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Algal metric approaches for assessing trophic condition and organic enrichment in U.S. streams and rivers

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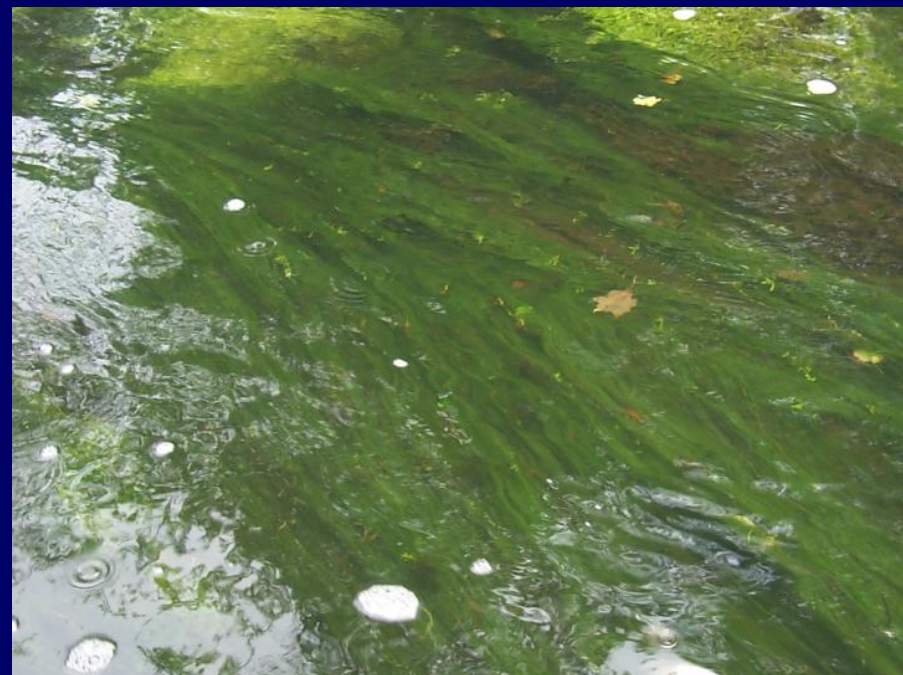

NWQMC Meeting
May 10, 2006

San Jose, CA

Why are algae important for assessing water quality?

EPA National Water Quality Inventory (305b Report to Congress)

- Causes of water-quality impairment
  - Siltation
  - Nutrients
  - Oxygen-depleting substances
- Sources of water-quality impairment
  - Nonpoint-source runoff from urban & agricultural land

EPA Nutrient Criteria – Streams and Rivers (U.S. EPA, 2000)

- Primary Variables
  - Nutrients (TN & TP)
  - Algal Biomass (chlorophyll *a*)
  - Water Clarity (turbidity, transparency, total suspended solids)
- Secondary Response Variables
  - Stream Metabolism—DO, pH
  - Biological Attributes (autecology, nature of response, grazers, IBIs)

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Objectives and Scope

1. Which algal metrics are most useful for assessing nutrient and organic enrichment in streams and rivers?

2. How well do these metrics correlate with nutrient concentrations Nationally? Regionally?

3. Do the algal metrics discriminate among land-use categories?

   Do algal metrics and nutrient concentrations provide complementary information about the effects of land-use practices on water quality?

4. How do algal metric scores respond along nutrient and land-use gradients?

5. Does algal biovolume (biomass, chlorophyll) vary significantly with nutrient concentrations, land-use conditions, or among major water-resource regions? How do trophic boundaries derived from USGS biovolume data compare with proposed nutrient criteria?

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Autecology…physiological requirements or tolerance range of species

Nutrients
- Nitrogen: N-fixing algae, N-heterotrophs
- N & P: eutrophic diatoms and soft (non-diatom) algae

Organic Enrichment
- Pollution Tolerance (saprobien system; nutrients+carbon)
- Dissolved oxygen requirements; tolerance to low DO

Major Ions
- Salinity (specific conductance); alkalinity (hardness); certain metals

Physical Properties (pH, temperature, velocity, light, etc.)

Algal Metrics...aggregation of species with similar autecological properties

Indicators of algal biomass
- Chlorophyll *a*, Ash-free Dry Mass, Biovolume

Indicators of water quality and trophic condition
- Qualitative – published literature accounts (~ 100 y history)

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Periphyton collection methods

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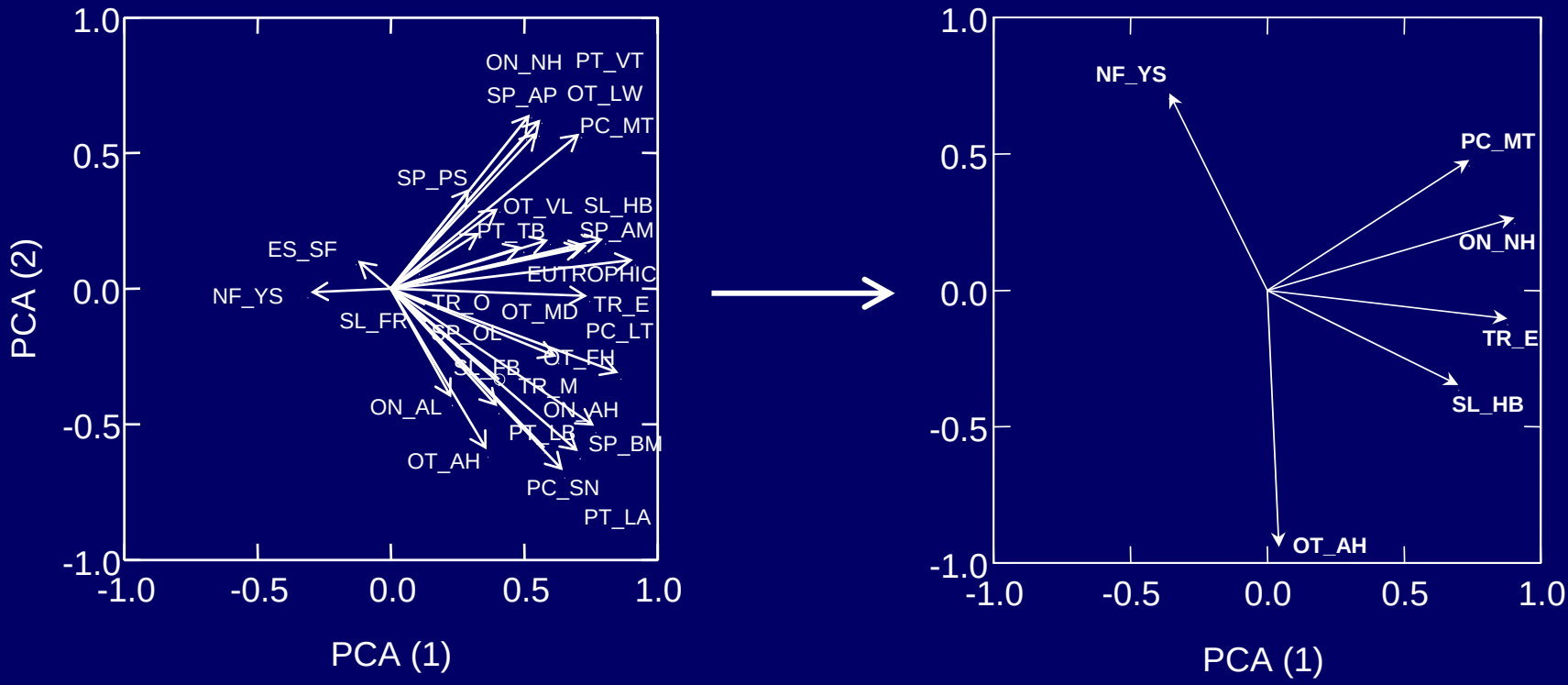
Which algal metrics are most useful for assessment?



PC_MT **Tolerant Diatoms—Indicator of nutrient & organic enrichment**

ON_NH **Nitrogen Heterotrophs—Indicator of organic nitrogen enrichment**

TR_E **Eutrophic Diatoms—Indicator of nutrient enrichment**

SL_HB **Halobiontic Diatoms—Indicator of dissolved constituents**

NF_YS **Nitrogen Fixers—Indicator of low nitrogen or N:P ratios**

OT_AH **High DO Indicators—Indicator of high dissolved oxygen concentrations**

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1 – Northeast -- New England and Mid-Atlantic Water-Resource Regions
2 – Southeast -- South Atlantic-Gulf and Tennessee Water-Resource Regions
3 – Midwest -- Upper Mississippi, Ohio, Great Lakes, and Souris-Red-Rainey Water-Resource Regions
4 – Northern Plains -- Missouri Water-Resource Region
5 – Southern Plains -- Lower Mississippi, Arkansas-White-Red, and Texas-Gulf Water-Resource Regions
6 – Southwest -- Rio Grande, Upper Colorado, Lower Colorado, and Great Basin Water-Resource Regions
7 - Northwest -- Pacific Northwest Water-Resource Region
8 – California -- California Water-Resource Region

Geographic regions based on aggregations of Water-Resource Regions

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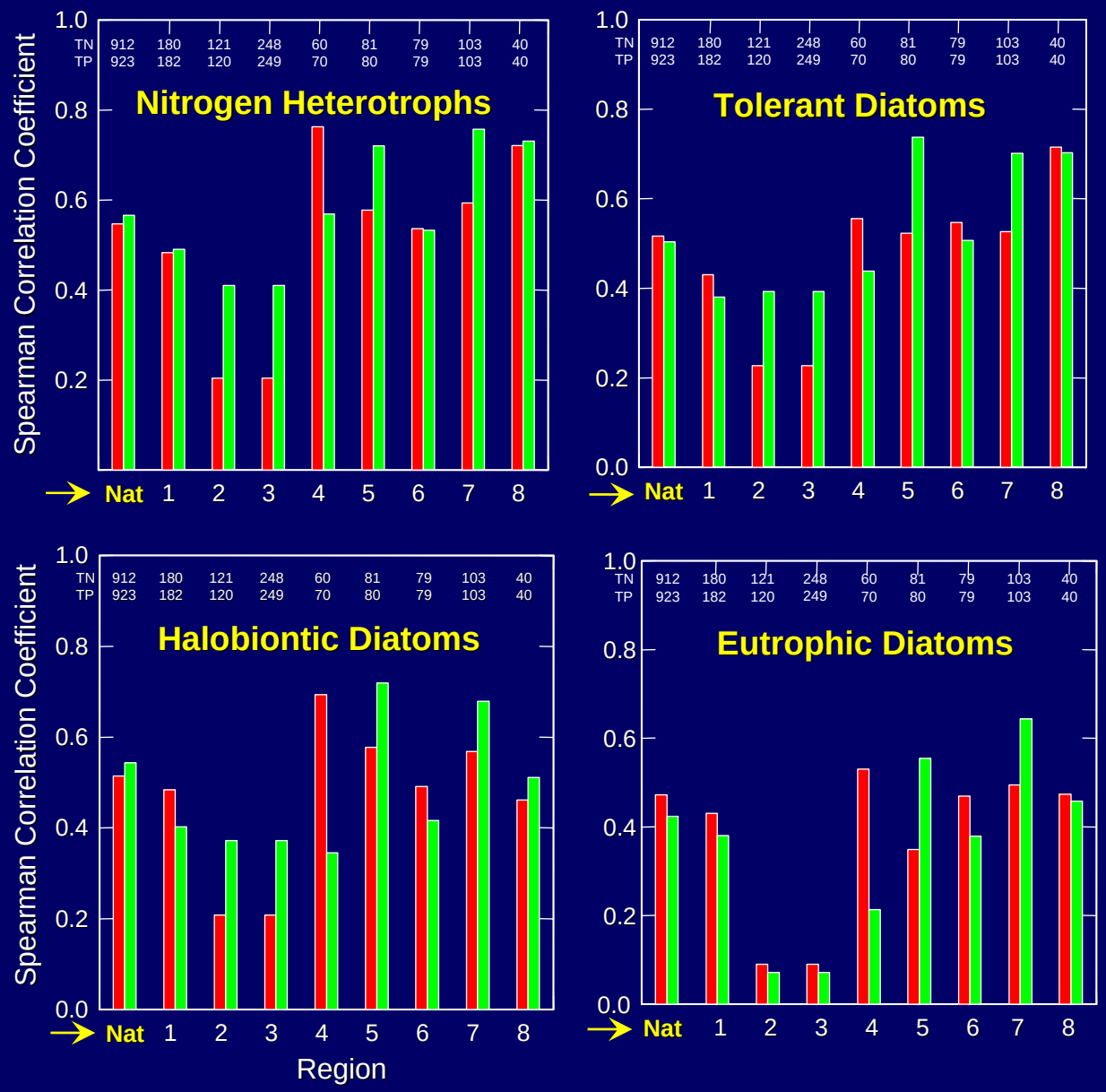
How well do “tolerant” algal metrics correlate with nutrients?

Total Nitrogen
Total Phosphorus



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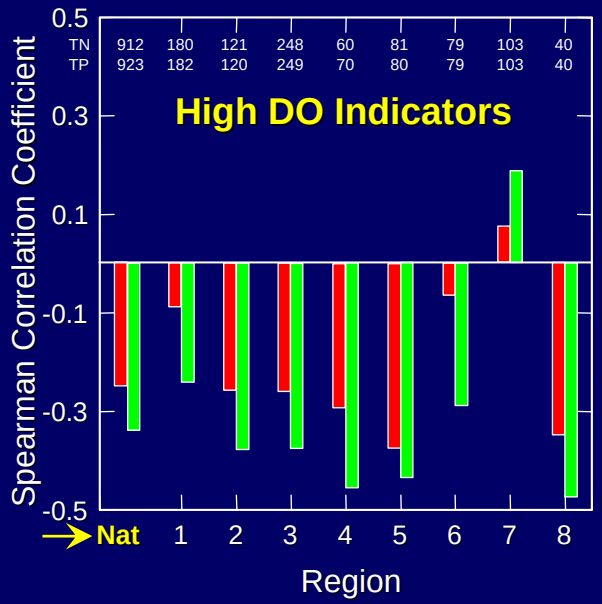
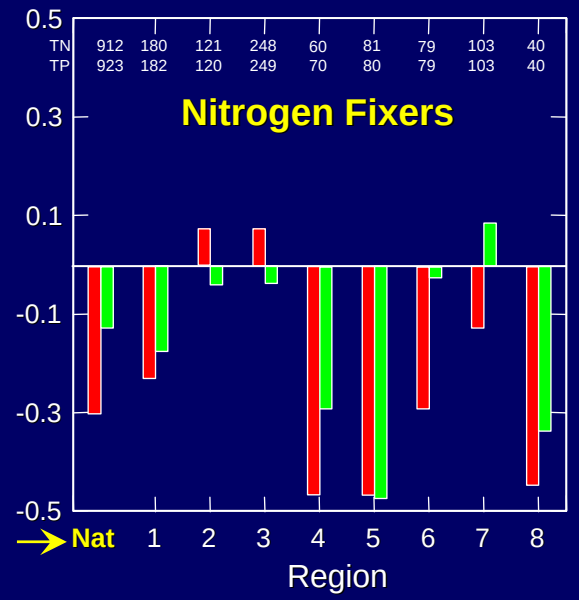
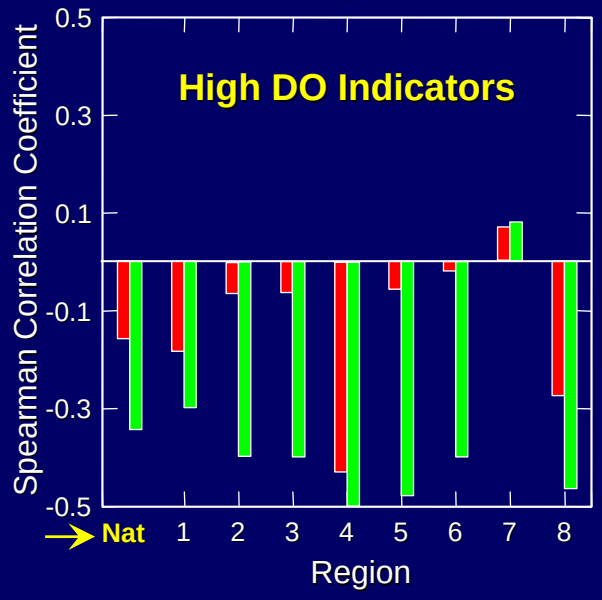
How well do “sensitive” algal metrics correlate with nutrients?

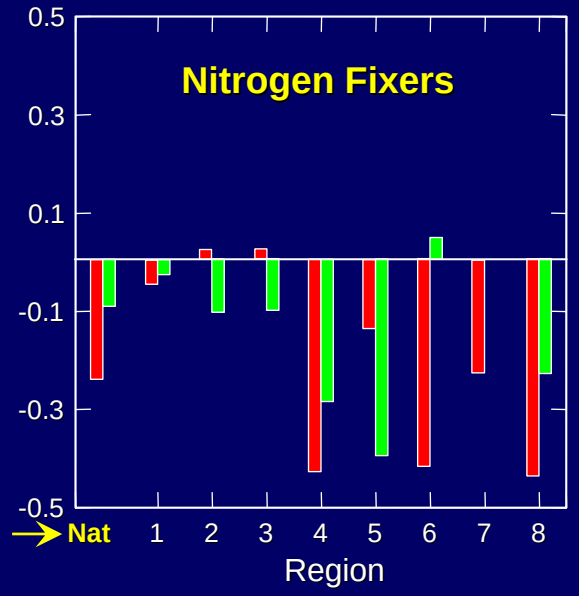
Total Nitrogen
Total Phosphorus





Nitrate
Orthophosphate





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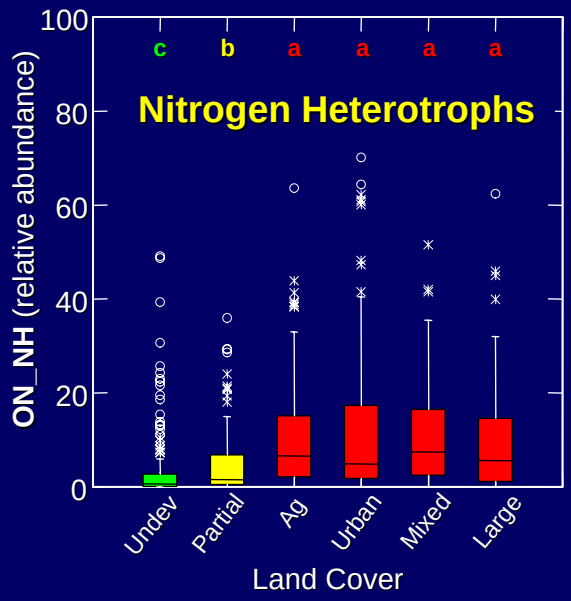
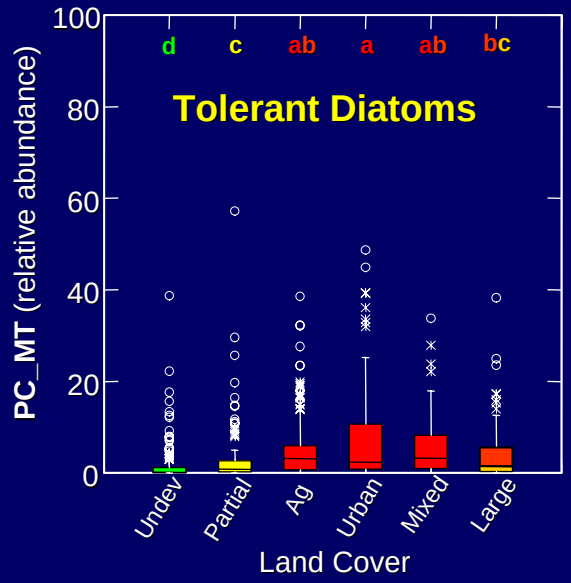
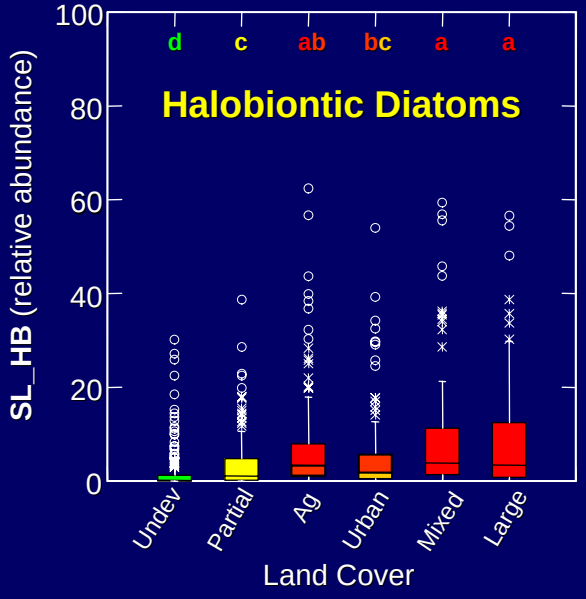
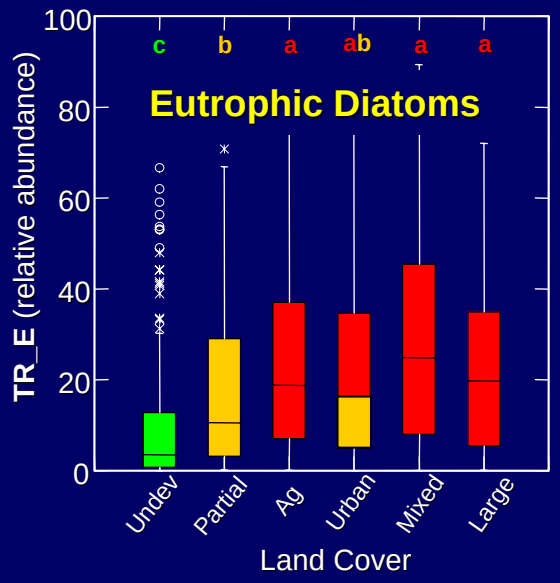
What do algal metrics tell us about land use?









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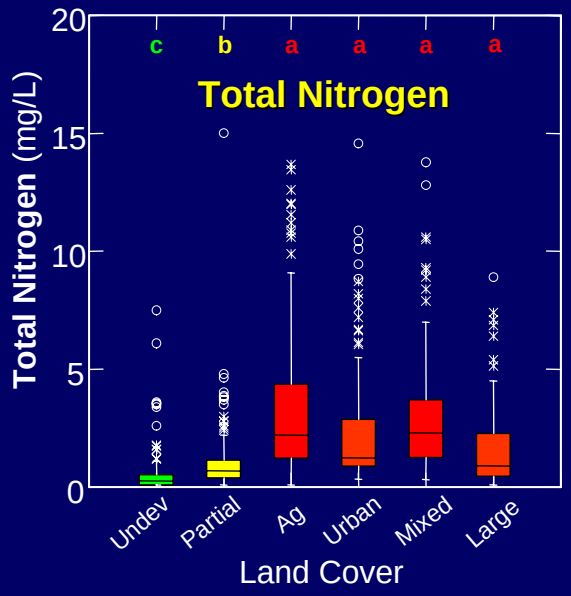
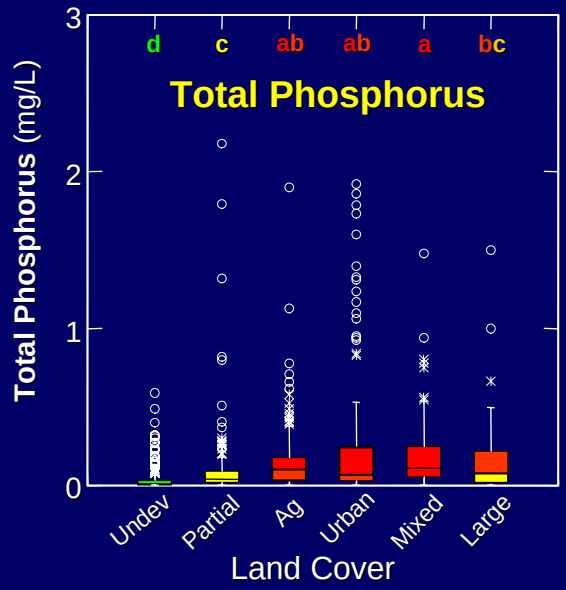
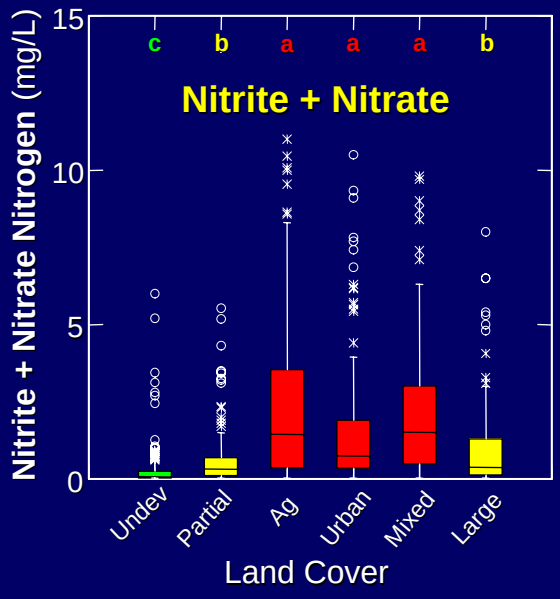
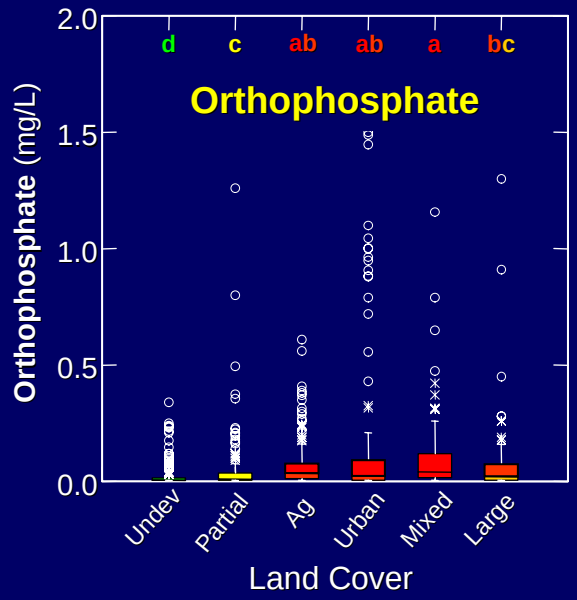
What do nutrient concentrations tell us about land use?









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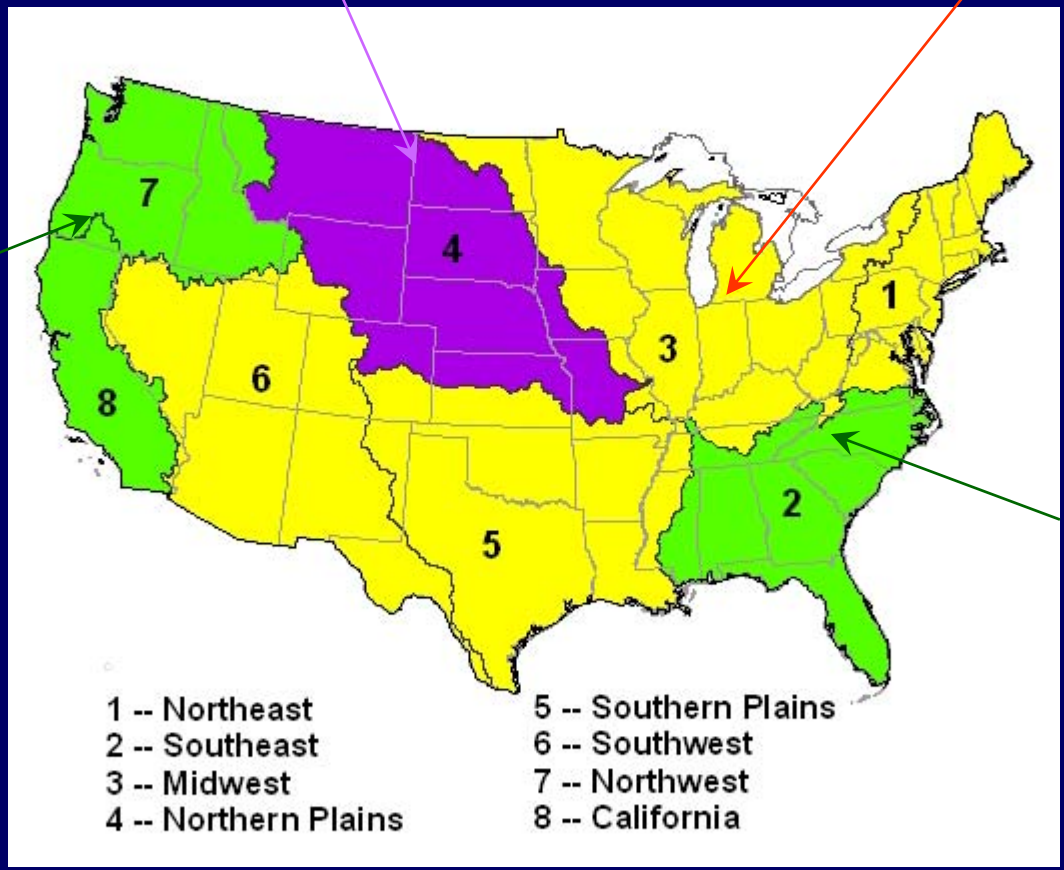
How well do algal metrics & nutrients discriminate between undeveloped and developed stream basins?

Neither Algae nor Nutrients

Algae = Nutrients

Nutrients better than Algae



Nutrients better than Algae

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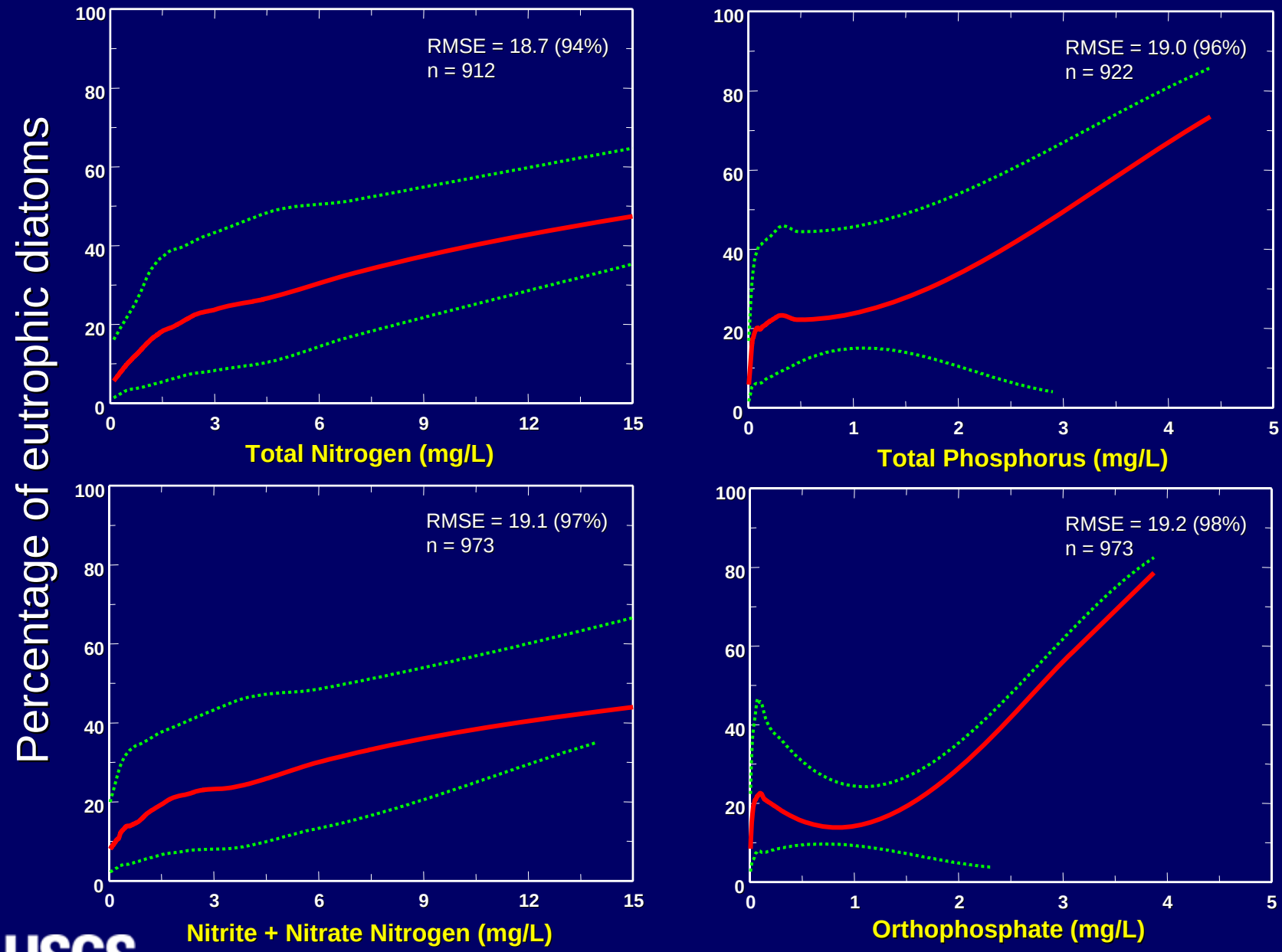
How do algal-metric scores respond along nutrient gradients?



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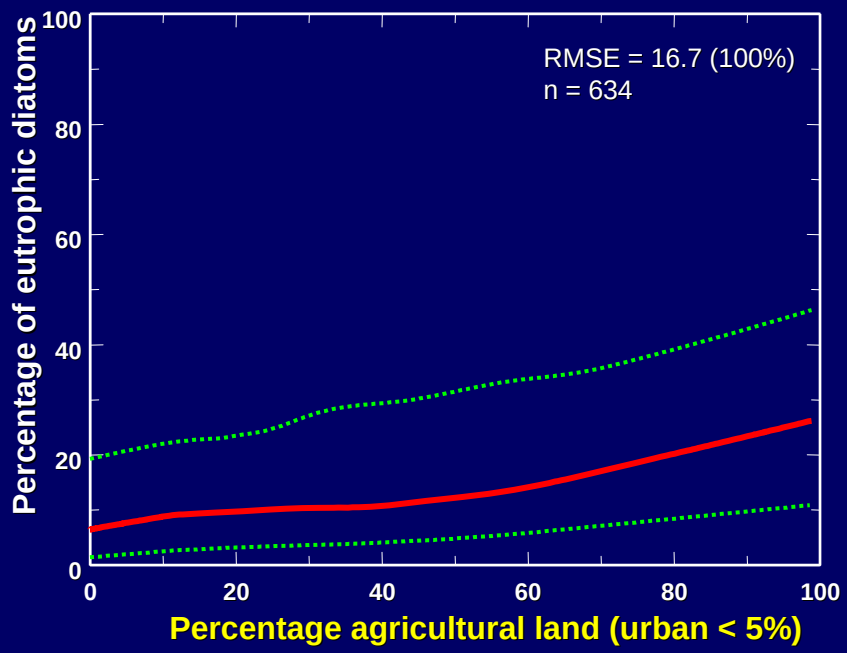
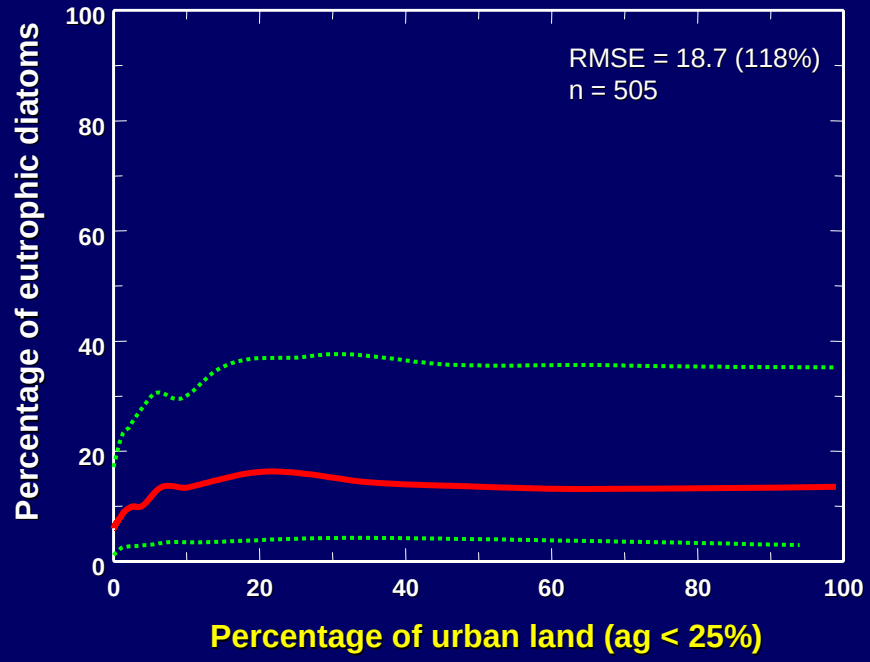
How do algal-metric scores respond along land-use gradients?





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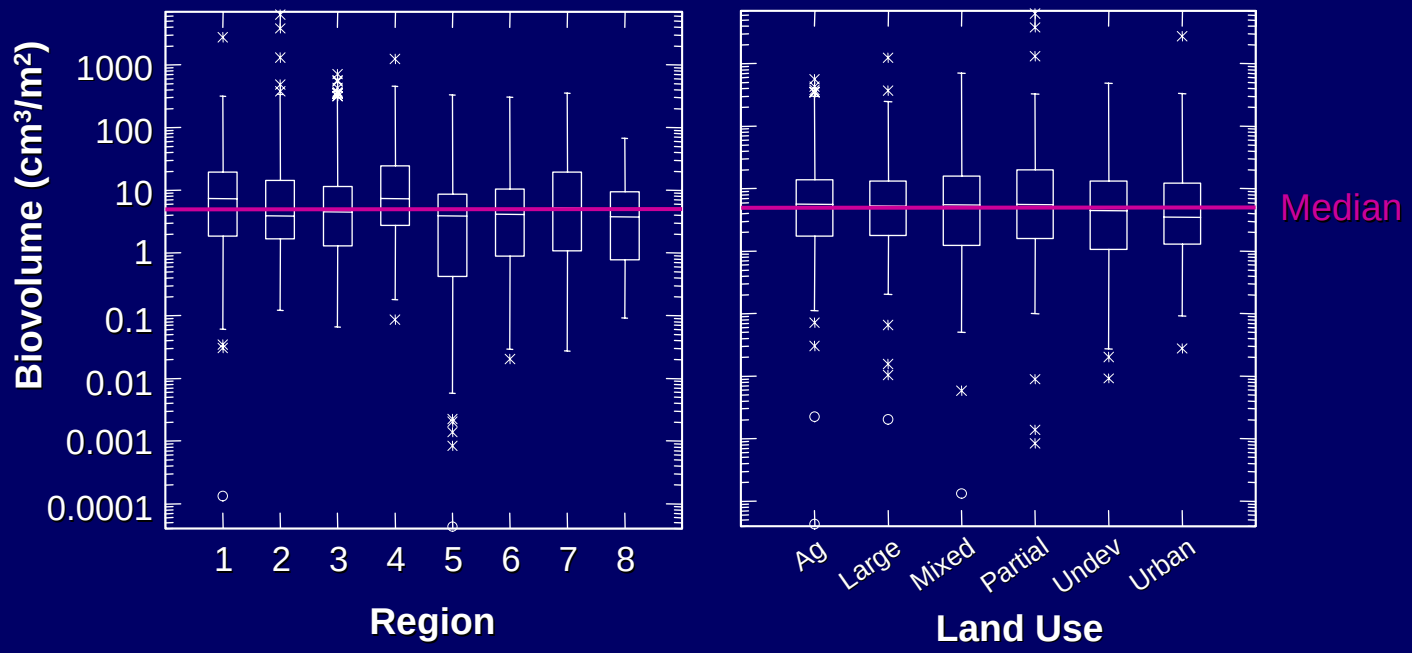
Algal biovolume relations with geographic region, water quality, and land use



National: (positive relation) Nitrate (ρ = 0.179, p<0.001)
(negative relation) Suspended Sediment (ρ = -0.168, p=0.001)

Regions 4, 7, & 8: (positive relation) TN, Nitrate, TP (ρ > 0.3)
Region 5: (negative relation) Suspended Sediment, TP (ρ < -0.4)

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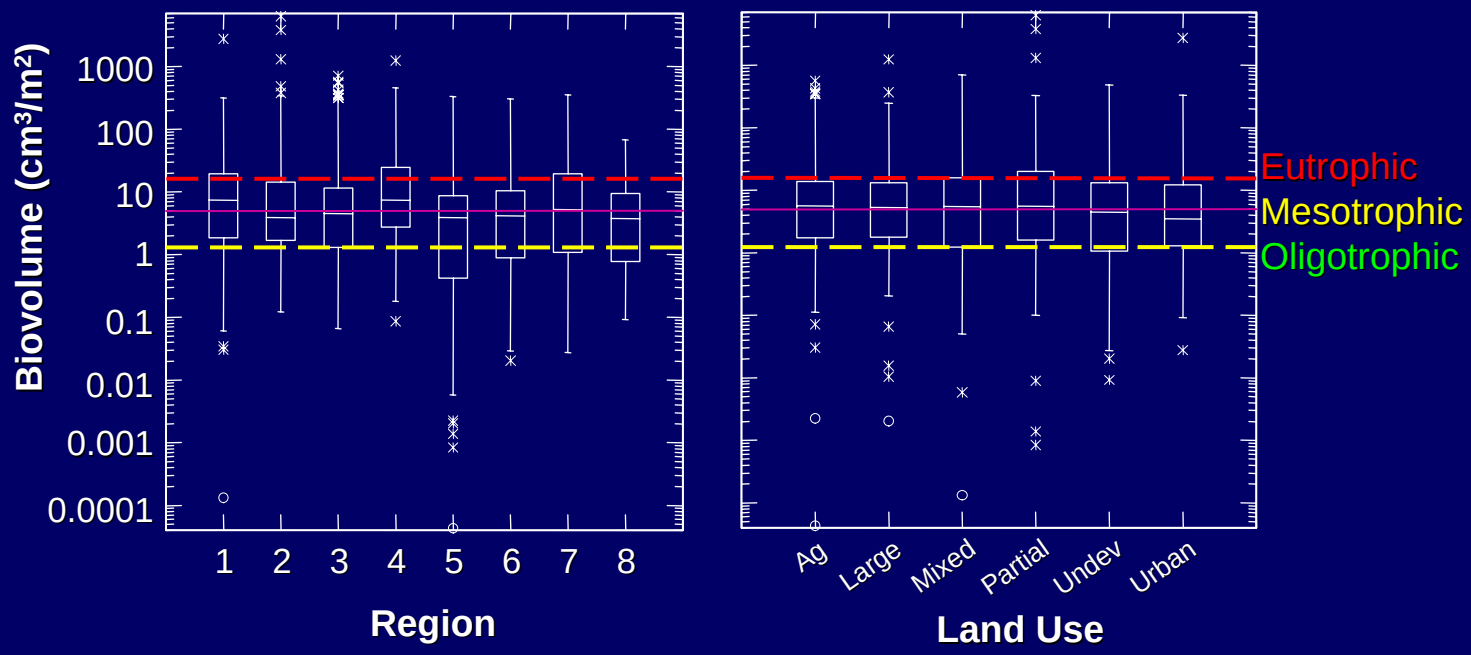
Estimating trophic boundary conditions



	Biovolume (cm^3/m^2)	*est.* CHLa (mg/m^2)	Dodds et al. (1998) *benthic* CHLa (mg/m^2)
Oligotrophic-Mesotrophic	1.35	21	20
Mesotrophic-Eutrophic	15	66	70

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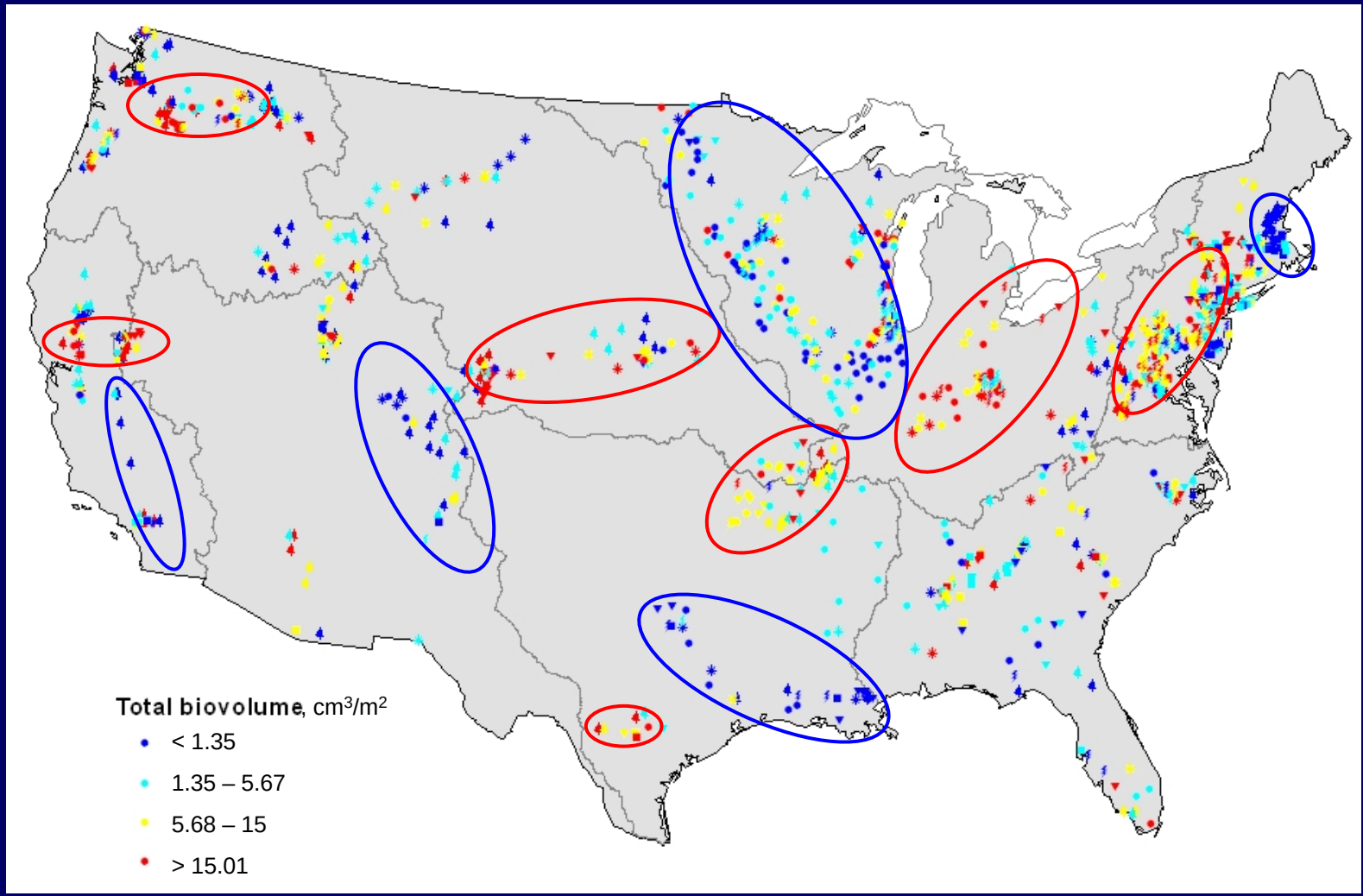
Distribution of algal biovolume



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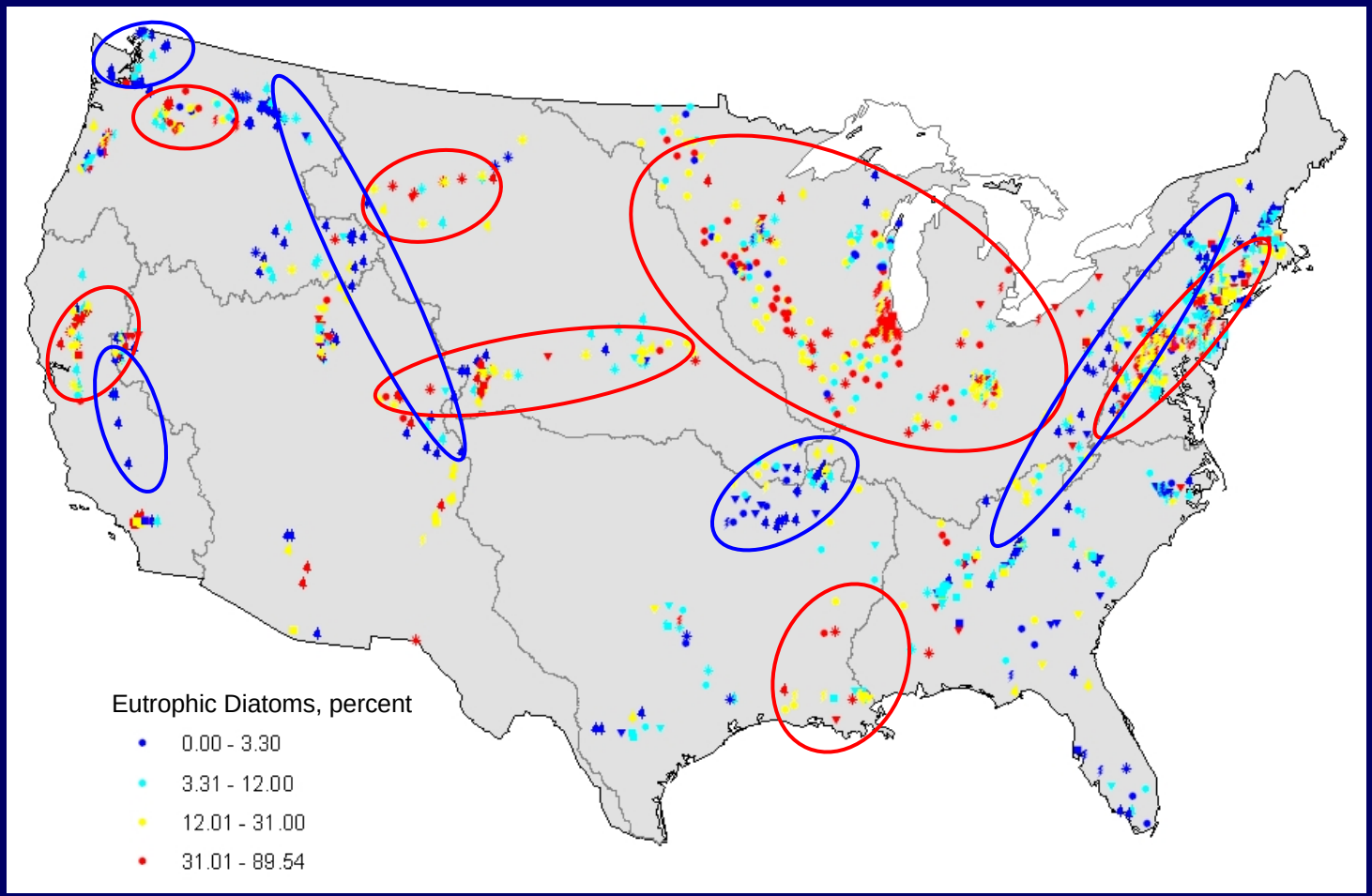
Distribution of eutrophic diatoms



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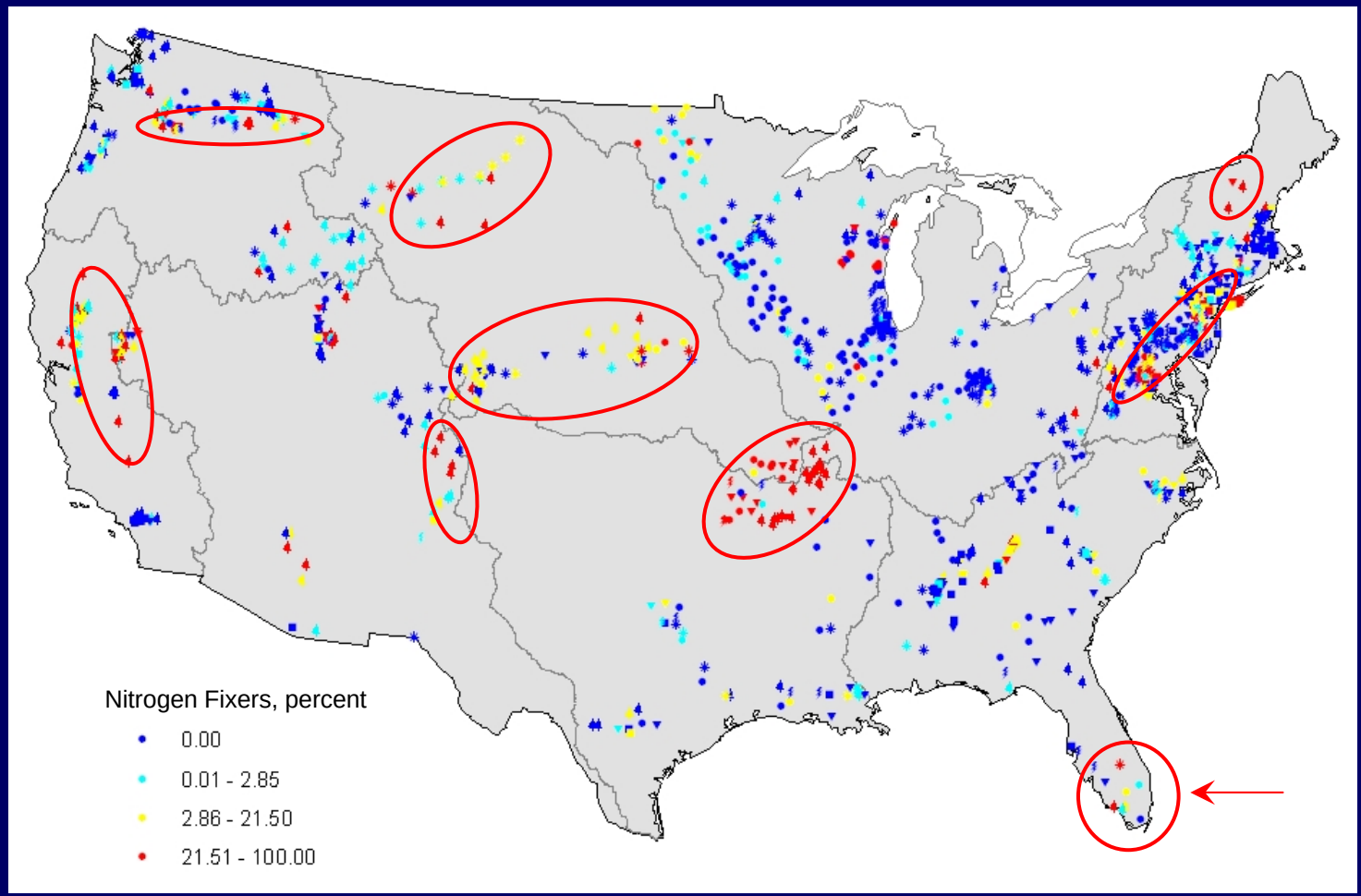
Distribution of nitrogen-fixing algae



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Summary & Conclusions

1. What do algal metrics tell us about water quality?

   Strong correlation with nutrient concentrations
   Discrimination between developed & undeveloped basins
   Responses along nutrient and land-use gradients

   Distribution of algal tolerance indicators corresponds with major agricultural and urban areas.

2. What does algal biovolume tell us about water quality?

   Weak correlation with nutrient and sediment concentrations
   No significant differences among land-use or regional categories

   Algal biomass may be controlled more by antecedent hydrologic disturbance, shading, or biological interactions (e.g. grazers) than land-use practices or nutrient concentrations. Local scale response.

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Summary & Conclusions

3. How can algal indicators of stream condition be applied to nutrient and biological criteria?

   Autecological metrics reflect responses to eutrophication processes
   Biovolume (standing crop)—hydrology relations (days of accrual)
   Indicators of organic enrichment

   Algal data available from NAWQA Data Warehouse
   Taxonomic consistency: ANSP http://diatom.acnatsci.org/nawqa/
   Autecology: NAWQA Algal Attributes table
   Data Analysis: Algal Data Analysis System (ADAS—T.F. Cuffney)
   PhycoAide (ANSP)

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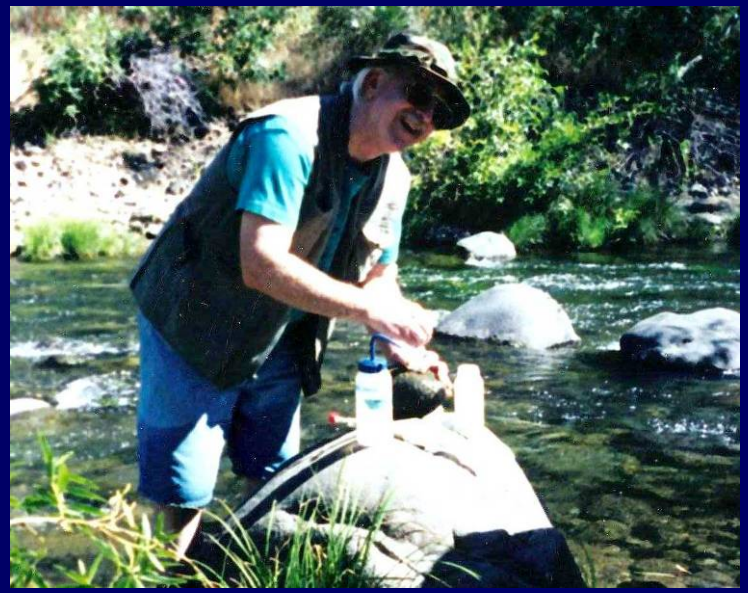

Literature Cited

Dodds, W.K., Jones, J.R., and Welch, E.B., 1998, Suggested classification of stream trophic state: Distributions of temperate stream types by chlorophyll, total nitrogen, and phosphorus. Water Resources, v. 32, no. 5, p. 1455-1462.

U.S. Environmental Protection Agency, 2000, Nutrient criteria technical guidance manual. Rivers and Streams. Washington, D.C.: U.S. Environmental Protection Agency, Office of Water, EPA-822-B-00-002, 240 p.

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