Stream Health Monitoring

A First Step to Adapting to a Changing Climate: Protecting Unci Maka and sustainable economies

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Workshop on Extreme Events and

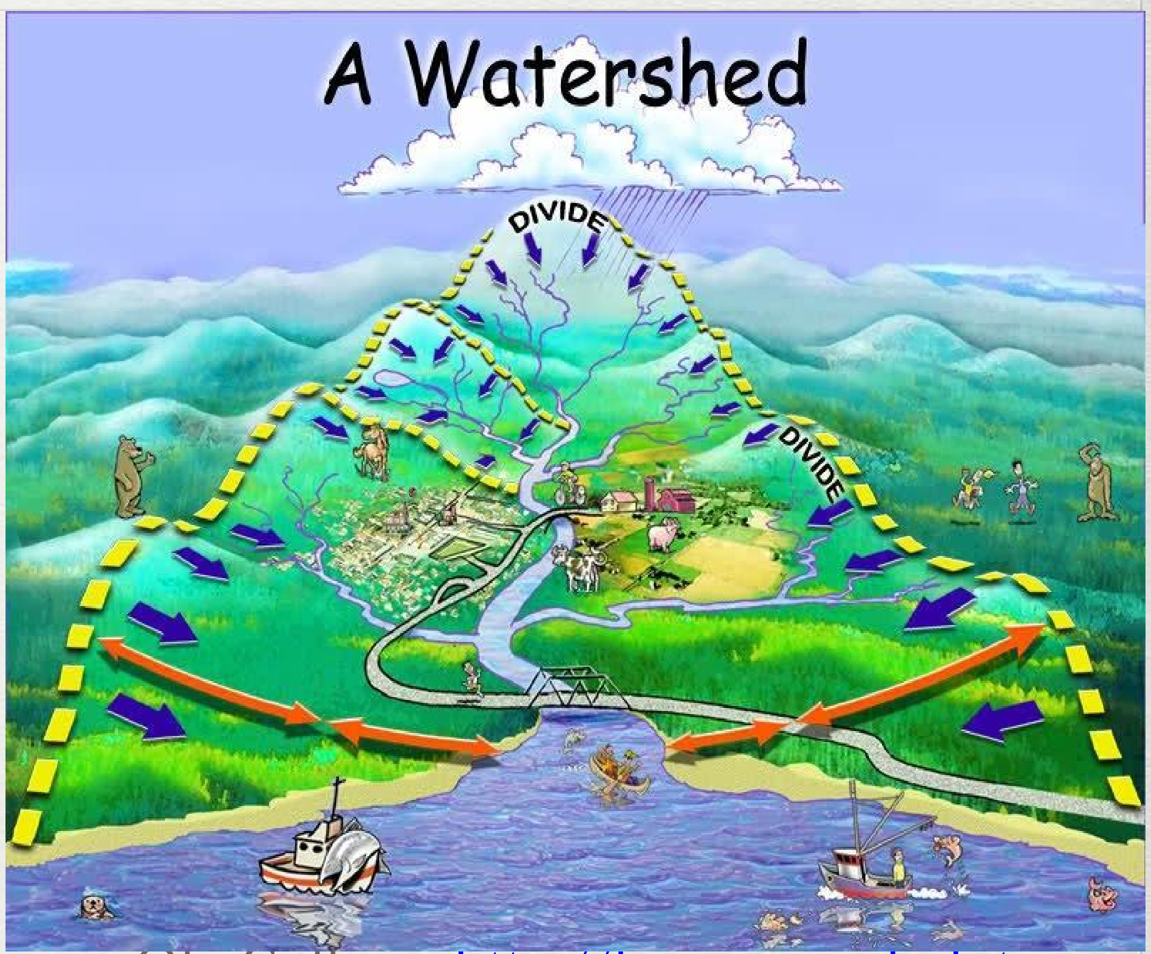
Why should Tribes and climate scientists be concerned with stream health monitoring?

- Systems monitoring is a necessary first step to adapting to climate change

- Stream ecosystems integrate both climate and land uses within the watershed.

- An unhealthy stream ecosystem is an indicator of a watershed that is out of balance – the pollution loading is exceeding a stream's ability to assimilate pollution.

- Changes in weather (e.g. higher intensity storms) and climate (more frequent floods and

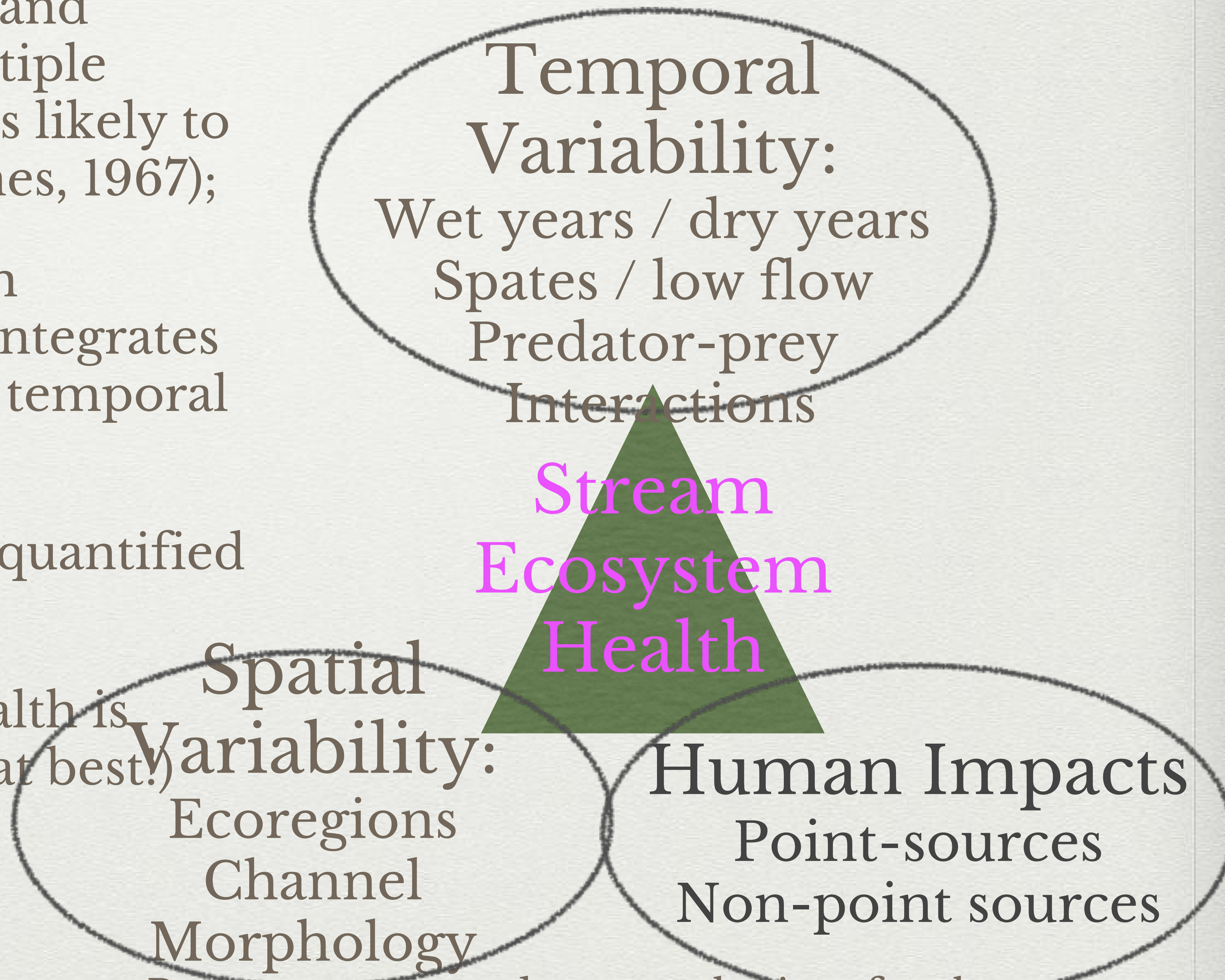


Oh, College; http://kaceann.wikidot.com/watershed

Through adaptive management we can protect both ecosystems and economic well-being on Tribal lands.

Why studying stream ecosystems is not rocket engineering... it's actually much harder*

- Streams are dynamic and heterogeneous at multiple scales - “each stream is likely to be unique” (HBN Hynes, 1967);
- The concept of stream assimilative capacity integrates watershed spatial and temporal variability;
- Multiple generally unquantified human impacts;
- Stream ecosystem health is indirectly measured (at best!)

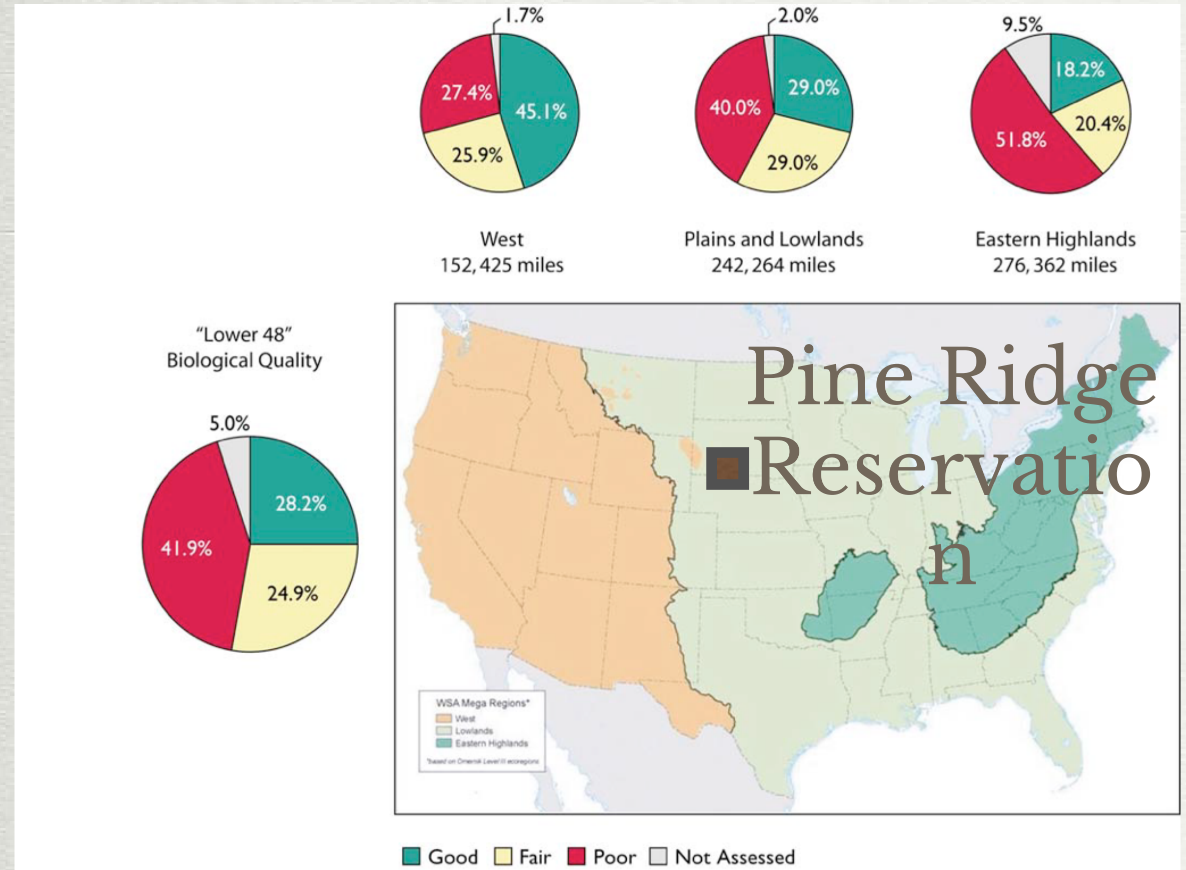


* With thanks from Dr. Camaron Barrows - a great desert ecologist - for the quote on ecosystems in general.

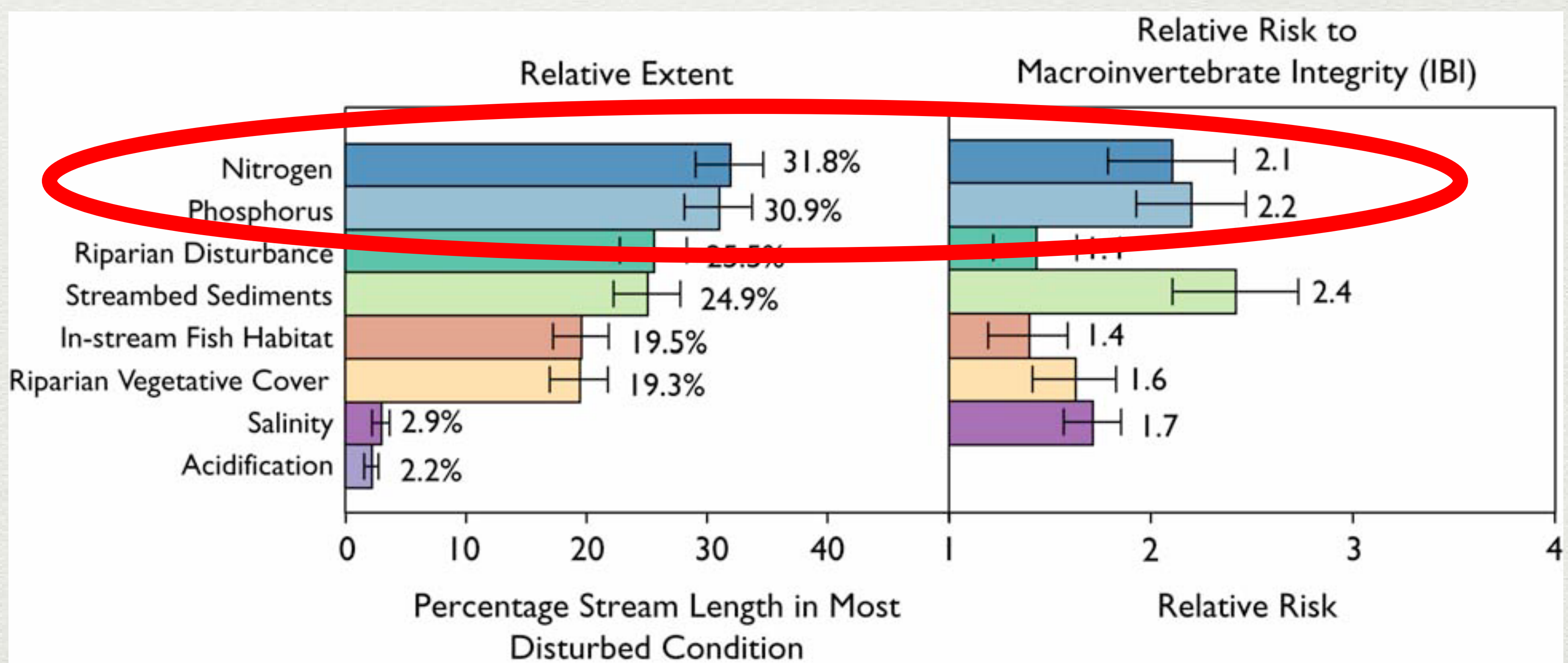
Watershed Protection is a National Challenge

Human caused stressors are impacting the Nation's Waters

Nutrients are the major source of stream ecosystem impacts



2006 EPA Wadable Stream Assessment



Non-Point Source Nutrient Loading Causes Eutrophication and Negative Ecosystem Changes

Sun + limiting nutrients = organic pollution (algal growth) -> low dissolved oxygen at night -> ecosystem changes

Biological Monitoring Should Inform our Water Quality Standards to Protect Stream Health

1) The Clean Water Act mandates **fishable (healthy ecosystems)**, swimmable (pathogen free), and drinkable (contaminant free) waters;

2) Water quality standards are the regulatory pathway to protect stream health;

3) Biological monitoring identifies if a water quality standards is appropriate **provided we choose valid**

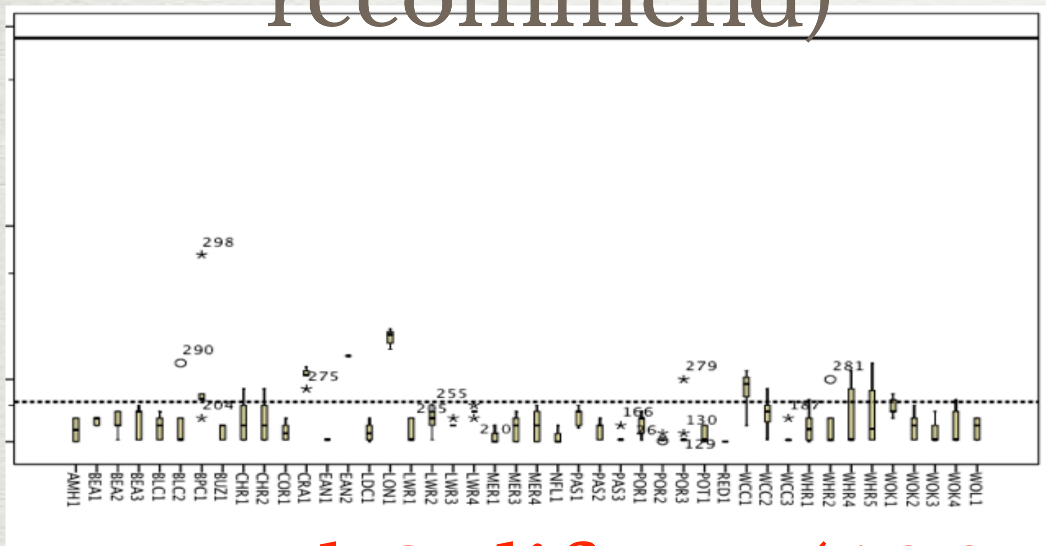
Upper Pass Creek during the first recorded algal bloom during a supraseasonal drought

Watershed physiography on the Pine Ridge Reservation (and capacity to assimilate pollution) is a response to watershed hydraulics

Grazing is the Major Land Use on the PRR

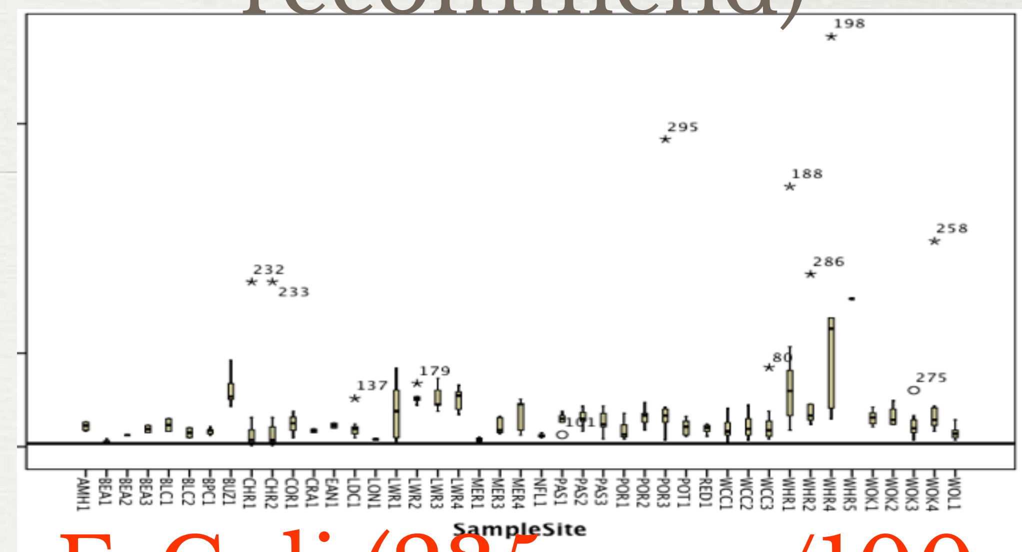
Nitrate (0.56 mg/L recommend)

I EPA Rec.



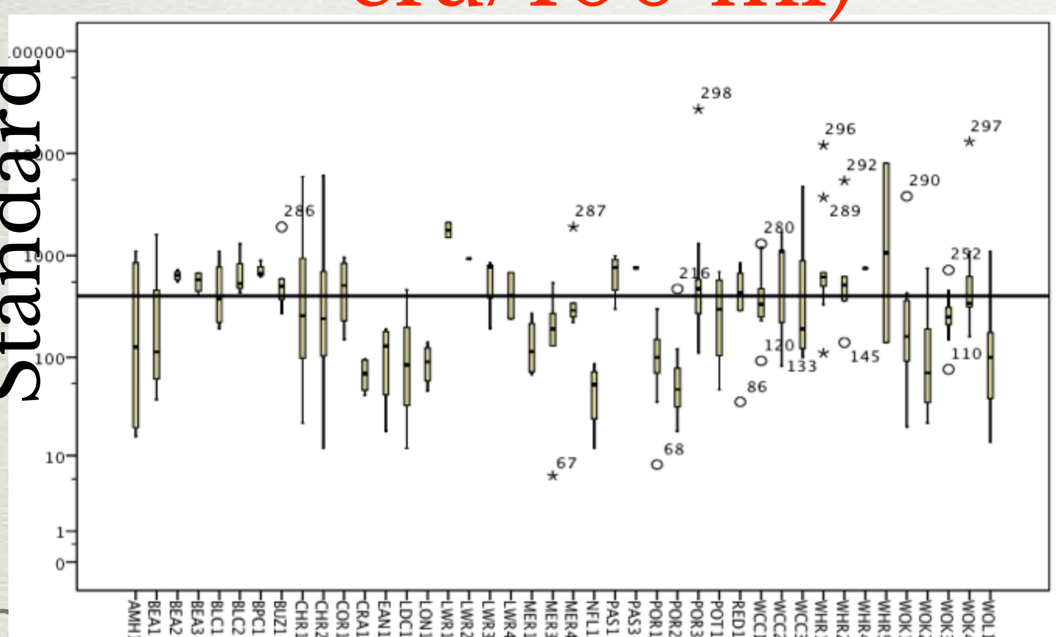
Total P (0.029 mg/L recommend)

I EPA Rec.



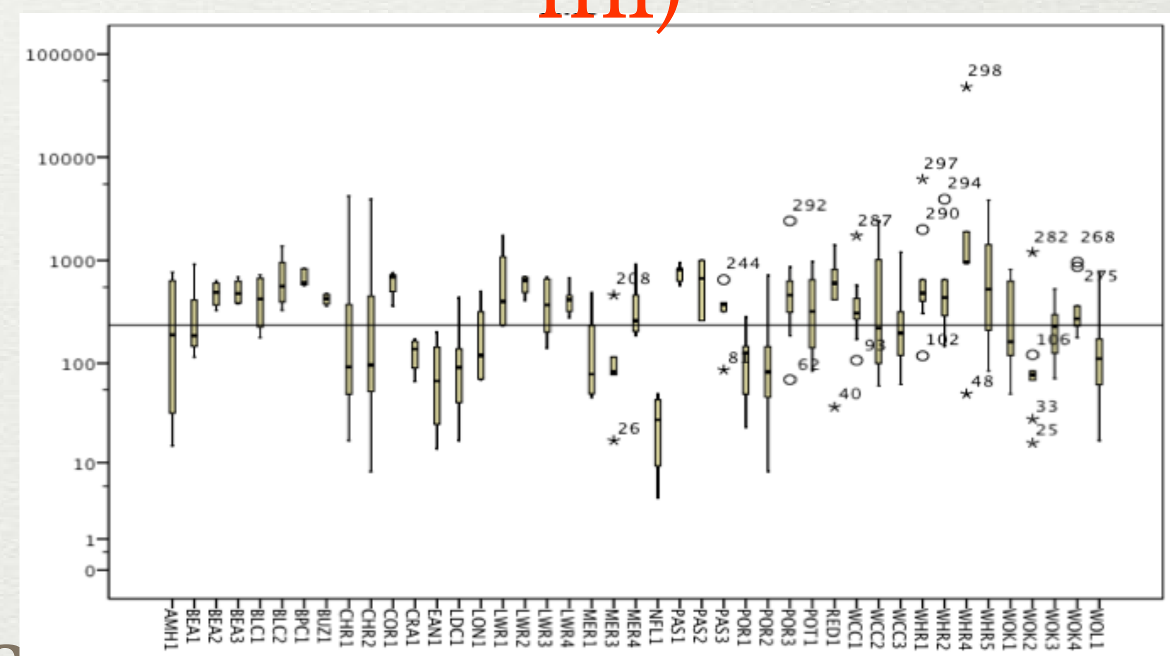
Fecal Coliform (400 cfu/100 ml)

EPA I Standard



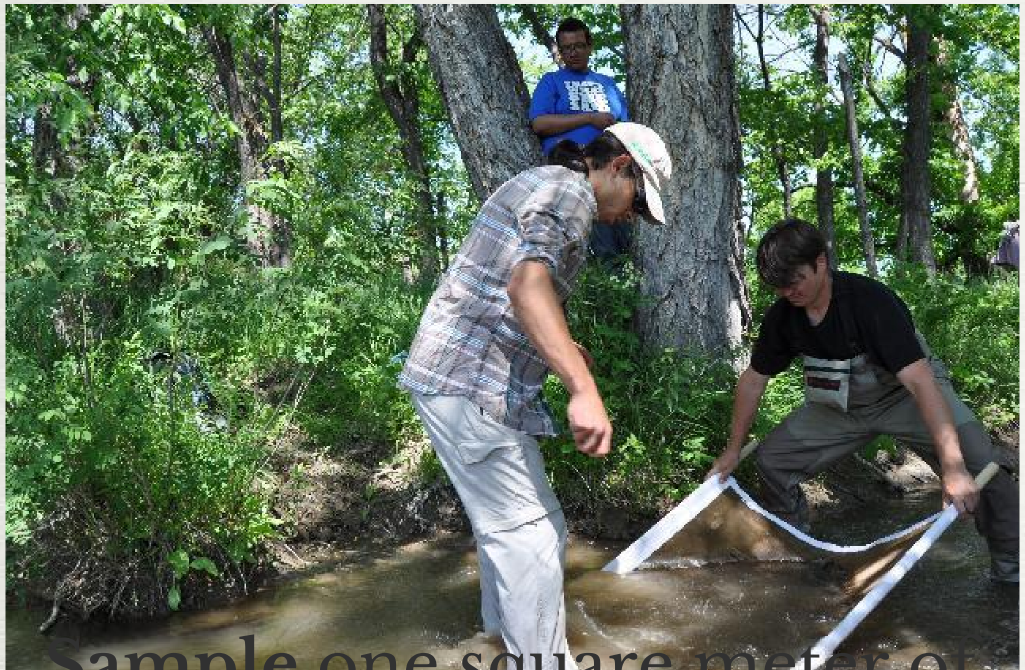
E-Coli (235 mpn/100 ml)

EPA I Standard



85% of Pine Ridge Reservation streams sampled in 2008-2011 did not meet existing water quality standards for bacteria. All samples exceeded phosphorus goal and ~ 30% exceeded nitrate goal.

Framework for Macroinvertebrate Biological Stream Health Assessment



Sample one square meter of benthos – collaborative activity with tribal agency

Sieve to 500 microns and preserve in EtOH – and **store** in archive (NSF ARI support)

Identify ~100 organism subsample to family level – student intern led

Assess a stream health score by ecoregion from metrics calculated from subsample

Study design to test effectiveness of **EPA designated metrics** to measure stream health of Pine Ridge Reservation streams

Stream Health Metrics	Ecoregion	"Land Use" *	Time 1990 vs. 2000	Interactions
Taxa Richness	Total number of families – measure of diversity – should decrease as organic pollution increases			
% **EPT**	Percentage of insects intolerant to organic pollution (mayflies, stone flies, caddis flies) – should decrease as organic pollution increases			
EPT Index	Number of EPT families (families intolerant to organic pollution) – should decrease as organic pollution increases			
Family Biotic Index	Population weighted index of tolerance to organic pollution – should increase as organic pollution increases			
% Dominance	Percentage of most numerous taxon in an ecological community – measure of evenness – should increase as organic pollution increases			
% Dipteran and Non insect	Percentage of taxa with adaptations to organic pollution – should increase as organic pollution increases			
% **Collector**	Percentage of taxa using generalist feeding strategies –			

Results from the MANOVA analysis

Bold column headings are significant overall	**Ecoregion p<0.001 h2=0.191**	**"Land Use" p<0.001 h2=0.534**	Time p<0.103 h2=0.138	**Land use x Ecoregion p<0.004 h2=0.127**
Taxa Richness				
% EPT	p<0.001 h2=0.295	p<0.001 h2=0.629		p=0.006 h2=0.191
EPT Index		p=0.005 h2=0.120		p=0.057 h2=0.132
Family Biotic Index		p<0.001 h2=0.378	p=0.011 h2=0.074	
% Dominance				
% Diptera and Non insect	p=0.039 h2=0.112	p<0.001 h2=0.610		
% Collector Gatherer	p=0.014 h2=0.137	p<0.001 h2=0.074	p=0.003 h2=0.102	p=0.019 h2=0.162

Significance values and effect size are for univariate ANOVA conducted as follow-up tests (>90% confidence reported)

Results Summarized

1. Aggregate stream health metrics can detect significant differences among ecoregions and land use

    - However, Taxa Richness and % Dominance do not contribute to our understanding of Pine Ridge reservation stream health;

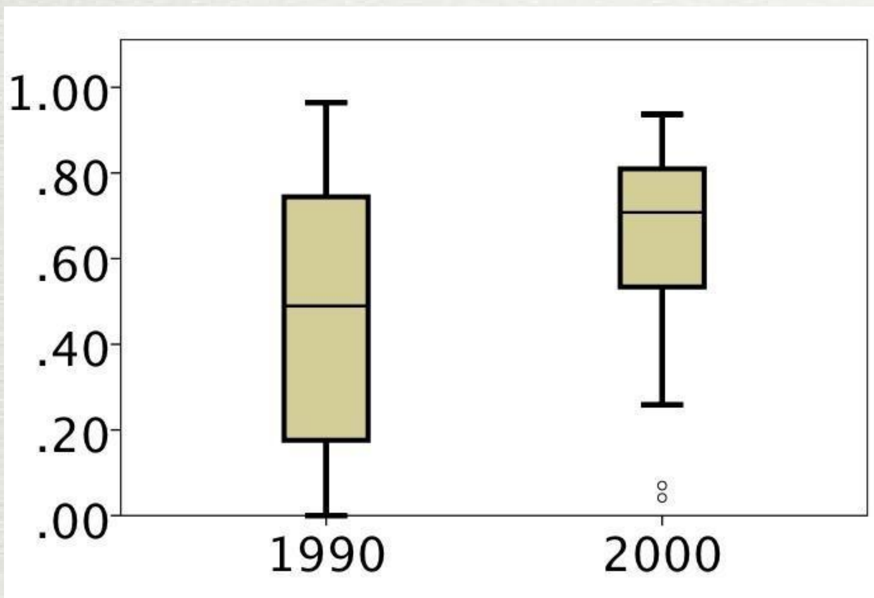
2. Some measures of stream health have decreased since the 1990s – as noted by increases in Family Biotic Index , and % Collector Gatherer;

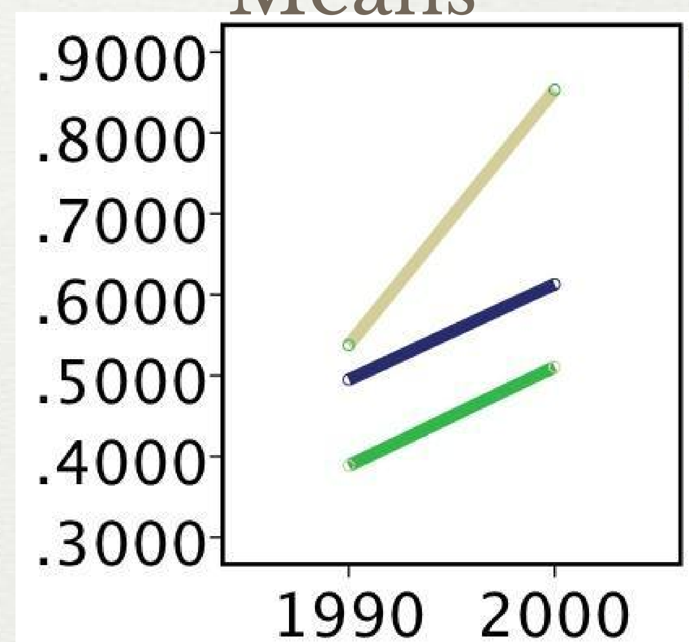
3. A previously unrecognized interaction between Badlands ecoregion and land use

1993 to 2011 Trend – Pine Ridge Reservation streams became less functionally diverse and more tolerant to organic pollution

Box Plots

Estimated Marginal Means



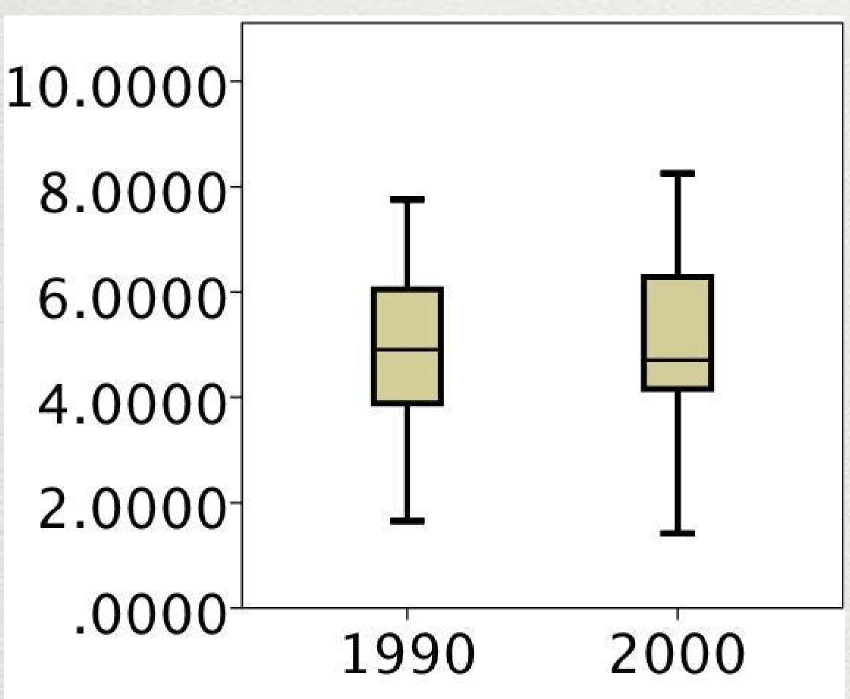


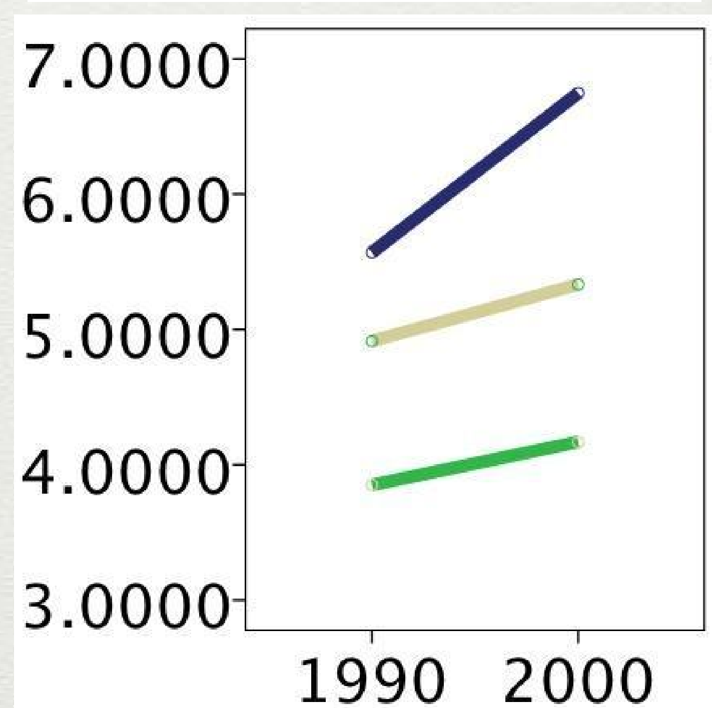
% Collector Gatherer Scores

High Use

Moderate Use

Low Use





Family Biotic Index Scores

High Use

Moderate Use

Low Use

Interaction - Badlands ecoregion (flashy) streams had greater sensitive organism abundance (EPT), but were less functionally diverse than other ecoregions.

Box Plots

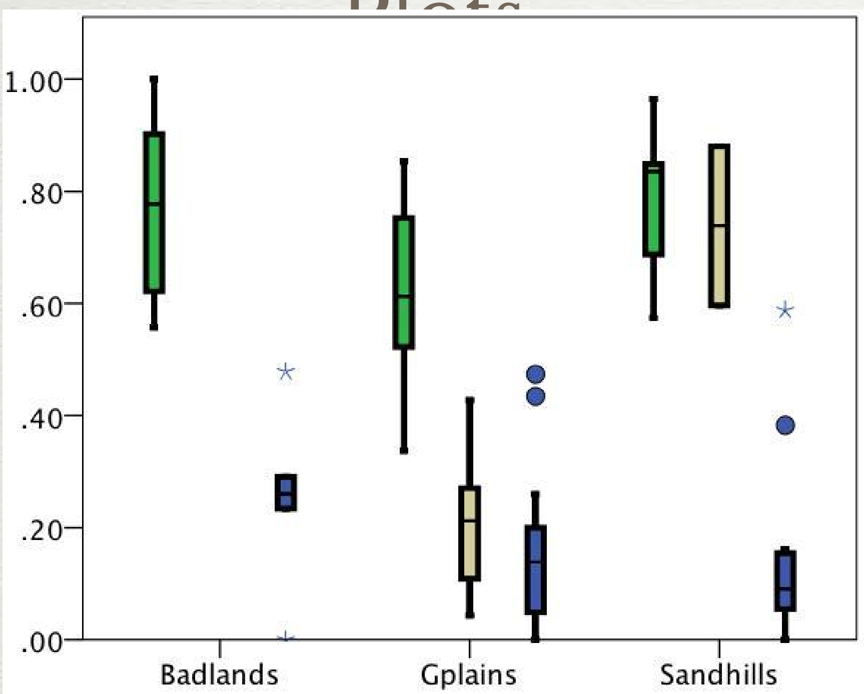
Estimated Marginal Means

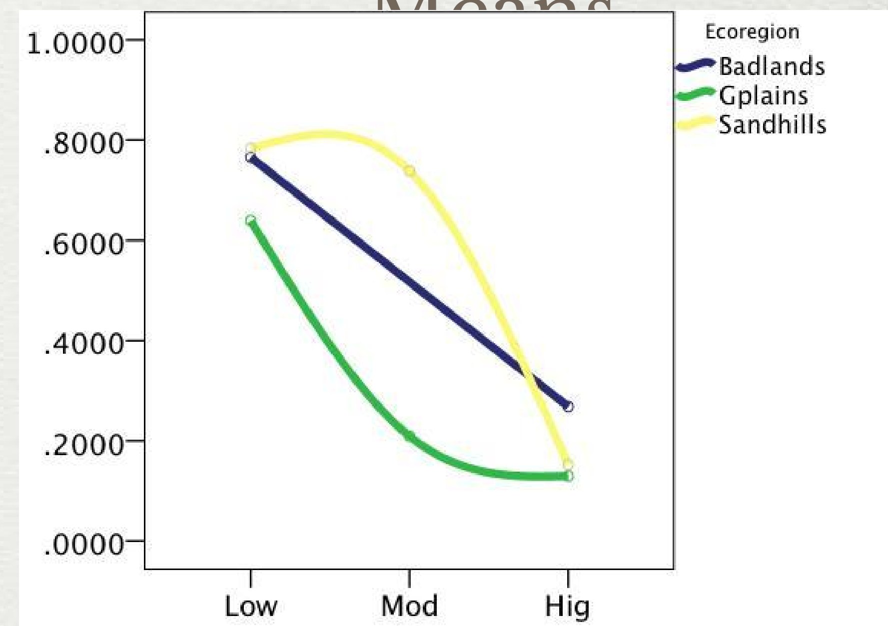
% EPT

Low Use

Moderate Use

High Use



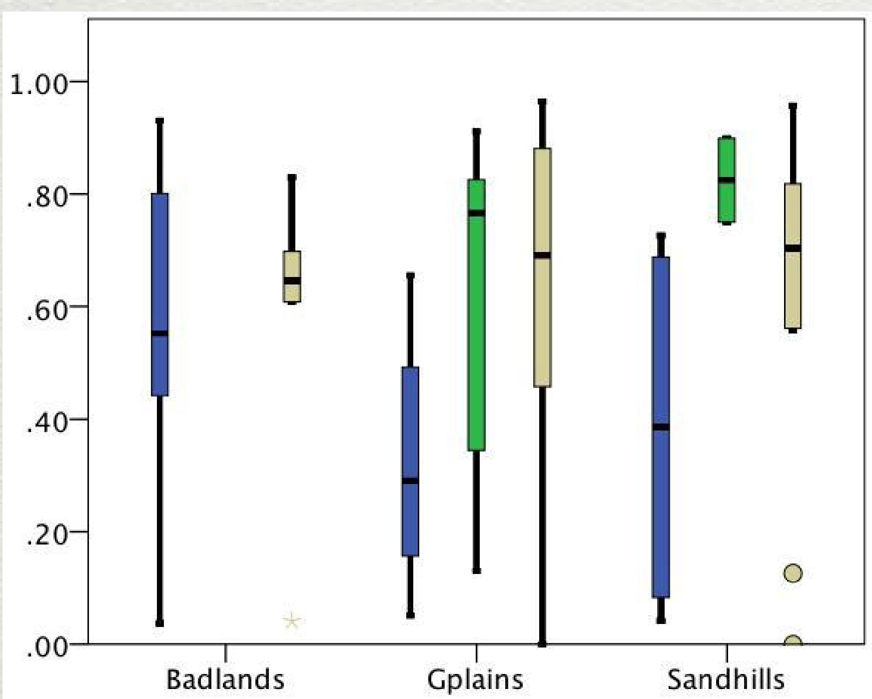


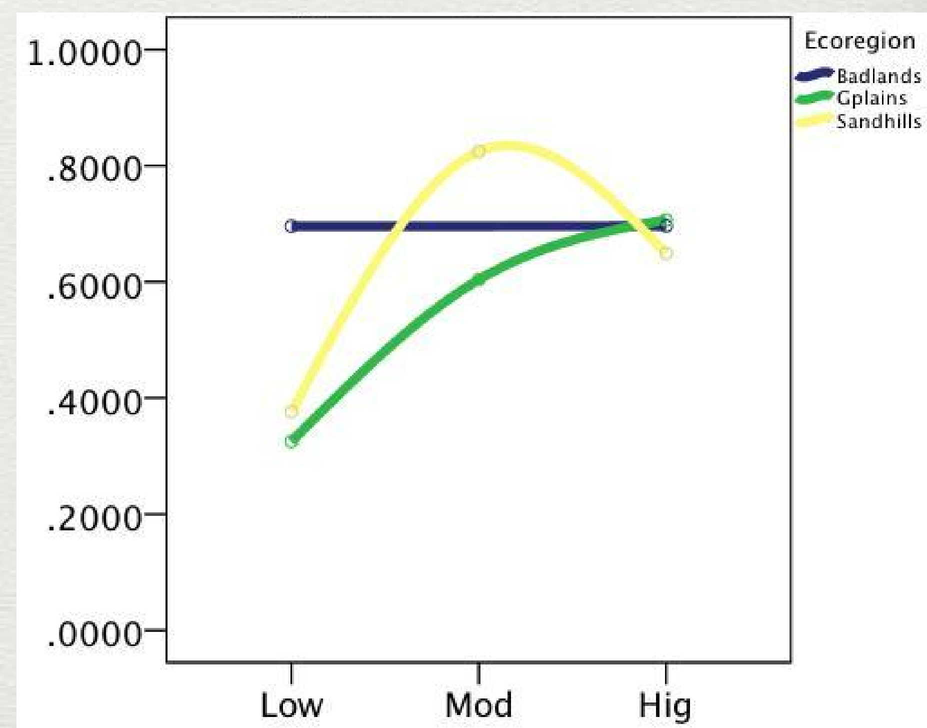
% Gatherer

Low Use

Moderate Use

High Use





Discussion – Are we on the cusp of an ecosystem change? Are we exceeding assimilative capacity in a changing climate?

- Results are consistent with the effects of moderate non-point source nutrient loadings:
  - Diversity and evenness may increase or decrease in early phases of community ecosystem change as niche availability increases;
- The changes across time – an increase in tolerance coupled with a decline in functional diversity may be related to increased algal concentrations caused from non-point source nutrient loadings;
- Differential assimilative capacity - Frequent high (e.g. flushing) flows in Badlands streams may result in lower average algal biomass and a naturally less

Stream health: are we measuring what we think we are measuring? And what does it all mean?

- Yes (mostly) – Our existing stream health monitoring framework is capable of detecting changes in stream health – this is guiding the collaborative development of the OST Watershed Protection Plan;

- 2) Pine Ridge Reservation streams health is declining over the last two decades –indicates an ecosystem change resulting from human non-point source impacts or as a response to a changing climate;

- 3) Streams ability to assimilate pollution differs among ecoregions – this is an important consideration in designing mitigation strategies (Best Management Practices).

Jake Ferguson downloading stream level data for a Badlands ecoregion stream

Future Work

- **Engineering –** Conduct a biological TMDL to establish watershed concentrations based on stream ecosystem health;

- **Science –** Test two new hypotheses identified: 1) macroinvertebrates community change is driven by wet year – dry year cycles, 2) aquatic producer biomass are a function of floods and drought;

- **Monitoring / Modeling:** (2014 field season) – Increase the stream flow monitoring network, monitor dissolved oxygen, chlorophyll *A*, alkalinity, nitrogen species, and total and soluble reactive phosphorus.

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