Water Quality Modeling in Delaware's Inland Bays: Where Have We Been and Where Should We Go?

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Feb 1st, 2019

Figure 8-1 GEMSS 3-D and 1-D model grids for the Delaware Inland Bays

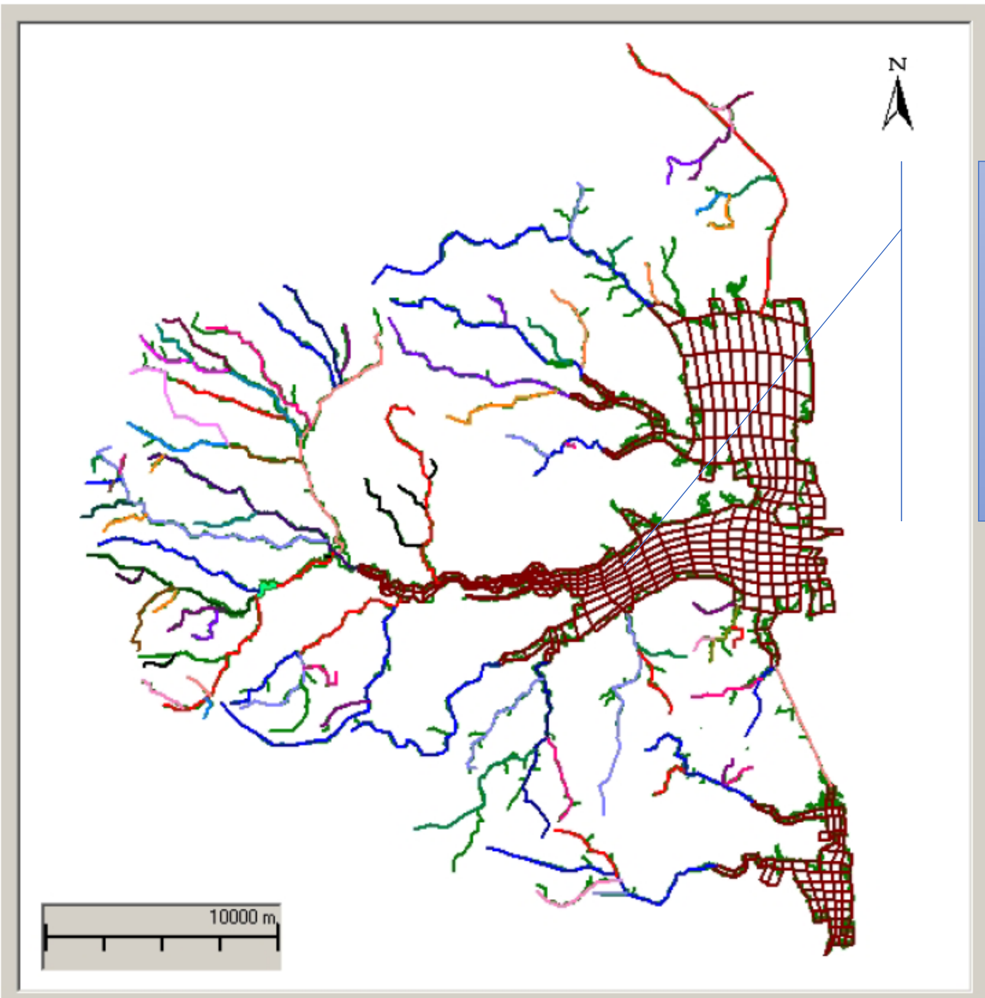
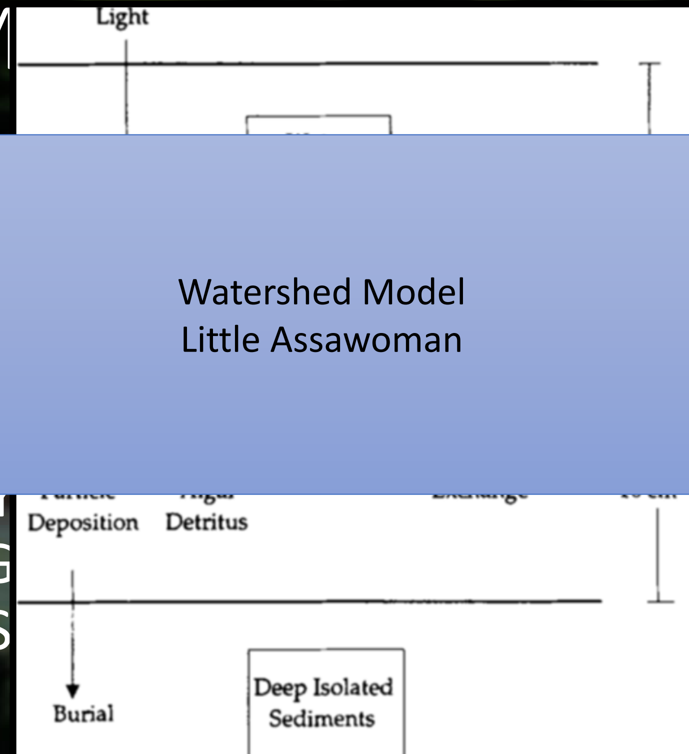


Figure 5-1

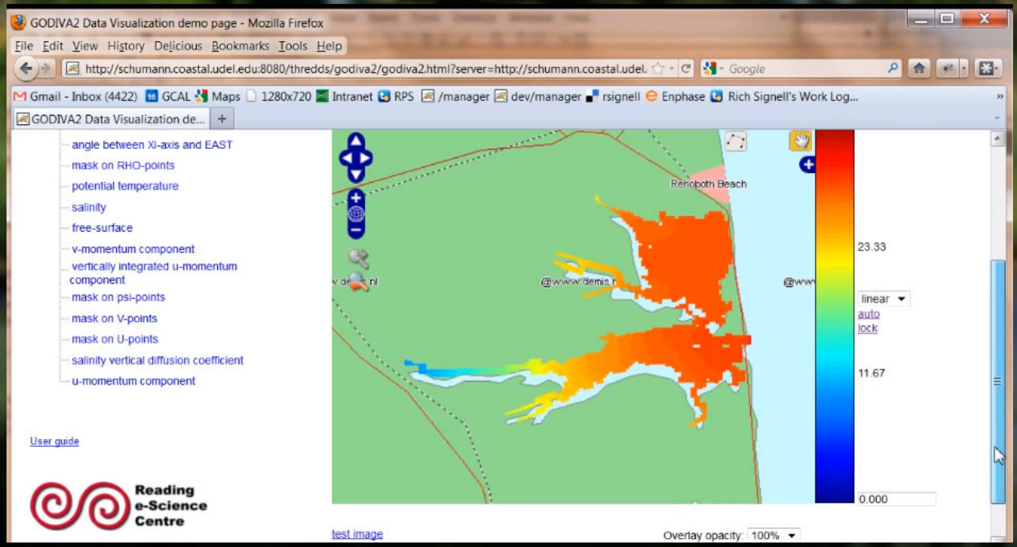


Watershed Model
Little Assawoman

temporal and spatial

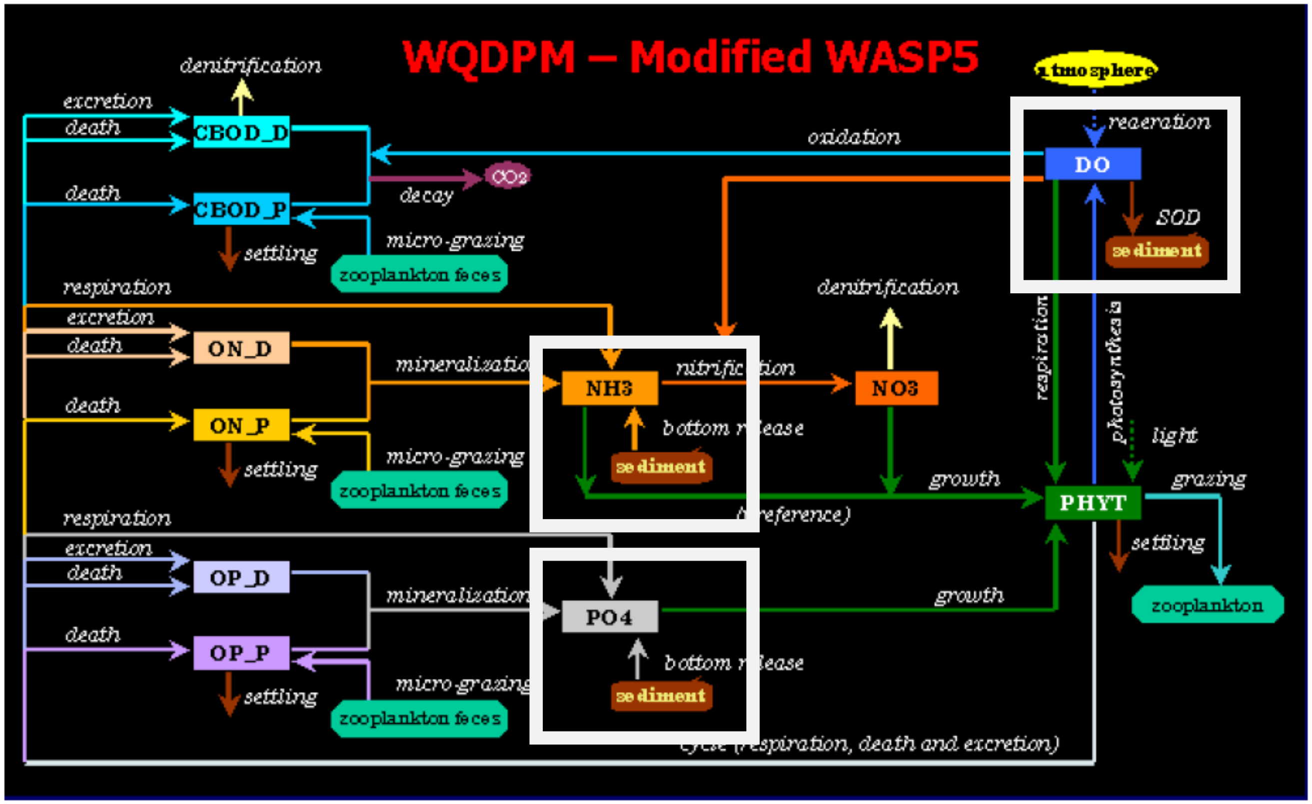
Recommendation

- Love them or hate them, models can be incredibly useful frameworks for integrating data streams
  - TMDL
  - Estuarine Productivity for Aquaculture
  - Zones of hypoxia for essential fish habitat analysis
  - Testing hypotheses (e.g., groundwater discharge, water quality lags between management and response)
- So they need to be accessible!
  - Consulting firms are professional and thorough but they also only deliver what is asked...so be sure to establish important questions and determine what format you want your answers in...



Concentration on Lessons

Figure 6-1 Process Flow Diagram for the WQDPM Model Component of GEMSS



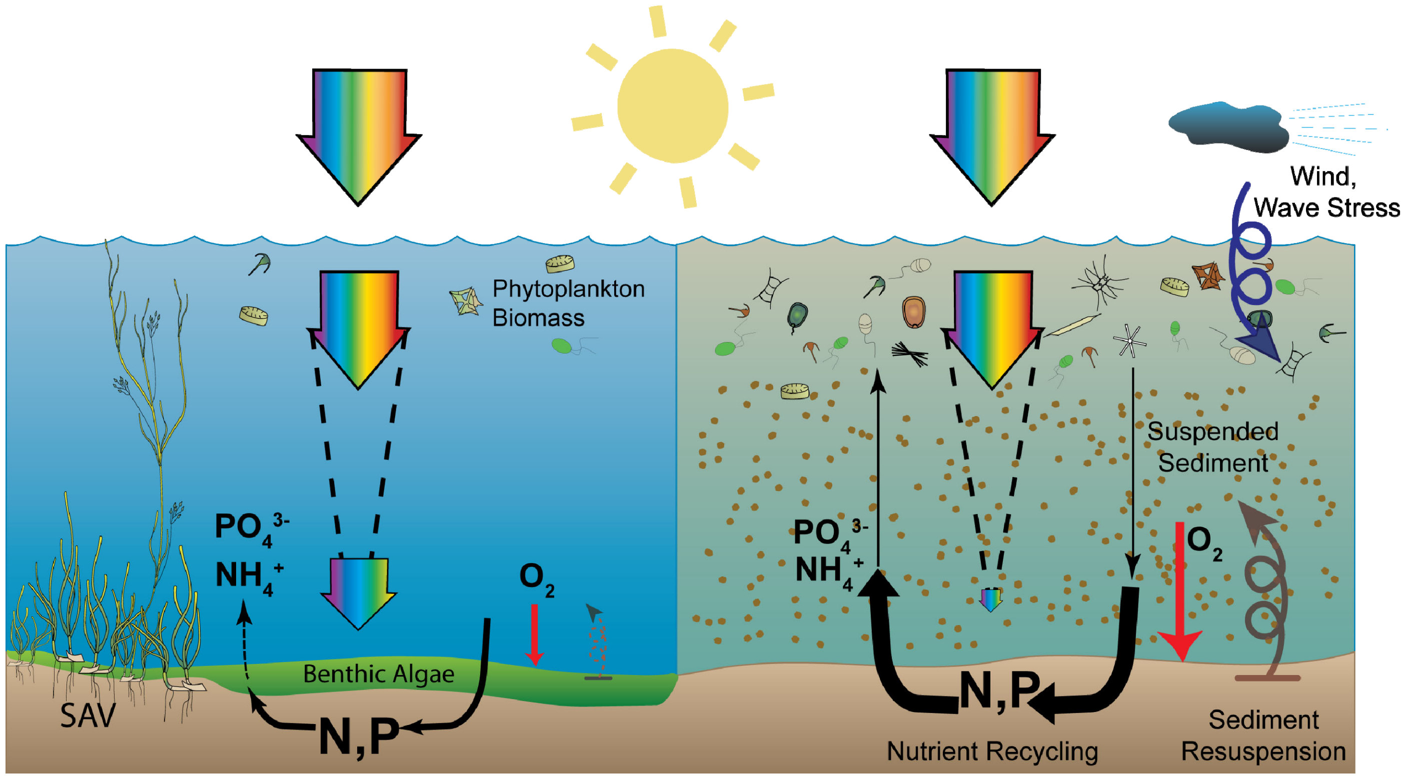


Figure 1: Key biogeochemical processes in shallow water habitats in Chesapeake Bay. The availability of light drives nutrient and carbon dynamics in shallow coastal ecosystems, as once light reaches the sediment, benthic algal communities can (1) absorb nutrients and retain them in sediments, (2) stabilize sediments and limit resuspension, and thus (3) lead to elevated water clarity. In the absence of light at the sediment surface, limited benthic algal growth leads to high sediment nutrient recycling and potentially less stable sediments.

Physics: Tides…check

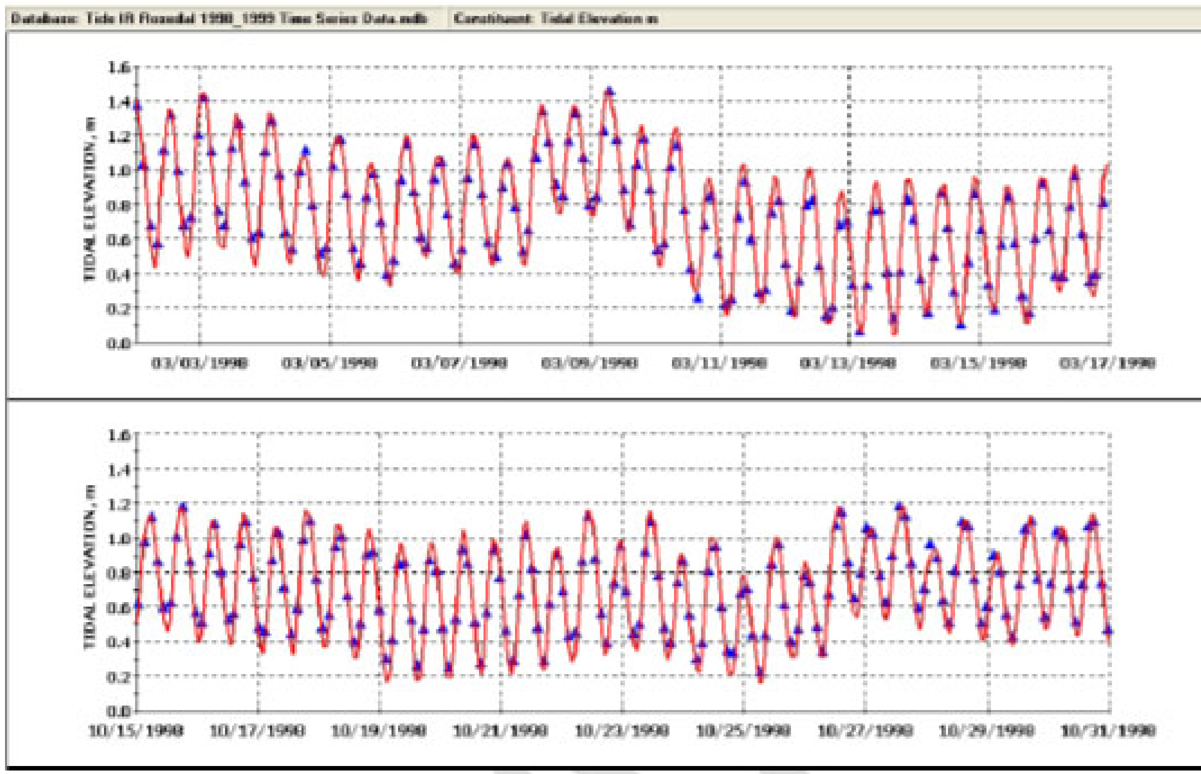


FIGURE 9. COMPARISON OF MODEL PREDICTIONS OF TIDE HEIGHT AT ROSEDALE BEACH FOR A TWO WEEK PERIOD IN THE BEGINNING AND END OF 1998

Physics: Temperature…check

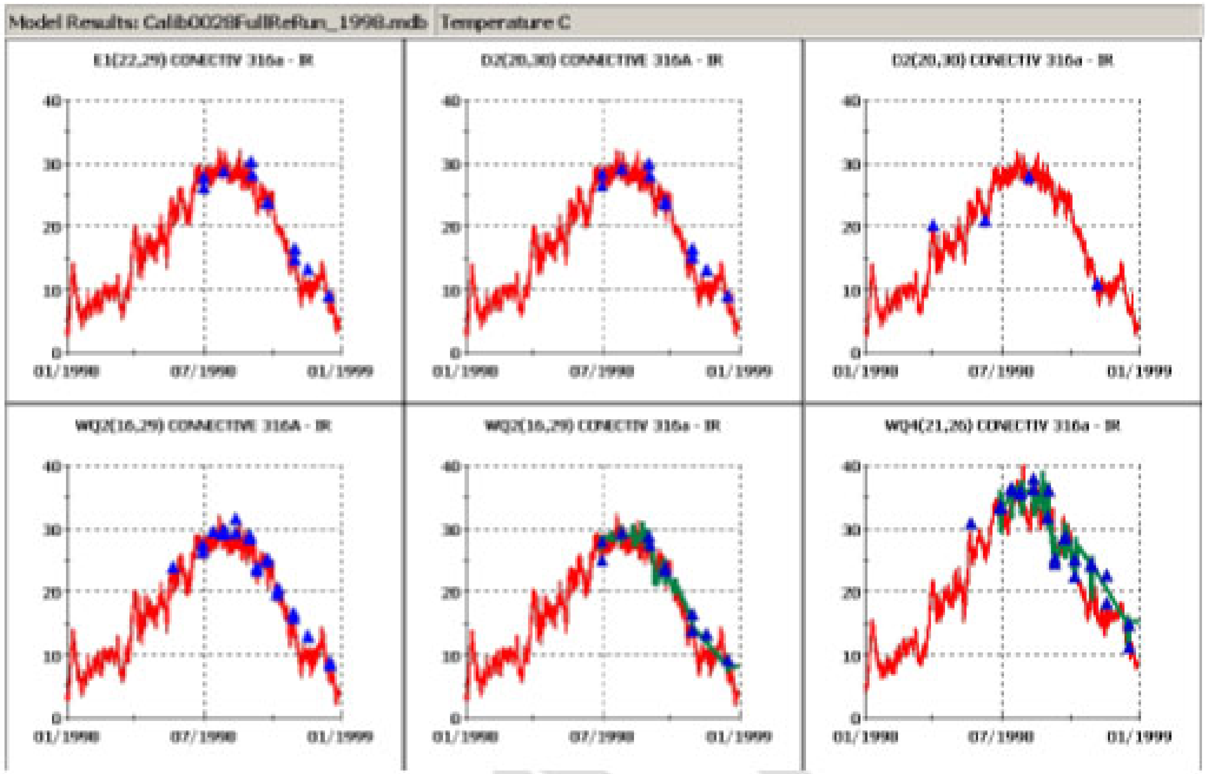


FIGURE 10. TEMPERATURE PREDICTIONS ALONG THE AXIS OF INDIAN RIVER BAY. GENERALLY, THE MODEL PREDICTS TEMPERATURE WELL BOTH TEMPORALLY AND SPATIALLY

Physics: Volumetric Flow Through Indian River Inlet...data from 1990

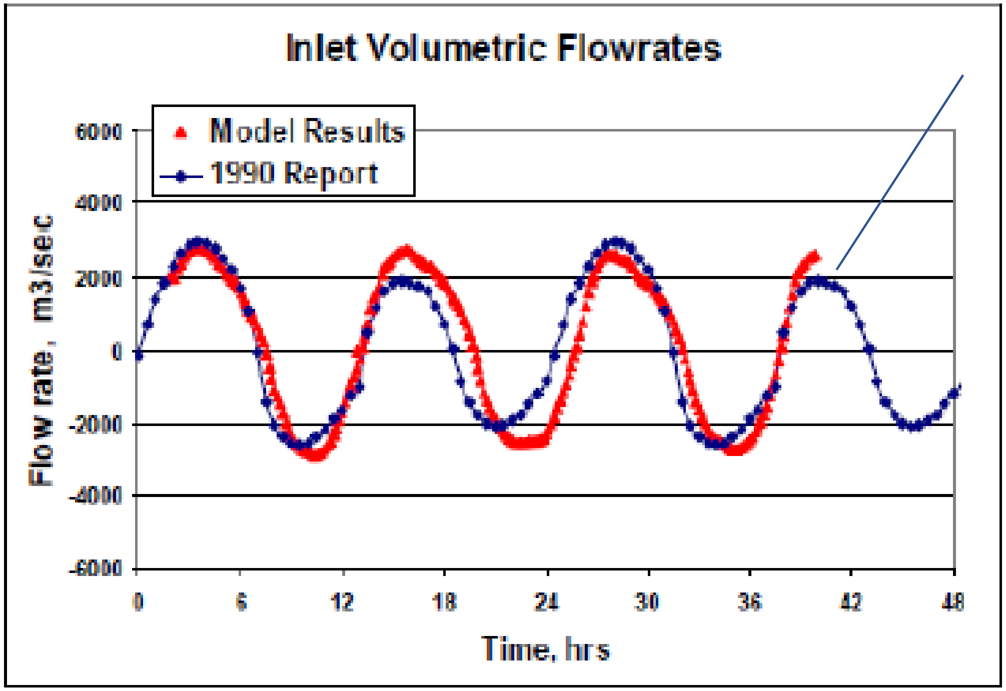
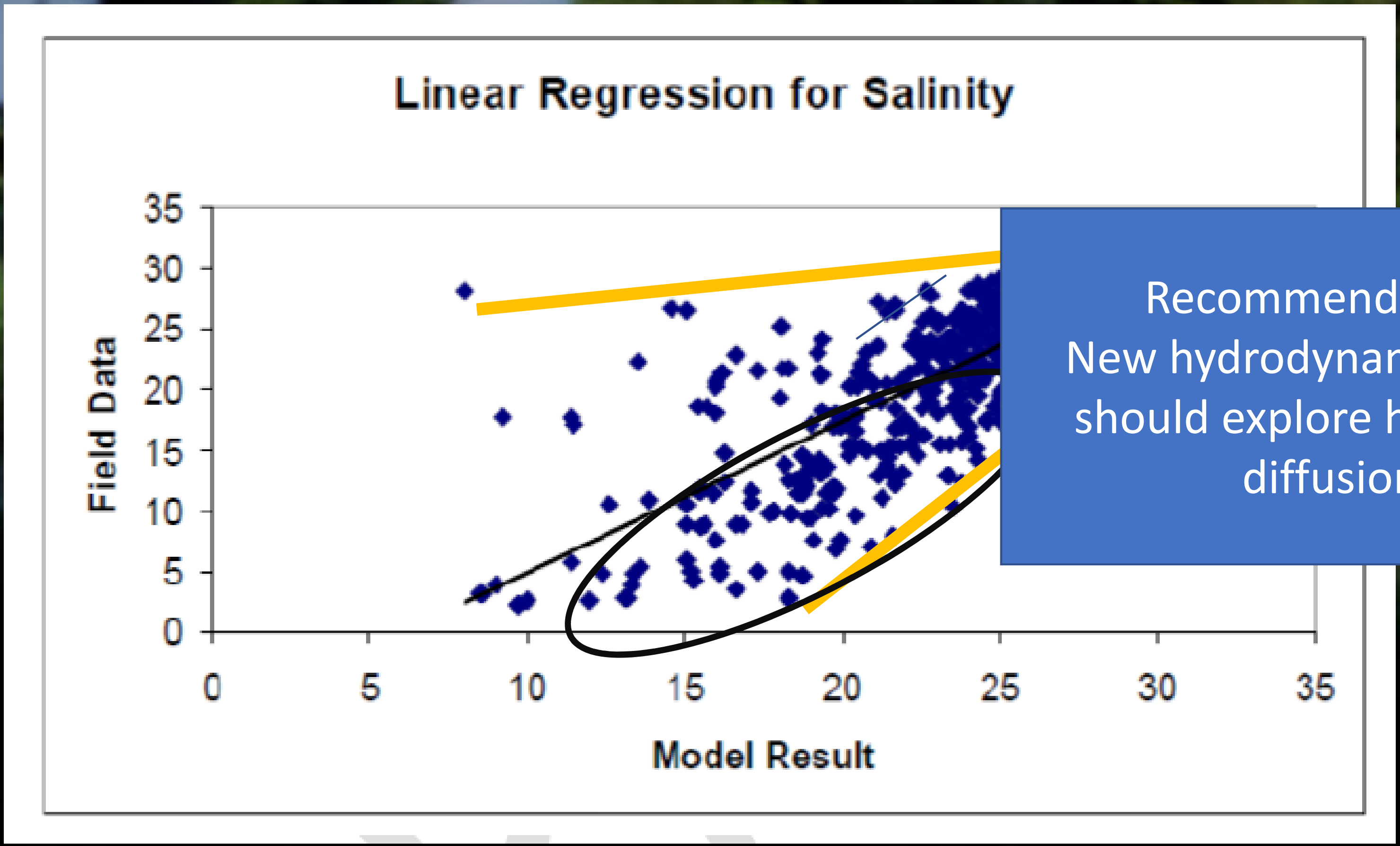


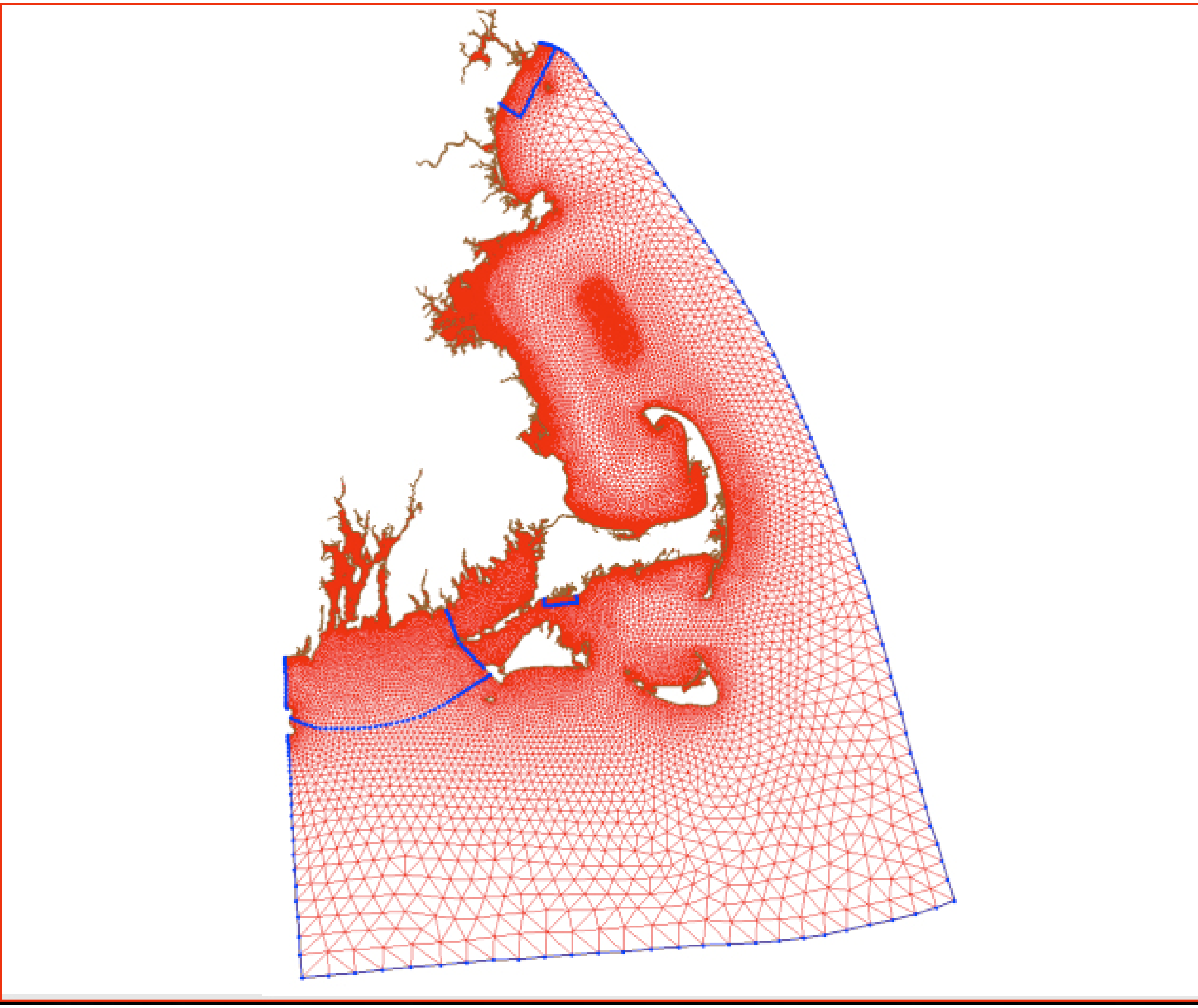
FIGURE 11. COMPARISON OF VOLUMETRIC FLOW RATE FROM GEMSS AND A 1990 REPORT.

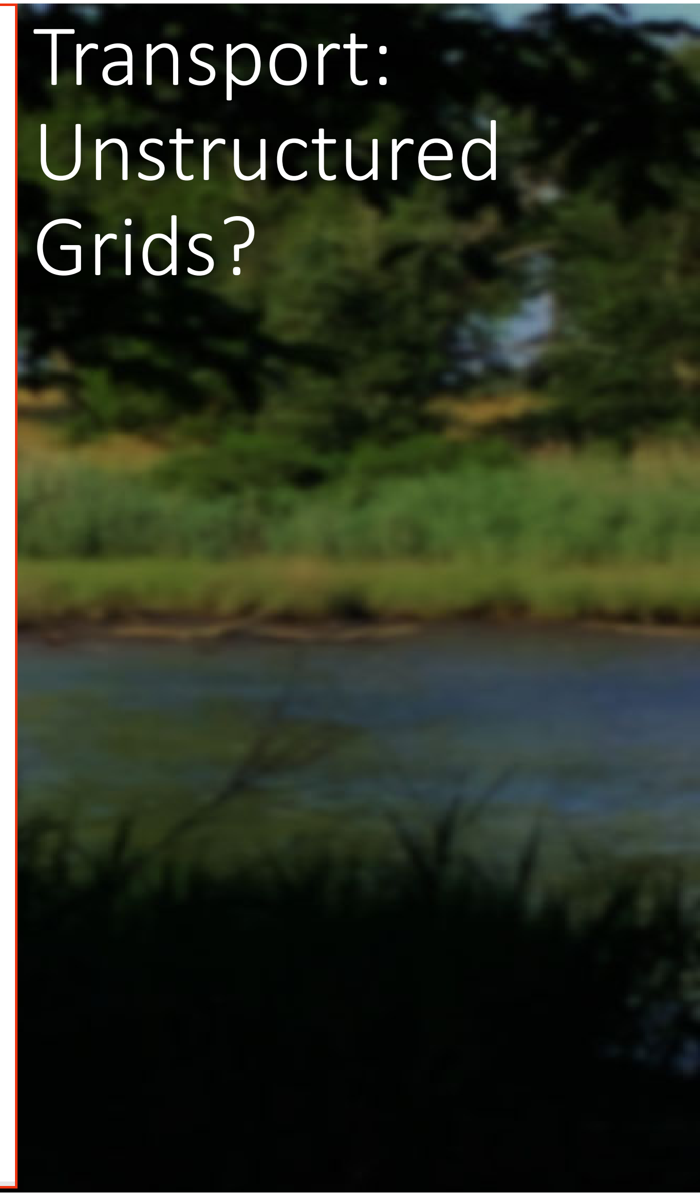
Recommendation: Scouring since 1990?

Mesohaline Predictions

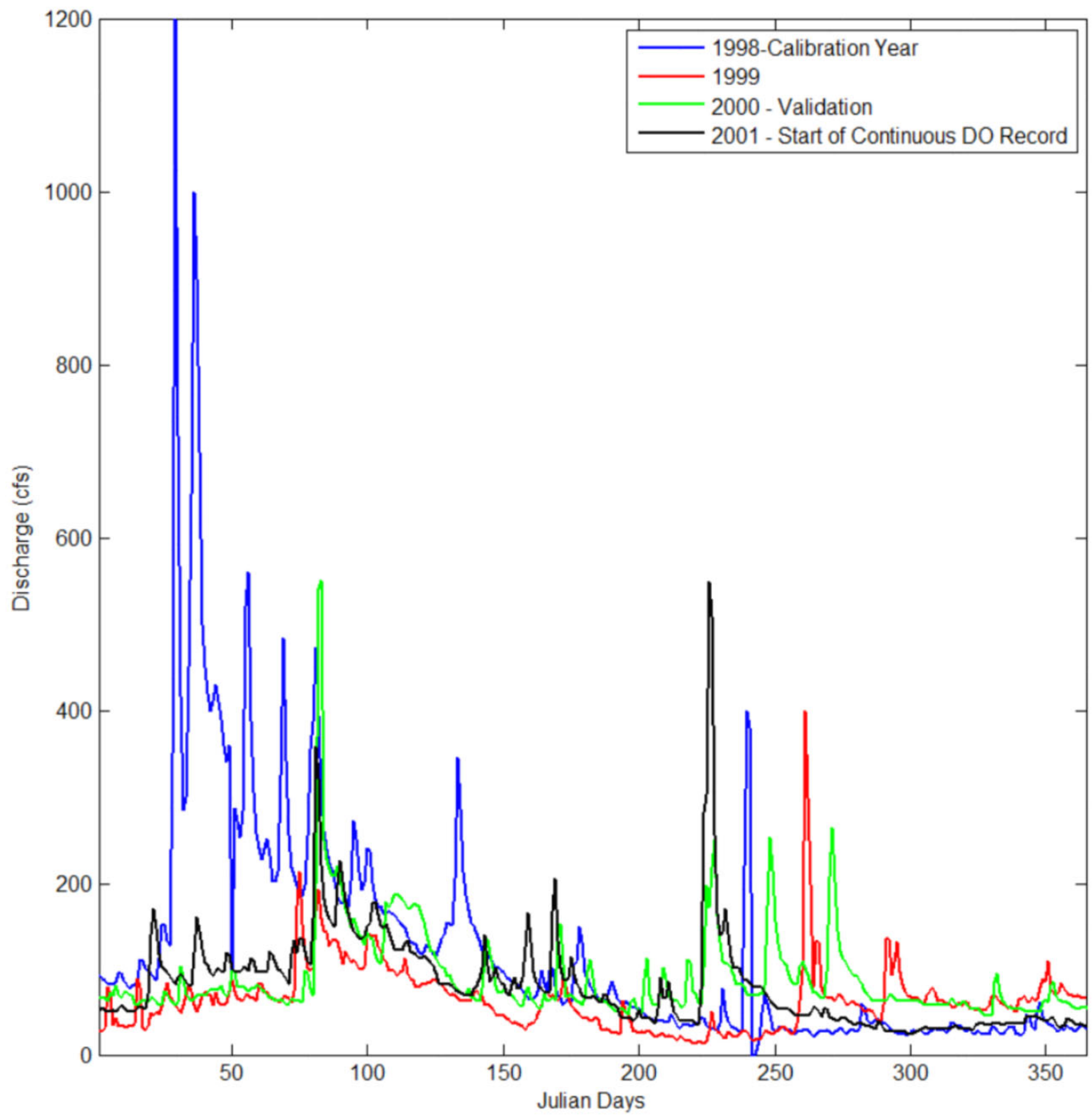


Recommendation:
New hydrodynamic model should explore horizontal diffusion





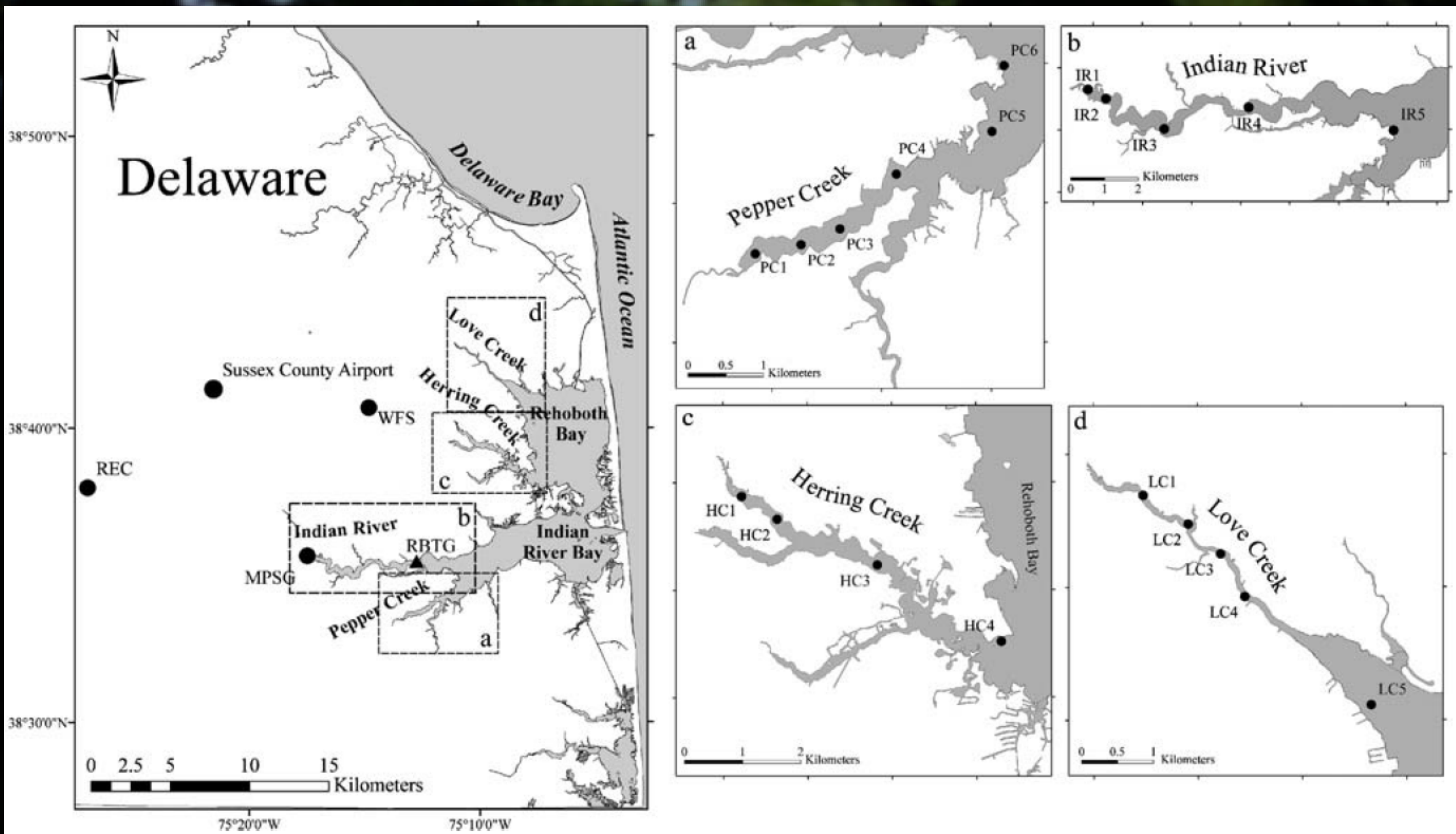
Transport: Unstructured Grids?



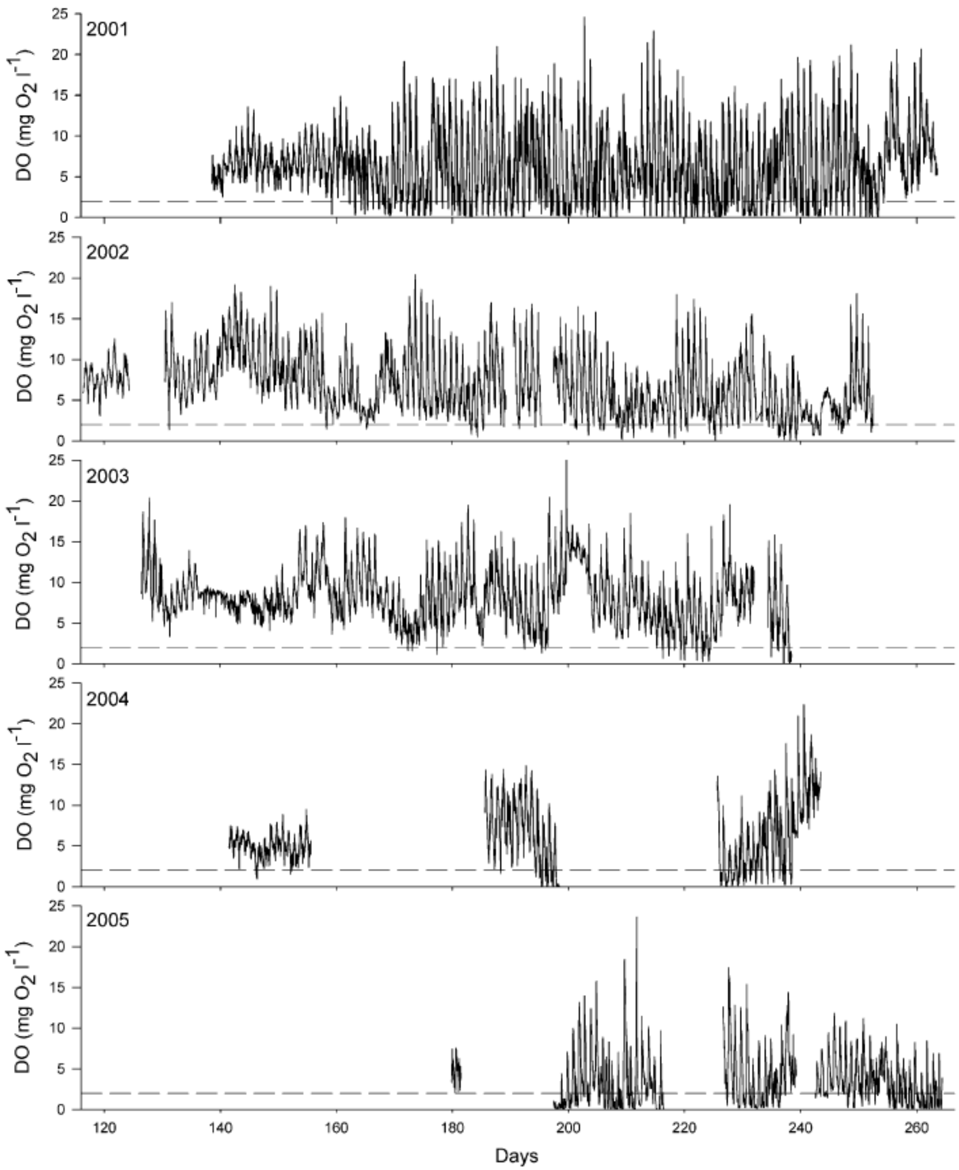
Hydrographs of Model Years

- With an increased amount of data (years), a modeling effort could choose wet, dry, and normal years

Tidal Headwaters

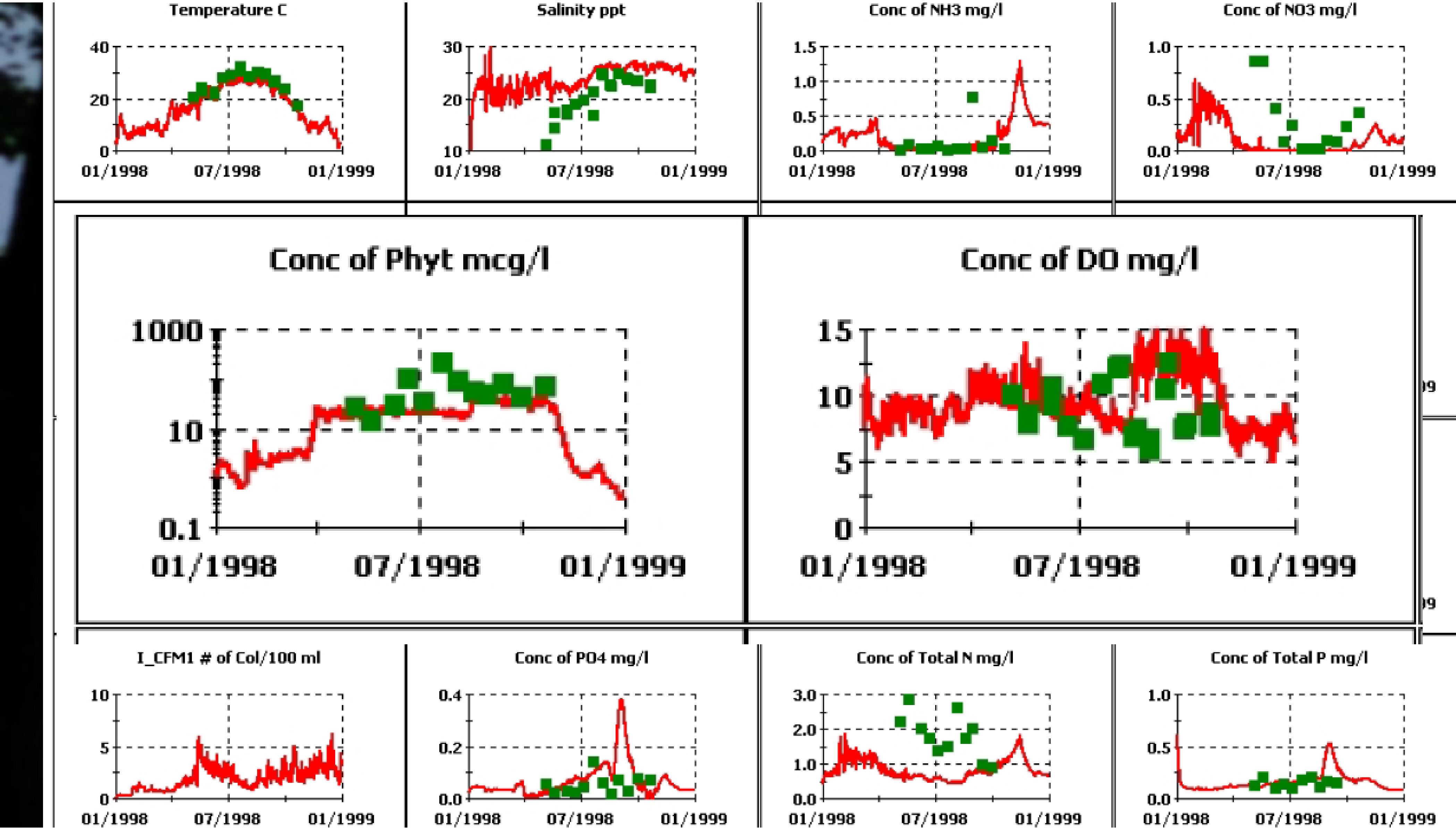


- Essential fish habitat



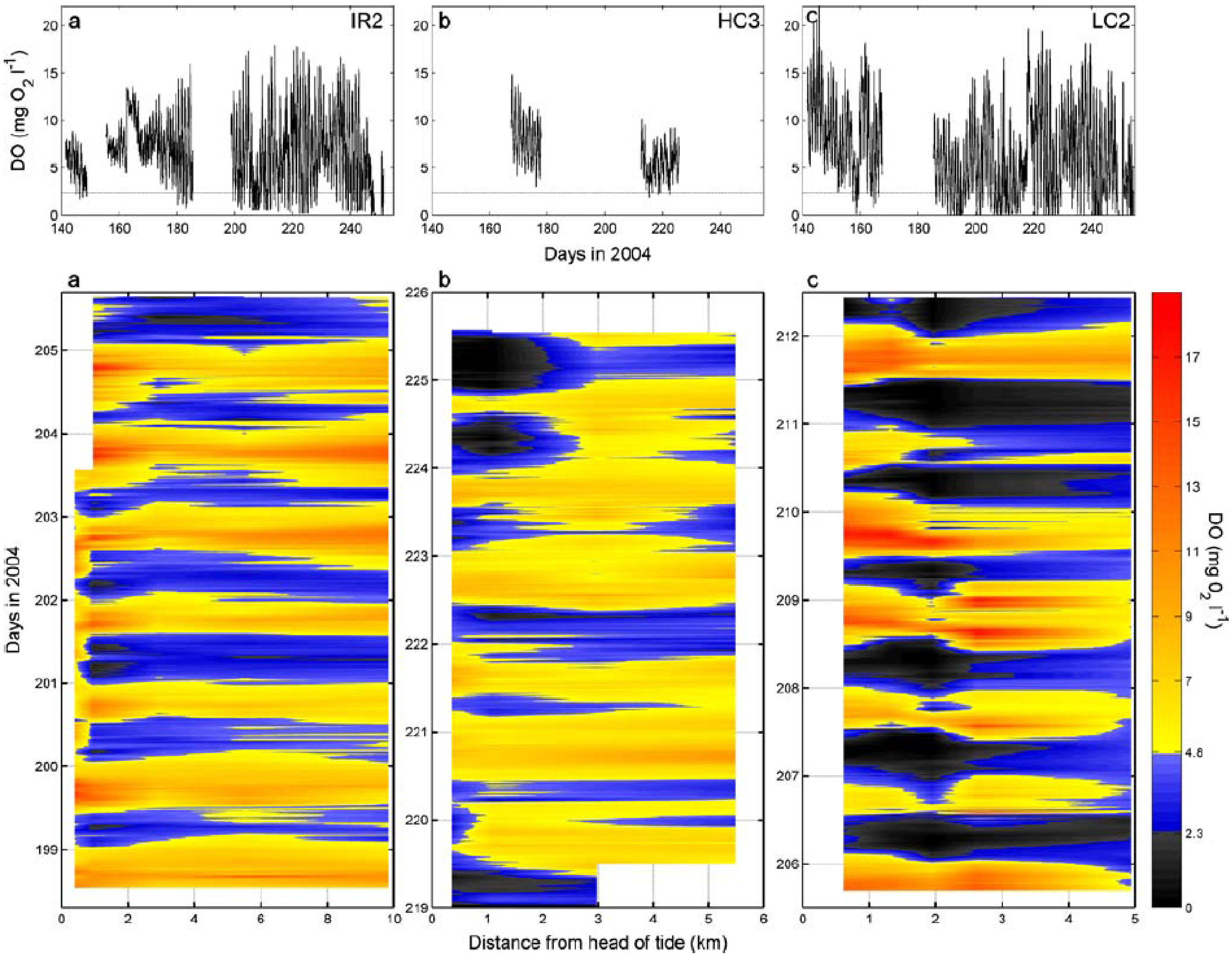
Upper Pepper Creek

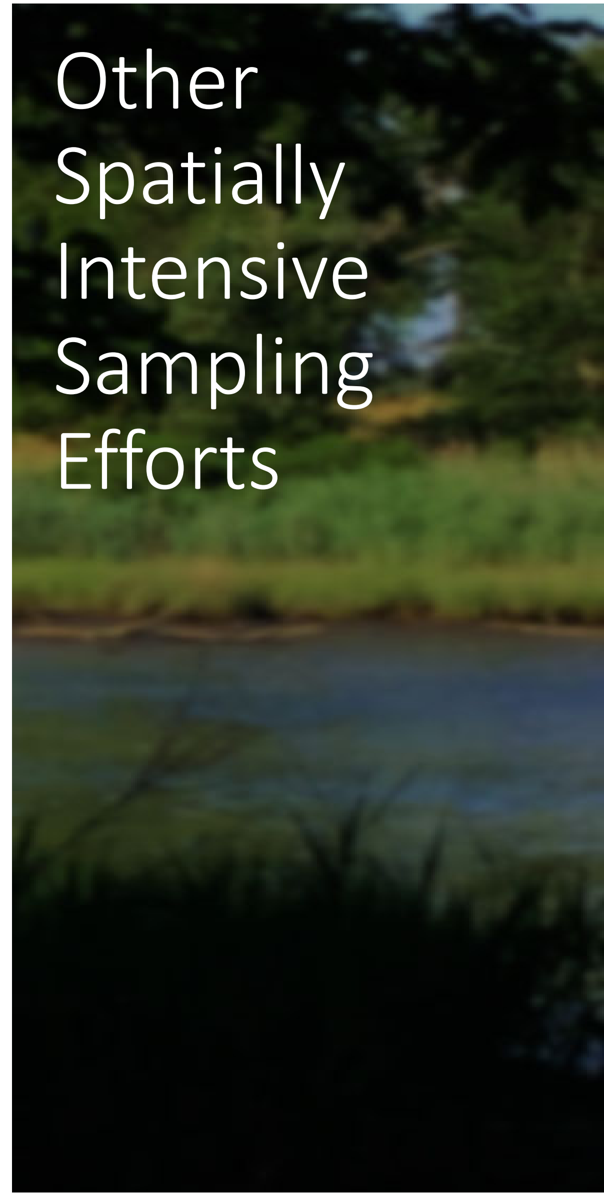
- Note amplitude and interannual differences

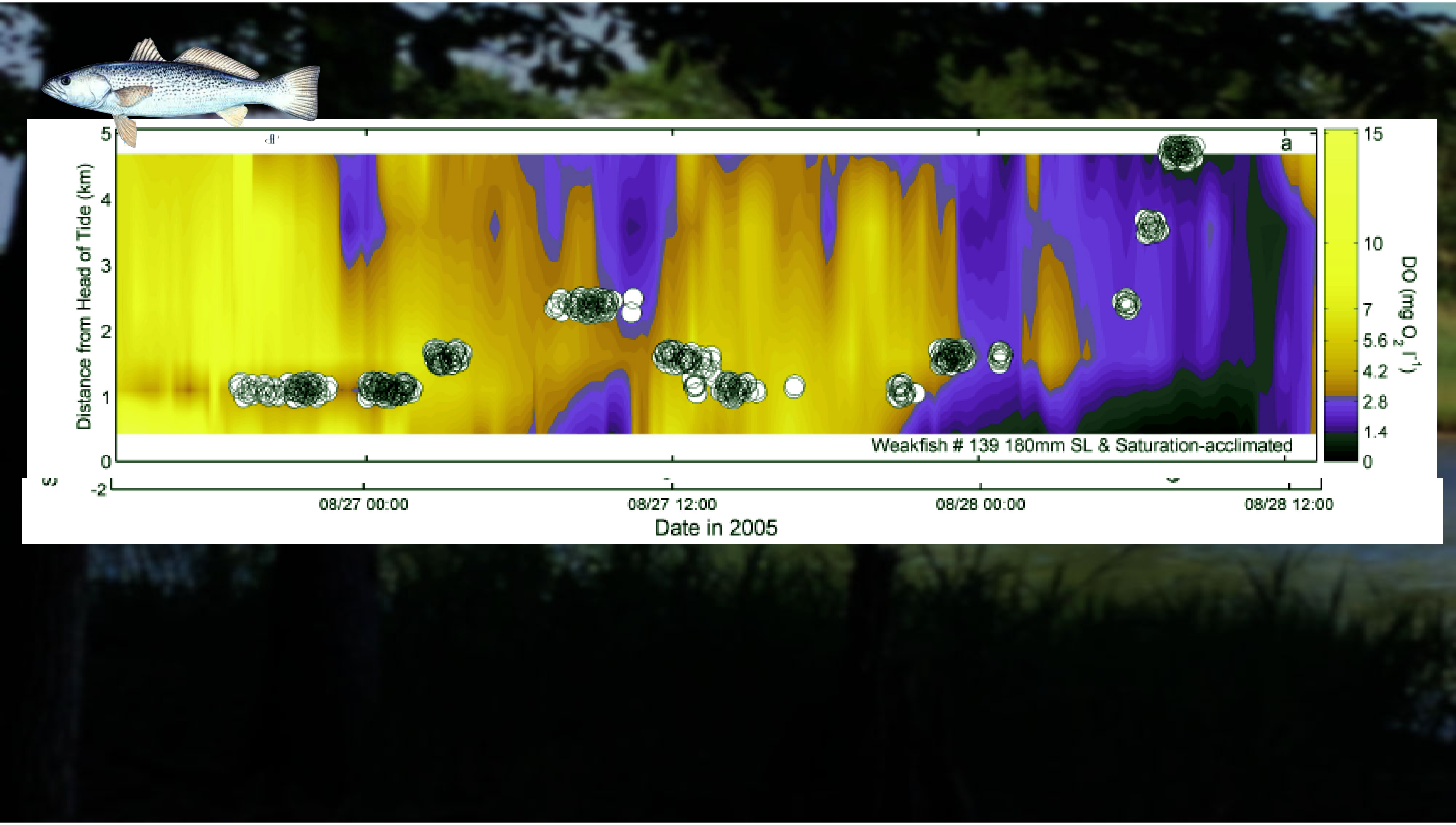


Temperature C
40
20
0
01/1998
07/1998
01/1999
Salinity ppt
30
20
10
Conc of NH3 mg/l
1.5
1.0
0.5
0.0
Conc of NO3 mg/l
1.0
0.5
0.0
Conc of Phyt mcg/l
1000
10
0.1
Conc of DO mg/l
15
10
5
0
I_CFM1 # of Col/100 ml
10
5
0
Conc of PO4 mg/l
0.4
0.2
0.0
Conc of Total N mg/l
3.0
2.0
1.0
0.0
Conc of Total P mg/l
1.0
0.5
0.0

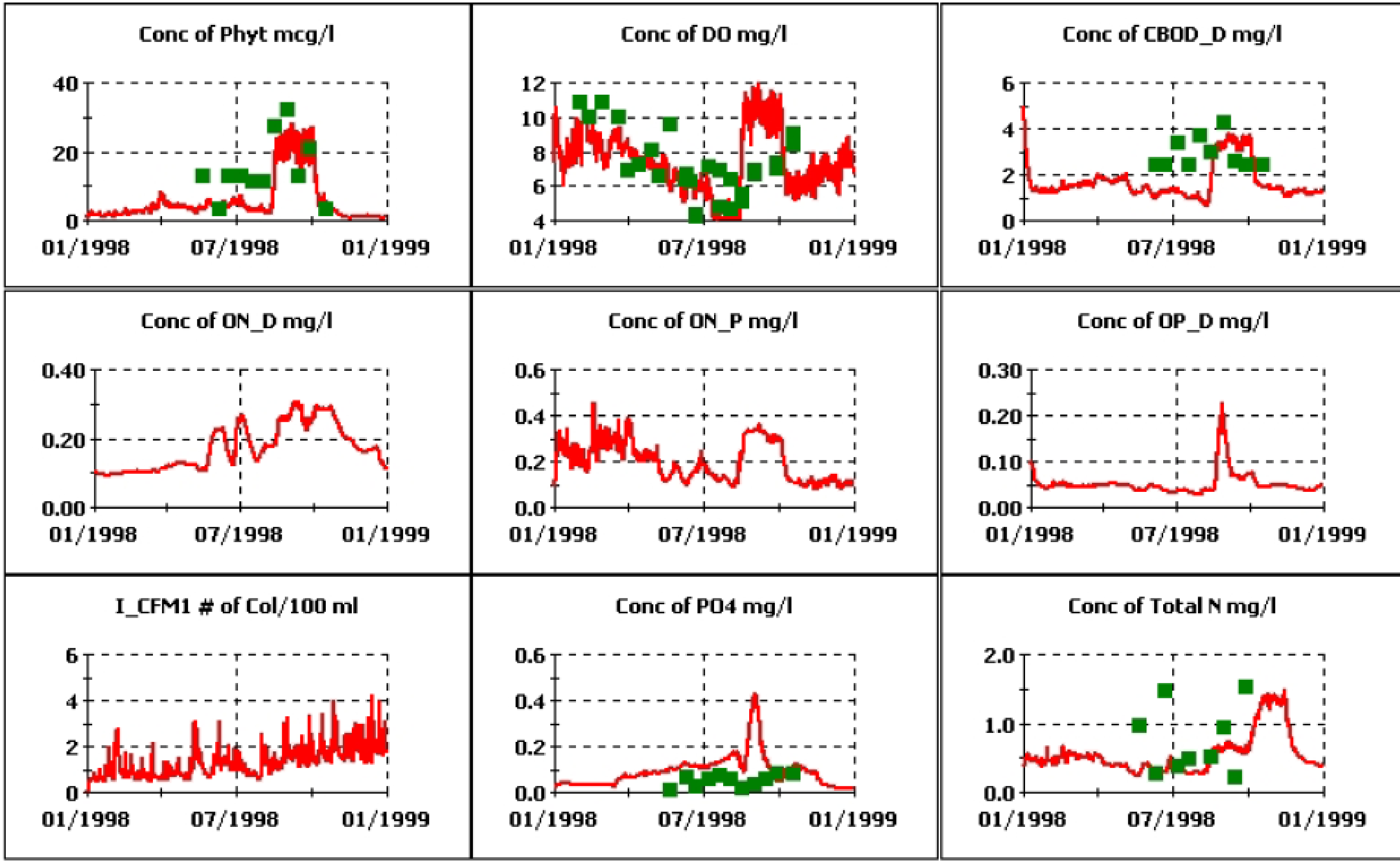
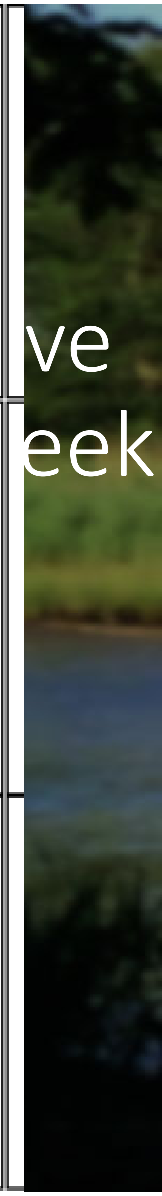
Other Spatially Intensive Sampling Efforts





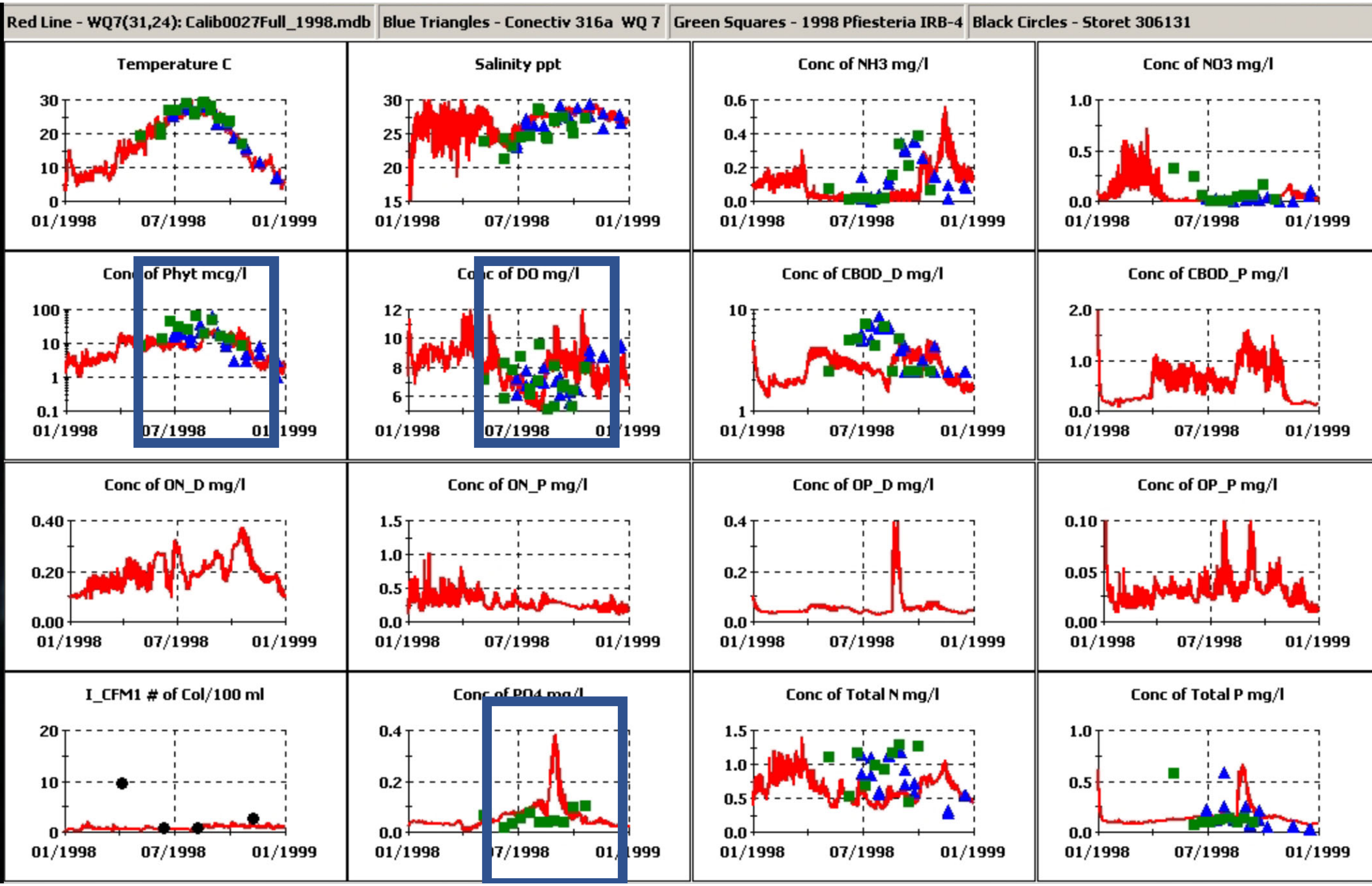


Distance from Head of Tide (km)
0
1
2
3
4
5
-2
a
Weakfish # 139 180mm SL & Saturation-acclimated
08/27 00:00
08/27 12:00
08/28 00:00
08/28 12:00
Date in 2005
DO (mg O_2 l^{-1})
15
10
7
5.6
4.2
2.8
1.4
0


Conc of Phyt mcg/l
Conc of DO mg/l
Conc of CBOD_D mg/l
Conc of ON_D mg/l
Conc of ON_P mg/l
Conc of OP_D mg/l
I_CFM1 # of Col/100 ml
Conc of PO4 mg/l
Conc of Total N mg/l
01/1998
07/1998
01/1999

ve
eek

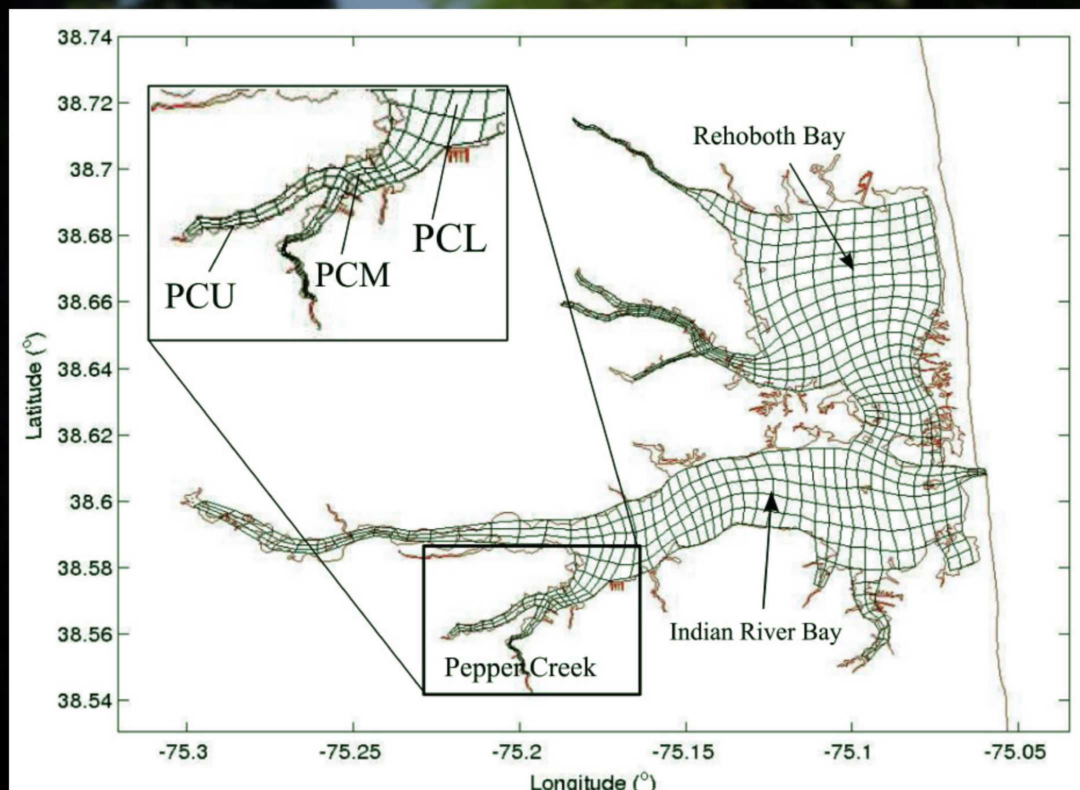
Recommendation:
Respiration and Primary Productivity

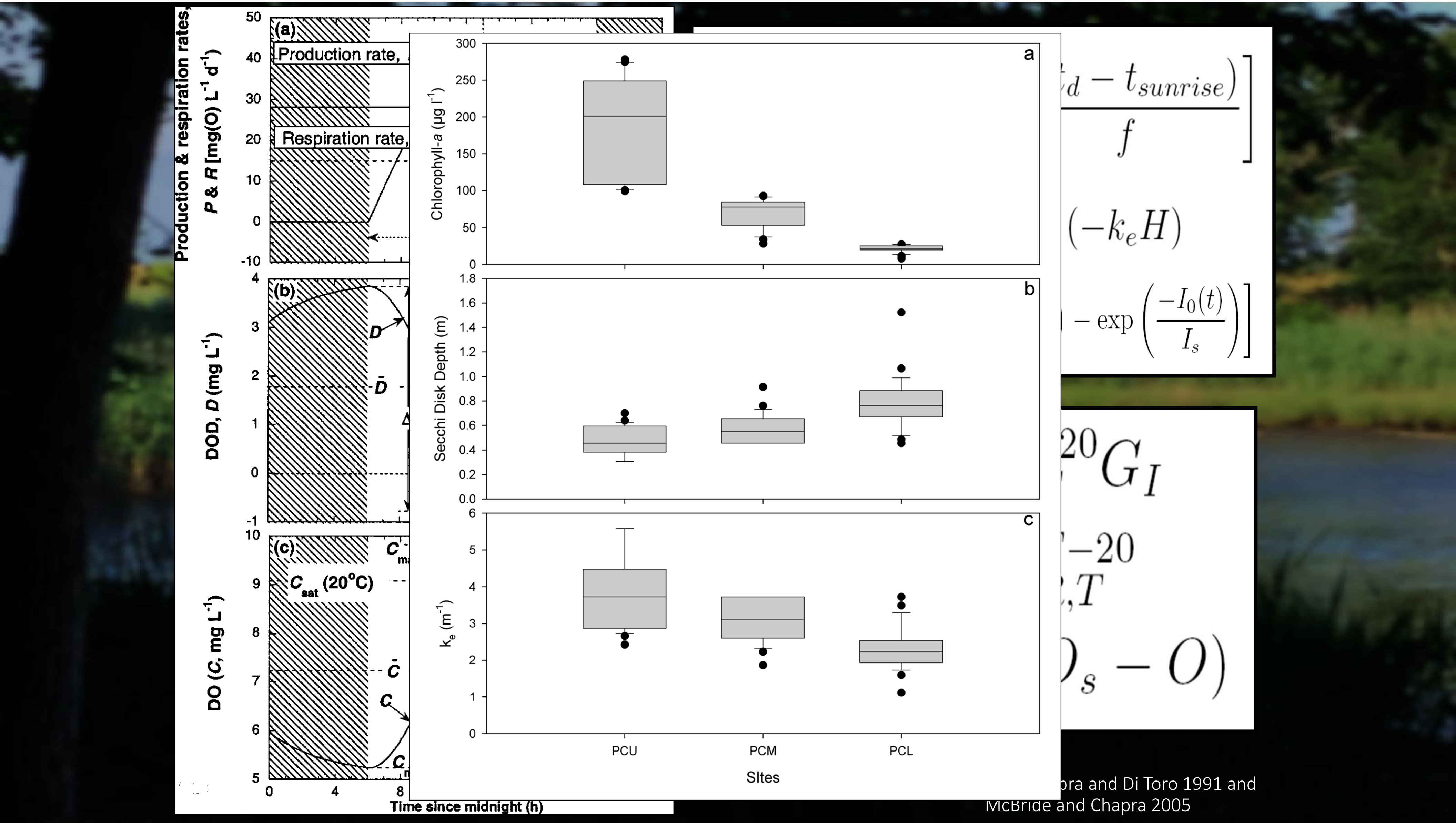
- Model does not incorporate any rate information
- Primary Productivity (phytoplankton growth) without attendant increases in Respiration and perhaps Sediment Oxygen Demand



Red Line - WQ7(31,24): Calib0027Full_1998.mdb
Blue Triangles - Conectiv 316a WQ 7
Green Squares - 1998 Pfiesteria IRB-4
Black Circles - Storet 306131
Temperature C
Salinity ppt
Conc of NH3 mg/l
Conc of NO3 mg/l
Conc of Phyt mcg/l
Conc of DO mg/l
Conc of CBOD_D mg/l
Conc of CBOD_P mg/l
Conc of ON_D mg/l
Conc of ON_P mg/l
Conc of OP_D mg/l
Conc of OP_P mg/l
I_CFM1 # of Col/100 ml
Conc of PO4 mg/l
Conc of Total N mg/l
Conc of Total P mg/l
01/1998
07/1998
01/1999

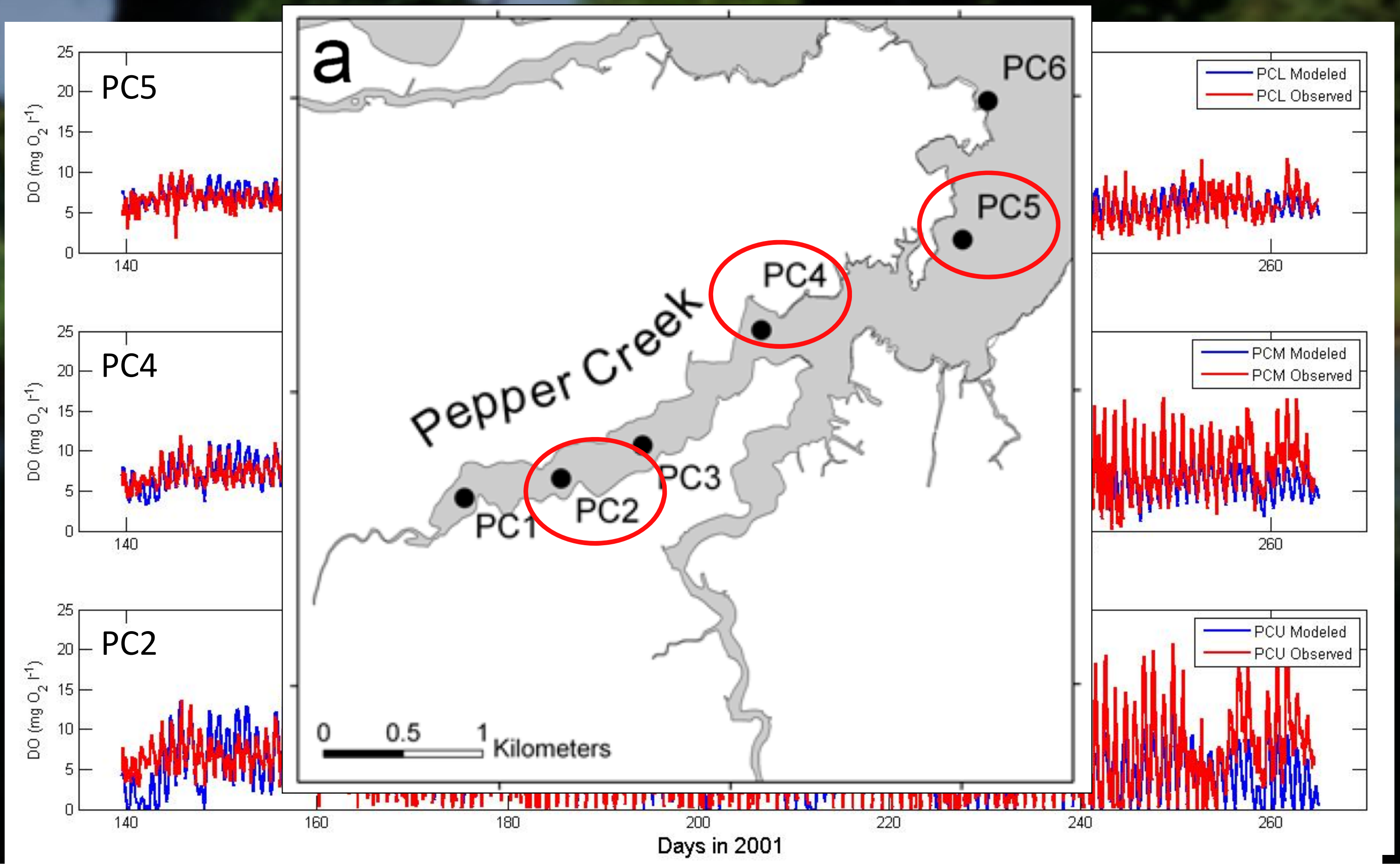
Here is the model we put together…it is designed to capture diel-cycling hypoxia, but not nutrient dynamics





...pra and Di Toro 1991 and McBride and Chapra 2005

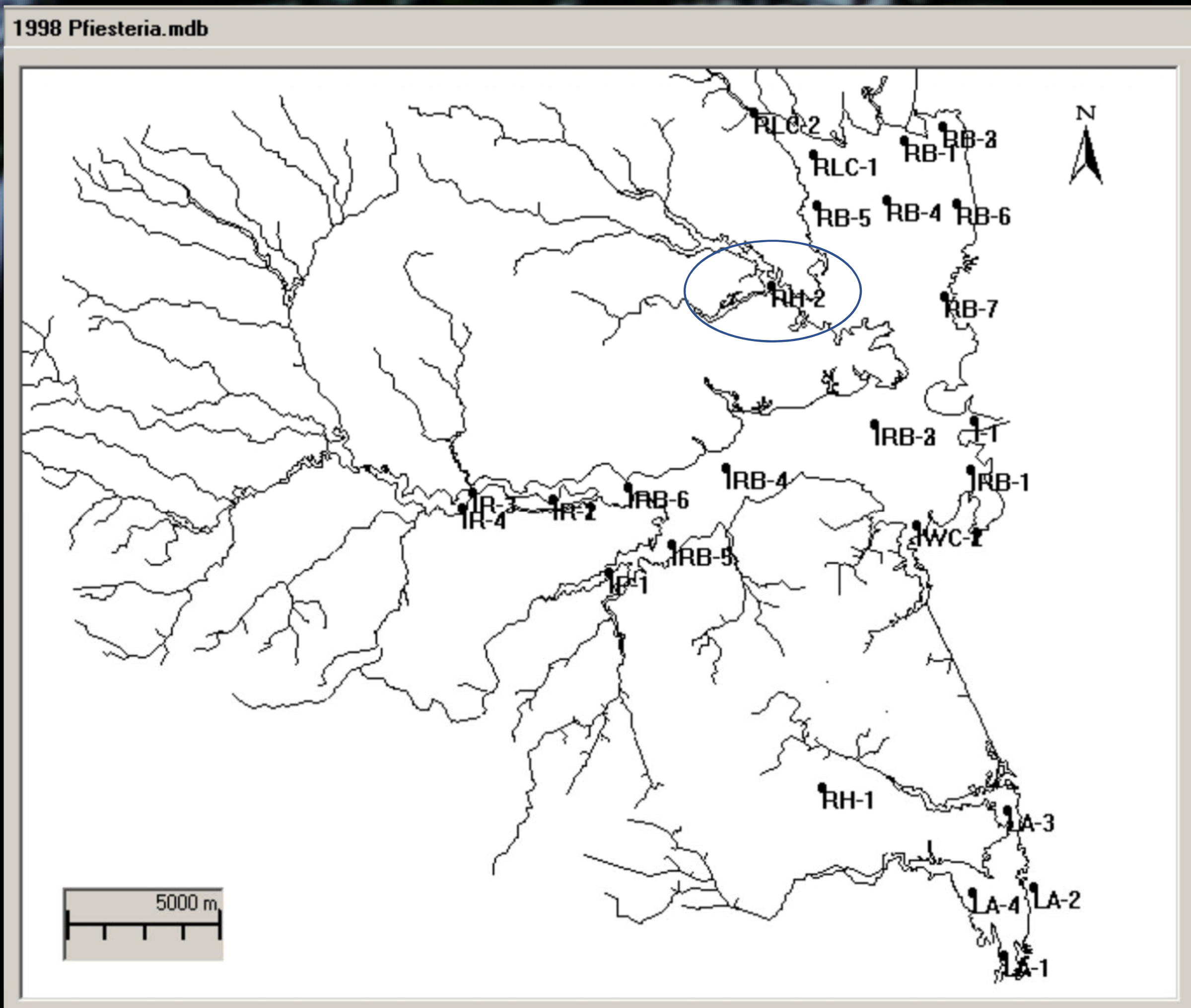
Model Performance

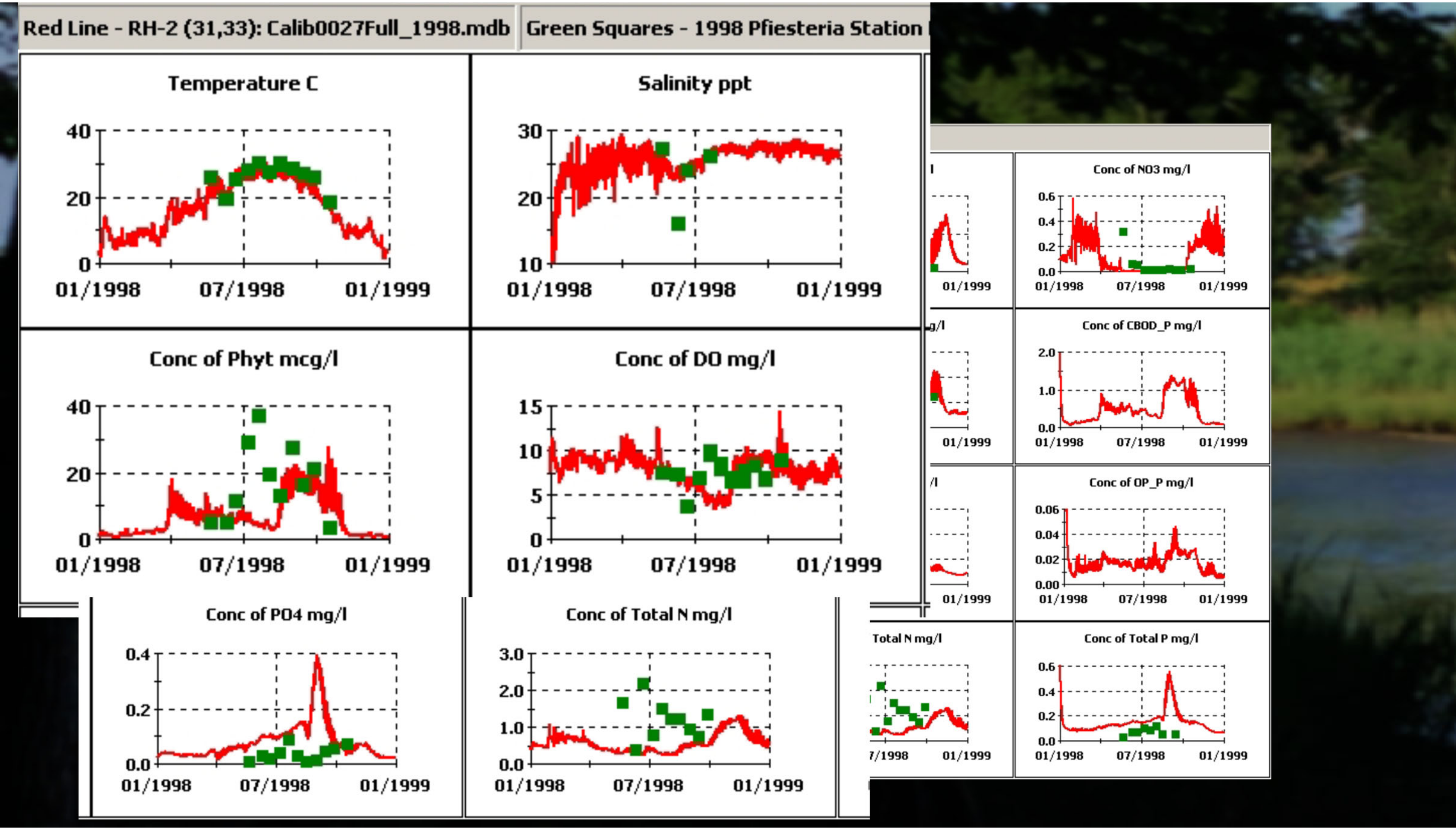


Recommendation:
Nutrient Cycling in the Sediment

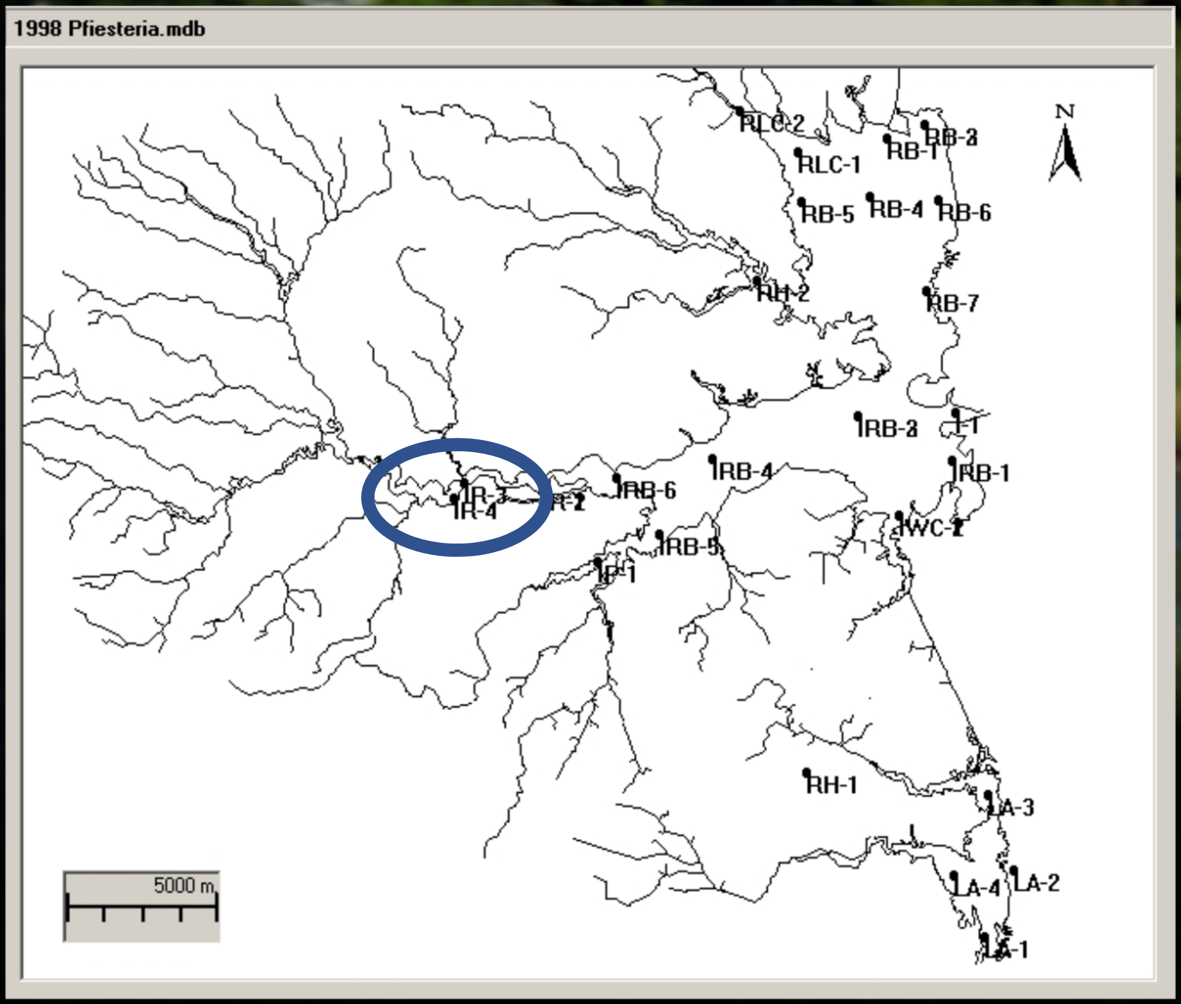
- Phosphorus storage in the model world
- Phosphorus release is likely in ‘real’ life due to frequent hypoxic events
- Nitrogen: recycling efficiency (amount of nitrogen maintained in the system) is likely to be higher during real life hypoxia
- Sediment oxygen demand in a sediment model calculates particulate sulfides (oxygen potential)

erring Creek

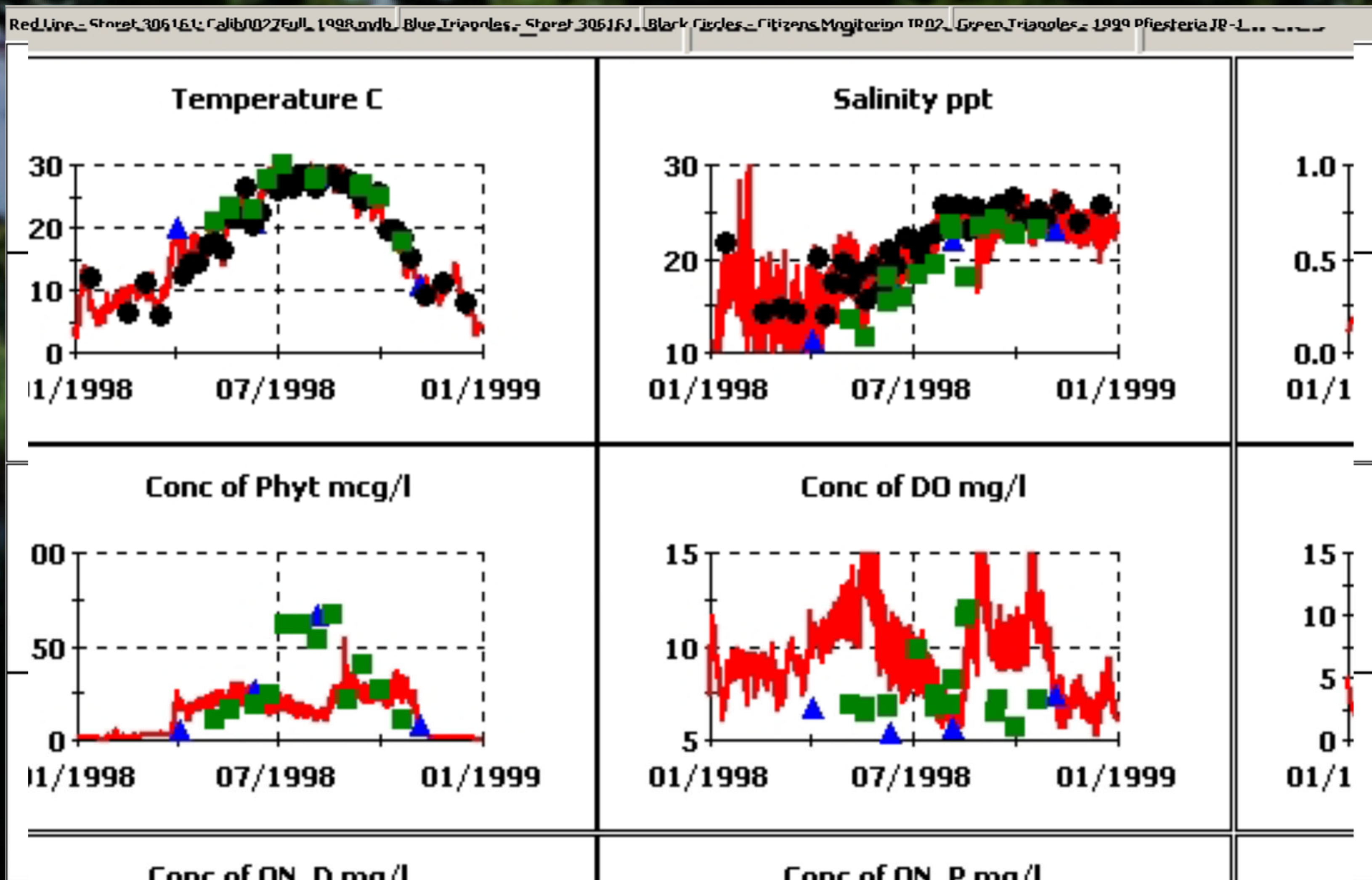



Red Line - RH-2 (31,33): Calib0027Full_1998.mdb
Green Squares - 1998 Pfiesteria Station
Temperature C
Salinity ppt
Conc of Phyt mcg/l
Conc of DO mg/l
Conc of PO4 mg/l
Conc of Total N mg/l
Conc of NO3 mg/l
Conc of CBOD_P mg/l
Conc of OP_P mg/l
Conc of Total P mg/l
01/1998
07/1998
01/1999

Indian River



Indian River



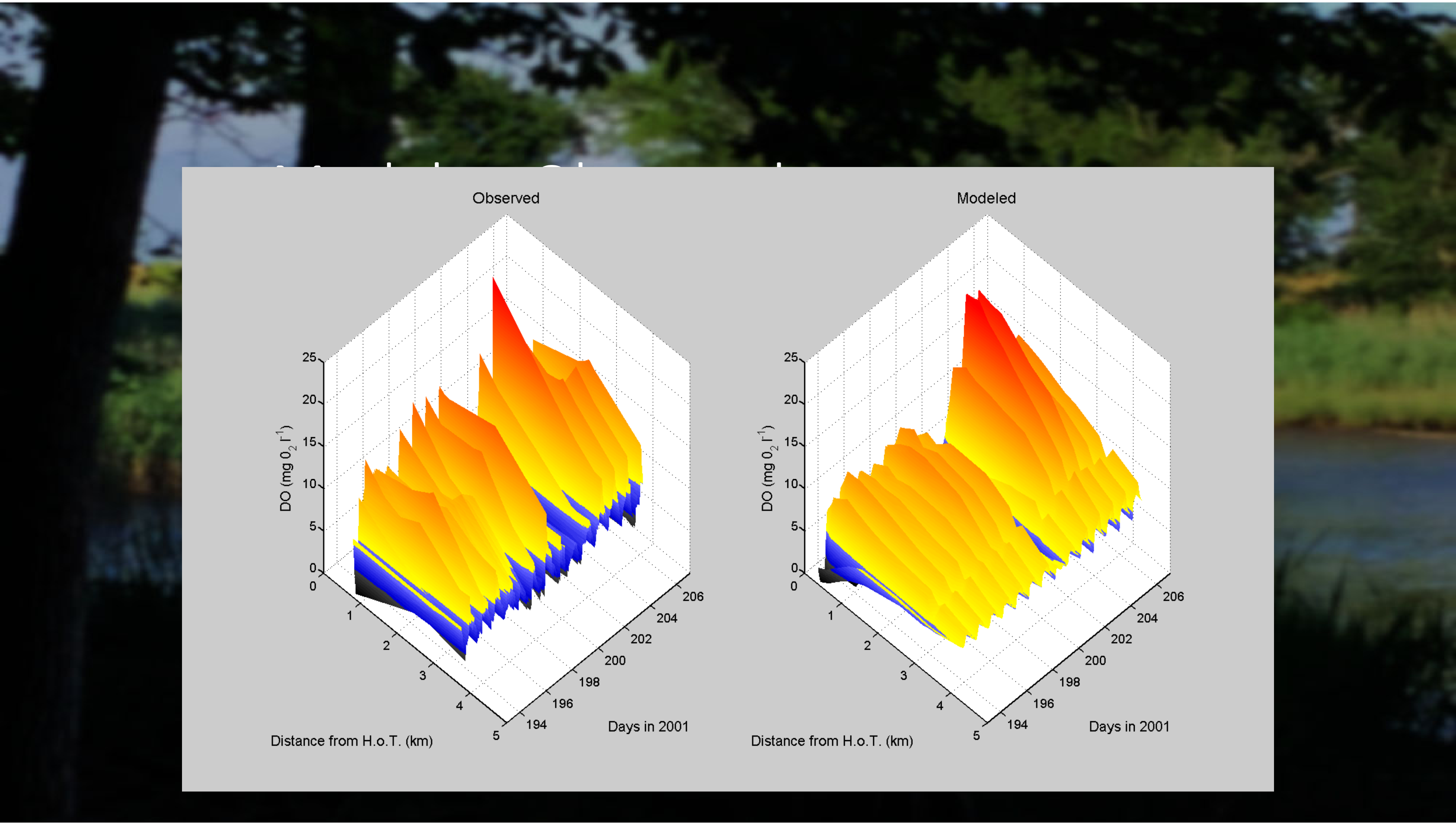
Sediment-Model Data

- Measurements of sediment to water column flux rates were obtained from two studies.
- DNREC – 2001 Delaware Coastal Bays Sediment-Water Exchange Study: For May, July, and October 2001, nutrient and oxygen flux measurements were taken at three locations – Assawoman Bay Buoy 6, Assawoman Bay Dirickson Creek, and in the Indian River.
- DNREC – 1992 Sediment-Water Interactions in Rehoboth and Indian River Bays: Seitzinger and DeKorsey (1994) In March, August, and November

Error Metrics

Table 12-7 Summary of year 2000 relative errors for 3-D receiving waterbodies

Constituent	Indian River Region	Indian River Bay Region	Little Assawoman Bay	Rehoboth Bay Region	Average
Temperature C	1.9	1.4	2.2	0.8	2
Salinity ppt	0.6	8.9	4.4	3.2	4
NH3 mg/l	64	60.3	183.5	18.2	82
NO3 mg/l	50.3	28.6	15.2	46.7	35
Phyt mcg/l	55.5	19.5	32.4		36
DO mg/l	91.7	18.5	5.1	8.3	31
CBOD_D mg/l	20.2	6.9	36.5	4.2	17
CBOD_P mg/l					
ON_D					
ON_P					
OP_D					
OP_P					
Entrococcus MF # of Col/100 ml	88.9	52.9	73.5	470	171
PO4 mg/l	12.8	7.8	30.3	19.5	18
Total N mg/l	49.6	38.8	55.3	2.2	36
Total P mg/l					



Observed
Modeled
DO (mg 0_2 l^{-1})
25
20
15
10
5
0
Distance from H.o.T. (km)
0
1
2
3
4
5
Days in 2001
194
196
198
200
202
204
206

Recommendations

- In this shallow estuary, benthic pelagic coupling between the water column and sediments is potentially a large source of oxygen demand. The current model uses relationships between proxies and fluxes measured from 1992-1993. More recent flux measurements and explicit incorporation of benthic algae will almost certainly be necessary to complete nutrient budgets
- RATES: Primary Productivity and Respiration
- Transport through Indian River Inlet and the Horizontal Diffusion
- Increased spatial resolution particularly in tidal headwaters where recent fish tagging evidence has highlighted potential fish exposure mechanisms reliant on spatial gradients in DO…unstructured grid?
- Incorporation of multiple meteorological records that were unavailable or offline during the calibration years (1998-2000) made available by the Delaware Environmental Observing System
- Evaluation of sampling protocols for mobile dinoflagellate species that may require vertical profiles to accurately characterize vertically integrated water column production and respiration
- Re-assessment of nutrient loading to include potential groundwater discharge being explored by many DIB researchers since 2000

Many Thanks to the Center for the Inland Bays

Groundwater Loading?

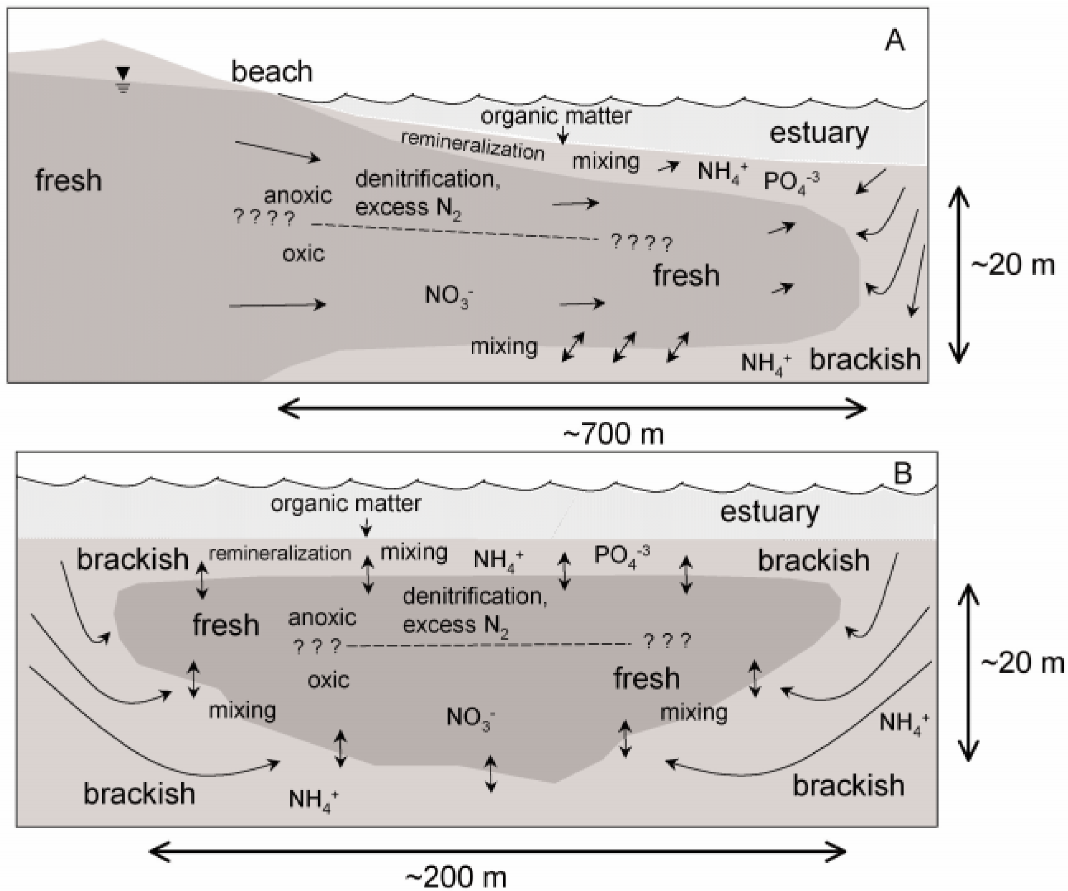


Figure 4. Schematic cross sections (a) perpendicular to and (b) parallel to the shore of a typical subestuarine plume of fresh water such as the one studied at Holts Landing in Indian River Bay.