UNDERSTANDING NUTRIENTS IN AGRICULTURAL STREAMS: BIOLOGICAL COMMUNITIES AND ECOSYSTEM FUNCTION

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U.S. Geological Survey

Water Lecture Series
2015

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Stream Ecosystems

Structure

Nutrient concentration

Biomass

Biological communities

Function (process)

Stream metabolism

Nutrient transformations and cycling

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Objectives

1. Determine the relations between biological communities and nutrient conditions.

2. Determine the relations between nutrients, algae and stream metabolism.

3. Determine the influence of biota and hydrologic exchange on nutrient loads and nitrogen transformations.

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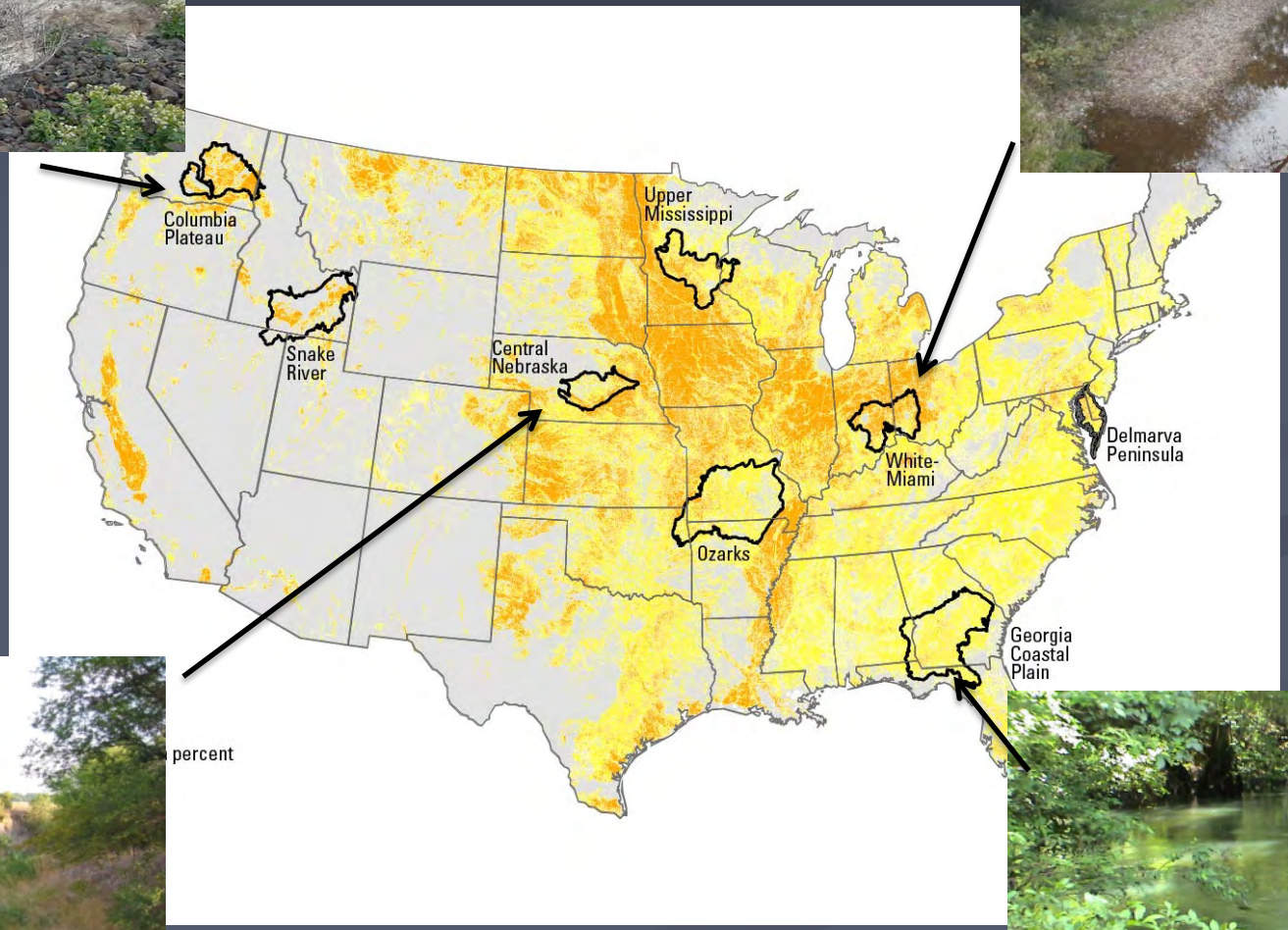
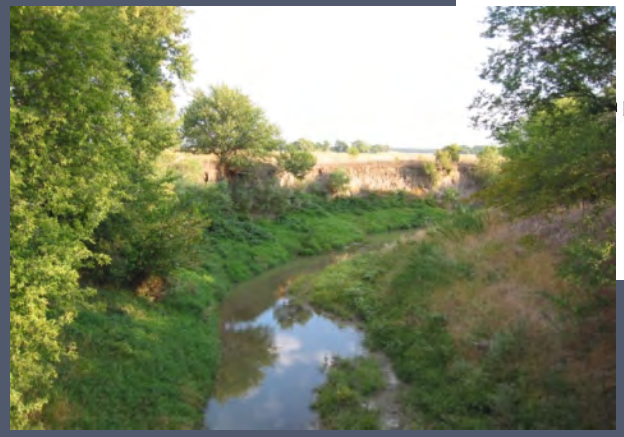
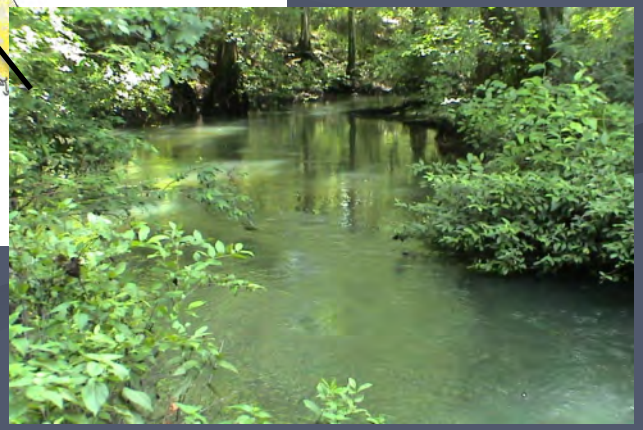
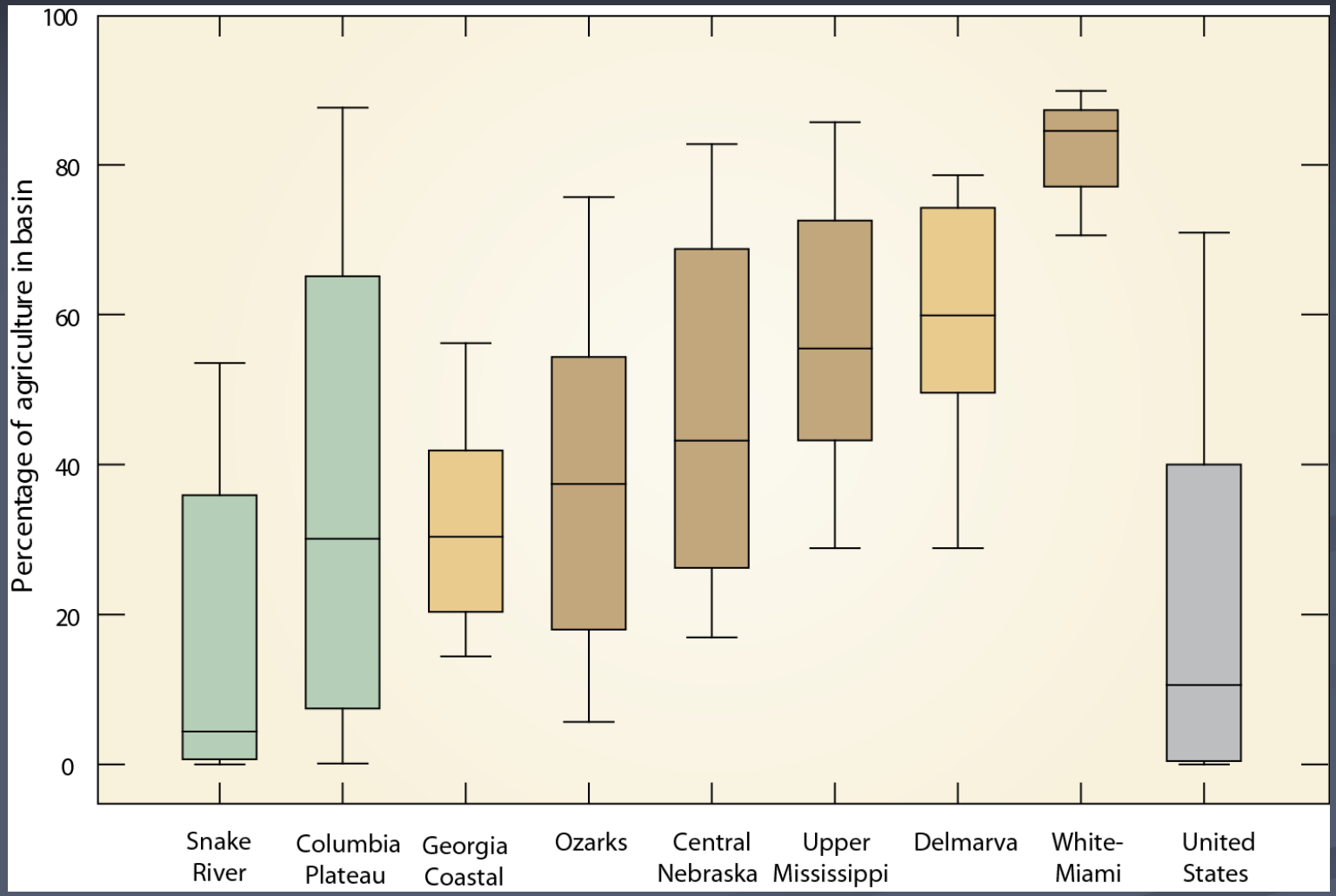
Study Areas


Columbia Plateau
Snake River
Central Nebraska
Upper Mississippi
White-Miami
Ozarks
Delmarva Peninsula
Georgia Coastal Plain
percent





Agricultural land use



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Objective 1: Determine the relations between biological communities and nutrient conditions.

- 30 independent wadeable streams (232 total)
  - Sites span nutrient gradient
  - Benthic algae and invertebrates
- Benthic algal biomass and macrophyte cover
- Stream habitat, riparian, and basin features
- Nutrient chemistry (2 times over 30 days)

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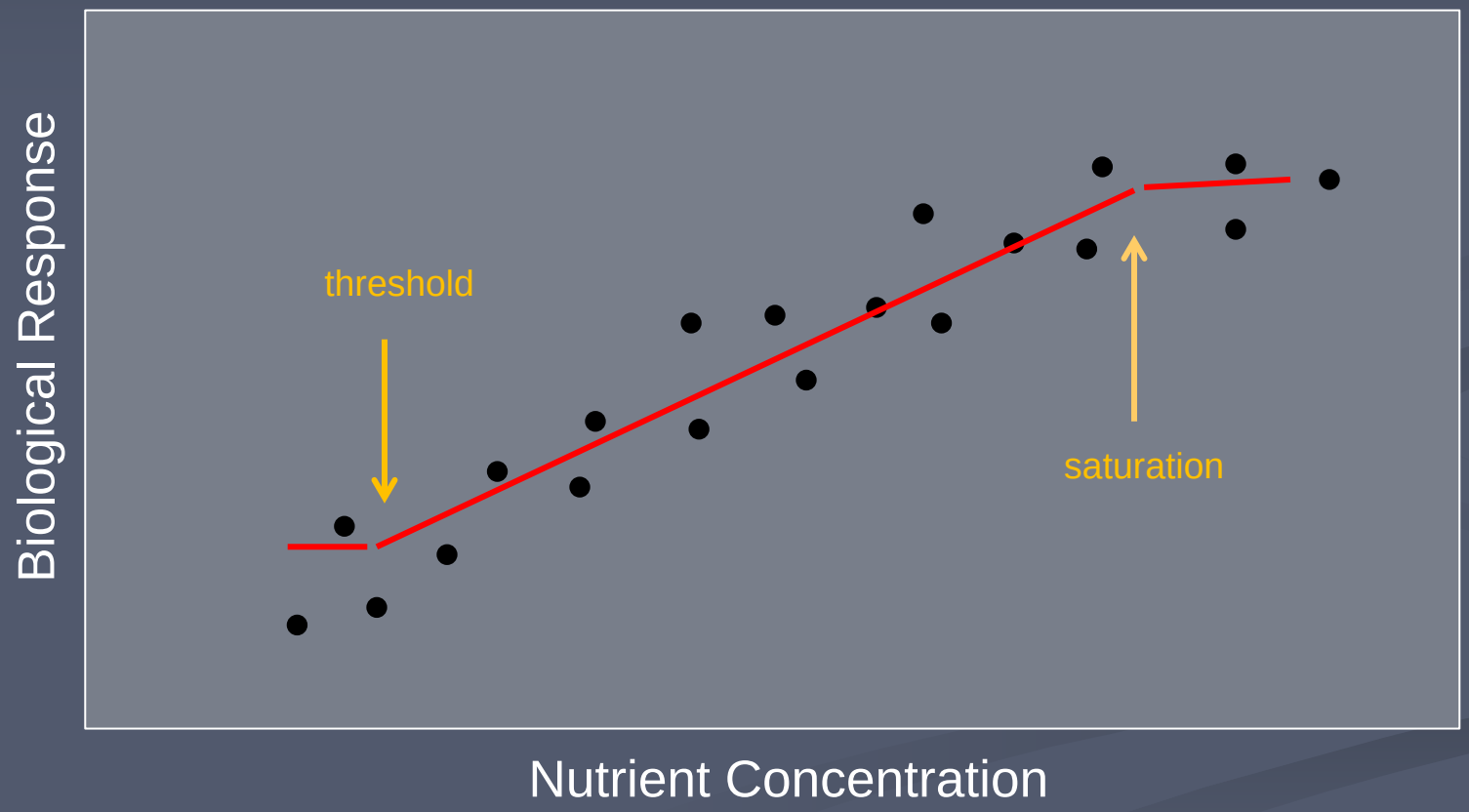
Optimal Design:
Nutrient gradient (reference + range)



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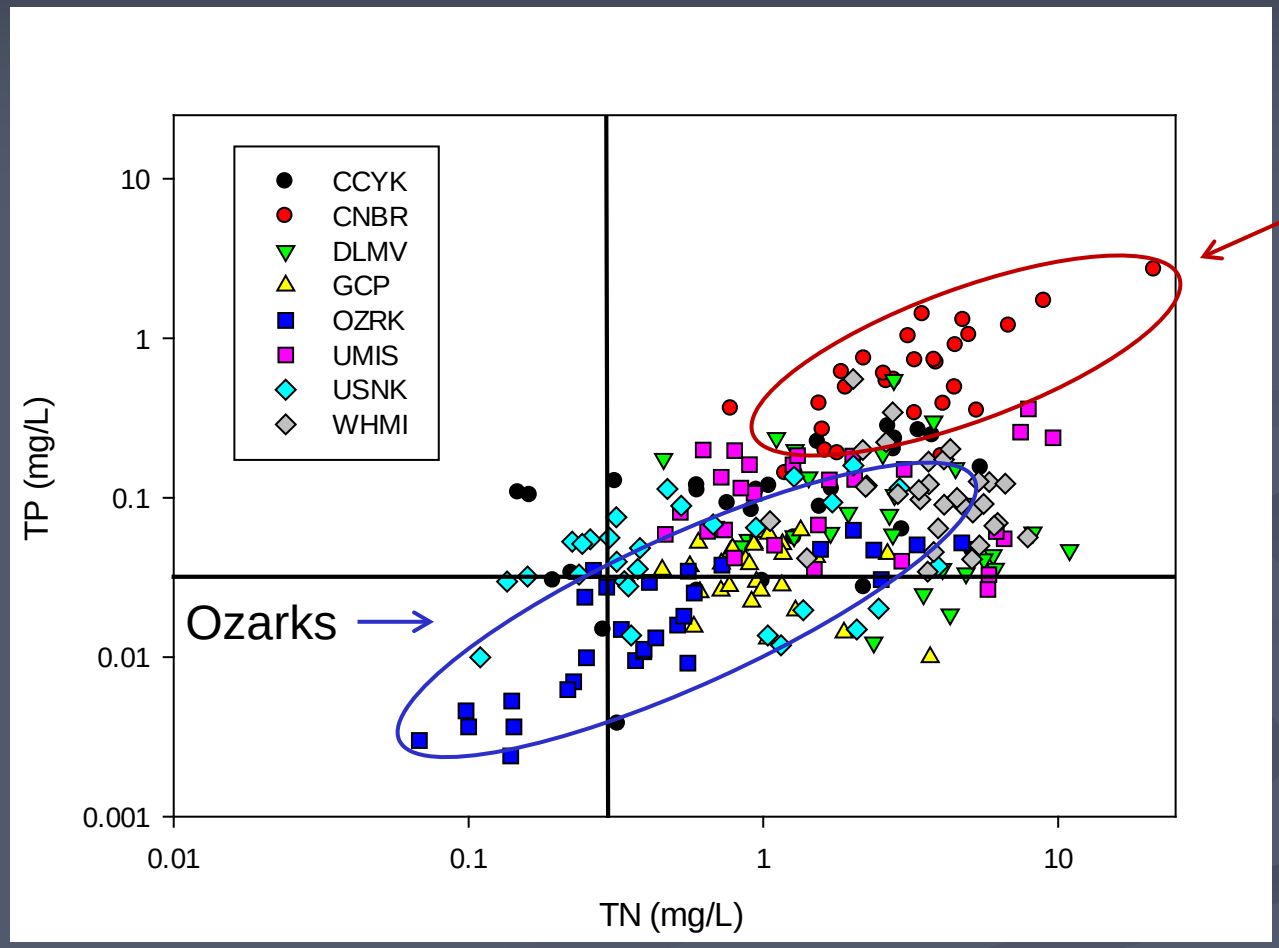
Total Phosphorous (TP) vs Total nitrogen (TN) in agricultural streams



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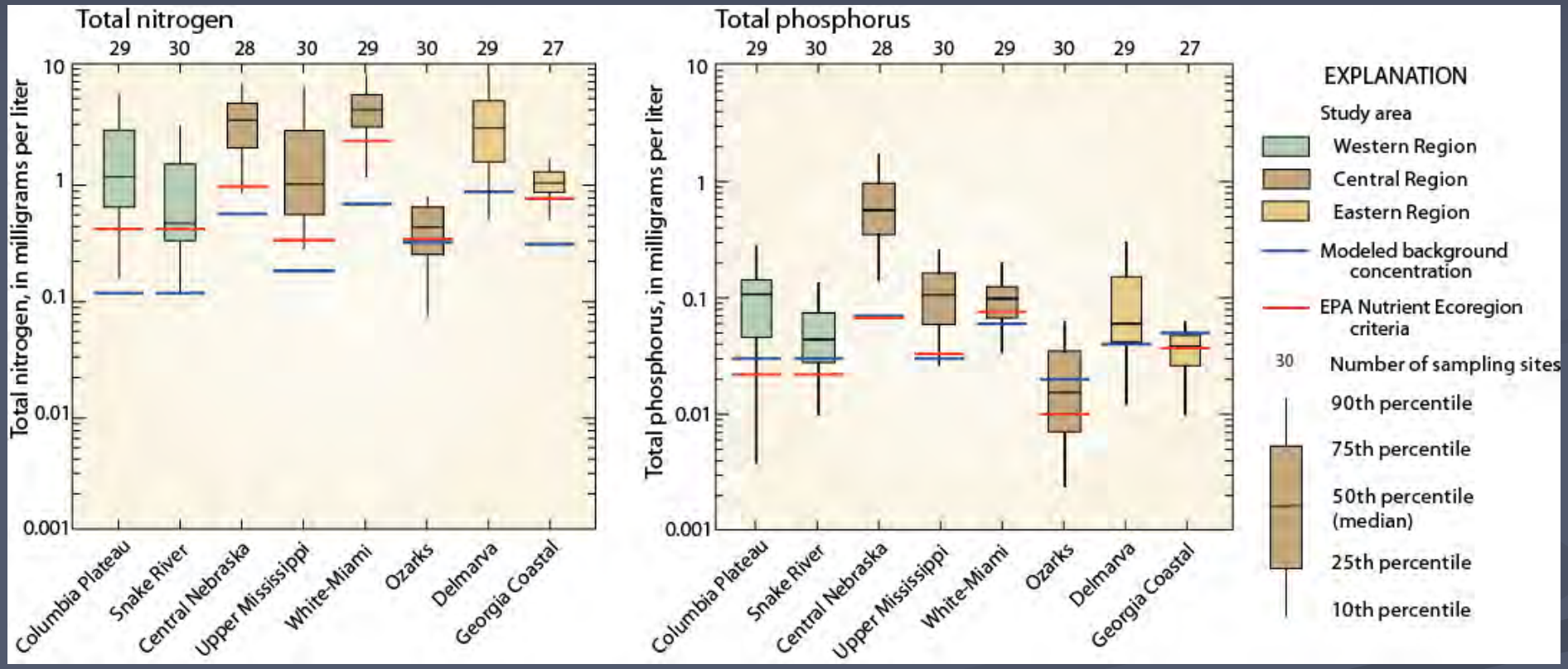
TN and TP generally exceed background concentrations



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Biological Assessment Metrics for Assessing Biological Condition

O/E

Observed: # native species

Expected: # native species

Model only as good as reference sites

EPT richness

Ephemeroptera

Plecoptera

Trichoptera

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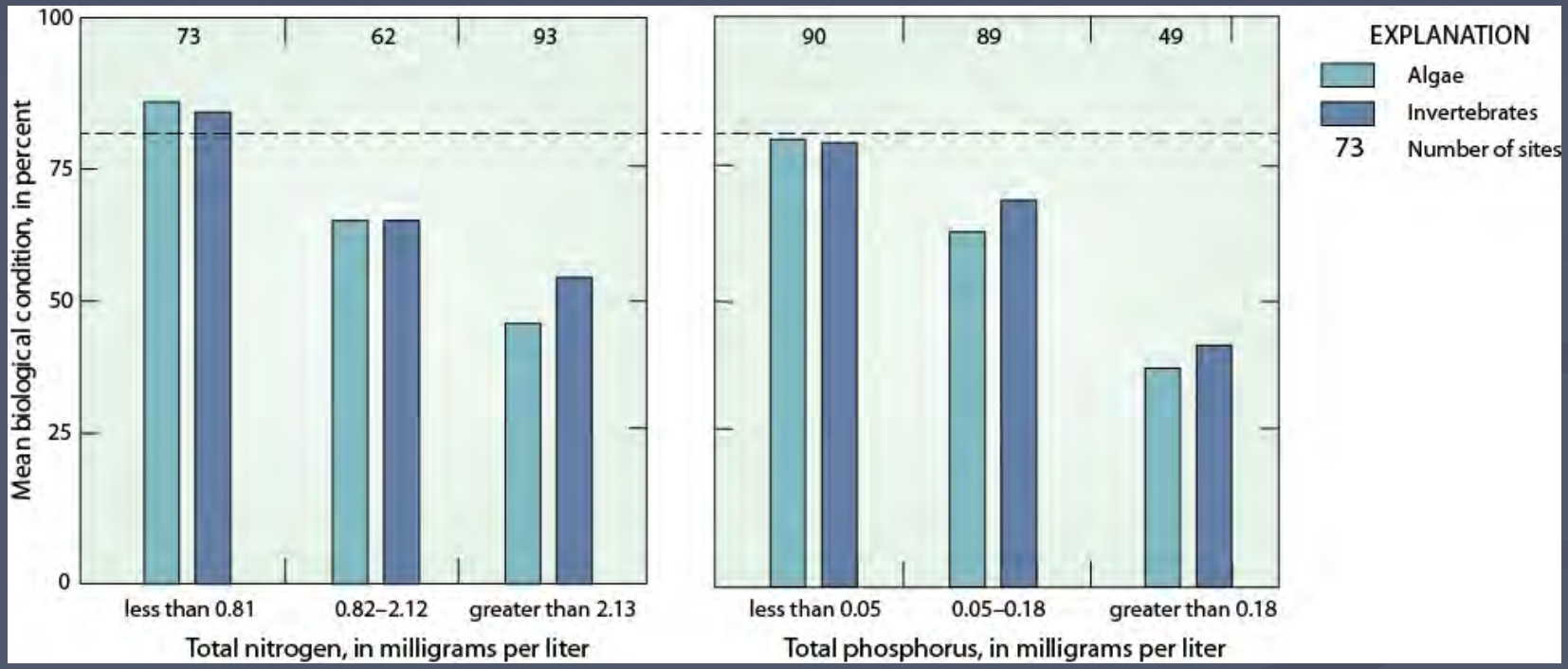
Biological condition* decreases with increasing nutrients



* Biological condition defined as mean O/E scores expressed as a percentage for algae and invertebrate communities

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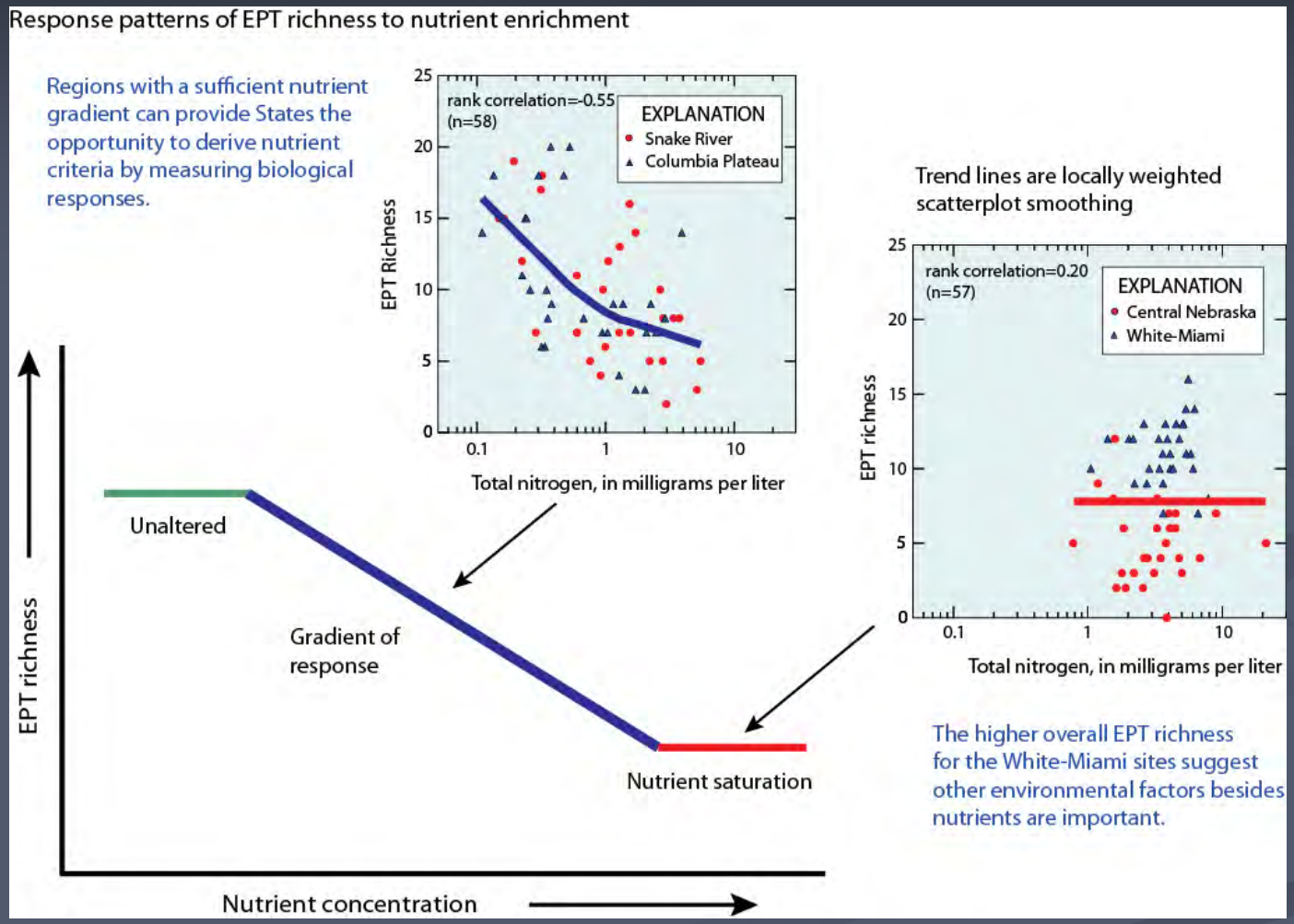
Provisional data

Importance of “reference” sites



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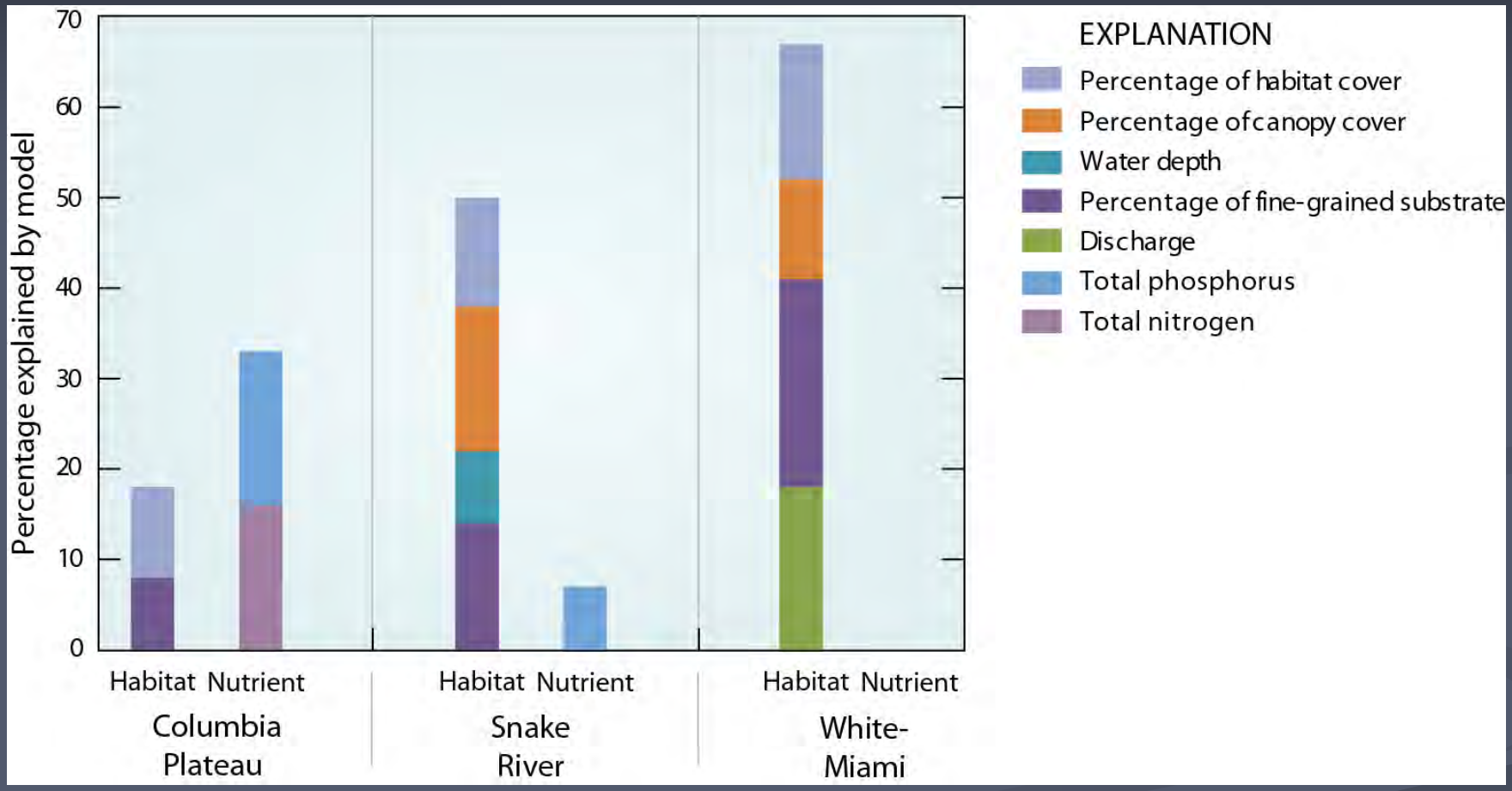
Provisional data

Multiple Regression: Importance of habitat vs nutrients in explaining invertebrate condition



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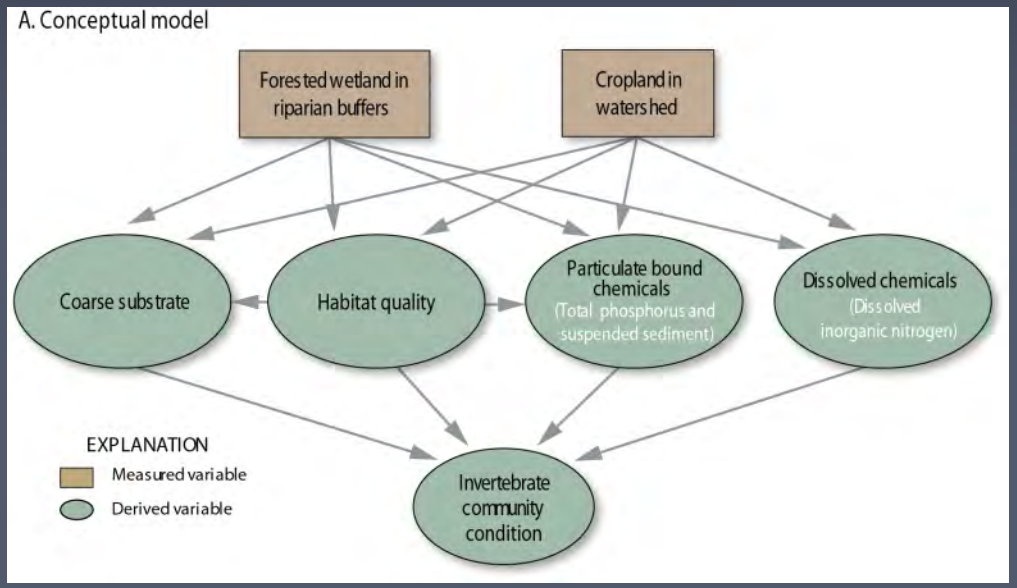
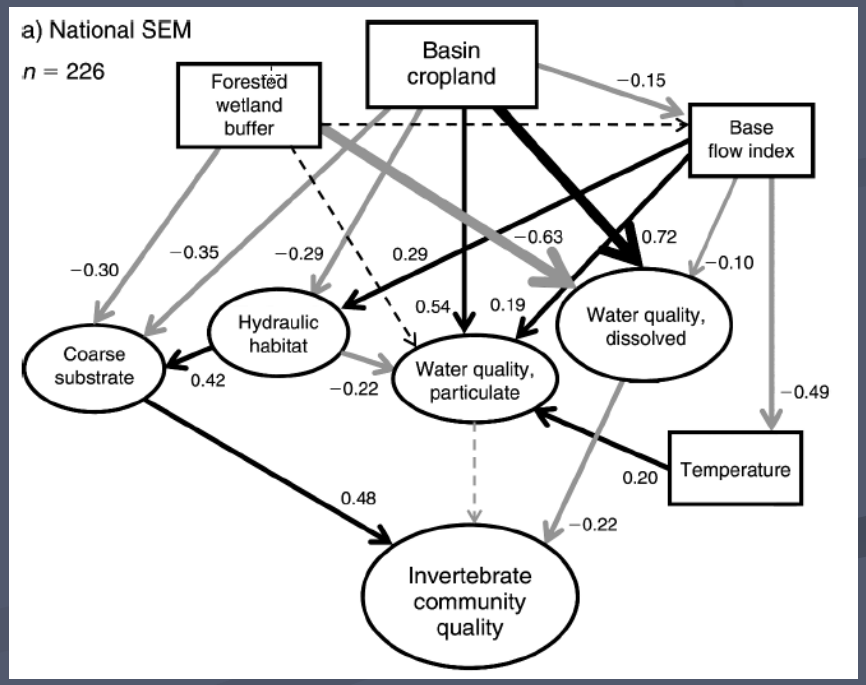
Provisional data

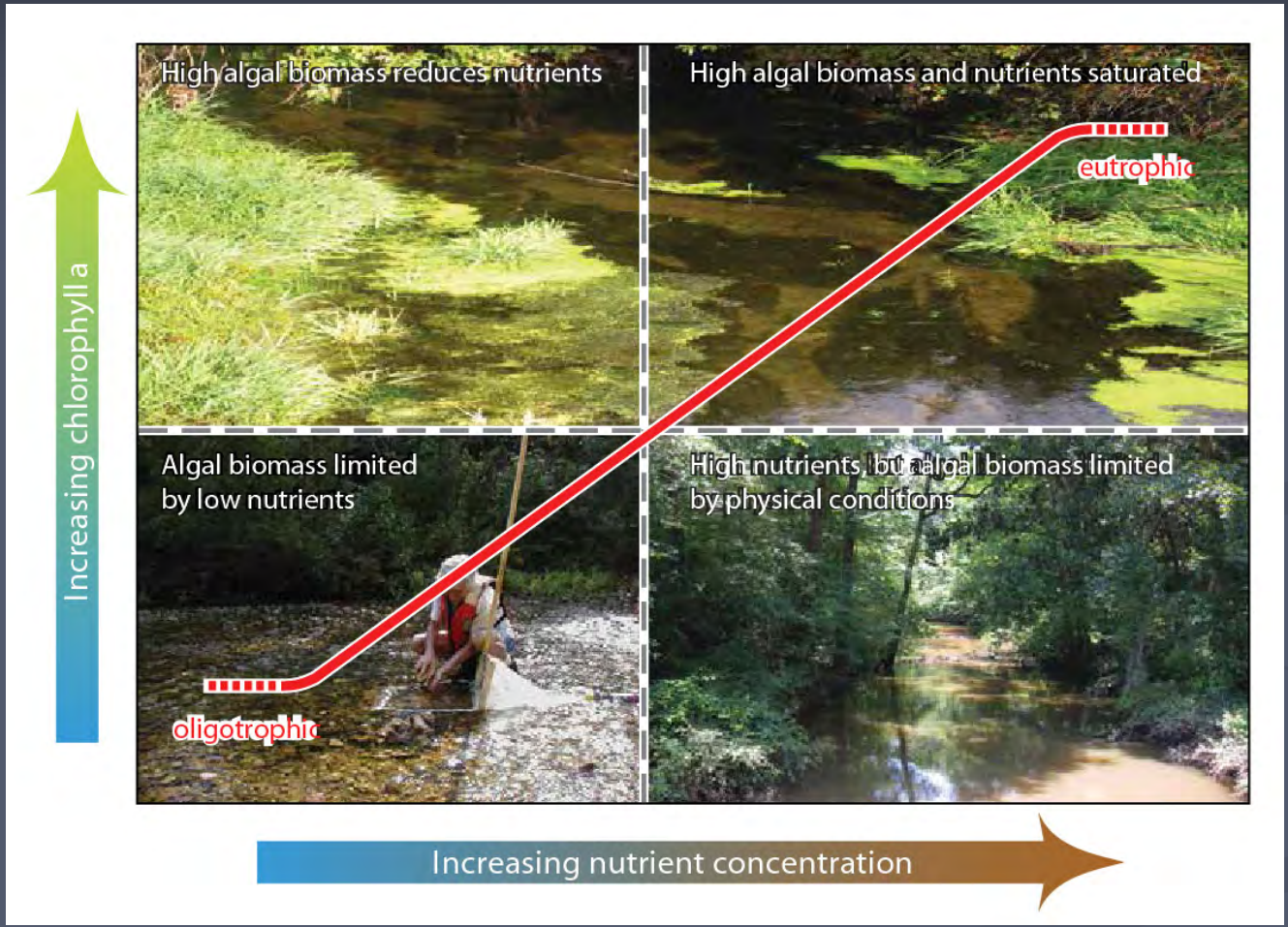
Structural equation modeling provides insight into pathways from land use to biological communities

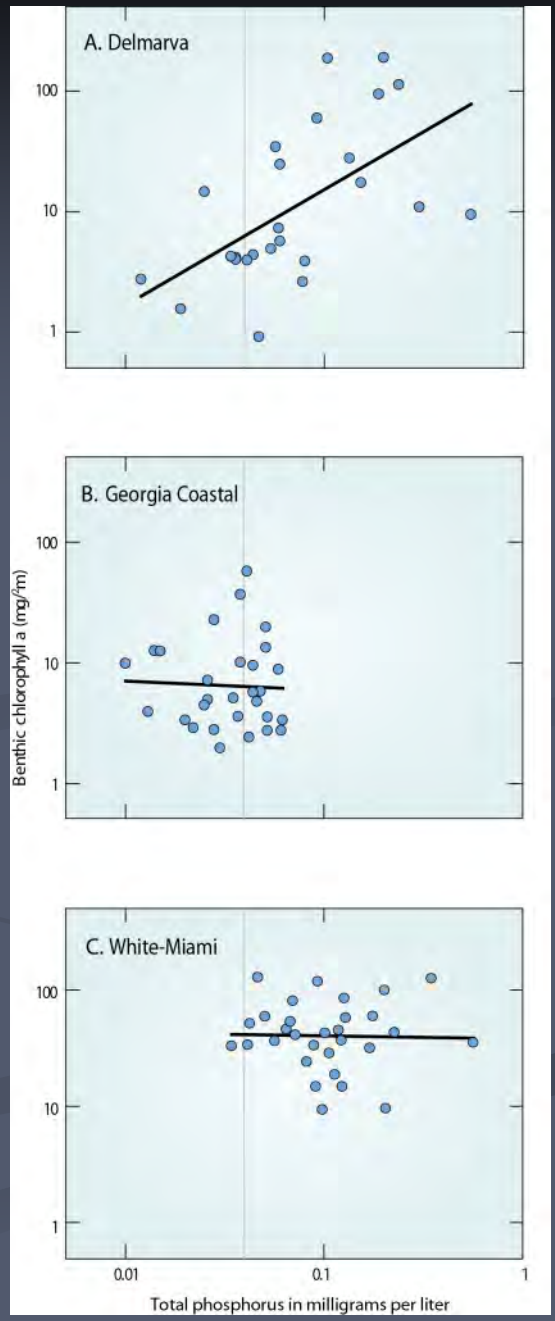




Riseng, C.M., Wiley, M.J., Black, R.W., and Munn, M.D., 2011, Impacts of agricultural land use on biological integrity: a causal analysis: Ecological Applications 21(8) pp. 3128-3146.

Nutrient-algal biomass relationship is complicated by habitat and biological uptake





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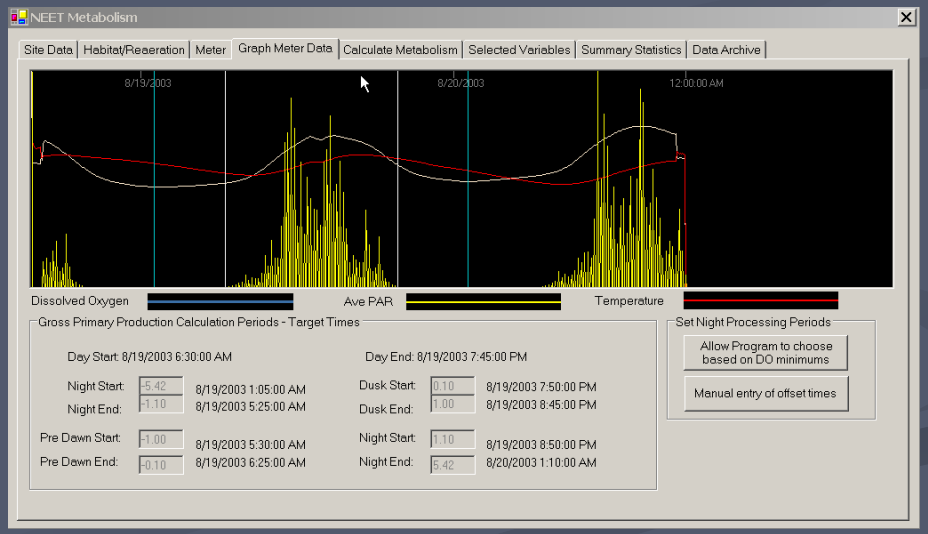
Munn, M., Frey, J., and Tesoriero, A., 2010, The influence of nutrients and physical habitat in regulating algal biomass in agricultural streams: Environmental Management, DOI 10.1007/s00267-010-9435-0.

Objective 2: Determine the relations between nutrients, algae and stream metabolism.



Stream metabolism measurements

- 46 two-station
- 48-hour deployment
- YSI XLM 600 meters
- PAR
- Reaeration-time of travel

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Bales, J.D., and Nardi, M.R., 2007, Automated routines for calculating whole-stream metabolism-Theoretical background and user's guide: U.S. Geological Survey Techniques and Methods 4-C2, 33 p.

Stream Metabolism

- Primary production: production of organic matter
- Respiration: total consumption of organic matter supplied by sources within (autochthonous) and outside (allochthonous) of system.
- P>R: autotrophic system, exports organic matter downstream
- P<R: heterotrophic system, stream dependent on external energy sources from land

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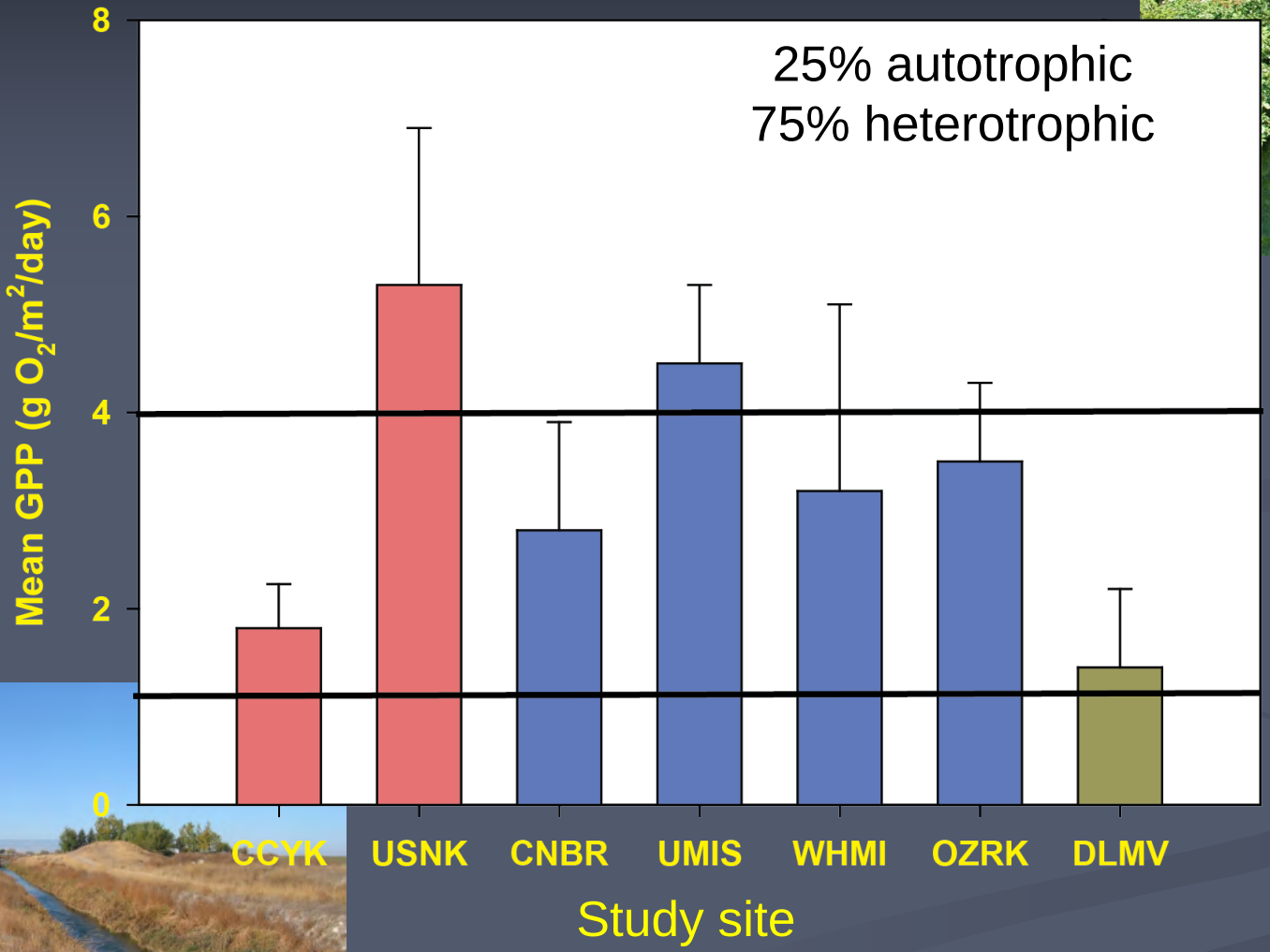
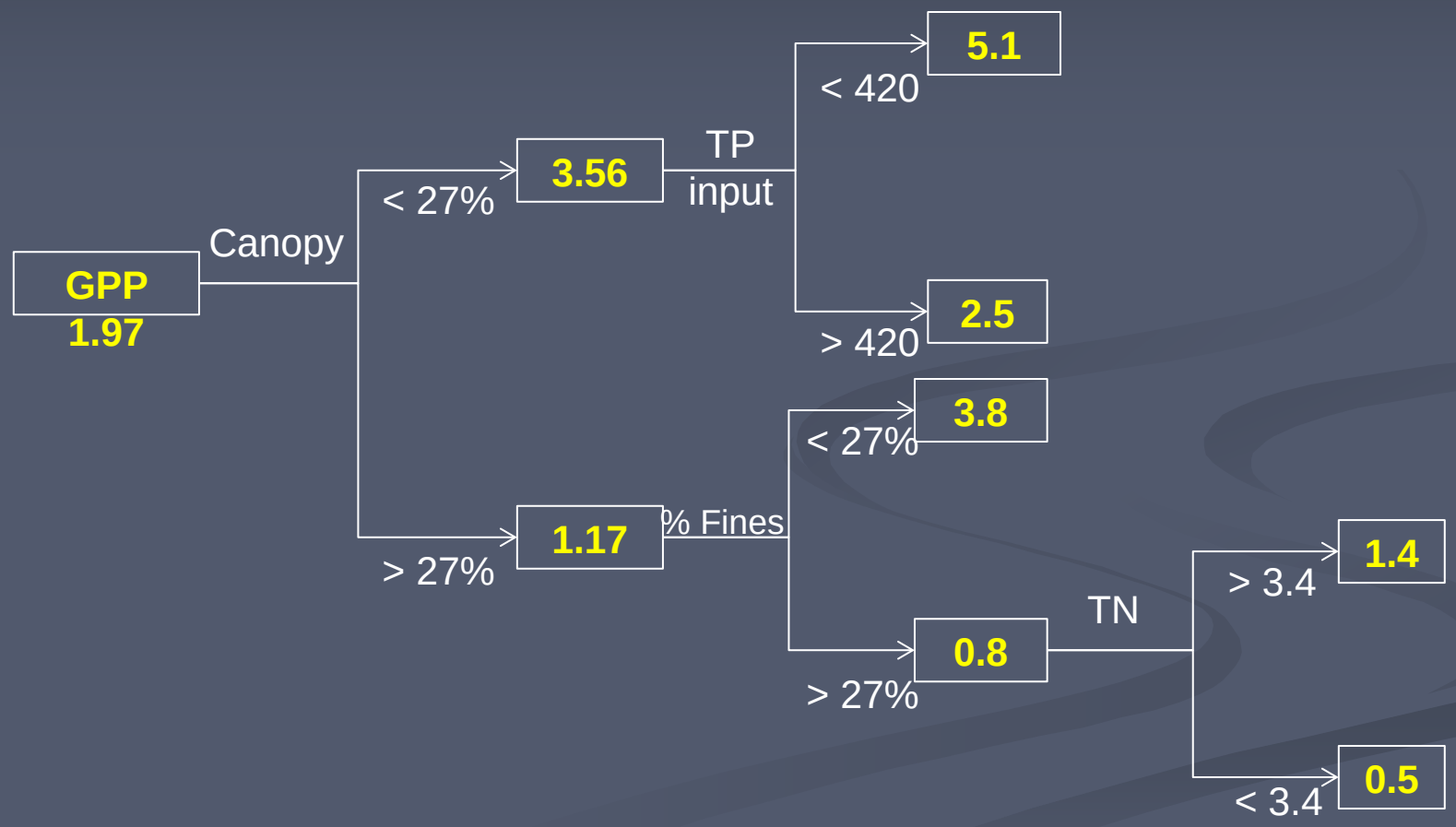
Gross primary production (GPP) varies widely in agricultural streams



Provisional data

Classification and regression tree (CART) demonstrated that GPP was regulated by different variables in open canopy (<27%) vs closed canopy (>27%) streams

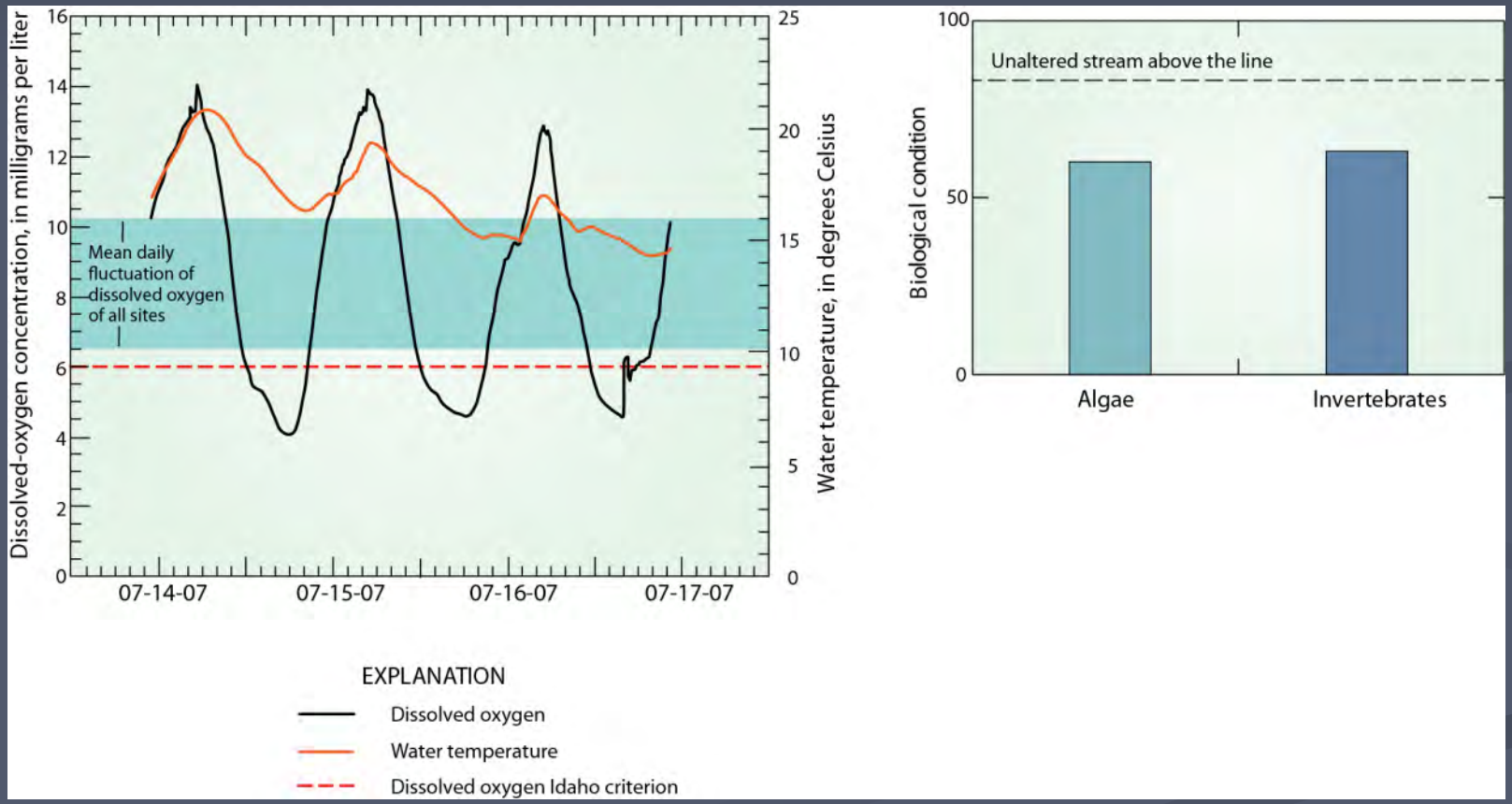


CART: GPP = Percent Canopy, Percent Fines, TP input to watershed, TN

Provisional data

Invertebrate biological condition was 50% lower in streams where dissolved oxygen fell below 5 mg/L (n=46)

Stalker Creek, ID



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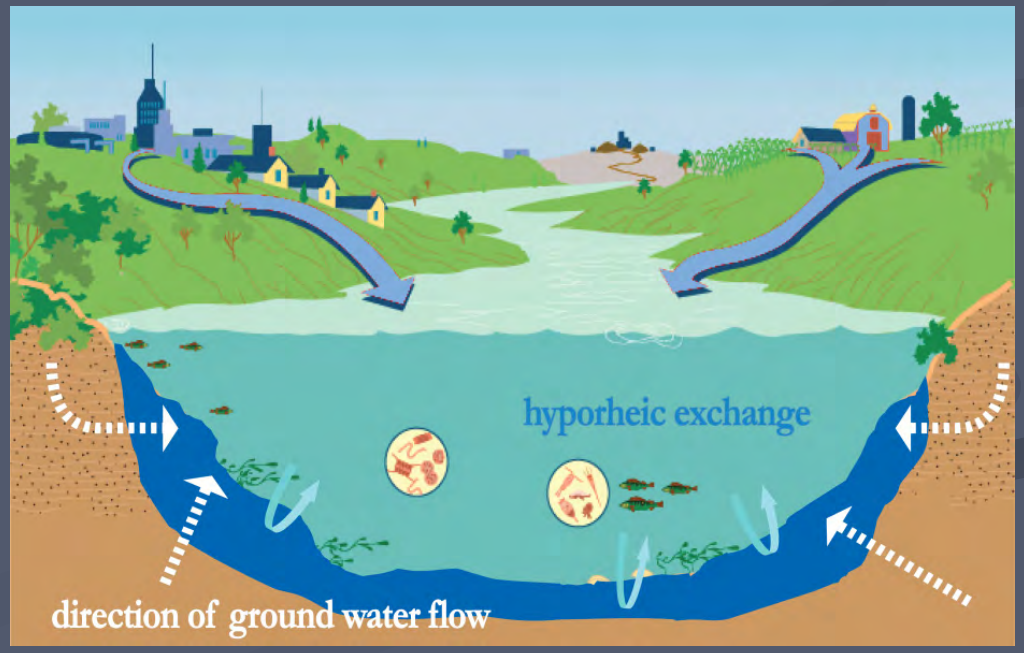
Objective 3: Determine the influence of biota and hydrologic exchange on nutrient loads and nitrogen transformations

1. Within-reach NO_3^- sources

2. Factors effecting in-stream NO_3^- processing
   - Nitrification, denitrification, N uptake
   - Surface water metabolism
   - Transient storage
   - Surface water exchange

3. NO_3^- retention potentials
   - Surface water
   - Groundwater



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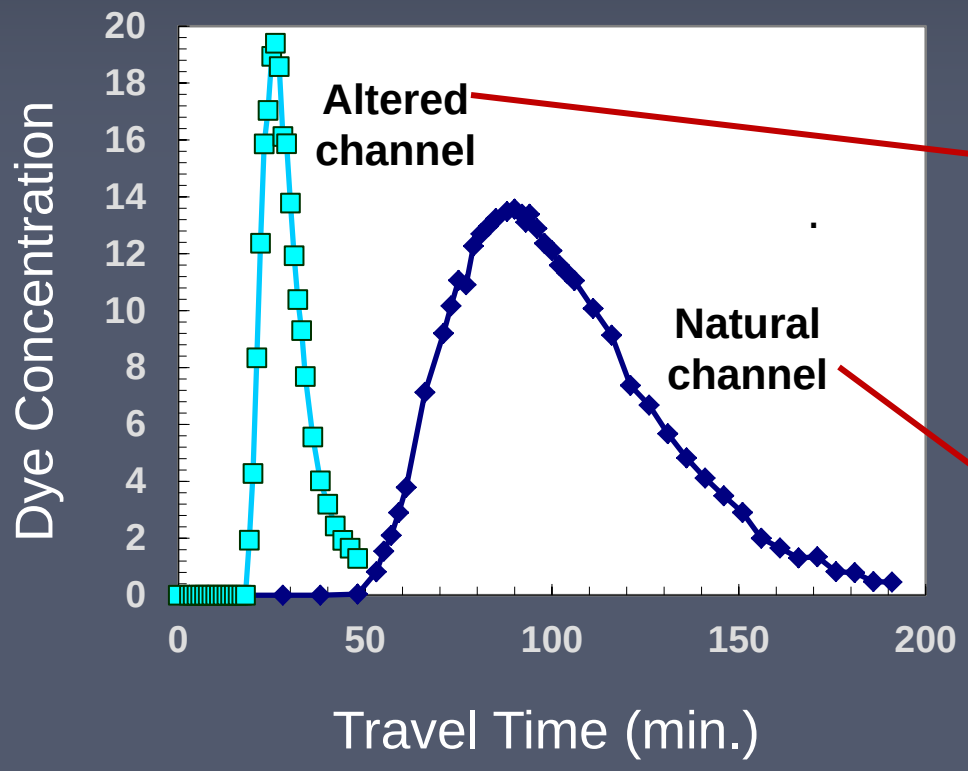
High retention time (long travel time) increases N loss through increased denitrification and uptake



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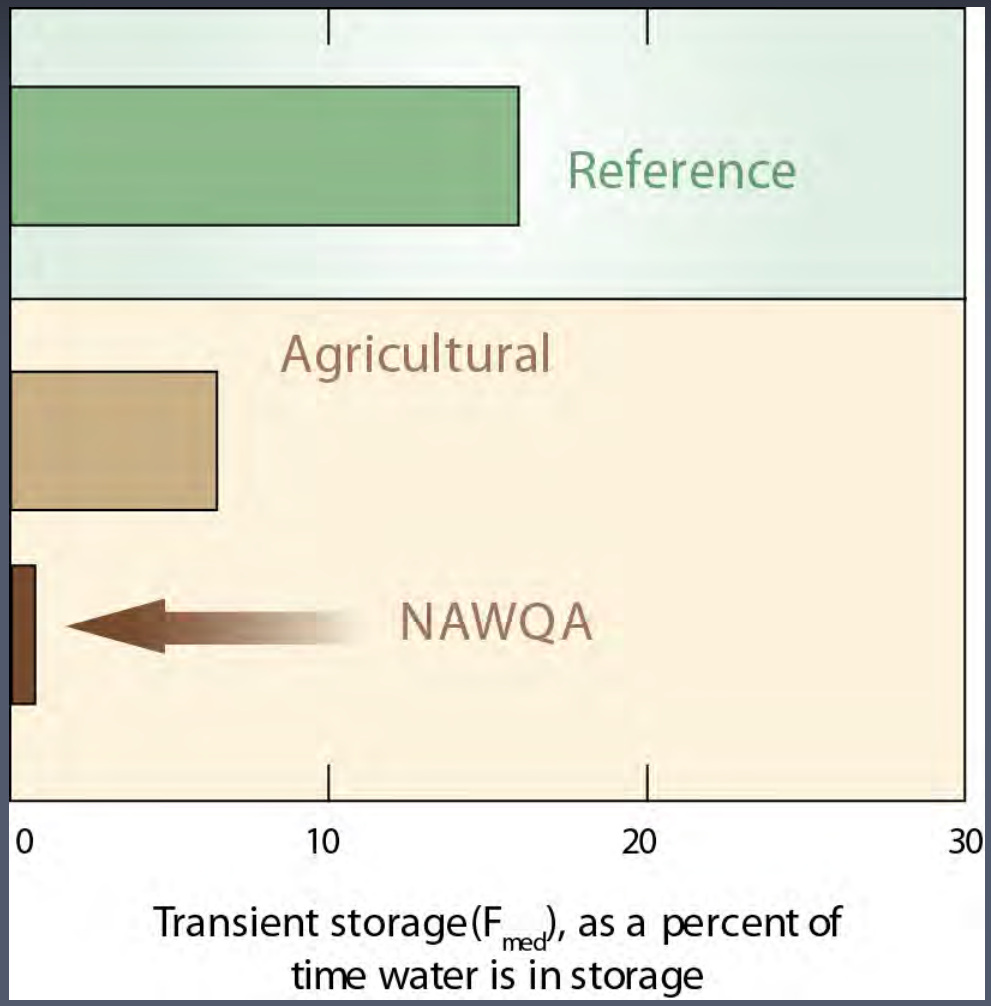
Duff, J.H., Tesoriero, A.J., Richardson, W.B., Strauss, E.A., and Munn, M.D., 2008, Whole-Stream Response to Nitrate Loading in Three Streams Draining Agricultural Landscapes: Journal of Environmental Quality, v. 37, p. 1133 - 1144



Low retention time in agricultural streams resulted in low N loss (less denitrification and biological uptake)

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Sheibley, R.W., Duff, J.H., and Tesoriero, A.J., 2014, Low Transient Storage and Uptake Efficiencies in Seven Agricultural Streams—Implications for Nutrient Demand: Journal of Environmental Quality, doi:10.2134/jeq2014.01.0034.

Structure vs function

	DR2: WA	Maple Creek: NE	Morgan Creek: DE
NO_3^- (mg N L^{-1})	3.1	0.9	2.6
Chl a (mg m^{-2})	1	65	9
P/R ratio	0.1	1.3	0.1
Fmed	0.002	0.012	0.0003
OE-Invertebrates	71	29	74
OE-Algae	72	91	54

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Summary

- Algae and invertebrates both respond to increased nutrients, but algae provide a more direct response.
- Nutrient concentrations and benthic algal biomass may not always provide the best indication of stream status.
- Agricultural streams can be nutrient saturated and habitat limited.
- Reduced N loss in agricultural streams results in increased nutrient loads downstream.
- Need management oriented sub-regional and/or stream-type specific predictive models that incorporate nutrients, habitat, and biological response.

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Nutrient Ecology Team

- Water Science Centers
  - Arkansas
  - Delaware
  - Georgia
  - Idaho
  - Indiana
  - Minnesota
  - Missouri
  - Nebraska
  - Washington

- Team scientists from many centers
- National Research Program
- Upper Mississippi Science Center
- University of Michigan
- Michigan State University

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All publications and data can be found at
http://wa.water.usgs.gov/neet/

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