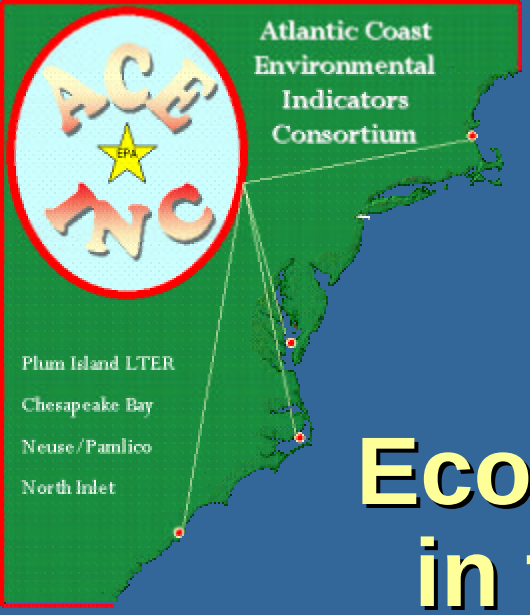


Long-Term Monitoring of Diagnostic Phytoplankton Photopigments to Assess Ecological Condition and Change in the Neuse River Estuary and Pamlico Sound, NC

Lexia M. Valdes

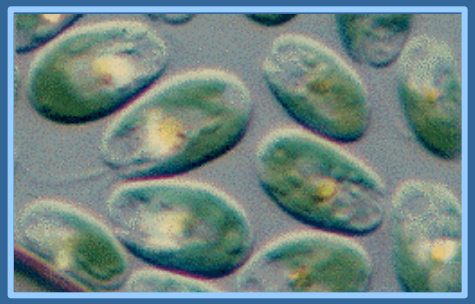
and Hans W. Paerl

2004 EMAP Symposium
May 6, 2004

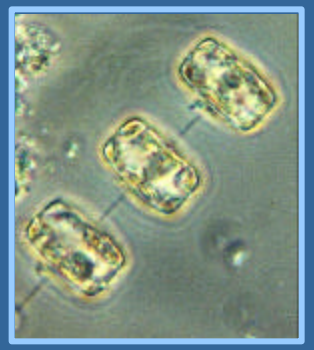
Diagnostic Phytoplankton Photopigments

Chlorophyll *a*
All Phytoplankton

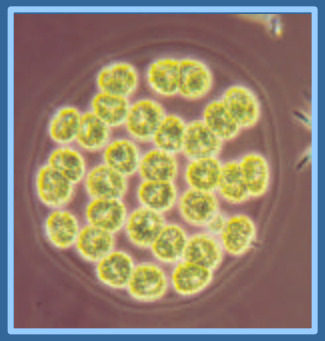
Alloxanthin
Cryptophytes



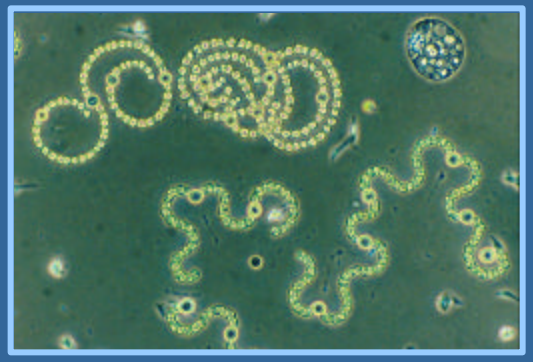
Fucoxanthin
Diatoms



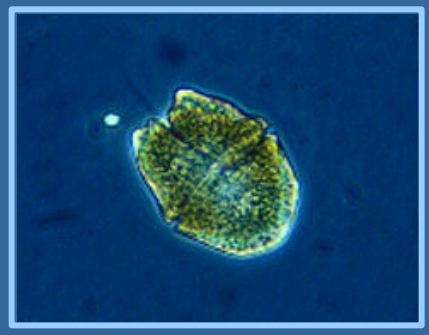
Chlorophyll b
Chlorophytes



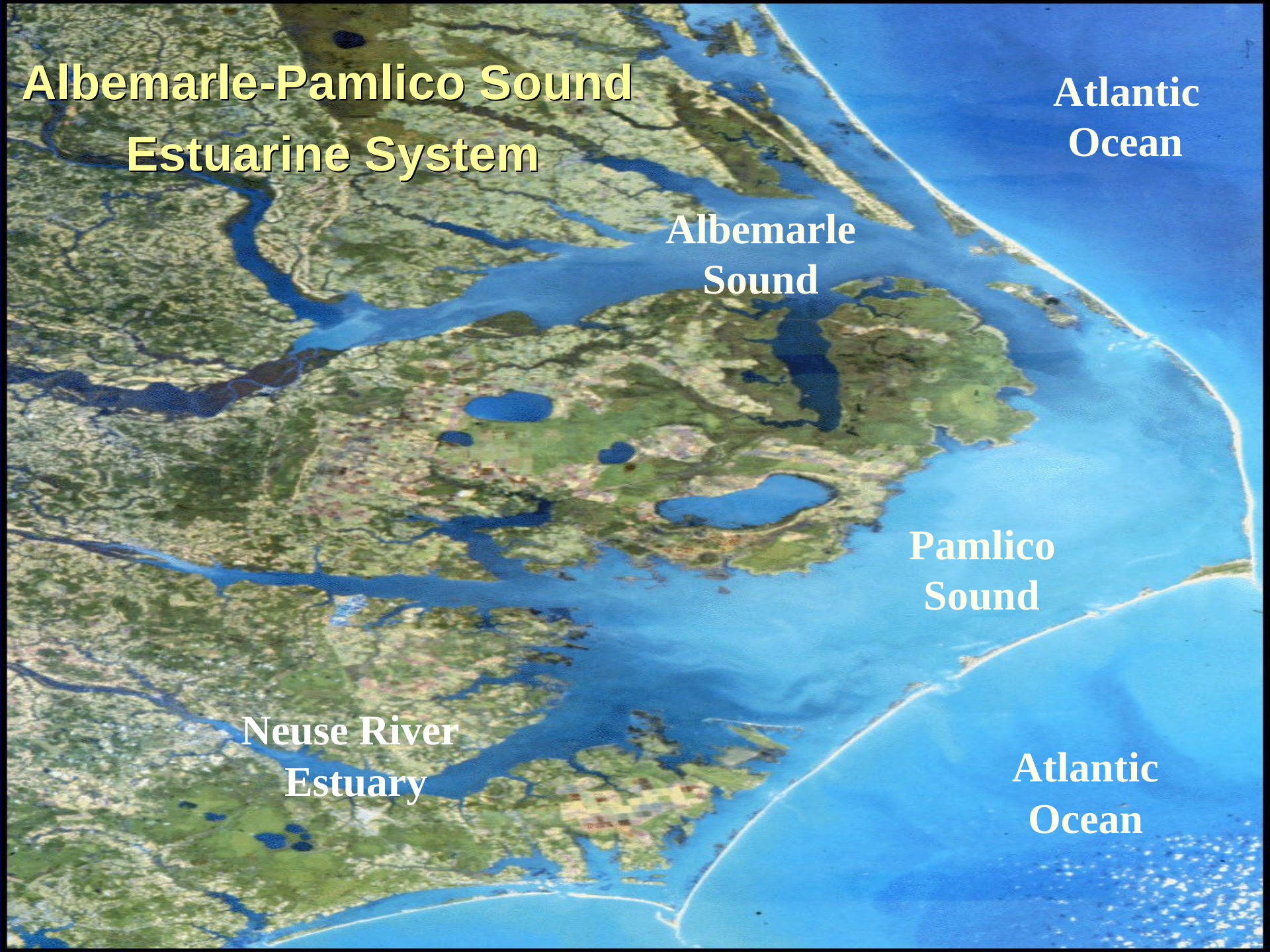
Zeaxanthin
Cyanobacteria



Peridinin
Dinoflagellates




Virginia
Atlantic Ocean
North Carolina
Neuse River Estuary - Pamlico Sound System
South Carolina

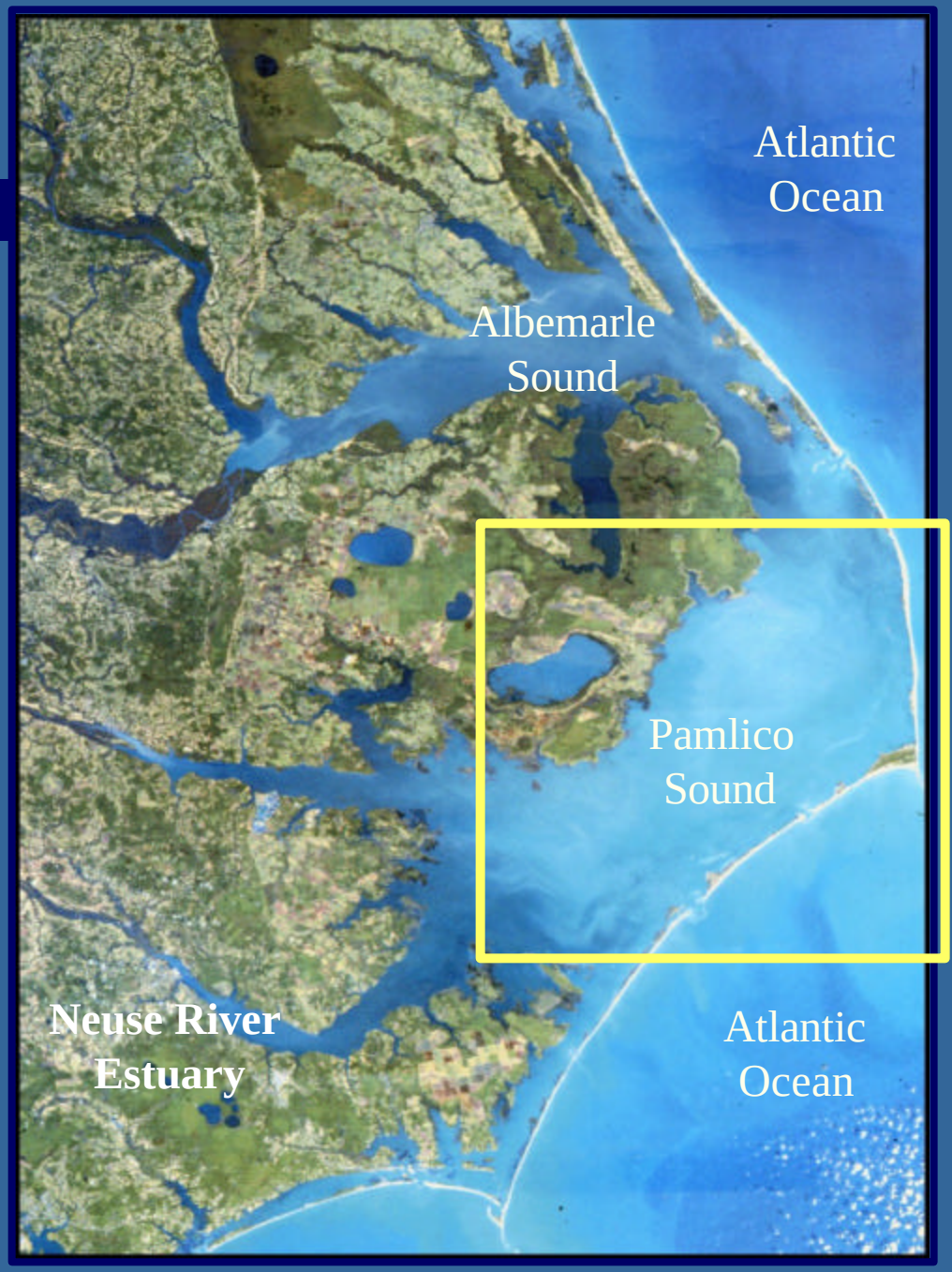

Albemarle-Pamlico Sound
Estuarine System
Atlantic
Ocean
Albemarle
Sound
Pamlico
Sound
Neuse River
Estuary
Atlantic
Ocean

Neuse River Estuary

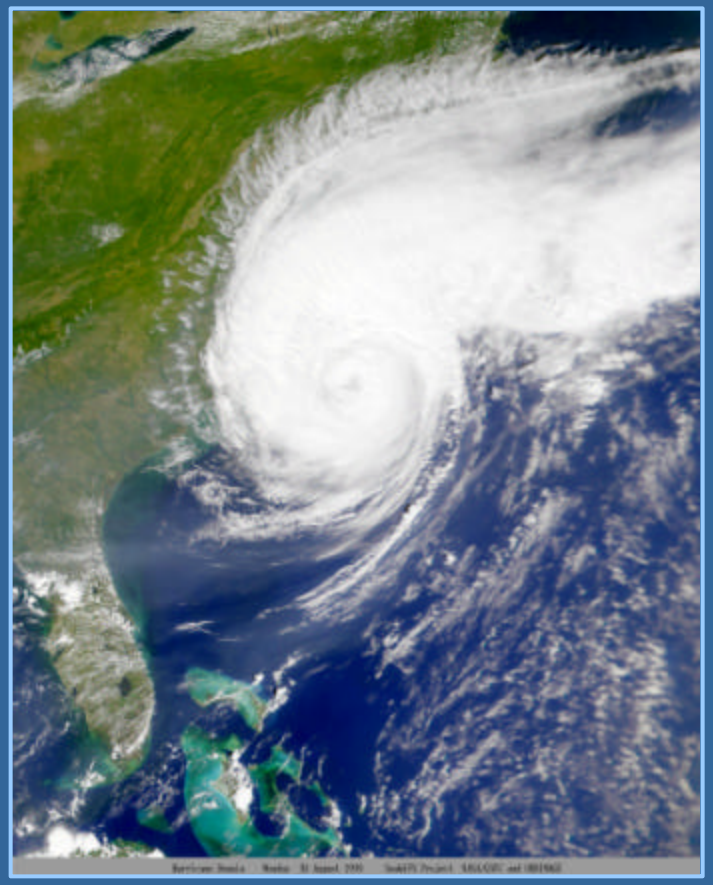
- Average depth: 2.2 m
- Salinity: river flow, precipitation, wind and tidal influx from Pamlico Sound
- Residence Time: 51 – >90 days
- Nuisance phytoplankton blooms, bottom water hypoxia and anoxia, fish kills and altered trophic structure

Pamlico Sound

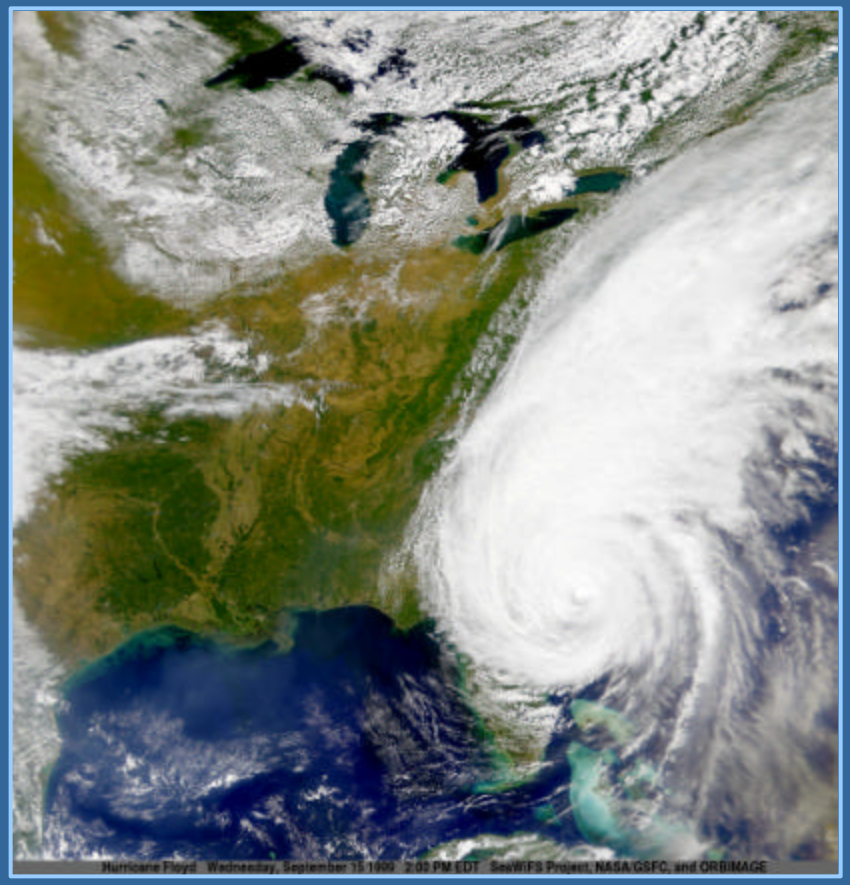
- Largest lagoonal estuary (surface area – 5,335 km^2)
- Important fish and shellfish nursery
  - >80% of NC's commercial & recreational catches
- Average depth: 4.9
  Maximum depth: 7.3 m
- Circulation: wind tides, river flow, four narrow inlets
- Residence Time: 11 months



Natural Disturbances



Hurricane Dennis
8/30/99



Hurricane Floyd
9/15/99

Effects of Hydrologic Disturbances on Estuarine Condition

Hurricanes/Seasonal Rainfall Pulses

- ↑ Rainfall
- ↑ Runoff
- ↑ River Discharge
- ↑ Nutrient Loading

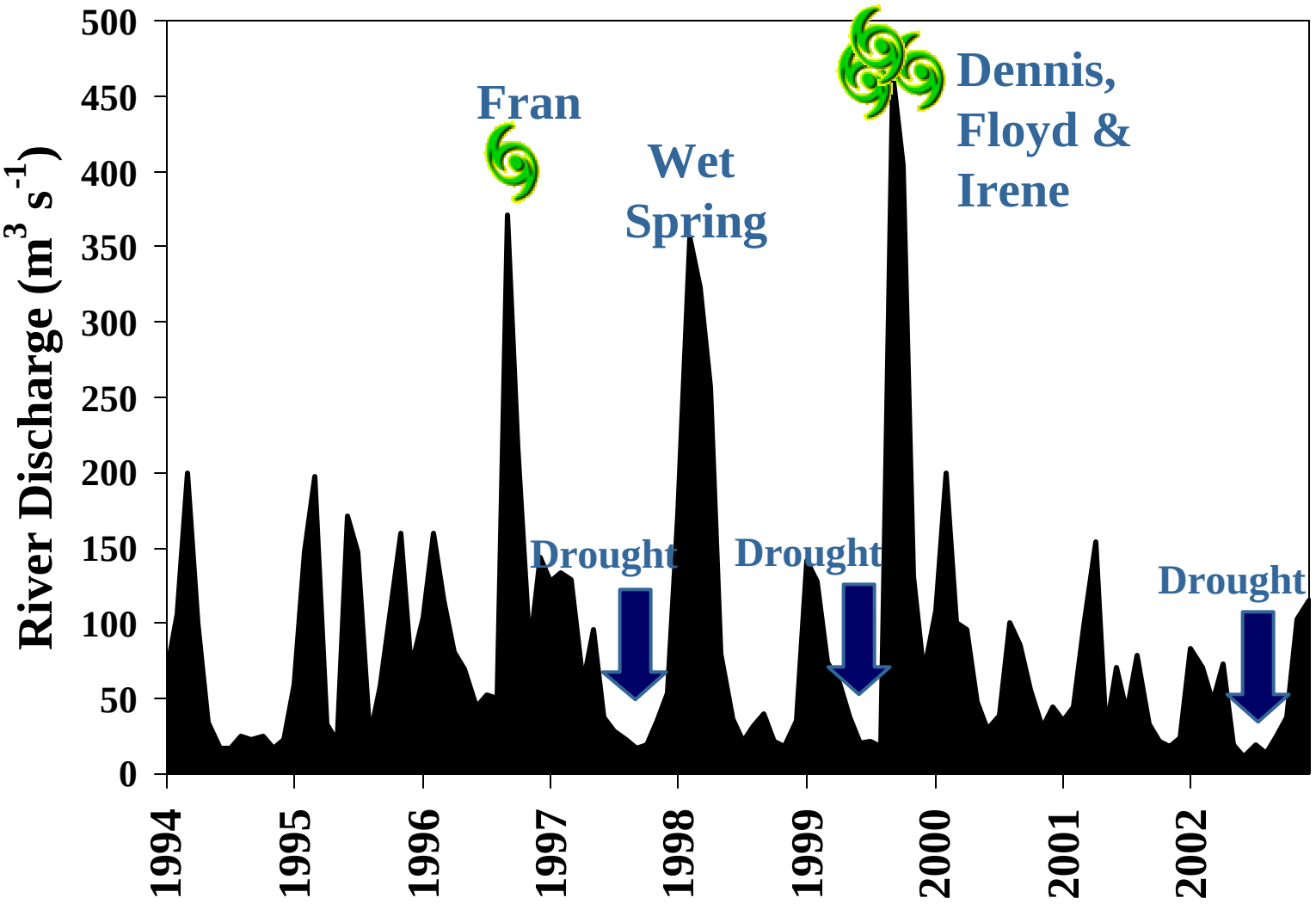
- ↓ Residence Time
- ↓ Salinity

Droughts

- ↓ Rainfall
- ↓ Runoff
- ↓ River Discharge
- ↓ Nutrient Loading

- ↑ Residence Time
- ↑ Salinity

Monthly Mean River Discharge



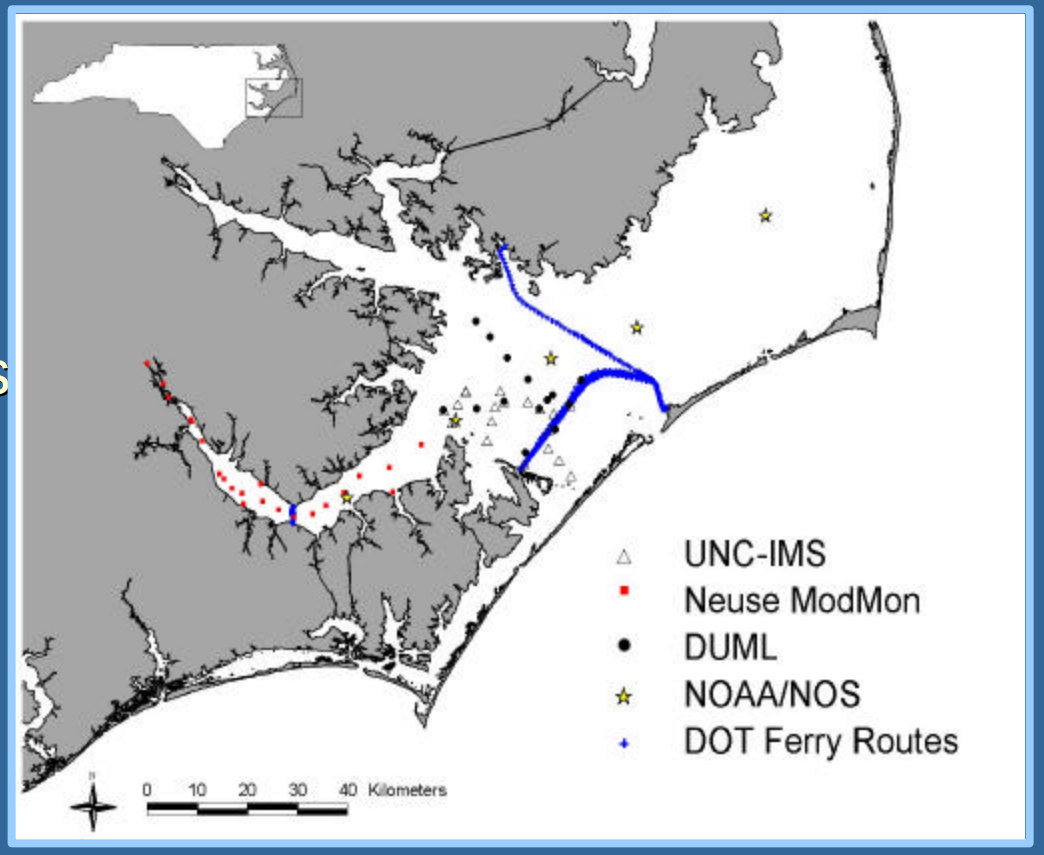
Data from USGS gauging station 2089500

Hypotheses

- Changes in phytoplankton abundance and community composition are due to hydrologic variability (droughts, hurricanes, seasonal rainfall pulses).
- Phytoplankton taxonomic groups are affected differently by the changes in estuarine condition that result from droughts, hurricane activity, and/or seasonal rainfall pulses.
- Therefore, phytoplankton community structure will be different during drought conditions than during hurricane conditions.
- The effects of these hydrologic disturbances on phytoplankton community structure will also vary with hurricane and drought intensity and duration.
- Conditions that were present prior to these hydrologic events will also determine the extent of the influence of these disturbances.
- During heavy rainfall events associated with hurricanes and seasonality, phytoplankton taxonomic groups are transported downstream.

Collaborative Monitoring Programs

- Neuse River Bloom Project (EPA-CISNET, USDA, NSF)
- Atlantic Coast Environmental Indicators Consortium (ACE INC) (EPA-STAR)
- Neuse River Modeling and Monitoring Program (ModMon) (NC DENR, UNC-WRRI)
  - www.marine.unc.edu/neuse/modmon
  - Partners: UNC, ECU, Duke, NCSU, USGS, NCDENR, EPA
  - Collaborators: NOAA-NOS, NASA, NADP, Weyerhauser

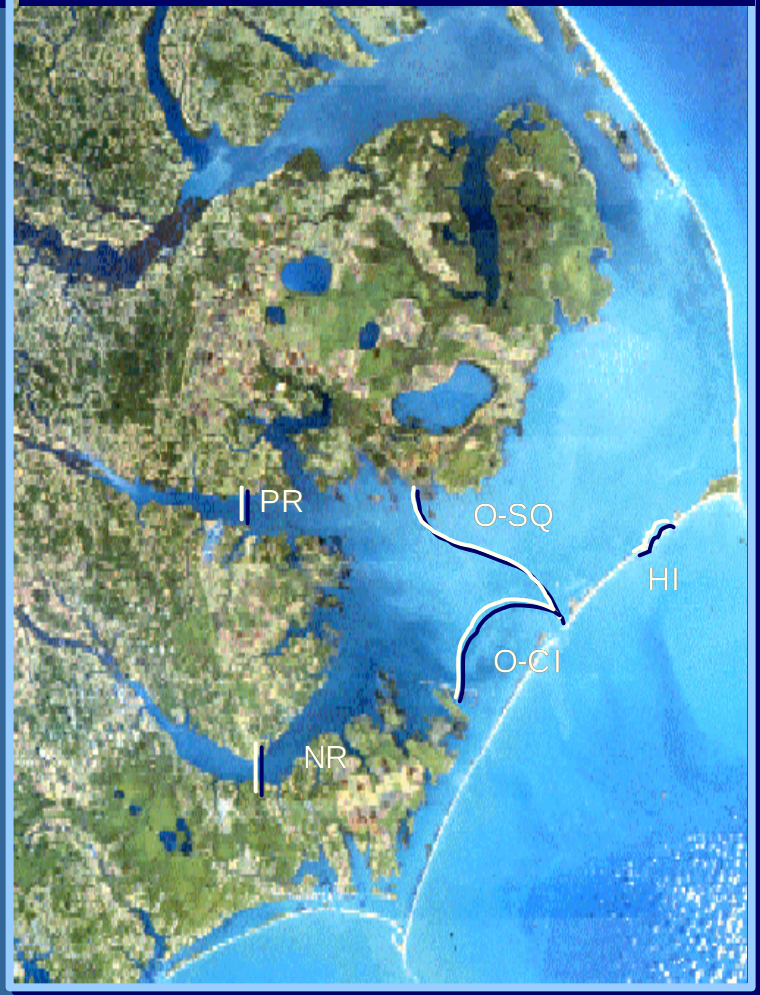


Scaling up: FerryMon (www.ferrymon.org)

Funded by: North Carolina General Assembly in a special appropriation for Hurricane Floyd Relief and administered by the North Carolina Department of Environment and Natural Resources (DENR), Water Quality Division.

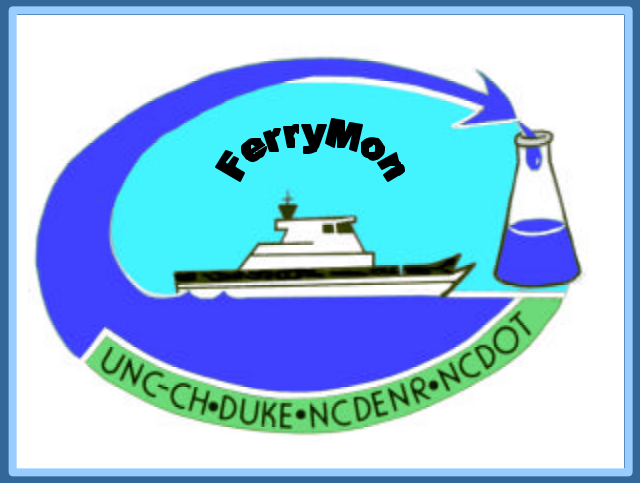
- Salinity
- Temperature
- Dissolved Oxygen
- Turbidity
- pH
- Chlorophyll *a* fluorescence

- Nutrients
- Diagnostic Photopigments



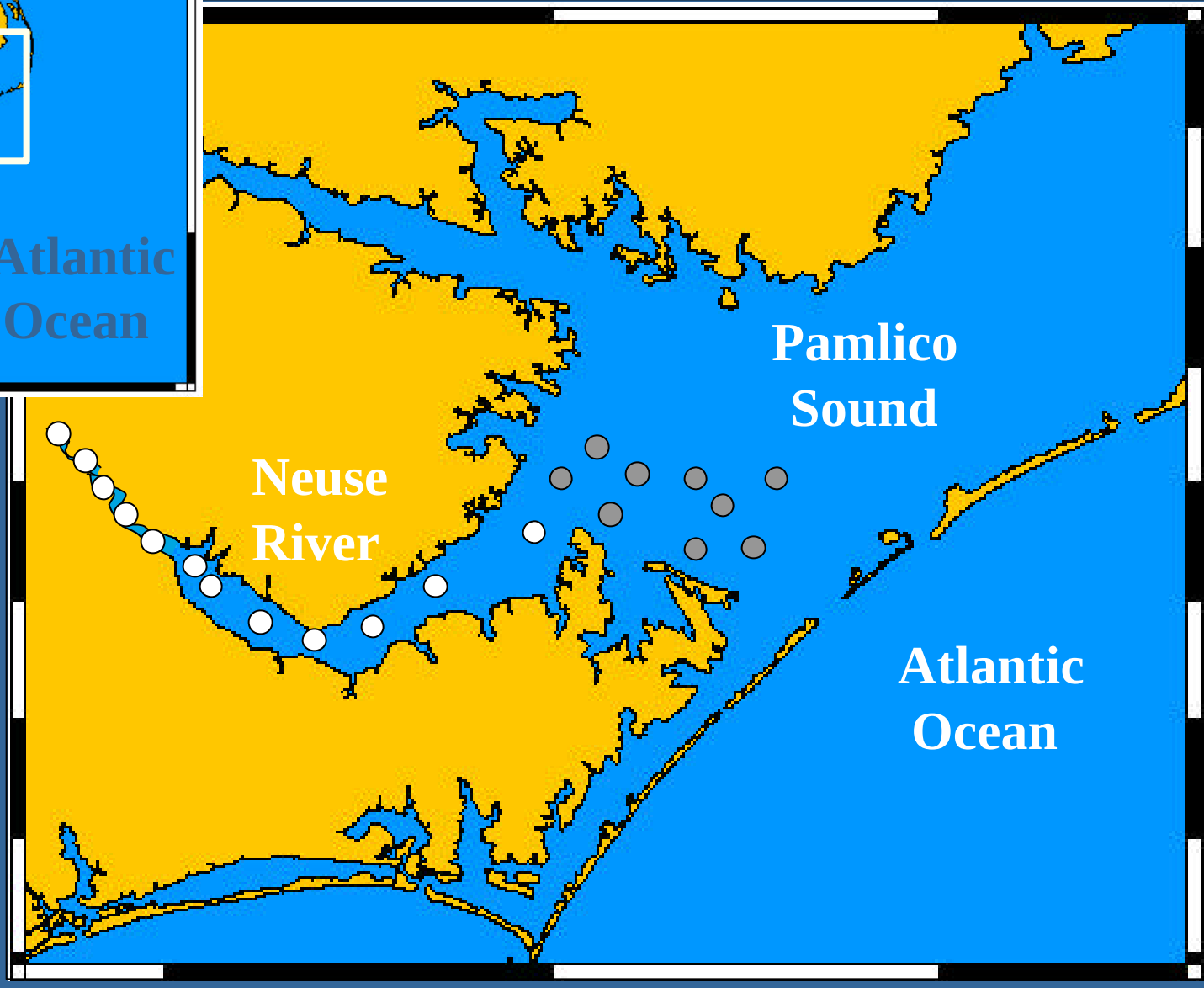
Scaling up: FerryMon (www.ferrymon.org)

- Innovative sampling method
- Cost-effective
- Allows more intensive spatial and temporal coverage
- Automatic
- Can be serviced at the dock
- National application
- Not dependent on weather conditions

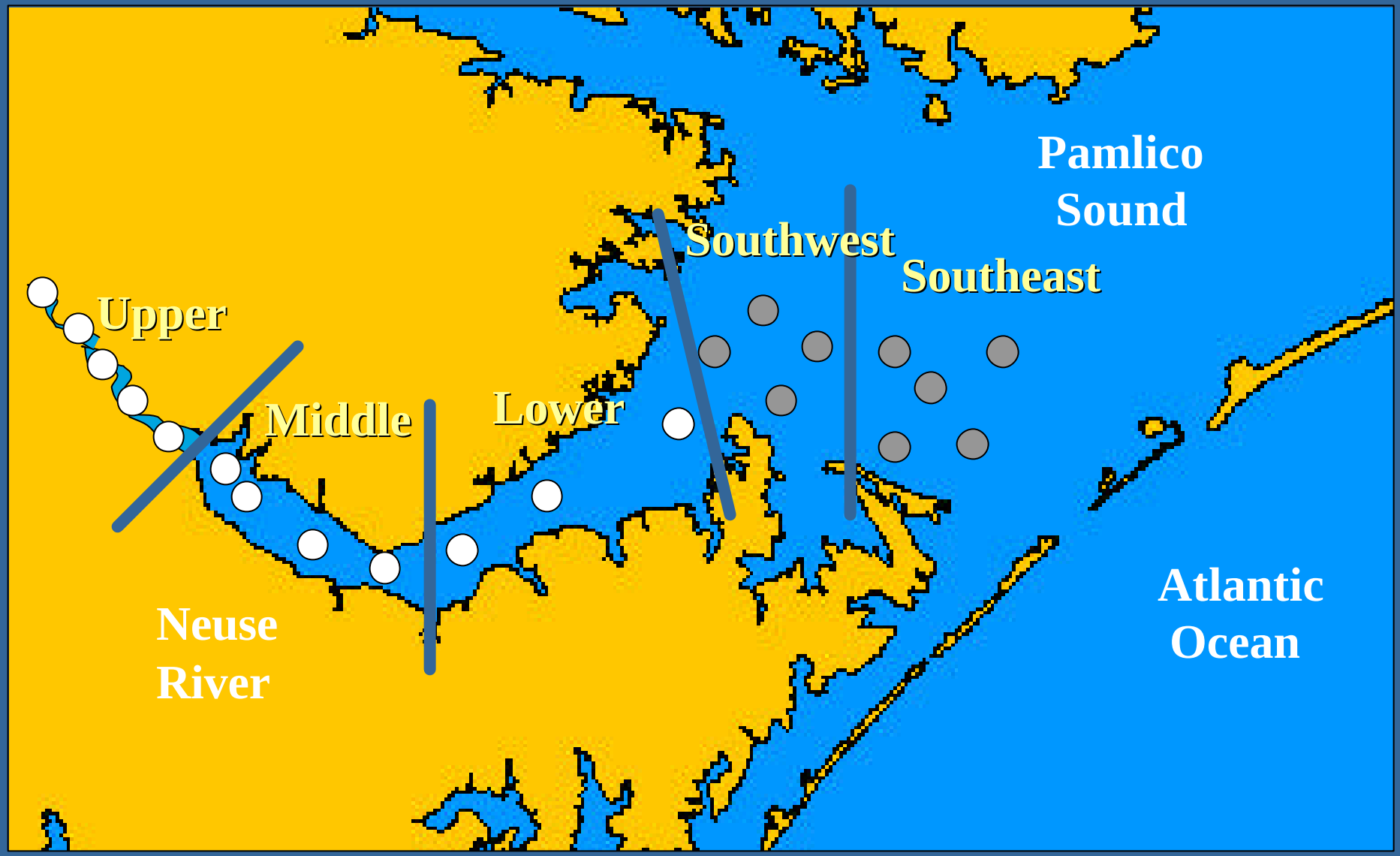


Funded by: North Carolina General Assembly in a special appropriation for Hurricane Floyd Relief and administered by the North Carolina Department of Environment and Natural Resources (DENR), Water Quality Division.

Sampling Locations



Study Regions



Methods:
Water sample ➡ ChemTax Results

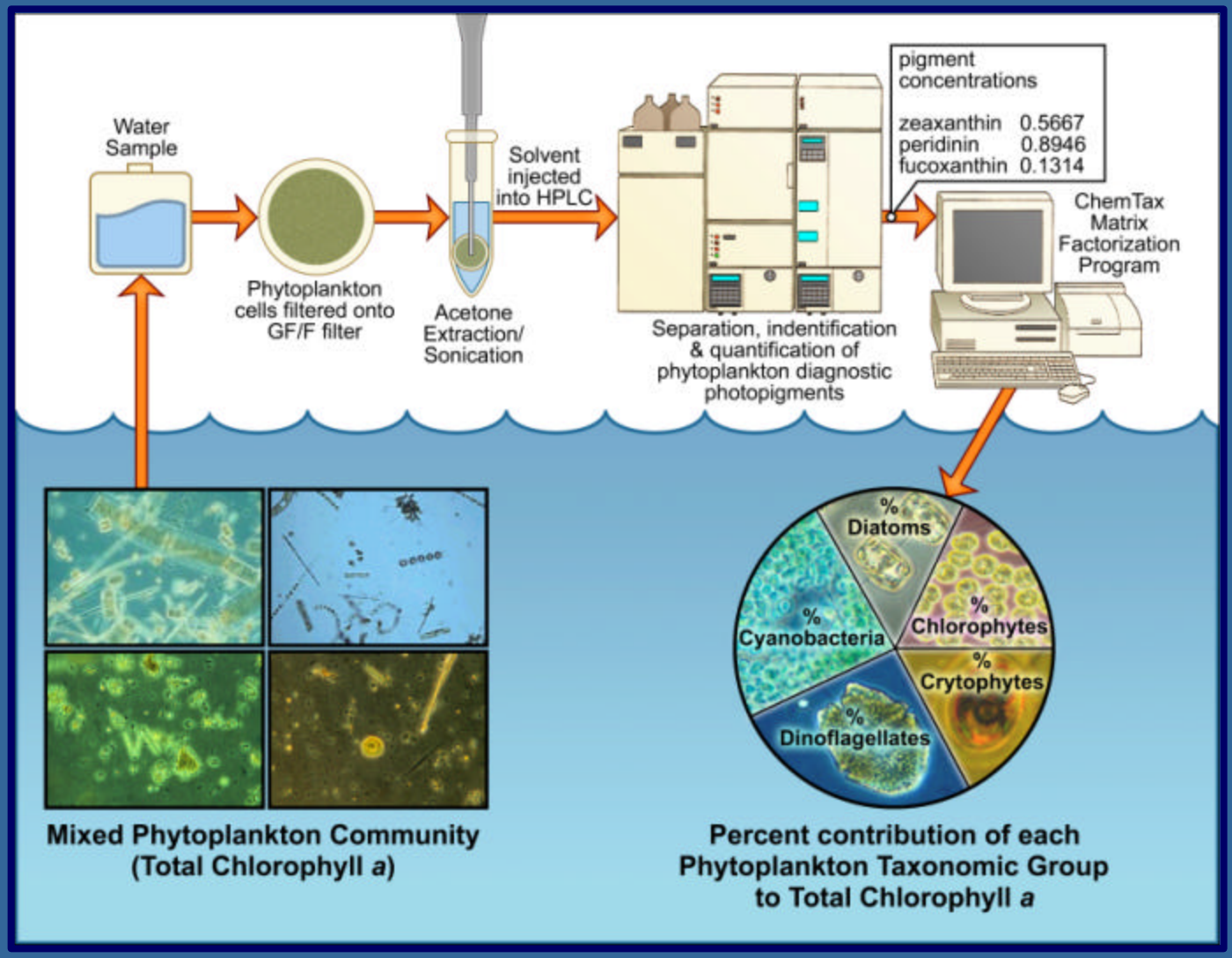
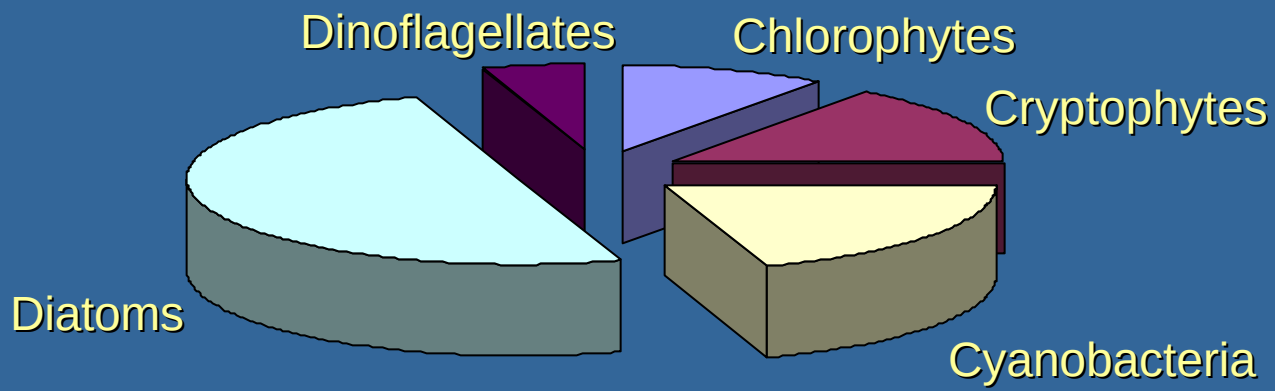


Figure by Alan R. Joyner

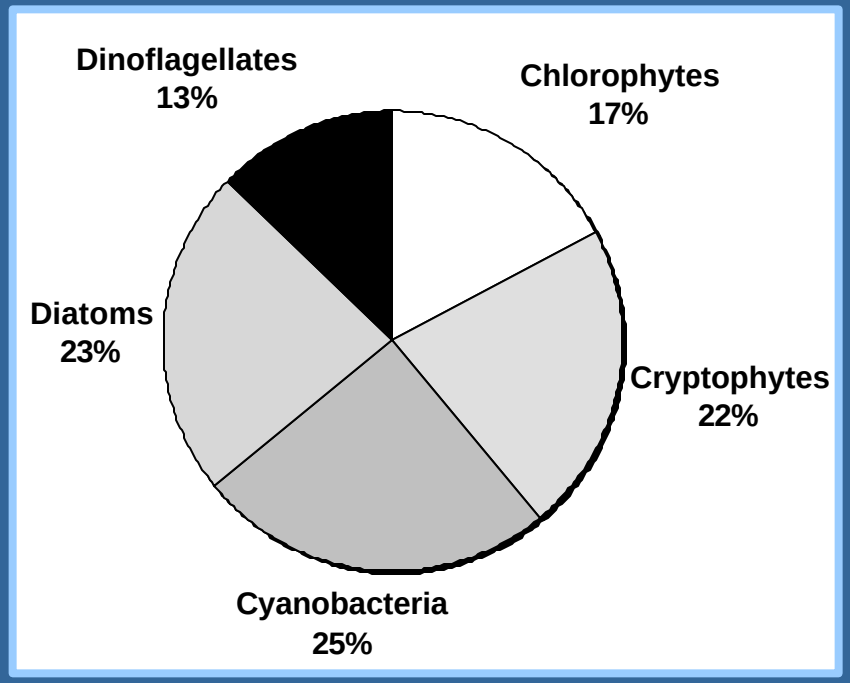
ChemTax

- Matrix-factorization program
- Partitions total chlorophyll *a* pool

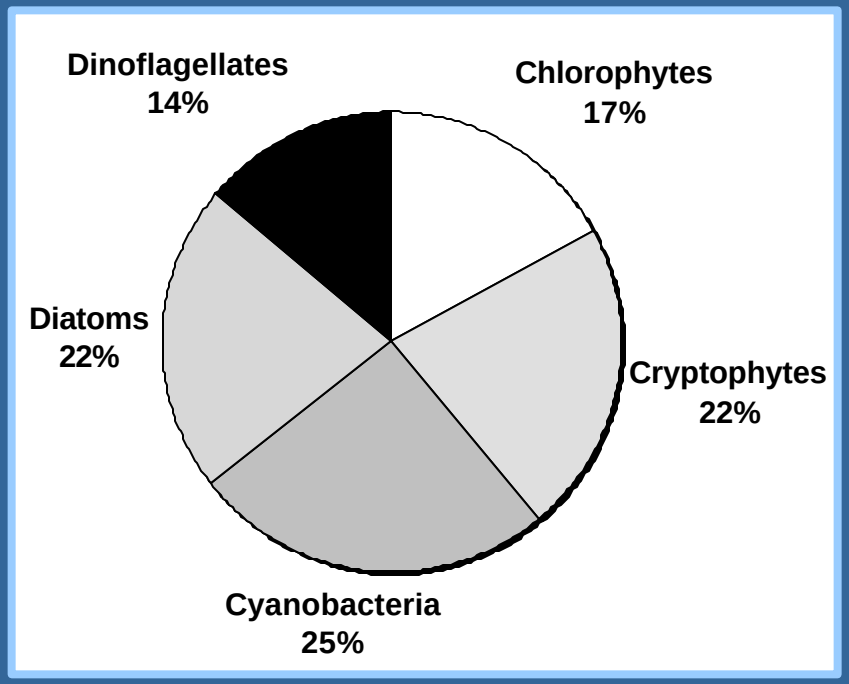


- Based on an initial pigment ratio matrix

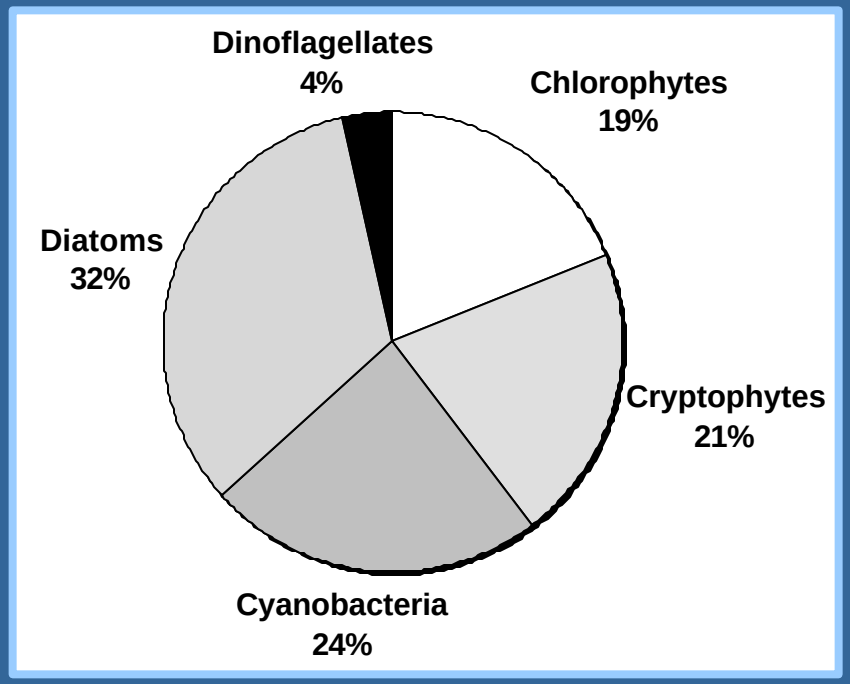
Neuse River & Pamlico Sound (1994-2002)



Neuse River Estuary (1994-2002)

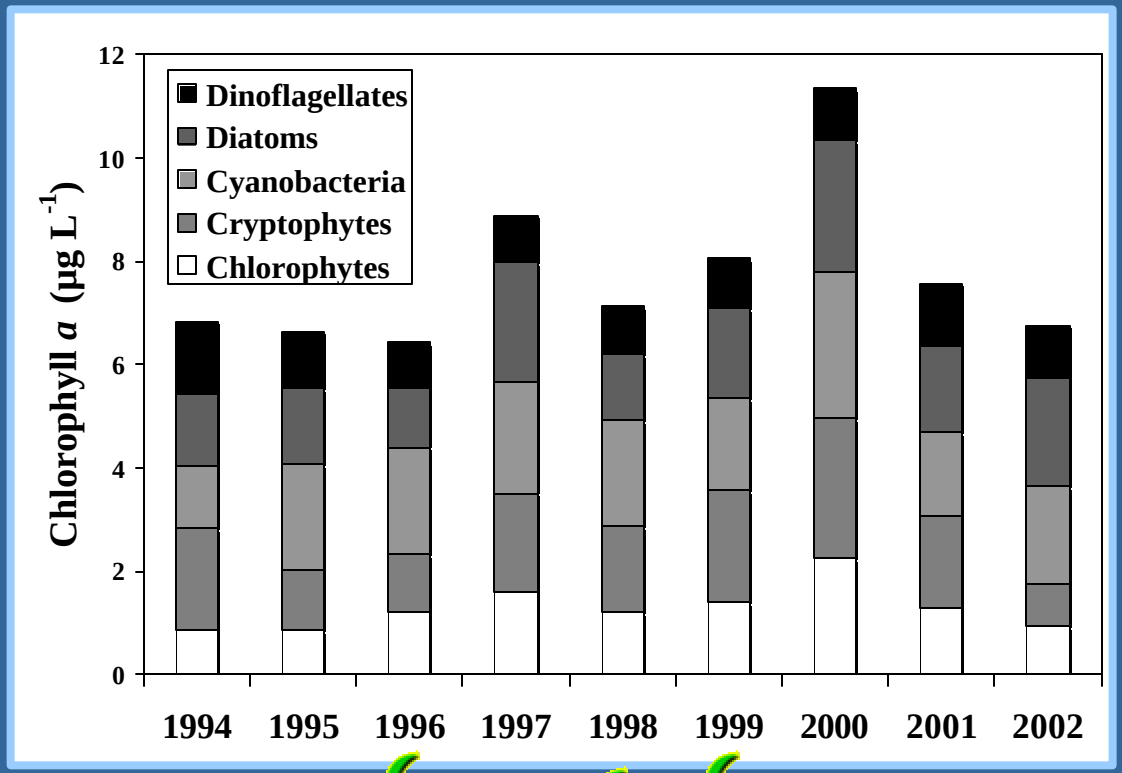


Pamlico Sound (Fall 1999-2002)



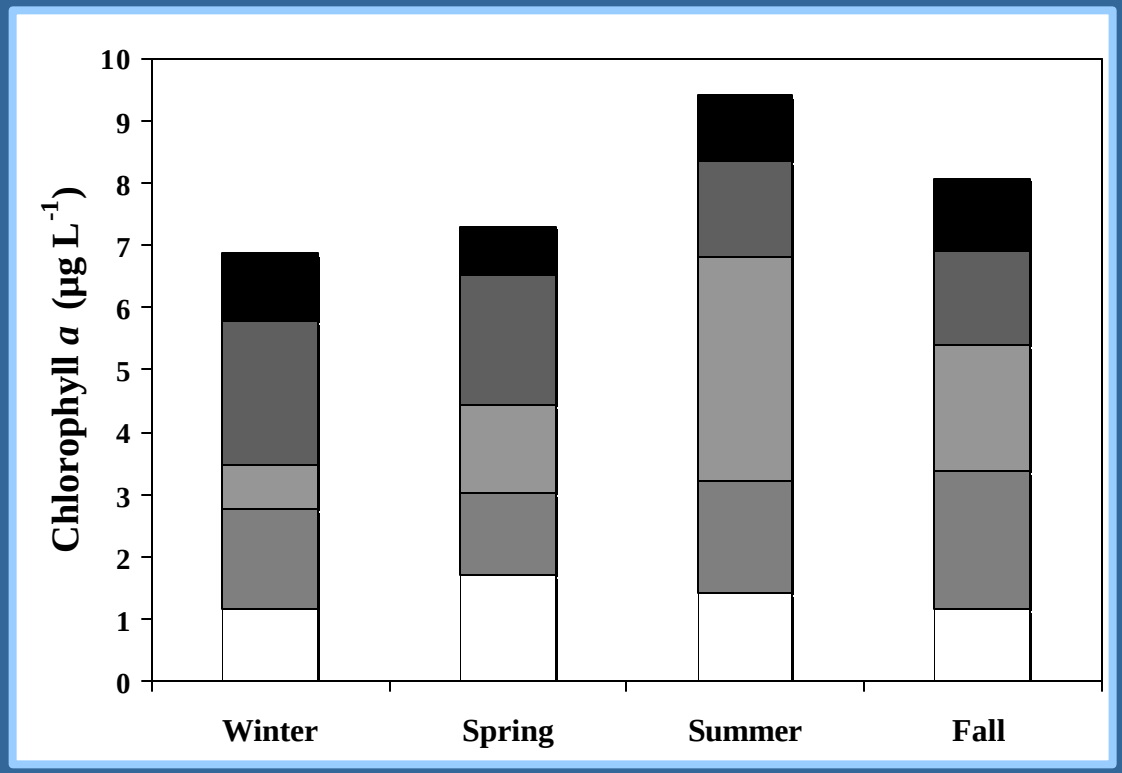
Annual Trends

- Total chlorophyll *a* and the abundance of each phytoplankton group was significantly different between years
- Significant differences were detected between the abundance of the different taxonomic groups within years



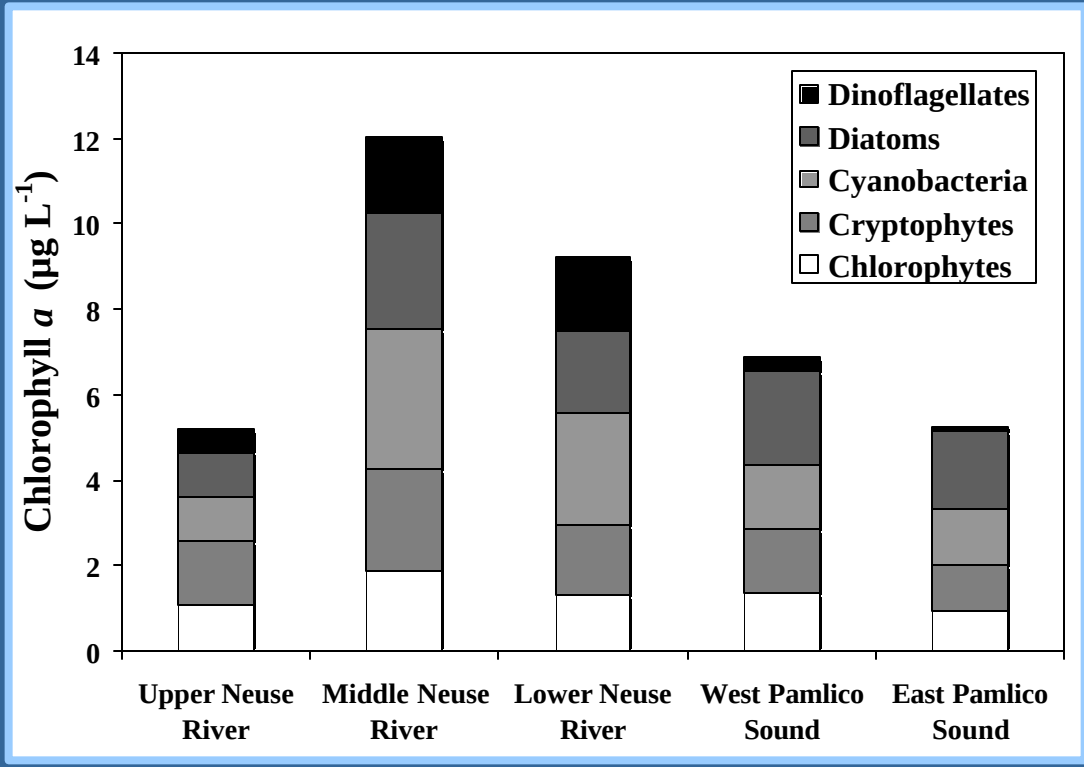
Seasonal Trends

- Winter
  - Diatoms are dominant
- Spring
  - Diatoms and chlorophytes are dominant
- Summer
  - Greatest total concentrations
  - Cyanobacteria are dominant
- Fall:
  - Cryptophytes and cyanobacteria have greatest abundance

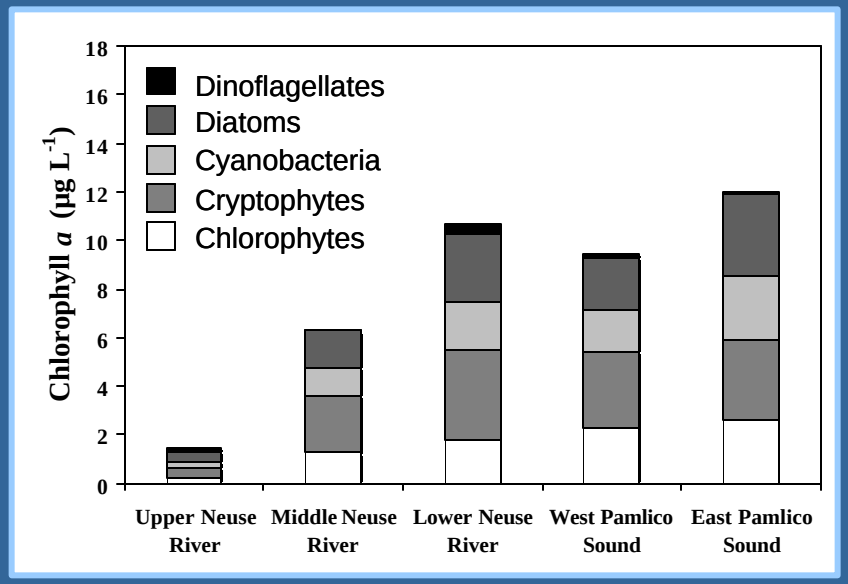


Spatial Trends

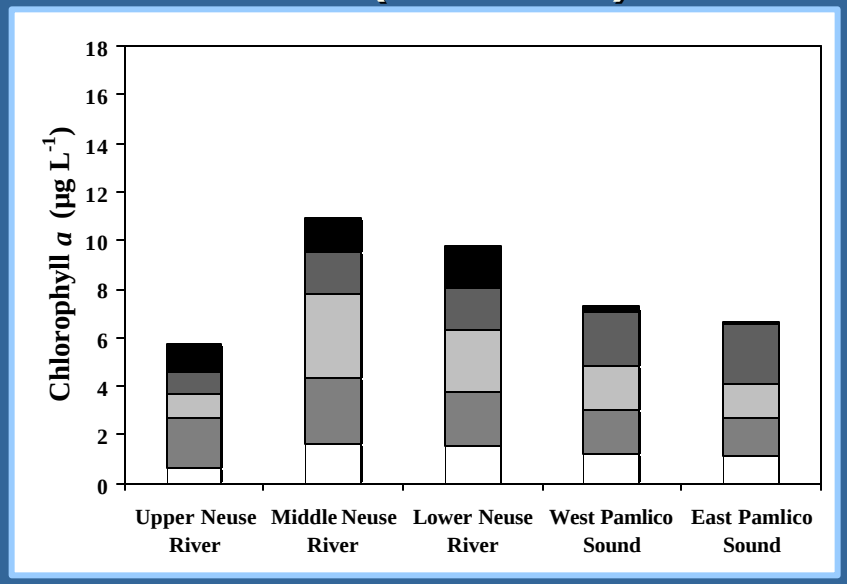
- Lowest total concentrations
  - Upper Neuse River and Pamlico Sound
- Highest total concentrations
  - Middle and Lower Neuse River
- All groups more abundant in Middle Neuse River
- Dinoflagellates more abundant in the Neuse River than in Pamlico Sound
- Diatoms least abundant in Upper Neuse River



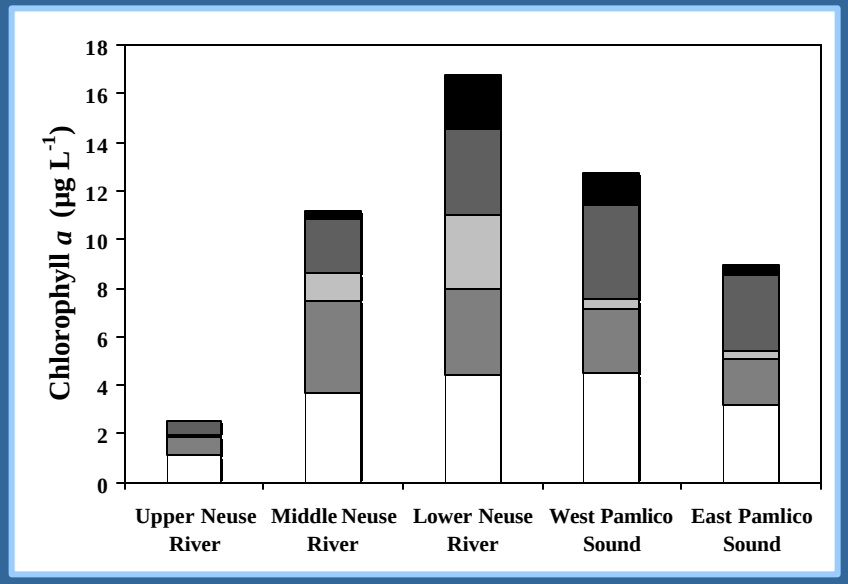
Hurricanes Dennis, Floyd, Irene, Fall 1999



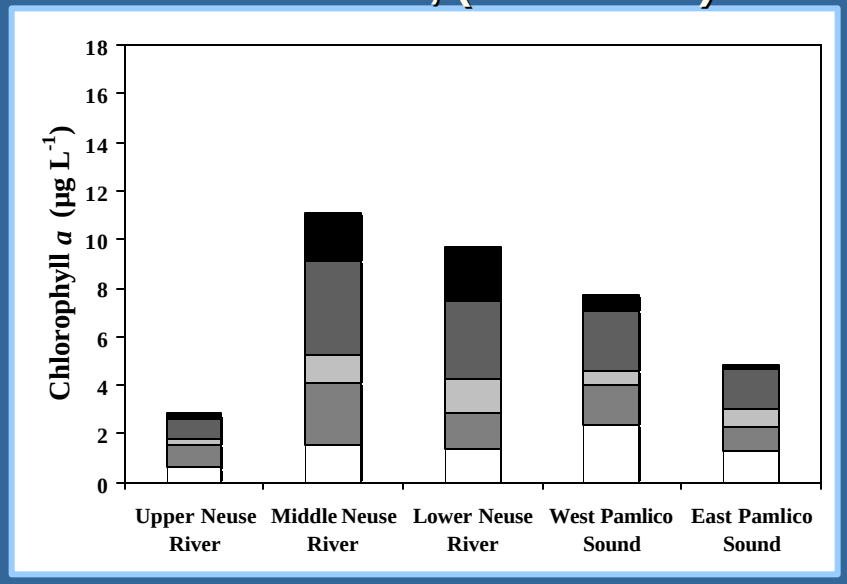
Long Term Mean Fall (1994-2002)



Winter 1999



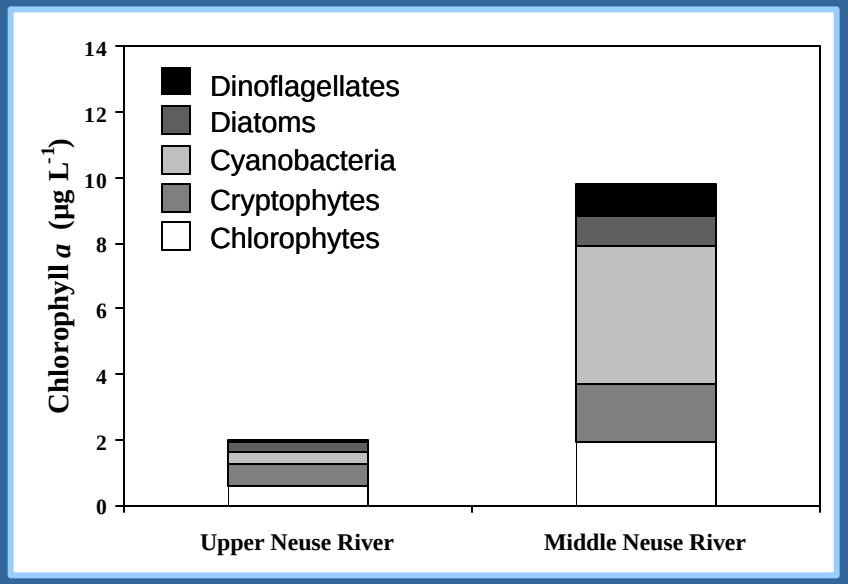
Winter LTM, (1994-2002)



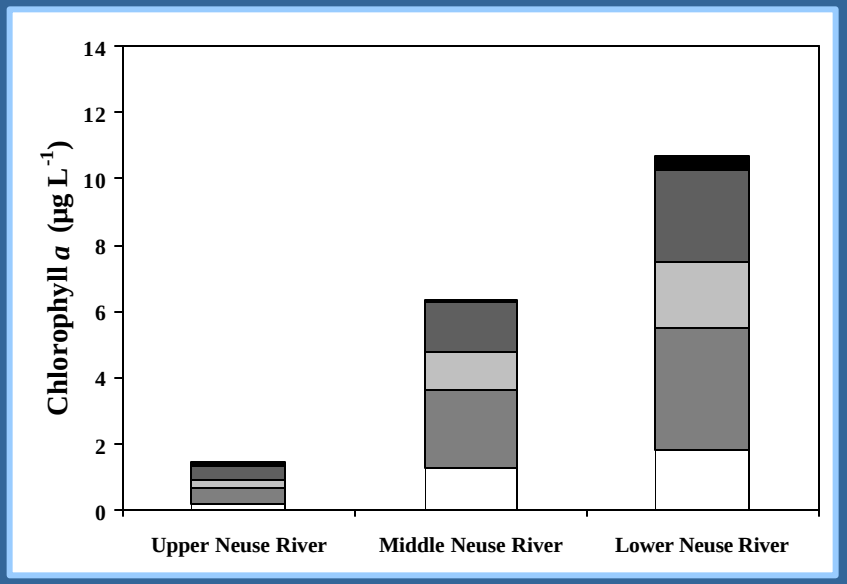
Hypotheses

- Phytoplankton community structure will be different during drought conditions than during hurricane conditions.
- The effects of these hydrologic disturbances on phytoplankton community structure will also vary with hurricane and drought intensity and duration.
- Comparisons can be made between Hurricane Fran 1996, the Fall 1999 Hurricanes and the 1997 drought.

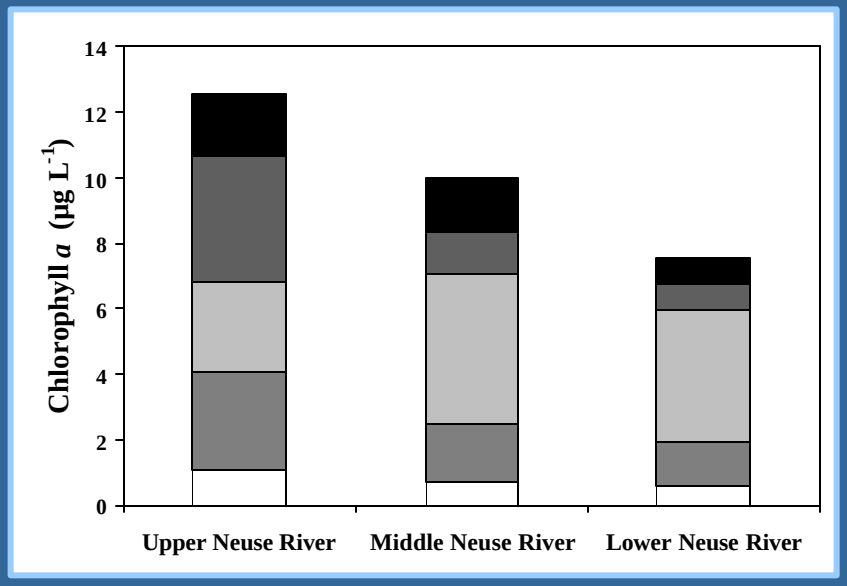
Hurricane Fran, Fall 1996



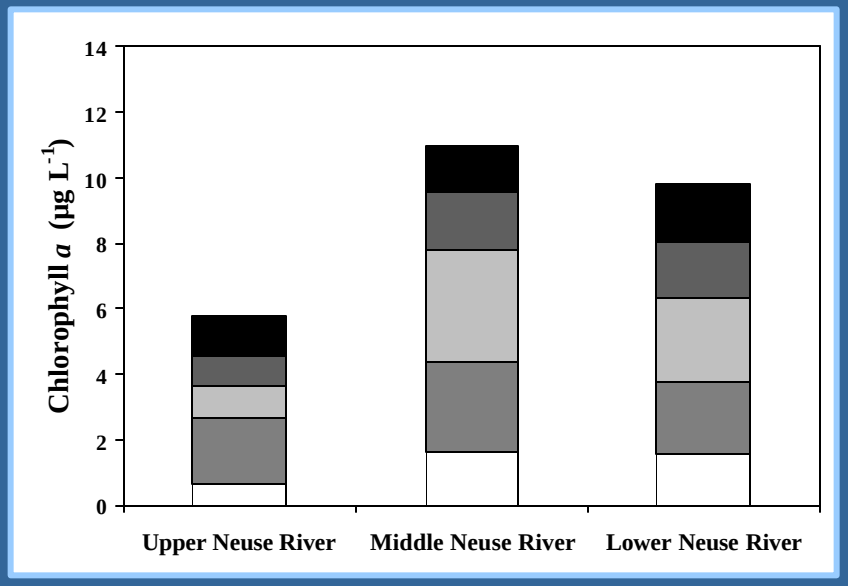
Hurricanes Dennis, Floyd, Irene, Fall 1999



Drought, Fall 1997

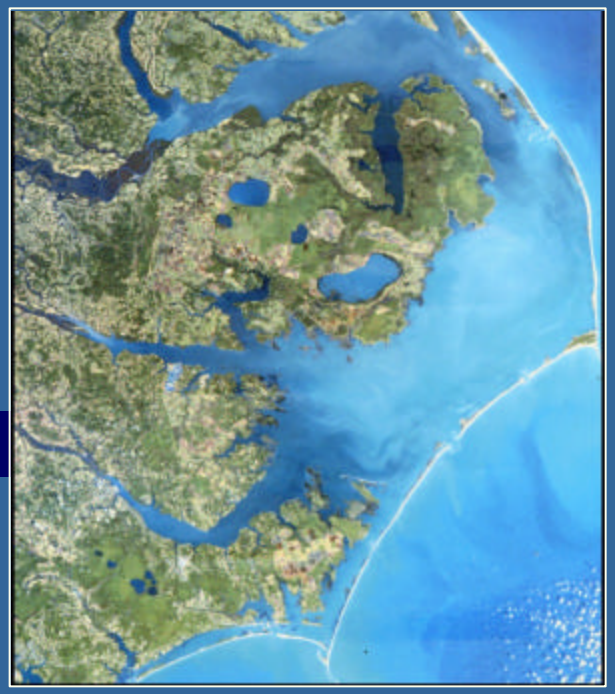


Fall LTM (1994-2002)



Applications of Long-term Monitoring Data

Establishing a Reference Condition for Phytoplankton Community Structure



- What is a pristine phytoplankton community?
  - What Groups? In what proportion? At what concentrations?
- What is considered to be a normal year in a dynamic estuary such as the Neuse River-Pamlico Sound system?
- Long term data allow us to estimate the baseline/reference condition
- Use the mean of the long term data (1994-2002) as the reference condition (spatial, annual, seasonal).
- Compare the phytoplankton community during hydrologic disturbance to these average (baseline) conditions.

Phytoplankton Taxonomic Groups as Indicators of Estuarine Ecological Condition and Change

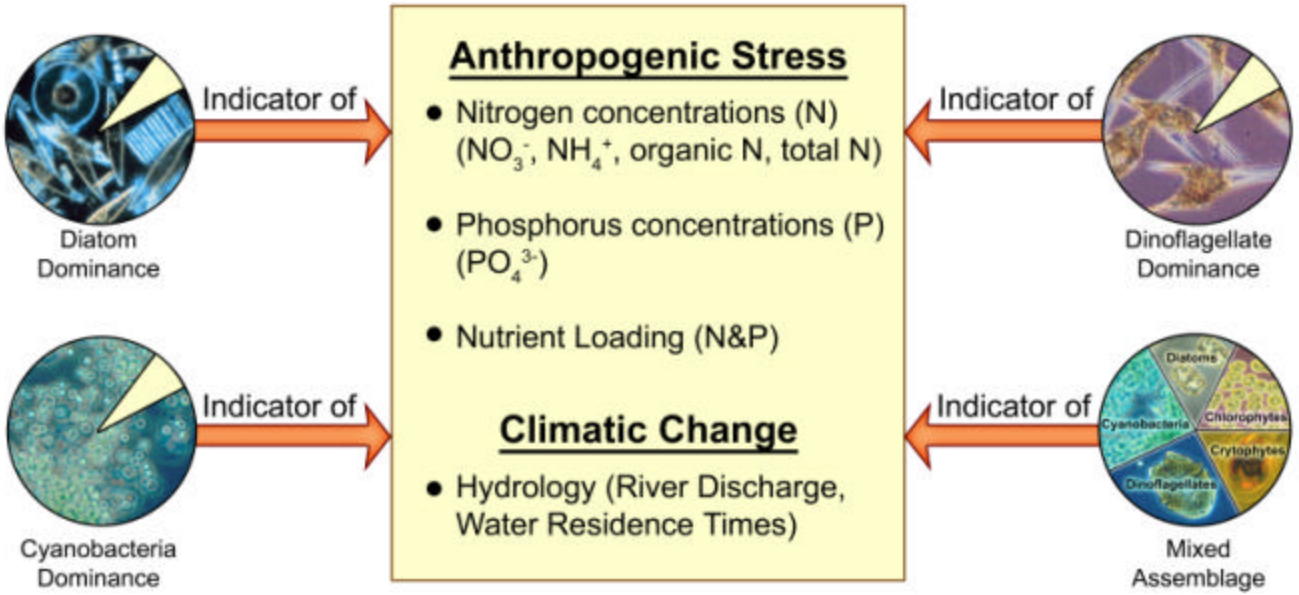
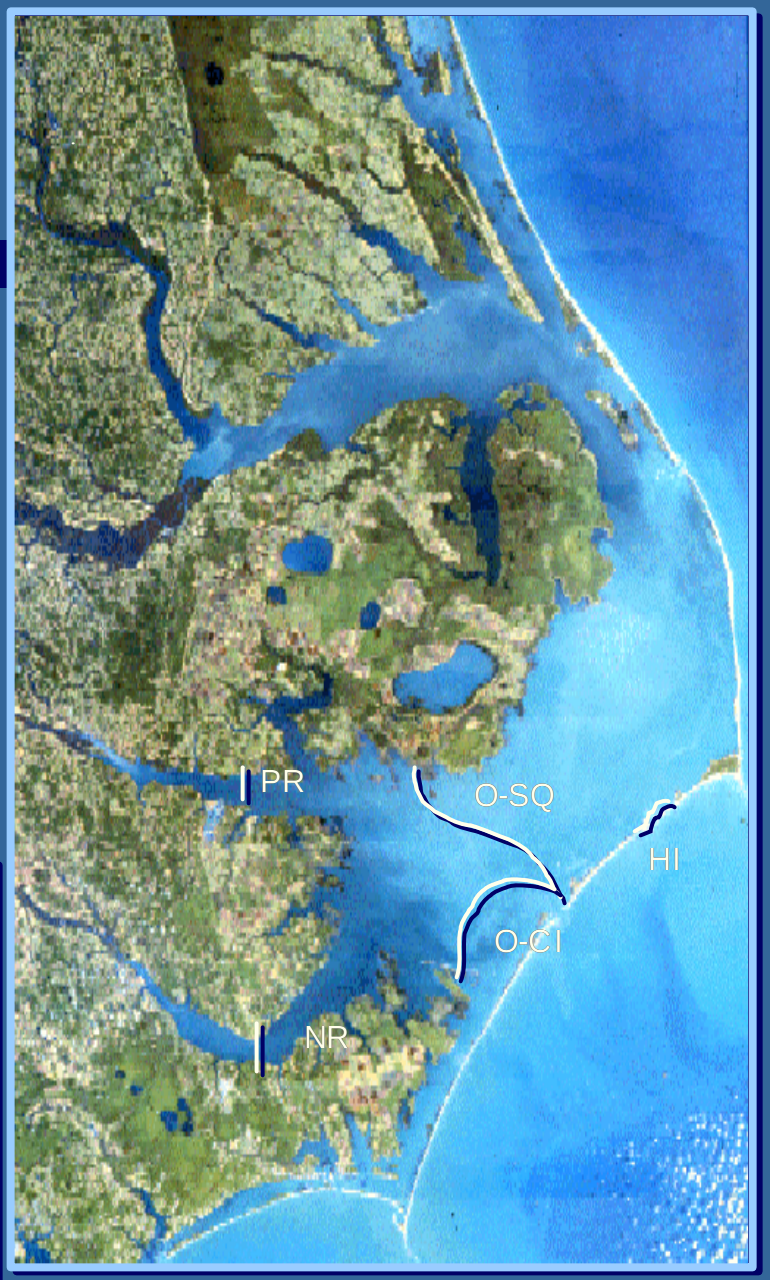


Figure by Alan R. Joyner

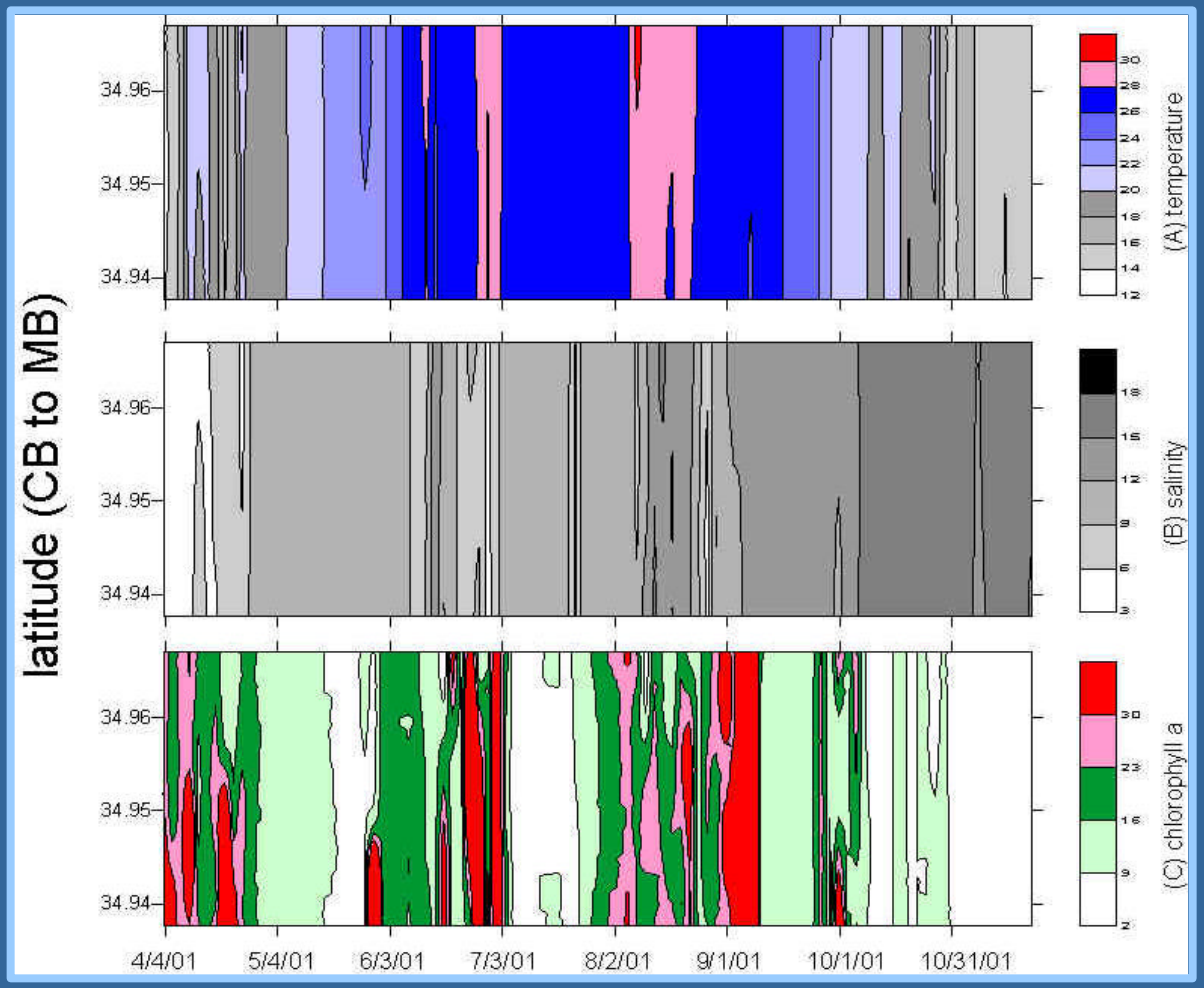
Scaling up: FerryMon (www.ferrymon.org)

- Salinity
- Temperature
- Dissolved Oxygen
- Turbidity
- pH
- Nutrients
- Chl a
- Diagnostic Photopigments



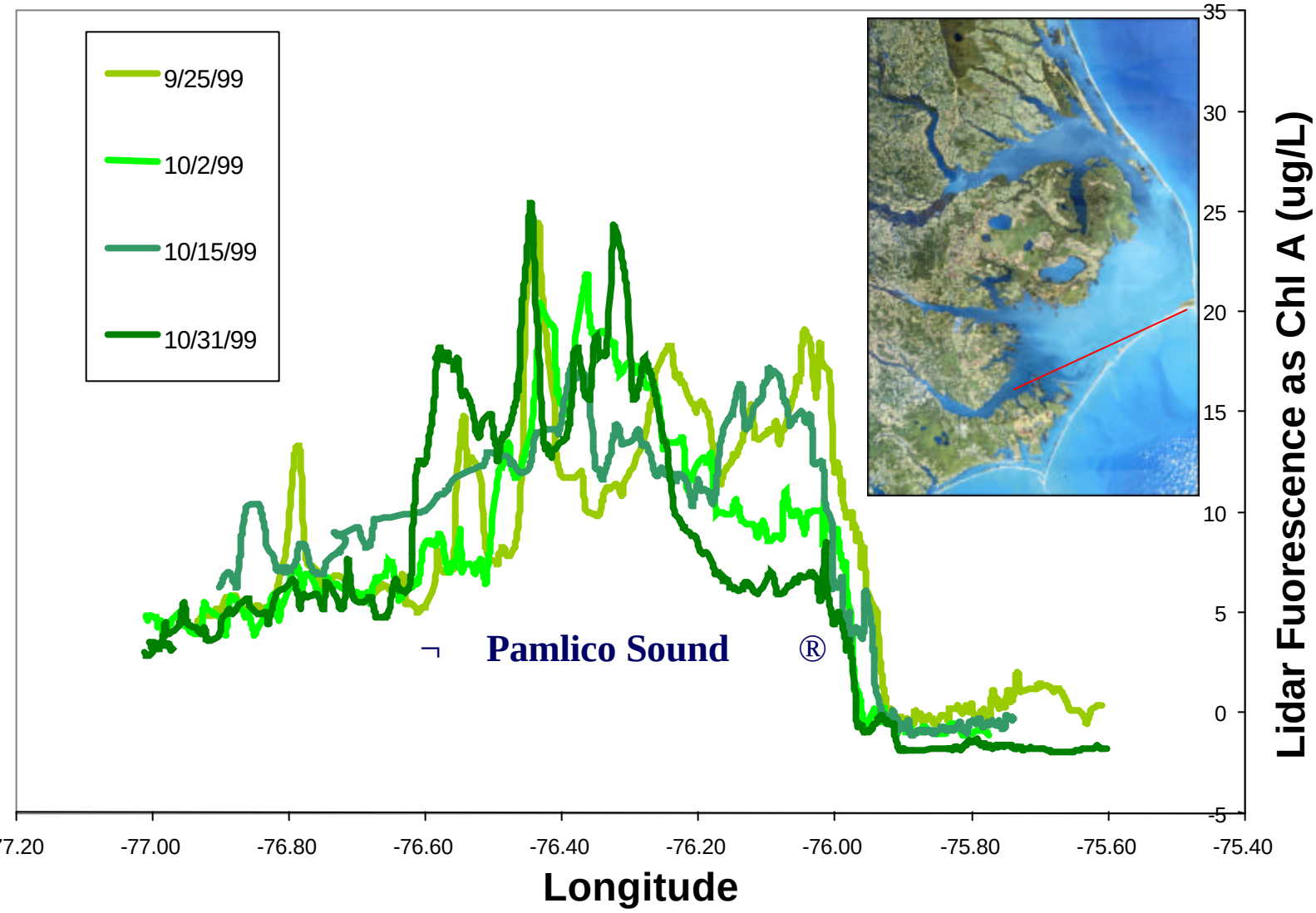
Neuse River Estuary Crossing: Interpolated Space-Time Plot

- Blooms occur in different areas of the river
- Frequency of bloom events is greater than sampling frequency
- Importance of intensive monitoring
  - -temporal
  - -spatial



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



Nutrient-Phytoplankton Relationships at the Chlorophyll *a* Maximum of the Neuse River Estuary

- Nutrient addition bioassays
- Upstream, downstream and at the estuarine chlorophyll *a* maximum (CMax)
- Long term data used to determine historical locations of the CMax
- Long term monitoring data provides valuable context for these and other manipulative experiments

Conclusions

- Temporally and spatially intensive monitoring is required in systems driven by large-scale events like the NRE-PS.
- HPLC/ChemTax analyses of pigments allow faster and more reproducible identification and quantification of phytoplankton taxonomic classes than traditional microscopic counting techniques.
- Monitoring of diagnostic photopigments:
  - Provides more information about the phytoplankton community than traditional chlorophyll *a* measurements alone.
  - Can easily be applied to already existing university, state and federal monitoring programs.
  - Provides ground truthing for remote sensing of phytoplankton pigments.

Acknowledgements

- This research has been supported by a grant from the US Environmental Protection Agency's Science to Achieve Results (STAR) Estuarine and Great Lakes (EaGLe) Coastal Program.
- NSF
- NC SeaGrant
- NC DENR
- USDA-NRI
- Paerl Lab