Long Term Observations in the Ipswich and Parker River Watersheds, MA

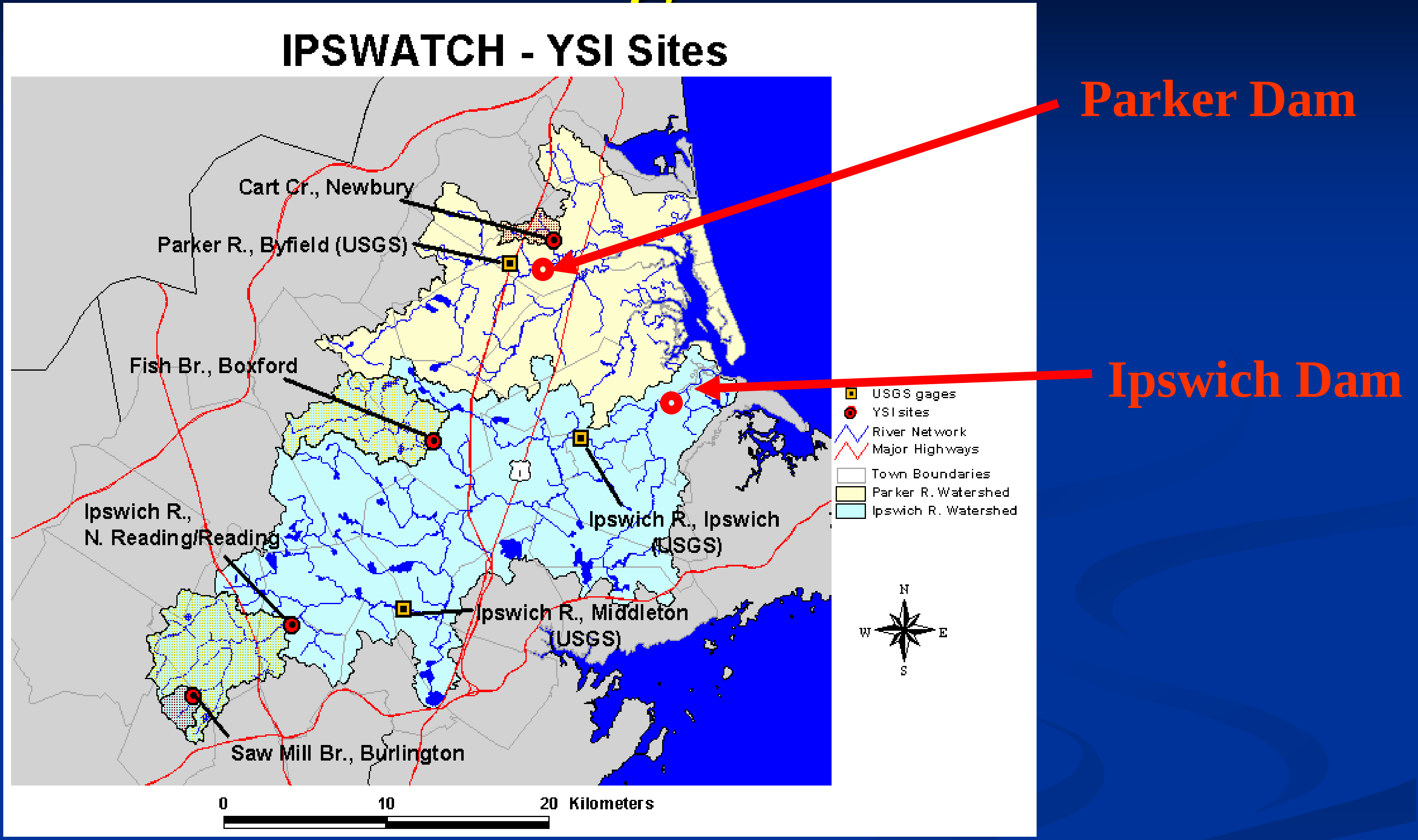
Plum Island Estuary (PIE) LTER

Lamprey River Hydrologic Observatory Symposium – January 4th, 2008

Why Am I Here Talking About Watersheds in Massachusetts?

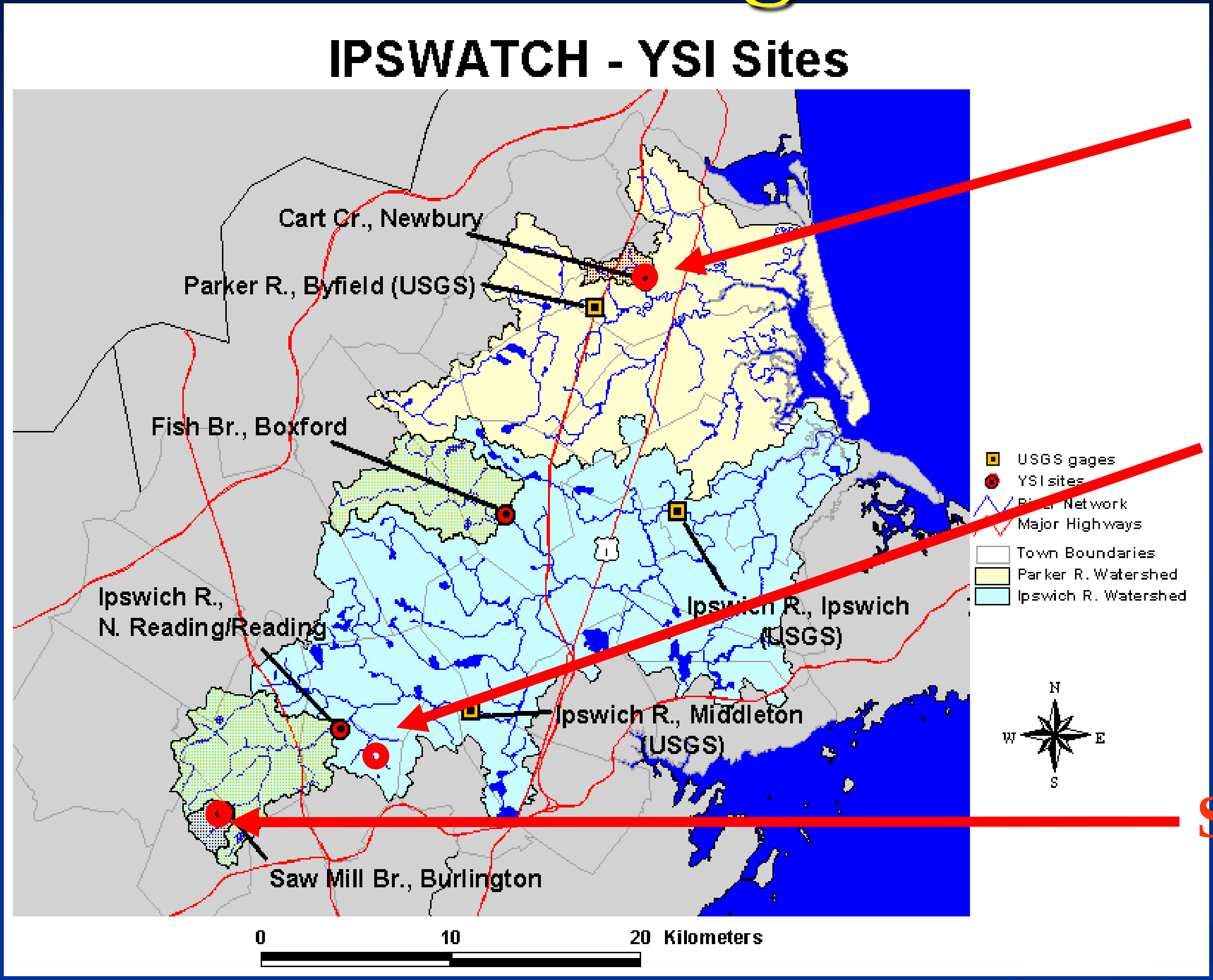
- PIE watersheds similar to Lamprey
  - Flat, coastal plain watersheds
  - Similar climate
  - High % wetlands
  - Urbanizing (30% urban in 2001)
- Hydrologic and water quality responses to land use change are similar to those in the Lamprey
  - Based on headwater observations
- Are the output (basin mouth) responses similar or dissimilar?
- Use multiple basins to understand mechanisms
  - River network processes
  - Experiments and Modeling

Core Monitoring – Basin outlets



- Characterize water, nutrient, carbon inputs to PIE
  - Monitoring at the Ipswich and Parker Dams

Core Monitoring - Headwaters



Forested (2001)

Wetland (2005)

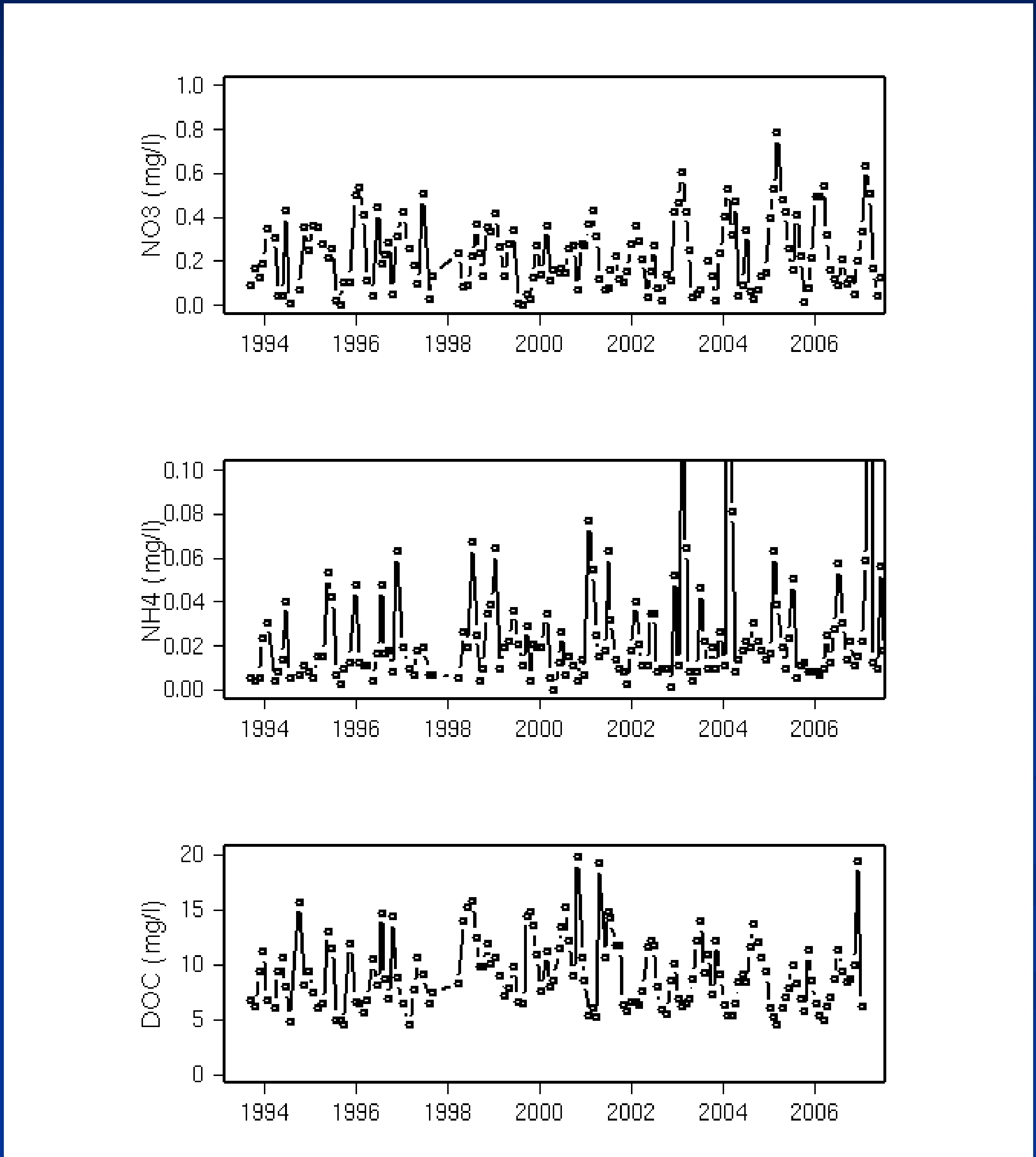
Suburban (2001)

Basin	Area (Km^2)	% Agr.	% Forest	% Wetland	% Ind.	% Resid.
Cart Creek	3.96	8	57	19	5	11
Saw Mill Br.	4.02	4	17	4	2	72
Cedar Swamp	1.40	6	36	49	0	9

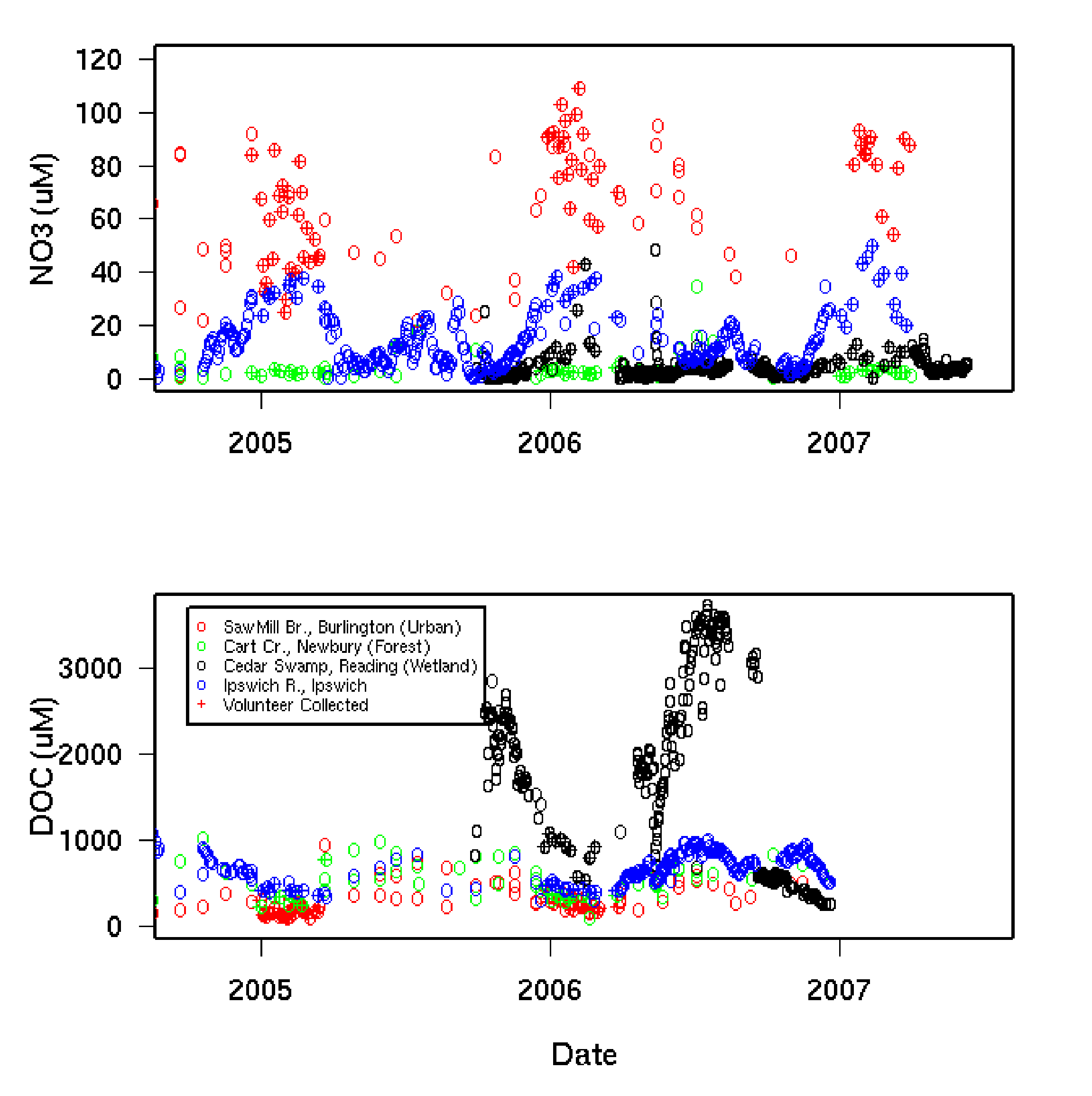
Core Monitoring: Sample Regime

- Frequency
  - Monthly grabs (since 1993)
  - Sigma Autosampler (since 2002)
    - Two-day Composites (dams)
    - Daily and/or Monthly Composites (headwaters)
  - Continuous YSI/Hobo data logger
- Measurements
  - Discharge, Water temperature
  - NO3, NH4, TDN, PON, TN
  - SRP, DOP, TP
  - DOC, POC
  - TSS
  - Cond, D.O., pH (2001-2004)
- Monthly synoptic surveys (2000-2002)

Long Term N and C Observations



Detailed Time Series



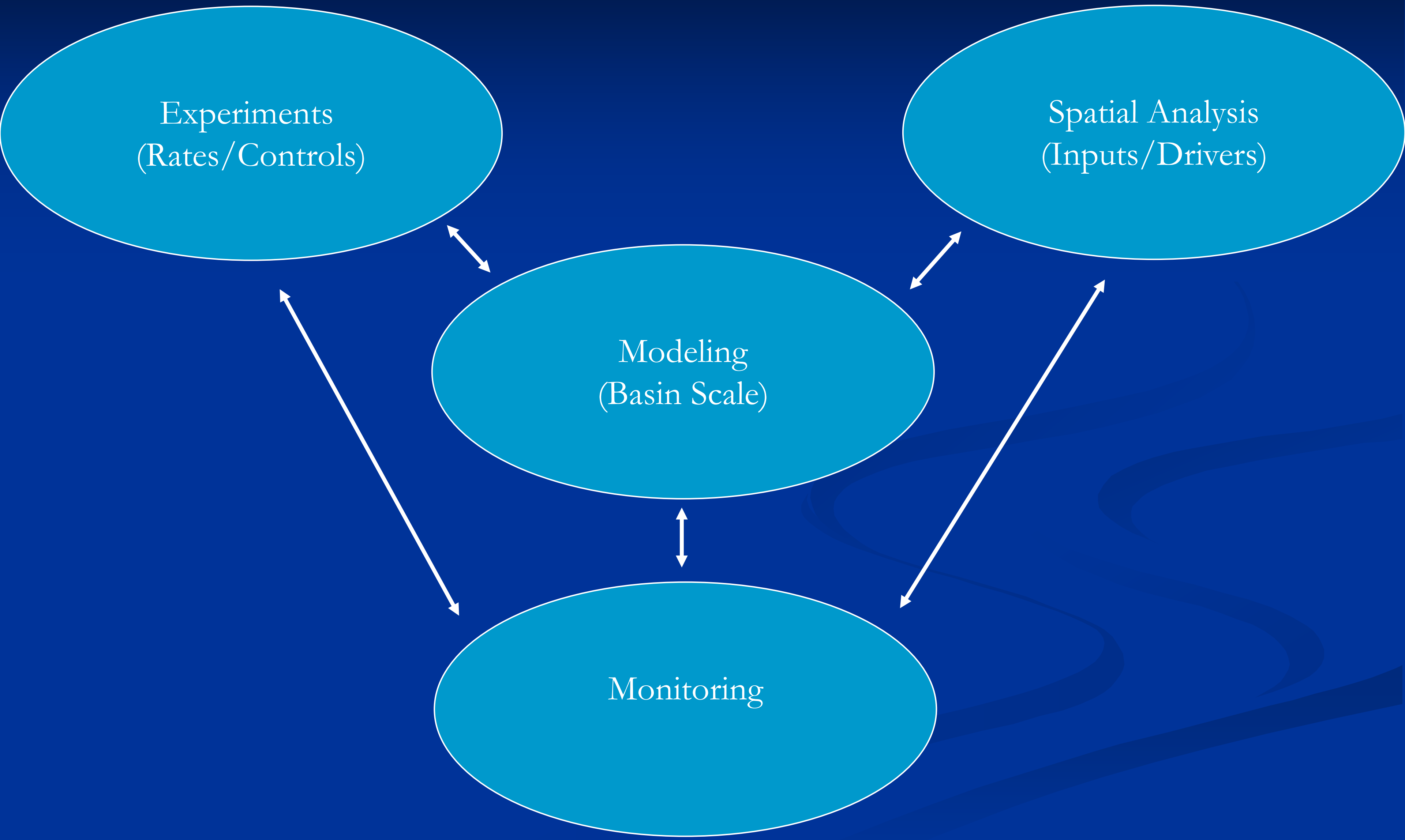
urban

Ipswich Mouth

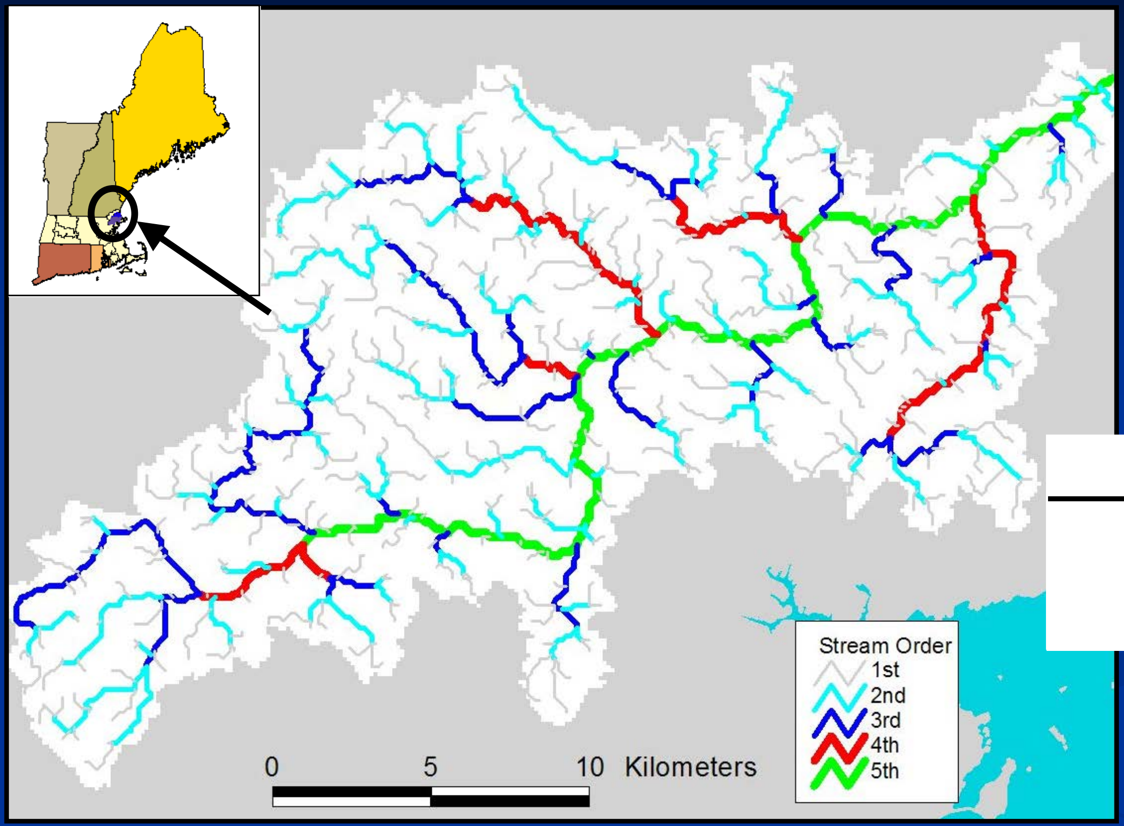
forest

wetland

Integration and Synthesis



River Network Modeling



	Direct Drainage (km2)	Mean Area (km2)	Mean Length (km)	Numbers
1	0.52	0.52	0.65	432
2	0.81	2.35	1.33	103
3	1.77	9.6	2.77	28
4	3.39	34.5	5.62	6
5	25.3	404	41.9	1

- Integration and Synthesis
  - Spatially distributed river network models
  - Mixing of inputs, processing

River Network Interactions

HUMAN IMPACTS

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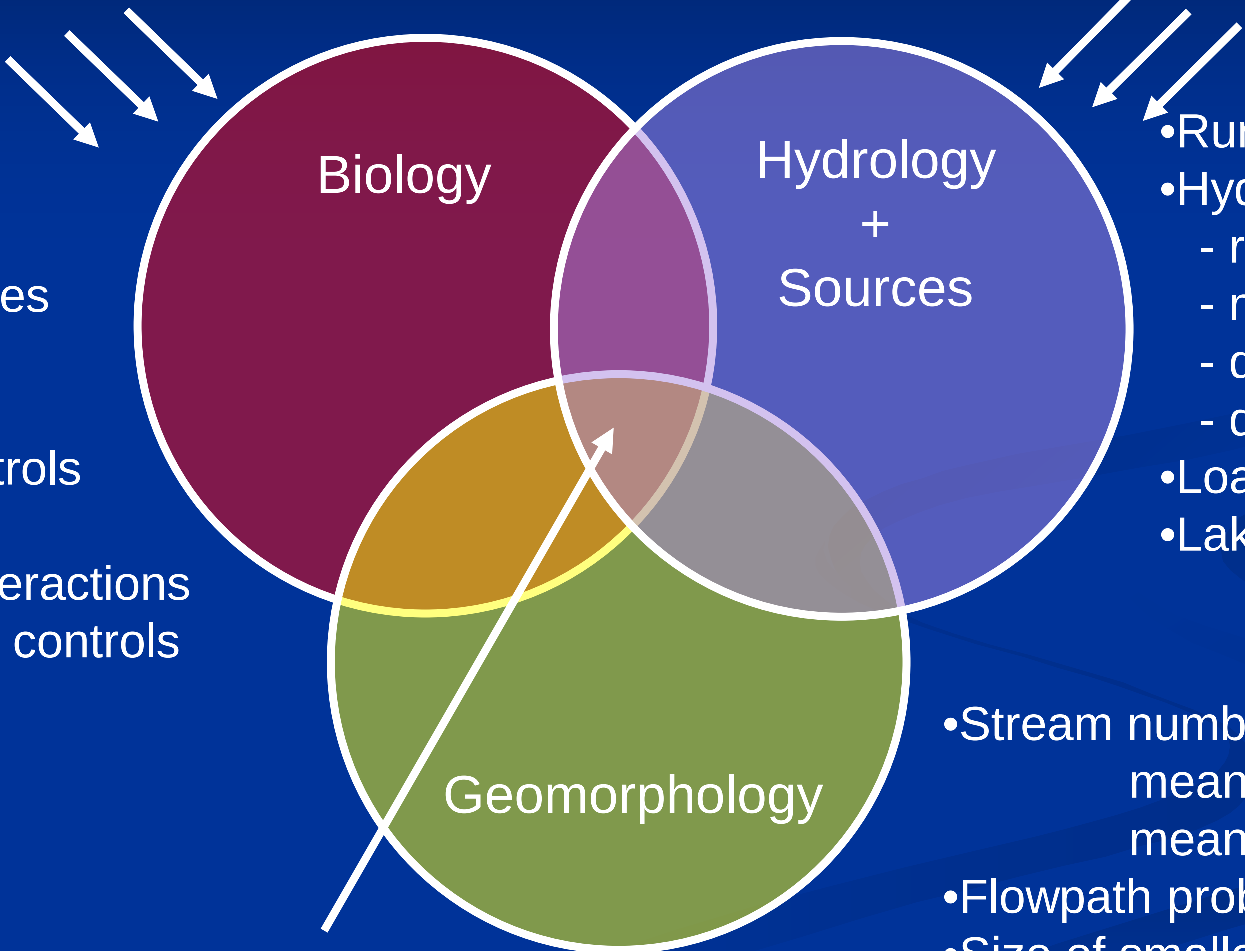


- Runoff
- Hydraulic gradients
  - residence time
  - mean depths
  - dW/dx
  - dW/dt
- Loading Distribution
- Lakes/Reservoirs

- Process rates
  dR/dx
  dR/dt
- Kinetic controls
  dR/dC
- Element interactions
- Community controls

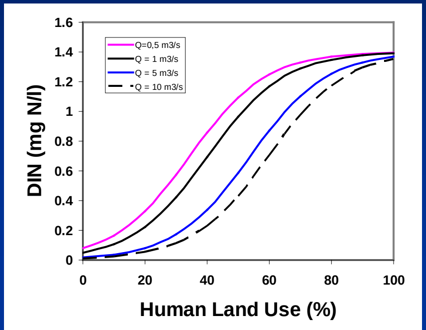
- Stream numbers
  mean drainage areas
  mean lengths
- Flowpath probabilities
- Size of smallest stream
  (map scale)

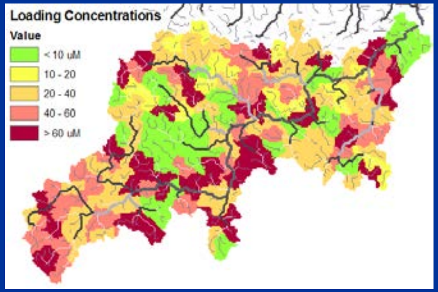
Nutrient Spiraling/
River Continuum

River Network N Removal Model

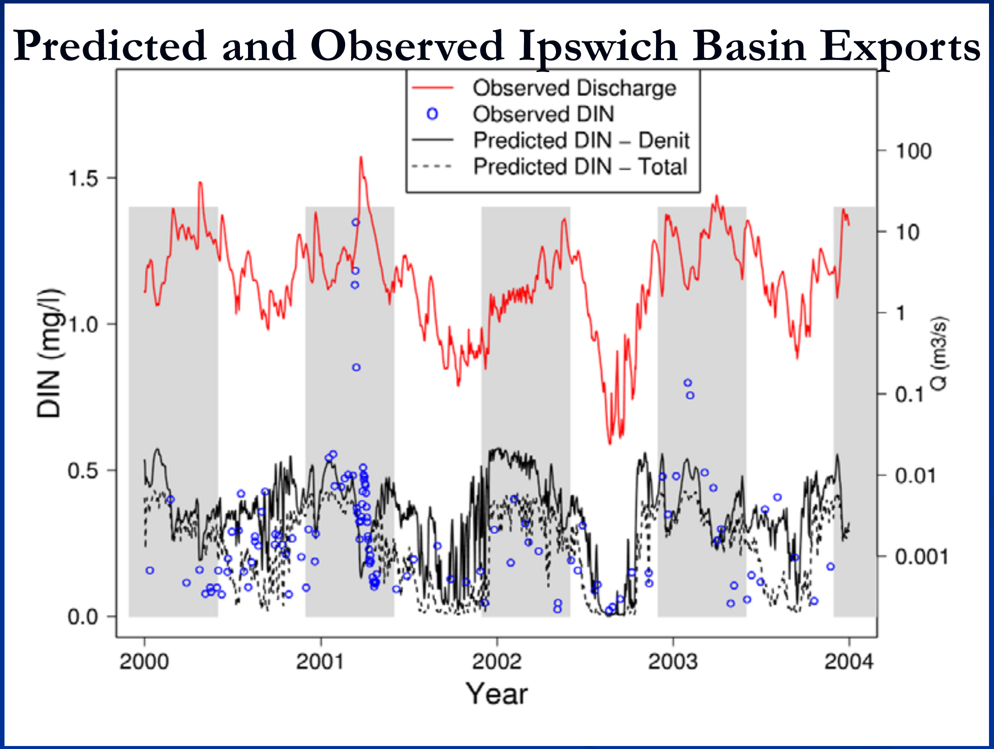
(Spatially Distributed, Time Varying)

DIN Loading (+ LINX process rates)





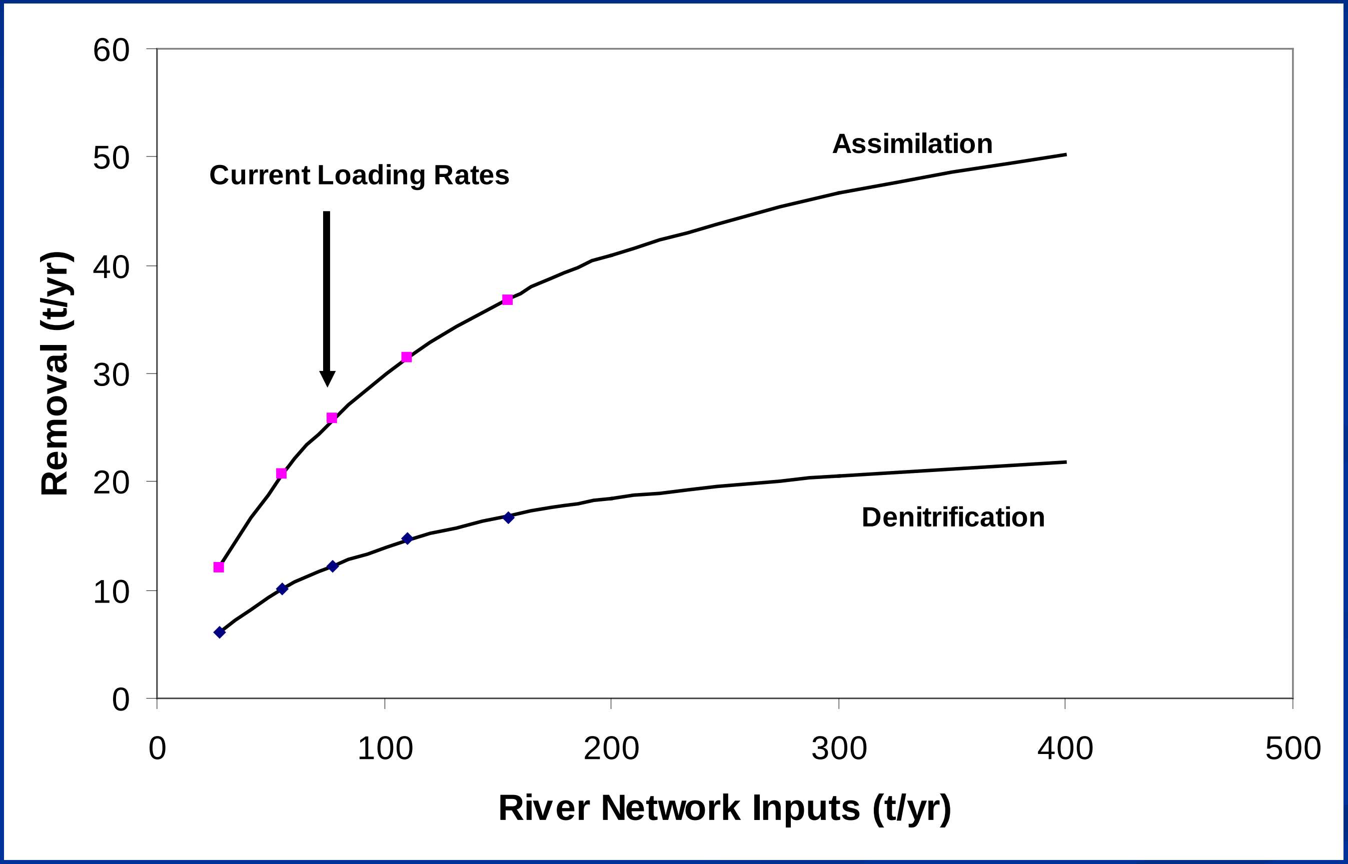
$$R = 1 - \exp(-U / (C^*H_L))$$



Discharge Category ($m^3\ s^{-1}$)	Annual runoff (%)	Annual inputs (%)	Annual exports (%)	Annual removal (%)	Inputs in flow category removed (%)
<2	6.9	12.6	8.5	35.3	42.5
2-5	19.7	27.2	25.6	35.7	20.0
>5	73.5	60.3	65.9	28.9	7.3

Network DIN removal is saturating

Results from different scenarios of N inputs to the river network using the Ipswich model (2000-2004 hydrology)



Further increases in inputs will lead to disproportionate increases in exports

Ongoing Efforts

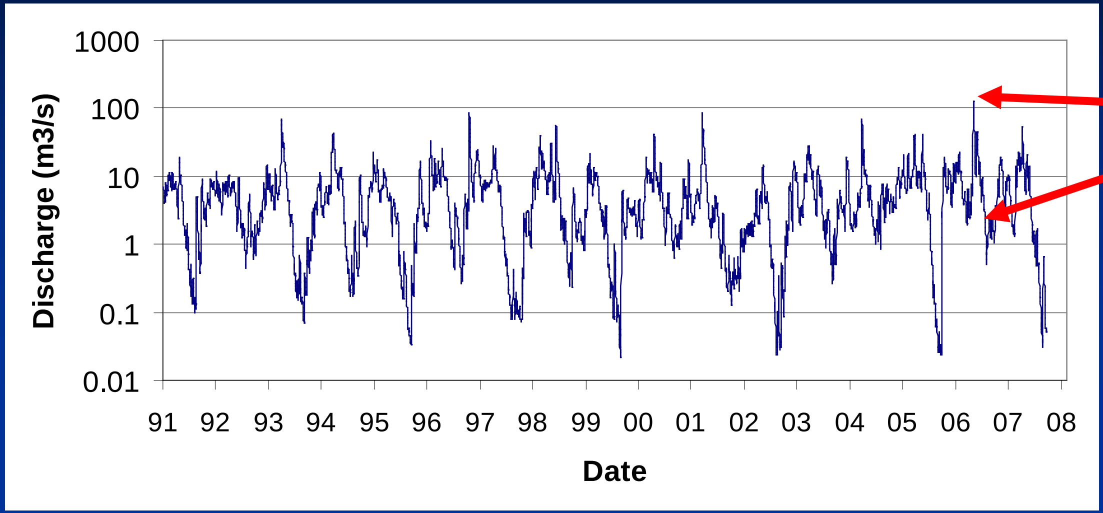
- What are the controls of aquatic denitrification rates across stream scale?
  - NSF-Ecosystems (UNH,MBL,Penn State collaboration)

- What are the mechanisms by which environmental responses feedback to influence societal actions?
  - NSF-Coupled Human Natural Systems (Clark U. , UNH, MBL collaboration)

- Responses and influences of higher trophic levels
  - Beaver activity (trapping laws, beaver explosion, hydro/bgc responses)
  - Herring runs (dams, low flows, restocking, water quality)

Questions?

Flow Variability



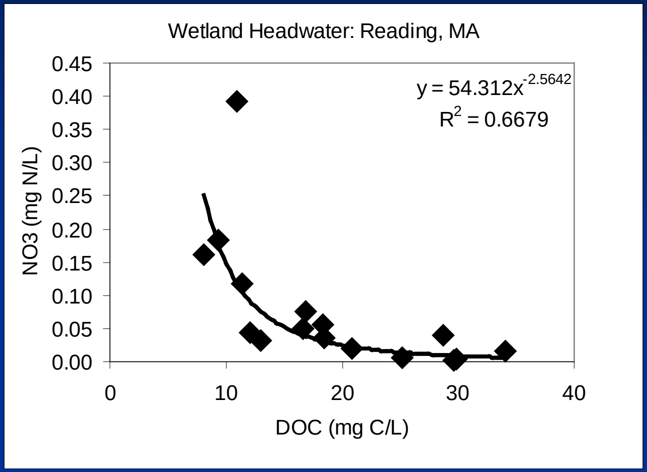
Flood of Record (May 2006)

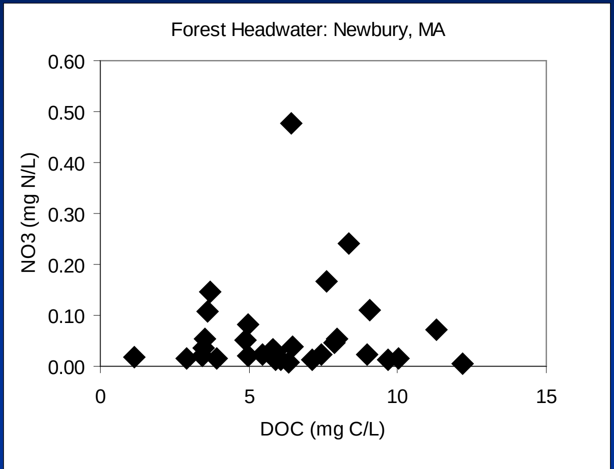
Low flow

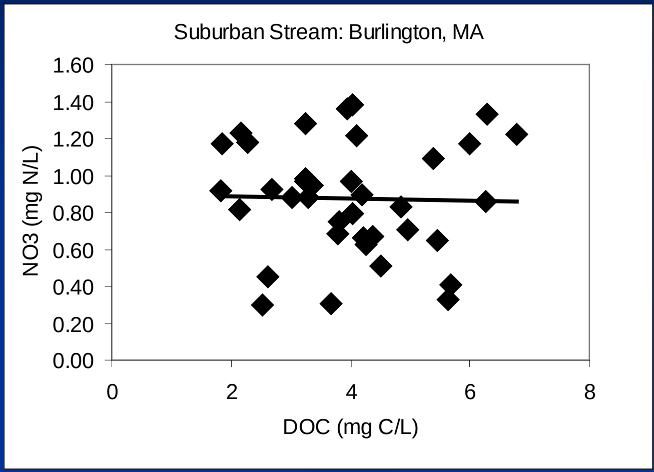
Ipswich Discharge

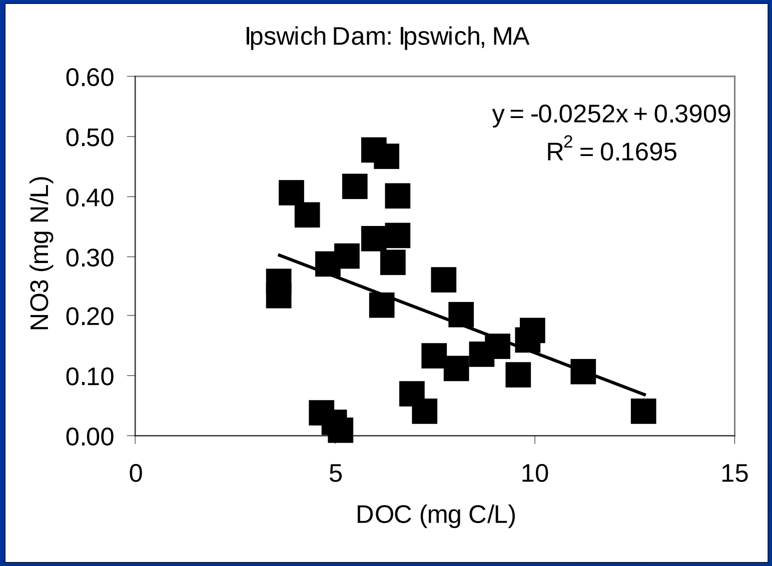
Sampling time series now includes the flood of record based on gauging since 1934

Nitrate vs. DOC









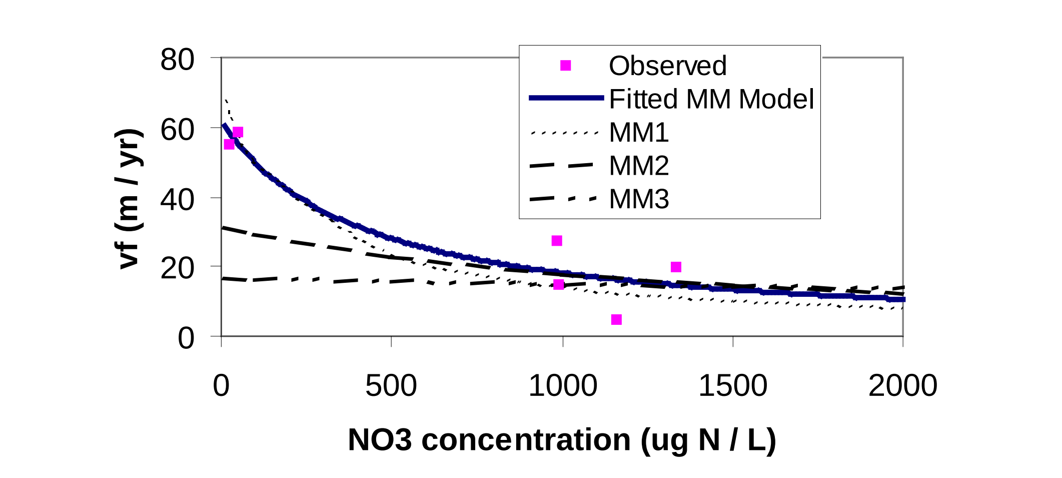
-Nitrate and DOC are highly correlated in wetland but not urban system.

-A wetland signal is apparent at the mouth of the Ipswich.

-High carbon exports from Ipswich associated with low inorganic nutrients.

Denitrification Saturates

- Uptake Velocity (U/C) declines with increasing NO_3

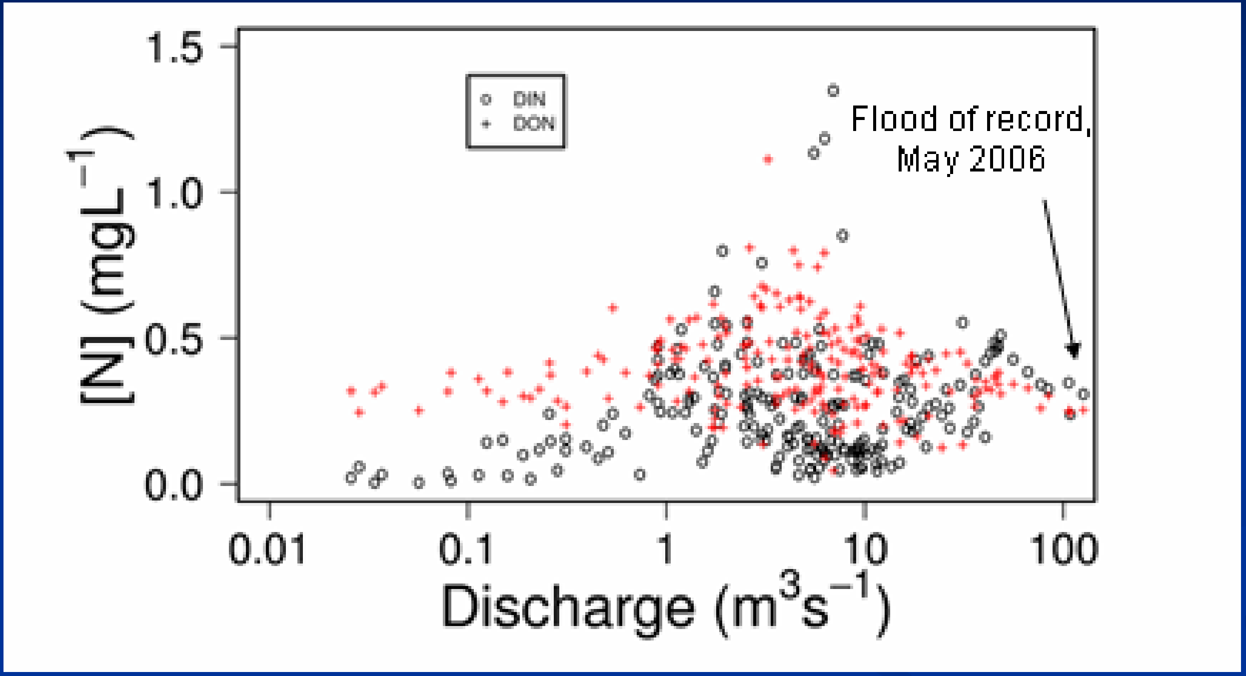


Michaelis-Menten Parameters: U = Umax C / (Ks + C)

		Observed	MM1	MM2	MM3
ks	ugN/L	416	252	1266	8900
Umax	mg/m2/d	70.3	48.3	109	408

Concentrations vs. Discharge

Concentration vs. Flow – Ipswich Dam



Complex relationship between concentration and flow levels

- Highest concentrations at intermediate flows (flushing)
- DIN greatly reduced during low flows (denitrification)
- Flood of record has nutrient levels in line with other peak flows
- DIN concentrations are depressed at ~ 10 m^3 s^{-1}
    - Source limitation? (Williams et al. 2004)
    - Floodplain removal? (Wollheim et al. in preparation)