# Re-evaluation of Ohio Reference Condition and Biocriteria Thresholds Based on 10-Year Interval Resampling

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# Examining Trends in Reference Conditions

- Most Midwest reference conditions represent range of BCG Tiers (e.g., Tiers 2-4, not simply Tiers 1-2)
- Ability to detection stressor changes related to climate change requires ability to:
  - Measure changes in reference condition
  - Link changes to stressors

# Ohio Reference Sites

- Generally span Tier 3 – Tier 4, a few 2 and 5
- All larger river reference sites downstream of some, sometimes substantial effluent
- Widespread agricultural and development changes to landscape
  - Suburbanization and urbanization increasing and changing during period of data collection
  - Agriculture also undergoing continual changes to practices (e.g., increase conservation tillage and not till, but also “refinements” and extensive of drainage)
  - Acid Mine abatement efforts, but also expansion of mining and re-mining
  - New challenges including natural gas “fracking,” increased pharmaceutical use, potential water withdrawal, etc., etc,

# Climate Change

- Need to be able to detect changes due to climate change at reference conditions
- Local changes can overwhelm climate
- Example from logging and riparian removal study:
  - Clearcut increased max temperature by 3.6 C
    - -1.48 C related to loss of shading
    - -1.35 C related to increase in stream width
    - -0.61 C related to air temperature
    - Other factors worked to reduce temperature: relative humidity, wind speed, and ground reflectivity (+0.13)

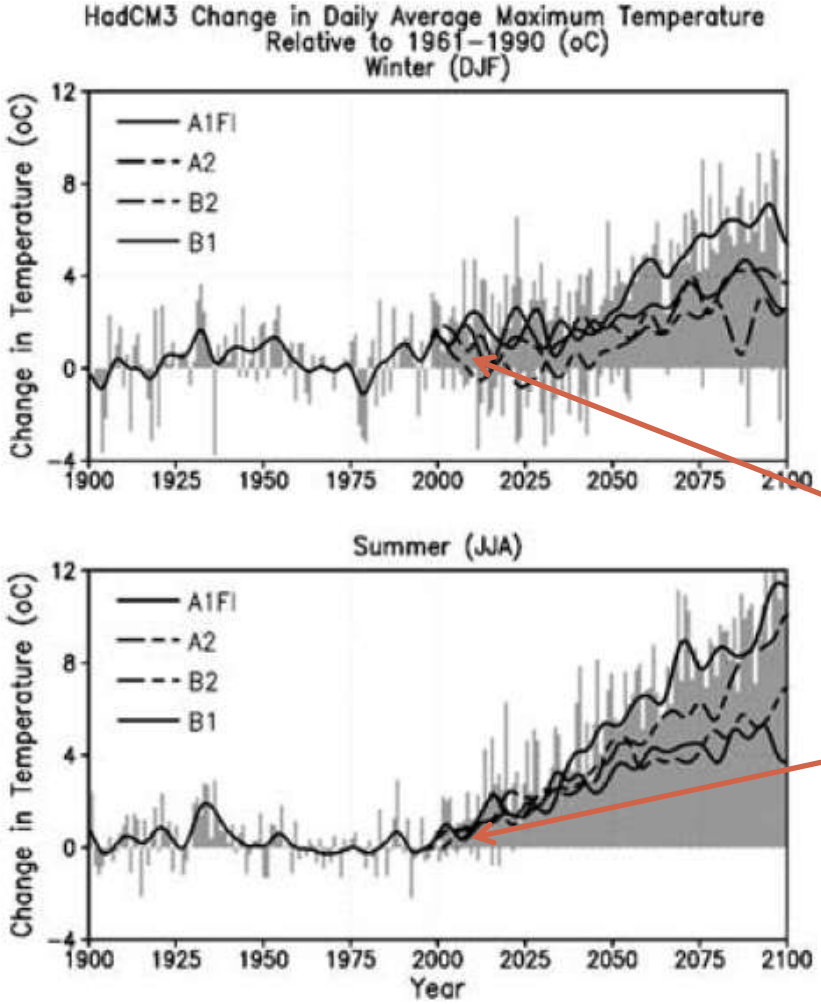
# Midwest: Climate Change Projected

- The observed patterns of temperature increases and precipitation changes are projected to continue
- Increasing precipitation in winter and spring and heavy downpours is expected to lead to more frequent flooding
- Heavy downpours can overload drainage systems and water treatment facilities
- In summer, with increasing evaporation and longer periods between rainfalls, the likelihood of drought will increase and water levels in rivers and wetlands are likely to decline

Karl et al. 2009

# Initial Approach: A Focus on Reference Sites and Biological Indices

- Are the effects of climate change strong enough to show up in biological indices
- Have biological indices at reference sites changed?
- If there have been changes to reference condition, can they be attributed to factors associated with climate change: temperature and stream flow related effects?
- Confounding factors: Taxonomy
- Also, how strongly have change been to date?




Should we be expected clear changes yet?

# Confounding Effects of Changing Macroinvertebrate Taxonomy

- We know macroinvertebrate taxonomy has been improving/changing over time. Can this account for some changes in index score trends over time?
- We focused primarily on the mayflies because:
  - they are an important component of the Ohio ICI,
  - taxonomic refinements are known to have occurred,
  - taxonomic refinements would be expected to influence multiple metrics (total taxa, mayfly taxa, qualitative EPT taxa, etc.).

# Methods

- We used the entire Ohio database to identify “earliest” and “latest” years for all taxa in order to extract a list of possible taxa that could affect ICI scoring via taxonomic refinement (splitting or lumping of taxa).
- We focused on the mayfly taxa at reference sites and identified taxa and sites that occurred in the original reference sites, but not the new sites and visa versa.

| Taxa Code | Taxon Name | Appear-ence | Explanation of Change |
|---|---|---|---|
| 11010 | Acentrella sp | Later | Improved taxonomy allow this taxa to be distinguished Pseudocloeon sp. |
| 11014 | Acentrella turbida | Later | Improved taxonomy allow this taxa to be distinguished from Pseudocloeon sp. |
| 11015 | Acerpenna sp | Later | Improved taxonomy allow this taxa to be distinguished from Baetidae sp. |
| 11018 | Acerpenna macdunnoughi | Later | Improved taxonomy allow this taxa to be distinguished from Baetidae sp. |
| 11020 | Acerpenna pygmaea | Later | Improved taxonomy allow this taxa to be distinguished from Baetidae sp. |
| 11110 | Acentrella parvula | Later | Improved taxonomy allow this taxa to be distinguished from Pseudocloeon sp. or was renamed from Pseudocloeon parvulum |
| 11115 | Baetis tricaudatus | Later | Improved taxonomy allow this taxa to be distinguished from Baetidae sp. |
| 11118 | Plauditus dubius | Later | Improved taxonomy allow this taxa to be distinguished Pseudocloeon sp. |
| 11119 | Plauditus dubius or P. virilis | Later | Improved taxonomy allow this taxa to be distinguished Pseudocloeon sp. |
| 11120 | Baetis flavistriga | Later | Improved taxonomy allow this taxa to be distinguished from Baetidae sp. |
| 11125 | Pseudocloeon frondale | Later | Improved taxonomy allow this taxa to be distinguished from Baetidae sp. |
| 11130 | Baetis intercalaris | Later | Improved taxonomy allow this taxa to be distinguished from Baetidae sp. |
| 11150 | Pseudocloeon propinquum | Later | Improved taxonomy allow this taxa to be distinguished from Baetidae sp. |
| 11155 | Plauditus punctiventris | Later | Improved taxonomy allow this taxa to be distinguished Pseudocloeon sp. |
| 11175 | Plauditus virilis | Later | Improved taxonomy allow this taxa to be distinguished Pseudocloeon sp. |
| 11250 | Centroptilum sp (w/o hindwing pads) | Later | Improved taxonomy allow this taxa to be distinguished Cloeon sp. |
| 11400 | Centroptilum sp or Procloeon sp (formerly in Cloeon | Earlier | Improved taxonomy allow this taxa to be distinguished Cloeon sp. |
| 11430 | Diphetor hageni | Later | Improved taxonomy allow this taxa to be distinguished from Baetidae sp. |
| 11503 | Heterocloeon curiosum | Later | Renamed Heterocloeon (H.) sp, Heterocloeon sp. |
| 11600 | Paracloeodes sp 1 | Later | Improved taxonomy allow this taxa to be distinguished from Paracloeodes sp |
| 11625 | Paracloeodes sp 3 | Later | Improved taxonomy allow this taxa to be distinguished from Paracloeodes sp |
| 11645 | Procloeon sp | Later | Was earlier classified as Centroptilum sp or Cloeon sp |
| 11650 | Procloeon sp (w/ hindwing pads) | Later | Was earlier classified as Cloeon sp |
| 11651 | Procloeon sp (w/o hindwing pads) | Later | Was earlier classified as Centroptilum sp |
| 11670 | Procloeon irrubrum | Later | Improved taxonomy allow this taxa to be distinguished from Cloeon sp |
| 11700 | Acentrella sp or Plauditus sp (formerly in Pseudoc | Earlier | Renamed as Pseudocloeon sp |
| 13010 | Leucrocuta hebe | Earlier | Renamed as Heptagenia hebe |
| 13030 | Leucrocuta maculipennis | Earlier | Renamed as Heptagenia maculipennis |
| 14501 | Leptophlebiidae | Earlier | Now coded as Leptophlebia sp |
| 14900 | Leptophlebia sp | Later | Leptophlebia sp |
| 14950 | Leptophlebia sp or Paraleptophlebia sp | Later | Small specimens lumped |

# Changes in Ohio Biocriteria: Summary

| Ecoregion | WWH | | MWH | |
|---|---|---|---|---|
| | Original | New | Original | New |
| **Headwater - IBI** | | | | |
| IP | 40 | 40 | 50 | 52 |
| EOLP | 40 | 36 | | |
| WAP | 44 | 42 | | |
| ECBP | 40 | 44 | | |
| **Wadeable - IBI** | | | | |
| IP | 40 | 44 | 50 | 52 |
| EOLP | 38 | 42 | | |
| WAP | 44 | 46 | | |
| ECBP | 40 | 40 | | |
| **Boatable - IBI** | | | | |
| IP | 38 | 47 | 48 | 52 |
| EOLP | 40 | 46 | | |
| WAP | 40 | 40 | | |
| ECBP | 42 | 42 | | |
| **Macroinvertebrates - ICI** | | | | |
| HELP | 34 | 42 | 46 | 50 |
| IP | 30 | 38 | | |
| EOLP | 34 | 44 | | |
| WAP | 36 | 40 | | |
| ECBP | 36 | 42 | | |

- No Change

- NS Change

- Significant Change

# Observed Changes to Biocriteria Between Time Periods 1979-1989 vs. 1990-2008

- The direction of change in the biocriteria between the original and latest reference site data was either positive (an increase) or neutral (no change) with only three instances where the new biocriteria were lower.
  - the ICI biocriterion for the non-acidic mine drainage modified use (-4 pts; possible small sample size);
  - the IBI for WWH headwater site type in the EOLP ecoregion (-2 pts); and,
  - the IBI for WWH headwater site type in the WAP ecoregion (-2 pts). None of these changes are considered to be greater than the non-significant departure for each index.

# Direction of Changes Due to Climate Related Change

- The direction of climate related changes in biological index scores could be in either direction.
- However, the most plausible expectation would be for a decline due to:
  - the immediate loss of highly intolerant species and taxa (i.e., temperature and flow sensitive taxa/species)
  - an increase in intermediate, moderately, and/or highly tolerant taxa/species.

# Influence of Taxonomic Changes on Trend Assessment in Ohio

- We focused on the taxonomic changes in mayflies to examine the quantitative contribution of the refined taxonomy on ICI scoring for three metrics; total taxa, mayfly taxa, and qualitative EPT taxa.
- We recalculated the mean number of taxa for each metric as it now occurs in the database (“refined” taxonomy) and then again with the taxonomy “lumped” to match the level of taxonomy that was prevalent during the derivation of the original biocriteria.
- We recalculated the biocriteria statistics (25th percentiles by ecoregion for WWH; 75th percentiles statewide for EWH) based on the newly refined and lumped taxonomy

# Influence of Taxonomy Changes on ICI

- Recalculation of ICIs from all sites indicated a 5.9 point increase in the mean ICI score between the two time periods.
- When mayfly taxonomy was lumped between these time periods the increase was 5.0
- Taxonomic refinement in mayflies accounted for 14% of the increase in the mean ICI between the two reference time periods

| Metric | Original Reference Sites | | New Reference Sites (Latest Data) | |
|---|---|---|---|---|
| | Standard Taxonomy Mean Taxa (Mean Score) | Lumped Taxonomy Mean Taxa (Mean Score) | Standard Taxonomy Mean Taxa (Mean Score) | Lumped Taxonomy Mean Taxa (Mean Score) |
| Total Taxa | 35.97 (4.89) | 35.93 (4.89) | 38.36 (5.18) | 37.65 (5.04) |
| Number of Mayfly Taxa | 6.95 (4.20) | 6.90 (4.17) | 7.42 (4.59) | 6.59 (4.16) |
| QUAL EPT Taxa | 11.29 (3.63) | 11.24 (3.60) | 15.16 (5.16) | 14.23 (4.91) |
| ICI Score | **39.59** | **39.53** | **45.35** | **44.56** |

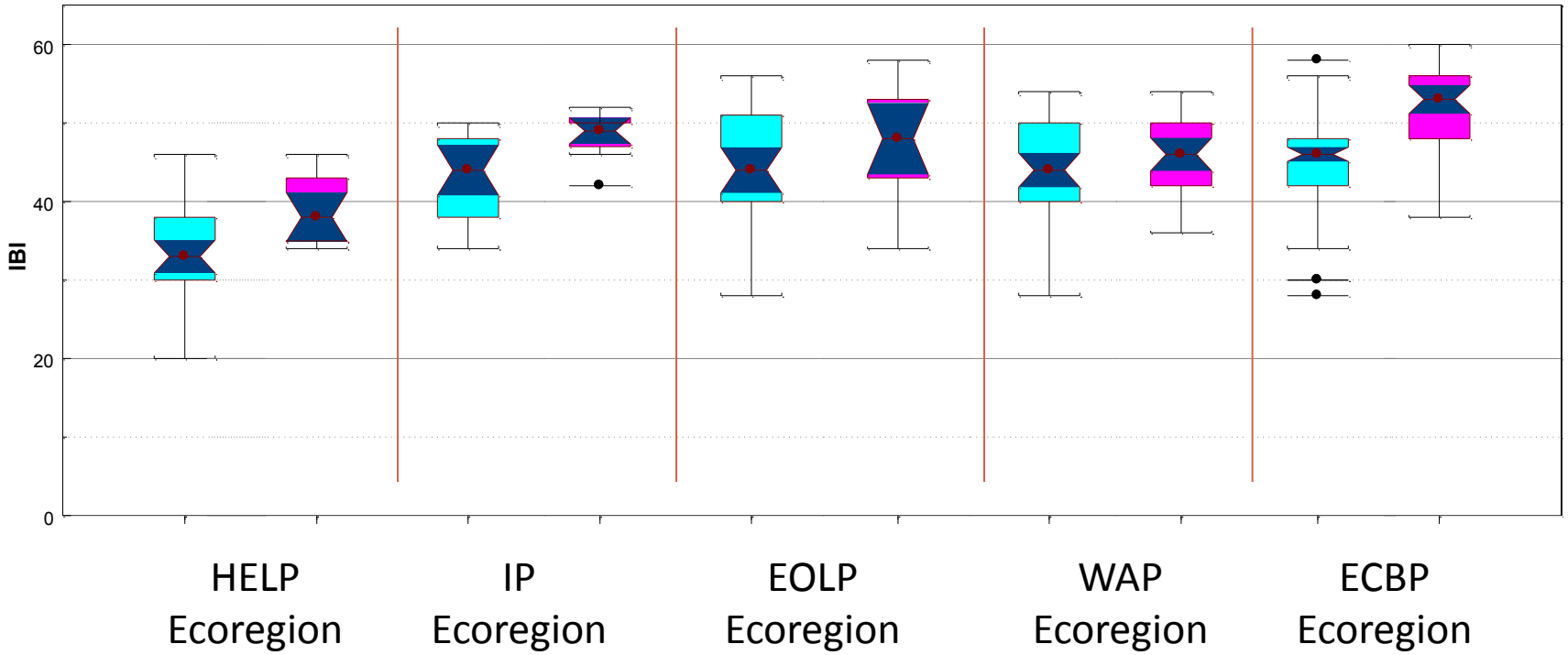
# Effect of Taxonomy on Biocriteria

| | Warmwater Habitat | | | Exceptional Warmwater Habitat | | |
|---|---|---|---|---|---|---|
| Ecoregion | Original Reference | Latest Reference | Latest Reference w/ Refined Taxonomy | Original Reference | Latest Reference | Latest Reference w/ Refined Taxonomy |
| HELP | **34** | **42** | **38.5** | **46** | **50** | **50** |
| IP | **30** | **38** | **38** | | | |
| EOLP | **34** | **44** | **42** | | | |
| WAP | **36** | **40** | **40** | | | |
| ECBP | **36** | **42** | **42** | | | |

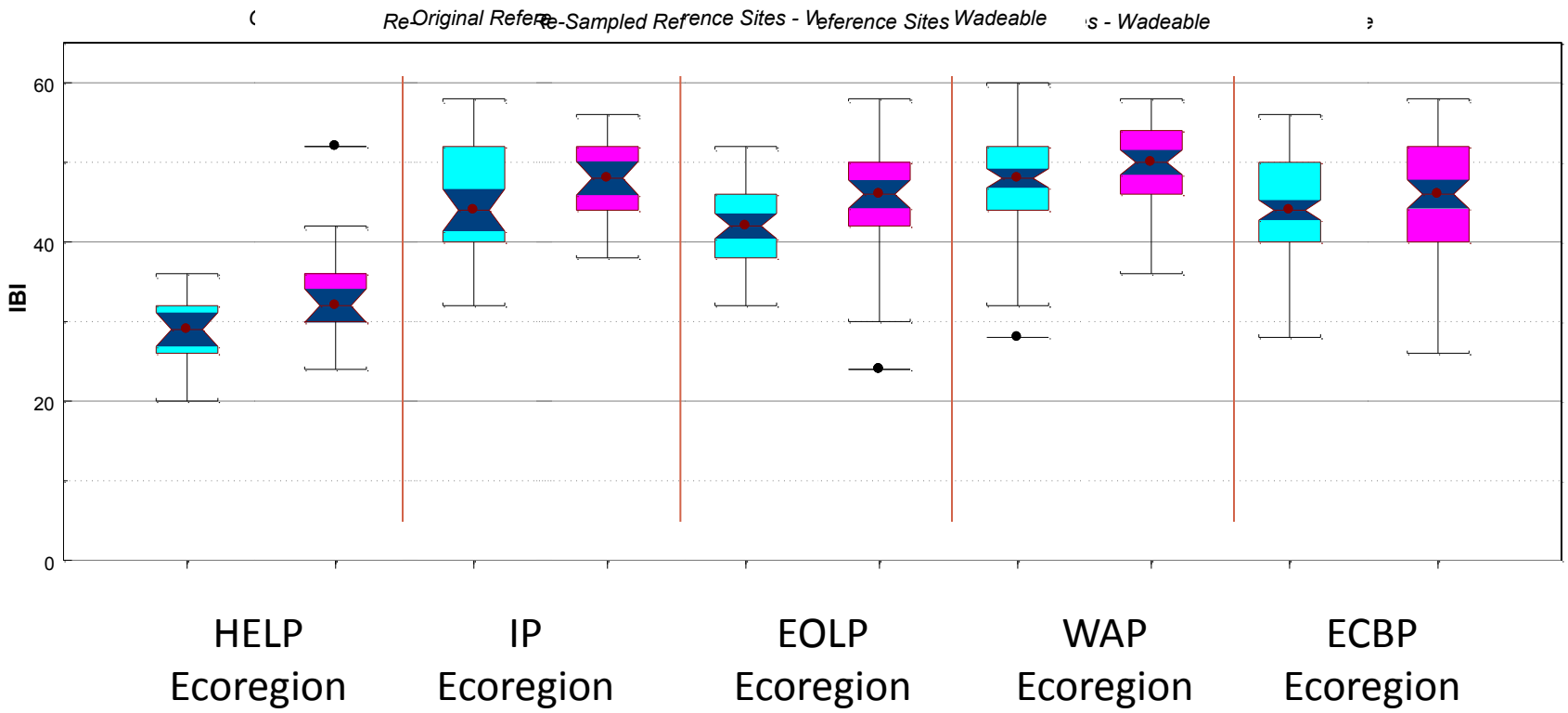
# Recalibration of the Biological Criteria in Ohio

- Ohio reference sites have generally improved over time
- Reasons for improvement differ among stream size categories
  - Large river reference sites have generally improved from continued point source reductions
  - Headwater and small streams have generally improved due to better agricultural practices (e.g., conservation tillage)
  - Large river pollution reductions have facilitated movement of intolerant species between watersheds (i.e., have become highways for recolonization)
- The ability to detect impacts from climate change effects (e.g., temperatures, hydrologic changes) confounding by positive changes in stressors

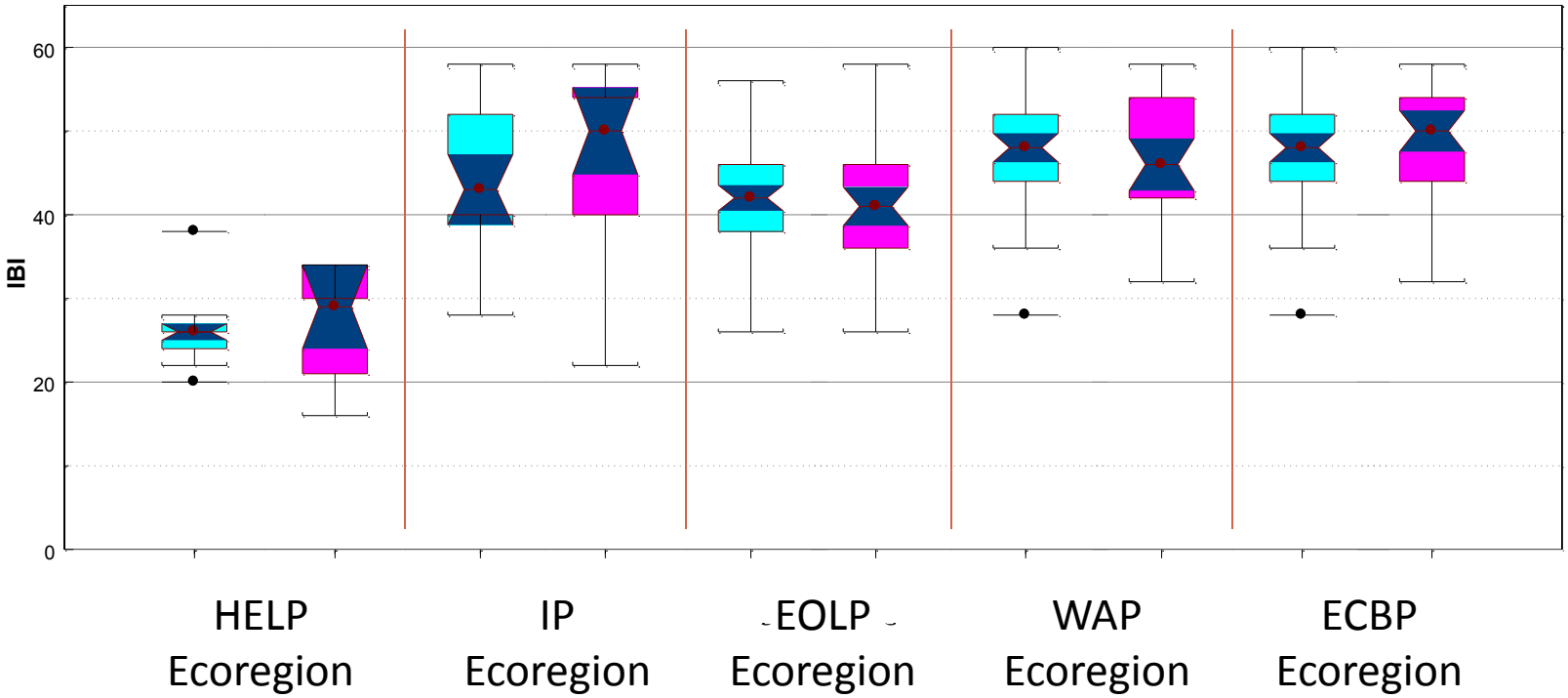
# Original vs. Re-Sampled Reference Sites, Fish: Boatable Stream and Rivers



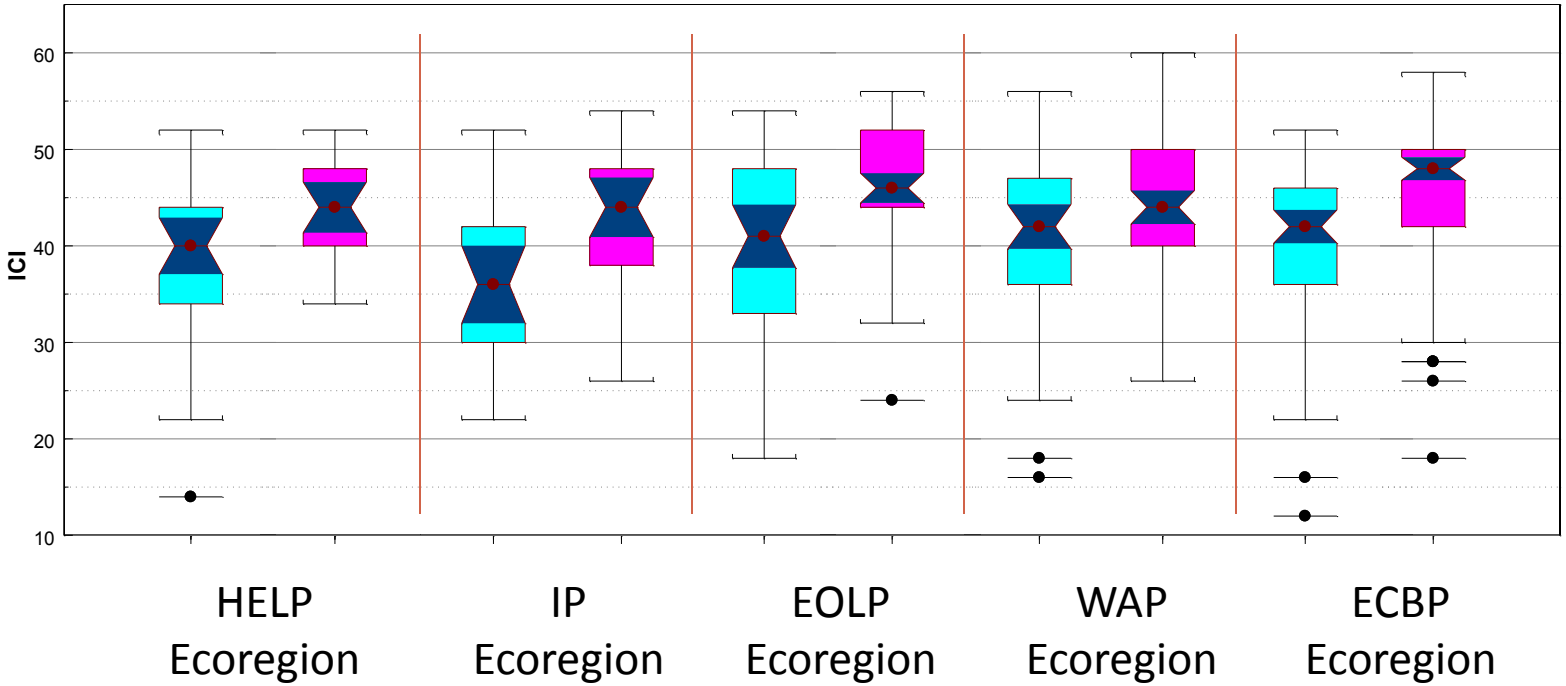
# Original vs. Re-Sampled Reference Sites, Fish: Wadeable Stream and Rivers



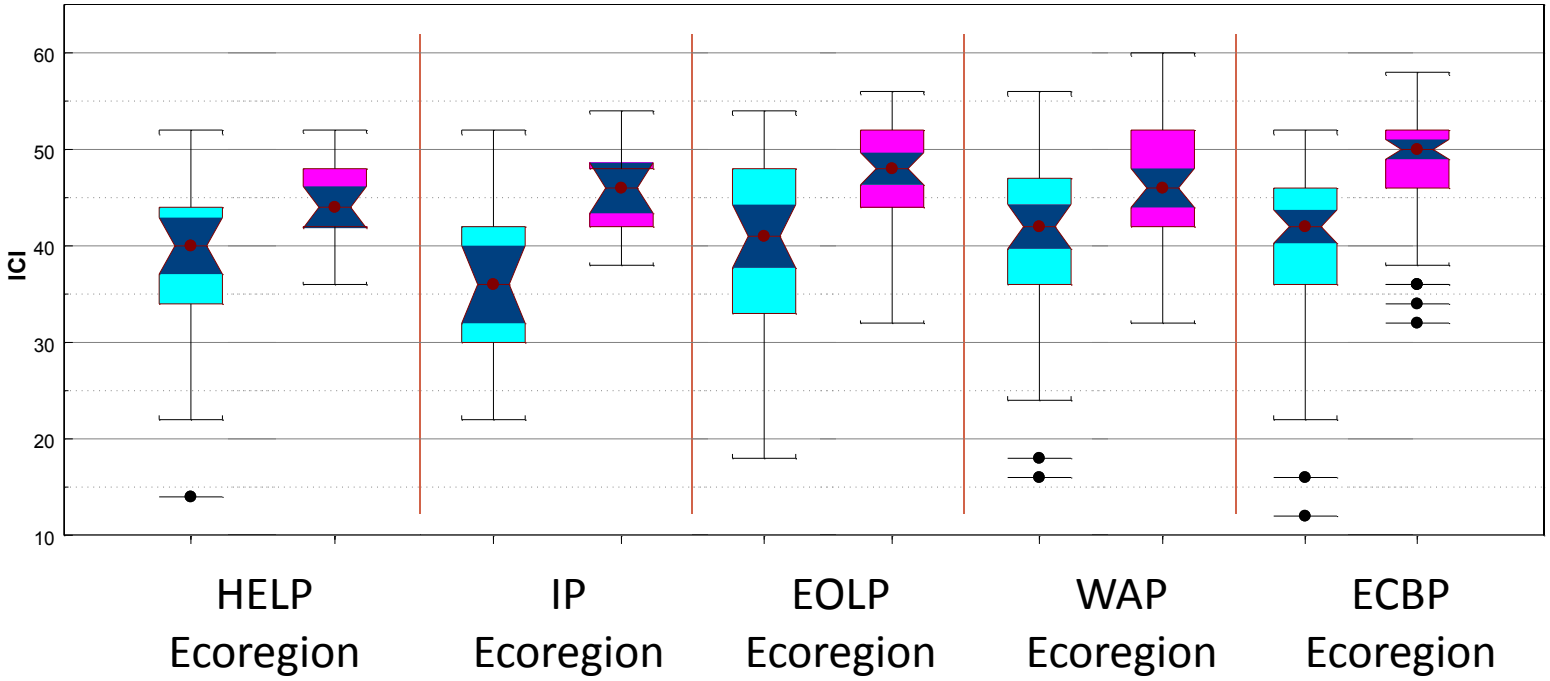
# Original vs. Re-Sampled Reference Sites, Fish: Headwater Stream and Rivers



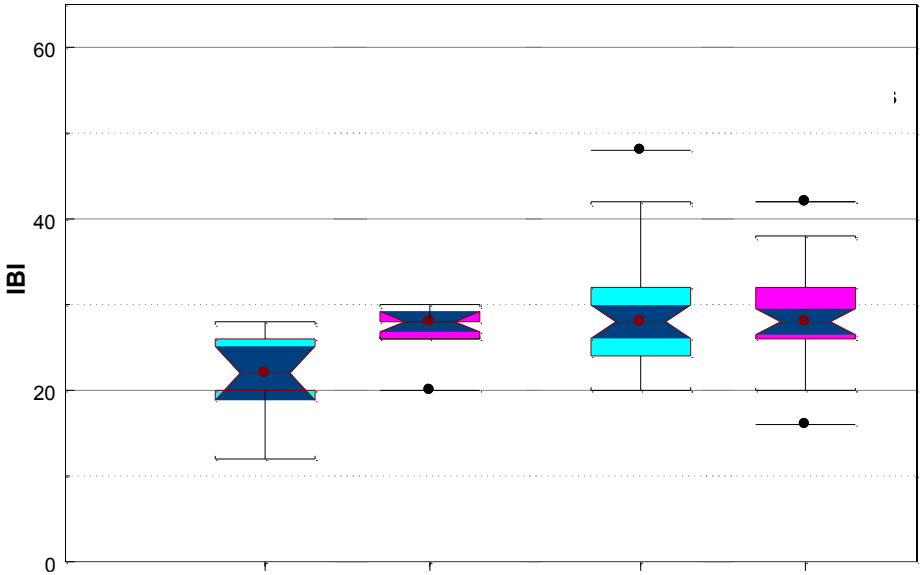
# Original vs. Re-Sampled Reference Sites, Macroinvertebrates



# Original vs. Re-Sampled Reference Sites, Macroinvertebrates, Low Flow Sites Excluded



# Channel Modified “Reference” Sites



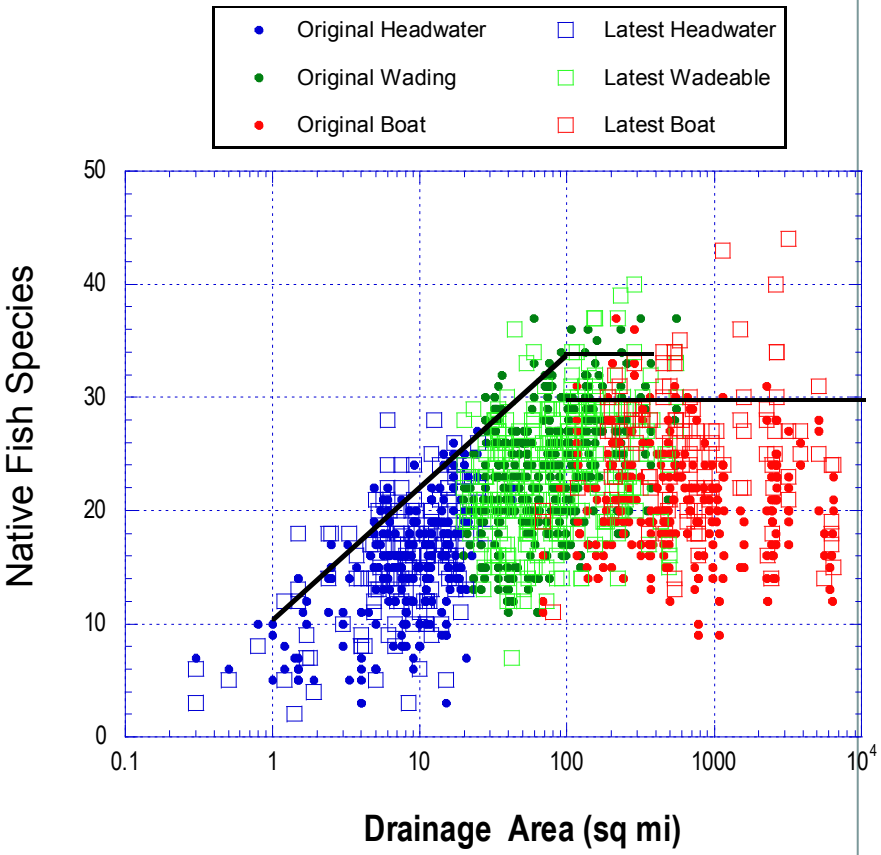

HELP Ecoregion

Other Ecoregions

# Native Species Trends at Reference Sites

Table 4. Number of native fish species for reference site by period and stream size category. Re-sampled reference sites are represented by the latest sample available.

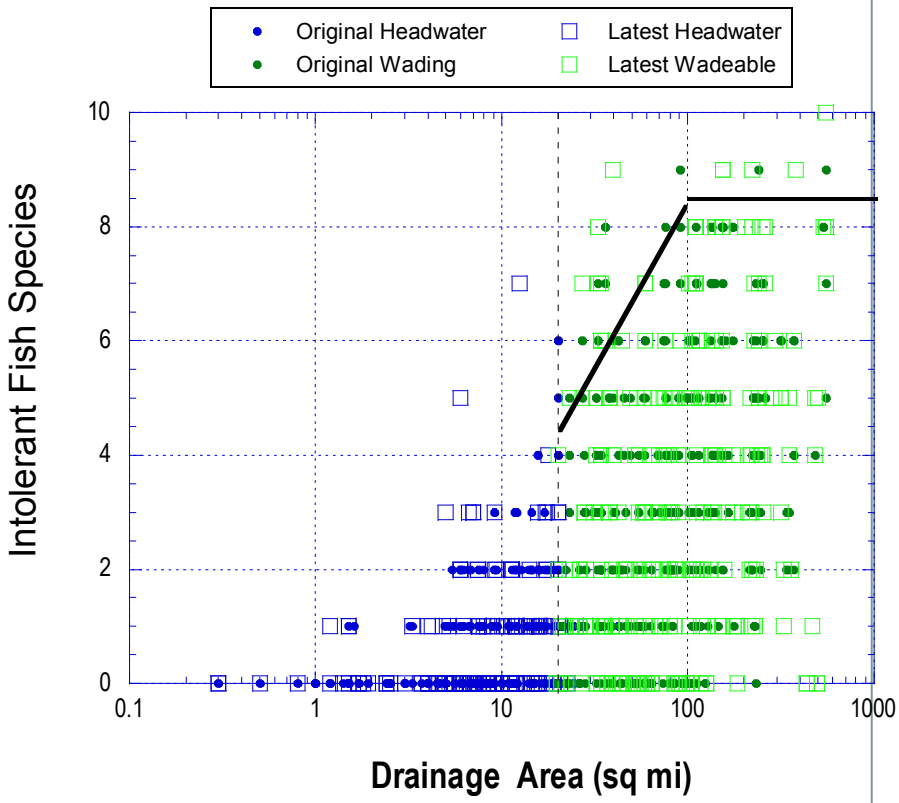
| Reference Period | Stream Size Type | N (Passes) | Mean Native Fish Species |
|---|---|---|---|
| Original Reference Sites | Headwater | 228 | **14.9** |
| | Wadeable | 402 | **23.3** |
| | Boat | 256 | **20.8** |
| Re-Sampled Reference Sites (latest) | Headwater | 150 | **15.7** |
| | Wadeable | 281 | **23.3** |
| | Boat | 120 | **25.2** |



# Intolerant Species

Table 12. Number of intolerant fish species for reference site by period and stream size category. Re-sampled reference sites are represented by the latest sample available.

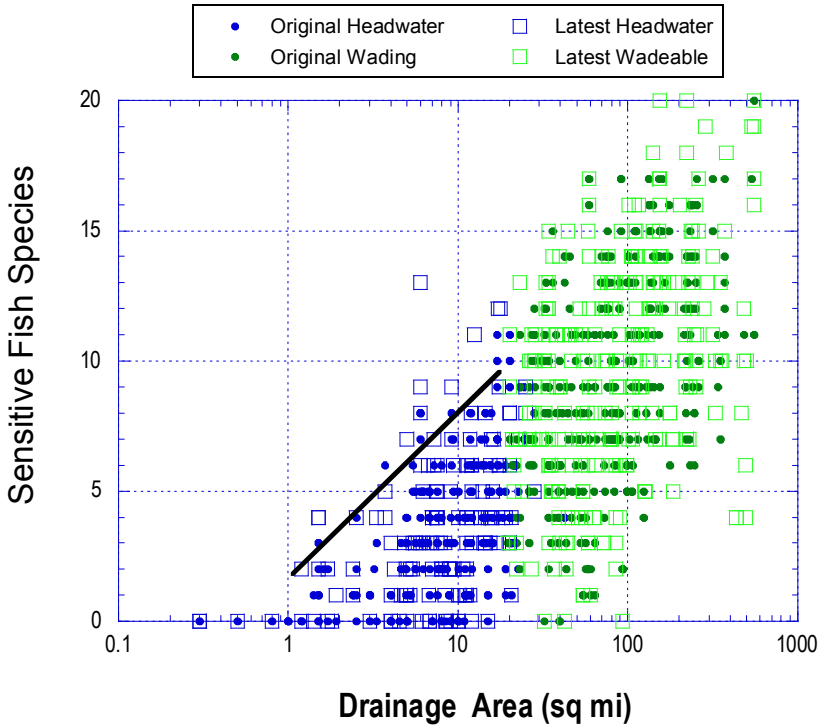
| Reference Period | Stream Size Type | N (Passes) | Mean Sensitive Fish Species |
|---|---|---|---|
| Original Reference Sites | Headwater | 228 | **0.7** |
| | Wadeable | 402 | **2.9** |
| | Boat | 256 | **2.0** |
| Re-Sampled Reference Sites (latest) | Headwater | 150 | **0.8** |
| | Wadeable | 281 | **3.2** |
| | Boat | 120 | **3.7** |



# Sensitive Species Trends

Table 13. Number of sensitive fish species for reference site by period and stream size category. Re-sampled reference sites represent the latest sample

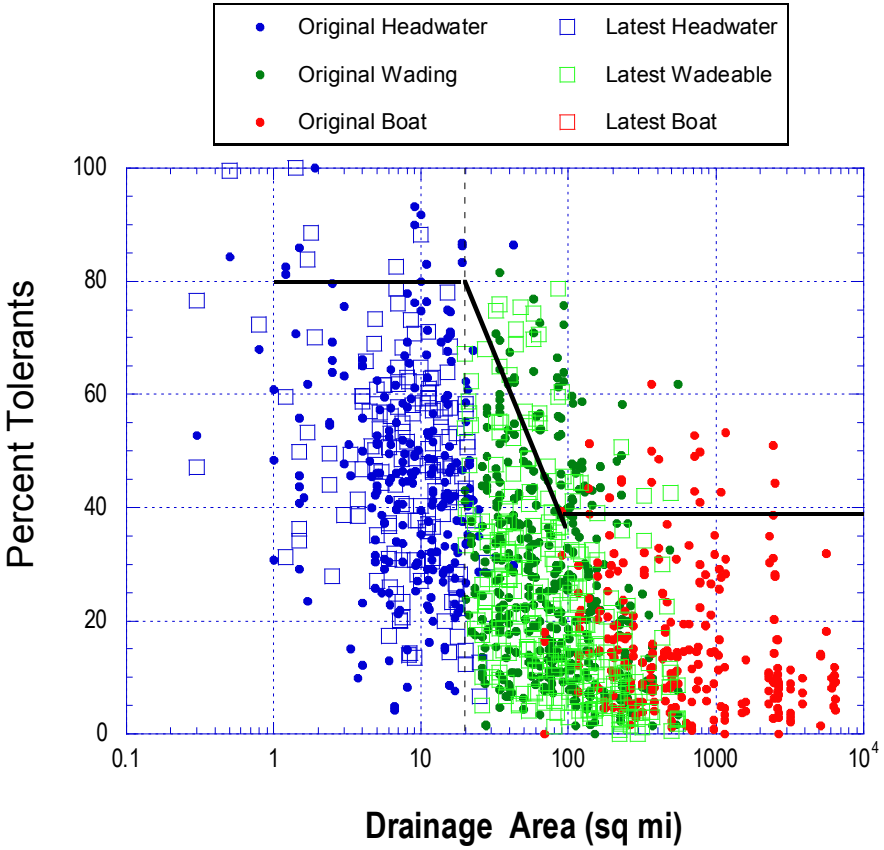
| Reference Period | Stream Size Type | N (Passes) | Mean Sensitive Fish Species |
|---|---|---|---|
| Original Reference Sites | Headwater | 228 | **3.3** |
| | Wadeable | 402 | **9.2** |
| | Boat | 256 | **8.0** |
| Re-Sample Reference Sites (latest) | Headwater | 150 | **3.6** |
| | Wadeable | 281 | **9.7** |
| | Boat | 120 | **11.3** |



# Tolerant Fish Species Trend

Table 14. Percent tolerant individuals for reference site by period and stream size category. Re-sampled reference sites represent the latest sample

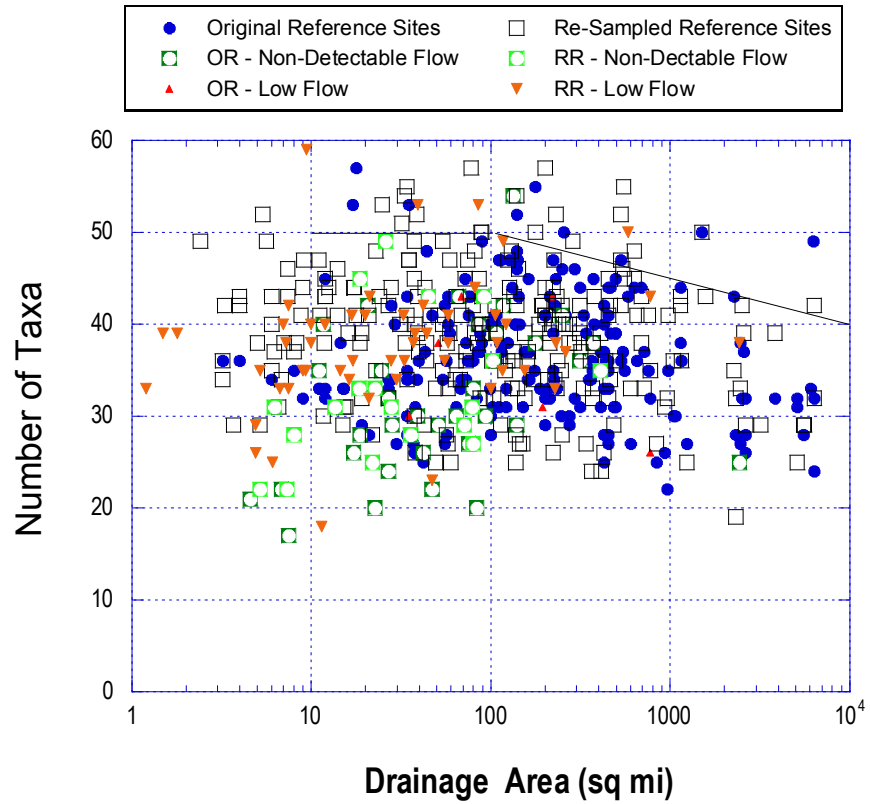
| Reference Period | Stream Size Type | N (Passes) | Mean Percent Tolerant |
|---|---|---|---|
| Original Reference Sites | Headwater | 228 | **46.2** |
| | Wadeable | 402 | **27.0** |
| | Boat | 256 | **16.4** |
| Re-Sample Reference Sites (latest) | Headwater | 150 | **47.2** |
| | Wadeable | 281 | **23.7** |
| | Boat | 120 | **9.5** |



# Macroinvertebrate Quant Taxa Trend

Table 19. Number of total taxa for reference site by period and by flow condition. Re-sampled reference sites represent the latest sample

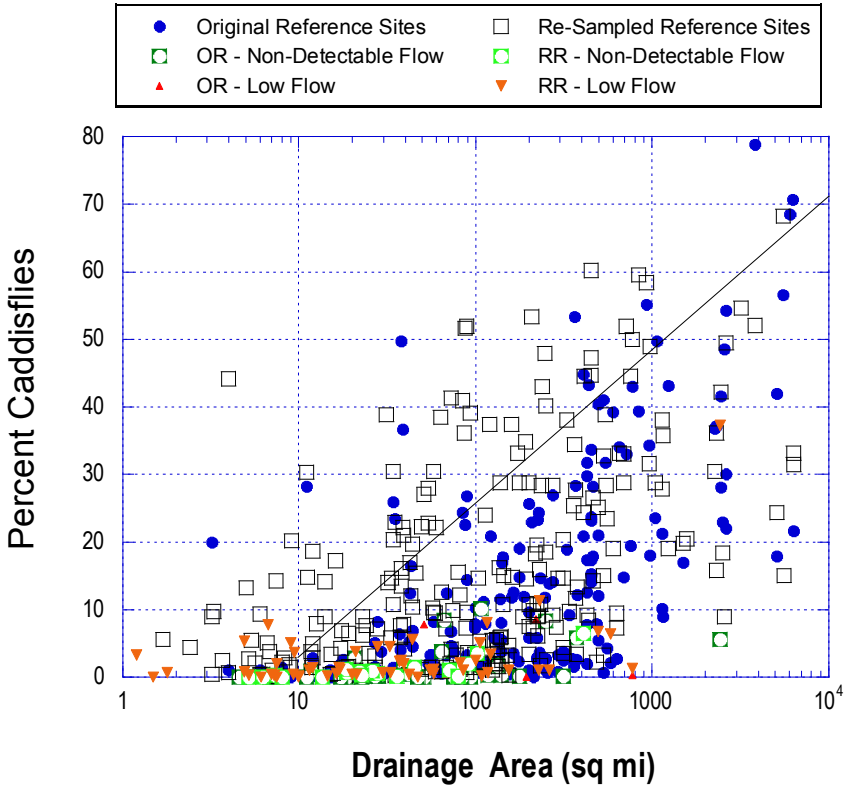
| Reference Period | Flow | N | Mean Total Taxa |
|---|---|---|---|
| Original Reference Sites | | 202 | **36.7** |
| | Non-Detectable | 33 | **31.6** |
| | Low Flow | 7 | **34.6** |
| Re-Sample Reference Sites (latest) | | 237 | **38.9** |
| | Non-Detectable | 19 | **32.7** |
| | Low Flow | 55 | **38.1** |



# Percent Caddisflies

Table 24. Percent caddisflies for reference site by period and by flow condition. Re-sampled reference sites represent the latest sample

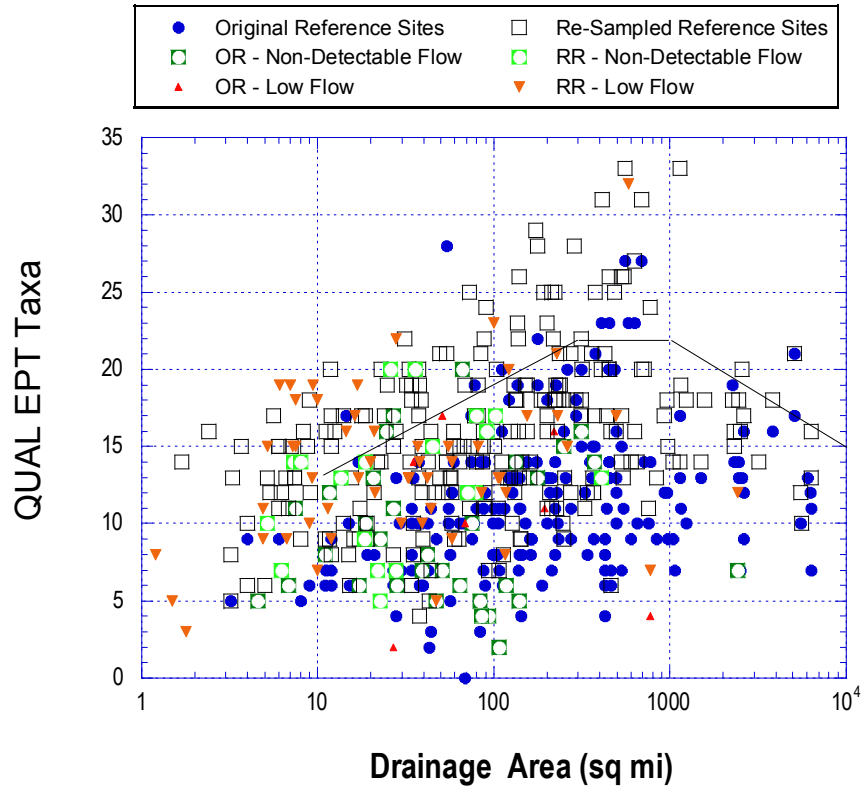
| Reference Period | Flow | N | Mean Percent Mayflies |
|---|---|---|---|
| Original Reference Sites | | 202 | **14.2** |
| | Non-Detectable | 33 | **1.6** |
| | Low Flow | 7 | **2.5** |
| Re-Sample Reference Sites (latest) | | 237 | **16.5** |
| | Non-Detectable | 19 | **1.1** |
| | Low Flow | 55 | **2.8** |



# QUAL EPT Taxa

Table 28. QUAL EPT taxa for reference sites by period and by flow condition. Re-sampled reference sites represent the latest sample

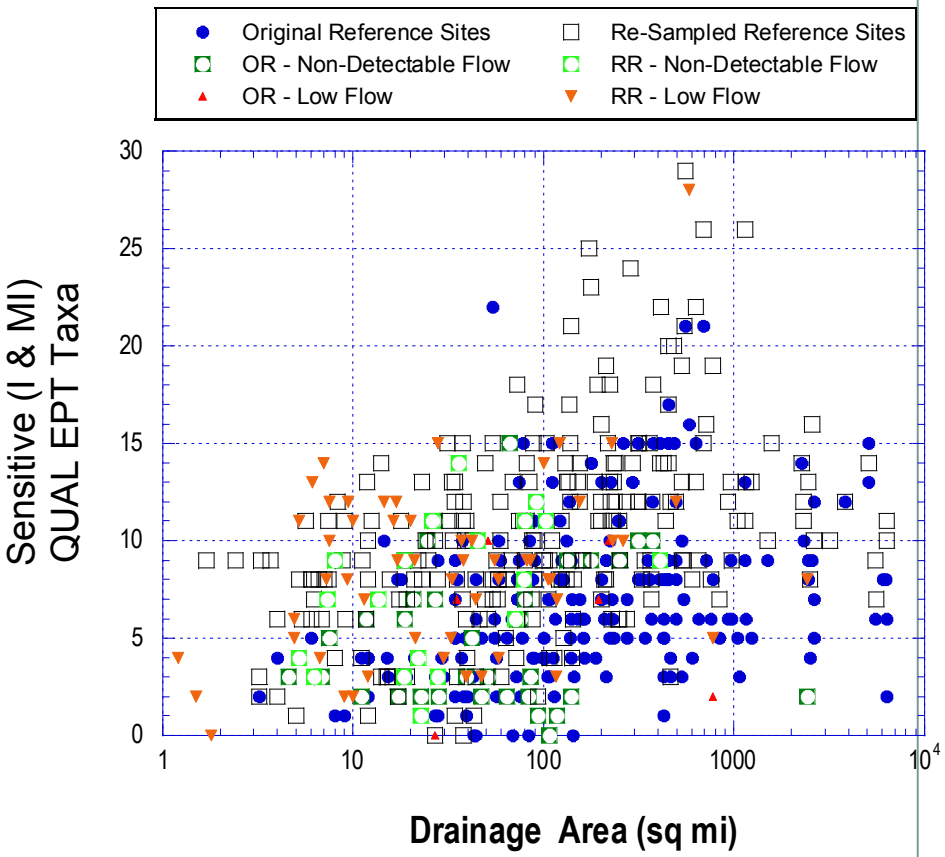
| Reference Period | Flow | N | Mean QUAL EPT Taxa |
|---|---|---|---|
| Original Reference Sites | | 202 | **11.6** |
| | Non-Detectable | 33 | **9.4** |
| | Low Flow | 7 | **10.6** |
| Re-Sample Reference Sites (latest) | | 237 | **15.6** |
| | Non-Detectable | 19 | **12.7** |
| | Low Flow | 55 | **13.8** |



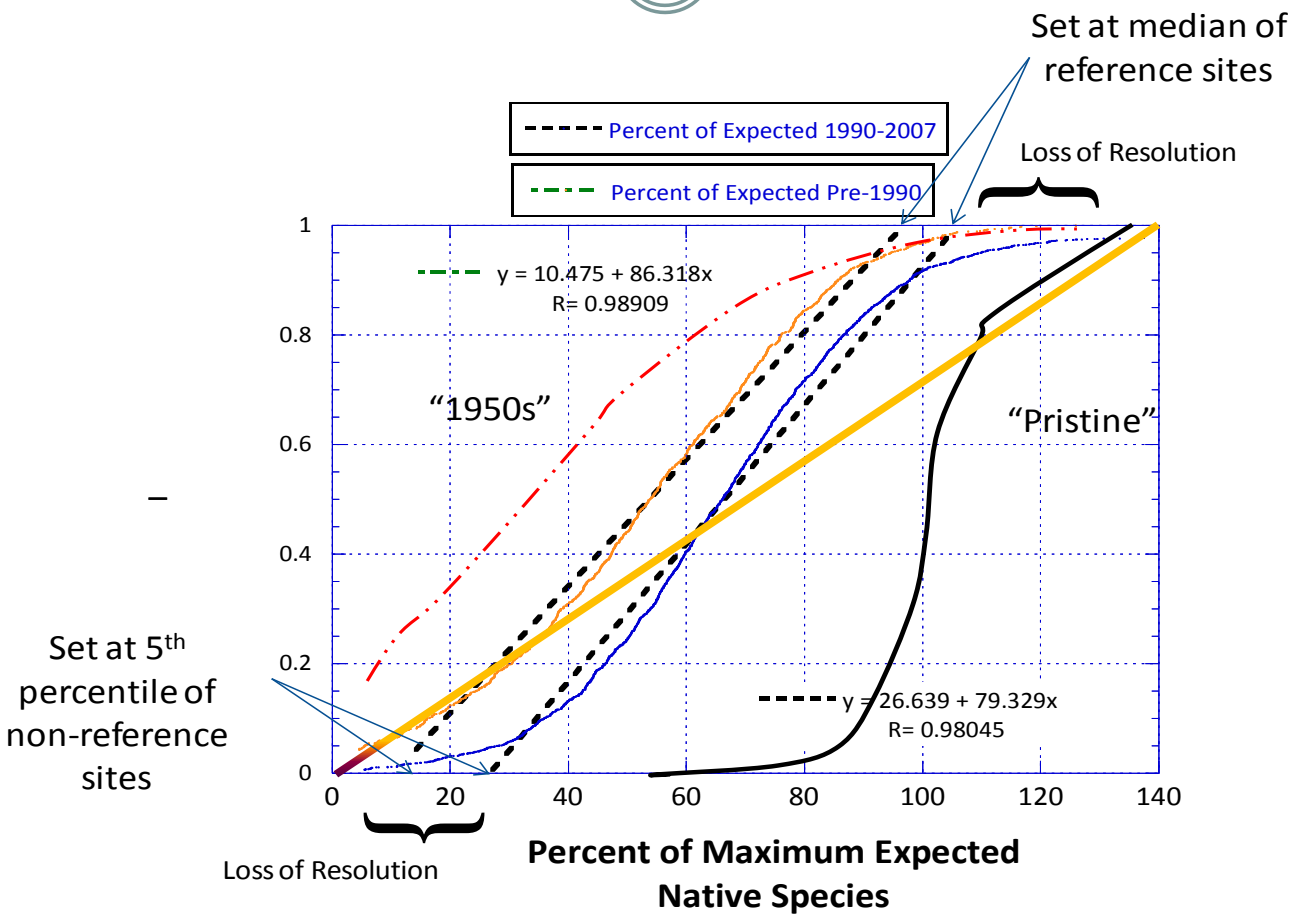
# Sensitive QUAL EPT Taxa

Table 30. Sensitive QUAL EPT taxa for reference sites by period and by flow condition. Re-sampled reference sites represent the latest sample

| Reference Period | Flow | N | Mean QUAL EPT Taxa |
|---|---|---|---|
| Original Reference Sites | | 202 | **7.2** |
| | Non-Detectable | 33 | **5.1** |
| | Low Flow | 7 | **6.0** |
| Re-Sample Reference Sites (latest) | | 237 | **10.3** |
| | Non-Detectable | 19 | **7.5** |
| | Low Flow | 55 | **8.6** |



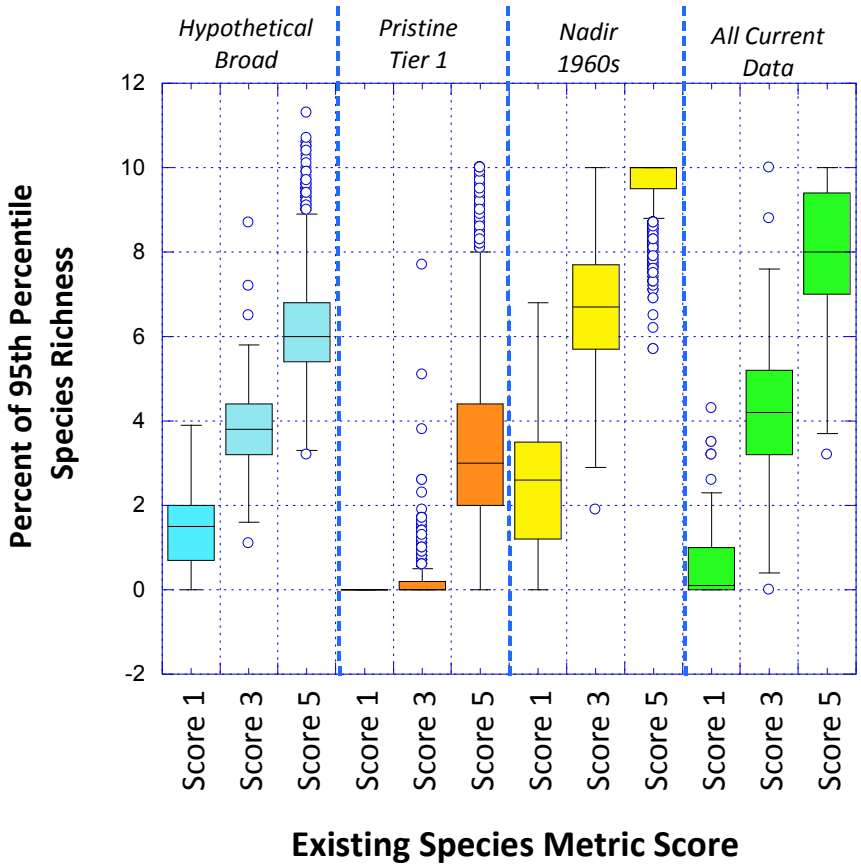
# Development of a BCG-Based Continuous IBI Index



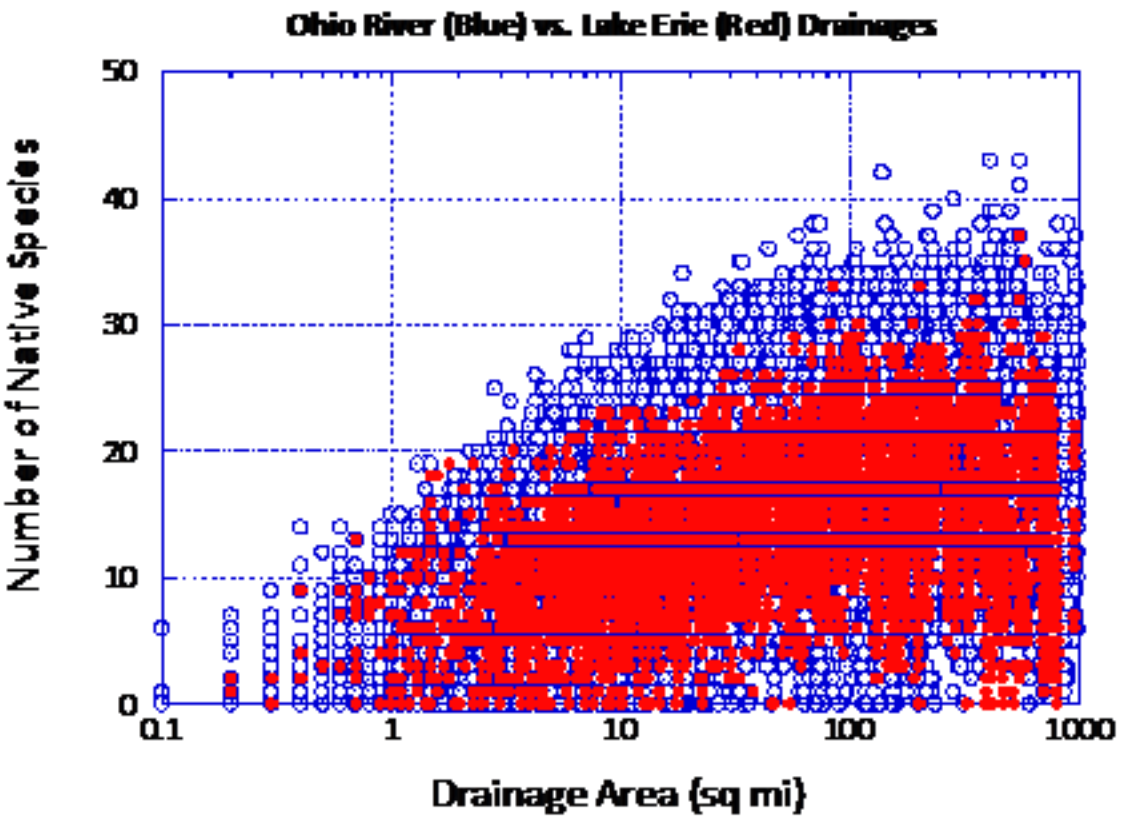
# Consequences of Scoring Compared to Existing Conditions

**Table 1. Scenarios used to demonstrate consequence of scoring methods**

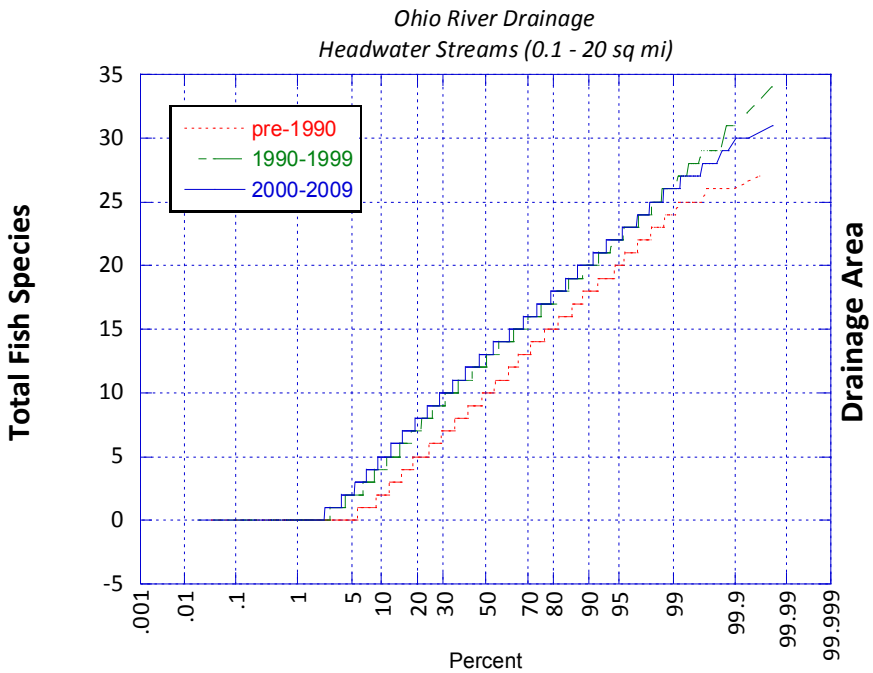
| Scenario | Description |
|---|---|
| **Base** | Existing 1-3-5 scoring metrics |
| **1** | Complete gradient (broad) approach |
| **2** | Hypothetical pristine conditions |
| **3** | Hypothetical nadir conditions |
| **4** | All current data |

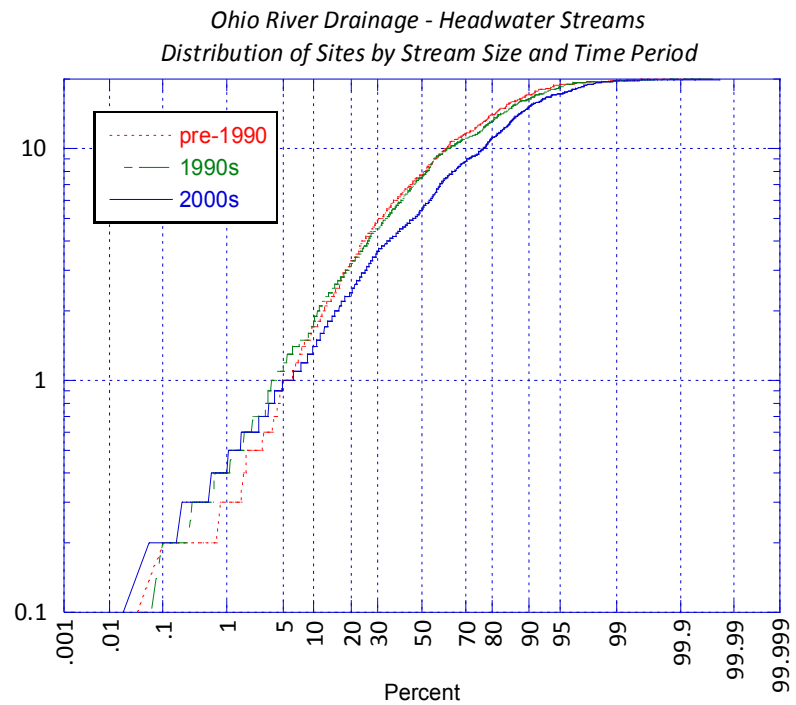


# Species Richness: Lake Erie vs. Ohio River Drainage

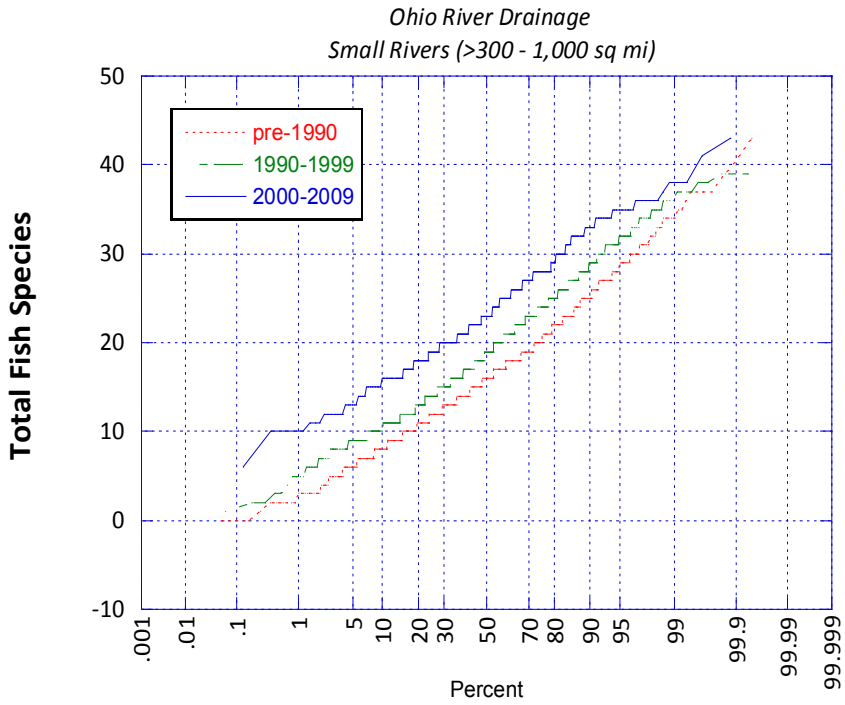


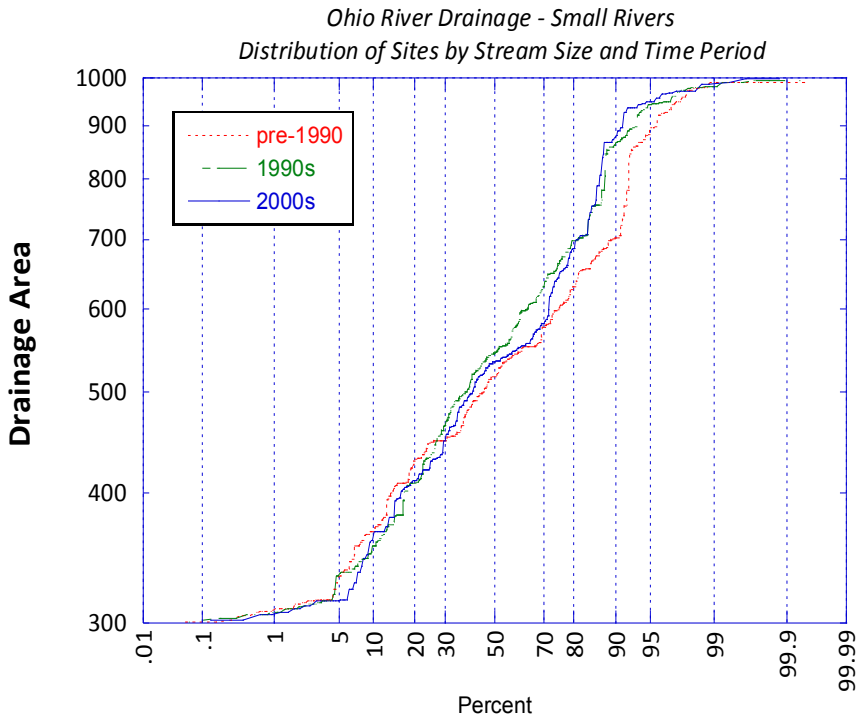
# Species Richness Trends at Reference Sites in Headwater Streams – Not Related to Stream Size



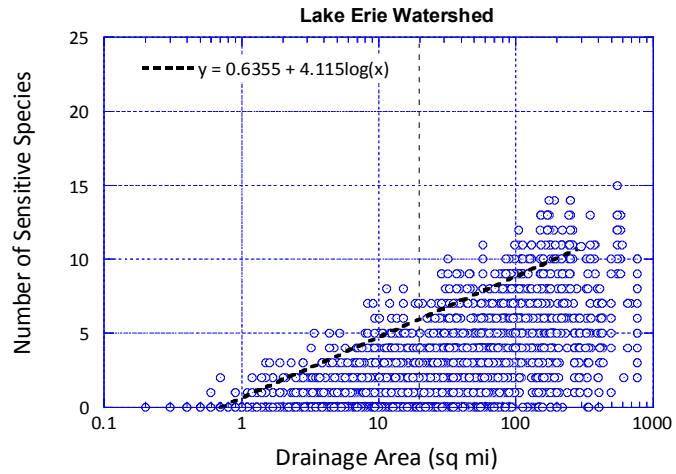



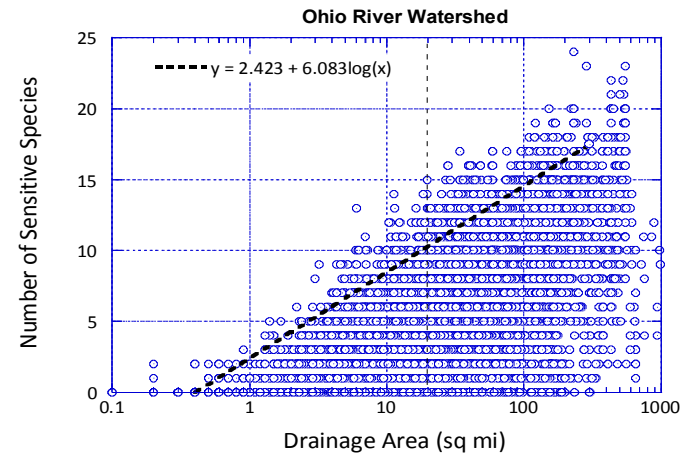
# Species Richness Trends at Reference Sites in Rivers– Not Related to Stream Size

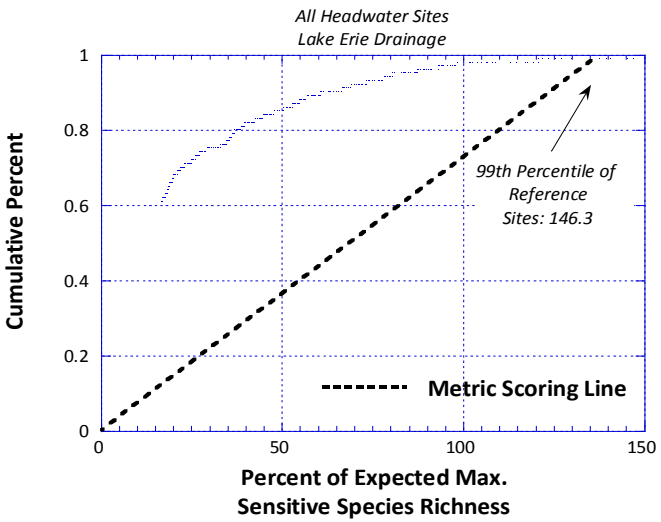


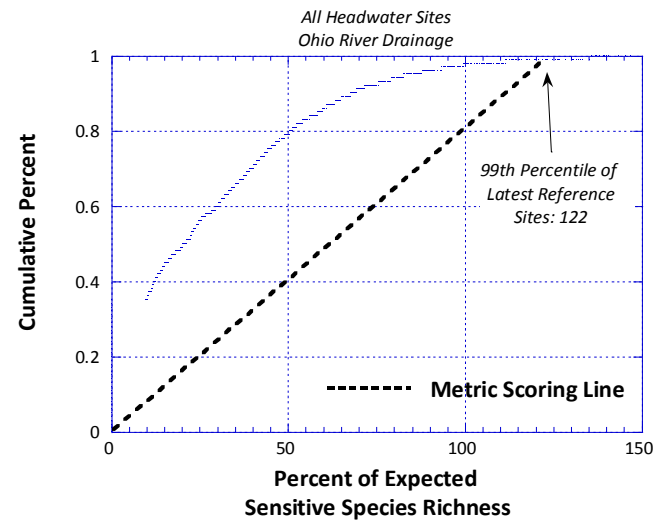



# Calibration of Metrics

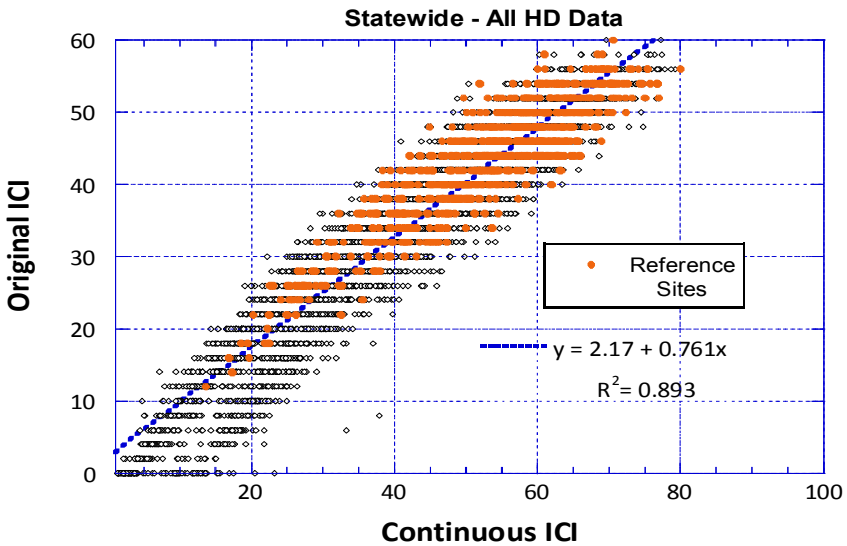


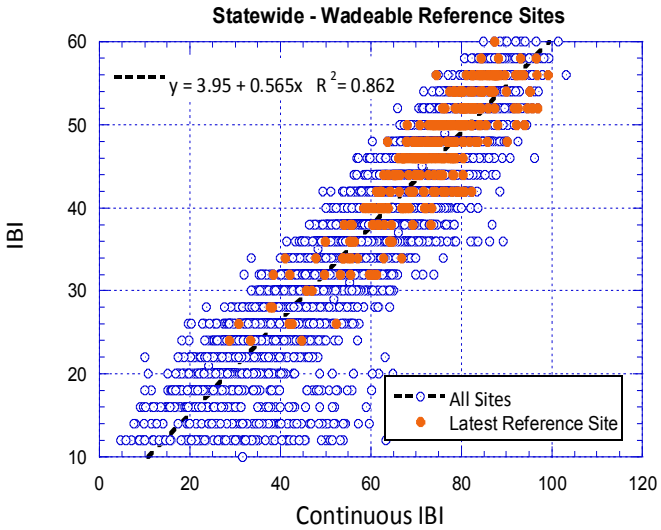



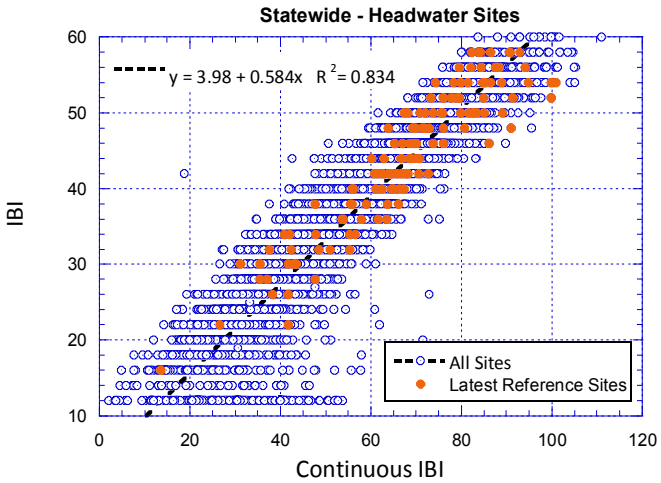



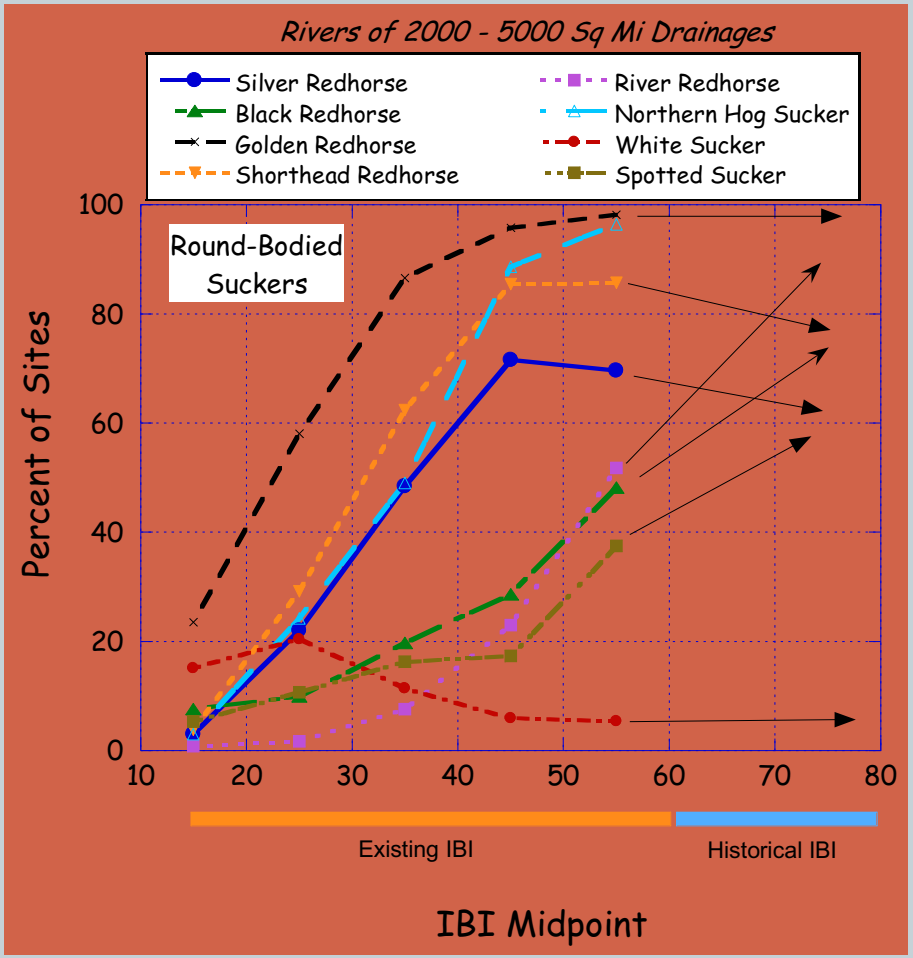
# Correlation of Continuous vs. Original ICI, IBI



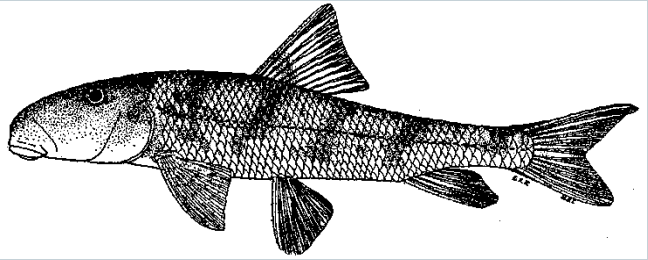



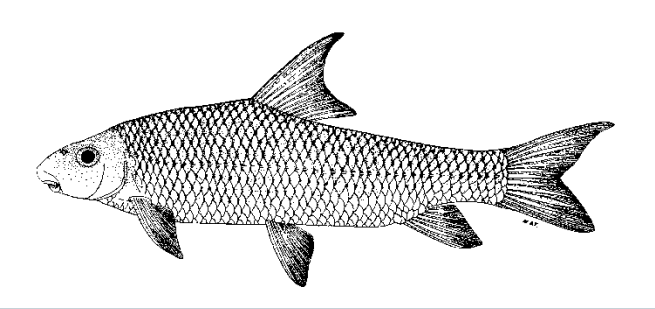



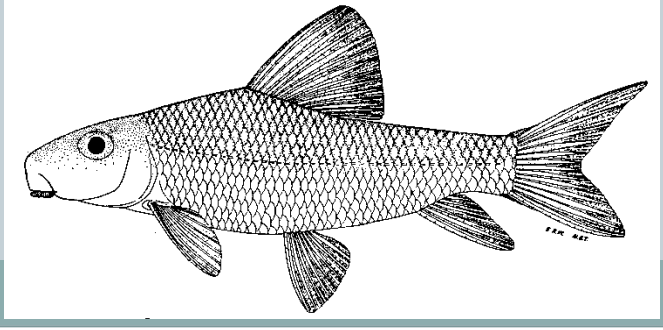
# Computer Generated Historical Fish Assemblages



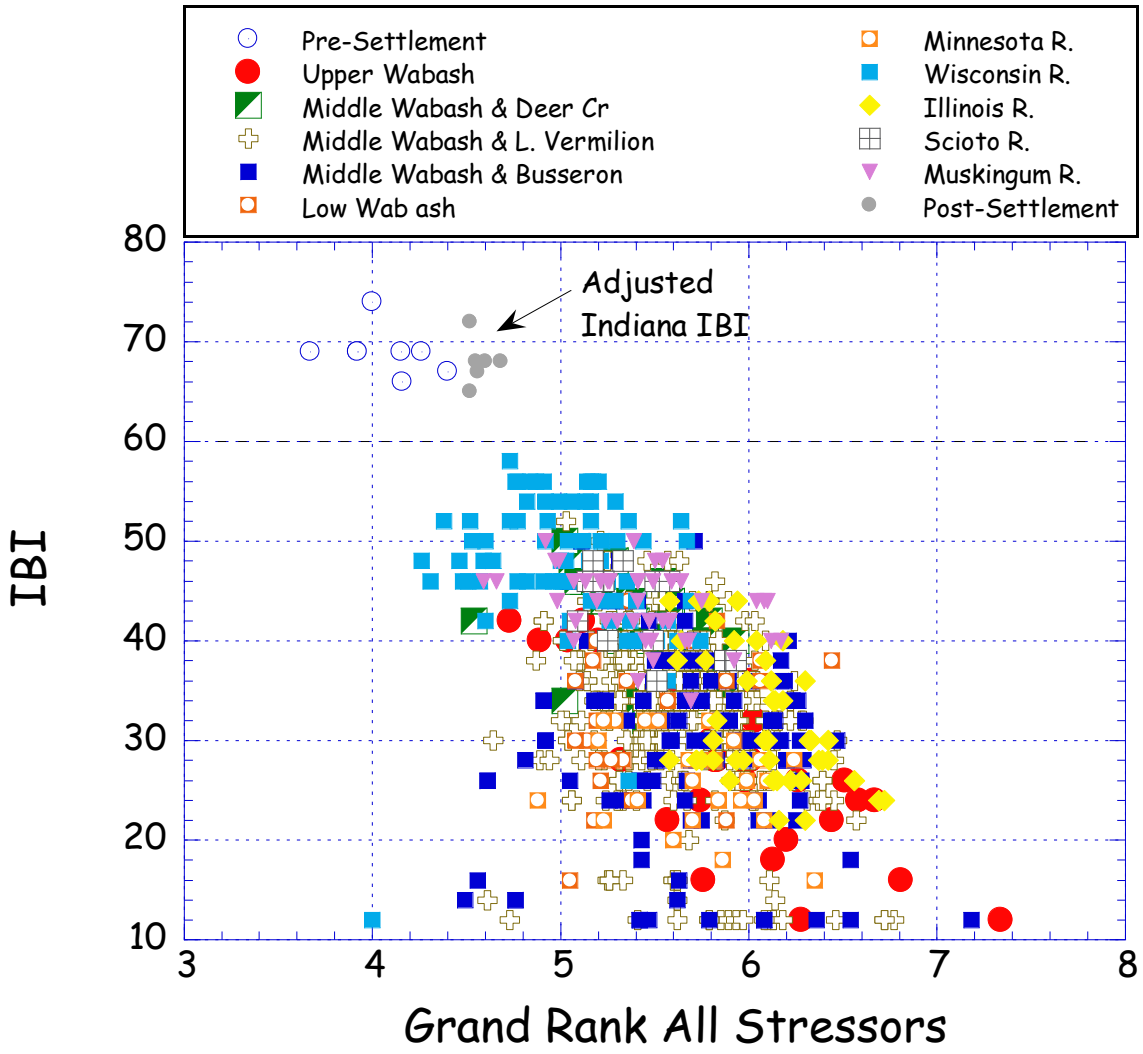

Round-bodied Suckers







# Estimate Assemblage Index Scores for Tier 1 and 2 Conditions



# Caveats

- Better point source treatment and better agricultural practices have caused improvements in Ohio reference conditions
- Can use predictions of expected changes due to climate change to make waters more resilient to climate change effects:
  - Maximizing shaded buffers reduces effects
  - Reconsideration of how we drain landscapes (e.g., controlled drainage, shallow drainage into biofuel benches and naturalization of streams habitat) may counteract some of the predicted effects of warming and hydrological changes)

# Where Do Expect Changes to Show Up First?

- Small headwater streams (currently undersampled)
- Streams already near “edge” of temperature and hydrologic thresholds
- Where there are species assemblages potentially sensitive to these changes
  - Cold water systems
  - Exceptional systems
  - Areas that are “islands” of the above categories
    - Would have difficulty in recovering from episodic stressors
    - Lack of refugia or recolonization areas