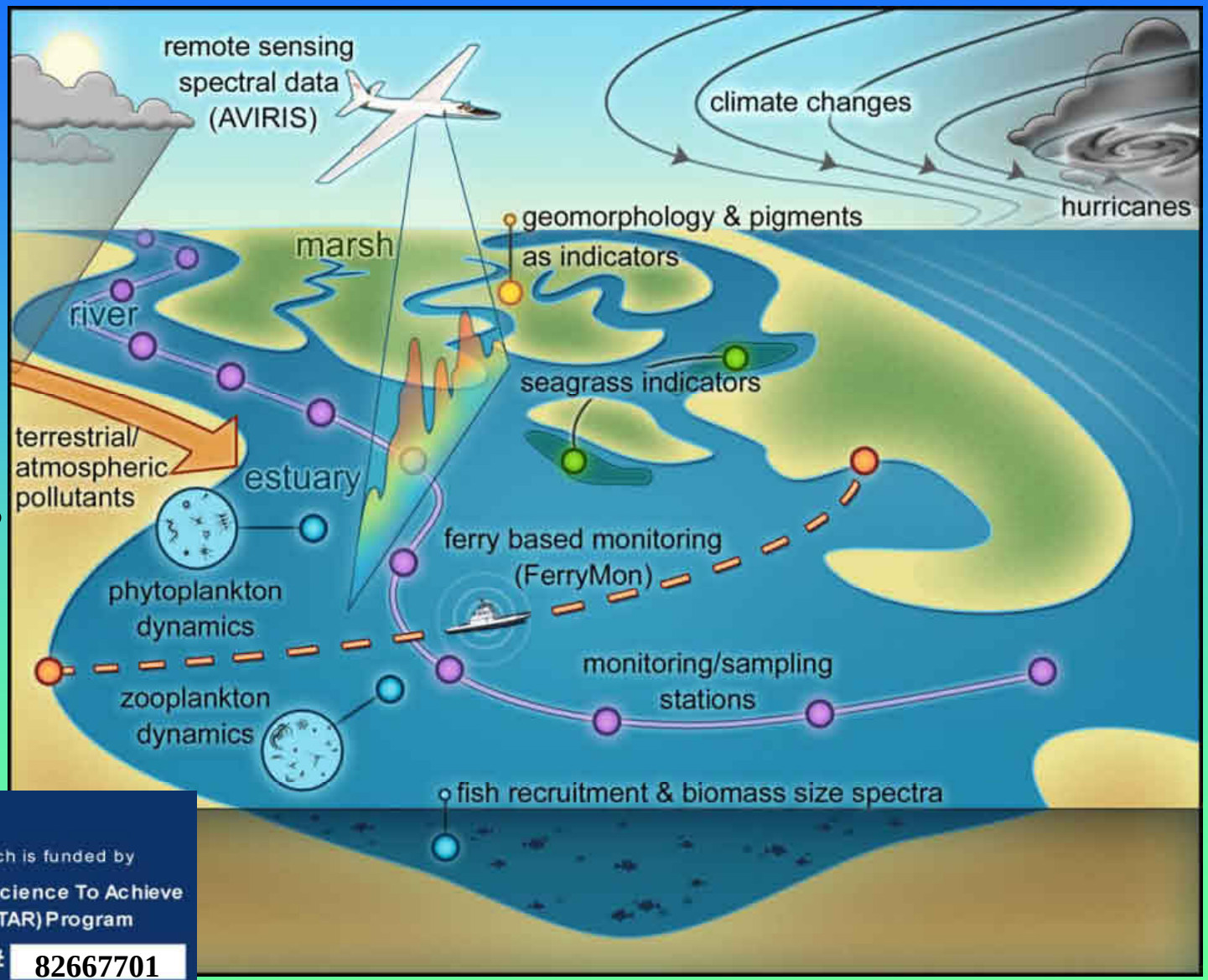
Atlantic Coast Environmental Indicators Consortium: Developing Indicators to Assess Human and Climatically- Induced change in Coastal Ecosystems

www.aceinc.org



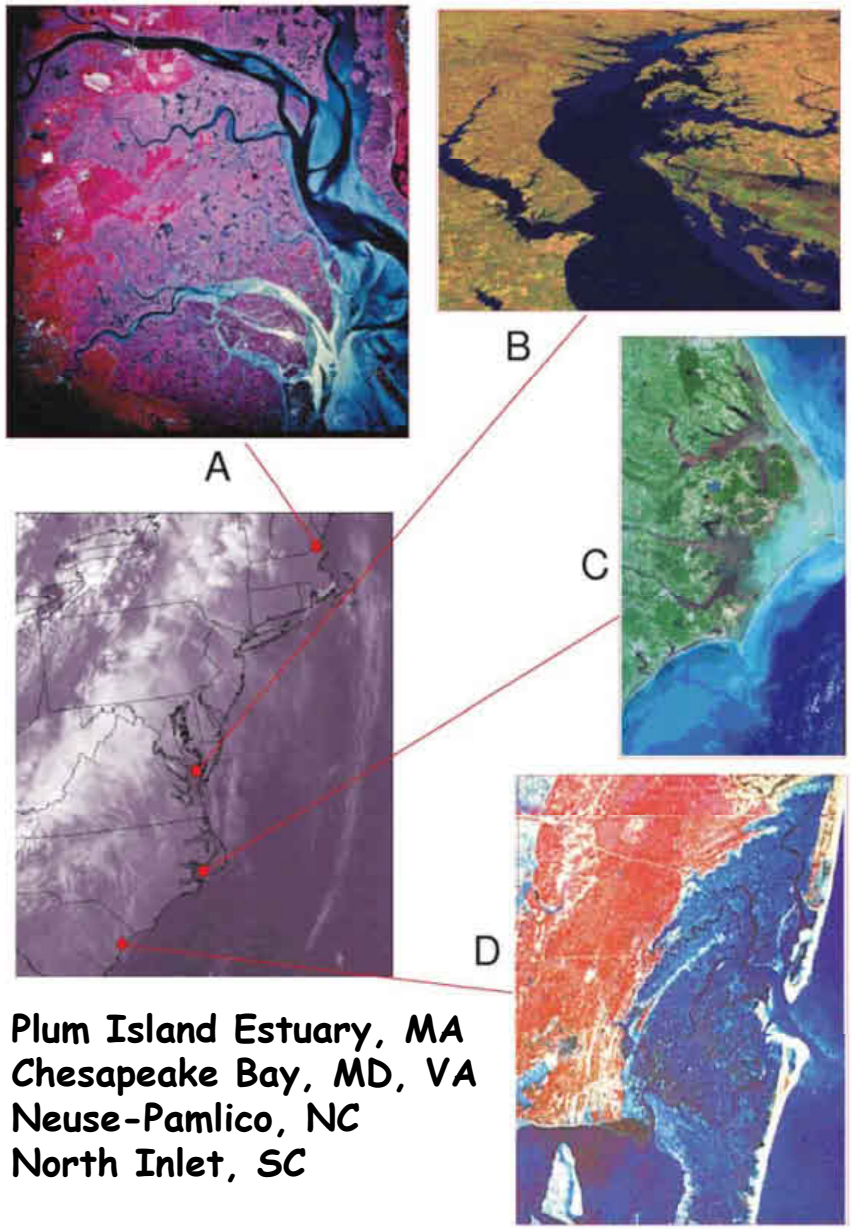
This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # 82667701

Regional and National Coastal Indicator Needs: Addressing Structure and Function

Objectives

- Detect, quantify and predict ecosystem change for a range of estuaries varying in trophic state and water residence time
- Clarify processes underlying change
- Evaluate human vs. natural impacts on WQ and habitat conditions
- Complement environmental monitoring and assessment tools
  - Plant/productivity-based indicators
  - Trophodynamic indicators
  - Geomorphometric & Physical indicators
  - Remote sensing
- Be available and useful to WQ/habitat management agencies

ACE INC's Estuarine/Coastal Ecosystems



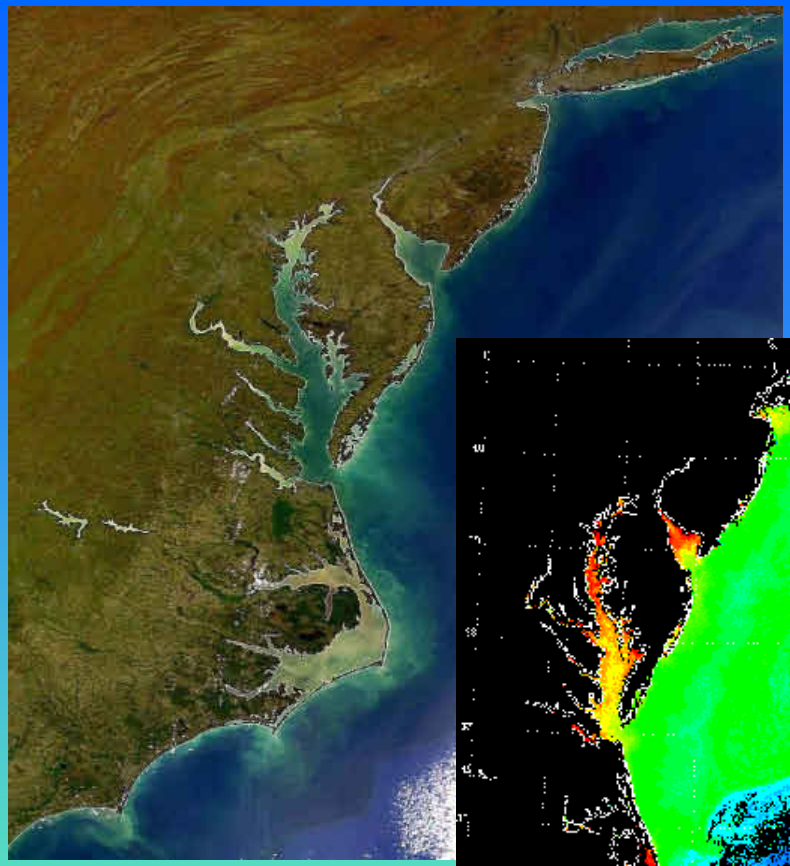
They represent a wide range in trophic state, productivity base and hydraulic residence time

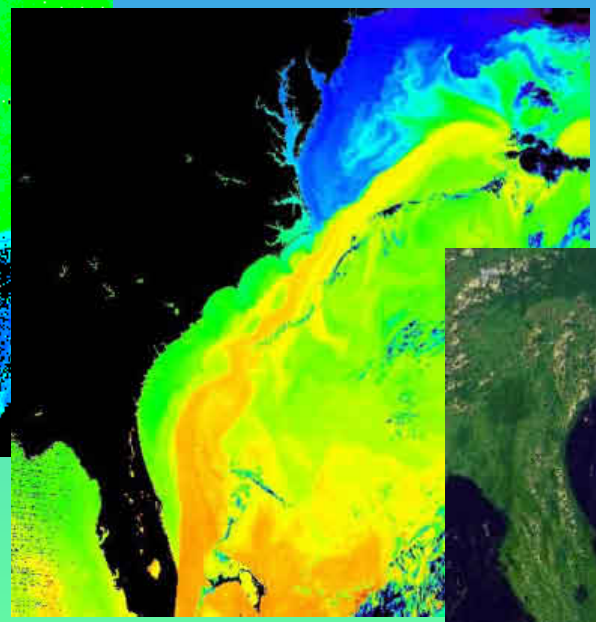
A. Plum Island Estuary, MA
B. Chesapeake Bay, MD, VA
C. Neuse-Pamlico, NC
D. North Inlet, SC

ACE INC Indicators

Planktonic Component	Wetland Component	Seagrass Component
Temperature, hydrodynamics, circulation	Landscape-scale pattern	Seagrass primary production
Photosyntheticaly Active Radiation (PAR)	Geomorphometry	FV/FM ratio (photosynthetic efficiency)
Dissolved oxygen, physical-chemical-biological coupling	Sediment elevation/relation to MSL	Plant morphology
Inorganic nutrients (nitrate, ammonium, phosphate, silicate), DIC	Sediment organic matter	Physico-chemical indicators of macrophyte stress
Organic nutrients (DOC & DON, particulate C, H, N)	Sediment N/P content	Algal distribution (chlorophyll a and species composition)
Microbial pathogens	Marsh Sedimentation/Metabolism	Water surface temperature
Phytoplankton composition via diagnostic pigments (HPLC)	Above ground net primary production	Water clarity
Phytoplankton cell counts and biomass (microscopic)	Plant photopigments	Water column biomass and primary productivity
Primary productivity (^{14}C and O_2)	Remote sensing/ SeaWiFS & LIDAR	Spectral impacts of suspended materials
Remotely sensed Chl data/linked to models of primary productivity		Water color
In-water bio-optical properties		
Zooplankton and fish community biomass size spectra		

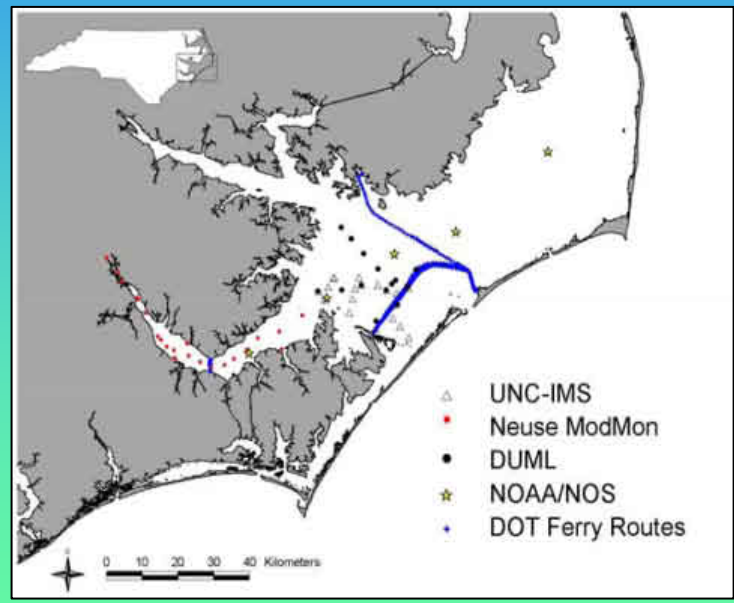
Developing Indicators to Assess Impacts of Anthropogenic & Climatic Stressors on Estuarine and Coastal Ecological Condition





Examples: Neuse River Estuary-Pamlico Sound

Excessive N loading → eutrophication → hypoxia → WQ/habitat decline



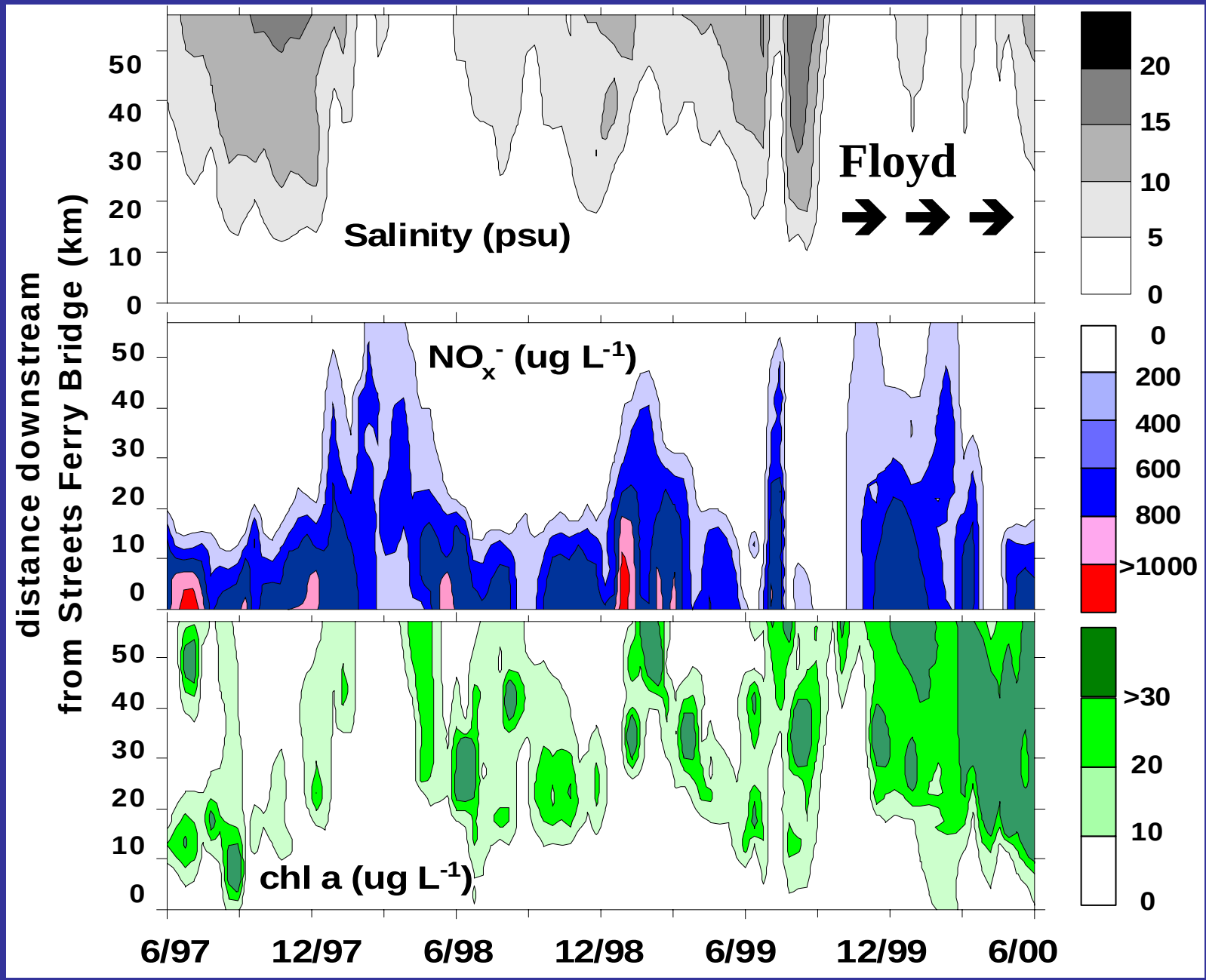
Neuse R Modeling & Monitoring Program (ModMon)

www.marine.unc.edu/neuse/modmon

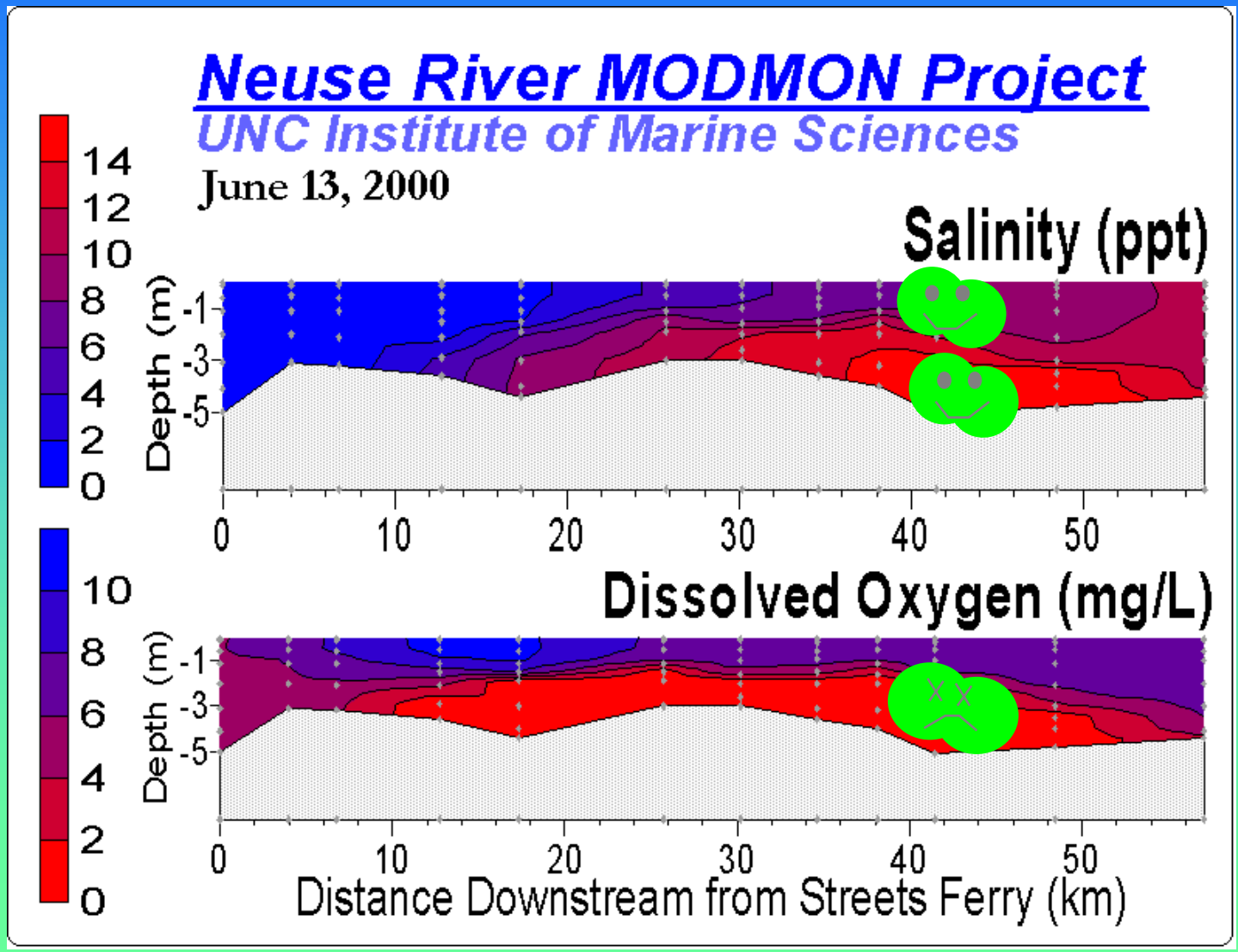
Partners: UNC, ECU, Duke, NCSU, USGS, NCDENR, EPA,

Collaborators: NOAA-NOS, NASA, NADP, Weyerhaeuser

N loading and algal production (Chl a) in the Neuse R. Estuary

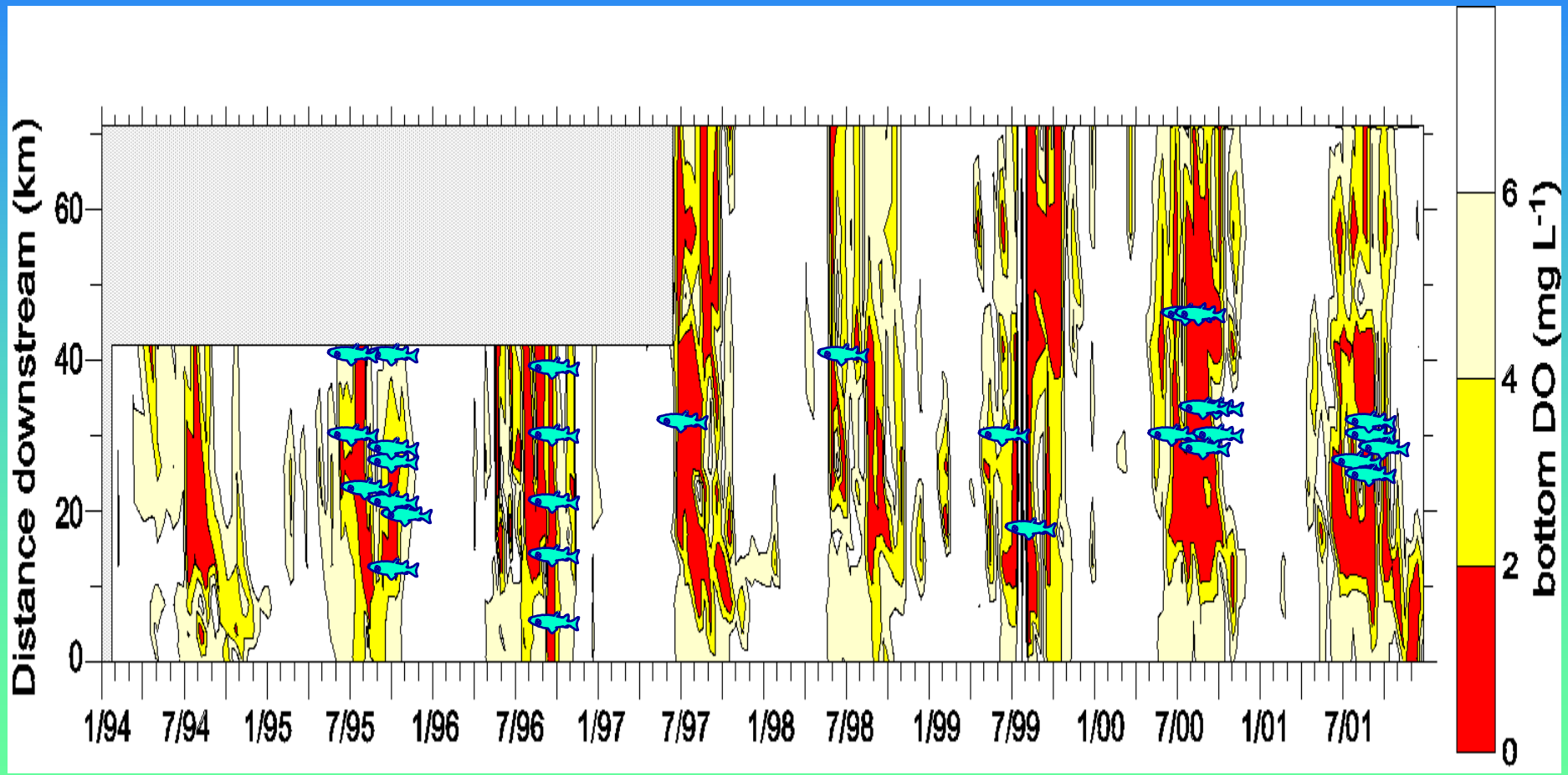


The connection to Hypoxia



Hypoxia and Fish kills in the Neuse River Estuary 1994-2001

Data Sources: ModMon Project & NC DENR-DWQ



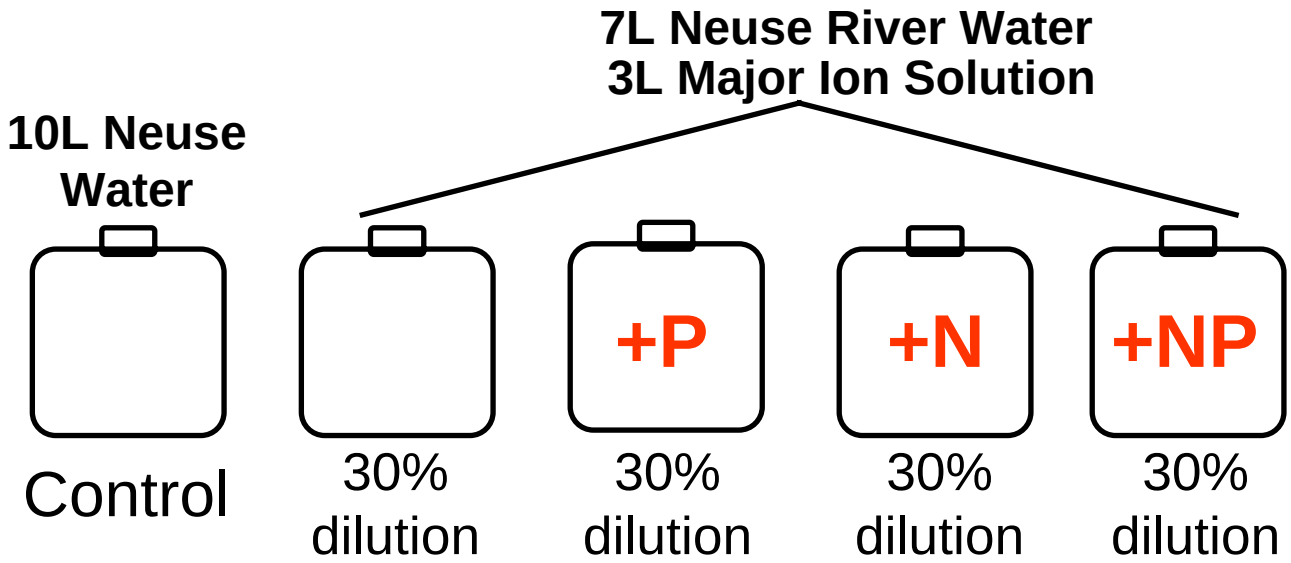
Fish kill data base: http://www.esb.enr.state.nc.us:80/Fishkill/fishkillmain.htm

Need: Reduce Estuarine Primary Production (*Chl a*) by Establishing an N Input Threshold

Scientific Consensus/Recommendation:
30% N Input Reduction (based on 1990-1995 loads)

Proof: Using photopigments to assess algal growth response to N reductions (i.e. mandated 30% N input reduction = TMDL)

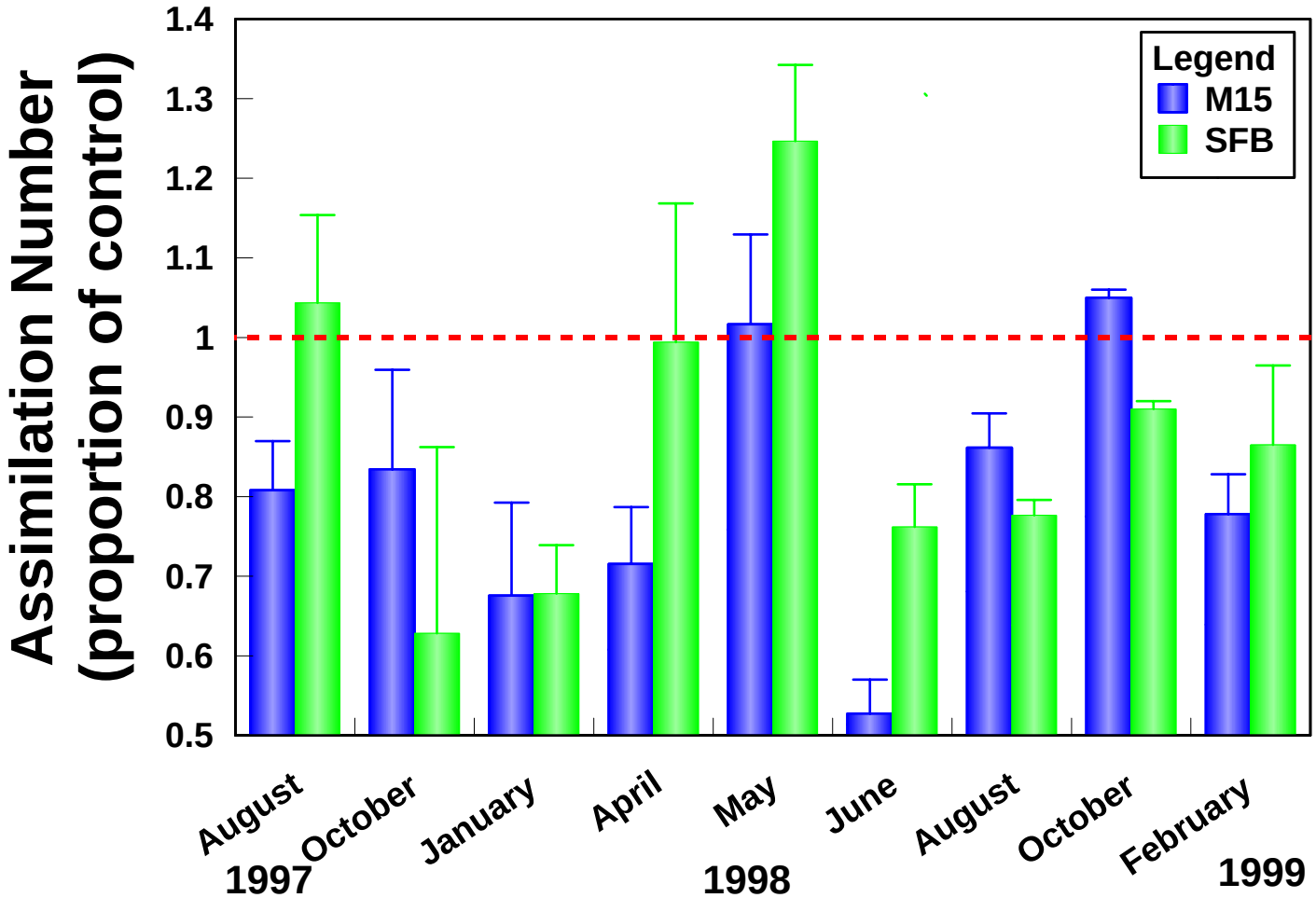
Asking the Phytoplankton: Dilution Bioassays



Response Indicators:

Chl *a*, primary productivity

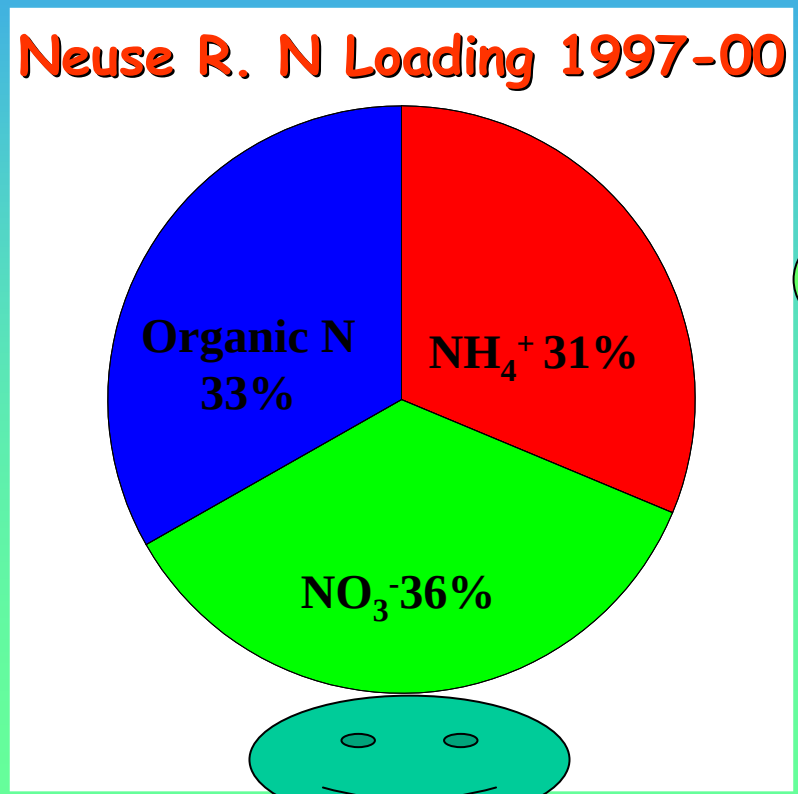
Seasonal Effect of 30% Reduction in N Concentration
84 Hour Incubation



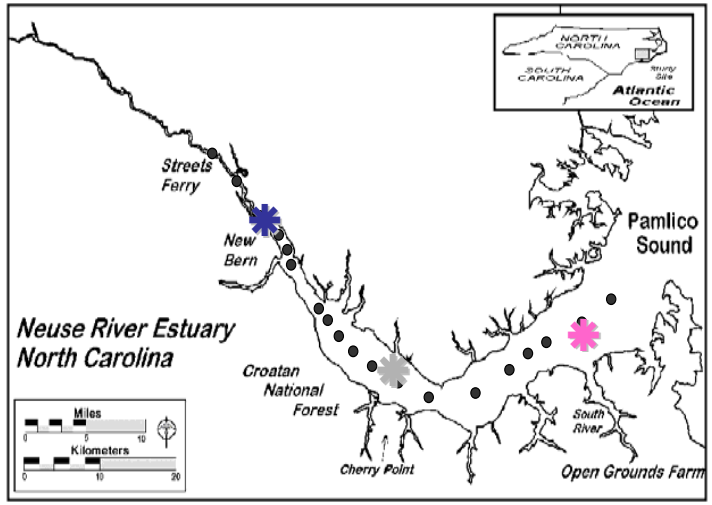
Piehler et al. 2001

However, when considering reductions…….
"New" N comes in different "flavors"

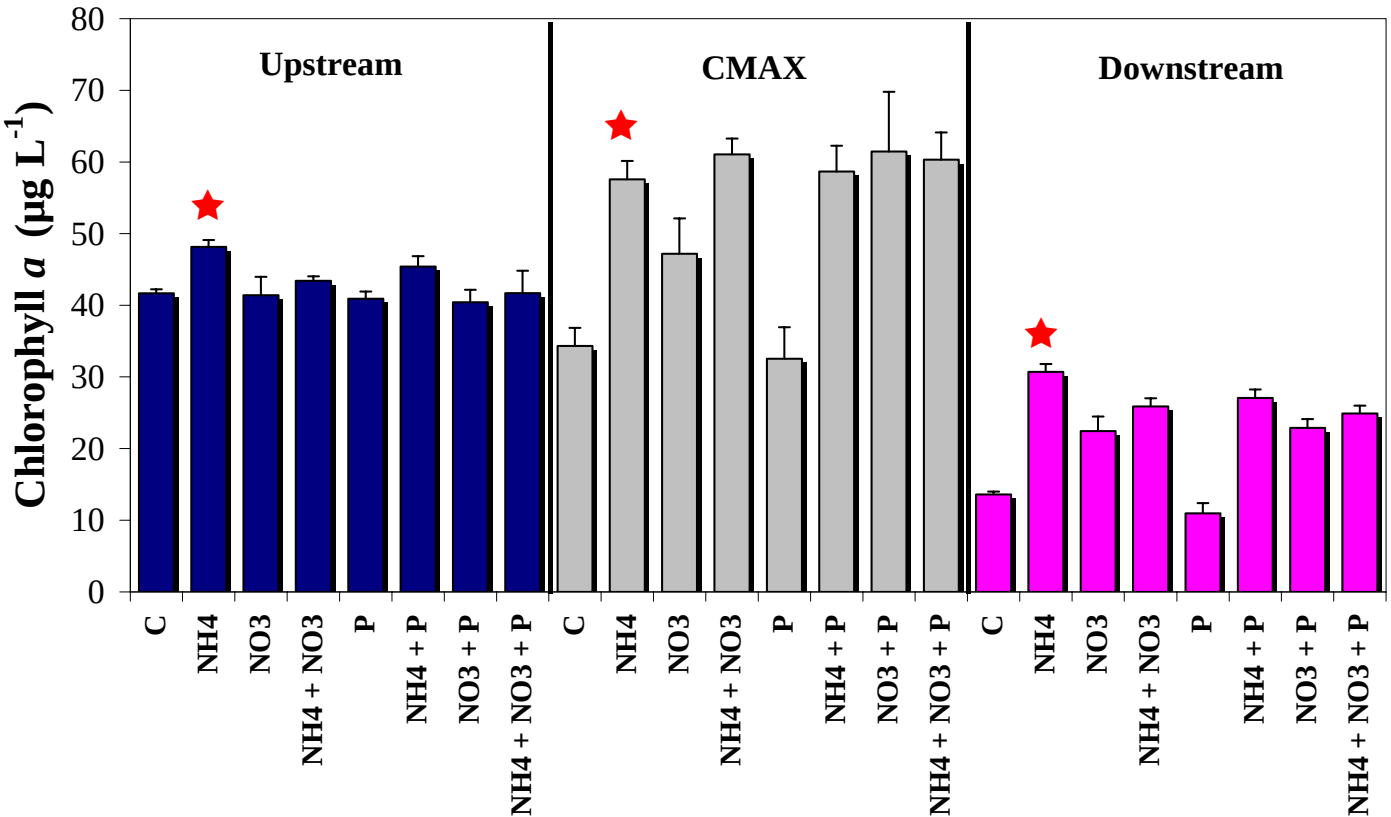
Why care?? Ecological impacts of specific forms of N enrichment?



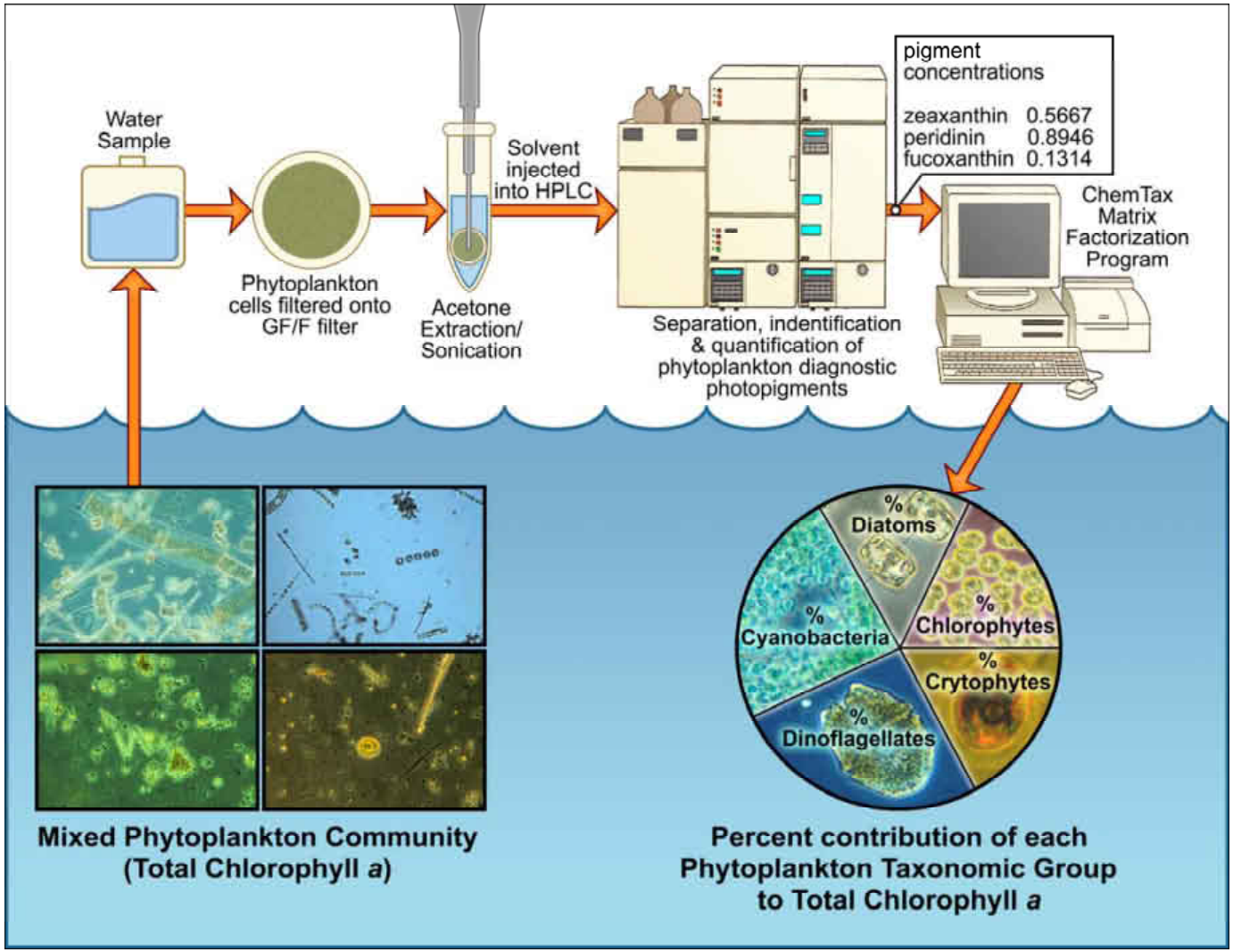
Ammonium is a Preferred N source: Effects on Phyto Community Structure



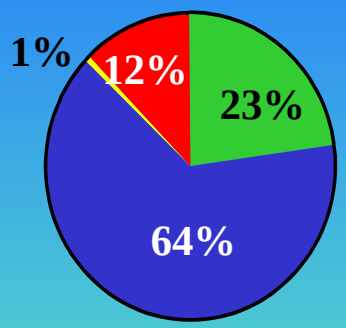
Nutrient Addition Bioassay Experiment, T1
Neuse River, July 2003



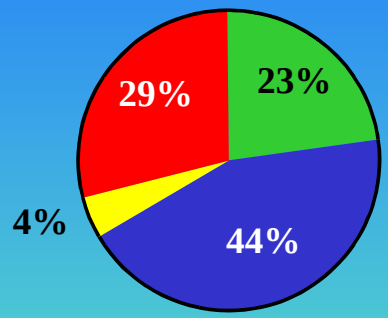
Looking into the "green box": Algal taxonomic group responses to nutrient and hydrologic perturbations by HPLC-ChemTax Analysis



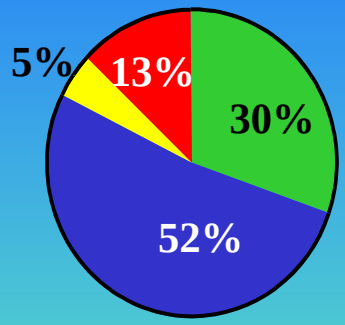
Evaluating Impacts of different N sources on Neuse Estuary phytoplankton composition



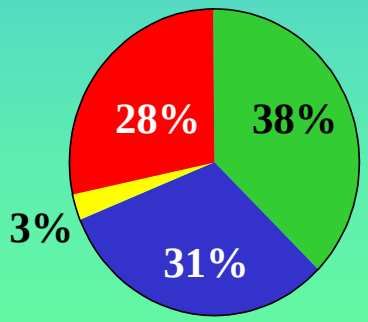
Control



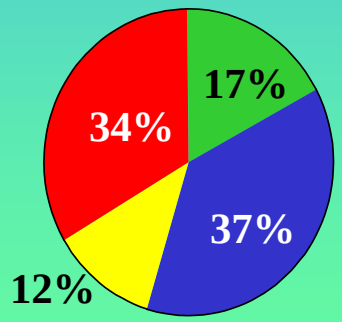
Ammonium



Nitrate



Urea



Amm/Nitr/Urea

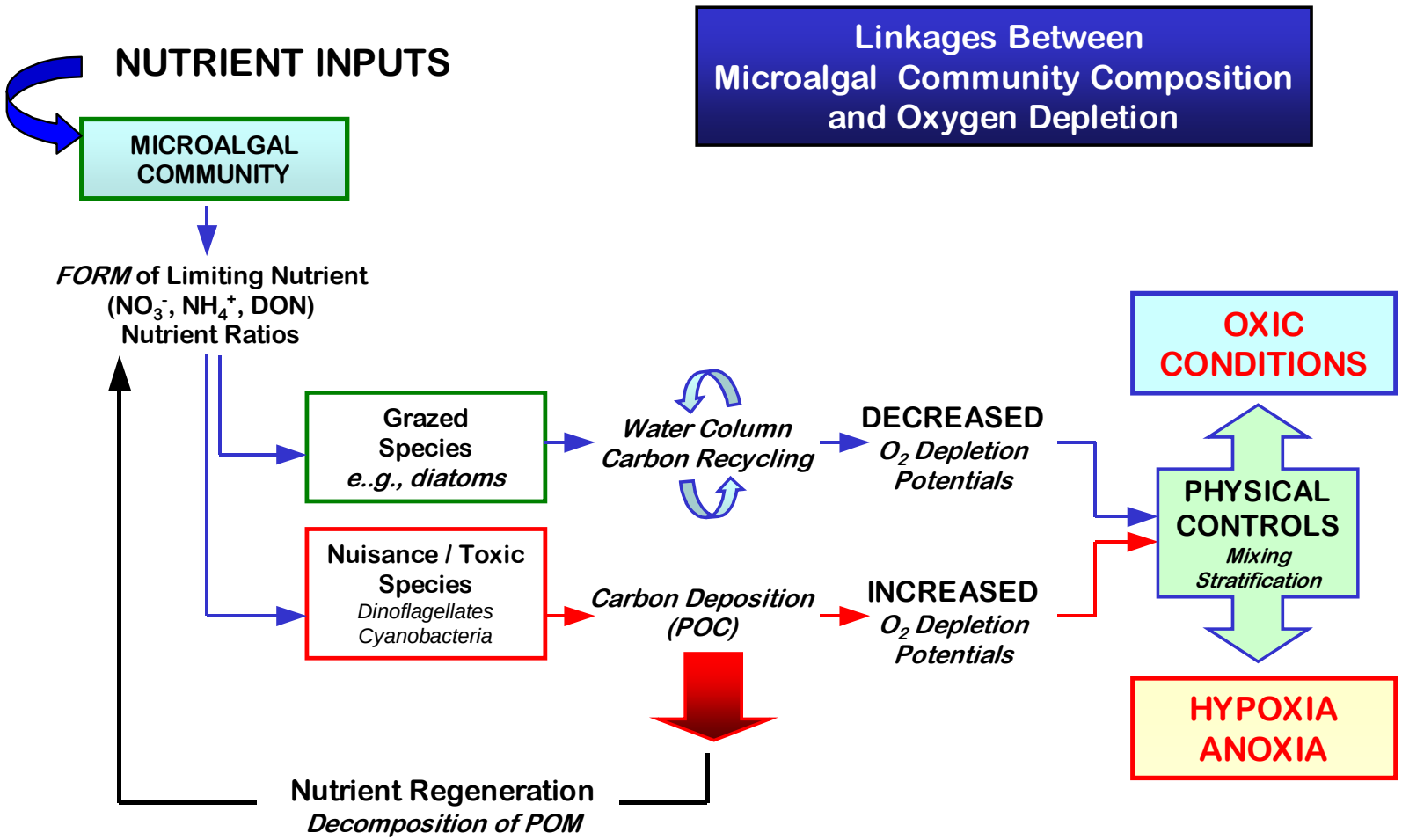
Chlorophytes

Cryptomonads

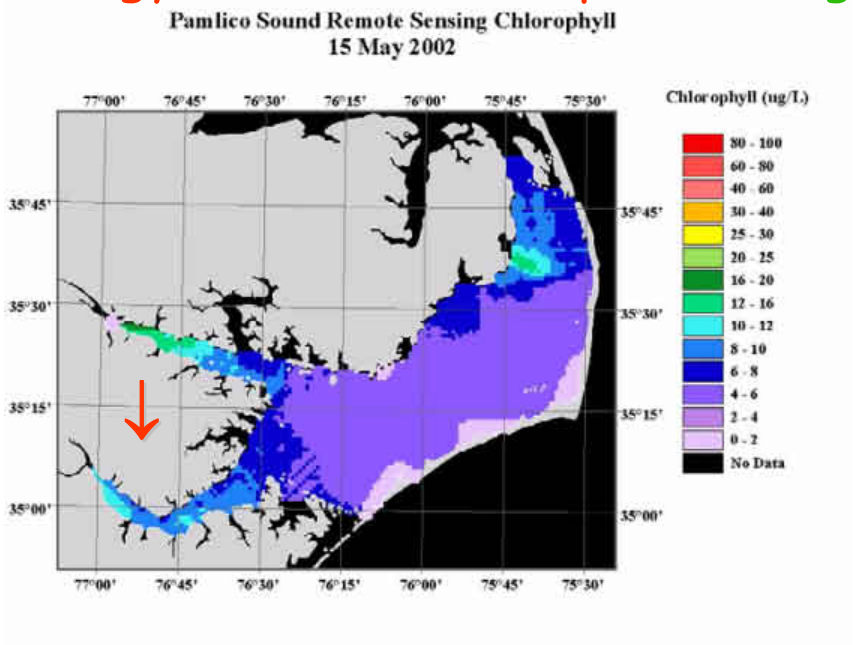
Cyanobacteria

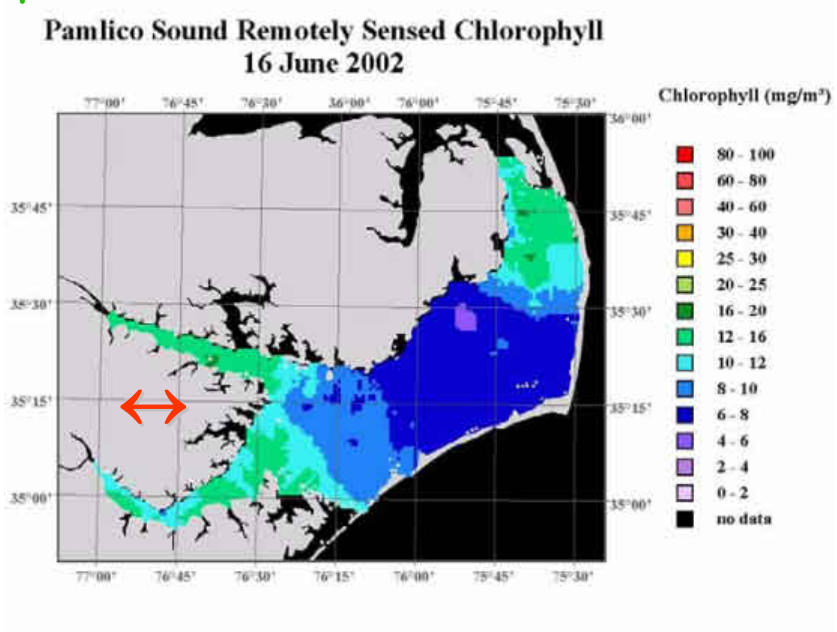
Diatoms

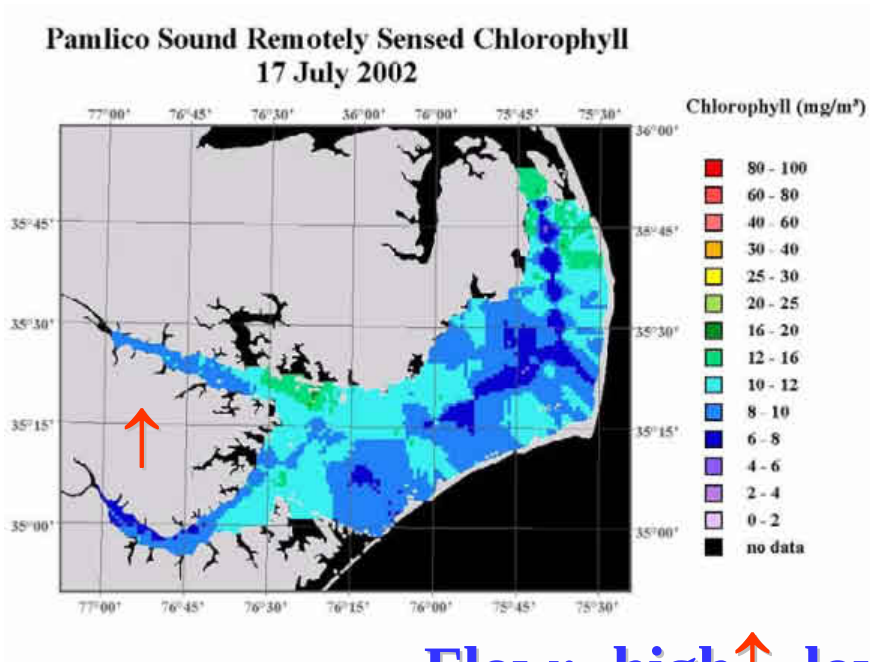
Why does this matter? Ecological Impacts of "Good" vs "Bad" Phytoplankton

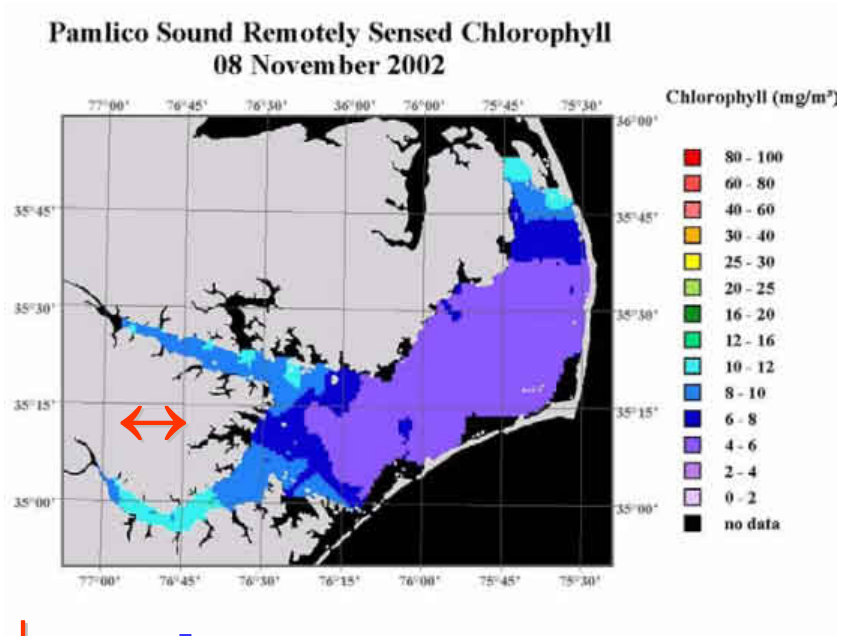


Hydrology matters too: impacts onalgal production (Chl *a*) in Pamlico Sound



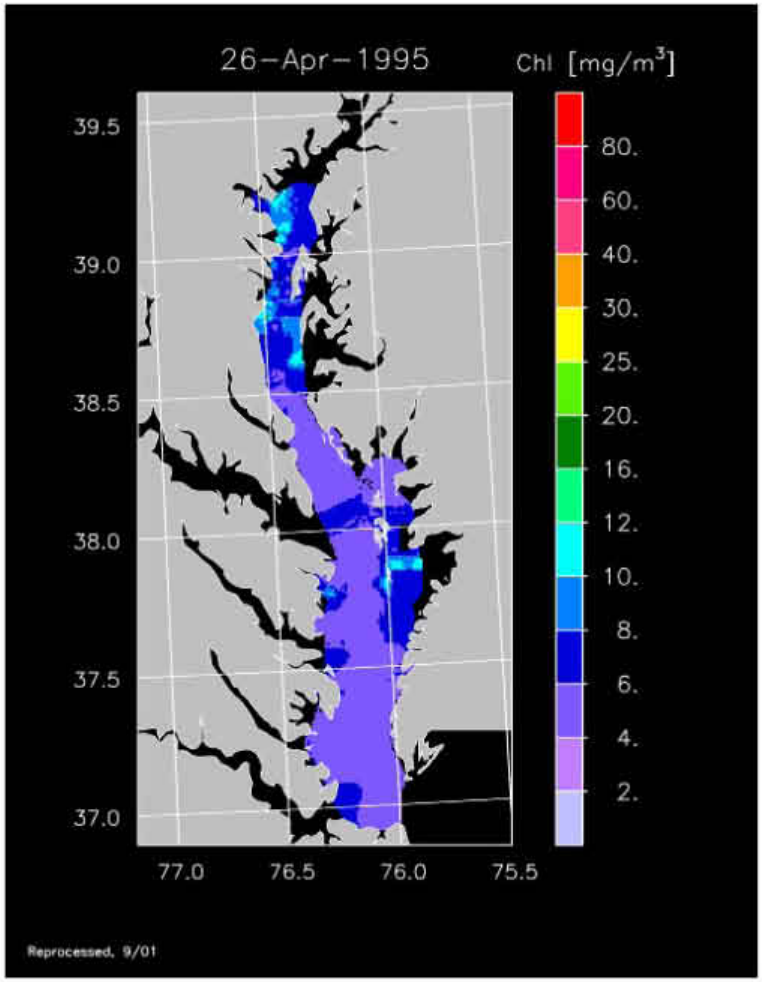




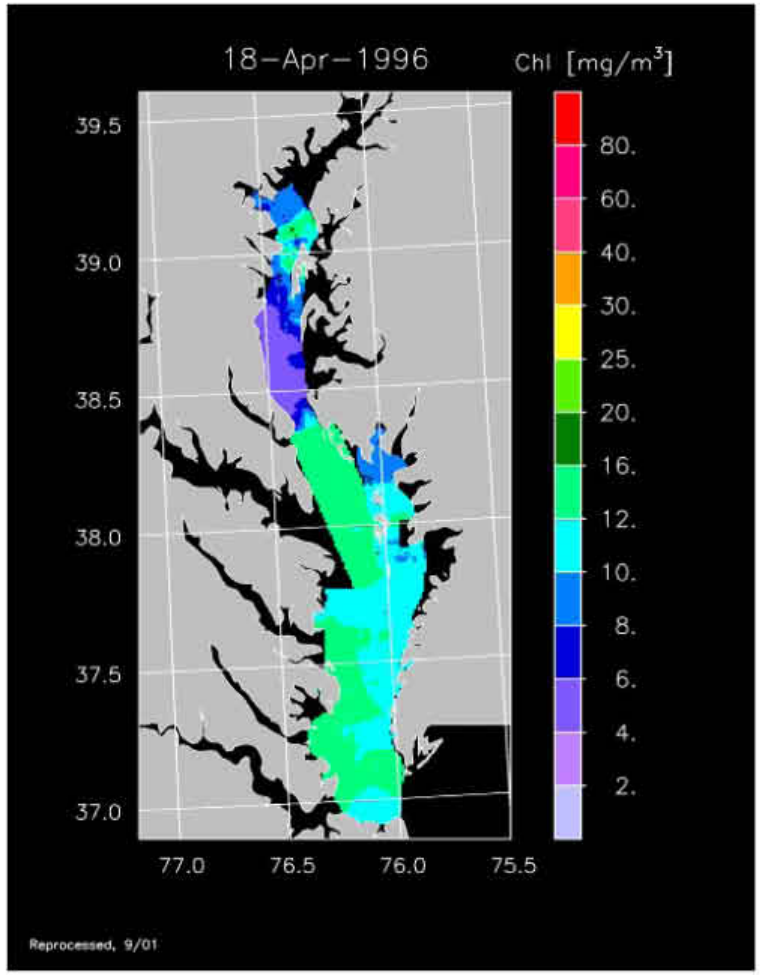


Flow: high↑, low↓, moderate↔

Chesapeake Bay: Remotely sensed chl-a from SeaWiFS Aircraft Simulator (SAS II) during low flow (’95) and high flow (’96) years

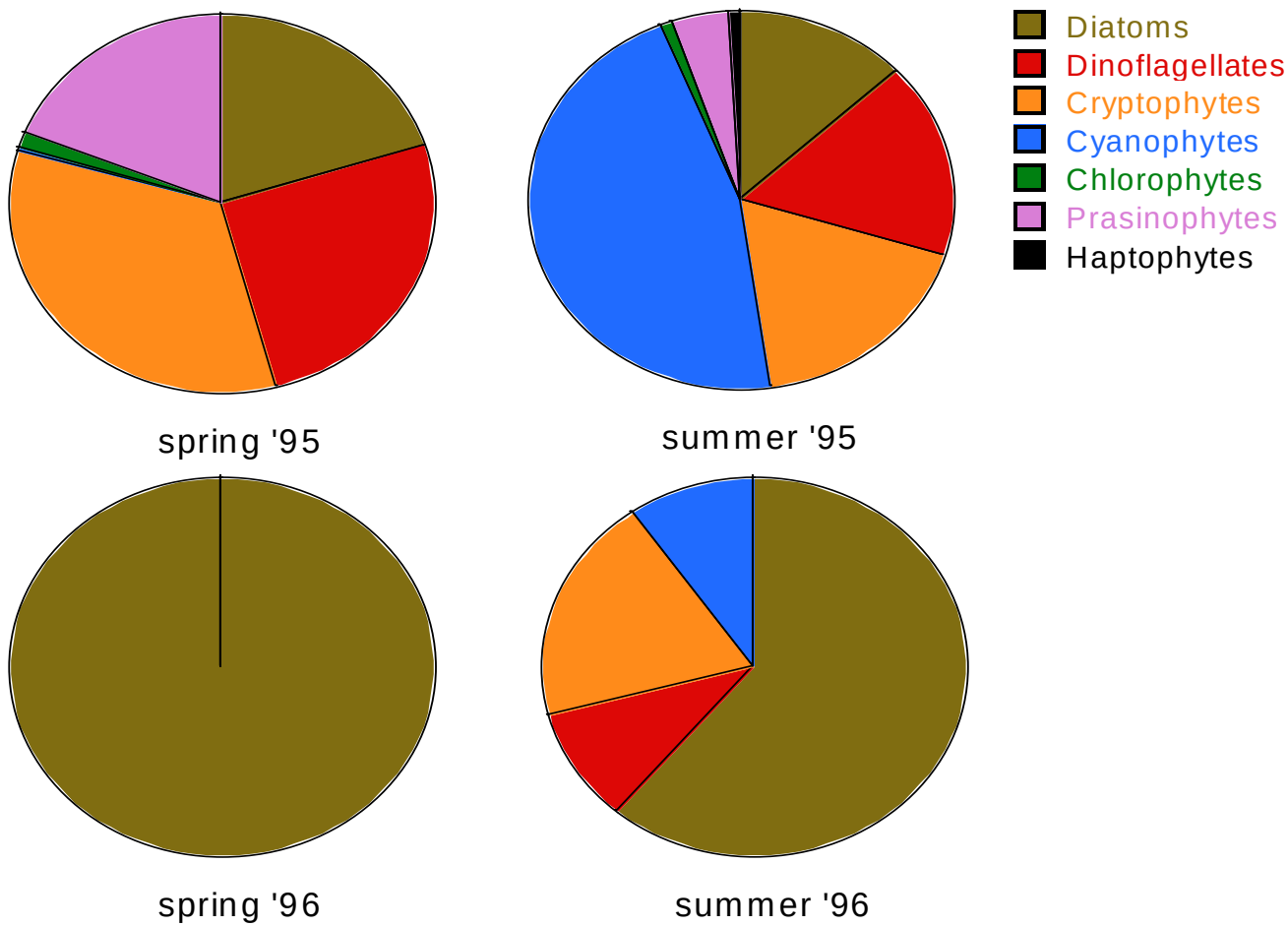


spring ‘95

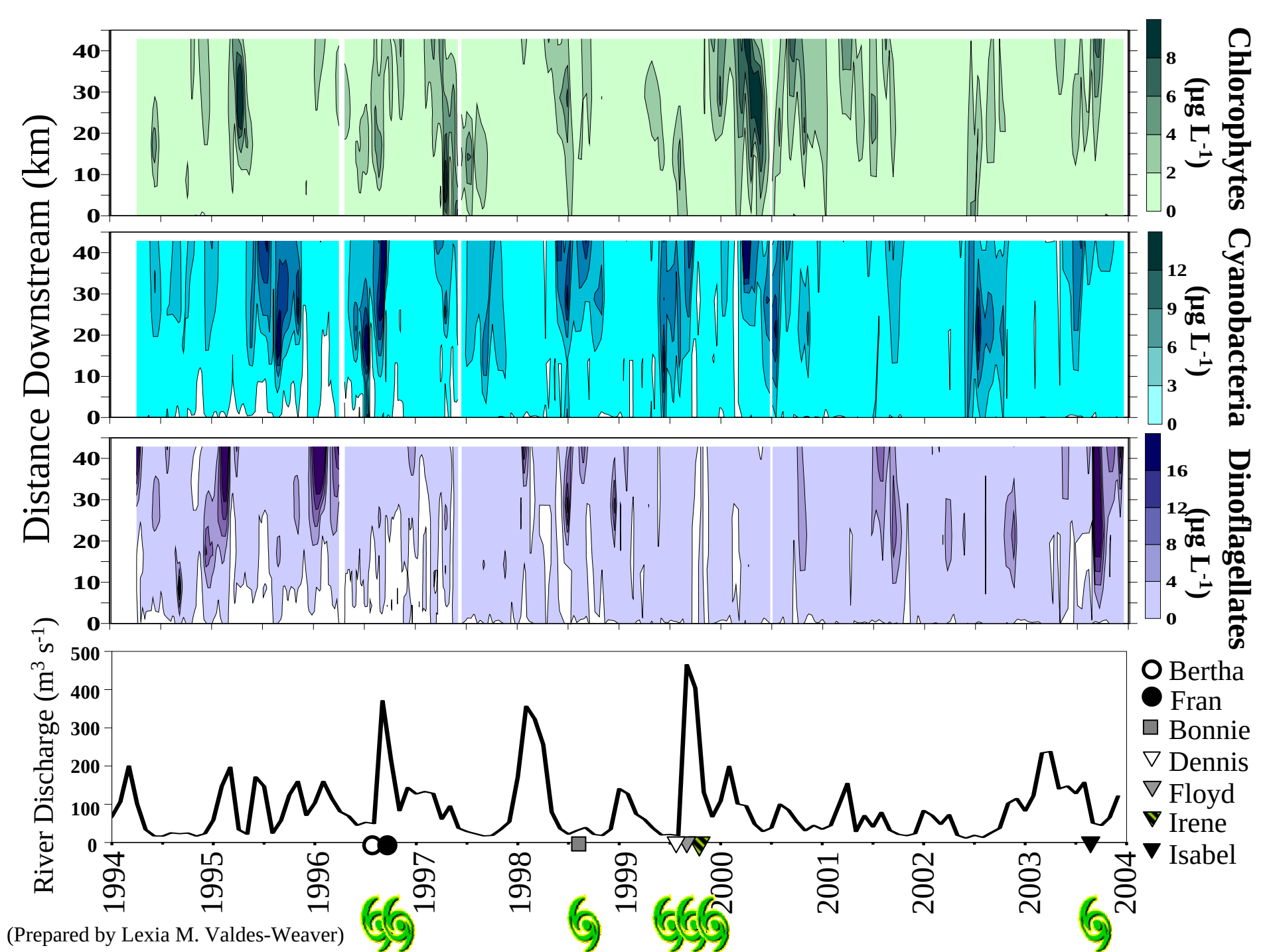


spring ‘96

Chesapeake Bay CHEMTAX – contrasting flow years



Assessing Anthropogenic and Climatic Impacts on Estuarine phytoplankton Communities: the Hurricanes of 1999



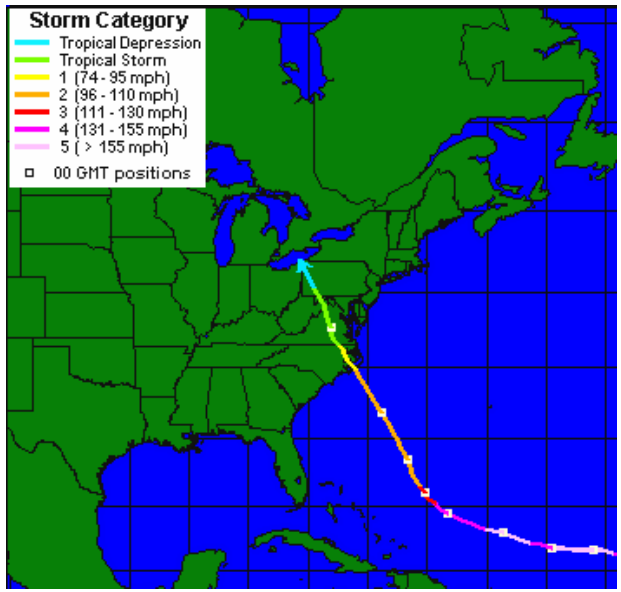
(Prepared by Lexia M. Valdes-Weaver)

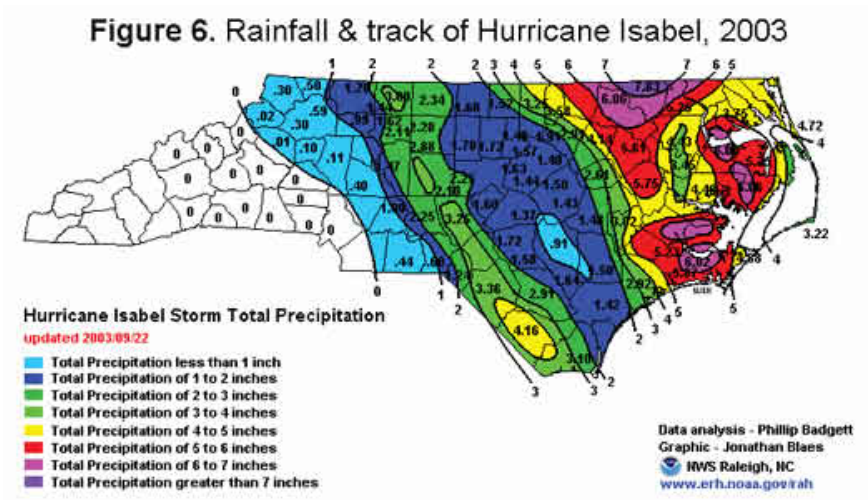
Effects of Hurricane Isabel (Sept. '03) on Phytoplankton Abundance, Composition and Spatial Distribution

"Windy, but no Floyd"

(rain-wise)

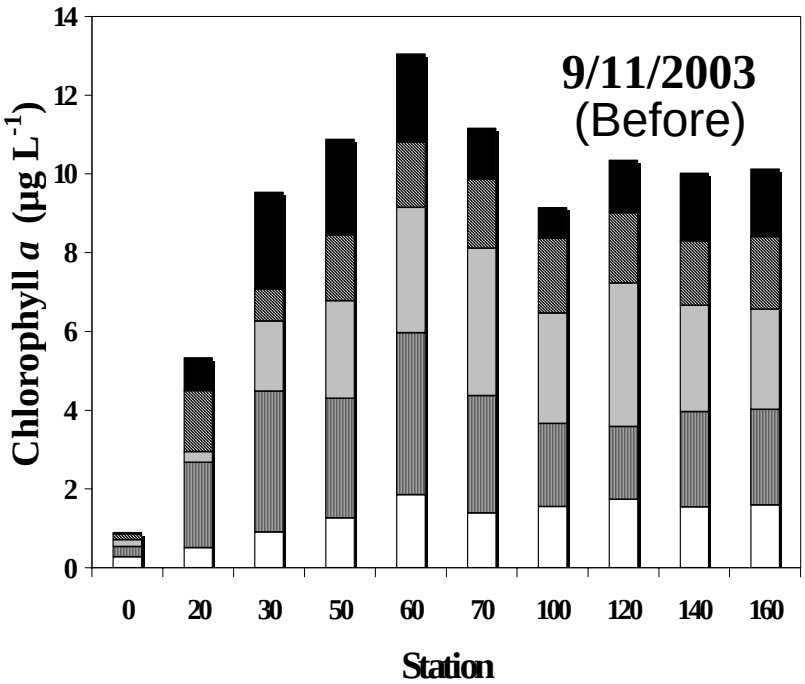
J. Ramus

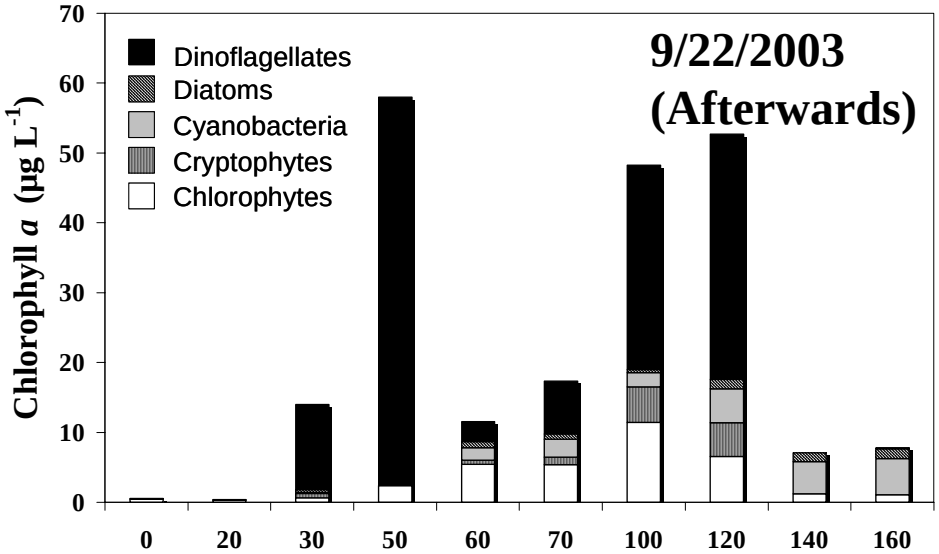


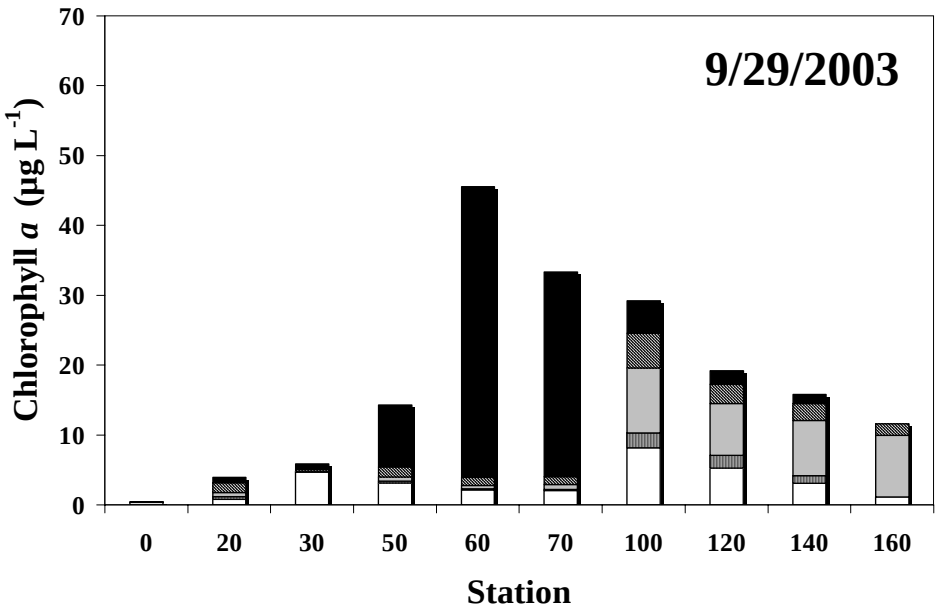


Hurricane Isabel, Sept. 18, 2003

- Low rainfall, high winds







Dinoflagellates, then cyanos ∗

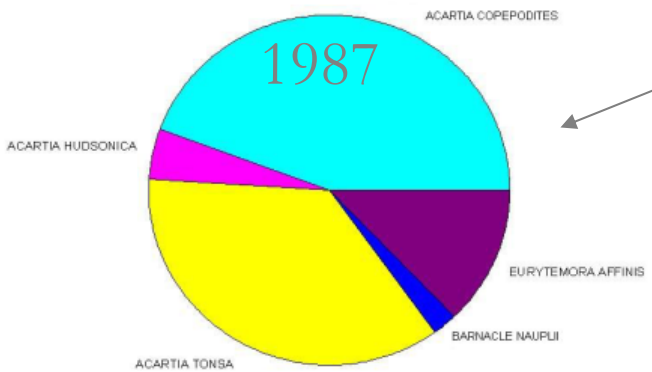
Zooplankton and Climate Forcing

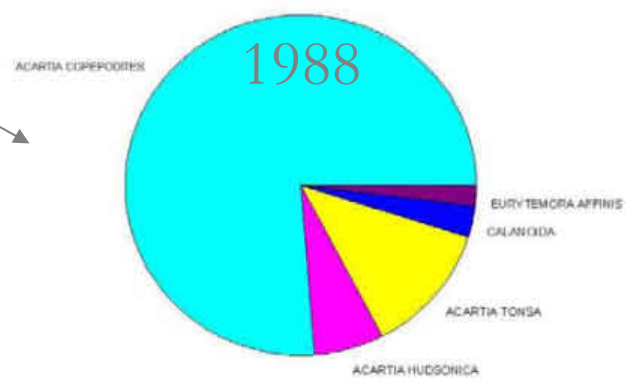
Abundances of predominant mesozooplankton species related to freshwater flow

Classification based on synoptic climatology linked to planktonic responses

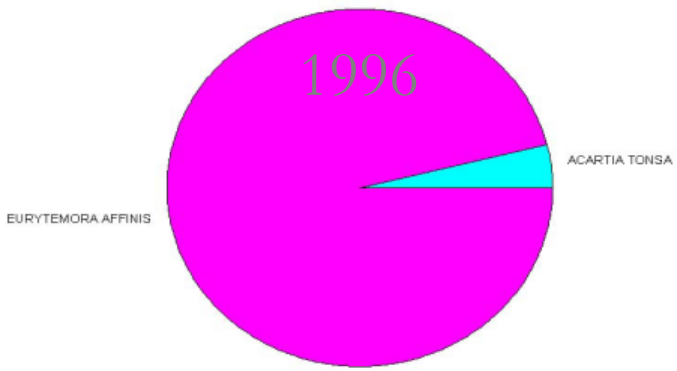
Zooplankton Community Composition at Station CB3.3C

Dry Years

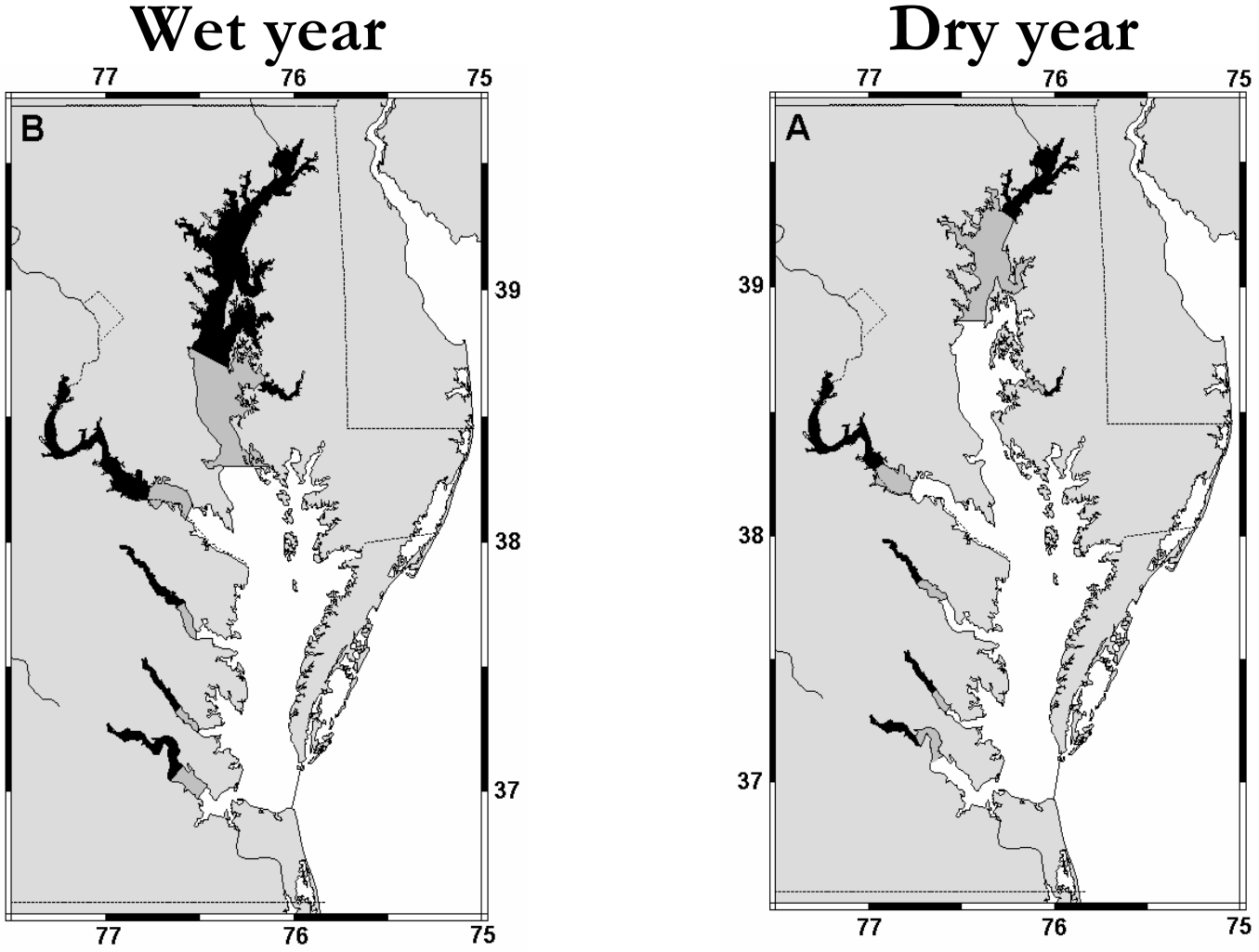




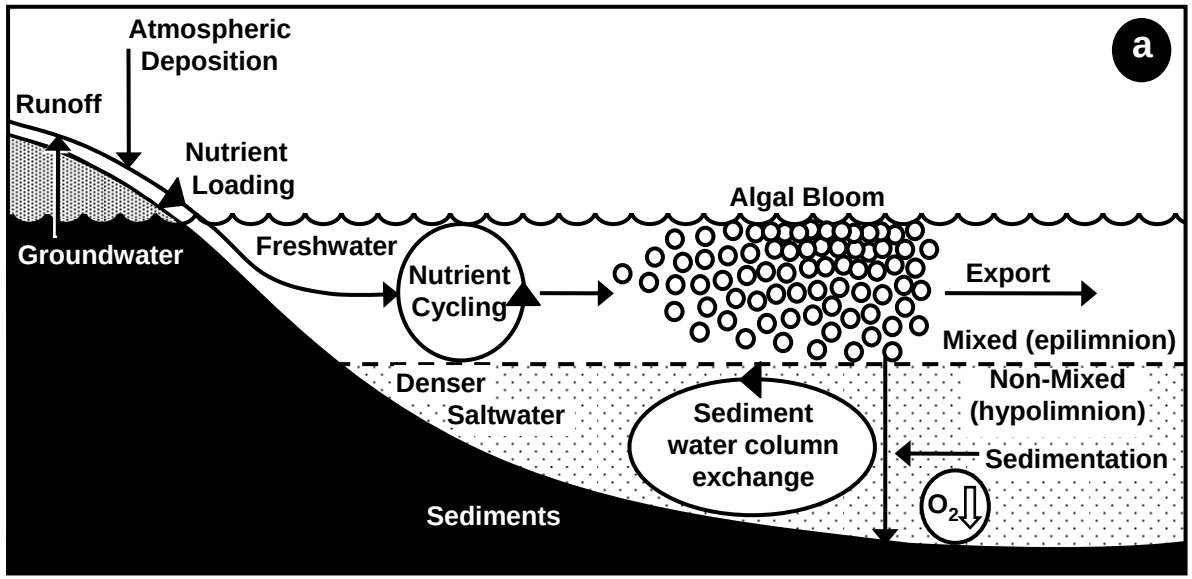
Wet Year

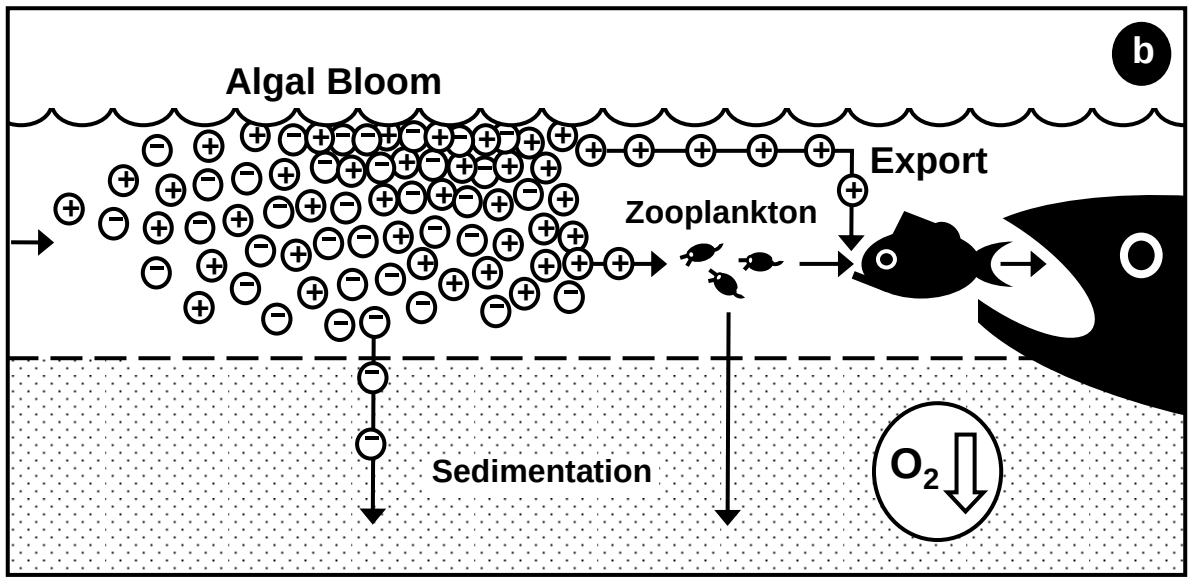


Eurytemora vs Acartia Dominance



Coupling and Aggregating Indicators





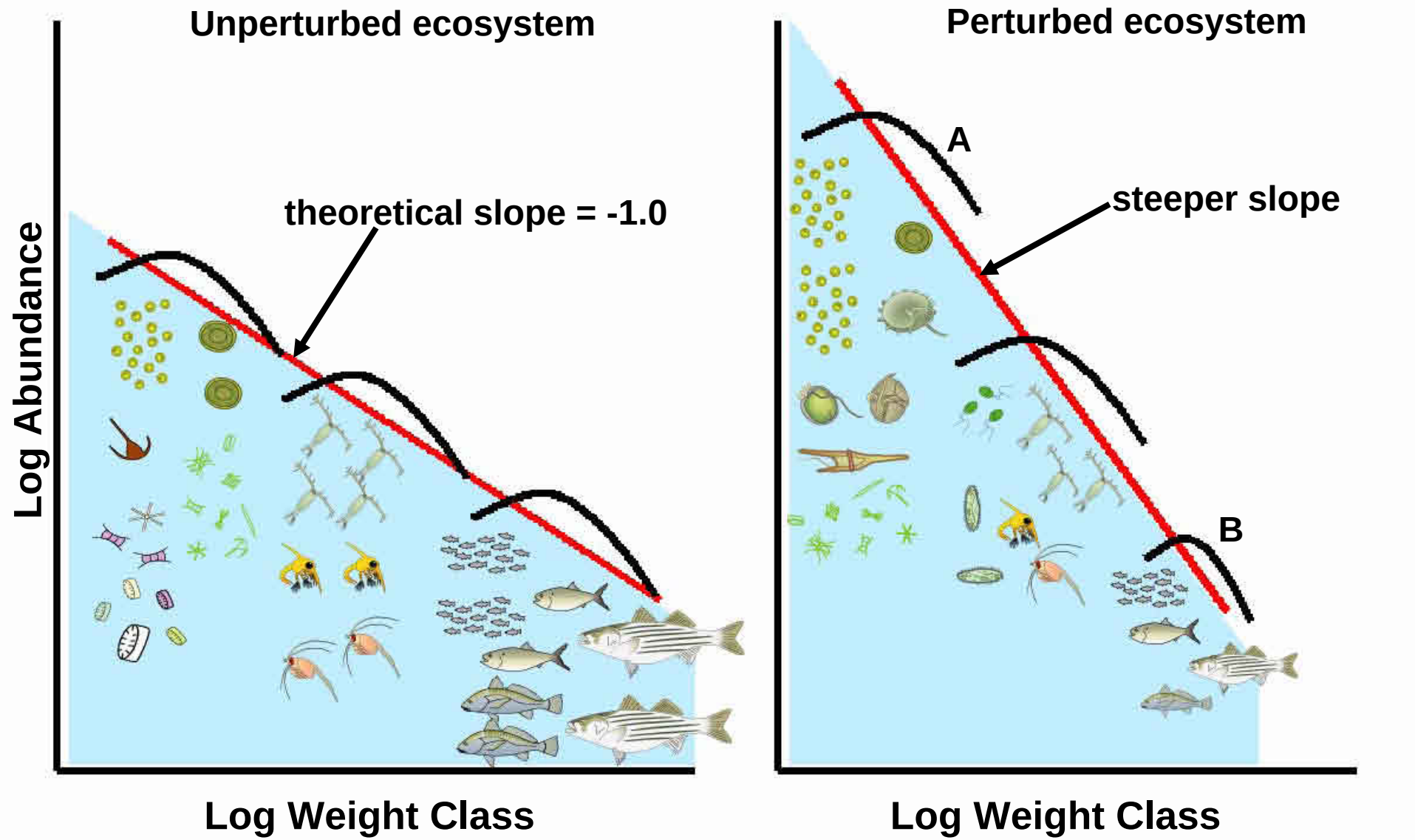
Biomass Size Spectra

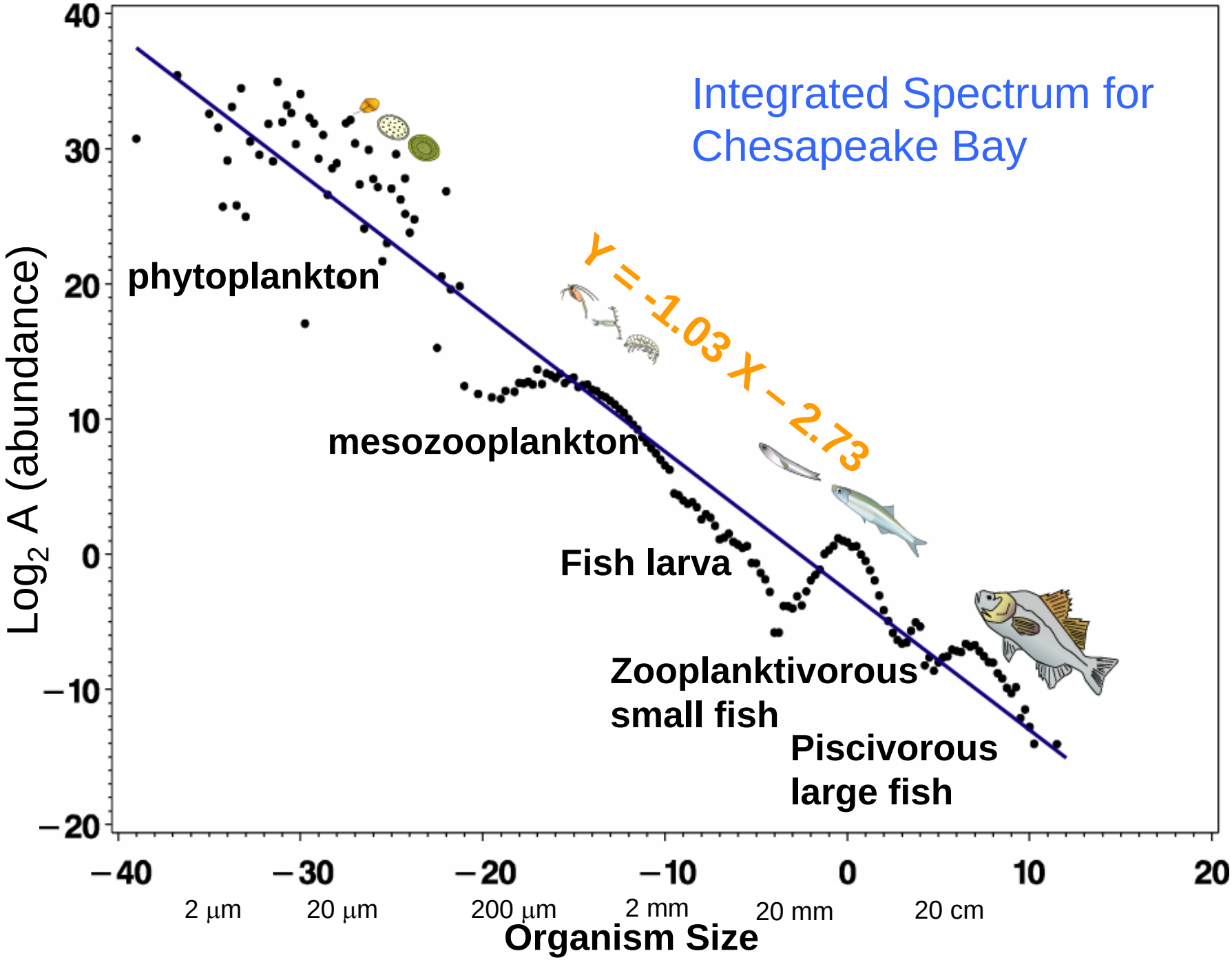
Size Spectra: Integrative Indicators Across Trophic Levels

Slopes of Spectra and Biomasses at Each Trophic Level are Indicators of Trophic State and Stress

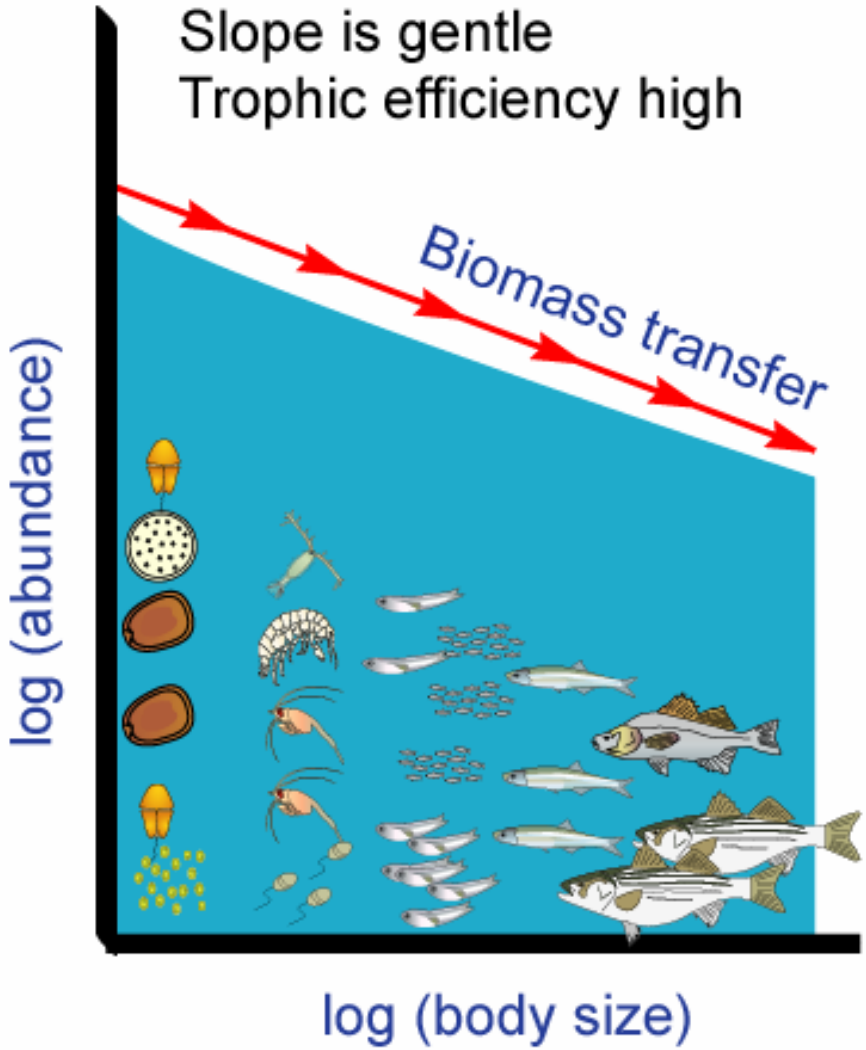
Objective: Explore Their Potential in Chesapeake Bay and Other Estuaries

Biomass Size Spectra as Indicators of Ecosystem Status

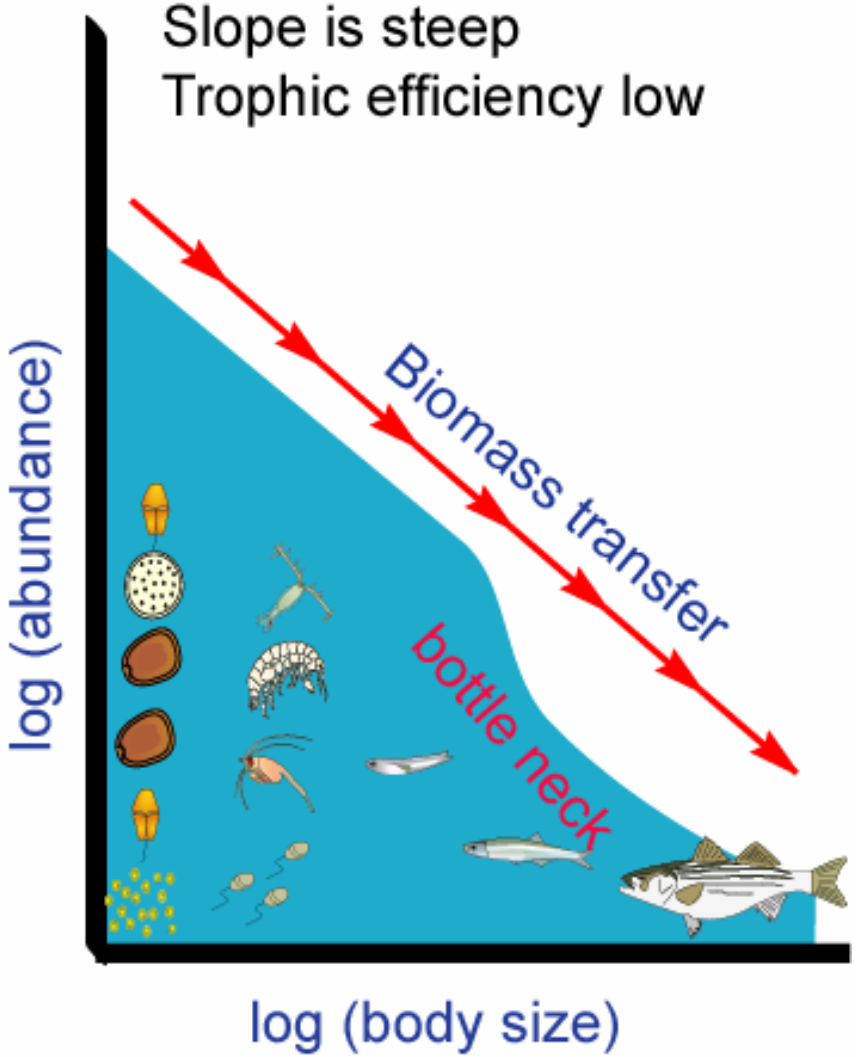


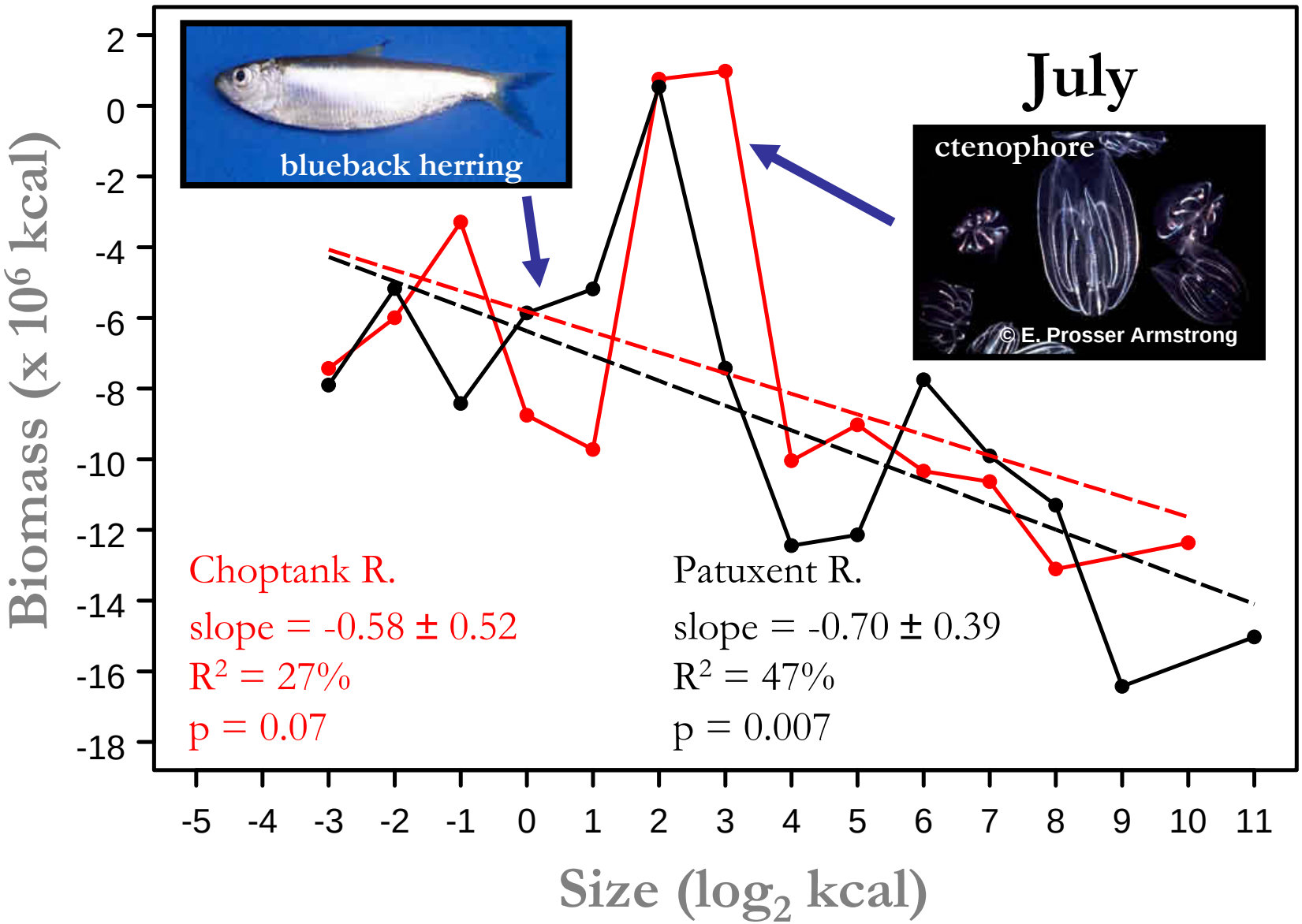

Integrated Spectrum for
Chesapeake Bay
Y = -1.03 X – 2.73
phytoplankton
mesozooplankton
Fish larva
Zooplanktivorous
small fish
Piscivorous
large fish
Log2 A (abundance)
40
30
20
10
0
–10
–20
–40
–30
–20
–10
0
10
20
2 μm
20 μm
200 μm
2 mm
20 mm
20 cm
Organism Size

Healthy System

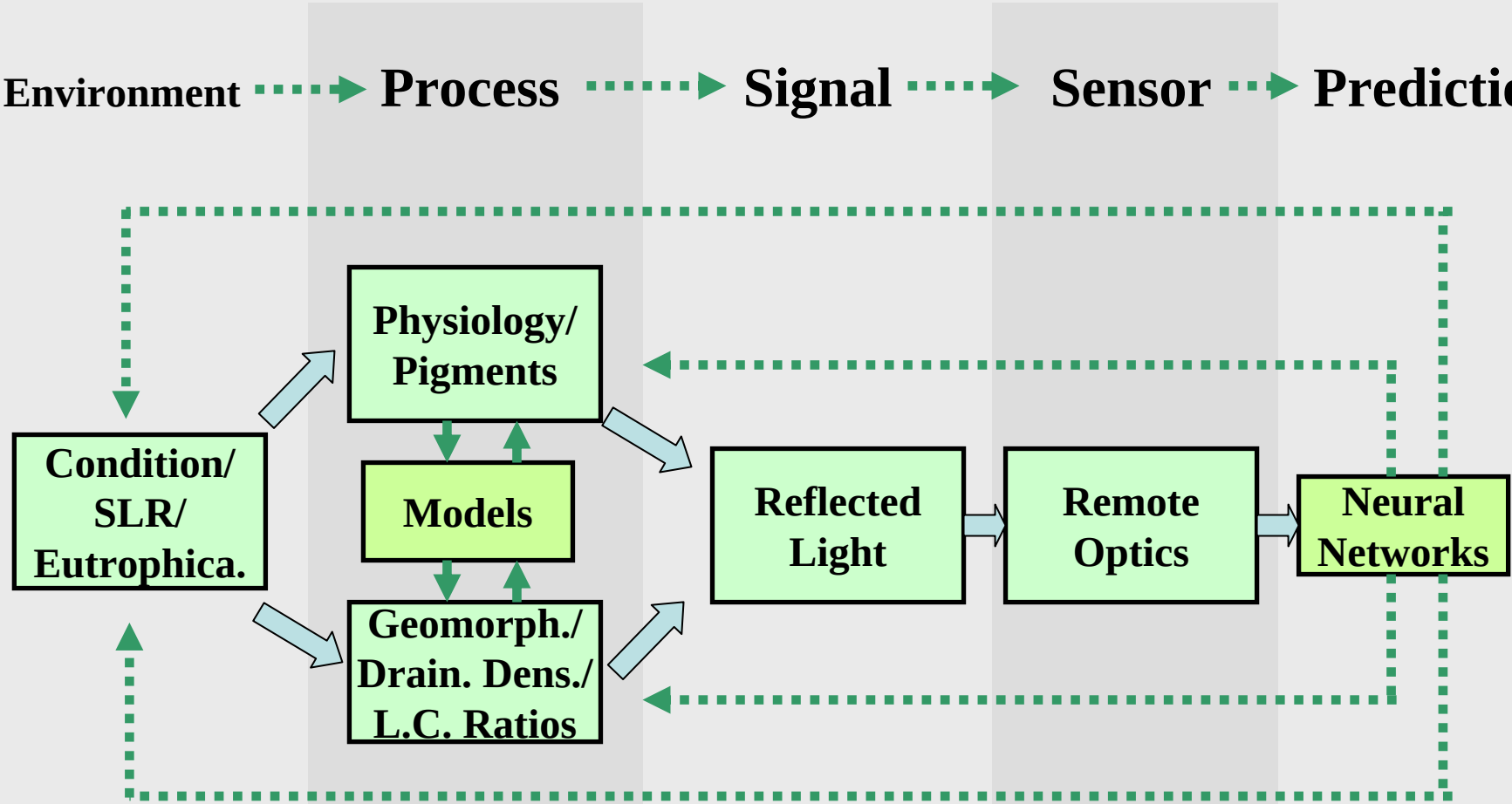


Unhealthy System

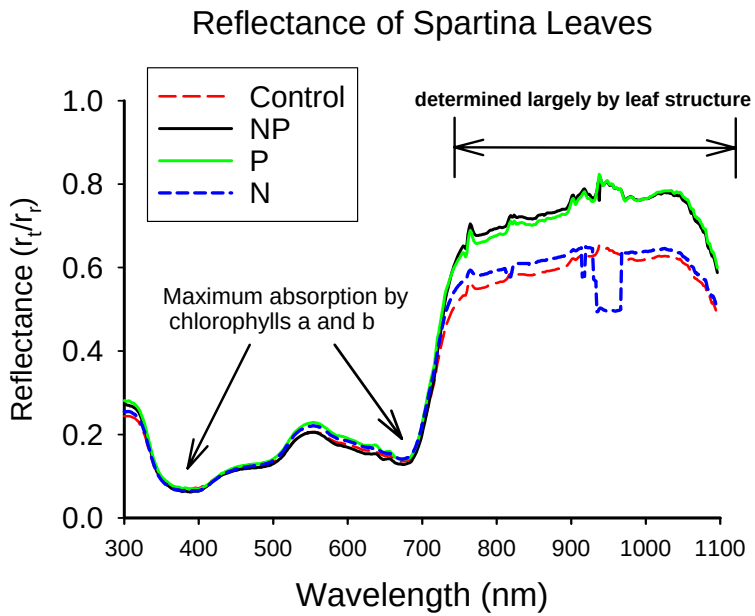



July
blueback herring
ctenophore
© E. Prosser Armstrong
Biomass (x 10^6 kcal)
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11
Size (log2 kcal)
Choptank R.
slope = -0.58 ± 0.52
R2 = 27%
p = 0.07
Patuxent R.
slope = -0.70 ± 0.39
R2 = 47%
p = 0.007

Coastal Wetland Indicator Development

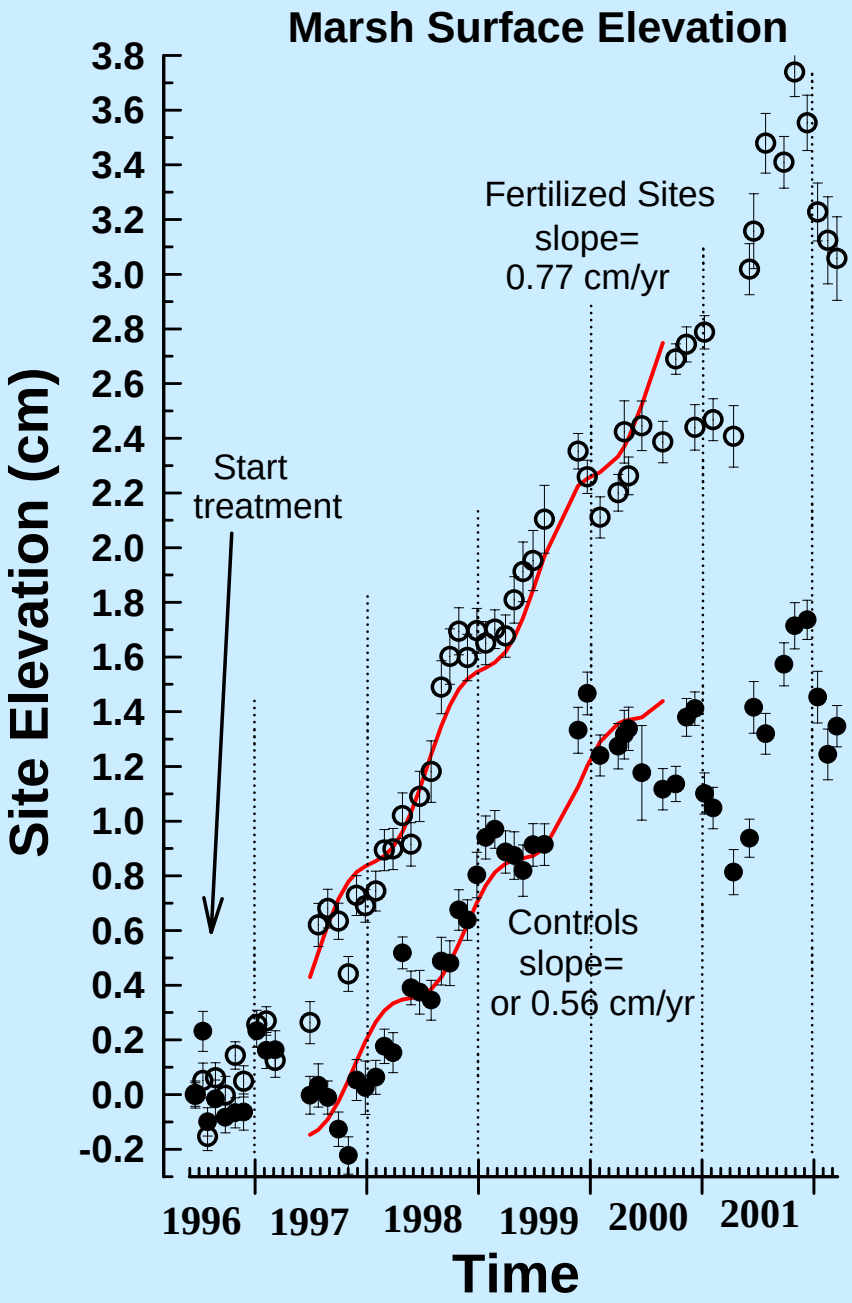


An ADAR image, classified to show chlorophyll density in a salt marsh at North Inlet, SC.



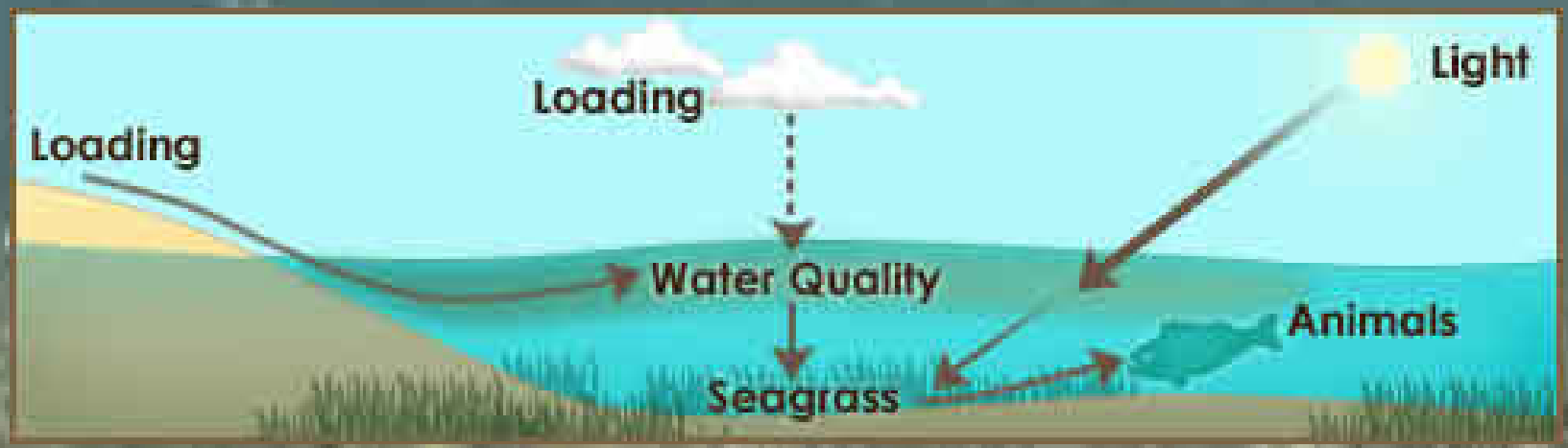
The spectrum of light reflected from the leaves of *Spartina alterniflora*. Plants treated with phosphorus had higher reflectance in the near infra-red .

Marsh geomorphology is regulated by feedbacks between biological and physical processes.



Importance of SAV

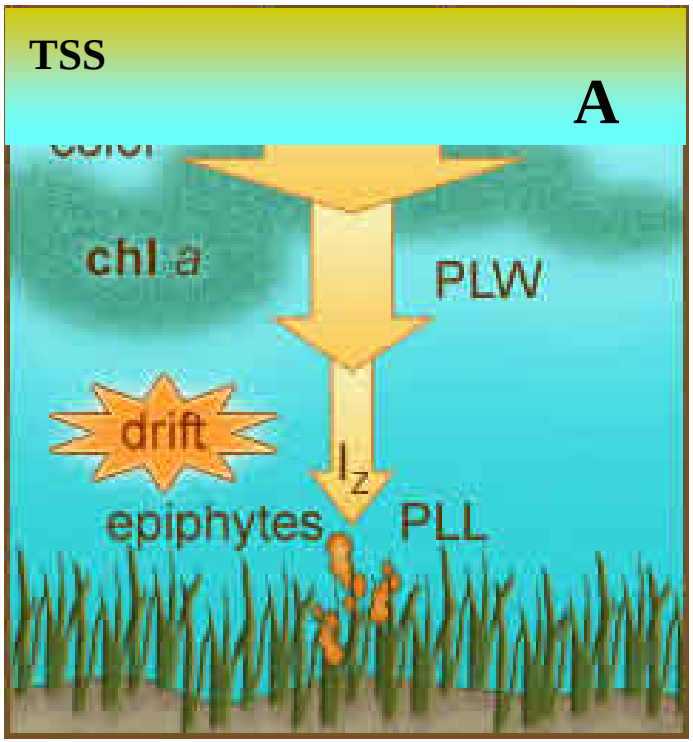
Conceptual Model (Virnstein *et al.* 2000)

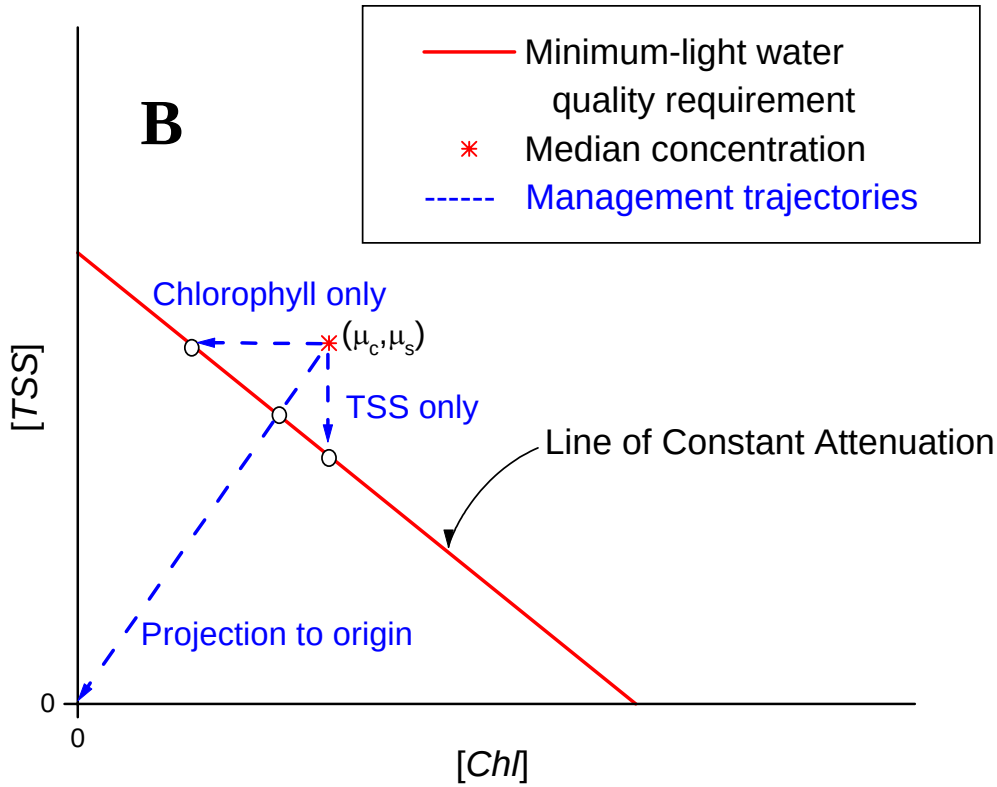


Loading (TMDL) → Water Quality →

Light → **Seagrass** → Animals($)

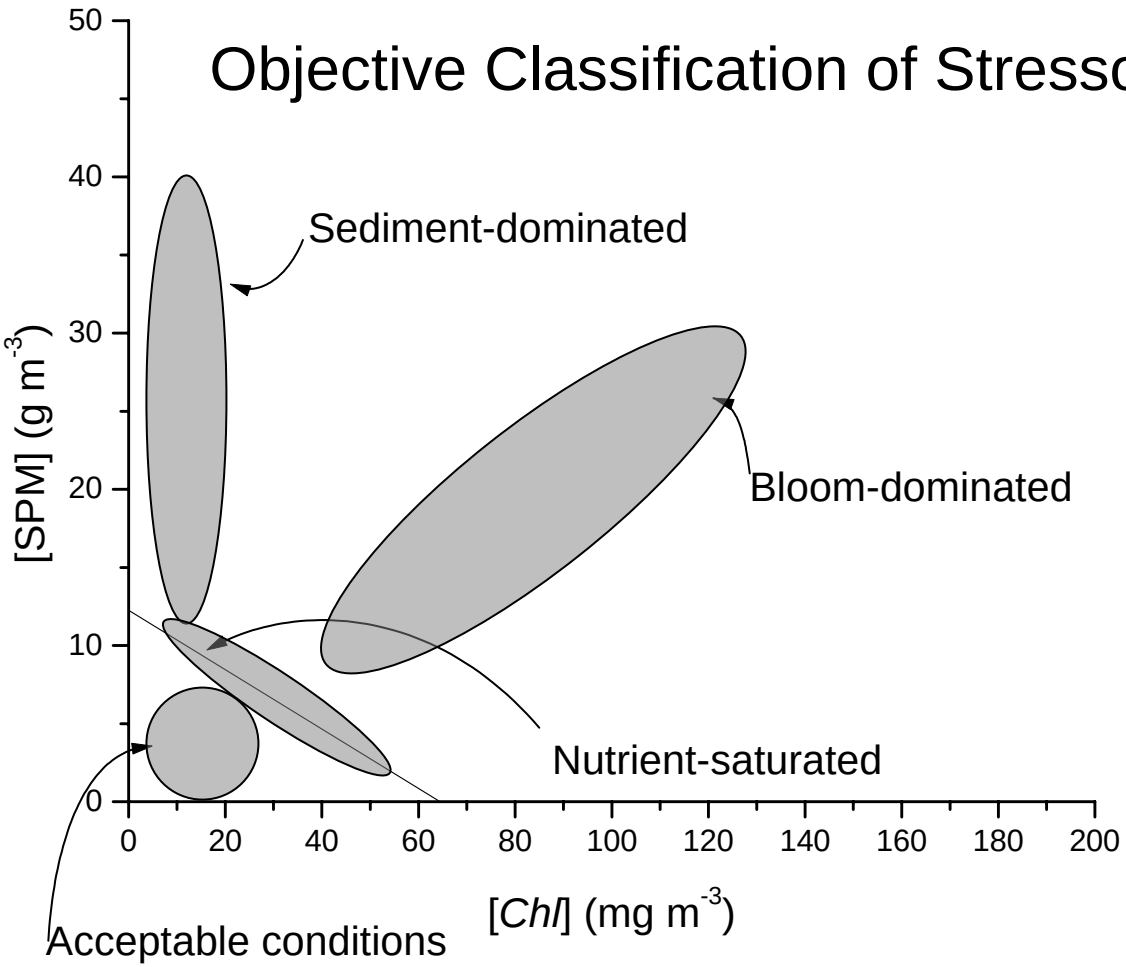
SAV Habitat Requirement Diagnostic Tool



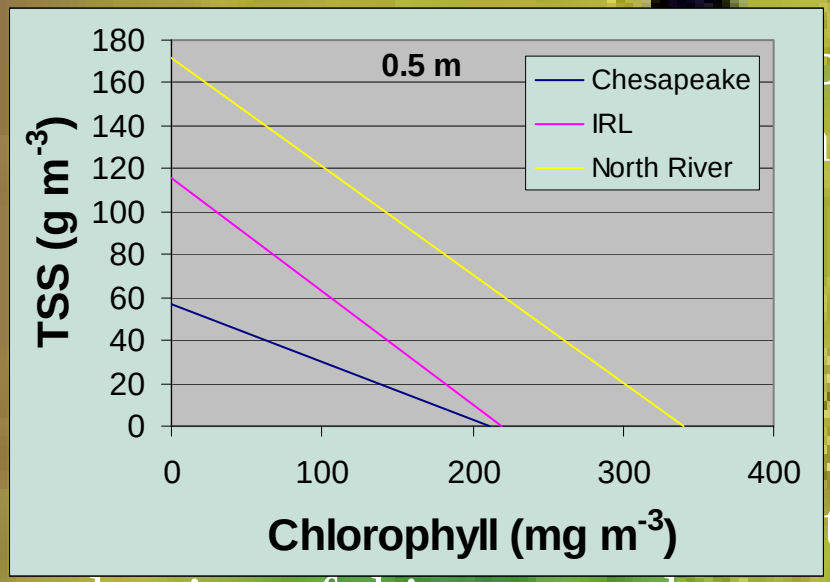


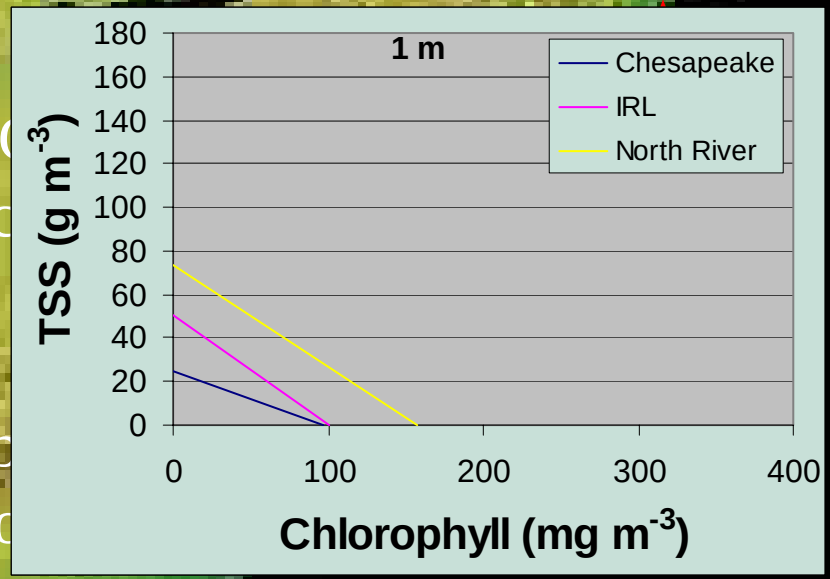
- **SAV are light-limited in turbid, bloom, or highly colored waters.**
- **Min. light requirements are known for some SAV**
- **Indicator could focus on light penetration from RS attributes of the water body (color, chl *a*, etc.)**

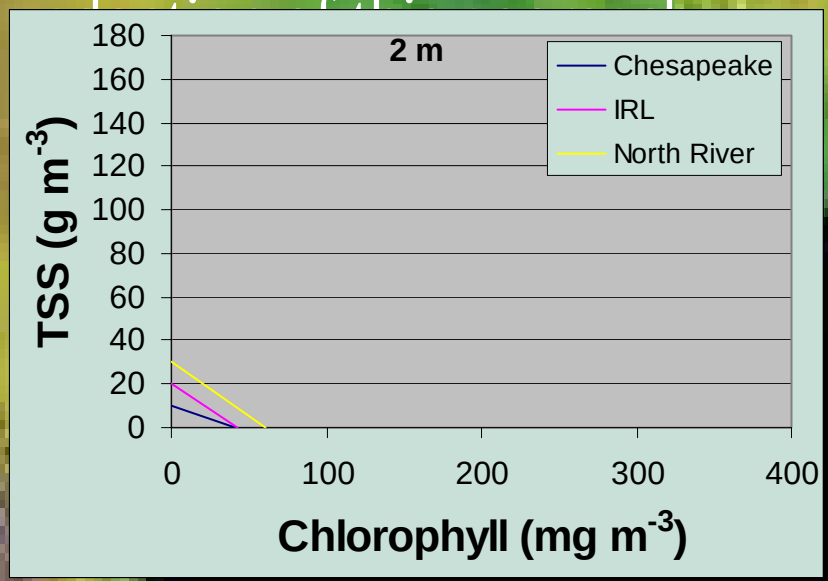
Development of Indicator Based on Quantification of Characteristic Modes of Variation



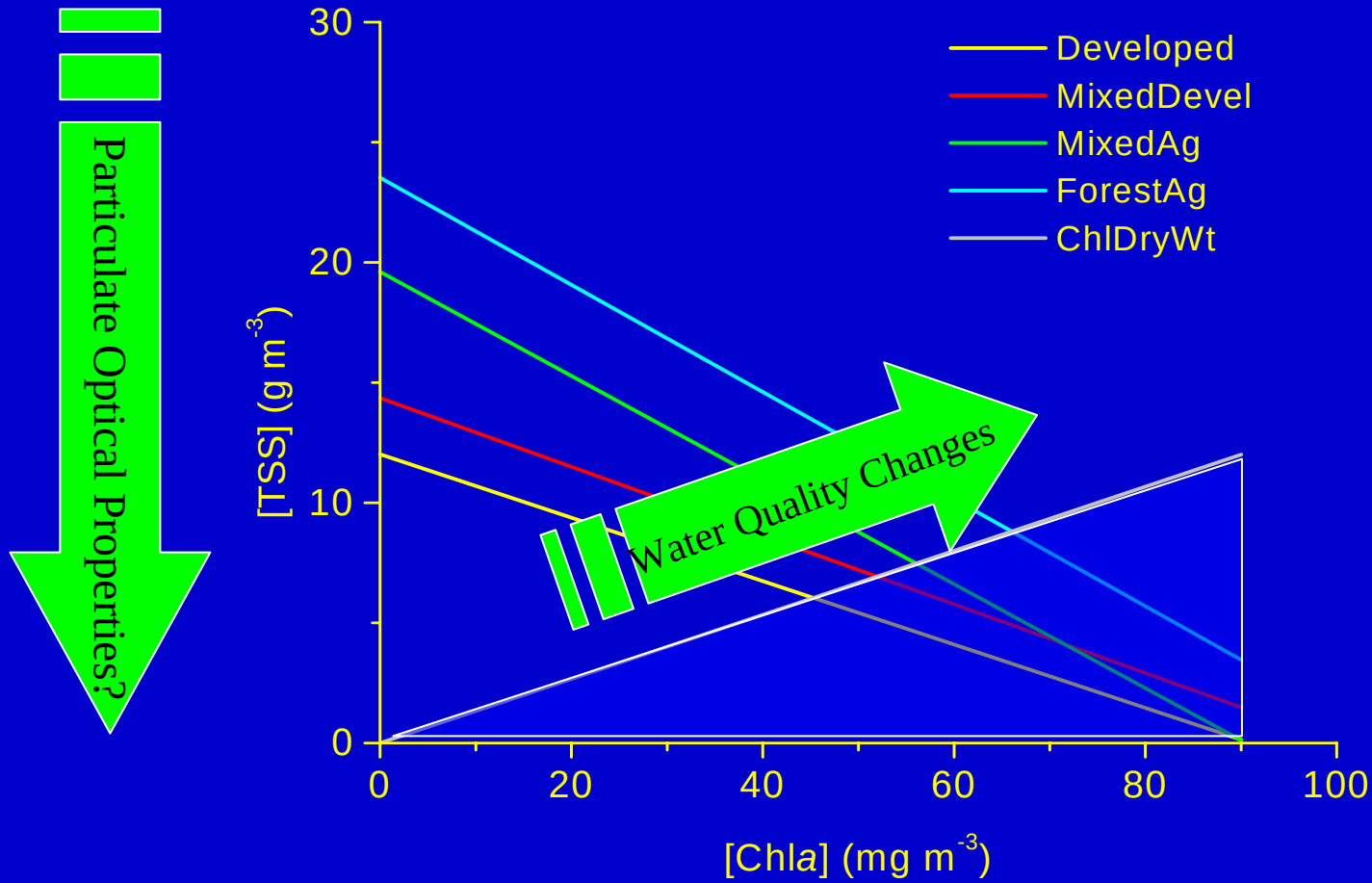
Indicator Status







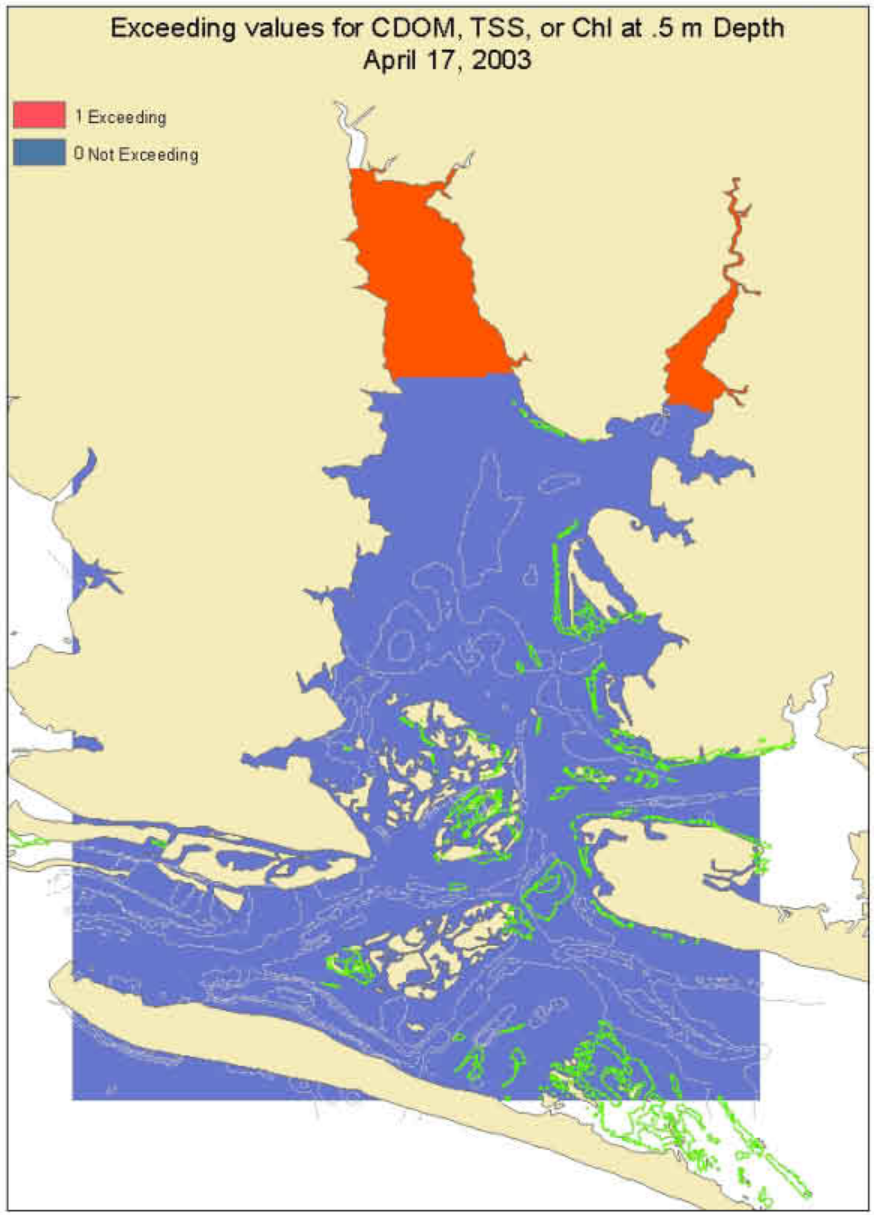
Challenges
Thresholds change with Eutrophication!



Client tools

Table 1: Threshold concentrations for three water-quality components, calculated from measured optical properties in North River, NC in 2003.

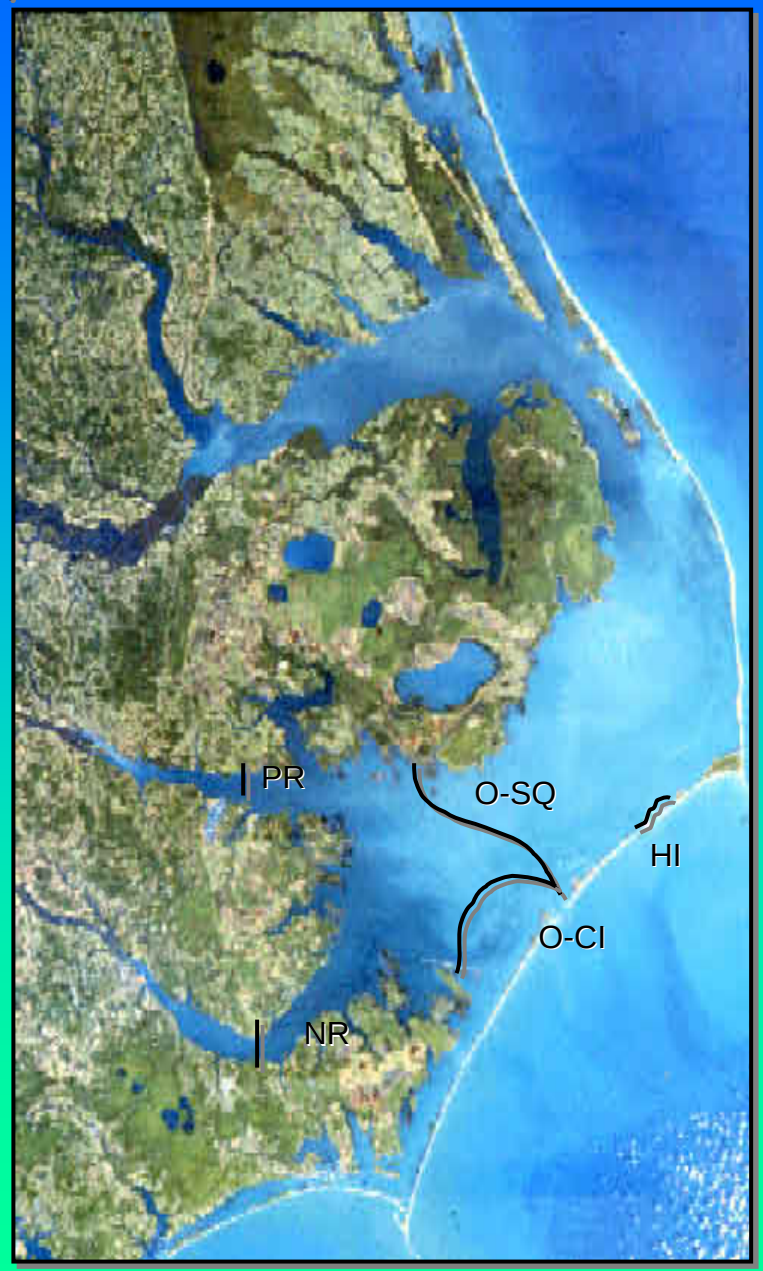
Depth (m)	Chl a (ug/L	TSS (mg/L)	CDOM (1/m)
0.5	*340.3*	*171.3*	*28.1*
1.0	156.8	73.8	11
1.5	96.6	44	5.83
2.0	61.1	30.1	3.55
3.0	38.8	17.1	1.66



Clients will include federal, state and local environmental agencies and water quality monitoring organizations with an interest in protecting seagrass as EFH. Can also include research and education organizations.

The Need to Scaling up for the Pamlico Sound: FerryMon

www.ferrymon.org



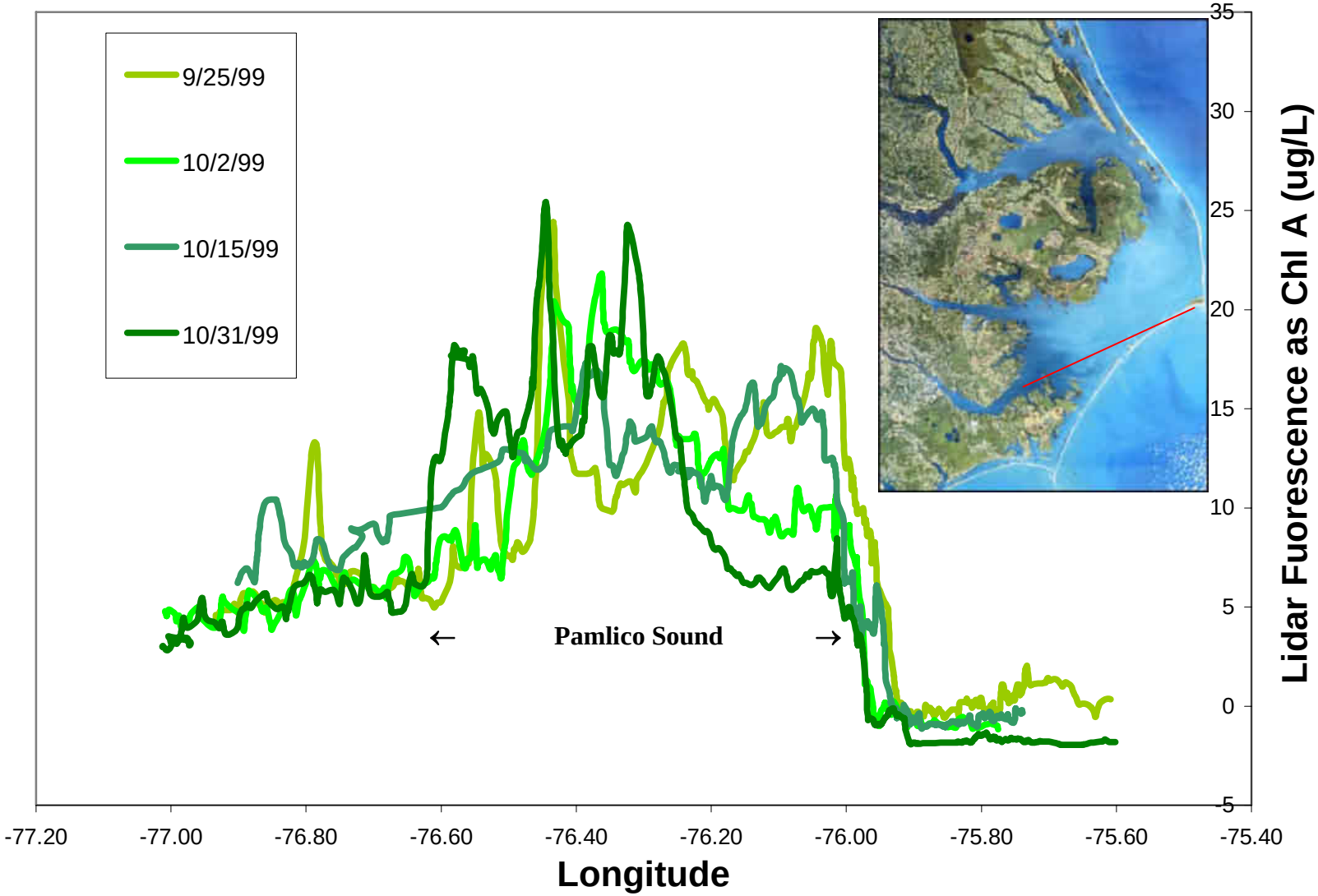
Salinity, Temp., dissolved O_2, turbidity, pH, diagnostic pigments, nutrients

FerryMon Applications

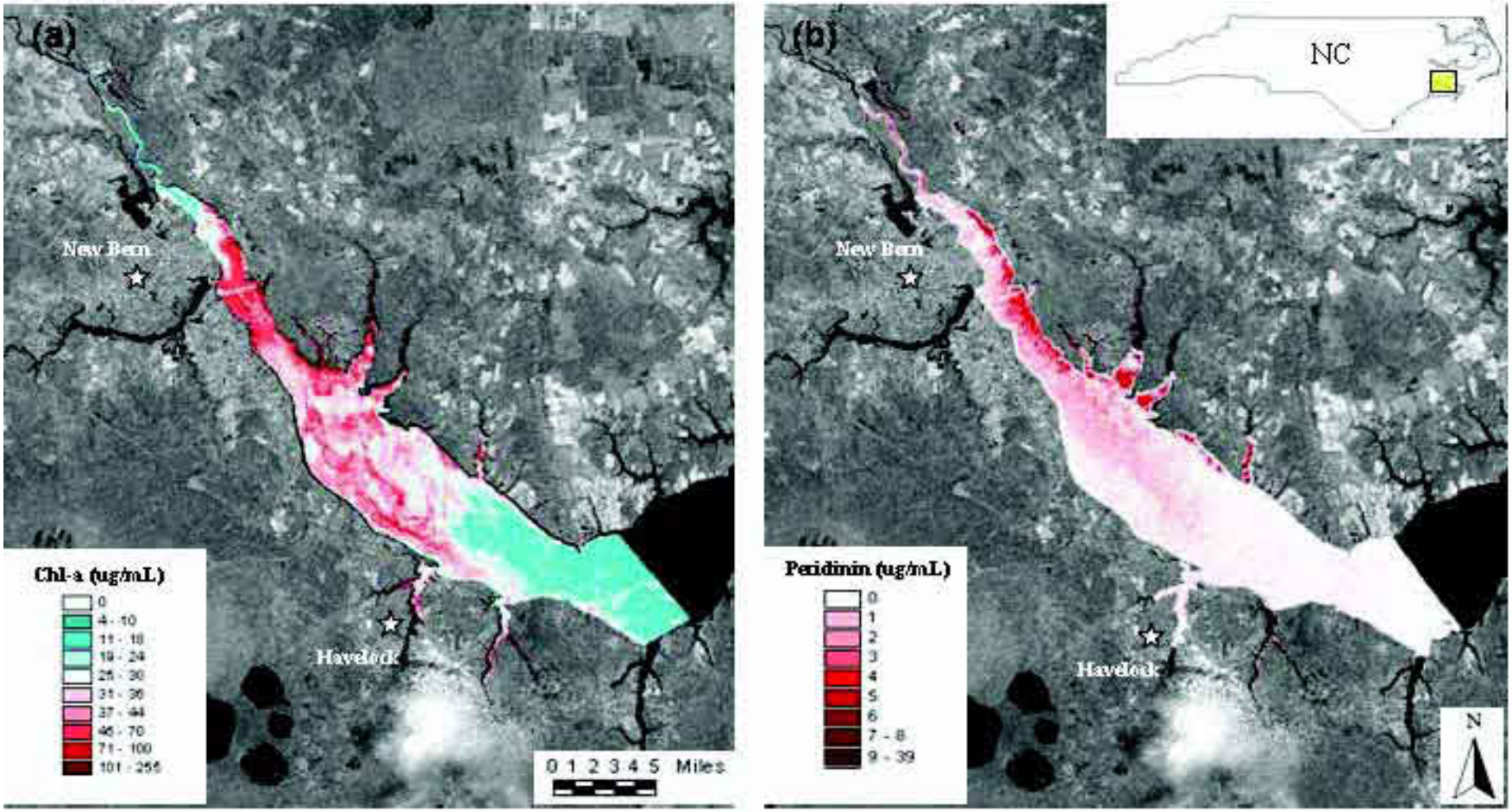
- Develop WQ data baseline against which to gauge change
- Calibrating Remote Sensing for "scaling up"
- Multiple WQ indicators
- Data for Developing WQ and other Models
- Assess Climatic vs. Anthropogenic Influences on WQ

Using FerryMon to calibrate remotely-sensed photopigments

Overflight Data from Line 5, Neuse River into the Pamlico Sound and out Ocracoke Inlet onto the shelf



Microalgal Indicators and Remote Sensing

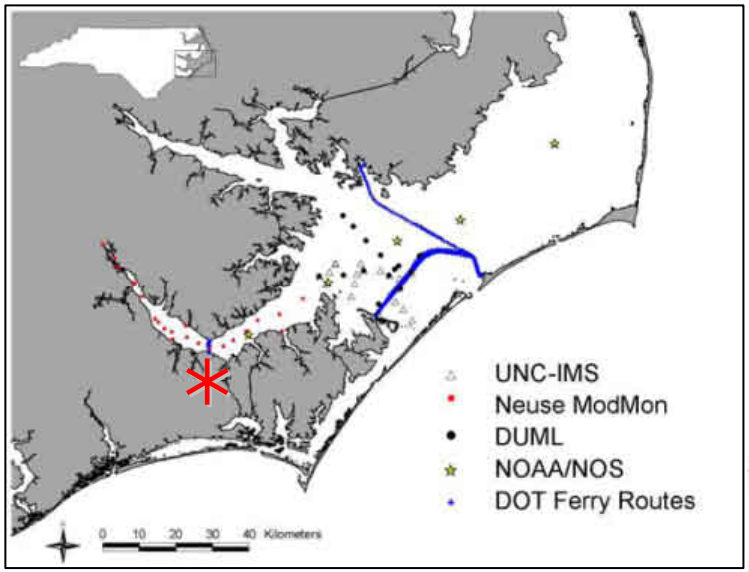


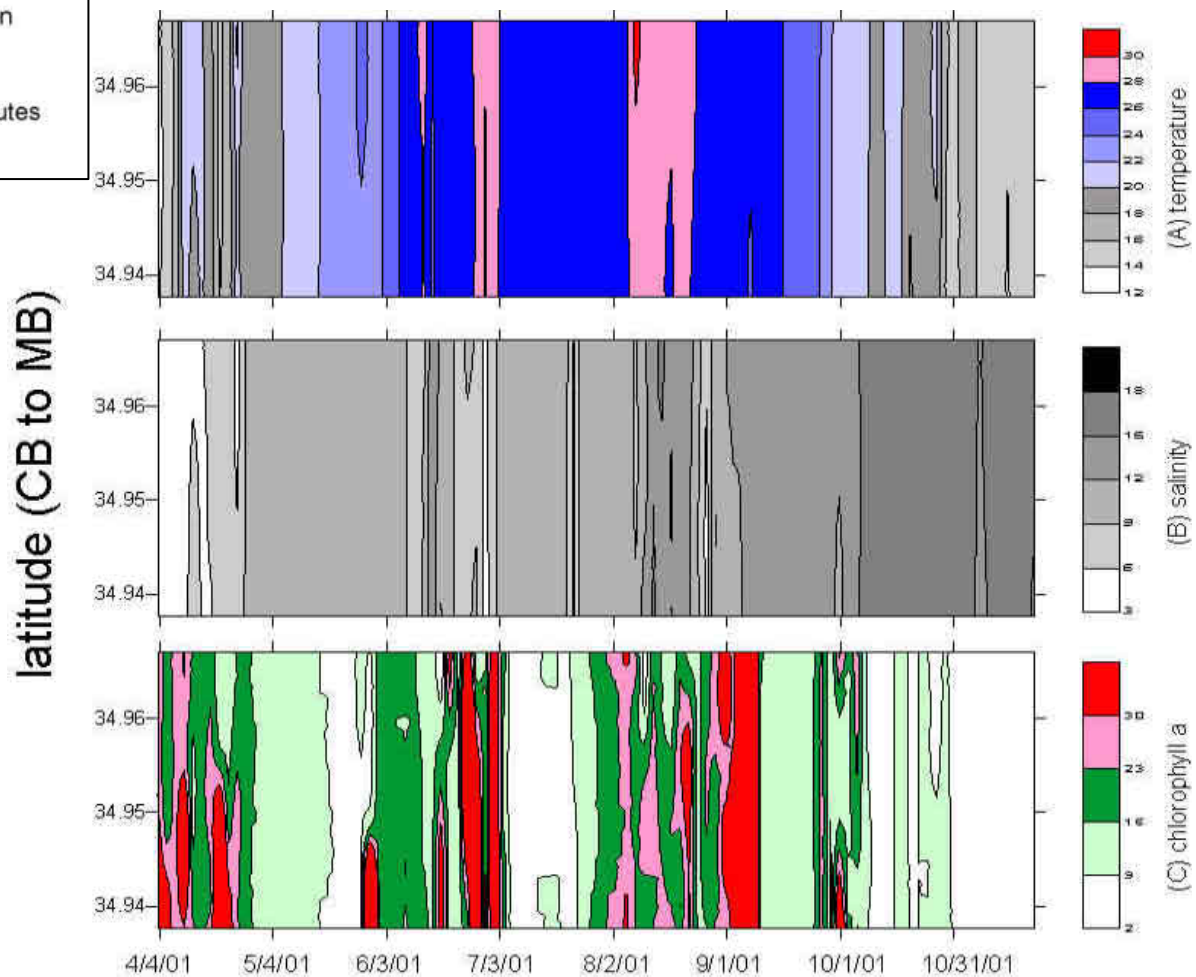
Estimated Chlorophyll-a and Peridinin concentrations in the Neuse River Estuary 15 May 2002 as determined with AVIRIS and ACE Eagles data. (Lunetta 2004 in prep)

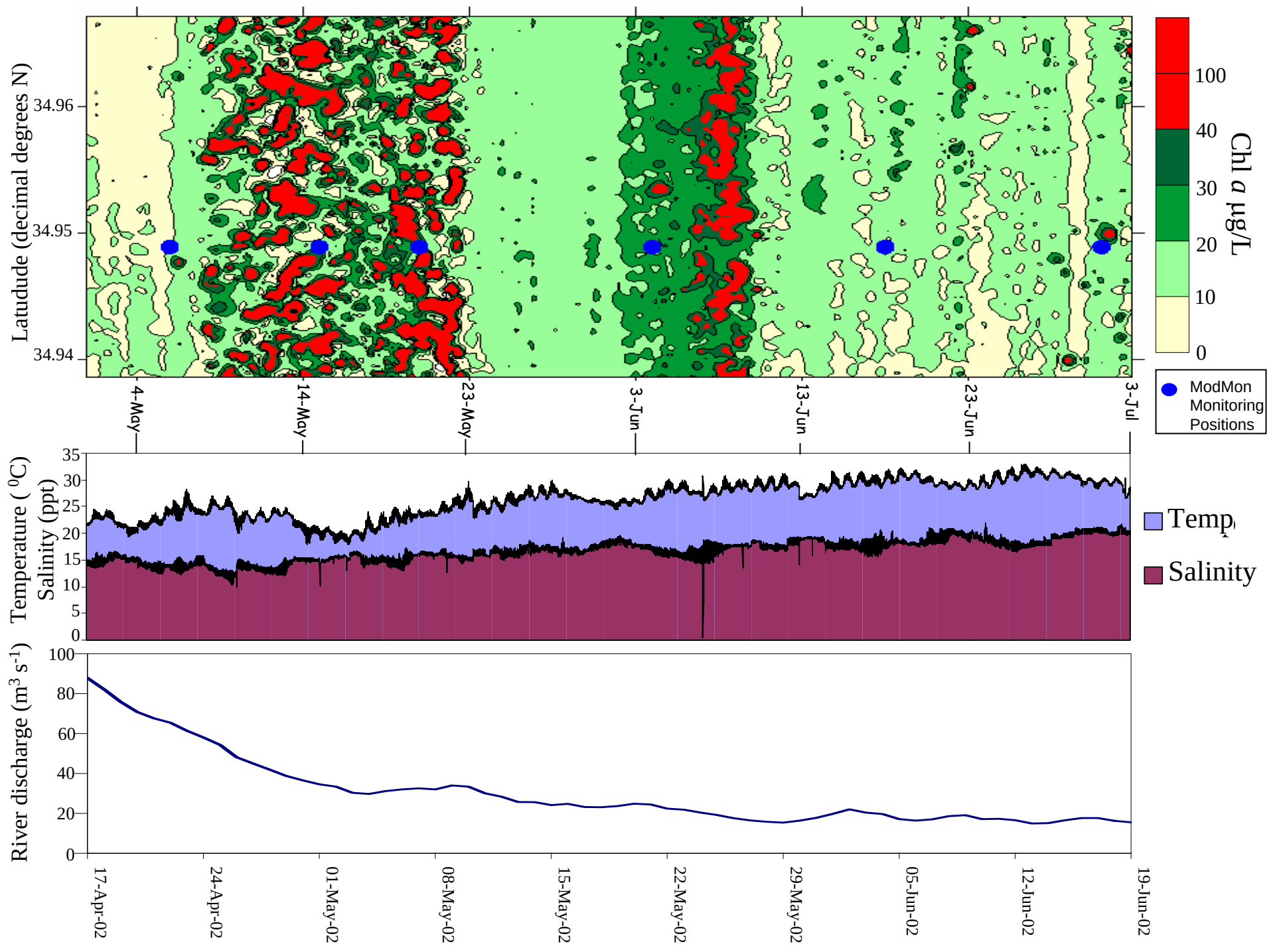
Users: EPA-RTP, NASA, NC DENR-DWQ

Detecting Algal Blooms

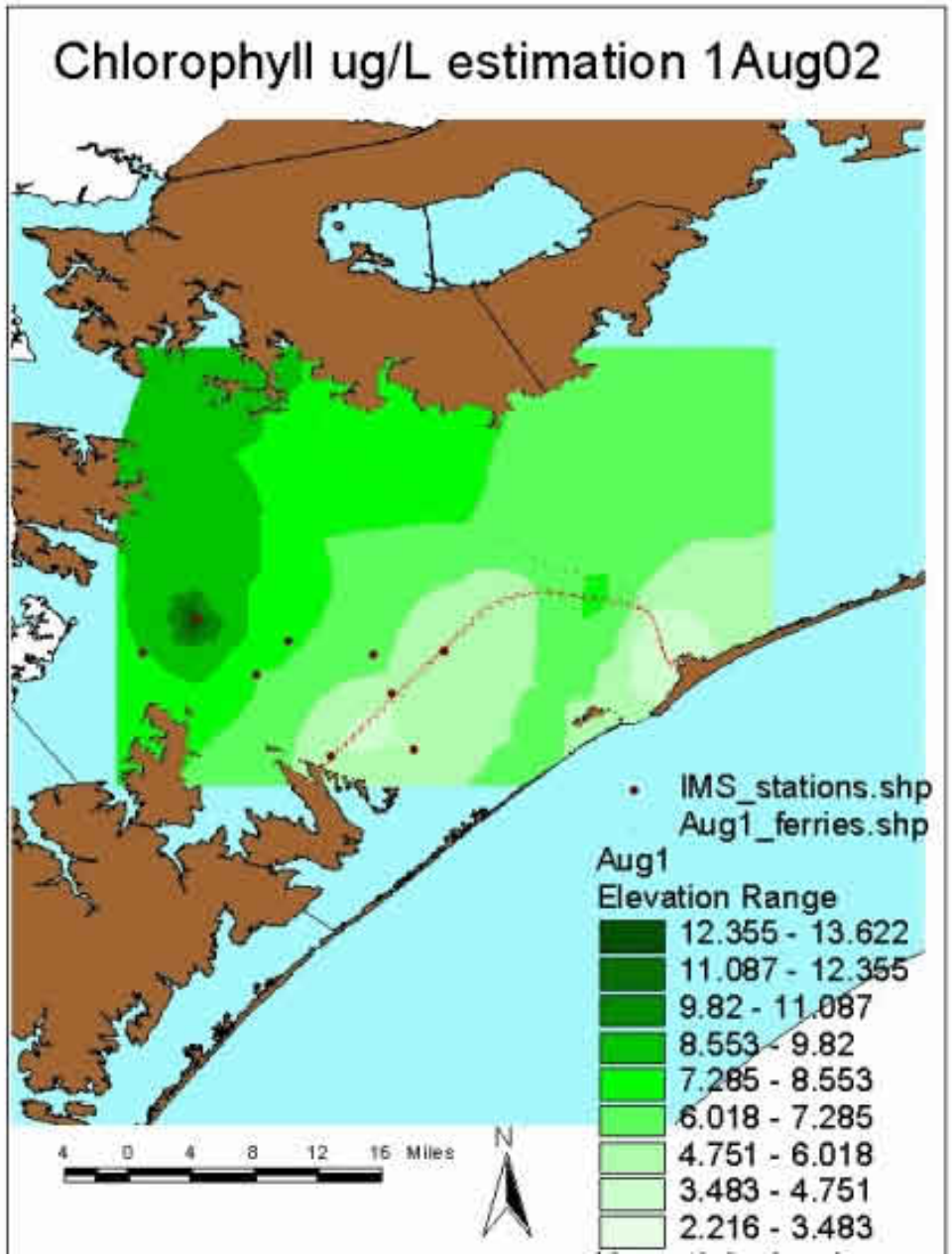
Cherry Branch-Minnesott Ferry



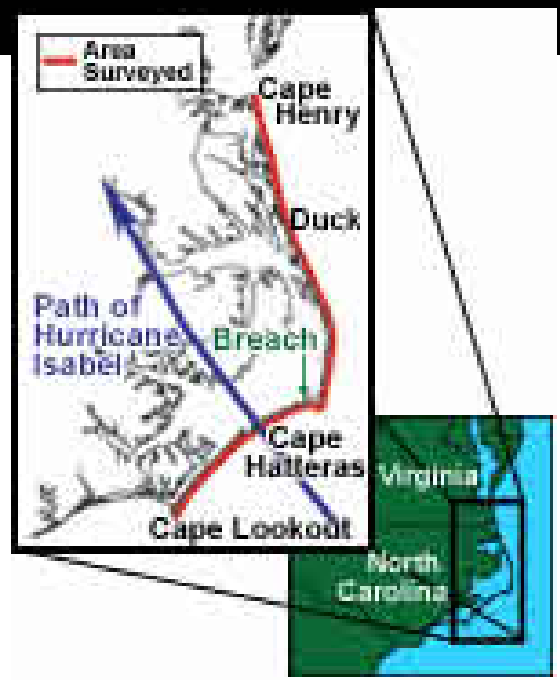



Latudude (decimal degrees N)
34.96
34.95
34.94
4-May
14-May
23-May
3-Jun
13-Jun
23-Jun
3-Jul
Chl a ug/L
100
40
30
20
10
0
ModMon
Monitoring
Positions
Temperature (0C)
Salinity (ppt)
35
30
25
20
15
10
5
0
Temp
Salinity
River discharge (m3 s-1)
100
80
60
40
20
0
17-Apr-02
24-Apr-02
01-May-02
08-May-02
15-May-02
22-May-02
29-May-02
05-Jun-02
12-Jun-02
19-Jun-02

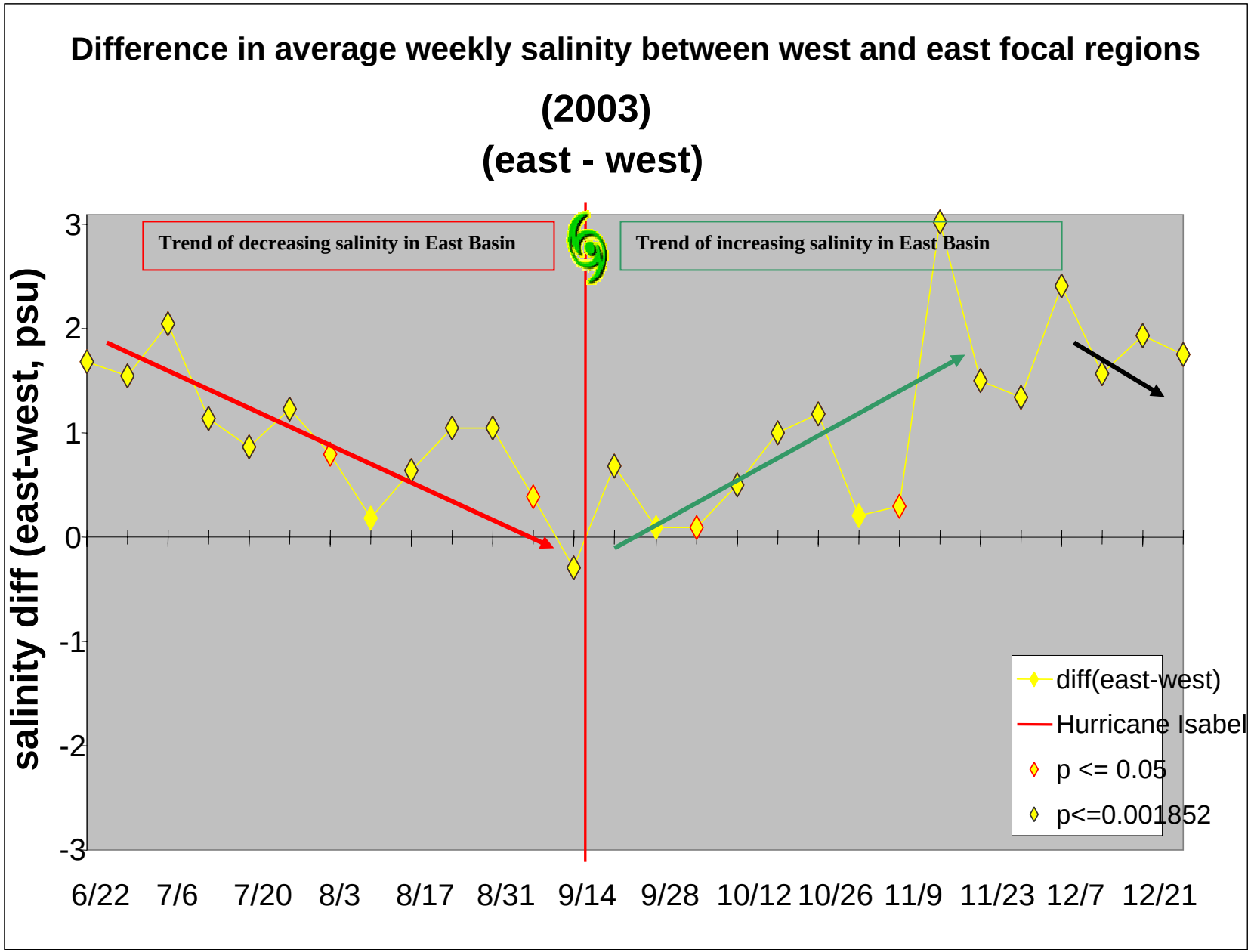
Using FerryMon for Modeling WQ responses on large scales



Isabel "creates" a new inlet in the Outer Banks



FerryMon characterizes hydrologic/salinity changes in Pamlico Sound



ACE INC Research and Management Products & Applications

- Regional development & application of pigment diagnostic WQ/habitat indicators (TMDL)
- Coupling remote sensing to pigments and morphometric indicators to “scale up”

Locations:

- Chesapeake Bay
- Albemarle-Pamlico Sound
- North Inlet
- Galveston Bay
- Long Island Sound
- Florida Bay
- St. Johns River
- San Francisco Bay
- Gulf of Mexico?
- Puget Sound?
- Great Lakes?

Collaborating agencies/ Clients:

- NC-DENR
- SC-DNR
- MD-DNR
- FL-SJWMD/SFWMD
- VA-DEQ
- EPA Regions 3 & 4
- EPA-RTP & Gulf Breeze, NASA
- NOAA-NOS/Sea Grant, USDA
- NSF
- USGS
- EaGLes (CEER-GOM, PEEIR, GLEI)

ACE INC Research and Management Products & Applications

- **Geomorphological indicators of coastal wetland WQ and condition**

Locations:

- SC-North Inlet
- MA-Plum Island LTER
- CEER GOM

Collaborating agencies/ Clients:

- SC-DNR
- NC-DENR/DOT
- NASA
- NSF
- MA-DEP
- NOAA-EPA

ACE INC Research and Management Products & Applications

- **Application of Bio-optical Model as criteria for seagrass habitats (w. C. Gallegos, ASC)**

Locations:

- SC-North Inlet
- MA-Plum Island LTER
- Chesapeake Bay Monitoring Program
- Indian River Lagoon
- St Johns River (FL)
- North R.-Pamlico Sound
- Massachusetts Bays

Collaborating agencies/ Clients:

- EPA-CBP
- NC-DMF
- SJWMD
- MA-DEP?
- NOAA-NOS

ACE INC Research and Management Products & Applications

- **Unattended deployment of indicators (DO, temp. salinity, pH, photopigments, turbidity, pathogens, bioptics) on moorings, platforms, ferries. Coupling to remote sensing**

Locations:

- Chesapeake Bay
- Albemarle-Pamlico Sound
- Galveston Bay
- St. Johns River
- Puget Sound?
- San Francisco Bay?

Collaborating agencies/ Clients:

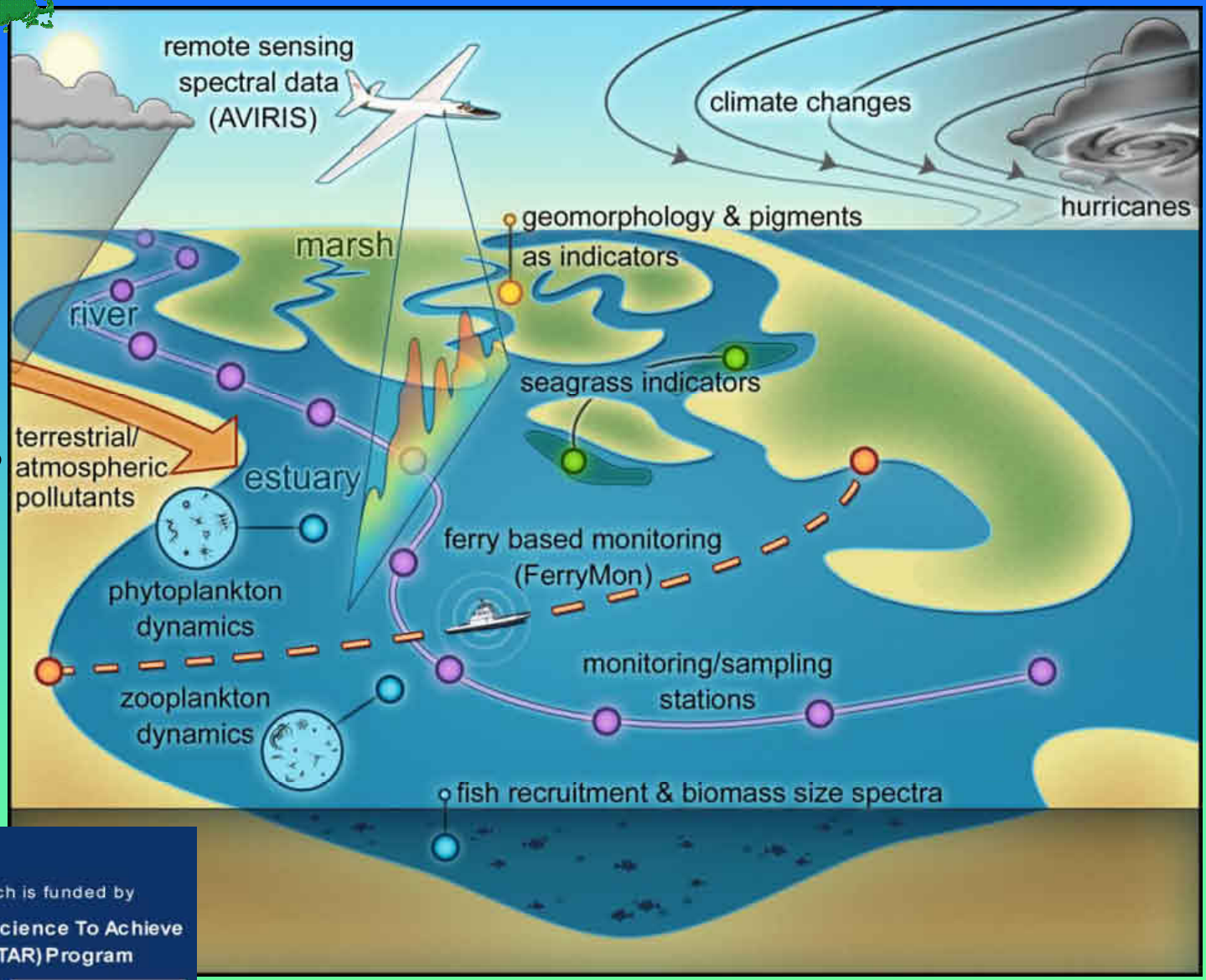
- NC-DENR
- SC-DNR
- MD-DNR
- FL-SJWMD/SFWMD
- NC-DOT/DENR
- EPA-NEP
- EPA Regions 3 & 4
- EPA Chesapeake Bay Program
- EPA-RTP
- NASA
- NOAA
- SJWMD-FL
- EaGLes (CEER-GOM, PEEIR, GLEI)

Coastal Indicators as Management Tools

Atlantic Coast Environmental Indicators Consortium

Plum Island LTER
Chesapeake Bay
Neuse/Pamlico
North Inlet

www.aceinc.org



Thanks to

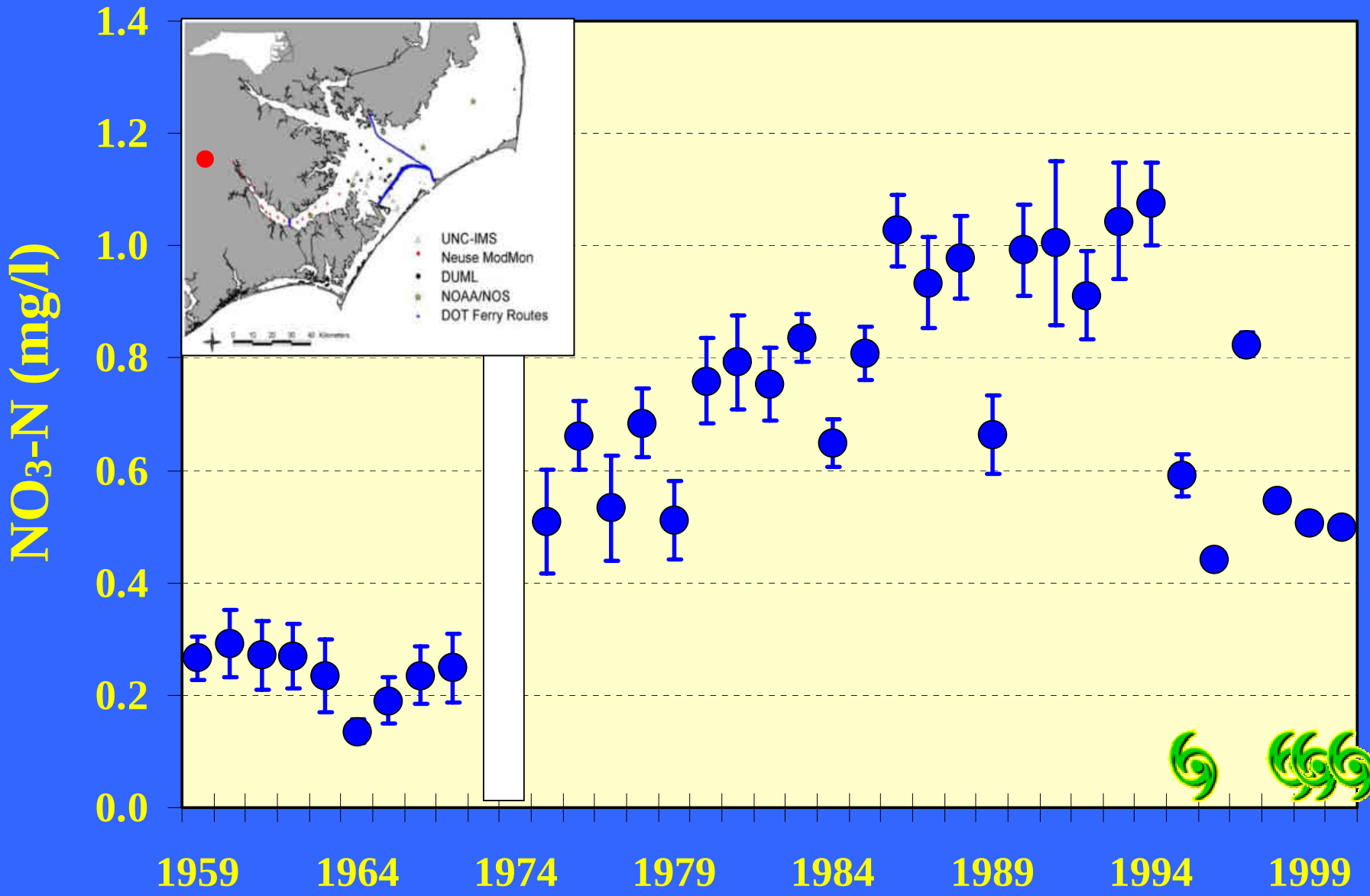
This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # 82667701

EPA, NSF, NC Sea Grant, & USDA-NRI

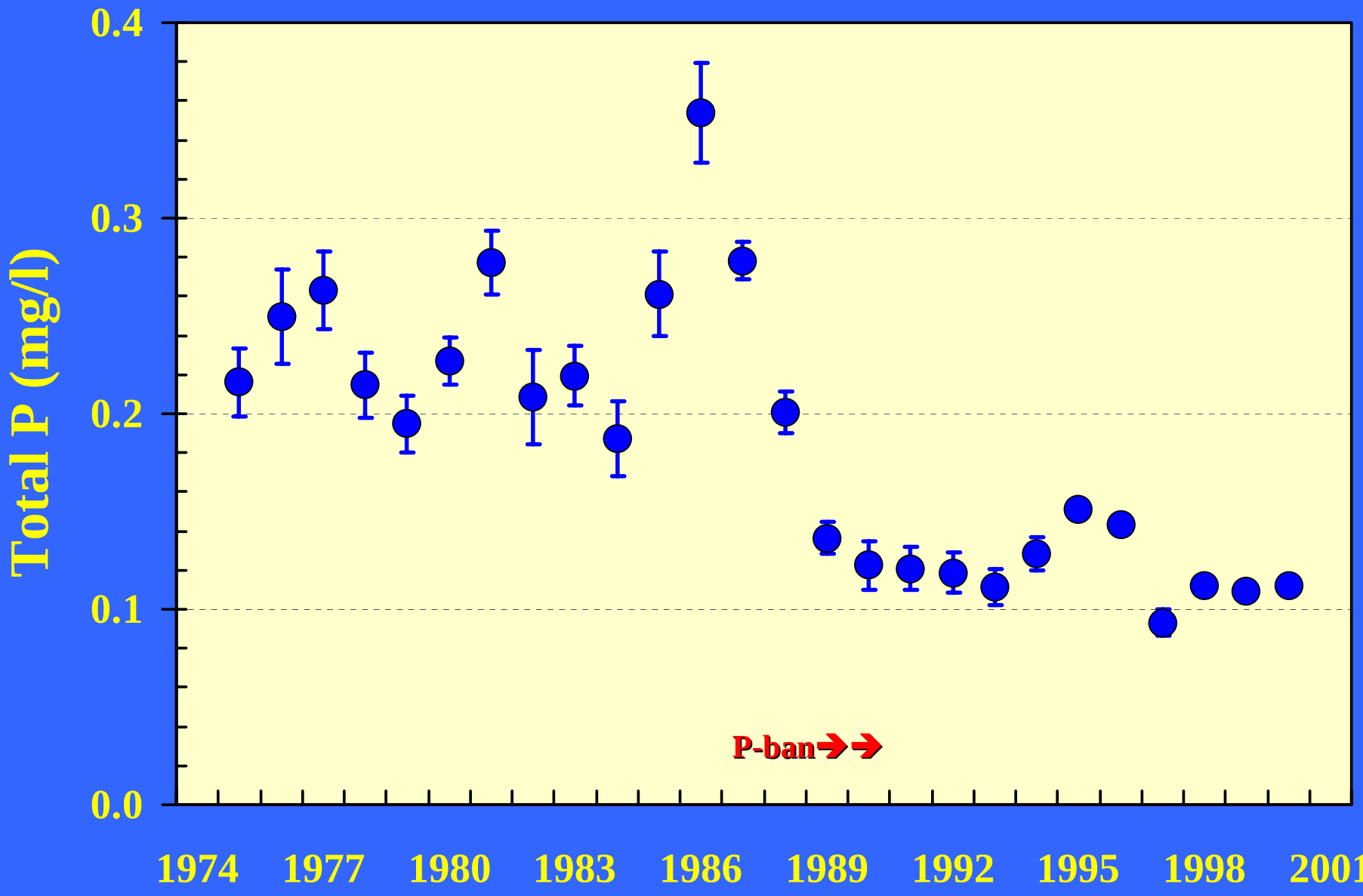
Questions

How did we get there (i.e. eutrophication history)
What do the long term data show?

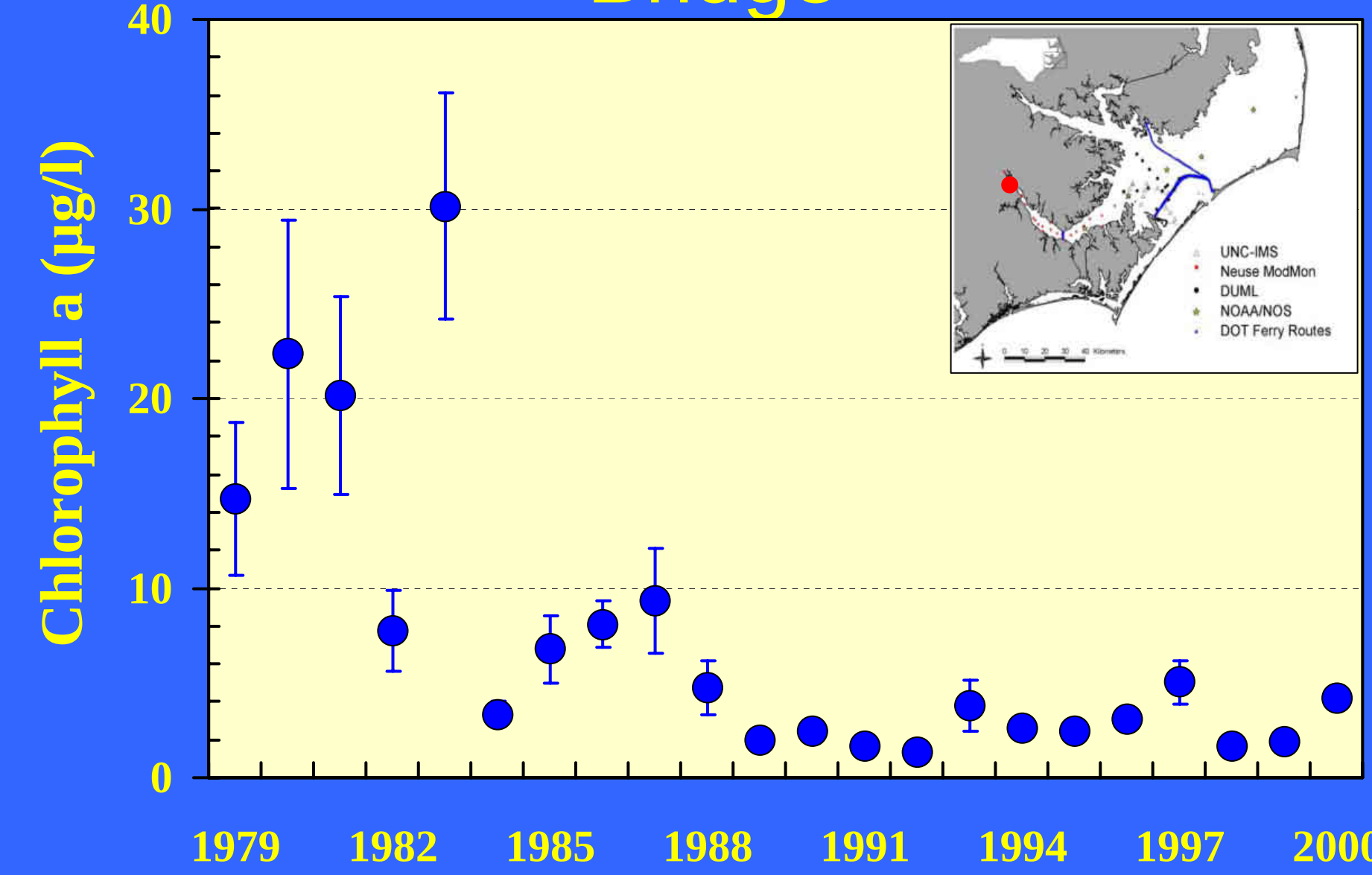
Neuse River @ Kinston



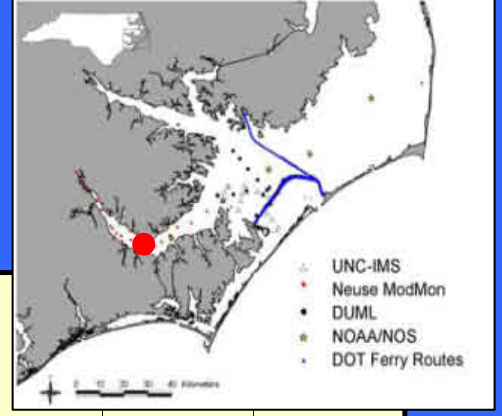
Neuse River @ Kinston



Neuse River @ Streets Ferry Bridge



Neuse Estuary @ 2-7 psu



Chlorophyll a (µg/l)

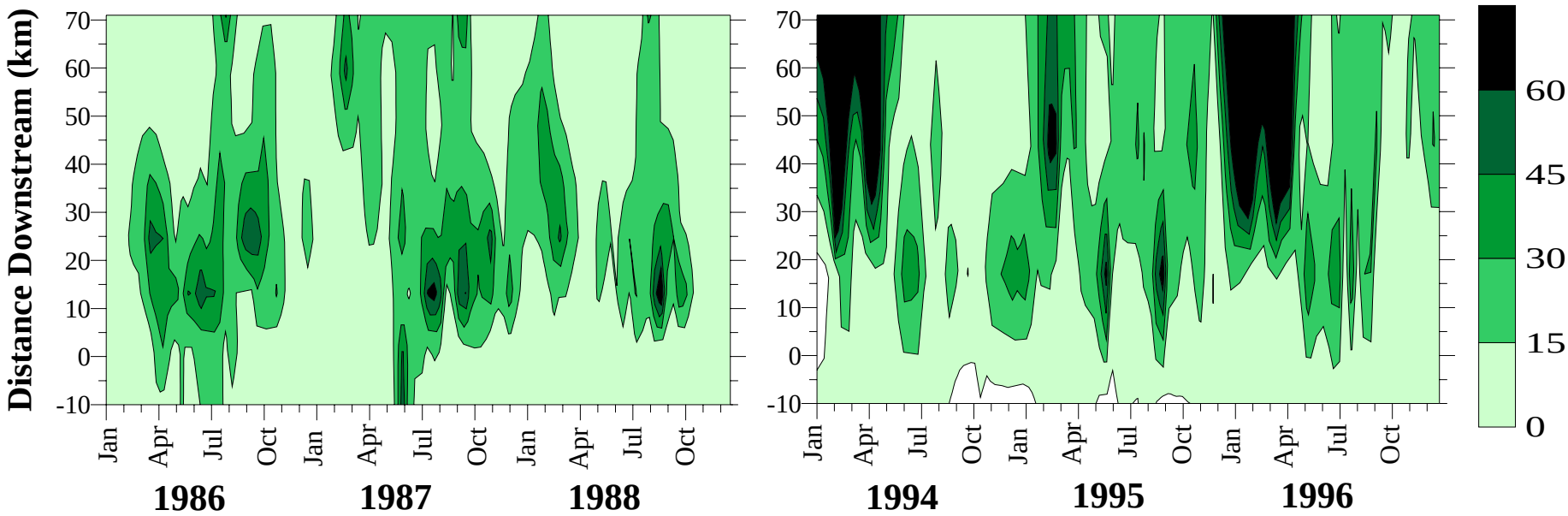
50
40
30
20
10
0

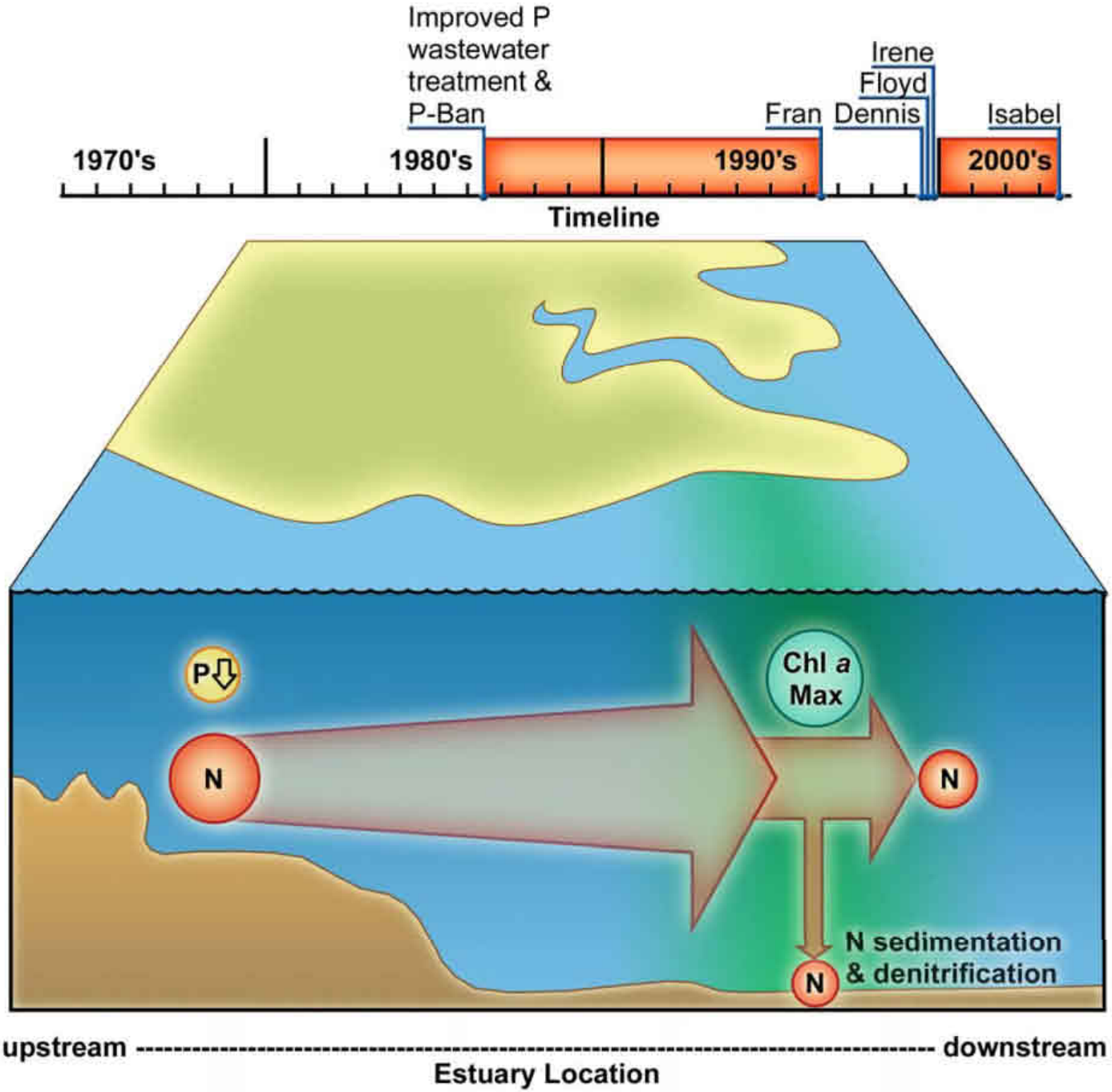
70-74
75-78
79-81
82-84
85-87
88-90
91-93
94-96
97-98
99-00

Has Freshwater P Reduction w/o Parallel N Reduction Exacerbated Estuarine Eutrophication?

Chlorophyll *a*

Neuse River Estuary




Improved P
wastewater
treatment &
P-Ban
Irene
Floyd
Fran
Dennis
Isabel
1970's
1980's
1990's
2000's
Timeline
P⇩
N
Chl a
Max
N
N sedimentation
& denitrification
N
upstream
downstream
Estuary Location

What are the Indicators?

Res. Time—Nutrient Loading: ACE-INC Estuaries