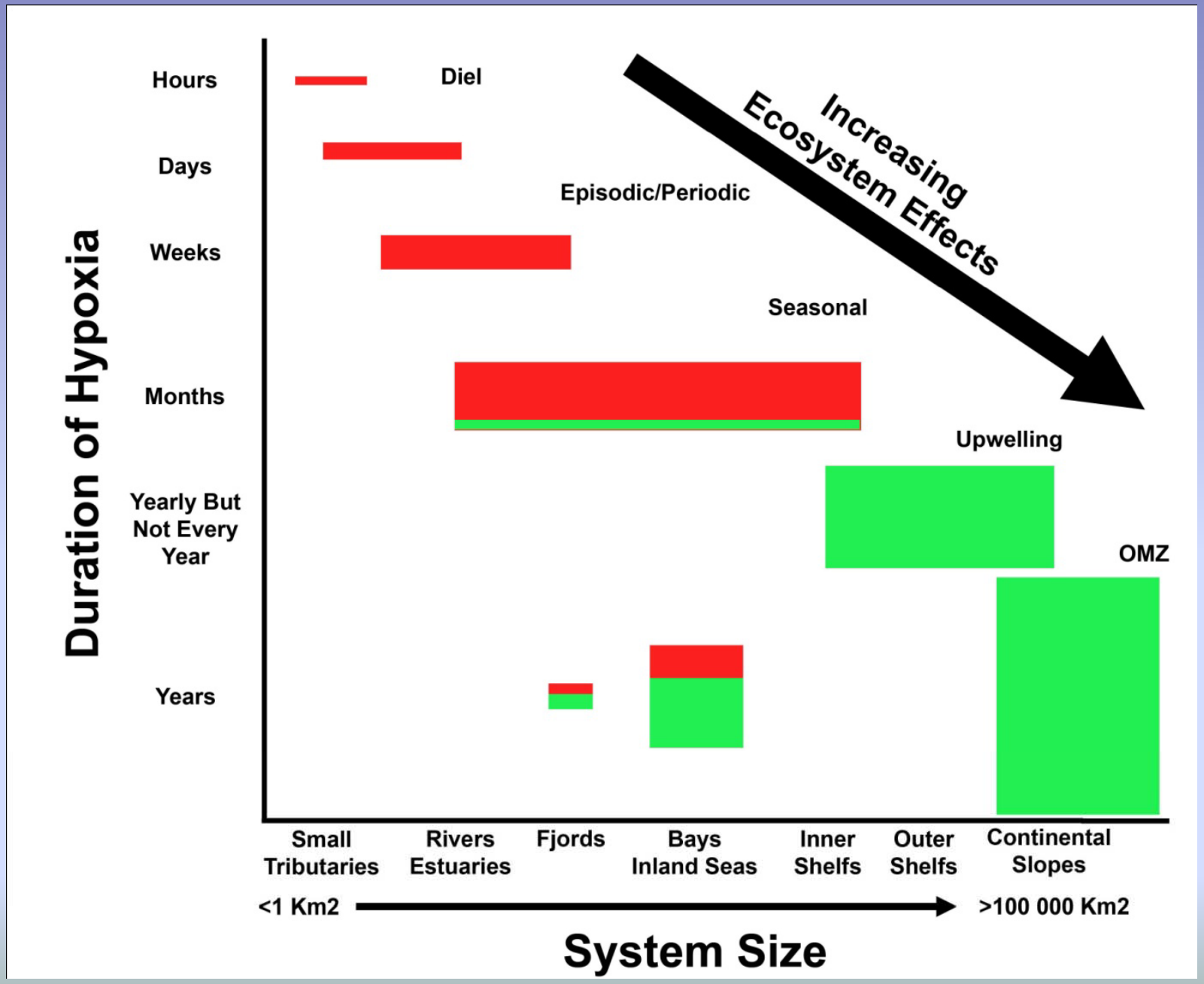
Rabalais et al. 2010



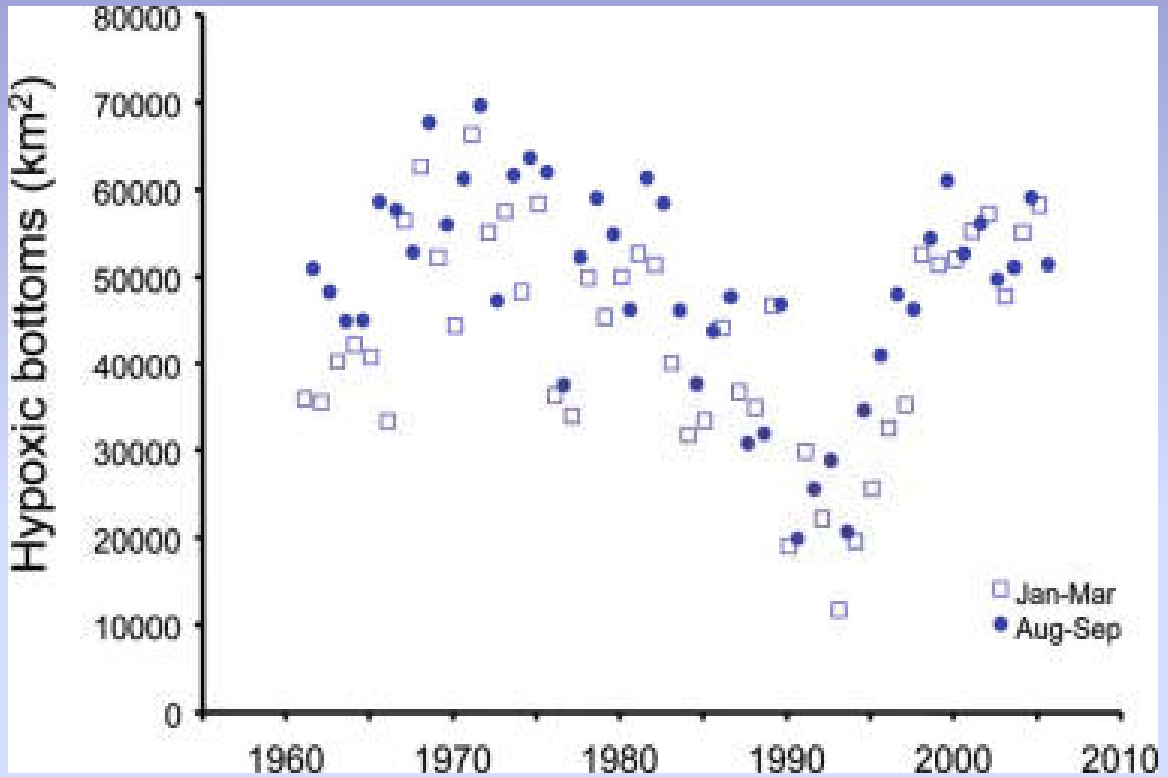
A global epidemic 400+

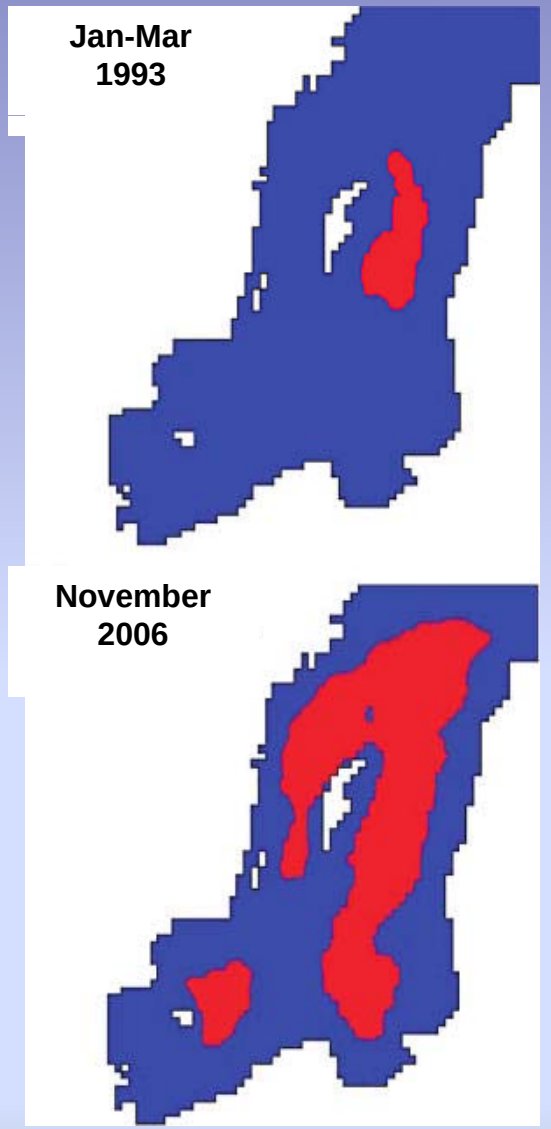


Rabalais et al. 2010; modified from Díaz and Rosenberg 2008



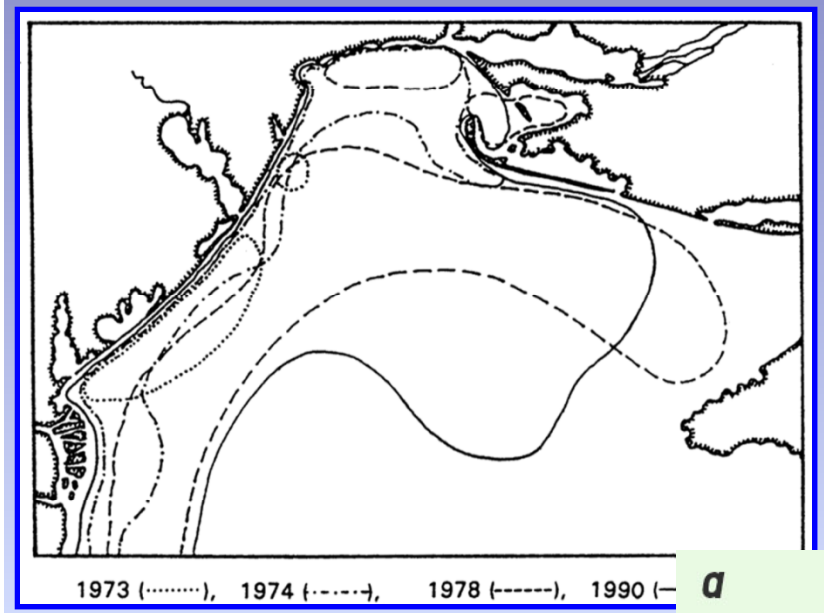
Rabalais et al. 2010





Conley et al., 2009

Reduce Nutrients, Reduce Hypoxia

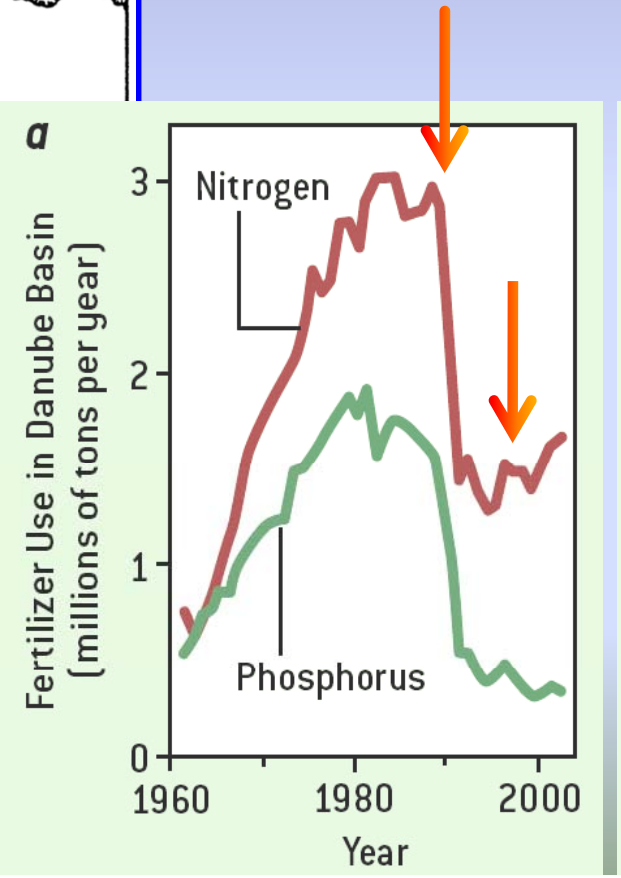


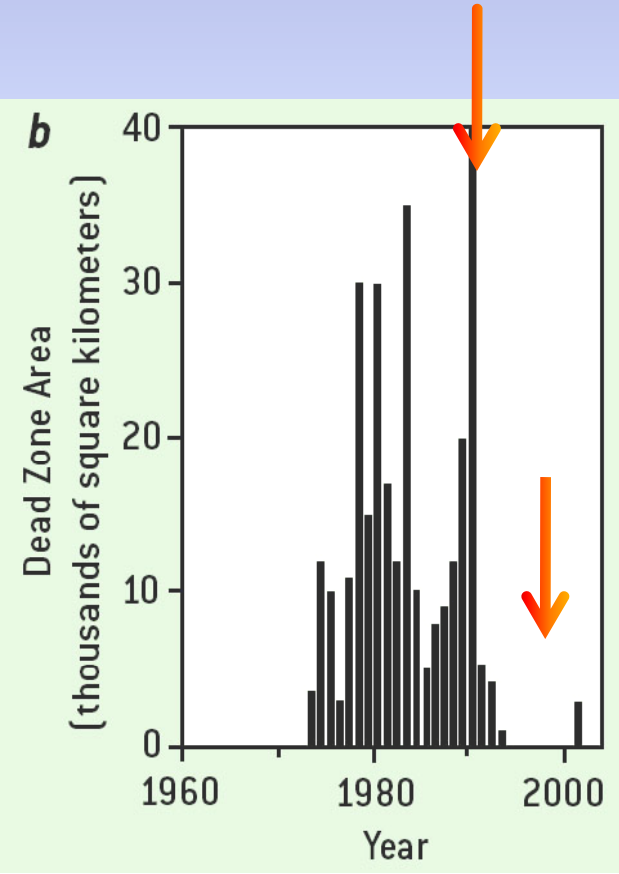
Zaitsev 1992

Northwestern Shelf Black Sea

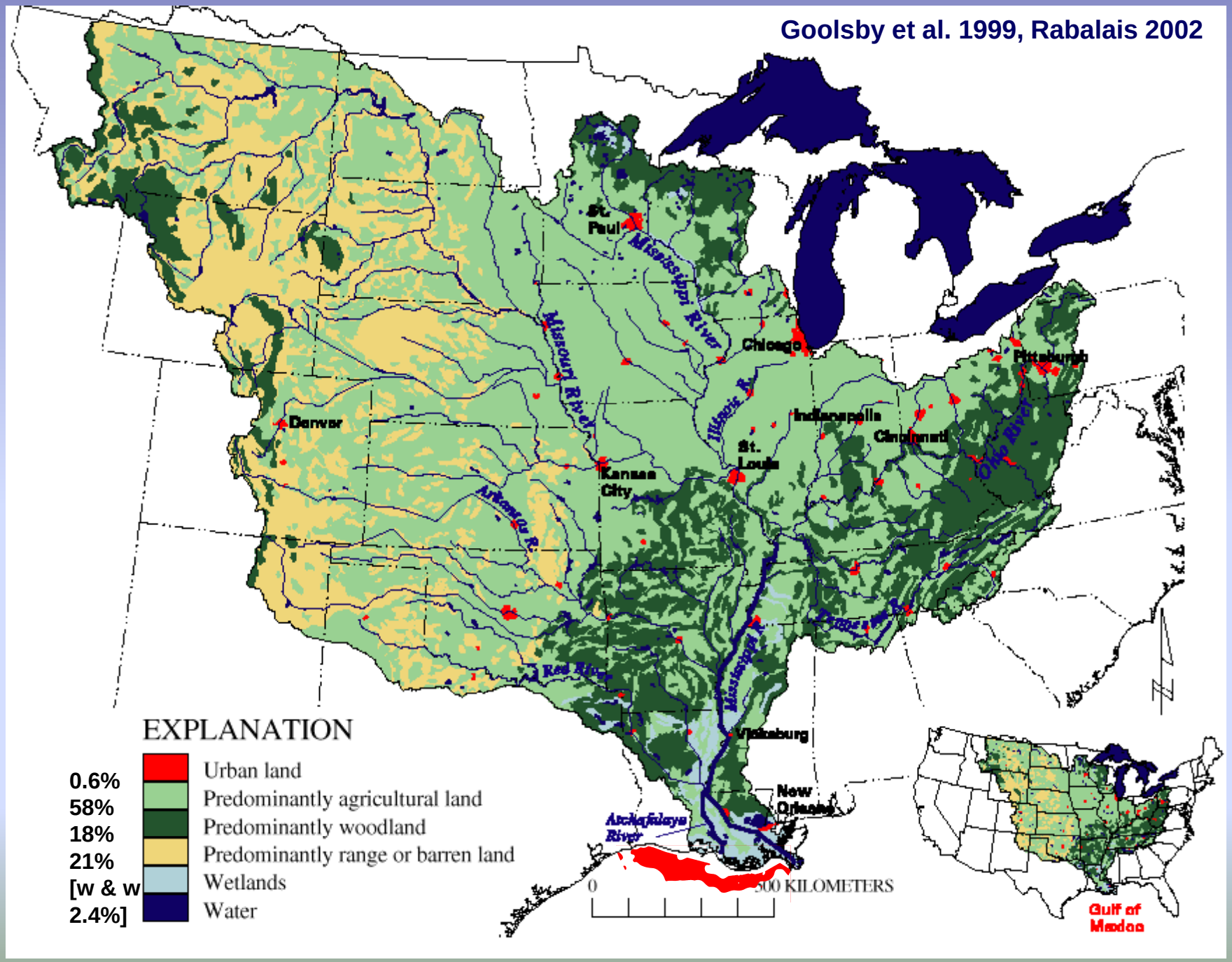
Hypoxic Area Up to 40,000 km²
Currently, non-existent or minimal

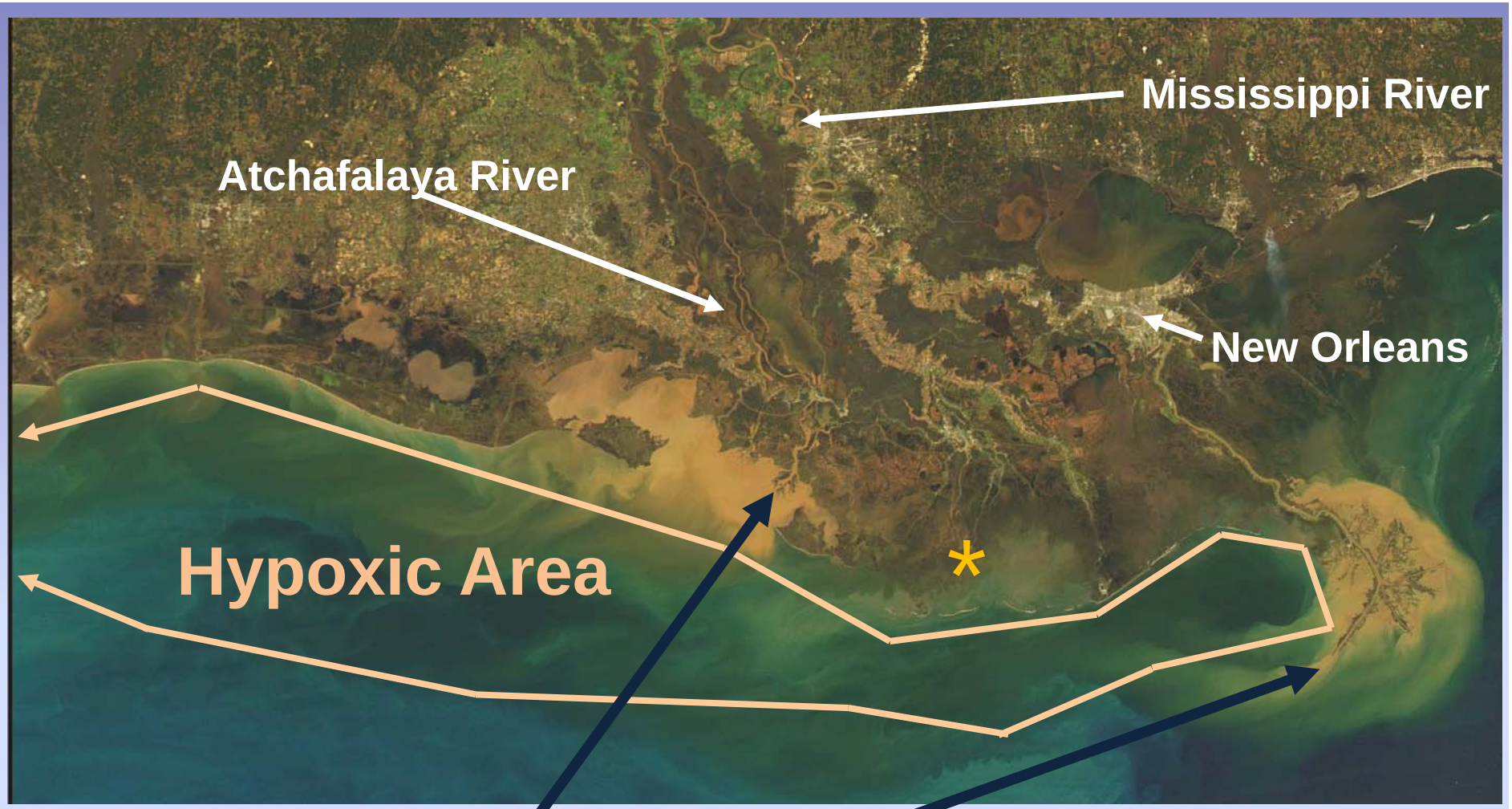
N and P Loads Correspond to Fertilizer Use





Mee 2006

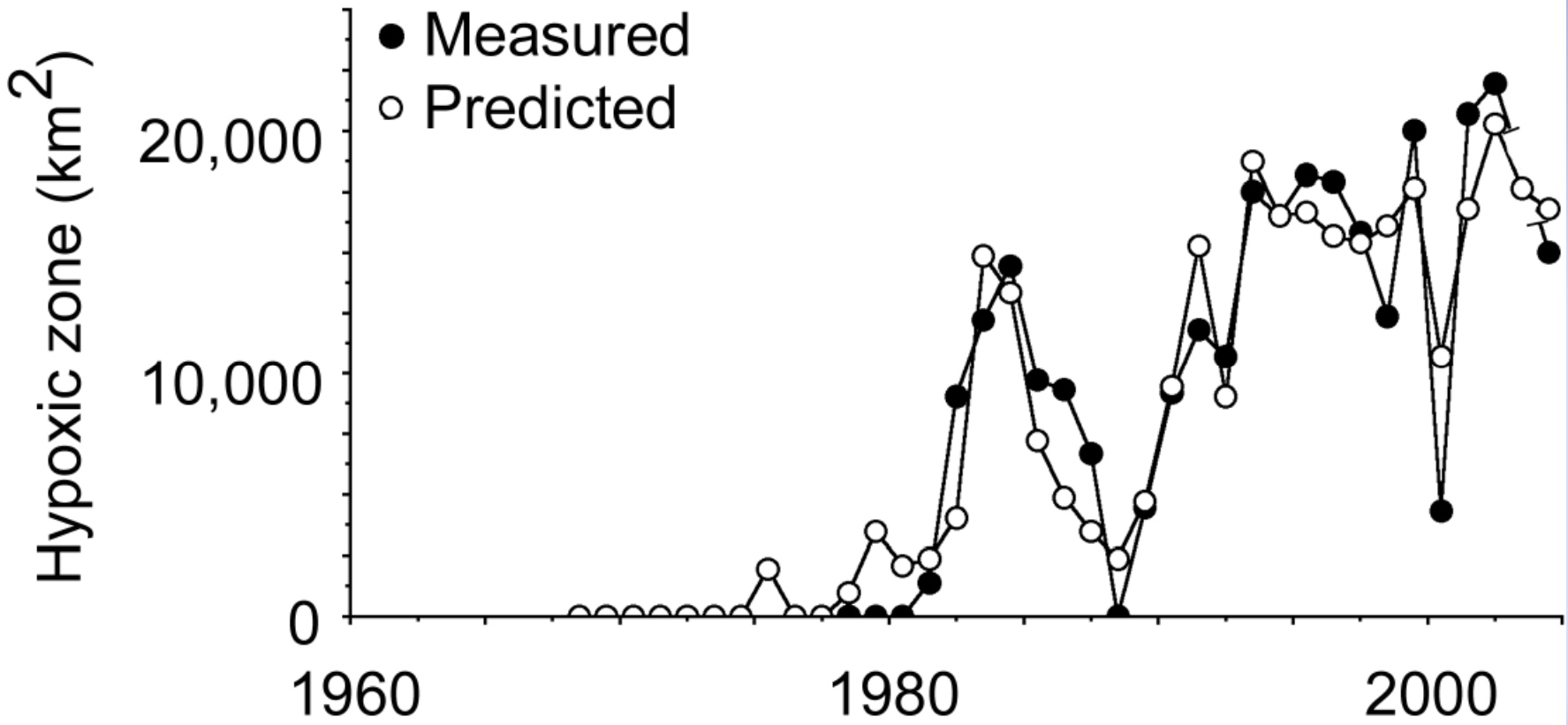

Goolsby et al. 1999, Rabalais 2002
EXPLANATION
0.6%
58%
18%
21%
[w & w
2.4%]
Urban land
Predominantly agricultural land
Predominantly woodland
Predominantly range or barren land
Wetlands
Water
0
500 KILOMETERS
St. Paul
Mississippi River
Missouri River
Chicago
Pittsburgh
Denver
Indianapolis
Cincinnati
St. Louis
Kansas City
Ohio River
Arkansas R.
Red River
Mississippi R.
Vicksburg
New Orleans
Atchafalaya River
Gulf of Mexico



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

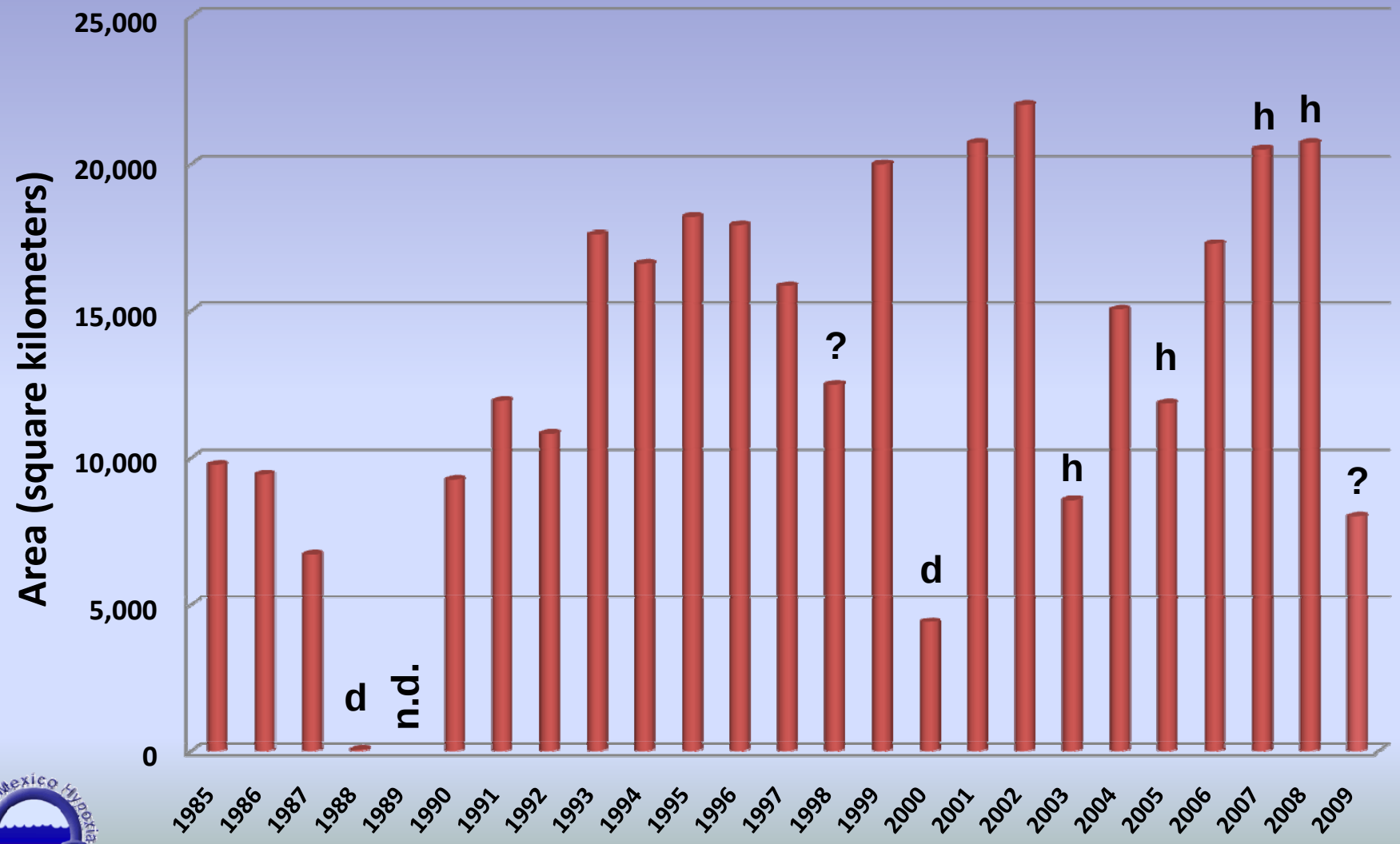
dominant wind direction

Predicting Hypoxia in summer (nitrate flux in May, year)



Turner et al. 2006

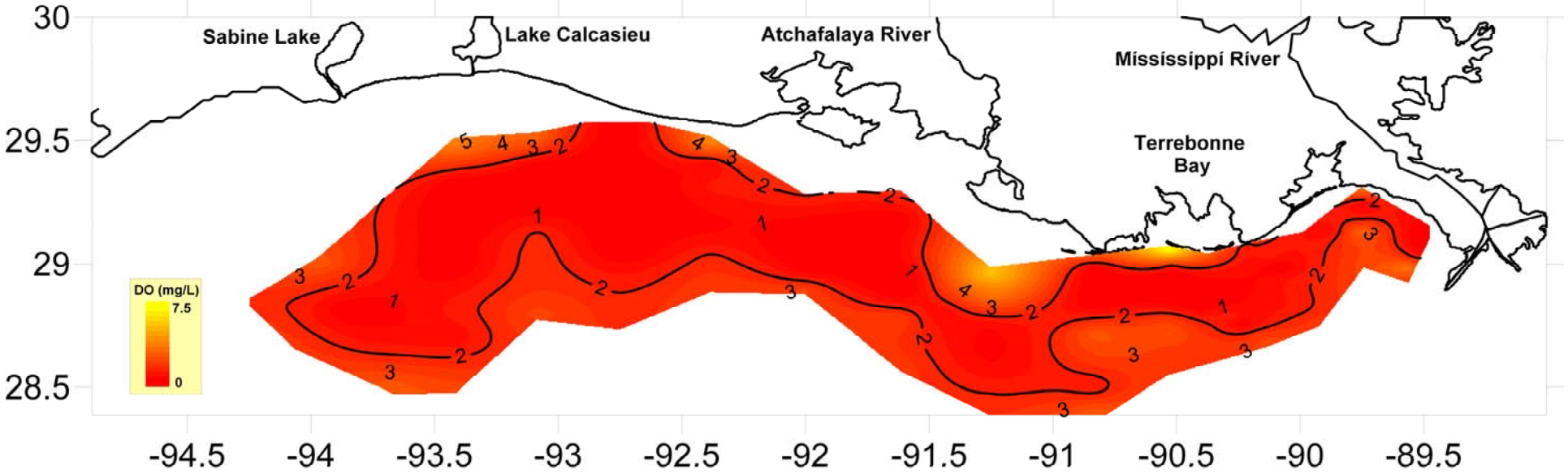
Area of Mid-Summer Bottom Water Hypoxia (Dissolved Oxygen < 2.0 mg/L)



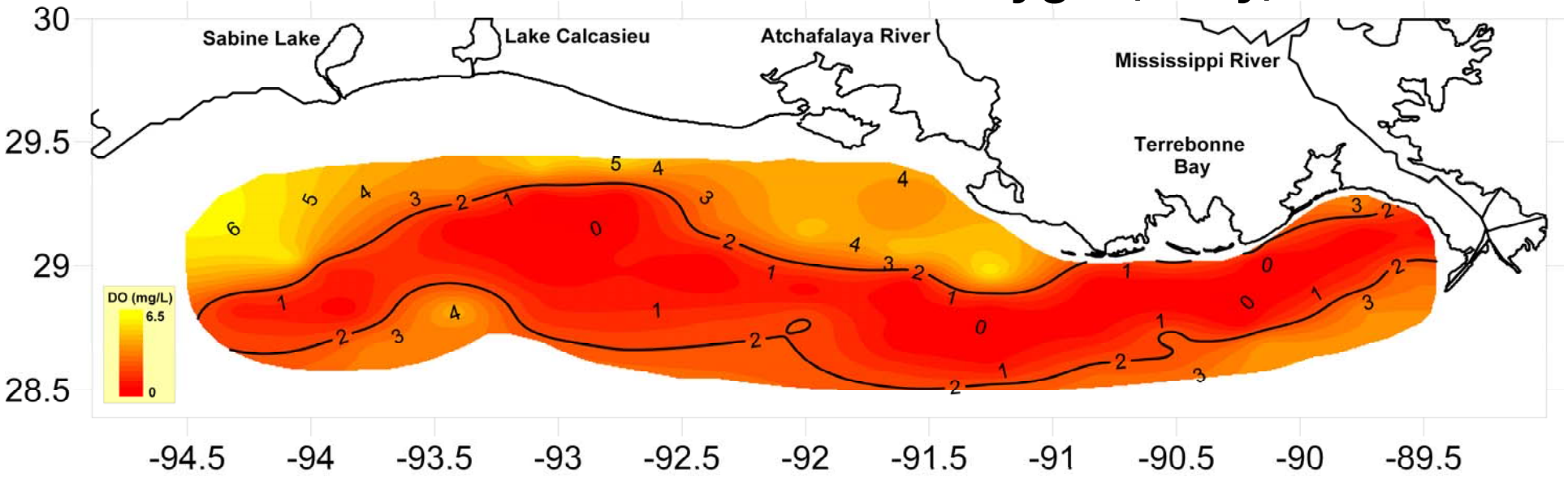
Data source: N.N. Rabalais, Louisiana Universities Marine Consortium, R.E. Turner, Louisiana State University

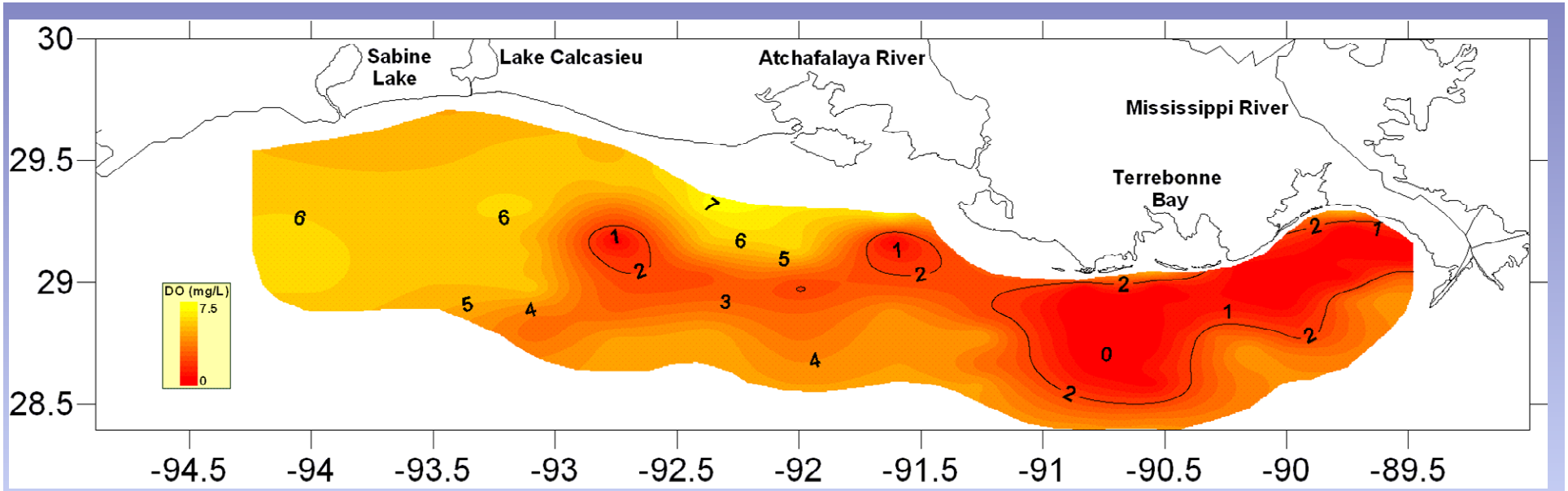
Funded by: NOAA, Center for Sponsored Coastal Ocean Research

Bottom-water Dissolved Oxygen, July, 2007



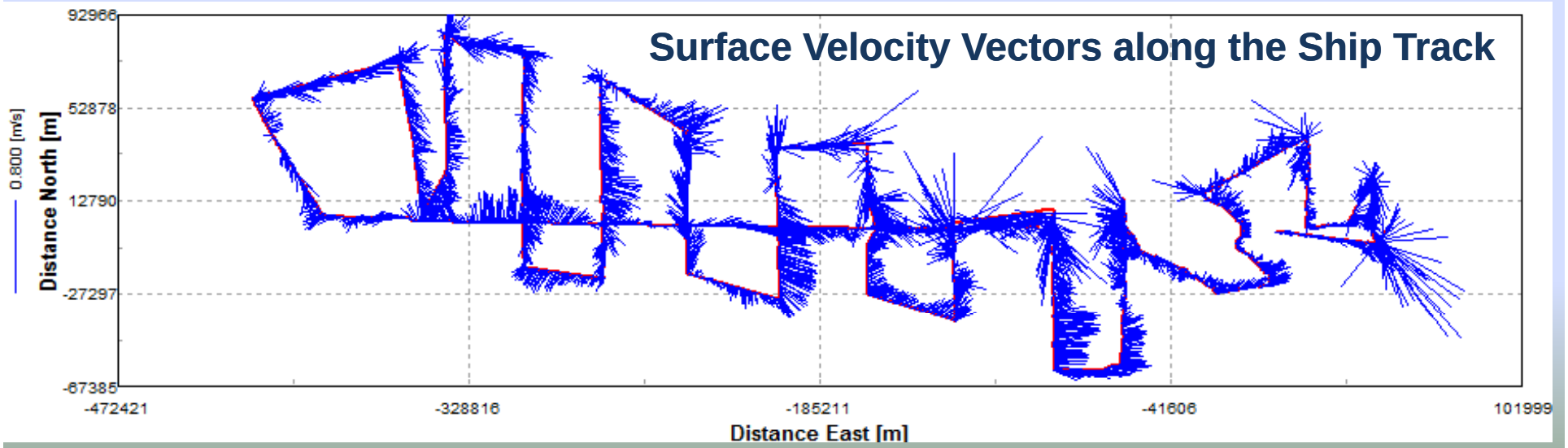
Bottom-water Dissolved Oxygen, July, 2008

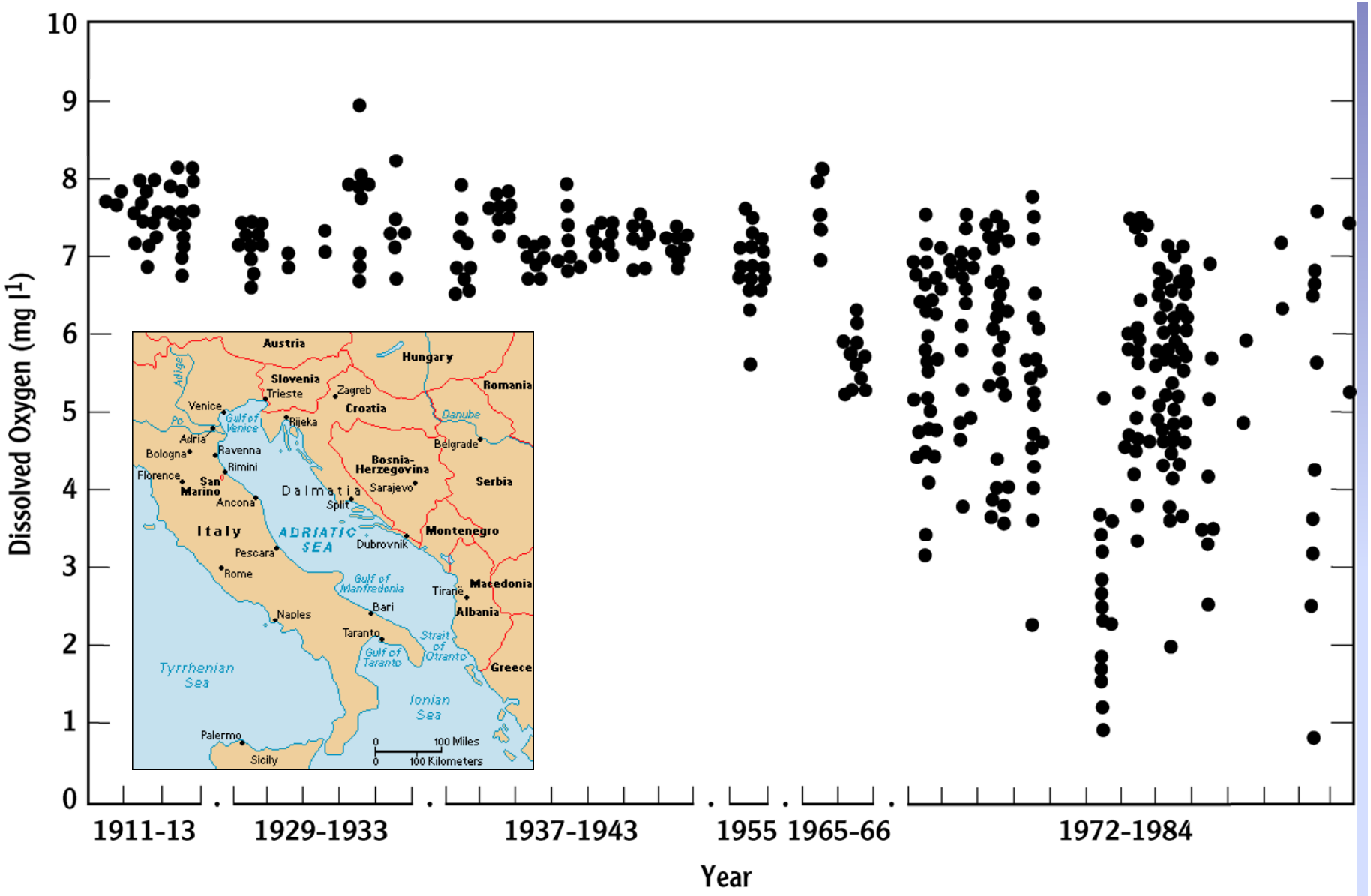




Data source: N.N. Rabalais, Louisiana Universities Marine Consortium, R.E. Turner, Louisiana State University
Funded by: NOAA, Center for Sponsored Coastal Ocean Research

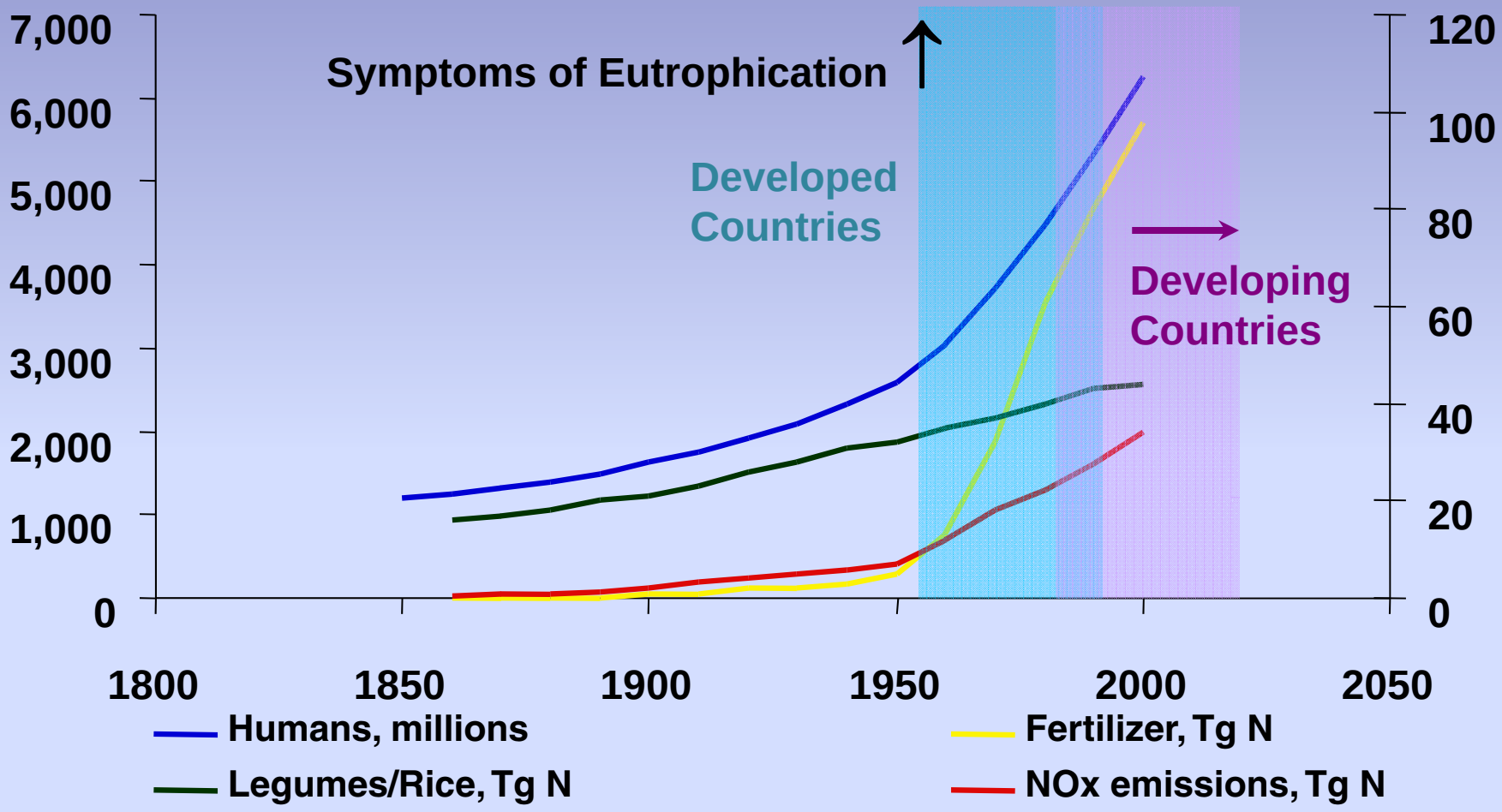
A relative strong east velocity (8.7 cm/s) for the 6.3 d survey
Over twice that of 2008





Oxygen content 2 m above the bottom during August-September in the northern Adriatic Sea from 1911 to 1984 for the periods indicated. Surface water oxygen content increased in the 1972-1984 summer period, and Secchi disk depth during April-May decreased dramatically in 1966 and in the 1972-1984 period. Statistical trends for the bottom water oxygen (shown), surface water oxygen and Secchi disk depth were all significant at $P = 0.05$. Redrawn from Justić (1991) with permission.

They are increasing.



(modified by N. Rabalais; Galloway and Cowling 2002; Boesch 2002)

Emerging Problems

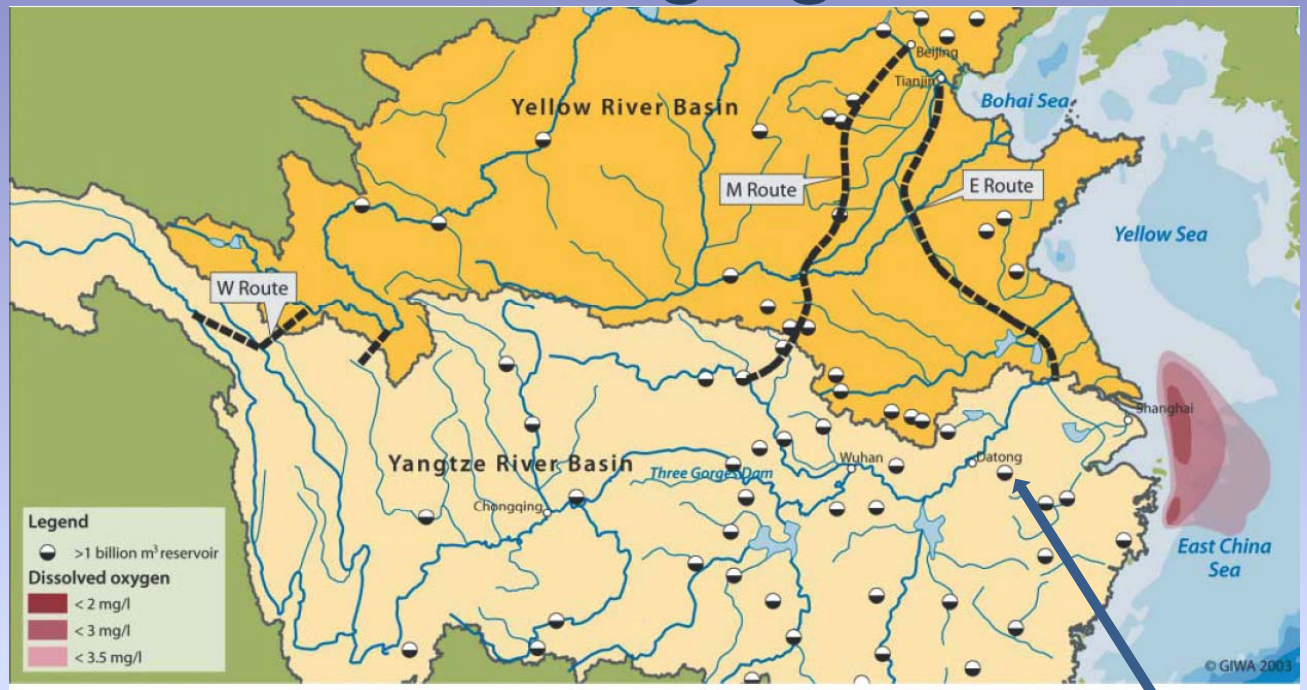


Figure 3. The Yangtze River drainage basin and the estimated hypoxy areas in the E

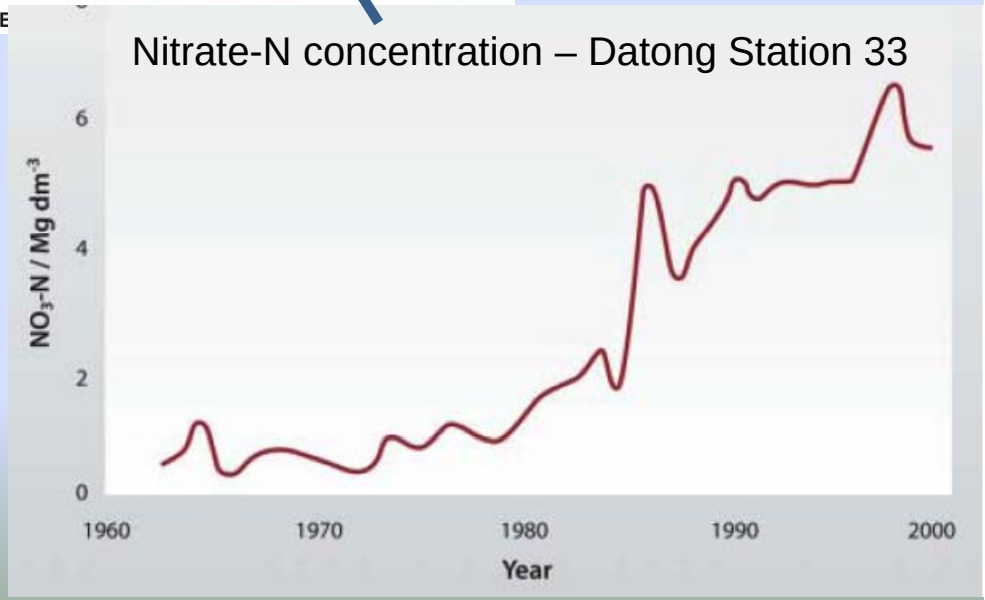
Li and Daler 2004

Increases in
Harmful Algal Blooms
~
Atmospheric N Deposition
in East China Sea

East China Sea

14,000 km² Annual Hypoxia

Nitrate-N concentration – 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

Dead Zone
Oregon/Washington
U. S. Pacific Northwest

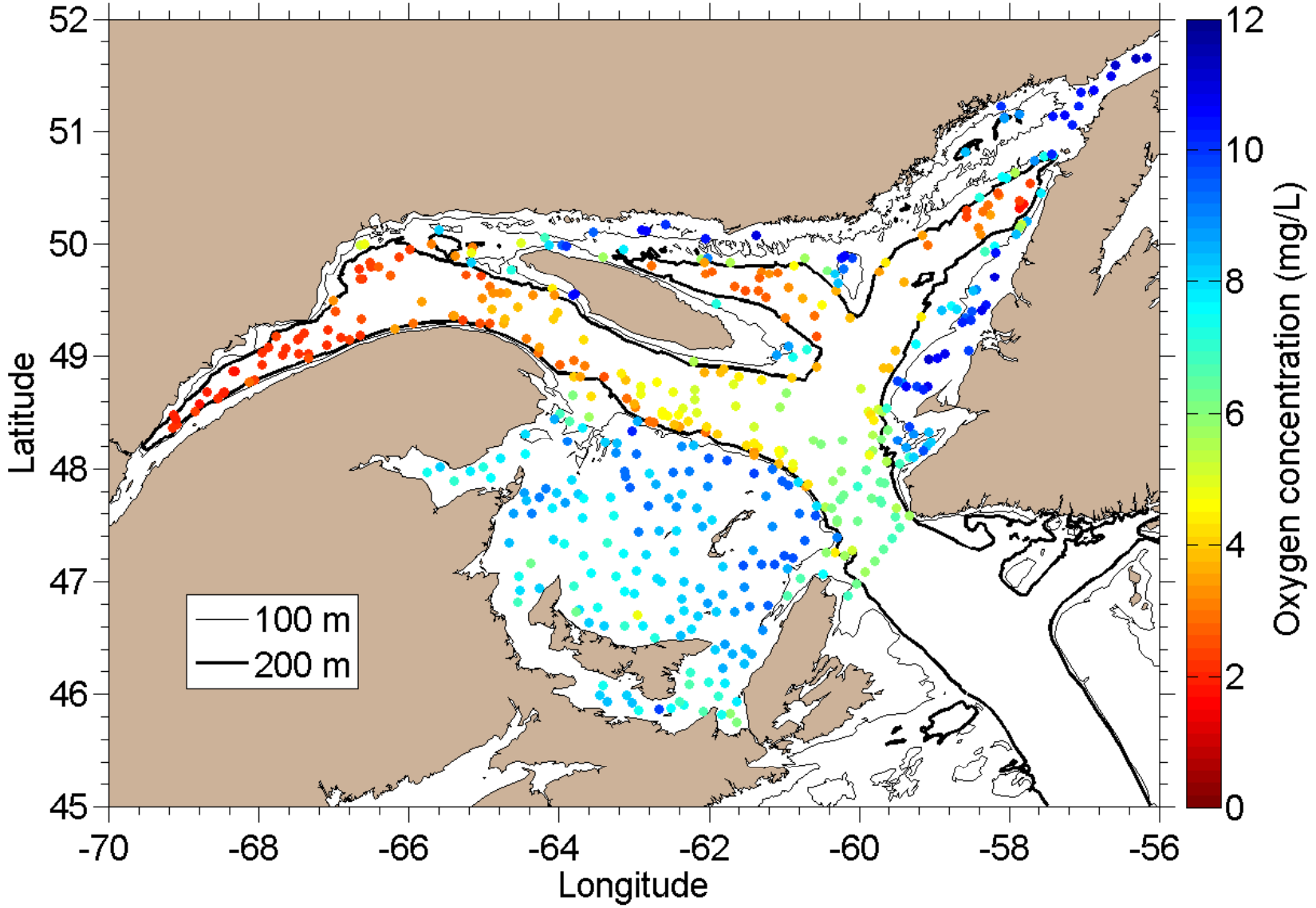
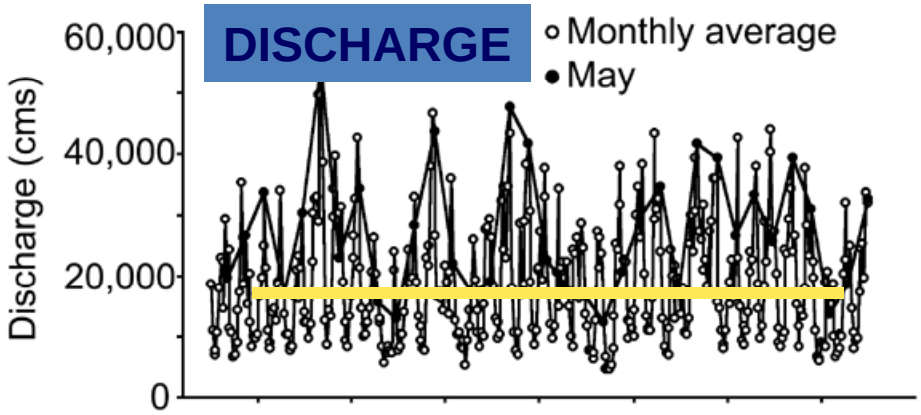


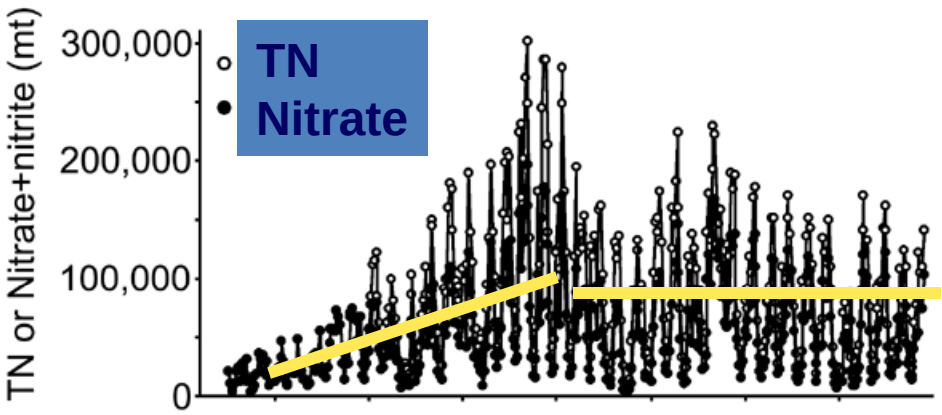
Fig. 9. Near-bottom oxygen concentration (mg L^{-1}) measured during the 2004 (southern and northern Gulf of St. Lawrence) and 2005 (only the northern part of the Gulf of St. Lawrence) fish stock assessment surveys. Modified from data published in Gilbert et al., 2007). Used with permission from Société Provancher.

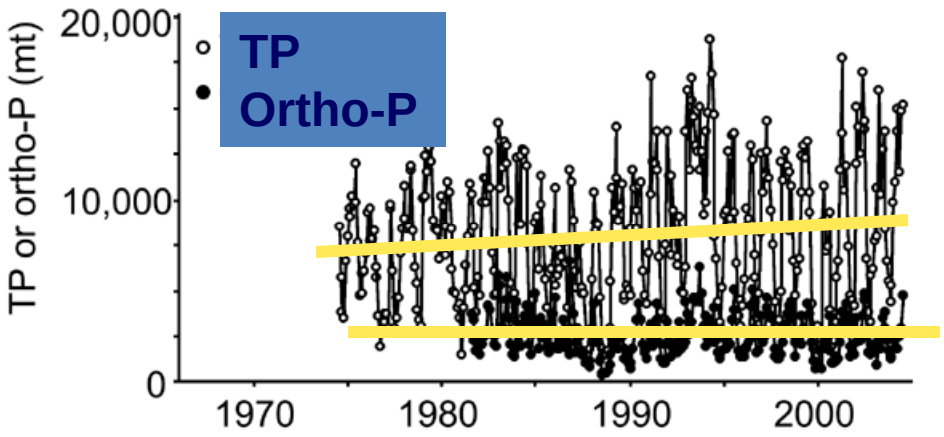
300% increase in N load

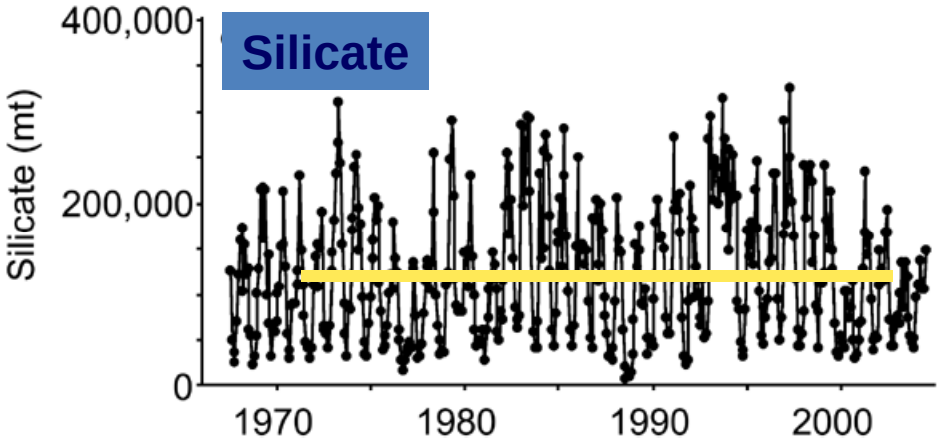
80% due to NO_3^- concentration ↑

20% due to discharge ↑



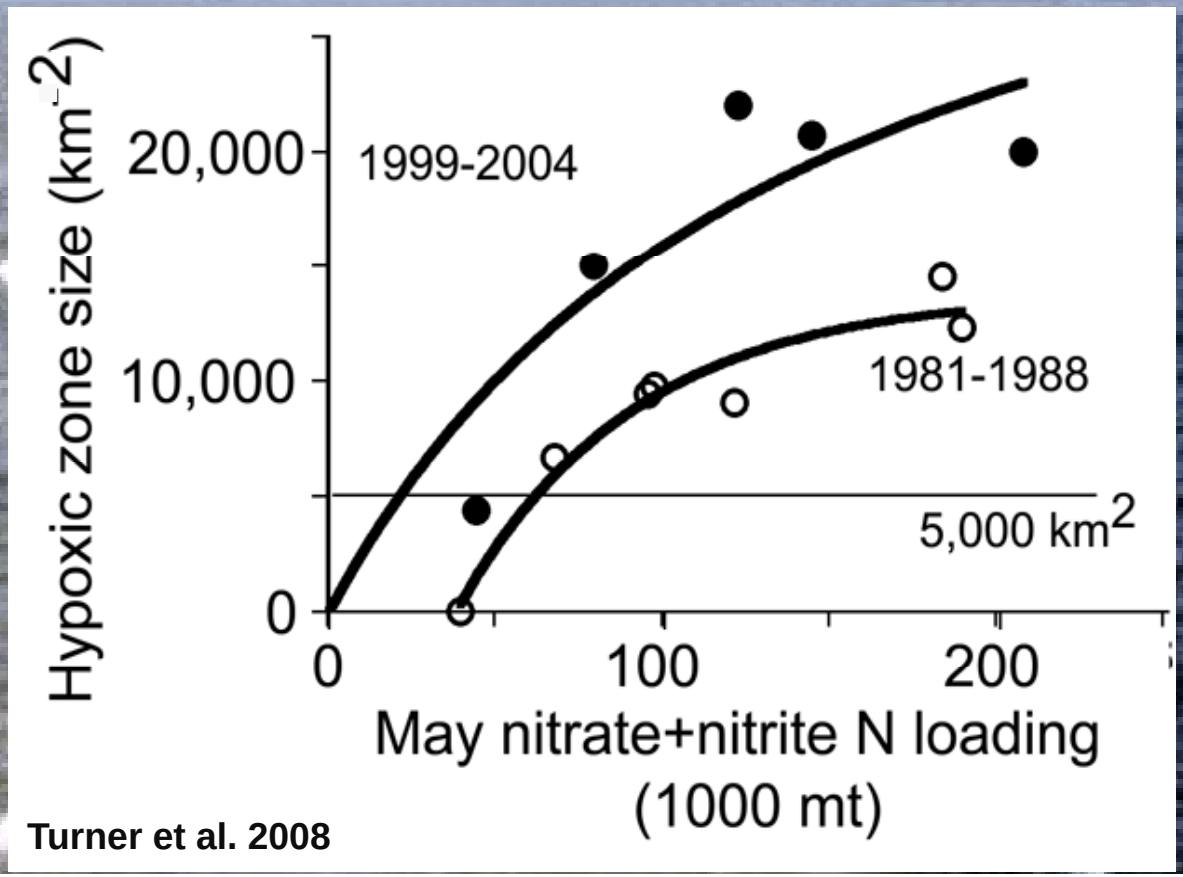






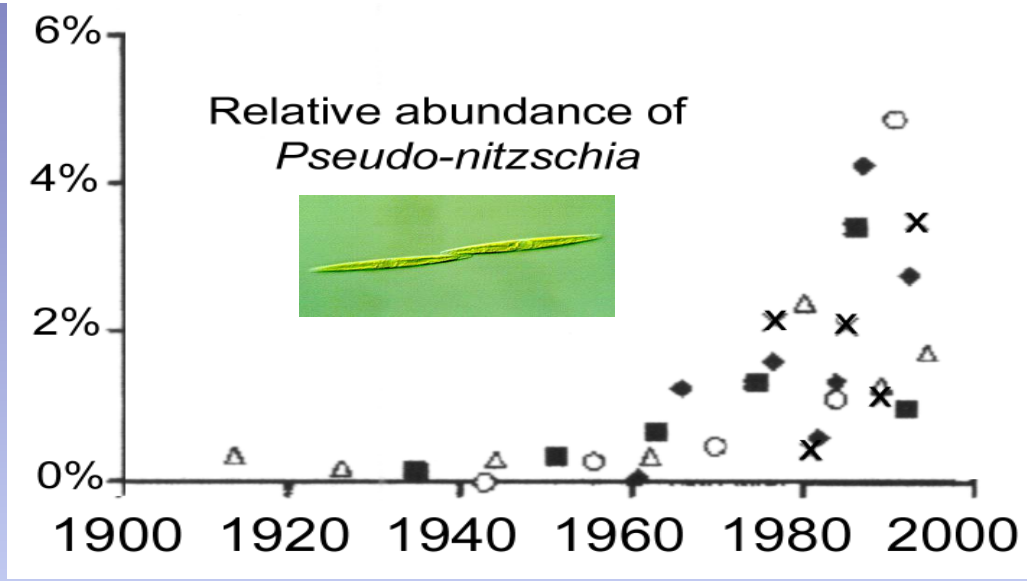
Turner et al. 2007

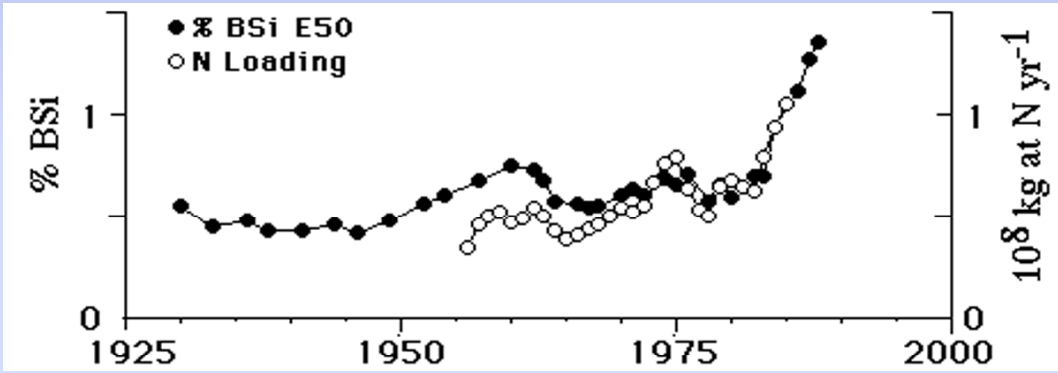
More Nutrients >>>
More Phytoplankton >>>
More Carbon Reaches the Bottom >>>
More Oxygen Consumed >>>
More Hypoxia
Verified by Paleoindicators

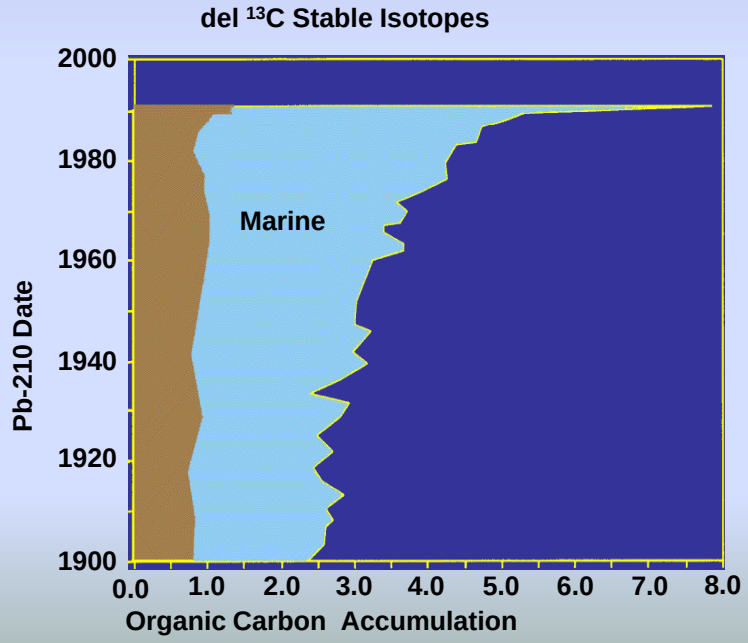


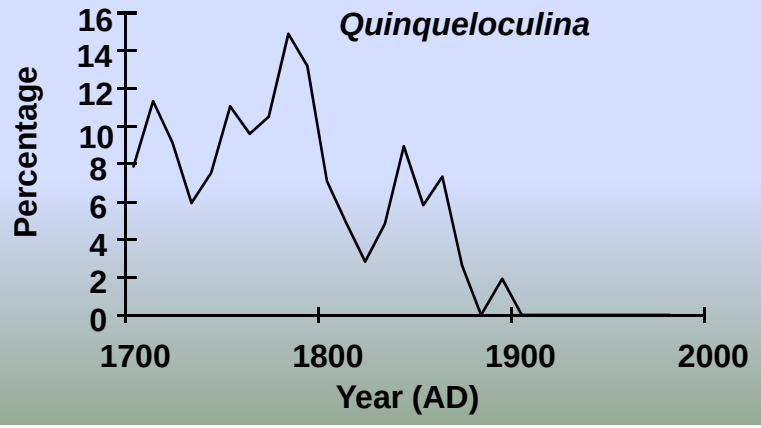
Turner et al. 2008

Photo: N. Rabalais, LUMCON


Relative abundance of
Pseudo-nitzschia
6%
4%
2%
0%
1900
1920
1940
1960
1980
2000

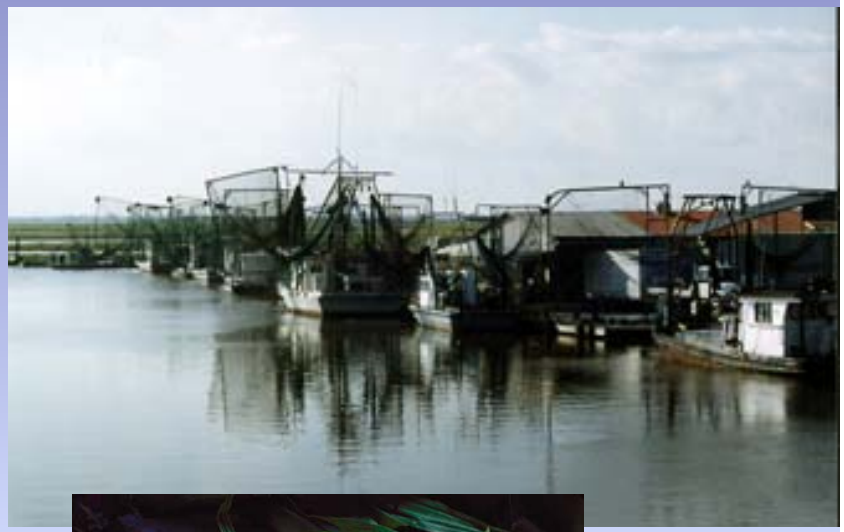

% BSi E50
N Loading
% BSi
1
0
1925
1950
1975
2000
10^8 kg at N yr^{-1}
1
0

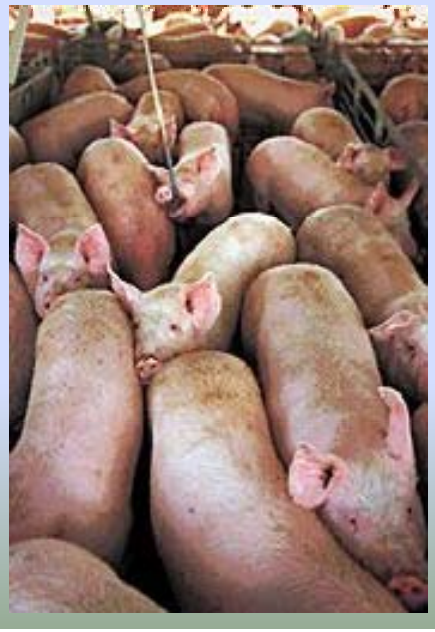

del ^{13}C Stable Isotopes
Pb-210 Date
2000
1980
1960
1940
1920
1900
Marine
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
Organic Carbon Accumulation

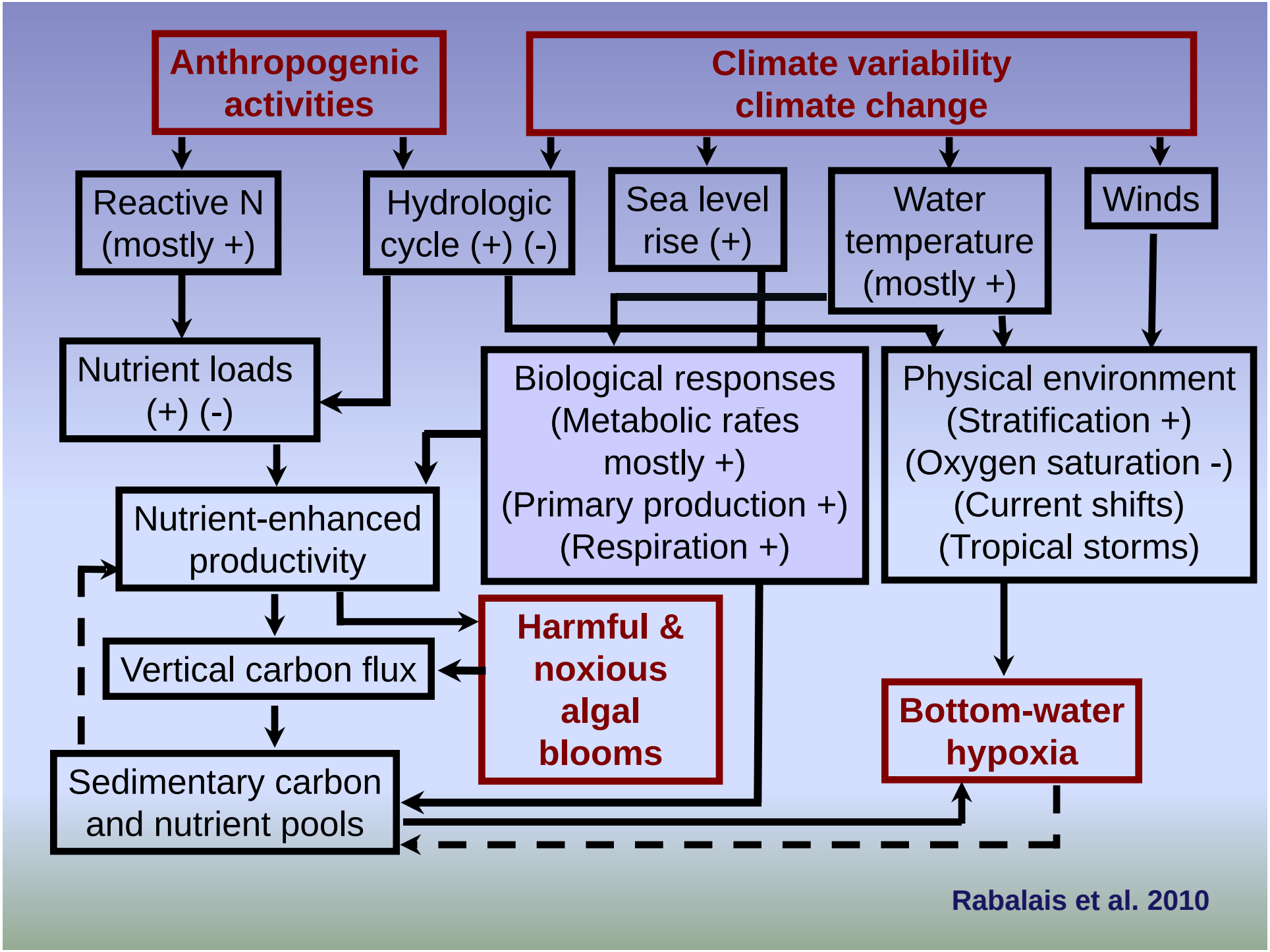

Quinqueloculina
Percentage
16
14
12
10
8
6
4
2
0
1700
1800
1900
2000
Year (AD)

The Future

Climate Change
Biofuels
Increased Population
Increased Agribusiness
Increased Atmospheric Deposition






Anthropogenic activities
Climate variability climate change
Reactive N (mostly +)
Hydrologic cycle (+) (-)
Sea level rise (+)
Water temperature (mostly +)
Winds
Nutrient loads (+) (-)
Biological responses (Metabolic rates mostly +) (Primary production +) (Respiration +)
Physical environment (Stratification +) (Oxygen saturation -) (Current shifts) (Tropical storms)
Nutrient-enhanced productivity
Harmful & noxious algal blooms
Vertical carbon flux
Bottom-water hypoxia
Sedimentary carbon and nutrient pools
Rabalais et al. 2010

“Thanks”
to all contributors and funding agencies