Connecting atmospheric deposition of nitrogen to coastal water quality

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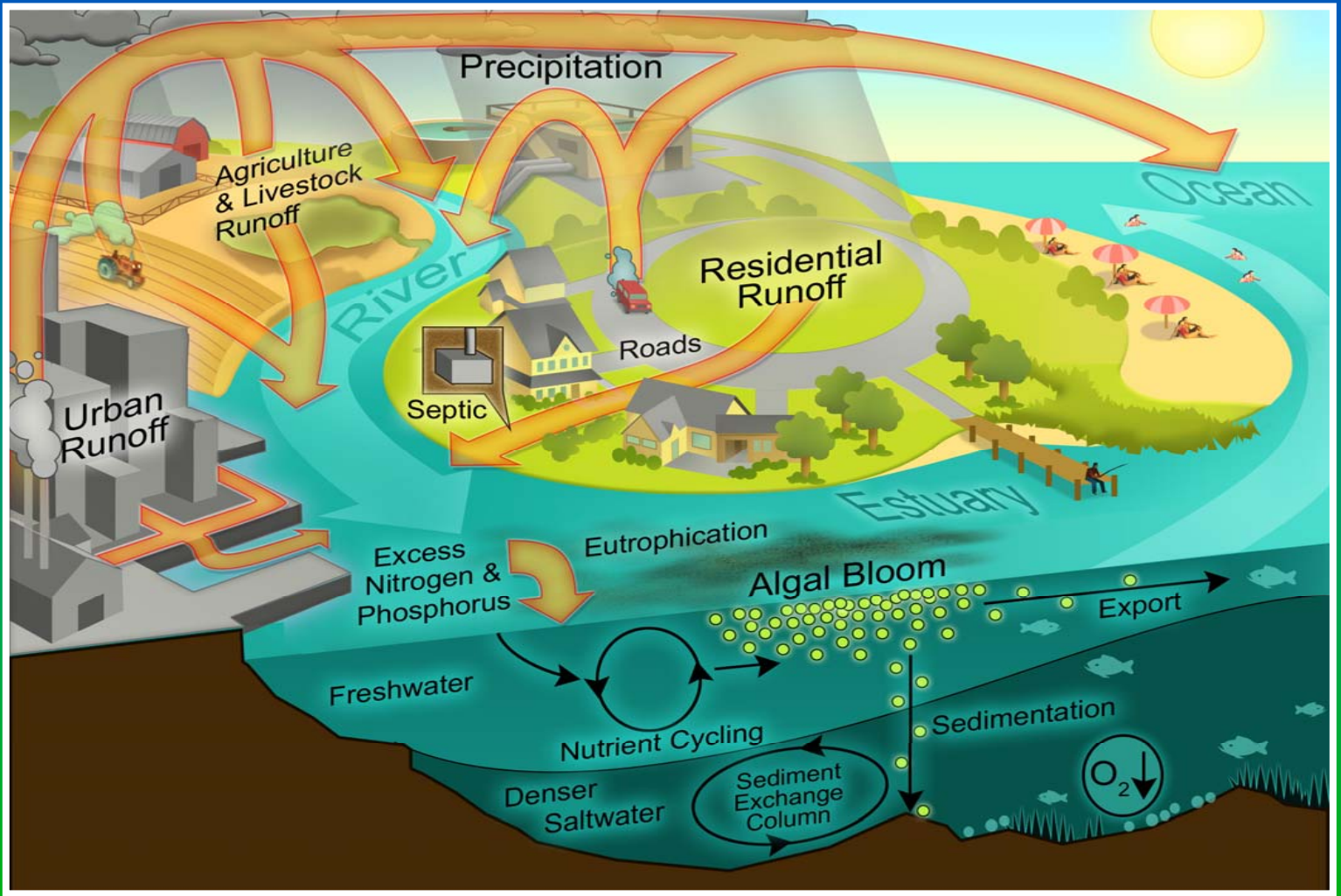
Questions

- How important is AD-N as a "new" N source?
- What are the origins & chemical forms of AD-N?
- What are the ecological impacts on specific coastal ecosystems?
- What are the spatio-temporal issues for monitoring and assessment?



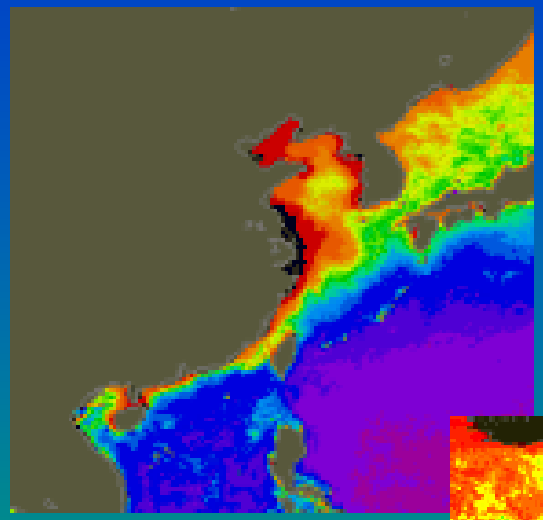
Estimated contributions of AD-N* to "new" N inputs in estuarine, coastal and open ocean waters

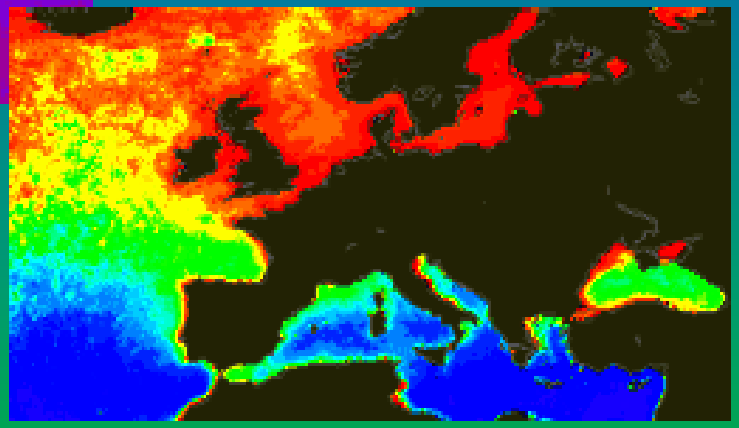
• Baltic Sea	~30 %	Elmgren et al. 2001
• North Sea (Coastal)	20-40%	Holland et al. 1999
• W. Mediterranean Sea	10-60%	Martin et al. 1989
• Waquoit Bay, MA	>29%	Valiela et al. 1996
• Narragansett Bay	12%	Nixon 1995
• Long Island Sound	>25%	L. I. Sound Study 1996
• New York Bight	38%	Valigura et al. 1996
• Barnegat Bay, NJ	~40%	Moser et al. 2002
• Chesapeake Bay	30%	Castro et al. 2002
• Rhode River, MD	40%	Correll and Ford 1982
• Neuse R., NC	~35%	Whitall et al 2003
• Pamlico Sound, NC	20->40%	Paerl et al. 2002
• Sarasota/Tampa Bay, FL	~ 30%	Sarasota Bay NEP 1996
• Mississippi River Plume	> 5 % ??	Goolsby et al. 2000

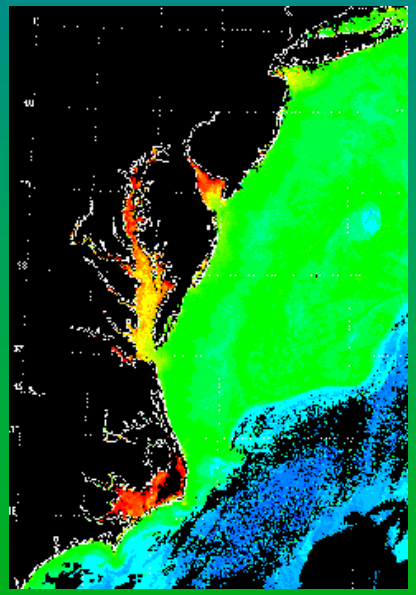
* Includes estimates of wet and dry deposition, inorganics and organics

Why The Ecological Concern About AD-N in Coastal Waters?

- Many of these N-sensitive eutrophying waters waters are currently impacted by AD-N







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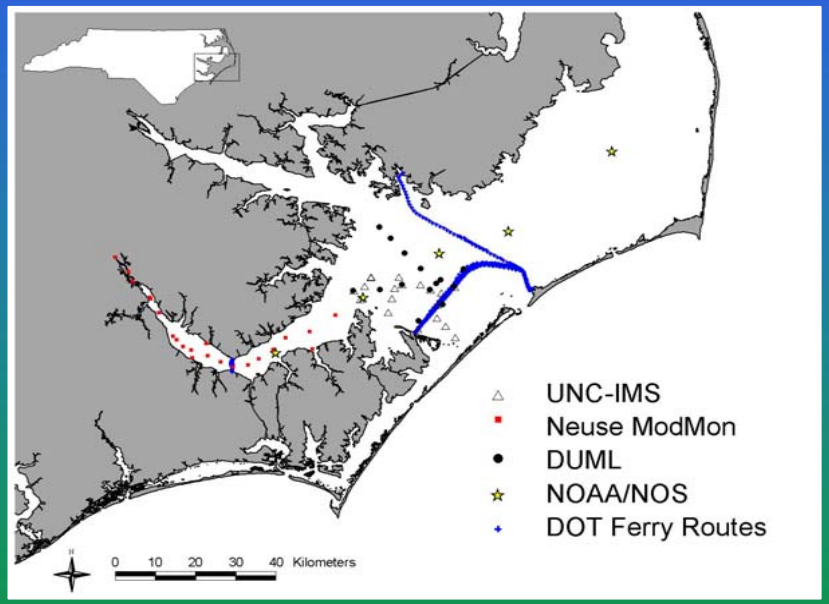
Example: The Neuse R. Estuary-Pamlico Sound

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



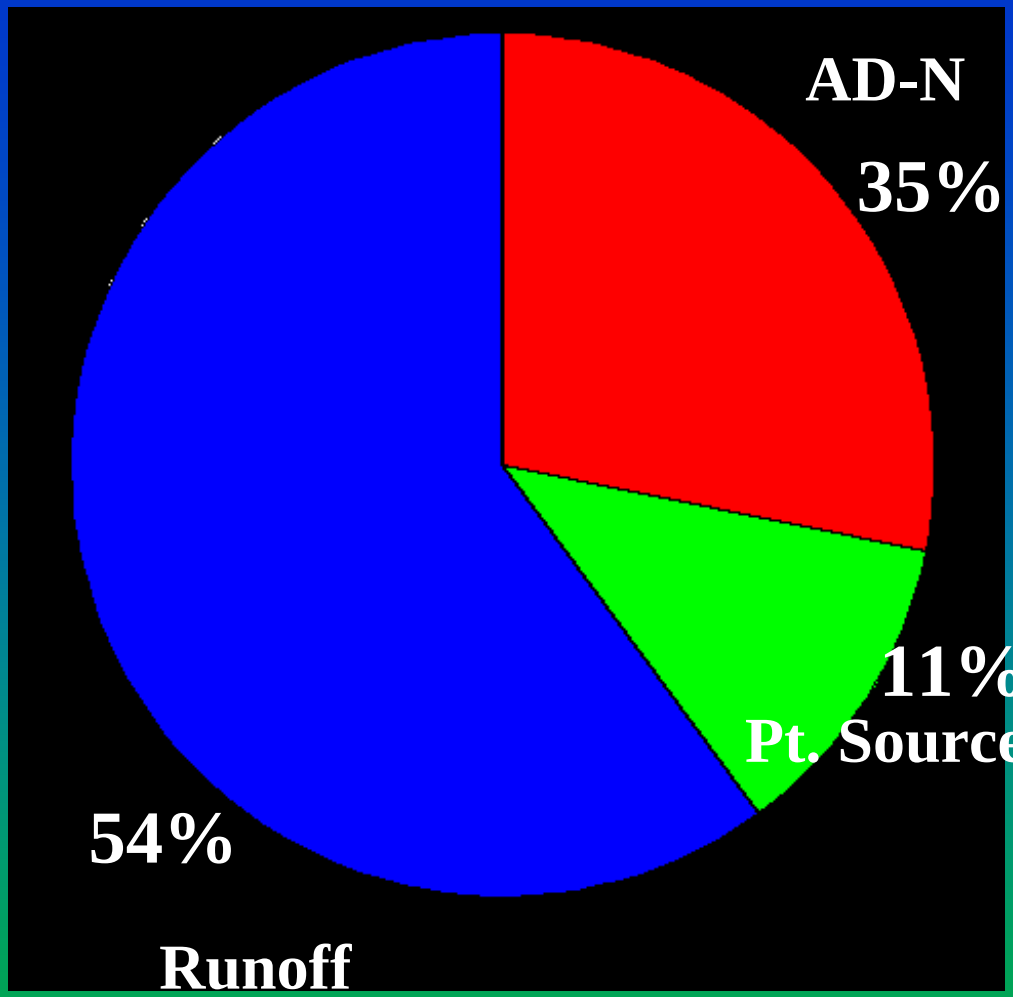
Neuse R Modeling & Monitoring Program (ModMon)

www.marine.unc.edu/neuse/modmon

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

Collaborators: NOAA-NOS, NASA, NADP, Weyerhaeuser

Neuse River Estuary N Sources (at head of estuary)



N Retention Values	
Forest	0.95
Pasture	0.90
Crop	0.70
Urban	0.70
Other	0.70

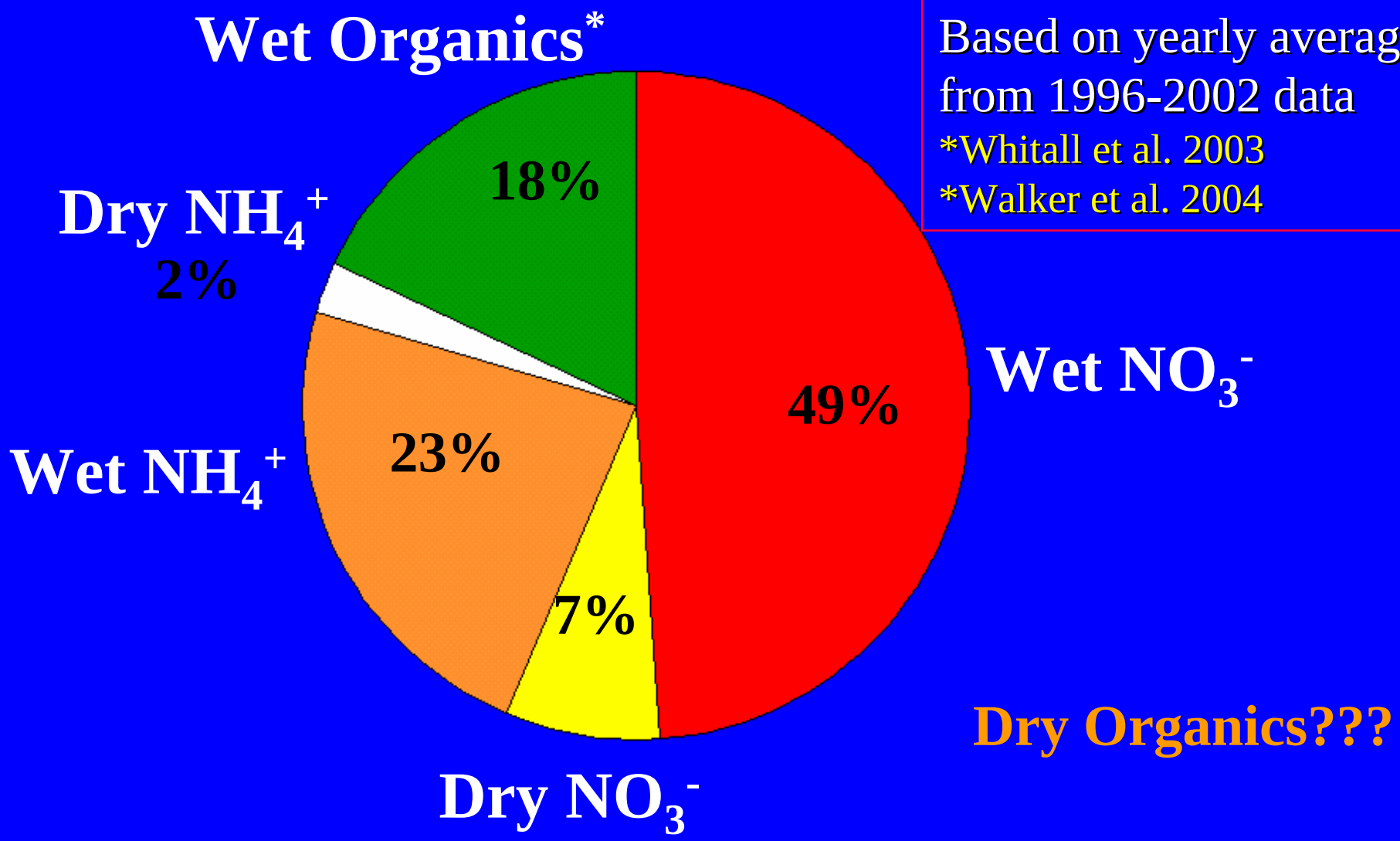
from Valigura et al. 1996

Runoff (excluding AD-N)and point source values from Dodd et al. 1992.

AD-N based on yearly averages from 1996-1999 data, from Whitall et al. 2003

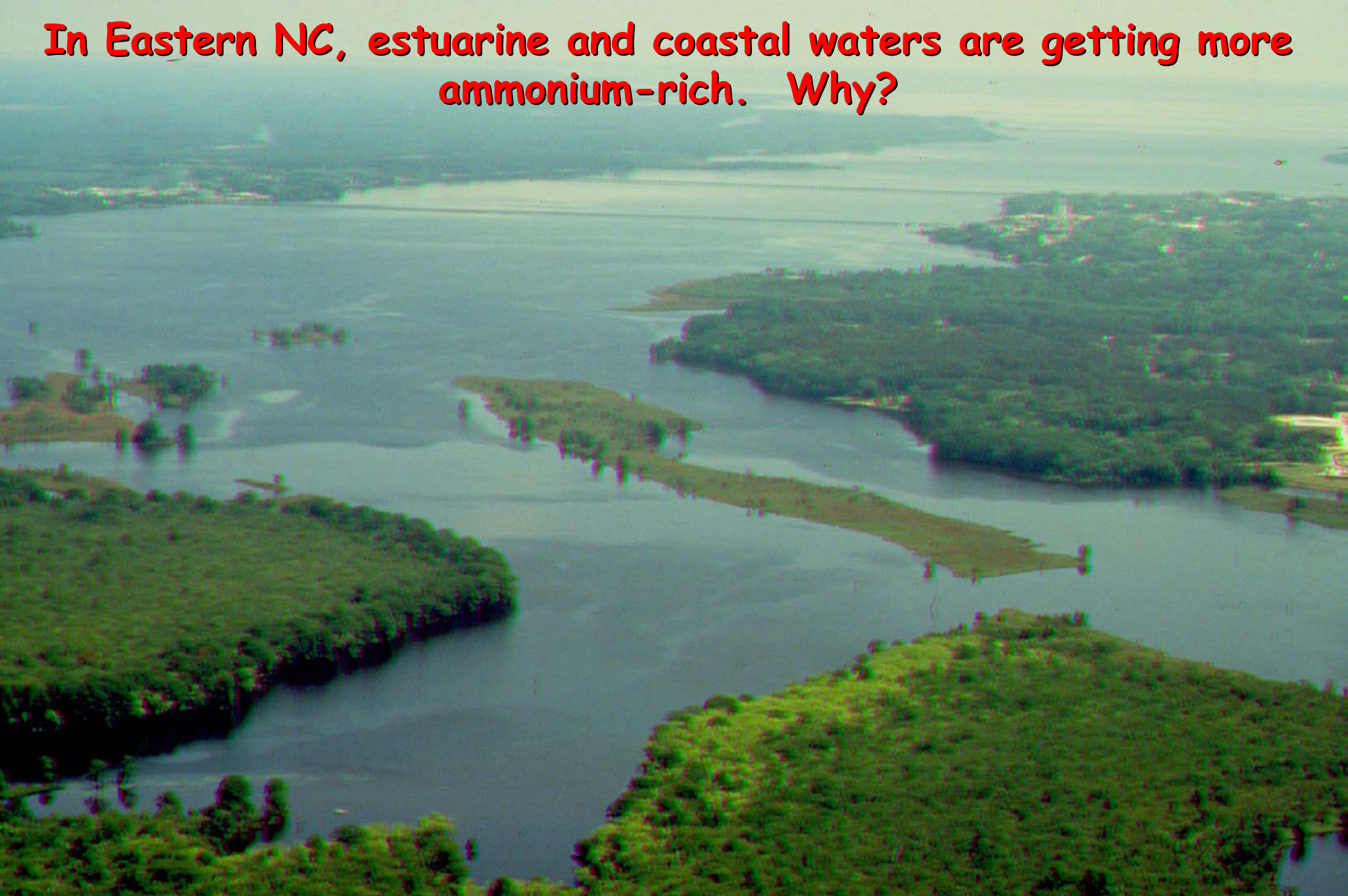
Total AD-N for Neuse R. Estuary

Based on yearly averages from 1996-2002 data
*Whitall et al. 2003
*Walker et al. 2004



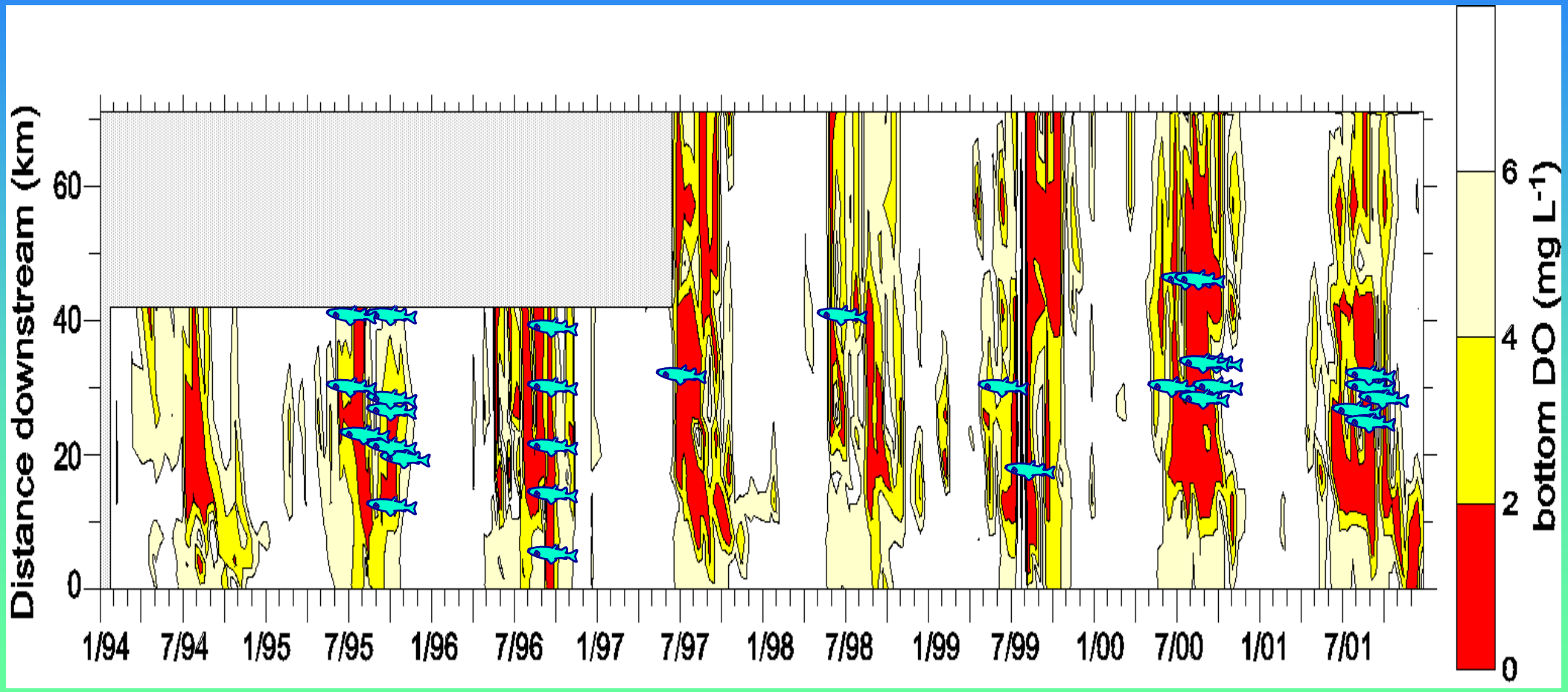
* Estimate based on previous studies and limited data from this study; wet organics comprise approx. 20% of total wet N deposition

In Eastern NC, estuarine and coastal waters are getting more ammonium-rich. Why?



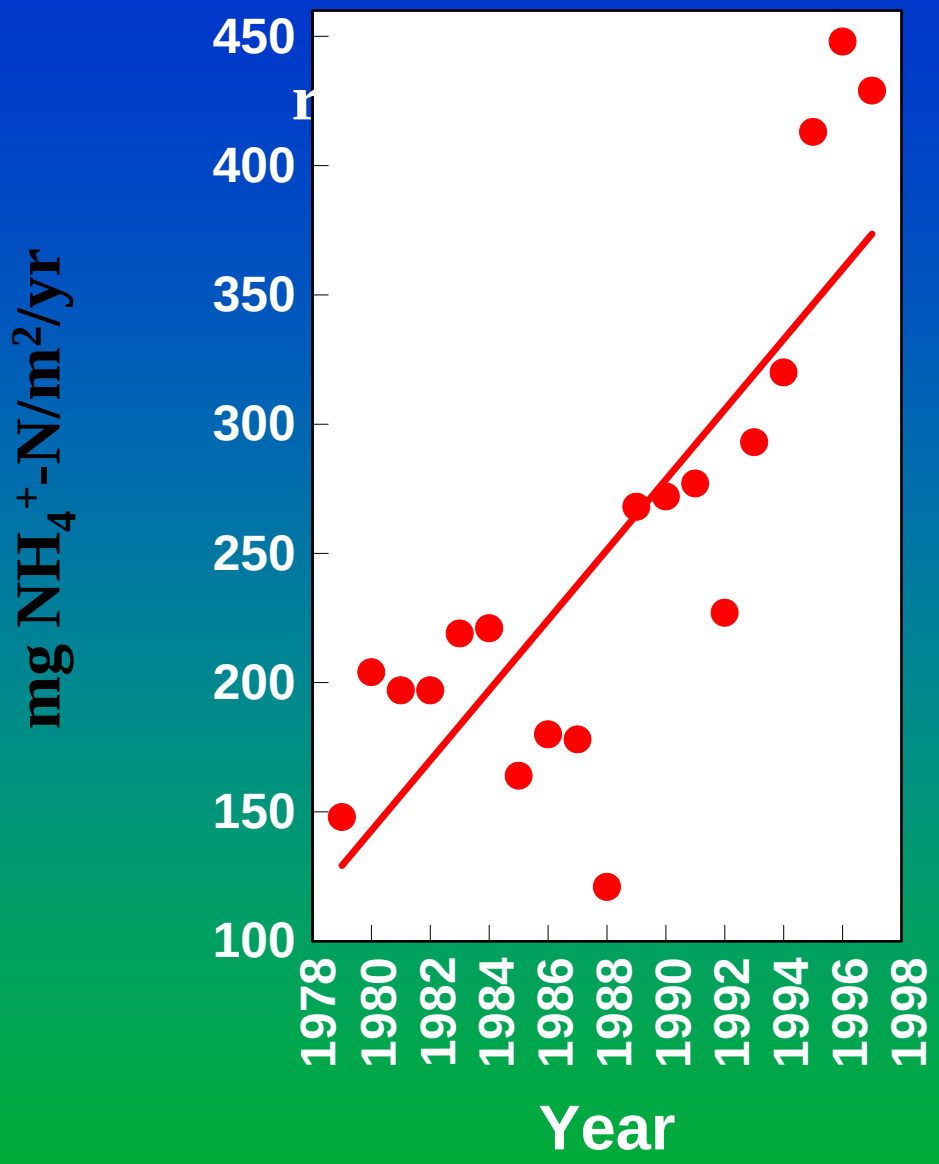
An possible increase in hypoxia may be one reason

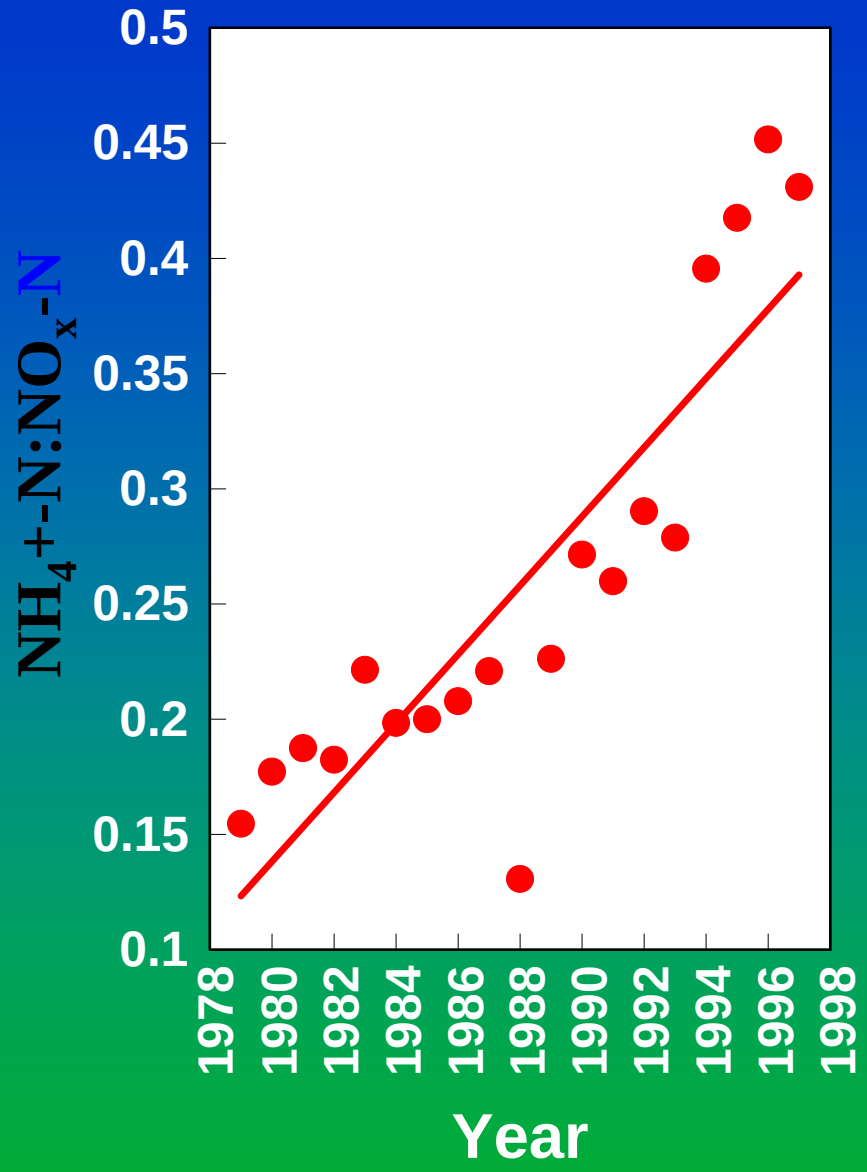
Data Sources: ModMon Project & NC DENR-DWQ



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

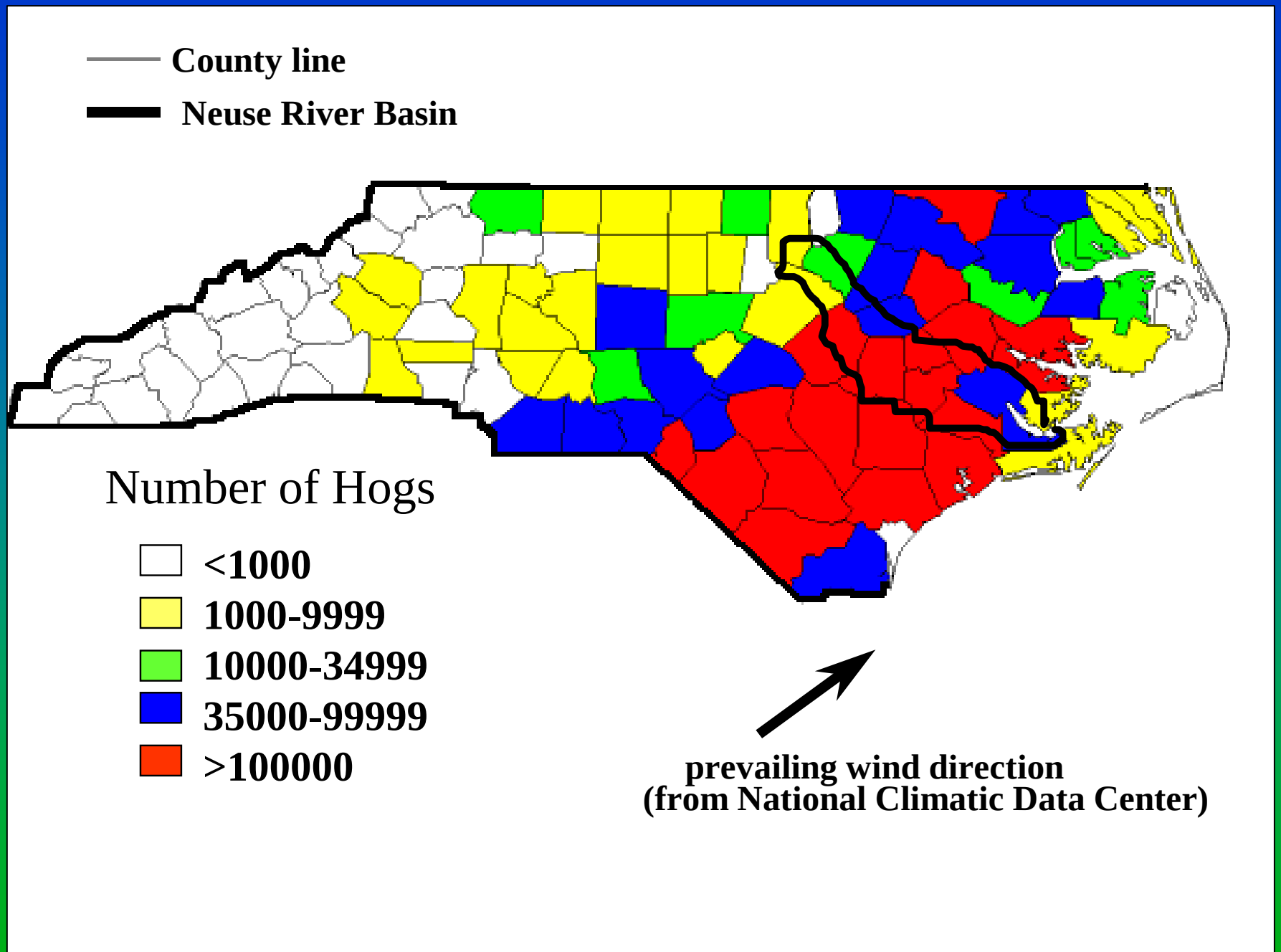
Another reason: More ammonia is being emitted locally and regionally



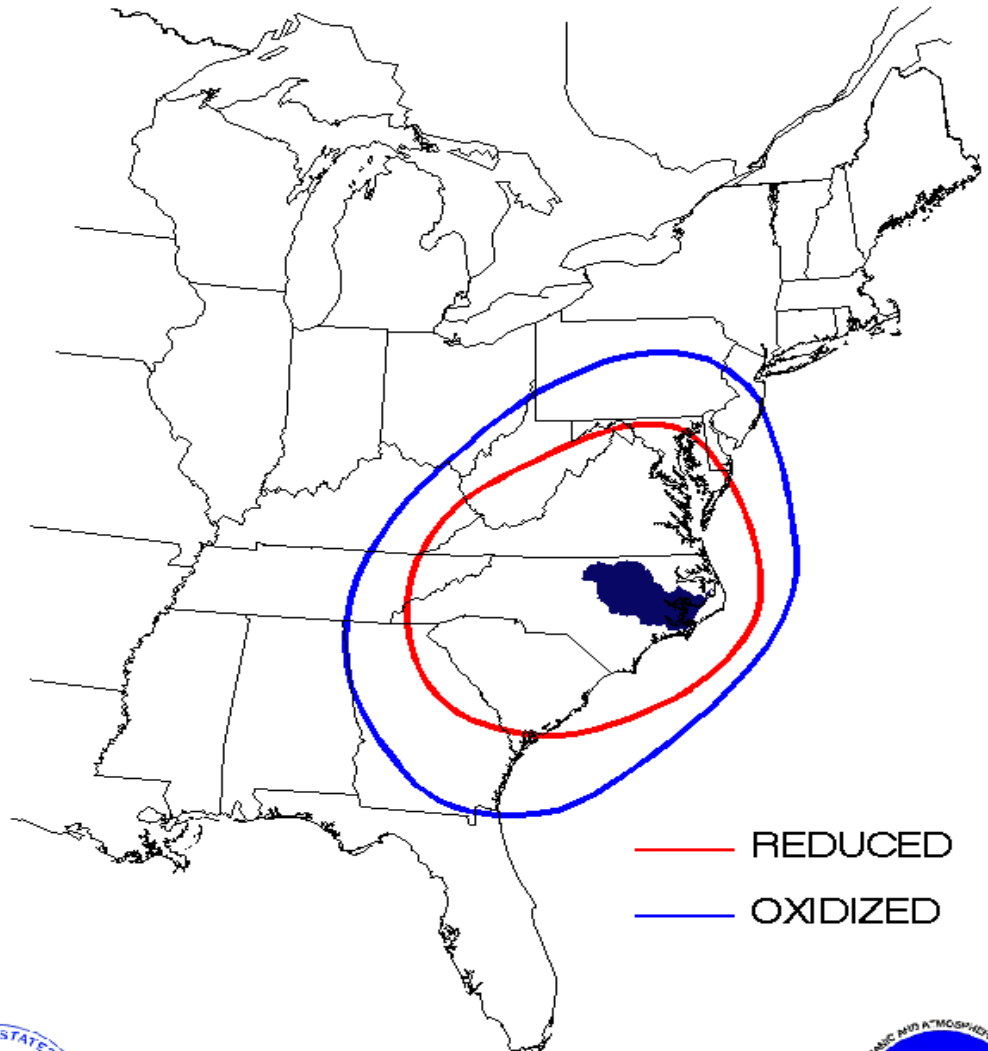


National Atmospheric Deposition Program Data
Sampson Co. North Carolina (NC35)

Where are the hogs relative to the N sensitive waters?



PRINCIPAL NITROGEN AIRSHEDS FOR: PAMLICO SOUND



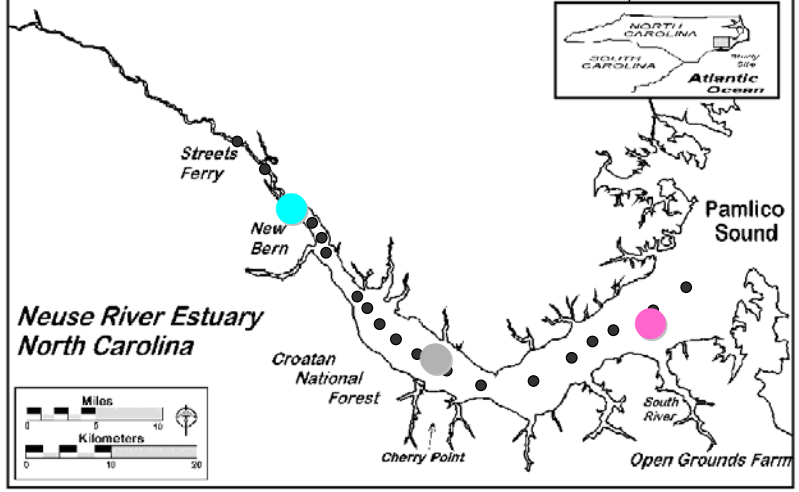
DEVELOPED BY R. DENNIS, ATMOSPHERIC SCIENCES MODELING DIVISION: ARL, NOAA, and NERL USEPA

Why the Ecological Concern About Ammonium?

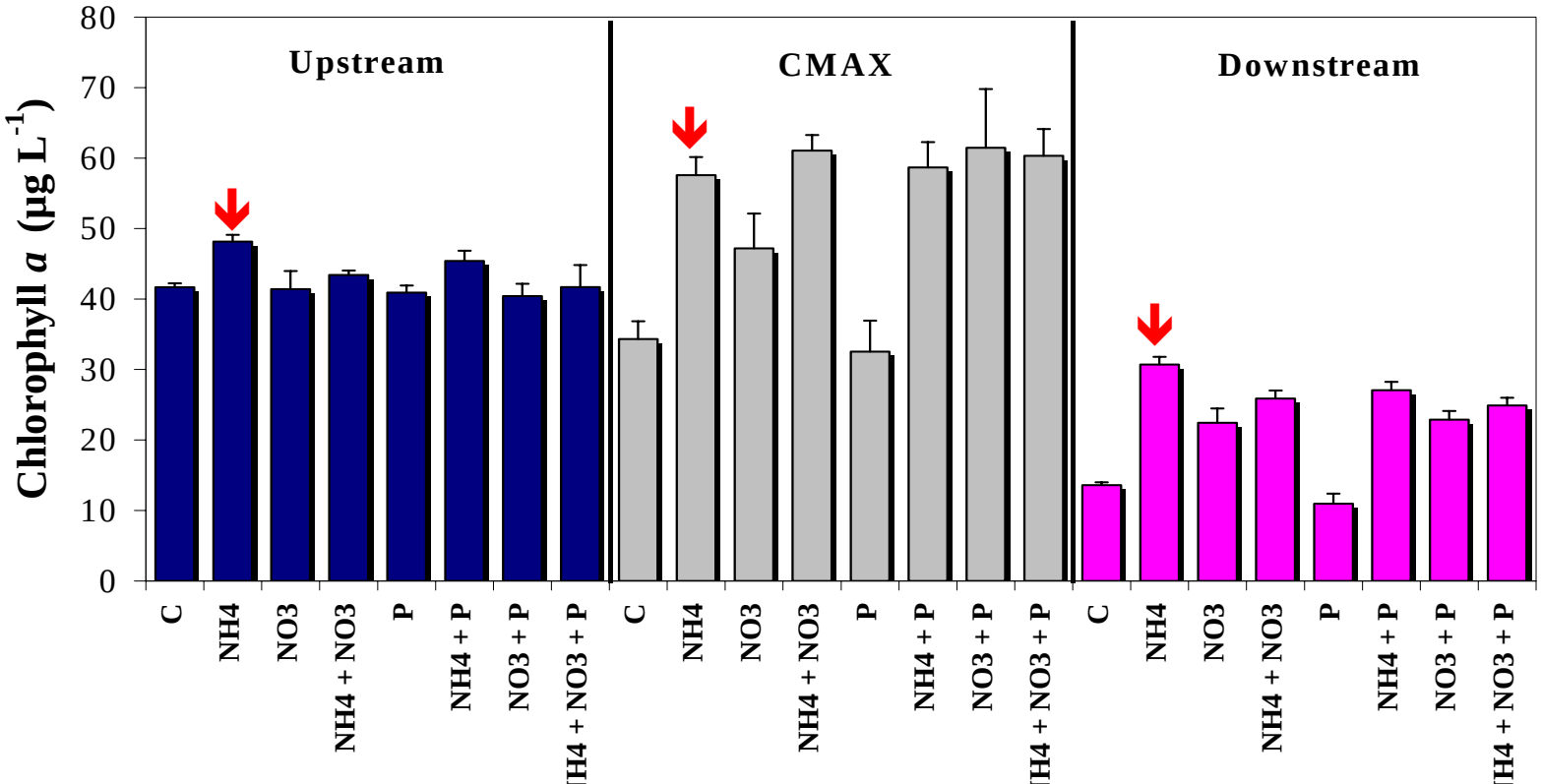
Not all forms of N are used equally

$NH_{3/4}^{+}$ vs. NO_3^{-} vs. Organic N

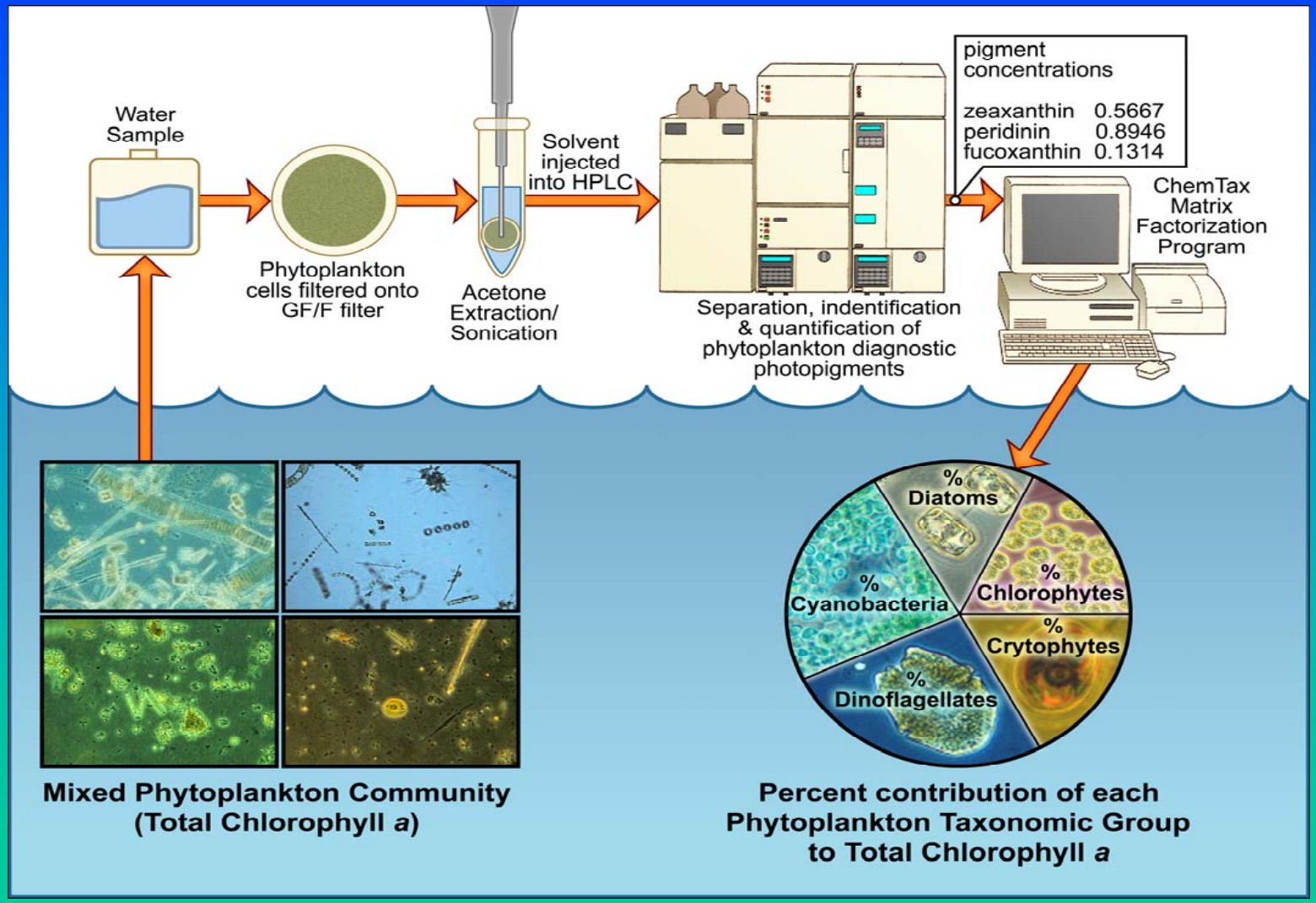
Ammonium is a preferred N source by phytoplankton



Nutrient Addition Bioassay Experiment, T1
Neuse River, July 2003

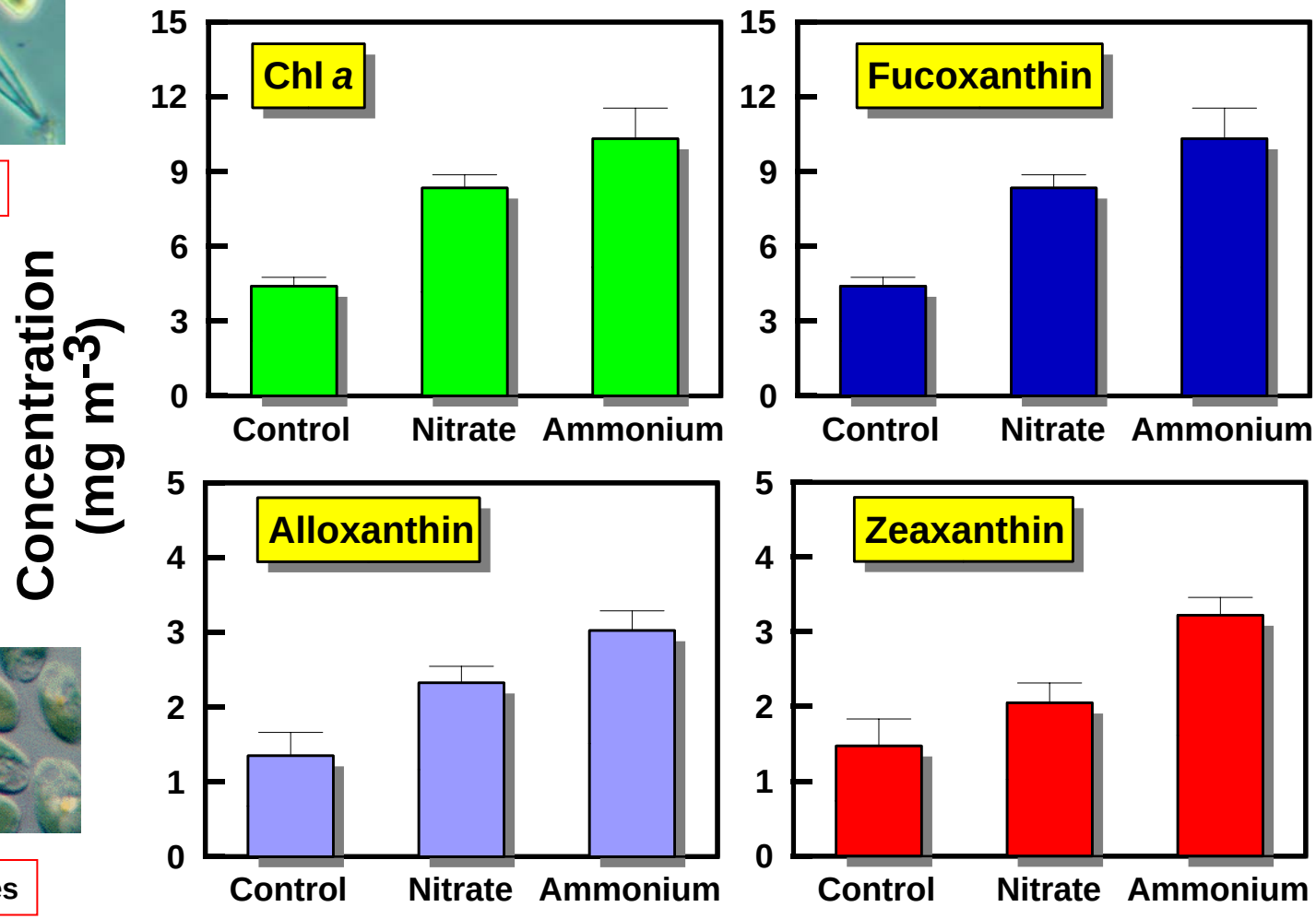


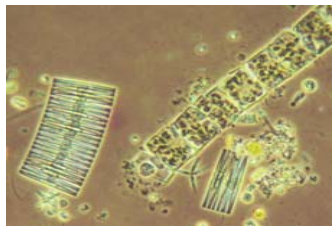
Looking into the green box: phytoplankton taxonomic group responses to specific forms of N enrichments by HPLC-ChemTax Analysis



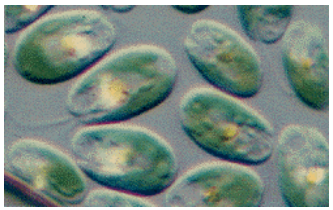
All phytos

Bogue Sound Bioassay August, 1996





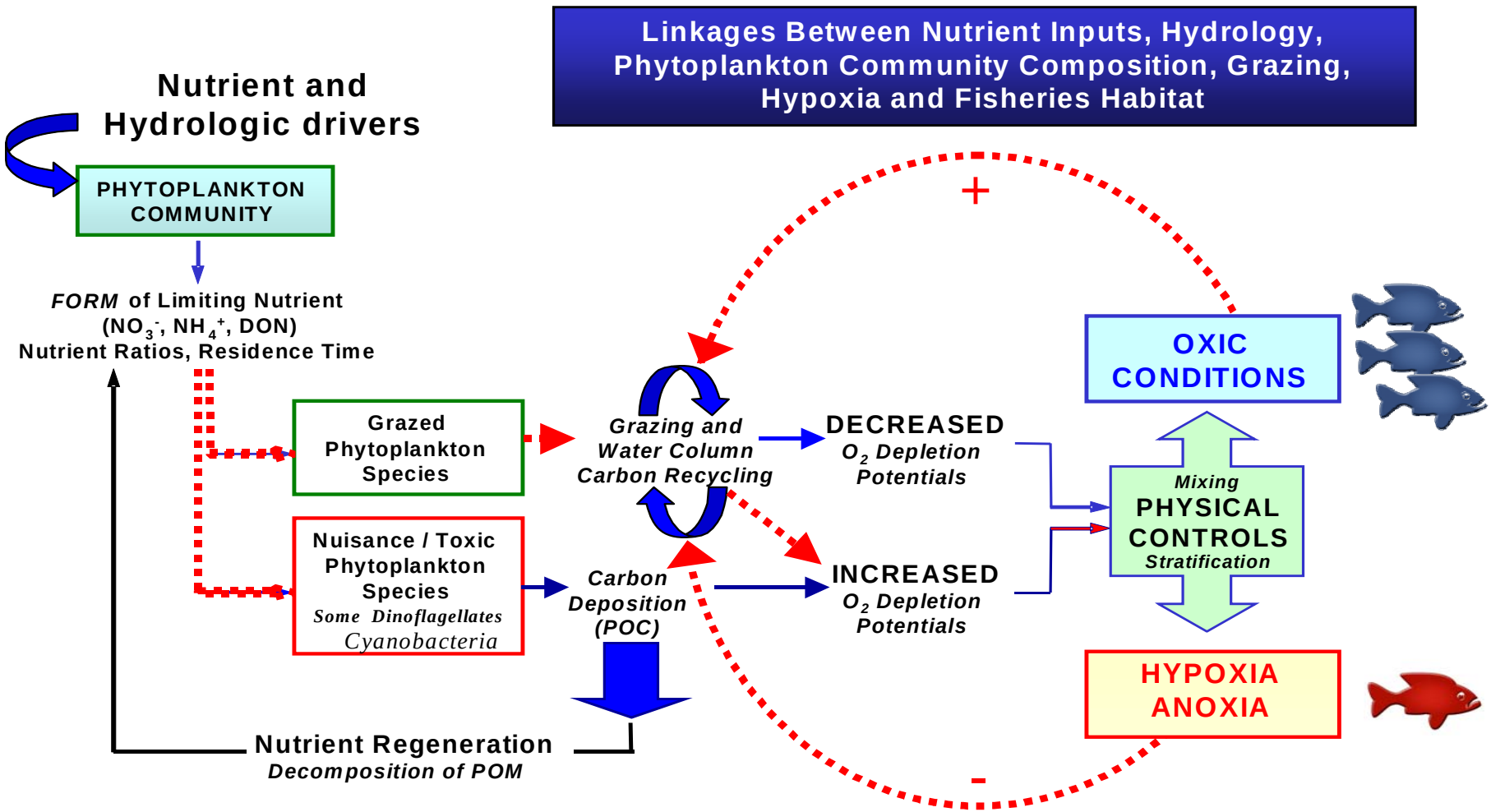
diatoms



cryptophytes

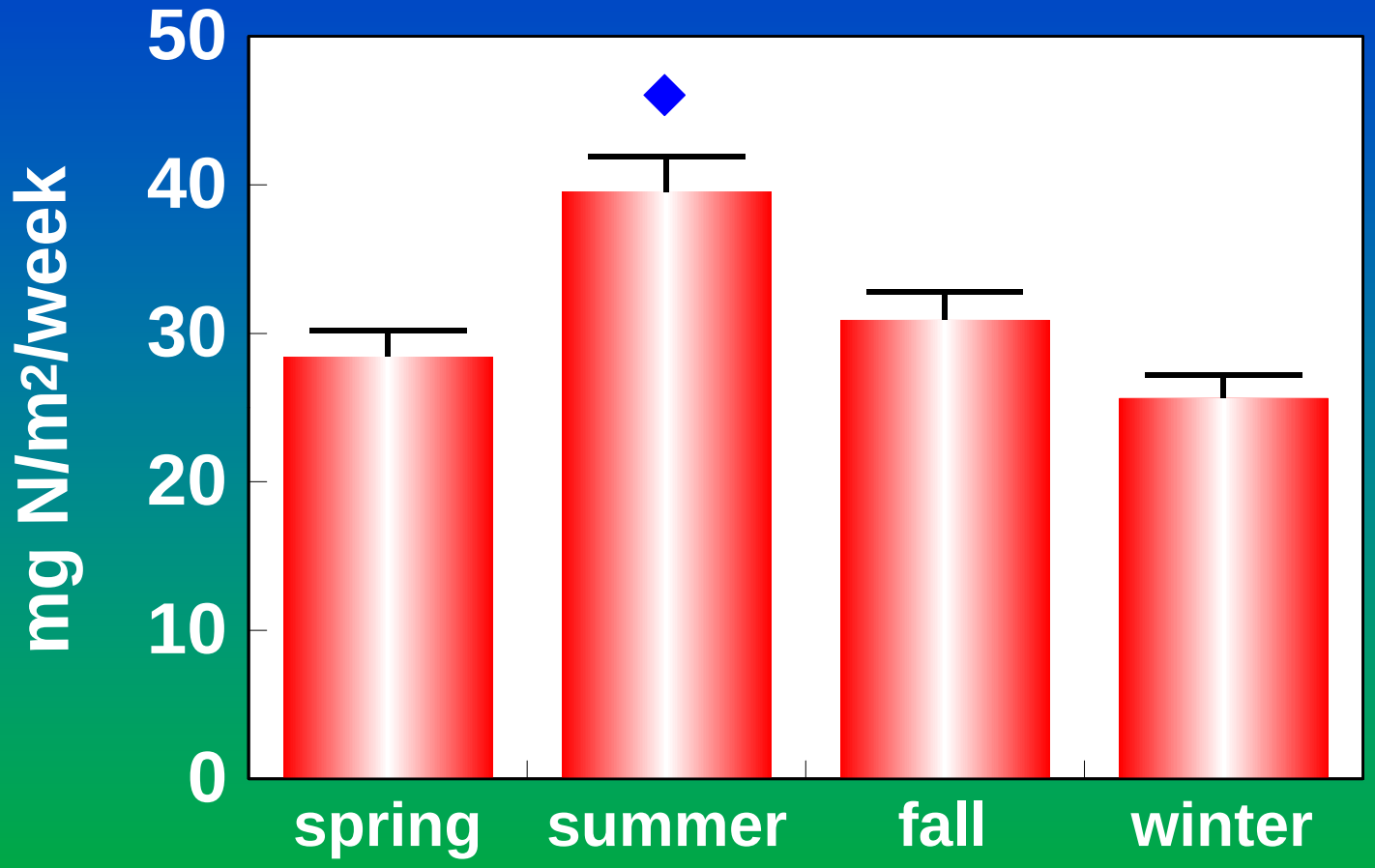
cyanobacteria

Scaling up to the Ecosystem



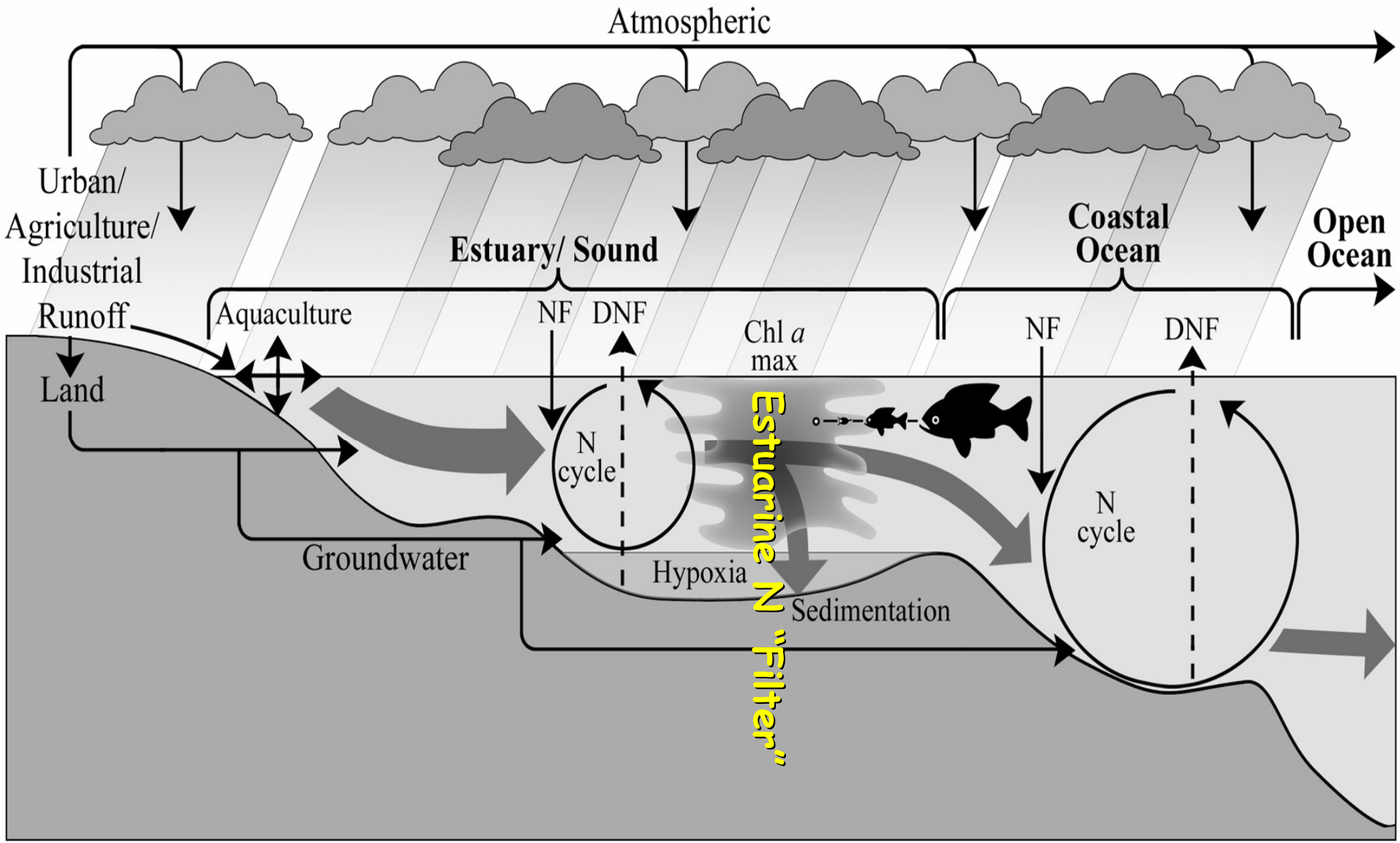
Seasonal Variability in ADN is also important

10 NRE Sites Pooled

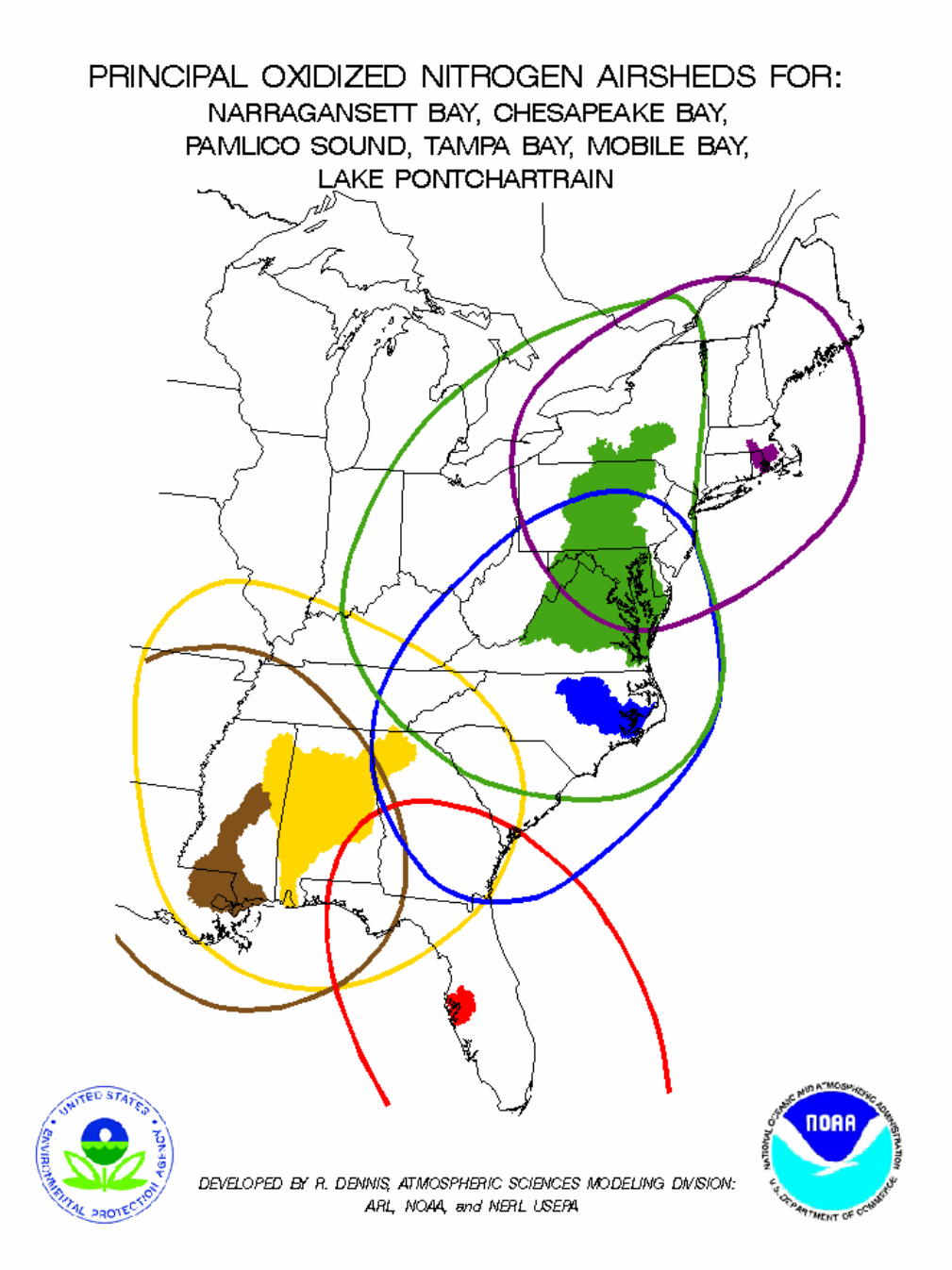


◆ **Significantly higher than spring, fall and winter at α=.01**

Atmospheric N inputs can bypass the estuarine N "filter"

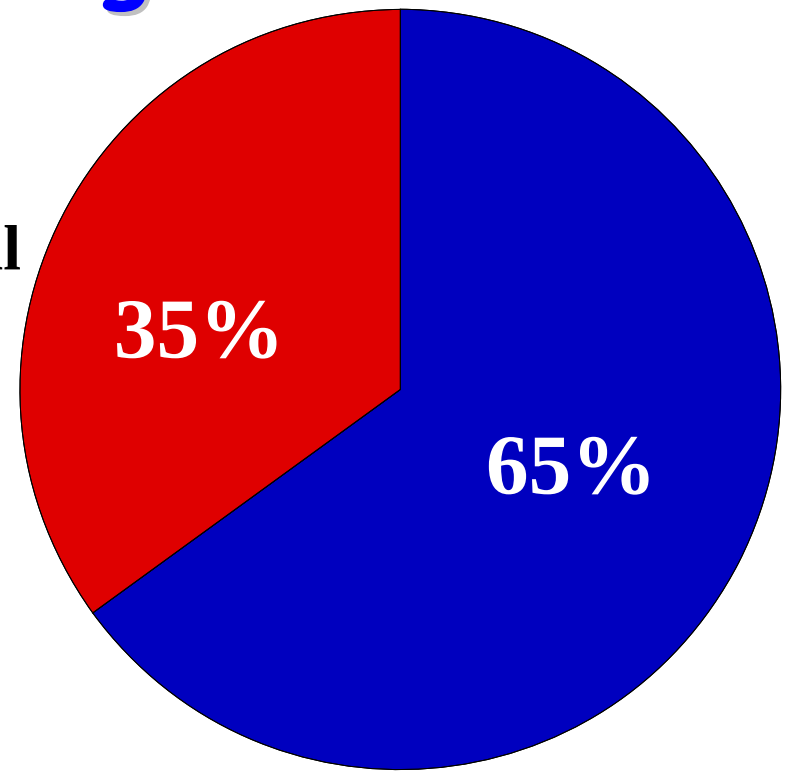


The Airshed Scale: Bypassing the Estuarine Filter & Influencing the Coastal Zone



Relative Importance of AD-N Flux to the Annual N Budget of NC Coastal Waters

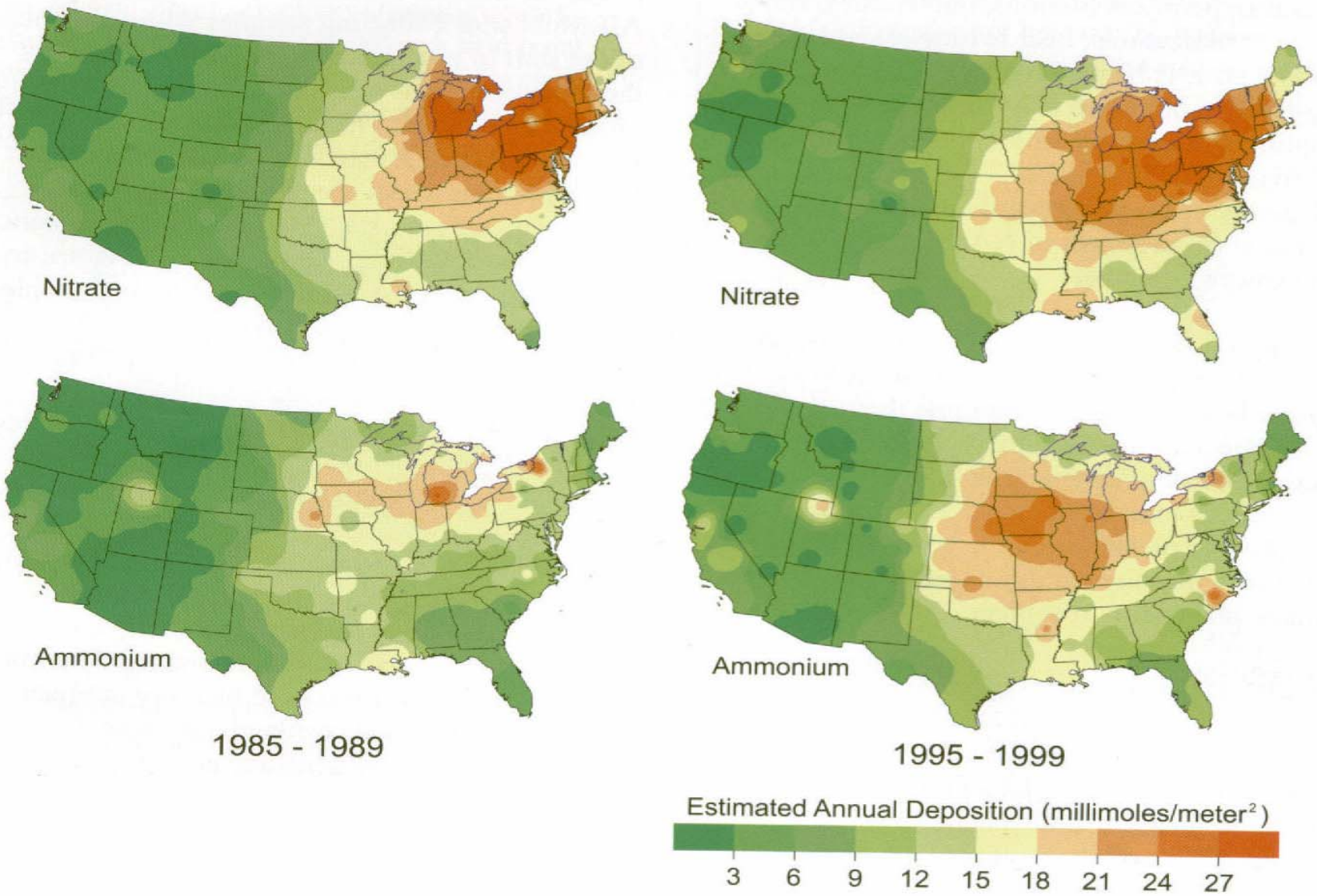
Direct Deposition of AD-N to Coastal Waters (903 kg N/km^2/yr)

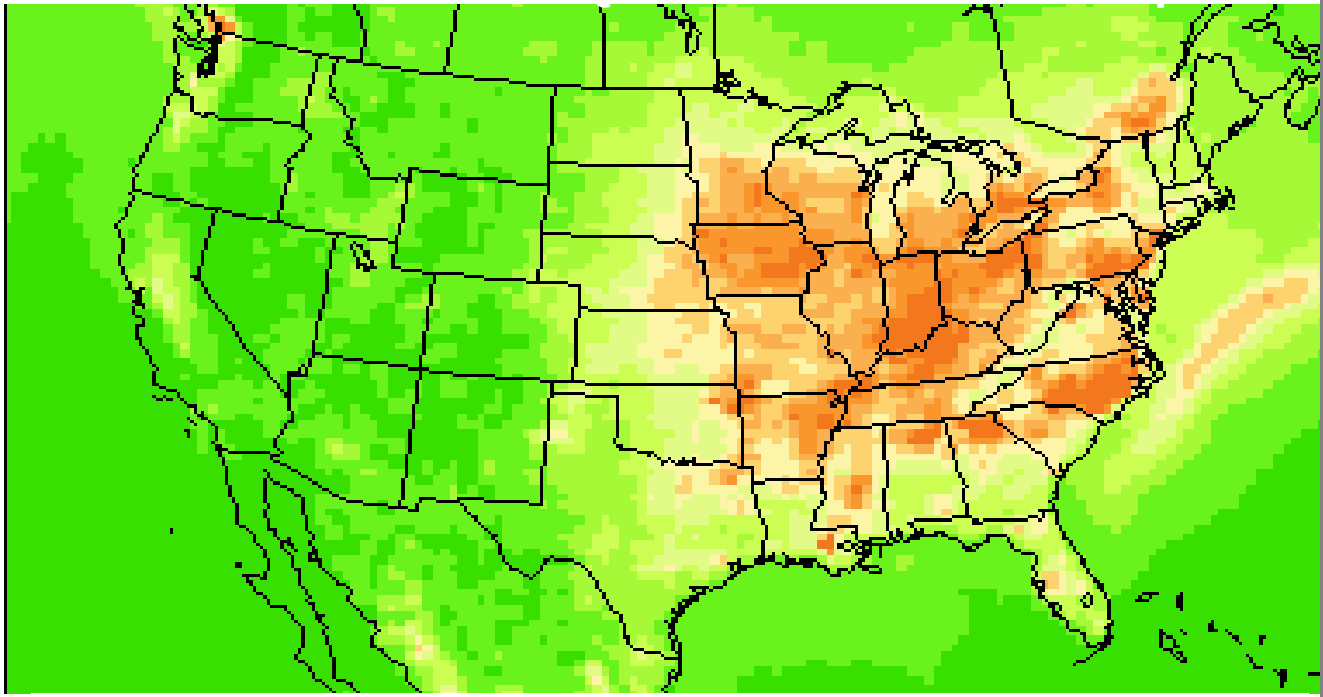


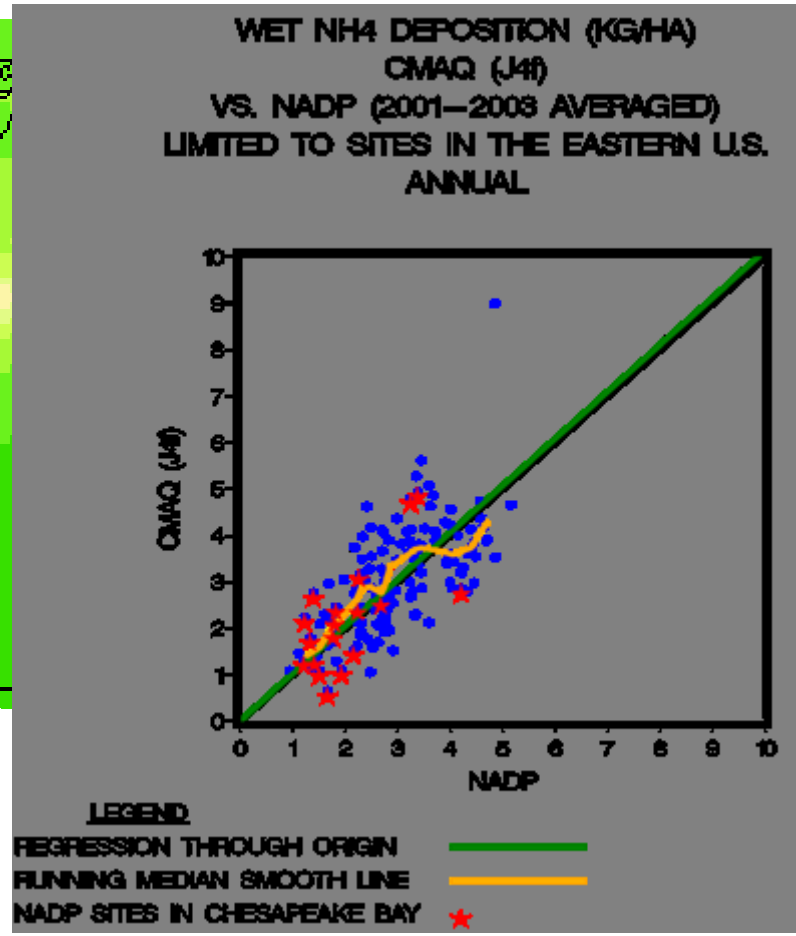
Land Based N Flux to Coastal Waters (1877 kg N/km^2/yr)

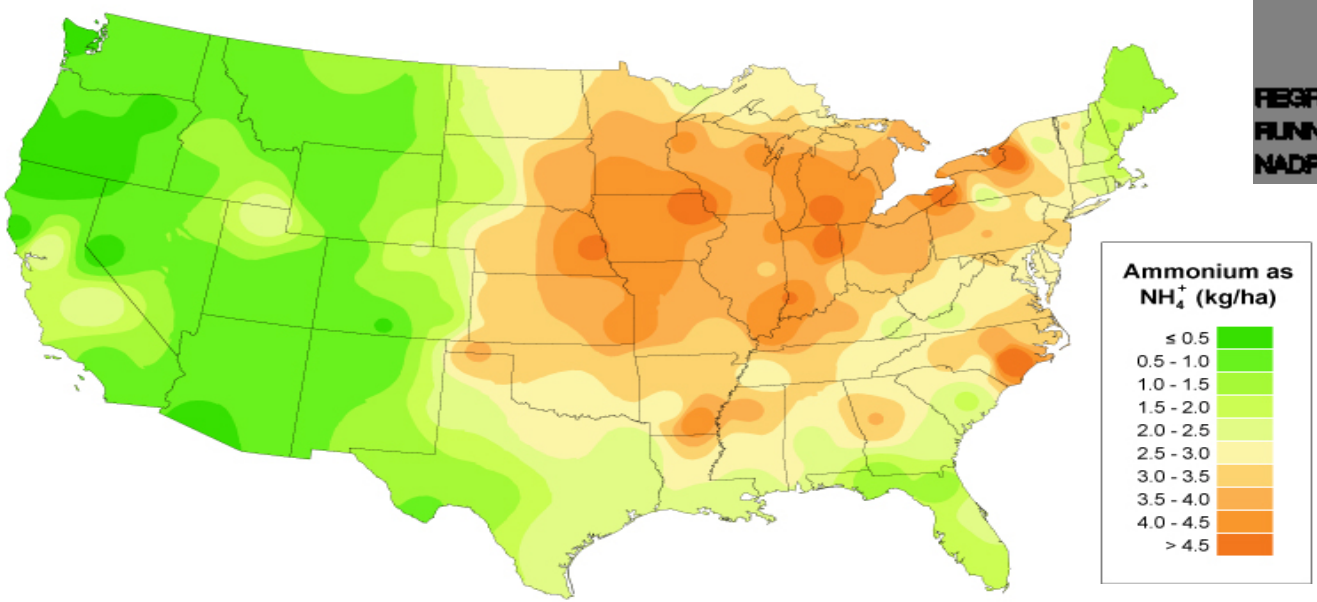
Land Based DIN Flux values for Southeastern U.S. region include AD-N deposition to land (Howarth et al. 1996), AD-N values from UNC-IMS 1990-2000 data (DIN+DON; where DON is estimated at 20% of DIN flux)

Spatial and temporal Issues: Implications for Monitoring



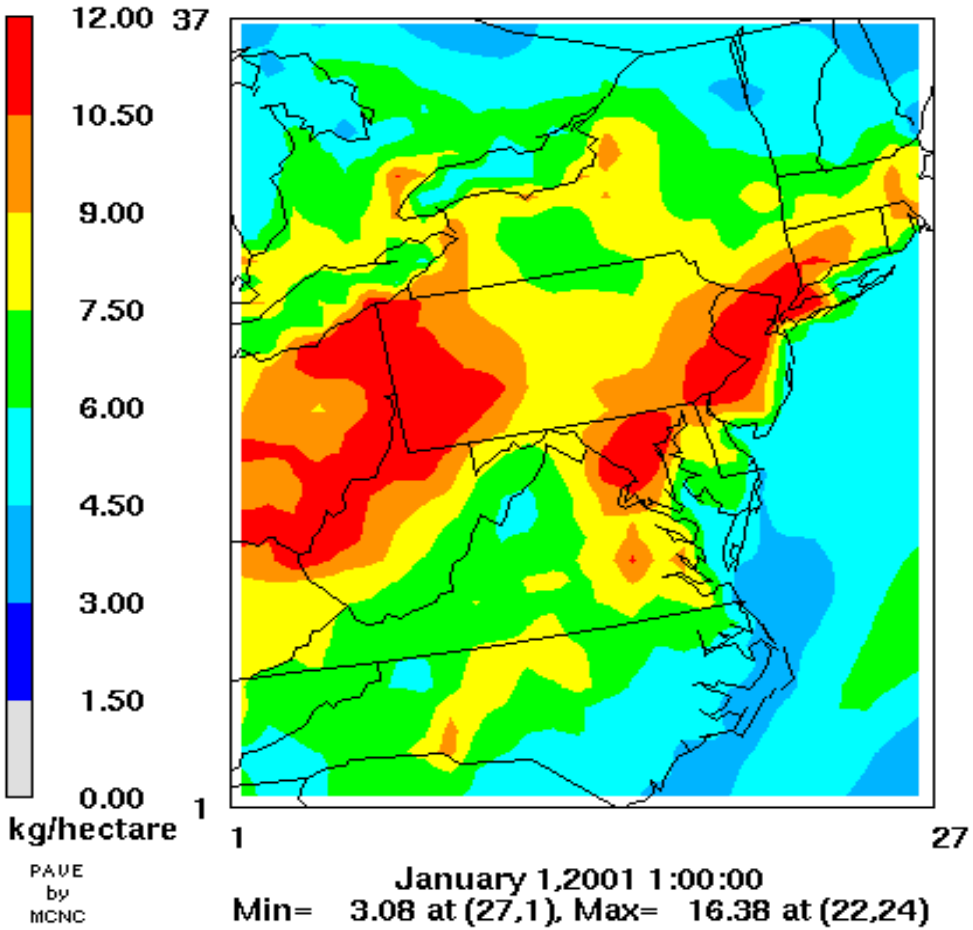



WET NH4 DEPOSITION (KG/HA)
CMAQ (J4f)
VS. NADP (2001–2003 AVERAGED)
LIMITED TO SITES IN THE EASTERN U.S.
ANNUAL
CMAQ (J4f)
NADP
0
1
2
3
4
5
6
7
8
9
10
LEGEND
REGRESSION THROUGH ORIGIN
RUNNING MEDIAN SMOOTH LINE
NADP SITES IN CHESAPEAKE BAY


Ammonium as
NH_4^+ (kg/ha)
≤ 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0
3.0 - 3.5
3.5 - 4.0
4.0 - 4.5
> 4.5

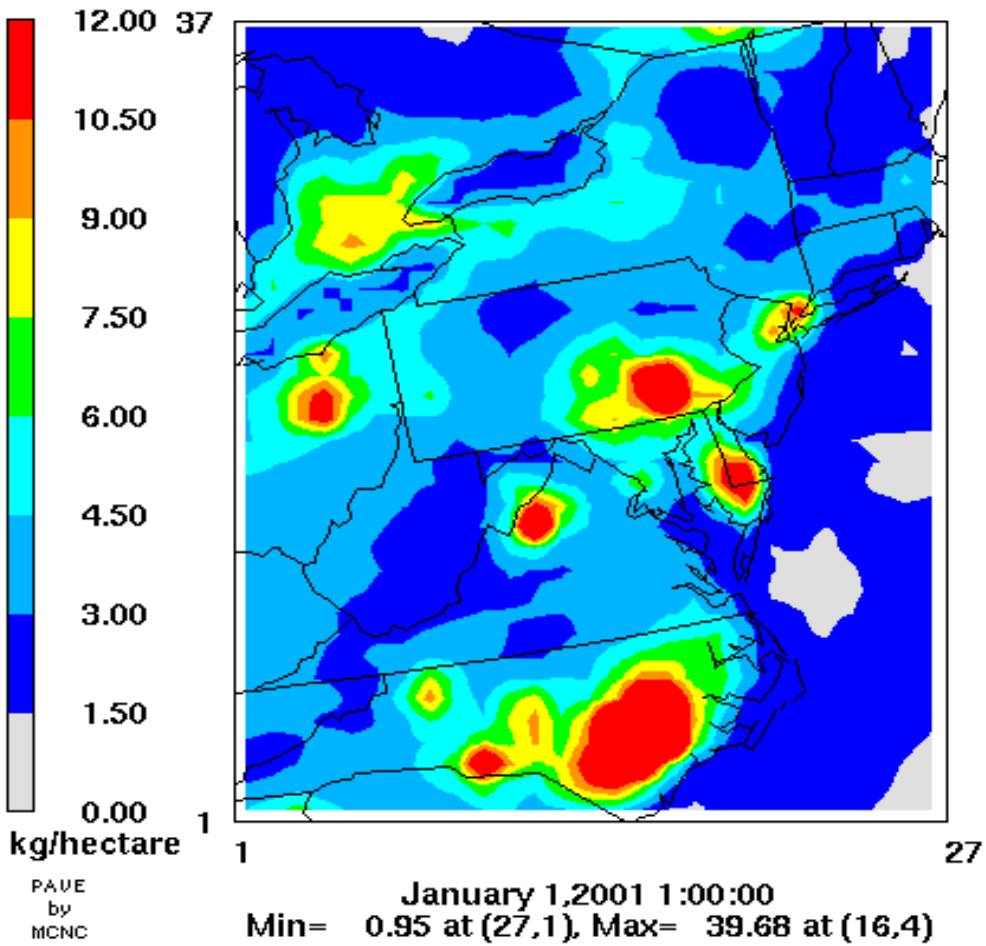
TOTAL OXIDIZED NITROGEN

2001 BASE - ANNUAL

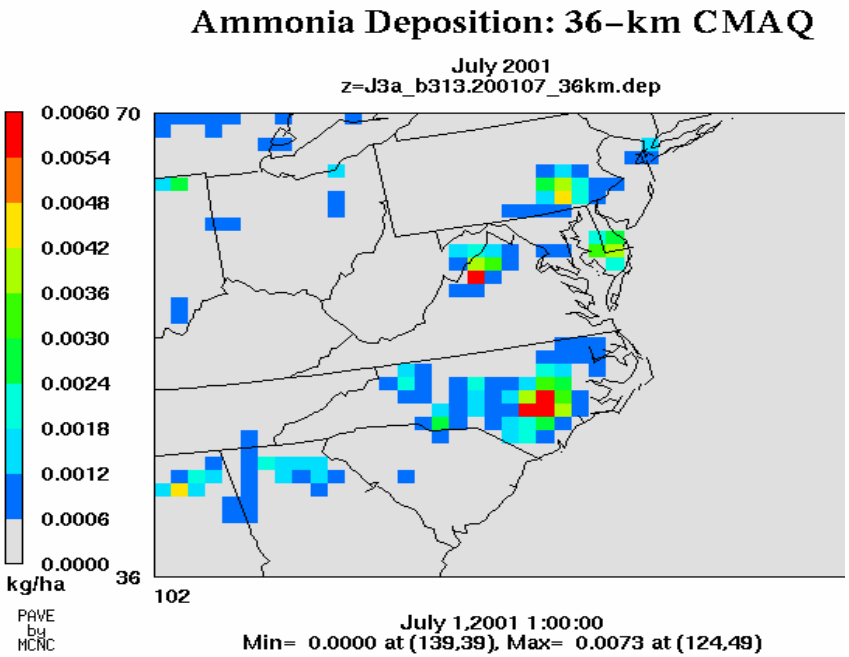


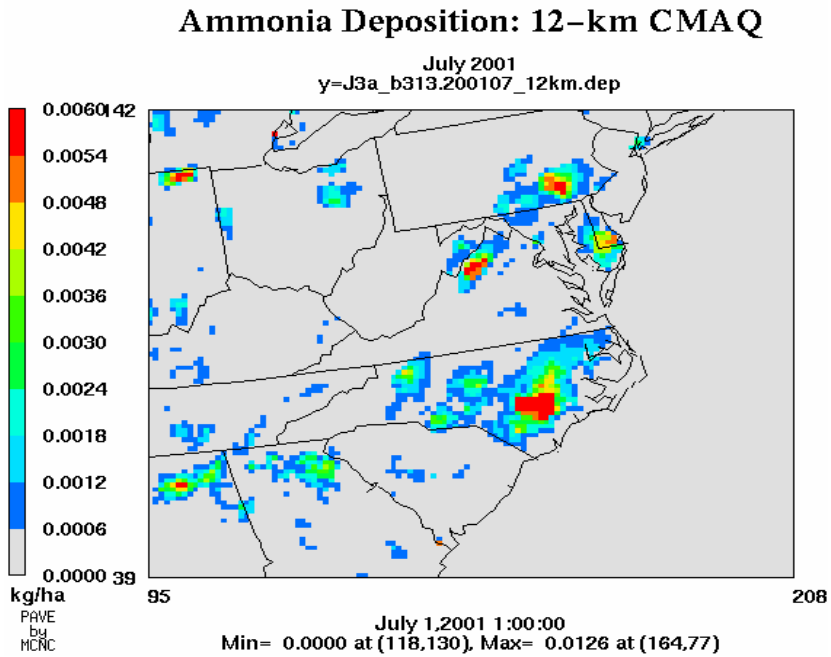
TOTAL REDUCED NITROGEN

2001 BASE - ANNUAL

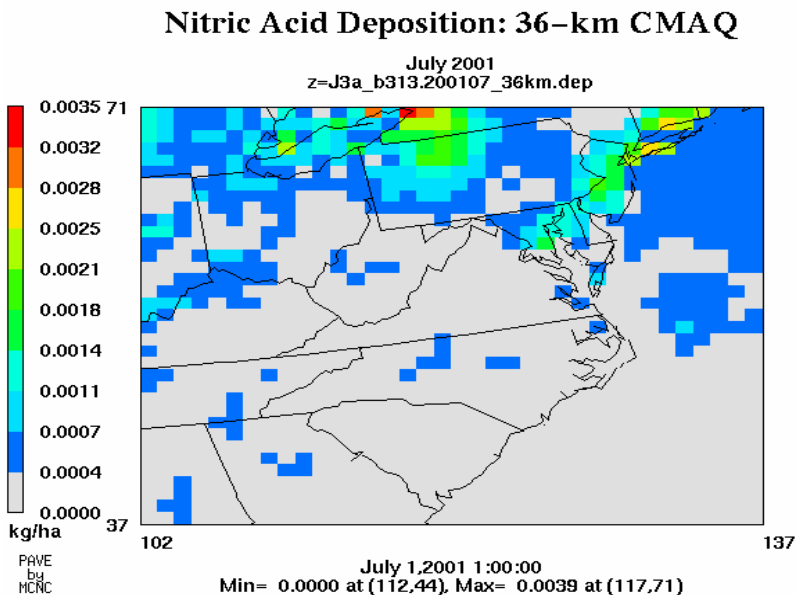


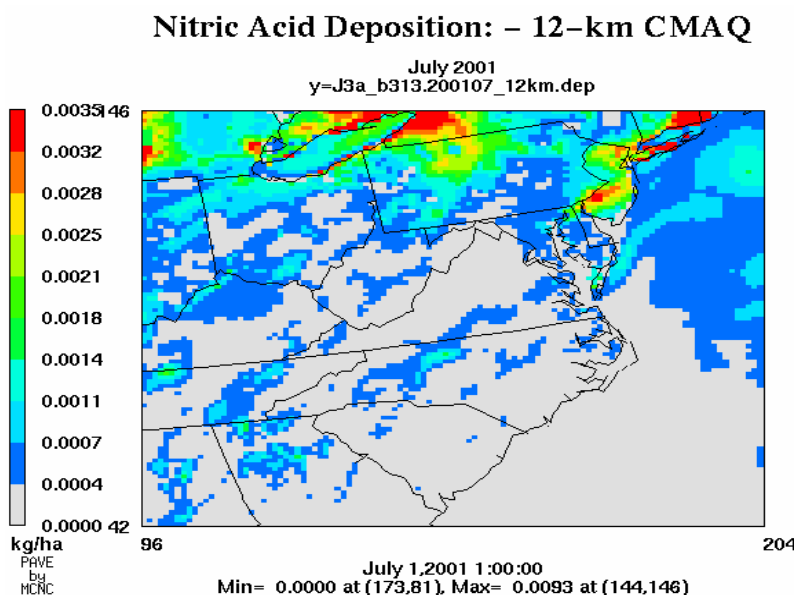
Finer grid: more accurate representation of ammonia hot spots



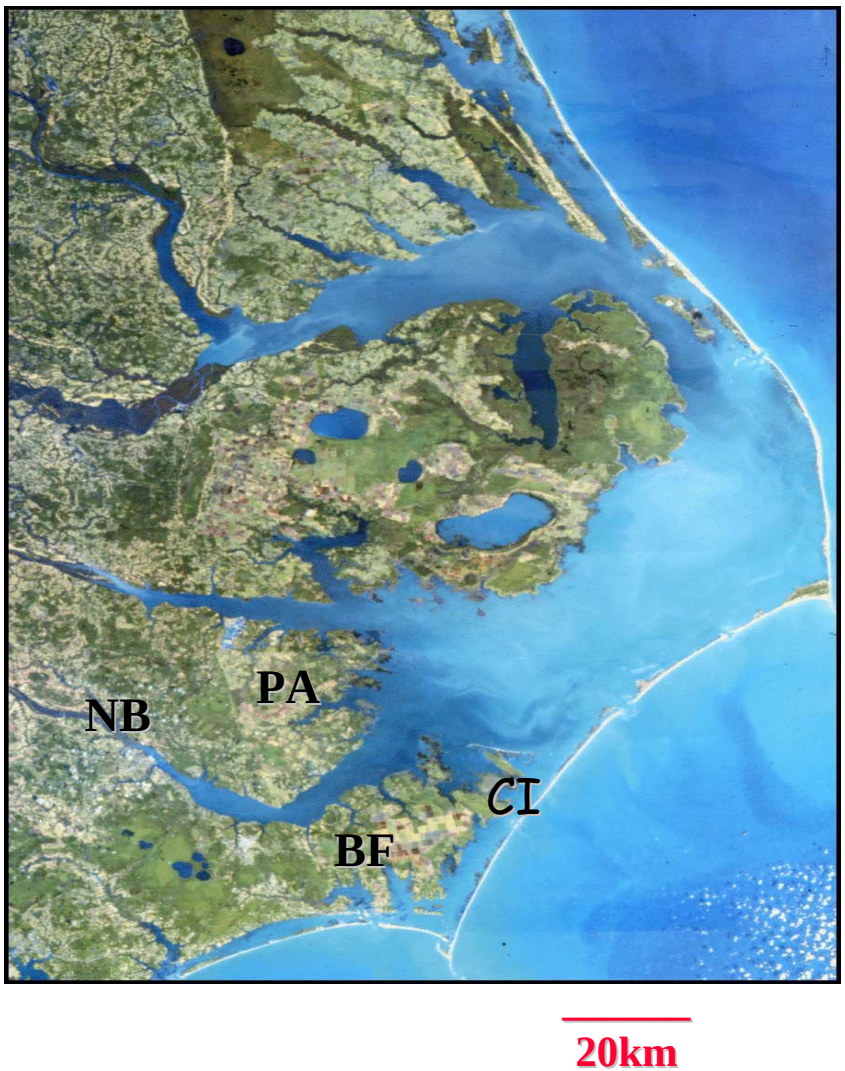


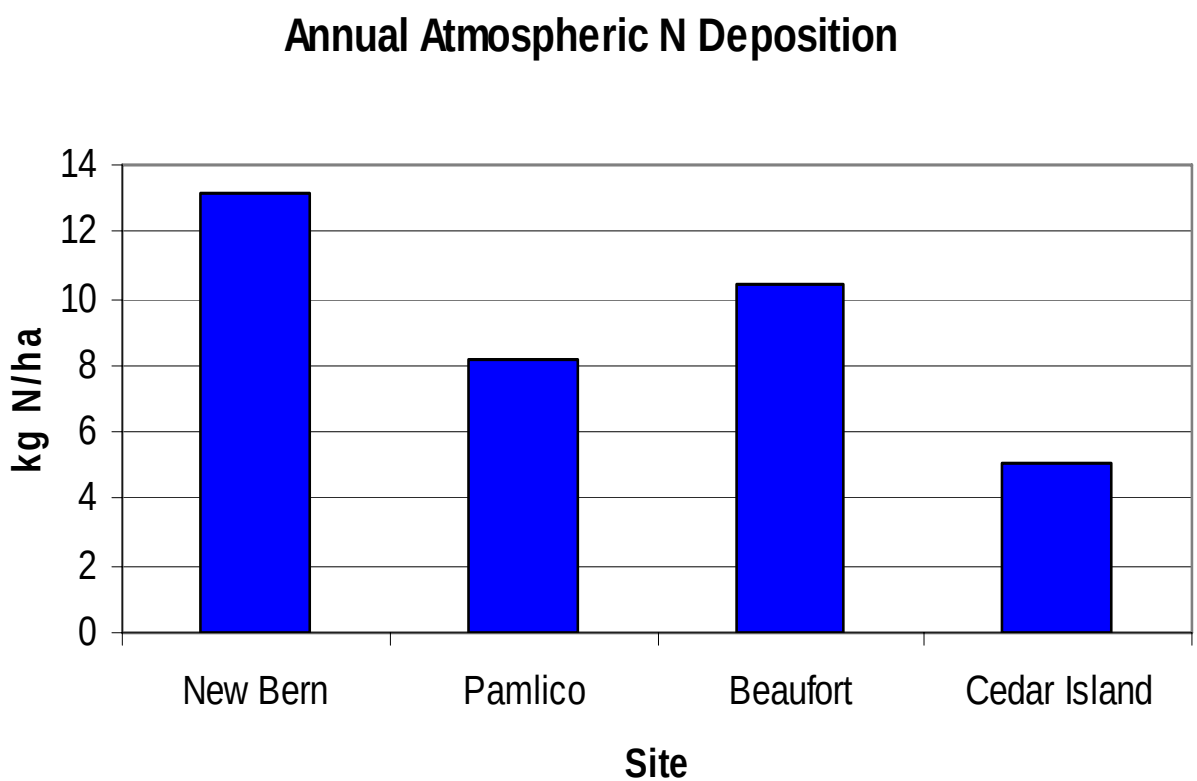
Finer grid: more accurate representation of urban hot spots





Spatial Heterogeneity of AD-N in the Neuse-Pamlico Sound System
Take-home message: 12-36 km grid is highly relevant





Conclusions

- AD-N is a significant source of N enrichment to coastal waters downwind of sources.
- AD-N impacts production and composition of phytoplankton. AD-N plays a role in eutrophication dynamics of these waters.
- Chemical forms of AD-N are important and ammonium is of growing concern
- Spatial heterogeneity is important, from both monitoring and ecological effects perspectives
- Impacts and management of AD-N should include local, regional, and global scales

Thanks to: P. Wyrick, K. Rossignol, A. Waggener, A. Joyner, M. Leonard, B. Peierls, J. Braddy, M. Piehler, R. Weaver

Supported by: US EPA STAR/EaGLe Program, NC Sea Grant, NSF-Ecosystems Program, USDA-NRI, Environmental Defense, NC DENR/DWQ/DAQ

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www.aceinc.org