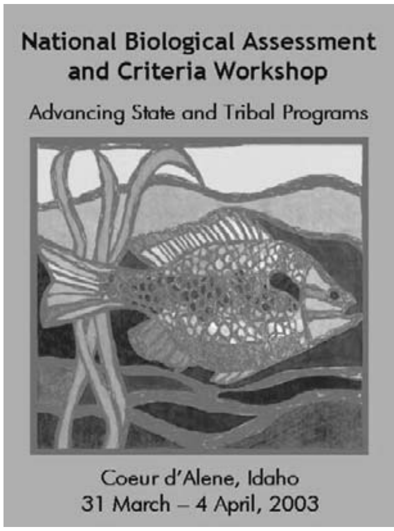
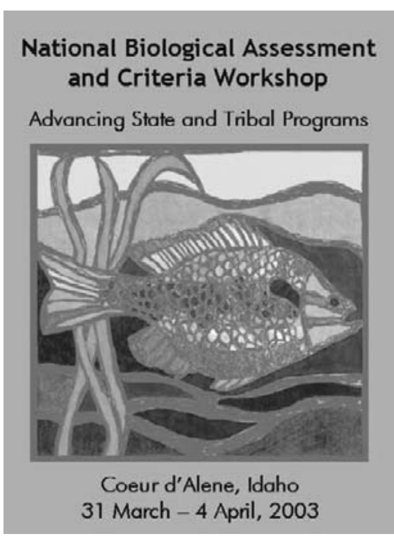


Index 201

BIOLOGICAL INDEX DEVELOPMENT METHOD: APPLICATIONS

Course Presenters and Contributors
Jeroen Gerritsen, Michael Paul, Karen Blocksom, Russ Frydenborg, Chuck Hawkins, Rick Hafele, Mike McIntyre, Susan Cormier



Index 201

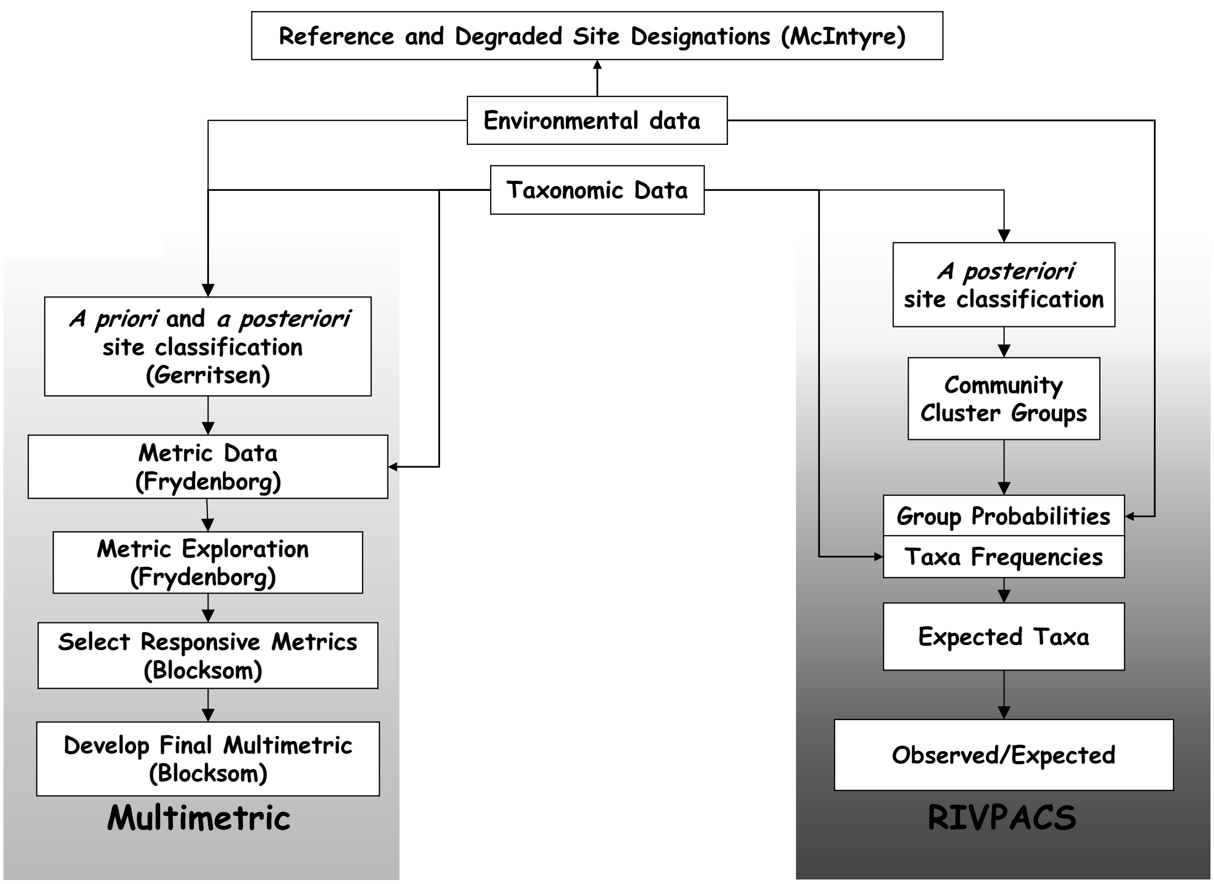
Biological Index Development Methods: Applications

(Introduction)

Presented by
Karen Blocksom, USEPA,
Office of Research & Development

Objectives

- Examine the steps of building multimetric and multivariate models in greater detail.
- Provide an understanding of how to apply the steps for one of the two methods of index development.



Why split into 2 groups?

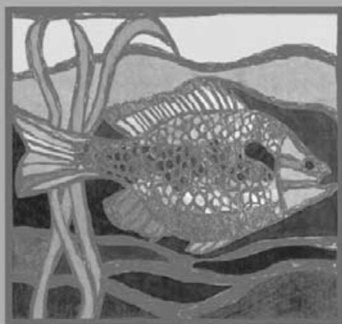
- Time limitations
- Level of detail
- Hands-on activities

Logistics

- 2.5 hours: 2 concurrent sessions
- 15 minutes: Break
- 1 hour: Reconvene for discussion of topics common to both methods

National Biological Assessment and Criteria Workshop

Advancing State and Tribal Programs

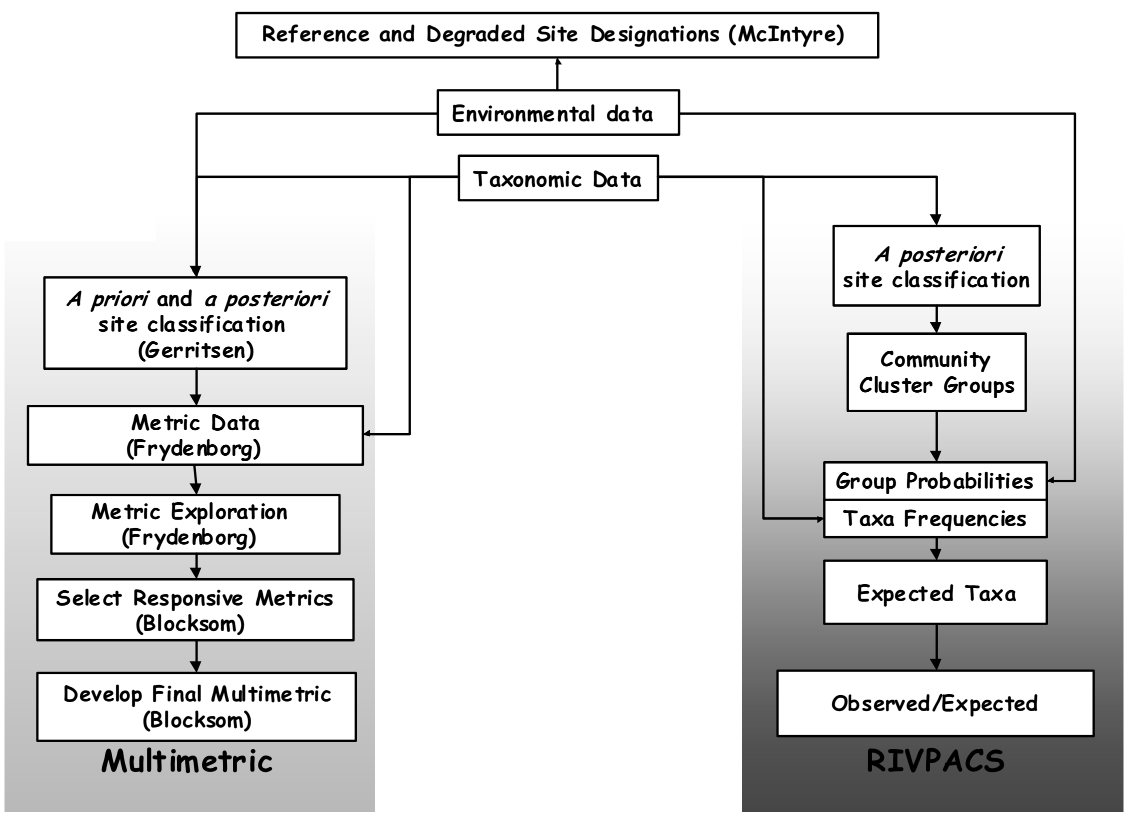


Coeur d'Alene, Idaho
31 March – 4 April, 2003

Index 201

Idaho's Index Development: Lessons Learned

Presented by
Michael McIntyre, Idaho DEQ



Idaho is Diverse

Overview

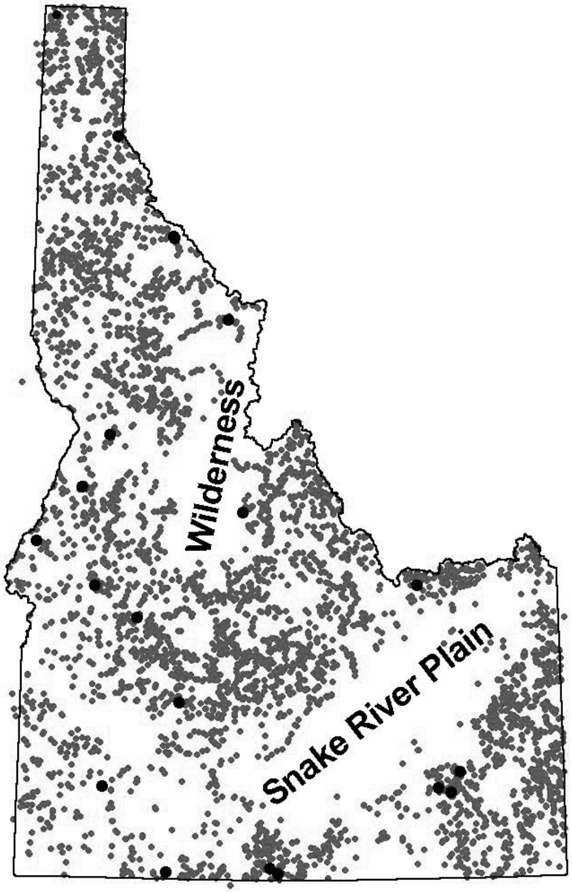
- **Idaho uses bioassessment approach in water quality decision making**
- **Bioassessment results are used in 305(b) report, 303(d) list, and TMDLs**
- **Bioassessment process is based on multimetric approach which requires identification of reference condition**

Clean Water Act & Bioassessment

- **1987, CWA re-authorization focused on non- point source pollution and introduced concept of bioassessment**
- **Prior to 1990, monitoring and assessment at DEQ was not structured or consistent**
- **In 1990, DEQ and many other states began to experiment with EPA's concept of rapid bioassessment (RBP)**

BURP

- **Early emphasis at DEQ was on monitoring and assessment, application of data came later**
- **Beneficial Use Reconnaissance Project (BURP) initiated in 1993, adopted statewide in 1994**
- **BURP monitoring based on RBP approach**



BURP Sites

- 5,205 BURP sites (1993-2002)
- Range of conditions
- Established annual reference trend network

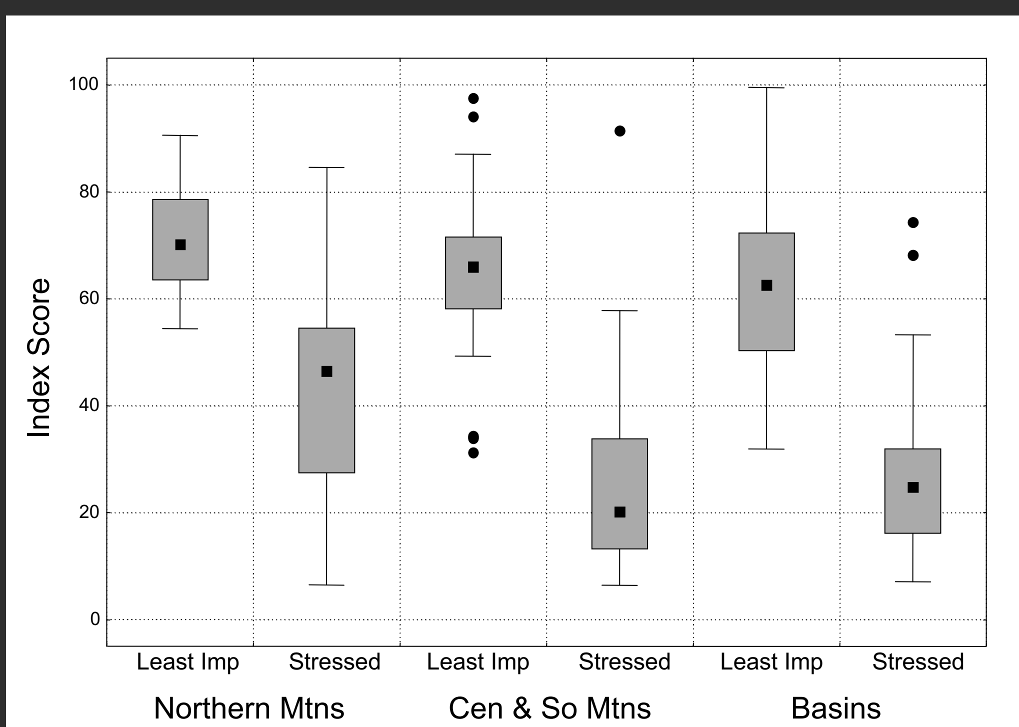
Outside Forces

- 1994-ICL et al. initiates lawsuit over Idaho 303(d) list
- Lawsuit focuses attention on how data collected and assessed for determining water quality
- Legal and regulatory ramifications of monitoring and assessment hits home for DEQ

Importance of Reference

- "The reference condition establishes the basis for making comparisons and for detecting use impairment" (Barbour et al. 1999).
- Karr and Chu (1999) and Hughes (1995) have also noted the significance reference condition plays in bioassessment.

How Reference is Used



Early Index Development

- 1989, contracted with Idaho State University (ISU) to develop a monitoring and assessment tool based on RBP model
- ISU used multiple sources to select reference: expert opinion, maps, and other resource professionals

Early Reference Selection

- ISU did field visits before monitoring to validate reference assumptions
- 1992, ISU delivers RBP tool
- Index based on macroinvertebrates
- Reference is for two ecoregions only (out of nine in the state)

Early Reference Selection

- 1995, limitations of ISU work becomes apparent as no reference sites exist for the other seven ecoregions
- DEQ selects reference using post hoc (*a posteriori*) approach from previously monitored sites
- Approach doesn't provide consistent or acceptable results. Statewide reference sites still questionable

Reference Selection: "Franken Stream"

- DEQ pushed to resolve reference question as 1996 305(b)/303(d) report/list imminent
- Choose an empirical model for determining reference
- Use the 95th percentile or best score for each of the seven metrics in the Macroinvertebrate Biological Index (MBI)

Reference Selection: "Franken Stream"

- Realize and accept that empirical model flawed- no one site consists of all the best values
- Now refer to this empirical model as the "Franken Stream" approach

Reference Selection: Next Attempt

- DEQ criticized internally and externally for "Franken Stream" model
- Moved to *a priori* approach incorporating regional staff expertise and Hughes (1995) reference methodology. Still draw from previously monitored sites

Reference Selection: Next Attempt

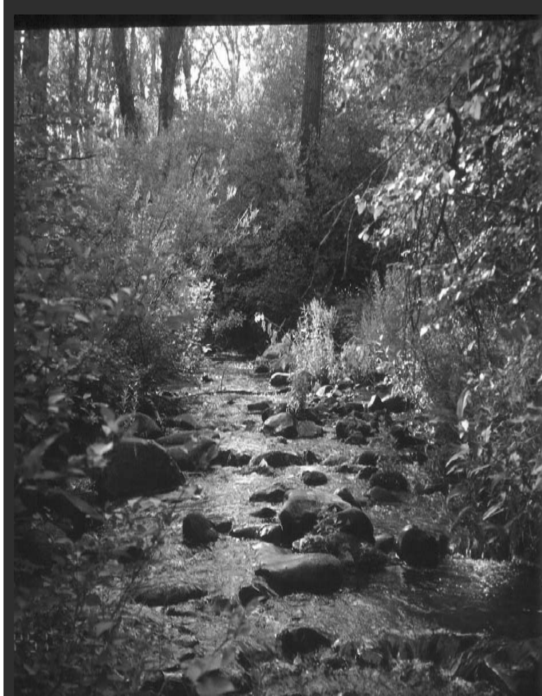
- *A priori* approach - not well defined
- Based on expert opinion
- No documentation of decision process
- Result: inconsistent definition of “reference” used by professionals

New Index Tool

- 1999, contract with Tetra Tech, Inc. to develop a new macroinvertebrate index
- Tetra Tech identifies “outliers” not only in the reference data set, but also in the impaired data set
- Site selection issue for both reference and impaired sites

Reference Selection: Another Round

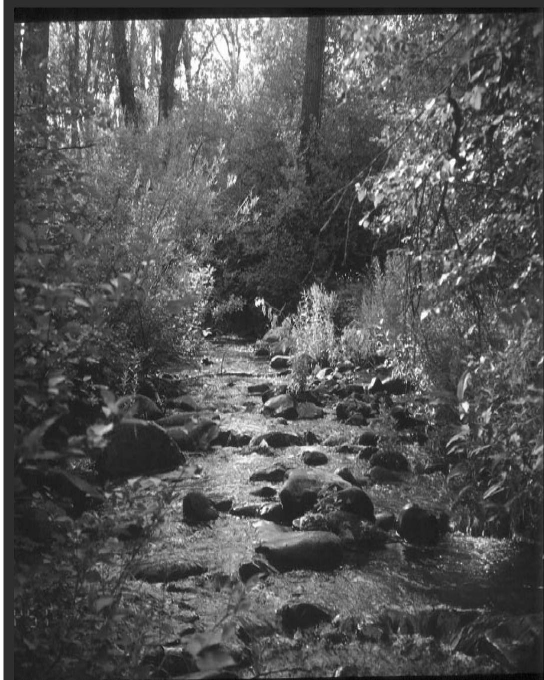
- *A priori* approach - provided better reference definitions and guidance
- Still based on best professional judgement
- Some documentation of decision process, but not consistent
- Result: better, but still inconsistent results and interpretations



Reference Selection: Most Recent Approach

- 2000, implement a more systematic approach (before monitoring!)
- Process involves:
  - definitive screening criteria
  - GIS filters for human impacts
  - independent field validation
  - documentation of all steps

Reference Selection: Most Recent Approach

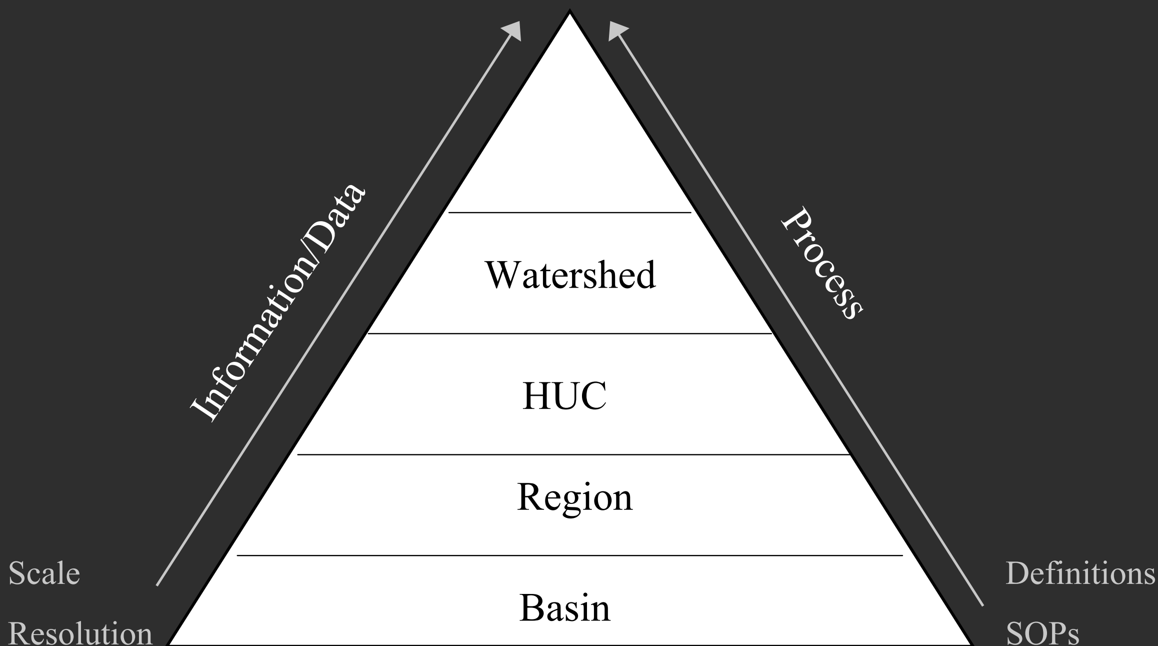


- Results reviewed by <u>multiple</u> regional staff and GIS tools used as checks
- Modify reference data set and index accordingly
- Refined reference set improves the discriminatory power of index significantly

Current Criteria

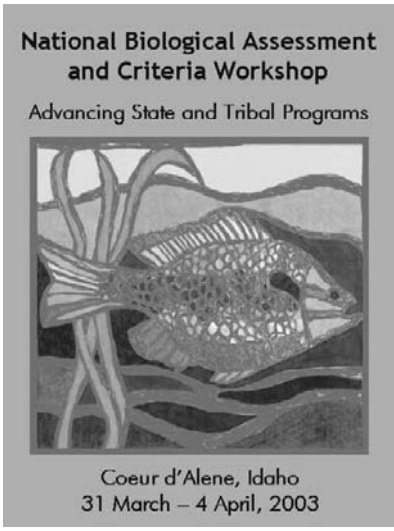
- Roads, distant
- Riparian vegetation extensive, varied, mature
- Riparian structure complex
- Natural channel morphology, minimal shoreline modifications
- Channel complex
- Habitat structure complex
- Chemical stressor minimal
- Channel/flow manipulation minimal

Reference Condition



Conclusions

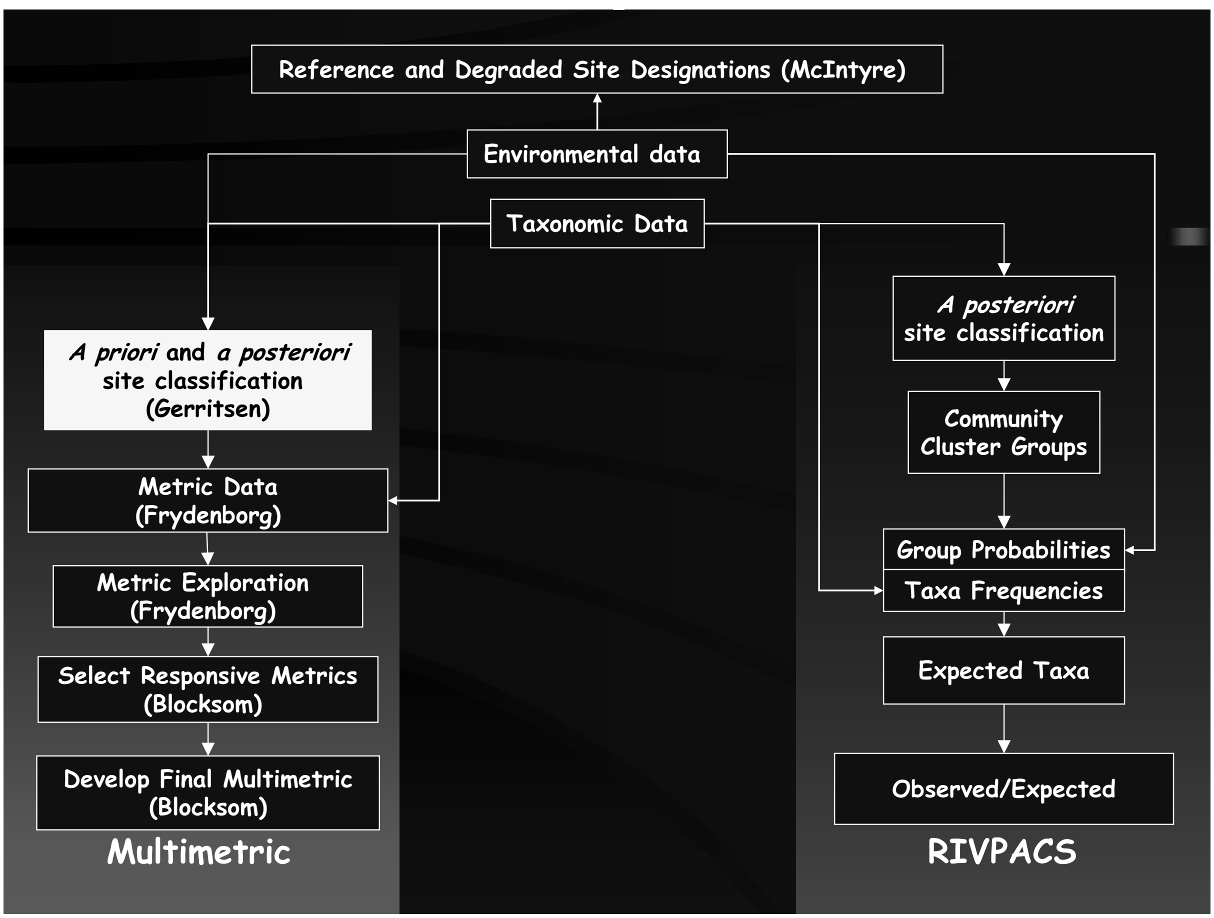
- **Obviously, reference condition determination is critical and the foundation of index development**
- **Make a sound plan and stick with it, don't deviate**
- **Document decisions and assumptions throughout the entire process, start to finish**



Index 201

Case Study: Classification of Western Streams

Presented by
Jeroen Gerritsen, Tetra Tech, Inc.



Multimetric Index Development

- Database consisting of reference and stressed populations (sites)
- Classify resource (reference sites)
- Identify and test candidate metrics
- Select metrics for dimensionless index
- Select thresholds for assessment

Classification of Sites (Streams)

- The intent of classification is to identify groups of sites that under ideal conditions would have comparable biological communities
- Classification should rely on those characteristics of sites that are intrinsic, or natural, and not the result of human activities

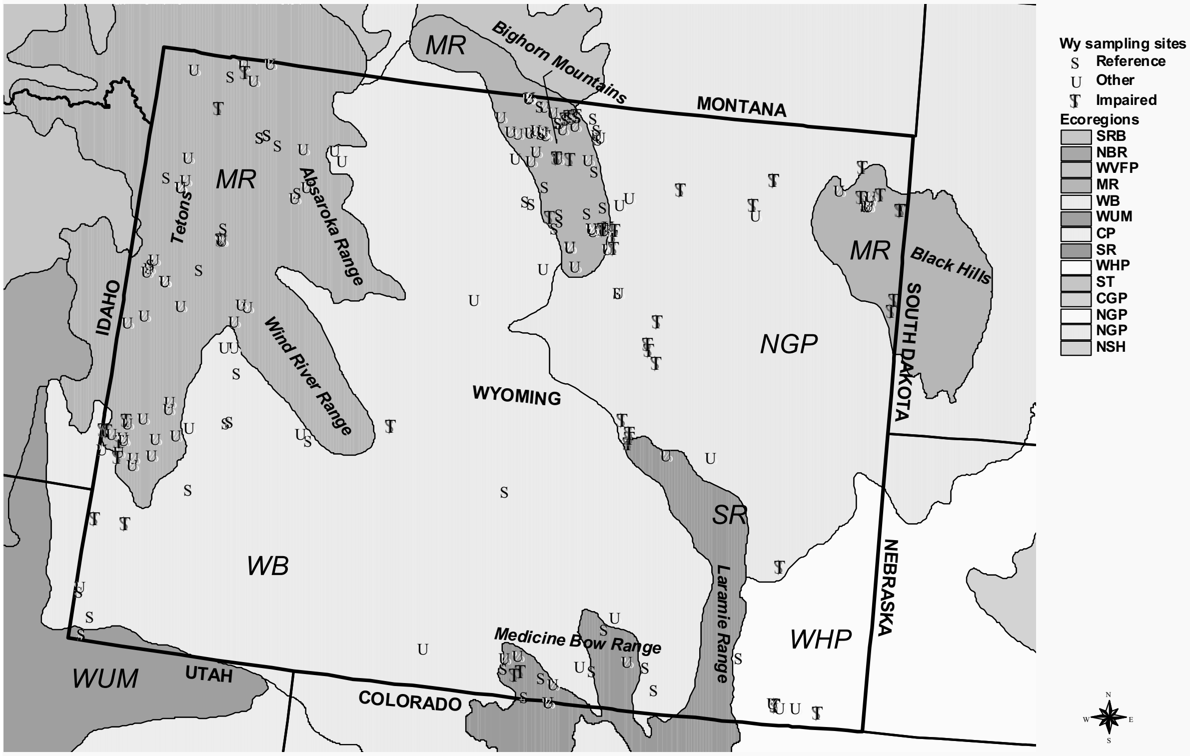
Classification approaches

- *A priori* rule-based models
  - geographic regions
  - salinity zones
- *A posteriori* development of rules
  - Cluster analysis followed by discriminant models
- Gradient and mixed models
  - Elevation, catchment size, salinity, depth, etc.

Classification of Wyoming streams

Testing an *a priori* model

Middle Rockies	
Western ranges	Tetons, Absaroka, Wind River Wyoming, Salt River
Central – Bighorns	Bighorns
East – Black Hills	Black Hills
Southern Rockies	Medicine Bow, Laramie ranges
Wyoming Basin	sagebrush high desert
Northwestern Great Plains	mostly tall grass prairie
Western High Plains	mostly short grass prairie

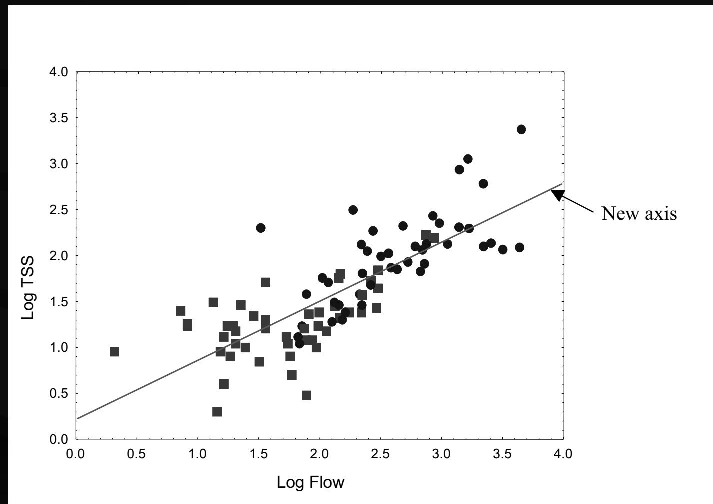


Other classifications

- Elevation
- Gradient
- Watershed area
- Climate
- Geology
- Latitude, longitude
- Natural water quality (alkalinity, color)
- Substrate

Ordination

- Putting things in order, according to their similarity
- Reduce dimensions: regression line is new axis
- What if we have 3 variables? 4 or more?



Ordination

- PCA (Principal Components Analysis)
  - Multivariate extension of regression
  - Assumption: normal distribution, linear
  - NOT suited for species data
- Correspondence analysis (CA)
  - Uses chi-square as similarity
- Non-metric multidimensional scaling (NMS)
  - Non-metric: converts distances to ranks, then does ordination on ranks
  - Recreates map using only distances between cities
  - Points close together are similar: use this to visually identify groups and structure

Similarity

- Ordination works on some measure of similarity (or dissimilarity)
- e.g., Jaccard similarity:

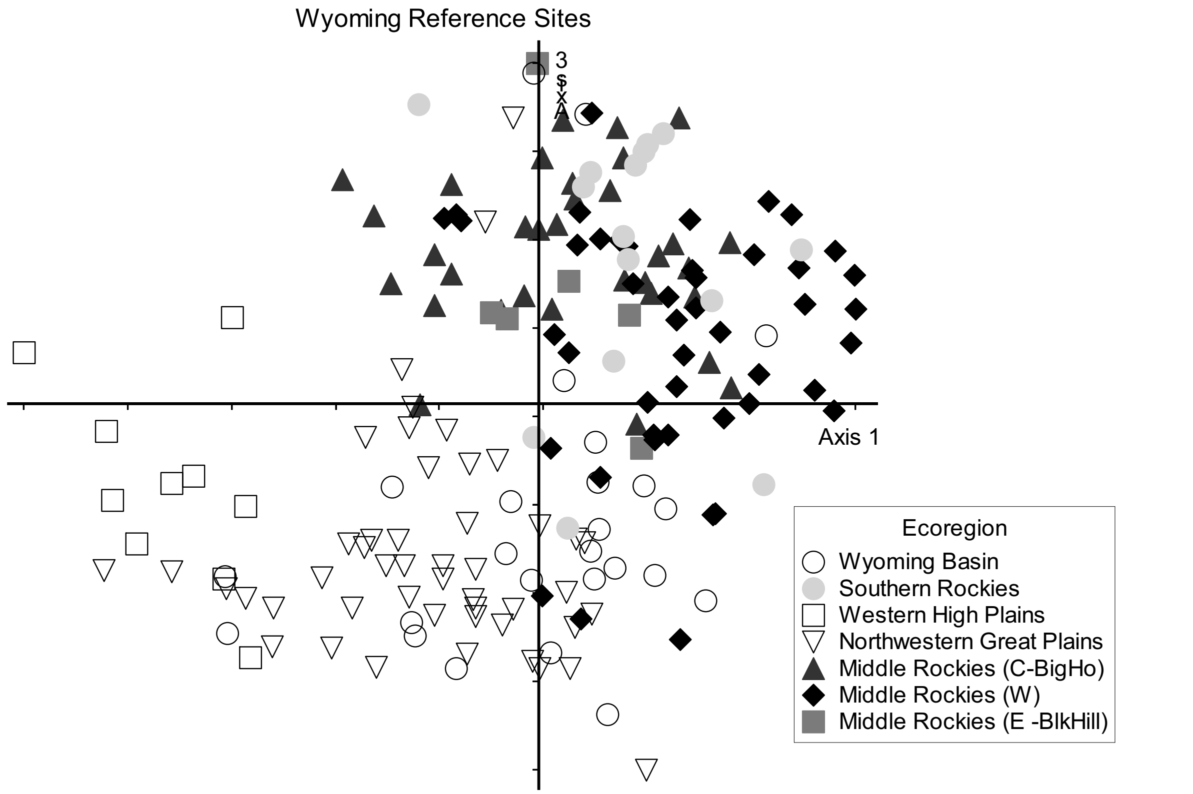
$$JI = \frac{\text{Taxa in common}}{\text{Total taxa}}$$

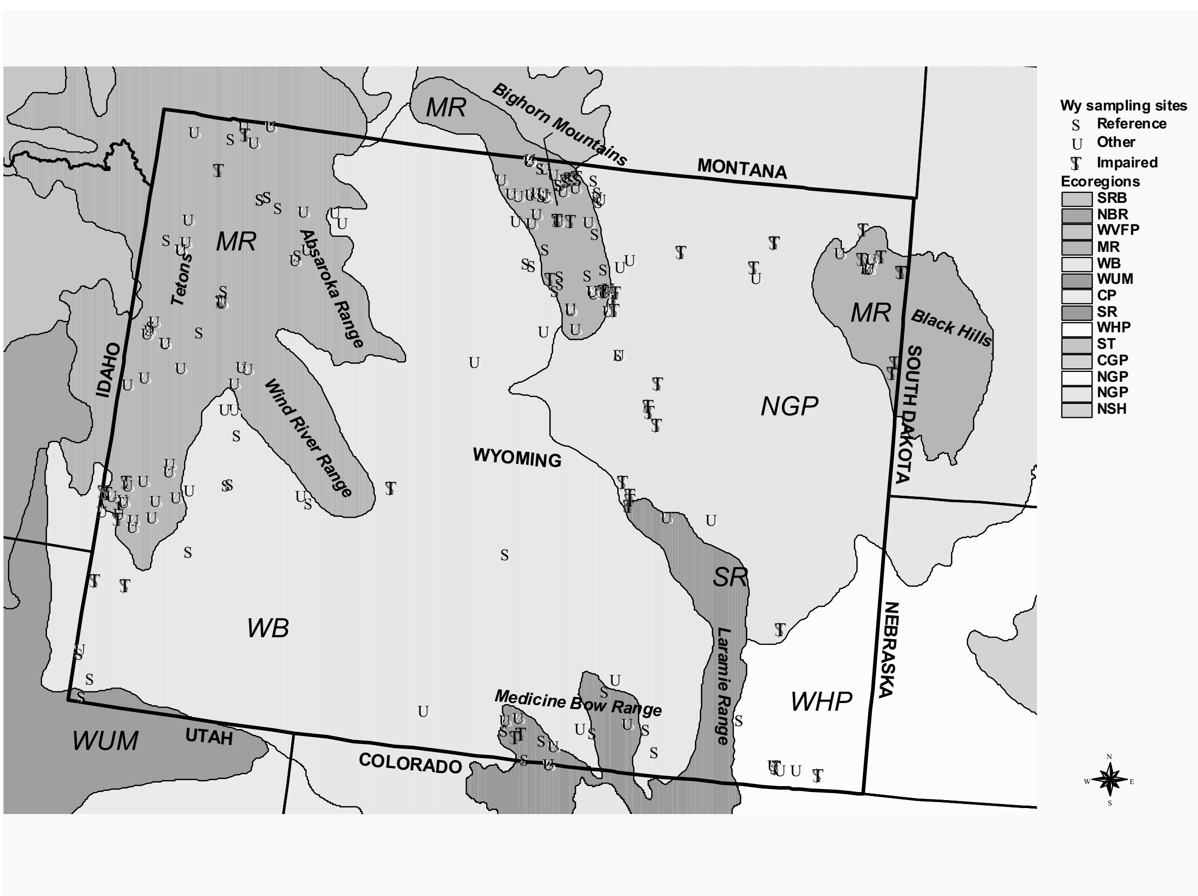
- There are many similarity indexes!

Ordination

Let's try it –

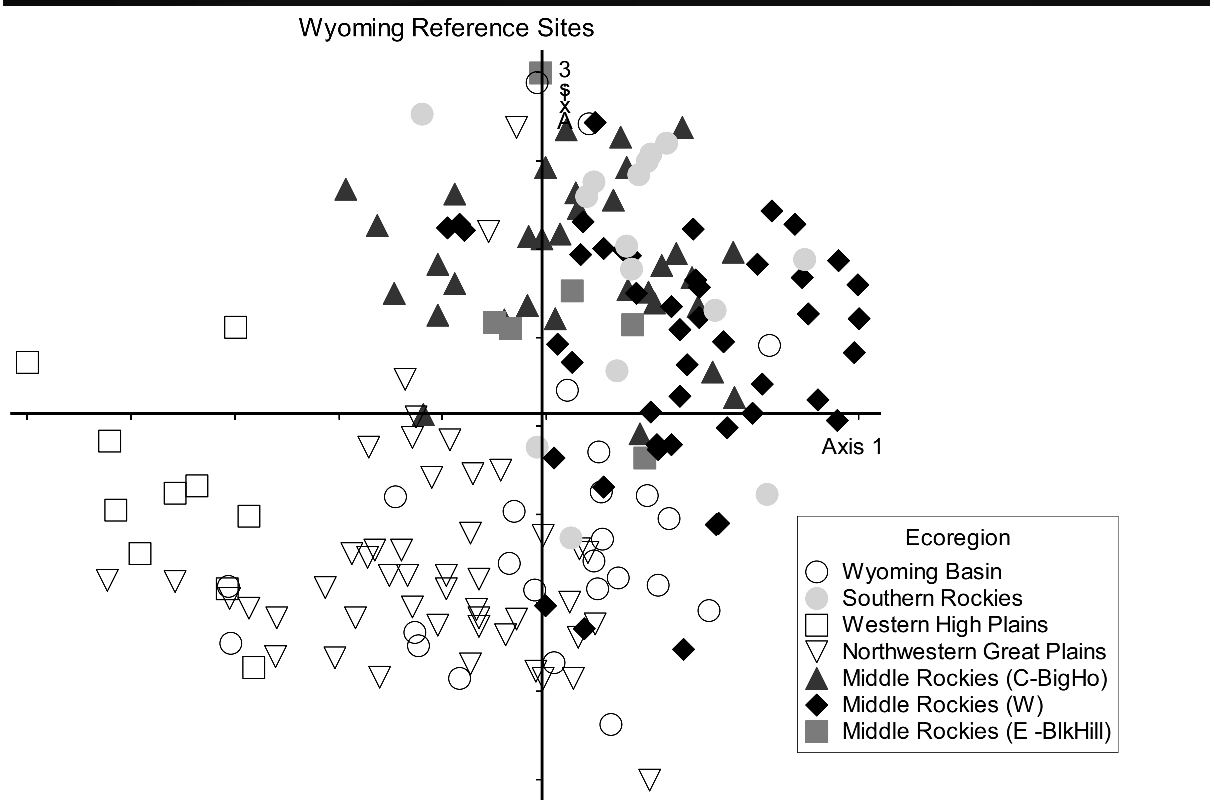
- NMS of Wyoming sites
- Similarity metric is proportional Bray-Curtis (a measure of % similarity)
- Plot sites in the reduced dimensions (called "ordination space")
- Look for structure with respect to *a priori* classes

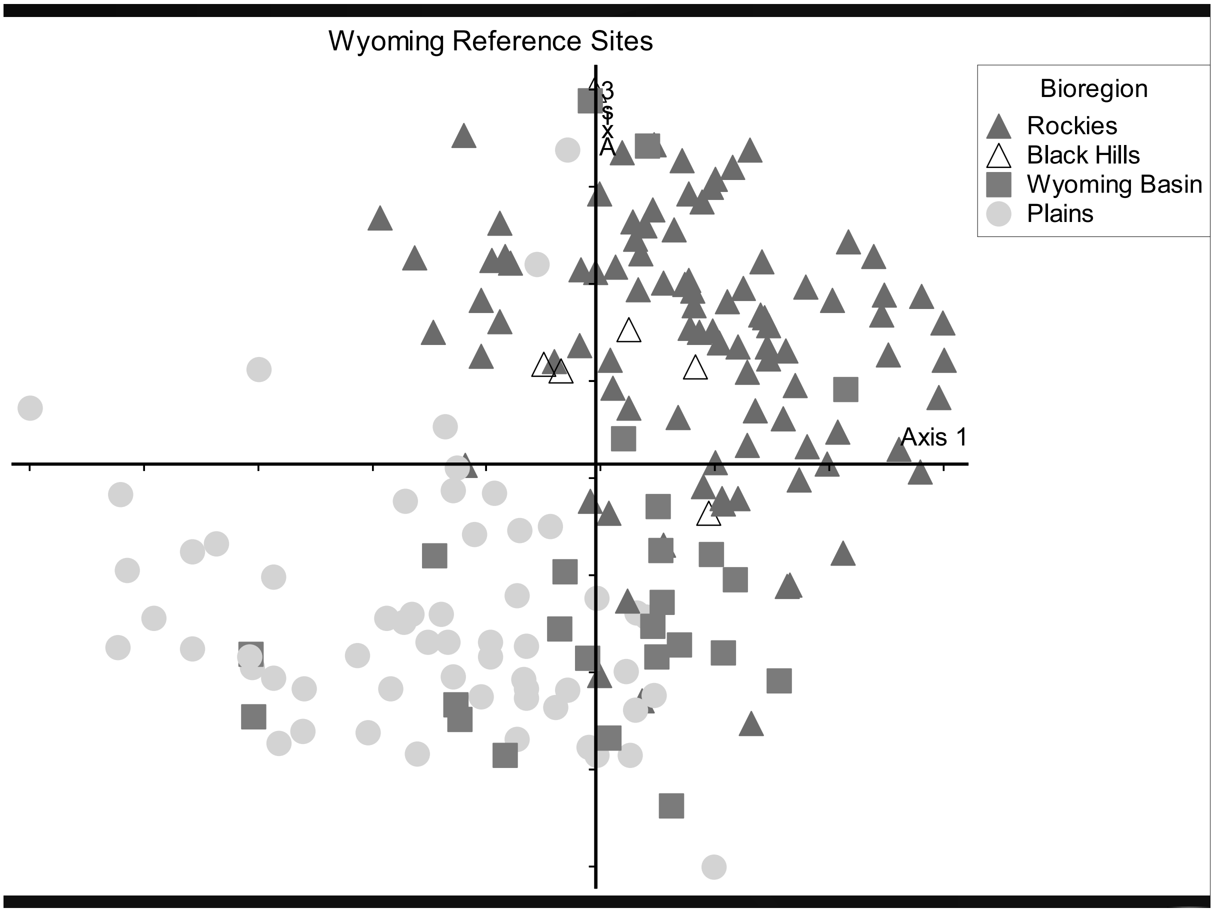

Wyoming Reference Sites
Axis 1
Ecoregion
Wyoming Basin
Southern Rockies
Western High Plains
Northwestern Great Plains
Middle Rockies (C-BigHo)
Middle Rockies (W)
Middle Rockies (E -BlkHill)


MR
Bighorn Mountains
MONTANA
MR
Tetons
Absaroka Range
Wind River Range
IDAHO
WYOMING
NGP
MR
Black Hills
SOUTH DAKOTA
SR
Laramie Range
NEBRASKA
WHP
WB
WUM
UTAH
COLORADO
Medicine Bow Range
Wy sampling sites
Reference
Other
Impaired
Ecoregions
SRB
NBR
WVFP
MR
WB
WUM
CP
SR
WHP
ST
CGP
NGP
NGP
NSH

How do we read these?

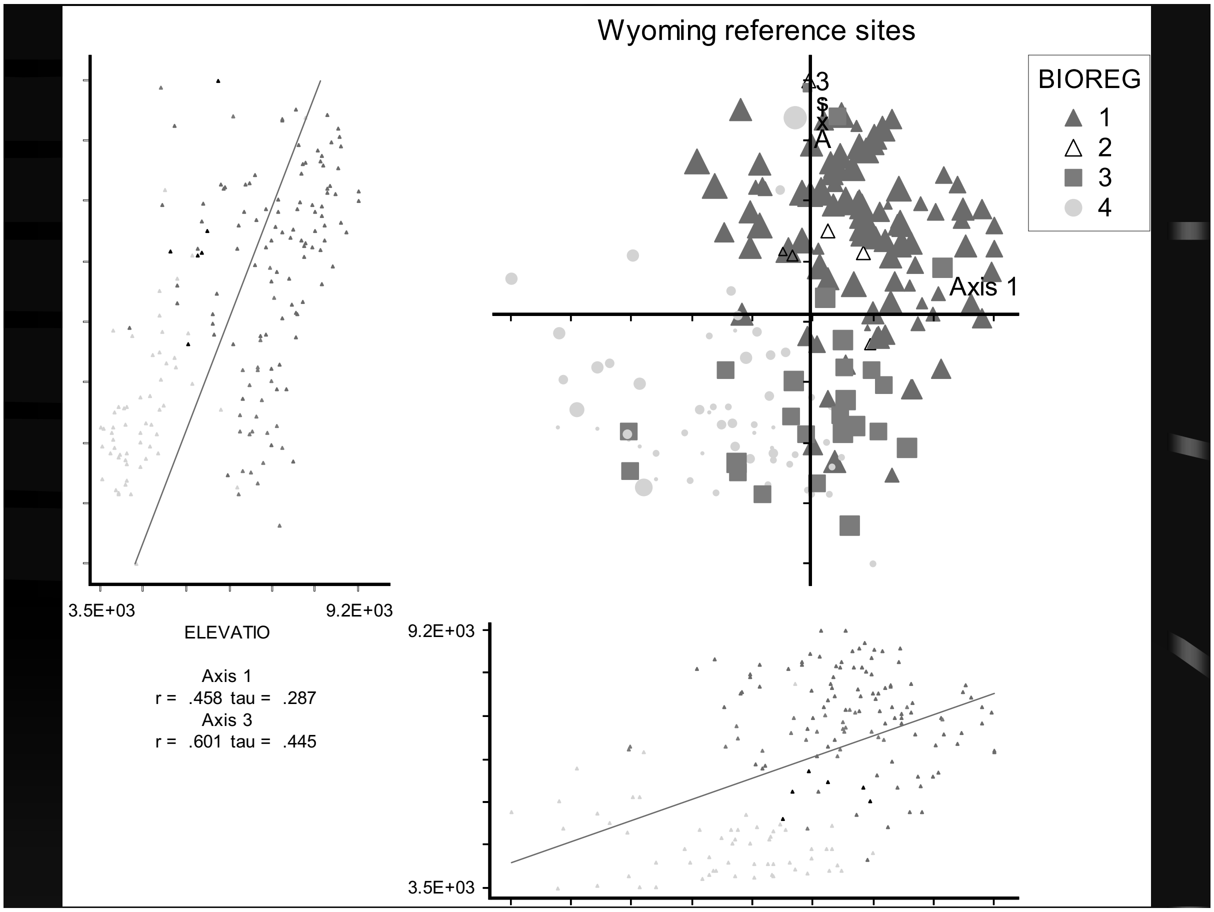
- Points close together are similar; far apart are dissimilar
- Look for patterns in grouping of a priori classes
- Axes (in NMS) are **not** meaningful by themselves





Now add other variables

- We consider a single continuous variable (e.g., elevation), and plot elevation against scores on the NMS axes to see if elevation is associated
- We can also scale the size of the symbols in the ordination plot to reflect the continuous variable (elevation)

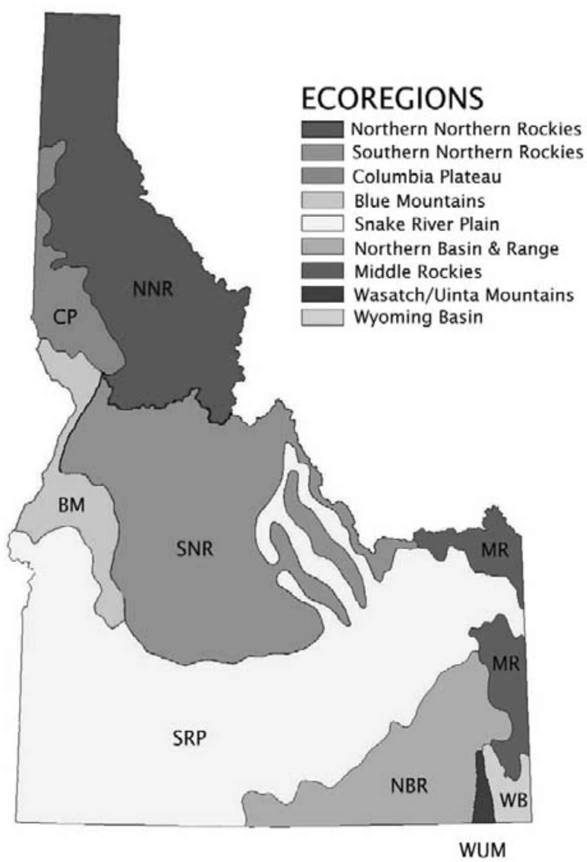


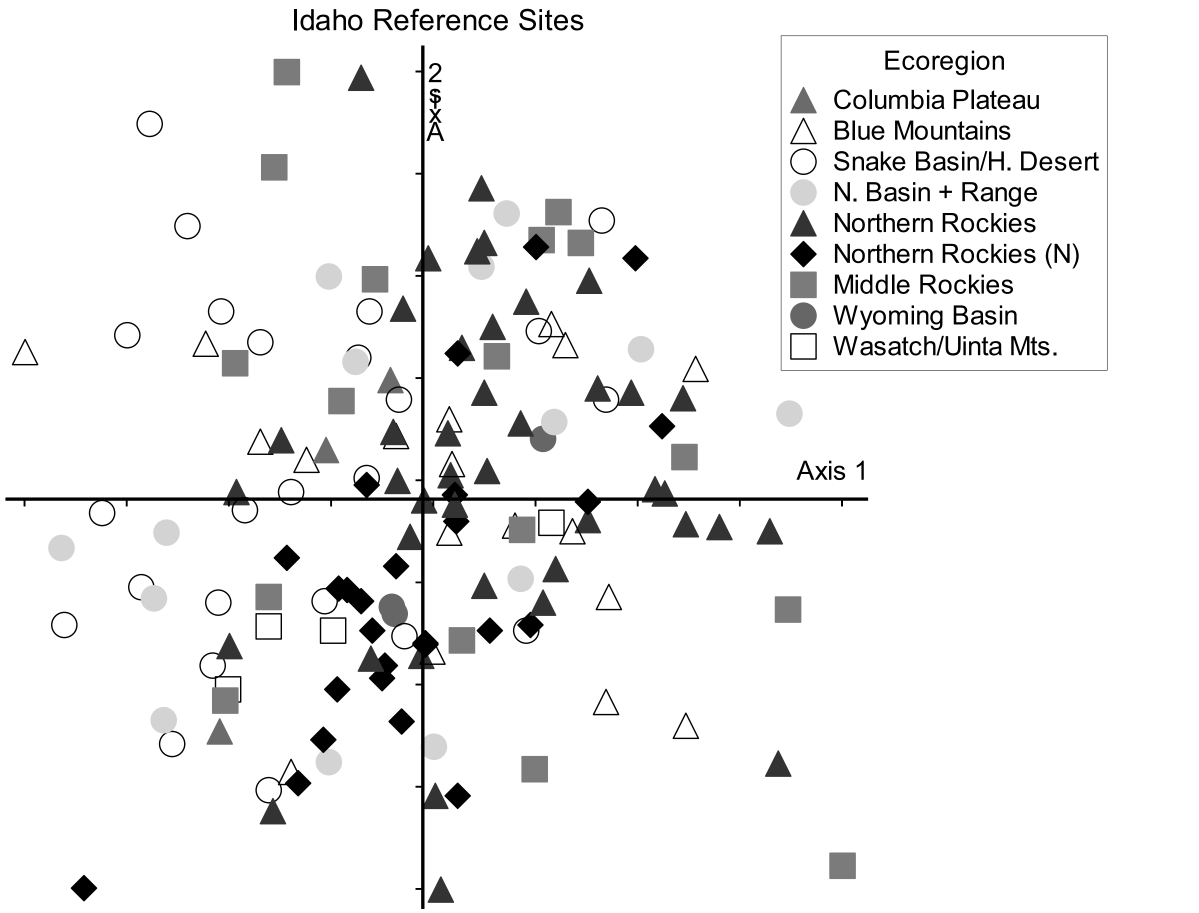
Classification exercise
1. Wyoming

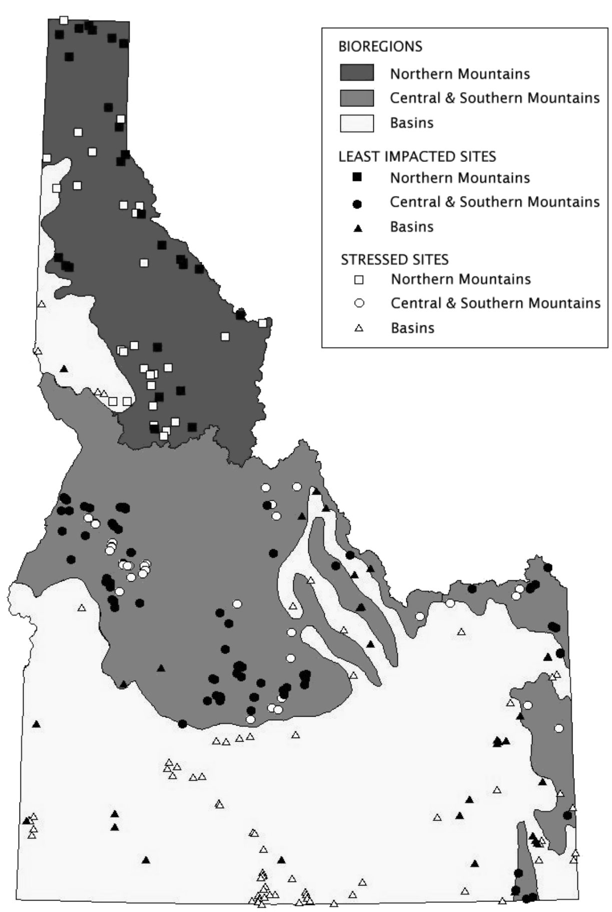
- **Objective: interpretation of classification information**
  - Pages 1-12 of handout (you have seen 2-5)
  - Look at pages 2-12: associations with other variables
  - Look at these associations and develop a conceptual model (in your head) of the factors that structure stream communities
  - Can you develop alternative classifications to the geographic one we have presented (bioregions)?
  - Which do you think is better?

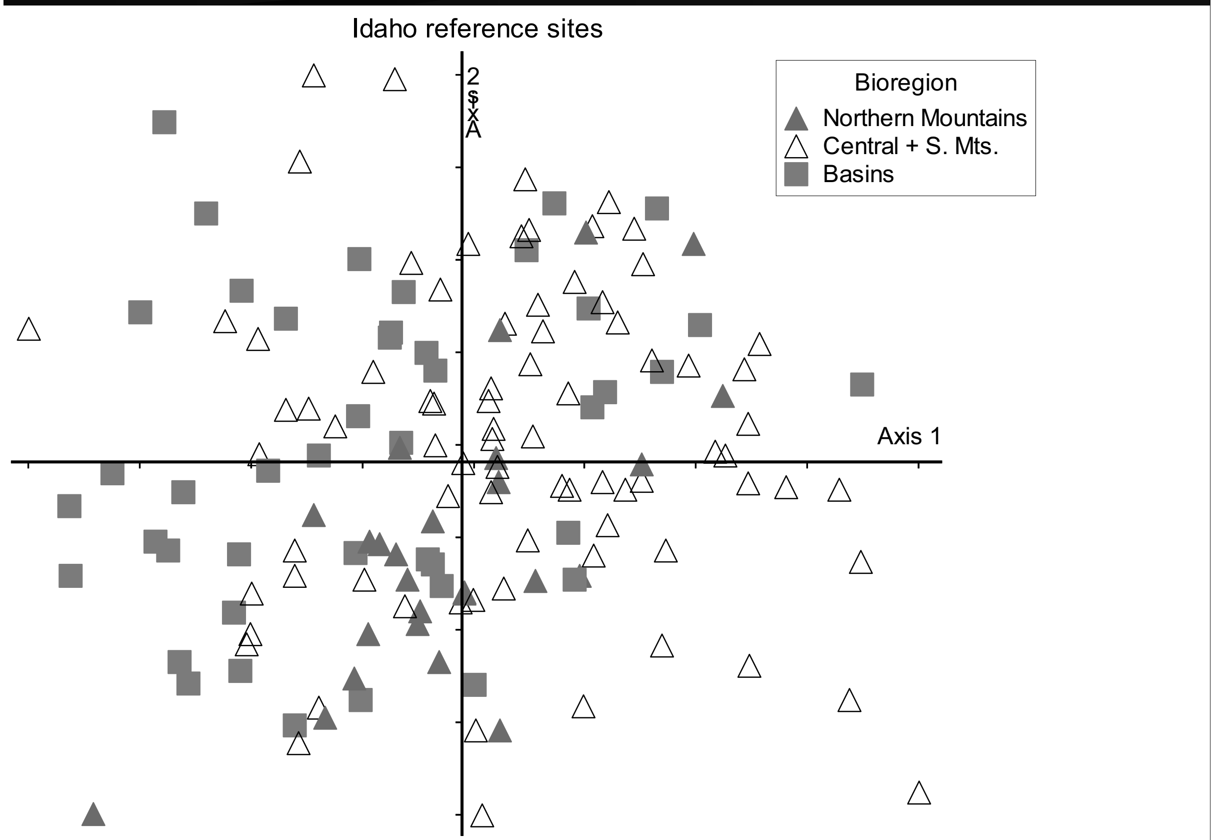
Part 2: Idaho

- Now look at pp 13-21
- We will run through 14-15, and a map, as a group
- Try to develop a classification for Idaho




Idaho Reference Sites
Axis 2
Axis 1
Ecoregion
Columbia Plateau
Blue Mountains
Snake Basin/H. Desert
N. Basin + Range
Northern Rockies
Northern Rockies (N)
Middle Rockies
Wyoming Basin
Wasatch/Uinta Mts.


BIOREGIONS
Northern Mountains
Central & Southern Mountains
Basins
LEAST IMPACTED SITES
Northern Mountains
Central & Southern Mountains
Basins
STRESSED SITES
Northern Mountains
Central & Southern Mountains
Basins

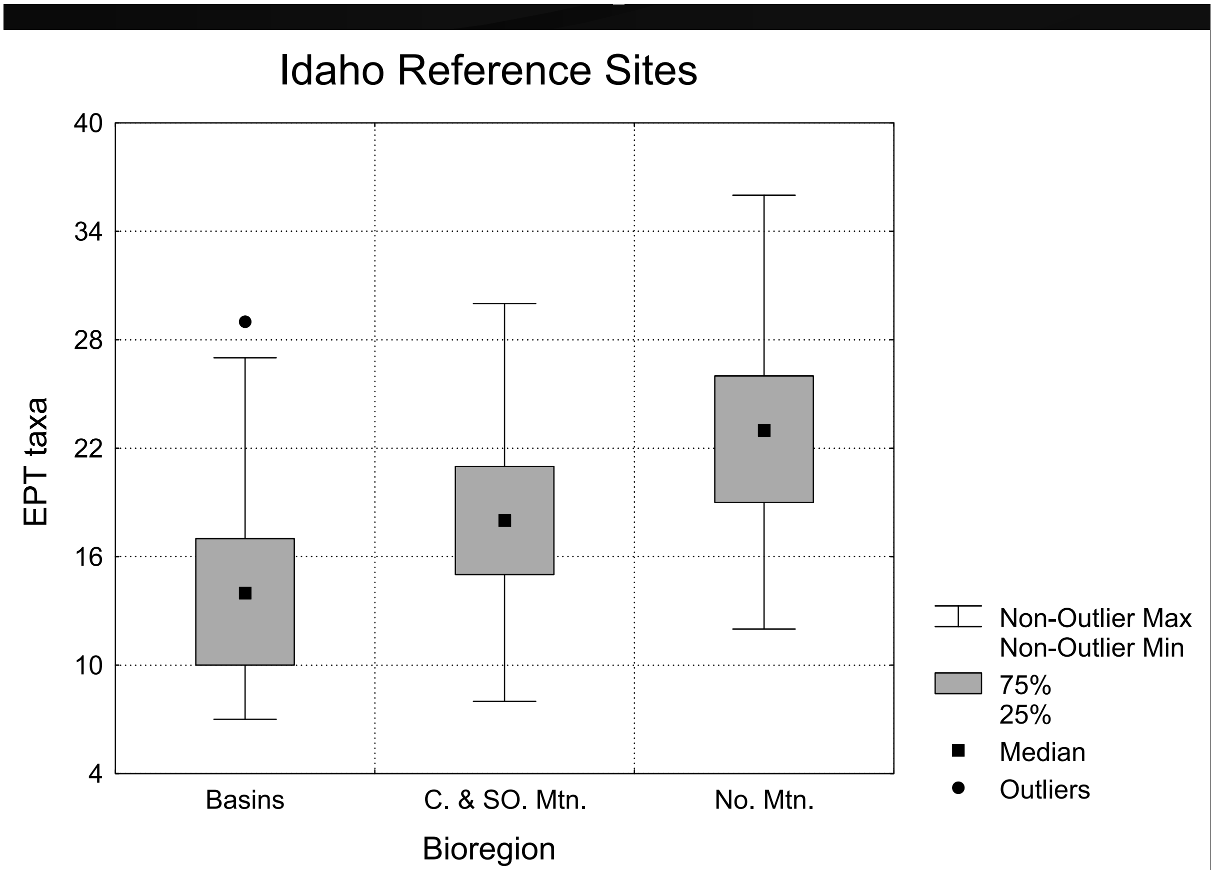


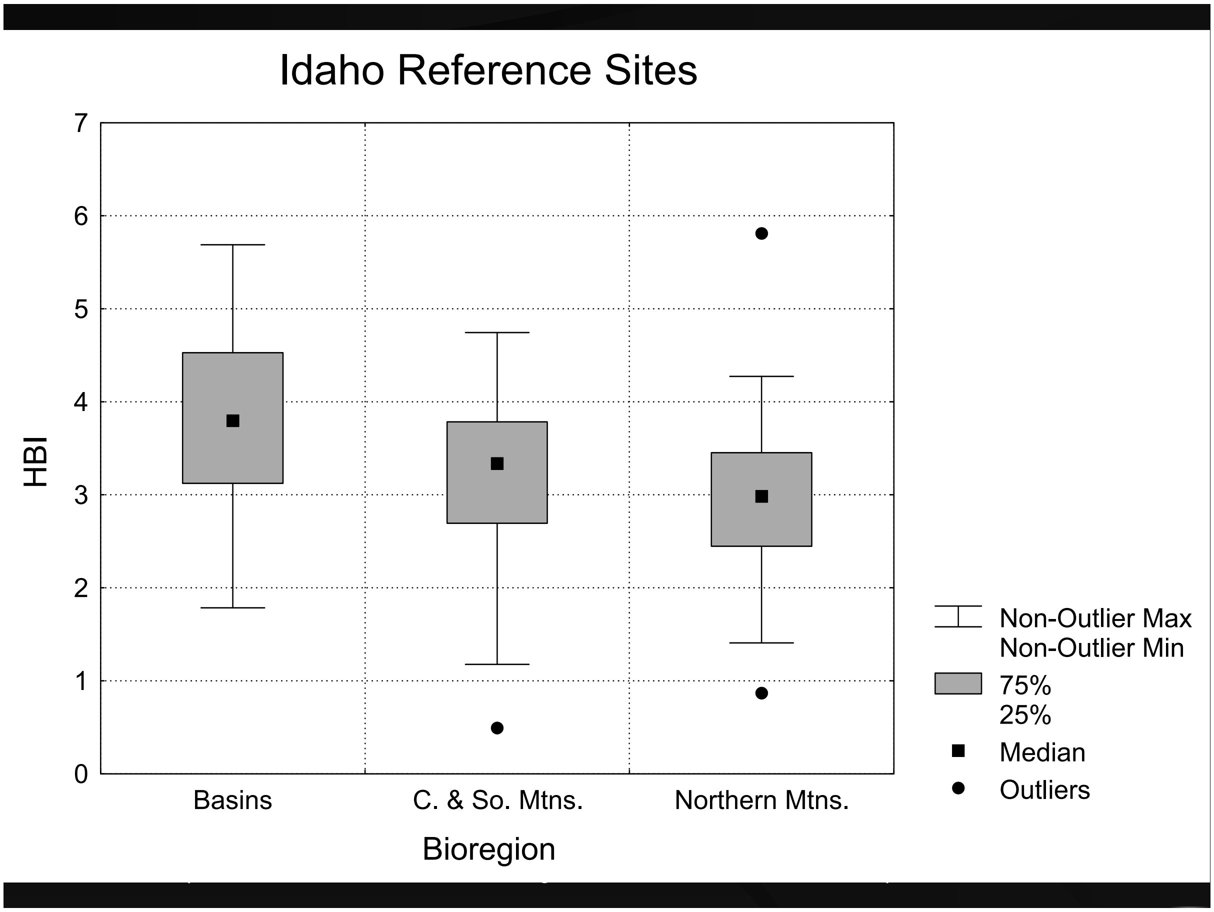
Idaho classification

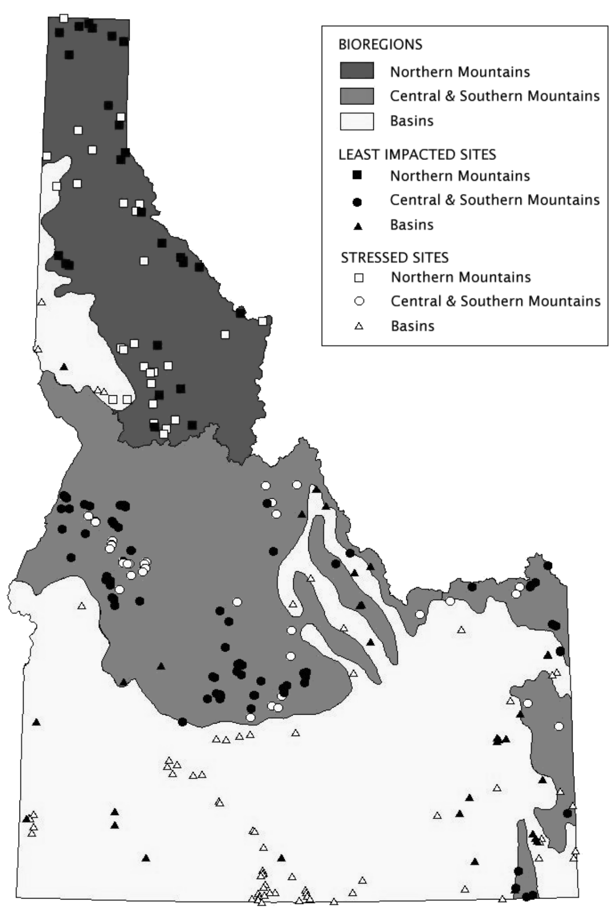
- Stream classification in Idaho was not as easy!
- There was no clear distinction among regions
- Environmental variables (elevation, etc.) were equally nebulous
- Why?

Classification

- We have built site classes so far on species composition. However, we will be building the index with metrics. Do the site classes make sense with metrics?

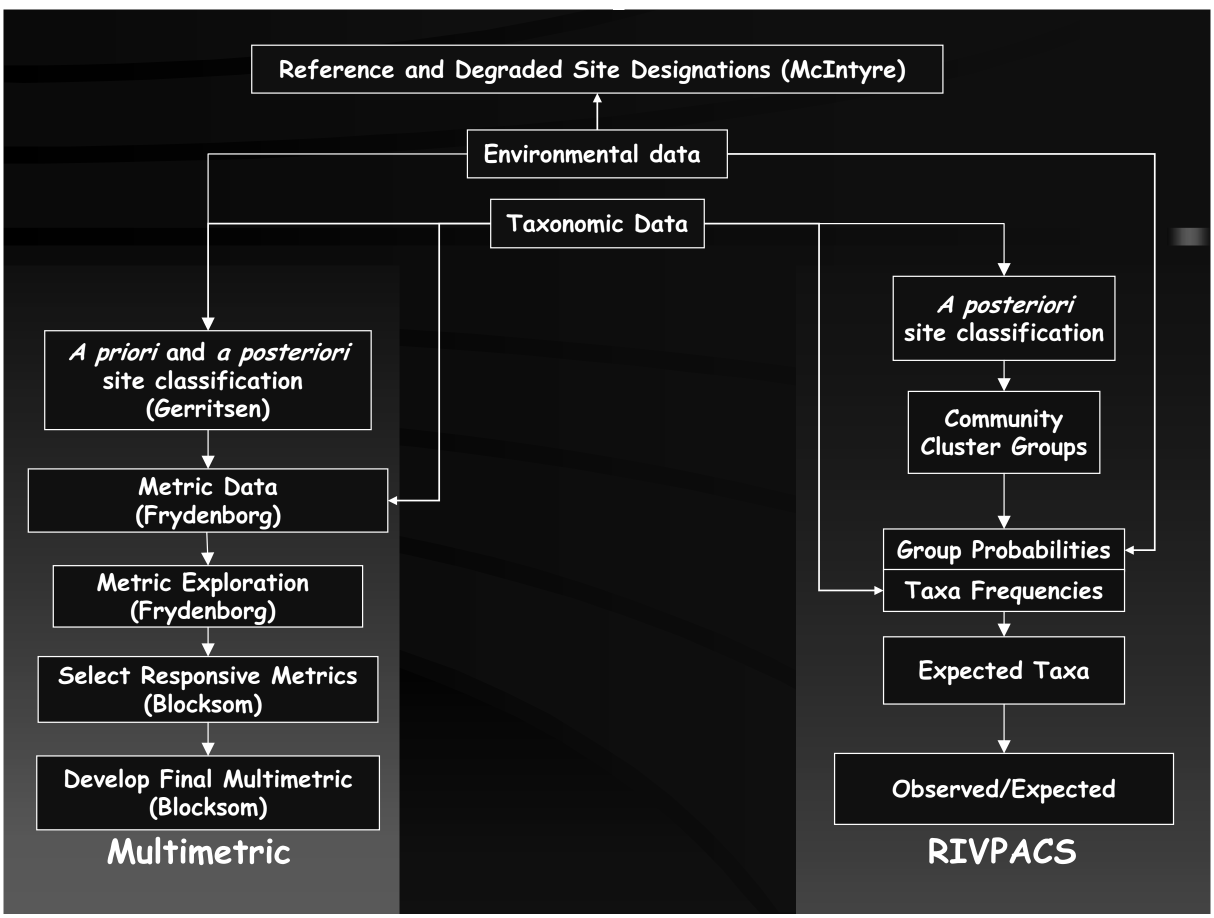


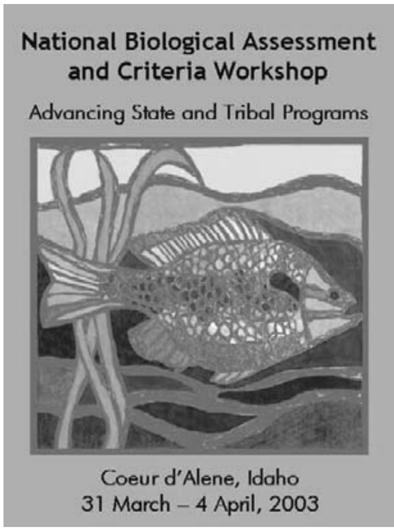

Idaho Reference Sites
HBI
7
6
5
4
3
2
1
0
Basins
C. & So. Mtns.
Northern Mtns.
Bioregion
Non-Outlier Max
Non-Outlier Min
75%
25%
Median
Outliers


BIOREGIONS
Northern Mountains
Central & Southern Mountains
Basins
LEAST IMPACTED SITES
Northern Mountains
Central & Southern Mountains
Basins
STRESSED SITES
Northern Mountains
Central & Southern Mountains
Basins

Idaho

- Classification is usually done with community composition. In Idaho, taxa were not predictable by geography or other variables
- Metric values **did** segregate on the geographic classes.
- For a multimetric index, classification must make sense for metrics: always check your classification with metric values!

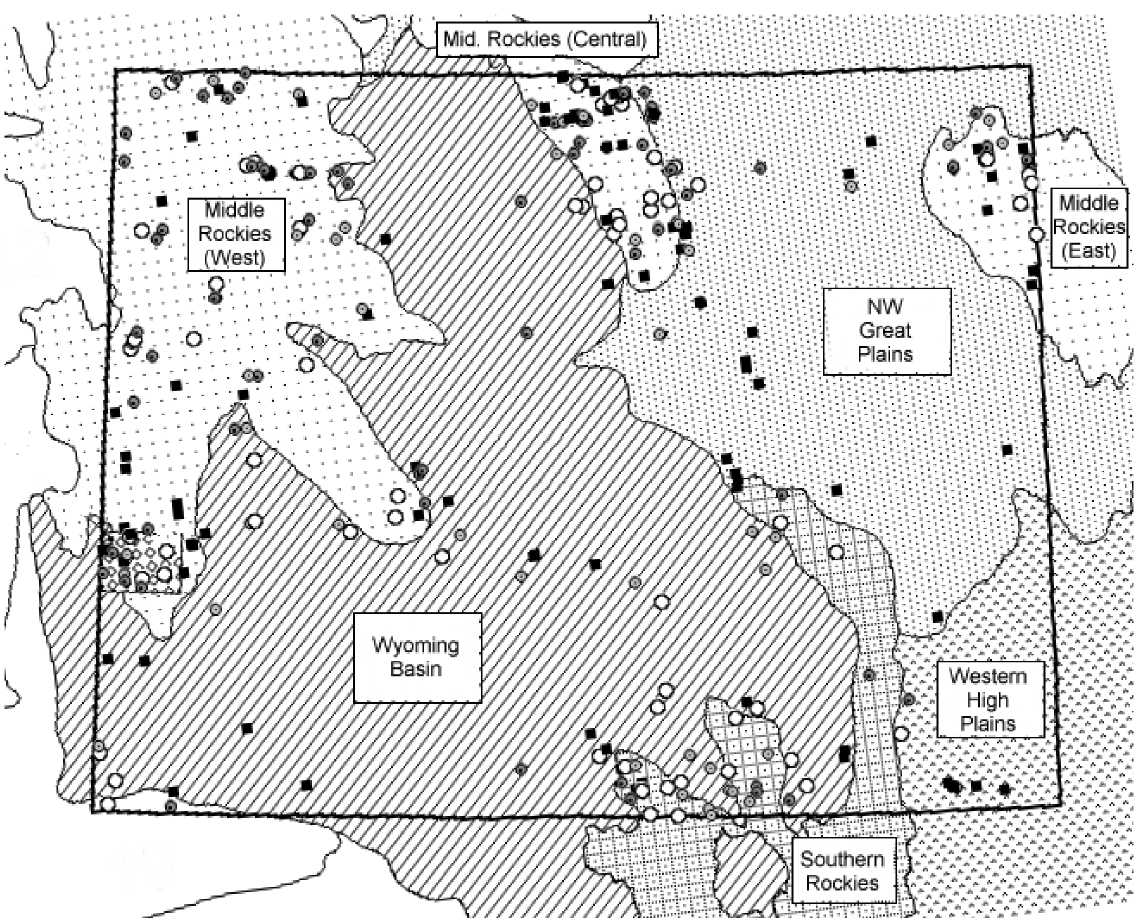




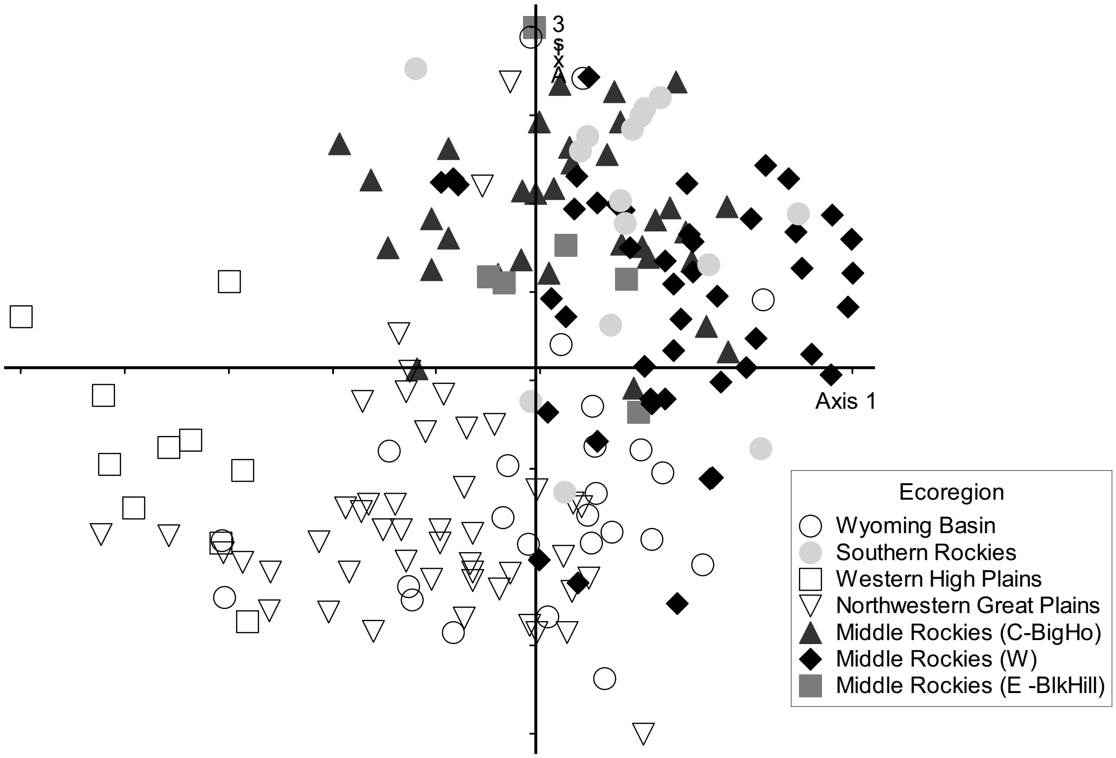
Index 201

Classification Exercise

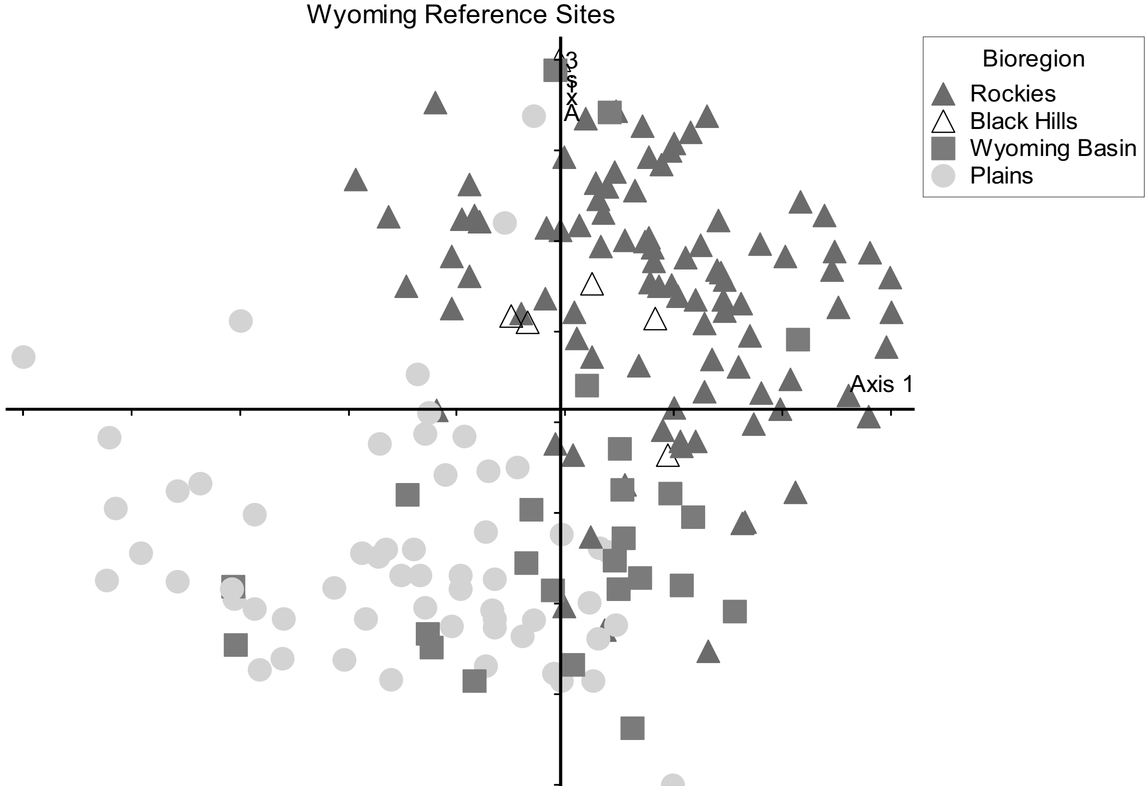
(Please see slides 20 & 21 in *Case Study: Classification of Western Streams*)

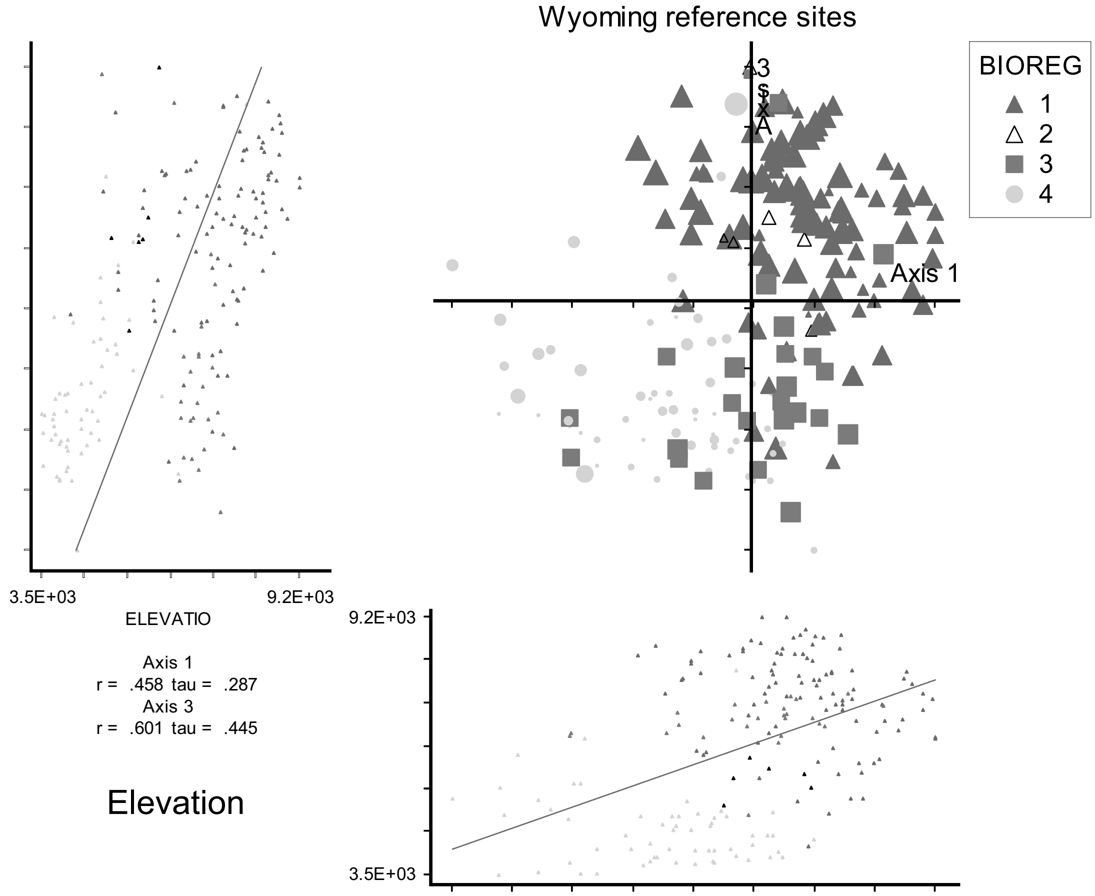


Wyoming Reference Sites

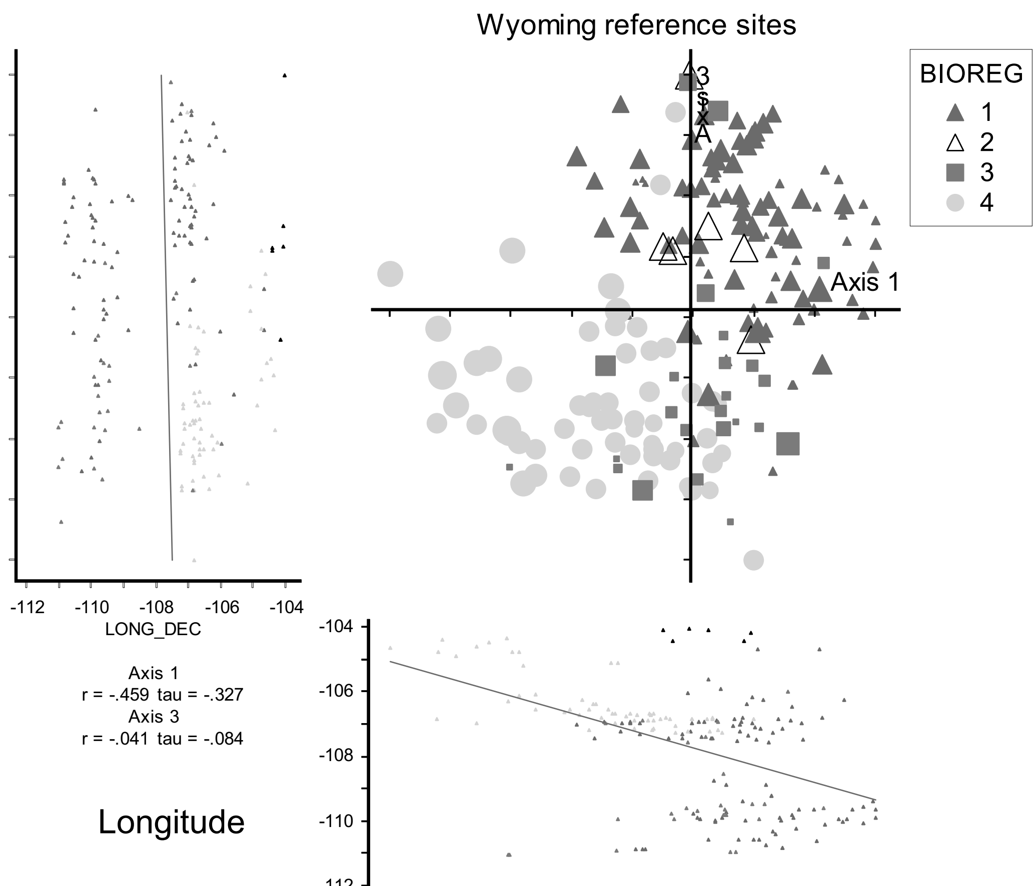


Wyoming Reference Sites

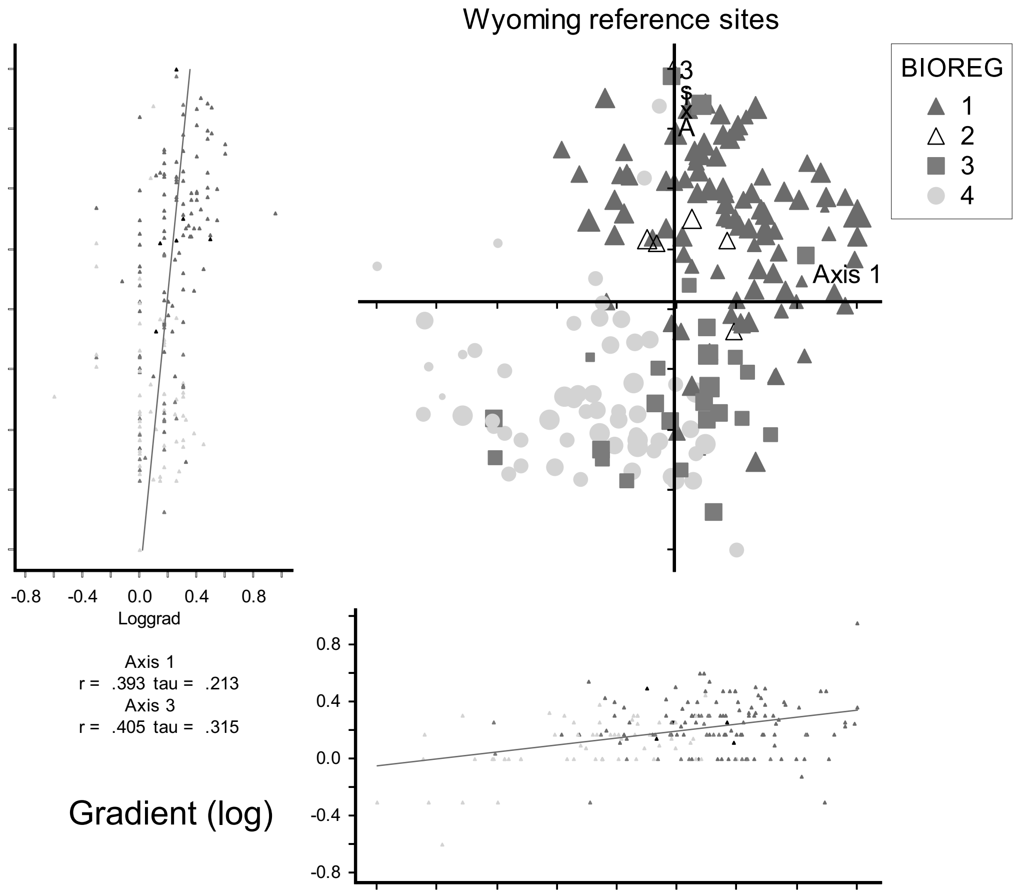




Wyoming reference sites
BIOREG
1
2
3
4
Axis 1
A3
s
x
A
3.5E+03
9.2E+03
ELEVATIO
Axis 1
r = .458 tau = .287
Axis 3
r = .601 tau = .445
Elevation
9.2E+03
3.5E+03

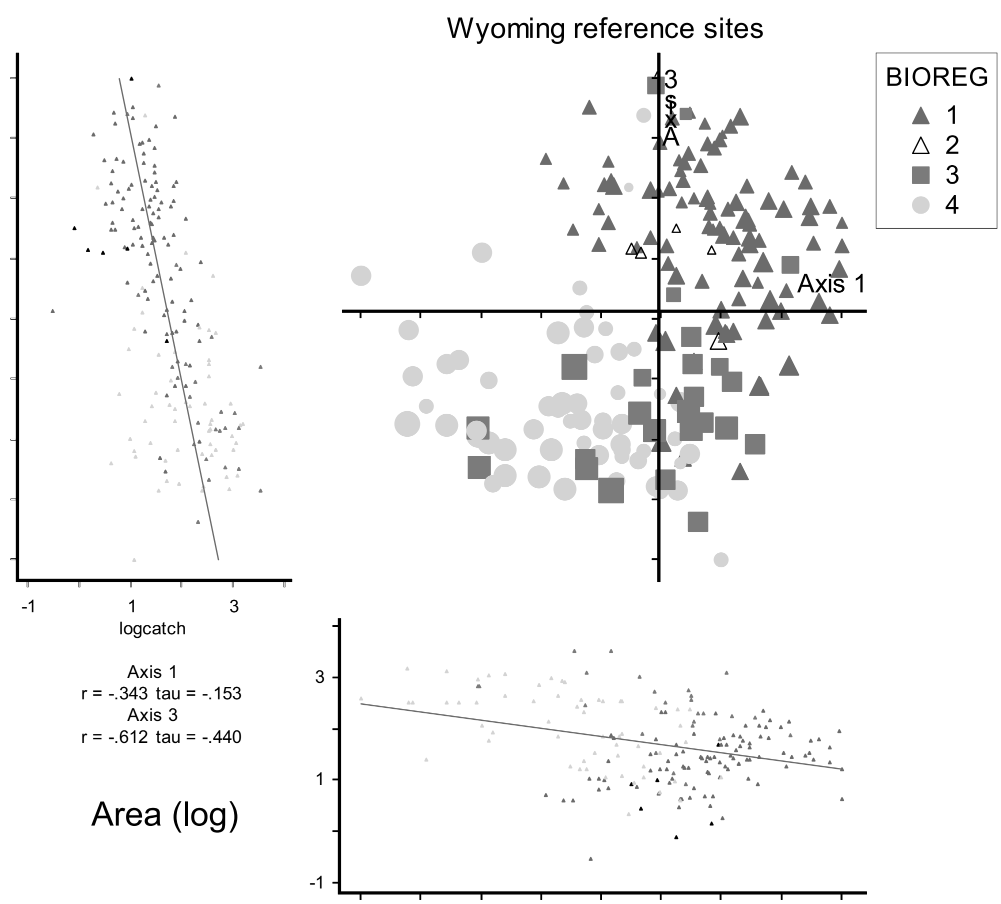


Wyoming reference sites
BIOREG
1
2
3
4
Axis 1
A3
s
x
A
-112
-110
-108
-106
-104
LONG_DEC
Axis 1
r = -.459 tau = -.327
Axis 3
r = -.041 tau = -.084
Longitude
-104
-106
-108
-110
-112



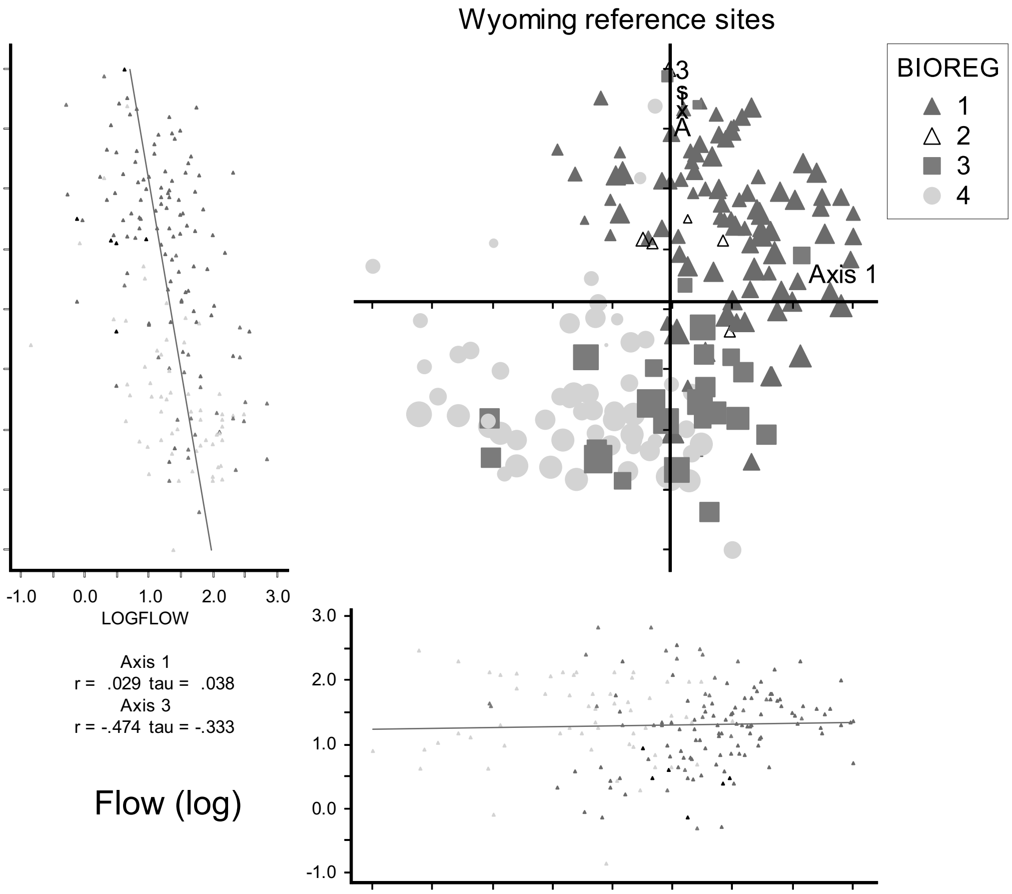
Wyoming reference sites
BIOREG
1
2
3
4
3
s
x
A
Axis 1
-0.8
-0.4
0.0
0.4
0.8
Loggrad
Axis 1
r = .393 tau = .213
Axis 3
r = .405 tau = .315
Gradient (log)

7



Wyoming reference sites
BIOREG
1
2
3
4
3
s
x
A
Axis 1
-1
1
3
logcatch
Axis 1
r = -.343 tau = -.153
Axis 3
r = -.612 tau = -.440
Area (log)

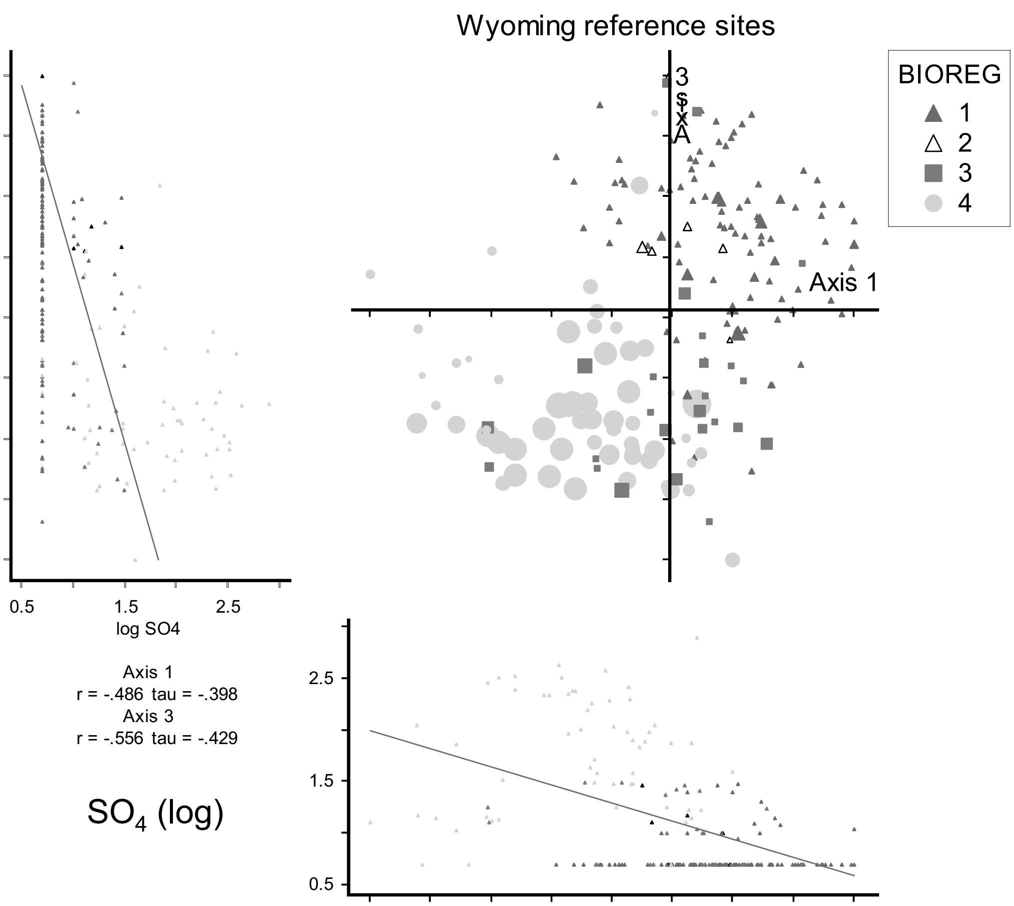
8



Axis 1
r = .029 tau = .038
Axis 3
r = -.474 tau = -.333

Flow (log)

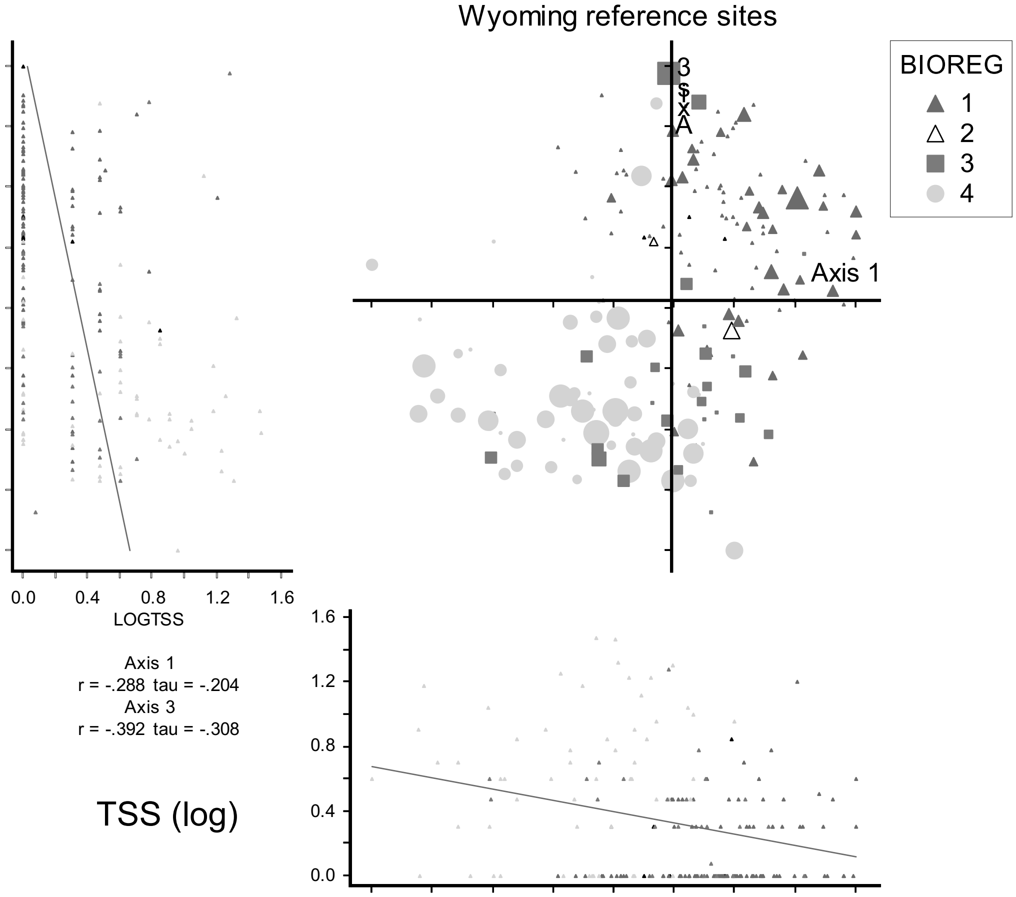
9



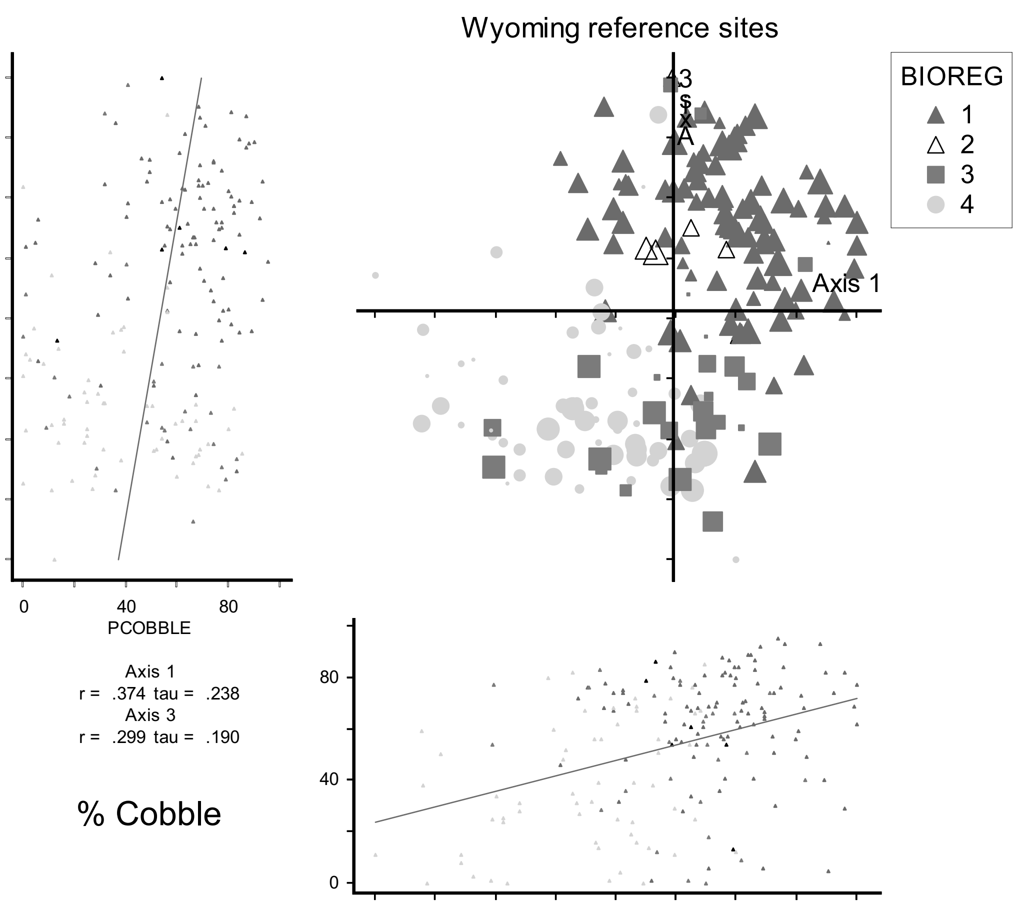
Axis 1
r = -.486 tau = -.398
Axis 3
r = -.556 tau = -.429

SO_4 (log)

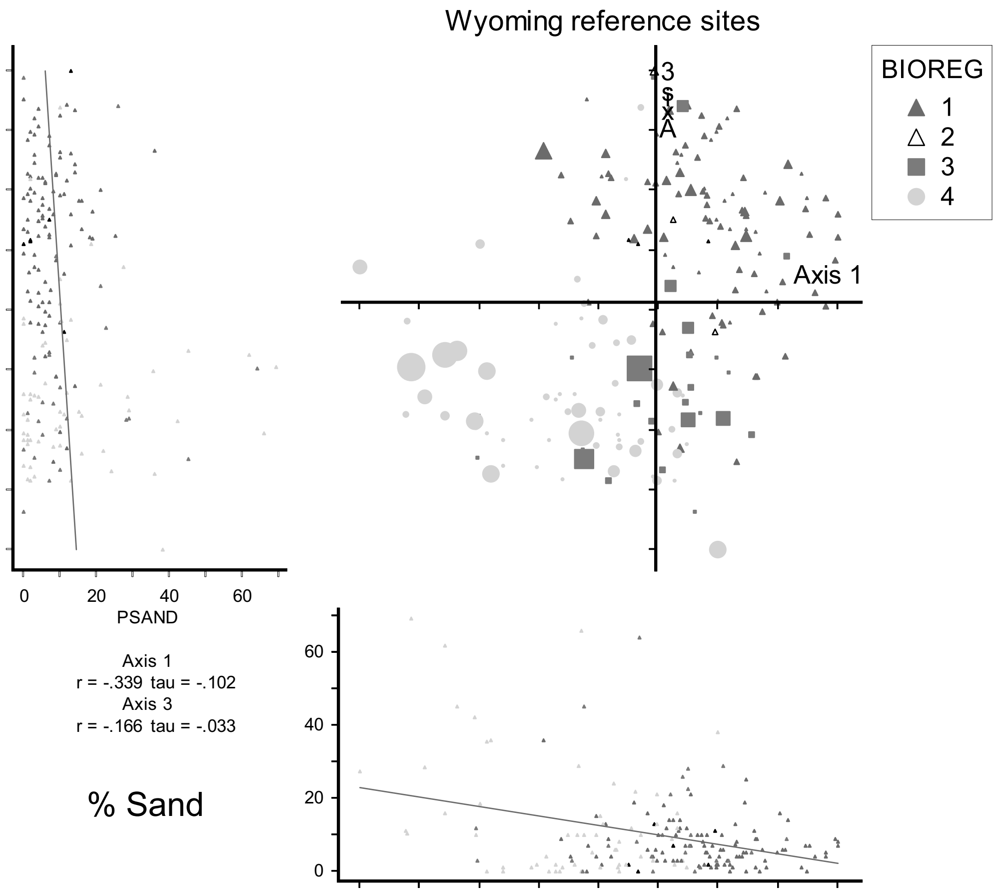
10



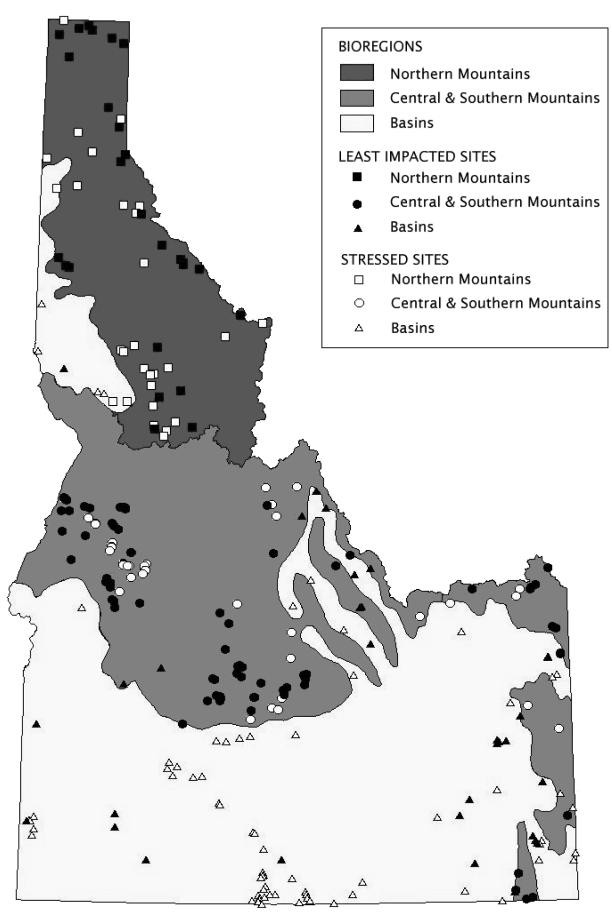
TSS (log)



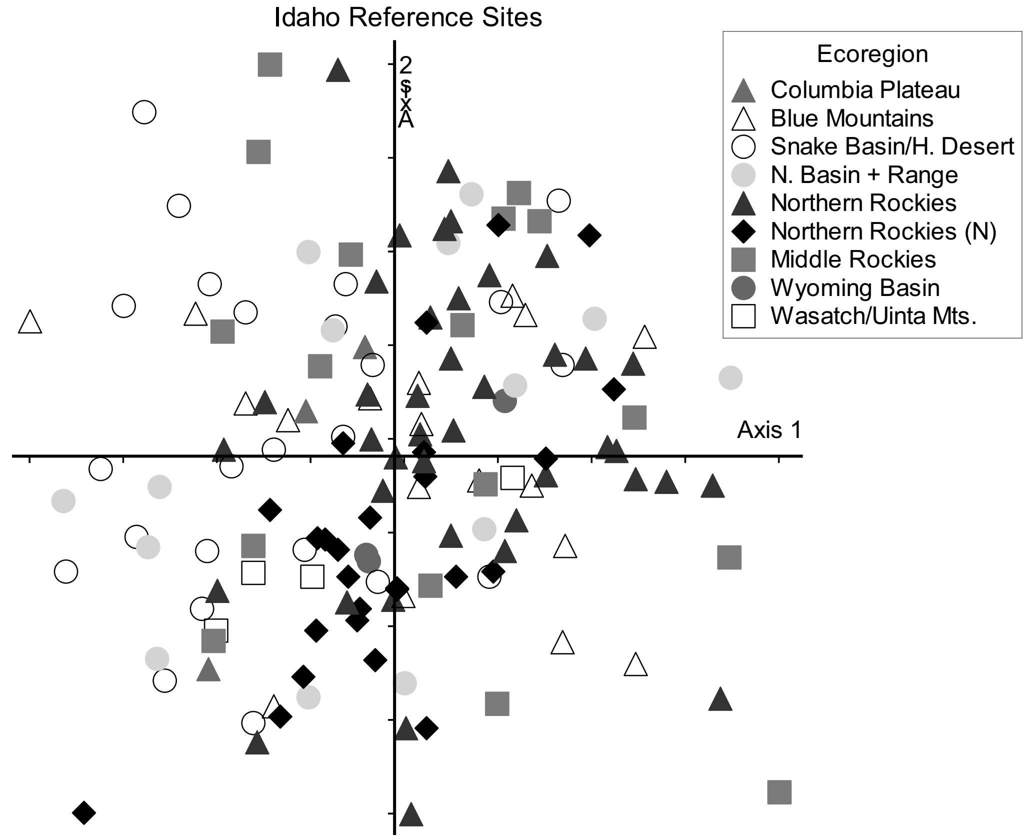
% Cobble

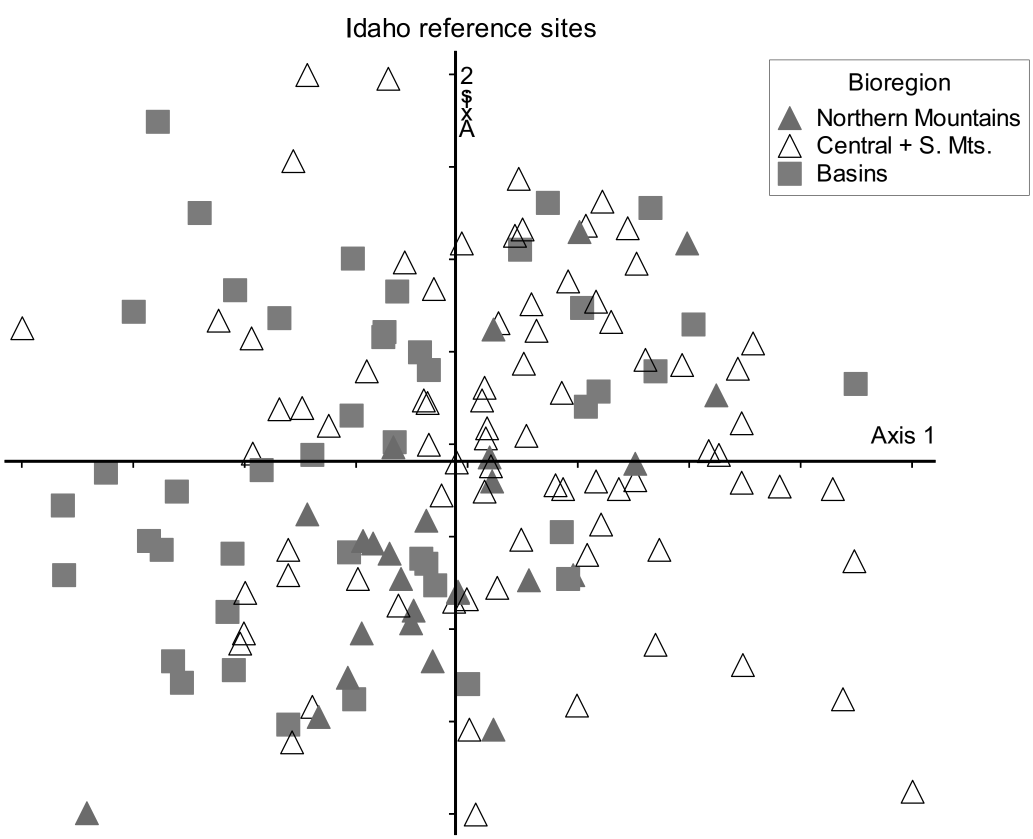

Wyoming reference sites
BIOREG
1
2
3
4
Axis 1
3
0
20
40
60
PSAND
Axis 1
r = -.339 tau = -.102
Axis 3
r = -.166 tau = -.033
% Sand

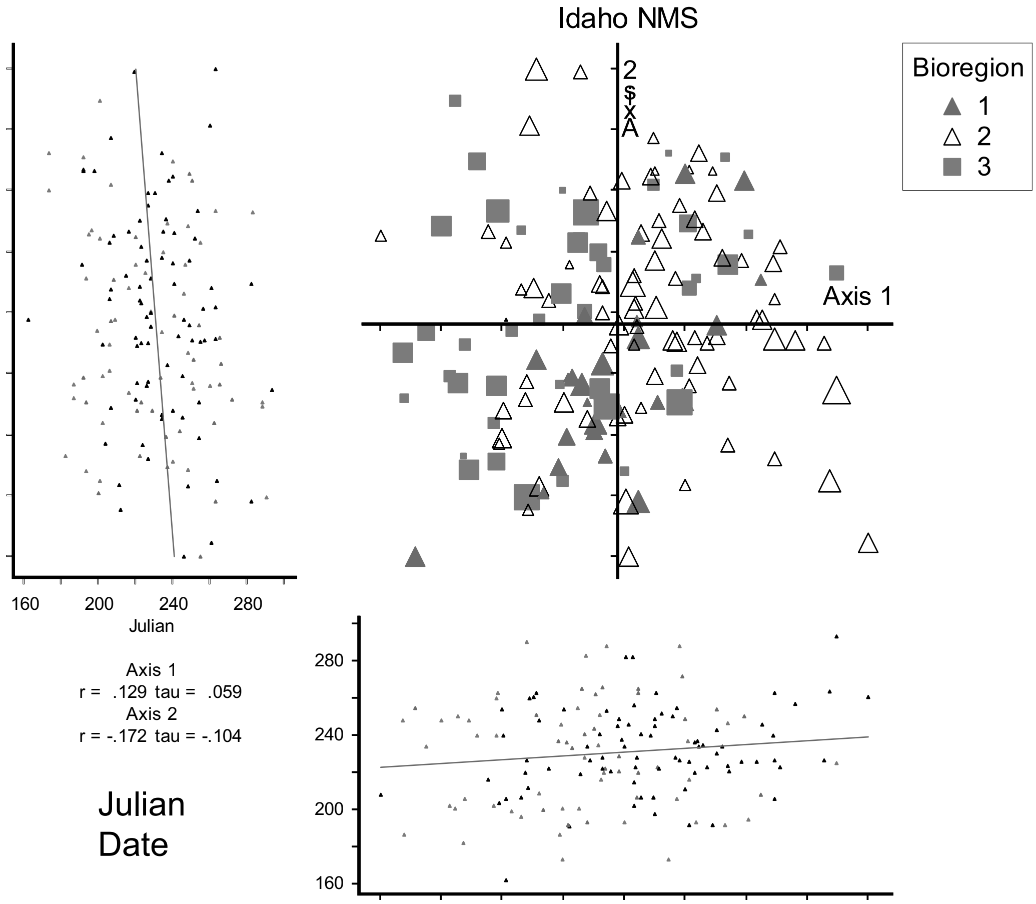
13


BIOREGIONS
Northern Mountains
Central & Southern Mountains
Basins
LEAST IMPACTED SITES
Northern Mountains
Central & Southern Mountains
Basins
STRESSED SITES
Northern Mountains
Central & Southern Mountains
Basins

14

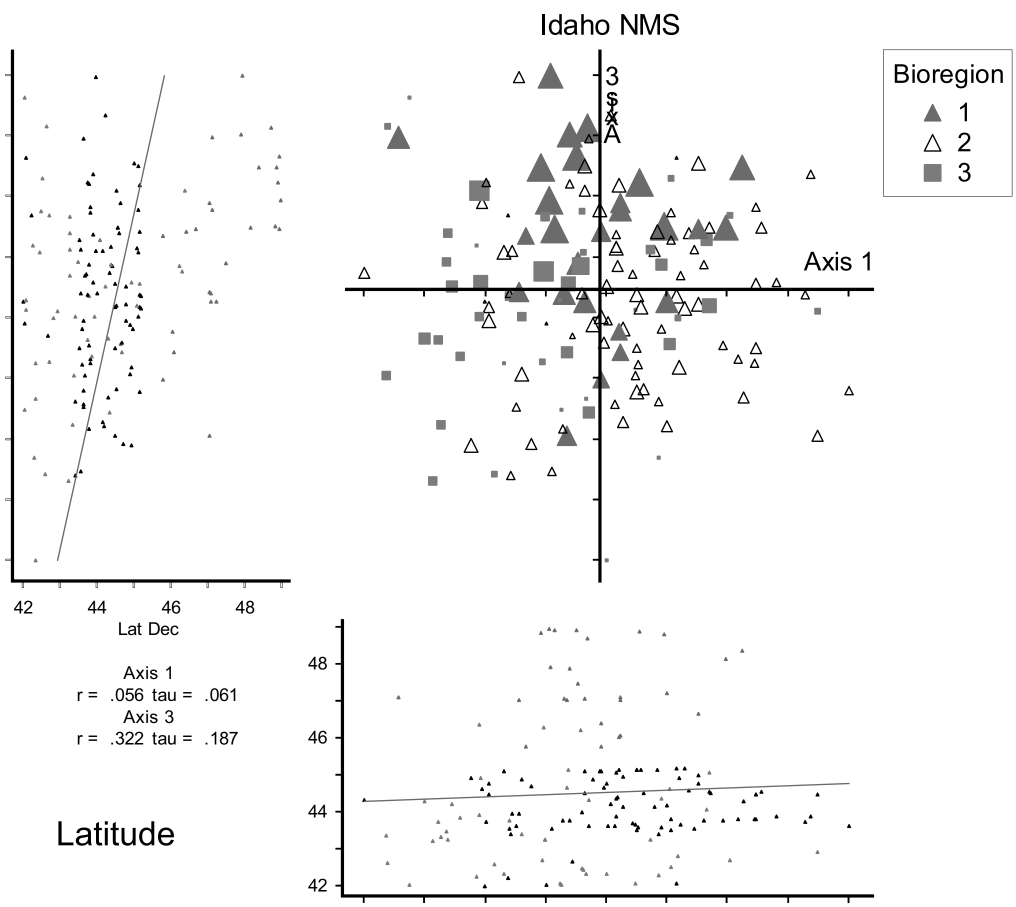

Idaho Reference Sites
Axis 2
Axis 1
Ecoregion
Columbia Plateau
Blue Mountains
Snake Basin/H. Desert
N. Basin + Range
Northern Rockies
Northern Rockies (N)
Middle Rockies
Wyoming Basin
Wasatch/Uinta Mts.


Idaho reference sites
Axis 2
Axis 1
Bioregion
Northern Mountains
Central + S. Mts.
Basins



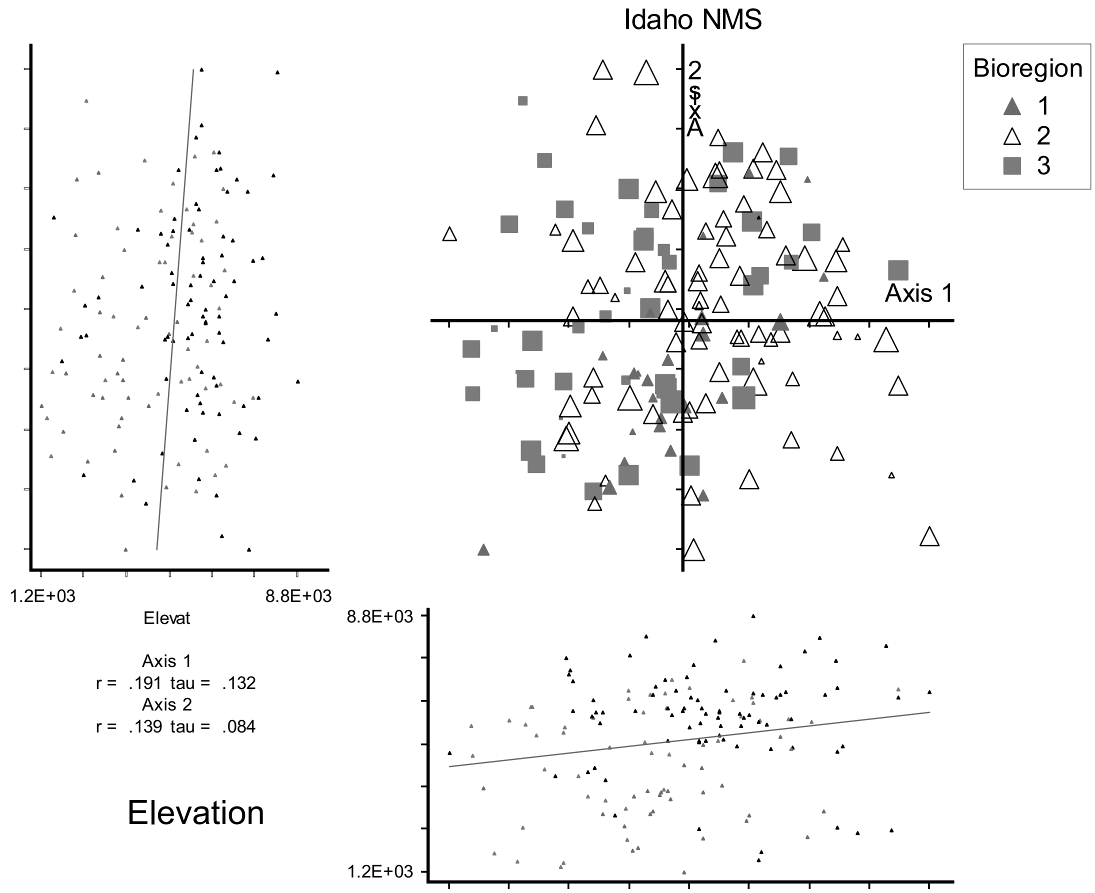
Axis 1
r = .129 tau = .059
Axis 2
r = -.172 tau = -.104

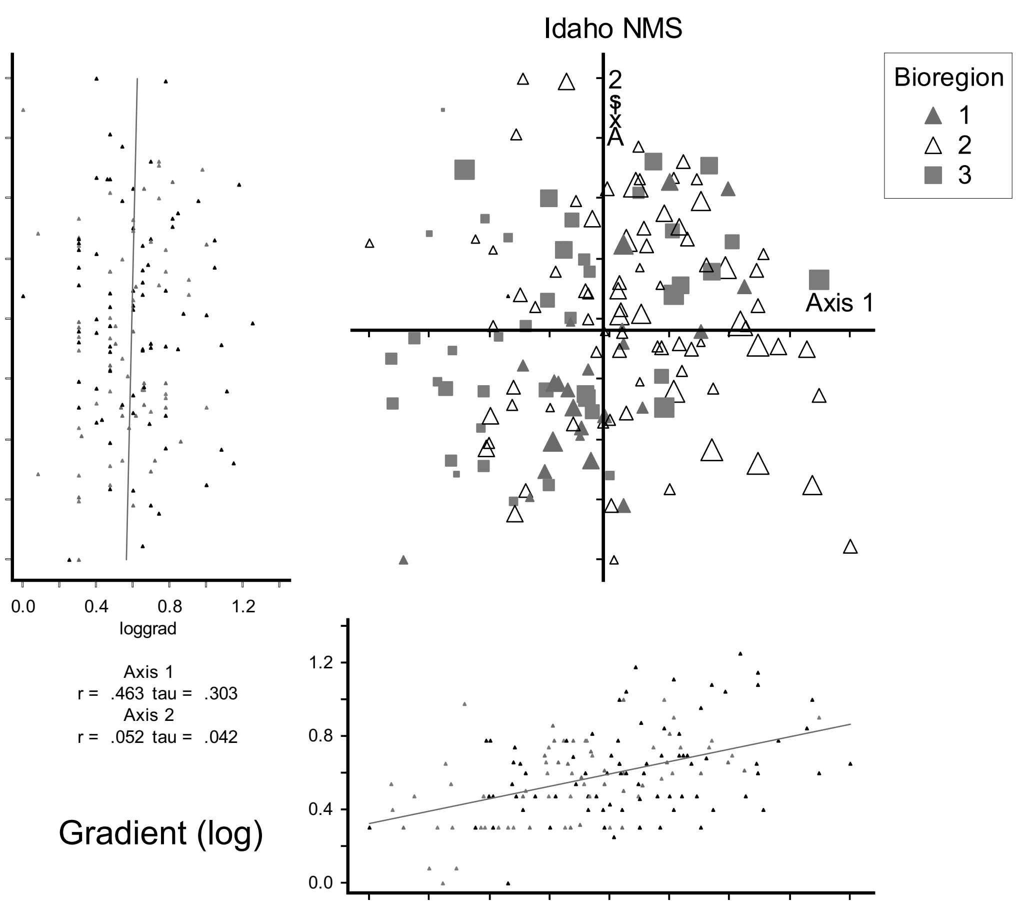
Julian Date

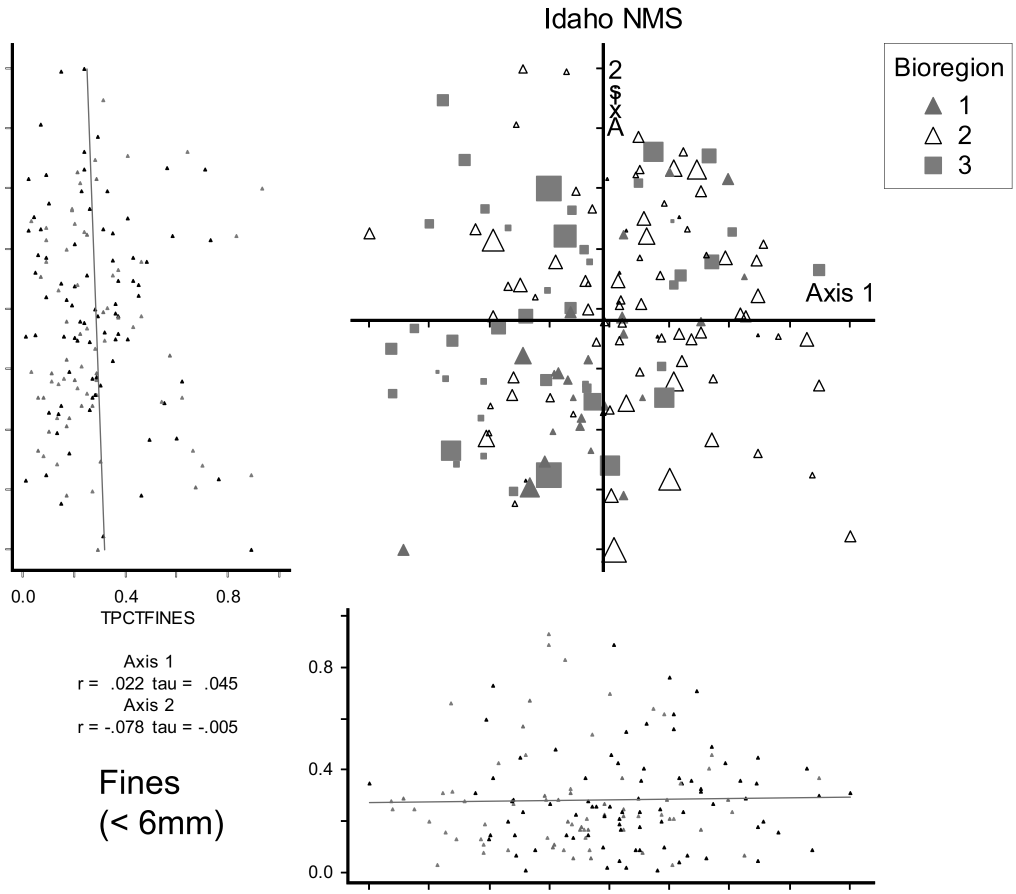


Axis 1
r = .056 tau = .061
Axis 3
r = .322 tau = .187

Latitude

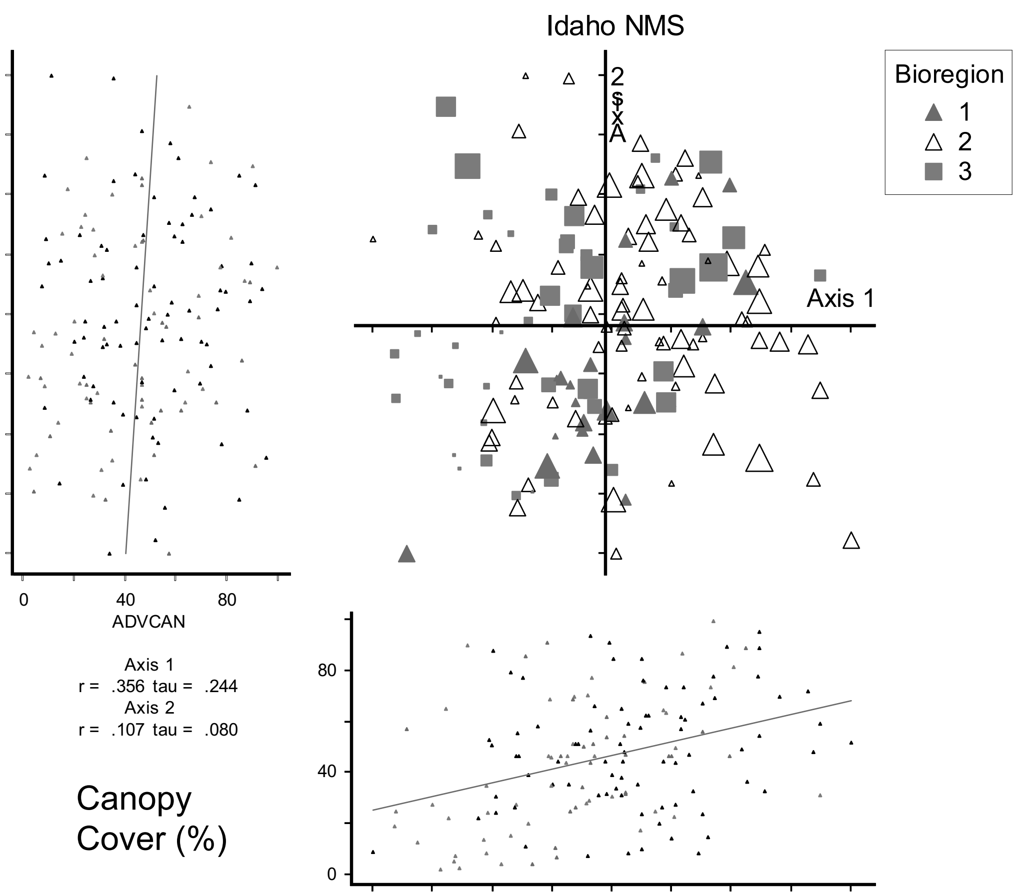

Idaho NMS
Bioregion
1
2
3
Axis 2
Axis 1
1.2E+03
8.8E+03
Elevat
Axis 1
r = .191 tau = .132
Axis 2
r = .139 tau = .084
Elevation
8.8E+03
1.2E+03


Idaho NMS
Bioregion
1
2
3
Axis 2
Axis 1
0.0
0.4
0.8
1.2
loggrad
Axis 1
r = .463 tau = .303
Axis 2
r = .052 tau = .042
Gradient (log)
1.2
0.8
0.4
0.0



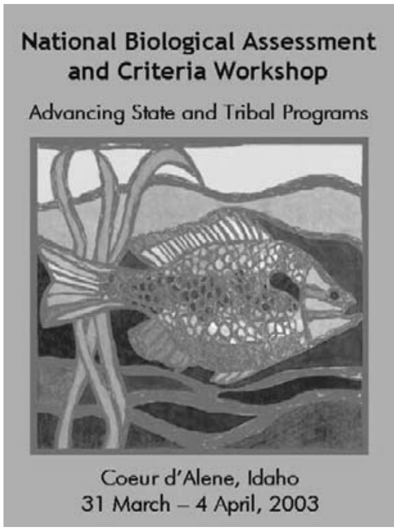
Axis 1
r = .022 tau = .045
Axis 2
r = -.078 tau = -.005

Fines
(< 6mm)



Axis 1
r = .356 tau = .244
Axis 2
r = .107 tau = .080

Canopy
Cover (%)



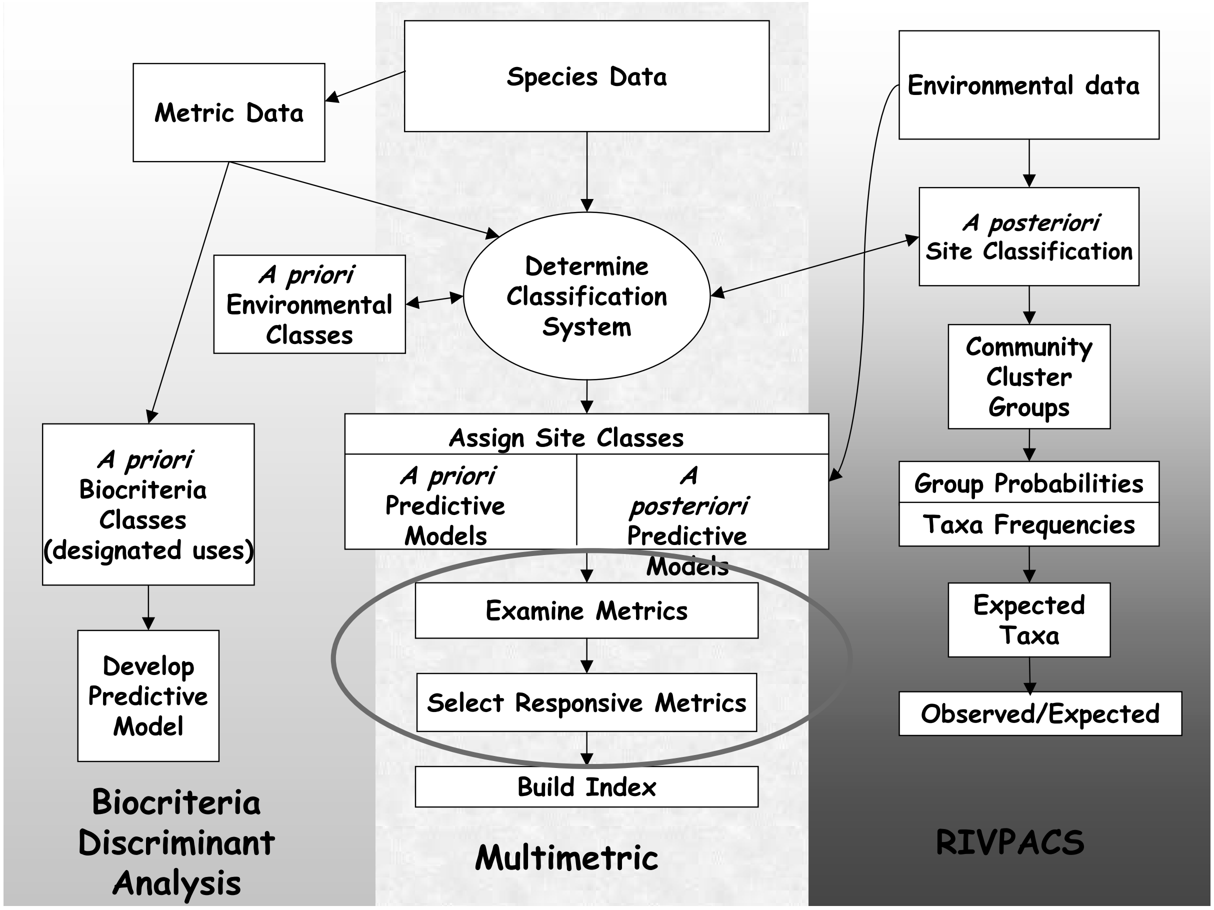
Index 201

Biological Attribute Exploration, Metric Development

Russ Frydenborg, FL DEP; Leska Fore, Statistical Design;
Jeroen Gerritsen, Tetra Tech, Inc.

Quick Review: Multimetric Index Development

1. Database consisting of reference and stressed populations (sites)
2. Classify resource
   - ✓ reference sites, ecoregions
3. Identify and test candidate metrics
4. Select metrics for dimensionless index
5. Select thresholds for assessment



Metric Selection Criteria

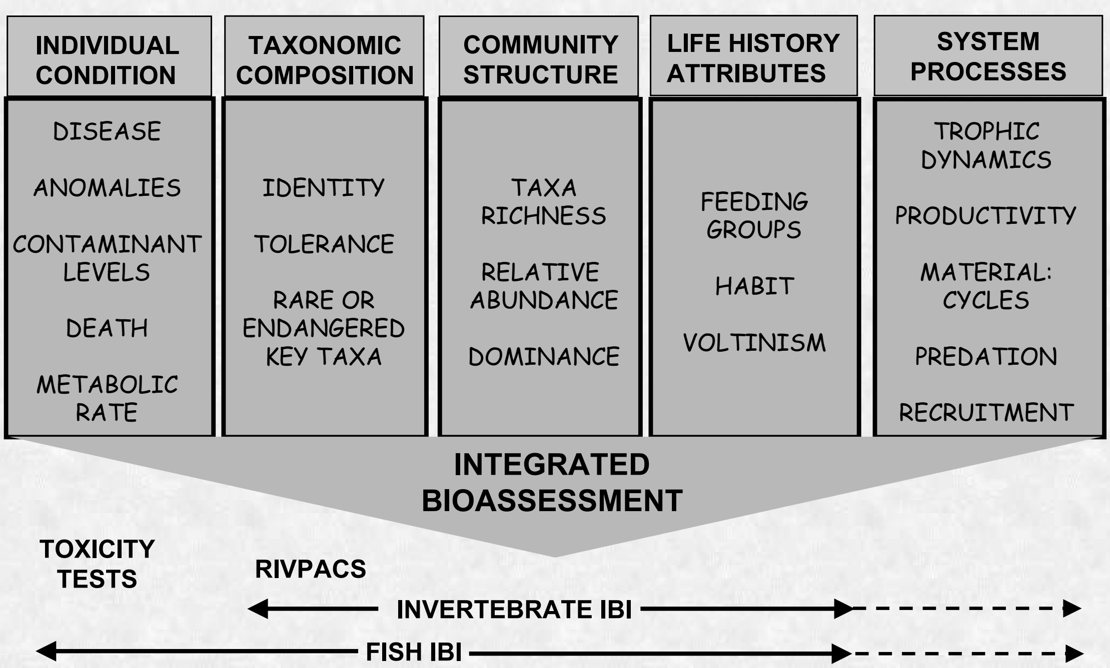
- Meaningful measure of ecological structure or function
- Strong and consistent correlation with human disturbance
- Statistically robust, low measurement error
- Represent multiple categories of biological organization
- Cost-effective to measure
- Not redundant with other metrics
  - Exception: "response signature" metrics

Metric Categories for Testing

1. Taxonomic richness & composition
2. Functional feeding groups
3. Life history, habit
4. Individual organism condition
5. Composition

   Tolerance and intolerance

Attribute Groups



Evaluating Metrics

Redundancy

23 Total Taxa

Discrimination Efficiency

Scoring

13% Ephemeroptera

12 EPT Taxa

72% Chironomids

Reference

10% Collector-Filterers

Precision

Desirable Metric Qualities

- Ecologically Justified
- Discriminating
- Represent Integrity
- Precise
- Sufficient range of values

Potential Metric Sources

- Review the literature.
- Examine state and regional programs.
- Mine your database for indicator taxa, taxa groups, or taxa attributes.

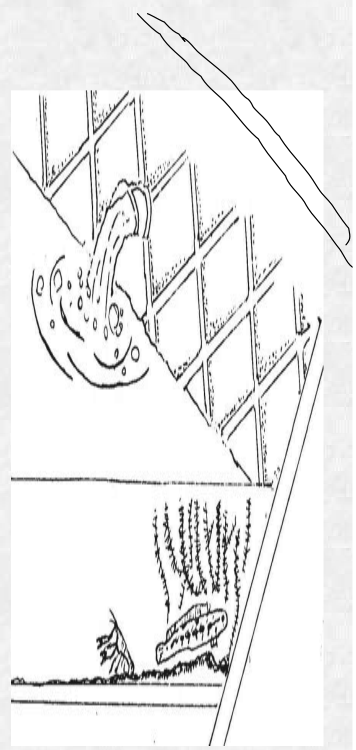
To Ensure Scientifically Defensible Metrics:

- Develop criteria, independent from biology, to determine which sites are impaired by humans vs. those that are not (the fabled "x axis")
  - Reference vs. Degraded Sites
  - Human Disturbance Gradient

Mining Existing Data Using the Human Disturbance Gradient

- Plot potential metric against HDG
  - Visual examination of patterns
  - Correlation coefficient
  - Excellent for determining tolerant vs. sensitive taxa

leaves and twigs	**Energy source**	domestic wastes
natural	**Chemical variables**	excess nutrients, toxins
natural flows	**Flow regime**	extreme flows
pools and riffles	**Habitat structure**	uniform
native taxa	**Biotic factors**	exotic taxa



Karr & Rossano

Human Disturbance Factor Analysis (Florida system)

- Landscape level
  - Landscape Development Intensity Index
- Habitat alteration
  - Habitat assessment data
- Hydrologic modification
  - Hydrologic scoring process
- Chemical Pollution
  - Ammonia, etc.

Summary of the Landscape Development Intensity* Coefficients

Category	Coefficient
Natural System	1
Pine Plantation	1.6
Pasture	3.4
Row Crops	4.5
Residential (low)	6.8
Residential (high)	7.6
Commercial	8.0
Industrial	8.3
Commercial (high)	9.2
Business District	10.0

*Developed by Mark Brown, University of Florida, based on non-renewable Energy inputs, Odom's "Embodied Energy" concept.

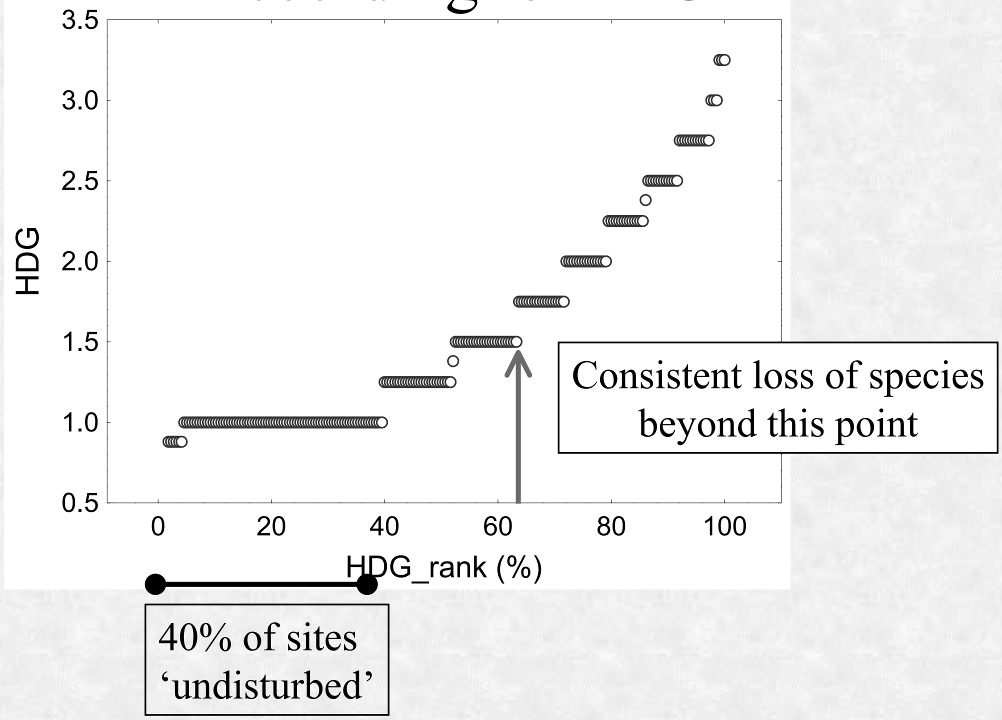
Hydrologic Modification Scoring

- Best, 1-2 points
  - Flow regime as naturally occurs (slow and fairly continual release of water after rains), few impervious surfaces in watershed; high connectivity with ground water and surface features delivering water (e.g., sandhills, wetlands; no ditches, berms, etc.)
- Very poor, 9-10 points
  - Flow regime entirely human controlled; hydrograph very flashy (scouring after rain events with subsequent reductions in flow, leading to stagnant or dry conditions, related to impervious surfaces and ditching throughout watershed); water withdrawals & impoundments fundamentally alter the nature of the ecosystem

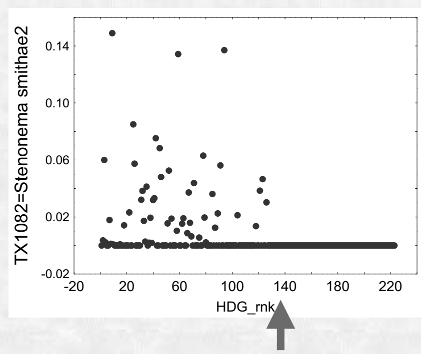
Florida's HDG: Combination of other Disturbance Measures

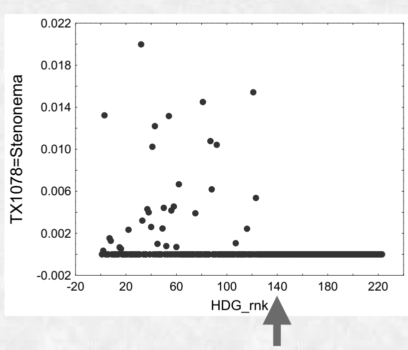
Scores Measure	1	2	3	4
NH3	<0.1	>0.1	>2	
Habitat	>65	>50 and <65	<50	
Hydro	<6	6-7	8-9	10
LDI (buffer)	<200	200-350	>350	
LDI (ws)	<200	200-350	>350	

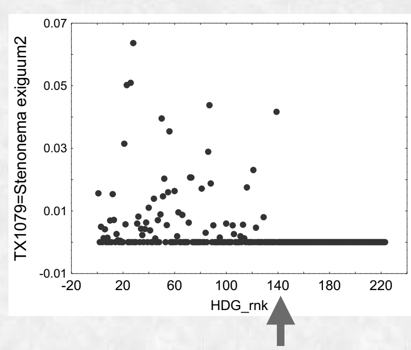
Florida Sites Ranked According to HDG



Example of a Sensitive Mayfly Genus (*Stenonema*)

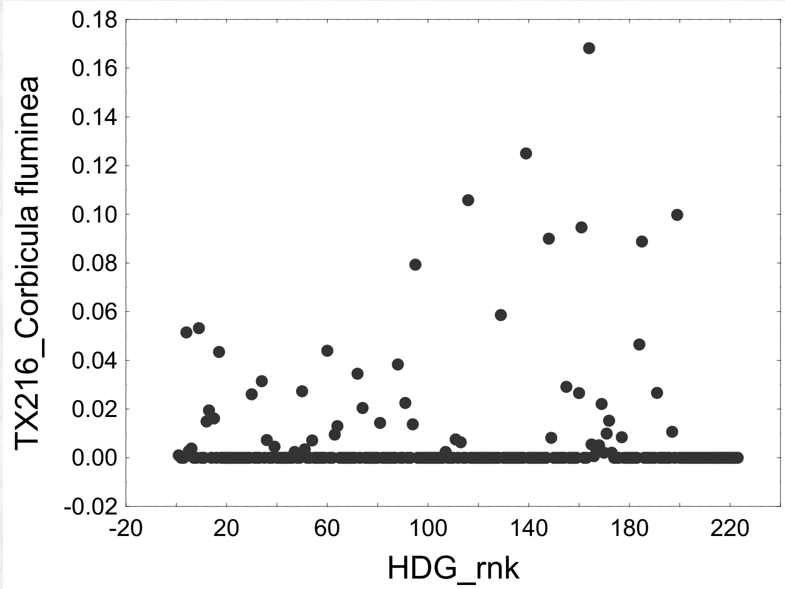






Increasing disturbance →

Example of a Tolerant Clam Species



Increasing disturbance →

Incorporating "Integrity"

Include Robust, Discriminating Metrics from a Variety of Categories:

- Richness
- Composition
- Tolerance
- Feeding Functions
- Habit
- Voltinism

Richness Measures

Total taxa
EPT taxa
Ephemeroptera taxa
Plecoptera taxa
Trichoptera taxa
Diptera taxa
Chironomidae taxa
Coleoptera taxa
Oligochaeta taxa
Insect taxa
Non-insect taxa
Shannon-Wiener Index

Composition Measures

% EPT
% EPT (no Baetidae or Hydropsychidae)
% Ephemeroptera
% Ephemeroptera (no Baetidae)
% Plecoptera
% Trichoptera
% Trichoptera (no Hydropsychidae)
% Diptera
% Diptera (no Chironomidae)
% Chironomidae
% Coleoptera
% Oligochaeta
% non-insects
% 5 dominant
% 10 dominant

Feeding Measures

% Collectors
% Scrapers
% Shredders
% Filterers
% Predators
Collectors taxa
Scrapers taxa
Shredders taxa
Filterers taxa
Predators taxa

Tolerance and Other Measures

HBI
BCI CTQa
Beck's Biotic Index
Intolerant taxa
% tolerant
% Clingers
Clingers taxa
% Semivoltine
Semivoltine taxa

Examples of Two Types of Successful Metric Exploration

- Idaho
  – Discrimination Efficiency Box and Whisker Plots
- Florida
  – Human Disturbance Gradient Correlations

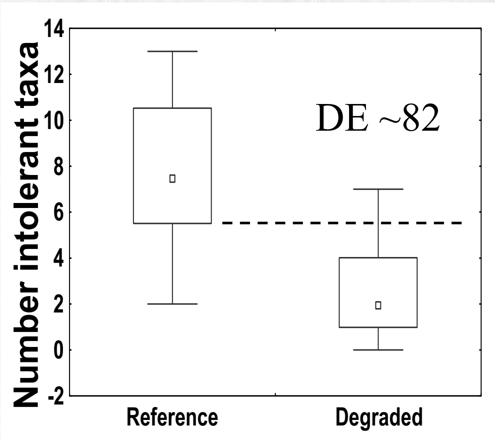
Discrimination Efficiency

- Measures the ability of an index (or metric) to indicate reference or degraded conditions.
- Definition: The percentage of stressed samples that have values below a selected percentile of the reference values.
- The 25th percentile of reference is commonly used as the threshold.

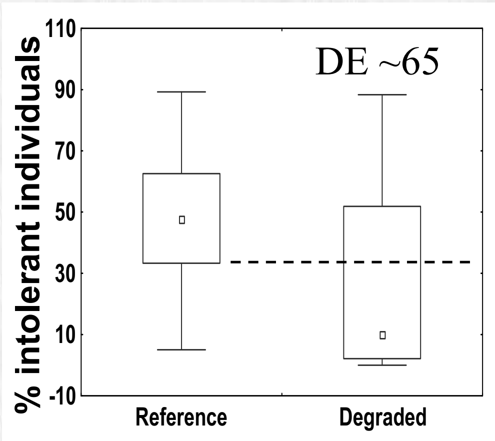
Calculating DE

1. Find the 25th or 75th percentile of reference values.
2. Find the number of stressed samples with values worse than the reference threshold (X).
3. Find the total number of stressed samples (Y).
4. Calculate DE = 100 * X / Y

Metric Discrimination

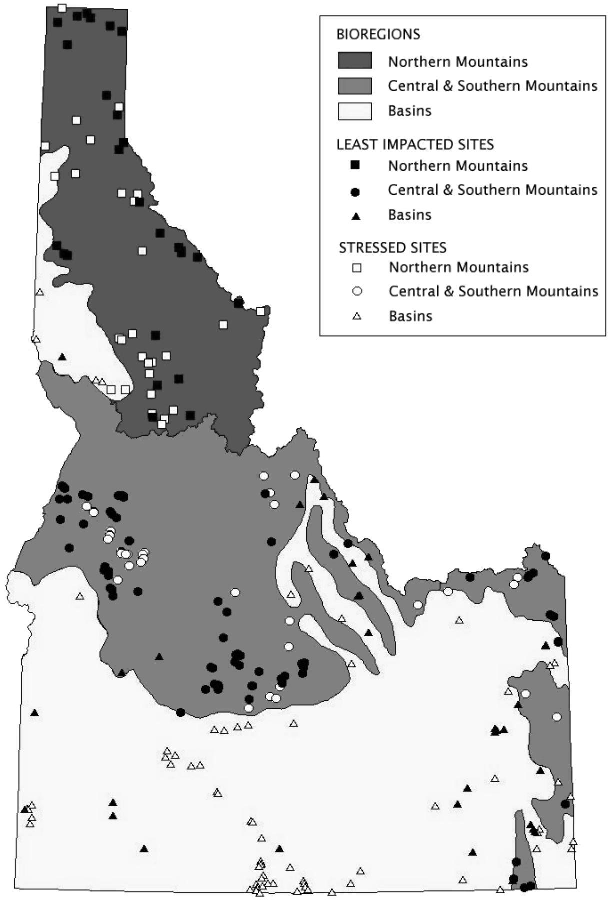


Strong response

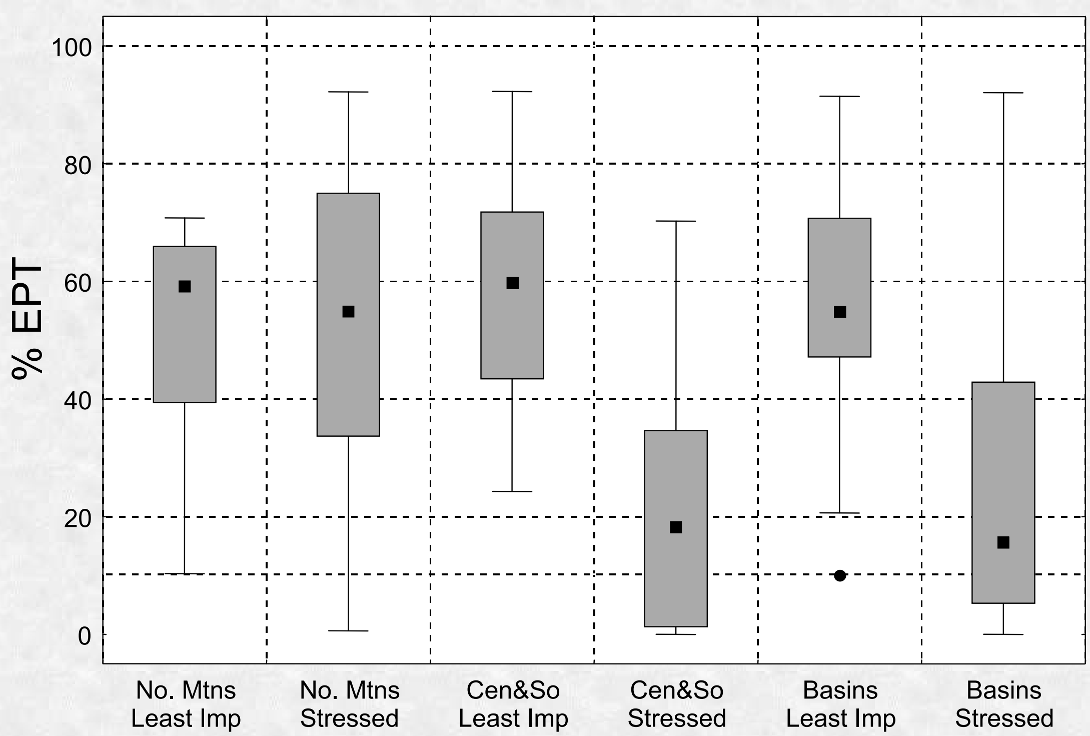


Weak response

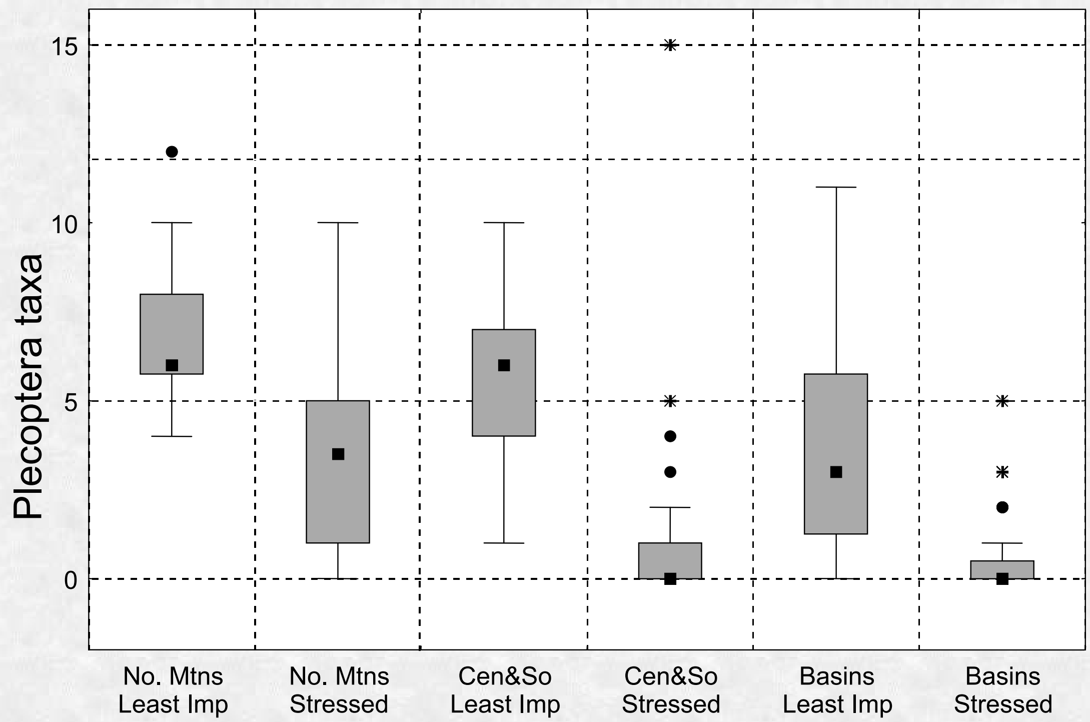
Bioregions of Idaho



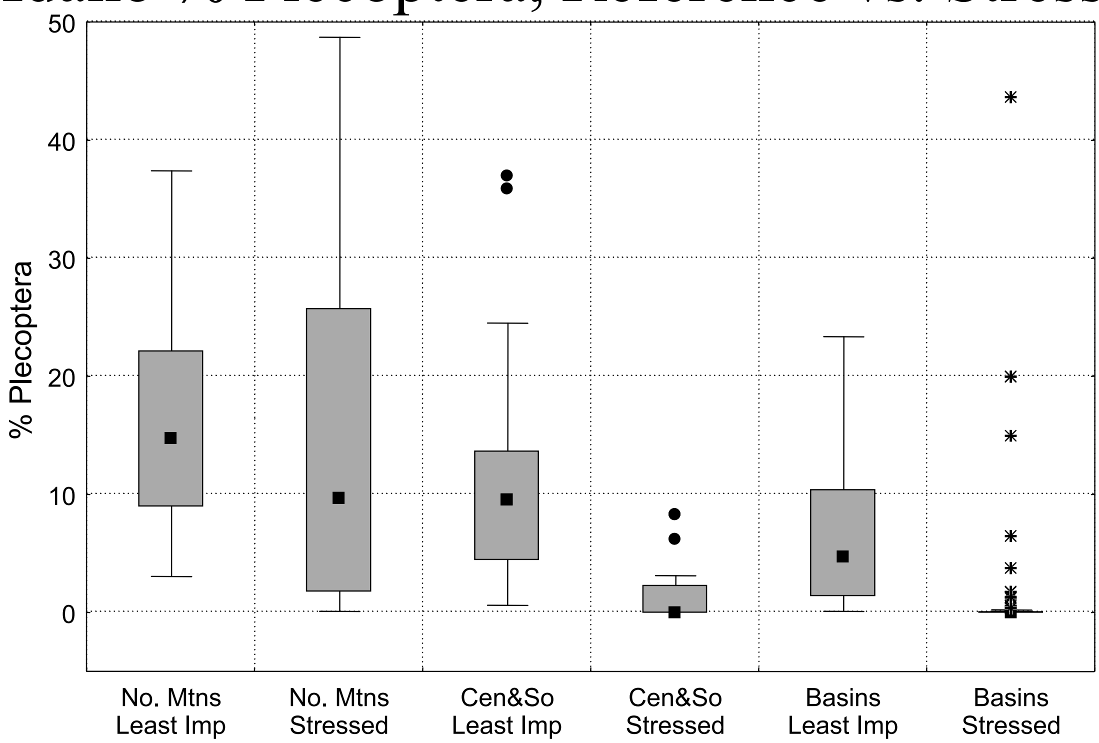
Idaho % EPT, Reference vs. Stressed



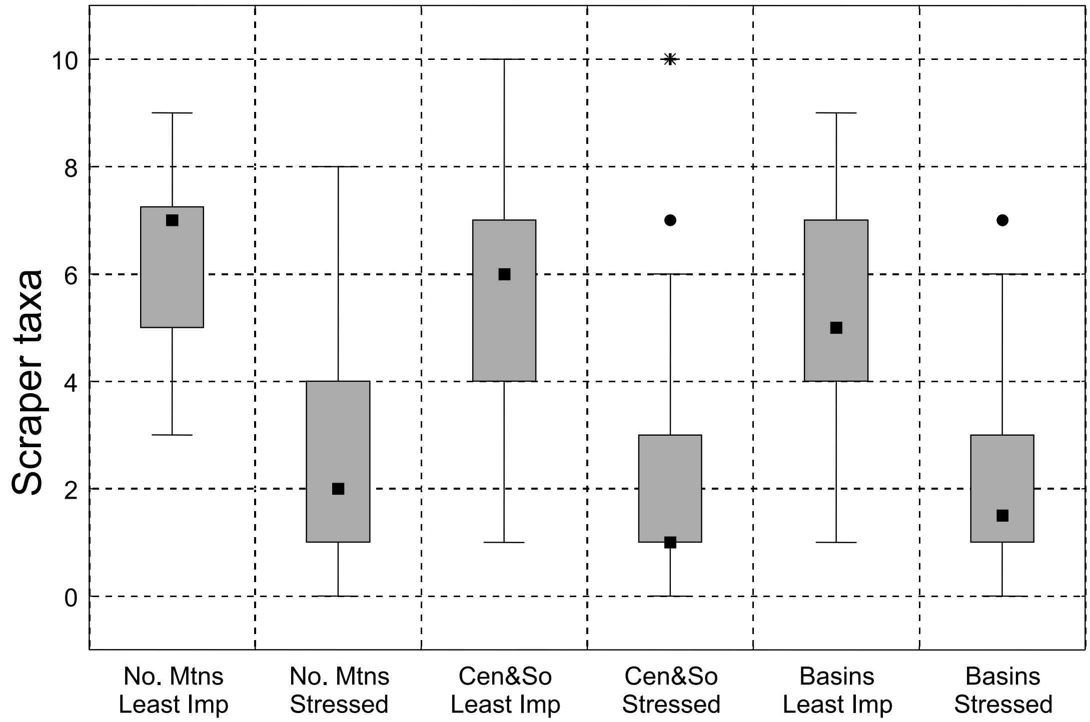
Idaho Plecoptera Taxa, Ref. vs. Stressed



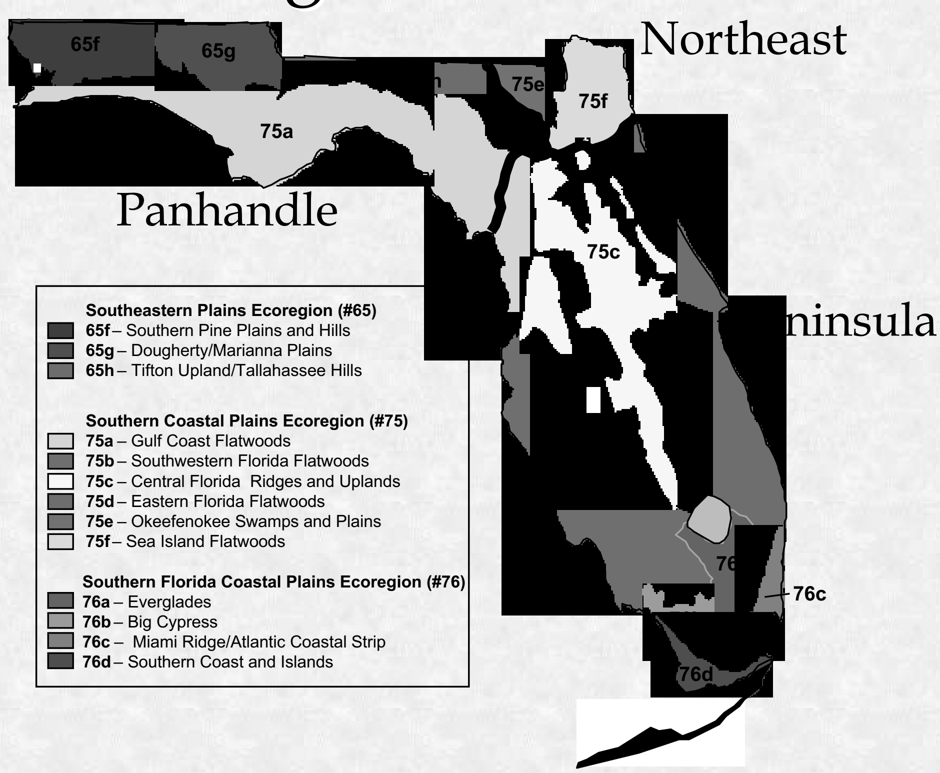
Idaho % Plecoptera, Reference vs. Stressed



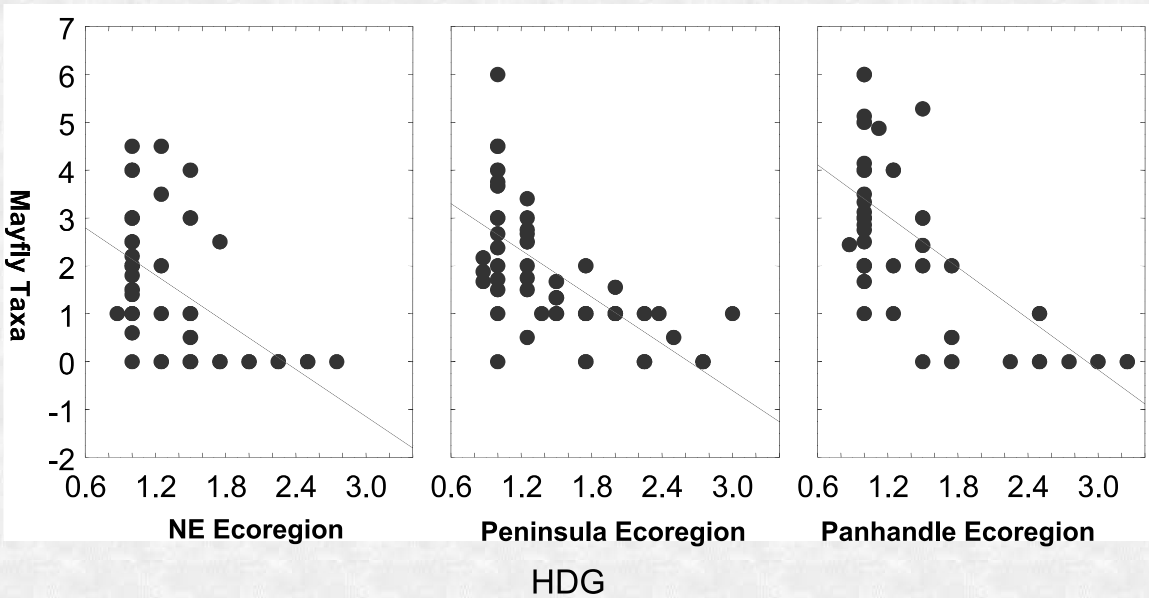
Idaho Scraper Taxa, Reference vs. Stressed



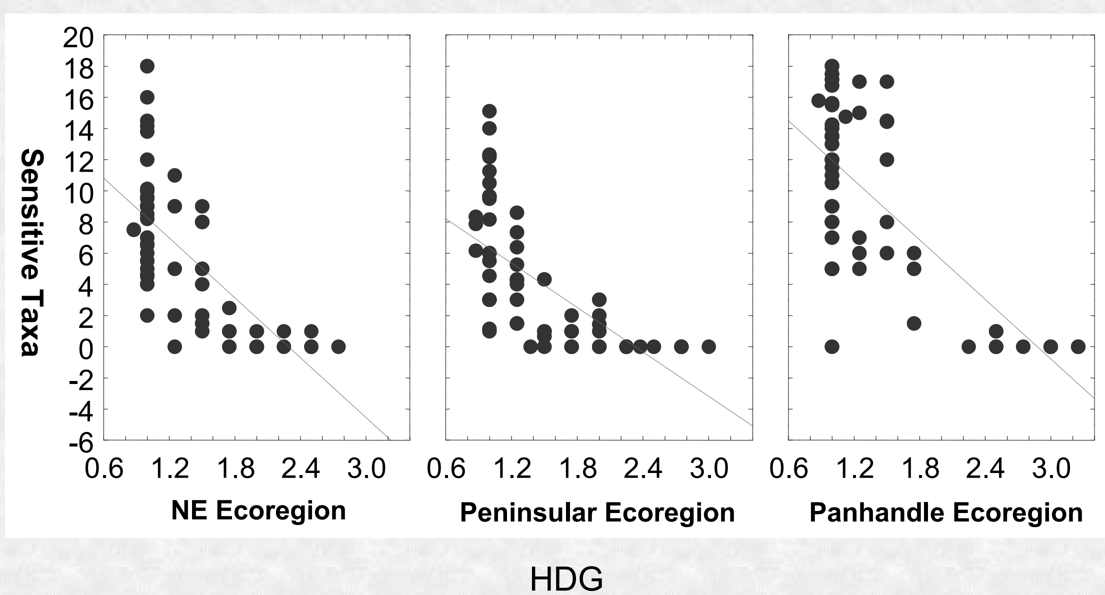
Bio-regions of Florida



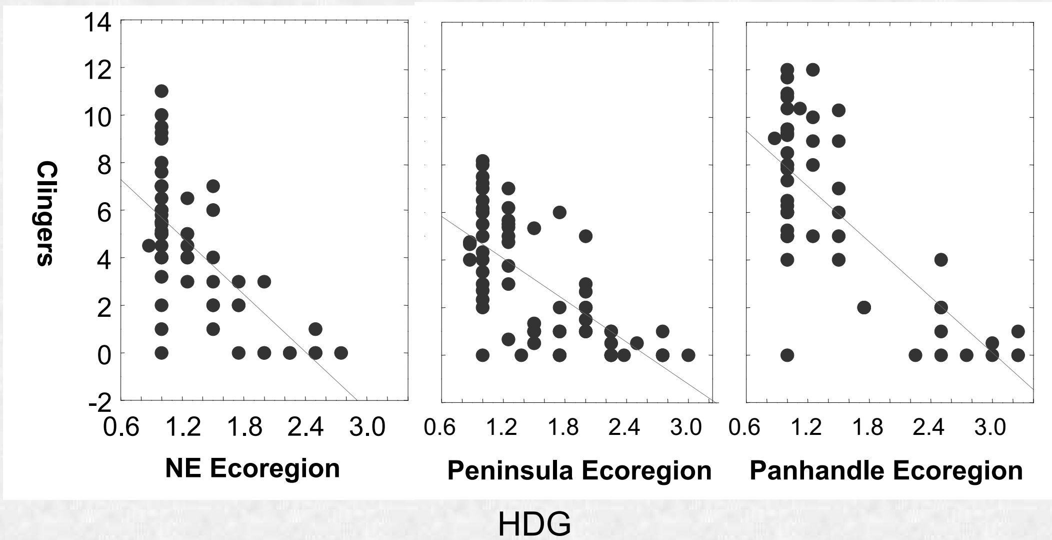
Florida Mayfly Taxa vs. HDG



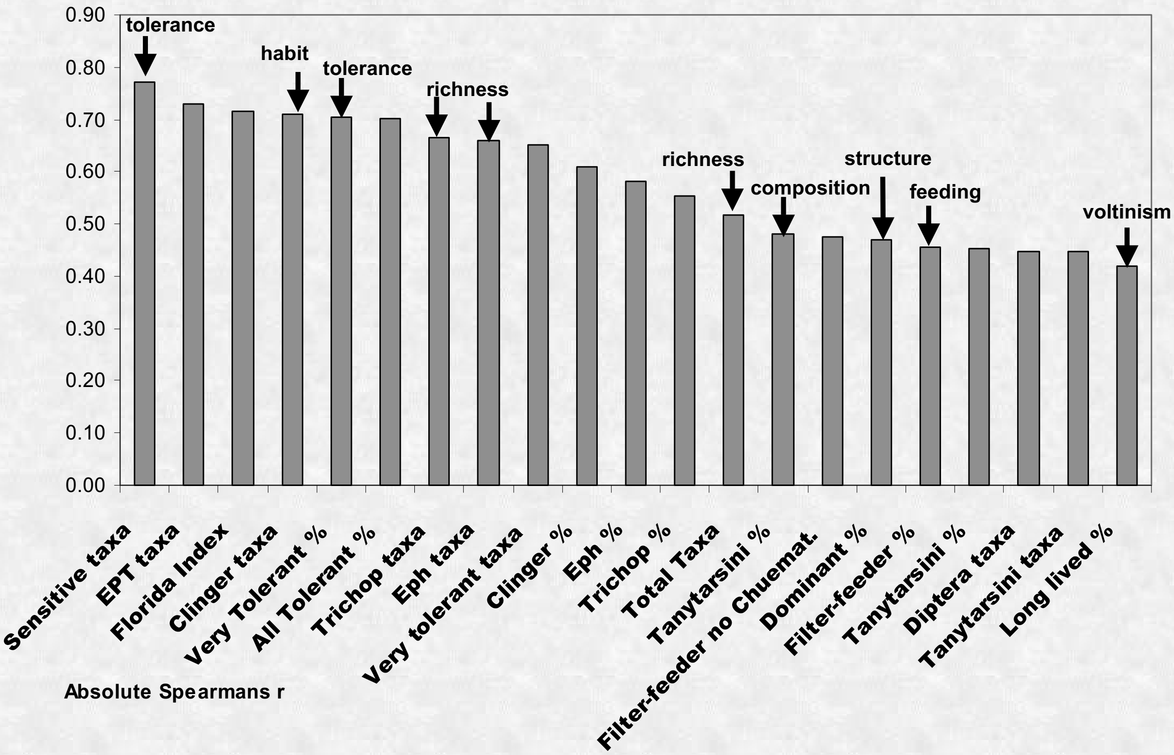
Florida Sensitive Taxa vs. HDG



Florida Clinger Taxa vs. HDG



Correlation Values for Metrics and HDG, Florida Selections



Some Discussion on Metrics

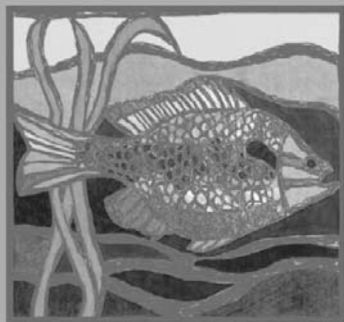
- Beware of "ratio" metrics
  - What do they really measure?
- Universal vs. regional metrics
  - Filter-feeders in Florida
- Redundancy
  - Choose only one or two correlated metrics from same category
- Responsiveness
- Range of Values

Final Words on Metric Exploration

- Human disturbance criteria top priority
- Examine range of attributes expected to relate to ecological health
- Select effective discriminators from major categories

National Biological Assessment and Criteria Workshop

Advancing State and Tribal Programs



Coeur d'Alene, Idaho

31 March – 4 April, 2003

Index 201

Selection of Metrics for Index Assembly

Presented by

Karen Blocksom, USEPA, NERL

Multimetric Index Development

- Database consisting of reference and stressed populations (sites)
- Classify resource (reference sites,ecoregions)
- Identify and test candidate metrics
- **Select metrics for dimensionless index**
- Select thresholds for assessment (set biocriteria)

Assembling an Index

1. Identify suites of metrics that meet the following criteria:
   - Ecologically justifiable
   - Responsive
   - Precise
   - Provide unique information
   - Represent a range of metric categories (richness, composition, tolerance, trophic, habit, voltinism)

Assembling an Index

2. Set aside a portion of the data for testing / validating the index.

3. Score all potential metrics.

4. Calculate index alternatives by summing or averaging metric scores.

Assembling an Index

5. Calculate the DE and precision of each index.

6. Evaluate the alternatives.

7. Test the favored alternatives using the reserved data.

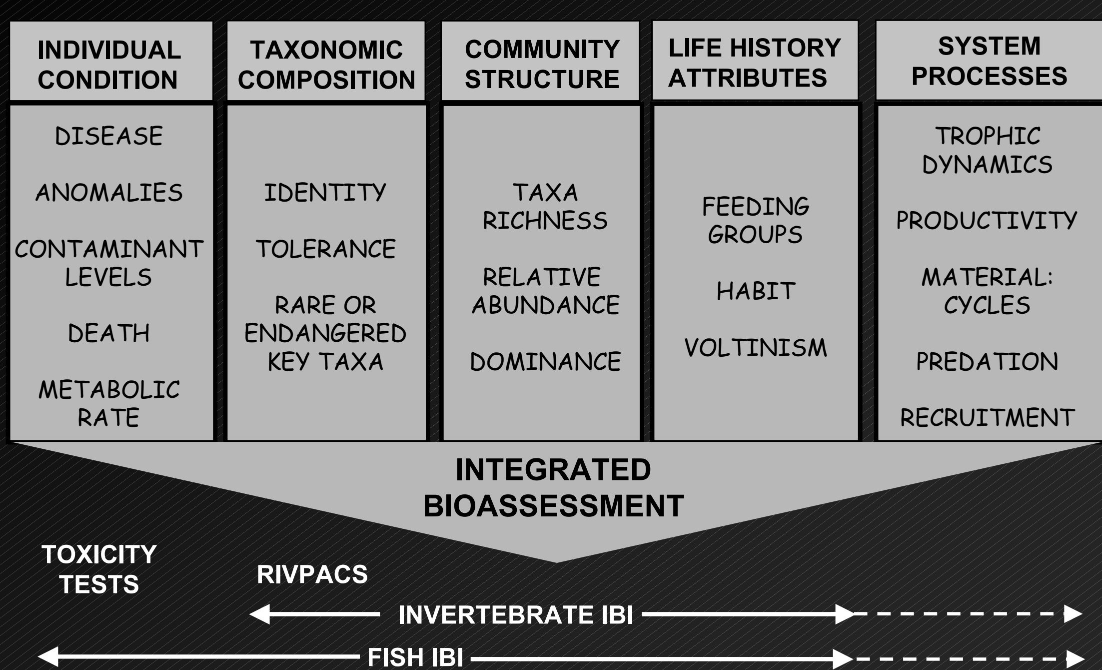
Identifying Redundancy

- Correlation analysis of potential metrics
- Identify pairs as redundant if the correlation coefficient, r, is > 0.9
- For $r > 0.8$, examine scatterplots
- Avoid suites of metrics containing both metrics in a redundant pair

Example Correlations

	Total taxa	EPT taxa	Ephemerop. taxa	Plecoptera taxa	Trichoptera taxa	% EPT	% Plecoptera	% Trichoptera	HBI	Intolerant taxa (0-1)
EPT taxa	**0.92**									
Ephemerop. taxa	**0.8**	**0.87**								
Plecoptera taxa	0.77	**0.86**	0.63							
Trichoptera taxa	**0.82**	**0.86**	0.6	0.63						
% EPT	0.26	0.43	0.4	0.4	0.31					
% Plecoptera	0.26	0.38	0.23	0.53	0.24	0.45				
% Trichoptera	0.2	0.23	0.09	0.13	0.37	0.31	0.01			
HBI	-0.38	-0.56	-0.48	-0.54	-0.44	-0.77	-0.53	-0.37		
Intolerant (0-1)	**0.84**	**0.94**	**0.81**	**0.83**	**0.82**	0.41	0.37	0.2	-0.59	
Intolerant (0-3)	**0.89**	**0.97**	**0.82**	**0.88**	**0.83**	0.41	0.4	0.2	-0.59	**0.97**

Attribute groups



Select Metric Suites-Examples

Metric	A	B	C	D
Total taxa	X			
EPT taxa		X		
Ephemeroptera taxa			X	X
Plecoptera taxa			X	X
Trichoptera taxa			X	X
% EPT		X	X	
% Plecoptera	X			X
% Trichoptera	X			X
HBI	X	X	X	X
% 3 Dominant			X	
% 5 Dominant	X	X		
Shannon-Weiner				X
Scraper taxa	X	X	X	X
% Scrapers	X	X	X	X
Clinger taxa			X	

Index Assembly Hands-on Exercise – Selecting metrics

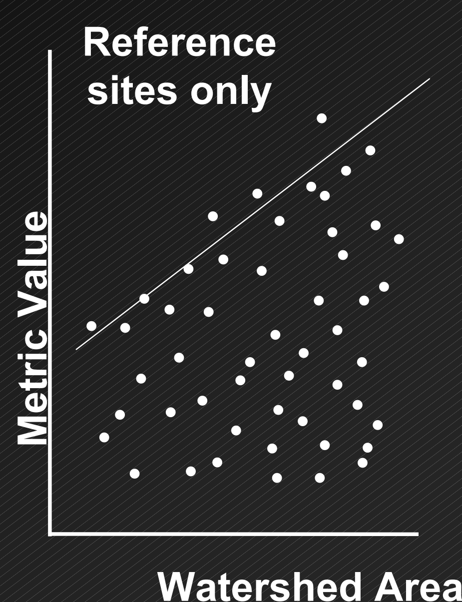
- Discrimination efficiencies (DE) and metric correlations for Idaho data
- **Goal:** Use metric evaluation information to select suites of candidate metrics and test as index alternatives

Scoring Metrics

- Creates dimensionless values that can be summed or averaged into a single index value.
- Standardizes metric values with respect to some expectation.
- Can be continuous or discrete.
- Can use expectations based on reference distributions or the entire distribution of values in a region.

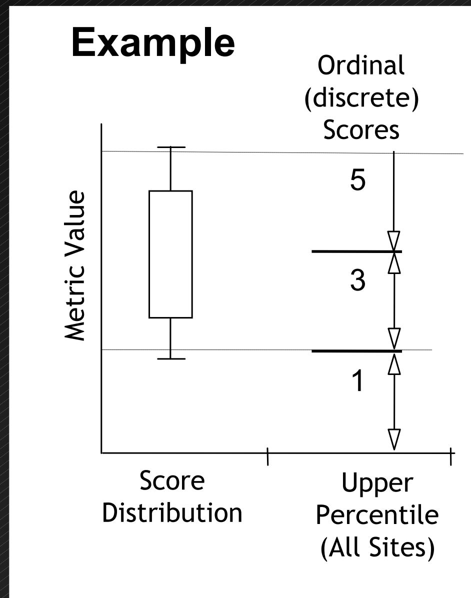
Scoring metrics – adjustment for natural variation

- Some metrics vary naturally with physical features, such as watershed area, elevation, gradient, and stream order.
- Adjustment for natural factors is necessary to set appropriate expectations for scoring these metrics.
- This type of adjustment can be done by eye or using quantile regression techniques.



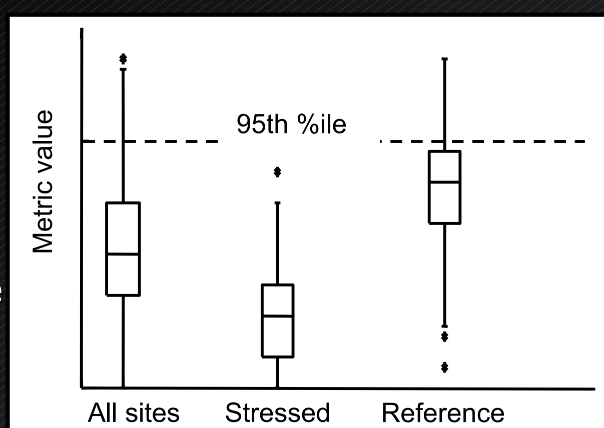
Scoring Metrics – Discrete

- Metric values receive a discrete score (e.g., 1, 3, or 5) based on comparison to some expectation.
- "Reverse" metrics are scaled so that higher values receive lower scores.
- Metric scores are summed, sometimes rescaled to a sum of 100.



Scoring Metrics – Continuous

- Scores are scaled to the 95th percentile of all values within each region.
- Scoring is on a continuous scale from 100 to 0.
- "Reverse" metrics are scaled to the 5th percentile.
- Metric scores are averaged (or summed) to obtain index value.



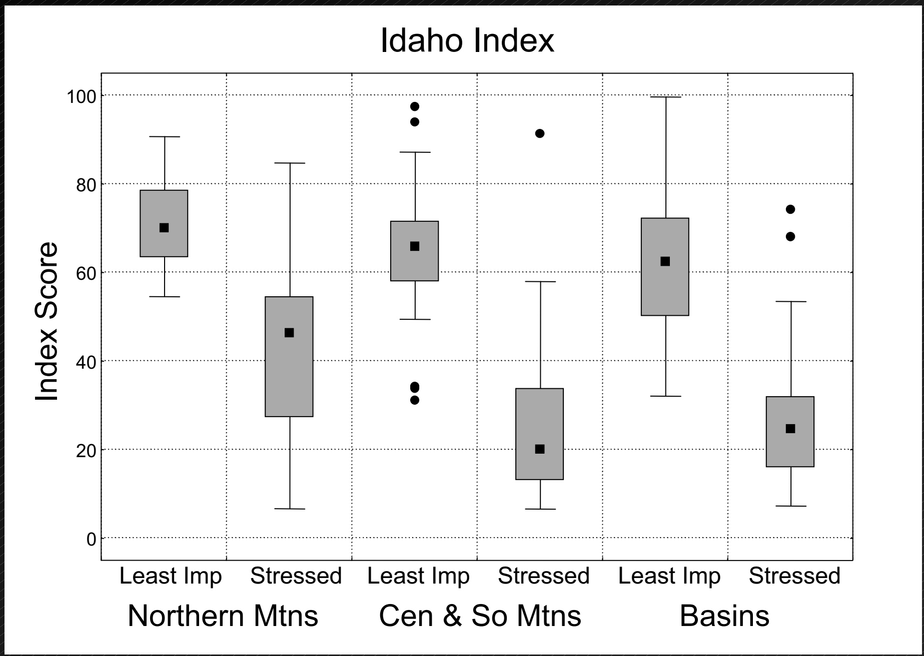
Formulas:

- Score = 100 * (Max - Value) / (Max - 5th%) ("reverse" metrics)
- Score = 100 * Value / 95th%

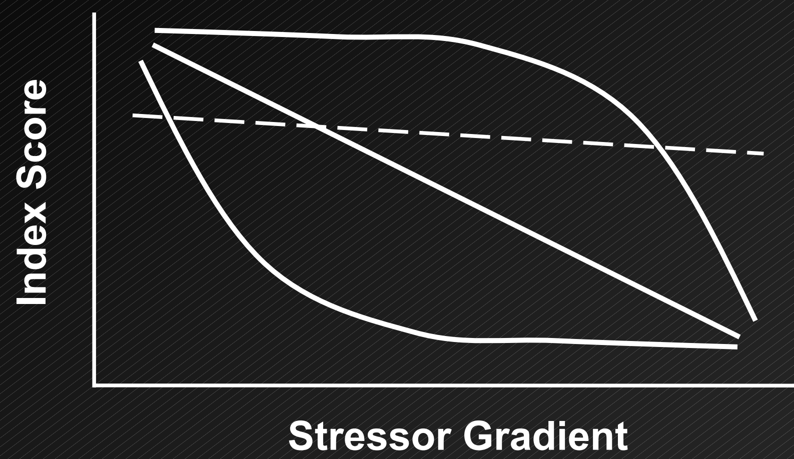
Evaluating Index Alternatives

Metric	Model 1	Model 2	Model 3
Total taxa	x	x	x
Ephemeroptera taxa	x	x	x
Plecoptera taxa	x	x	x
Trichoptera taxa	x	x	x
% EPT		x	
% Plecoptera	x		x
% Clingers	x	x	
Clinger taxa			x
Scraper taxa			x
HBI			x
% 5 Dominant taxa			x
Basins DE (25th)	93.1 (47.6)	96.6 (57.1)	96.6 (50.5)
N. Mtns DE (25th)	83.8 (58.1)	89.2 (67.9)	89.2 (65.2)
C&S Mtns DE (25th)	85.7 (55.0)	90.5 (57.3)	90.5 (57.7)
DE (Wtd avg)	88.8	93.1	93.1

Index Discrimination



Index Responsiveness to Stressor Gradient



Index Precision

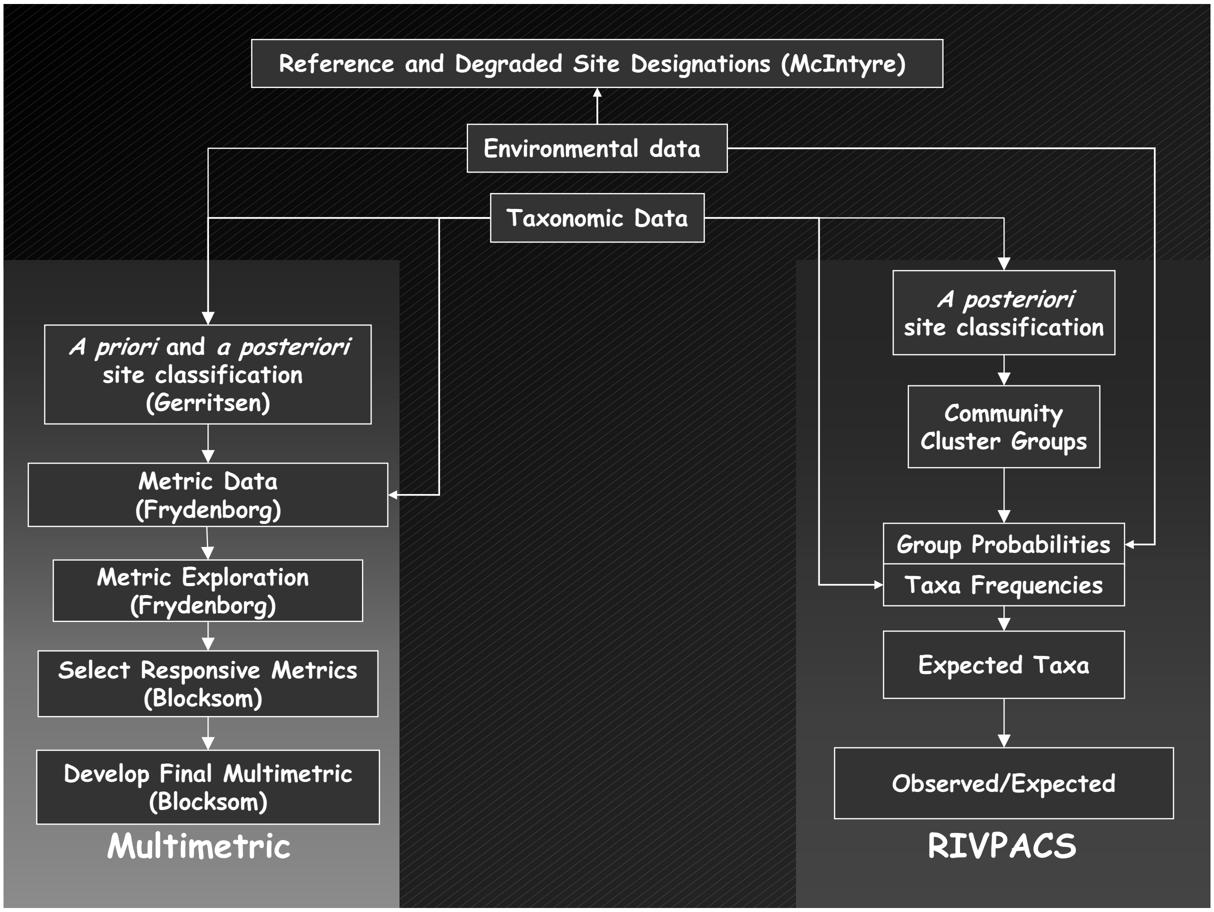
1. Find replicated samples.
2. Run ANOVA with Station as the grouping variable.
3. Use the MSE term as an estimate of variance.
4. Take the root of the MSE as an estimate of standard deviation.
5. Calculate CV or CI

Testing / Evaluating the Index

- Calculate the selected index using the reserved (validation) data.
- Check the "validation" samples against the "calibration" reference 25th percentile.
  - Are approximately 75% of validation reference samples above the threshold?
  - Is the percentage of validation stressed samples below the threshold comparable?

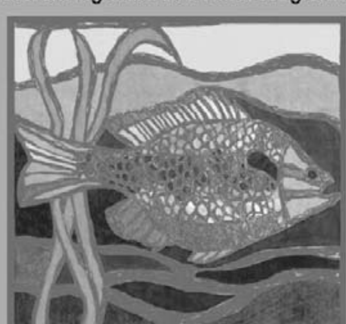
Summary

- Select suites of metrics that meet criteria.
- Score metrics and average or sum scores into index value.
- Calculate DE and precision of alternatives.
- Select appropriate index.
- Test the DE of index with validation data.



National Biological Assessment and Criteria Workshop

Advancing State and Tribal Programs



Coeur d'Alene, Idaho
31 March – 4 April, 2003

Index 201

RIVPACS

Presented by
Chuck Hawkins, Utah State University;
Rick Hafele, Oregon Dept. of Environmental Quality;
Mike Paul, Tetra Tech, Inc.

Quick Review of 101

- Understanding the units of measure (O/E).
- *Predicting the expected taxa.*
- *Calculating O/E, the biological condition value.*
- Determining if an assessed site is impaired.

Focus of 201

- Mechanics
  - Predicting the expected taxa.
  - Calculating O/E.
- Application / Case Example

The accuracy and precision of RIVPACS-type assessments are completely dependent on how well we estimate the probabilities of capture of all individual taxa in the regional taxa pool.

Remember this example from 101?
(Units of Measure & the Expected Taxa)

Species	Replicate Sample Number										Freq
	1	2	3	4	5	6	7	8	9	10	(P_c)
A	*	*	*	*	*	*	*	*	*	*	1.0
B	*	*		*	*	*		*	*	*	0.8
C	*		*		*	*			*		0.5
D		*	*				*		*	*	0.5
E					*						0.1
Sp Count	3	3	3	2	4	3	2	2	4	3	2.9

Species Richness is the Currency.

$E = \sum P_c$ = • •number of species / sample = 2.9.

How do we estimate probabilities of capture from single samples at a site?

The basic approach to modeling pc's and estimating E was worked out by Moss et al.*

River InVertebrate Prediction and Classification System (RIVPACS)

*Moss, D., M. T. Furse, J. F. Wright, and P. D. Armitage. 1987. The prediction of the macro-invertebrate fauna of unpolluted running-water sites in Great Britain using environmental data. Freshwater Biology 17:41-52.

RIVPACS-type Models: 8 Basic Steps

1. Establish a network of reference sites.
2. Establish standard sampling protocols.
3. Classify sites based on their biological similarity.
4. Estimate individual probabilities of capture by relating environmental setting to the biological classification (multivariate statistics).

For each assessed site:

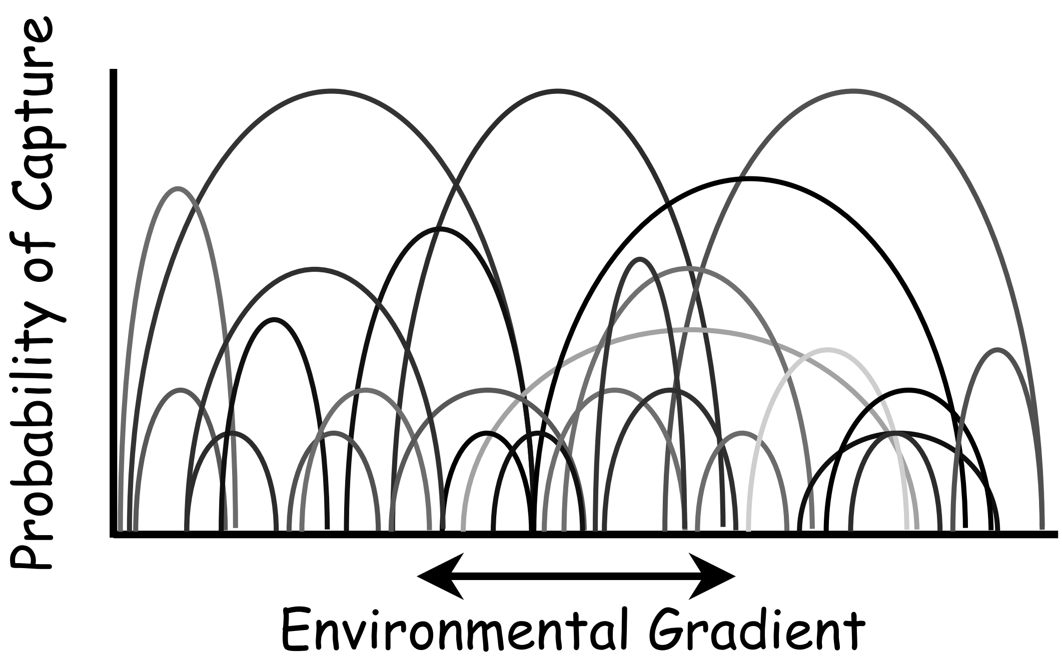
5. Sum p_c's to estimate E.
6. Count O
7. Calculate O/E.
8. Determine if observed O/E is different from reference?

The 'Complicated' Steps

3. Classify sites based on their biological similarity.
4. Estimate individual probabilities of capture by relating environmental setting to the biological classification (multivariate statistics).

In RIVPACS models, site classification is really just a clever mathematical shortcut toward predicting the continuous biological response that occurs along natural environmental gradients.

Remember, we ultimately want to be able to estimate the probabilities of capture of every taxon in the regional taxa pool at any location.



There are at least two approaches to modeling probabilities of capture

1. Logistic regression avoids classification and models each taxon separately. The output of these separate models can be combined to estimate E, the expected number of taxa, but.....

   many models would be necessary, and rare taxa are difficult to model!

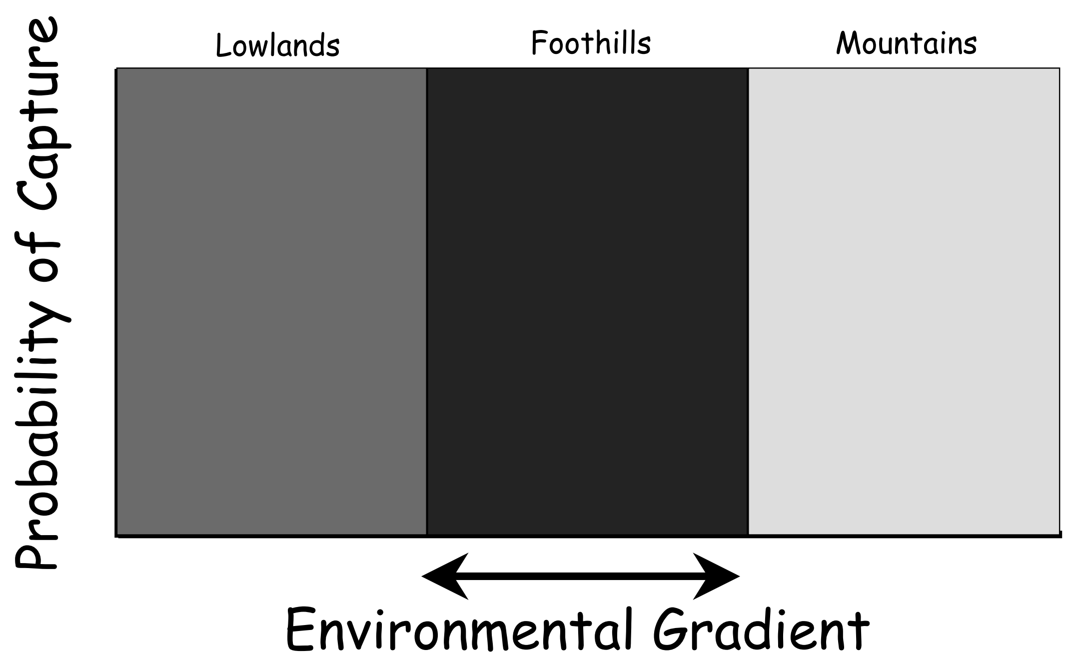
2. The RIVPACS approach creates 1 model and in doing so also potentially circumvents the rare taxa problem, but.....

   it requires some statistical machinations that are a bit complicated, including the *biological* classification of sites.

In RIVPACS, reference sites are classified based on their compositional similarity to one another

- This type of classification involves two steps:
  1. Calculation of a pairwise similarity matrix among all sites, followed by
  2. Cluster analysis to identify biologically similar 'classes'.
- A variety of methods exist for conducting both steps, but we would like to use the methods that result in the most precise predictions.

How can we let the biology define a classification that will allow us to later predict species composition at a site?



But how do we actually get the organisms to tell us where to 'draw the lines'?

Two Commonly Used Similarity (Distance) Measures

- Jaccard Distance = 1-(2W/(A+B-W))
- Sorensen (Bray-Curtis) = 1-(2W/(A+B))

  In both measures, W is the sum of shared abundances and A and B are the sums of abundances of taxa found only in individual sample units. Values of both measures range from 0 to 1. The Jaccard measure can be interpreted as % of taxa shared, but in the Sorenson measure, shared taxa are weighted.

- The Sorensen measure has generally been shown to be superior to the Jaccard measure for RIVPACS applications.

A simple example of calculating a similarity matrix: the raw data

	Species					
Sites	A	B	C	D	E	F
1	1	1	1	1	0	0
2	1	1	1	0	0	0
3	1	1	0	0	1	1
4	0	0	0	0	1	1
5	1	1	1	1	1	1
6	0	0	0	1	1	1

The distance matrix based on the Sorensen Measure

	1	2	3	4	5	6
1	0.00					
2	0.14	0.00				
3	0.50	0.43	0.00			
4	1.00	1.00	0.33	0.00		
5	0.20	0.33	0.20	0.50	0.00	
6	0.71	1.00	0.43	0.20	0.33	0.00

A similarity or distance measure is the intermediate step to classification

- The next step is to create a cluster diagram, which is produced by applying one of several possible clustering algorithms to the matrix. The different algorithms may produce different looking dendrograms and thus different classifications.
- Experience has shown that two methods produce better models:

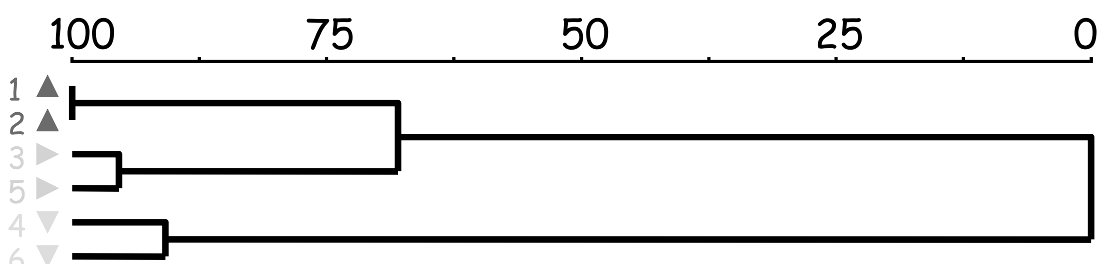
  flexible beta and Ward's

The dendrogram produced from the practice data by flexible beta clustering.

So how many classes are there?

In general, for RIVPACS, classes should be defined as finely as possible as long as ≥ 5 sites occur within classes.

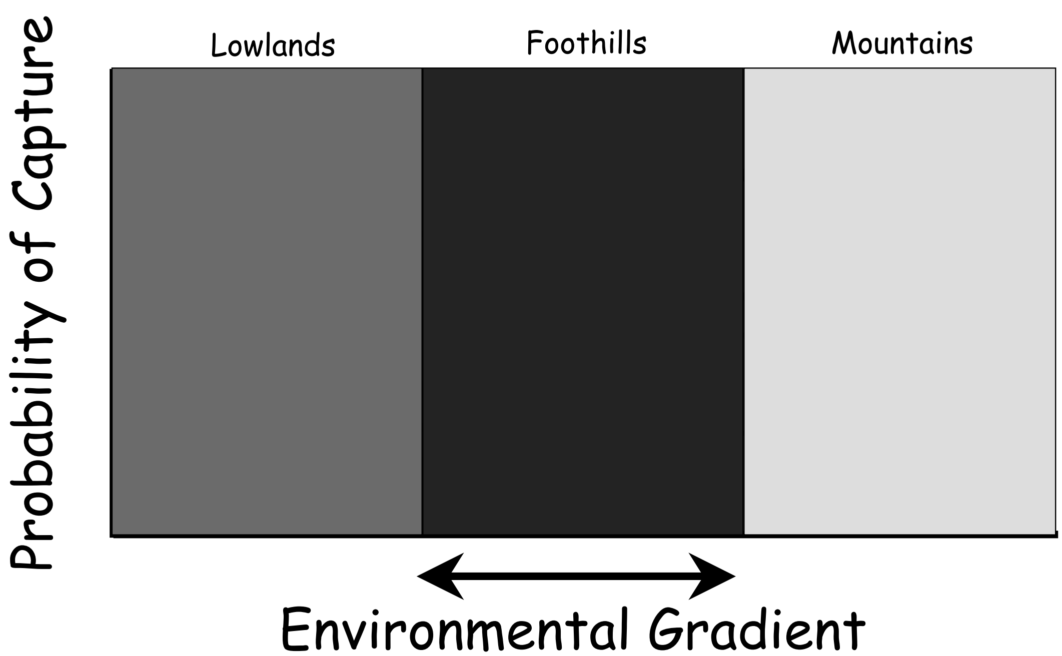
Information Remaining (%)



What do we do with the classification?

- If classes were truly discrete, we could calculate frequencies of occurrence of different taxa within classes, and use these values as estimates of probabilities of capture, but
- We know the classes are not discrete, they are simply the artifact of our chopping up a continuous world into chunks.

Some species occur only in one class, but not at all sites; other species occur in more than one class; no species occurs everywhere.



How do we apply this classification to new sites?

- This is the modeling part, and…
- how we predict continuous gradients from the 'discrete' classification that we produced.

The next 'step' is actually a series of 4 linked calculations

1. Calculate the frequencies of occurrence of each taxon within each class.
2. Estimate the probability that a new site belongs to each of the classes.
3. Use these probabilities of class membership to weight the frequencies of occurrence within classes.
4. Sum the weighted frequencies of occurrence for a taxon to estimate the probability of capturing that taxon at that site.

Estimate frequencies of occurrence of each taxon in each biotic class as (n_i/N).

Class	Sp 1	Sp 2	Sp 3	Sp 4	Sp 5	Sp 6
A	0.33	0.89	0	0.25	1.00	0
B	0.80	0.99	0.21	0.36	0.87	0
C	0.60	0	0.16	0.28	0.98	0.05
D	0.10	0.54	0.09	0.29	1.00	0

Derive a model to predict (from environmental features) the probabilities (P_G) that a new site belongs in each of the biologically-defined classes.

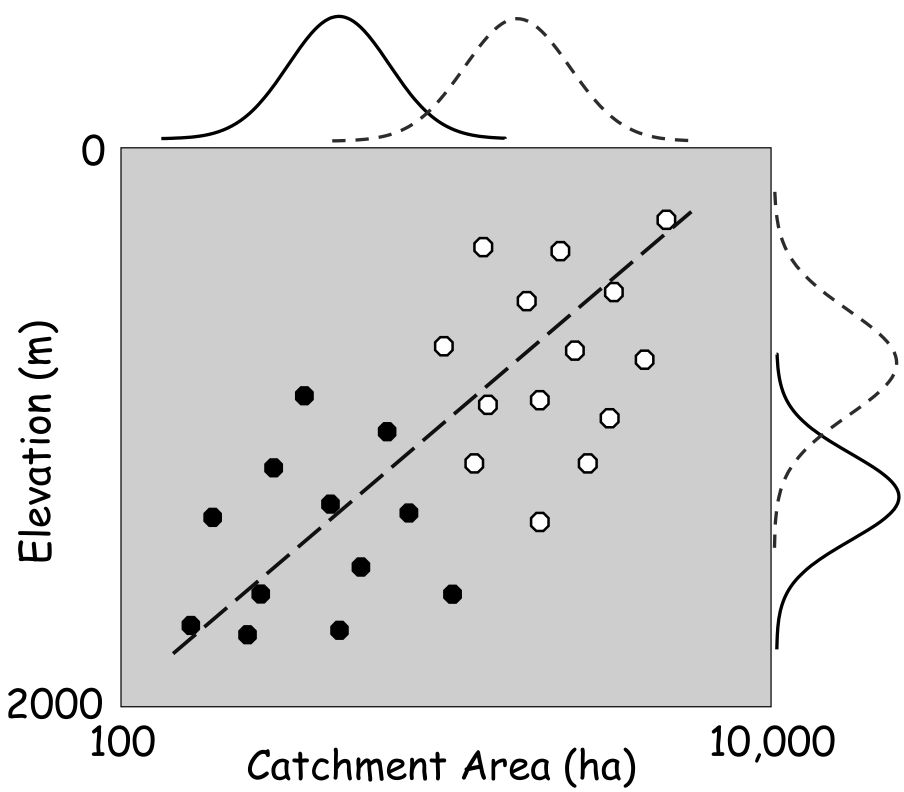
Discriminant functions, e.g.,

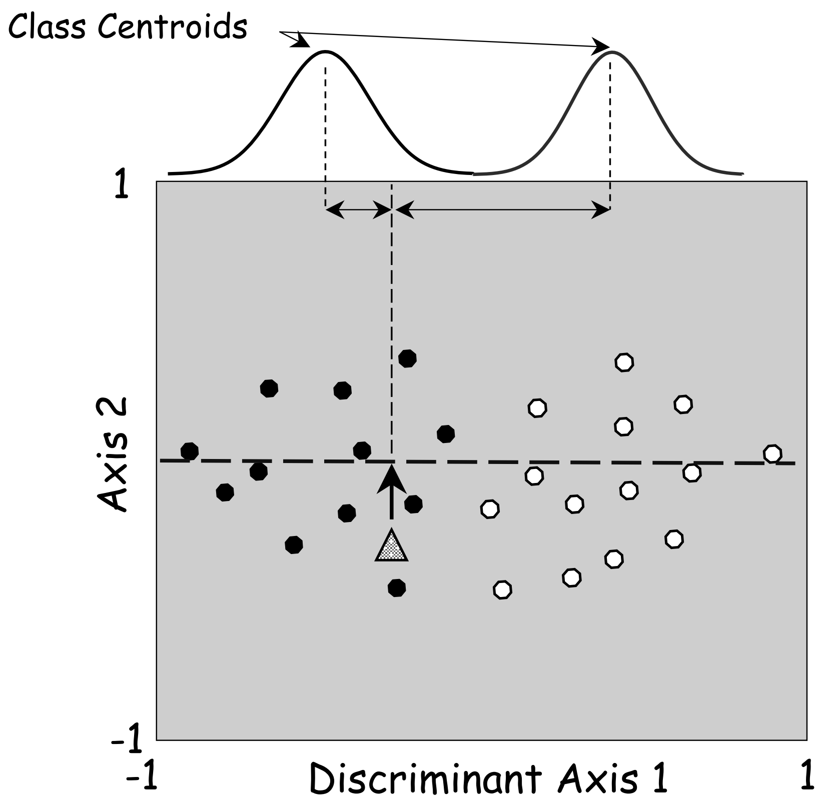
P_g = f(elevation, watershed area, geology)

Predictors should be insensitive to human alteration

This is not a class in multivariate statistical procedures, but… let's take a quick graphical look at how discriminant functions models work.

A simple graphical explanation of discriminant models

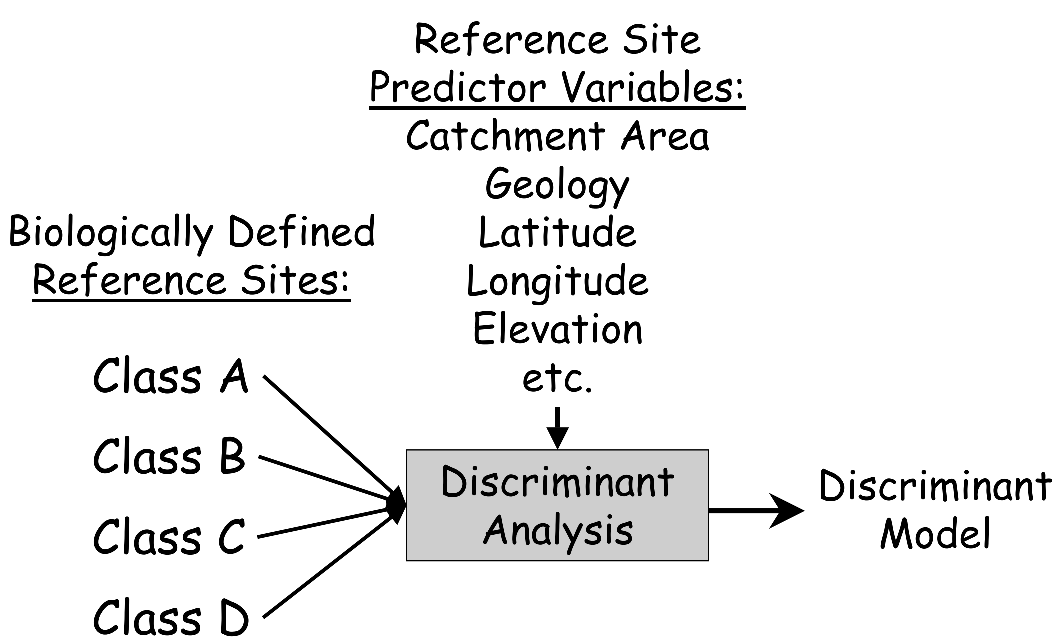




Centroids are the combination of predictor variables that represent the average site in a class. The taxa at a centroid will therefore represent the best estimate of the taxa expected at a site classified into a discrete class.

We can refine estimates of the taxa expected at individual sites by recognizing that nature is seldom discrete and using probabilities of class membership.

The Discriminant Model



Combining the Discriminant Model + Frequencies of Occurrence Provides Estimates of Probabilities of Capture

Test Site Predictor Variables → Discriminant Model

Class Probabilities		Taxon 1 Reference Site Frequencies	
50% Class A	*	60% Class A	= 0.30
40% Class B	*	20% Class B	= 0.08
10% Class C	*	0% Class C	= 0.00
0% Class D	*	0% Class D	= 0.00

$P_c = 0.38$

Weight frequencies of occurrence of taxa within classes ($F_{i,g}$) by (P_g) and sum to calculate p_c's for the new site.

Sp 1

Class	P_g	$F_{i,g}$	$P_g \times F_{i,g}$
A	0.50	0.60	0.30
B	0.40	0.20	0.08
C	0.10	0.00	0.00
D	0.00	0.00	0.00

$P_C = \Sigma (P_g \times F_{i,g}) = 0.38$

We have to do this for every taxon in the regional taxa pool!

Now that we have estimates of probabilities of capture, we can estimate O/E.

Sum p_c's to estimate the number of taxa (E) that should be observed at the site based on standard sampling.

Species	P_c
1	0.70
2	0.92
3	0.86
4	0.63
5	0.51
6	0.32
7	0.07
8	0.00
E	4.01

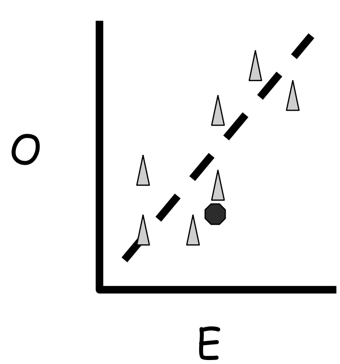
Determine O, the number of predicted taxa that were collected.

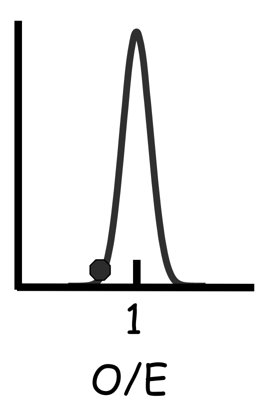
Calculate O/E.

Species	P_c	O
1	0.70	*
2	0.92	*
3	0.86	
4	0.63	
5	0.51	*
6	0.32	
7	0.07	
8	0.00	
E	4.01	3

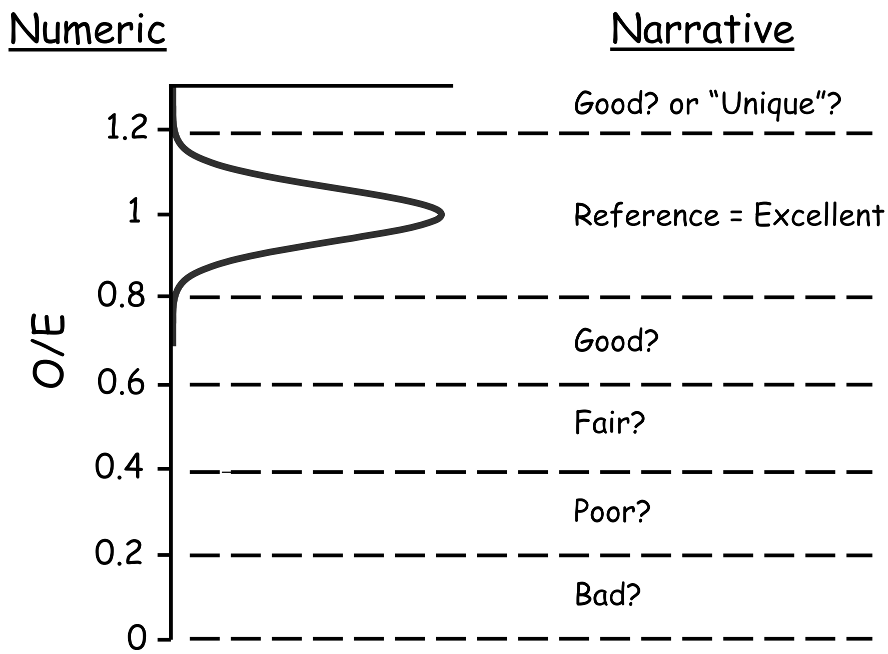
O/E = 3 / 4.01 = 0.75

Determine if the O/E value is significantly different from the reference condition by comparing against model predictions and error.





Relating Numbers and Narratives: Some Cautionary Comments



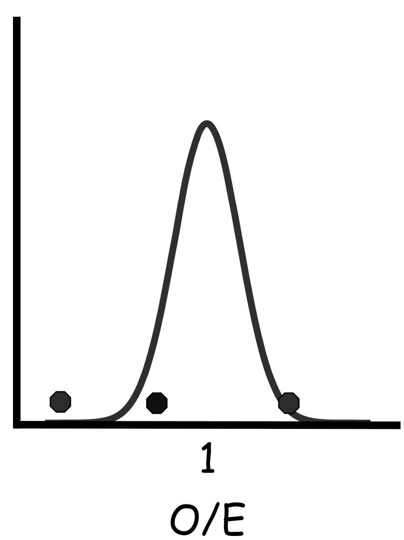
Do narrative terms convey an accurate sense of our numerical assessment of a site?

We need to think carefully about what narrative terms imply about the condition of the biota.

Statistical Issues Regarding Inferences of Impairment

Single Sites/Samples

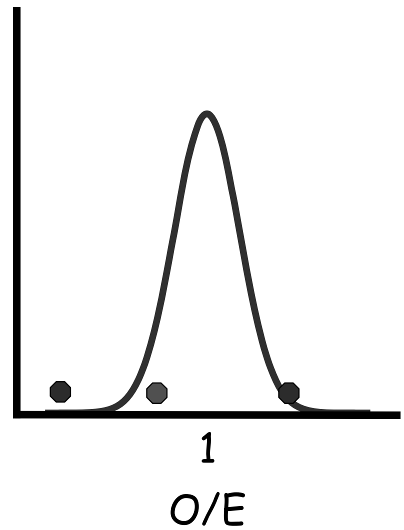
Hypothesis: the observed O/E value is from the same distribution of values estimated for reference sites, i.e., the site is equivalent to reference.



Statistical Issues Regarding Inferences of Impairment

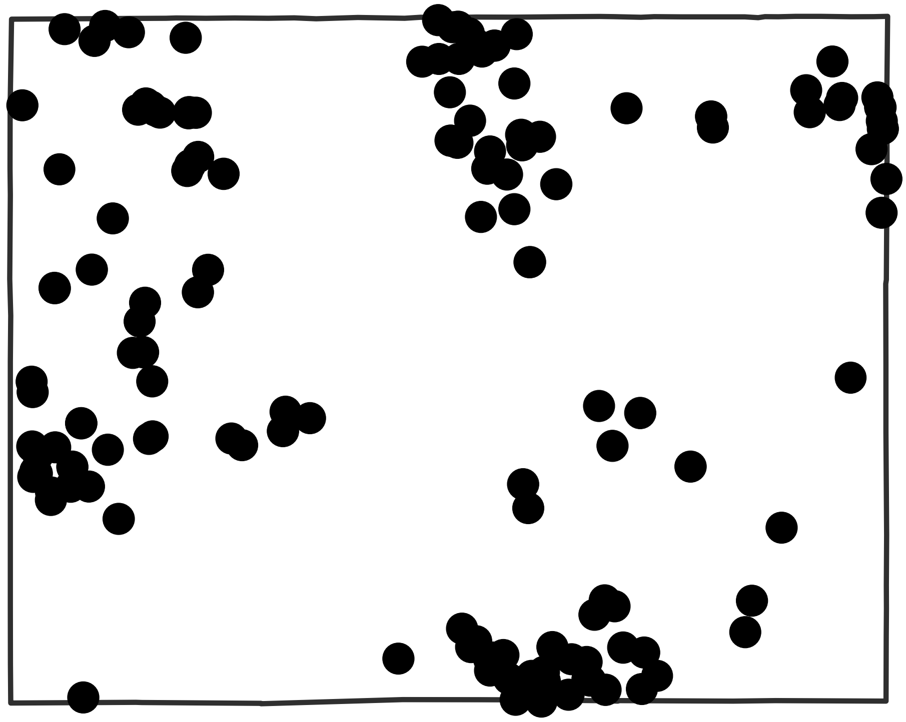
Multiple Sites or Replicated Samples at a Site

Hypothesis: the observed mean is different from 1 (the reference mean).

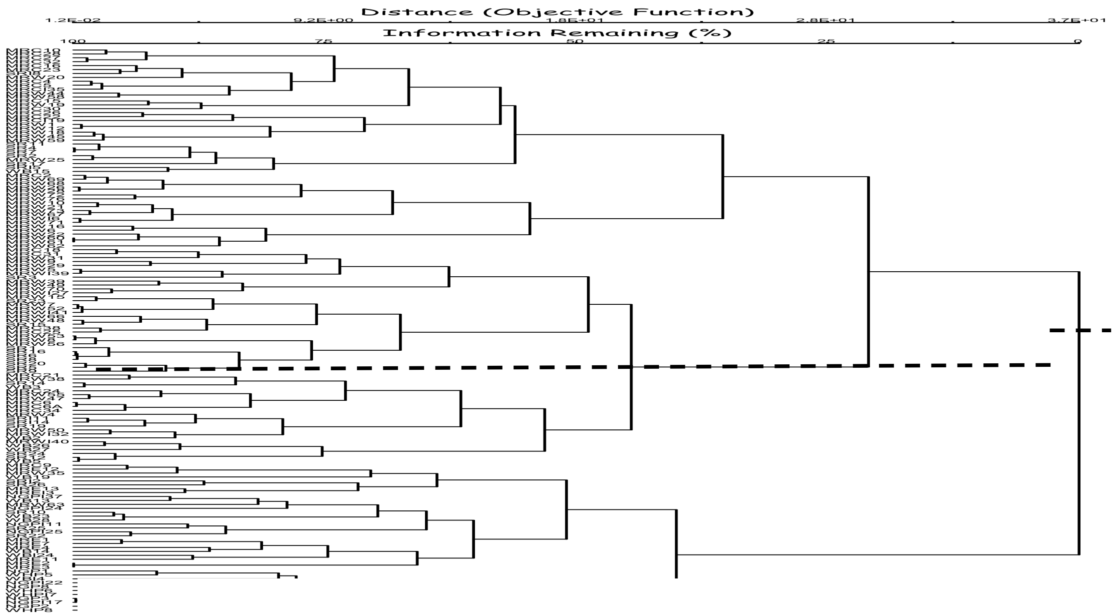


To illustrate the application of RIVPACS to real systems, we will use a case study from Wyoming

142 Reference Sites in Wyoming

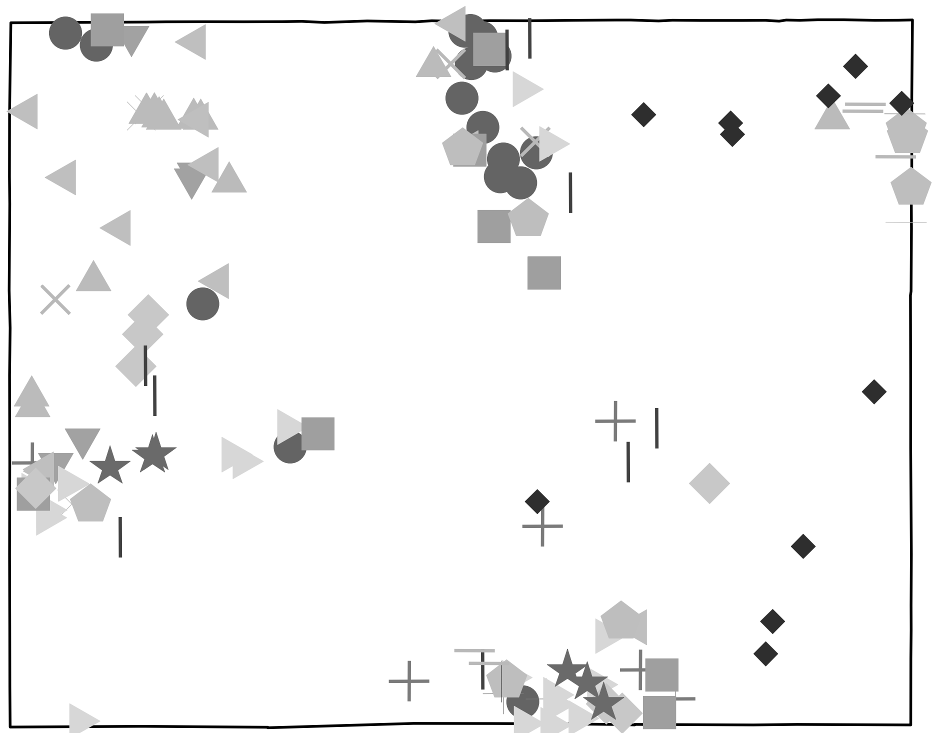


What did the dendrogram look like for the Wyoming data?



119 taxa were used to classify sites and 14 "classes" were identified.

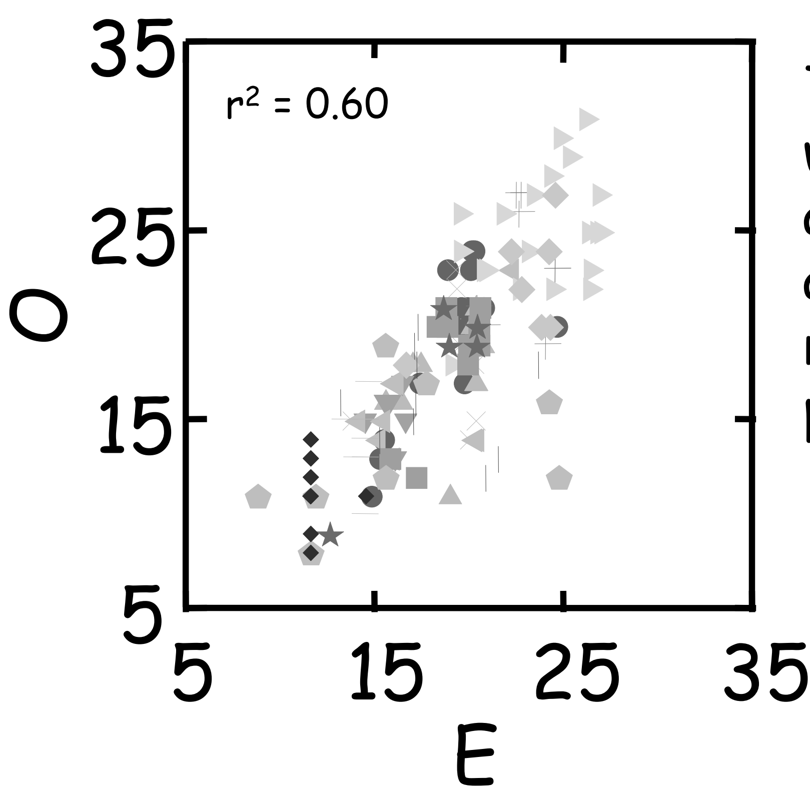
Spatial Distribution of Reference Sites Coded by Biotic Class



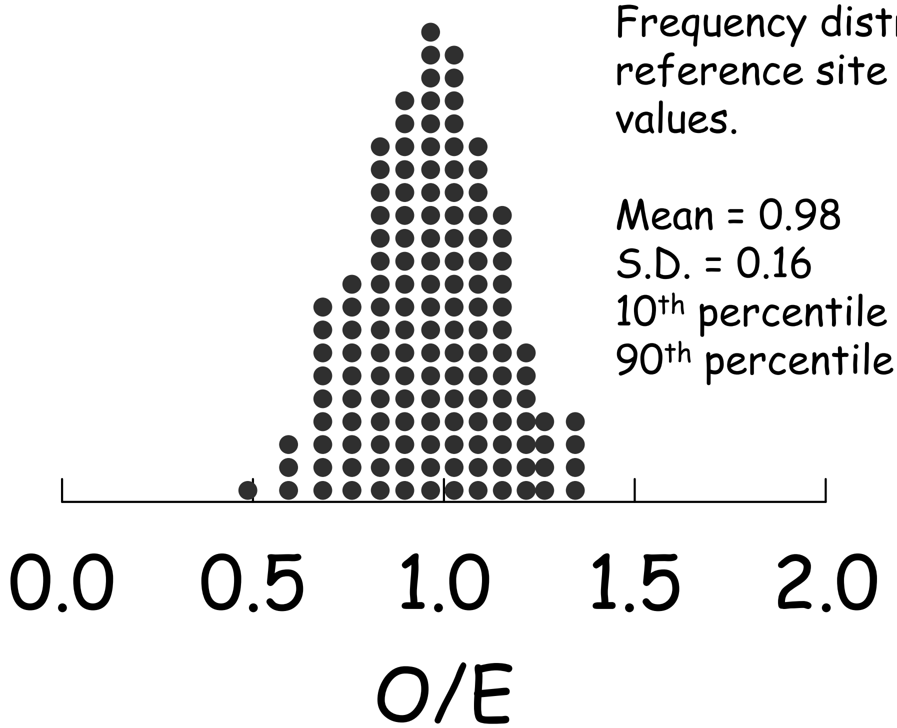
Two Discriminant Models

Continuous Variables	
% Cobble	9.39
Log WS Area	6.54
Latitude	6.39
Longitude	5.13
Elevation	2.88
Velocity	2.60
Date	2.49
Log Alkalinity	2.33

Mixed Variables	
Wyoming Basin ER	7.75
Log WS Area	5.77
Plains landscape	4.89
Mid-Rockies	4.41
Longitude	4.39
Latitude	4.26
Date	3.89
% Cobble	3.86
TWP geology	3.47
NG-Montane	3.39
Elevation	3.31
PPM geology	2.86
Velocity	2.73
MD geology	2.40
Log Alkalinity	2.17



The model was globally accurate and reasonably precise.

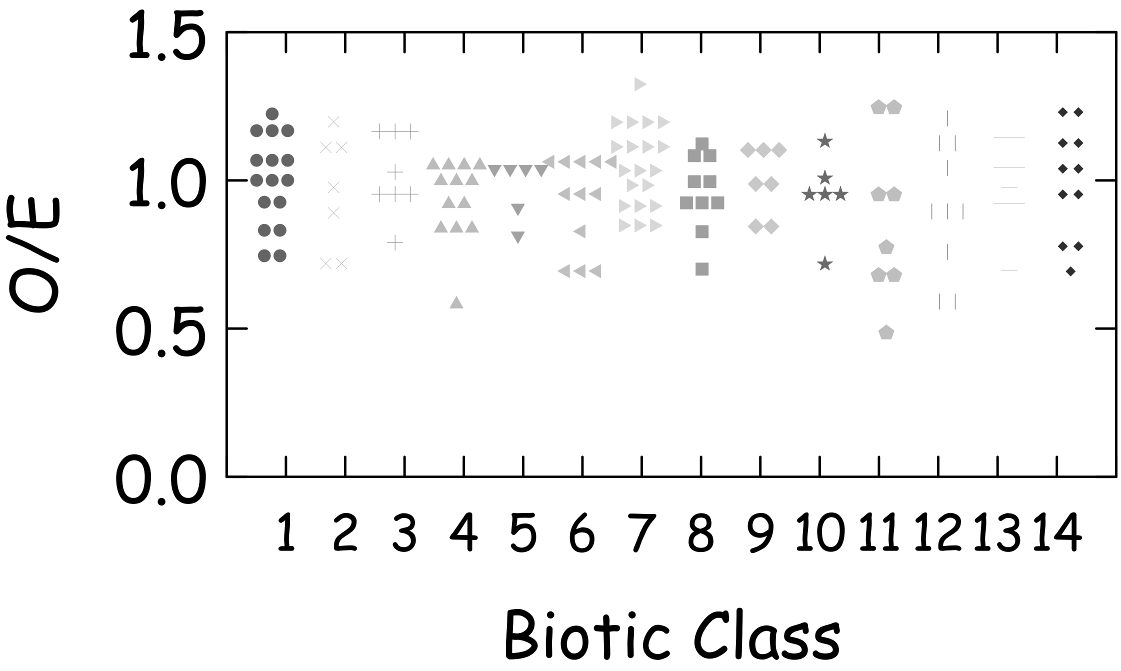


Frequency distribution of reference site O/E values.

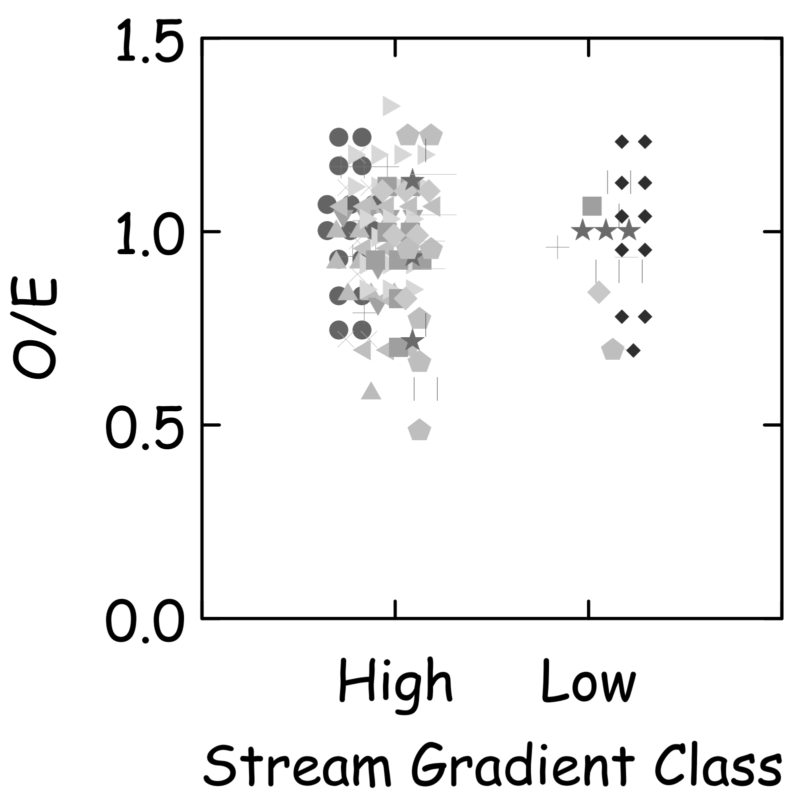
Mean = 0.98
S.D. = 0.16
10^{th} percentile = 0.73
90^{th} percentile = 1.19

Models can potentially be globally accurate, but locally biased, so we need to check if model predictions are biased under various local conditions.

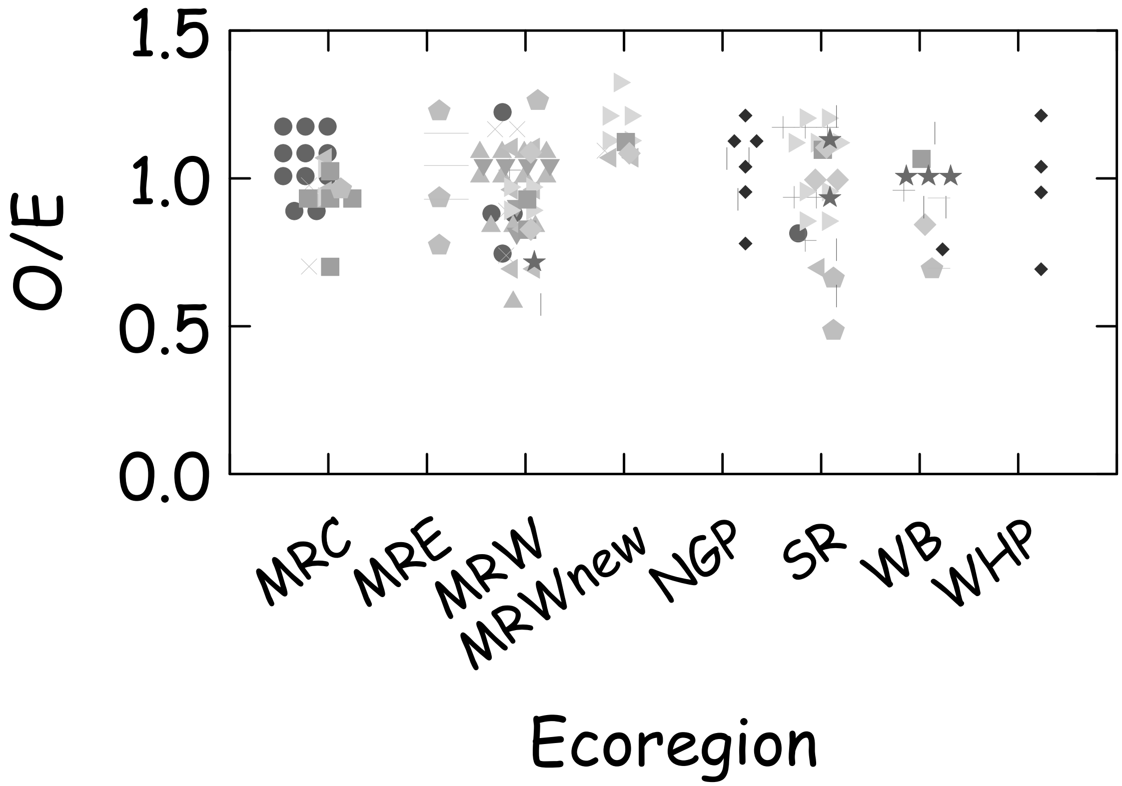
O/E values were not associated with the biotic class to which reference sites were assigned.



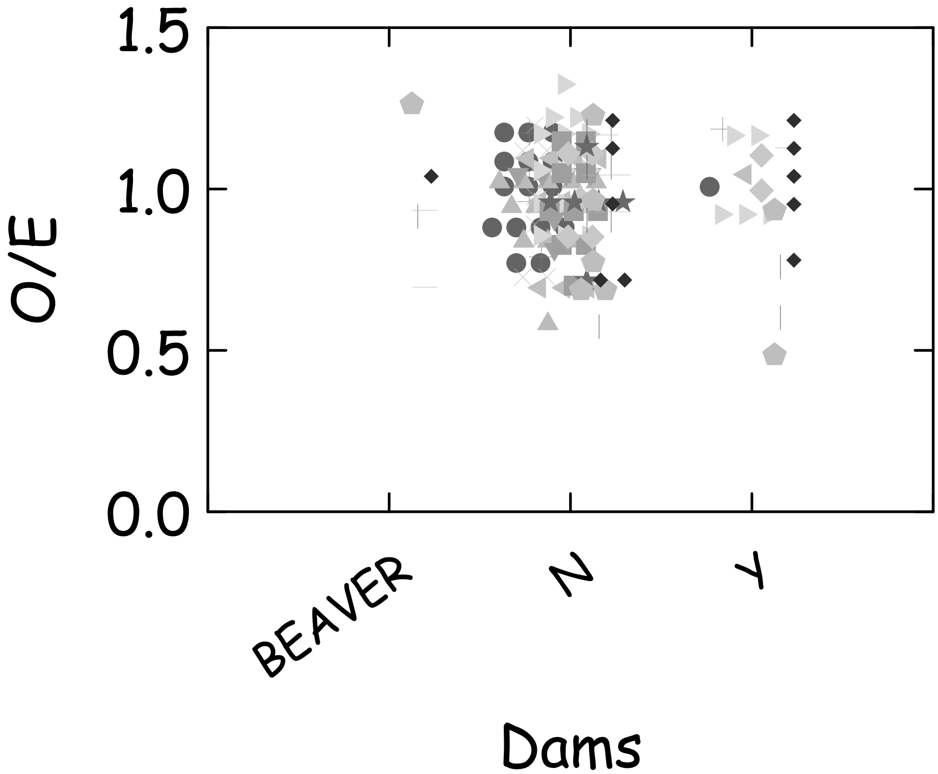
O/E values were not associated with stream gradient.



O/E values were not associated with ecoregion.



Upstream dams did not affect O/E values at reference sites.

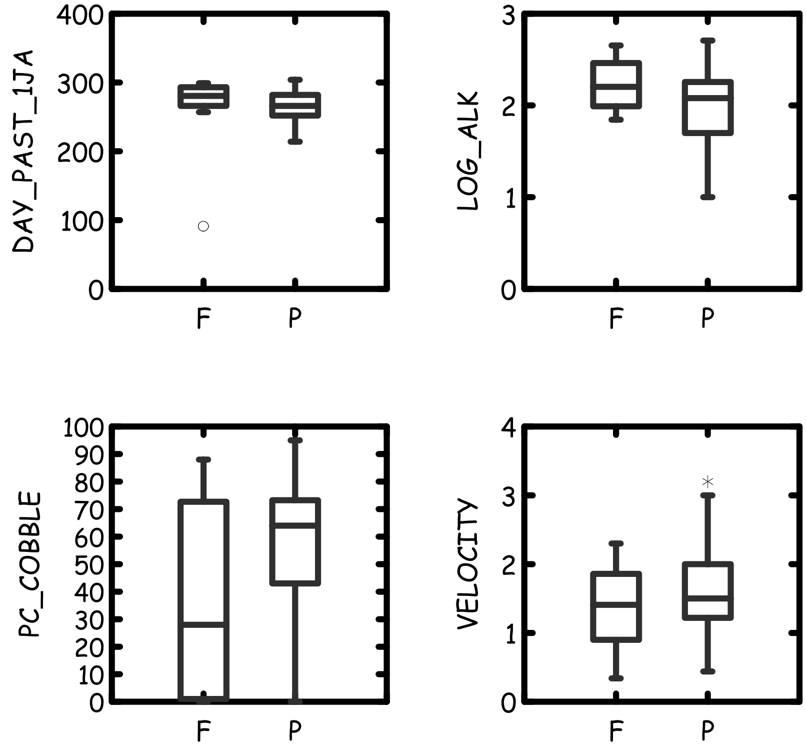


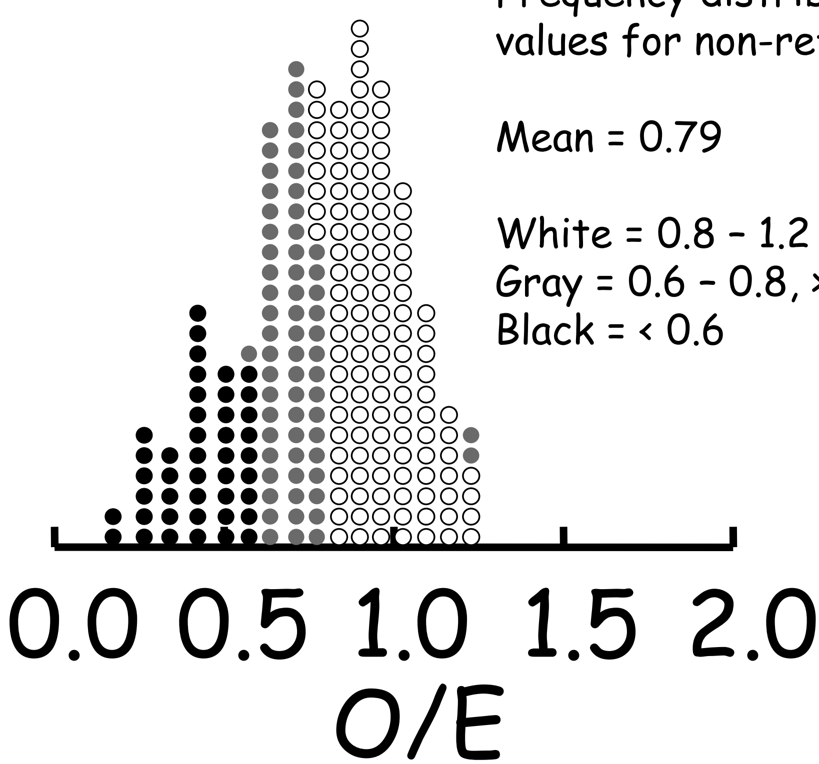
Applying the Model to Test Sites

Simple statistical tests can be applied to the predictor variables measured at a new site to determine if the model applies.

If it doesn't, the program is prevented from conducting an assessment.

Of 241 non-reference sites, 14 (6%) were outside of the experience of the model and an assessment was not calculated.



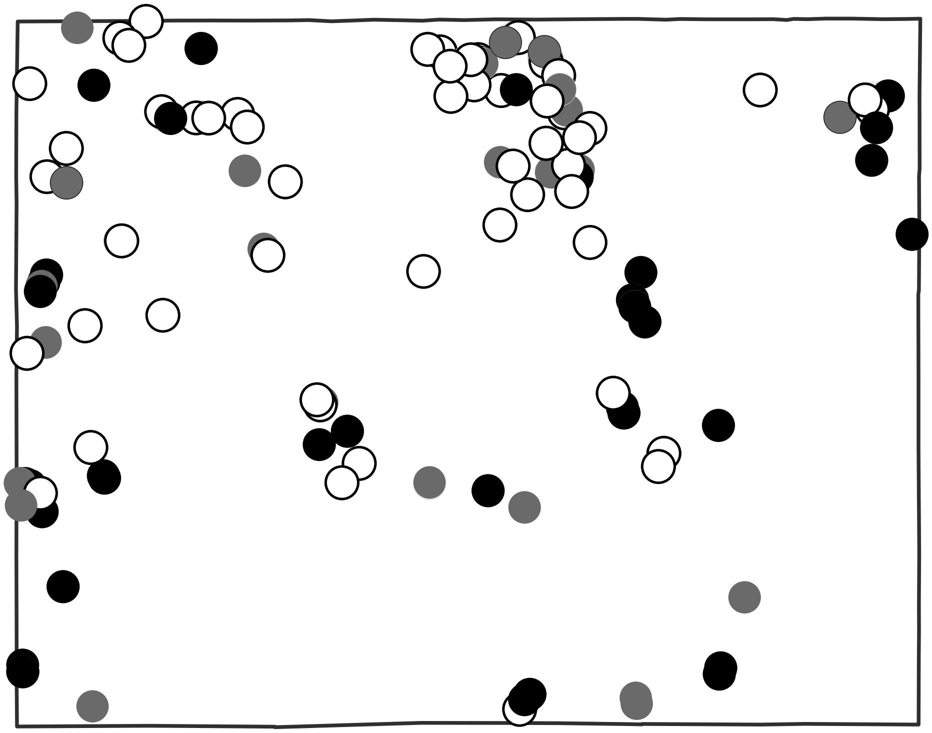


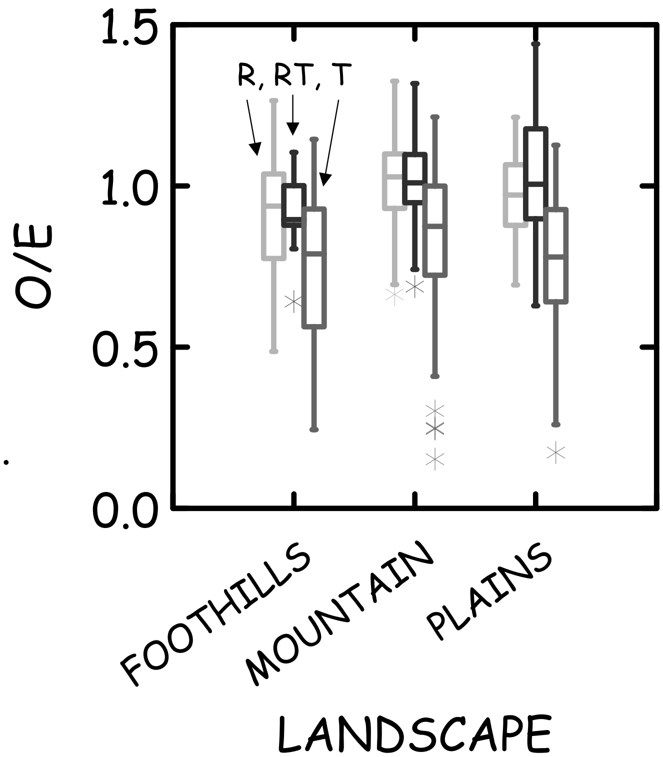
Frequency distribution of O/E values for non-reference sites.

Mean = 0.79

White = 0.8 – 1.2 (53%)
Gray = 0.6 – 0.8, > 1.2 (28%)
Black = < 0.6 (19%)

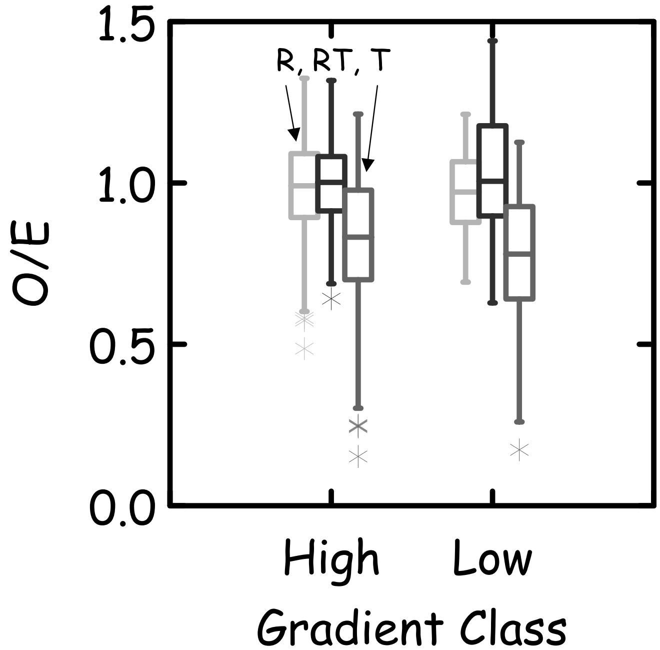
Spatial Distribution of O/E Classes for Non-Reference Sites



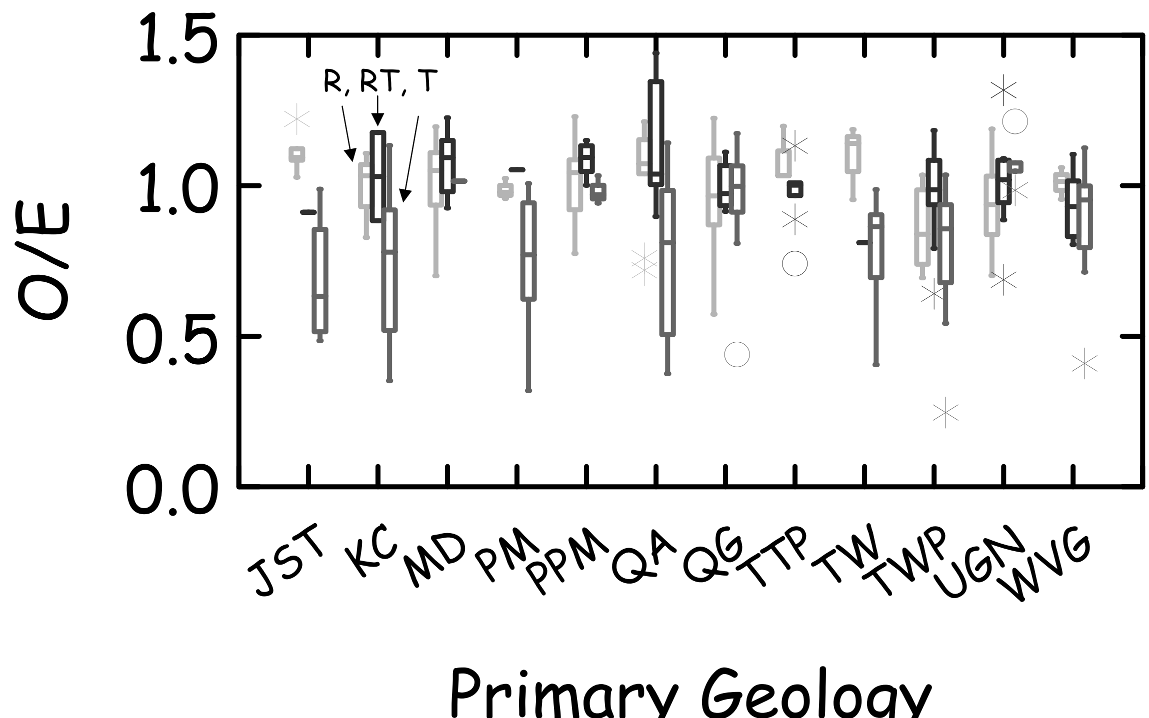


Mountain streams were slightly less impaired than streams in other landscapes.

Low-gradient test sites were no more impaired than high-gradient test sites.



The difference between reference and test site O/E values did depend on geologic setting.



Taxon Specific Responses Can be Used to Help Diagnose Causes of Impairment

From the Test Site Probability Matrix, we can see that across all of the test sites, some taxa decreased, some increased, and others showed little change.

Model outputs can also be used to identify potentially sensitive and tolerant taxa.

Sensitivity Index (SI)

$$\frac{\text{\# sites taxon was observed}}{\text{\# sites taxon was expected}}$$

SI is different than a conventional tolerance value. SI measures 'tolerance' or 'sensitivity' relative to a taxon's natural tolerance/sensitivity.

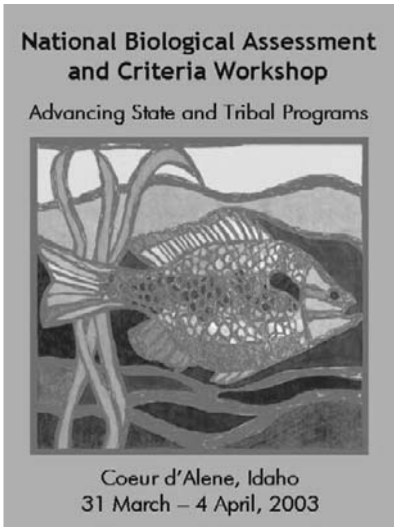
Wyoming Decreaser Taxa

TAXA	Mean PC	Expected	Observed	SI
Rhyacophila_betteni_grp	0.16	36.22	8	0.22
Deuterophlebia	0.06	13.30	3	0.23
Stempellinella	0.07	15.89	4	0.25
Wiedemannia	0.05	11.53	3	0.26
Rhyacophila_cyalinata_grp	0.08	18.25	5	0.27
Neophylax	0.05	10.98	4	0.36
Dolophilodes	0.12	26.65	10	0.38
Lepidostoma	0.30	68.28	27	0.40
Rhyacophila_pellisa	0.19	42.40	19	0.45
Zapada_columbiana	0.13	29.01	13	0.45
Ecclisomyia	0.08	19.08	9	0.47
Megarcys	0.24	55.14	28	0.51
Tanytarsus	0.07	15.72	8	0.51
Rhyacophila_coloradensis_grp	0.23	52.91	28	0.53
Neothremma	0.20	44.99	25	0.56
Parapsyche_elsis	0.28	63.90	36	0.56
Caudatella	0.05	12.36	7	0.57
Epeorus	0.51	114.76	66	0.58
Doroneuria	0.15	34.63	20	0.58
Drunella_coloradensis_flavilinea	0.33	75.64	44	0.58

Wyoming Increaser Taxa

TAXA	Mean PC	Expected	Observed	SI
Pseudochironomus	0.01	1.53	9	5.88
Nais_variabilis	0.01	3.13	18	5.76
Cryptochironomus	0.02	4.59	21	4.57
Hesperophylax	0.03	6.05	20	3.31
Paratanytarsus	0.01	3.06	10	3.27
Prodiamesa	0.01	3.13	9	2.88
Phaenopsectra	0.02	4.60	12	2.61
Pseudodiamesa	0.02	3.84	10	2.61
Planorbidae	0.02	4.82	12	2.49
Stenonema	0.02	5.26	13	2.47
Hydrobaenus	0.08	18.21	44	2.42
Hydrophilidae	0.03	7.10	16	2.25
Hemerodromia	0.06	13.98	31	2.22
Ceratopogonidae	0.05	10.91	23	2.11
Parametriocnemus	0.04	10.02	21	2.09
Microtendipes	0.06	14.03	28	2.00

It's time for questions and some exercises!



Index 201

Confidence: Variability & Reliability

Presented by

Jeroen Gerritsen, Tetra Tech, Inc.

Problem

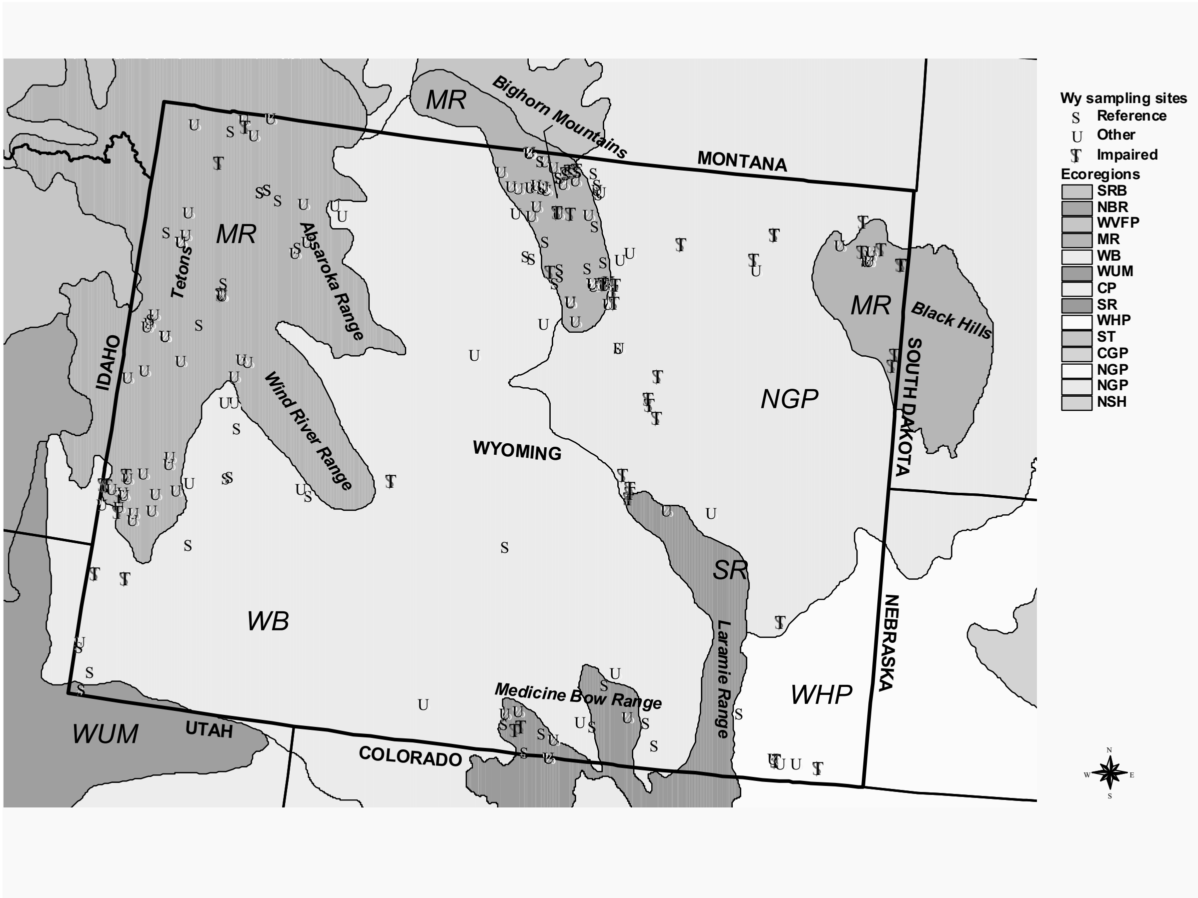
- Perceived variability of community-level bioassessment
  - Many species, taxonomic uncertainty
  - Here today, gone tomorrow
  - Plethora of sampling and analytical methods; no standardization

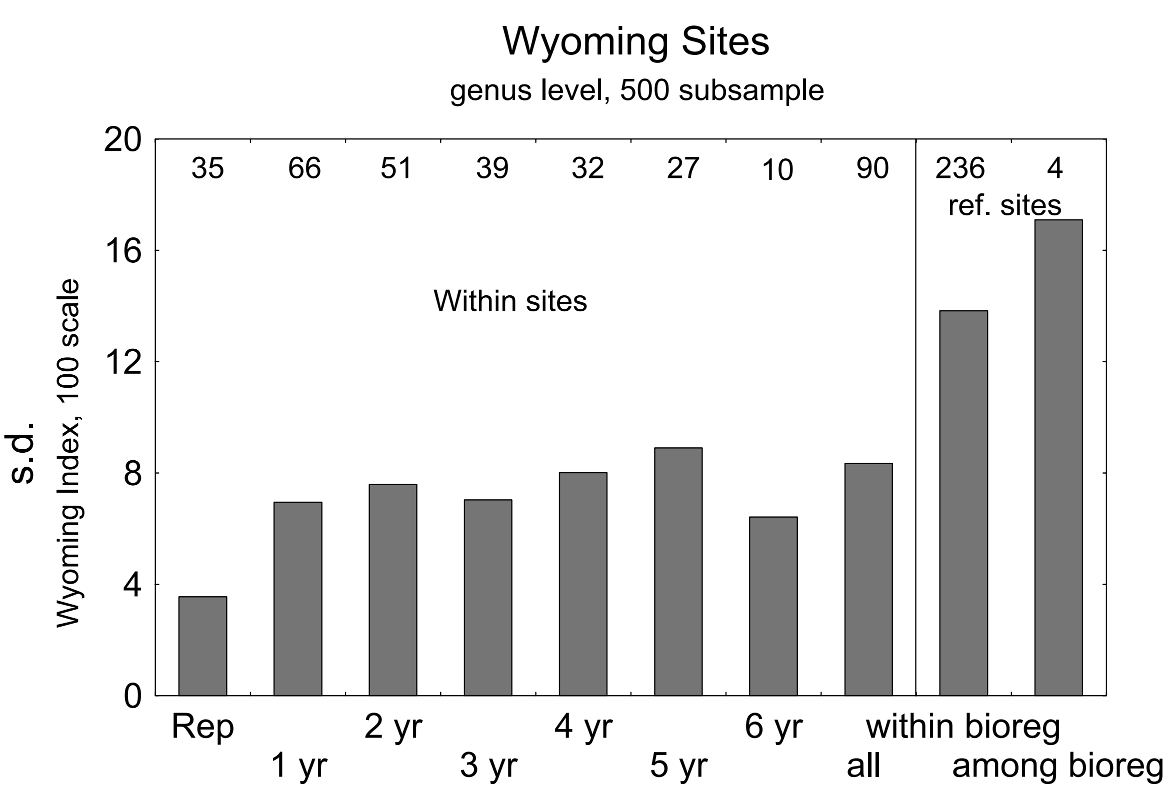
Solutions

- Standardized collection methods
- Stable metrics and indexes (no abundance, ratio metrics)
- Estimate variability!

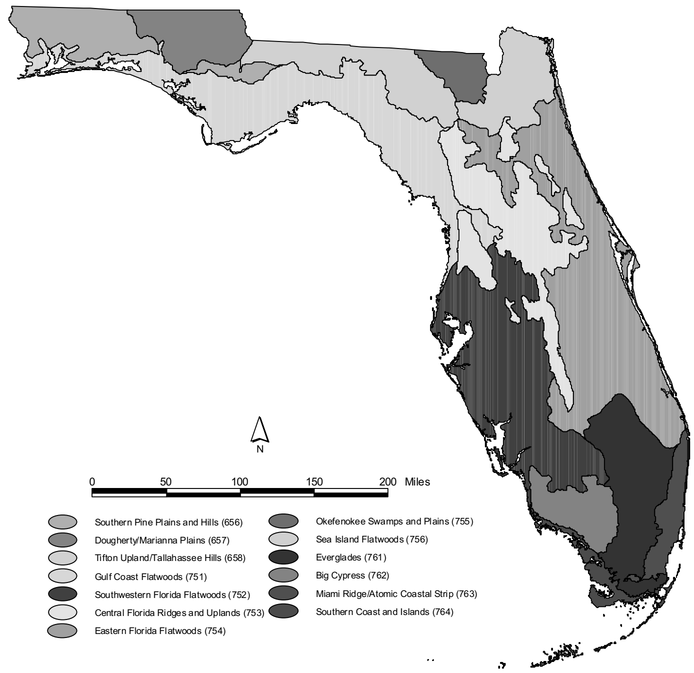
Estimating variability

- Replicate samples: measurement error
- Seasonal: among index periods (spring, fall)
- Interannual: repeat site visits (2-6 yr)
- Among sites within regions
- Among regions


Wy sampling sites
S Reference
U Other
T Impaired
Ecoregions
SRB
NBR
WVFP
MR
WB
WUM
CP
SR
WHP
ST
CGP
NGP
NGP
NSH
MR
Bighorn Mountains
MONTANA
MR
Tetons
Absaroka Range
IDAHO
Wind River Range
WYOMING
NGP
MR
Black Hills
SOUTH DAKOTA
SR
Laramie Range
NEBRASKA
WHP
WB
Medicine Bow Range
WUM
UTAH
COLORADO

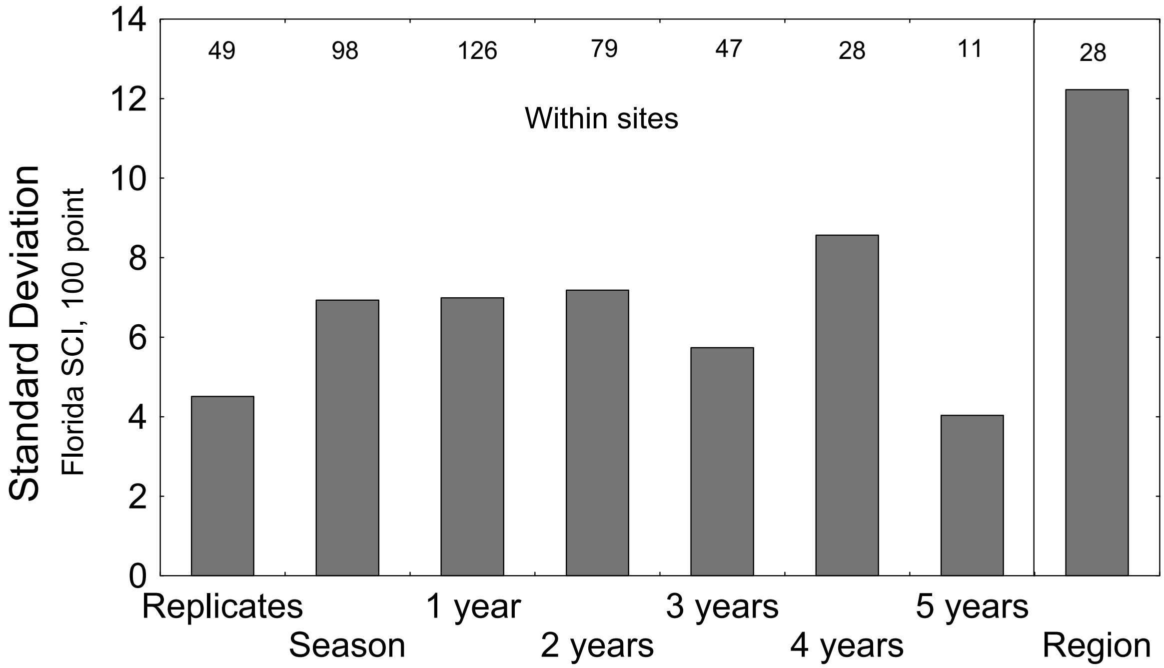

Wyoming Sites
genus level, 500 subsample
s.d.
Wyoming Index, 100 scale
20
16
12
8
4
0
35
66
51
39
32
27
10
90
236
4
ref. sites
Within sites
Rep
1 yr
2 yr
3 yr
4 yr
5 yr
6 yr
all
within bioreg
among bioreg

Level IV Sub-Ecoregions for Streams



Florida Peninsula

Genus level, 100 subsample



Chemical and biological

- Biotic indexes (100 pt)
  - Multiyear s.d. = 7
  - Or, approximately 9-11% of reference site scores
- Conductivity (VA)
  - Log-transformed s.d = 0.145
  - 1 s.d. is –29% to +40% of measured conductivity
- Total P (Florida)
  - 1 s.d. is –50% to +100% of measured value

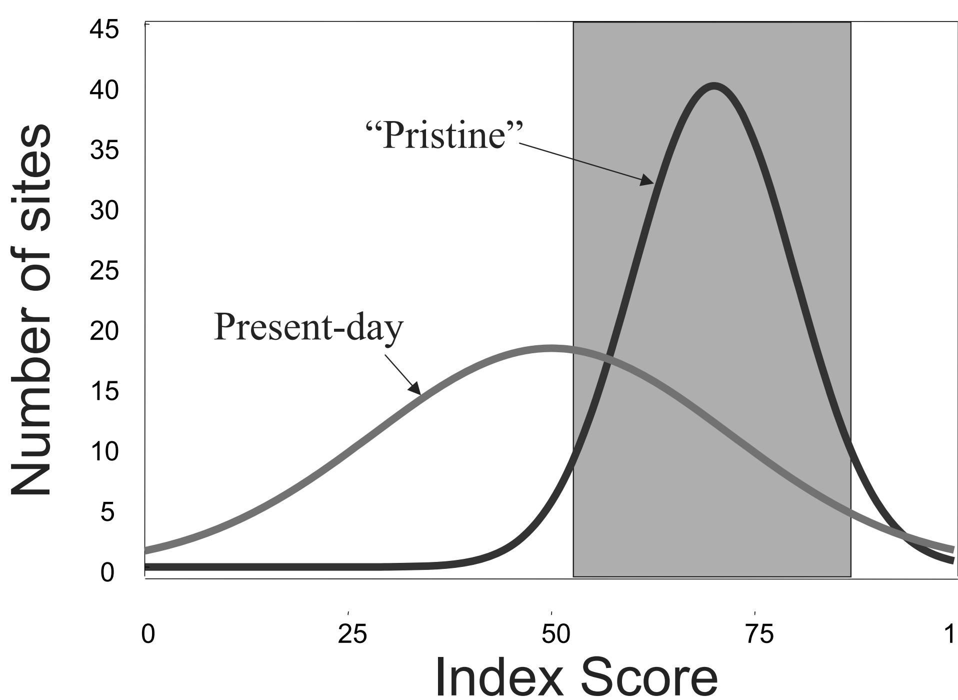
Conclusions

- High variability of biological measures is a myth!
- Equivalent power of detection for a **10%** decline in biotic index, and a **doubling** of nutrient concentrations

Biocriteria decision points

Where is the threshold?

Reference sites in an imperfect world



Decision Errors

- Type I - false positives, i.e., reject the null hypothesis when it is true
  - ***Unnecessary regulation***
- Type II - false negatives, i.e., accept the null hypothesis when it is false.
  - ***Continued degradation of the resource***

Decision Errors

Decision

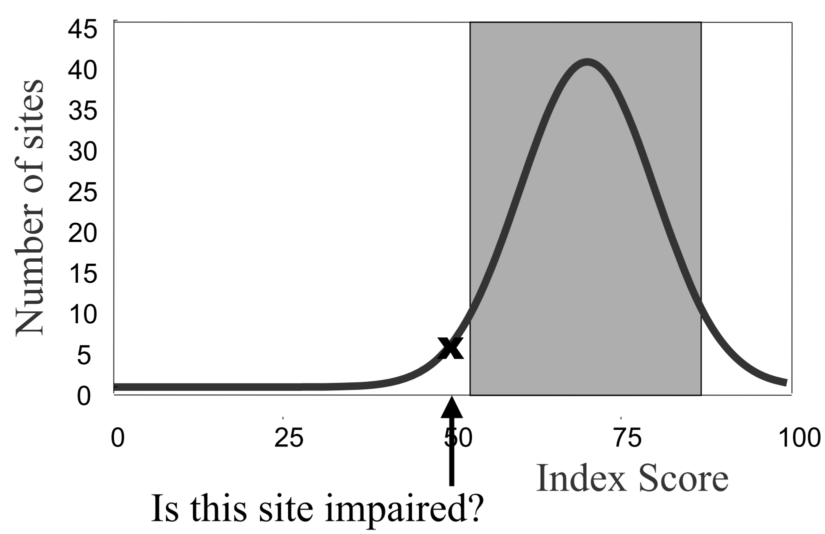
State of the world

	Accept null (Do not detect effect)	Reject null (Detect effect)
Null is true (no effect)	Correct p=1-α confidence	Type I error $p = \alpha$ significance (false positive)
Null is false (effect exists)	Type II error $p = \beta$ (false negative)	Correct p =1- β power

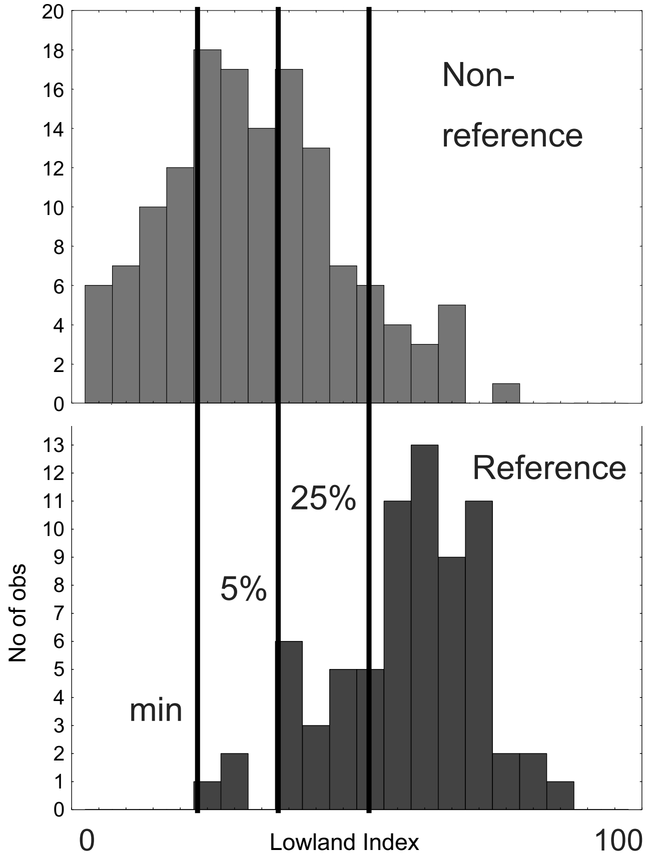
Issues in setting thresholds

- What is balance between Type 1 and Type 2 errors?
- Variability
- Confidence in reference site selection
- What is politically acceptable or desirable?

Where does impairment begin?



Null hypothesis: site is member of unimpaired population.
Test: Estimate the percentile.



Wyoming Plains
Multimetric index

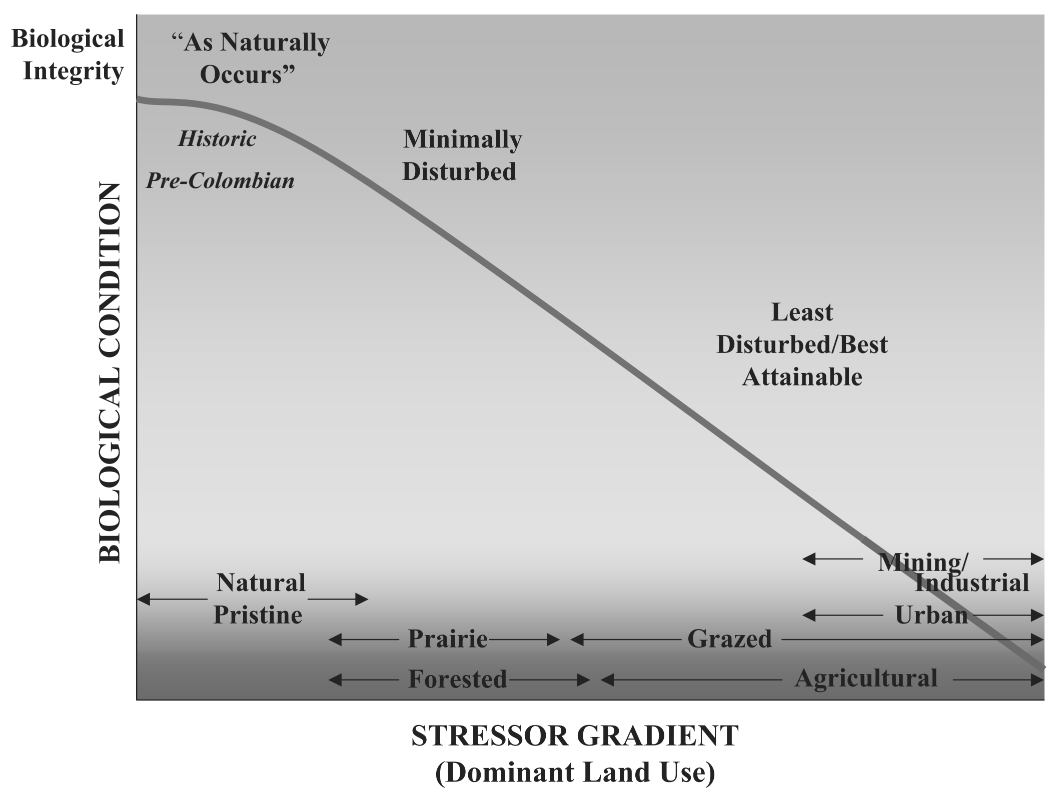
Reference sites
Mean = 59
Median = 61
s.d. = 13.5
25% = 51
5% = 36
Minimum = 21

Biocriteria

Indexes
And
Tiered Aquatic Life Use

Draft Tiered Aquatic Life Use

- Human disturbance gradient
- Biological condition gradient



*Protection & Propagation of Fish, Shellfish and Wildlife

Biological Condition Gradient

1. Native or natural condition
2. Minimal loss of taxa; some density changes
3. Some replacement of sensitive-low abundance taxa; functions fully maintained
4. Some sensitive taxa maintained; notable replacement by tolerant taxa; altered distributions; functions maintained
5. Tolerant taxa more dominant; sensitive taxa rare; functions altered
6. Severe alterations of structure and function

Tiers

1. Native or natural condition
2. Minimal loss of taxa; some density changes

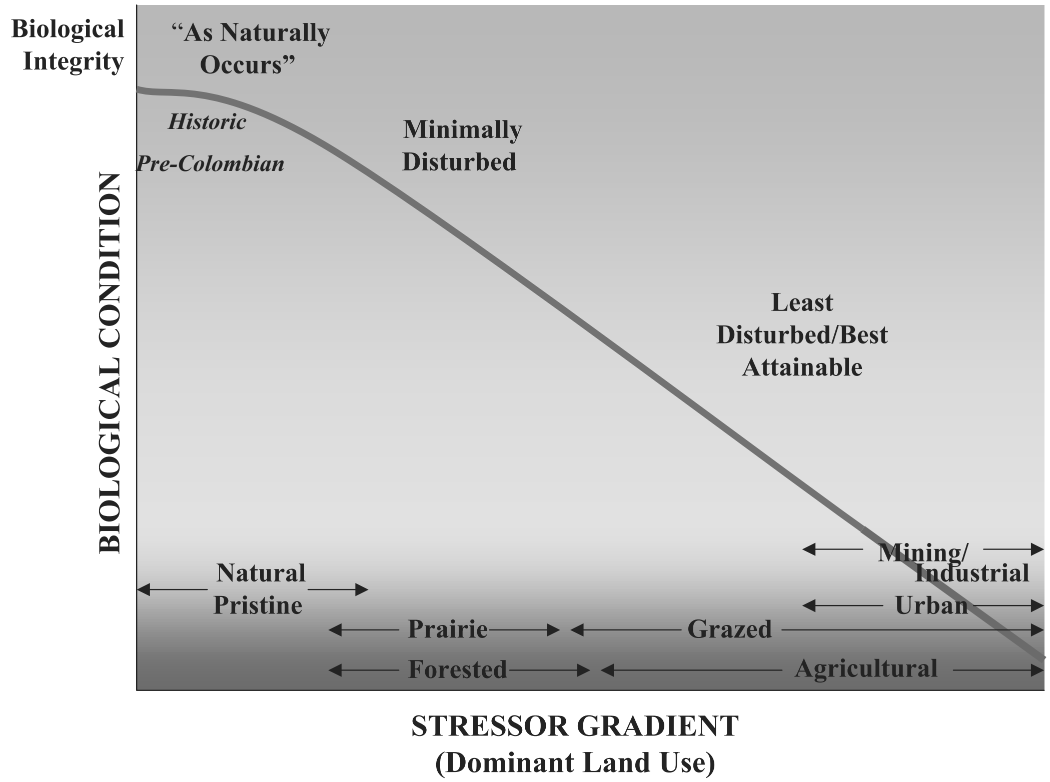
CWA Goal: biological integrity

3. Some replacement of sensitive-low abundance taxa; functions fully maintained
4. Some sensitive taxa maintained; notable replacement by tolerant taxa; altered distributions; functions maintained

CWA Interim Goal: degraded, but fishable-swimmable

5. Tolerant taxa more dominant; sensitive taxa rare; functions altered
6. Severe alterations of structure and function

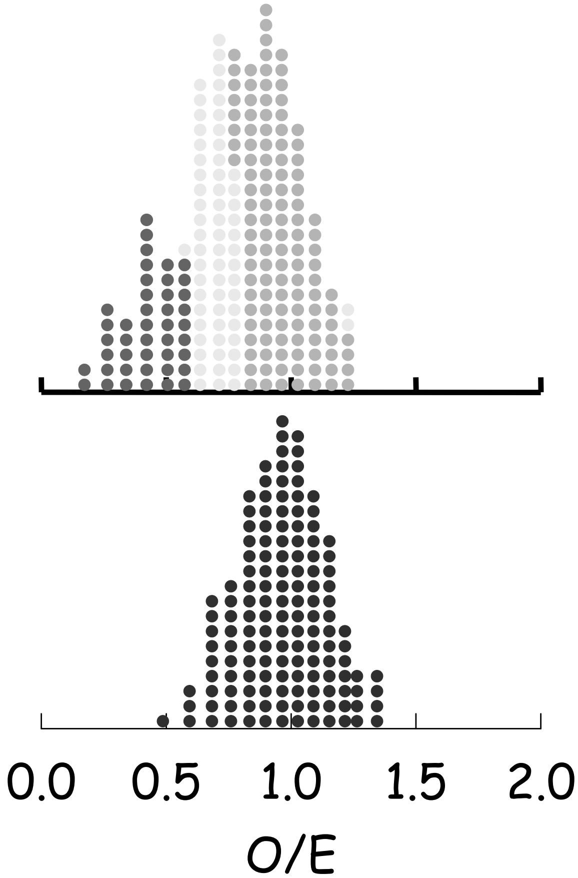
Unacceptable



*Protection & Propagation of Fish, Shellfish and Wildlife

How many tiers can we detect?

- Depends on variability of our indicator
- What is range of index value for single category in biological condition gradient?
- Assessment "bands"



Wyoming O/E

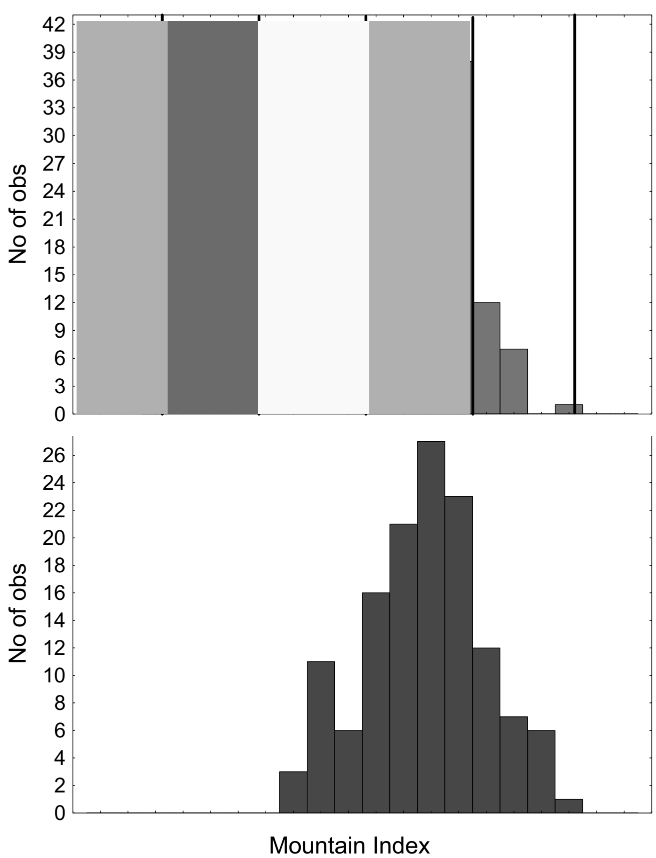
Non-reference sites.

Mean = 0.79

Green = 0.8 – 1.2	(53%)
Yellow = 0.6 – 0.8	(28%)
Red = < 0.6	(19%)

Reference site O/E values.

Mean = 0.98
S.D. = 0.16
10th percentile = 0.73
90th percentile = 1.19

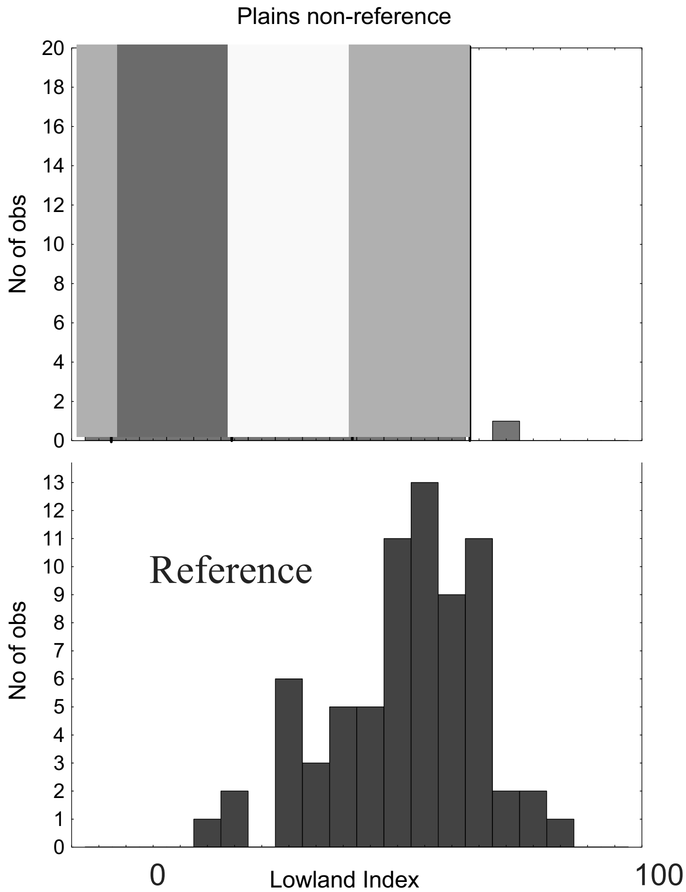


Wyoming Rocky Mts.
Multimetric index

Non-Reference

Green, 51-70 = 48%
Yellow, 32-51 = 36%
Red, 14-32 = 6.6%
Gray, <14 = 2%

Reference
Mean = 61
Median = 61
s.d. = 11.0
20% = 51
80% = 70



Wyoming Plains Multimetric index

Non-Reference

Green, 49-71 = 14%
Yellow, 27-49 = 41%
Red, 5-27 = 40%
Gray, <5 = 4%

Reference
Mean = 59
Median = 61
s.d. = 13.5
20% = 49
80% = 71