

Modeling the Reference Condition for Use in Bioassessments:

Environmental Heterogeneity, Niche Models and the “O/E” Index

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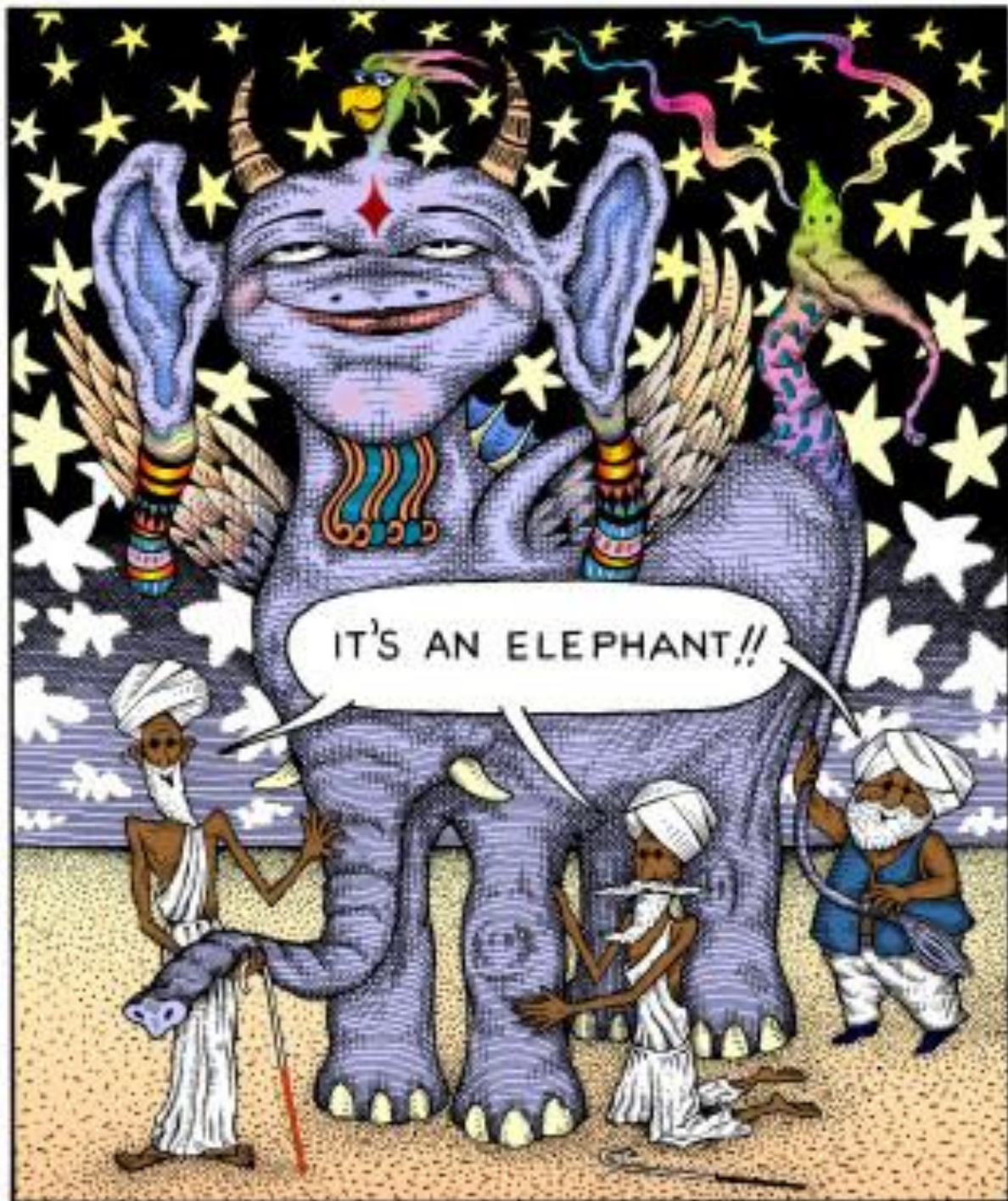
Lower Truckee River Bioassessment Symposium

5 January 2009

The state of bioassessment

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摸象之圖



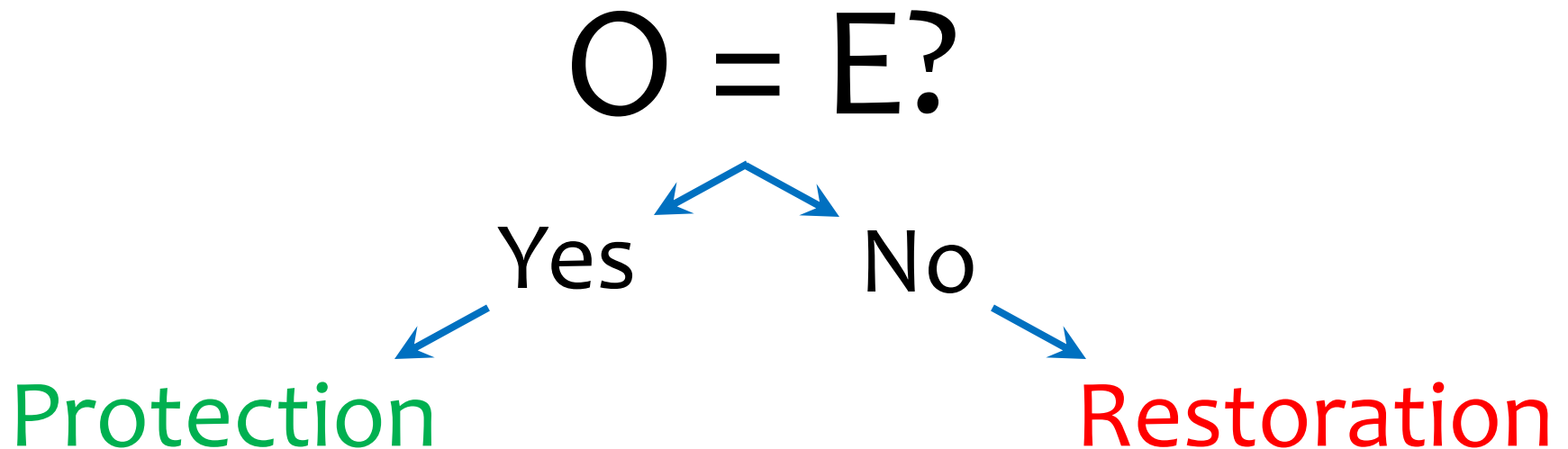


Today

- Reference condition concepts & issues.
 - Does $O = E$? Effects of different sources of index variability on errors of inference.
 - Natural environmental heterogeneity, random error, and systematic error.
- O/E_{taxa} : an index of taxonomic completeness.
- Niche modeling to predict E_{taxa} .
- Examples of the application of O/E_{taxa} .

The Reference Condition

All bioassessments
compare O with E:



The Reference Condition

O and E are the observed and expected values of biological attributes or properties or INDICES of interest:

biodiversity, ecosystem function, etc.

The Reference Condition

E = reference or benchmark values defined by society but often interpreted to mean ‘natural’ or near natural or “least disturbed”.

The Reference Condition

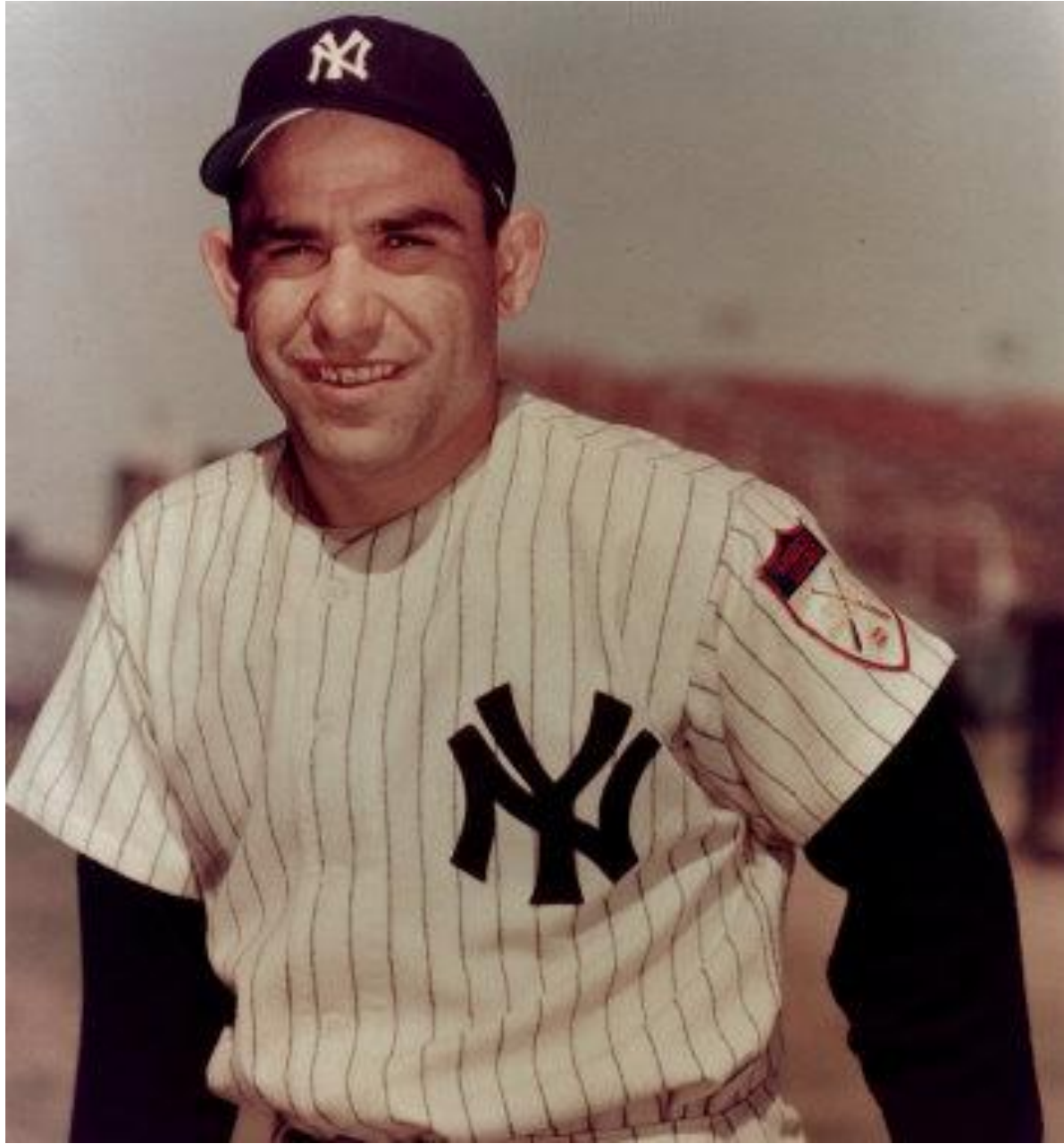
E varies naturally with environmental setting, ...
thus creating one of the major technical challenges in bioassessment.

Important Issues

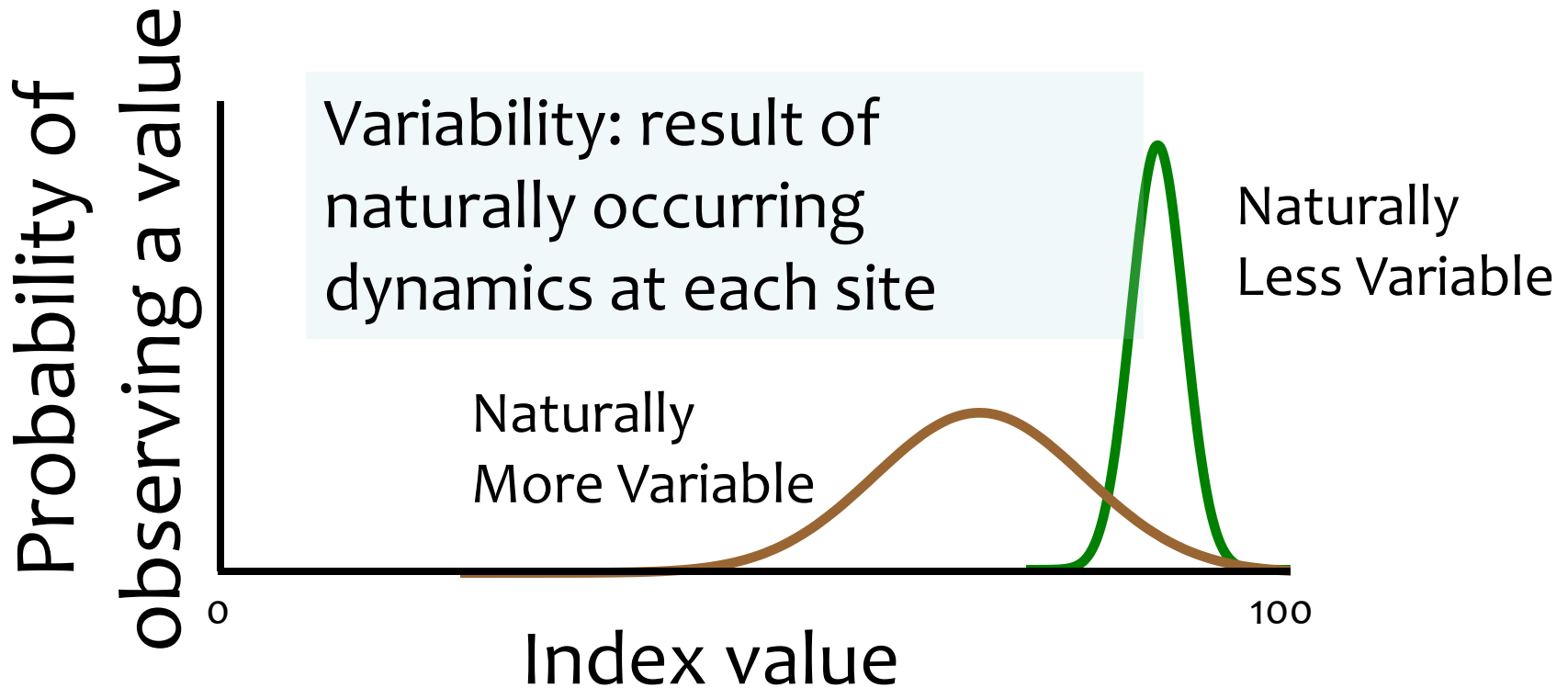
- Reference sites: used to infer (predict) the appropriate reference conditions.
- Reference is not static – it represents “**the range of natural variation**”, but...
 - We seldom parse variation associated with measurement error, natural temporal variation, and systematic variation.
- The spatial and temporal scales of inference are often not fully defined or understood.
 - e.g., is reference a site-specific or a regional property?

The reference condition as a probability statement

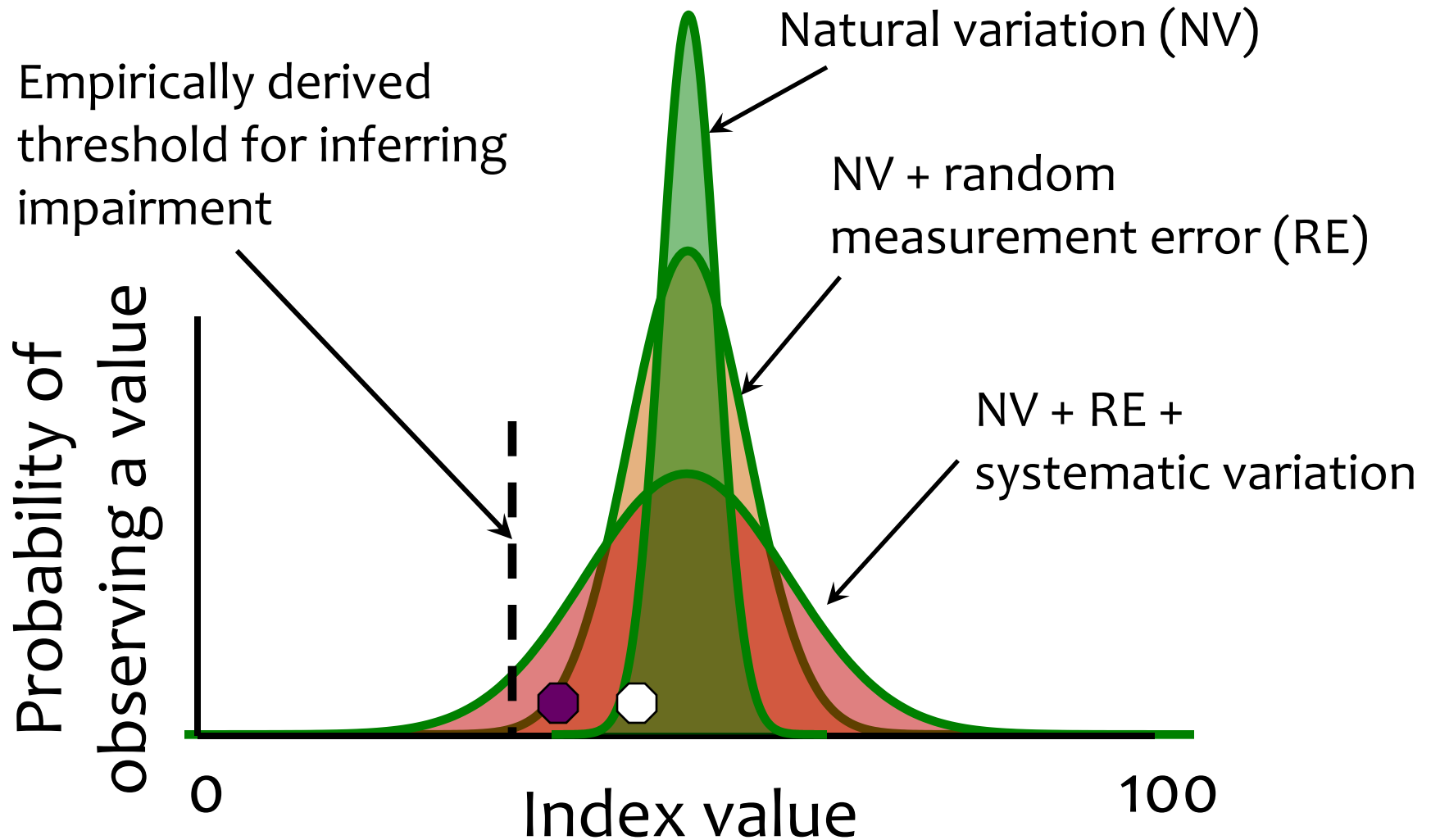
“90% of the game is half mental.”
(Yogi Berra)



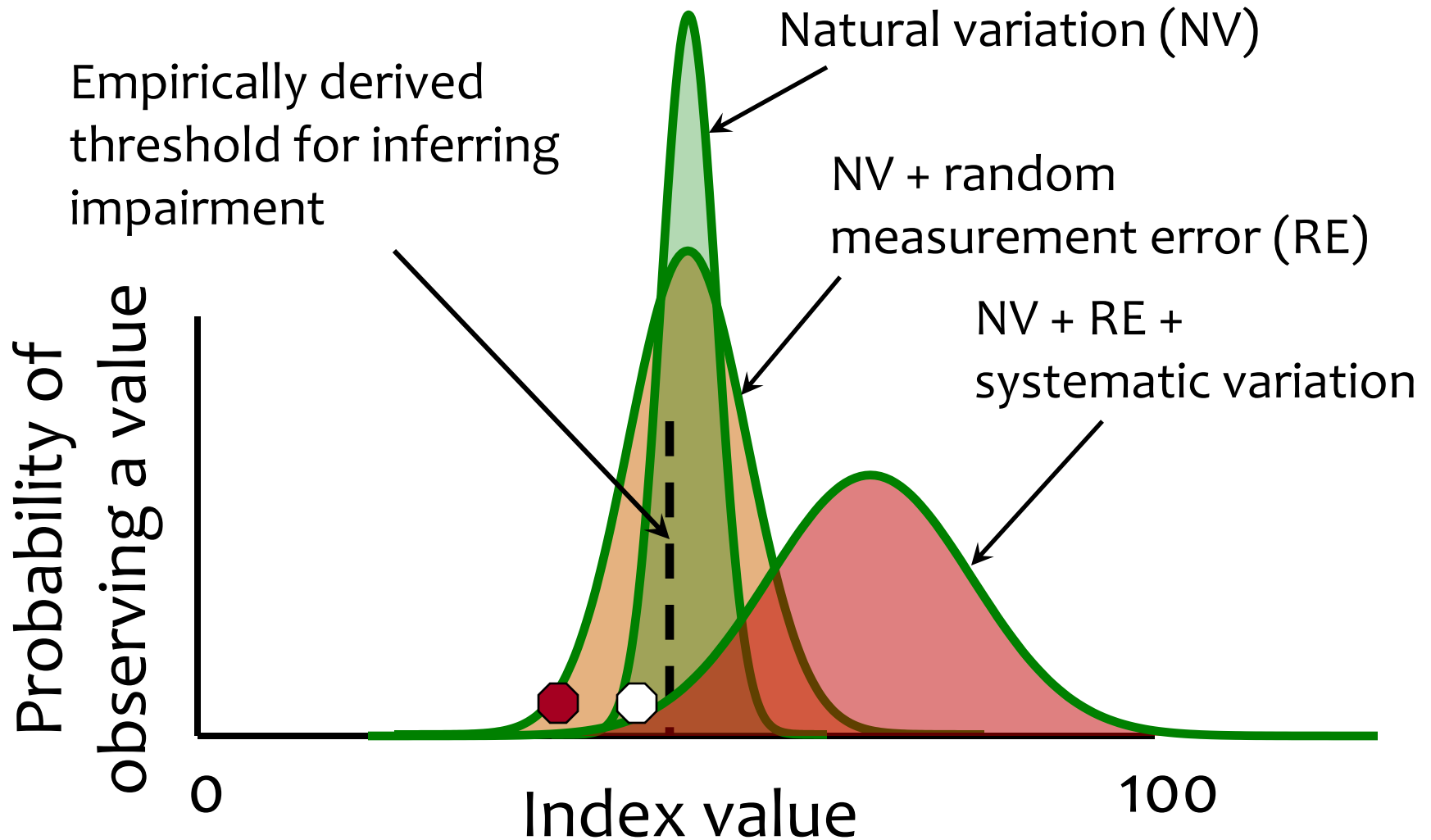
Reference: the likelihoods of observing different attribute values under 'natural' conditions



Sources of Variability in Index Values



Sources of Variability in Index Values



$$O/E_{\text{taxa}}$$

an index of
taxonomic
completeness

$O/E_{(taxa)}$ measures how closely the observed taxa matches the expected taxa.

It is an index of biodiversity – a critical component of biological integrity.



$E = 8$ taxa



$O = 3$ taxa

$$\frac{O}{E}$$
$$0.38$$

Why I like this index

- As a ratio, it allows **standardized assessments** within and across heterogeneous regions.
- Continuous modeling of E allows **site-specific assessments**.
- Calibration does not require **stressed sites**.

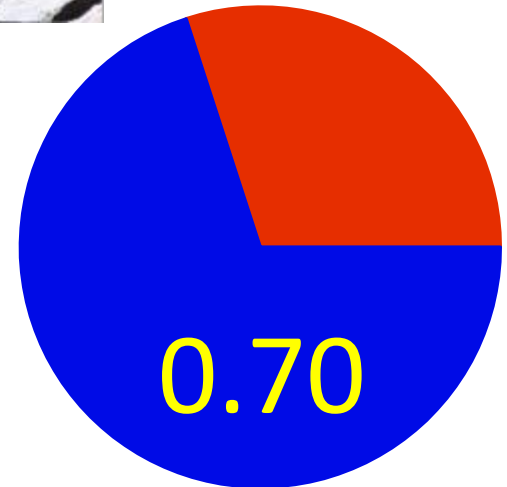
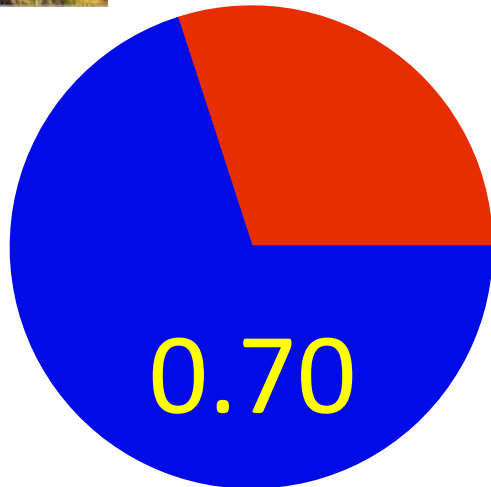
A Hypothetical Example of Using O/E_{taxa} to Compare “Apples and Oranges”



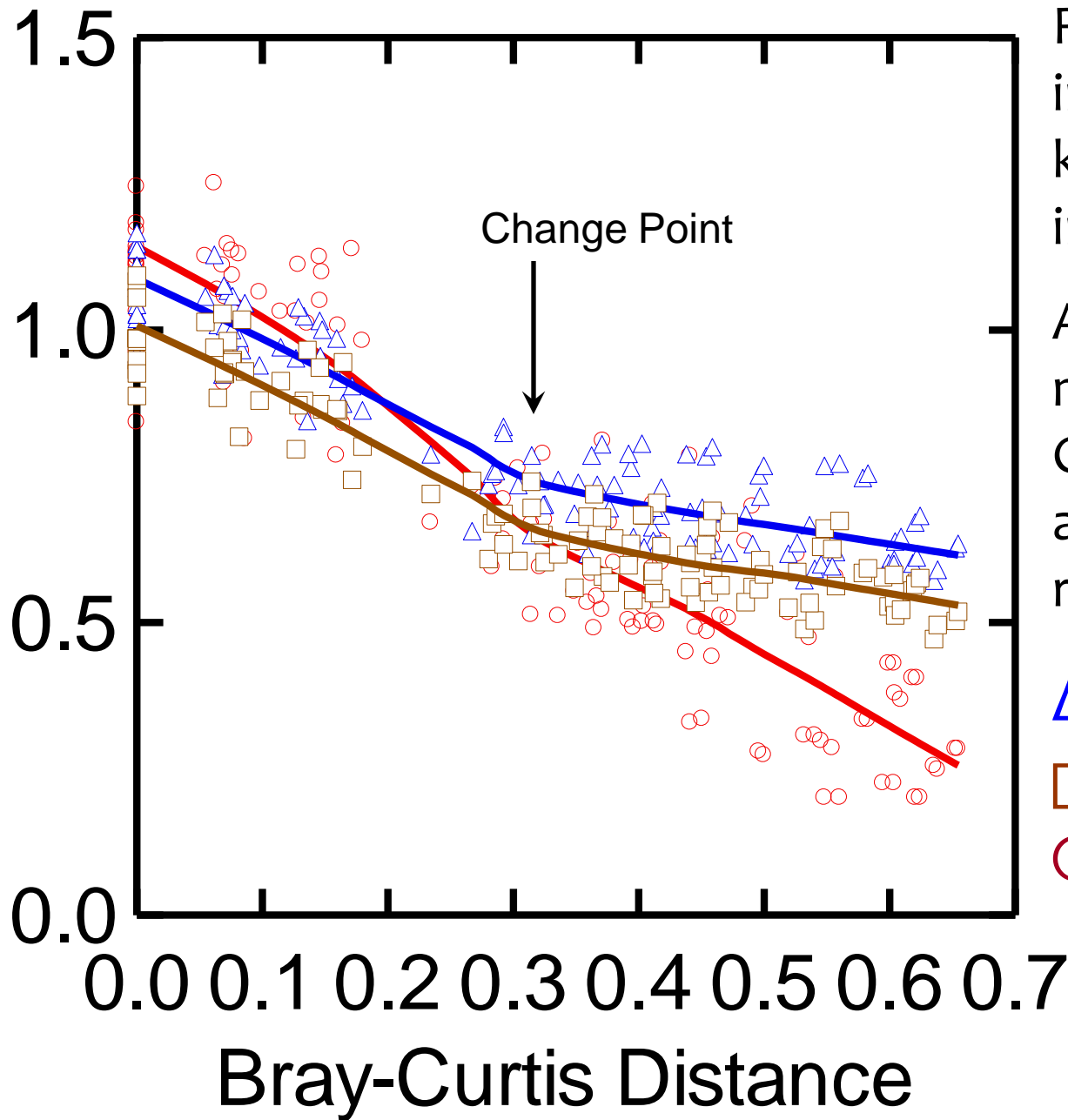
$$O = 7$$
$$E = 10$$



$$O = 21$$
$$E = 30$$



Standardized Indicator



Response of indicators to known alteration in 13 assemblages.

Alteration measured as Bray-Curtis distance (log abundance) from reference.

- △ = Traditional MMI
- = CART Modeled MMI
- = O/E

The Technical Challenge:

Accurately and precisely predicting the biota expected in different waterbodies.



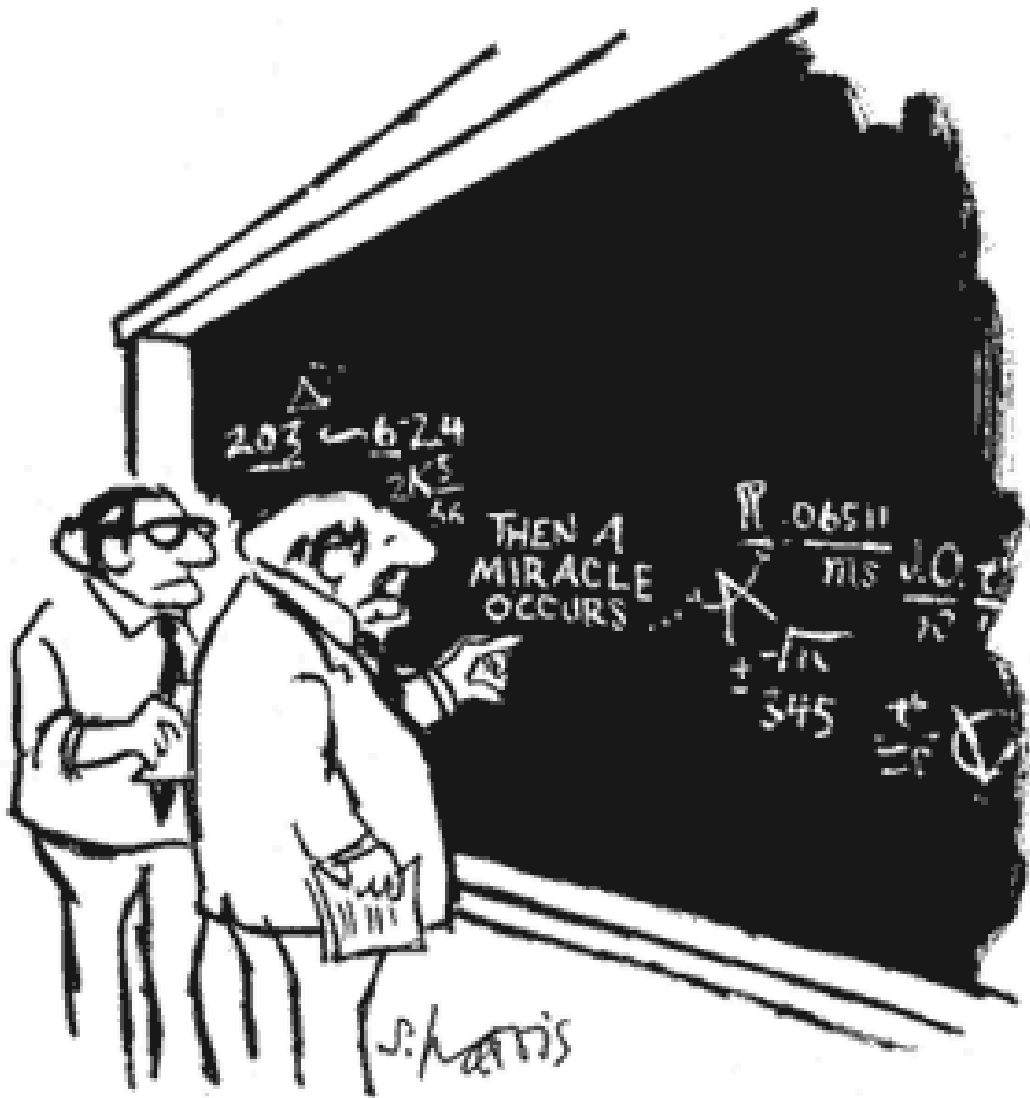
The O/E_{taxa} Approach

1. Develop predictive models that relate variation in taxa occurrences to natural environmental heterogeneity.
2. Quantify model error.
3. Compare the biota observed at a site to that predicted (expected) to occur under natural site conditions.
4. Develop biological criteria and standards that incorporate measures of error and are consistent with the designated uses of different waterbodies.

How O/E is Calculated

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

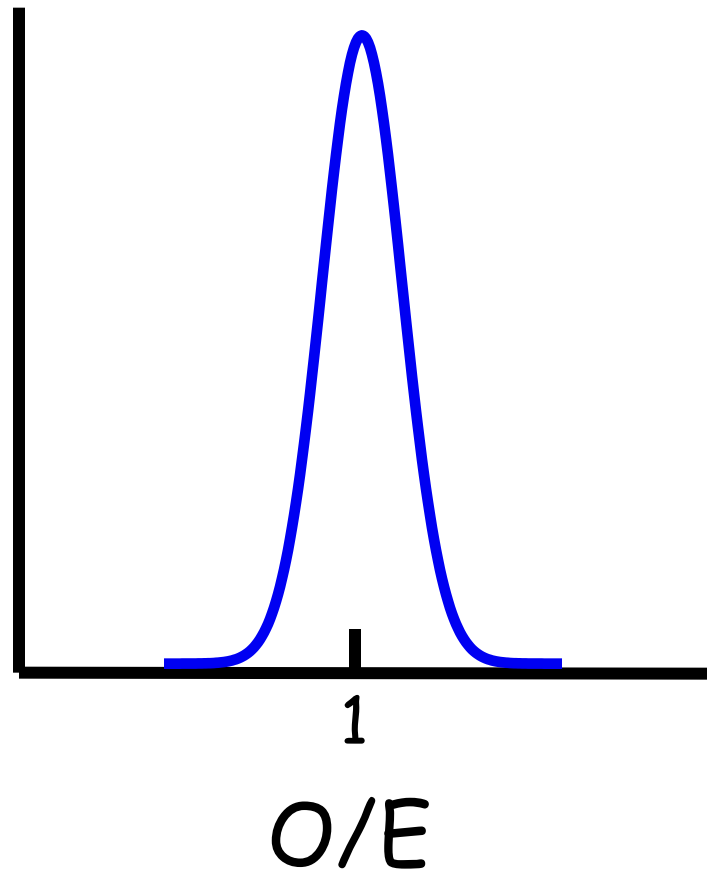
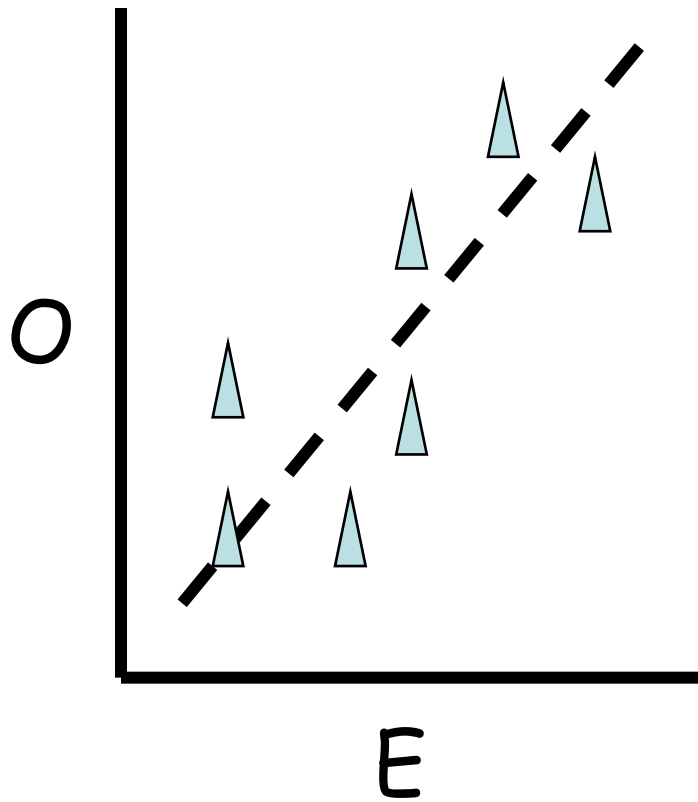
$$O/E = 3 / 4.01 = 0.75$$



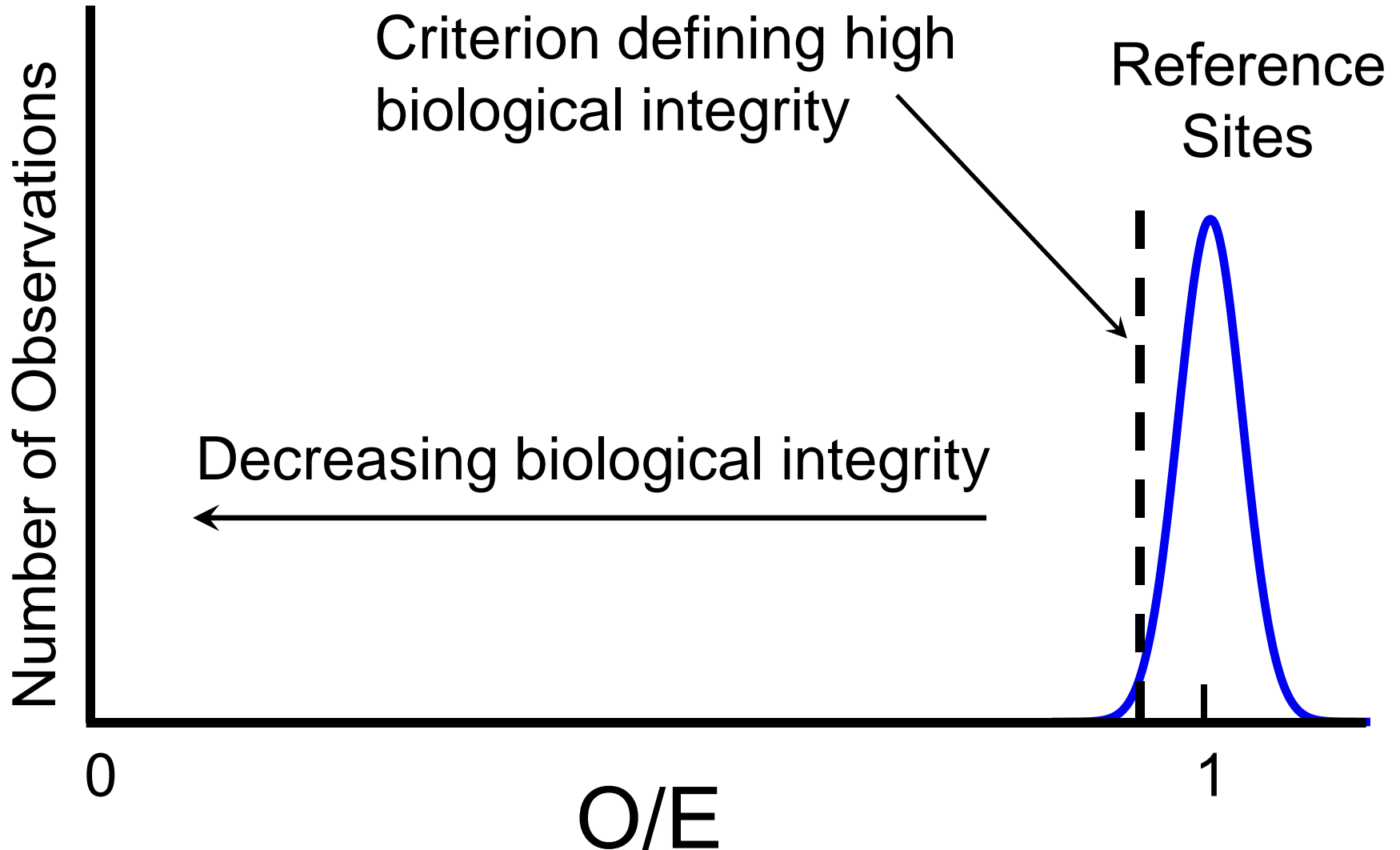
"I THINK YOU SHOULD BE MORE EXPLICIT HERE IN STEP TWO."

RIVPACS models are niche models - they predict probabilities of observing taxa under different environmental settings.

Describing Model Error

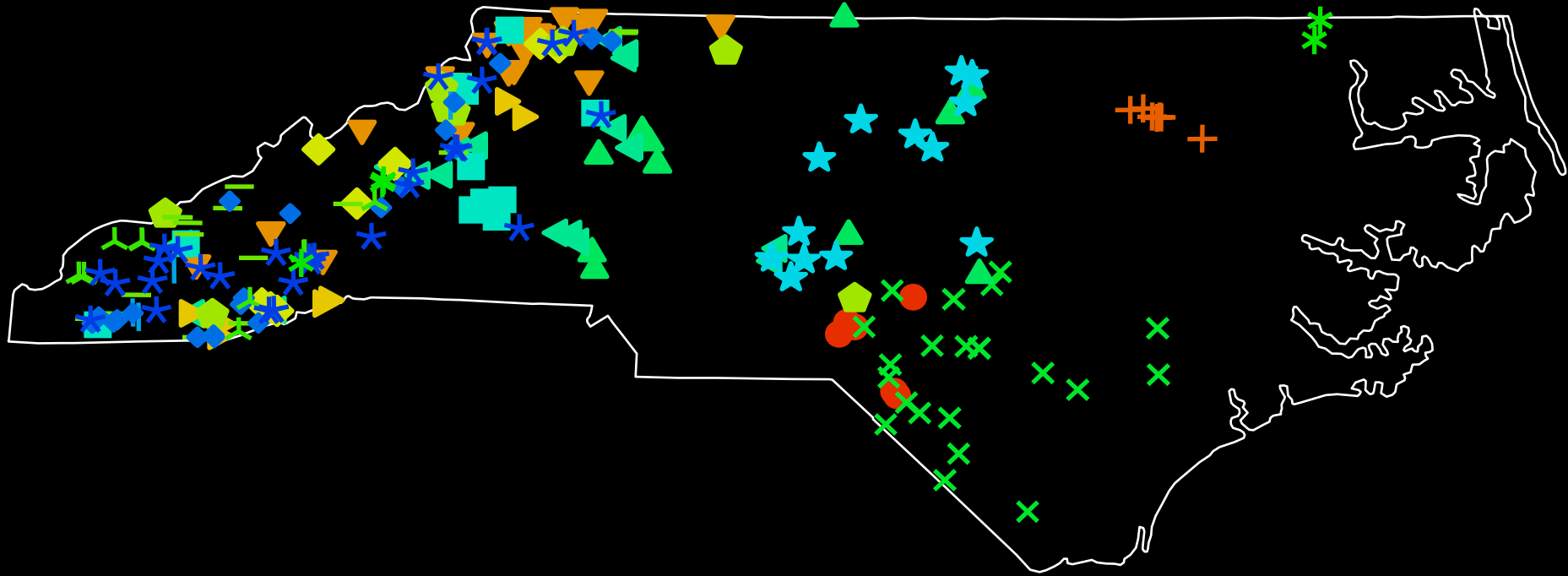


Assessing Biotic Condition



Some Examples

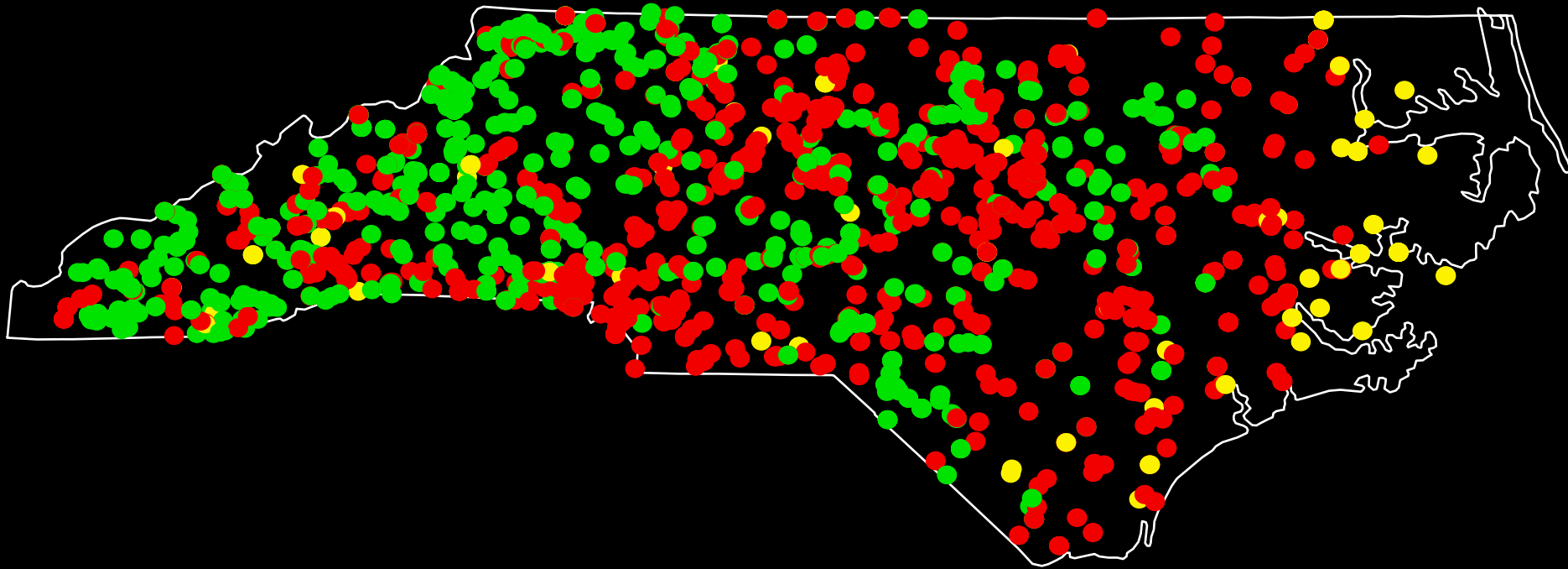
Distribution of 17 reference site groups defined by invertebrate species composition.



Predictor Variables

- latitude
- longitude
- elevation
- distance
from source
- drainage
area
- stream width
- stream
depth
- gradient
- day of year

Distribution of samples that passed (green) and failed (red) assessment based on the O/E threshold of 0.84 (5th percentile of reference values).

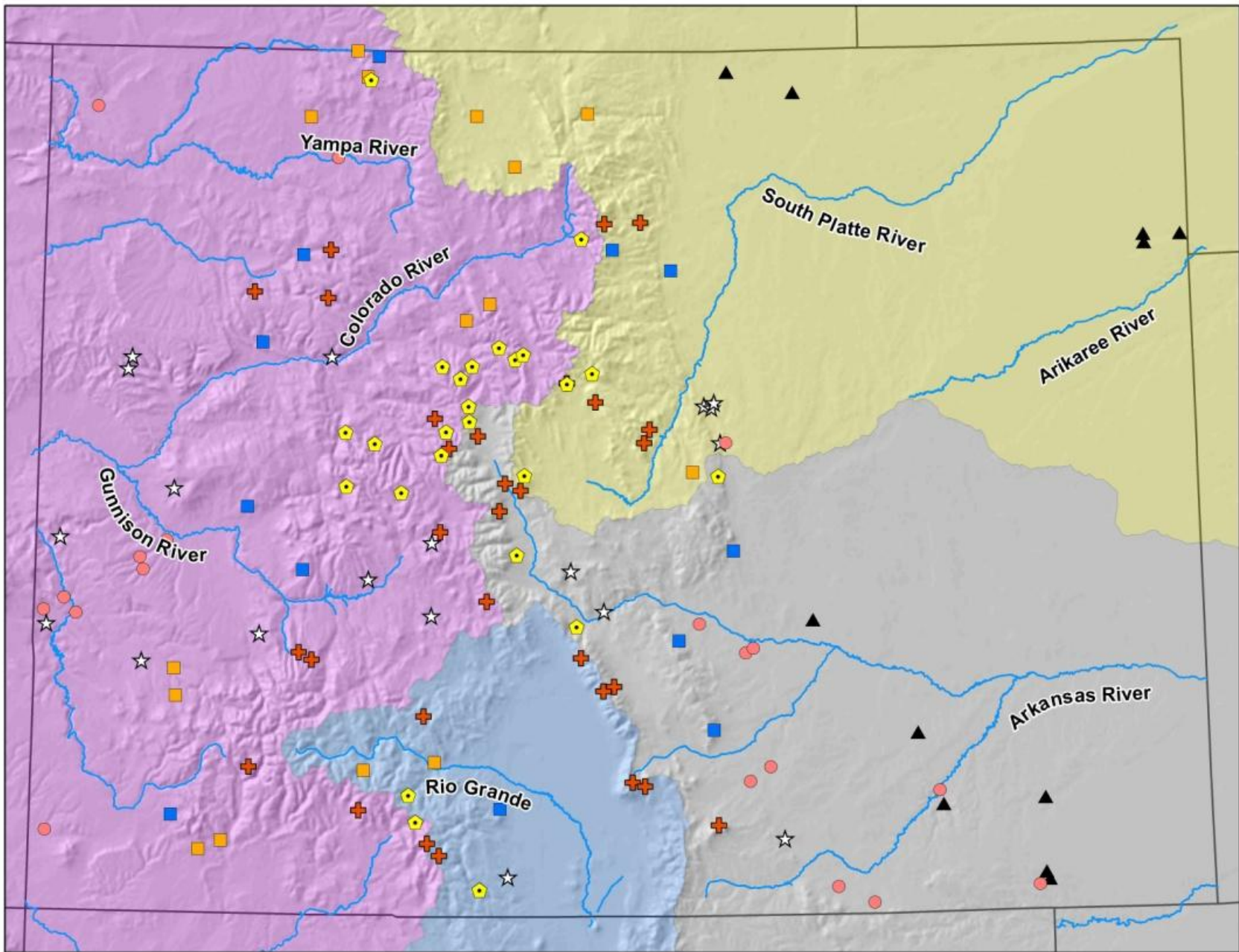


<u>Ecoregion</u>	<u>% of Test Sites ≠ Reference*</u>	<u>Mean O/E**</u>
Coastal Plain	72	0.54
Piedmont	56	0.66
Mountains	36	0.77

* 5th % of reference site values

** Species model ($p > 0.5$)

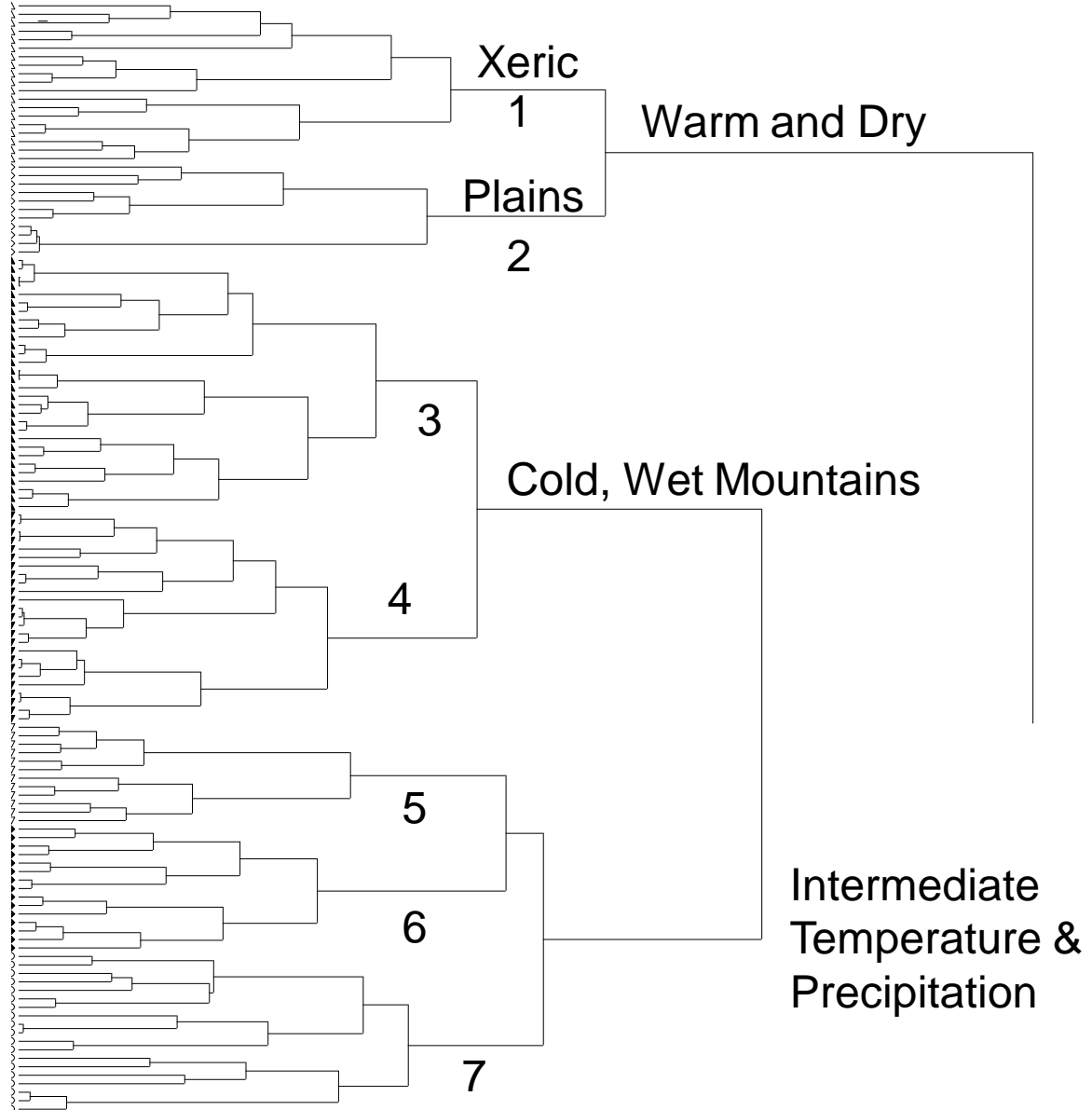
The recently revised Colorado O/E Index



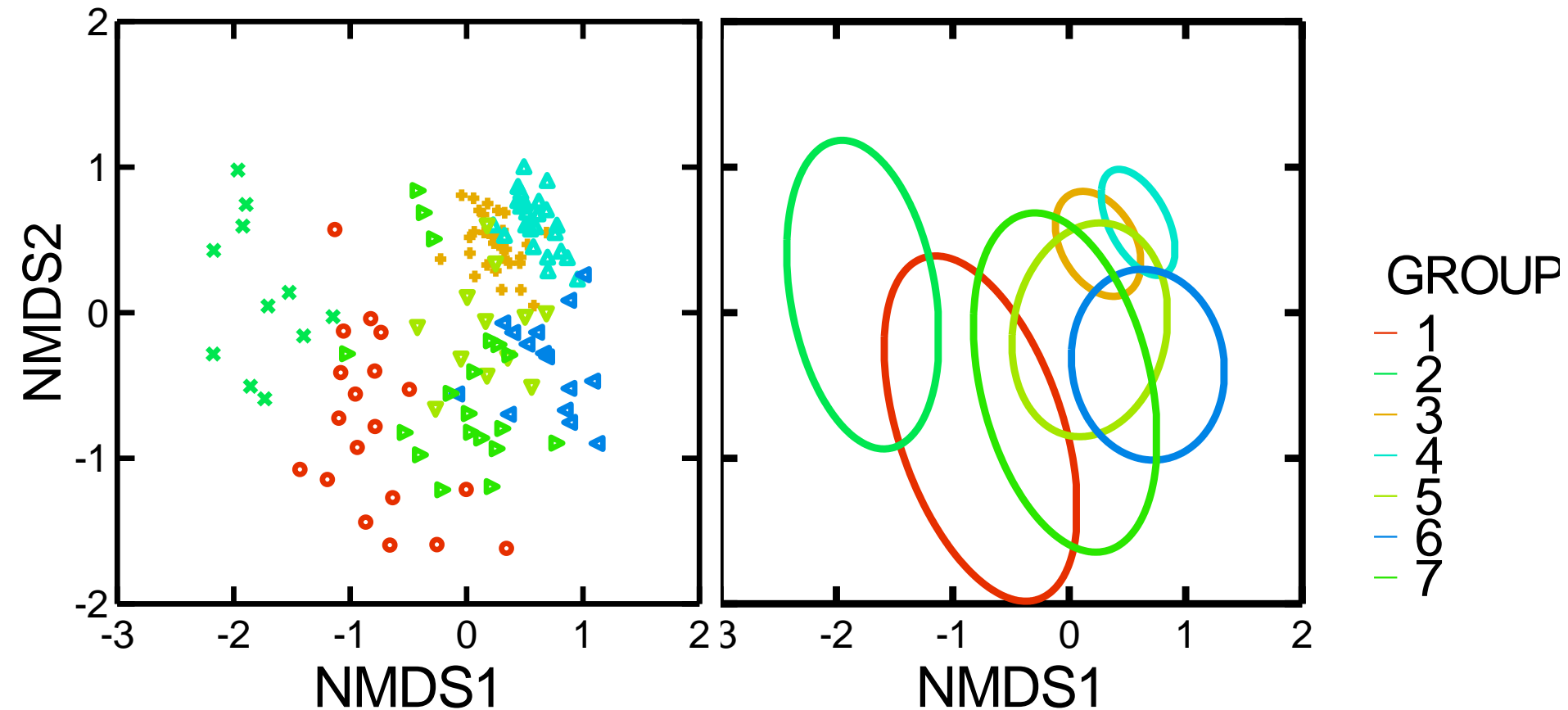
Groups

- 1
- ▲ 2
- ✚ 3
- ⬠ 4
- 5
- 6
- ☆ 7

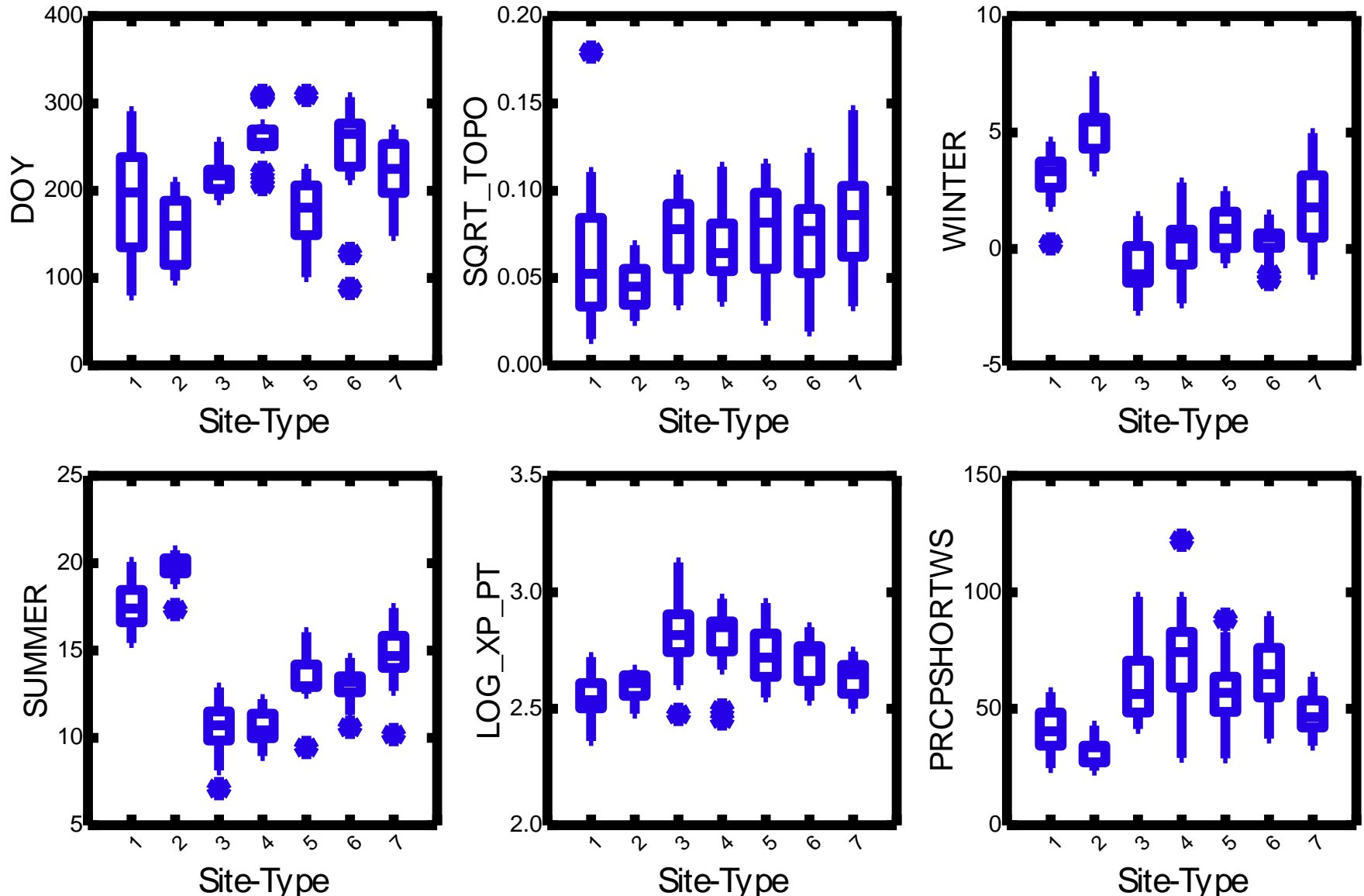
Compositional Similarity Among Sites



Variability in taxa among sites varies with environmental setting

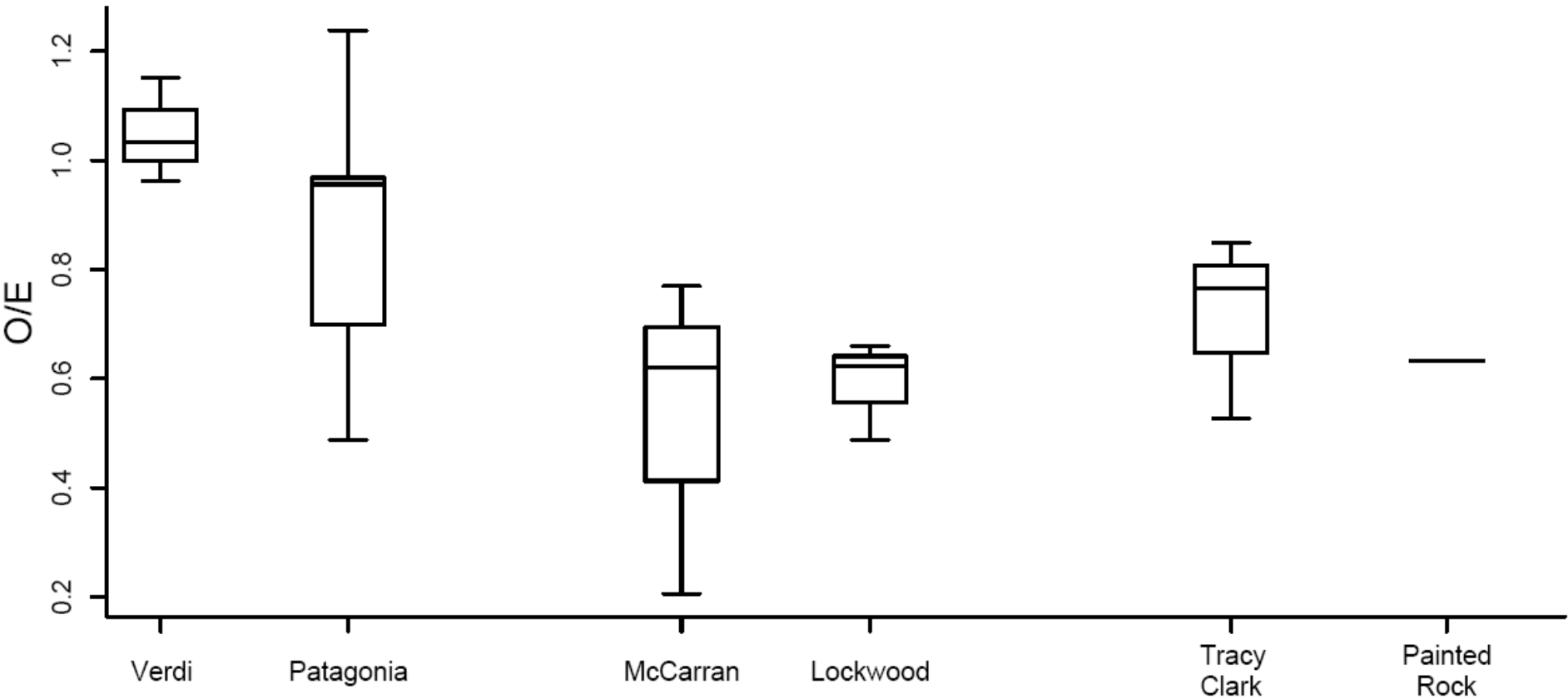


Discrimination of taxa groups by predictor variables



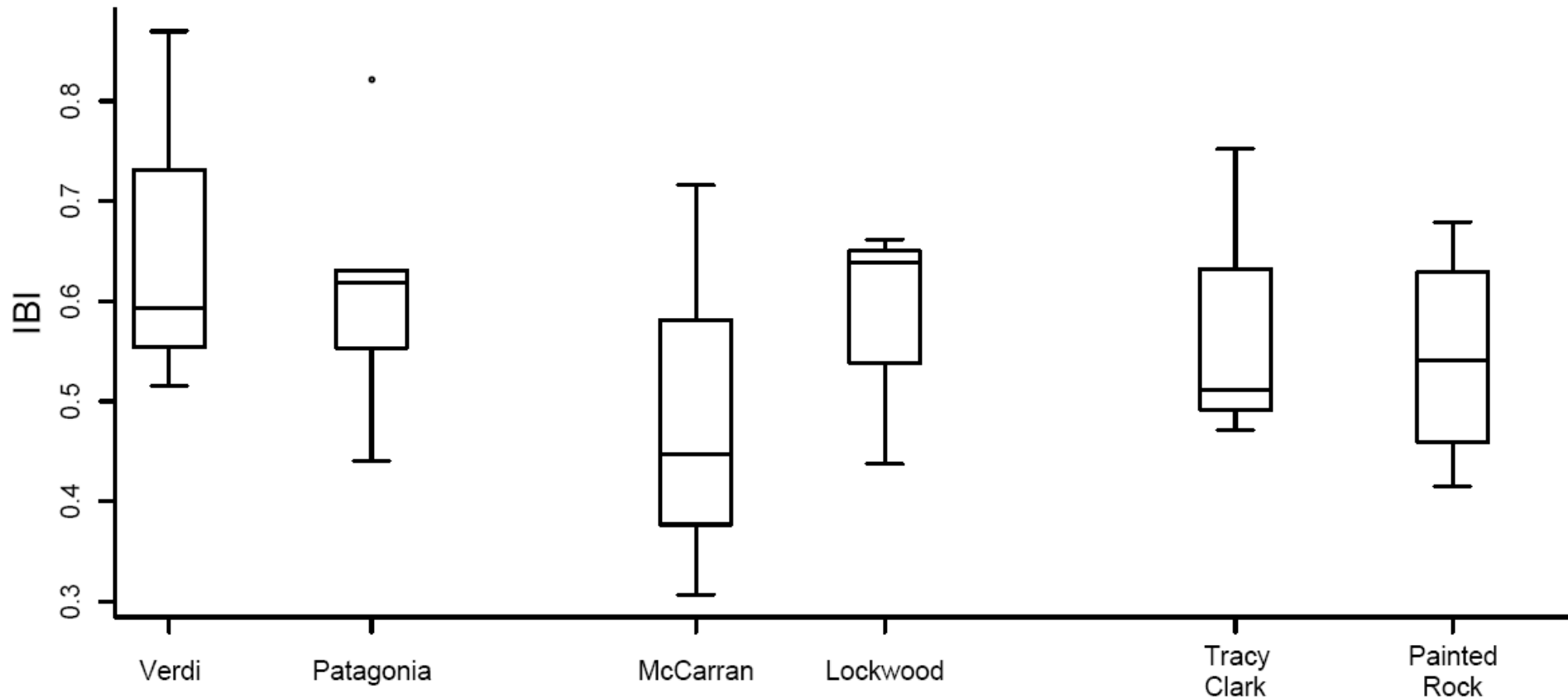
Some Preliminary Results for the Truckee River

Truckee River O/E values based on the Western EMAP Mountain + Xeric model



Graph courtesy of Lester Yuan

O/E_{taxa} may assess sites differently than MMIs



Assessing Individual Taxa



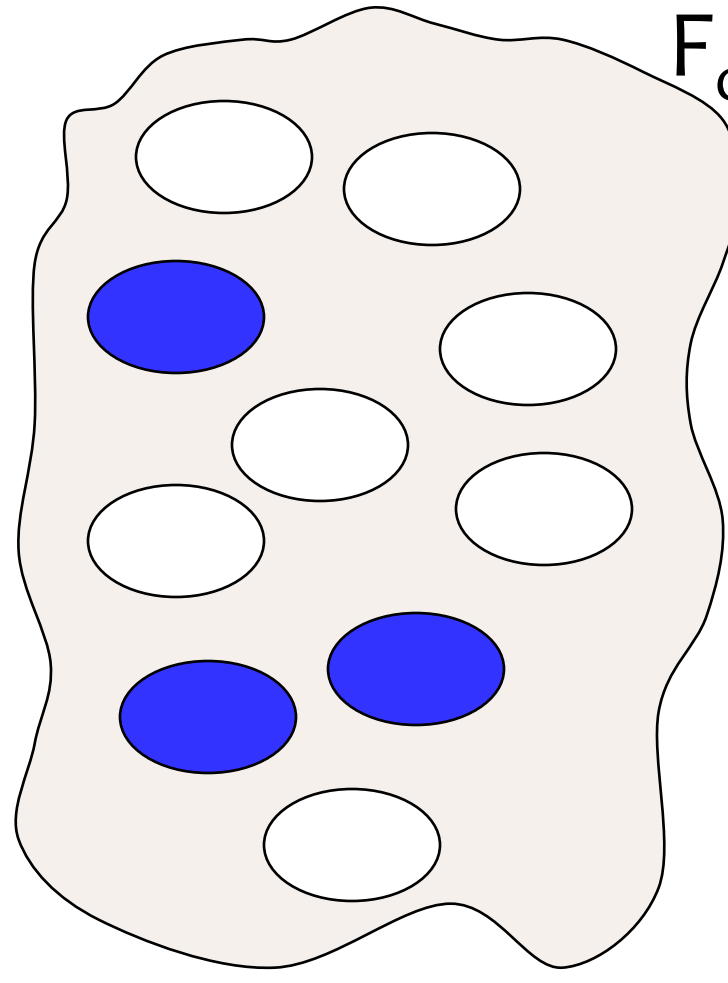
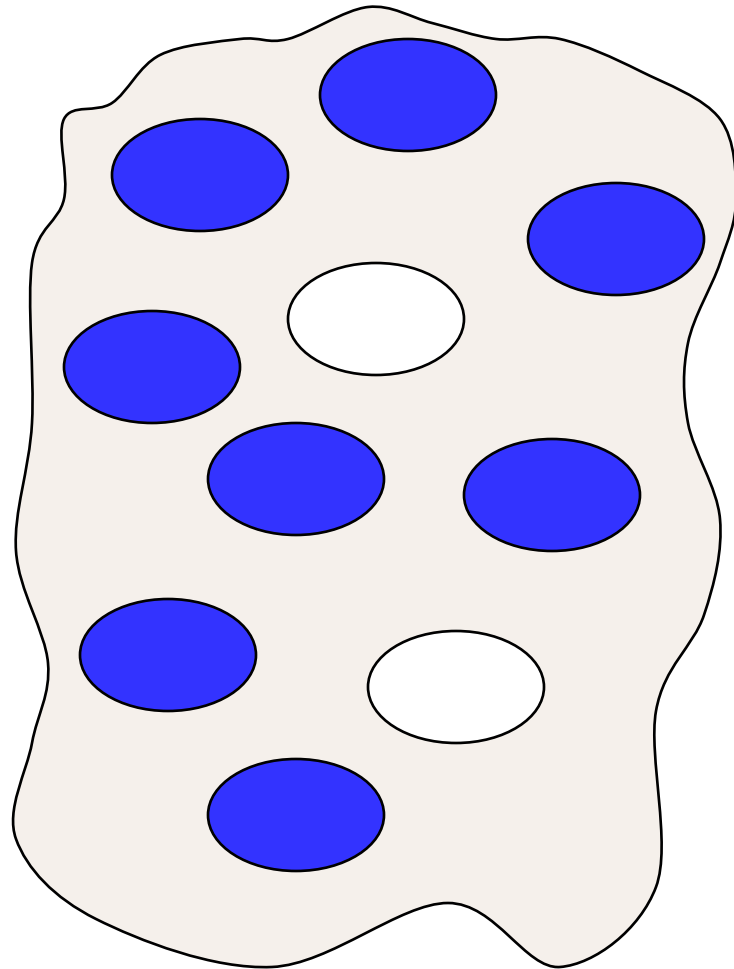
Monitoring frequencies of detection (FD) measures changes in a taxon's region-wide status.

Baseline Conditions

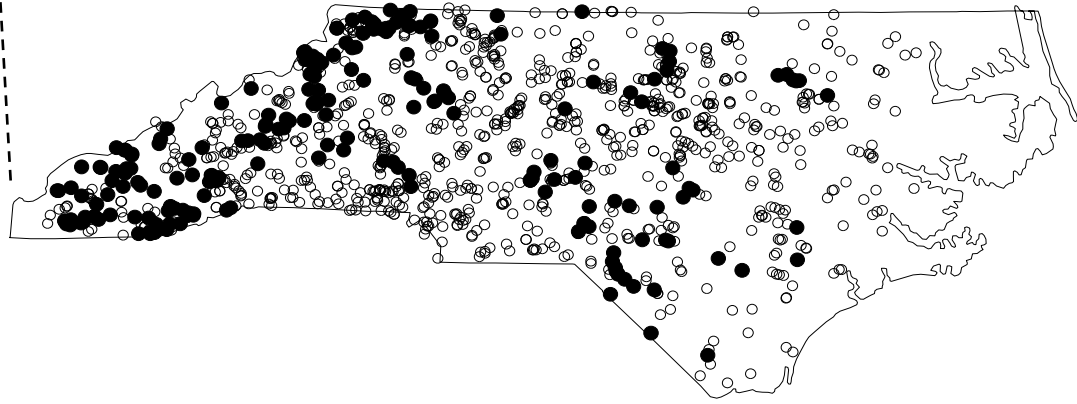
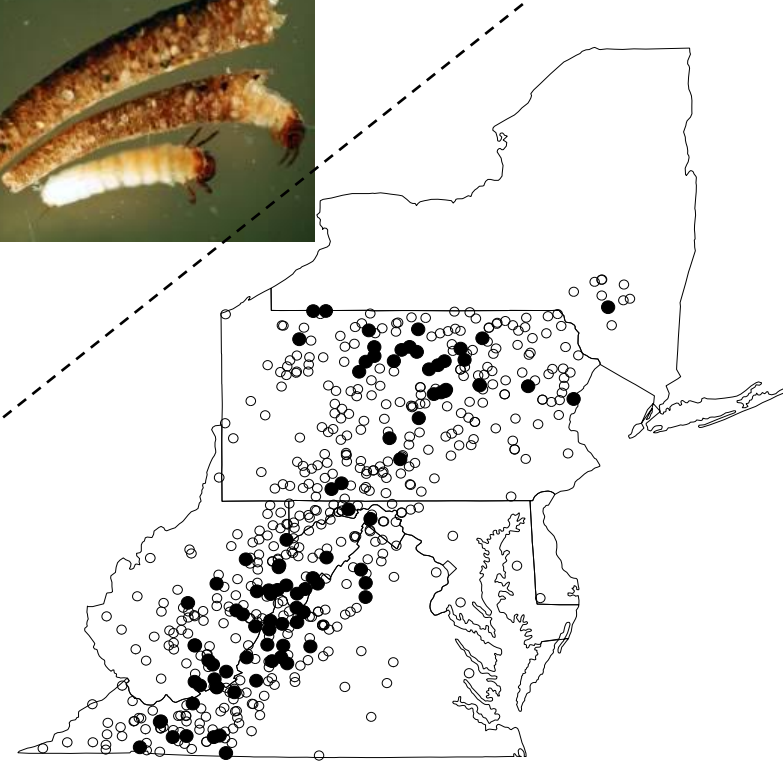
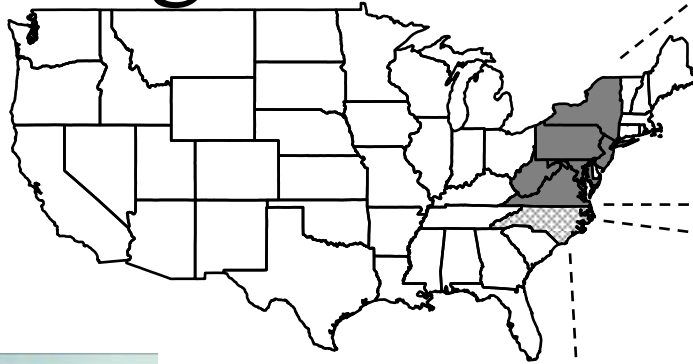
Current Conditions

$$\Delta FD = 0.5$$

$$F_o/F_e = 0.37$$



Example with stream invertebrate data from North Carolina and the Mid-Atlantic Highlands



% of Decreaser (%D) and Increaser (%I) Taxa
Z-Test ($F_o \neq F_e$)

Taxon	North Carolina			MAH		
	N	%D	%I	N	%D	%I
Dragonflies	47	13	23	15	7	27
Clams/Snails	30	27	17	21	17	19
True Flies	291	28	13	177	21	23
Beetles	55	20	15	32	16	25
Worms	82	11	18	45	2	24
Stoneflies	71	54	0	35	46	3
Caddis Flies	157	65	4	51	35	12
Mayflies	131	50	4	33	55	9
Total Taxa	910	36	11	432	23	21

The tip of an iceberg?

How bad are
systematic errors?

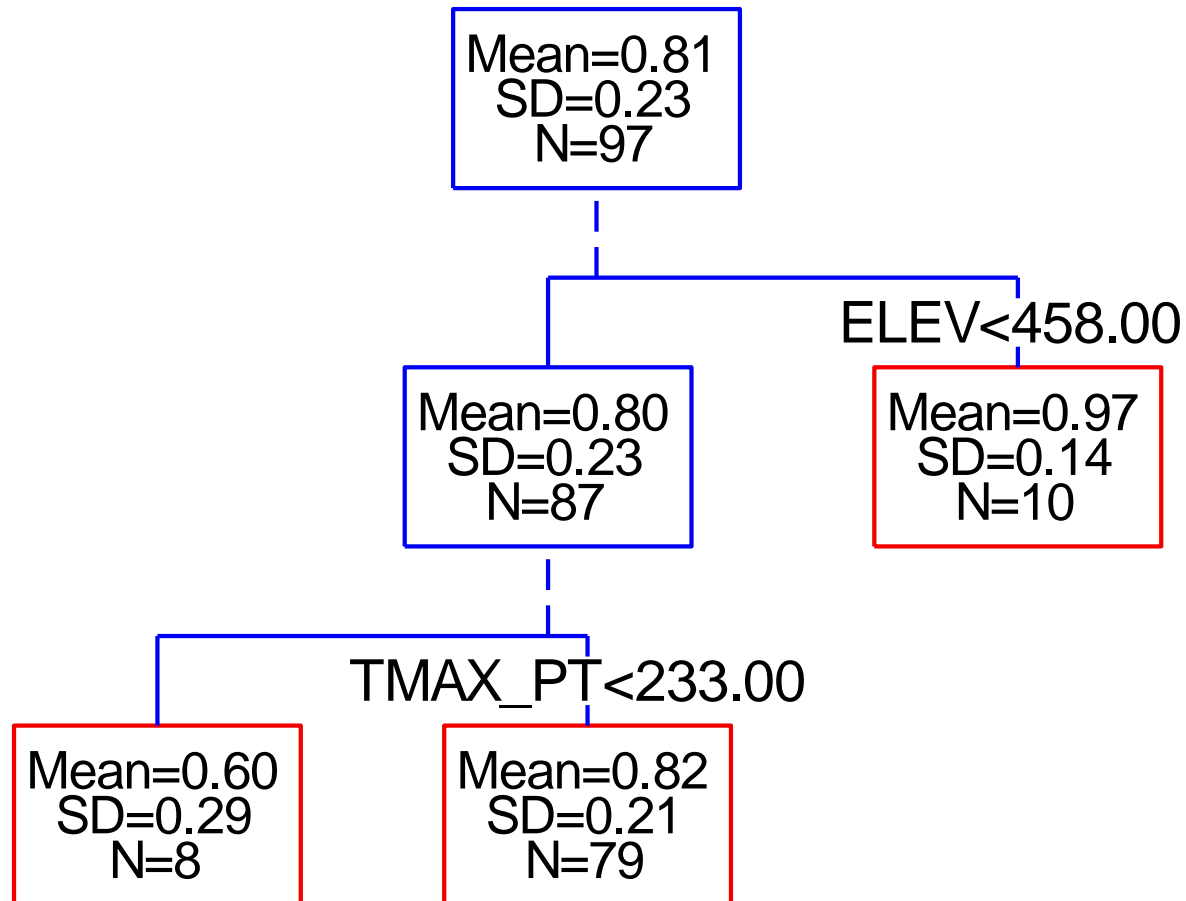
or

How well are we really
accounting for natural
variation?

Xeric West Reference Sites

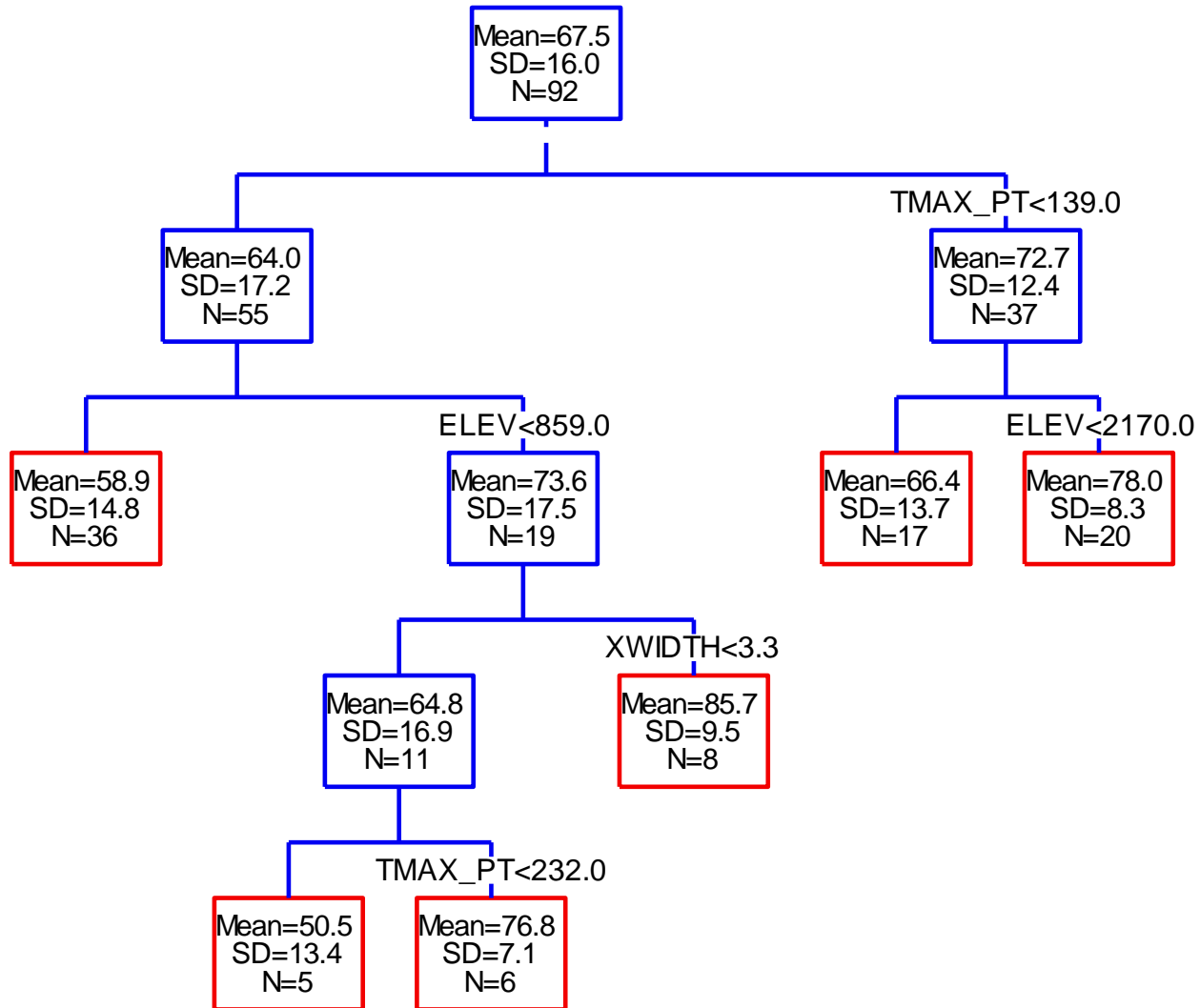
$$R^2 = 0.13$$

OE



Xeric West Reference Sites

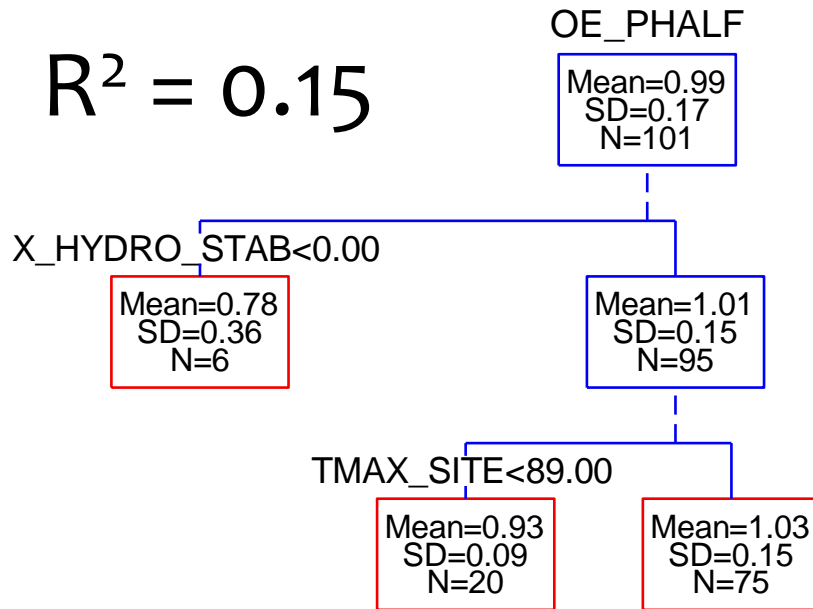
$R^2 = 0.40$
MMI



Montana Examples

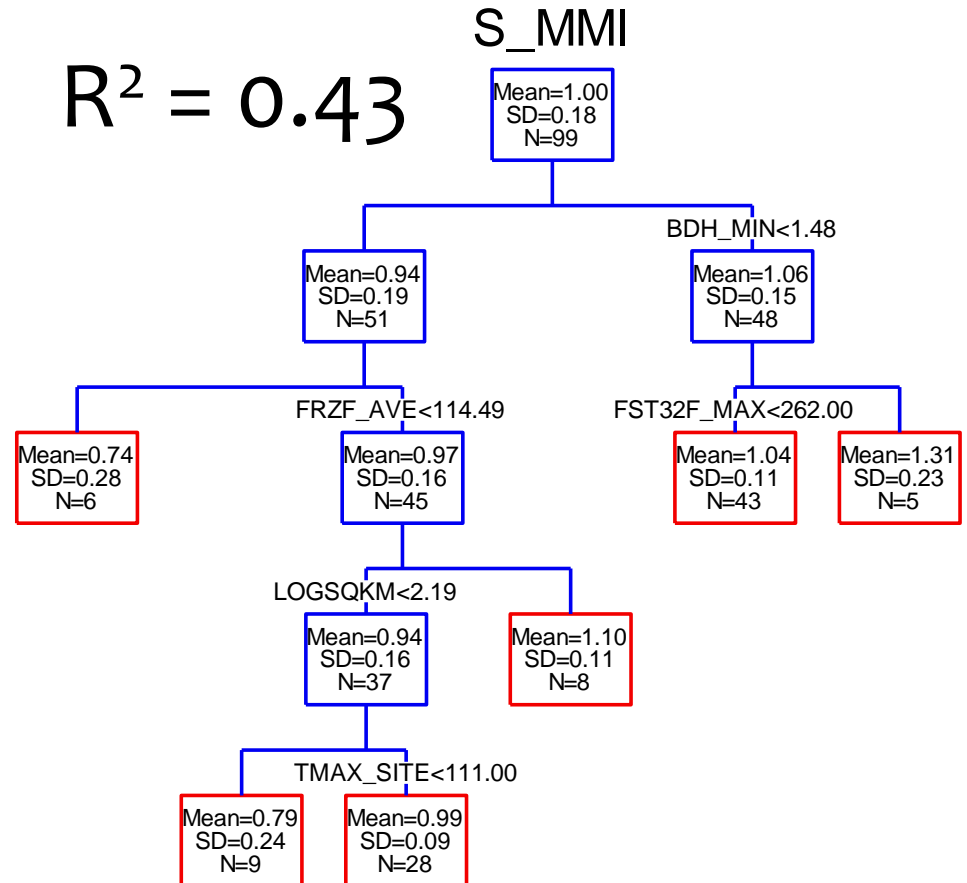
O/E (modeled E)

$R^2 = 0.15$

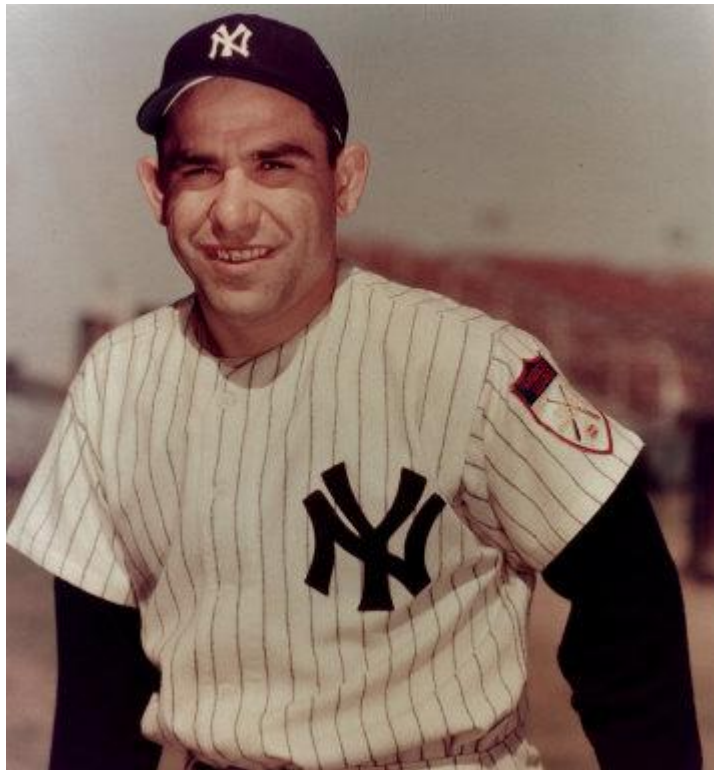


MMI (3 classes of E)

$R^2 = 0.43$



Measuring the condition of aquatic ecosystems:



"You've got to be very careful if you don't know where you're going, because you might not get there."