The IBI Development Process

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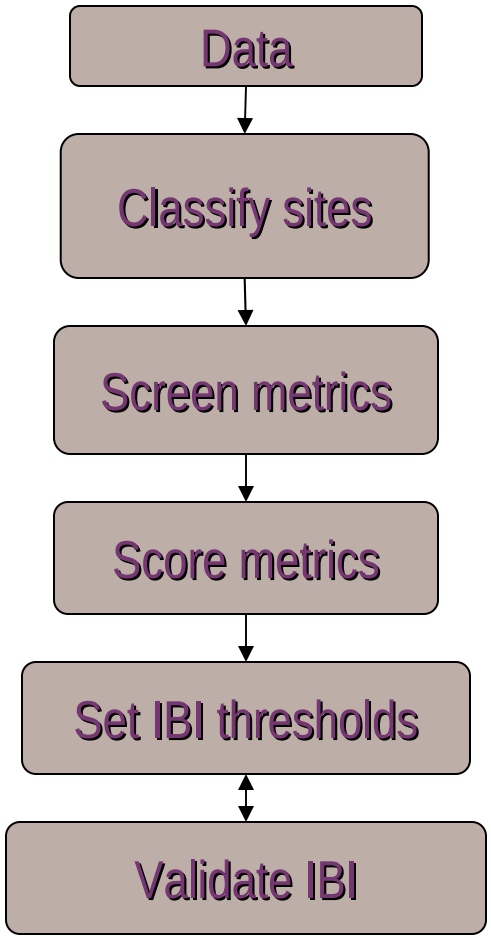
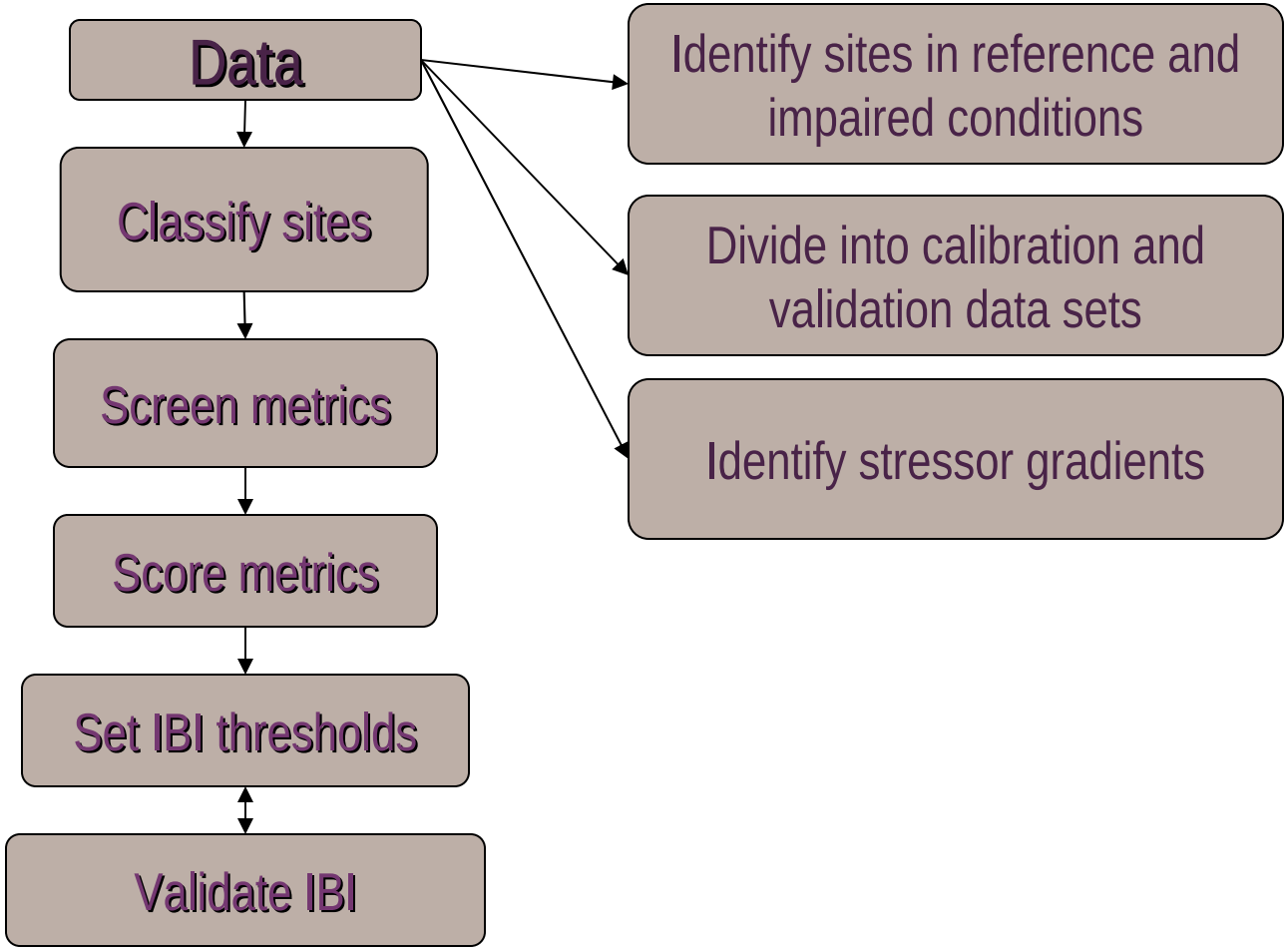
*Although this work was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy.

Components of the process



The process is never really completely objective – it is always a combination of statistics and professional judgment.

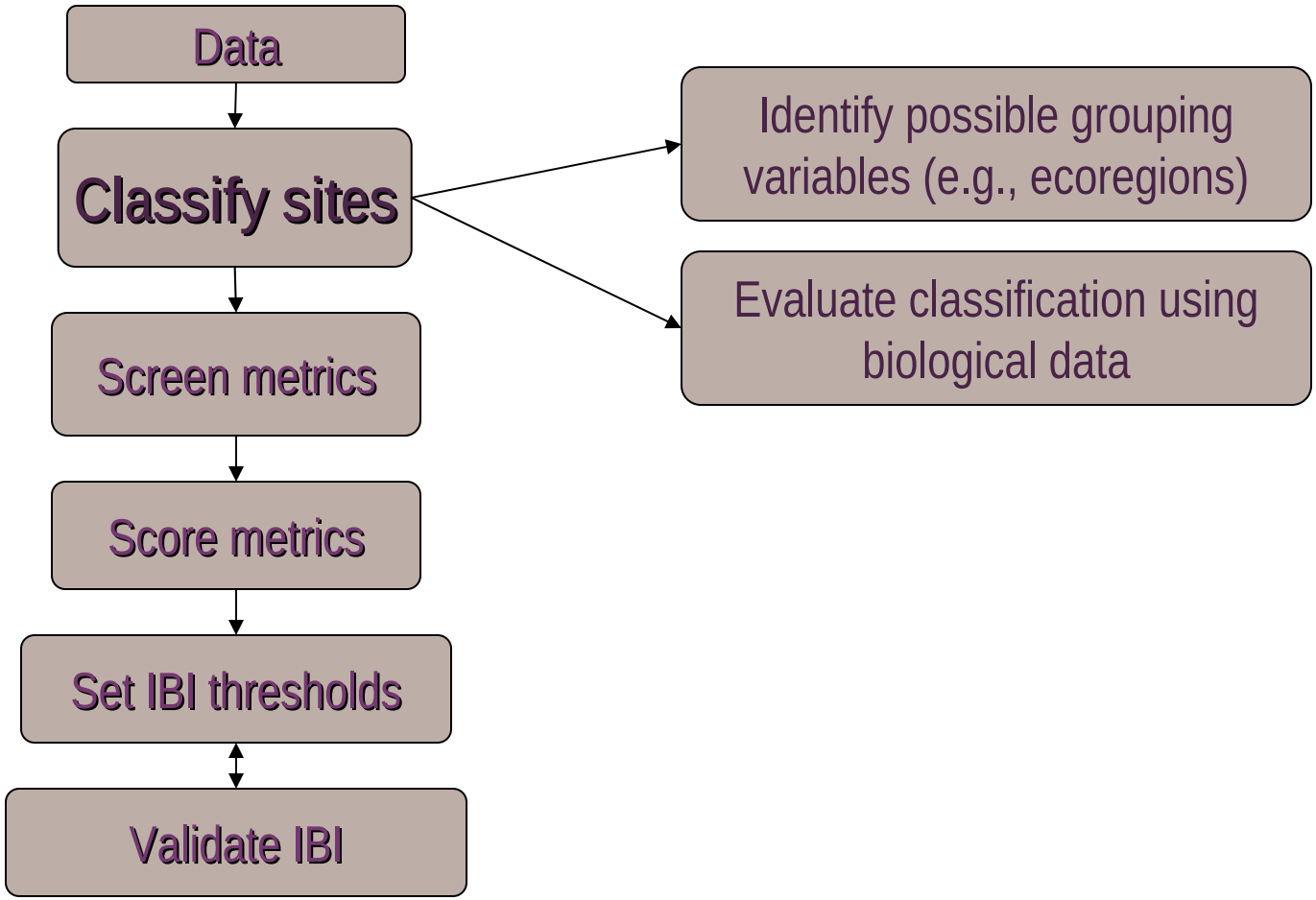
Components of the process



Data

- Reference (least disturbed/minimally disturbed) and impaired ("trashed") conditions:
  - Determine *a priori* using non-biological data if possible
  - Can affect many aspects of IBI development, so spend time getting this right
- Divide data into calibration and validation data sets
  - Randomly but with some stratification to ensure representation across rivers and other major areas
  - Approximately 20-30% of samples in validation data set
  - Depending on size of data set, may postpone this step until assembling index
- Identify stressor gradients
  - These will be relevant for assessing metric and IBI responsiveness

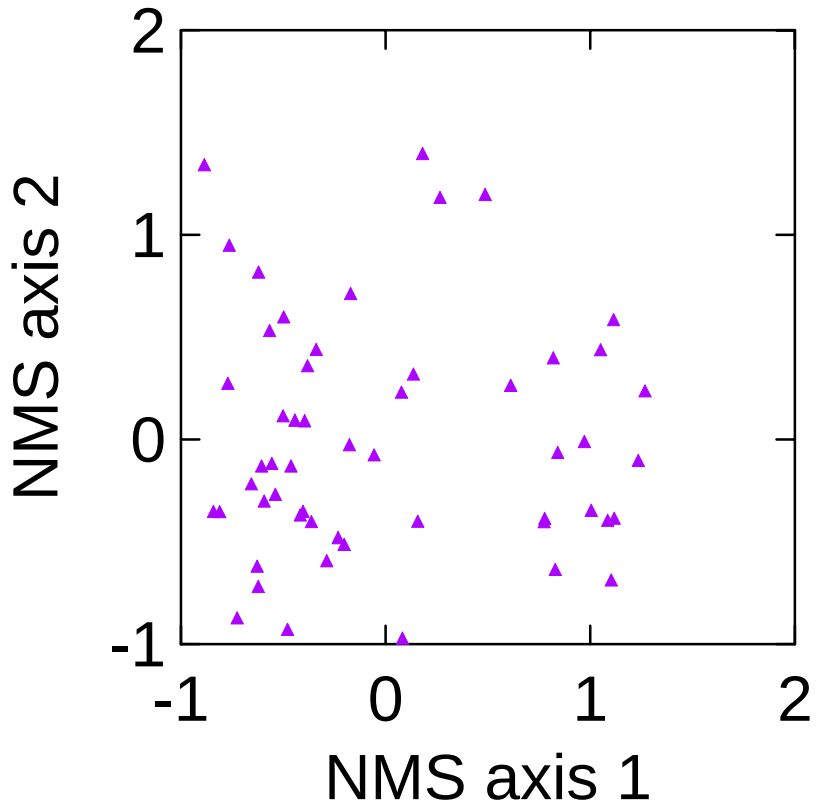
Components of the process



Classification

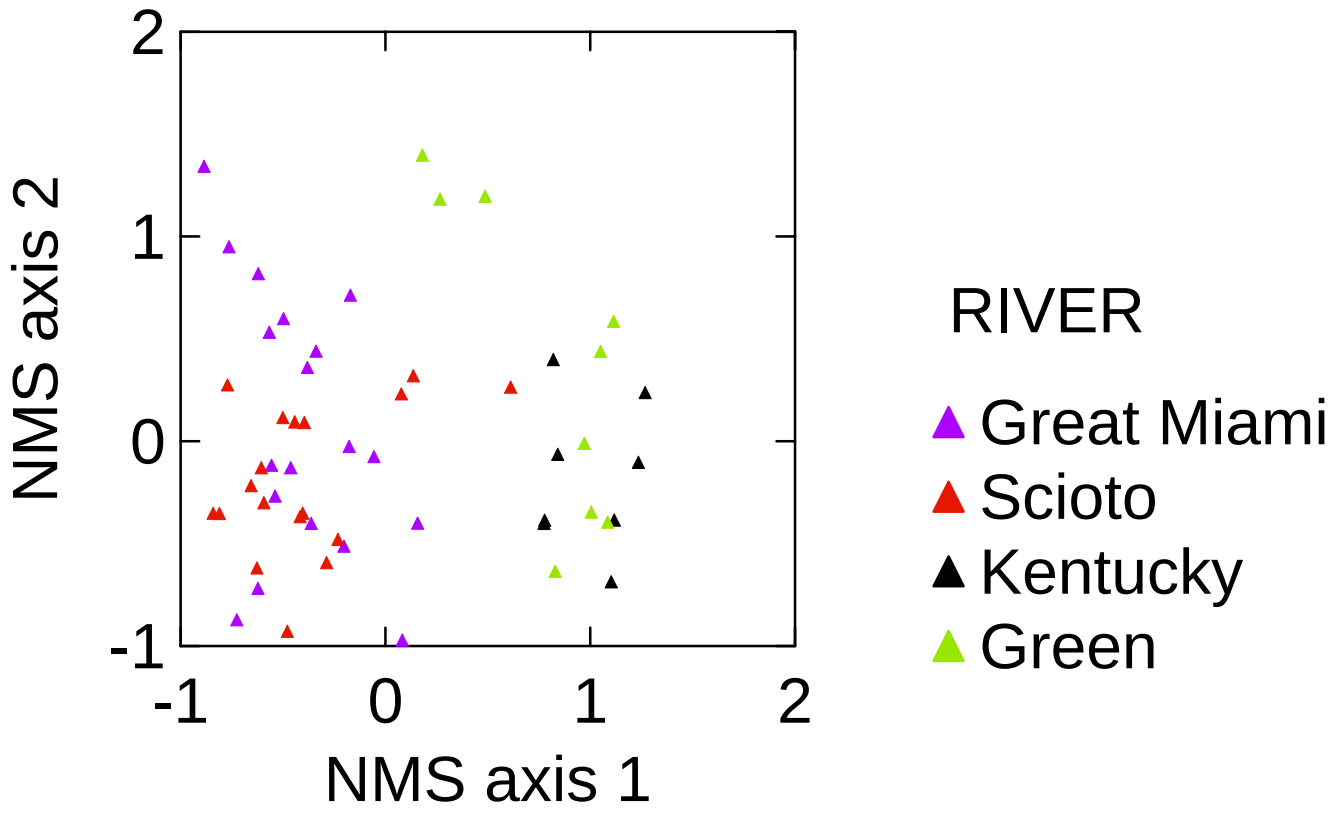
- Typically reference sites only, to avoid introducing stressor gradients into process – segregate by river (i.e., Missouri, upper Miss, Ohio)?
- Non-metric multidimensional scaling (NMDS) on raw abundance data
  - Smaller stress value is better, <20 or better
  - May drop rare taxa (e.g., present at fewer than 5% of sites, or <5% of abundance at <10% of sites)
  - Bray-Curtis distance measure commonly used
- Identify alternative (pre-existing) classification schemes:
  - Omernik ecoregions
  - Basins
  - Other classifications based on hydrology, geomorphology, etc. (e.g., The Nature Conservancy, Forest Service)
- Look for separation or clustering in NMDS based on different classification schemes

Classification - example

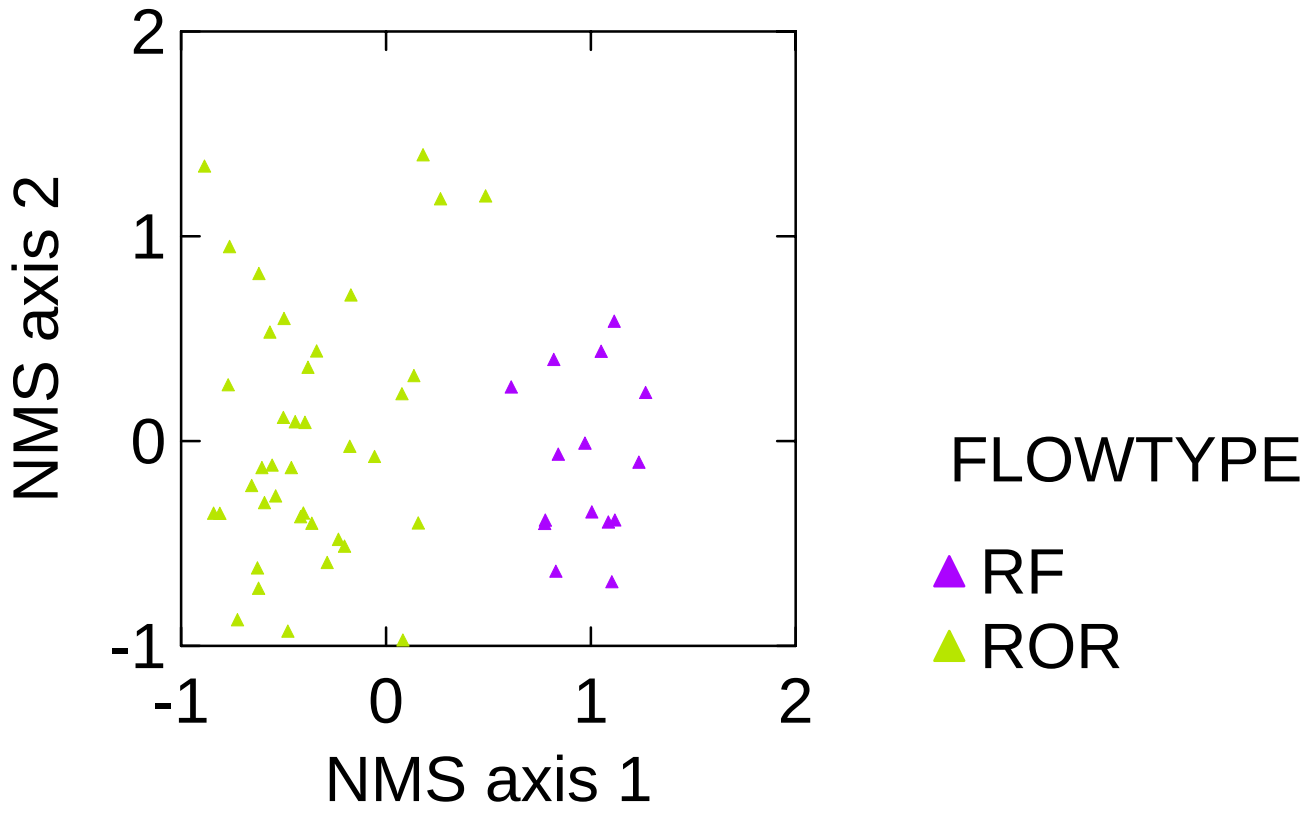


- Large river study
- 54 sites
- 4 rivers
- Macroinvertebrates
- Genus-level data

Classification - example



Classification - example



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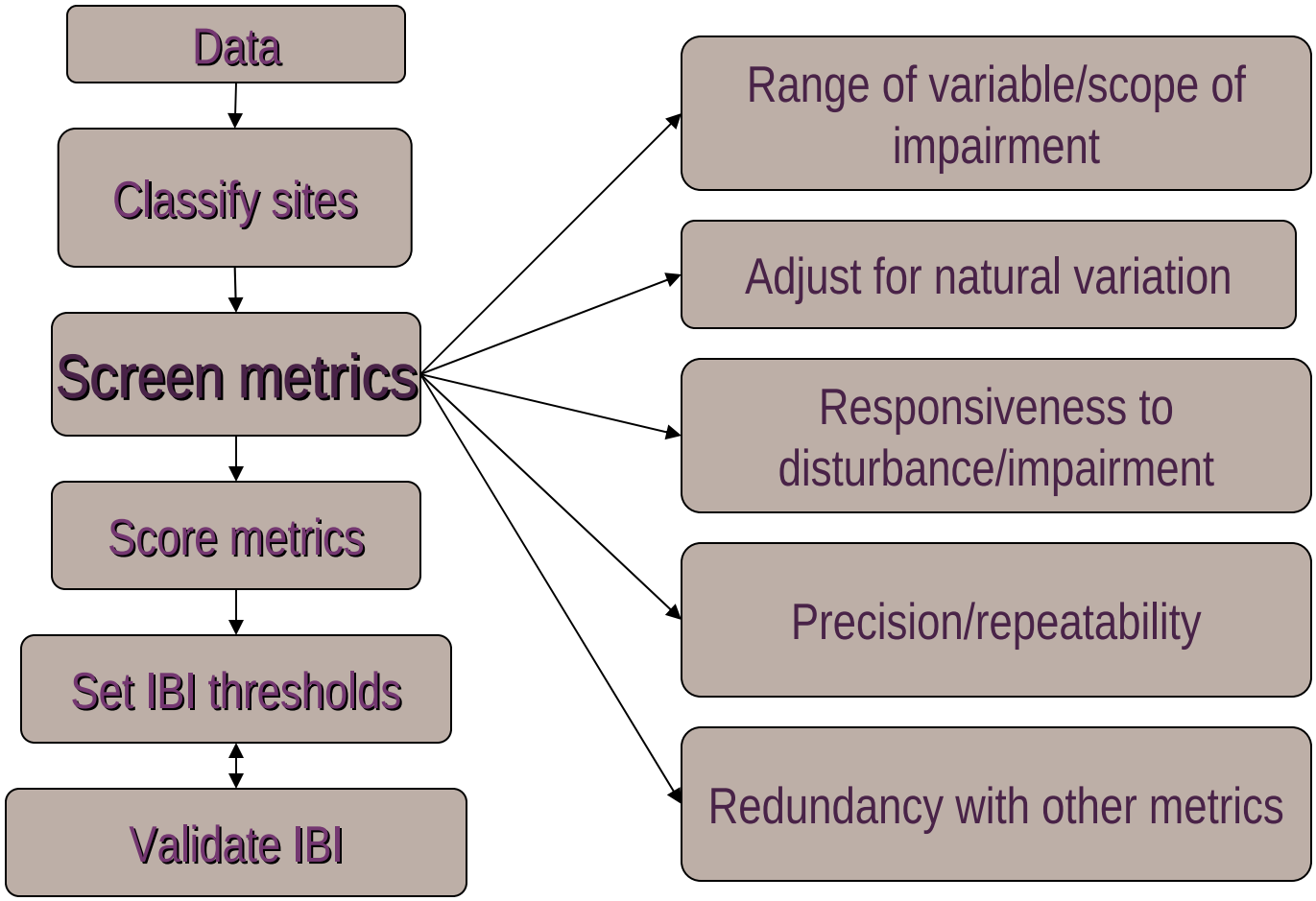
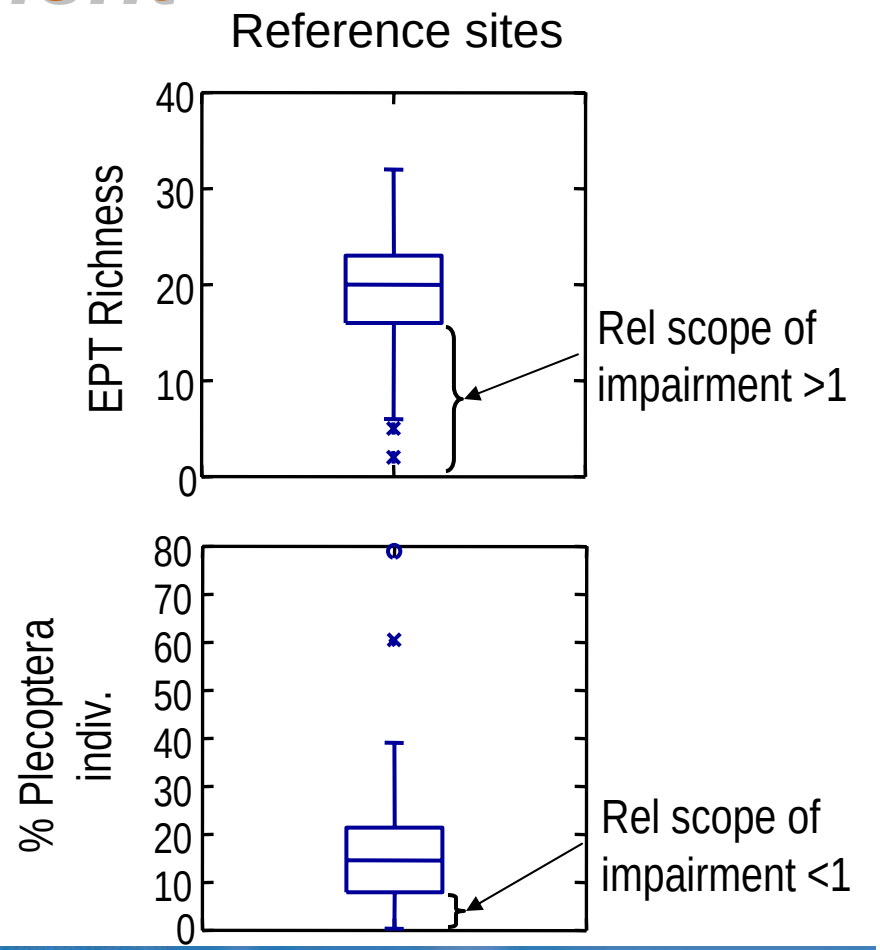


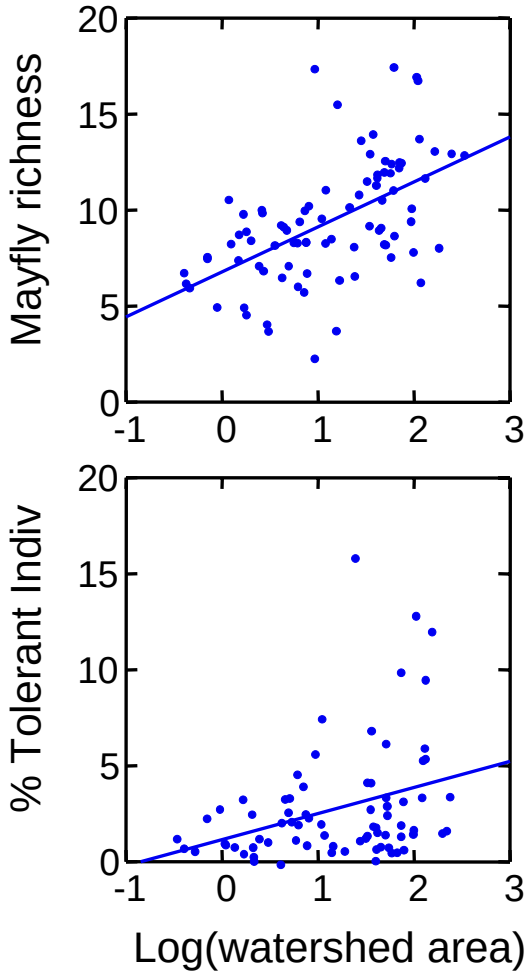
Screening metrics: Range/scope of impairment

- Set criteria for different types of metrics
- Examples:
  - Percentage metrics-range <10
  - Richness metrics-range <5
- Scope of impairment
  - Variable range below reference 25th percentile
  - Compare to interquartile range of reference sites (relative scope of impairment)
  - >1 acceptable, <1 unacceptable



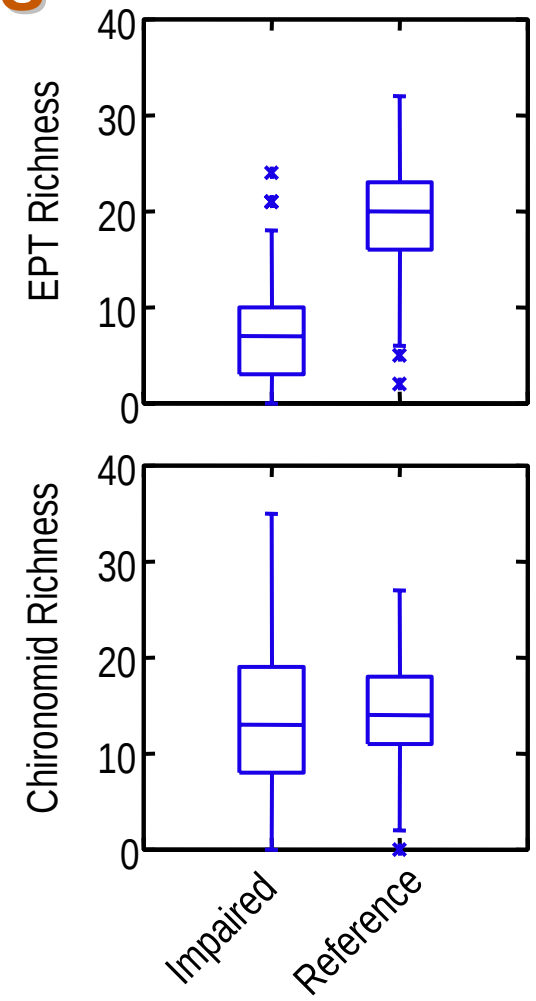
Screening metrics: Adjust for natural variation

- Examine plots of metrics vs. continuous natural factors (e.g., Julian day, river mile, flow)
- Use only reference sites in plots
- Calculate residuals for all sites from regression
  - Type of regression may depend on type of trend detected (i.e., linear or wedge-shaped)
  - Quantile regression available in R
- Avoid automation using simple correlations, as many important relationships may be missed
- Make sure relationships make ecological sense to avoid spurious correlations
- Use caution with variables which might be strongly related to stressors of interest



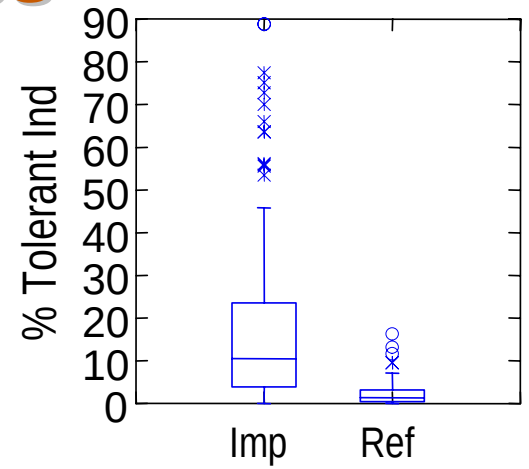
Screening metrics: Responsiveness

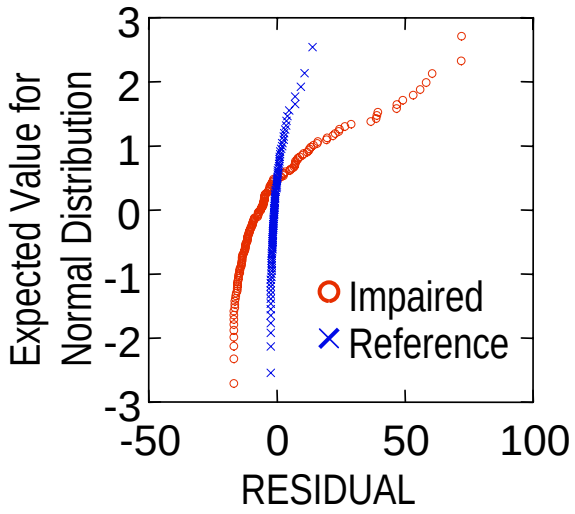
- Box plots of reference vs. impaired sites
  - Assess degree of overlap of interquartile ranges (boxes) and medians
  - Accept only metrics with some minimum level of separation
  - May also calculate discrimination efficiency (DE) as proportion of impaired sites with values below 25th percentile of reference (or similar)
- Formal tests
  - May not be appropriate to apply simple F- or t-tests to all metrics without checking assumptions (i.e., normality, homogeneous variance)
  - Nonparametric tests do not consider degree of difference if significant



Screening metrics: Responsiveness

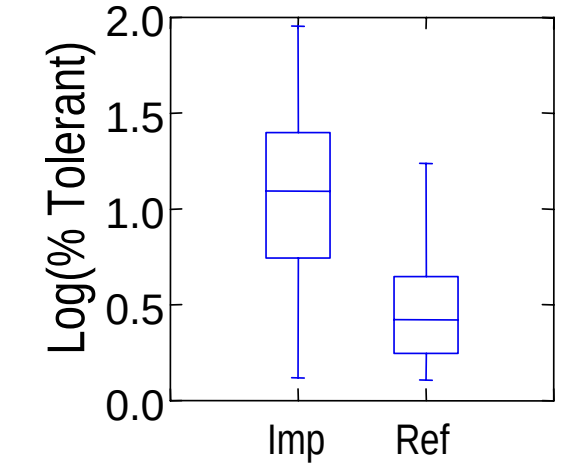
- Example: % Tolerant Individuals
- Untransformed, difficult to assess separation of impaired/reference
- From ANOVA, F=49
- BUT, very skewed distributions apparent in residuals

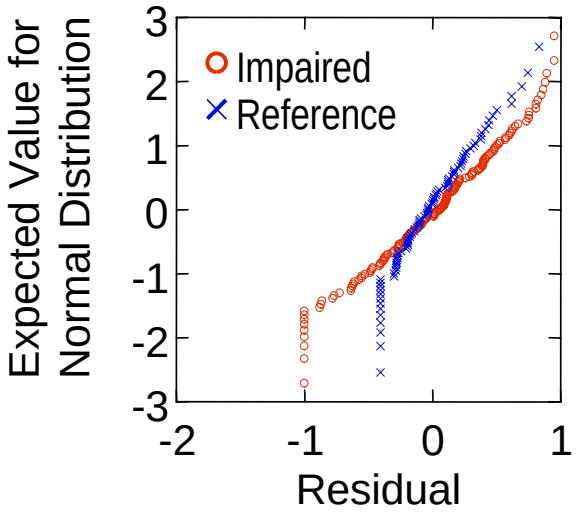




Screening metrics: Responsiveness

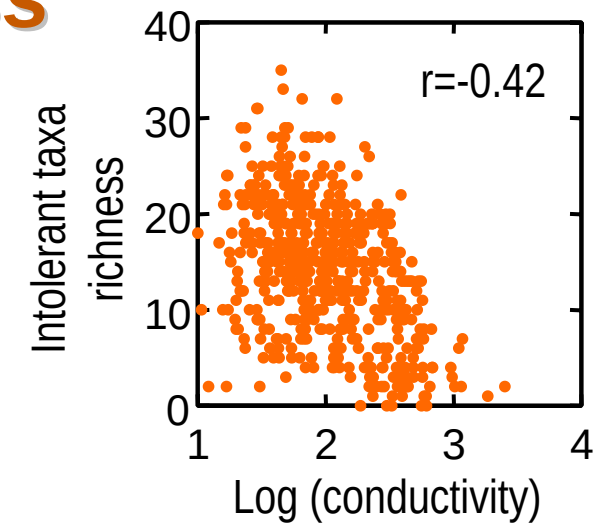
- When transformed as log(x+1), more normally distributed
- More clear separation of reference/impaired – F ~106
- Residuals no longer as strongly skewed

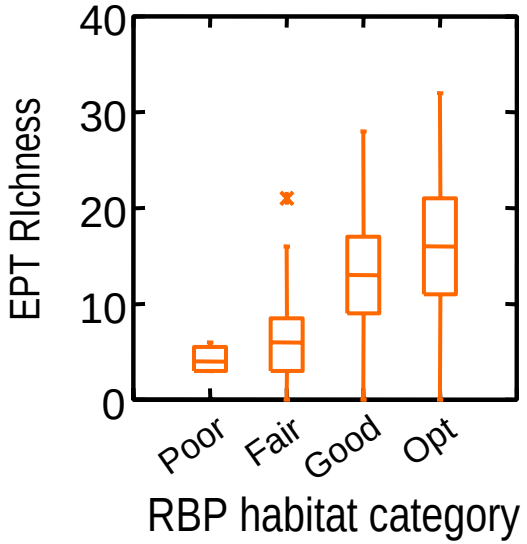




Screening metrics: Responsiveness

- Plots of individual or composite measures of disturbance vs. metrics
- Categorizing variables into several levels can show patterns more clearly
- Correlations do not provide as much information on relationships if large sample sizes





Screening metrics: Precision/Repeatability

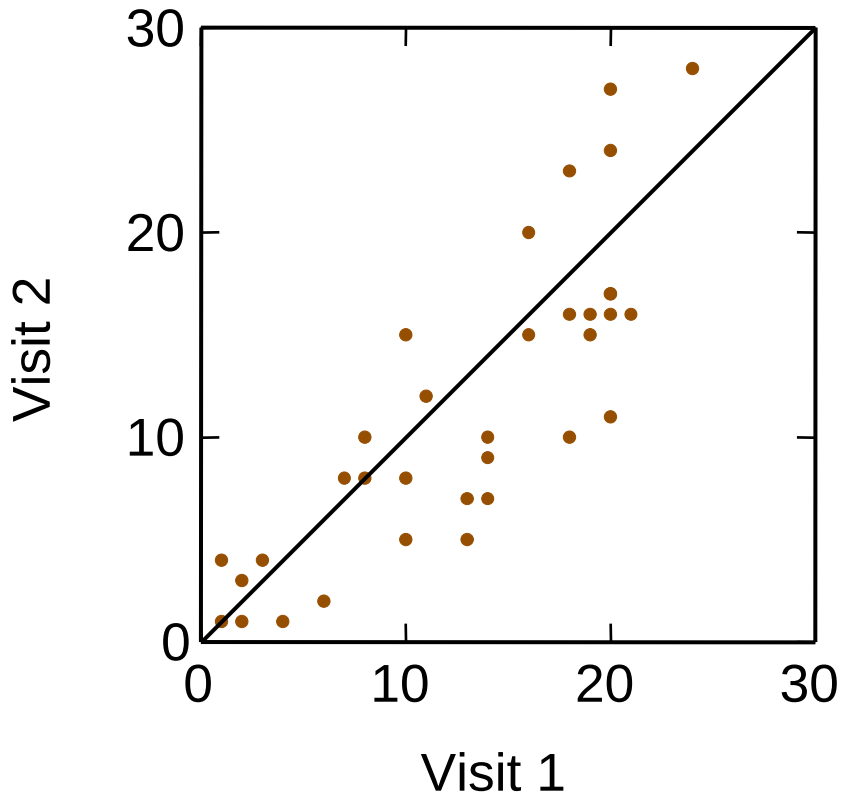
- Calculate Signal:Noise ratio (S/N) based on Kaufmann et al. (1999):
  - Signal/Noise = (Variance among sites)/(Variance within sites)
  - ANOVA with site ID(year) as random factor, year as fixed effect
  - Sites with revisits, include all sites to "enhance" signal
  - $S/N=(F_{site}-1)/c_1$, where c_1 is:
    - number of reps if all the same (e.g., 2 per site)
    - otherwise, coefficient of site ID component in Type III expected mean squares (SAS)
  - Meaning of values:
    - Under 2 – poor repeatability/precision
    - 2-6 – moderate
    - >6 – good

Screening metrics: Precision/Repeatability

Example of S/N:

EPT Richness

S/N = (9.44 – 1)/2
= 4.22



Screening metrics: Precision/Repeatability

- Alternative approaches
  - Relative Percent Difference (RPD):

$$RPD = \frac{|Y_1 - Y_2|}{\overline{Y}} \times 100$$

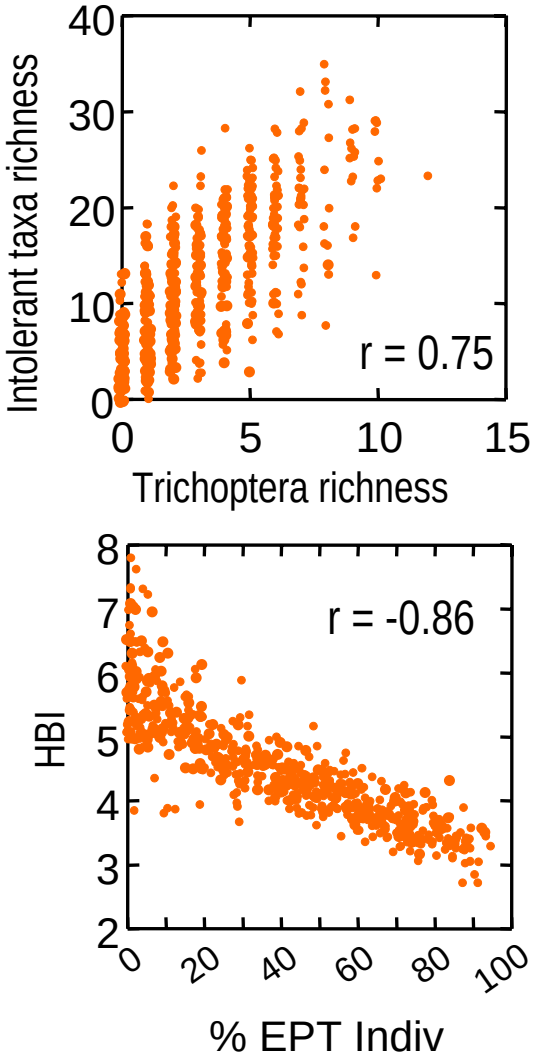
  - Coefficient of Variation (CV):

$$CV = \frac{RMSE}{\overline{Y}} \times 100$$

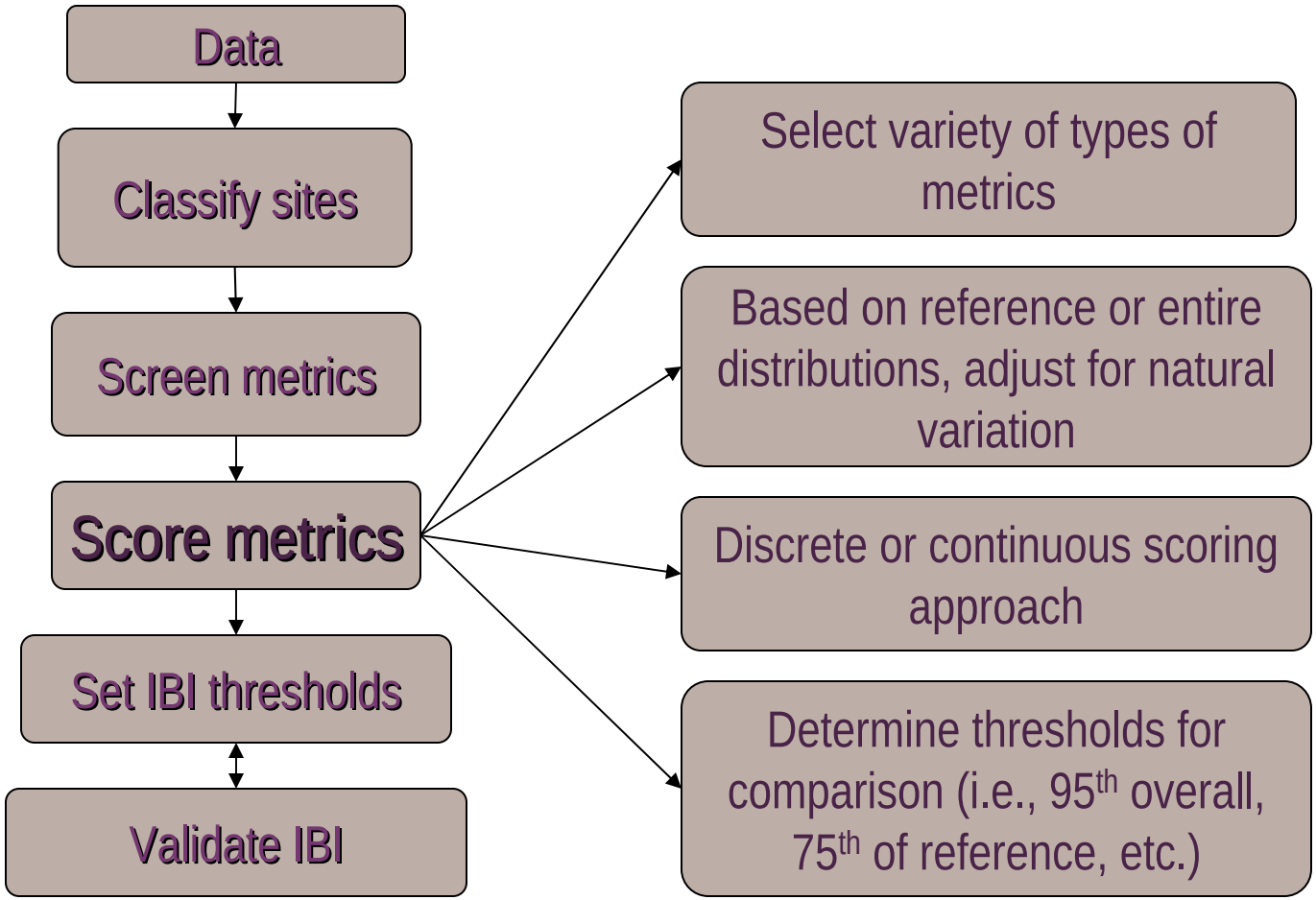
- Both approaches require setting some criteria for judging adequate metric precision/repeatability

Screening metrics: Redundancy

- Pearson correlations of among all (remaining) metrics
- For r>0.8 (or other predetermined value), choose one of pair, based on:
  - Other measured characteristics of metric
  - Ease of calculation
  - Ecological meaning
- May also look at bivariate plots to verify redundancy



Components of the process

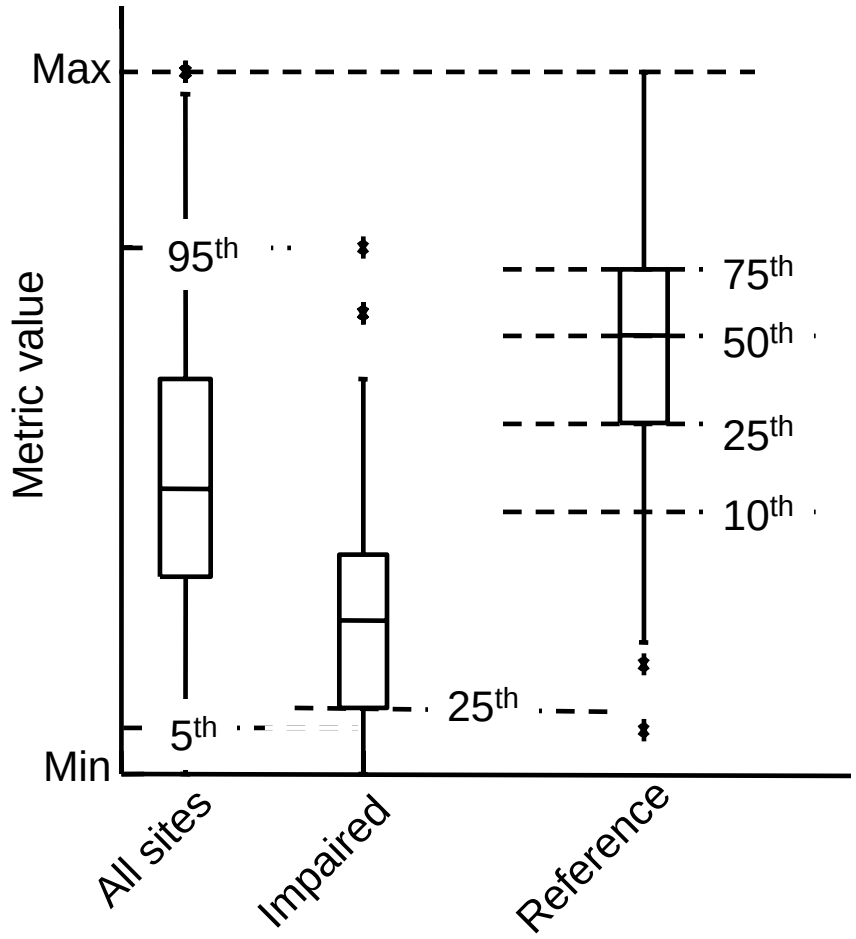


Scoring metrics: Selecting metrics

- Use metric evaluation information to select suites of candidate metrics and test as index alternatives
- Incorporate metrics representing various assemblage characteristics:
  - Taxa richness
  - Taxonomic composition
  - Tolerance
  - Trophic level
  - Reproductive guilds
  - Behavioral habits (e.g., clingers)
- Identify separate suites of metrics for each class?
- Try to include more metrics rather than fewer
- Use calibration data only for this step

Scoring metrics: Select scoring approach

- Many types of scoring approaches
- Set thresholds based on:
  - reference/impaired sites
  - all sites
- Scoring can be:
  - Discrete (e.g., 1-3-5)
  - Continuous (e.g., 0-100)



Scoring metrics: Setting thresholds

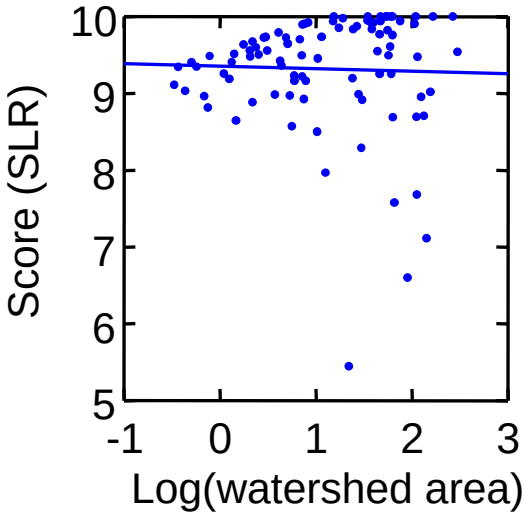
- Reference/Impaired Approach:
  - Placement of thresholds depends on confidence in quality or accuracy of reference/impaired designations
  - Larger percentile of reference corresponds to lower confidence in quality (i.e., using 10th percentile implies higher quality reference relative to using 25th percentile)
  - Avoid extremes to exclude outliers
- All Sites Approach
  - Typically use 95th percentile/5th percentile, depending on direction of response to stress
- Use consistent approach across metrics

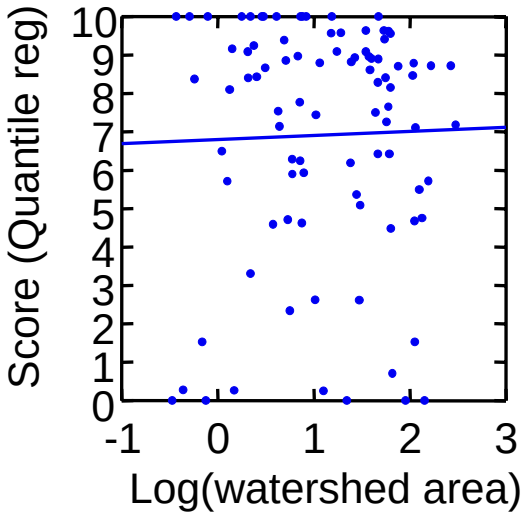
Scoring metrics: Setting thresholds

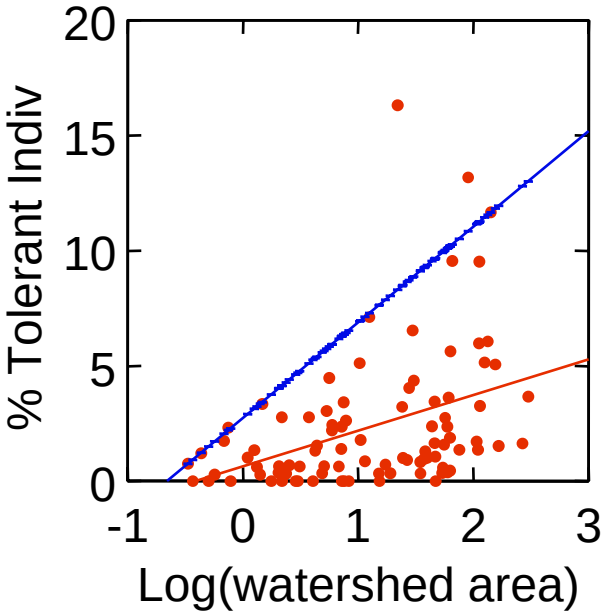
- When continuous scoring is performed, thresholds are used as the "ceiling" and "floor", and scores are the position of the observed value in that interval
- Scoring is applied differently for metrics that increase and those that decrease with disturbance
- Typically, we apply thresholds with the assumption that the metric decreases with increasing disturbance (e.g., EPT taxa) – for example:
  - Score = (Metric value – Floor)/(Ceiling – Floor)*10
- However, metrics like HBI, % Tolerant taxa, etc. increase with disturbance, so the floor is the more desirable state – for example:
  - Score = (Ceiling – Metric value)/(Ceiling – Floor) *10

Scoring metrics: Adjusting for natural variation

- If relationship to natural factors (i.e., watershed area) is wedge-shaped, use quantile regression to establish thresholds
- Simple linear regression in these cases affects scores at ends of natural gradients







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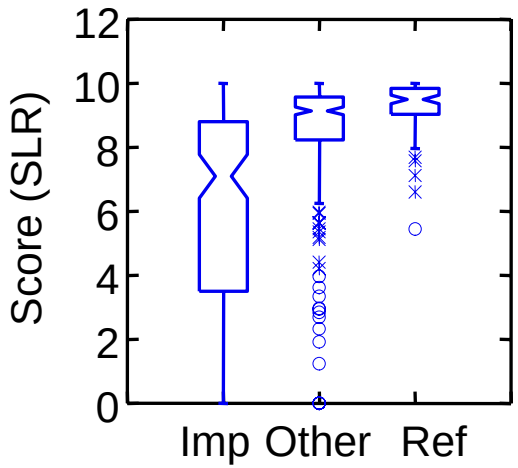
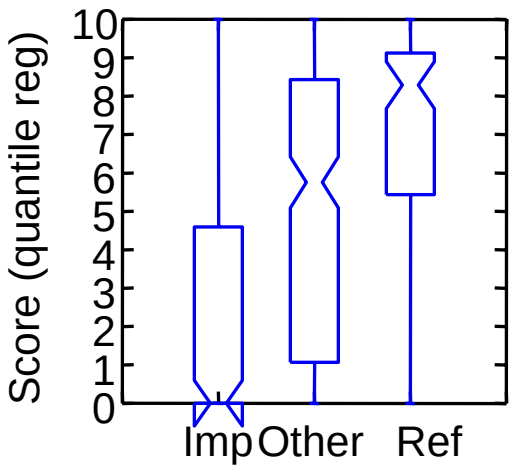
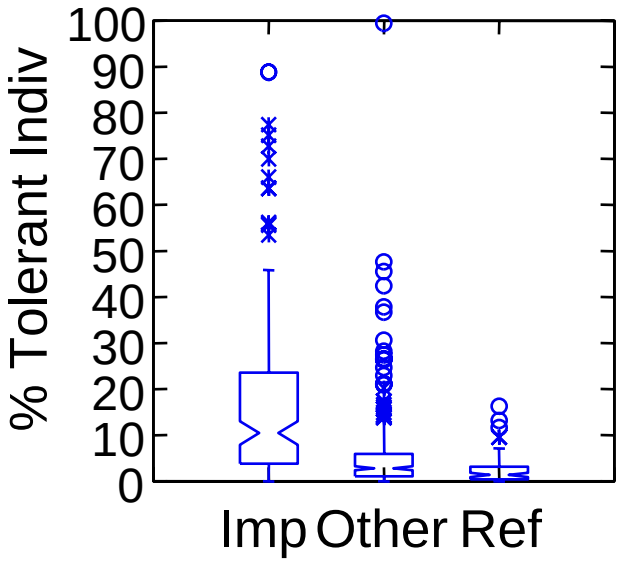






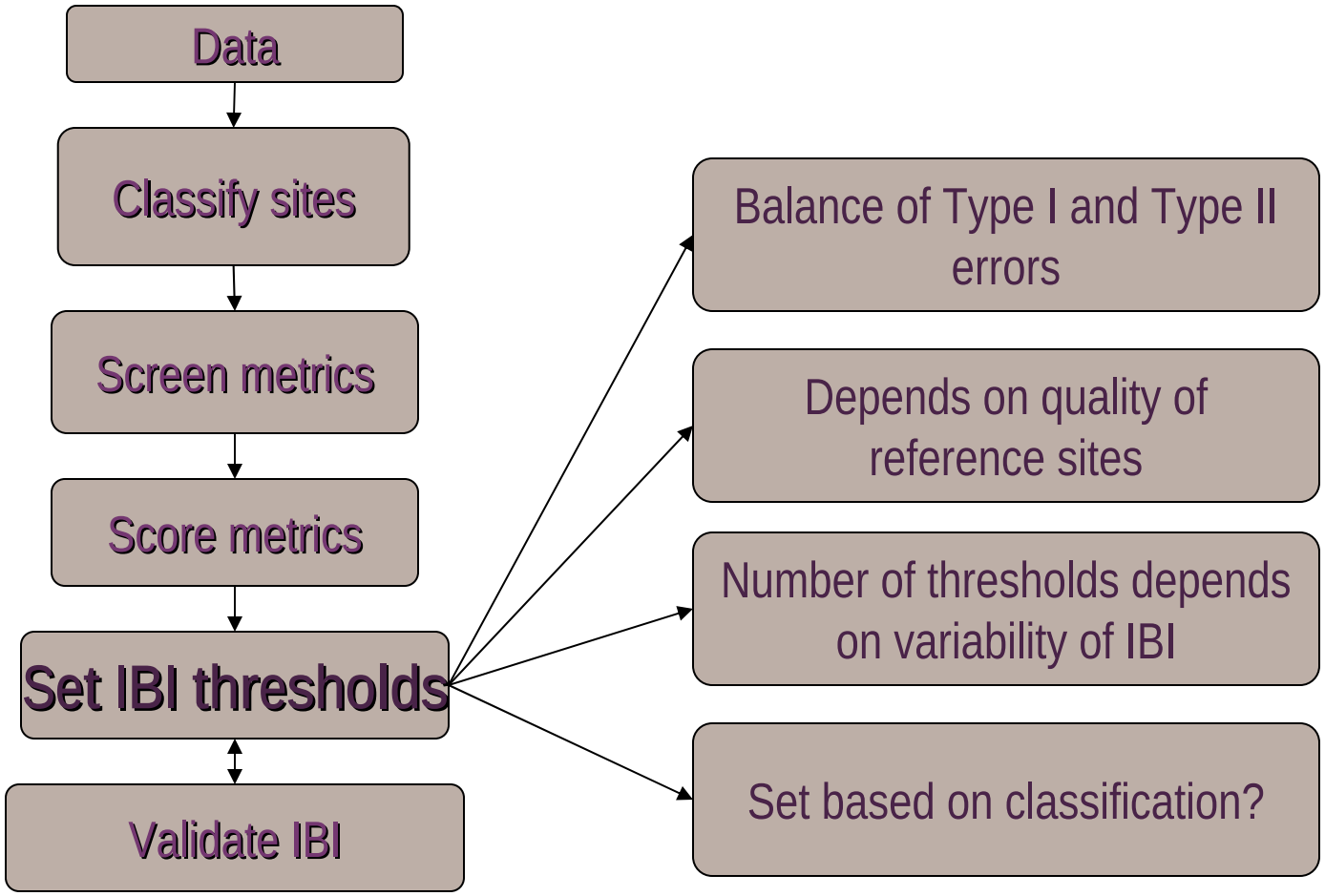
Scoring metrics: Aggregate into index

- Ensure that all metrics scores are in the same direction (i.e., a higher score = better condition)
- Combine metrics into index using either average or sum
- Perform this step for all suites of metrics being considered

Next steps:

- Validation of IBI
- Setting biocriteria or condition thresholds
- Not necessarily a linear process

Components of the process



Set IBI thresholds

- Typically a percentile of reference condition is identified as threshold(s) for condition classes
- Set for different classes if reference site index scores do not strongly overlap
- Step may occur before or after validation of IBI – may use condition classes in validation
- Number and placement of thresholds could be based on:
  - Balance of Type I and II errors
  - Response to disturbance gradient
  - Overlap of reference and impaired sites
  - Distribution and variation of reference

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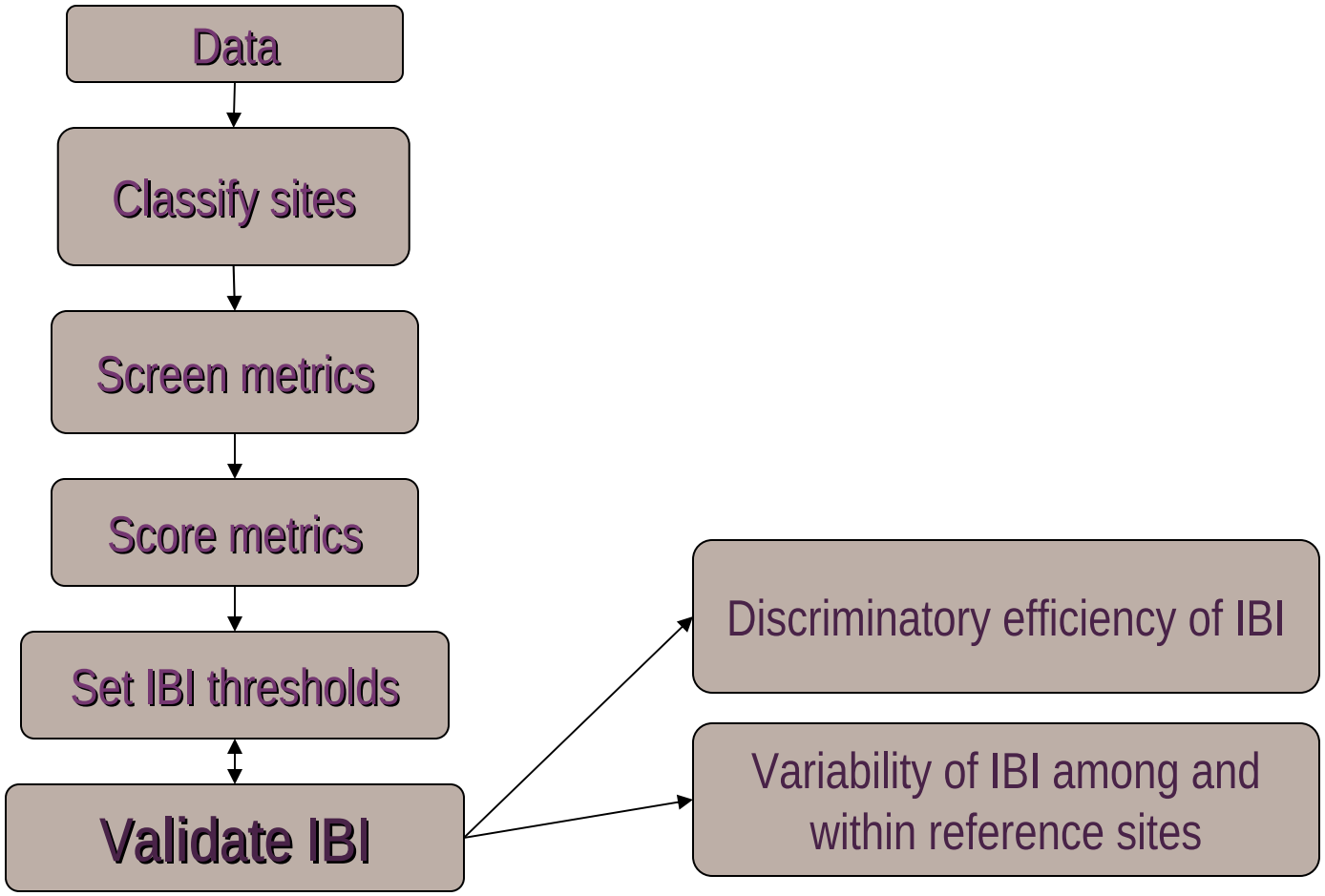

Validate IBI

- Calculate precision and responsiveness measures for IBIs for calibration and validation data sets
- Compare outcomes between data sets
- Poor consistency in results may indicate a less desirable option
- Also may mean that disturbance or other gradient is not consistent between the two data sets
  - If this is the case, redivide data but also recalibrate metric scores using new calibration data
- Use characteristics of IBI to determine the most effective and robust choice

Final Thoughts

- There is no single “right” way to develop an IBI- multiple alternatives are available at each step
- Reference sites should be re-evaluated periodically
- Thresholds should be revisited occasionally or with specific regularity
- Should not be a one-time process, particularly if overall condition improves over time