Long-term changes in water quality and productivity in the Patuxent River estuary:

Interacting effects of nutrient management, climate, and food web dynamics

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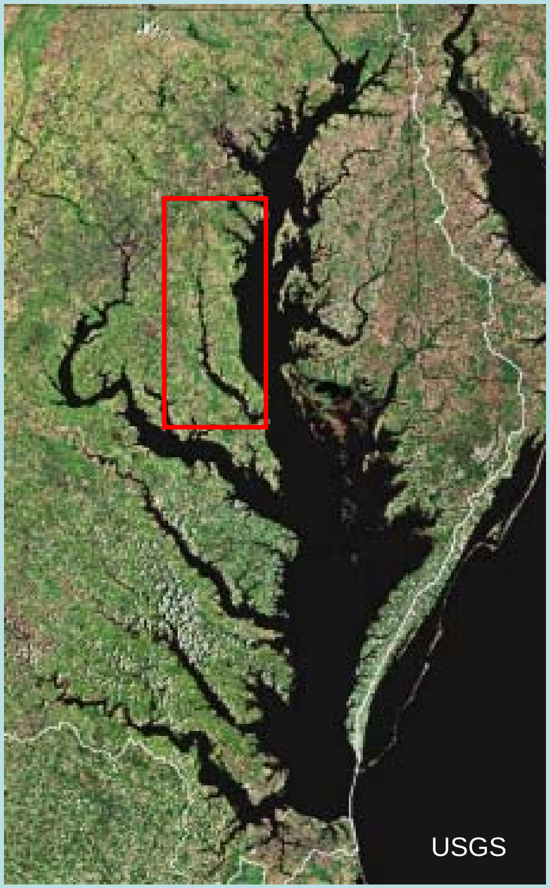
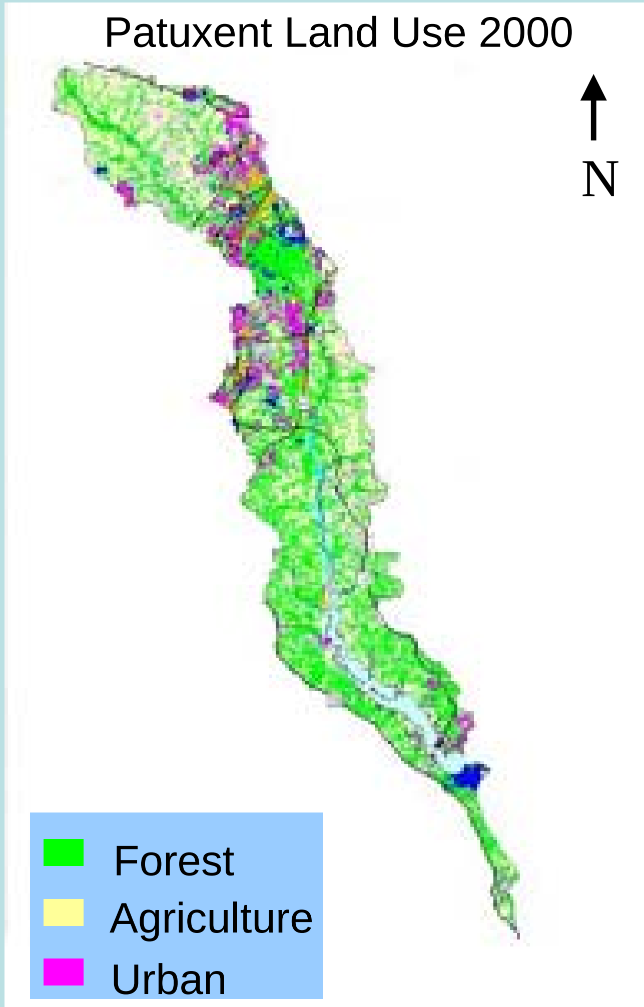
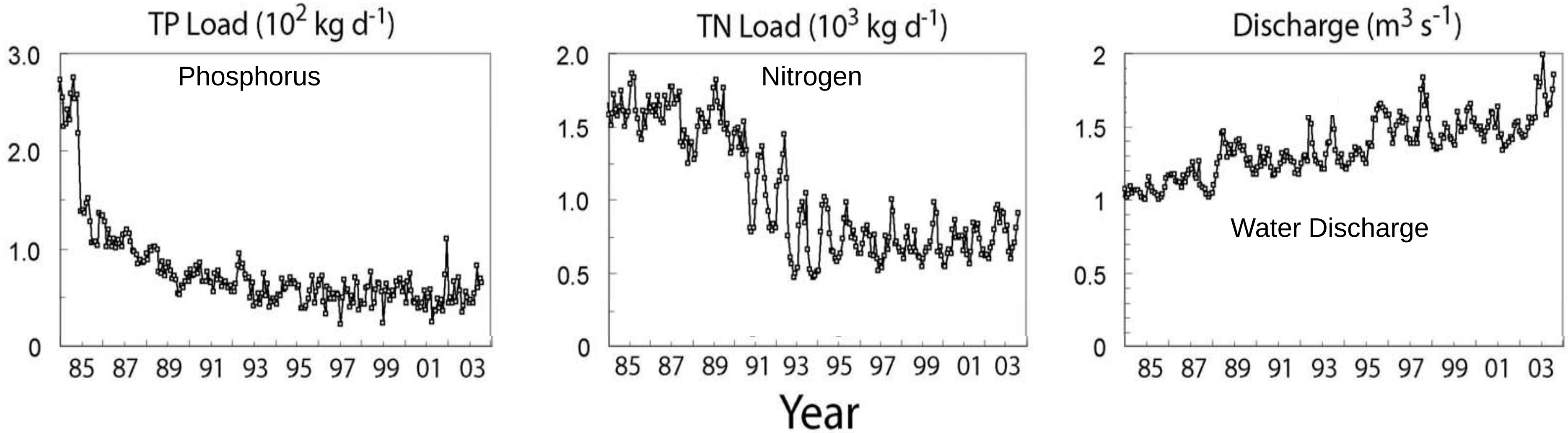
The Patuxent River Watershed





- Patuxent is 6th largest Chesapeake tributary
- Watershed land use reflects human affects
- Residential and Urban lands dominate upper watershed (DC suburbs)
- Lower watershed mostly forest, pasture, agriculture
- Sewage effluents are particularly important nutrient sources

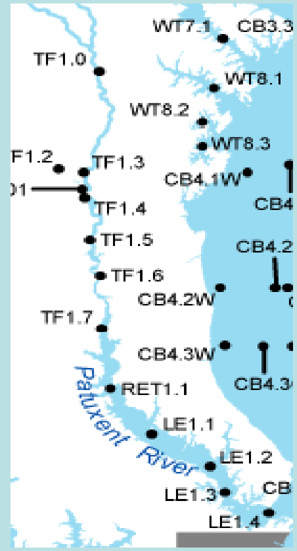
Point phosphorus & nitrogen loading to Patuxent have declined in response to sewage treatment upgrades



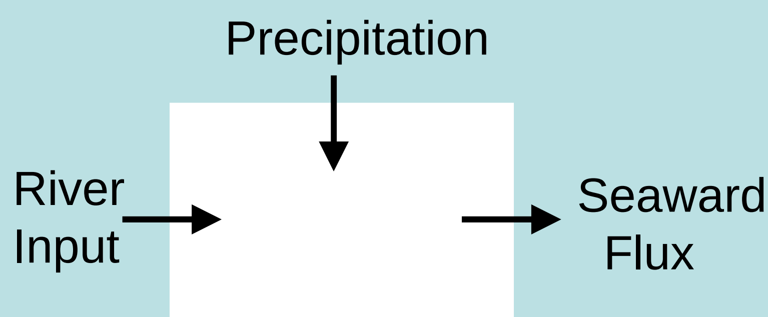
- Biological nitrogen removal (BNR) initiated in 1991
- Rapid declines in P (60%) loading from 1985 – 1990 (detergent P ban)
- Gradual decline in N (40%) loads from 1990 – 1995 (BNR, seasonal variation)

Methods to Assess Estuarine Response to Nutrient Load Declines

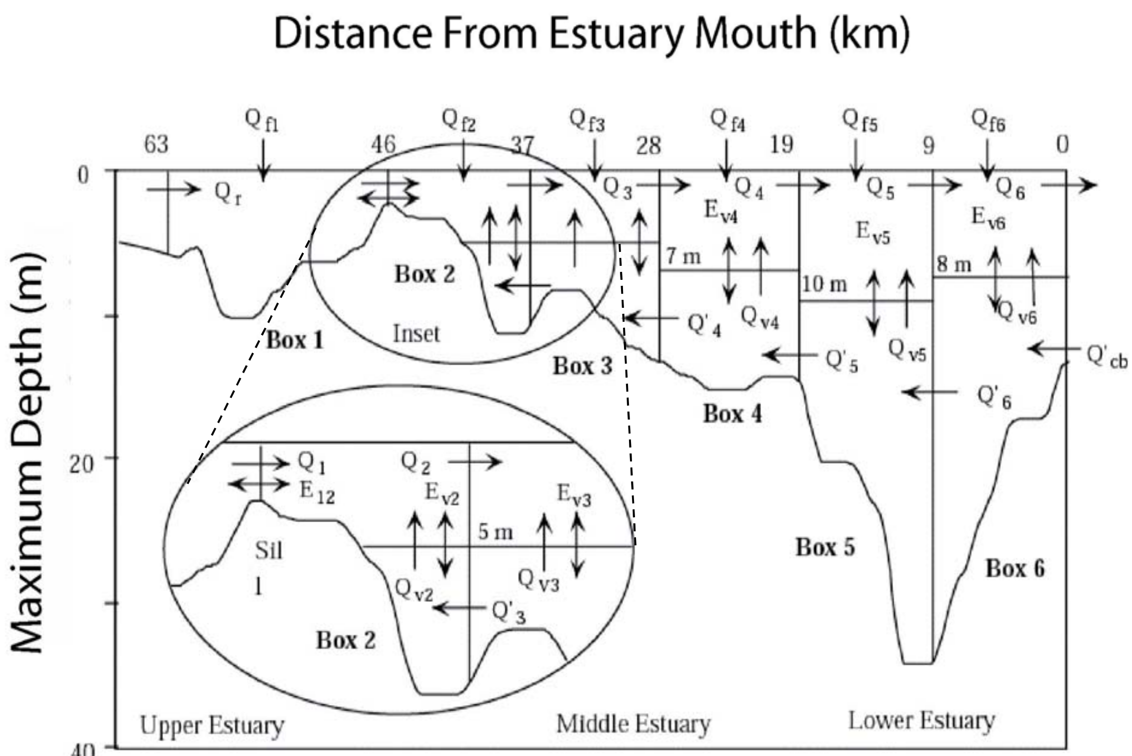
- **Trend analysis of water quality variables (nutrients, chl-a, O_2, zooplankton)**



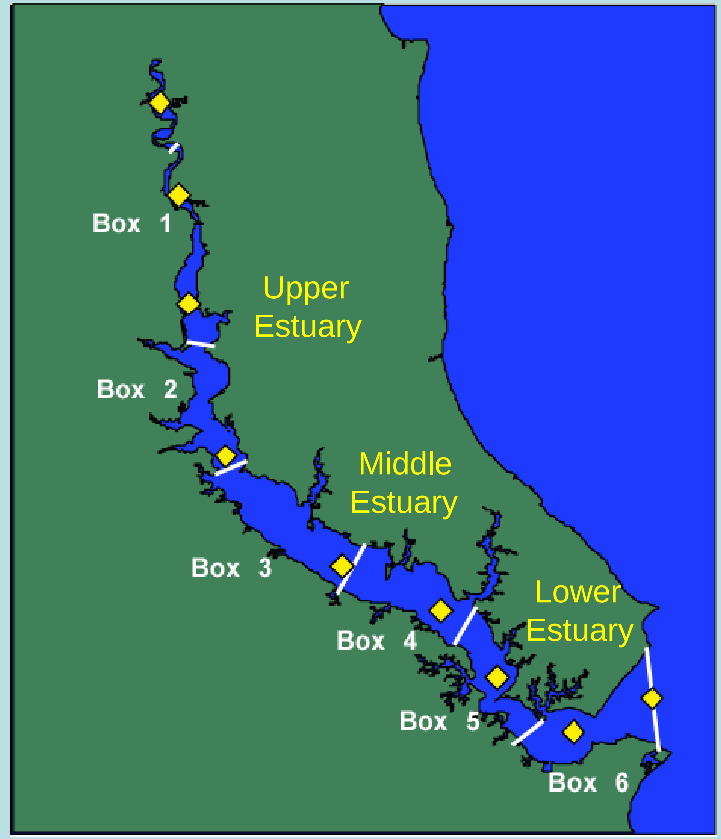
- **Use WQ data and box-model to compute *net productivity*, *nutrient uptake/regeneration,* and *nutrient transport rates***



Longitudinal Section of Patuxent Showing Region Boundaries and Fluxes Between Regions (Boxes)

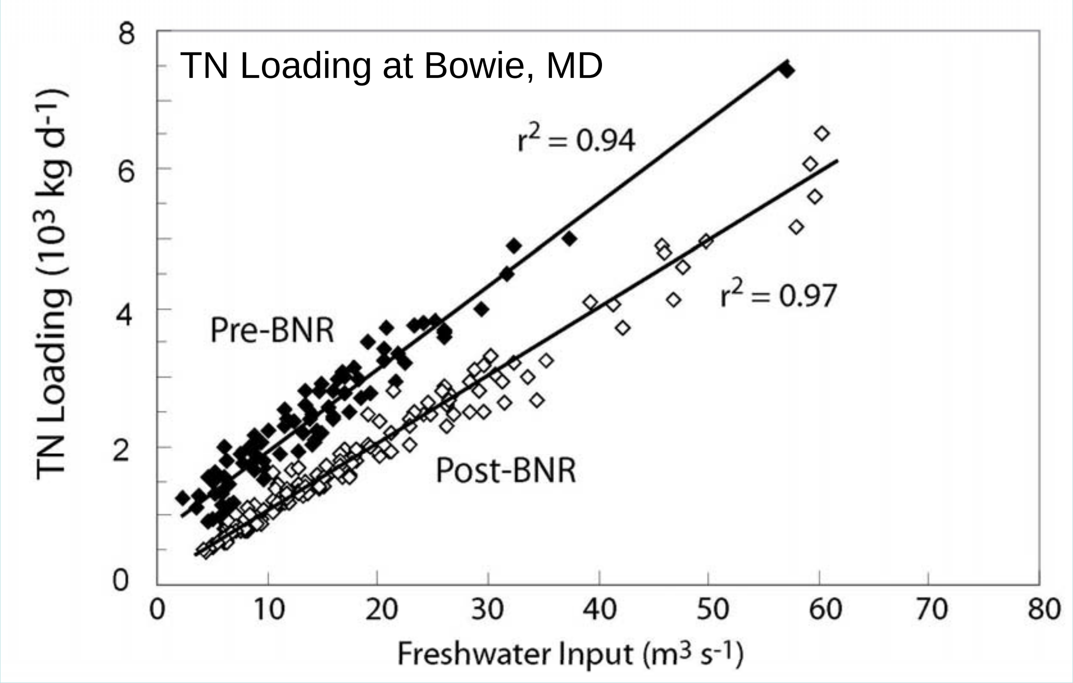


(Hagy et al. 2000)



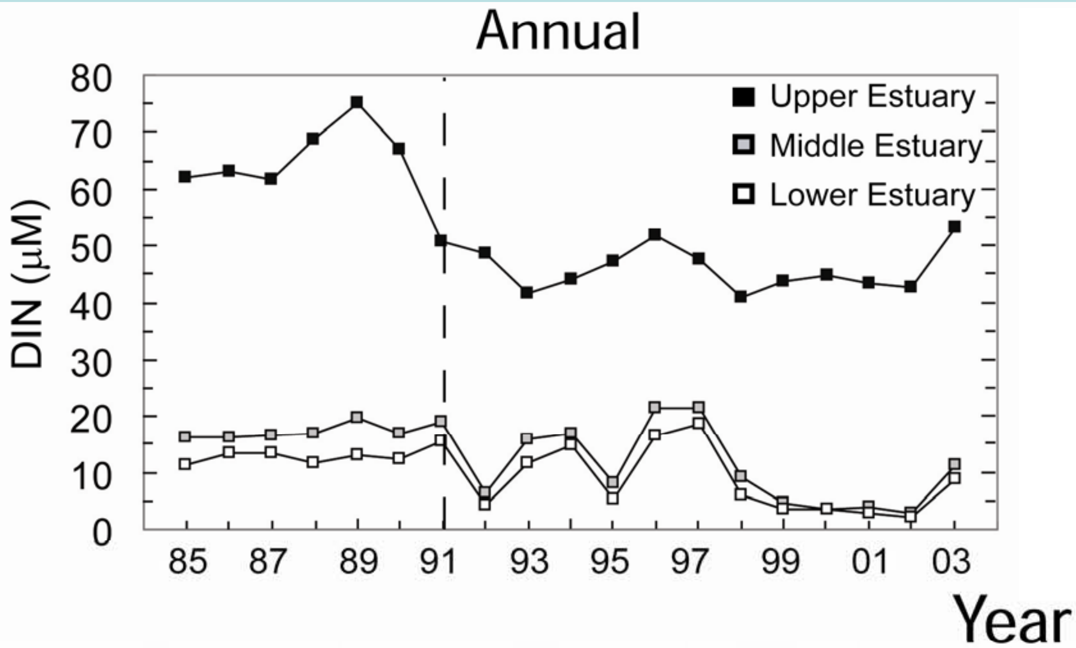
Use flow balance and salt balance equations for each box to compute unknown values for water flows (Q’s) and mixing rates (E’s), given salinities and FW inputs.

N Transport Declined in Response to Management



- TN loading to upper estuary is highly correlated with river flow
- TN loading at gauging station substantially reduced with BNR

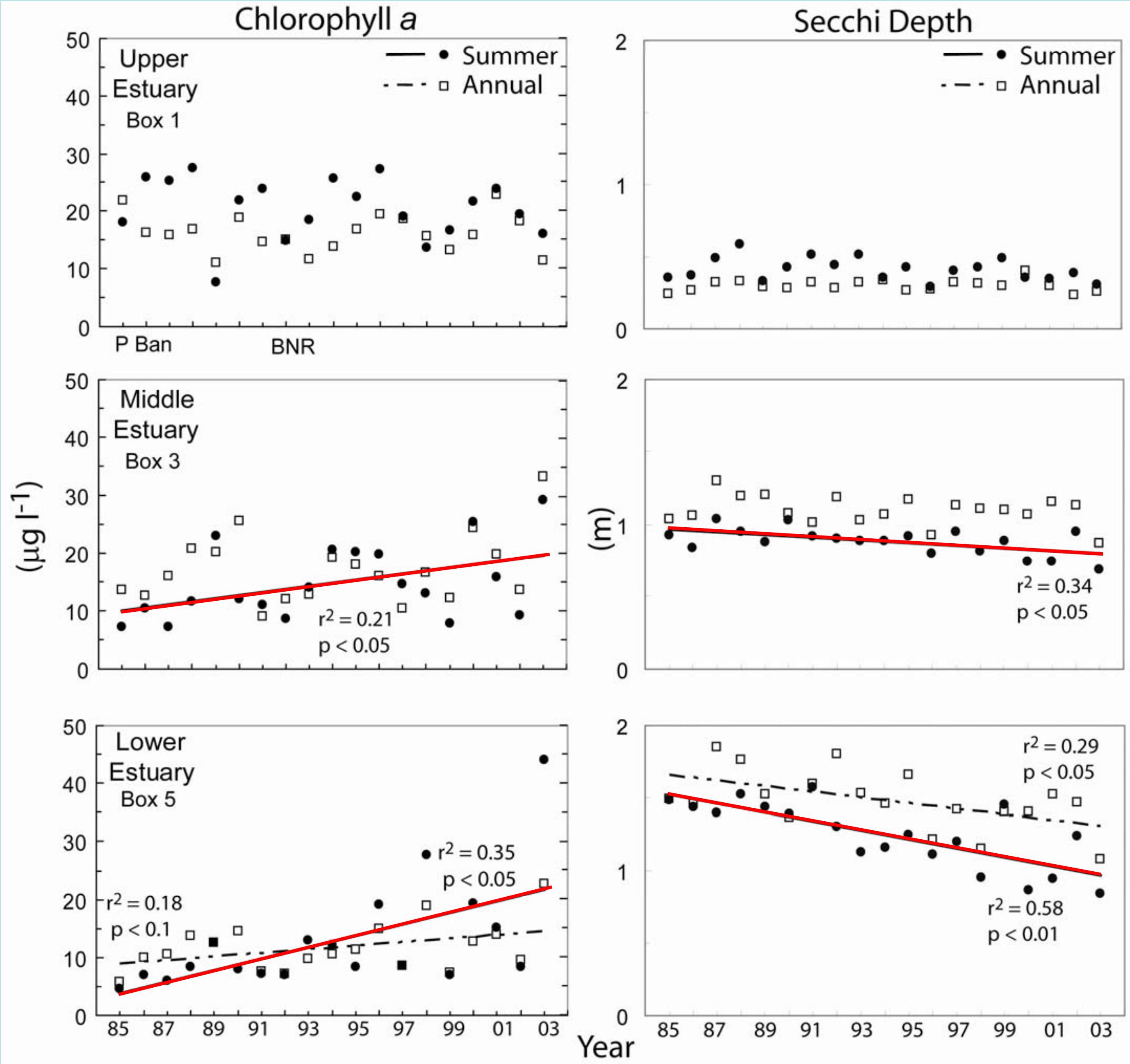
[DIN] Declined in Response to Management



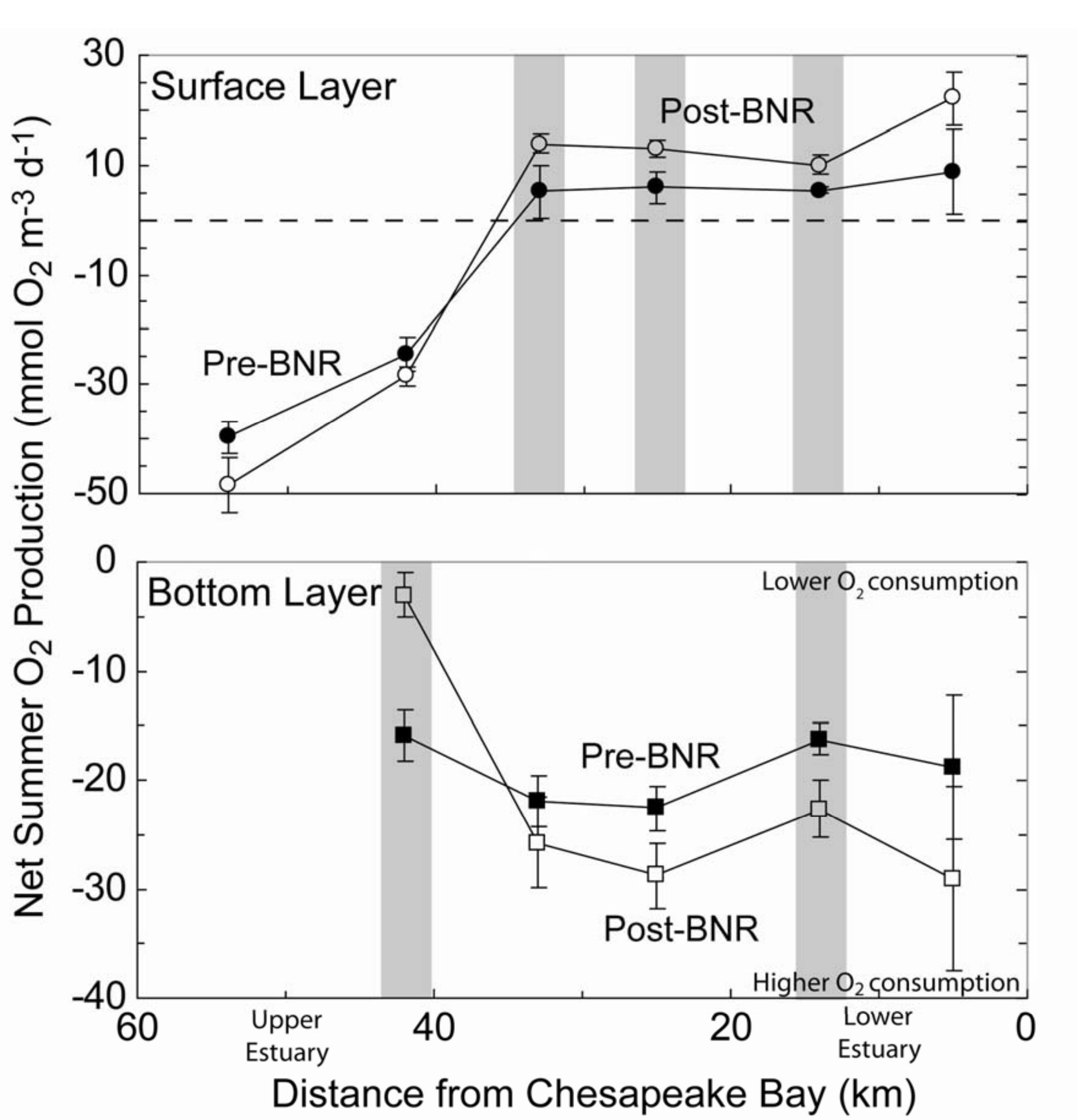
• DIN Concentrations decline in response to management in all estuarine regions

• Decline more abrupt in summer data for lower estuary (June-August)

Regional & Annual Water Quality Trends: Chl-a, Z_{sd}



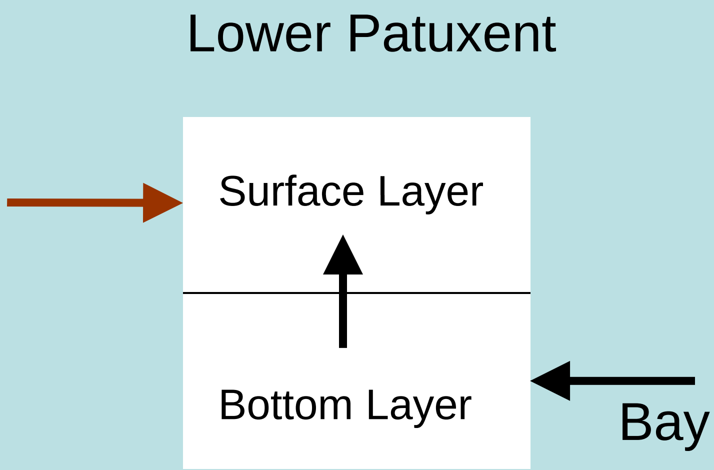
O_2 Production/Consumption Response is Regional

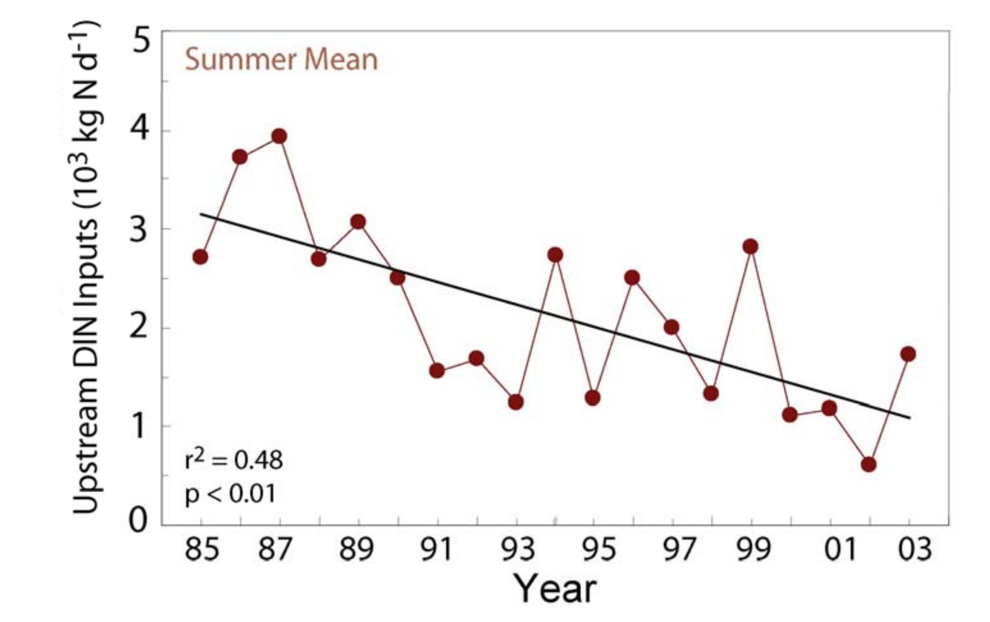


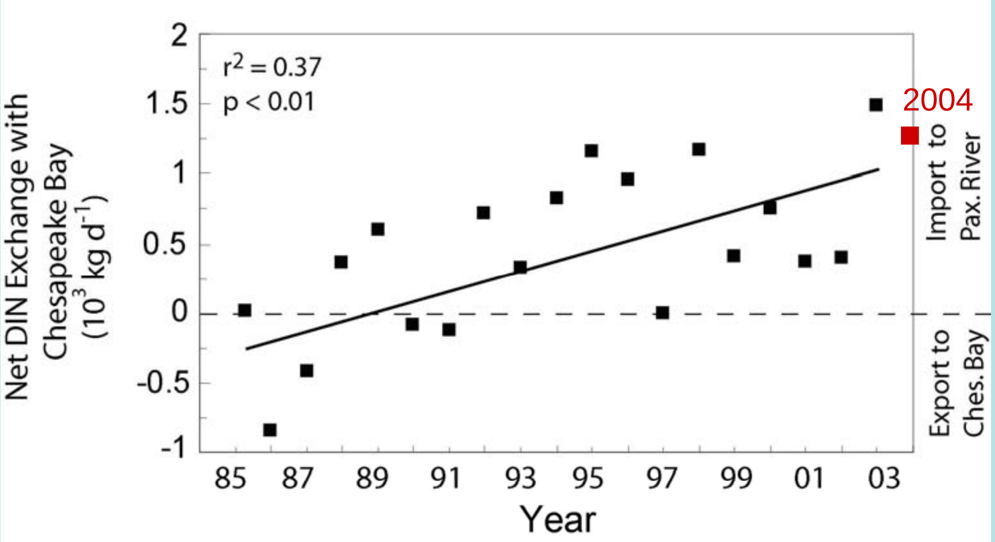
- Surface layer net O_2 production increased after load reductions in lower estuary

- Bottom layer net O_2 consumption declined in upper estuary, increased in lower estuary after load reductions

Hypothesis 2: Increasing DIN Input from Bay to Patuxent

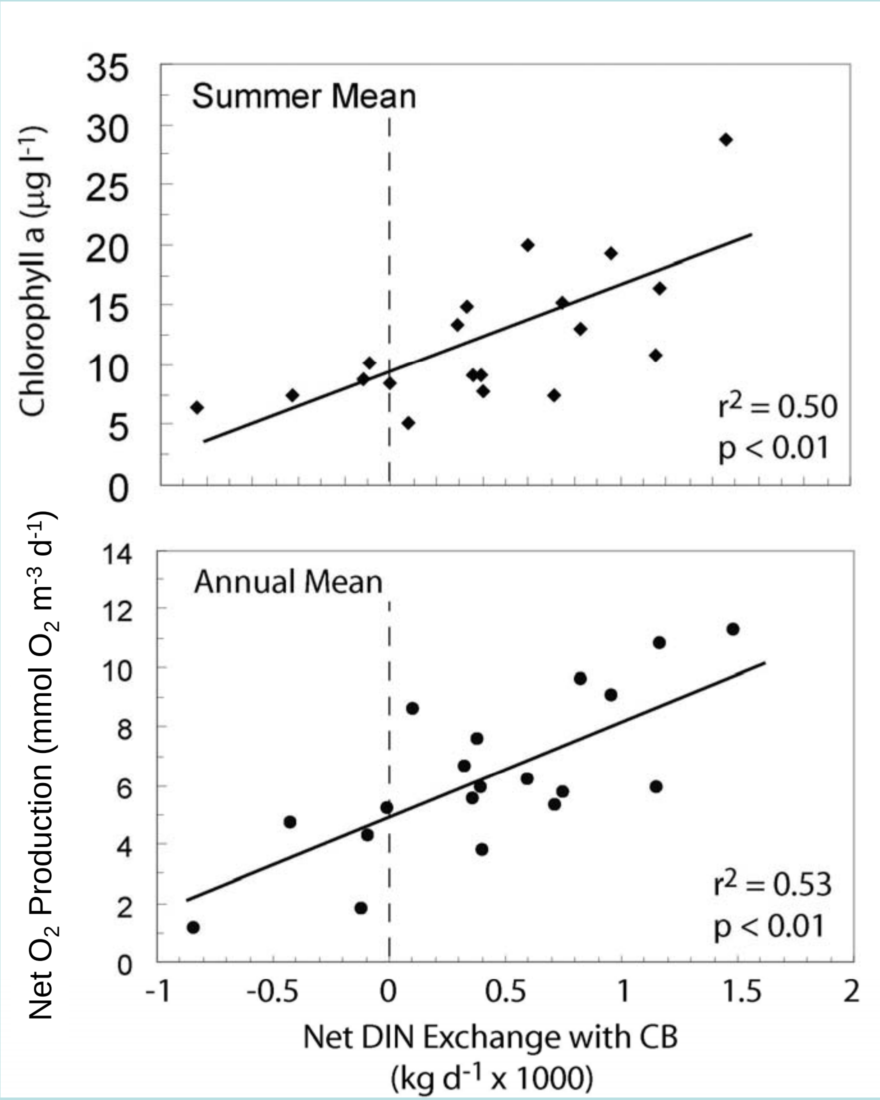






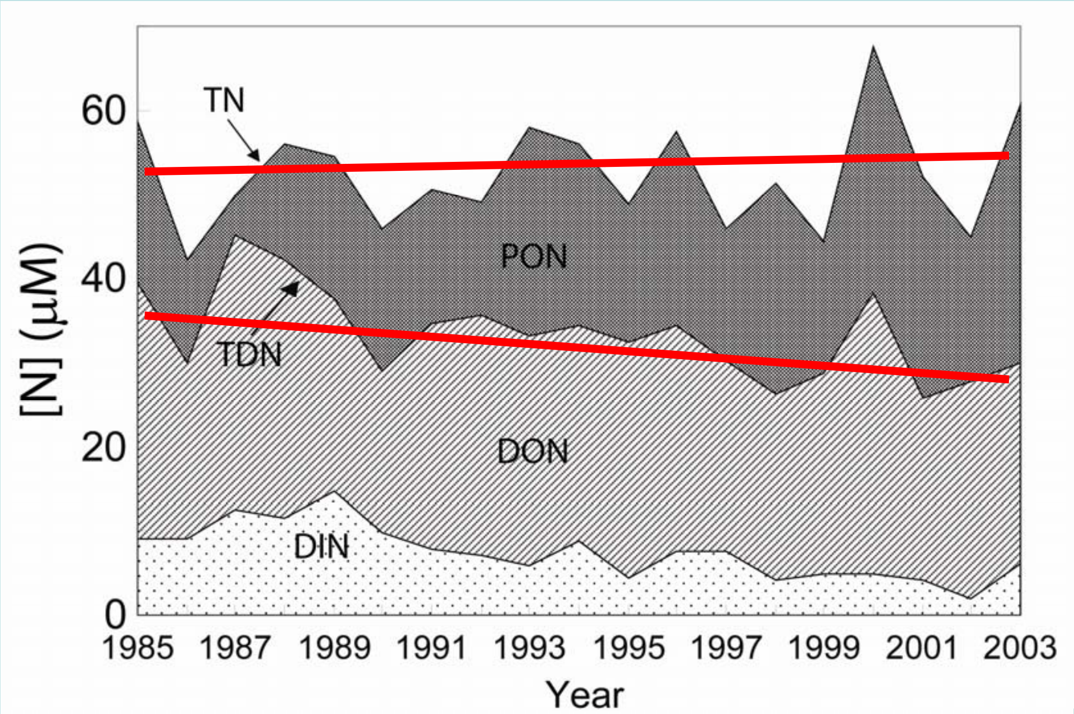
- Upwelling a dominant DIN source to lower estuary surface layer
- Cause of trend related to concentration gradient between Bay and PAX

DIN Input from Bay Drives Lower Estuary NEP, Chl-a



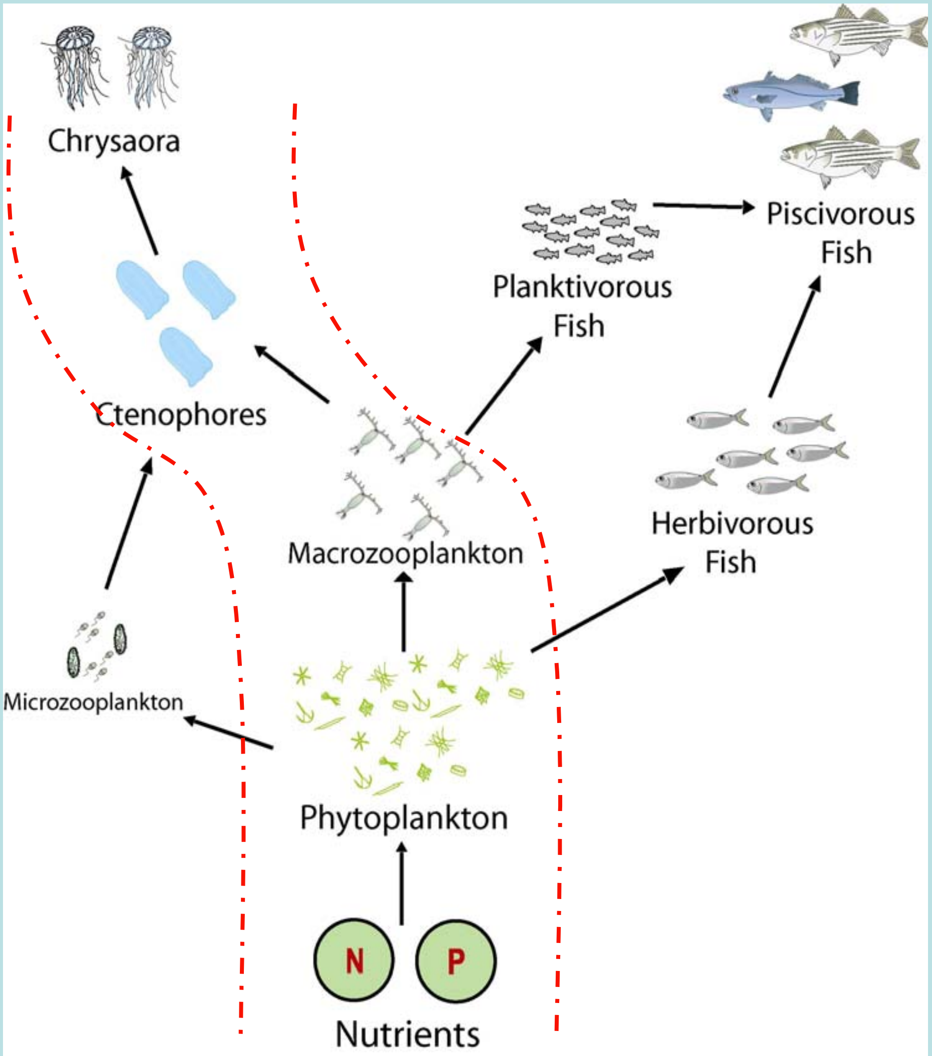
- Summer mean phytoplankton chlorophyll-*a* levels in Box # 6 Upper Layer correlate with DIN inputs from Bay
- Also, annual mean rates of net O_2 Production in Box # 6 Upper Layer correlate with DIN inputs from Bay
- Suggests that DIN inputs from Bay drive primary production in Lower Patuxent estuary

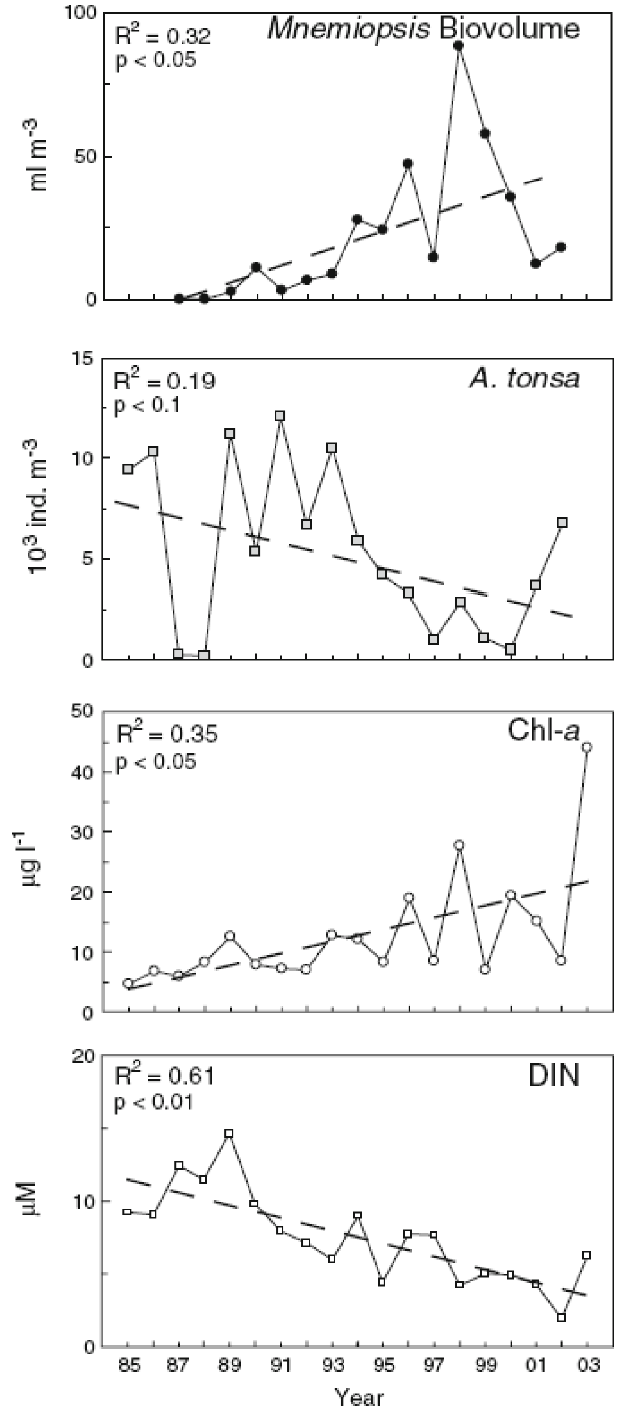
How Did Chlorophyll Increase If DIN Decreased?



- Despite DIN declines, TN has been stable in the lower estuary
- These trends correspond to a significant increase in particulate organic nitrogen (PON)
- This suggests that DIN inputs from Chesapeake Bay are converted to algal biomass

More Complexity? Food Web Changes May Have Allowed Chl-a Increase?





Summary and Conclusions

- Sewage treatment upgrades caused reduced nutrient inputs and concentrations, some improvement in upper estuary

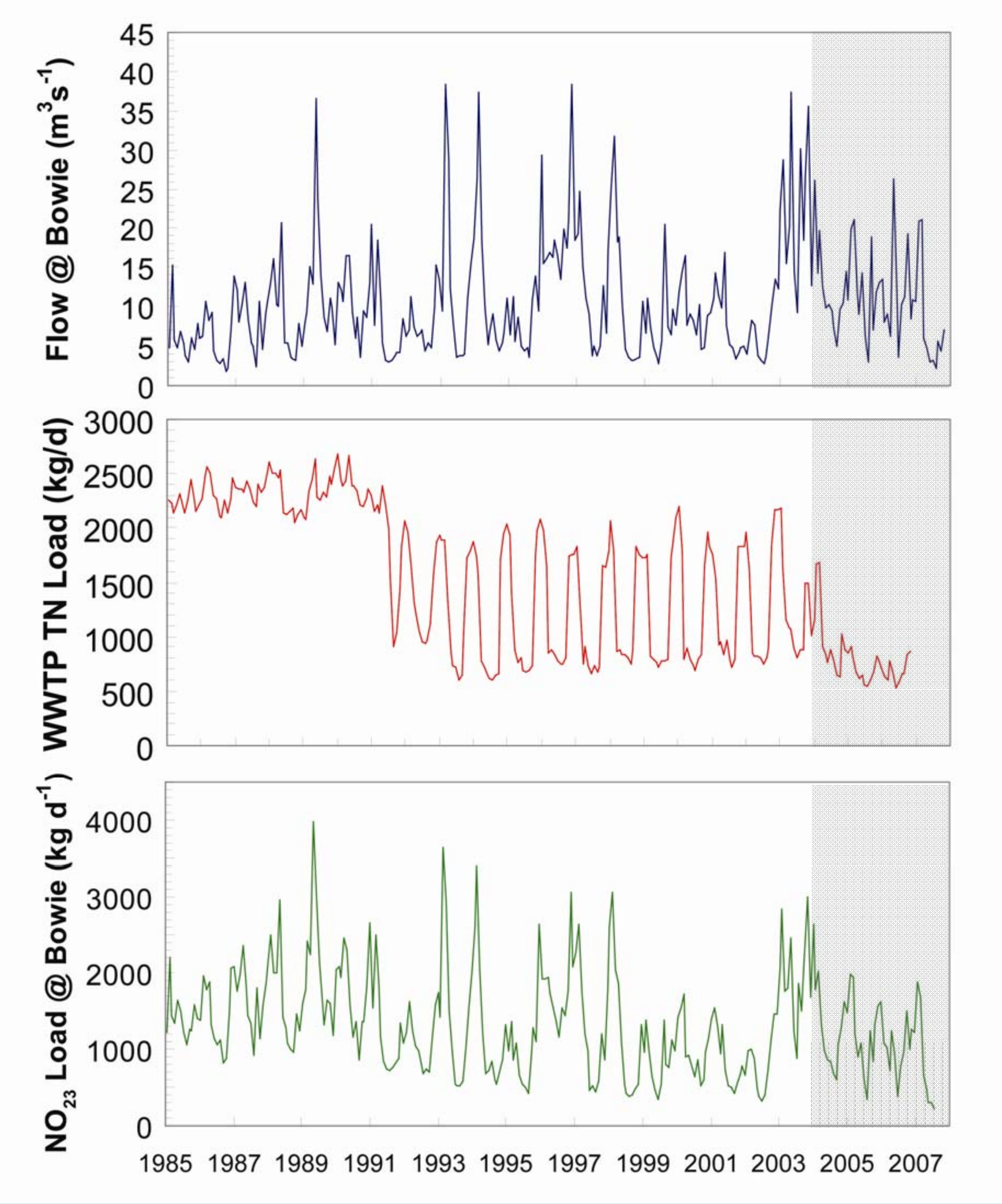
- Degrading water quality in lower estuary due to:
  (1) Increasing nutrient loads from Chesapeake Bay
  (2) Elevated river flow after 1990
  (3) Changes zooplankton grazing

- Box-modeling and long-term data sets produce valuable data for understanding coastal processes

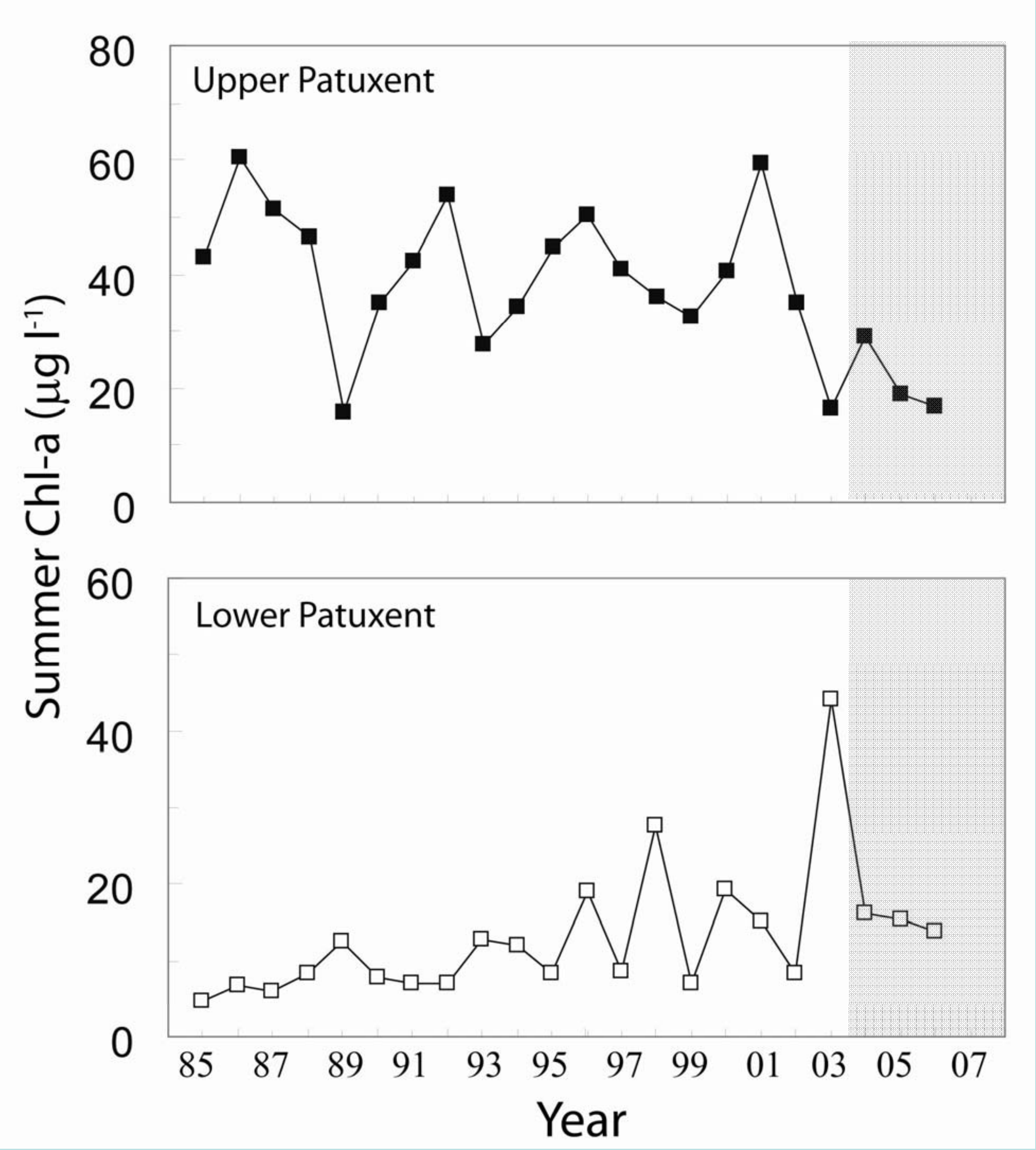
- Lessons Learned:
  (1) Long-term datasets (and revisiting long-term datasets) are key to fully understanding climate + management effects
  (2) We need to balance: "upstream-bottom up" perspective with "downstream-top down" perspective
  (3) Climatic changes and effects still not fully understood

- But….

Time-Series Extended: 1985-2007 Flow and Loading



Time-Series Extended: 1985-2007 Water Quality



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Data Sources
Chesapeake Bay Program
Maryland Department of Natural Resources
United States Geological Survey
National Oceanic and Atmospheric Administration