

# Sediment Nutrient Fluxes in the Tidal Chesapeake Bay



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# Motivating Questions

- (1) What are the spatial patterns and controls on sediment-water nutrient and oxygen fluxes in Chesapeake Bay?
- (2) What are the implications of these controls for the potential water-column impacts of reservoir-derived particulate material flux to Chesapeake Bay?

# Some Controlling Mechanisms

- (1) Deposition of labile organic material to sediment  
(Carbon, Nitrogen and Phosphorus)
- (2) Oxygen availability in the overlying-water  
(Nitrogen and Phosphorus)
- (3) Iron-Sulfur Interactions along a salinity gradient  
(Phosphorus)
- (4) Iron-Phosphorus Interactions along a salinity  
gradient (Phosphorus)

# Sediment Process Observations in Chesapeake Bay

Still Pond

R-78

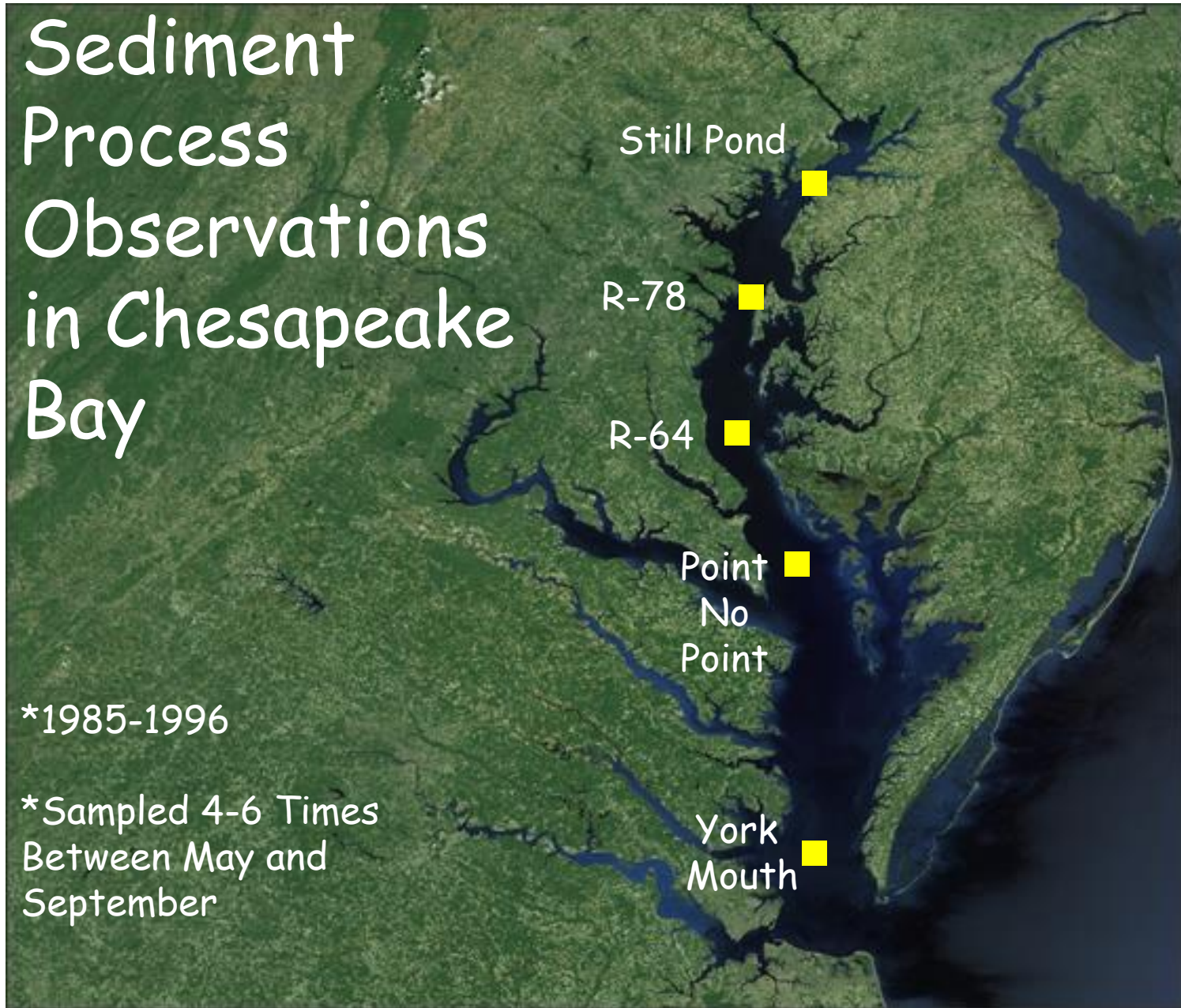
R-64

Point  
No  
Point

York  
Mouth

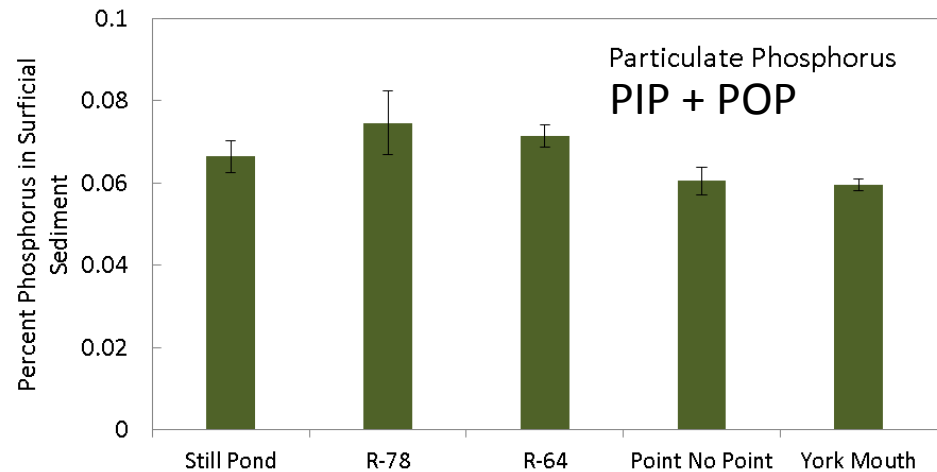
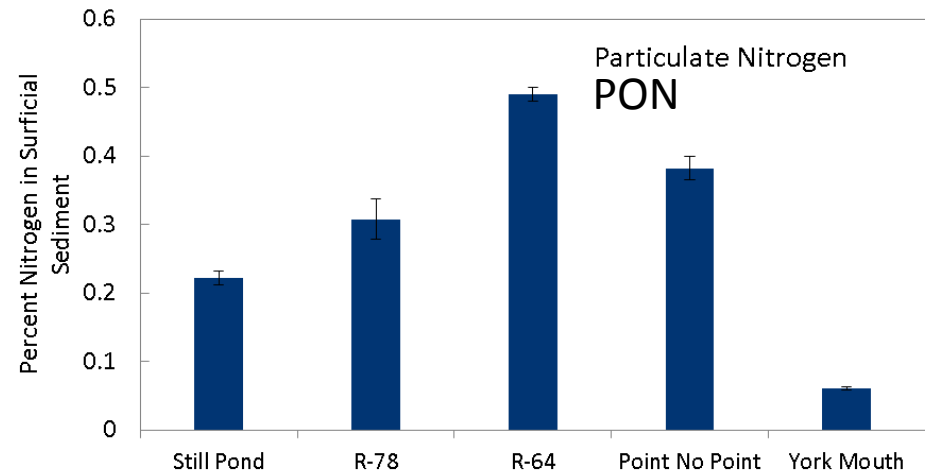
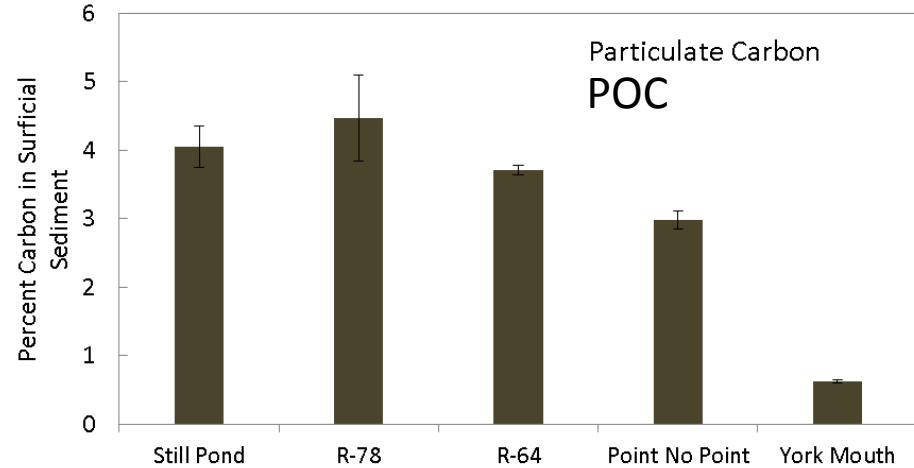
\*1985-1996

\*Sampled 4-6 Times  
Between May and  
September



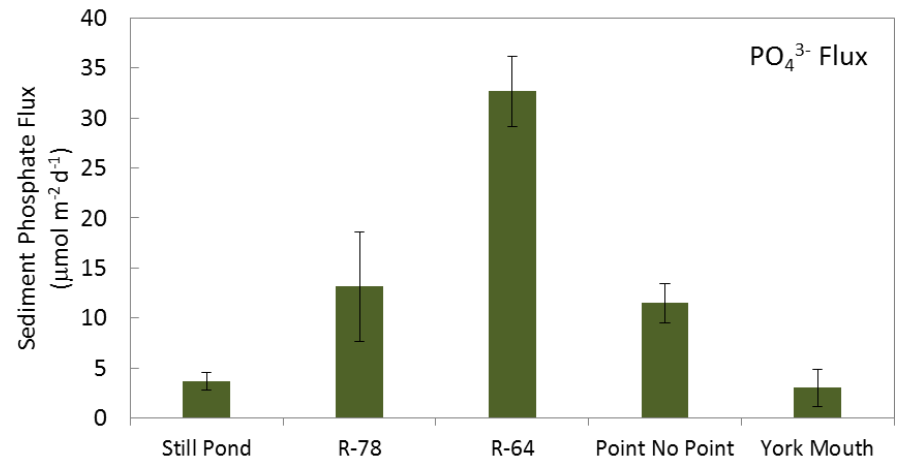
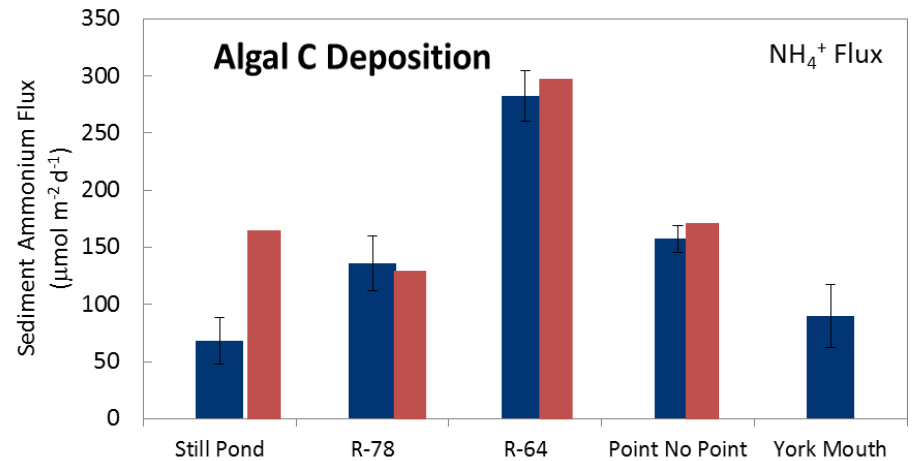
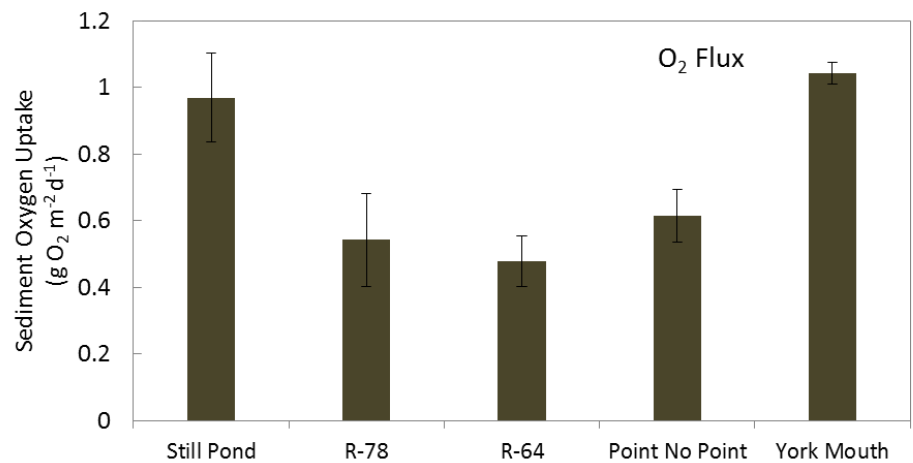
# Spatial Variation in Sediment Nutrient Content

- Particulate Carbon peaks in upper-bay
- Particulate nitrogen peaks in mid-Bay
- Particulate P has less spatial variation

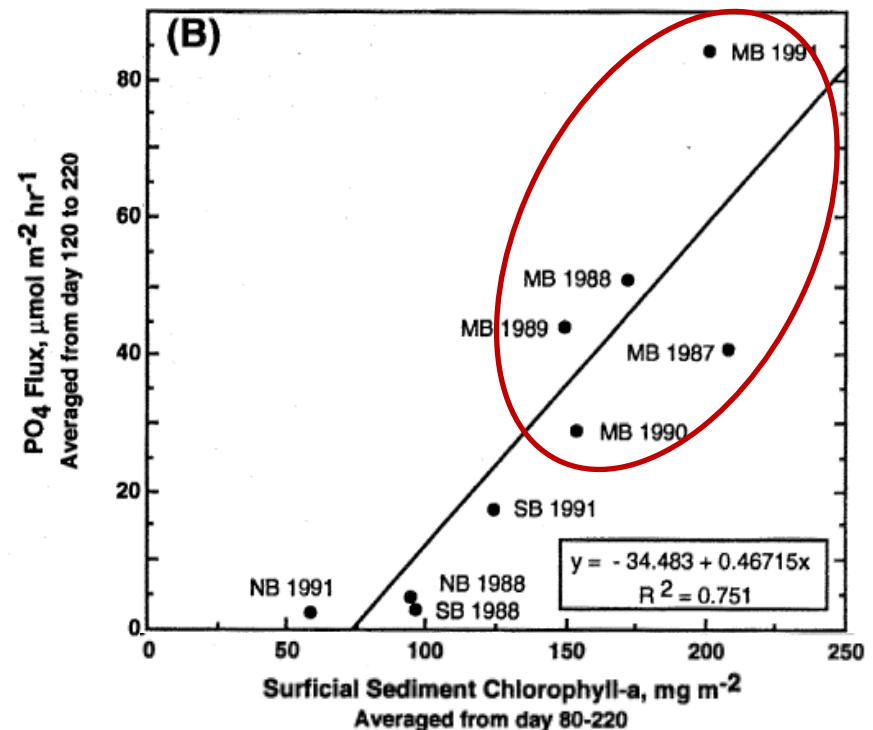
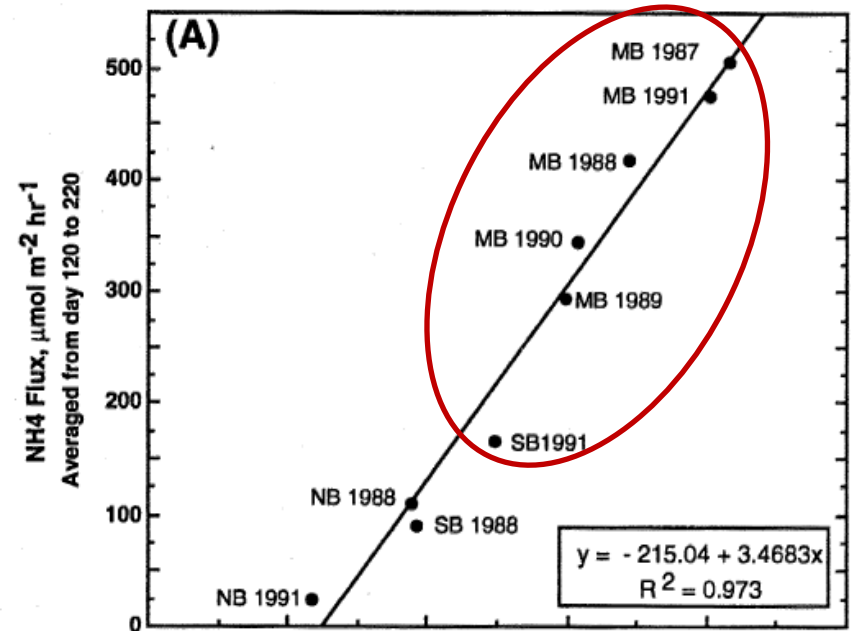


# Spatial Variation in Sediment-Water Fluxes

- Sediment  $O_2$  Uptake lowest in region between Bay Bridge and Patuxent
- $NH_4^+$  and  $PO_4^{3-}$  fluxes peak in mid-Bay

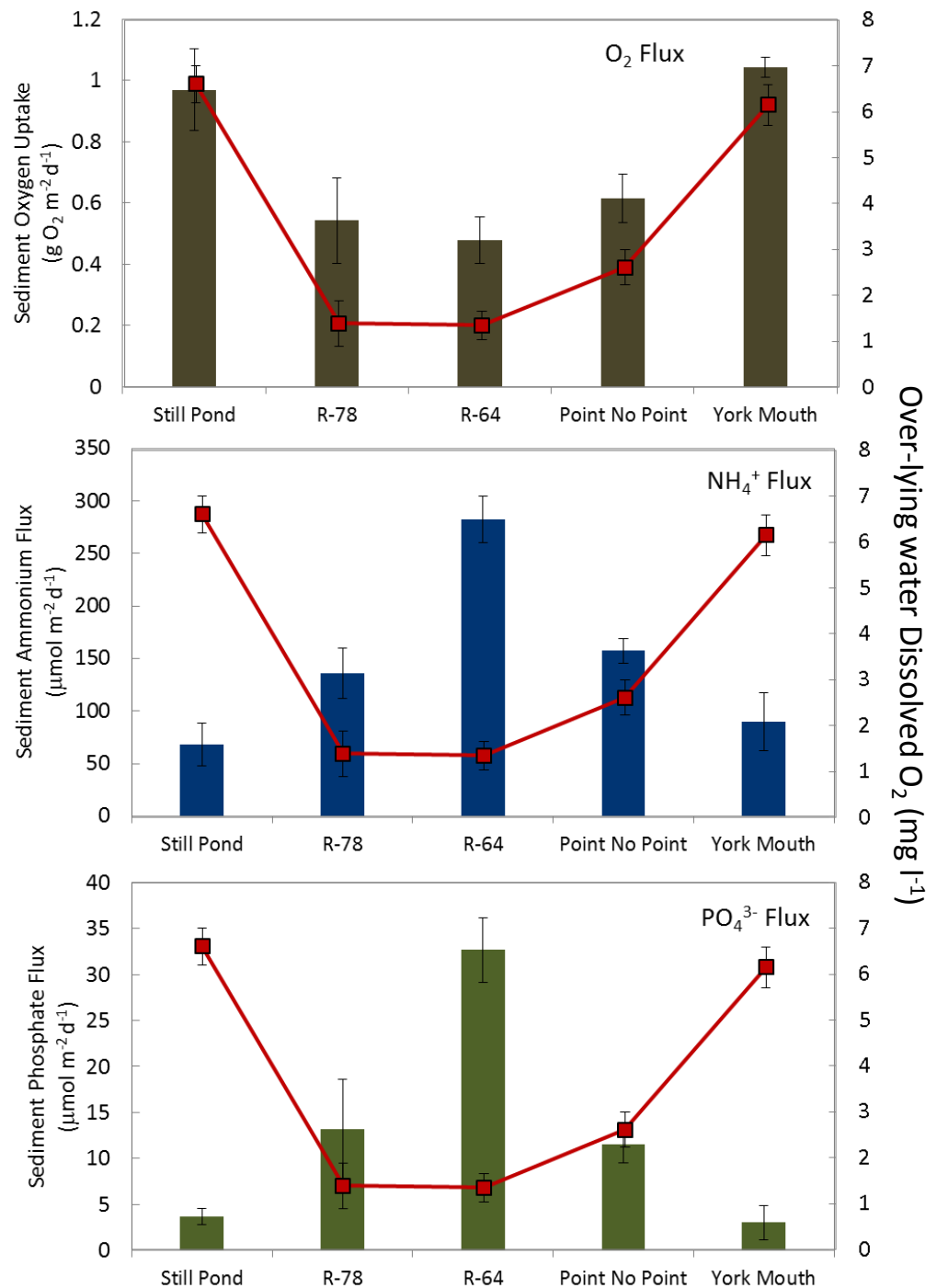


# Sediment-Water Fluxes Respond to Labile Organic Matter

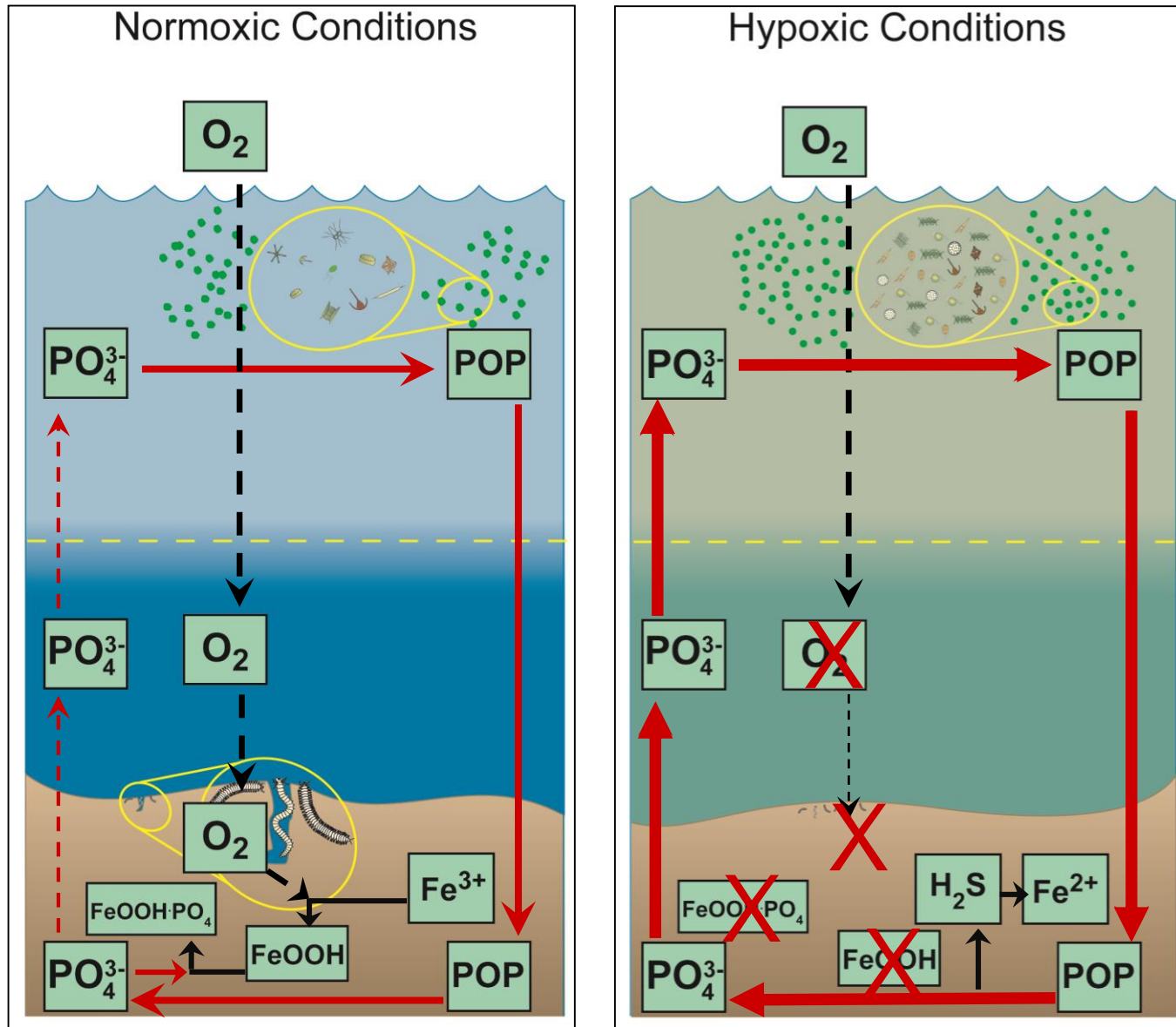


# Spatial Variation in Sediment-Water Fluxes

- Sediment  $O_2$  Uptake lowest in region between Bay Bridge and Patuxent
- $NH_4^+$  and  $PO_4^{3-}$  fluxes peak in mid-Bay
- Bottom-water  $O_2$  low where N and P fluxes peak



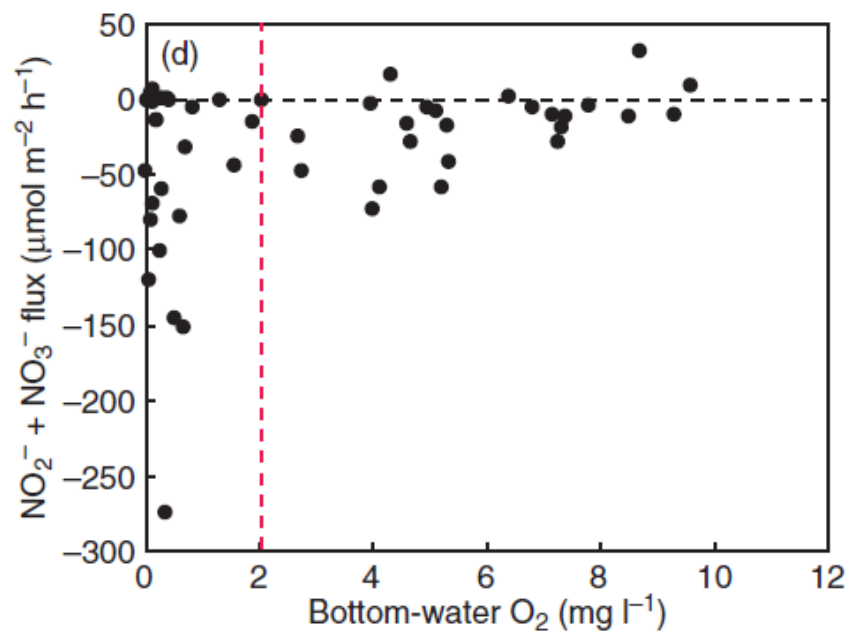
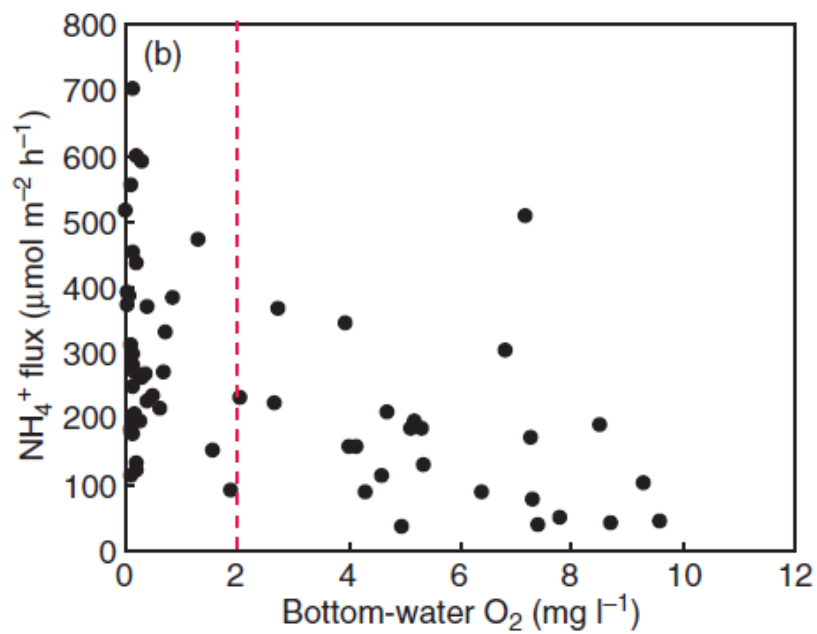
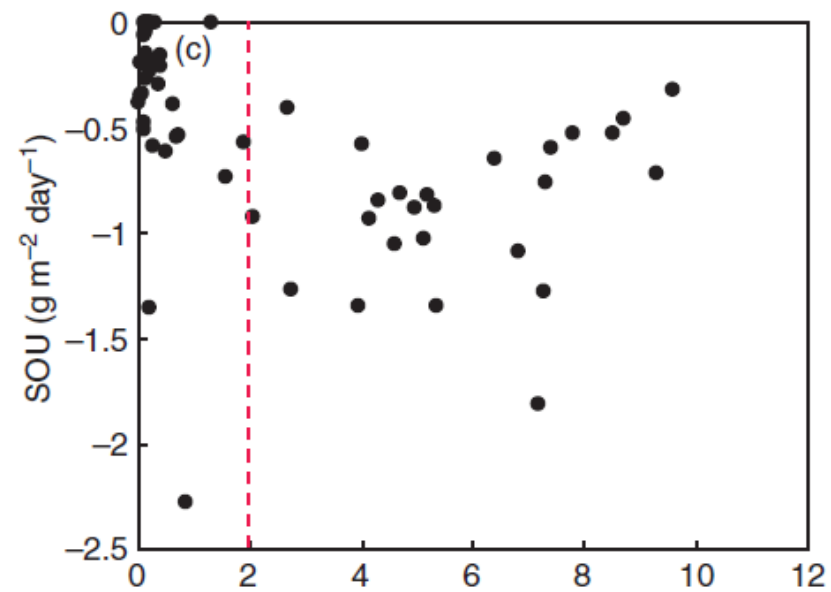
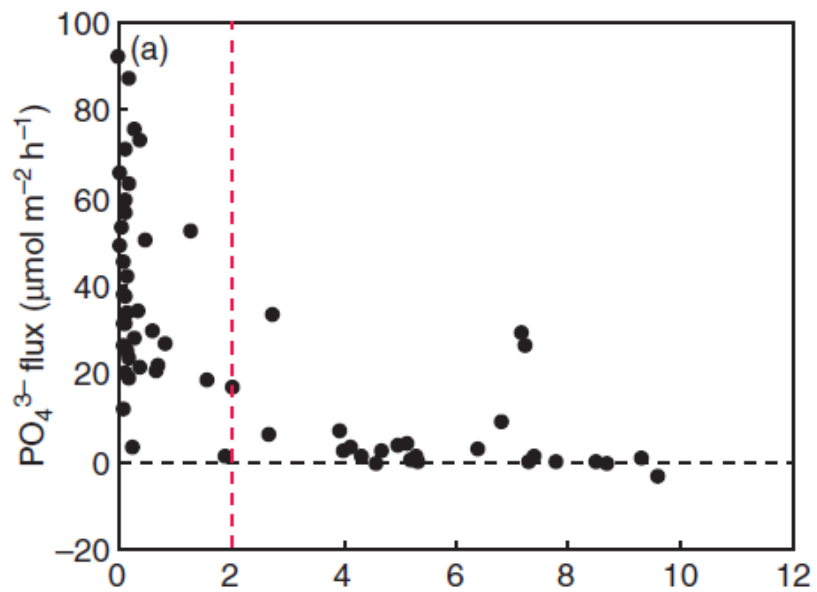
# Conceptual Model of O<sub>2</sub> Interactions with P-Cycle



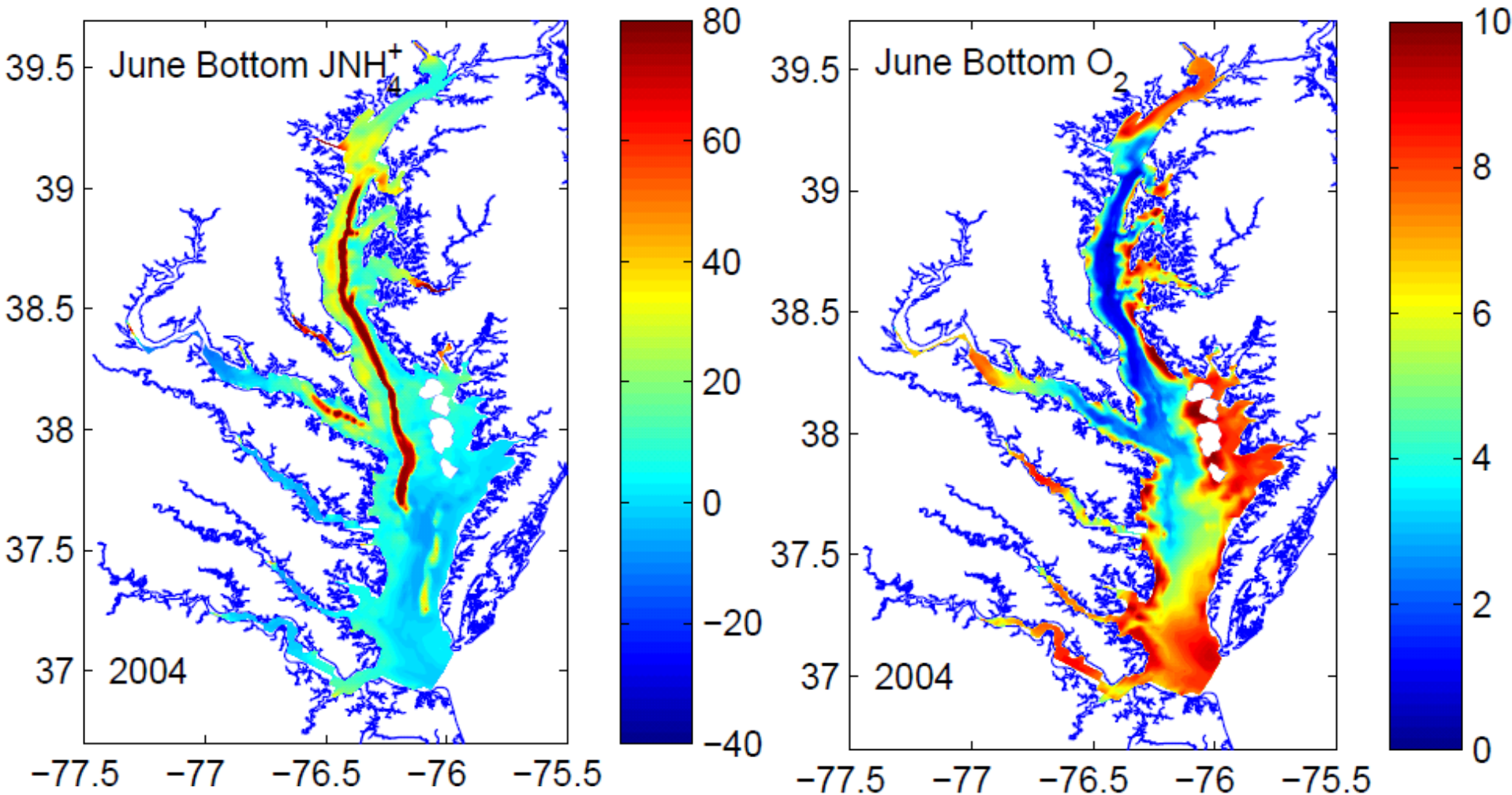
# Water-Column Oxygen Drives Fluxes



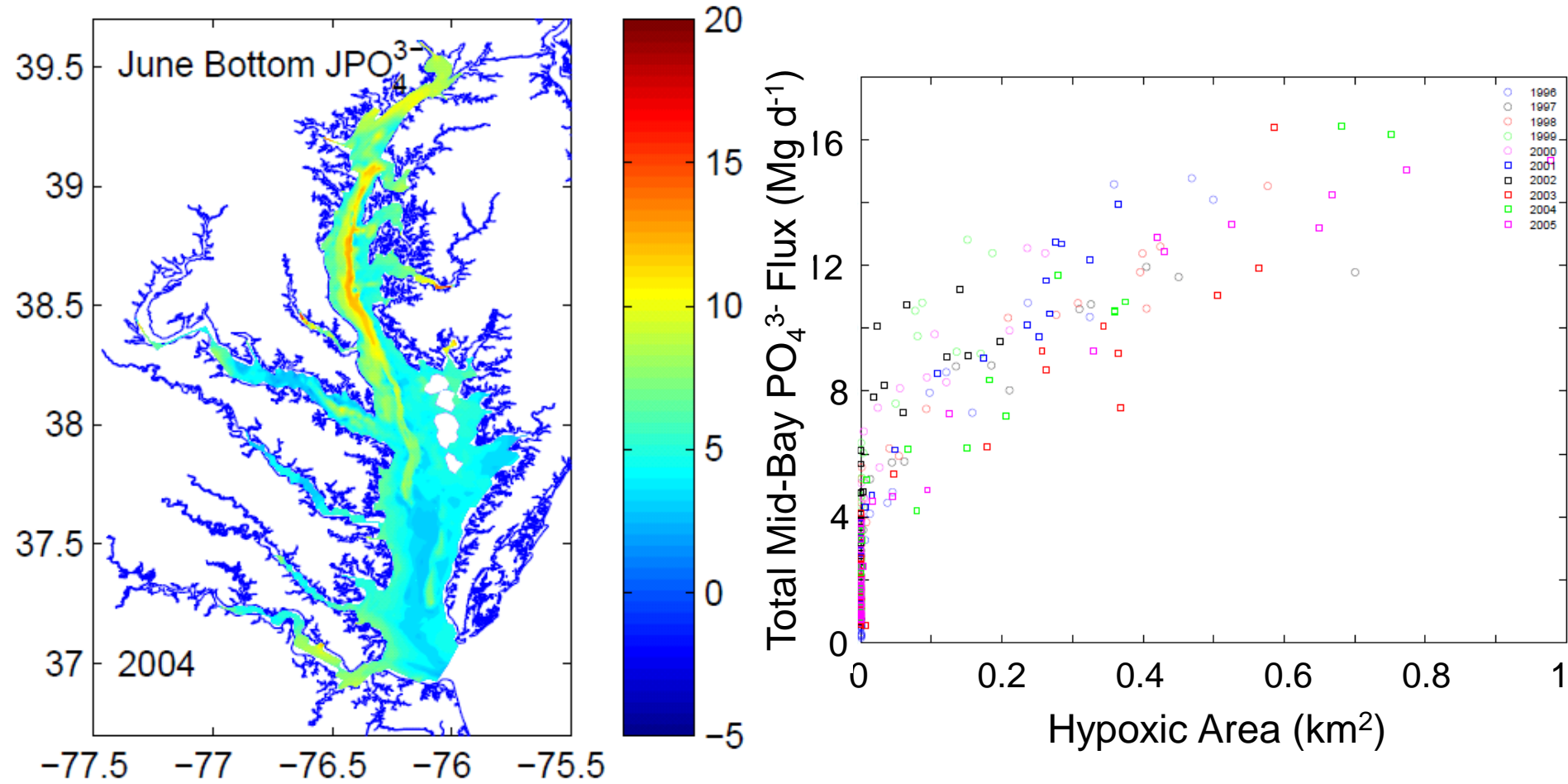
R-64 (Mid-Chesapeake Bay)



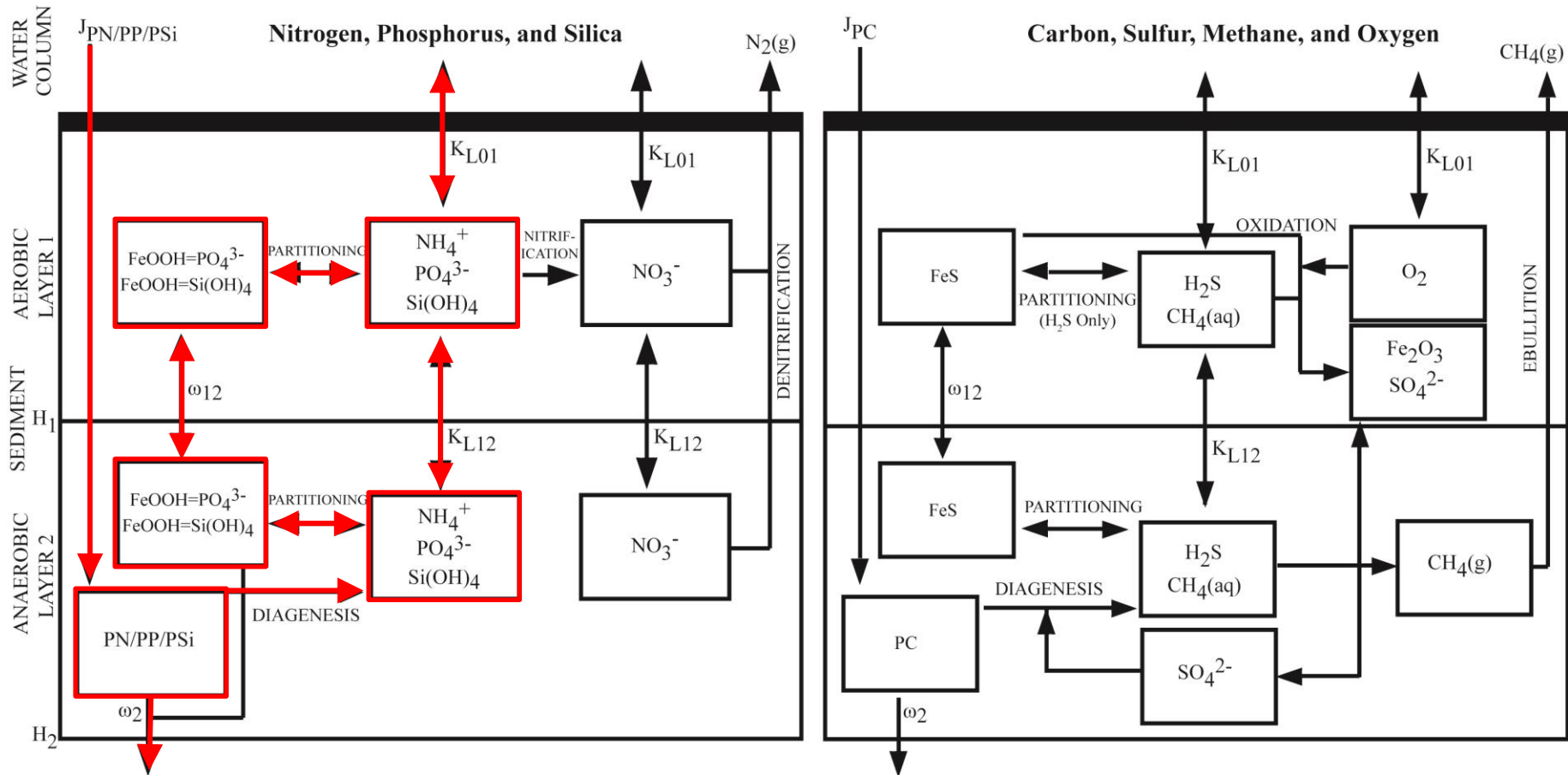
# Numerical Model Distributions of N Flux



# Numerical Model Distributions of P Flux

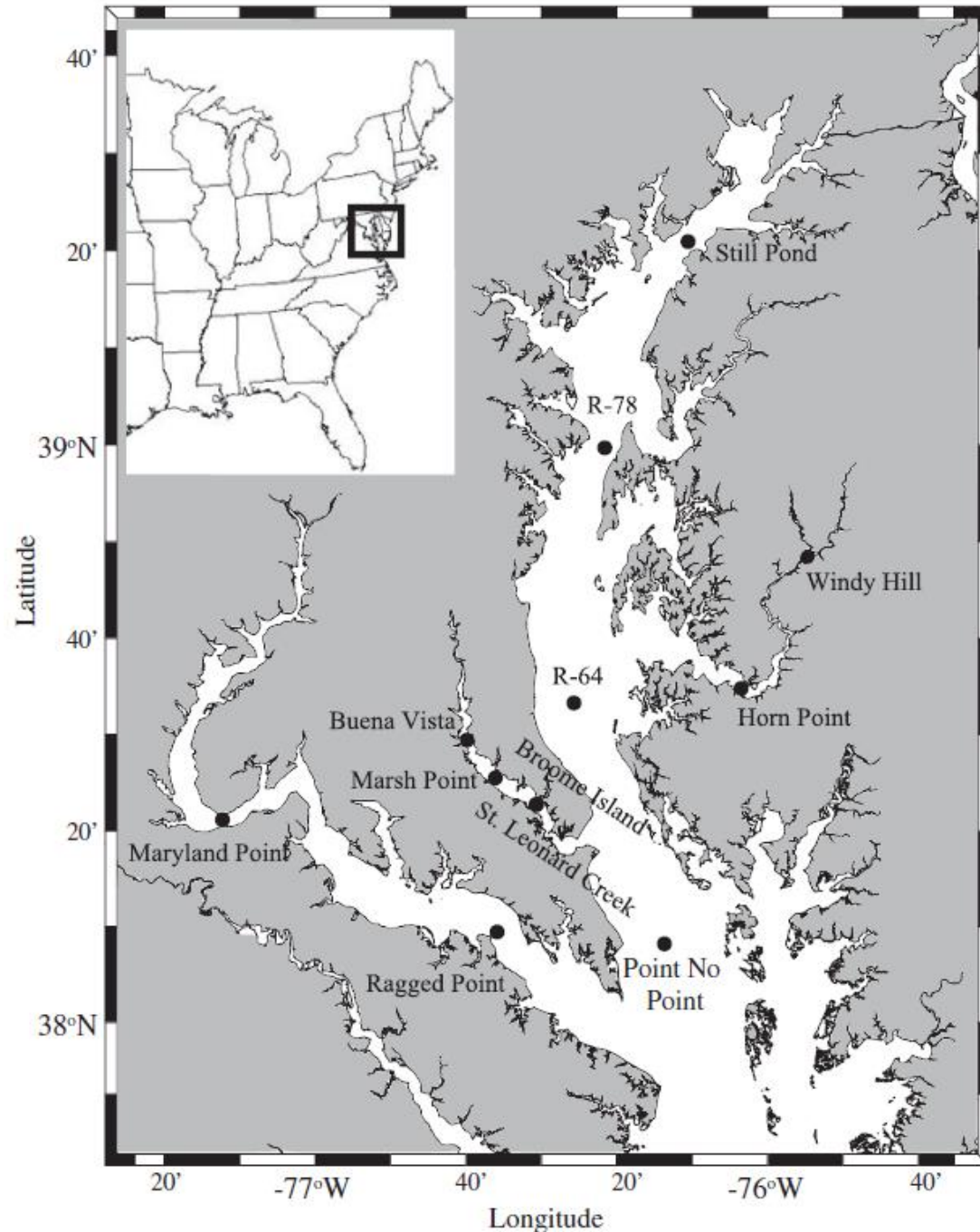


# Sediment Flux Model Schematic



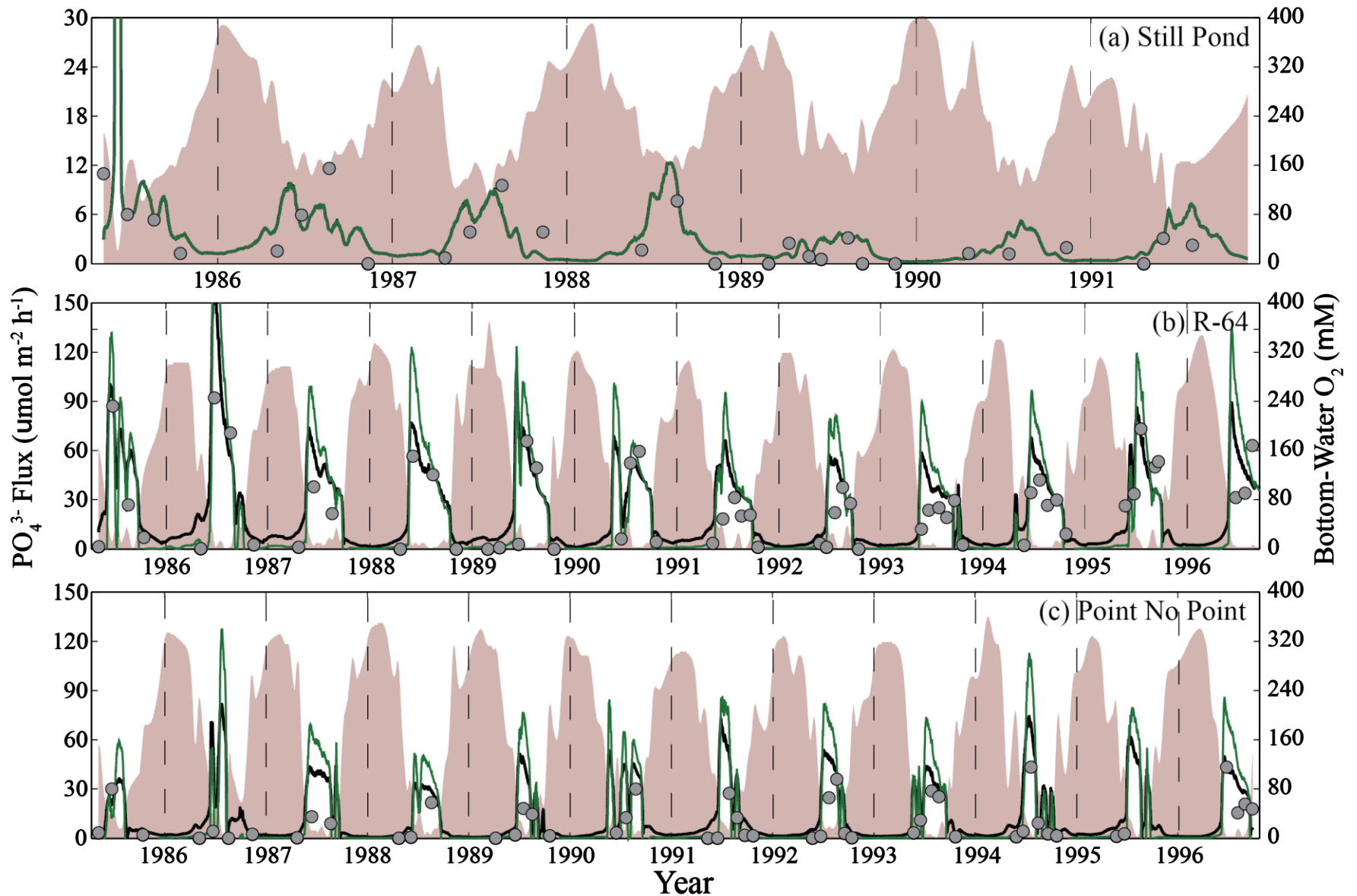
\*Deposited organic matter partitioned into 3 reactivity classes, representative of algal material or non-algal material

# Sediment Flux Model Run in "Stand-Alone" For Chesapeake Bay

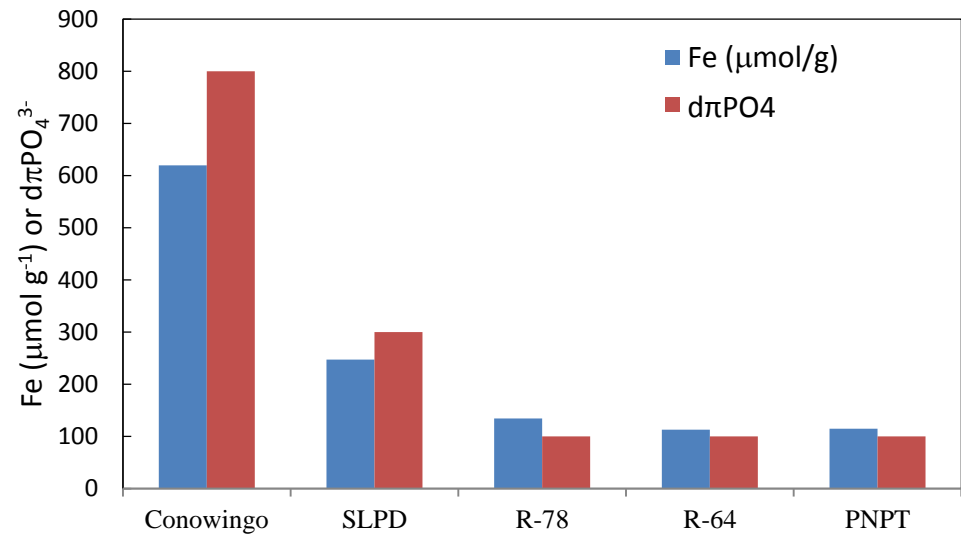
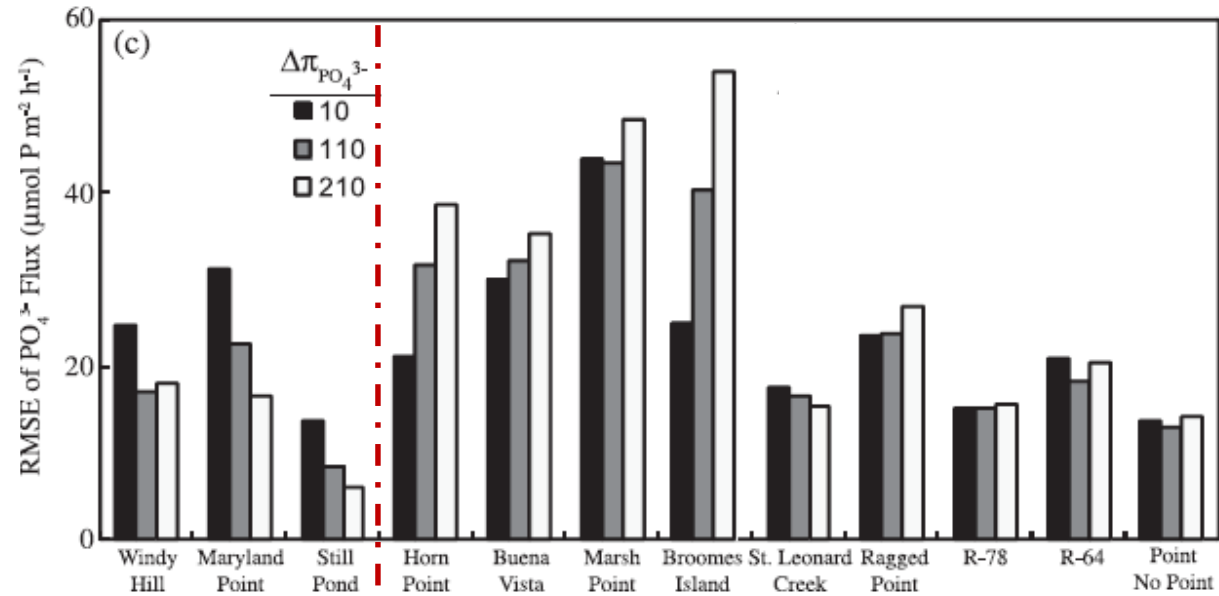
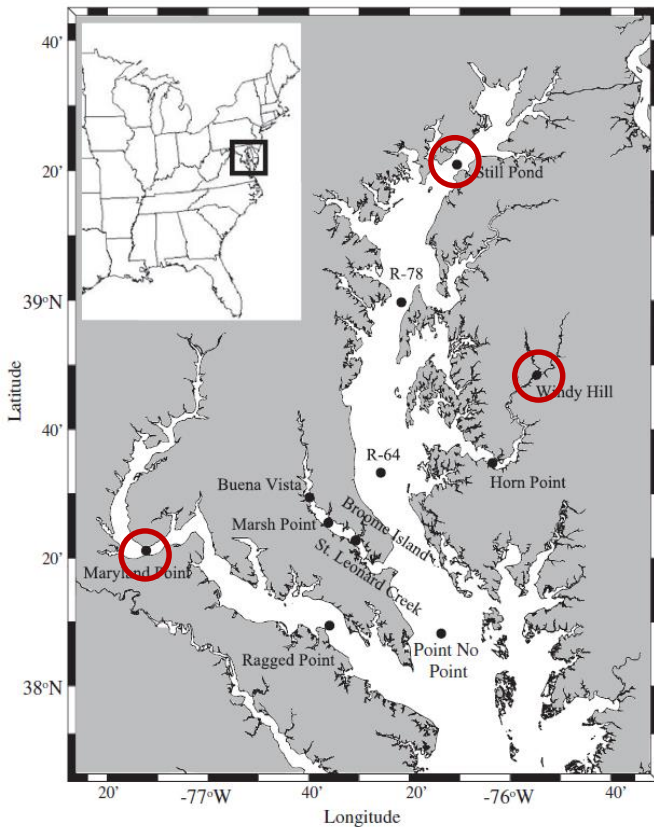


- Model forced by overlying-water nutrient and oxygen concentrations
- POM deposition estimated by fitting model  $\text{NH}_4^+$  flux to observations
- Rapid runs allow for sensitivity runs, scenarios

# Model Time-Series of $\text{PO}_4^{3-}$ Flux and $\text{O}_2$

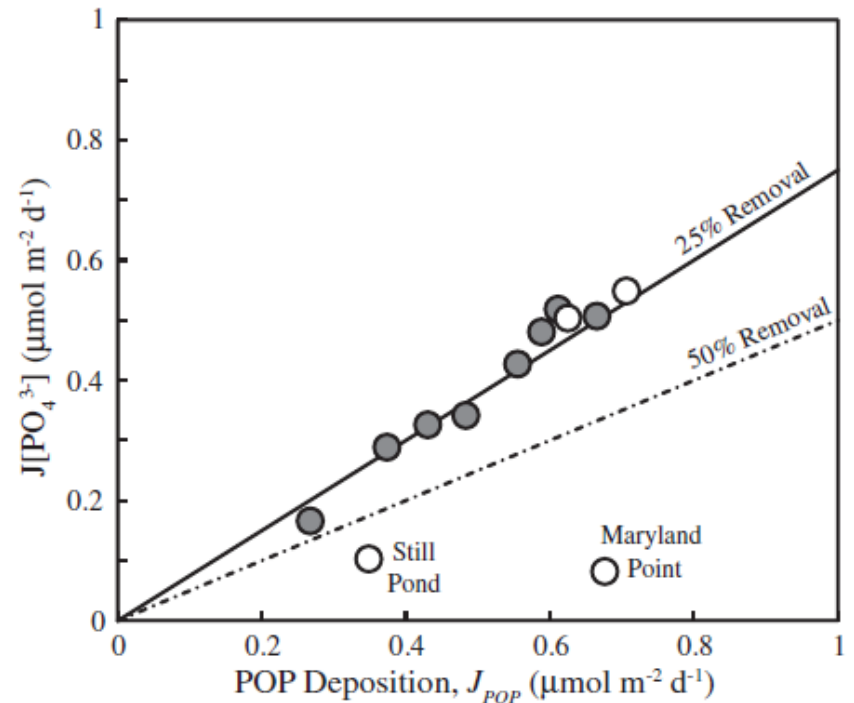
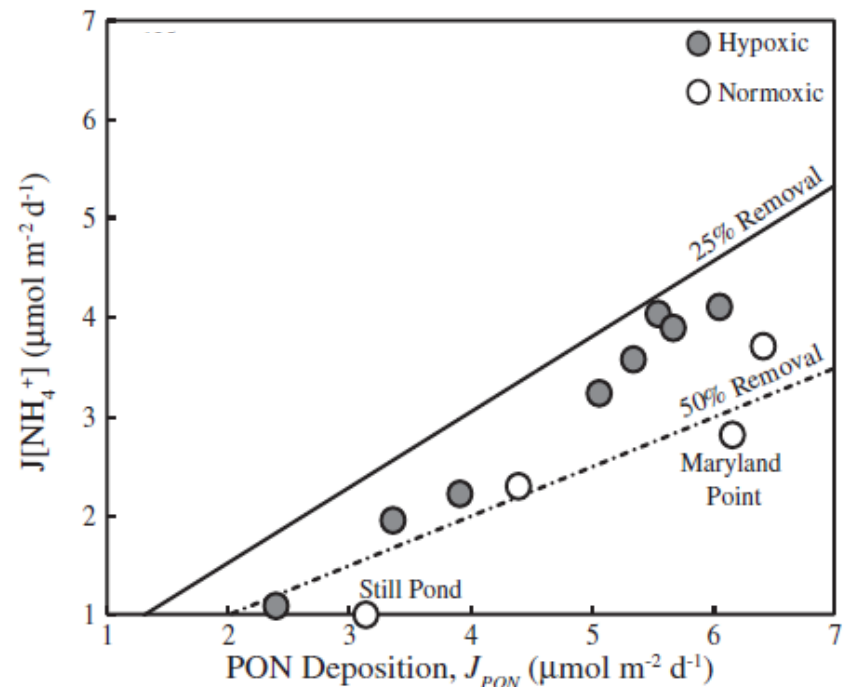


# Spatially-Dependent Model Optimization

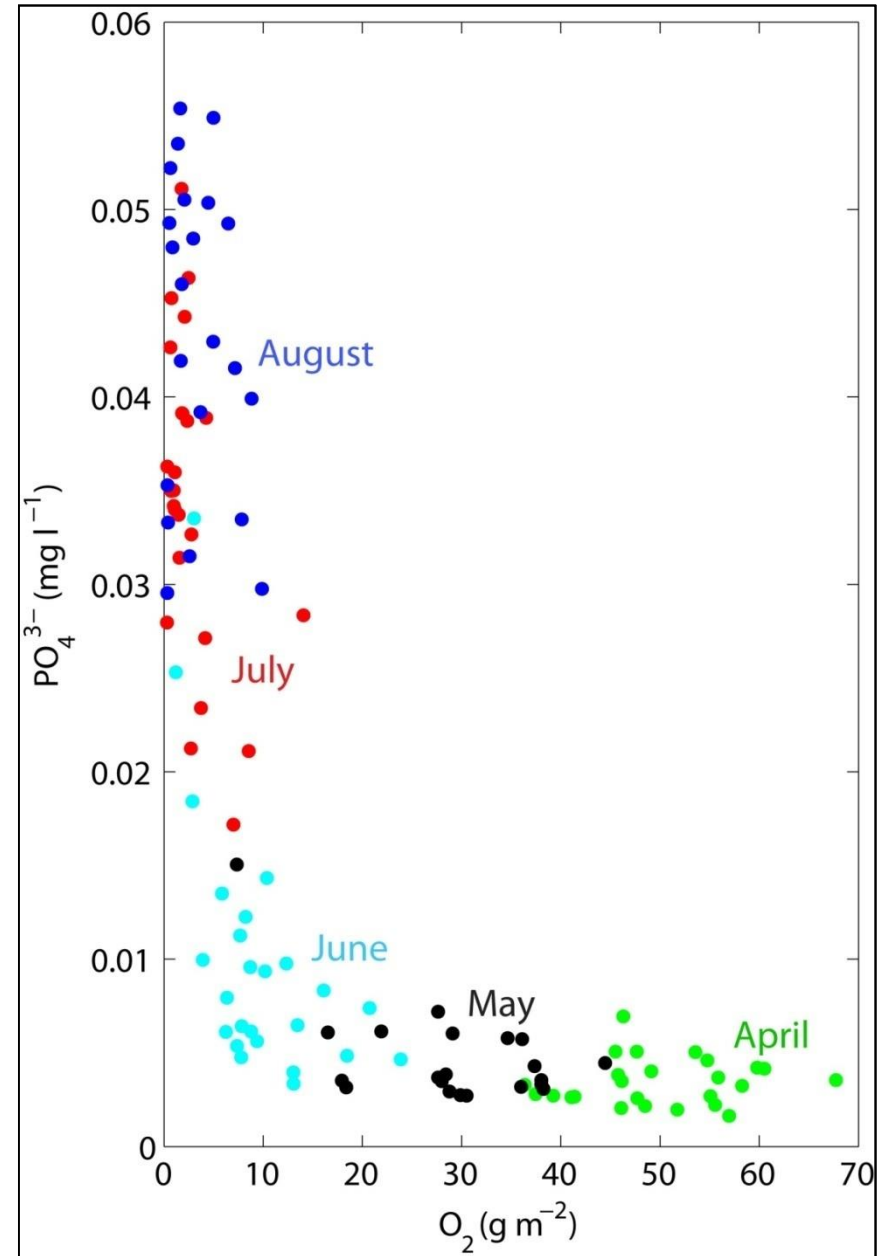
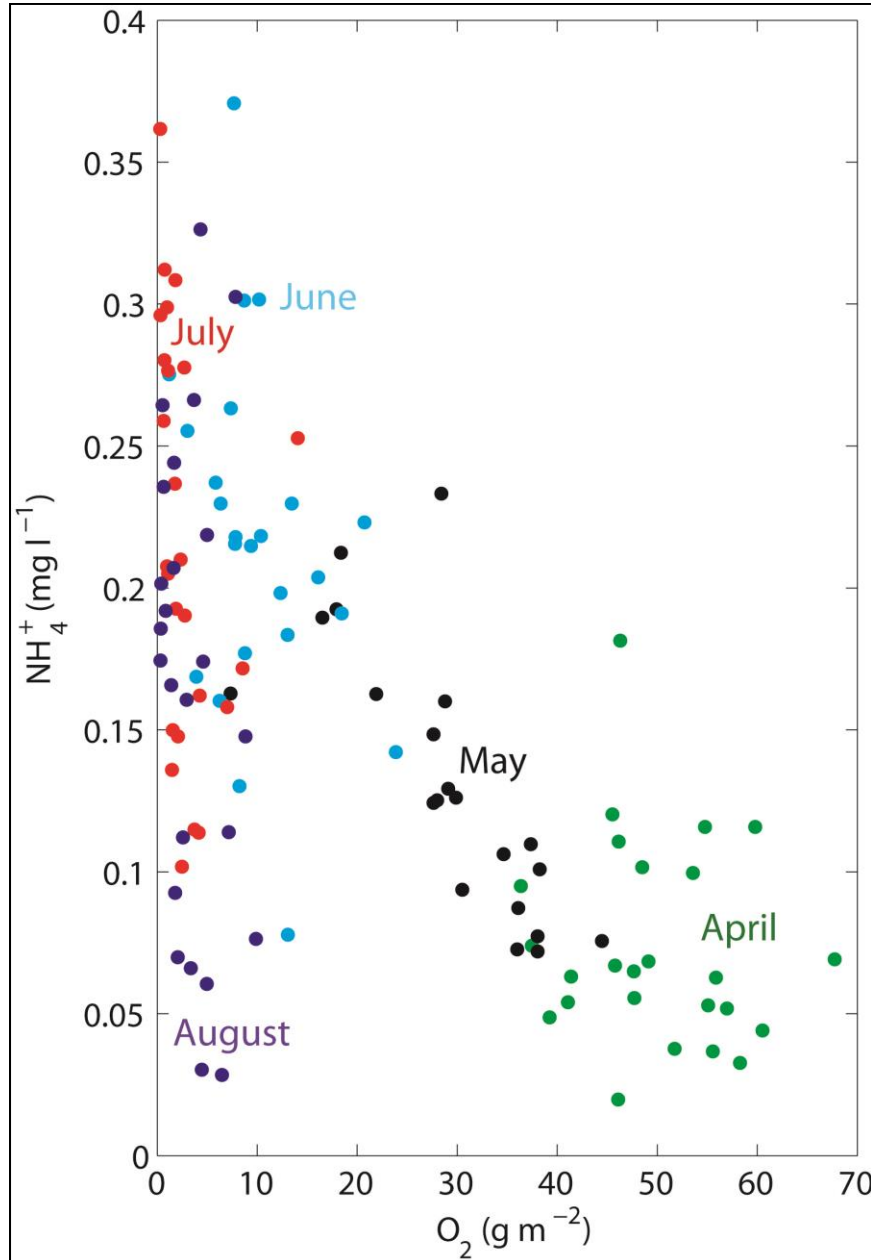


# Fraction of Recycled N and P Varies by Location

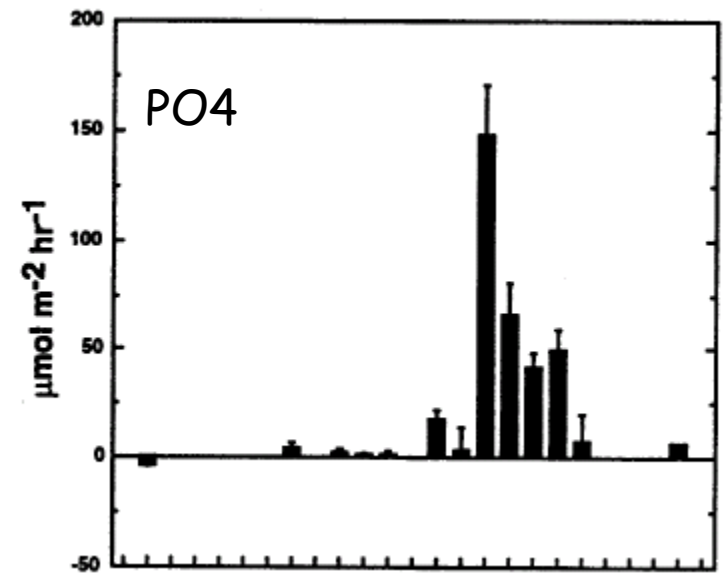
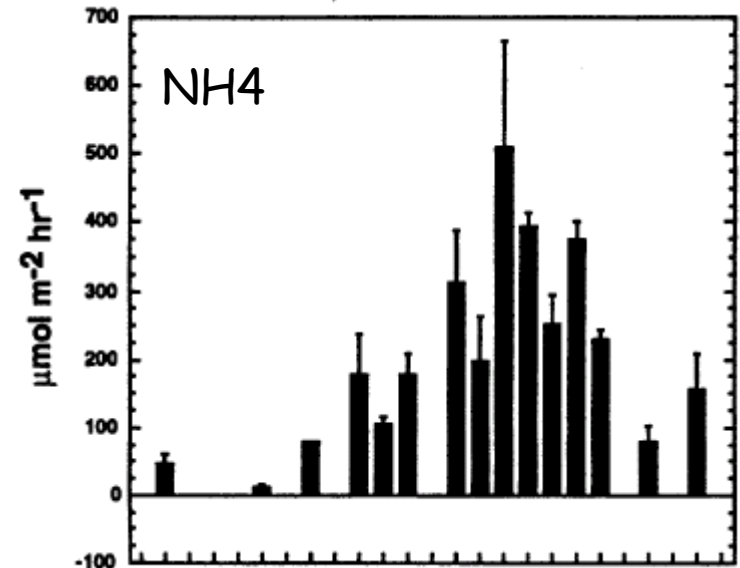
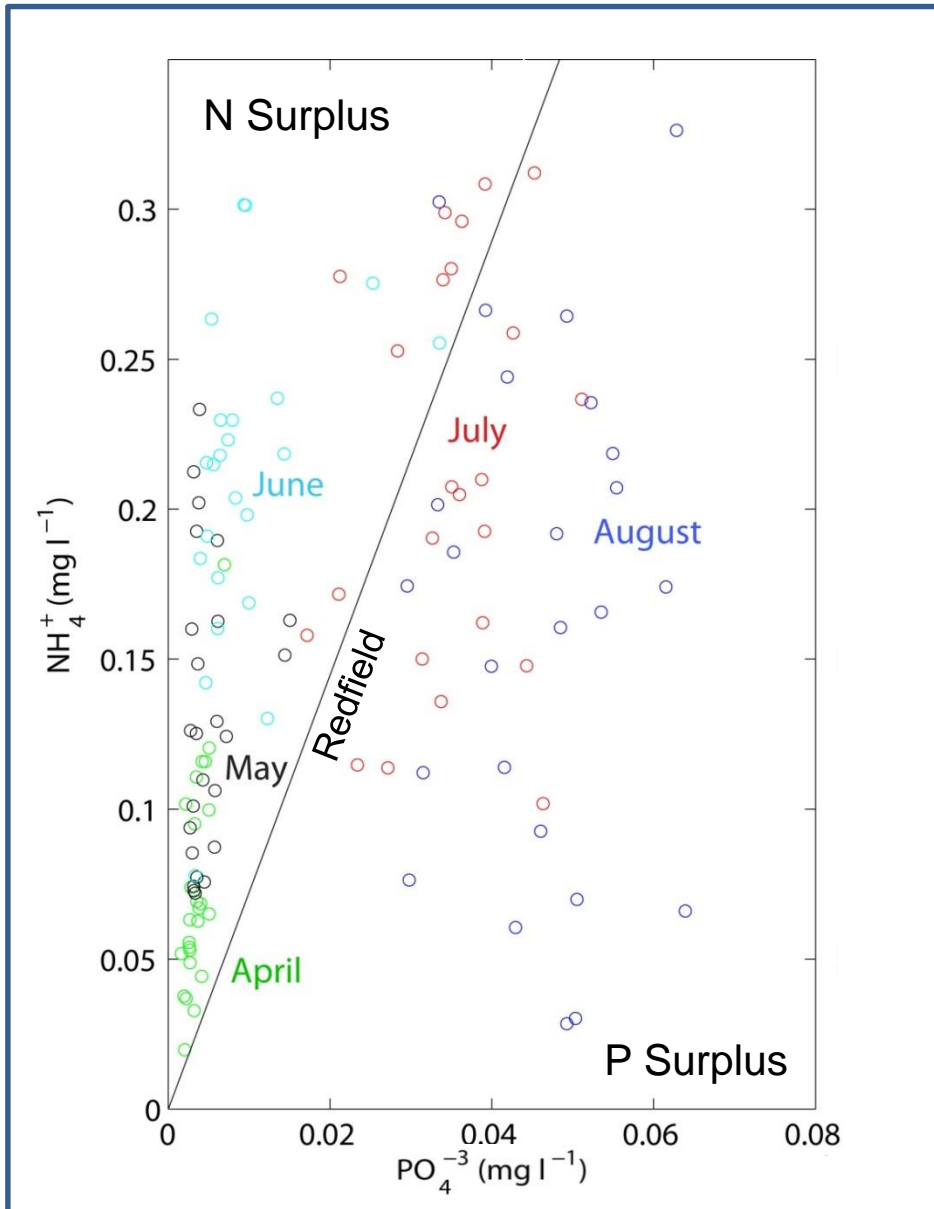
- Roughly 35% of N removed, but ~50% at oxygenated stations
- Roughly 25% of P removed, except at oxic, high-Fe locations



# Seasonal Trends in Bottom $\text{NH}_4^+$ & $\text{PO}_4^{3-}$ vs. $\text{O}_2$



# Temporal Mismatch in Fluxes Drives N:P Ratios



# Summary

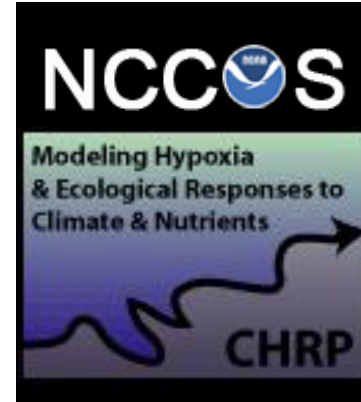
- (1) Upper Bay sediment N and P fluxes generally lower than mid-Bay region, despite higher POM deposition
- (2) Fate of N and P deposited to sediment in Chesapeake Bay dependent on sediment properties and overlying-water dissolved oxygen
- (3) Differential behavior of N and P in sediments drives timing of water-column  $\text{NH}_4^+$  and  $\text{PO}_4^{3-}$

# Acknowledgements

Funding:



Exelon.



Data:

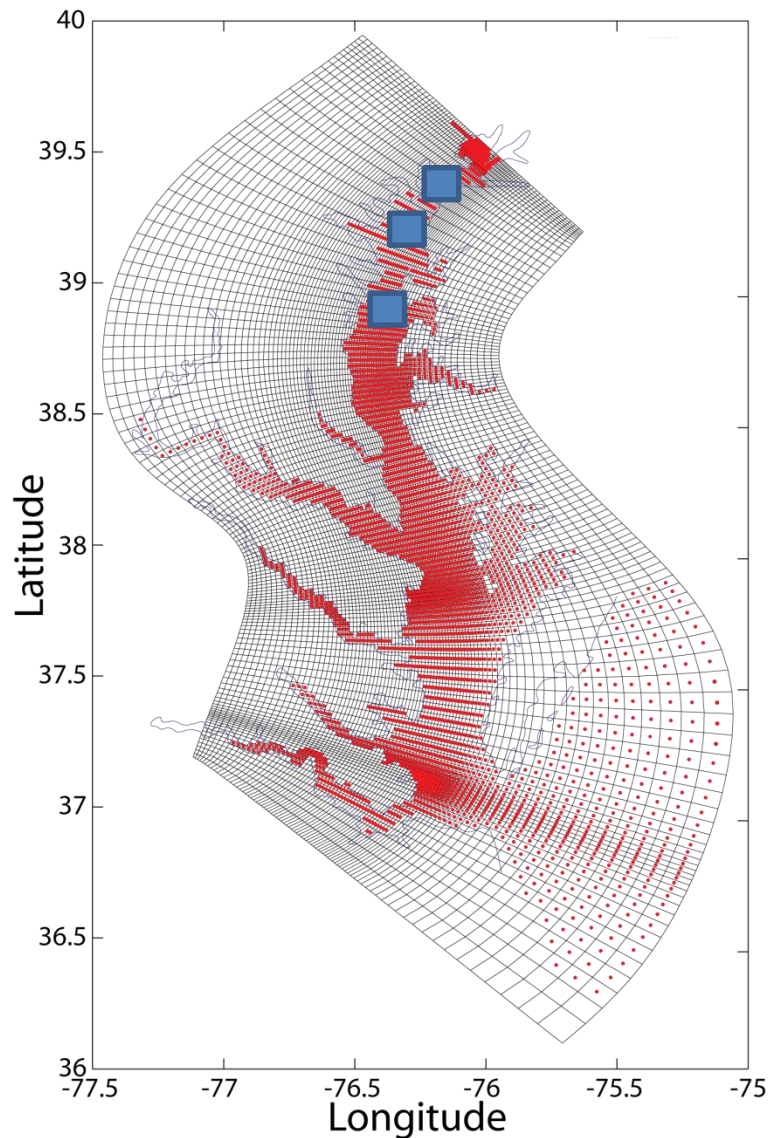
Chesapeake  
Bay Program



Maryland Department of  
Natural Resources

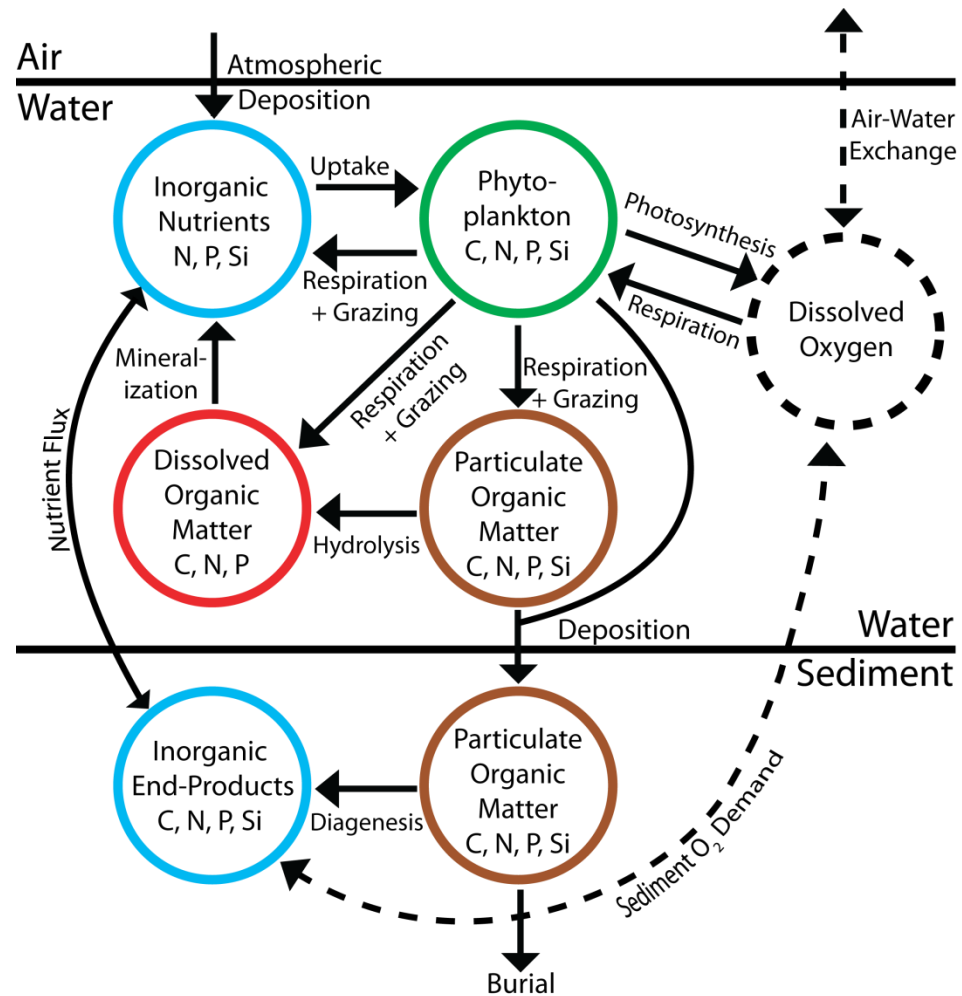


# ROMS



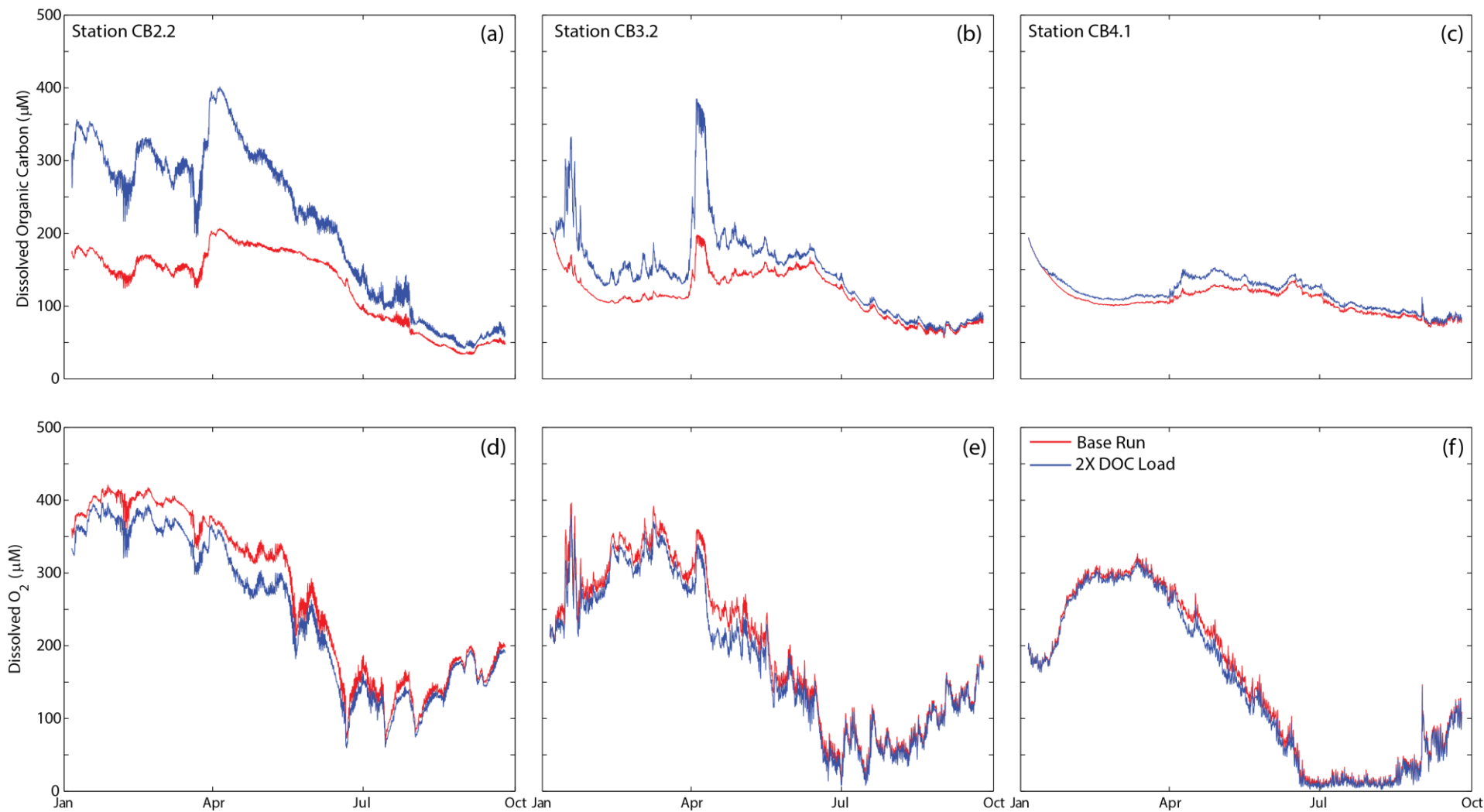
- Forced by freshwater from 8 major tributaries
- Resolution = 80 cells east-west, 120 cells north-south  
20 vertical layers, 68,000 Cells

# RCA



- 23 state variables
- Coupled sediment biogeochemical model
- External loads from 8 tributaries, point sources, atmospheric deposition
- Calibrated to water-column concentrations, sediment and water-column metabolic rates

# Direct Oxidation of Organic Carbon Relevant

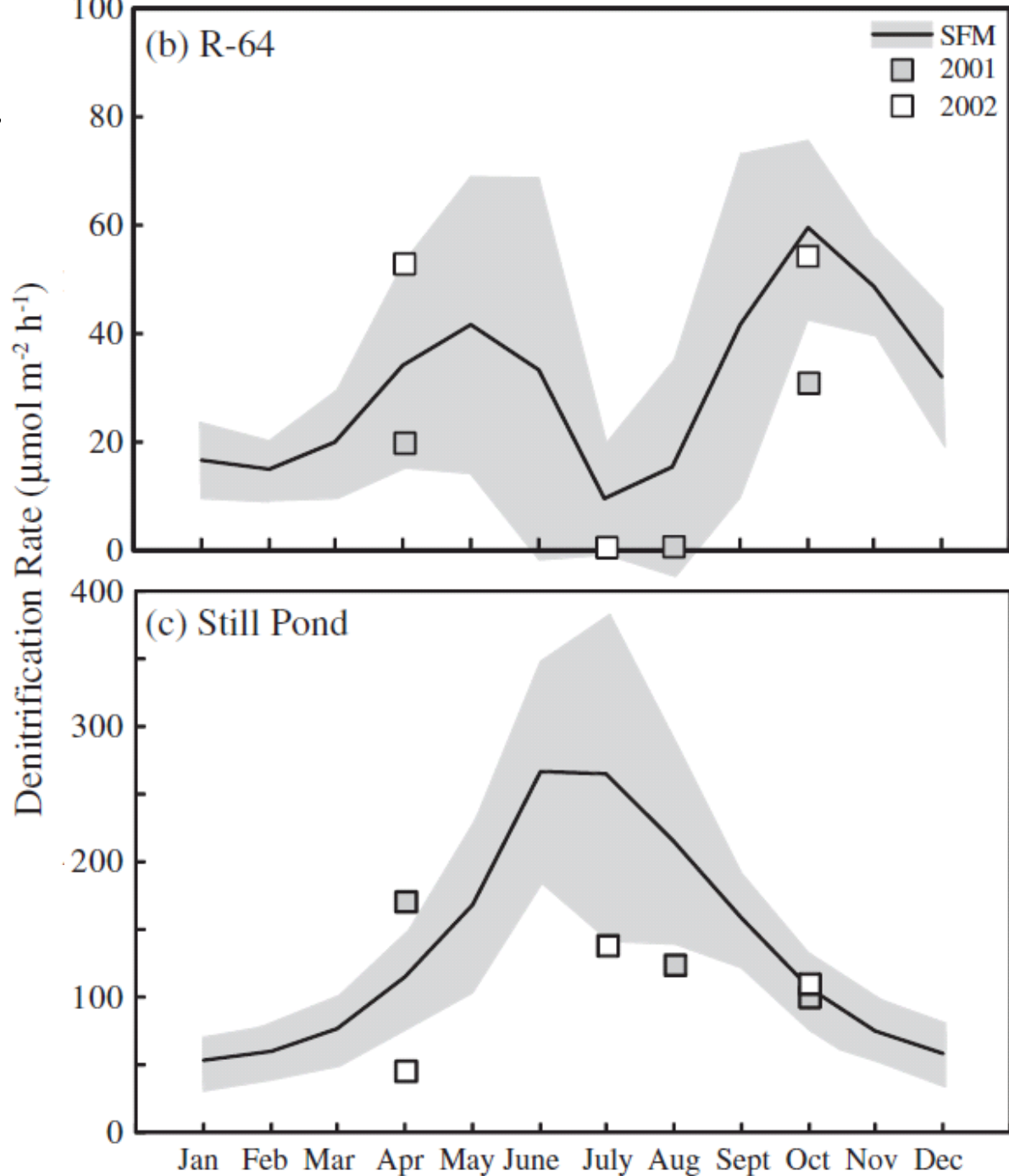


Seaward

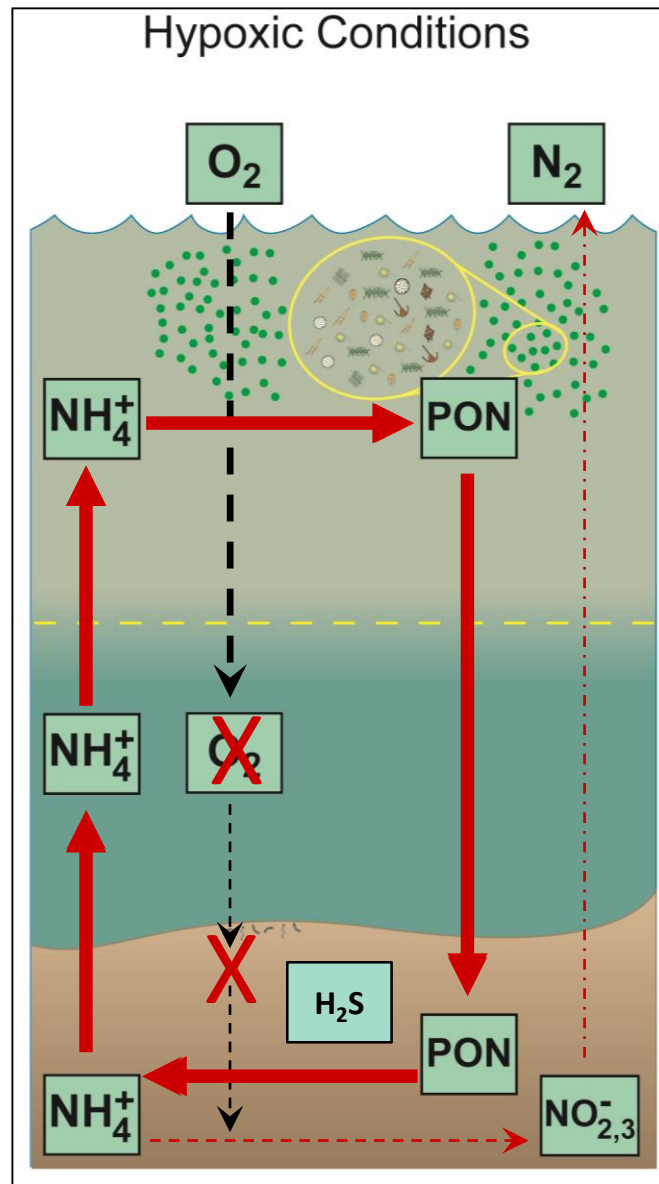
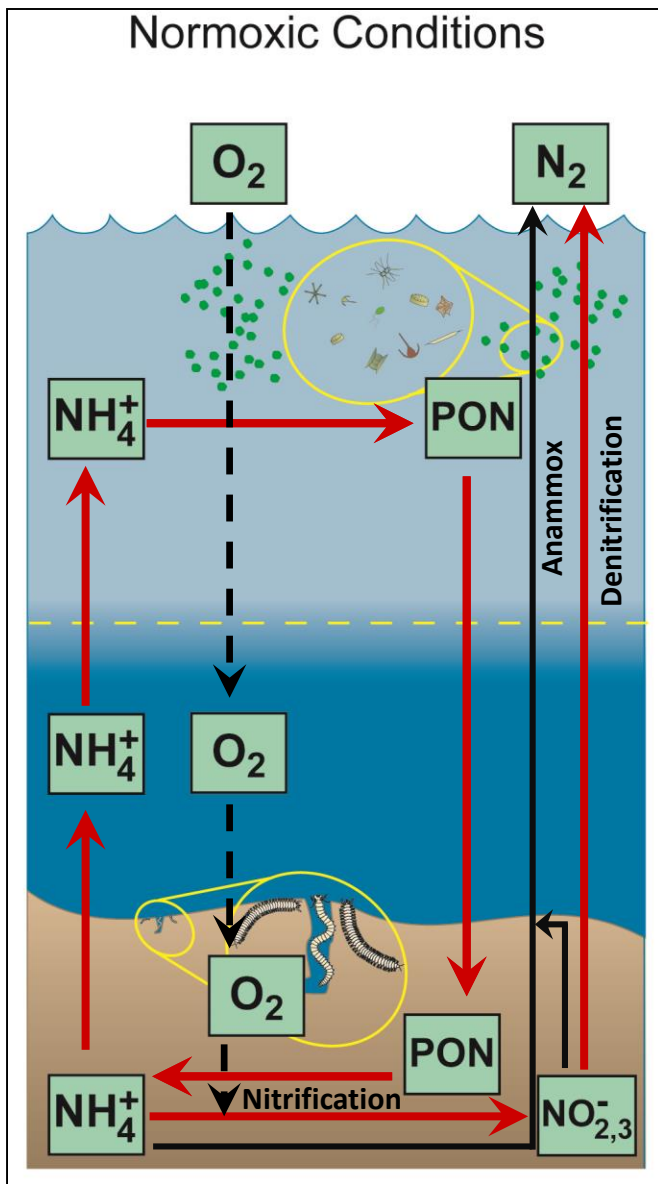


# Denitrification: Upper and Mid-Bay

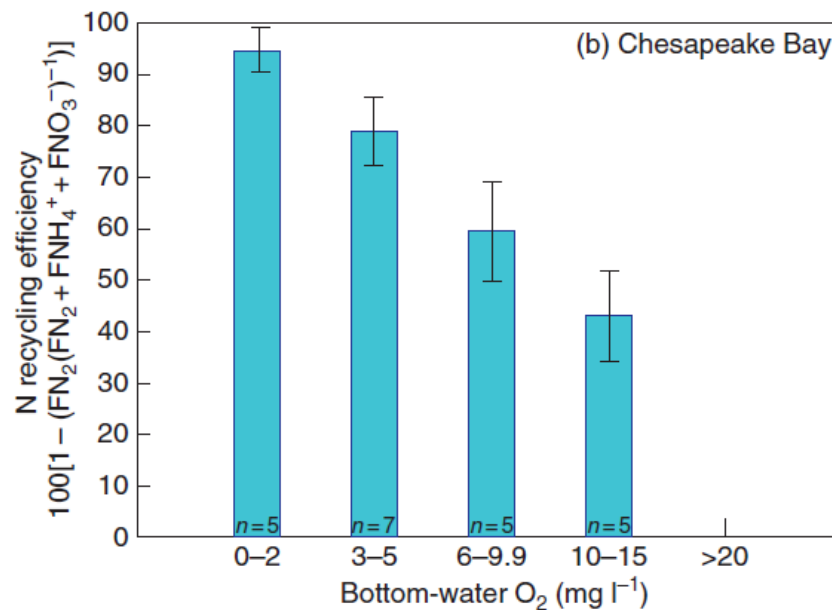
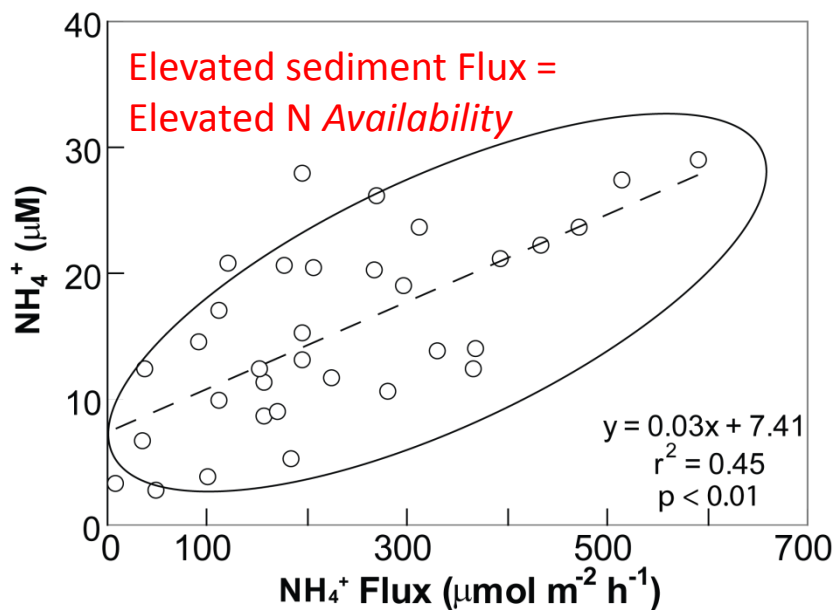
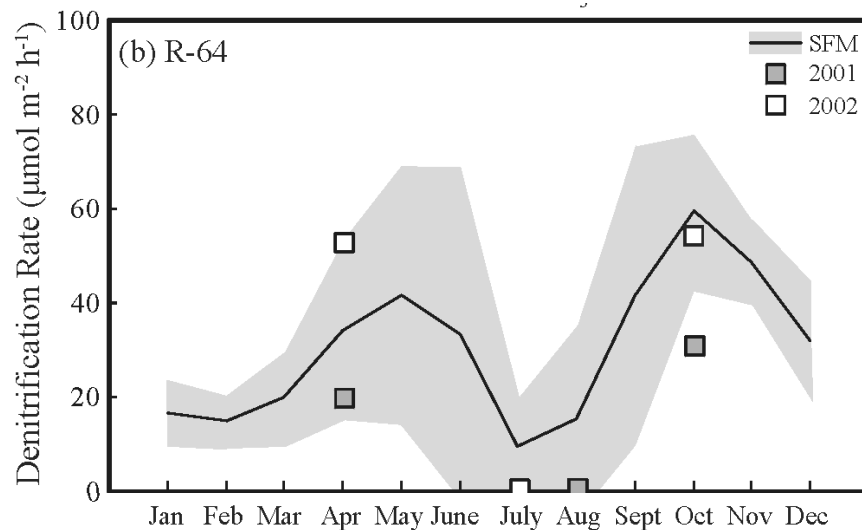
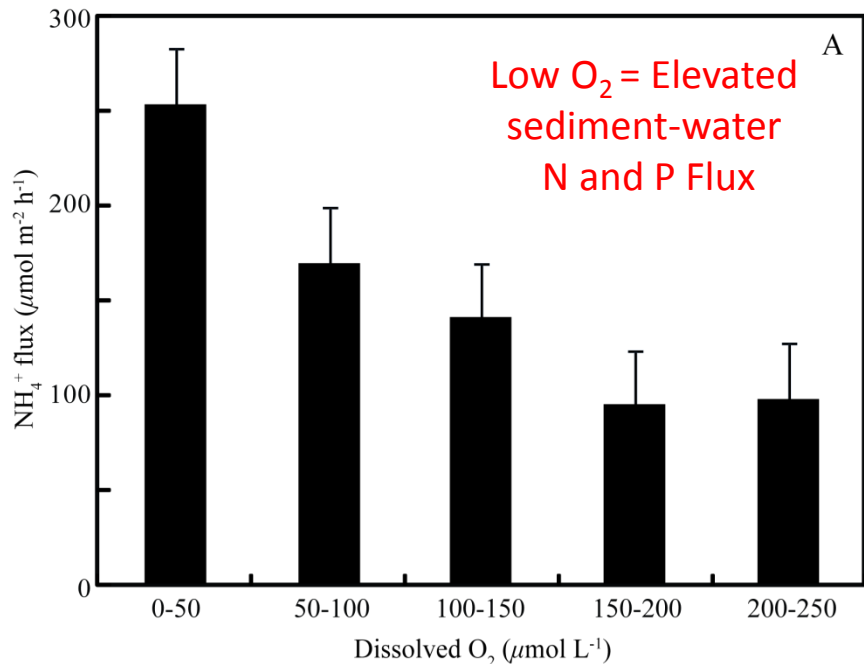
- Rates generally lower in Mid-Bay, as  $\text{NO}_3$ -limited in mid-summer
- Rates generally higher in upper Bay,  $\text{NO}_3$  abundant, no anoxia



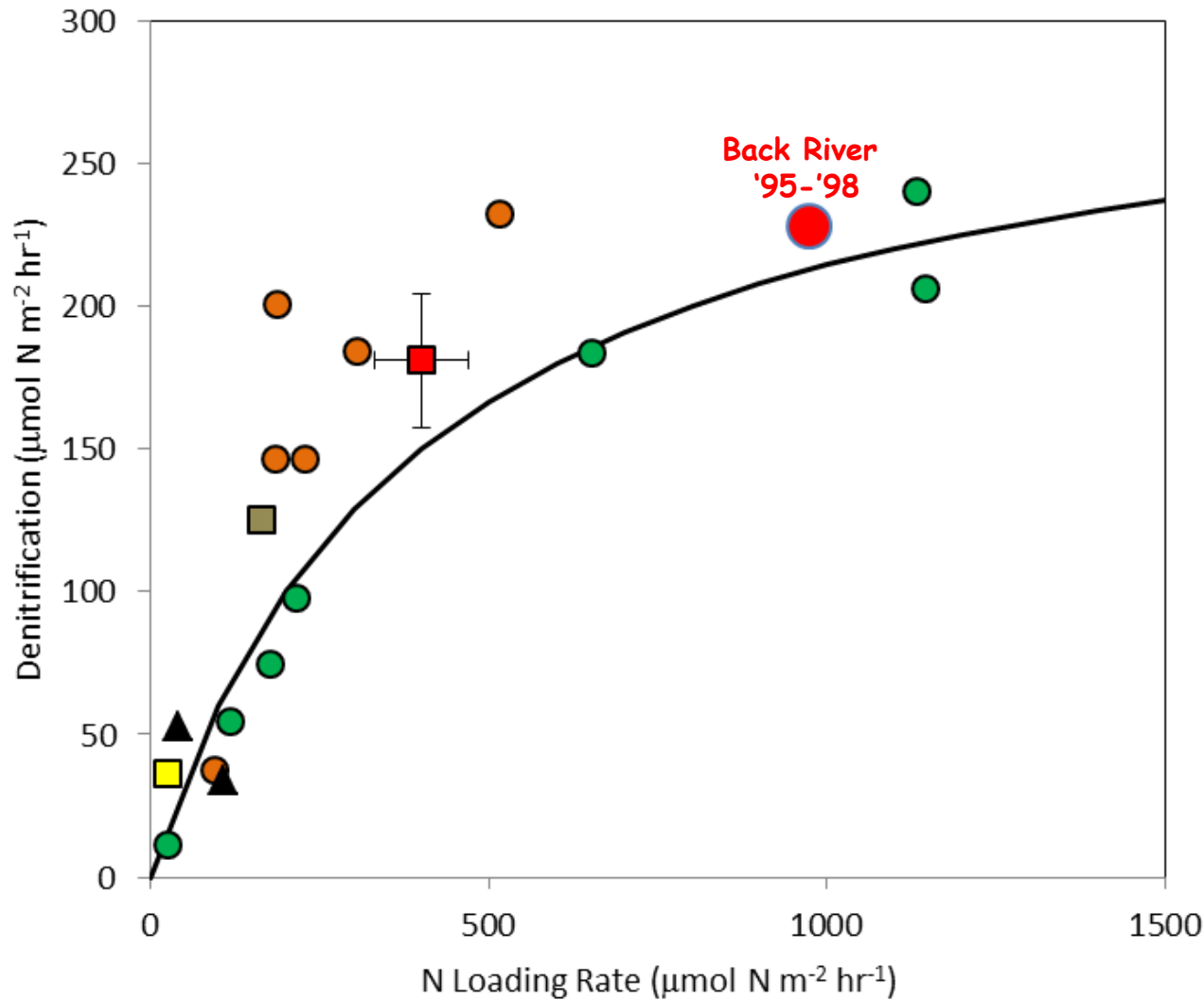
# Conceptual Model of O<sub>2</sub> Interactions with N-Cycle



# Hypoxia Enhances Sediment Nitrogen Recycling



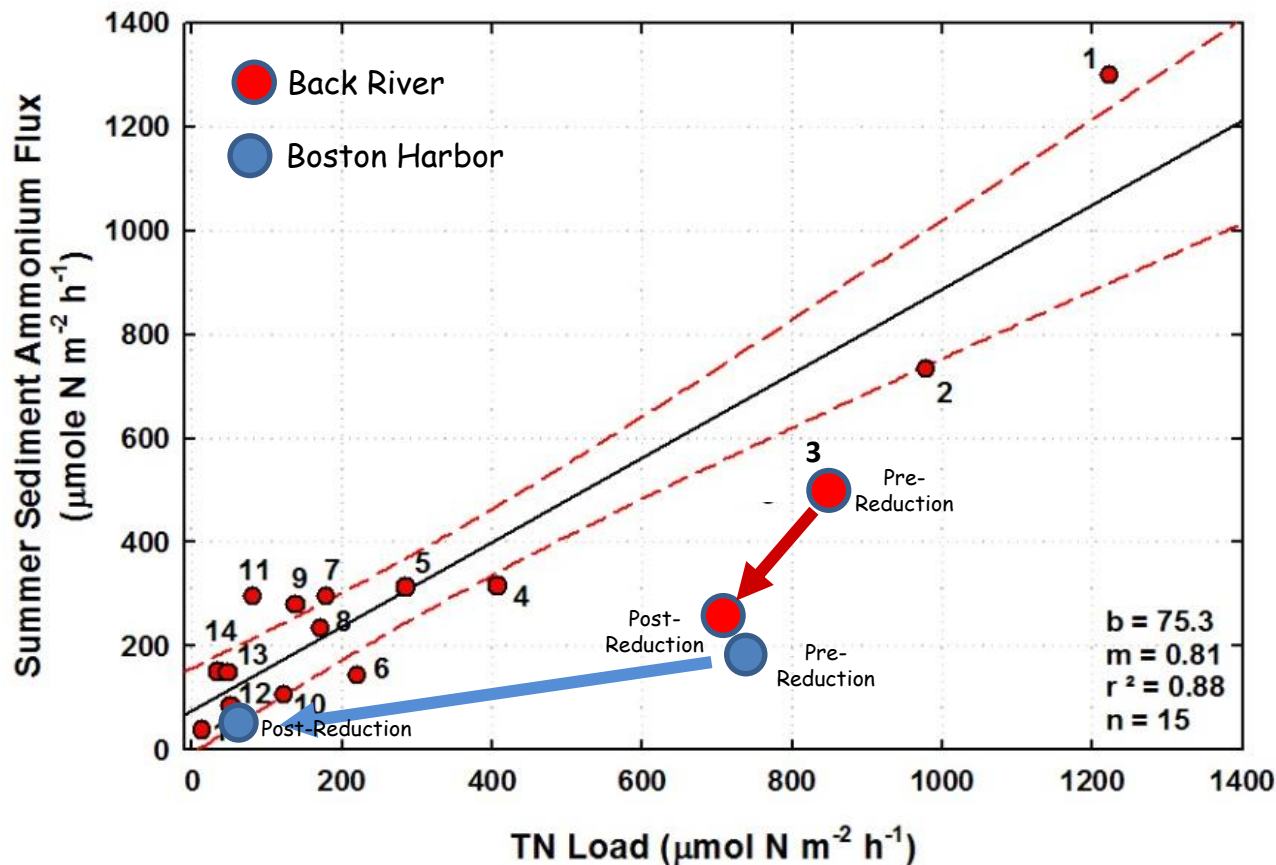
# Comparative Analysis: Denitrification vs N Loading



- Denitrification positively related to N loads in diverse systems
- Possible saturating response
- Back River in mid-1990s near-maximum
- Preliminary simulations suggest Back River denitrification has declined substantially

**Sites code:** (green circles) Summary from Kamp-Nielsen 1992, (yellow square) Moreton Bay, Eye and McKee 2002, (black triangles) Texas coastal bays, Yoon and Benner 1992, (orange circles) Roskilde Fjord, Kamp-Nielsen 1992, (Brown square) upper Chesapeake Bay, Testa et al. 2013, (red square) Boston Harbor, Tucker et al. 2014 and Taylor et al. 2011.

# Comparative Analysis: Sediment N Flux vs N Loading



- Chesapeake sites respond to N loads

- N loads  $\rightarrow$  phyto biomass  $\rightarrow$  deposition  $\rightarrow$  remineralization

- Back River fluxes also responded to N load changes

- Boston Harbor fluxes exhibited similar pattern

**Sites code:** 1) Baltimore Harbor, 2) Anacostia River, 3) Back River, 4) Patapsco River, 5) Potomac River, 6) Elk River, 7) Corsica River, 8) Mainstem Chesapeake Bay, 9) Patuxent River, 10) Sassafra River, 11) Chester River, 12) Assawomen/Isle of Wight Bays, 13) Pocomoke River, 14) Choptank River and 15) Chincoteague Bay

**Boston Harbor data from Tucker et al. 2014 and Taylor et al. 2011. Many Thanks!!!**

Negative relationship between flow and chl in upper Bay  
- lower sediment chl<sub>a</sub> in boynton dataset and all fluxes low in that year

Lower labile chl<sub>a</sub>, less flux

ROMS-RCA Slide!