Nitrogen-Eutrophication Dynamics in Estuaries

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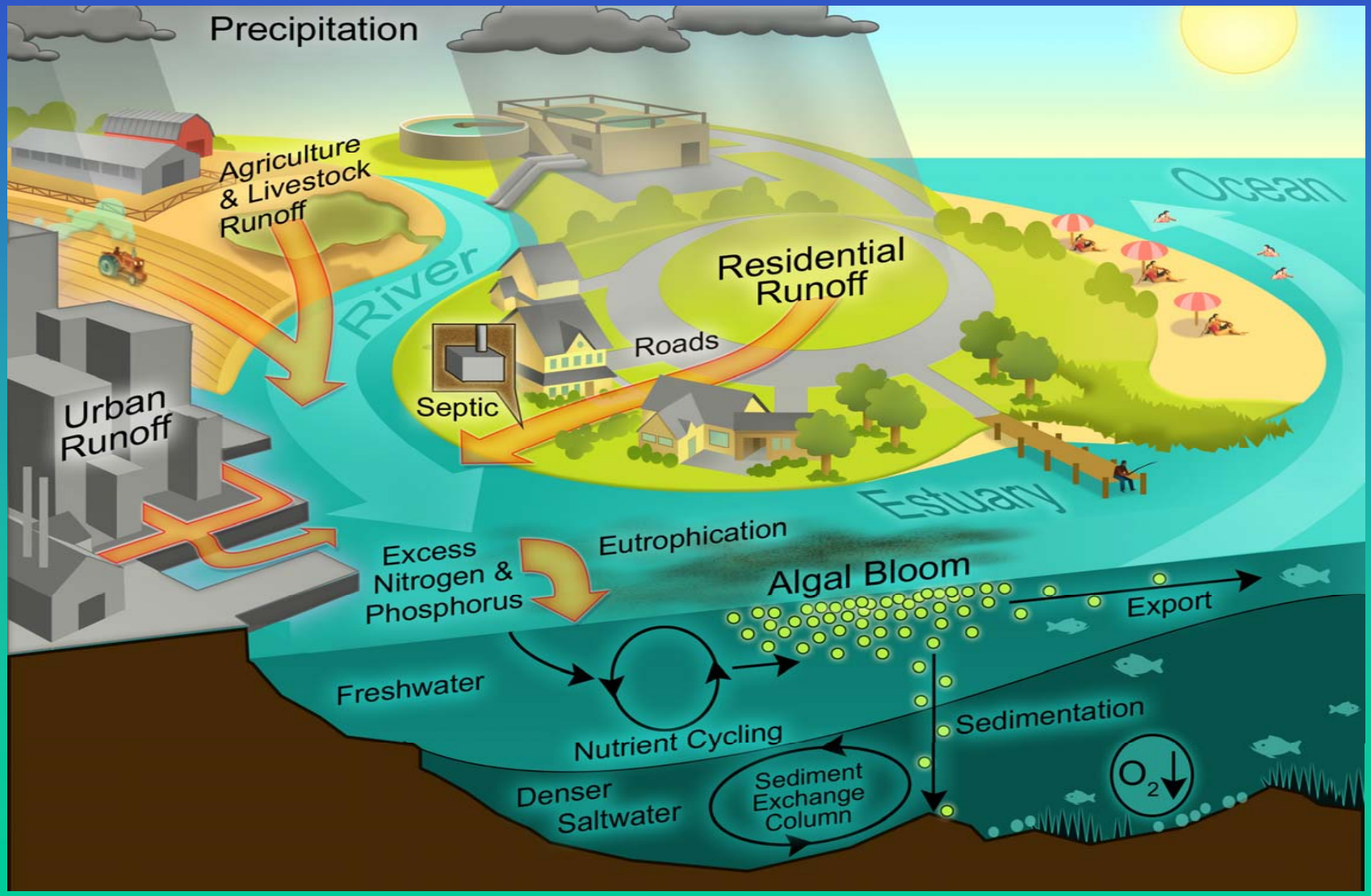


Key Estuarine Nutrient Issues

- Primary production in estuarine waters is largely N limited; however some systems are N & P co-limited or P limited

- N (& P) Over-enrichment linked to eutrophication

- Sources, forms and proportions of N loading are changing

  e.g. point & non-point surface runoff, atmospheric deposition, groundwater

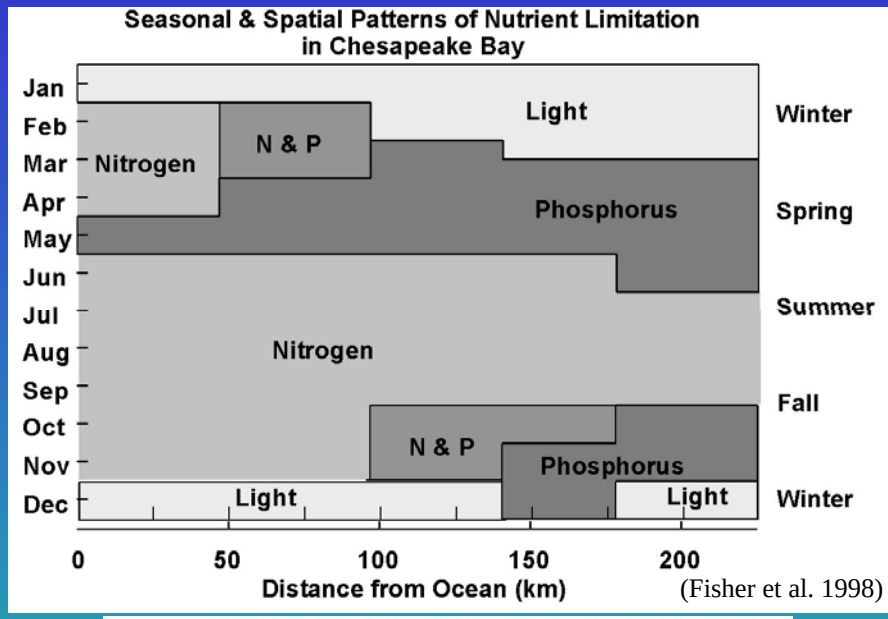
- Ammonium is increasing as a N source

  Hypoxia, Increased wastewater loads, Ag runoff

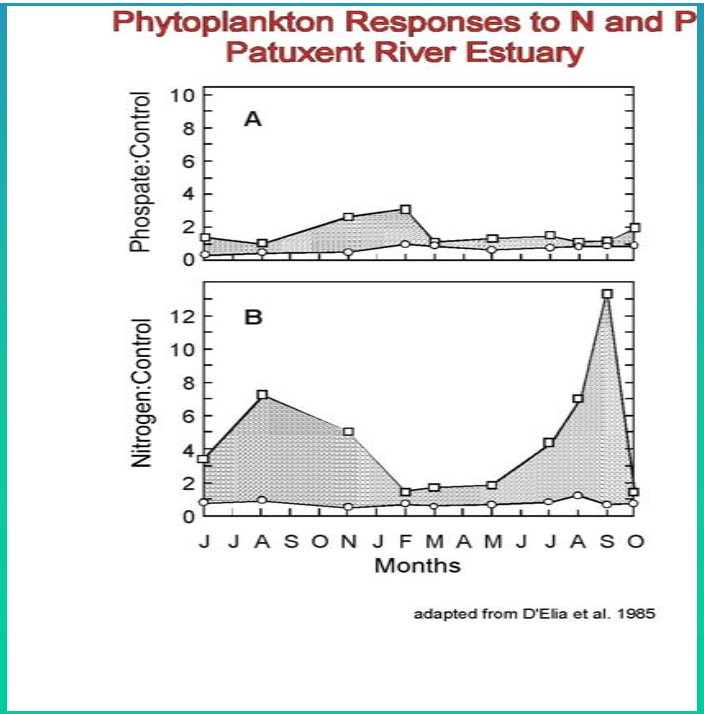
- Ecological Effects?*

* nuisance algal blooms, toxicity, hypoxia/anoxia, food web alterations

Nutrient limitation in the Chesapeake Bay

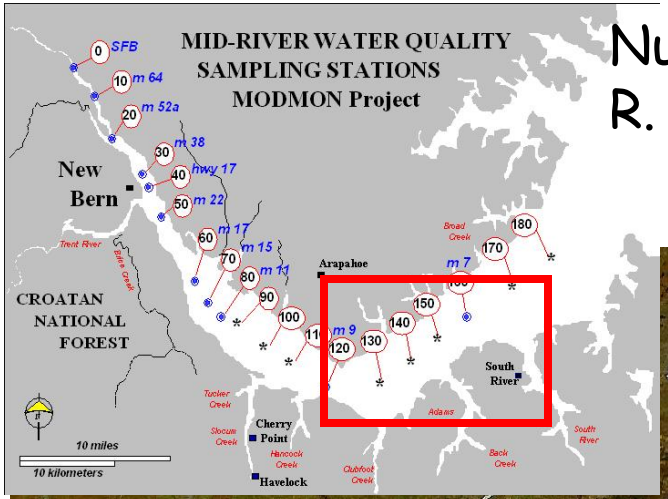


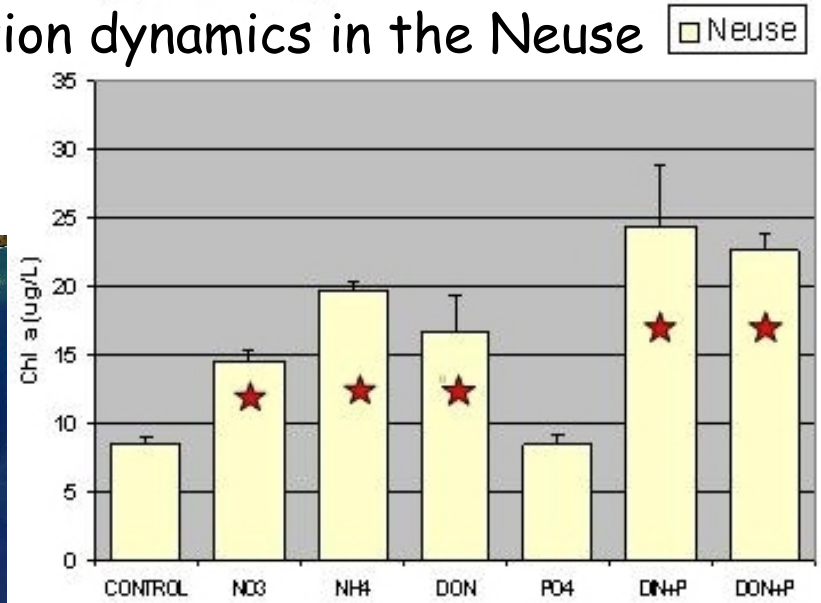
(Fisher et al. 1998)

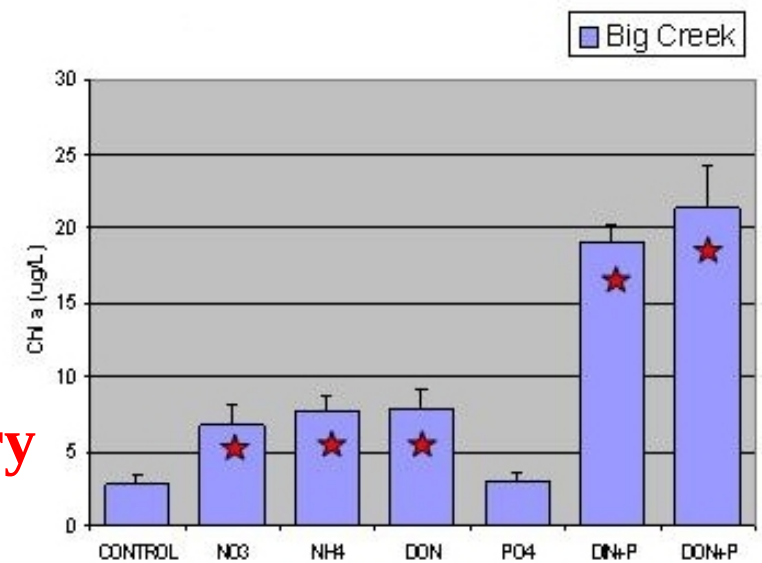


Fisher et al. 1998

Nutrient limitation dynamics in the Neuse R. Estuary, NC

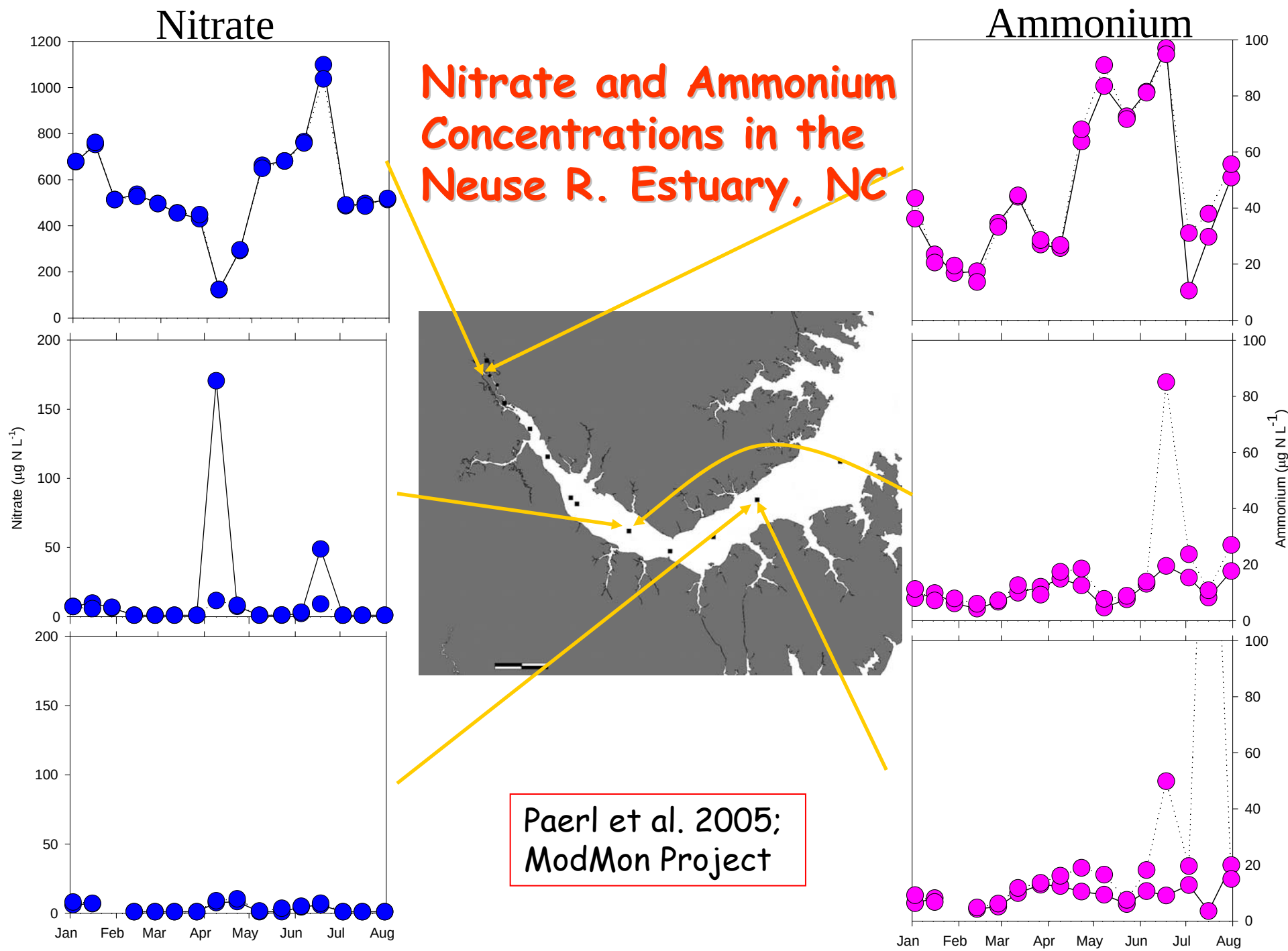






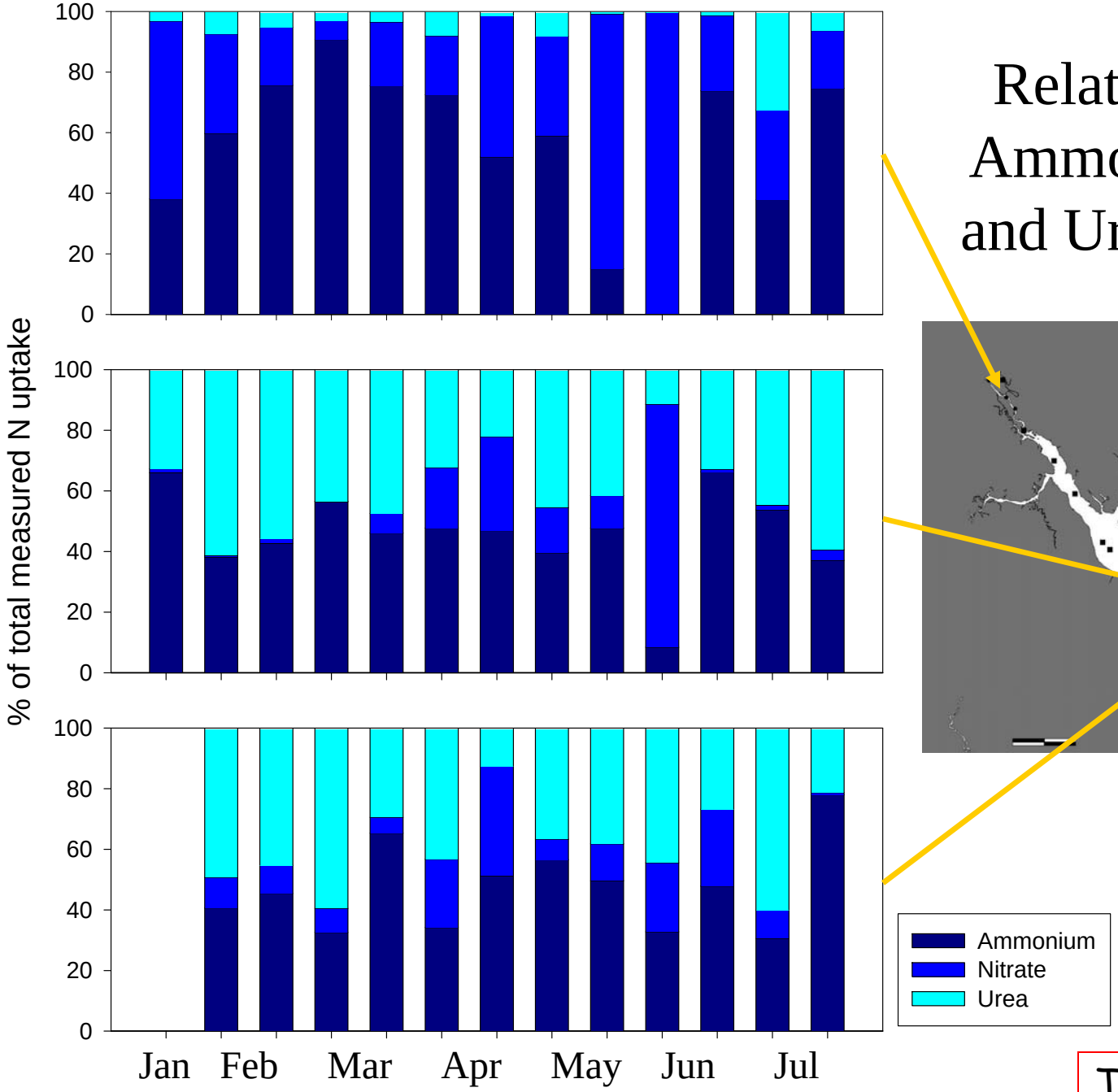
Gallo 2004

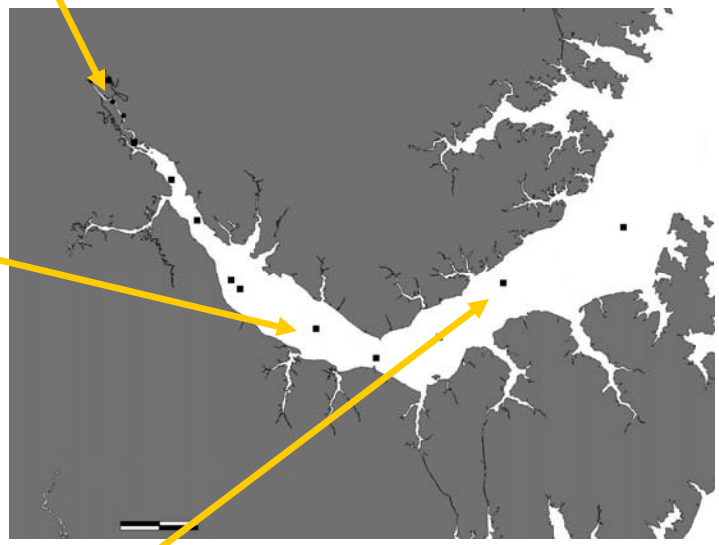
Nitrate and Ammonium Concentrations in the Neuse R. Estuary, NC



Paerl et al. 2005;
ModMon Project

Relative uptake of Ammonium, Nitrate and Urea in the NRE



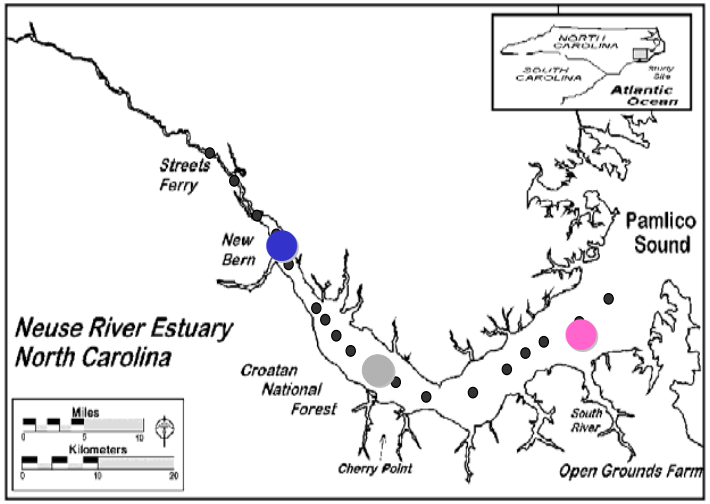


Twomey et al. 2005

Conclusions (For Neuse R. Estuary)

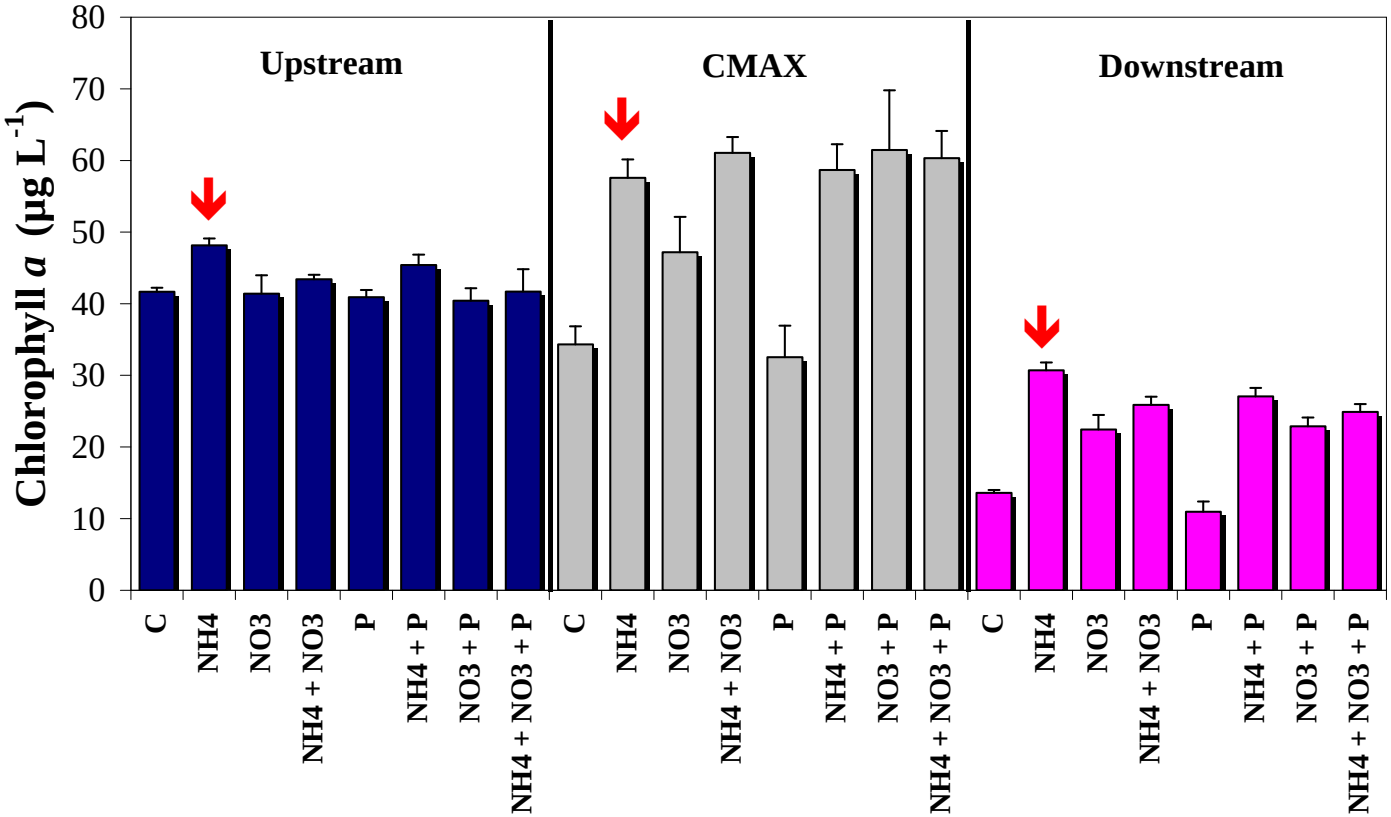
- All forms of N are readily utilized
- Uptake of various N forms reflects their availability & concentrations

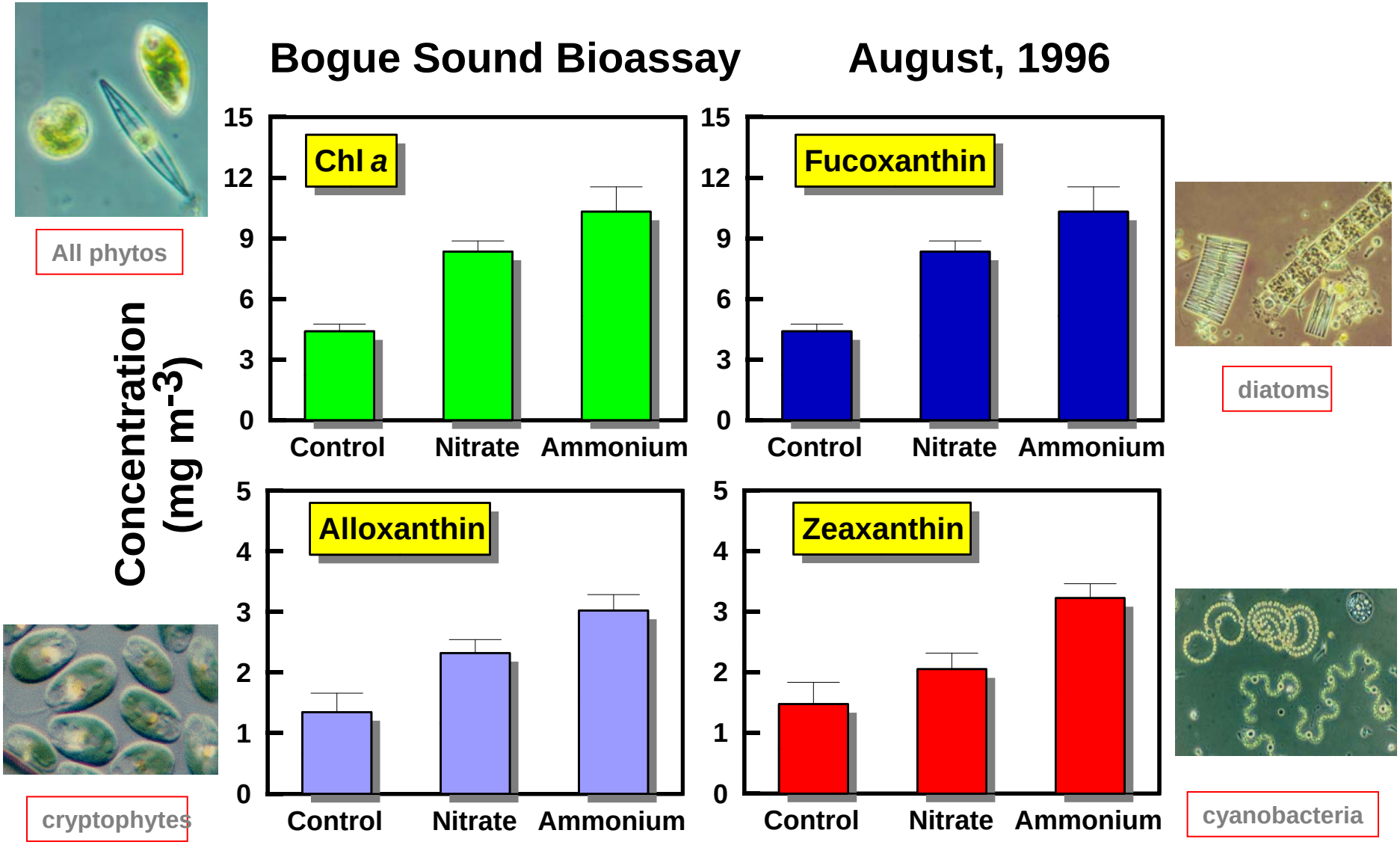
Ammonium is often a preferred N source, and it is increasing. What are the effects on phyto community structure?



Twomey et al. 2005

Nutrient Addition Bioassay Experiment, T1
Neuse River, July 2003

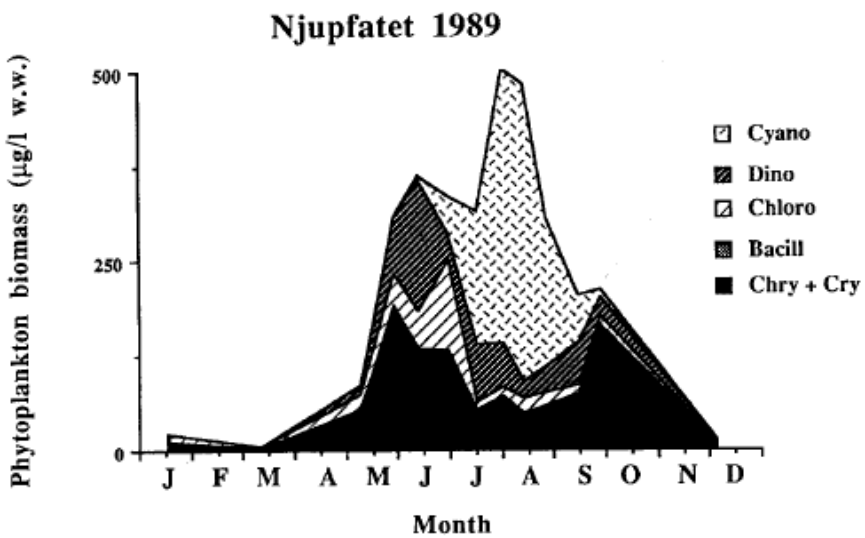




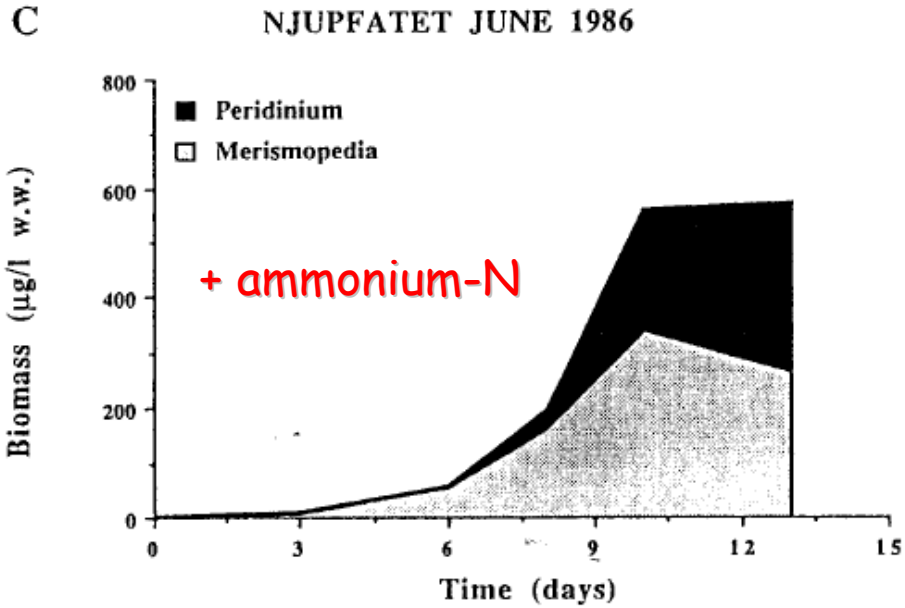
Paerl et al. 2006

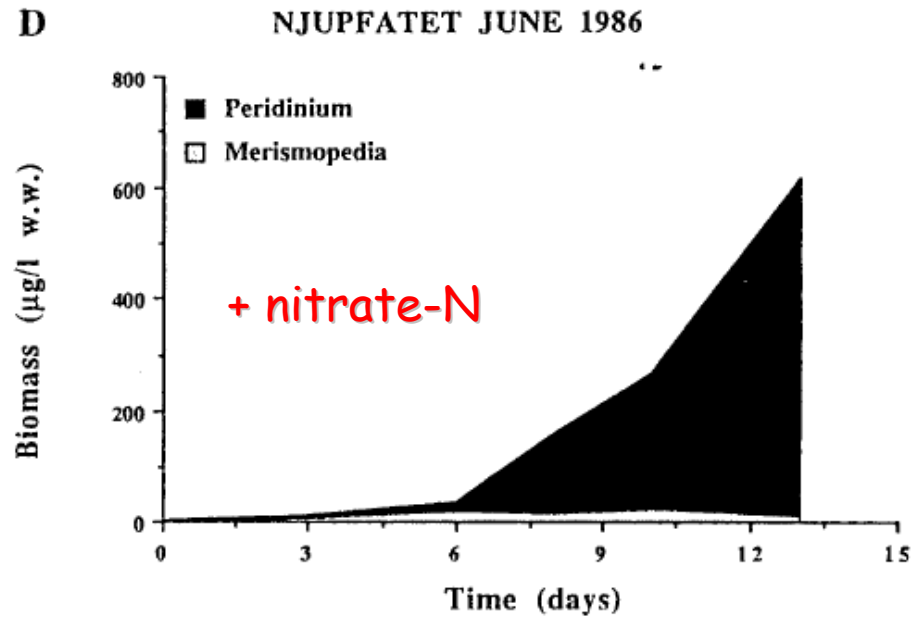
N source can affect cyanobacterial dominance: Lake Njupfatet, Sweden

148 Peter Blomqvist, Annette Pettersson and Per Hyenstrand



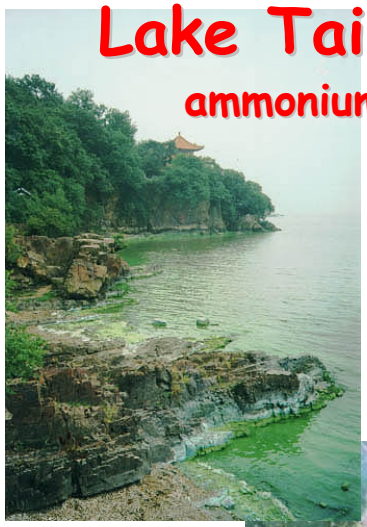
Ammonium and dominance of cyanobacteria 155



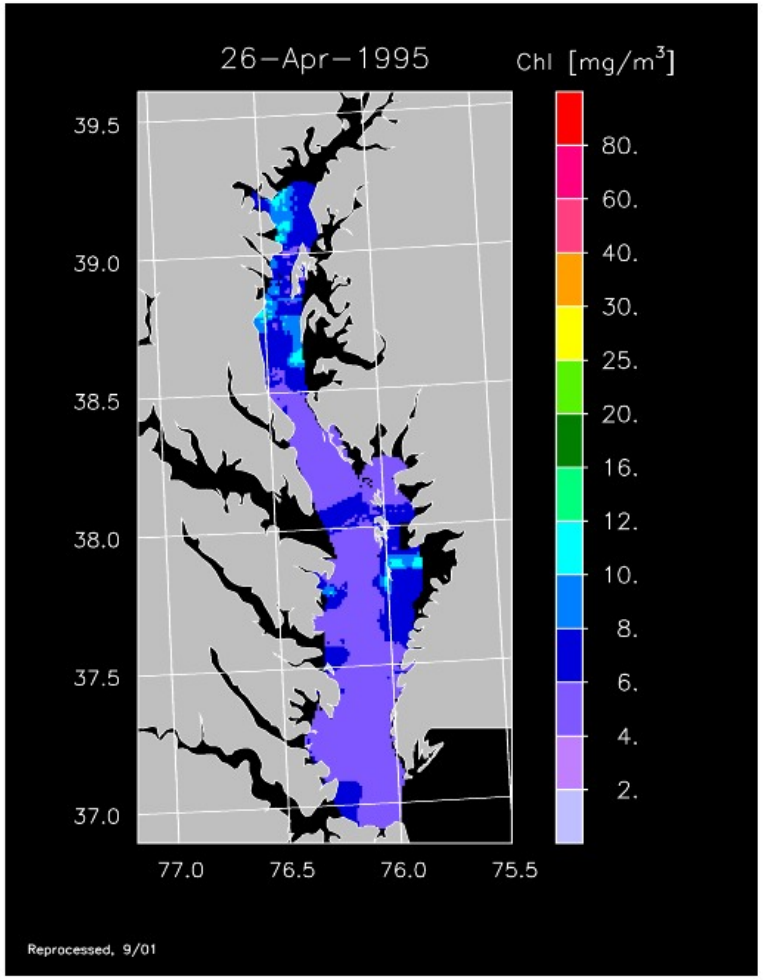


Blomqvist et al. 1994

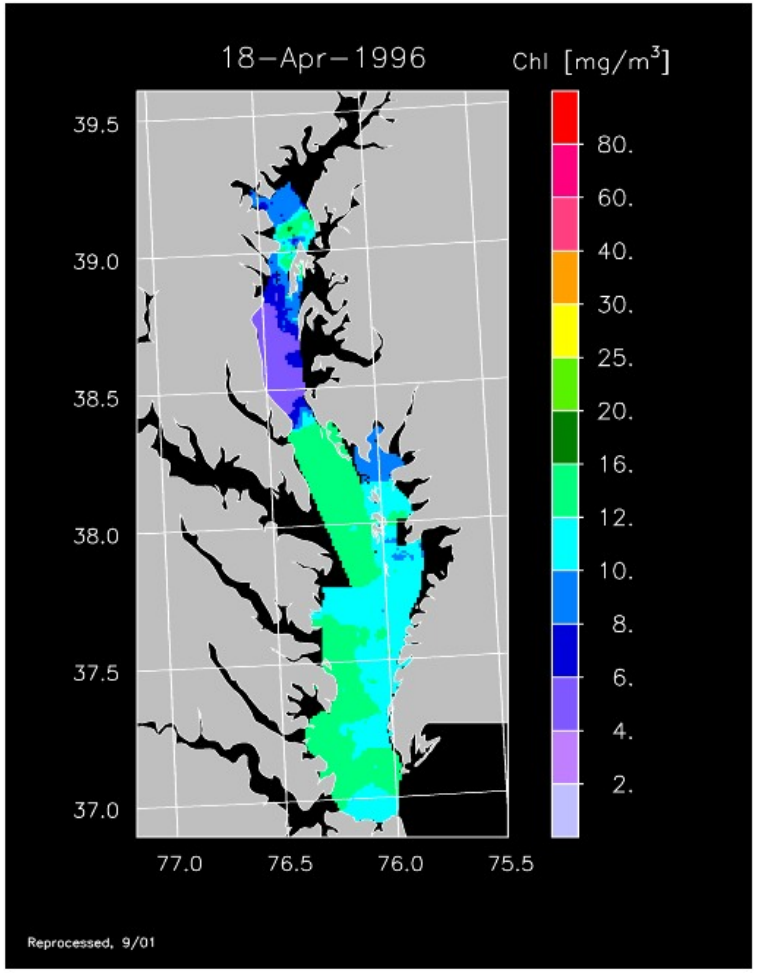
Lake Taihu 3rd largest lake in China. Increased N loads (dominated by ammonium) . Blooms have grown to "pea soup" conditions within a decade



Freshwater discharge and residence time matter as well
Hydrologic controls of chl-a production and composition:
SeaWiFS (SAS II) during low flow ('95) and high flow ('96) years



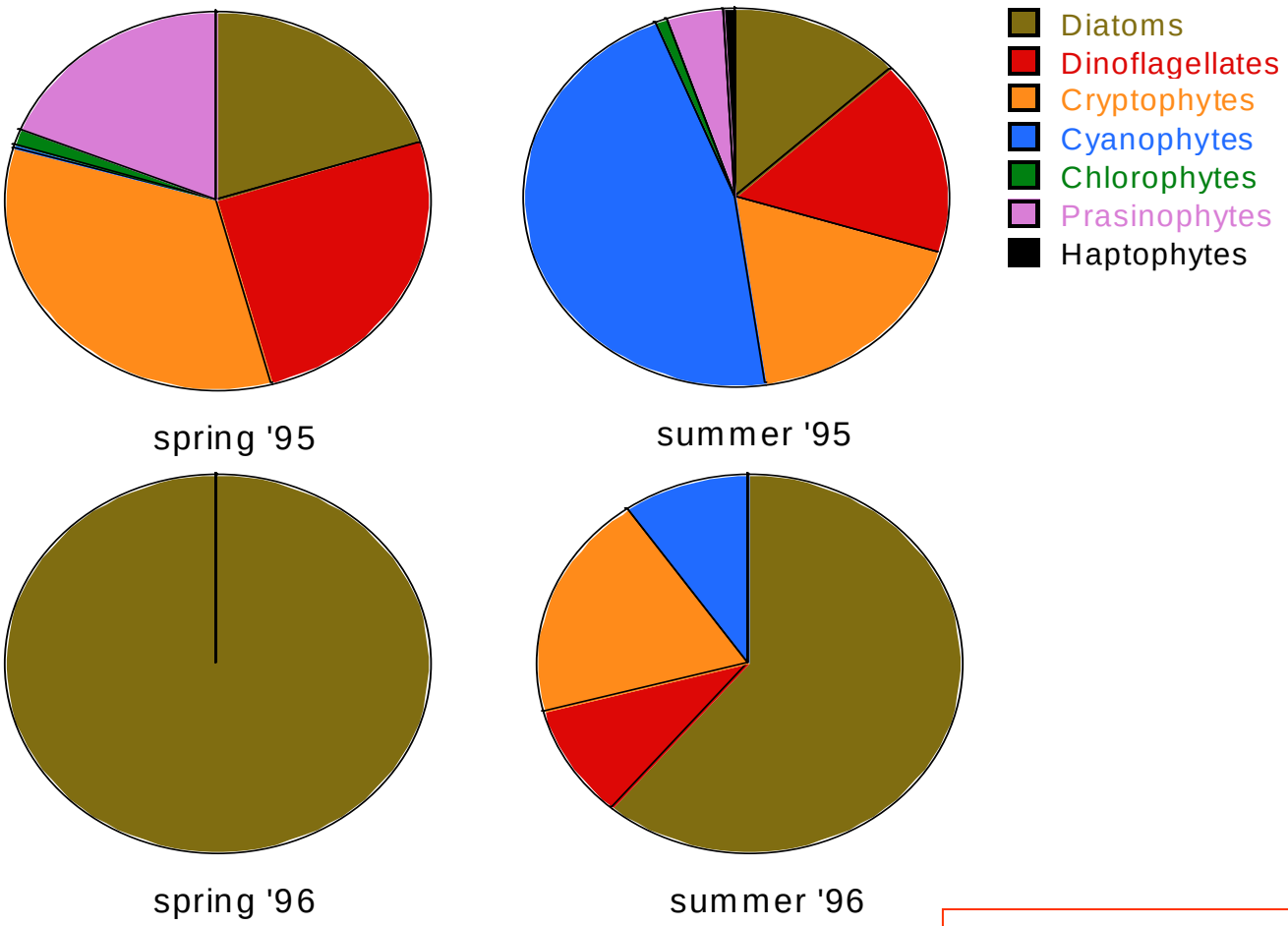
spring '95



spring '96

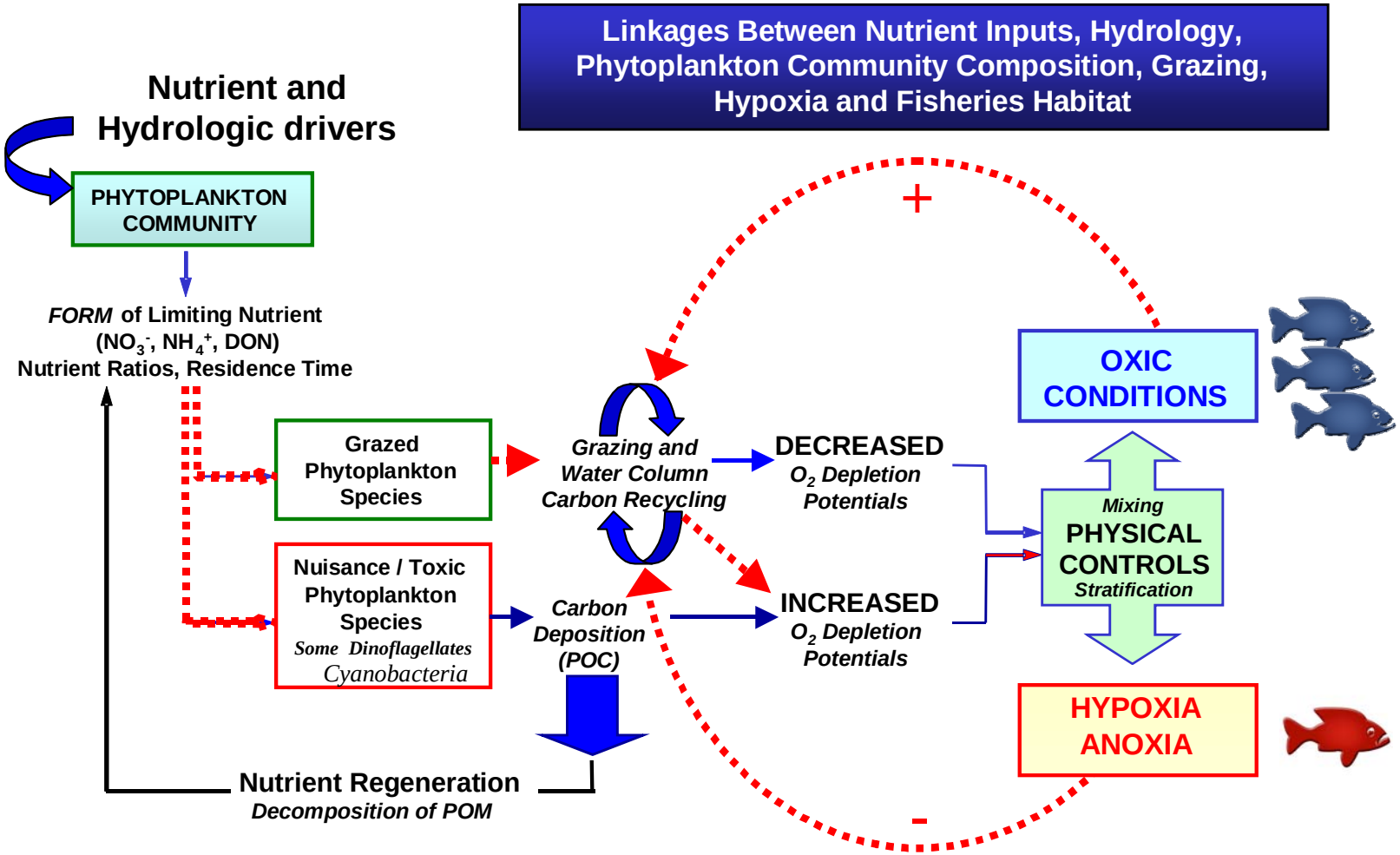
Harding et al. 2006

Chesapeake Bay phytoplankton composition by CHEMTAX – contrasting flow years



Adolph et al 2007

Nutrient cycling and food web implications

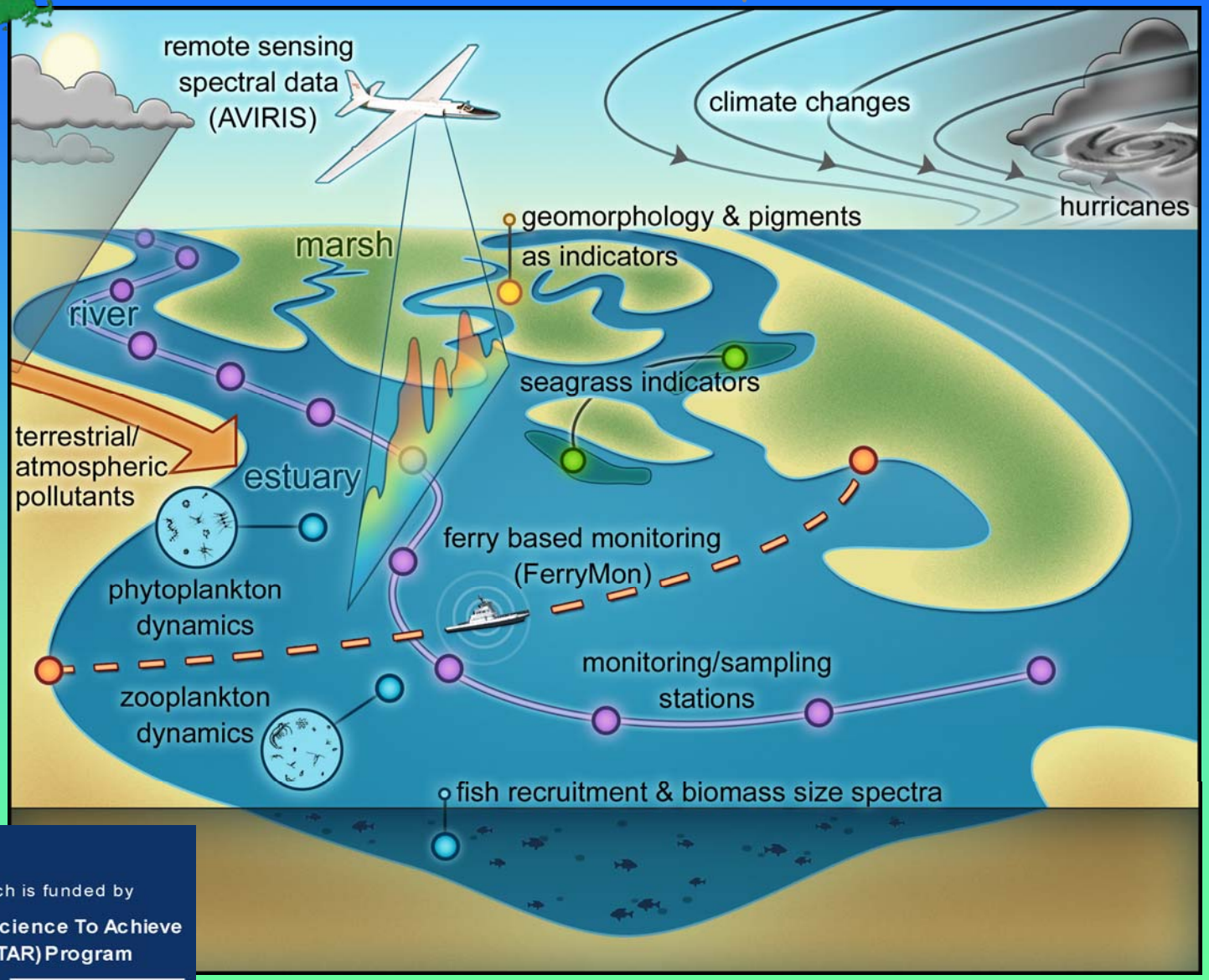


Management Implications

- In most estuaries, including regions of the SFO Bay N plays role as limiting nutrient.
- DIN utilization reflects supply rates: However, some forms (e.g., ammonium) may be preferred.
- Sources of N influence algal composition: Potential food web and biogeochemical implications
- Light-N interactions may be important, especially in turbid waters
- Hydrology (storms, floods, droughts) and residence time are important interactive variables, especially for slower growing phytoplankton like cyanobacteria.
- Develop appropriate *in situ* response assays and indicators to assess responses and impacts

Estuarine & Coastal Indicators of Nutrient Enrichment

www.unc.edu/ims/paerllab/



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U.S. EPA - Science To Achieve Results (STAR) Program
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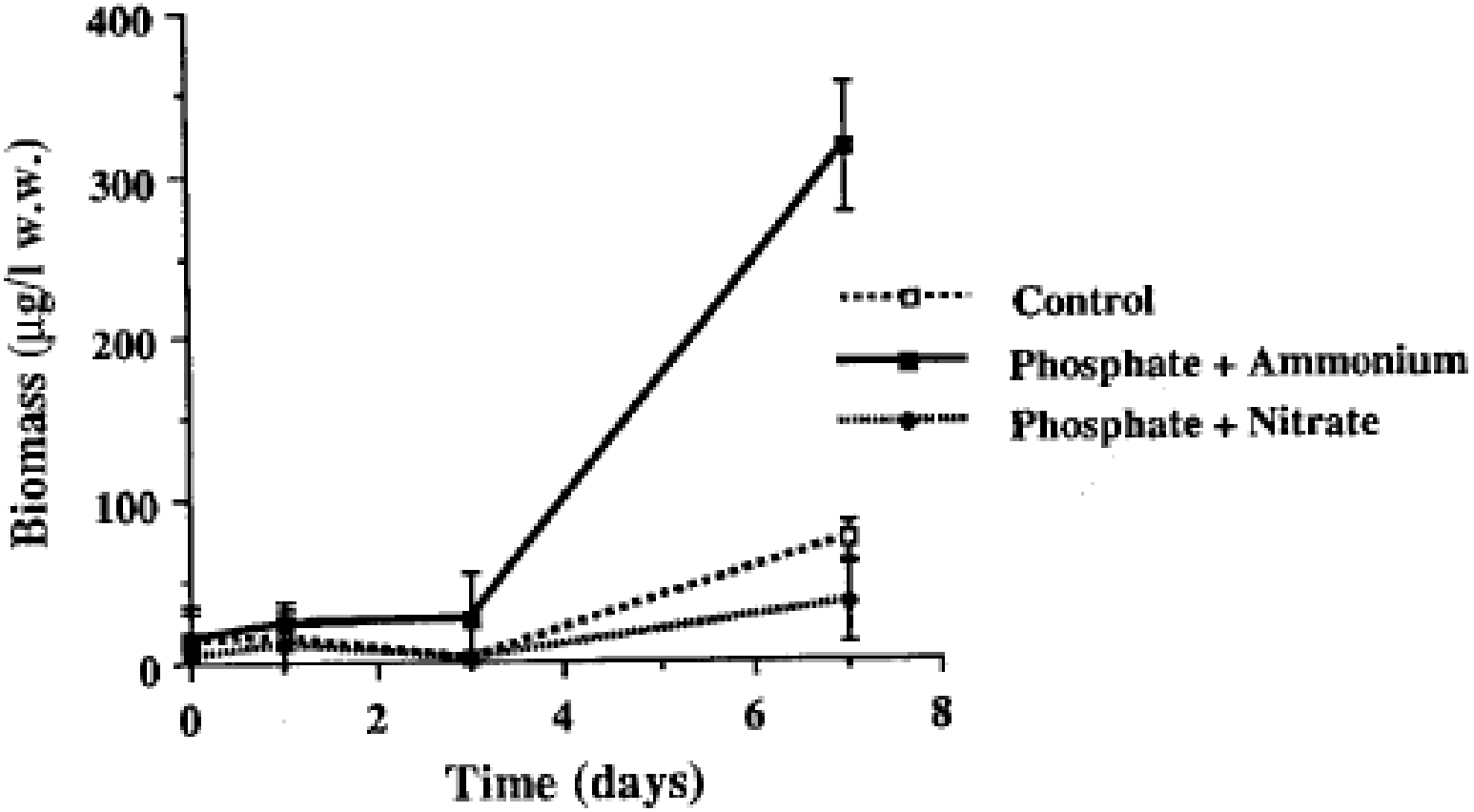
Effects of Ammonium or Nitrate (10 μg N L^{-1}) additions (+P) on phytoplankton biomass in eutrophic Lake Erken, Sweden

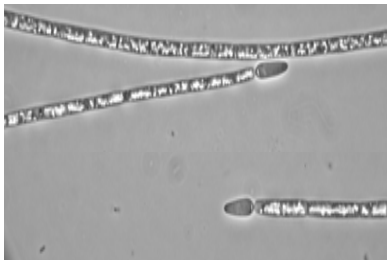


Blomqvist et al. 1994

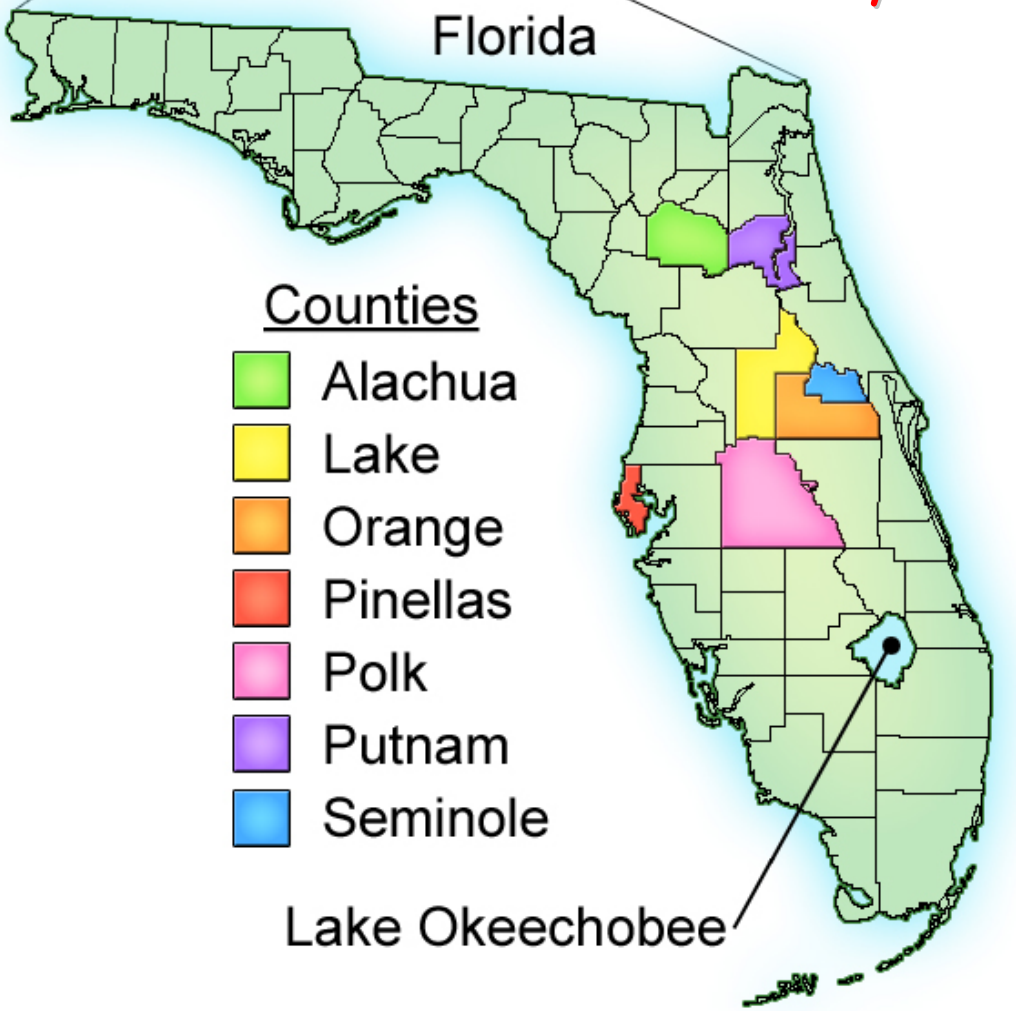
Lake Okeechobee, Florida: Nutrient enrichment, water withdrawal, drought conditions. Lots more ammonium

Photo, K. Havens

Expansion of *Cylindrospermopsis Raciborskii*

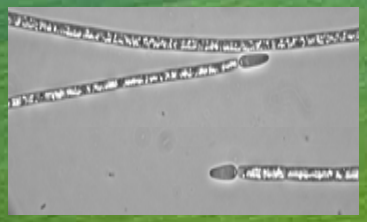


Why?



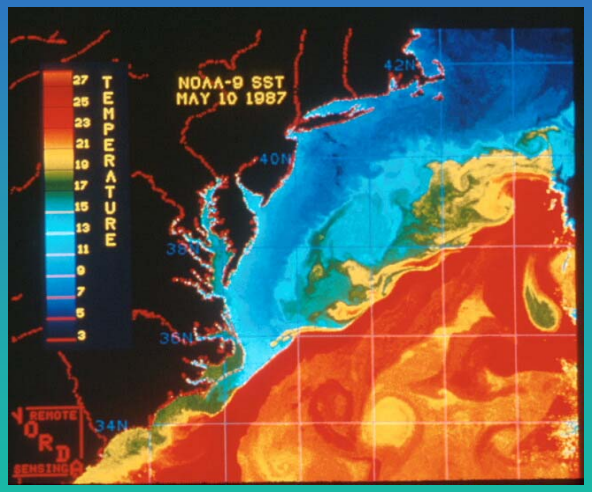
Nutrient/light strategies of *Cylindrospermopsis raciborskii*

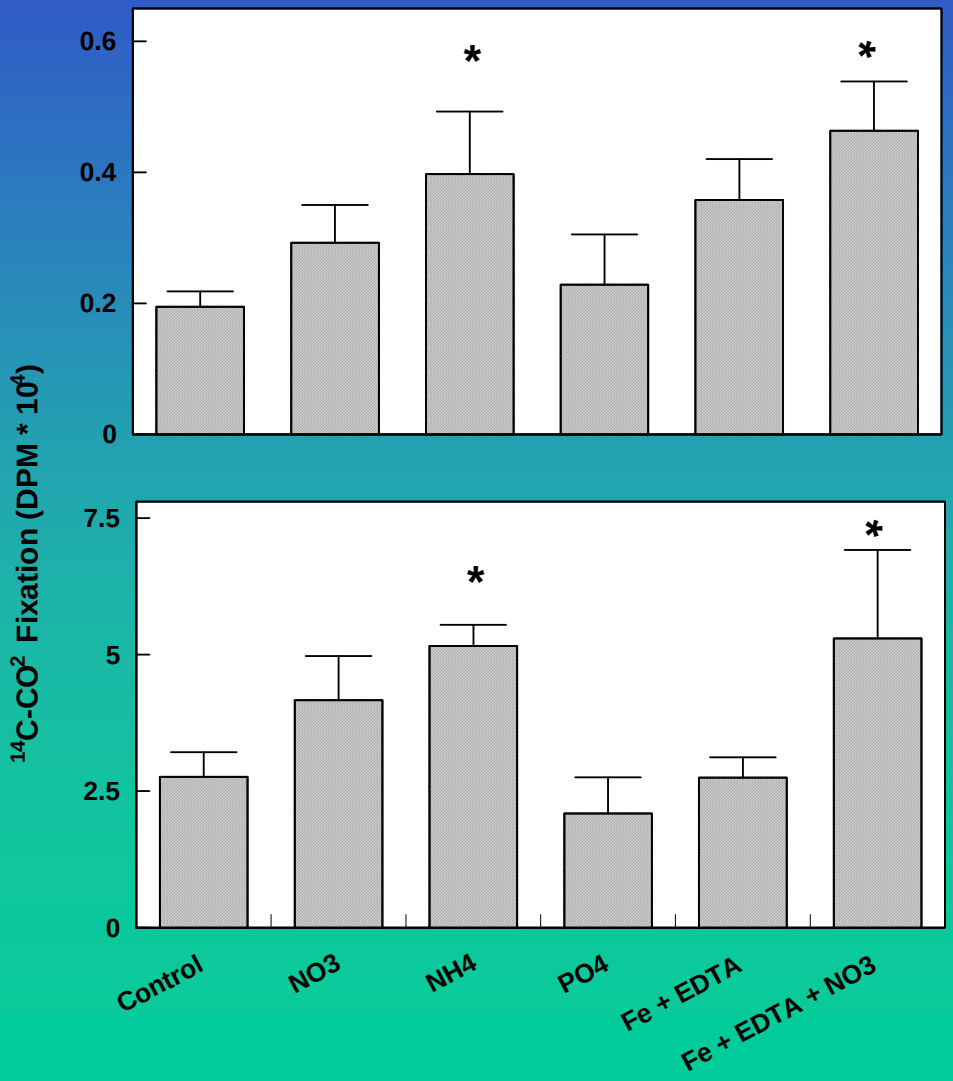
- High P uptake and storage capacity (Isvanovics *et al* 2000)
- N_2 Fixer



- High NH_4^+ uptake affinity
  - N additions (NH_4^+ NO_x) often significantly increase growth (chl *a* and cell counts) and productivity (Presing *et al* 1996)
- Tolerates low light intensities
  - "Tracks" eutrophication (expand in waters w/ increasing turbidity)
  - Can coexist in water column with other cyanoHABs (Fabbro and Duivenvoorden 1996)

N stimulation of primary production in the Coastal W. Atlantic Ocean



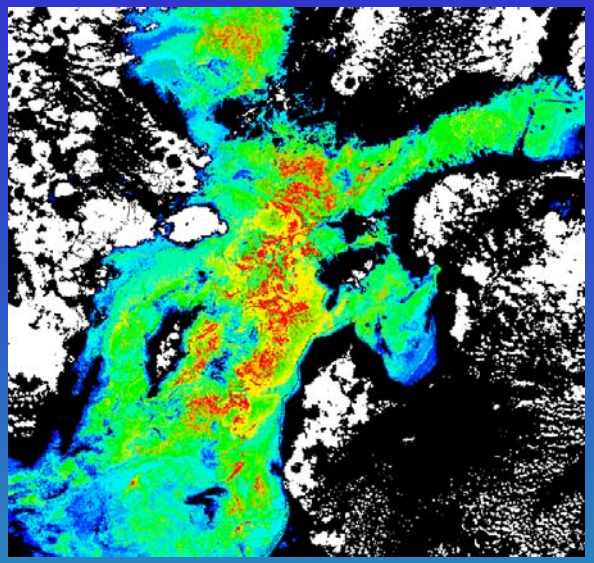


Gulf Stream

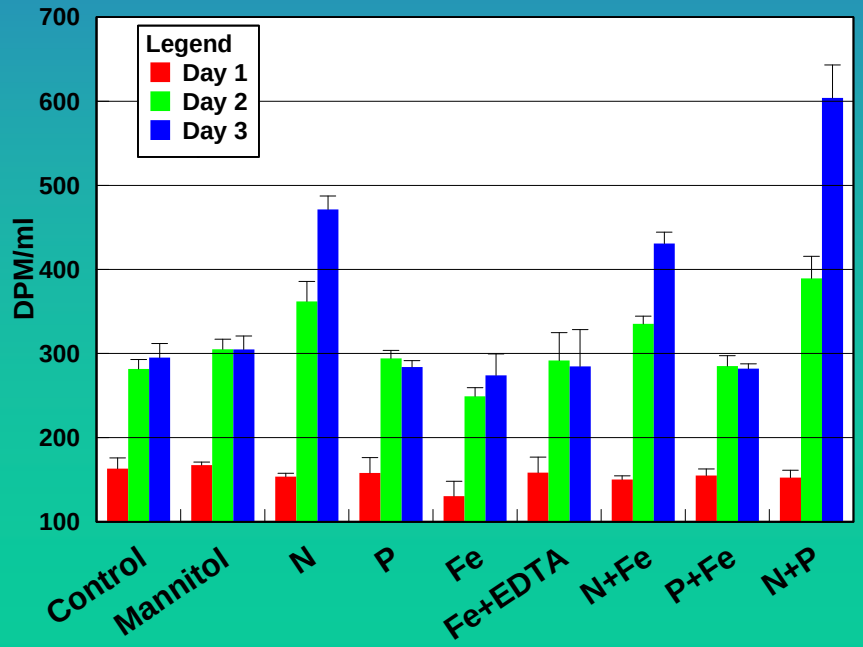
Inshore

Paerl et al., 1999

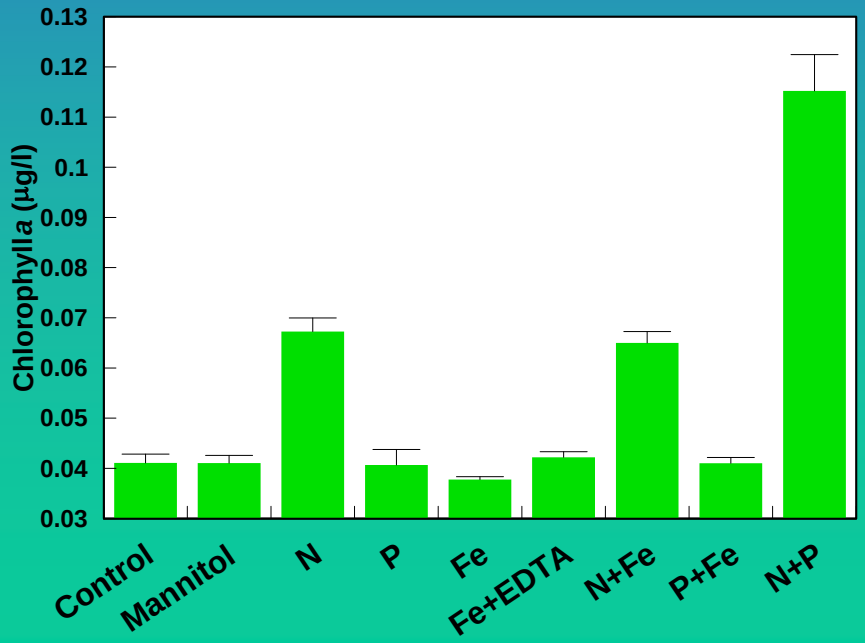
N (+P) stimulation of primary production in the brackish Baltic Sea



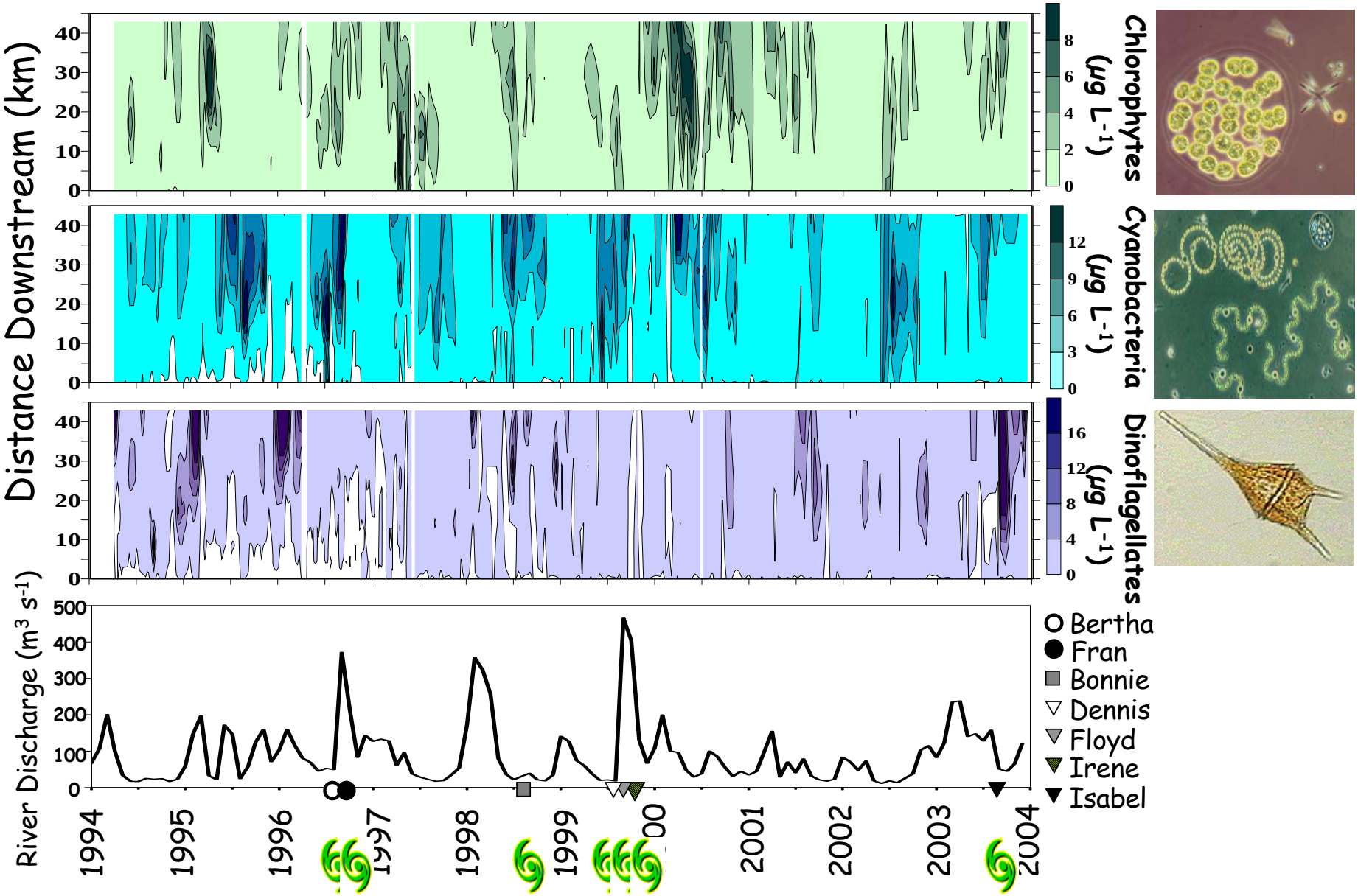
Baltic Sea 2000, Bioassay A
Primary Productivity



Baltic Sea 2000, Bioassay A
Chlorophyll

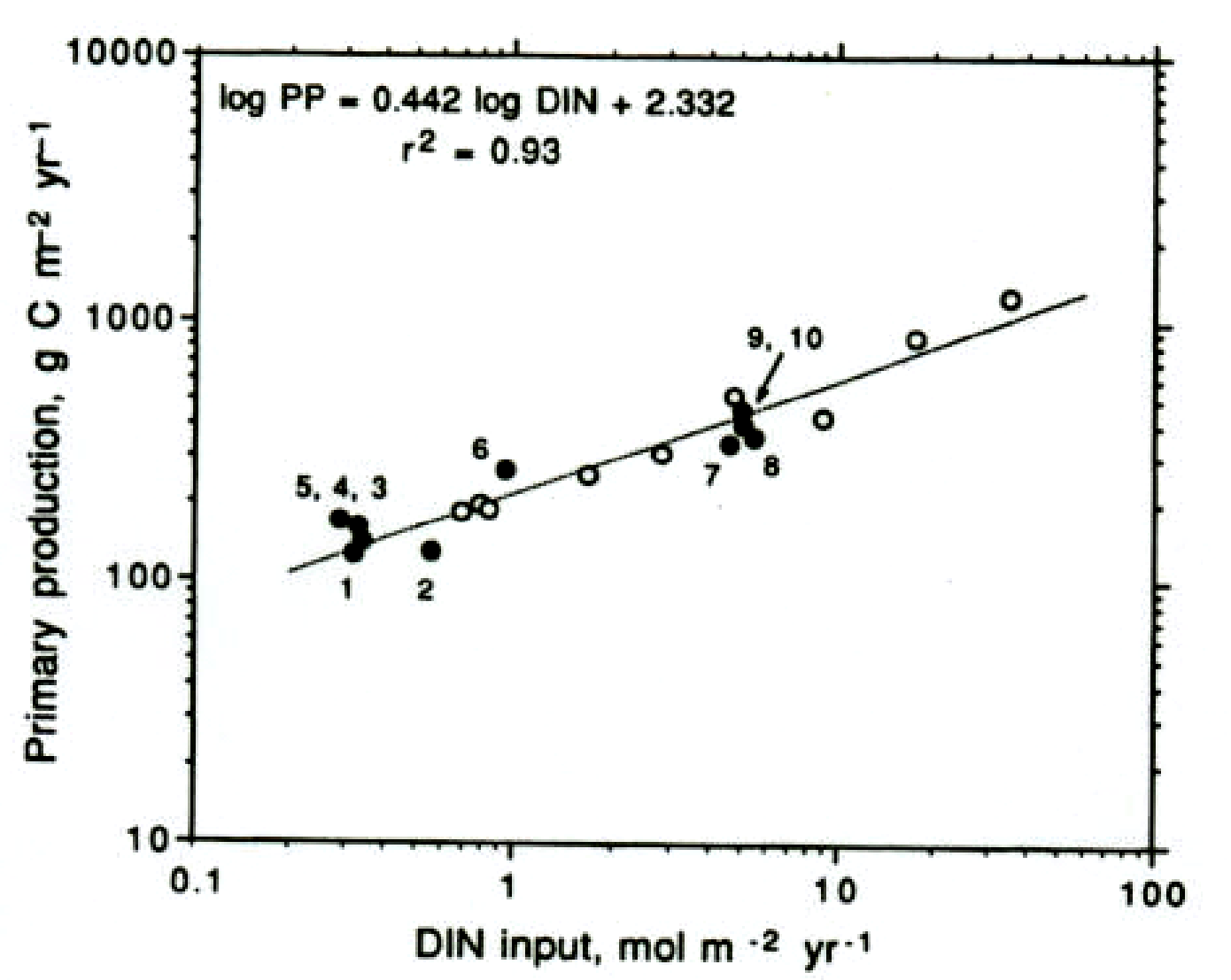


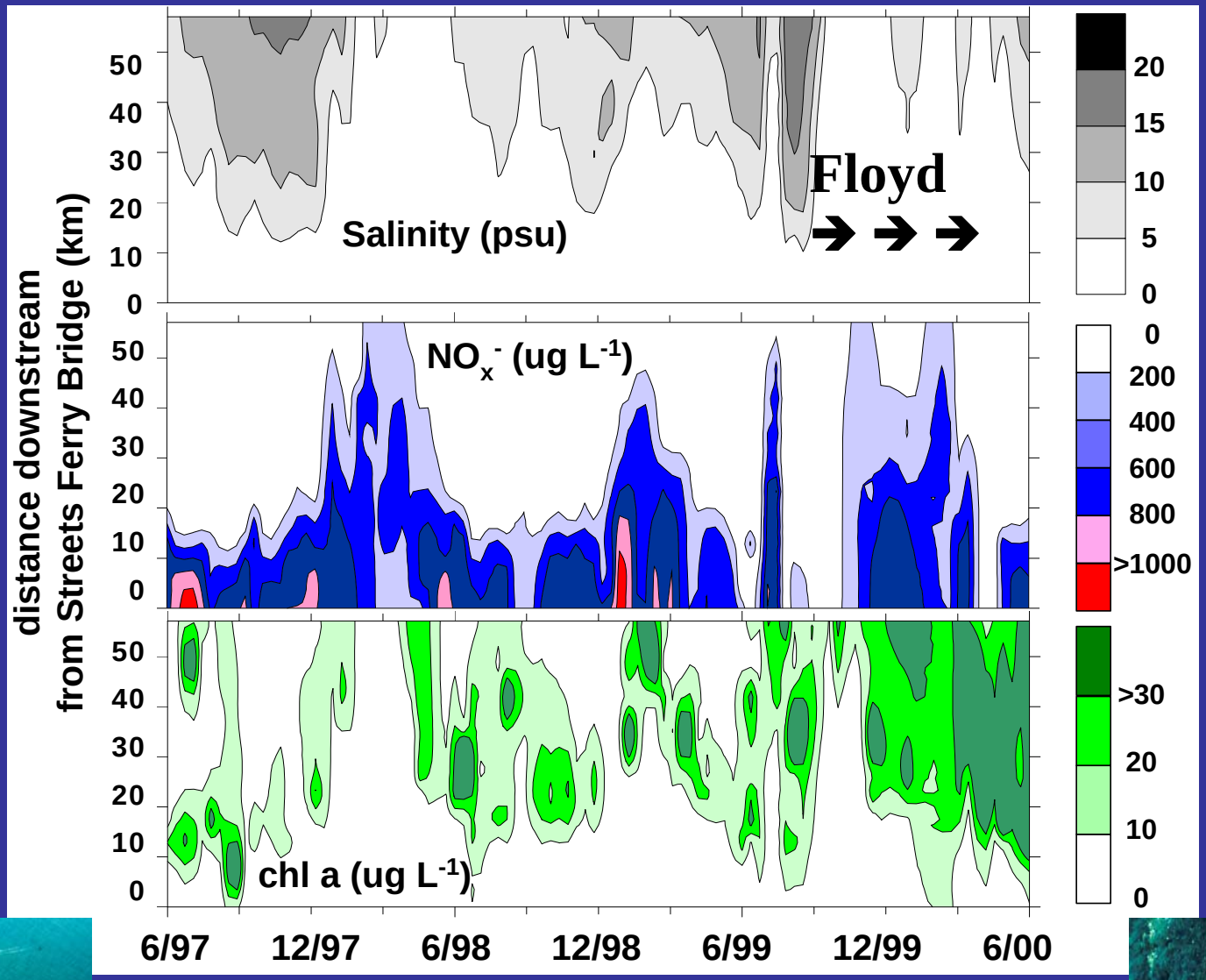
Phytoplankton functional group responses



What do the data show?

DIN Loading vs. primary production in a range of N. American and European estuaries



(Nixon 1996)

N loading and algal production in the Neuse R. Estuary