Big questions and challenges—
enzymes in the aquatic environment

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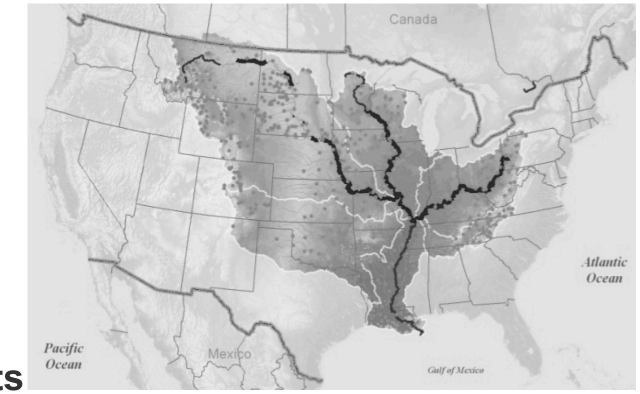
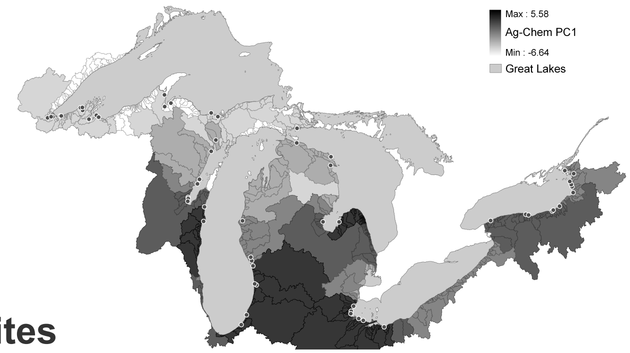
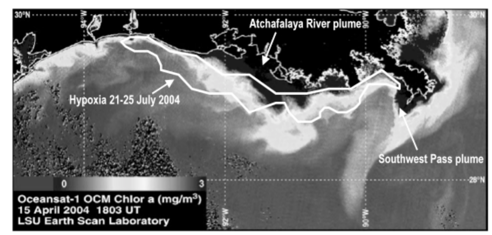
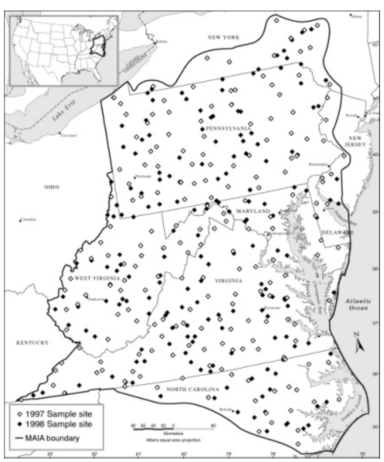
Microbial enzyme activity—
regional scale studies

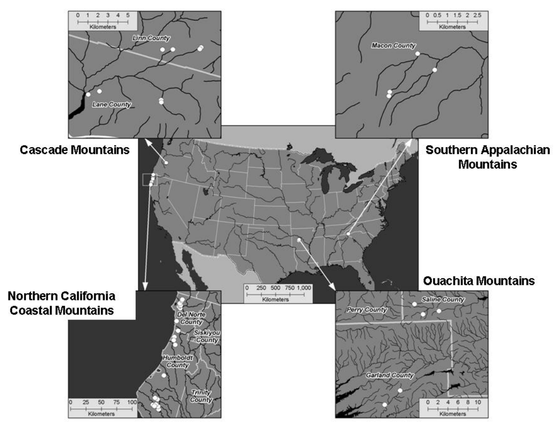
- EMAP Appalachian streams (1993-1994) – 130 sites
  - o Phos
- EMAP Appalachian stream & rivers (1997-1998) – 130 sites
  - DHA, Phos
- NH_4 & PO_4 uptake in forested streams (1999-2002) – 187 site-visits
  - o DHA, Glyc, Pept, Phos, Sulf
- Great Lake Environmental Indicators (2002-2003) – 54 sites
  - o Glyc, Pept, Phos, Sulf
- EMAP Great Rivers Ecosystems (2004-2006) – 447 sites
  - o DHA, Glyc, Pept, Phos, Sulf
- Gulf of Mexico (2007-2008) – 5 coring sites
  - o Glyc, Pept, Phos, Sulf
- National Rivers & Streams Assessment (2008-2009) – >2200 sites
  - o DHA, Glyc, Pept, Phos, Pox, Perox, Sulf



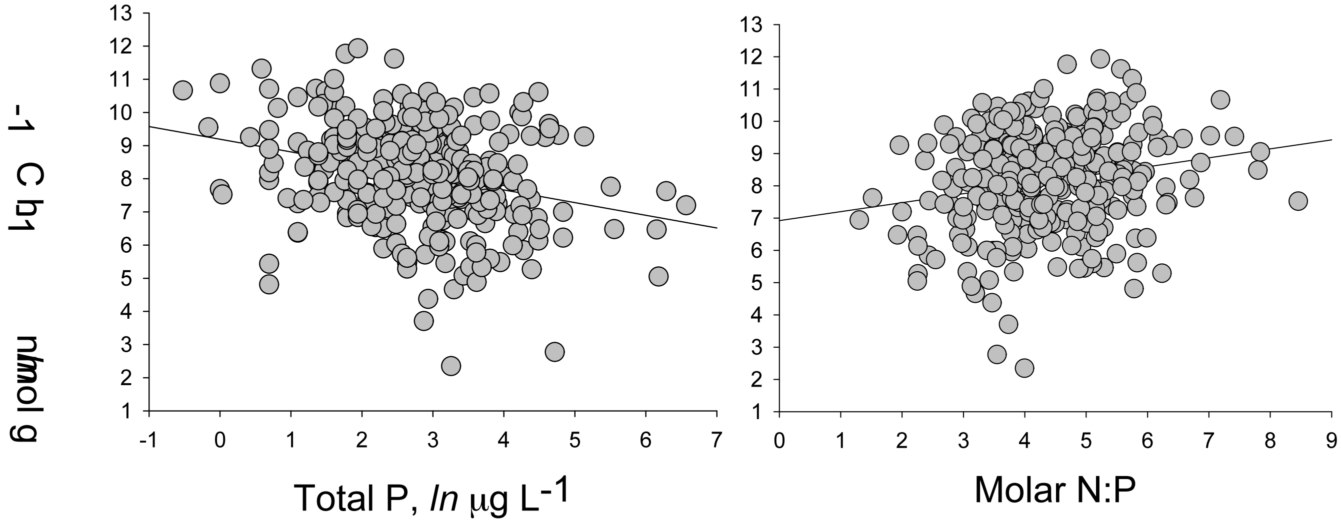


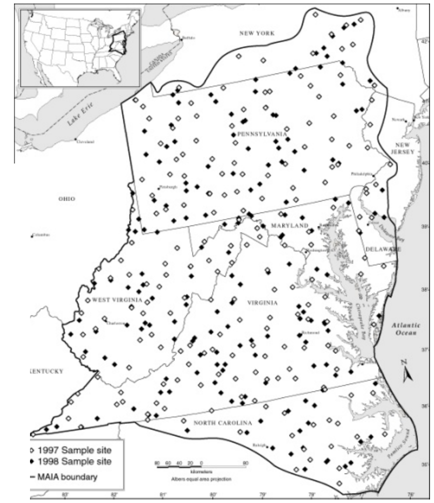




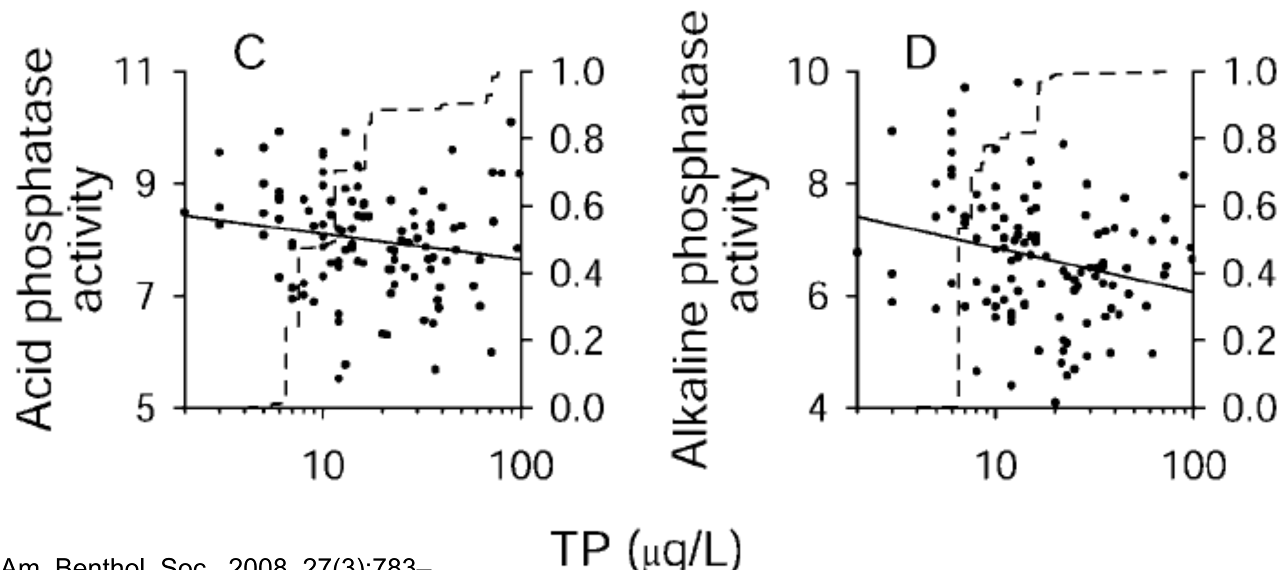


Appalachian streams—
Phosphatase



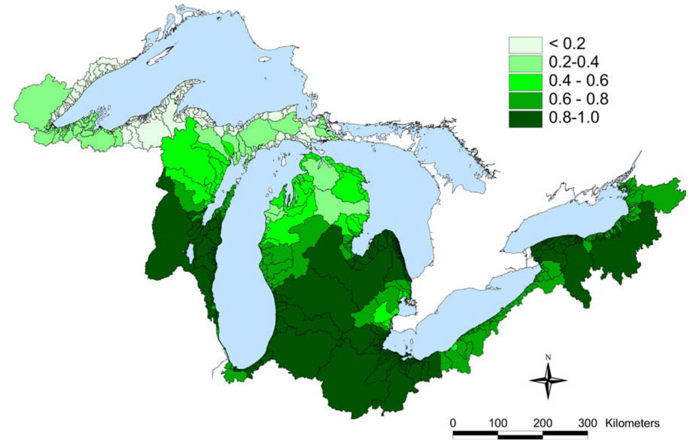


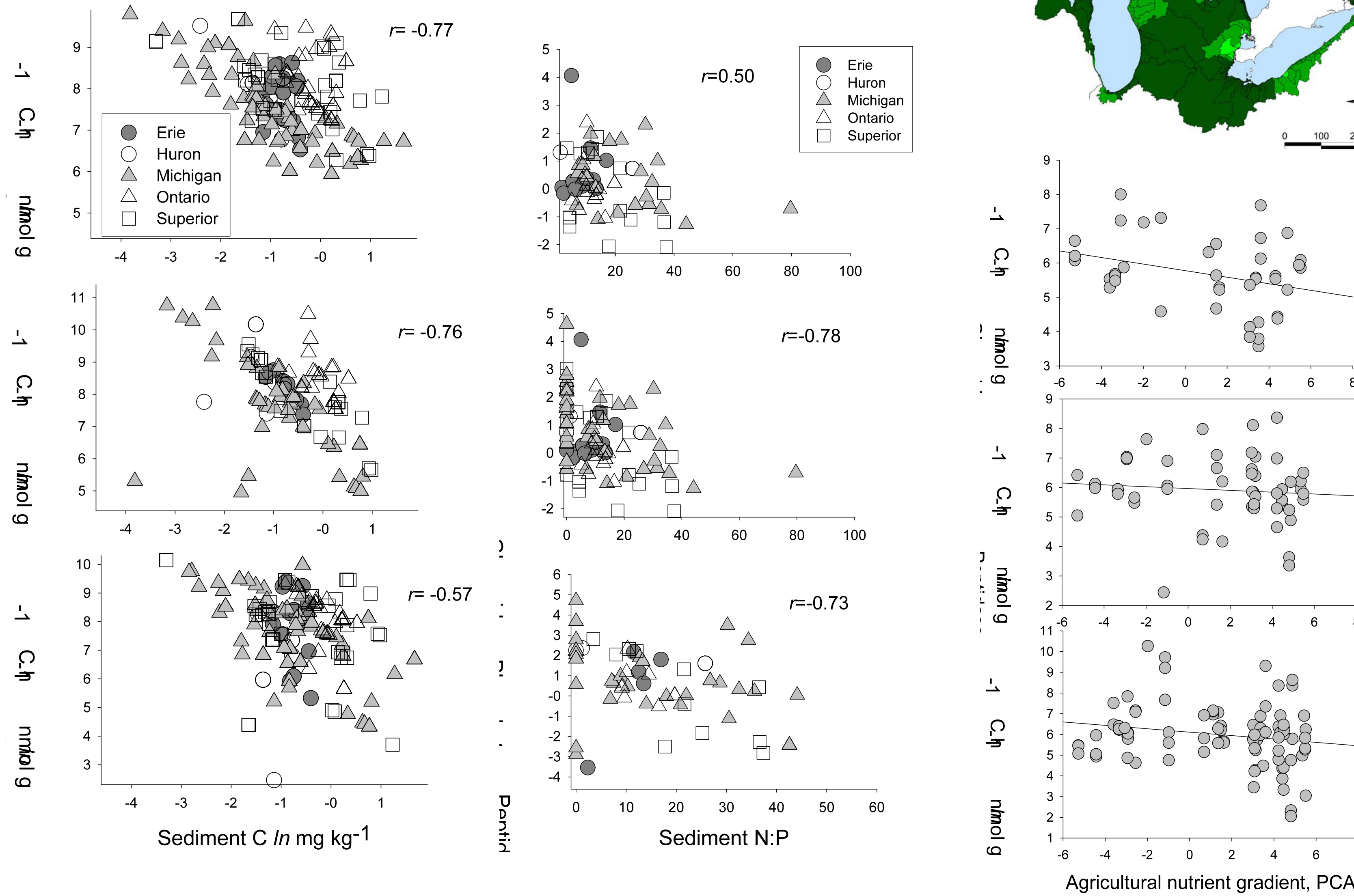
Change-point detection indicated a 10-20 µg P L-1 threshold for AP



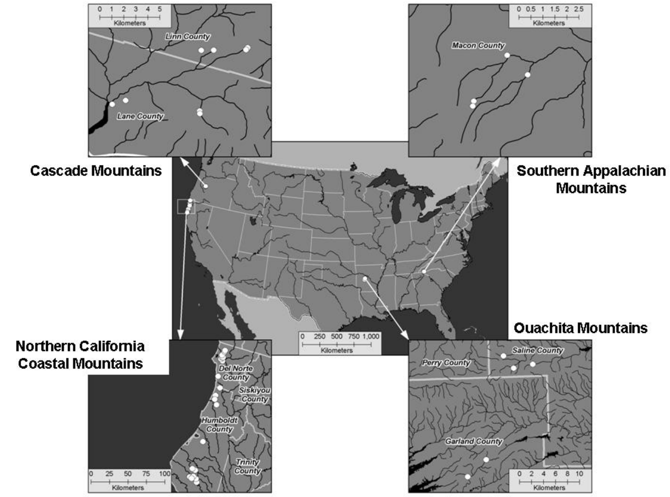
Stevenson et al. J. N. Am. Benthol. Soc., 2008, 27(3):783–799

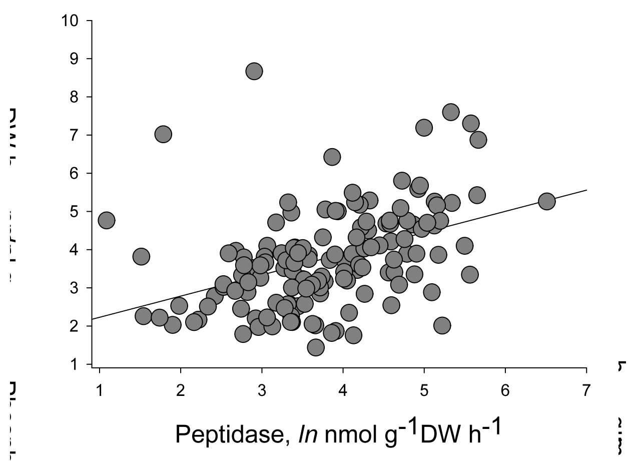
Great Lakes Coastal wetlands—

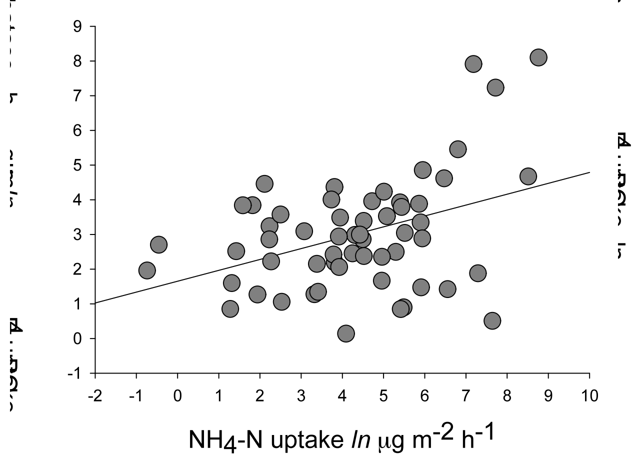


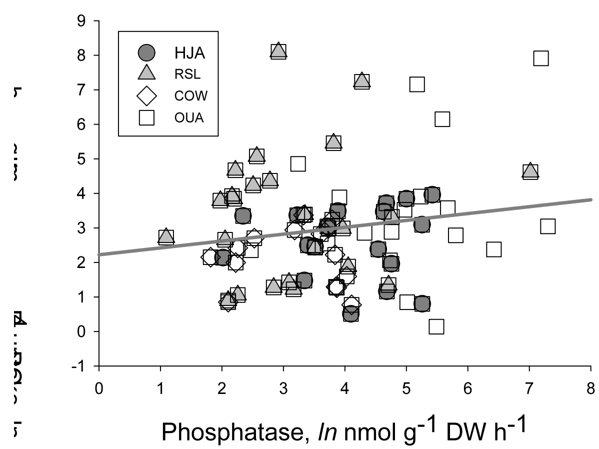


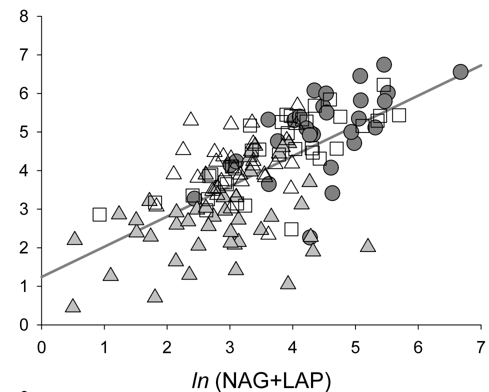
Forested streams—
Enzymes & nutrient uptake

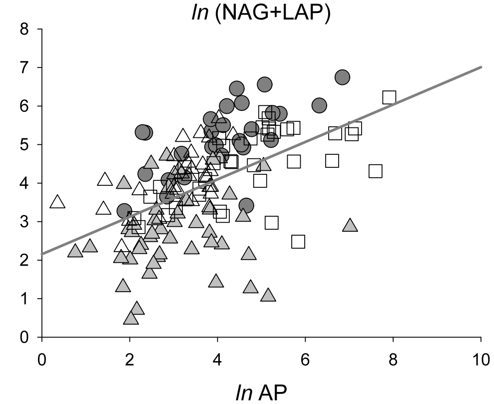




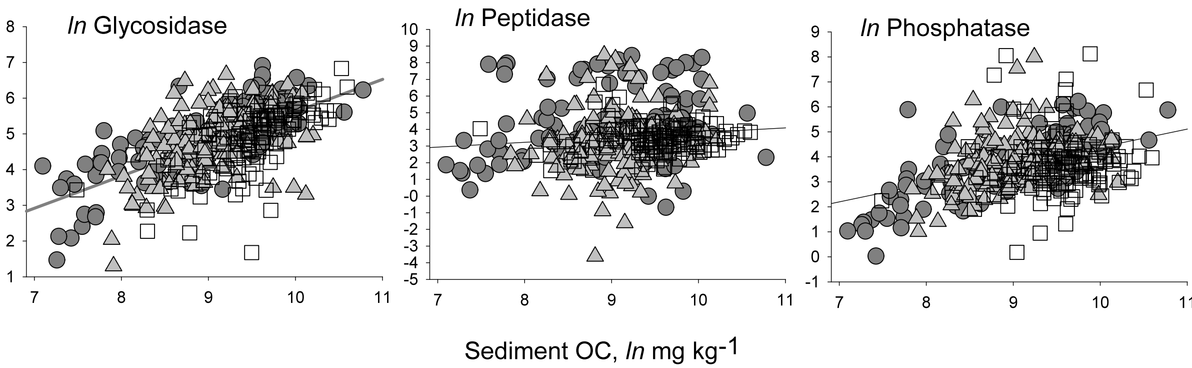


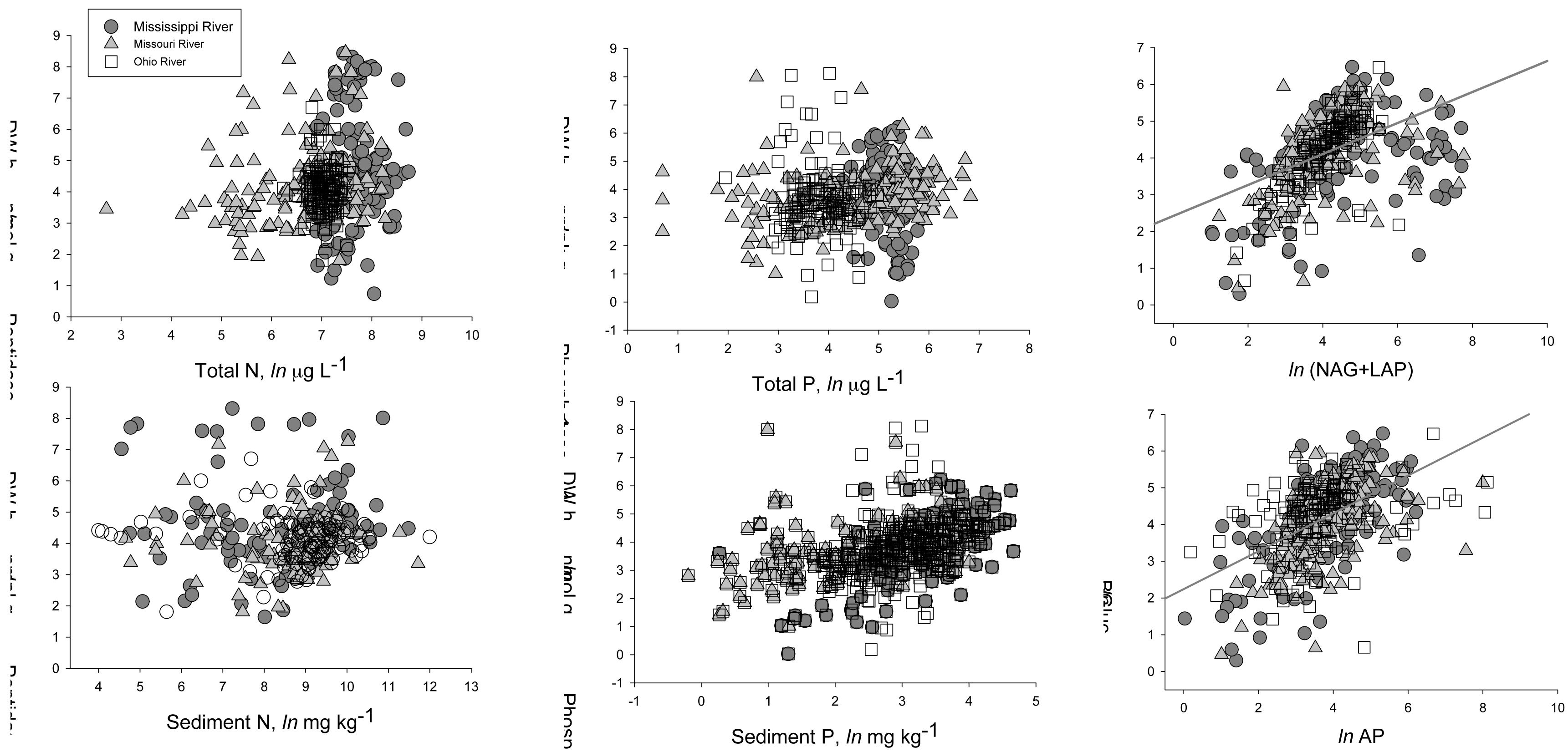




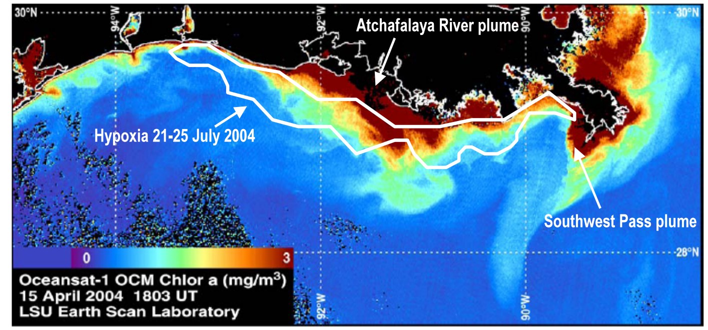


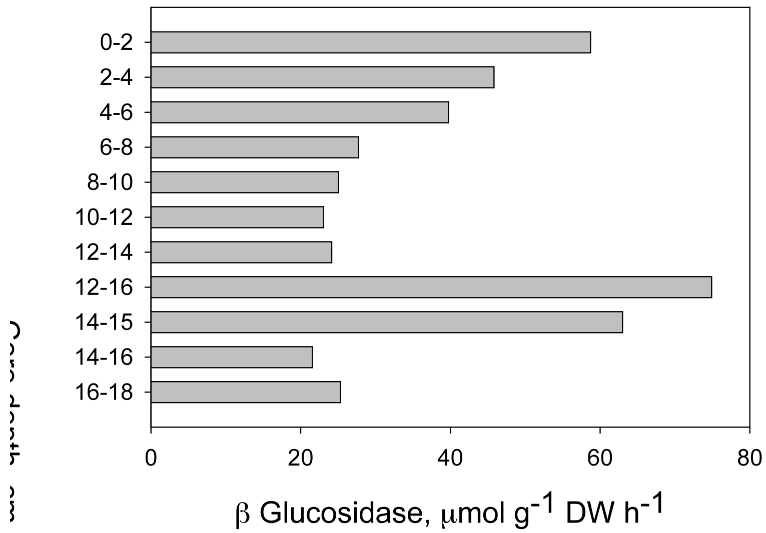
EMAP Great Rivers—
Enzvmes & nutrients

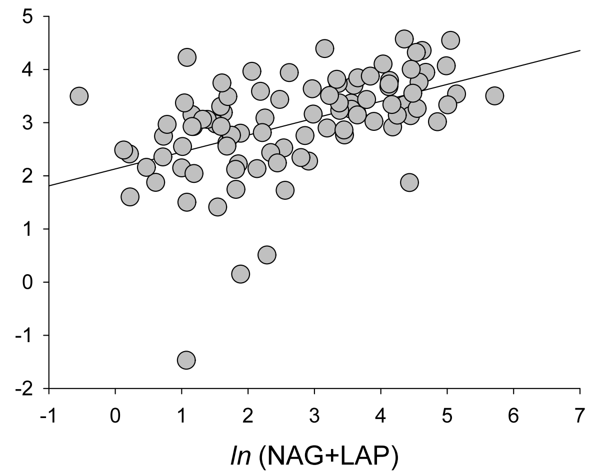


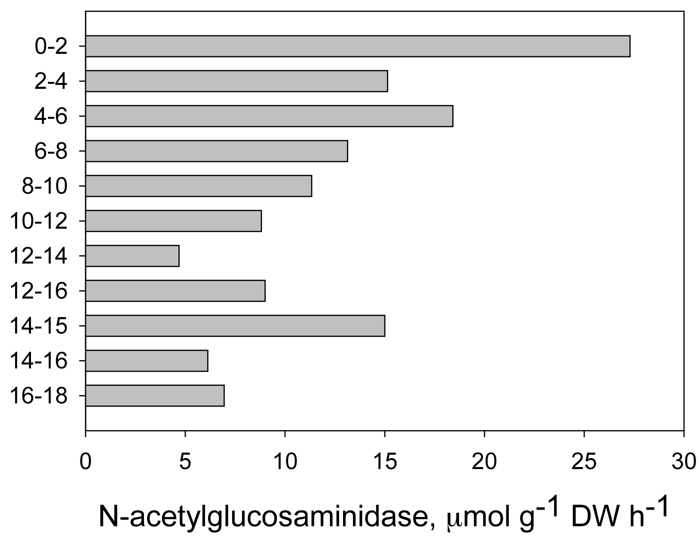


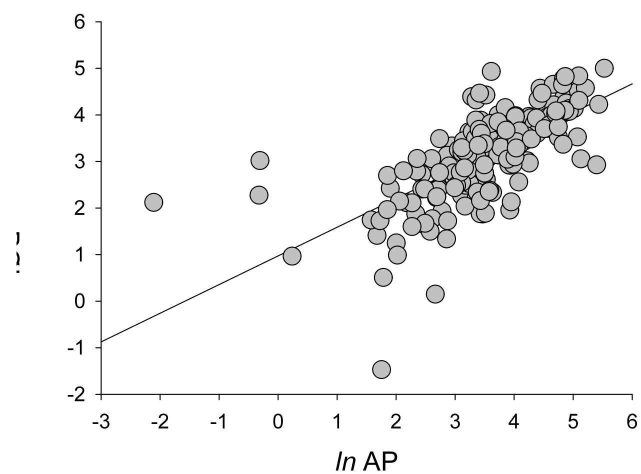
Gulf of Mexico—
Enzymes in the hypoxic zone



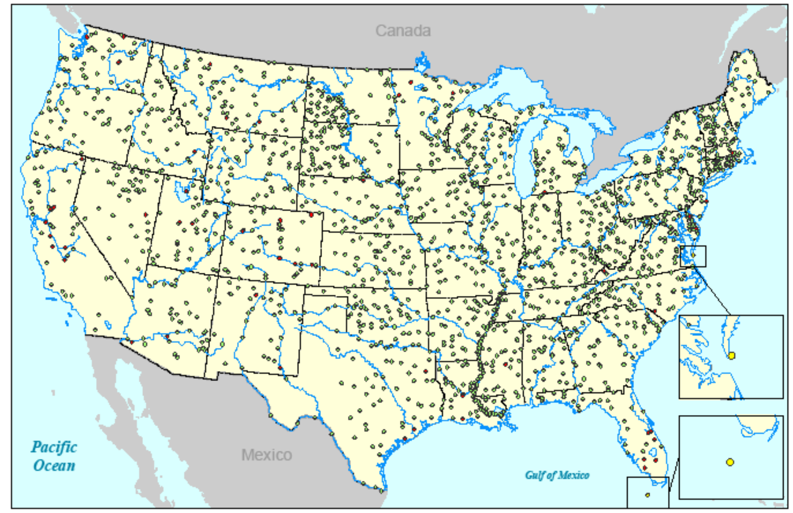


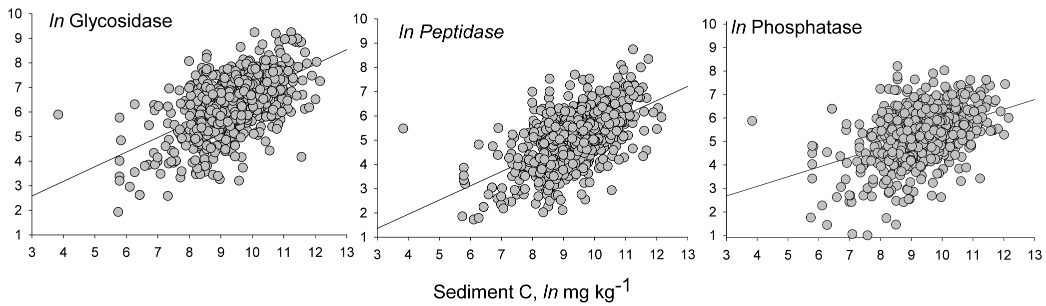


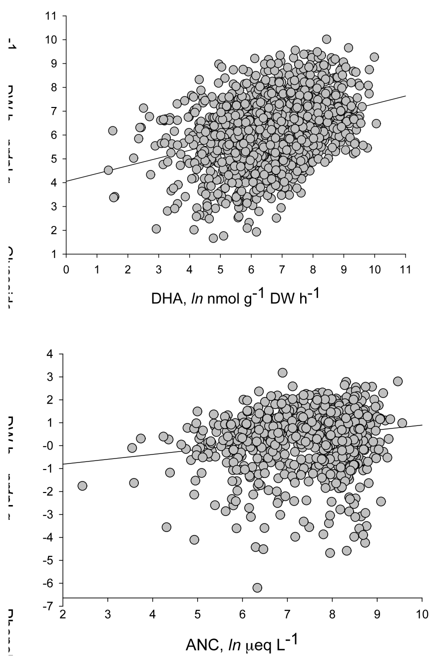


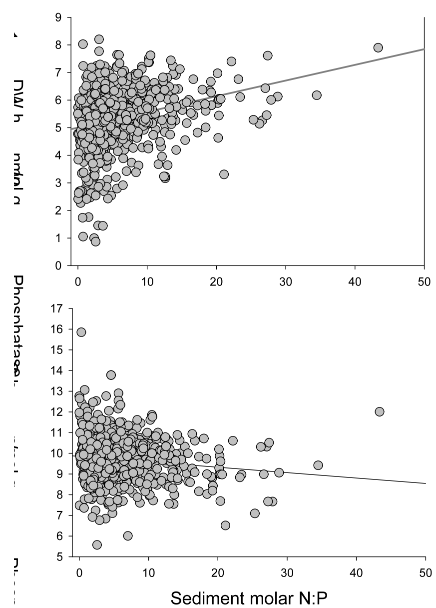


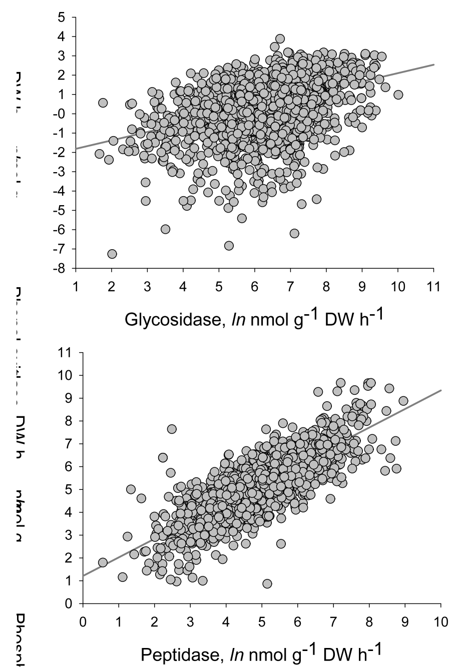
National Rivers & Streams Assessment—
Enzymes at a really big scale

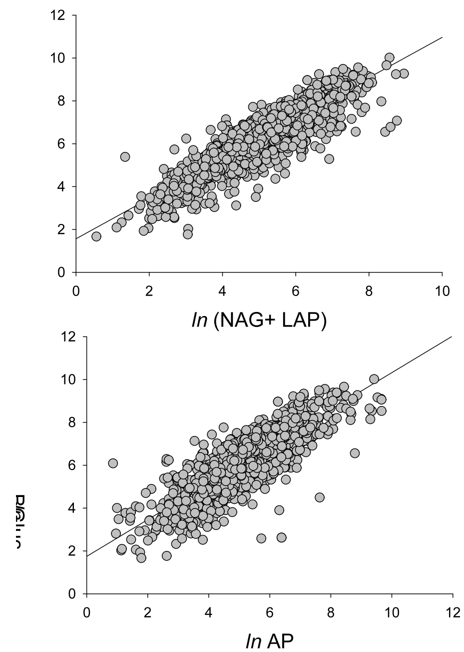








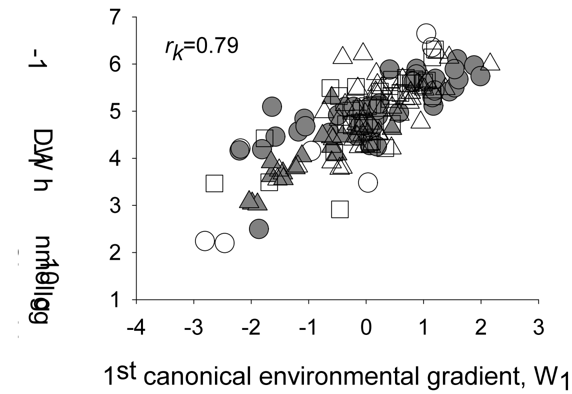


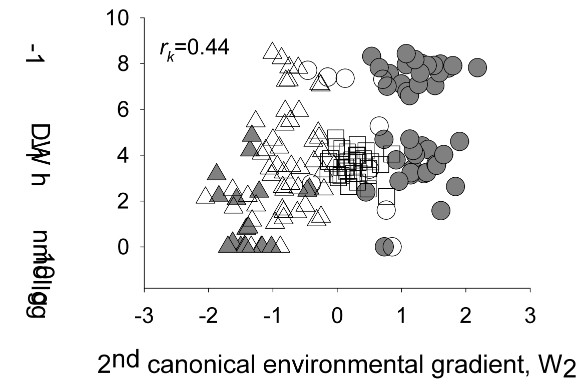


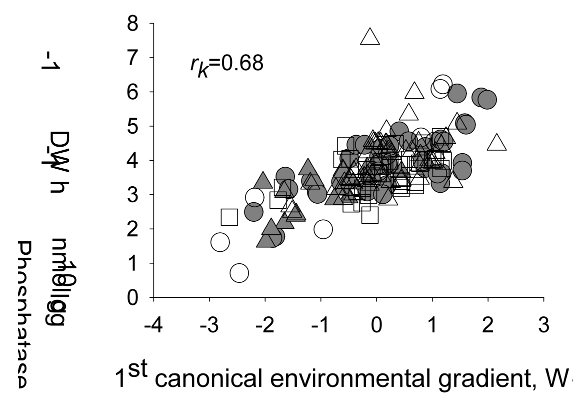
What drives enzyme activity in aquatic ecosystems?—

canonical correlation with environmental variables—Great Rivers

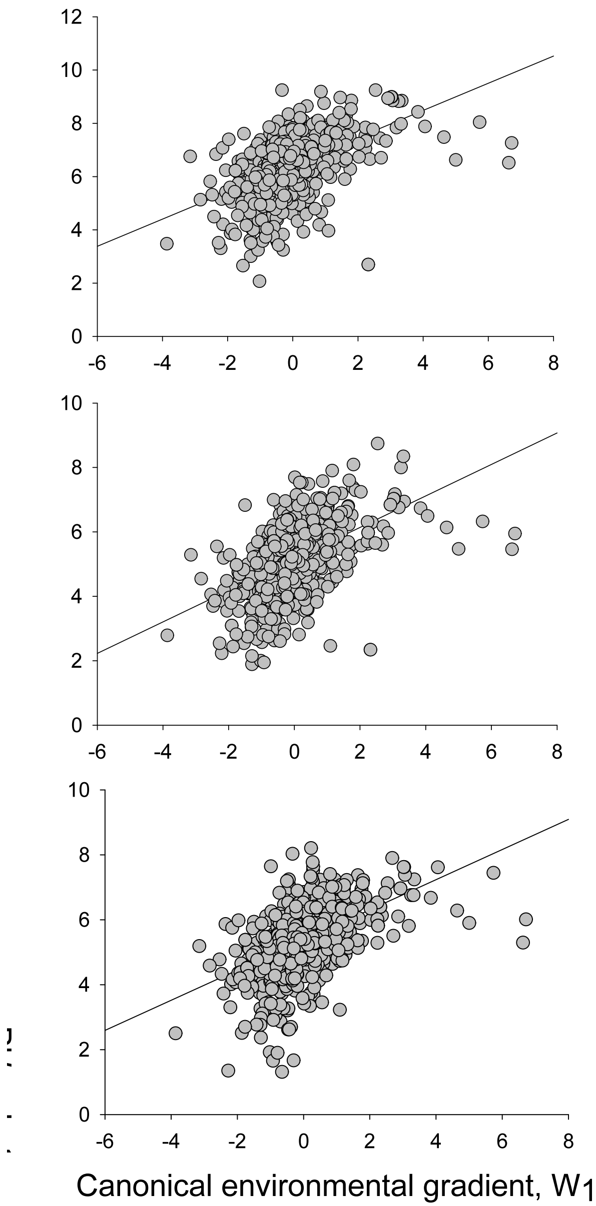
Variable	W1	W2
TN	**0.33**	**0.71**
TP	**0.39**	0.31
TOC	0.22	**0.78**
SO_4	-0.14	**-0.87**
Sediment TN	**0.40**	0.19
Sediment TP	**0.48**	**0.38**
Sediment TOC	**0.85**	-0.10
% fine sediment	**0.77**	-0.30
% agriculture	0.15	**0.78**
% developed	0.13	**0.67**
% wetlands	0.09	**0.71**
NADP TN	0.28	**0.52**
NADP SO_4	0.28	**0.53**
Variance explained	78%	10%







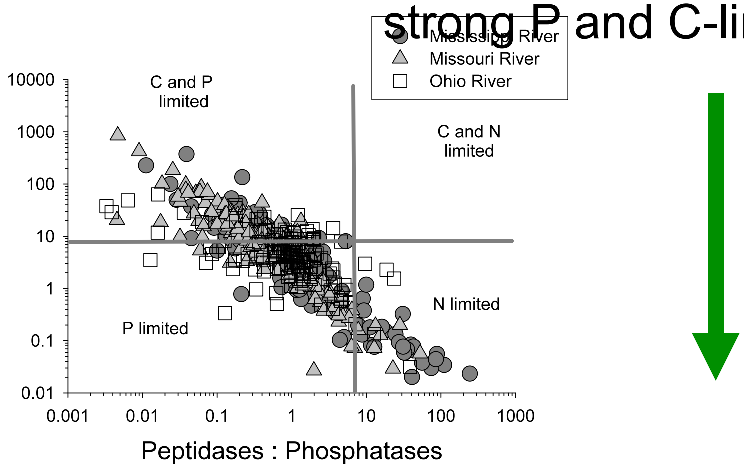
What drives enzyme activity in aquatic ecosystems?—
canonical correlation with environmental variables—NRSA



Variable	W_1	W_2
pH	**-0.68**	**0.54**
DOC	-0.13	0.22
TN	-0.02	**0.35**
TP	-0.12	**0.34**
SO_4	-0.27	**0.44**
Sediment TC	**0.69**	**0.65**
Sediment TN	**0.70**	0.28
Sediment TP	0.21	0.24
Variance explained	78%	10%

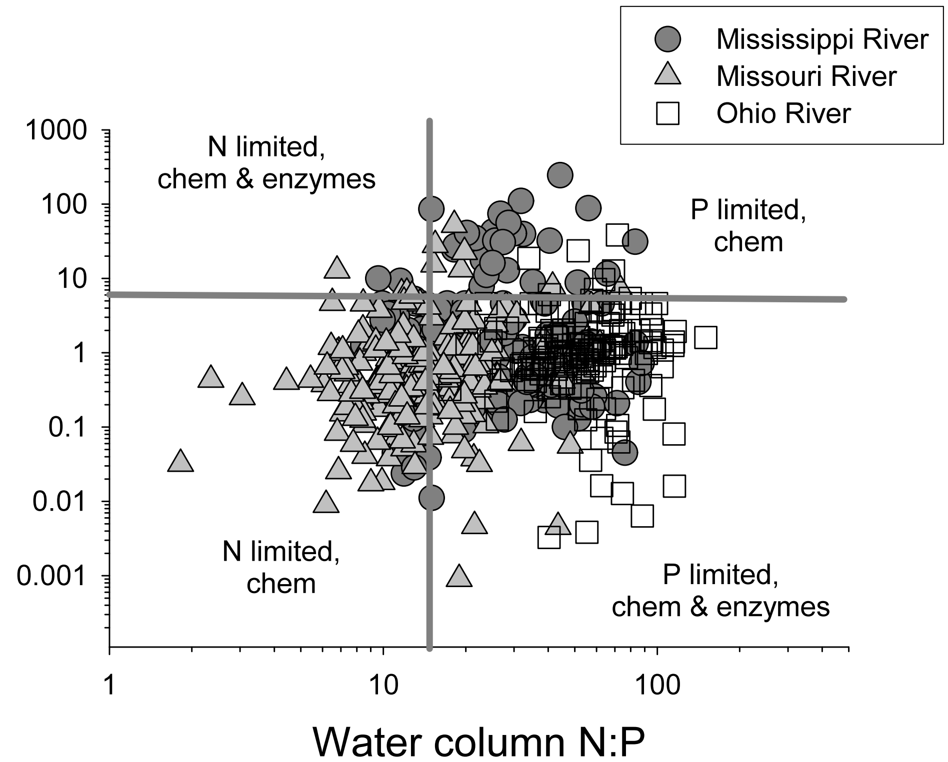
Nutrient stoichiometry—Great River enzymes

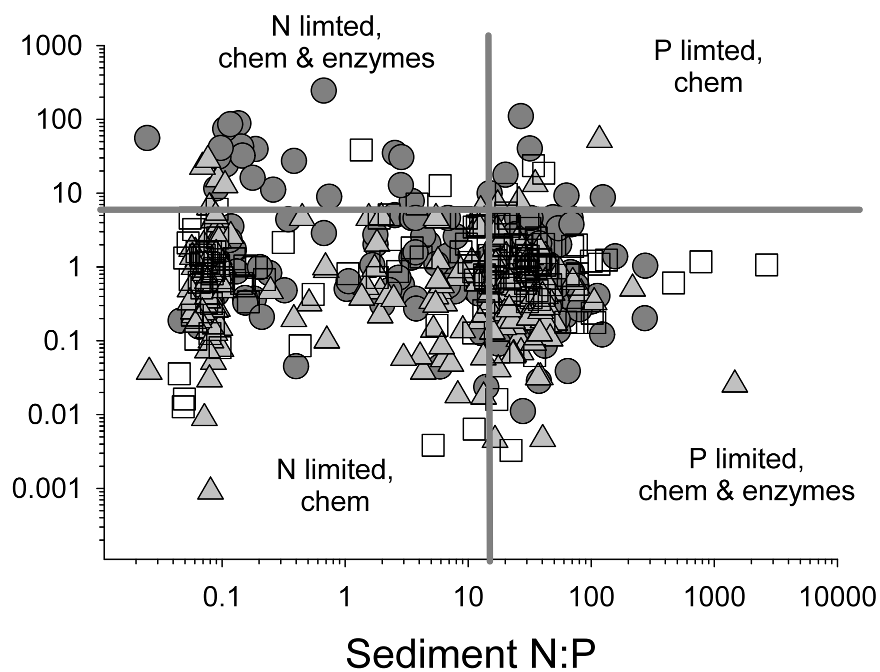
strong P and C-limitation



Nutrient stoichiometry—enzymes vs. chemistry

good agreement between
chemistry and enzymes





C, N, and P limitation (%)—

	C, N, & P			N & P only		
Upper Mississippi River	*Water*	*Sed*	*Enz*	*Water*	*Sed*	*Enz*
C-limitation	16	100	76	---	---	---
N-limitation	0	0	0	49	54	13
P-limitation	48	0	24	51	46	87
No limitation	36	0	0	0	0	0
Missouri River						
C-limitation	48	100	64	---	---	---
N-limitation	9	0	0	15	61	3
P-limitation	12	0	36	12	39	97
No limitation	31	0	0	73	0	0
Ohio River						
C-limitation	1	100	79	---	---	---
N-limitation	0	0	1	0	60	3
P-limitation	97	0	20	98	40	97
No limitation	1	0	0	2	0	0

Questions & Challenges—

❖ What drives enzyme activity in aquatic environments?

❖ How robust is the relationship between enzyme activity & environmental variables?

❖ How is enzyme activity related to catchment land use?

❖ Scaling issues—sediment particles → reach → river networks→ landscapes → national

❖ Predictability—if we know the relationship of enzymes to environmental & landscape attributes, can we predict activity across landscapes?

❖ How can we use enzymes to help understand/predict the impacts of climate change?