National Biological Assessment and Criteria Workshop

Advancing State and Tribal Programs

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

Index 101

BIOLOGICAL INDEX DEVELOPMENT METHOD: BASIC CONCEPTS

Course Presenters and Contributors

Jeroen Gerritsen, Michael Paul, Mick Micacchion, Russ Frydenborg, Chuck Hawkins, Rick Hafele, Tom Danielson, Dave Courtemanch, and Susan Cormier

Index 101

National Biological Assessment and Criteria Workshop

Advancing State and Tribal Programs

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

Biological Index Uses, Types, and Development

Presented by
Mick Micacchion,
Ohio EPA

Index 101 Course Outline

1. Overview of uses, types and development of indices

2. Steps in developing a multimetric index and Example from Florida

3. Steps in developing a multivariate predictive model (RIVPACS) index and Example from Oregon

4. Maine's approach to developing and using a biological index

Introduction to Index 101

- Regulatory basis of indices

- Why are indices used

- What do indices represent

- What data are needed

- What types of indices are there

Why Use Biological Indices?

● Clean Water Act Section 101(a) Purpose:

- "To restore and maintain the chemical, physical and <u>biological integrity</u> of the Nation's waters."

Biological Integrity: Operational Definition

"The ability of an aquatic community to support and maintain a structural and functional performance comparable to the natural habits of a region."

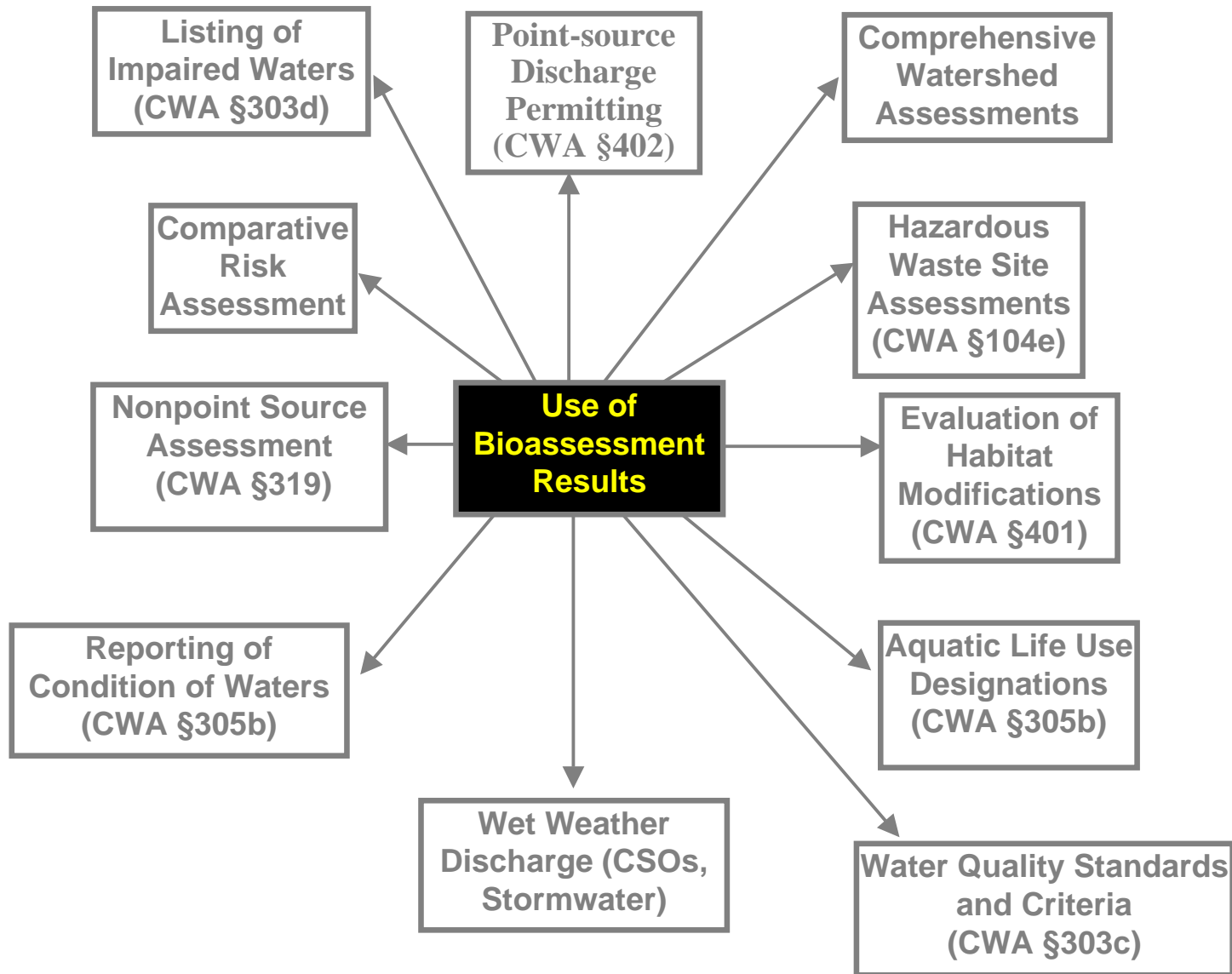As modified from Karr and Dudley (1981)

Water Quality Standards and the Use of Biological Indices

- Beneficial Use Designations

    - Aquatic Life Uses

- Numeric Criteria

    - Biological Criteria

- Narrative Criteria

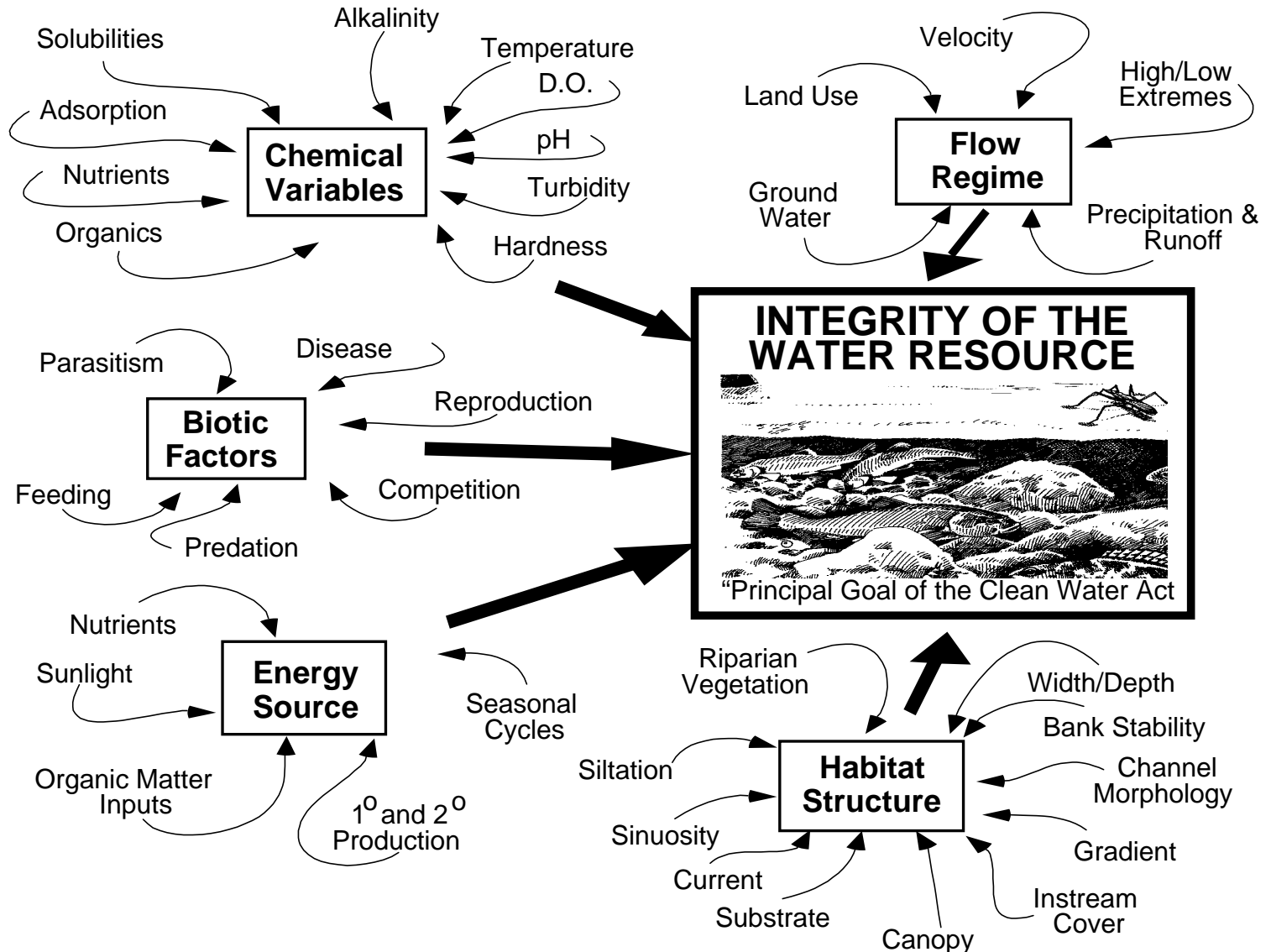   - Protection of aquatic life

- Antidegradation

Use of Biological Indices for Other CWA Programs

- 305(b)

  - Water Body Condition Reports

- 303(d)

  - Impaired Waters Listings

- TMDL Process

Some Program Objectives

Listing of Impaired Waters (CWA §303d)

Point-source Discharge Permitting (CWA §402)

Comprehensive Watershed Assessments

Comparative Risk Assessment

Hazardous Waste Site Assessments (CWA §104e)

Nonpoint Source Assessment (CWA §319)

Use of Bioassessment Results

Evaluation of Habitat Modifications (CWA §401)

Reporting of Condition of Waters (CWA §305b)

Aquatic Life Use Designations (CWA §305b)

Wet Weather Discharge (CSOs, Stormwater)

Water Quality Standards and Criteria (CWA §303c)

The Five Major Factors that Determine the Integrity of Aquatic Resources

Solubilities

Alkalinity

Adsorption

Temperature

D.O.

Nutrients

Chemical Variables

pH

Turbidity

Organics

Hardness

Velocity

Land Use

High/Low Extremes

Flow Regime

Ground Water

Precipitation & Runoff

Parasitism

Disease

Reproduction

Biotic Factors

Feeding

Competition

Predation

INTEGRITY OF THE WATER RESOURCE

"Principal Goal of the Clean Water Act

Nutrients

Energy Source

Sunlight

Seasonal Cycles

Riparian Vegetation

Width/Depth

Bank Stability

Organic Matter Inputs

Siltation

Habitat Structure

Channel Morphology

1° and 2° Production

Sinuosity

Gradient

Current

Instream Cover

Substrate

Canopy

Why Use Taxonomic Assemblages as Indicators ?

• Bioassessment <u>provides indications of cumulative impacts</u> of multiple stressors, not just chemical water quality.

• Biological community integrates past chemical, physical and biological events, <u>both short- and long-term</u> and directly evaluates the condition of the water resource.

• Properly developed methods, measures and reference conditions provide a tool that enables a <u>direct reporting of the ecological condition</u> of a water body.

Symptoms of Ecological Degradation

A Partial List:

- Reduced populations of native species.
- Fewer size (age) classes.
- Reduced number of intolerant species.
- Increased proportion of exotic species.
- Reduced proportion of ecological specialists.
- Simplified trophic web and interactions.
- Increased incidence of serious disease & anomalies.

Important Considerations for Biological Indices

- The measures used must be biological

- The measures must be interpretable at or extend to multiple trophic levels

- The measures must be sensitive to the condition being assessed

- The response range must be suitable for intended uses

- The measure must be reproducible and sufficiently precise

- The variability of the measures must be low enough to detect and quantify changes

Basic Premises of Biological Indices

- Least impacted biological systems have distinctive structural and functional attributes.
- Some attributes can be measured in the field and aggregated into an index.
- Departure of index scores from a reference condition is correlated with the degree (severity) of a perturbation.
- An index that measures many intrarelated factors of ecosystem structure and function best reflects the overall integrity of the community.

Important Steps in Biological Index Development

- **Classify** ecotypes - streams, rivers, lakes, wetlands, cold & warm water, etc.
- **Develop** cost-effective and reproducible sampling methods.
- **Test and evaluate** to select reliable and relevant measures
- **Define analytical procedures** to extract and display results on different spatial and temporal scales.
- **Communicate** results to different users and audiences.

Different Types of Indices

- Multimetric (IBI)

- Multivariate Predictive (RIVPACS)

- Others

Multimetrics (IBI)

Multimetrics (IBI)

- Developed in 1980s
- Improvement on original single metrics (e.g. Hilsenhoff alone)
- Idea is to incorporate several attributes (metrics) reflecting 'biological integrity' into one synthetic multimetric score
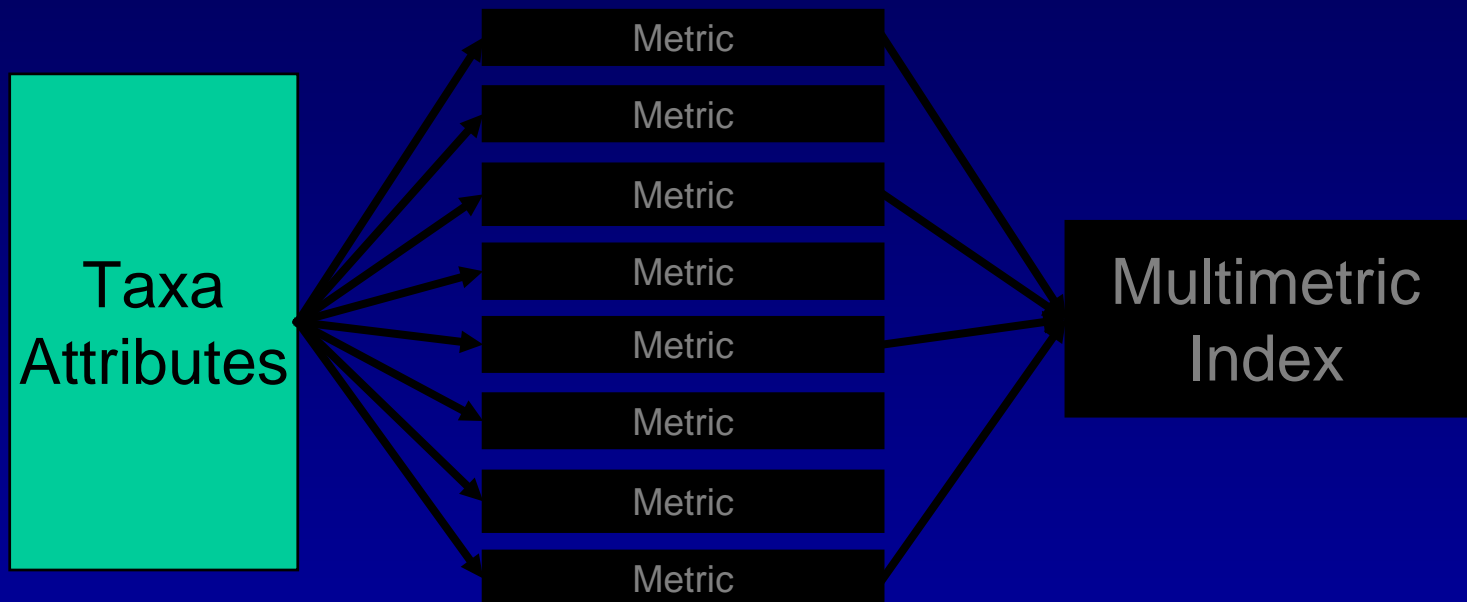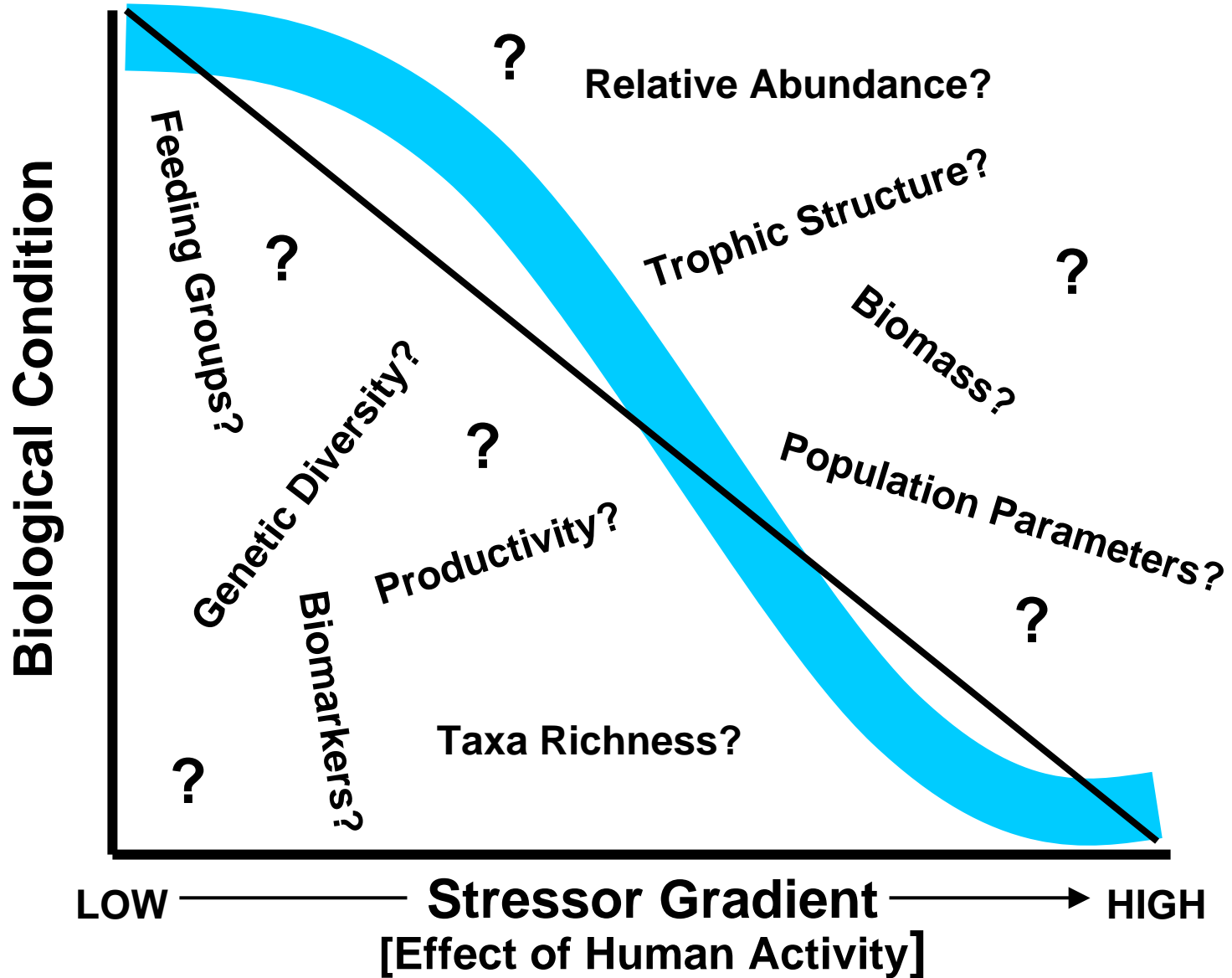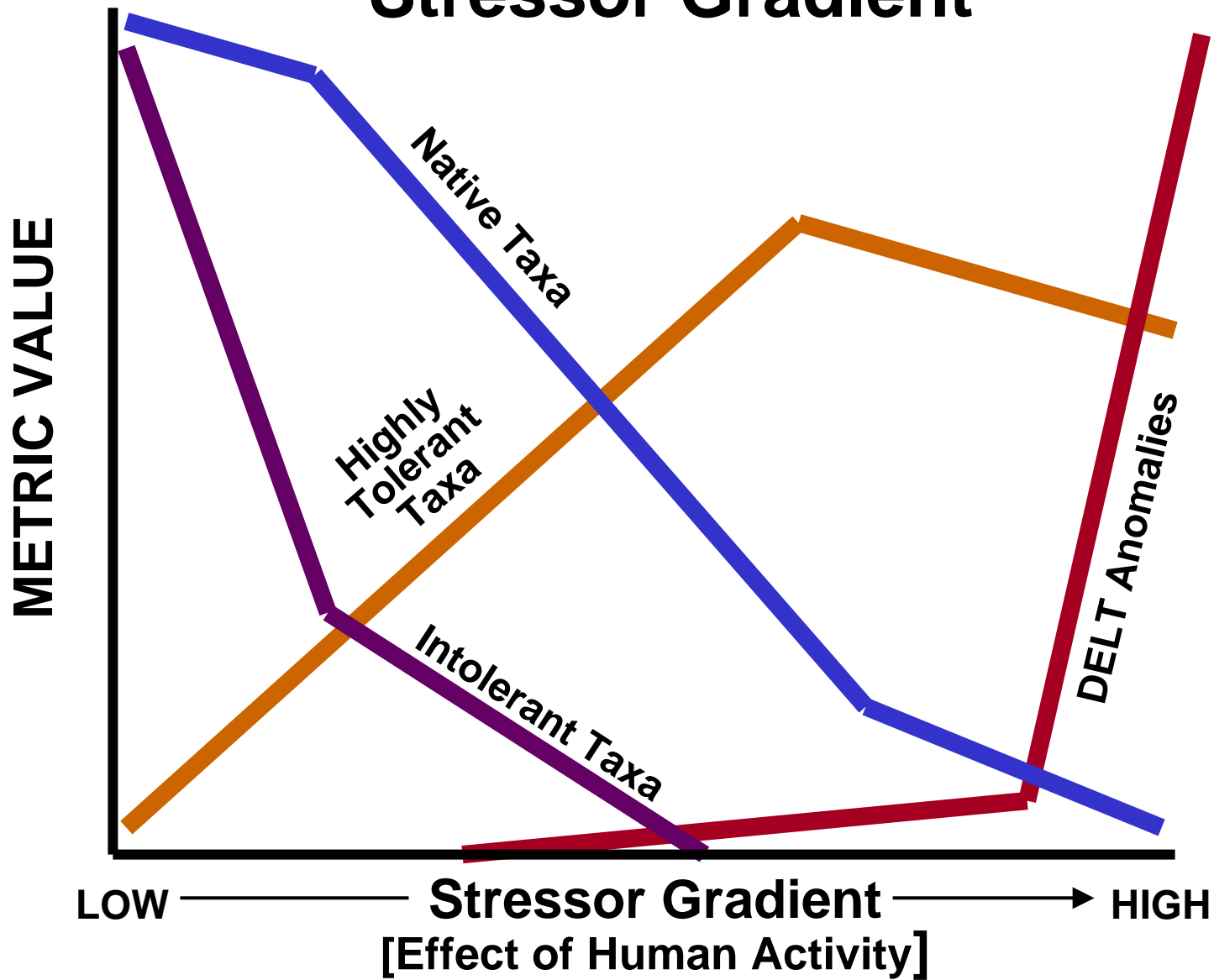
Multimetrics (IBI)

Definition

- **A metric is a characteristic (attribute) of the biota that changes in some predictable way with increases in human disturbance**
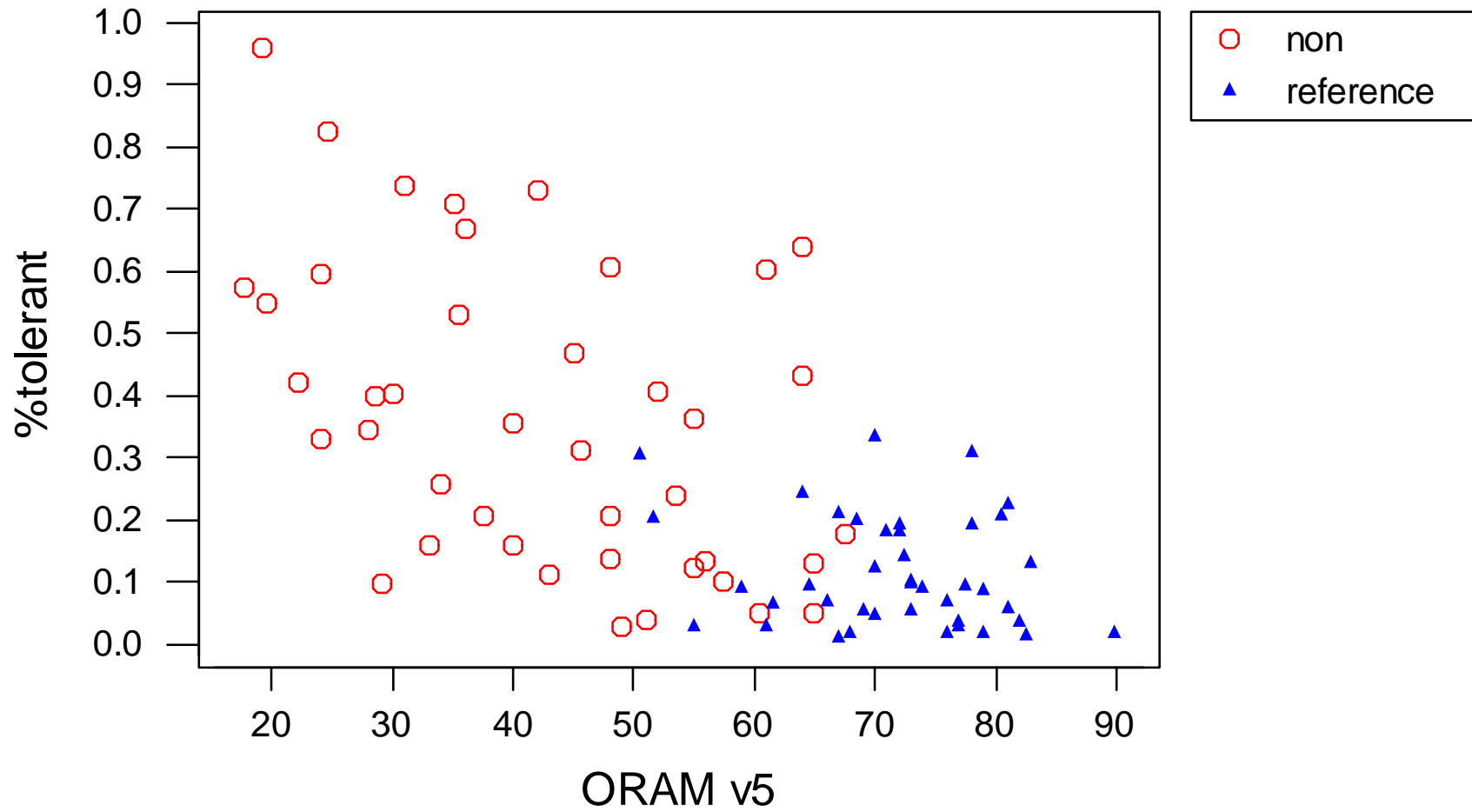
Metric Behavior Along the Stressor Gradient

Native Taxa

Highly Tolerant Taxa

Intolerant Taxa

DELT Anomalies

METRIC VALUE

LOW ——————→ Stressor Gradient ——————→ HIGH

[Effect of Human Activity]

Index of Biotic Integrity (Karr 1981)

12 Metrics

- Species richness
- #Darter species
- #Sunfish species
- #Sucker species
- %Intolerant species
- %Green sunfish
- %Omnivores
- %Insectivores
- %Top Carnivores
- %Hybrids
- %Diseased individuals
- Number of Fish

Community Composition

Environmental Tolerance

Community Function

Community Condition

- 5,3,1 metric scoring categories.
- 12 to 60 scoring range.
- Calibrated on a regional basis.
- Scoring adjustments needed for very low numbers.

Multimetrics (IBI)

- Reference and degraded sites used to select metrics that discriminate
- Also used to test final multimetric combinations that discriminate
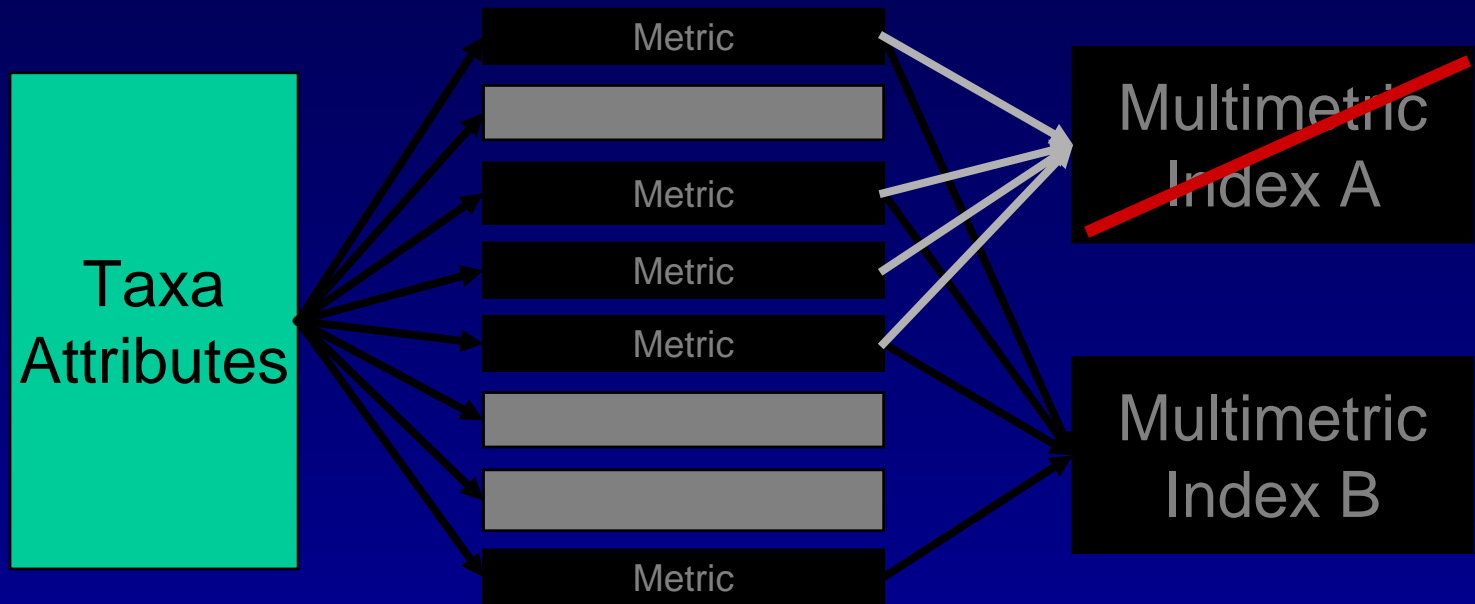
Multimetrics (IBI)

- Classification used to separate reference sites into similar biogeographic groups
- IBIs built for individual classes or groups of similar classes
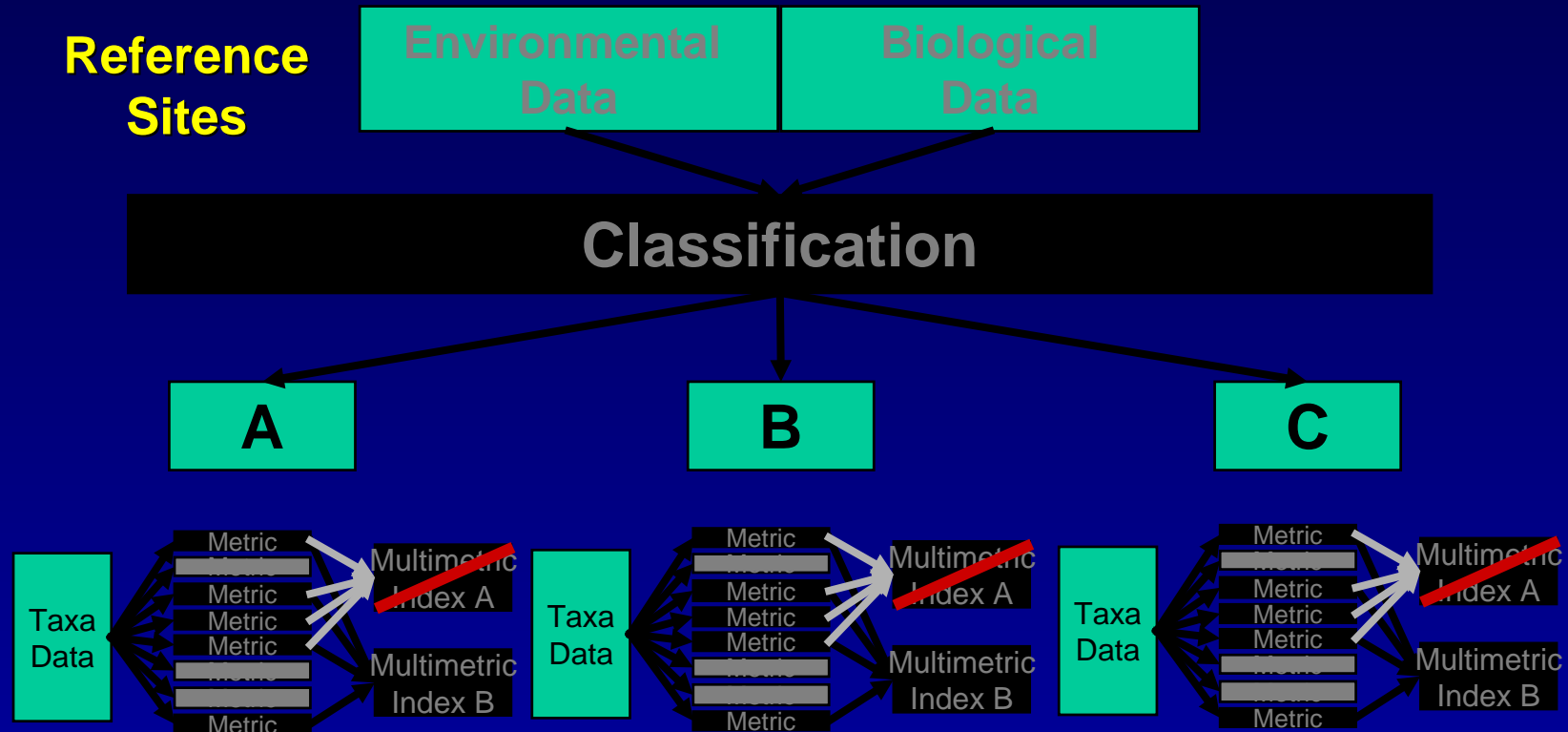
Aquatic Life Use Designations Ohio WQS

Based on Biological Community Attributes

• Exceptional Warmwater Habitat (EWH): Preserve & maintain existing HQ

• Warmwater Habitat (WWH): basic restoration goal for most streams

• Modified Warmwater Habitat (MWH): attainable condition for streams under drainage maintenance or other essentially permanent hydromodifications (e.g. dams)

• Limited Resource Waters (LRW): essentially irretrievable, human induced (e.g. widespread watershed modifications) or naturally occurring conditions (e.g. ephemeral flow)

Exceptional Warmwater Habitat (EWH)

Kokosing River (Knox Co.)
State Scenic River

Lost Creek (Miami Co.)

Big Darby Creek (Madison Co.
State and National Scenic River

Bluebreast darter
(Etheostoma camurum)
Ohio Threatened Species

Bokengehalas Cr. (Logan Co.)
E. Corn Belt Plain Ecoregion

Powell Creek (Definace Co.)
Huron/Erie Lake Plain

Warmwater Habitat (WWH)

Wolf Creek (Summit Co.)
Erie/Ontario Lake Plain Ecoregion

Duck Cr. Subbasin (Wash. Co.)
W. Allegheny Plateau Ecoregion

Modified Warmwater Habitat (MWH)

Drainage Maintenance is Common in Western and Northwest Ohio: MWH – Channelization
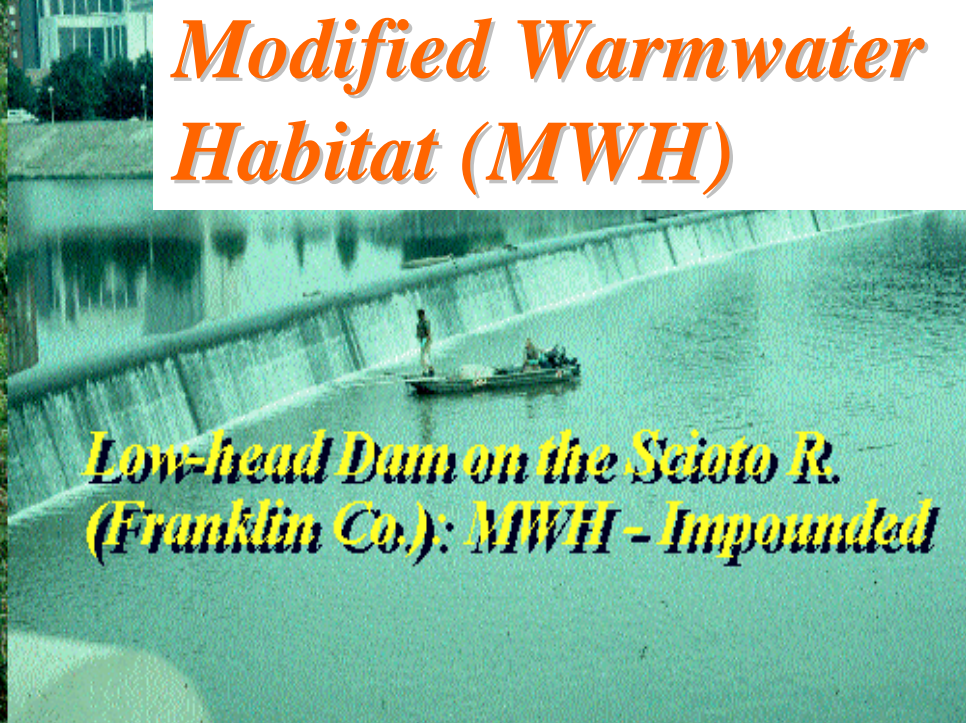
Low-head Dam on the Scioto R. (Franklin Co.): MWH – Impounded

Non-Acidic Runoff From Abandoned Mine Lands Results in Severe Sedimentation: MWH – Mine Drainage

Creek Chub With Blackspot: MWH Streams are Predominated by Tolerant Species

E. Fk. Duck Cr. - Hamilton Co.; LRW - Small Drainageway Maintenance

Hurford Run - Stark Co.; LRW - Small Drainageway Maintenance

Limited Resource Waters (LRW)

Cuyahoga River Navigation Channel; Cuyahoga Co. LRW - Other

Moxahala Cr. - Perry Co.; LRW - Acid Mine Drainage

Multivariate Predictive (RIVPACS)

Multivariate Predictive (RIVPACS)

- Developed in late 1980s-1990s (RIVPACS)
- Started as a method for classifying unpolluted streams
- Predict the expected taxa at a site and compare to observed taxa (O/E) (1.00 = Reference Condition)
- Lower the ratio, worse the quality

Sample Data

Observed Taxa

Expected Taxa

Non-human Impacted Environmental Variables
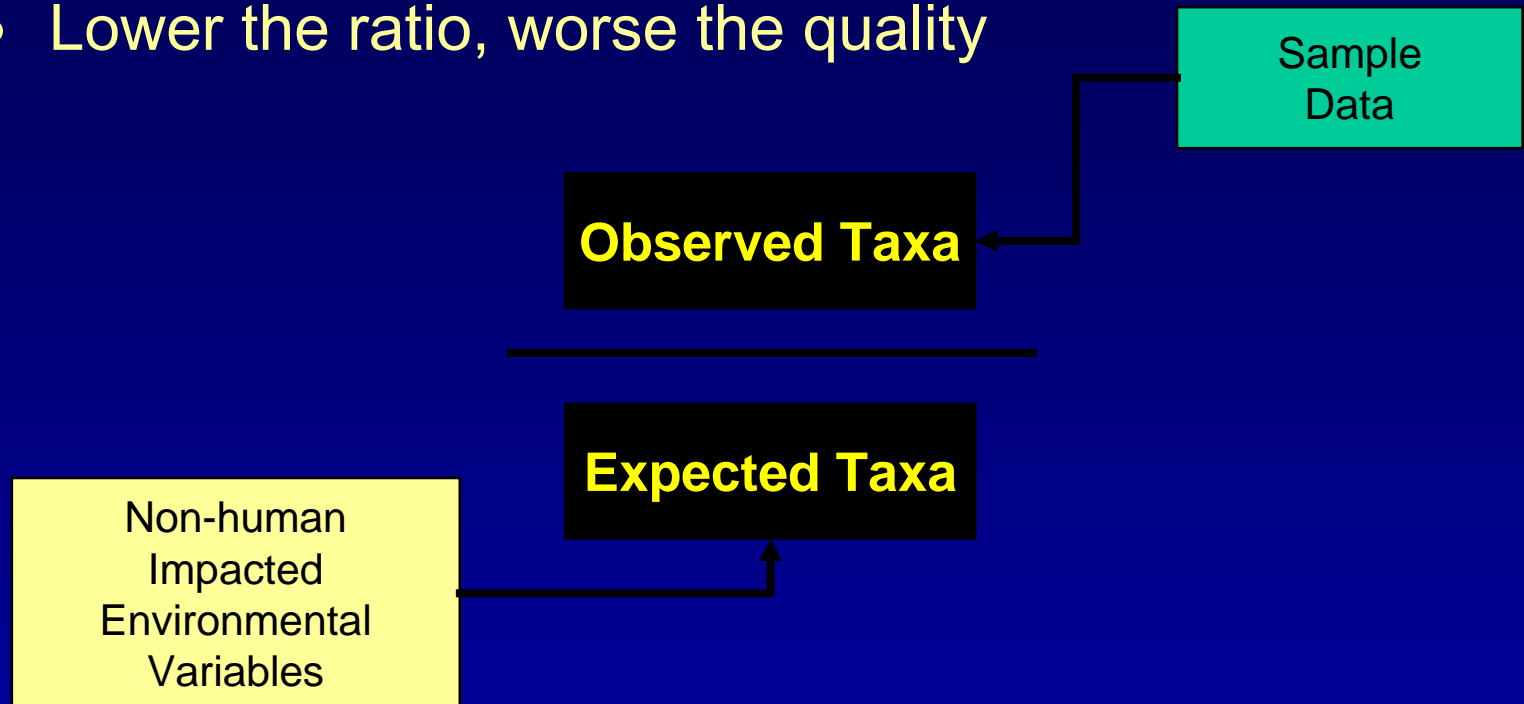
Multivariate Predictive (RIVPACS)

- Reference sites used to build model for predicting expected taxa

- Classification used to approximate continuous gradient

- Results in a predicted "reference" for each test site = expected taxa

Expected Taxa

Predictive Model

Classification

Non-human Impacted Physical/Chemical Variables

Reference Sites
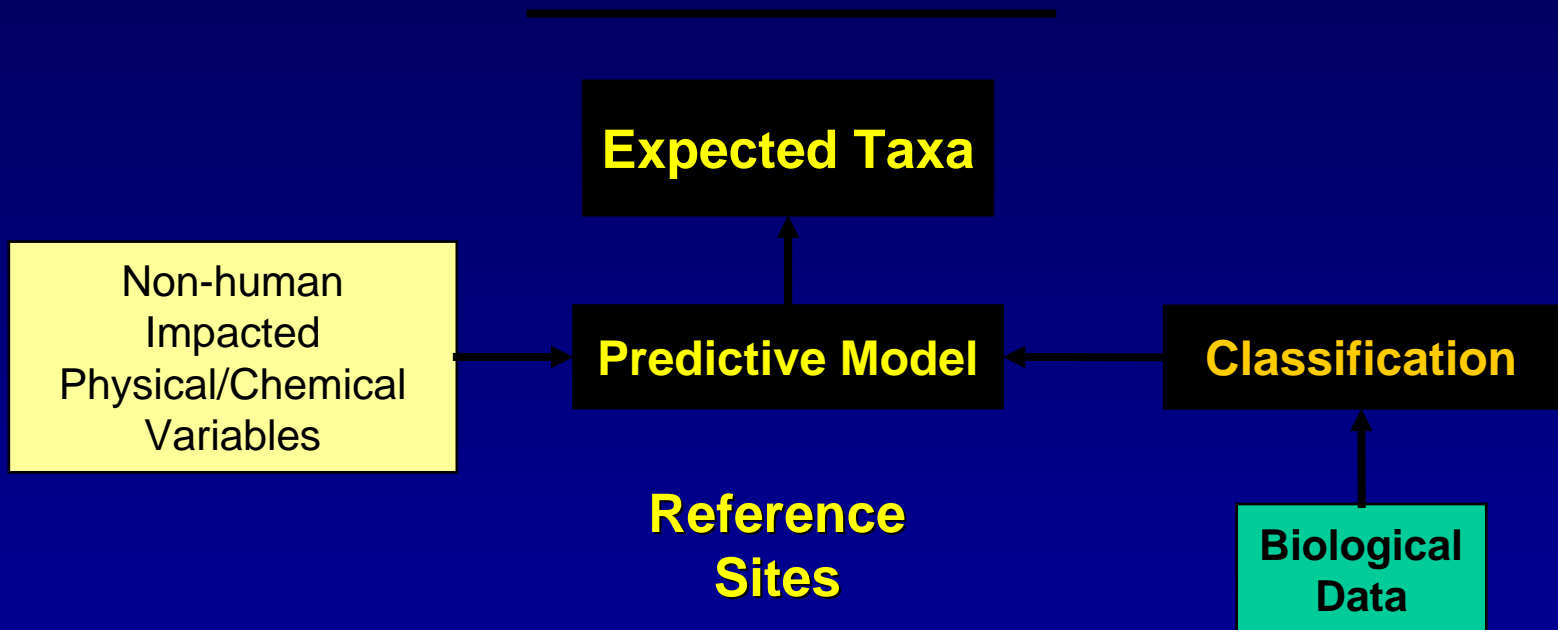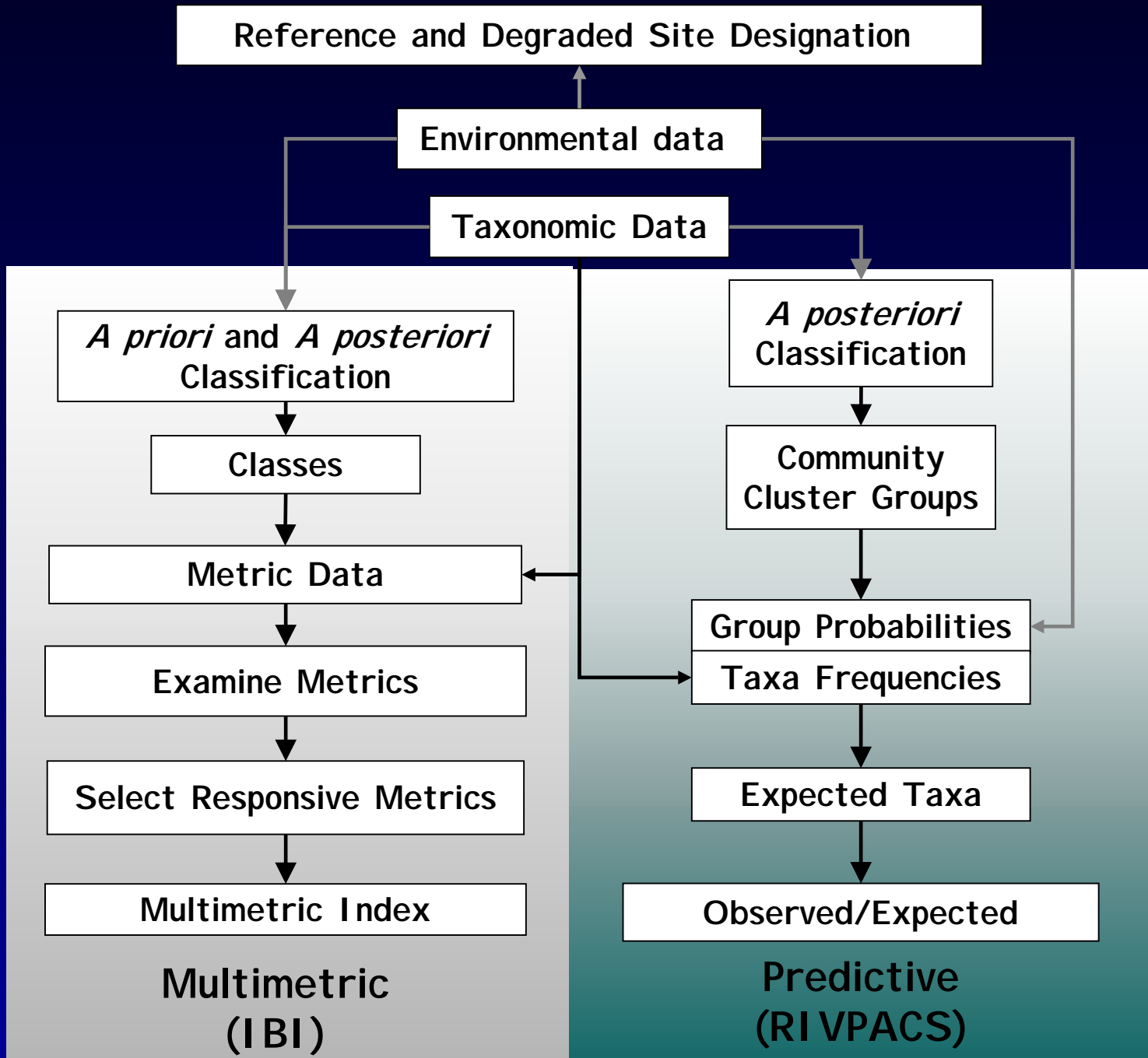
Biological Data

Other Biological Indices

- Maine Approach

- Floristic Quality Assessment Index

- Amphibian Quality Assessment Index

- Hilsenhoff Index

- Many Others (Got any ideas?)

Tiered Aquatic Life Use Conceptual Model: Draft Biological Tiers

(10/22 draft)

Condition of the Biotic Community [Specific to Ecotype]

1 — *Natural structural, functional, and taxonomic integrity is preserved.*

2 — *Structure and function similar to natural community with some additional taxa & biomass; no or incidental anomalies; sensitive non-native taxa may be present; ecosystem level functions are fully maintained*

3 — *Evident changes in structure due to loss of some rare native taxa; shifts in relative abundance; ecosystem level functions fully maintained through redundant attributes of the system.*

4 — *Moderate changes in structure due to replacement of sensitive ubiquitous taxa by more tolerant taxa; overall balanced distribution of all expected taxa; ecosystem functions largely maintained.*

5 — *Sensitive taxa markedly diminished; conspicuously unbalanced distribution of major groups from that expected; organism condition shows signs of physiological stress; ecosystem function shows reduced complexity and redundancy; increased build up or export of unused materials.*

6 — *Extreme changes in structure; wholesale changes in taxonomic composition; extreme alterations from normal densities; organism condition is often poor; anomalies may be frequent; ecosystem functions are extremely altered.*

LOW —— Human Disturbance Gradient ——> HIGH

Designated Aquatic Life Uses: Ohio/Streams & Rivers

natural

Biological Condition

Exceptional Warmwater Habitat: an unusual, balanced integrated community of organisms having a species composition, diversity and functional composition comparable to the 75%ile of statewide reference sites

Warmwater Habitat:
… comparable to the 25%ile of ecoregional reference sites

Modified Warm Water Habitat: …irretrievable, human modifications of physical habitat …

Limited Resource Waters: lack potential … substantially degraded….irretrievable habitat modifications

Low   **Human Disturbance**   *High*