Water Quality Modeling in Estuaries
Lessons Learned

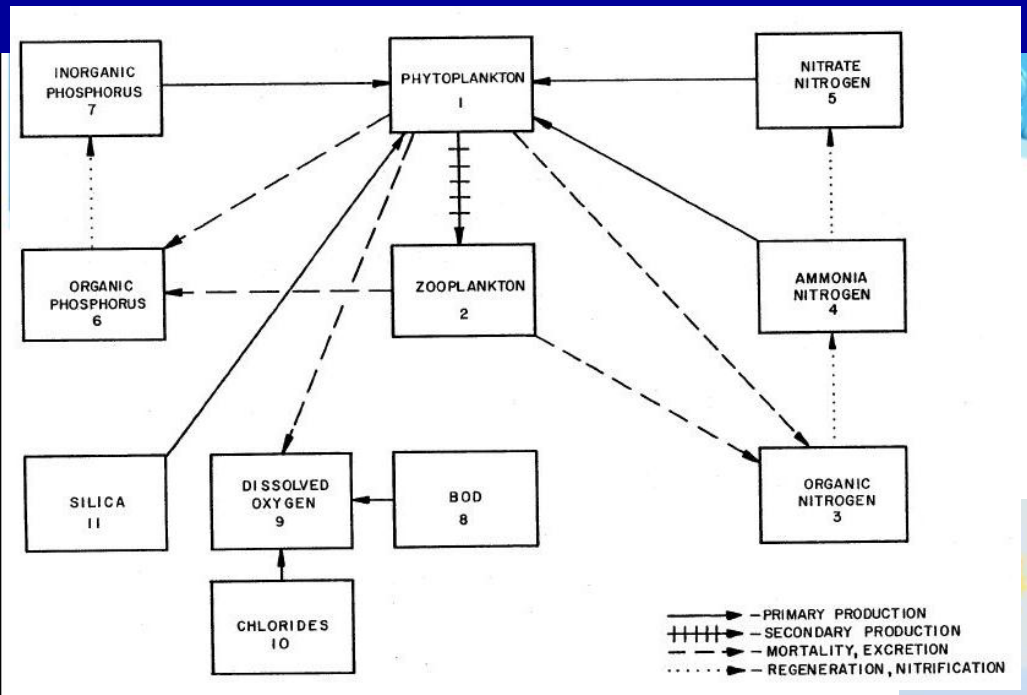
Jim Fitzpatrick

HDR | HydroQual

Outline

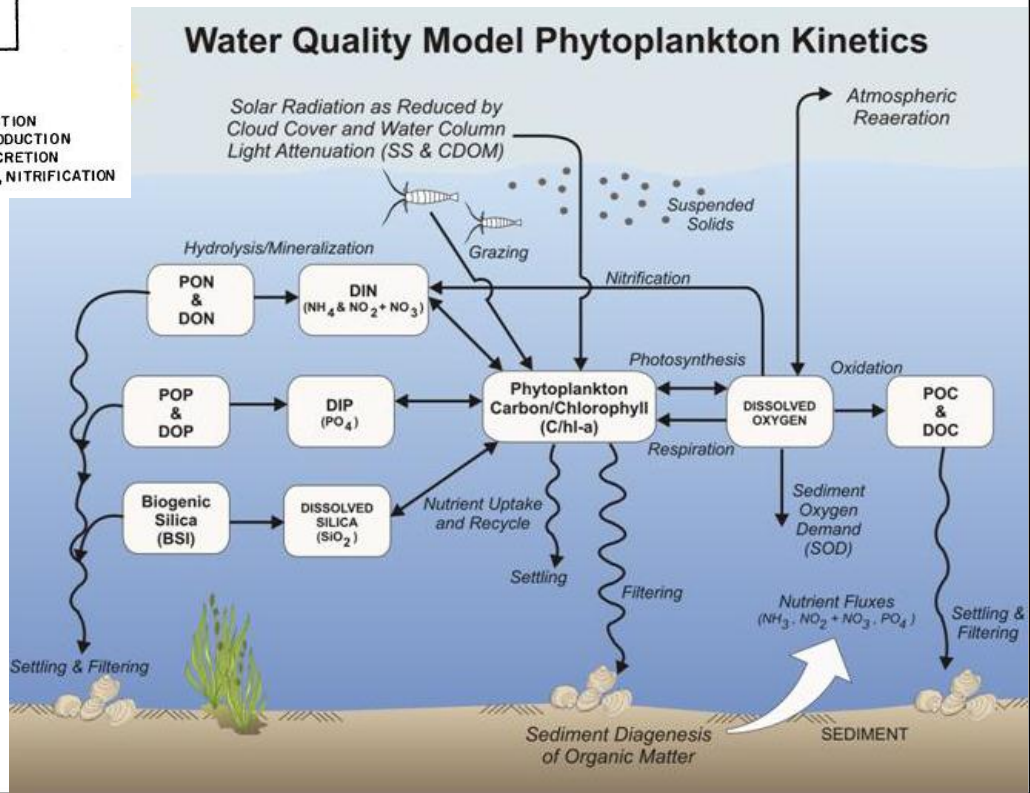
- **Evolution of models**
  - State-variables and processes
  - Model grids
- **Data issues**
  - Inputs
  - Calibration
- **Expect the unexpected**
  - System perturbations
- **Simple still has utility**
  - Utility of “simple” models

Evolution of Models

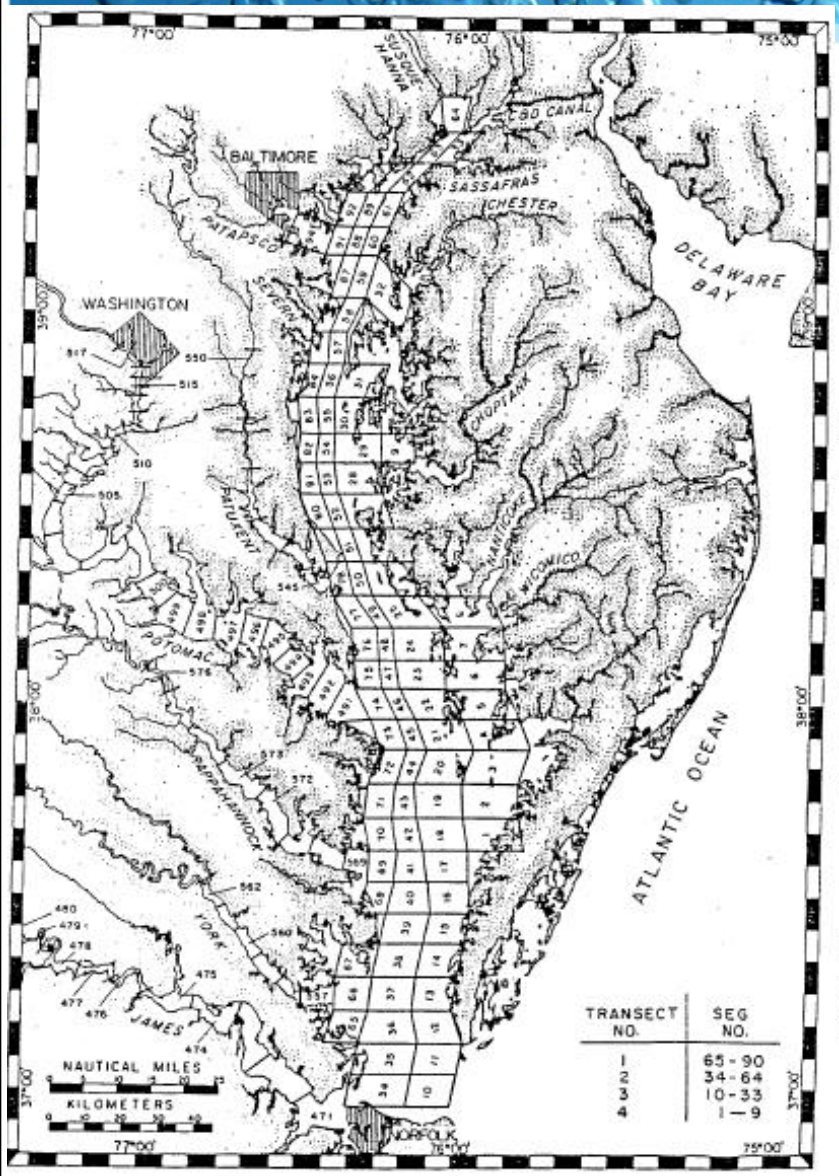


1970's

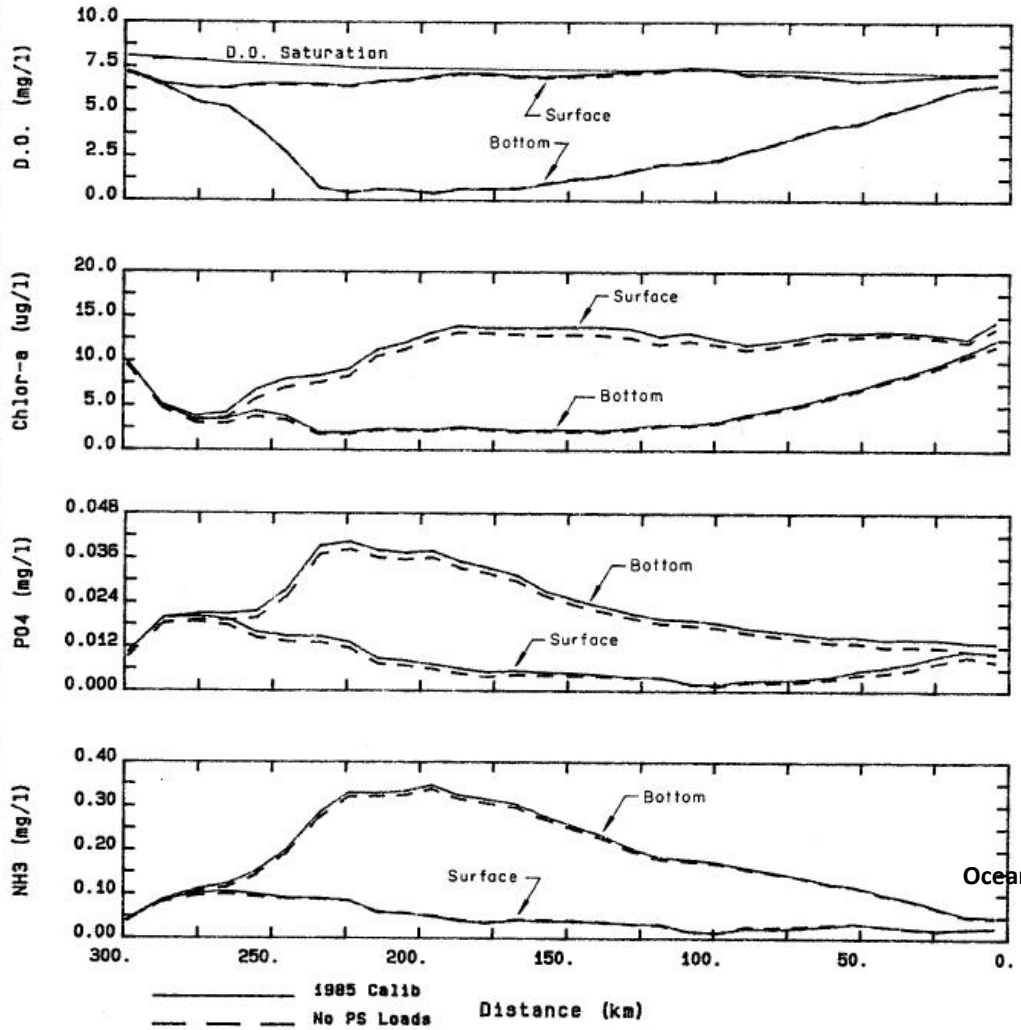
Modern



Evolution of Models



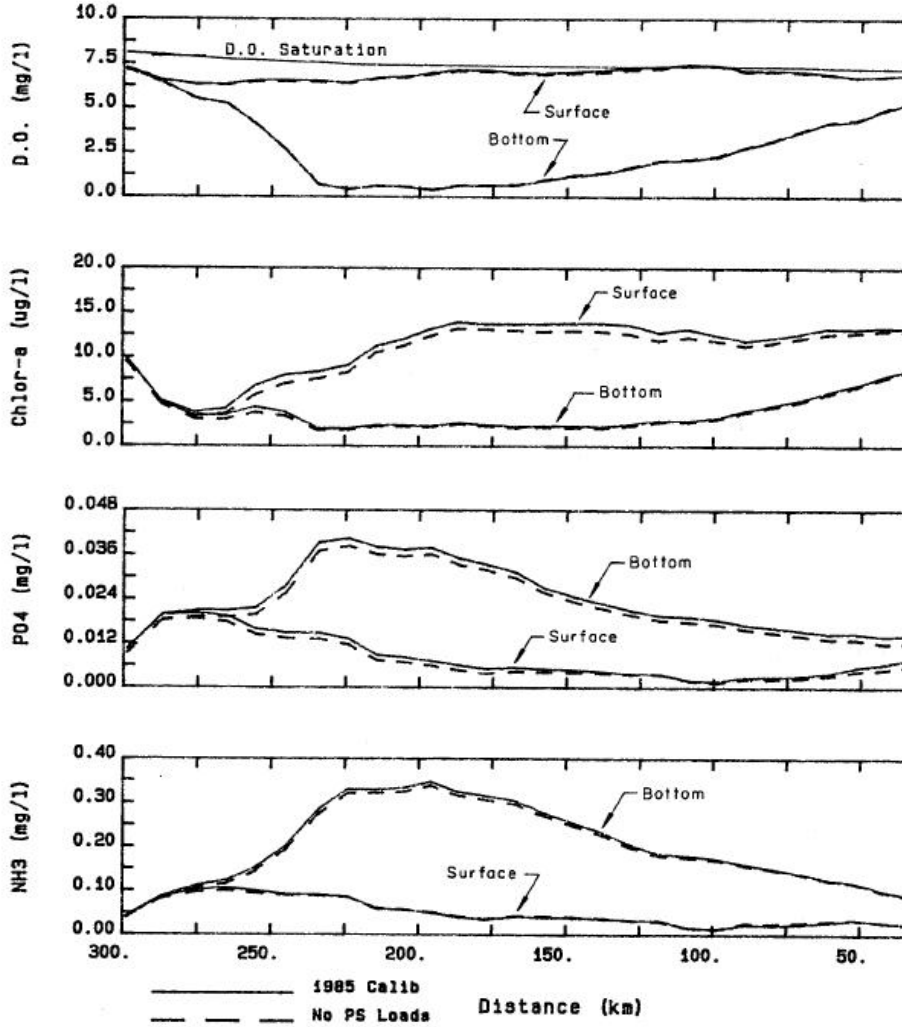
Sediment oxygen demand and nutrient fluxes based on observed data

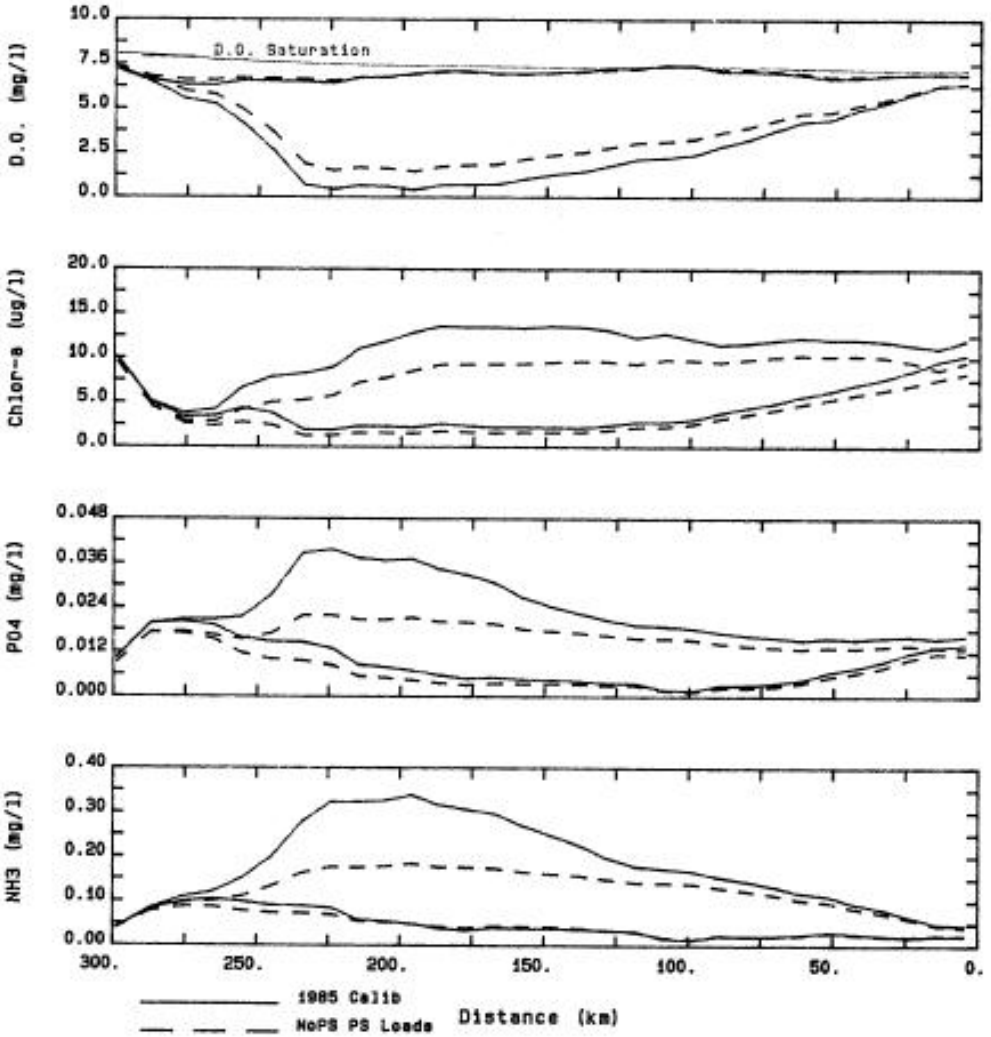


Ocean

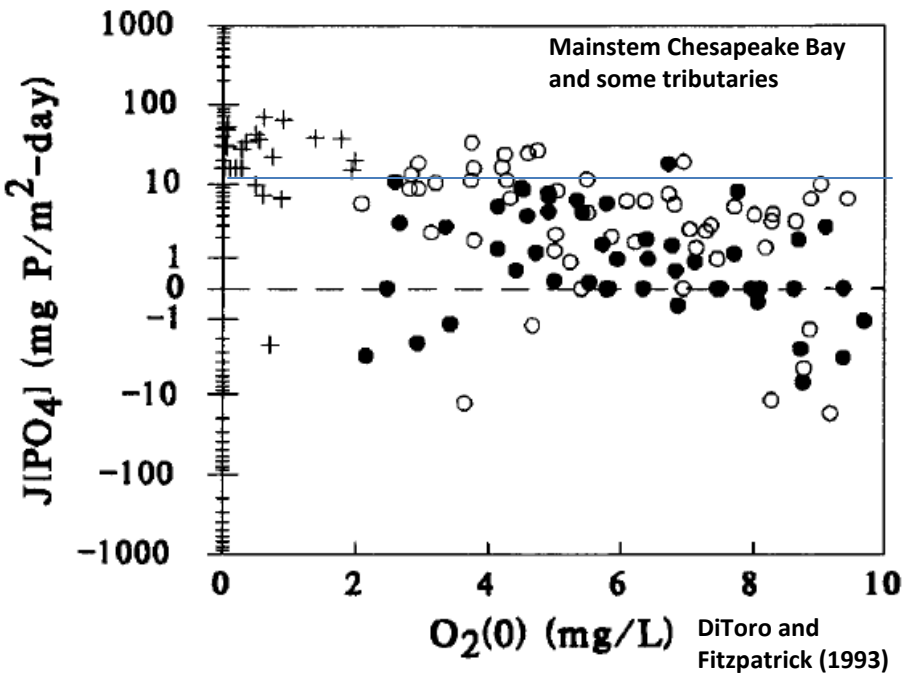
Evolution of Models

Reduce calibrated fluxes in proportion to decrease in organic matter deposition





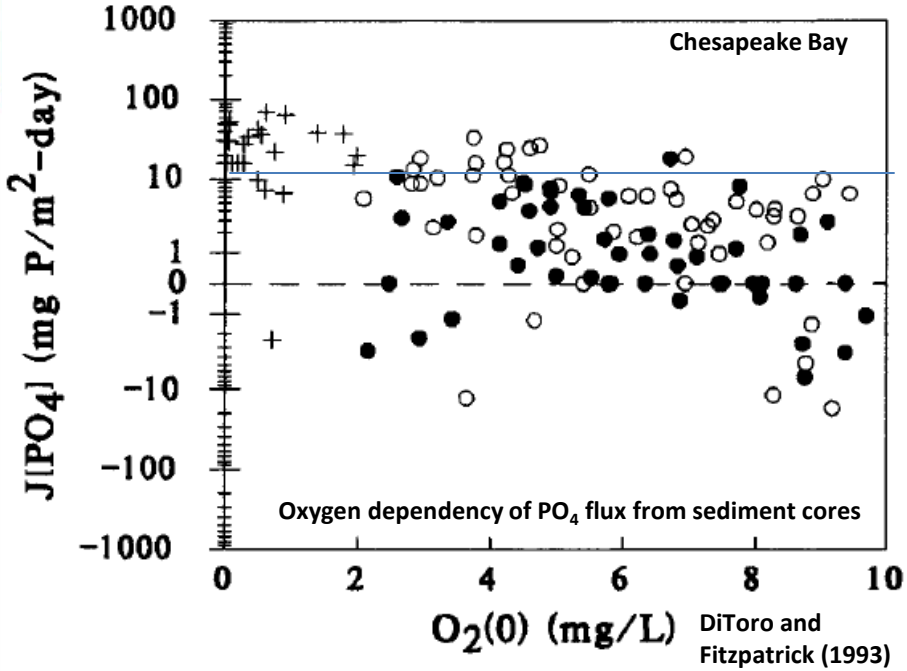
Evolution of Models



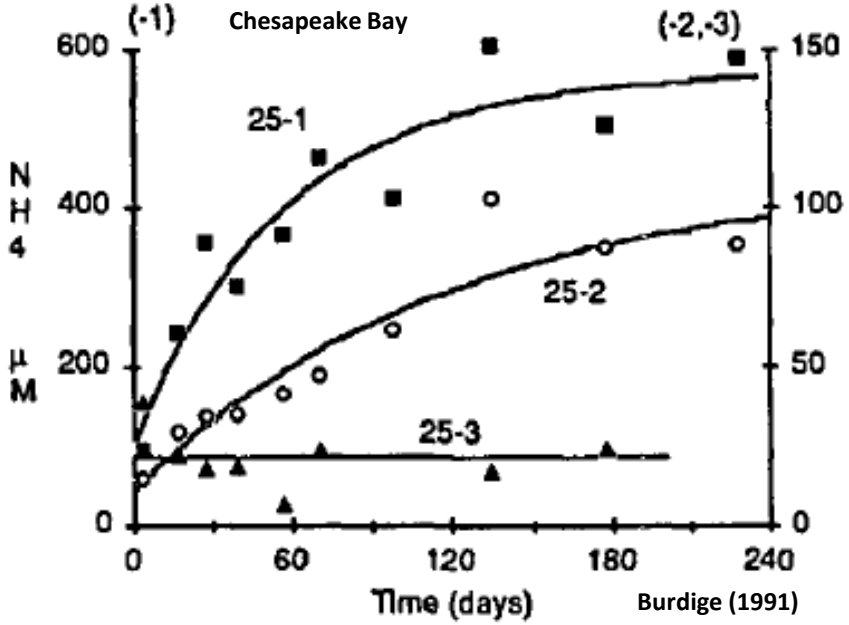
DiToro and Fitzpatrick (1993)

Oxygen dependency of PO_4 flux from sediment cores

Evolution of Models



DiToro and Fitzpatrick (1993)



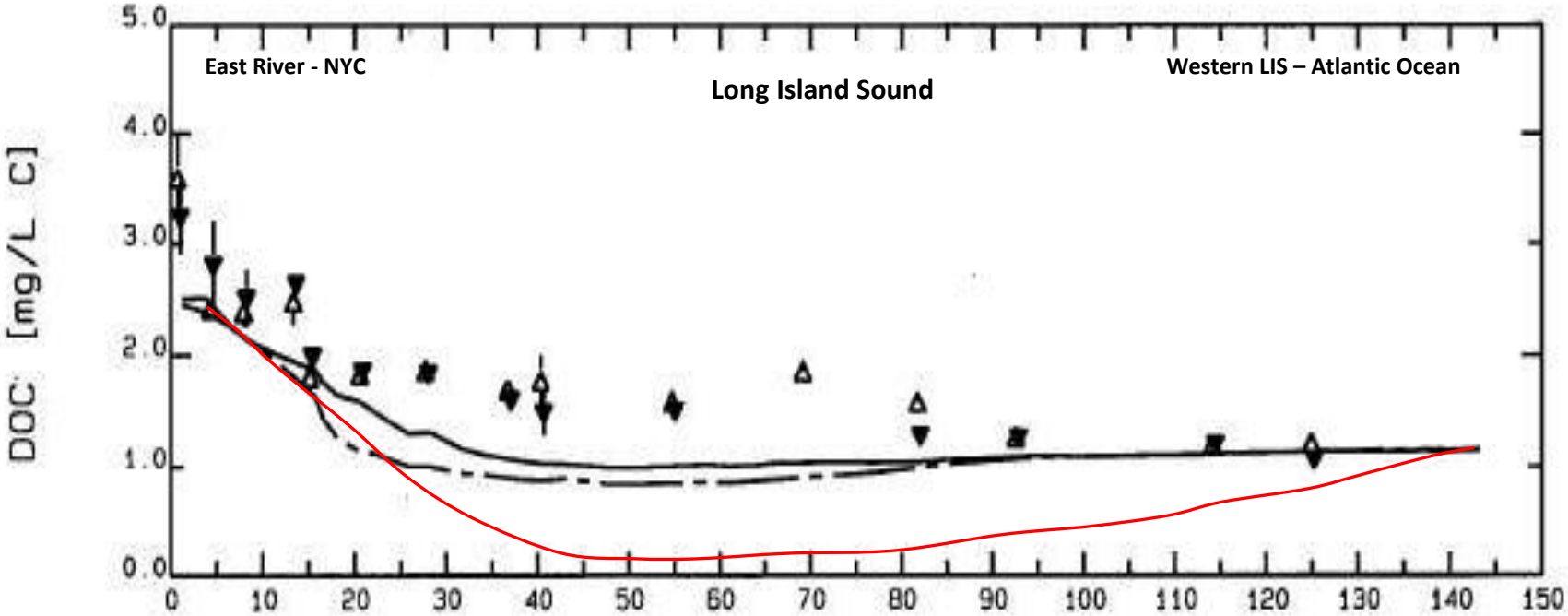
Burdige (1991)

Incubation of segmented Chesapeake Bay sediment cores to analyze decomposition of organic matter in the sediment

25-1 = 0-2 cm depth 25-2 = 5-7 cm depth

25-3 = 12- 14 cm depth

Evolution of Models



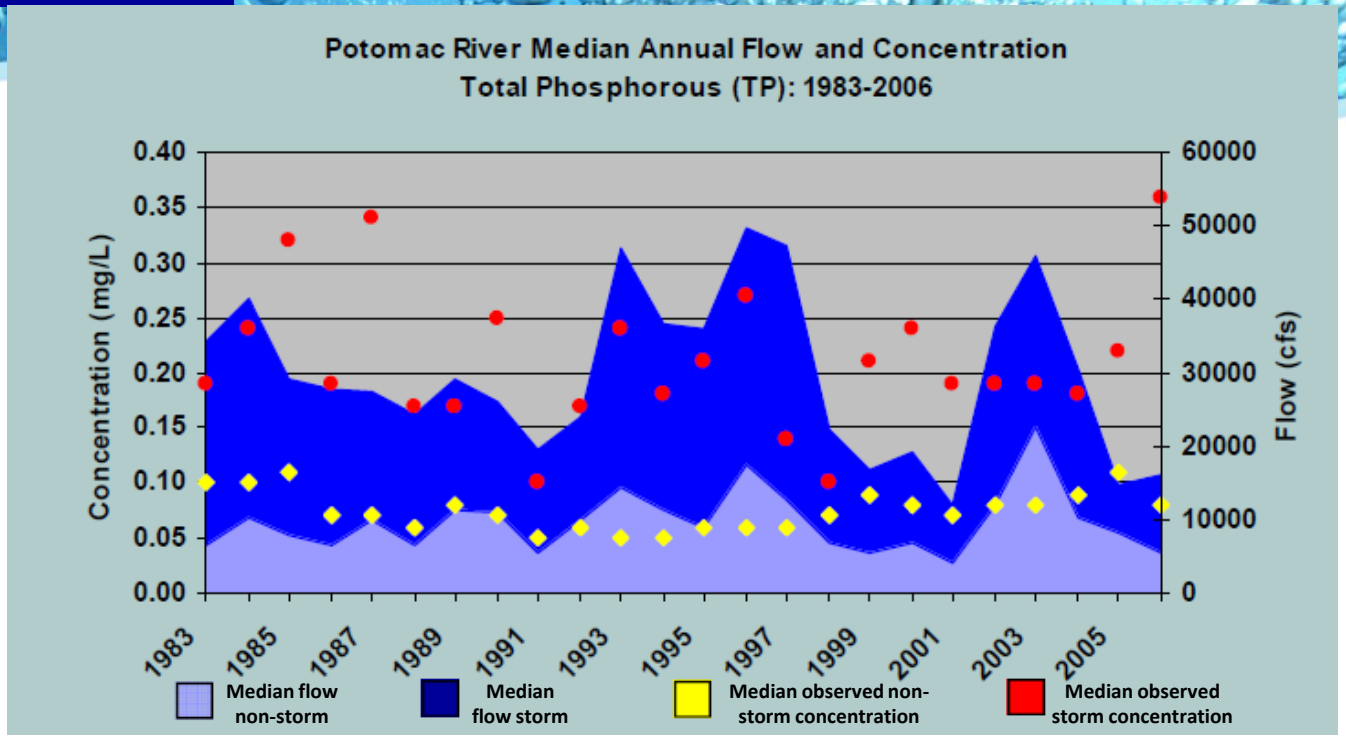
One organic carbon pool

vs.

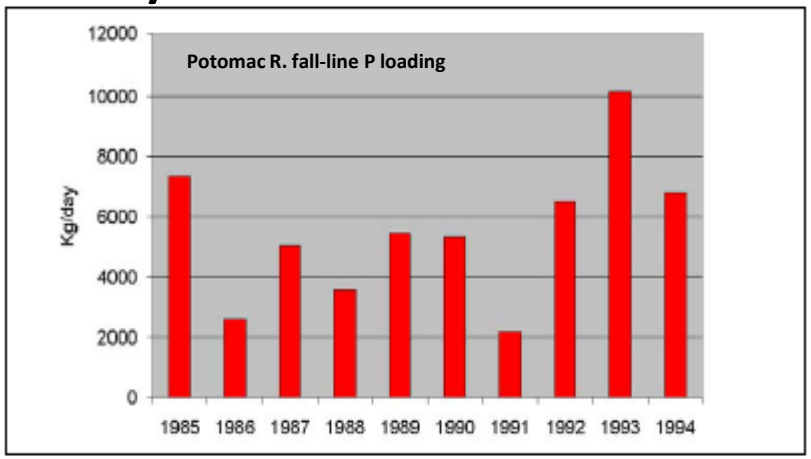
Split dissolved organic carbon into labile and refractory pools

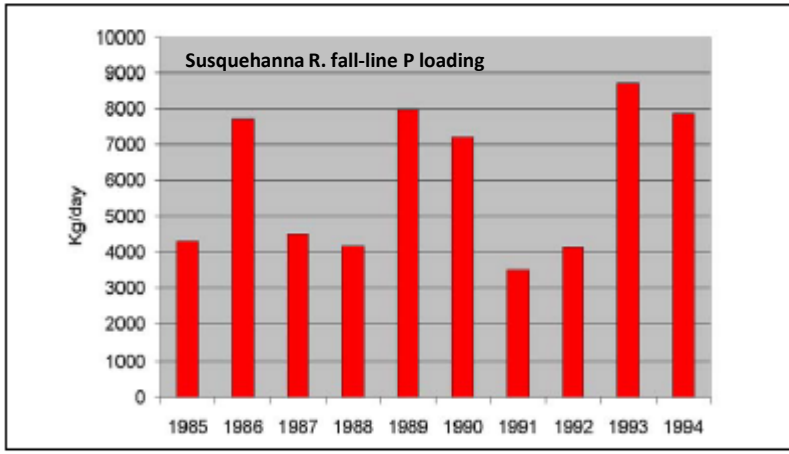
Data Issues: Inputs Loadings

Importance of storm related sampling

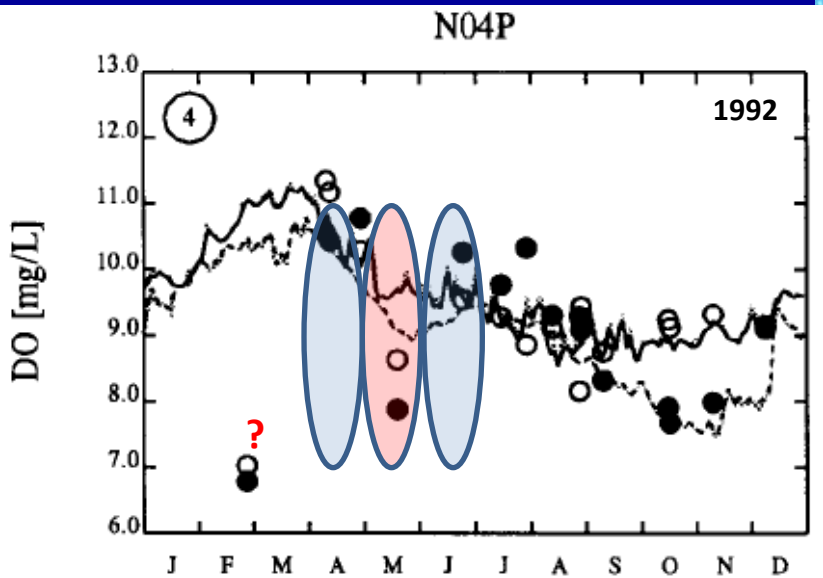


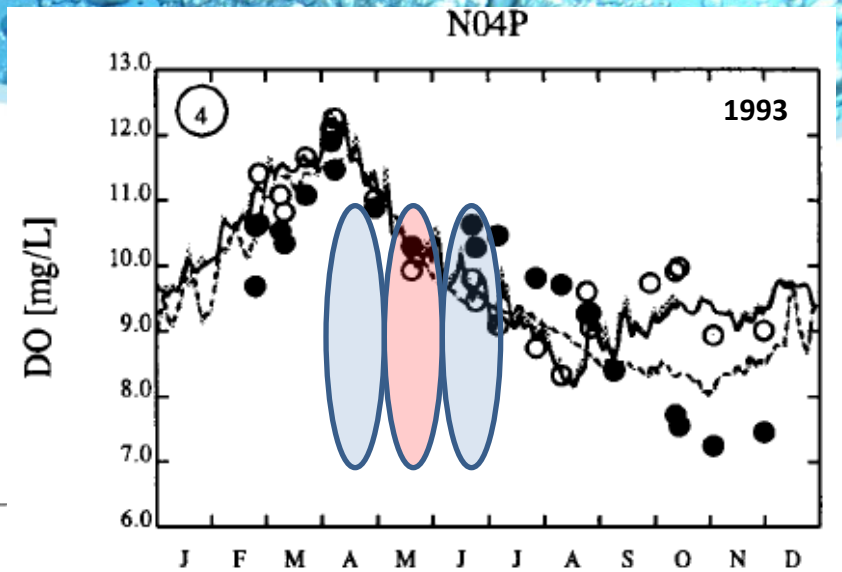
Spatial variability in rainfall

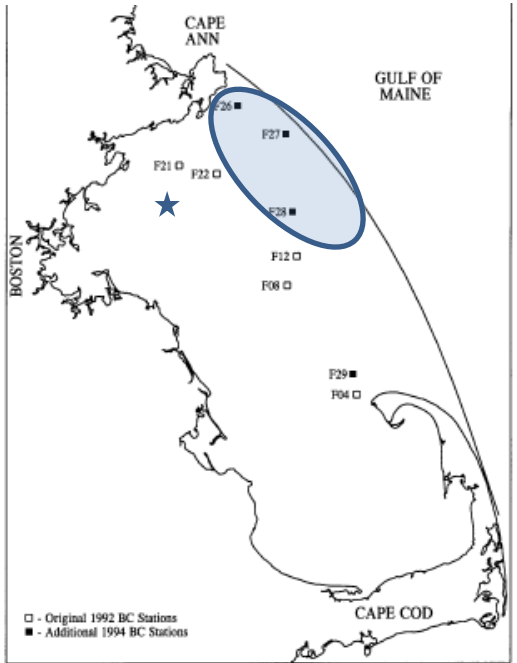




Data Issues: Inputs Boundary Conditions







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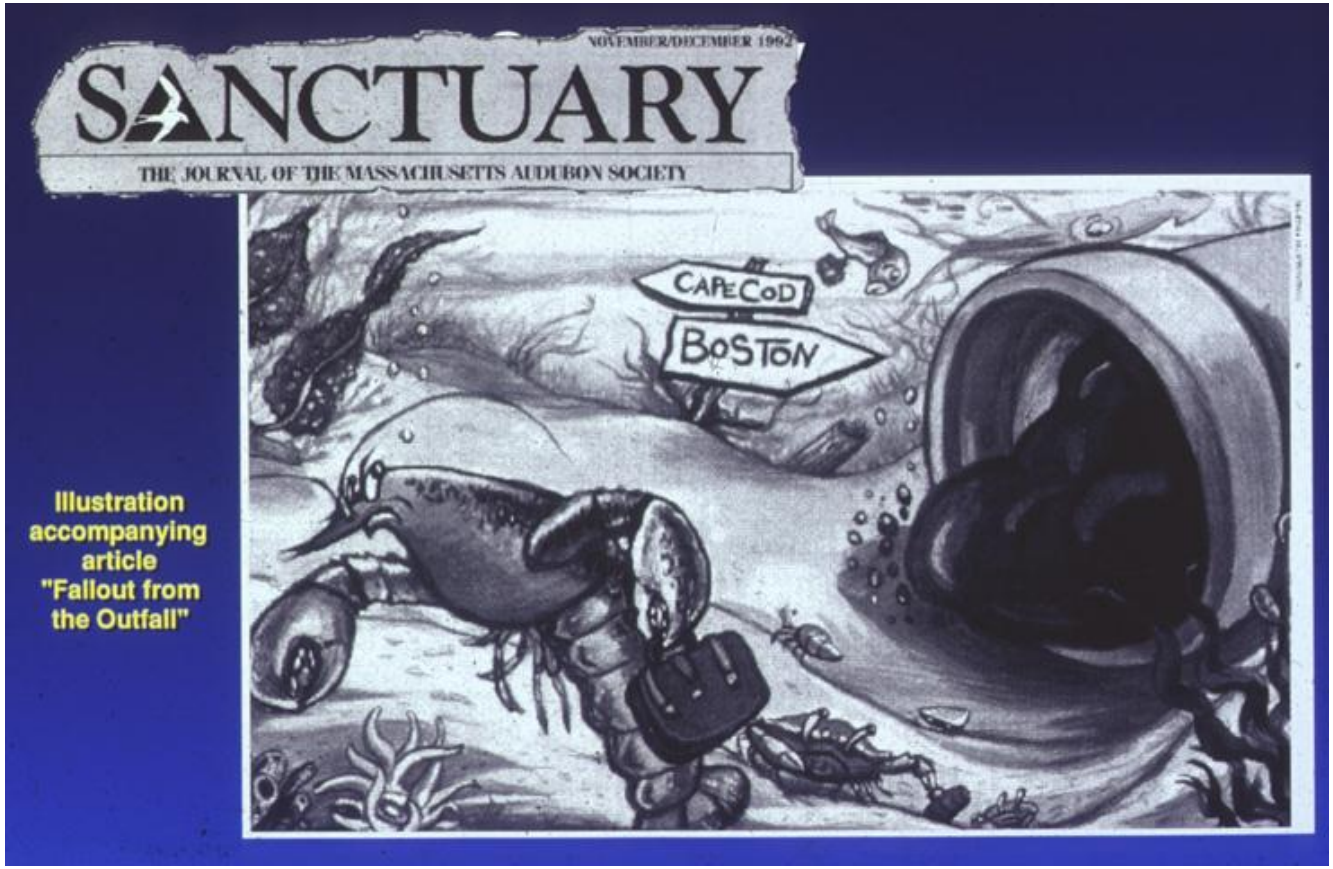

Illustration accompanying article "Fallout from the Outfall"

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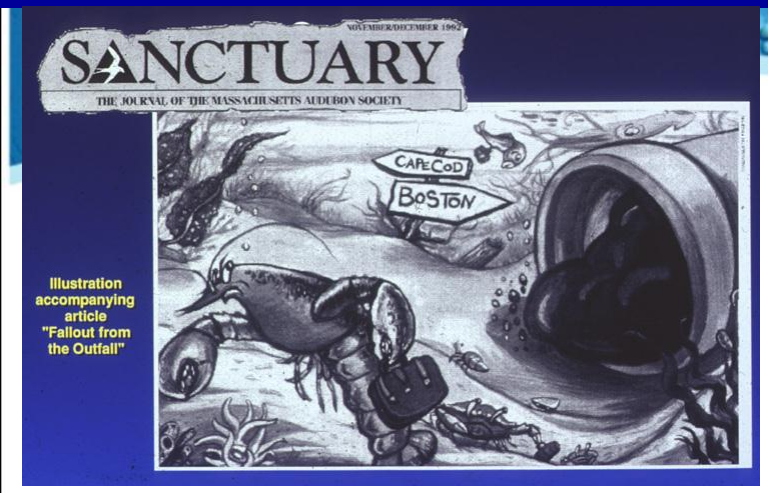

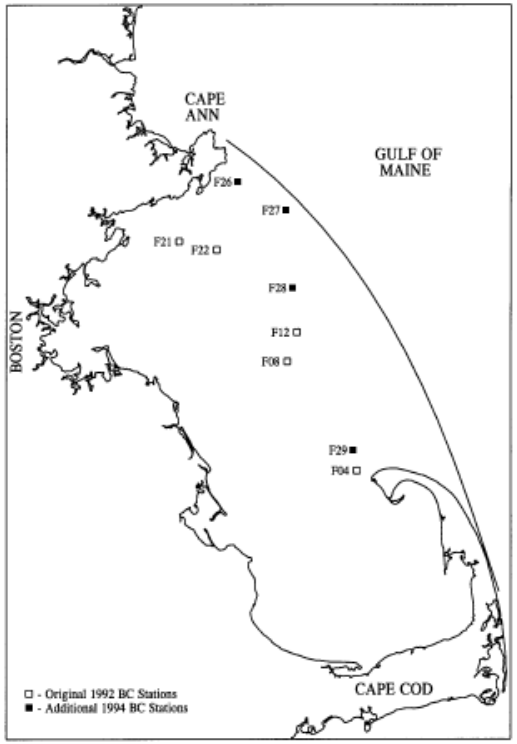

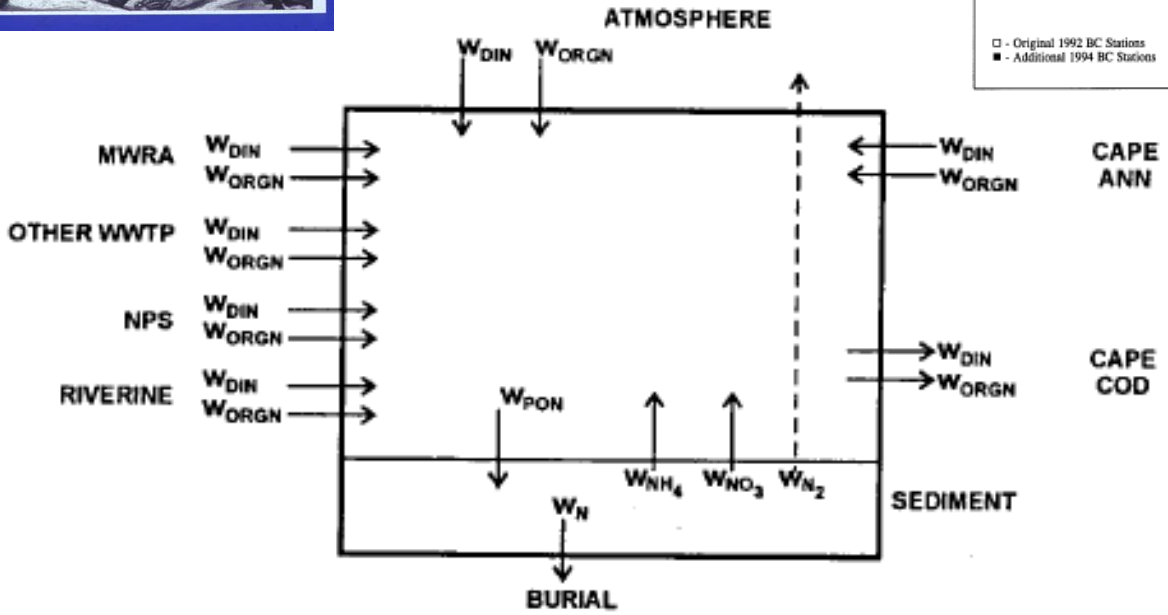

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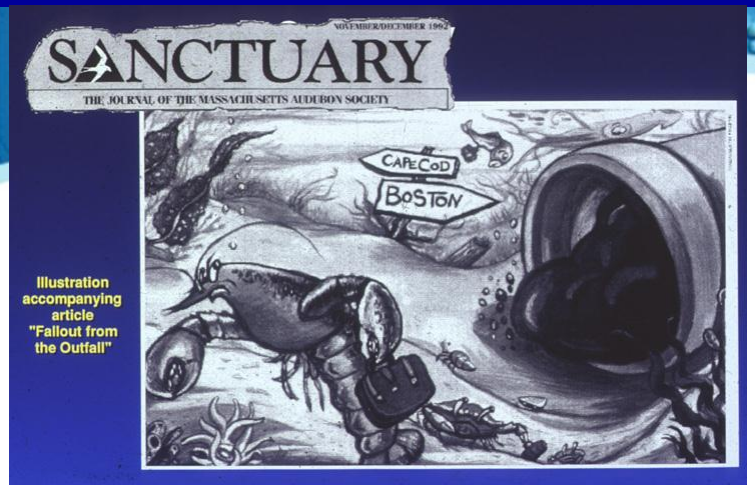

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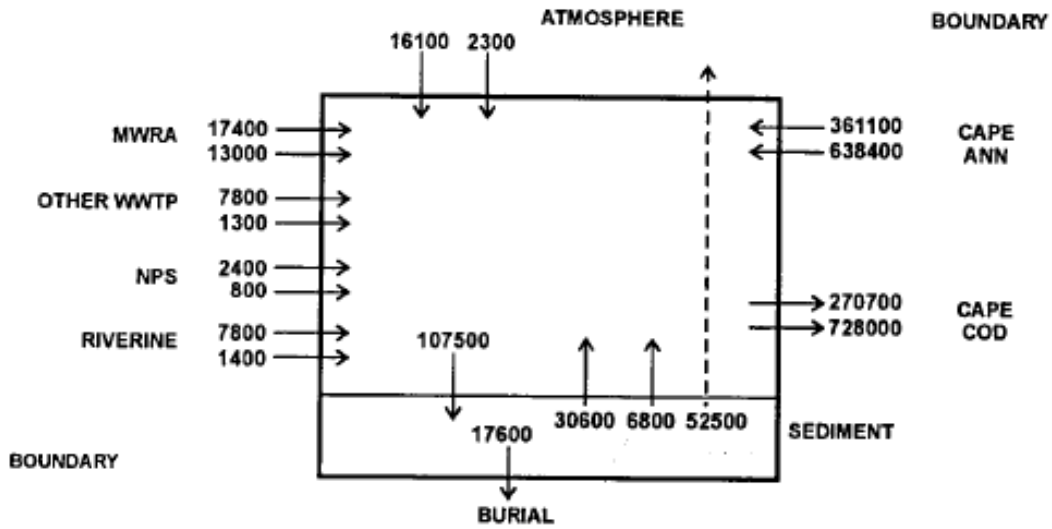
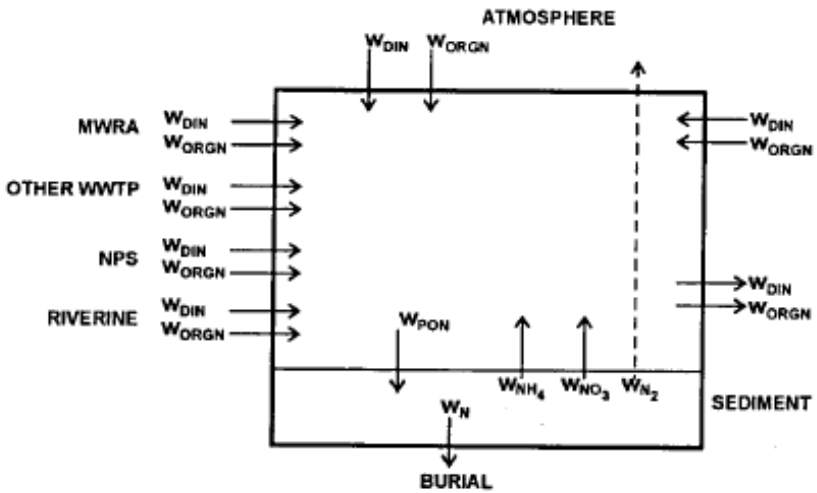
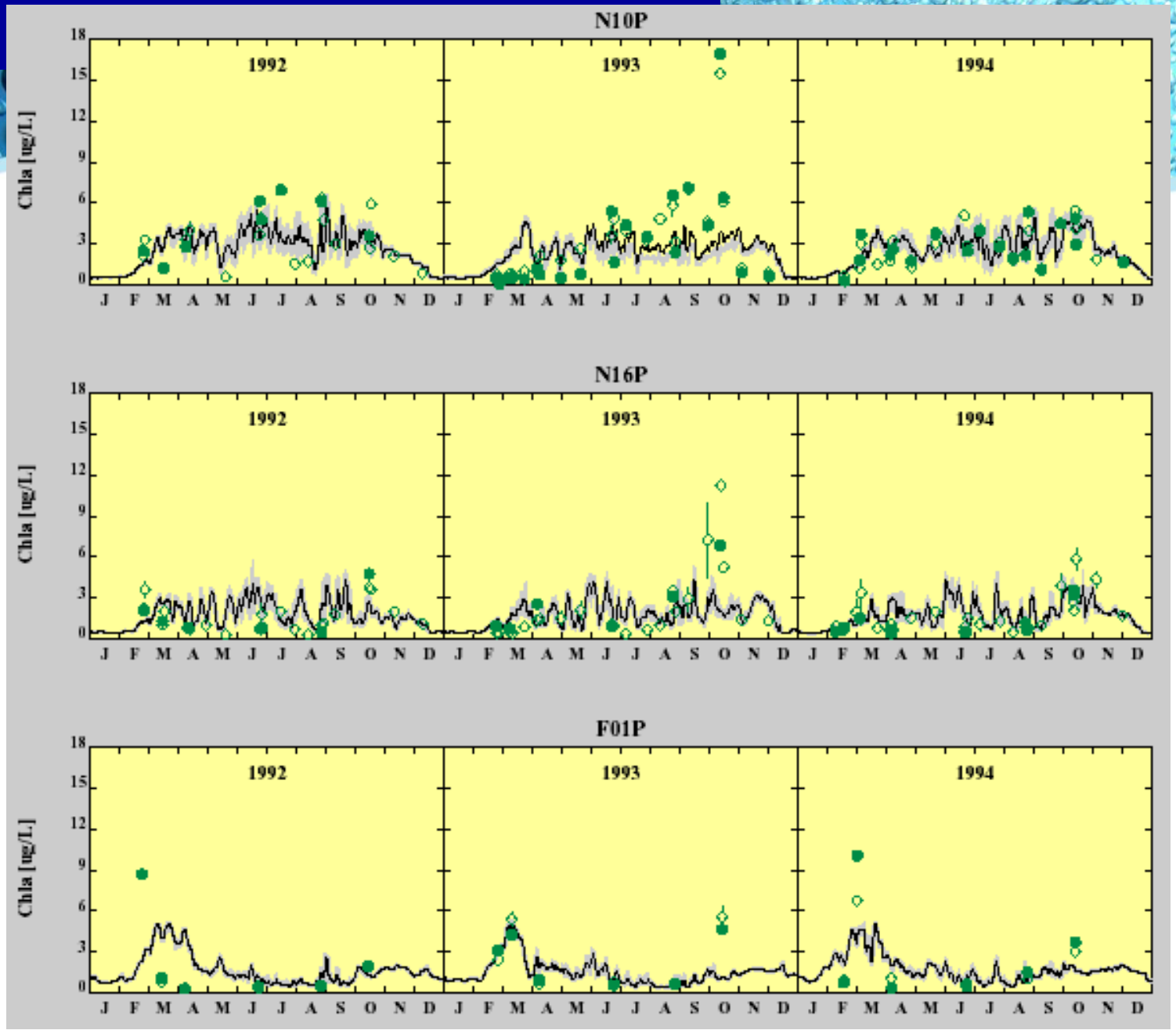




(All units are kg/day)

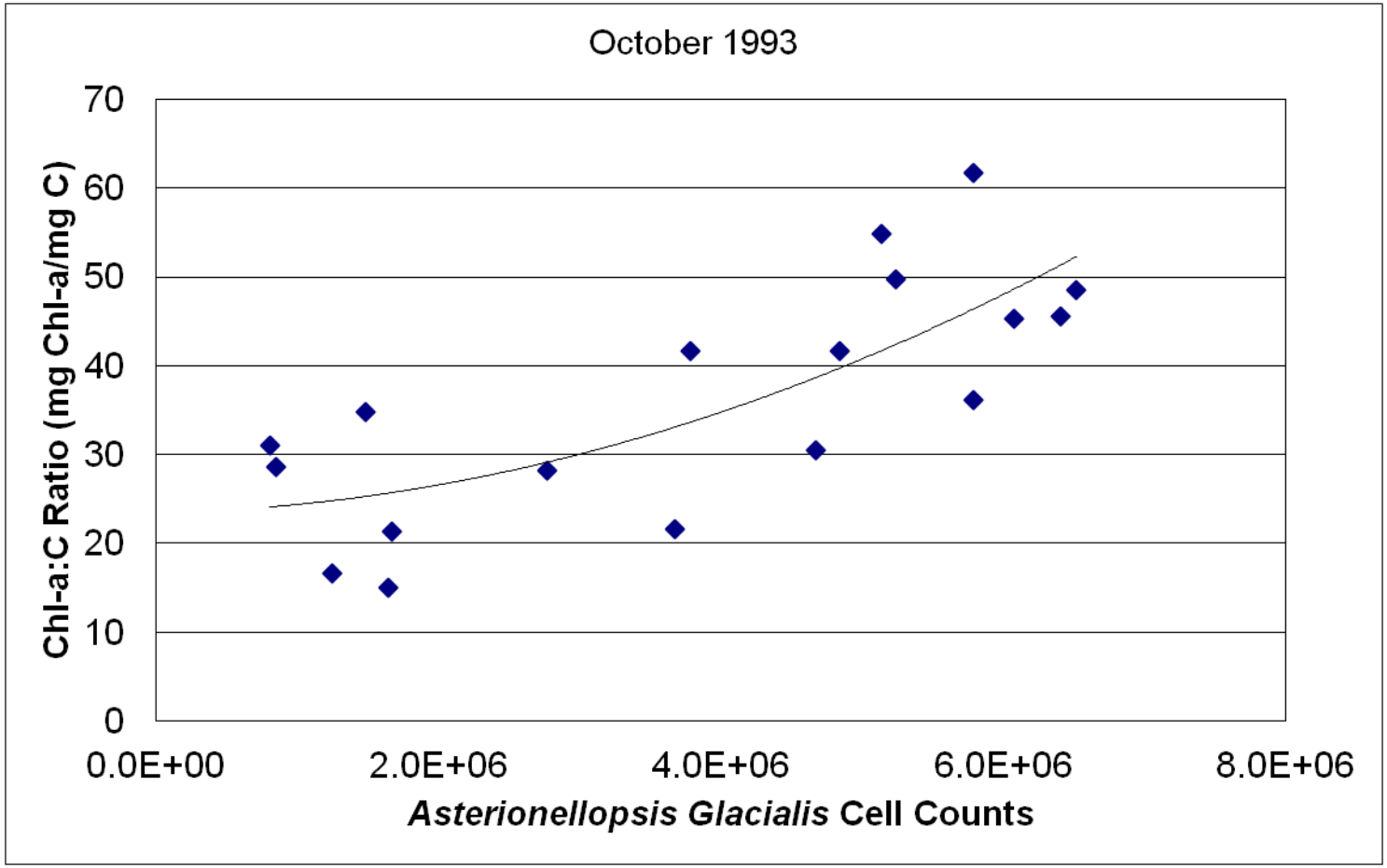
SUMMARY	DIN	ORGN	TN	%TN
MWRA	17400	13000	30400	3
NON-MWRA	34100	18800	52900	5
BOUNDARY	361100	638400	999500	92

Data Issues: Calibration

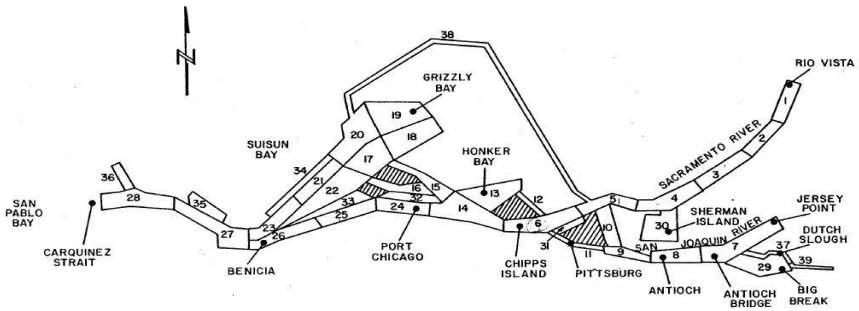


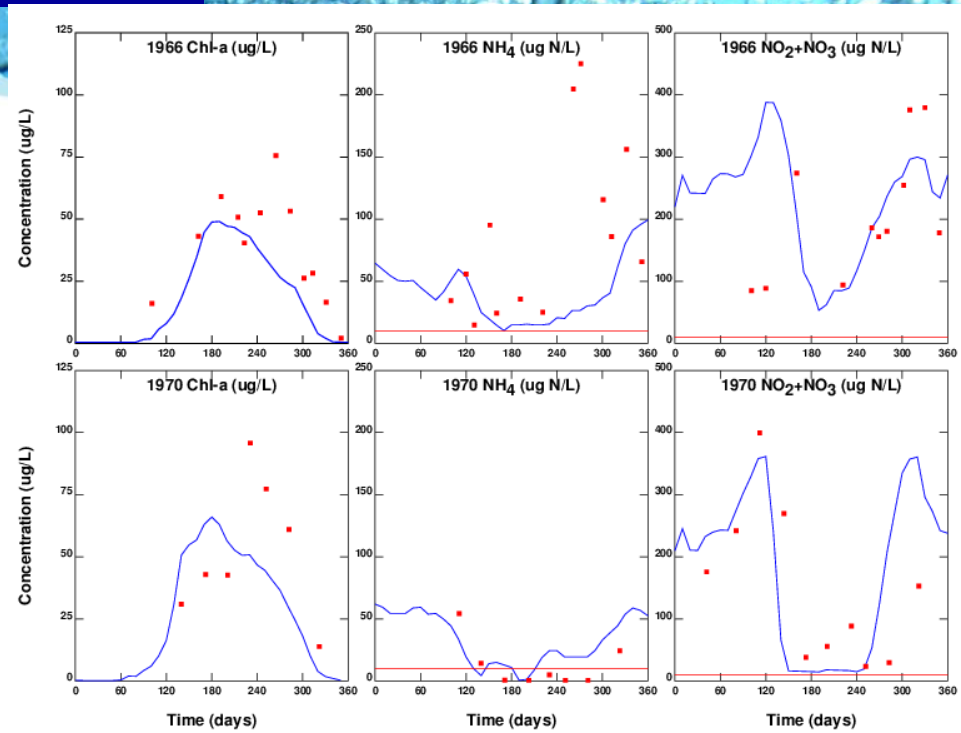
Data Issues: Calibration

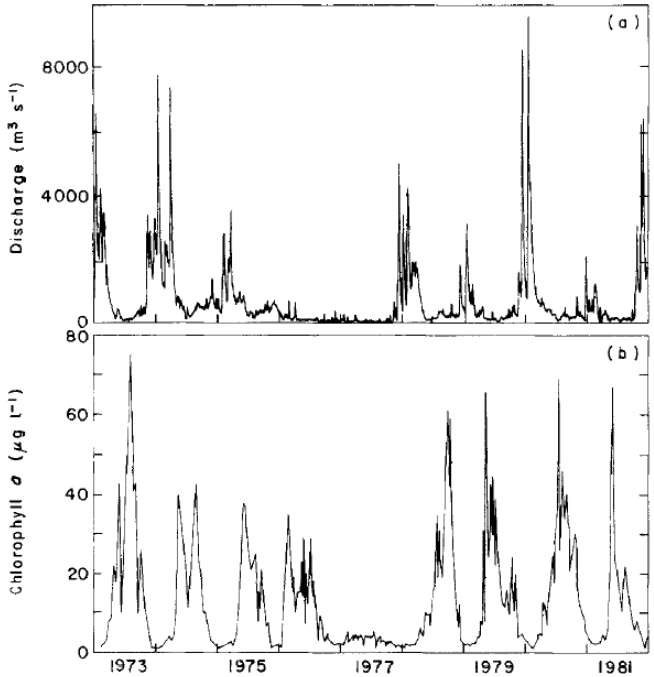
Chlorophyll-a to Carbon Ratio



Expect the Unexpected







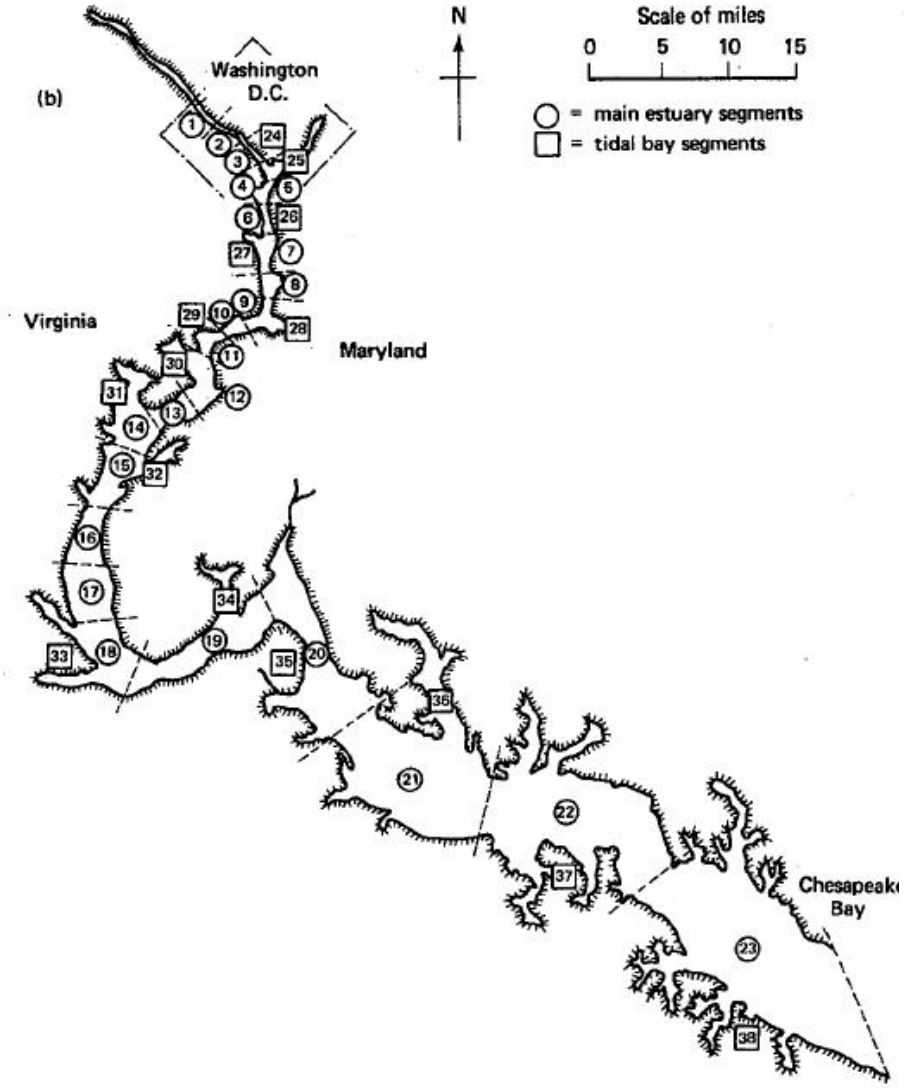
but then

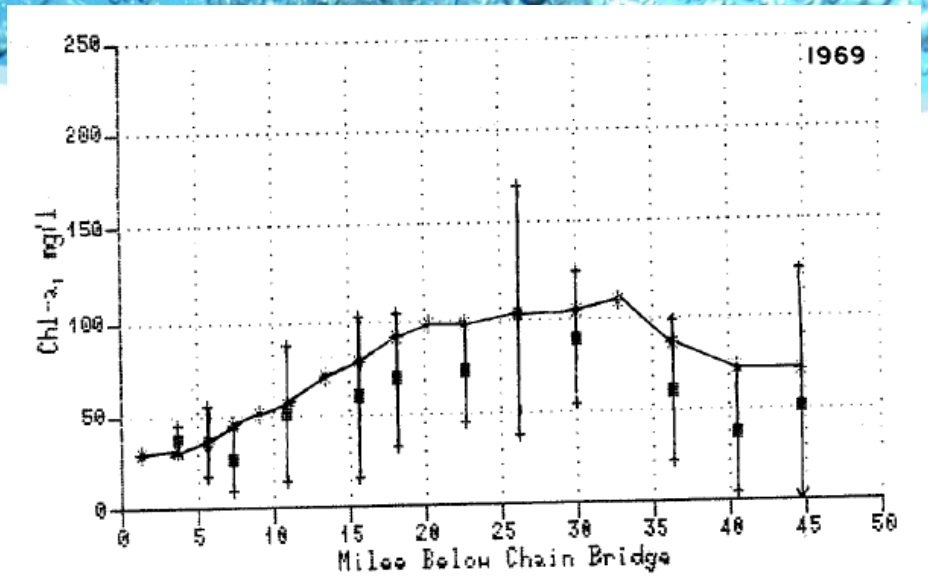
Causality?

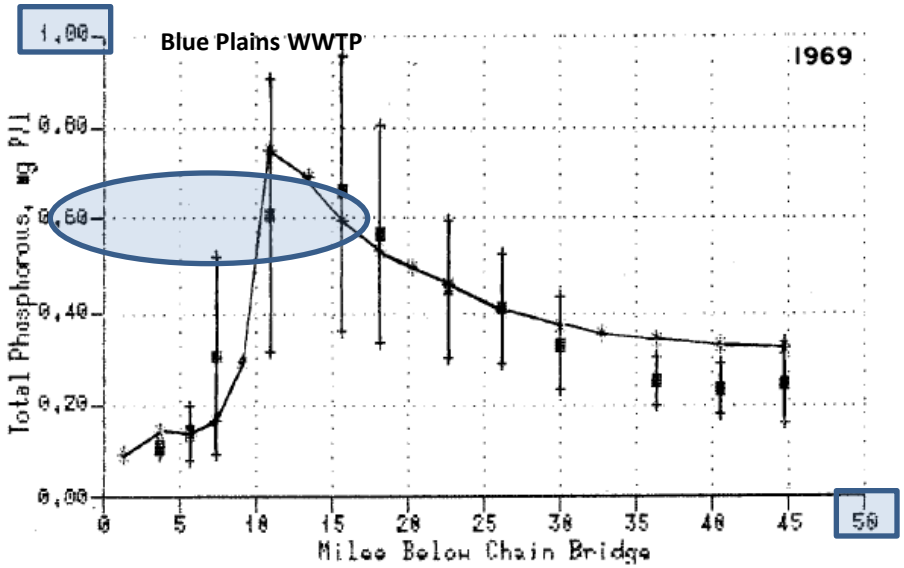
Hypotheses:

- **low flow caused the location of the null zone to move upstream of Suisun Bay (Arthur and Ball, 1979)**
- **more saline conditions allowed more salinity tolerant benthic species (*Mya arenaria)* to move into Suisun Bay and increased filtration of the water column (Nichols, 1985)**
- **present condition – dominance by *Cobula amurensis***

Expect the Unexpected







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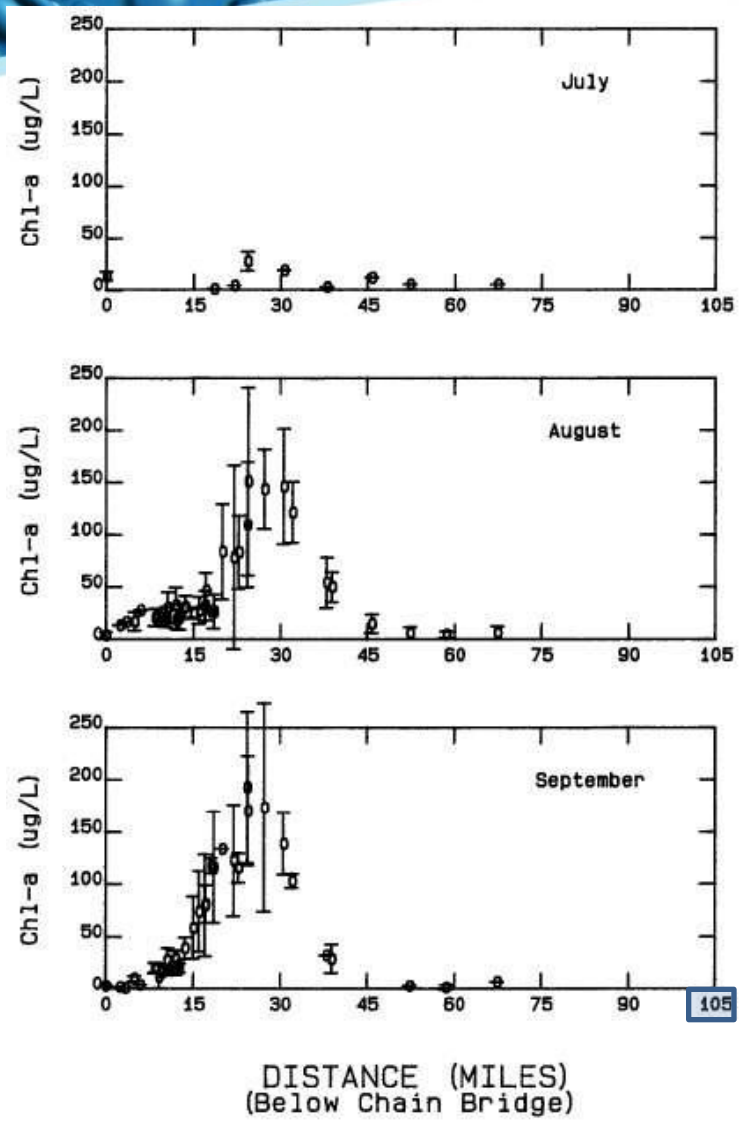
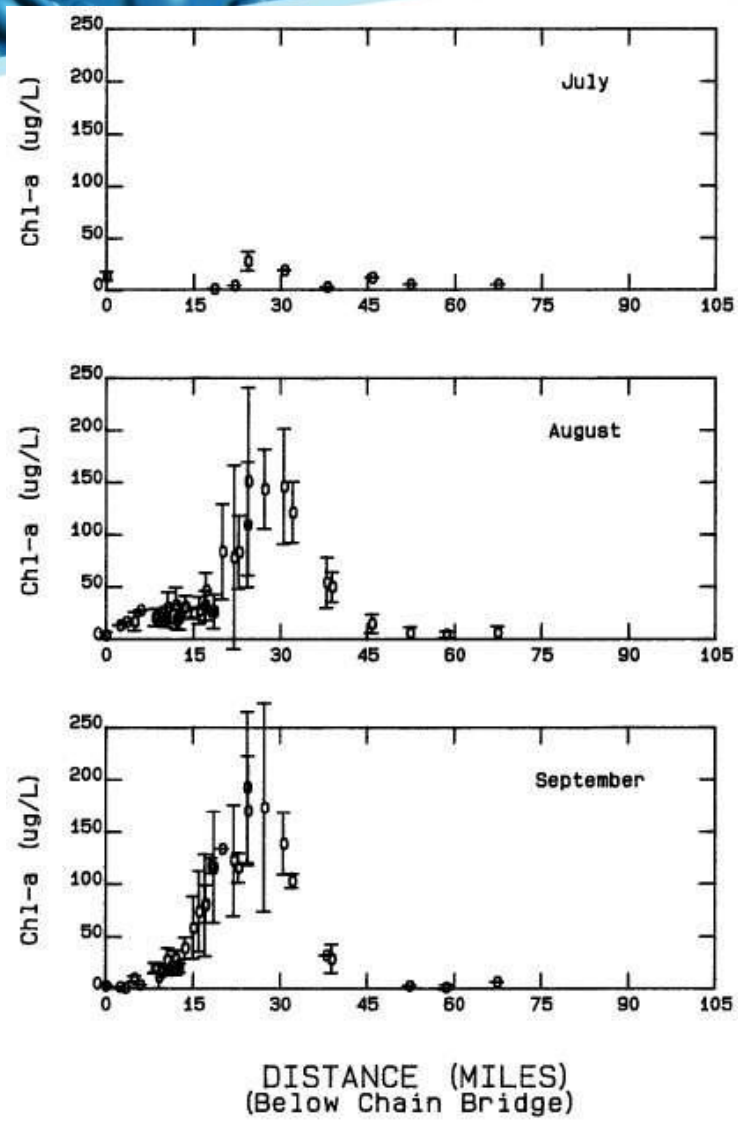
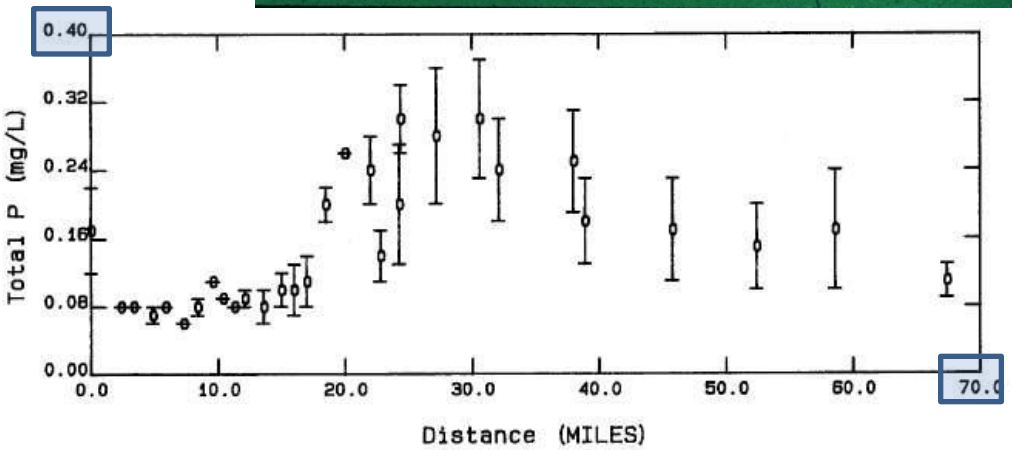


Despite reductions in total phosphorus from the Blue Plains WWTP from 24,000 lb/day in 1970 to 4,100 lb/day in 1980 to 2,100 lb/day by 1983 a large bloom of the blue-green algal *Microcystis aeruginosa* occurred late in the summer of 1983.

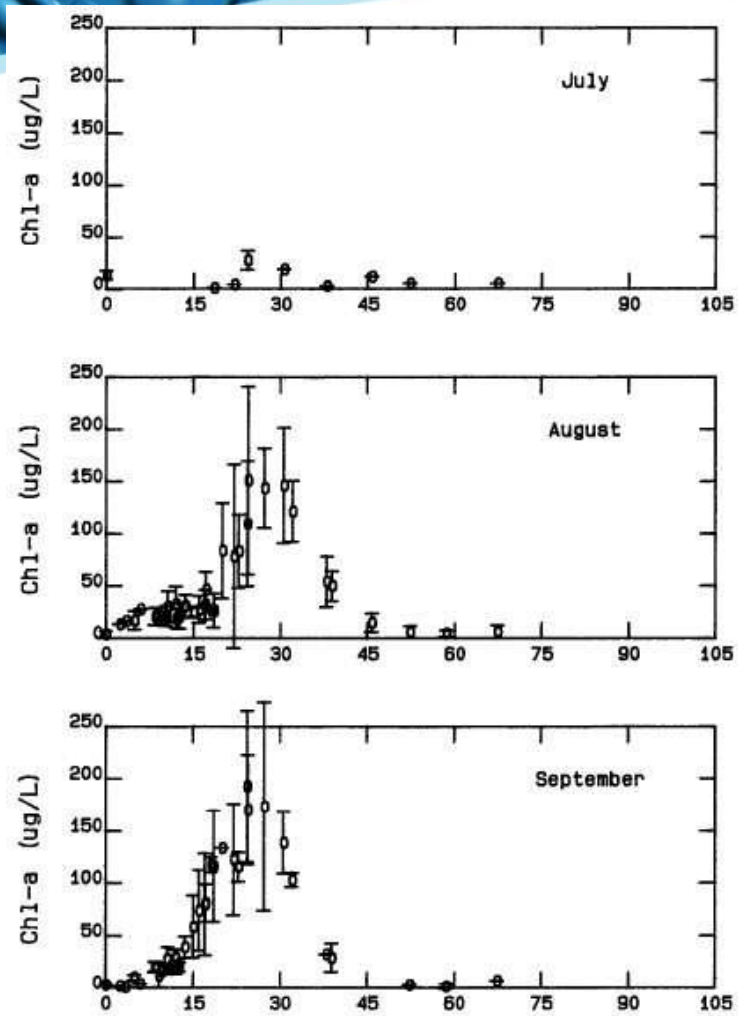
Expect the Unexpected

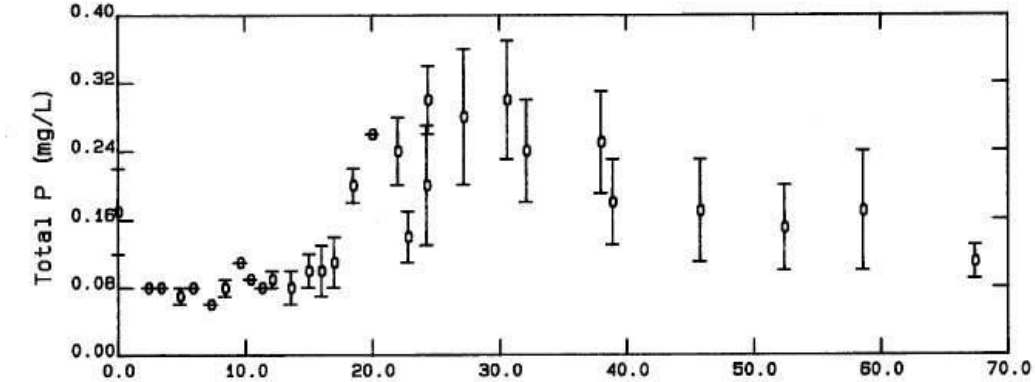


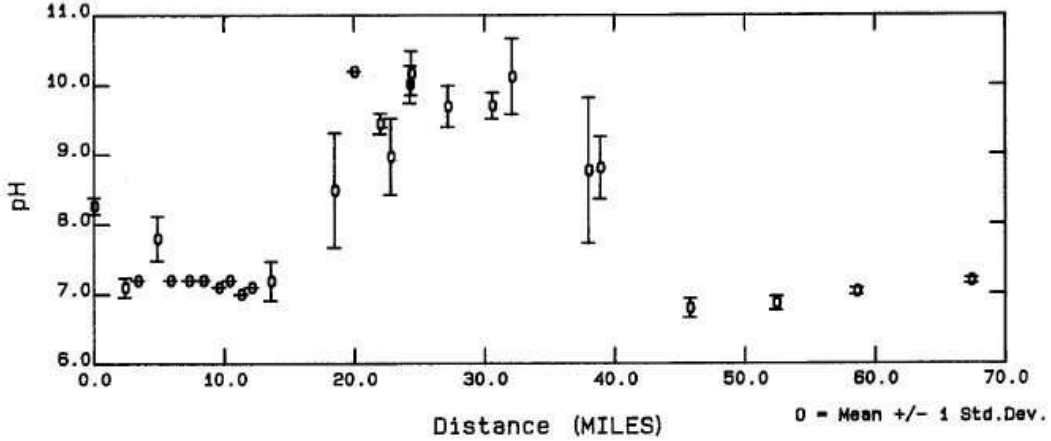


Interestingly, maximum total phosphorus levels were well downstream of the Blue Plains WWTP and in the vicinity of the peak chlorophyll-a concentrations

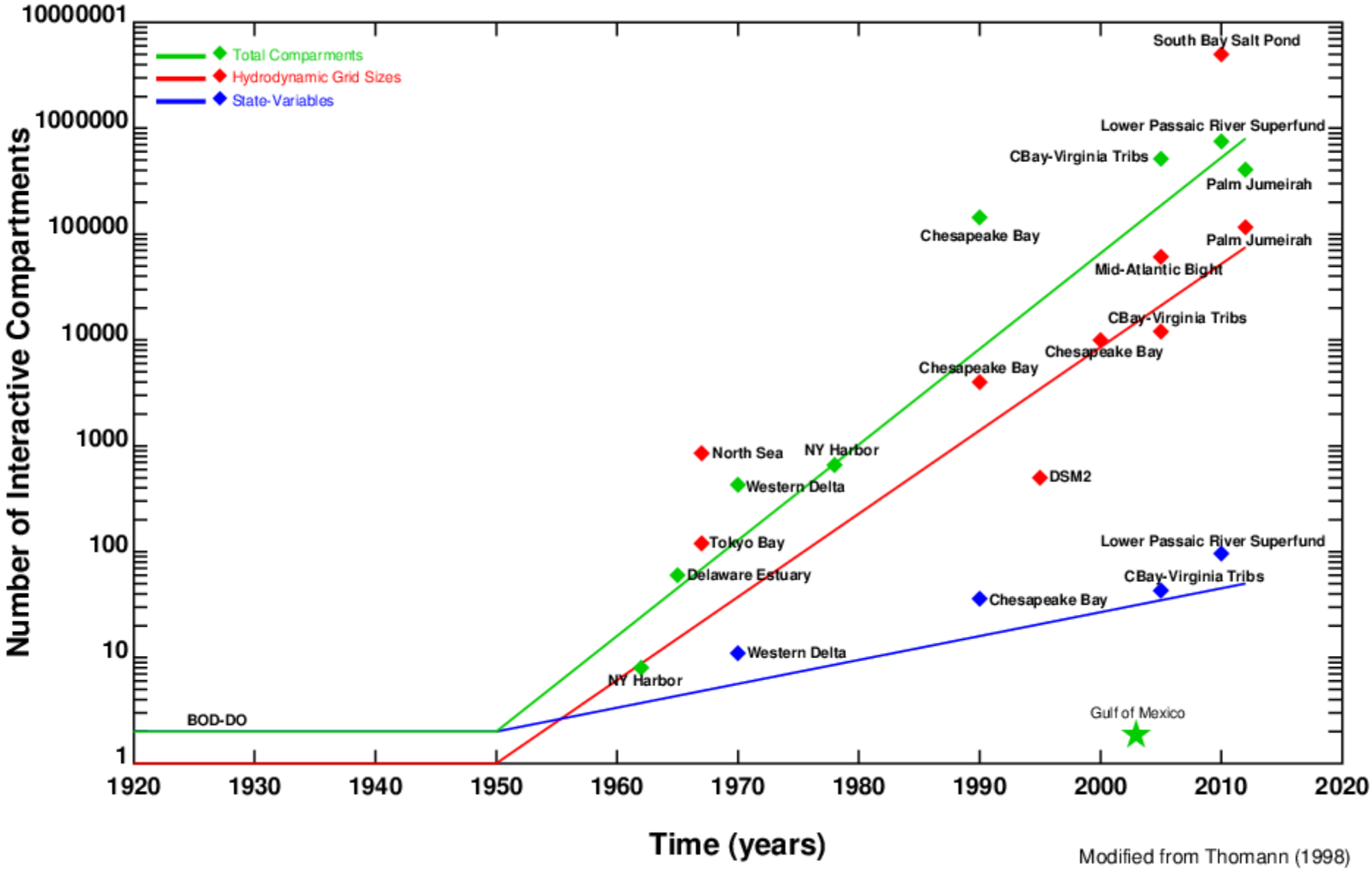
Expect the Unexpected





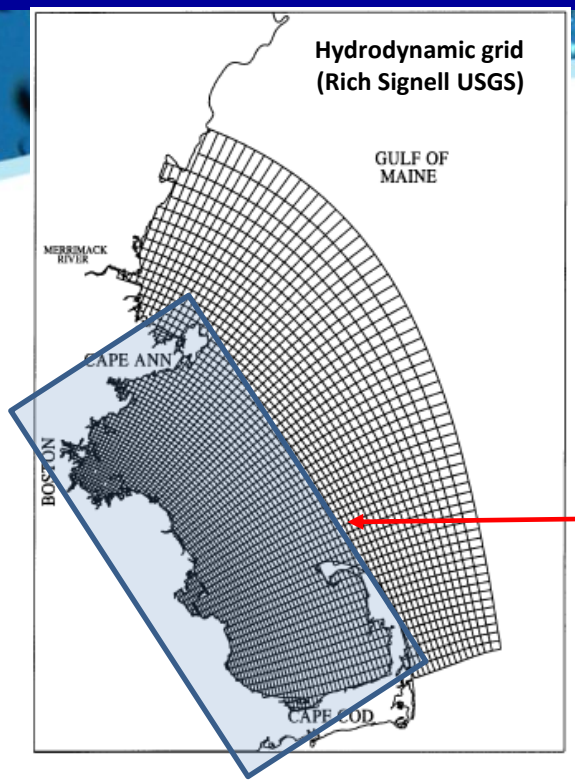


Evolution of Models Revisited



Modified from Thomann (1998)

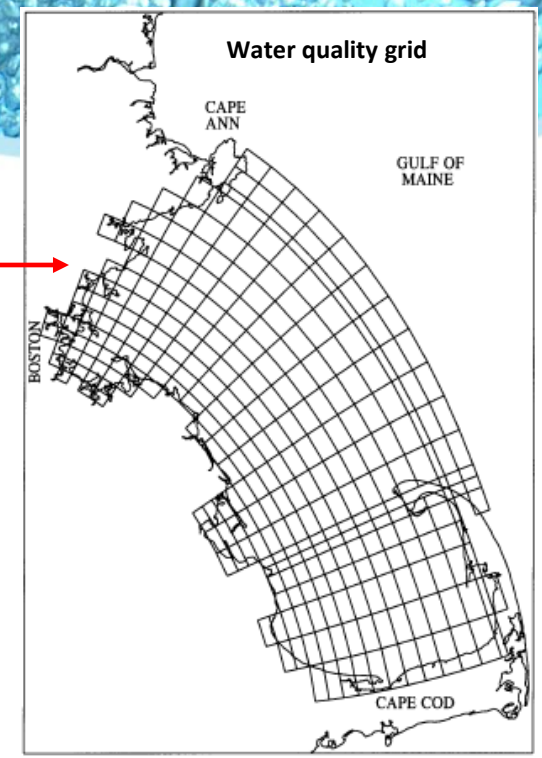
Evolution of Models Revisited



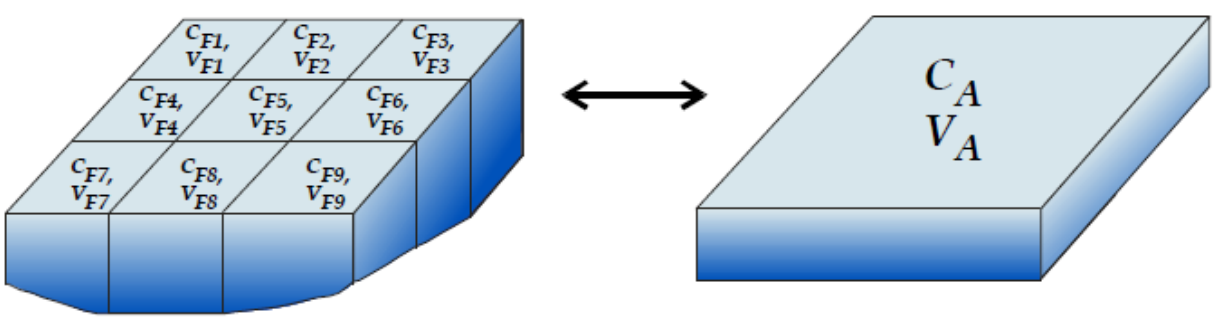
644 x 10 cells (6,440)

4624 x 12 cells (55,488)

Reduction in execution time ~ 20:1



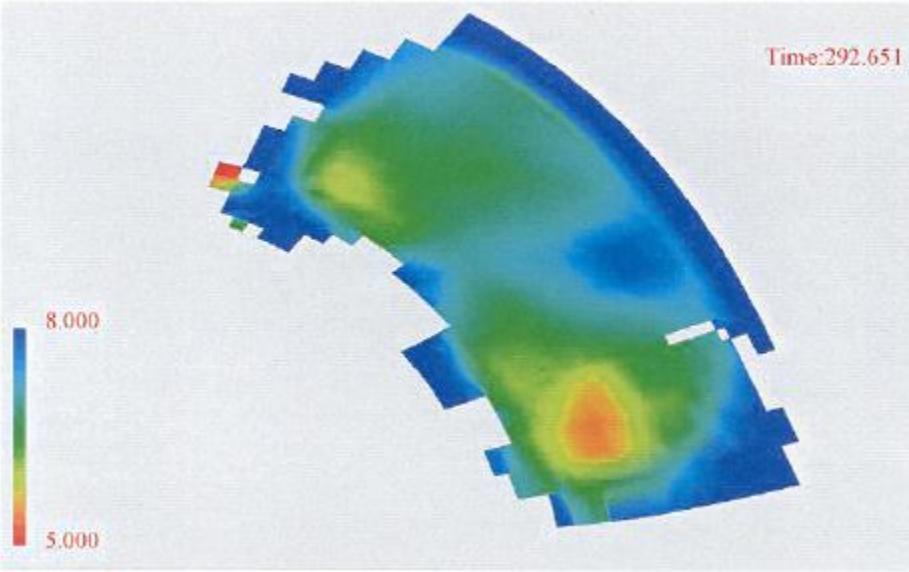
Fine Grid *Aggregated Grid*



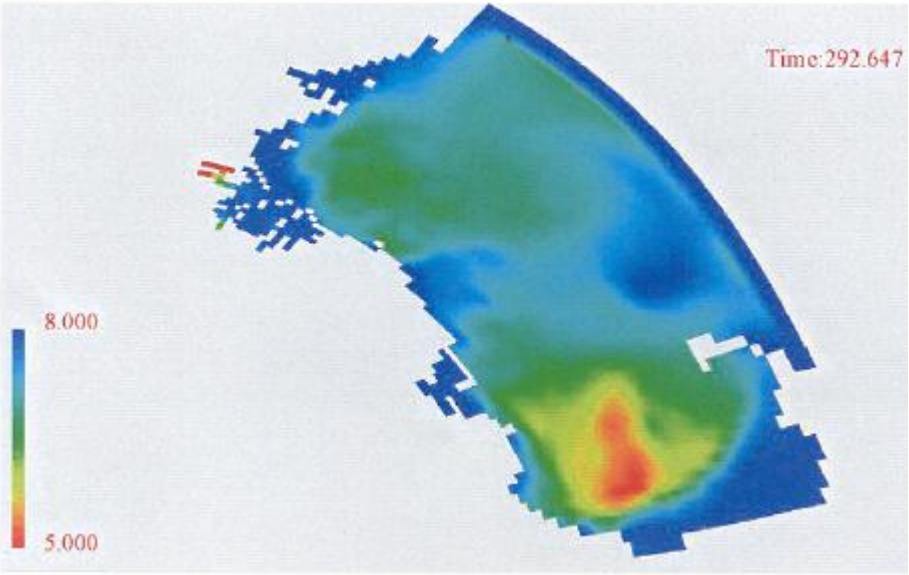
Evolution of Models Revisited – Grid Aggregation

Comparison of Aggregated Grid Dissolved Oxygen vs. Unaggregated Grid

Aggregated Grid



Unaggregated Grid



Bottom water dissolved oxygen – end of September

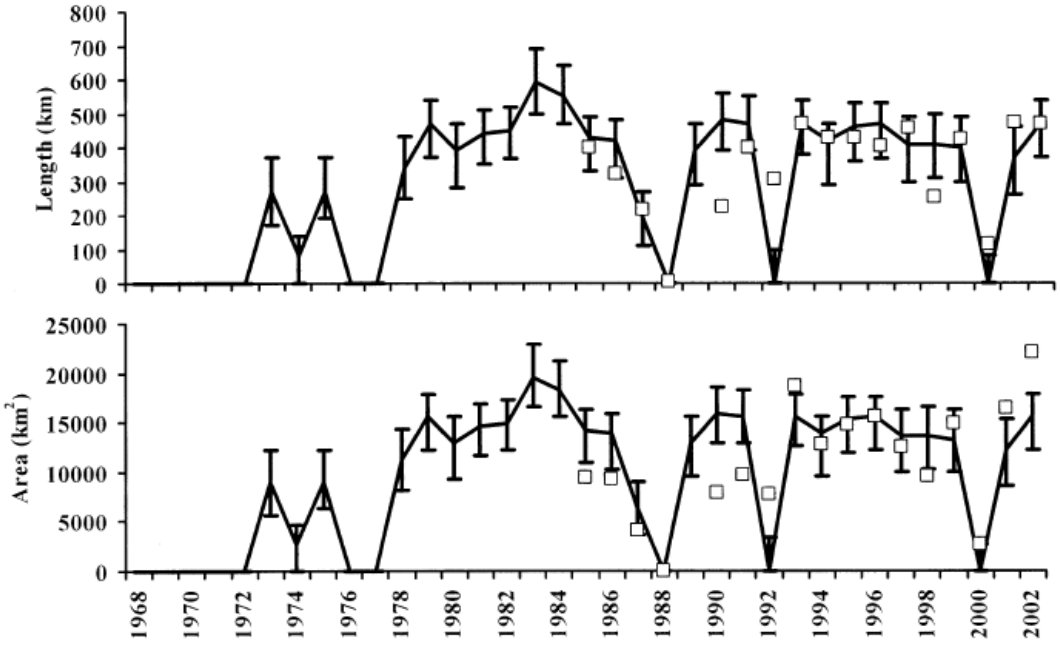
Simple Still Has Utility

<u>Gulf of Mexico Hypoxia Model</u>

Streeter-Phelps framework (BOD-DO deficit)

Assumptions:

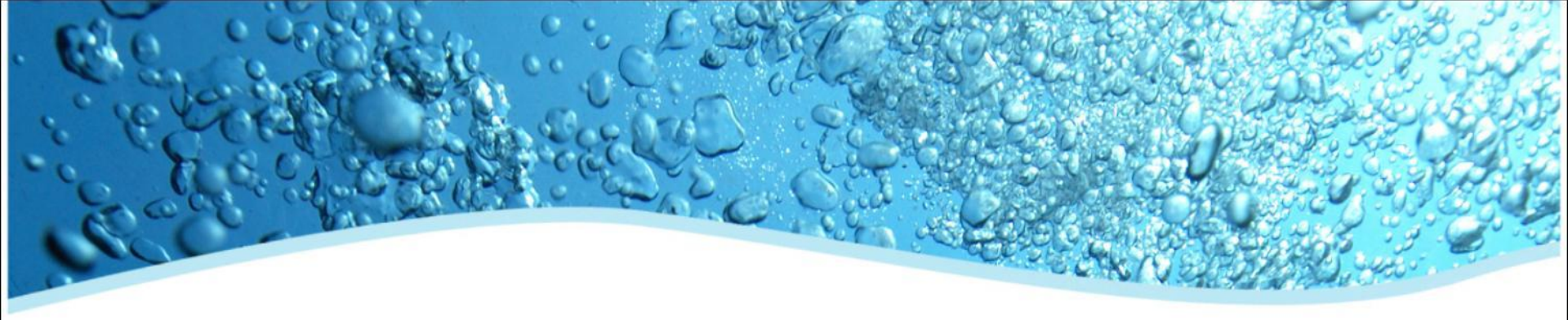
- **assume that sub-pycnocline water can be modeled as 1-D**
- **hypoxic zone length characterizes hypoxic area (r^2=0.79)**
- **river nitrogen load is a surrogate for sub-pycnocline biological oxygen demand**
- **sub-pycnocline oxygen demand is 1st order**
- **oxygen flux across pycnocline is 1st order proportional to oxygen deficit**



Scavia et al. (2003)

Summarizing

- **Design the models to answer the question(s)**
  - Get managers, scientists and modelers working together early
- **Data quality important**
  - Collect the data appropriate for calibrating the model
  - More data is (usually) good
- **Ecosystems change**
  - System perturbations/climate warming
- **Simple still has utility**
  - Build on existing understanding



Questions