Ohio Stream Surveys – TIC Principles and Scoring

Nutrient TAG Meeting

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Introduction

- Part 1 – Basics of Survey Program
  - CWA background, survey basics
  - Q/As
- Part 2 – TIC principles and operational issues
  - Data collection and interpretation
  - Scoring

Clean Water Act

- Title 33, Chapter 26, Subchapter 1, Sec. 1251 Congressional Declaration of Goals and Policy
  - (a) Restoration and maintenance of chemical, **physical** and **biological integrity** of Nation's waters; national goals for achievement of objective..
  - ...In order to achieve this objective it is hereby declared that...control of nonpoint sources of pollution be developed and implemented ...to enable the goals of this chapter to be met...

State's CWA Obligations Simplified*

Decide

- Set standards for water quality - 304(a)(1); 303(c)

Measure

- Measure quality; are standards met? – 305(b)(1)

Report

- Report on water quality and prioritize problems – 305(b)(1)

Analyze

- For waters not meeting the goal, prepare a TMDL – 303(d)(3)

Fix

- Implement changes: permits, grants, etc. – 402, 319, State $

* Primary Clean Water Act sections listed

Establishing Water Quality Standards

a Gentle Reminder...

"To be acceptable to the public and useful in field situations, protection of aquatic organisms and their uses should be defined as prevention of unacceptable long-term and short-term effects on (1) commercially, recreationally, and other important species and (2) (a) **fish and benthic invertebrate assemblages in rivers and streams**, and (b) fish, benthic invertebrates, and zooplankton assemblages in lakes, reservoirs, estuaries, and oceans. **Monitoring programs intended to be able to detect unacceptable effects should be tailored to the body of water of concern so that necessary samples are obtained at enough times and places to provide adequate data on the populations of important species**, as well as data directly related to the reasons for their being considered important."

1985 Guidelines for Deriving Numerical National Water Quality Criteria for the Protection Of Aquatic Organisms and Their Uses

Summary of Ohio EPA Monitoring

Where

- Historic emphasis on point sources (1980s & 1990s)
  - (NPDES, construction grants)
- Expanded emphasis to include non-point (late 1990s)

What

- Fish, macroinvertebrates, habitat
- Water quality, sediment & tissue contaminants
- Loadings, land use, spills/kills, other (e.g., i&i, violations)

Why

- Support for *all* water quality management programs
- Bridge gaps left by administrative and exposure indicators
- Build long-term database for applied research

Summary of OEPA Monitoring

Scope & Frequency

- Catchment-scale surveys 400-1000 mi^2 (e.g., Big Darby)
- Large River surveys – e.g., lower Great Miami River
- 5-year rotation to cover a major watershed (e.g., GMR)
- 70 – 100 sampling locations within a catchment
- 10-12 Sentinel sites established for load estimates
  - flow, water chemistry collected biweekly starting in January of survey year
- Water chemistry 6x during summer index period
- Fish 1-2x; Macroinvertebrates 1x
- Continuous dissolved oxygen monitoring & chlorophyll at a subset of stations (sentinels; longitudinal reach bracketing point sources; other targeted sampling) 1-2x
- Habitat quality 1x

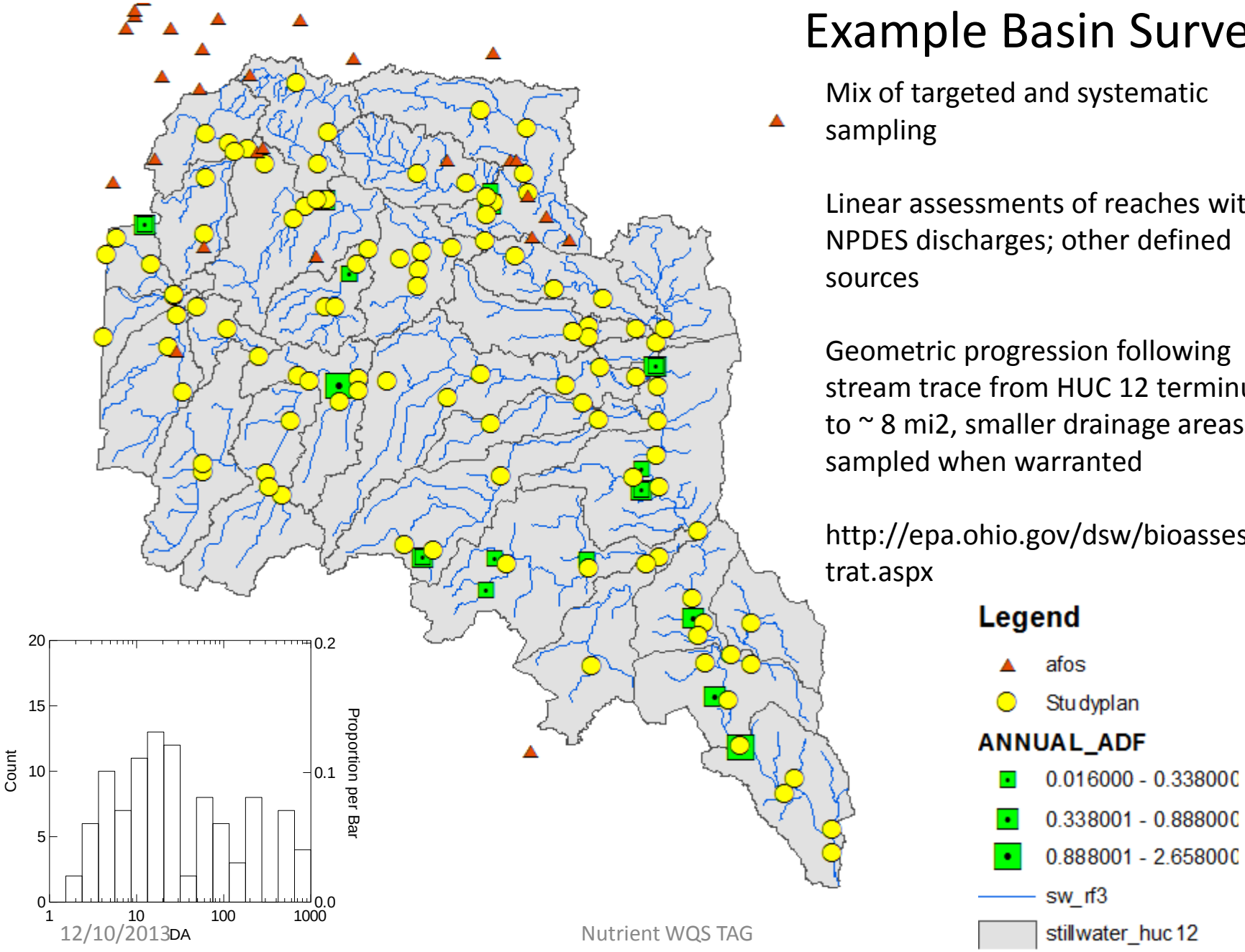
Example Basin Survey

Mix of targeted and systematic sampling

Linear assessments of reaches with NPDES discharges; other defined sources

Geometric progression following stream trace from HUC 12 terminus up to ~ 8 mi2, smaller drainage areas sampled when warranted

http://epa.ohio.gov/dsw/bioassess/ohstrat.aspx



Measuring and Managing Environmental Progress: Hierarchy of Indicators

1. Management actions
2. Response to management

Administrative indicators
[permits, plans, grants, enforcement, [technologies used, BMPs installed]

3. Stressor abatement

Stressor indicators
[effluent reduction, changes in land-use]

4. Ambient conditions
5. Direct exposure to effects of pollution

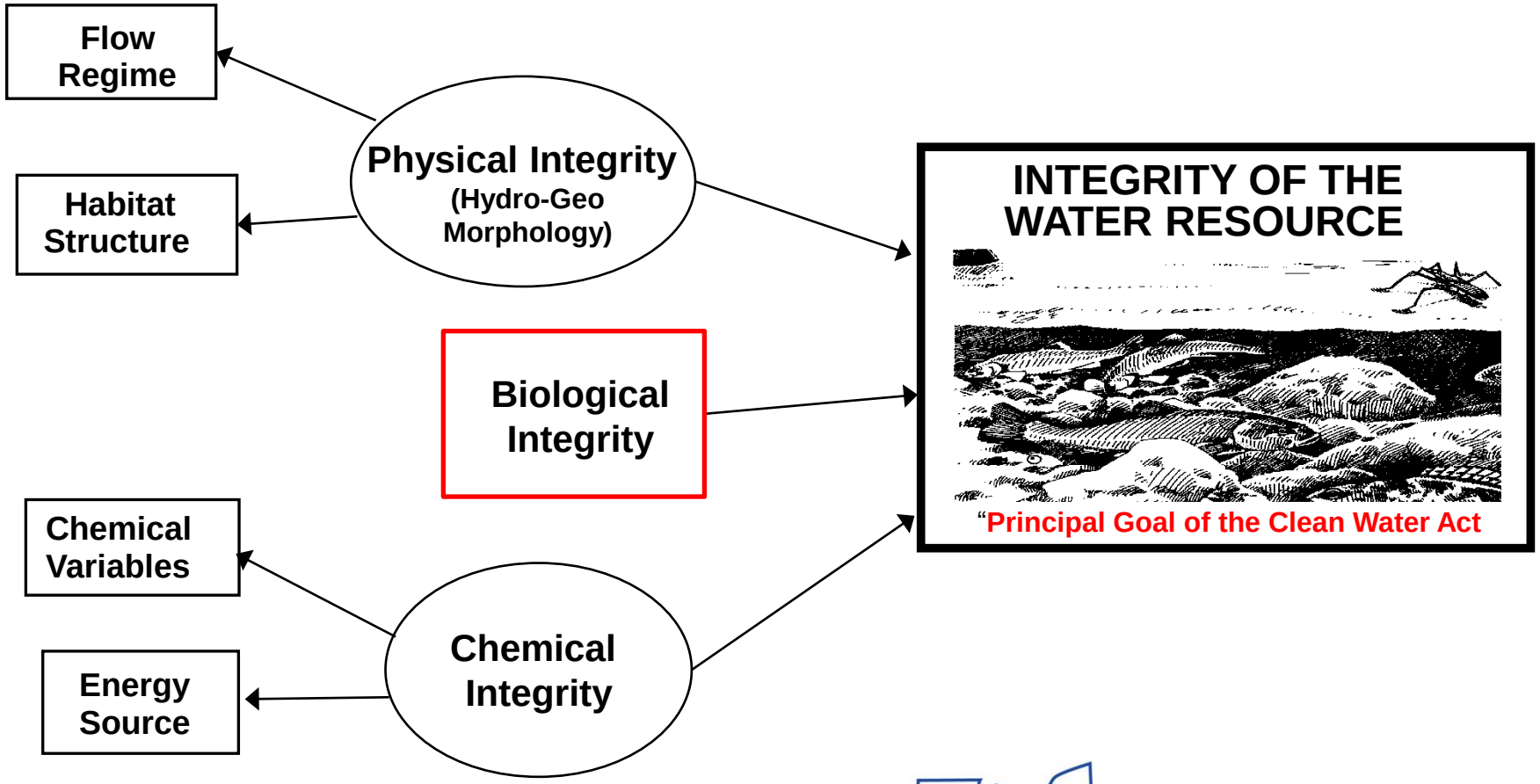
Exposure indicators
[pollutant conc., flow or physical habitat alteration, uptake of pollutants, reduced spawning habitat, nutrient dynamics, sedimentation effects, etc.]

6. Biological response

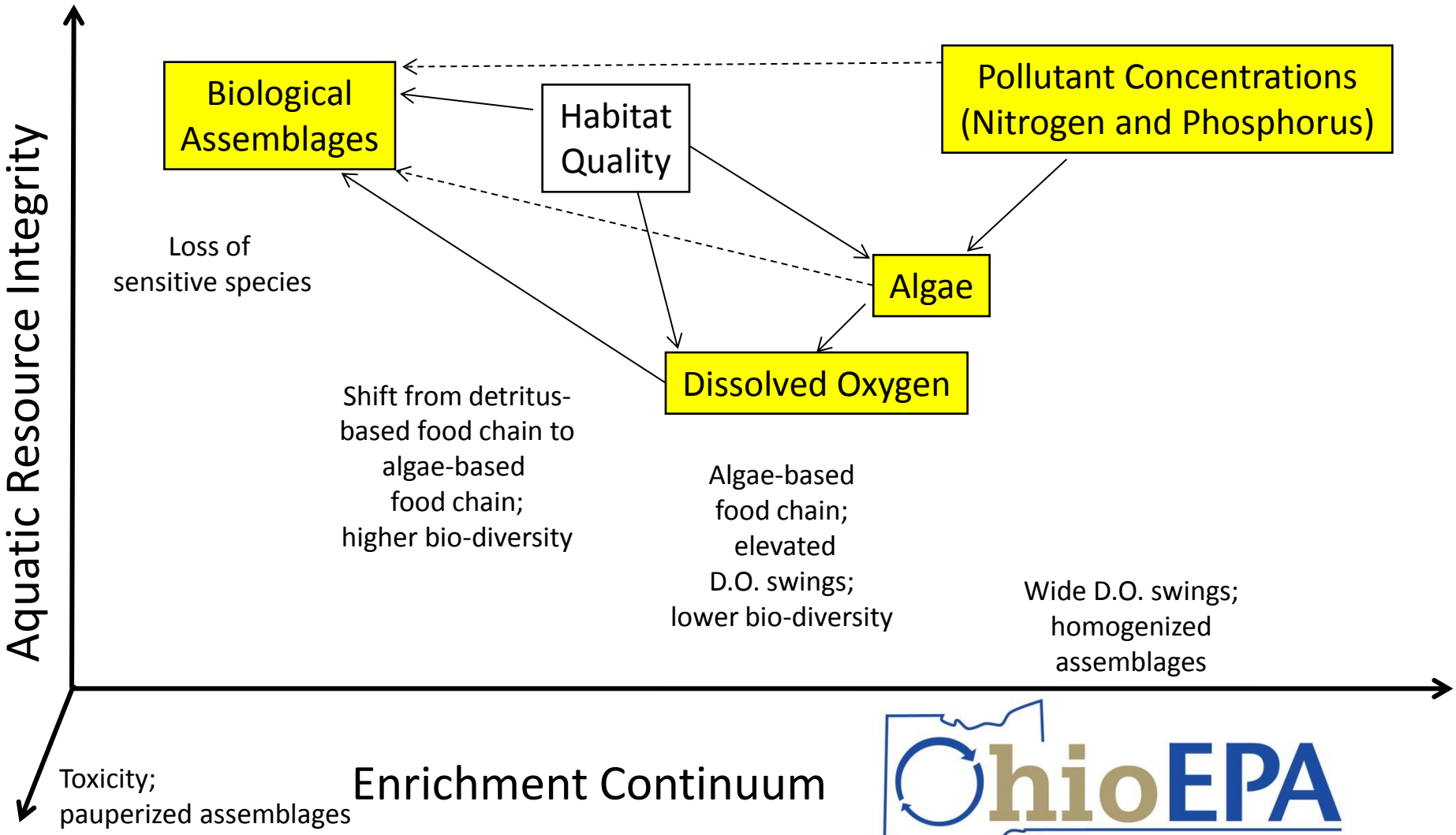
Response indicators
[biological metrics, multimetric indexes, target species, other biological measures]

Endpoint of Concern: "ecological health"

The Five Major Factors Determining the Integrity of Aquatic Resources



Positioning a Waterbody on the Enrichment Continuum



Inventory and Assessment

- Condition assessments are collectively inventoried to fulfill 305(b) requirements
  - essentially an accounting report of waters meeting/not meeting designated uses
- For waters not meeting designated uses, causes of non-attainment must be identified
  - causal assessments inventoried for 303(d) reporting

Assessments and Condition Status

- Assessment of biological assemblages determines condition status
  - fish and macroinvertebrate assemblages scored as numeric indexes
  - water quality criteria (biocriteria) exist for numeric scores
  - biological criteria stratified by stream size and ecoregion (see handout)
    - Failure of one assemblage indicator indicates that the condition status is compromised
    - Assessments are narratives based on the degree of failure or attainment
      - Full
      - Partial
      - Non
- Chemical concentrations in excess of WQ criterion are not **independently applied** as determinant of condition status

Condition Status and Impairments

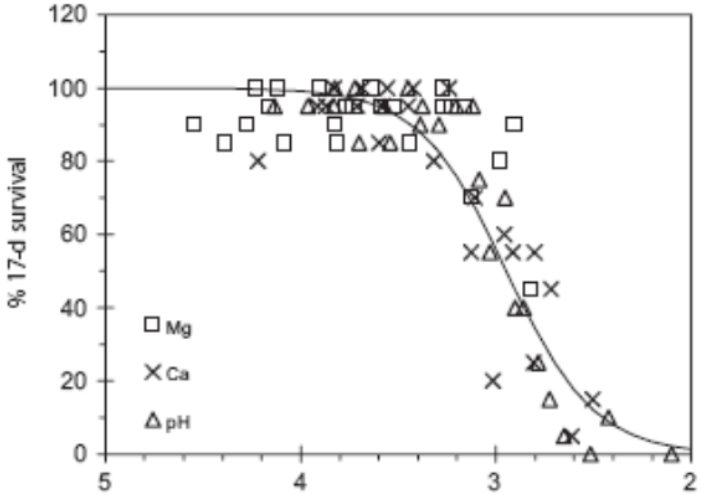
- Waters with jeopardized biological condition are deemed impaired
  - Agent or factor causing the impairment, and the sources of the causative agents are identified
  - Cause and source determines management option
    - reporting categories
    - traditional management (e.g., NPDES limits, infrastructure repairs or upgrades, etc.)
    - TMDL
      - habitat
      - nutrients
      - sediment

Identifying Causes of Impairment

Exposure Indicators

- Mix of correlative and inferential methods
  - e.g., probability of an intact biological condition co-occurring with high ammonia concentrations is very low
  - WQ standards embody the "Bayesian" inference

Thomas Bayes



Deleebeeck et al. (2007) Ecotoxicology and Environmental Safety 67:1-13

- Independently applied for determination of **reasonable potential**

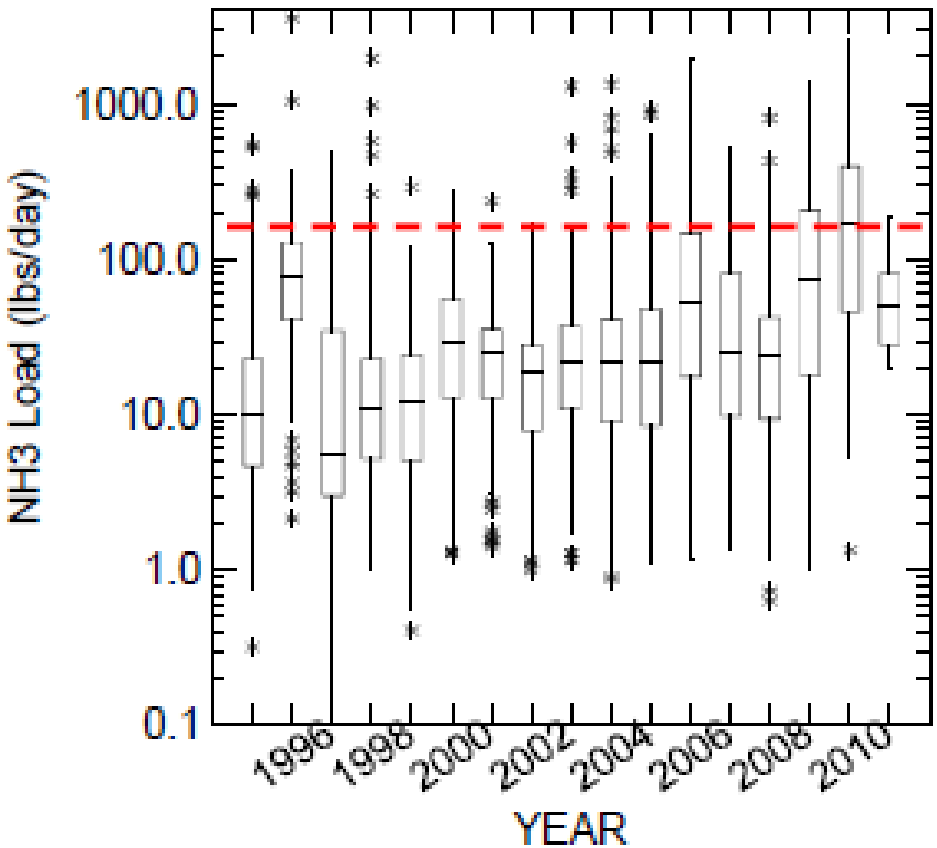
Stressor Indicators

- Spills
- % impervious cover
- habitat quality
- barriers (e.g., culverts)
- mining
- treatment plant performance (i.e., monthly operating reports)
- construction

Identifying Causes of Impairment

Stressor Indicators

- Inspection of MOR data to evaluate WWTP performance during and antecedent to biological survey – e.g., ammonia concentrations and loads



Causal Linkage

The Correlative Approach and Multicolinearity

IBI		P410	P530	P610	P625	P630	P665	P70300
0.02325	P410	1						
0.05581	P530	-0.32357	1					
-0.30297	P610	0.16062	0.11679	1				
-0.14351	P625	-0.30886	0.22598	0.50785	1			
0.18574	P630	-0.05579	0.29232	-0.11818	-0.02633	1		
-0.02996	P665	-0.37101	0.32119	0.18791	0.60786	0.46452	1	
-0.06631	P70300	0.81911	-0.24459	0.15657	-0.24181	0.13399	-0.25614	1
-0.07289	P900	0.87967	-0.30094	0.06716	-0.34002	0.00334	-0.39174	0.91118

all subsets or stepwise regression

factor analysis (PCA)

ionic strength

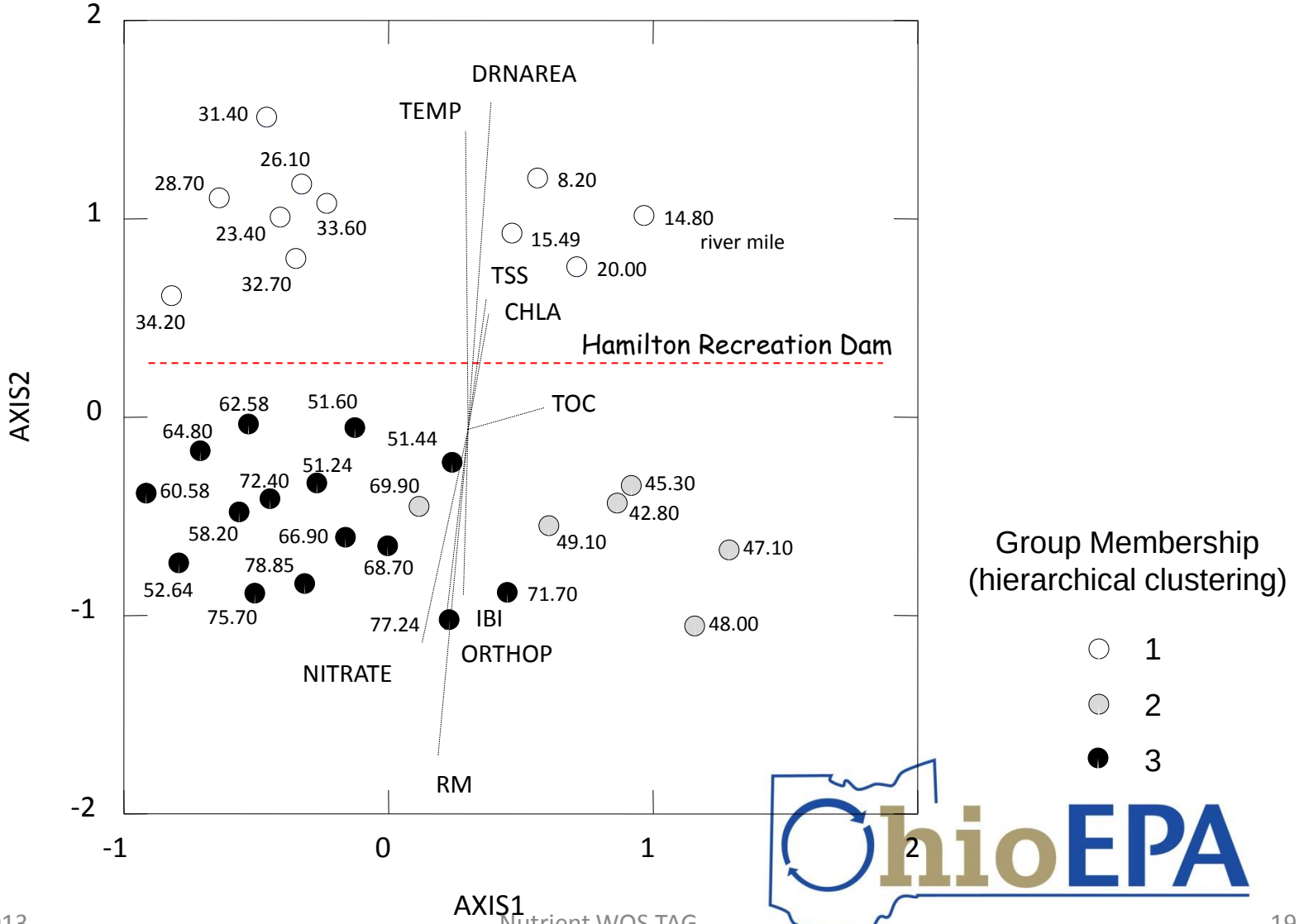
nutrients

TSS

linear regression

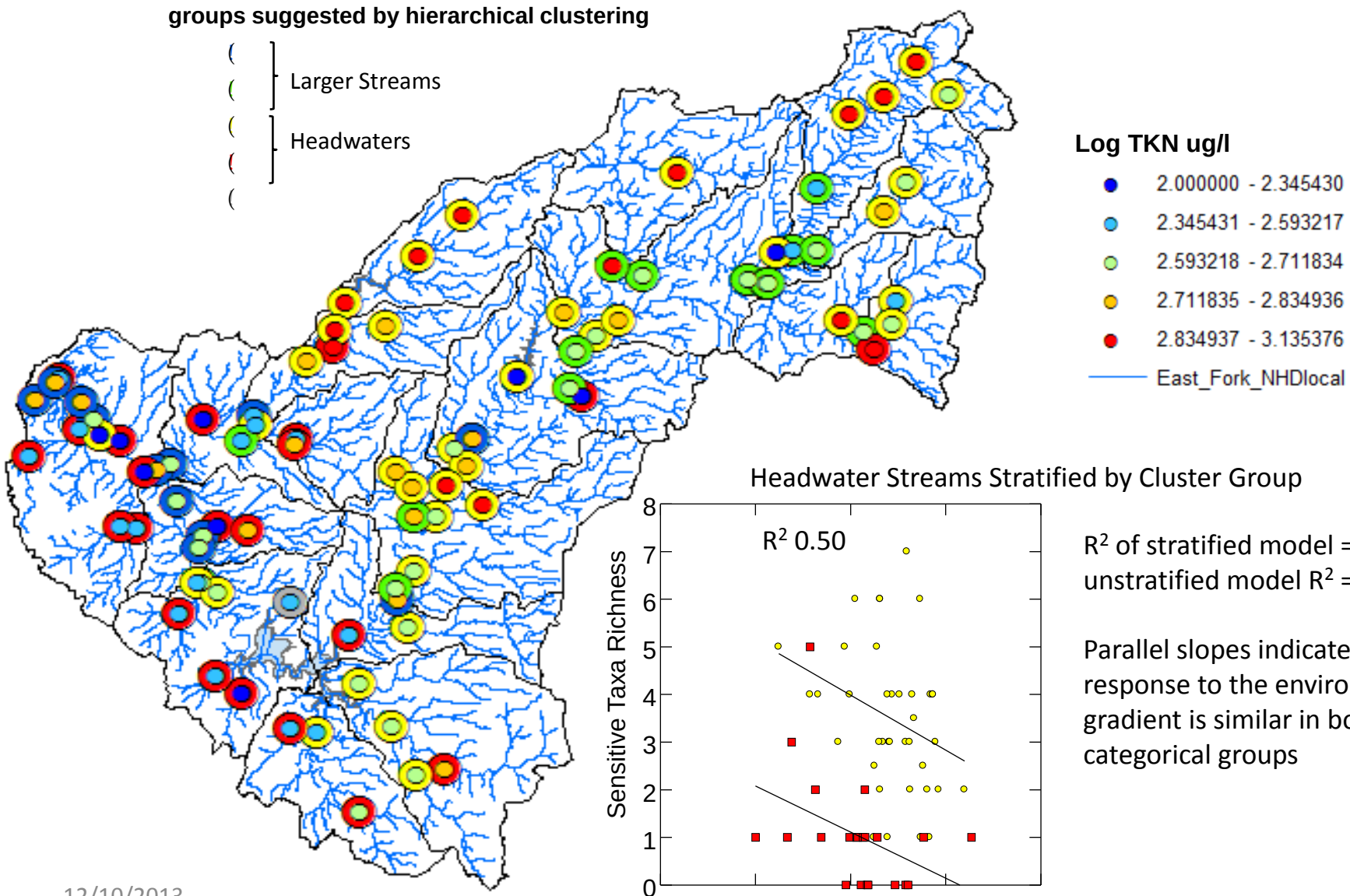
Fish Assemblage Similarity and Correlation with Environmental Variables

Lower Great Miami River Mainstem, 2010

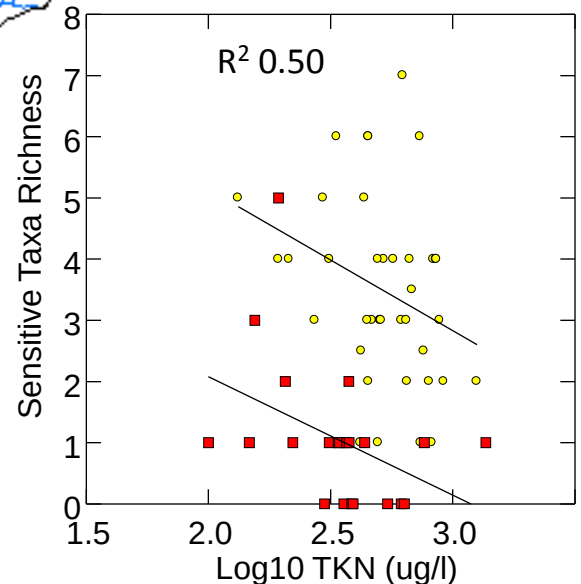


Watershed Assessment & Stressor ID

East Fork Little Miami River 2012



Headwater Streams Stratified by Cluster Group



R^2 of stratified model = 0.50; unstratified model R^2 = 0.25

Parallel slopes indicate that response to the environmental gradient is similar in both categorical groups

Where the TIC Fits Into Assessment and Permitting

TIC components used to determine where the waterbody is positioned on the enrichment continuum

TIC score used to confirm/rule-out nutrients

Reporting under 305(b) & 303(d)

study plan | basin survey | condition status | determination of causes and sources | management options

NPDES Permit 5-year cycle | determination of reasonable potential | management options

402 permits

TIC score used to determine where the waterbody is positioned on the enrichment continuum

Understanding 303(d) Reporting Categories & Management Options

Condition Status Determined
& Causal Assessment Made

1

Have all data
Meets WQS

2

Have some data
Meets WQS

3

Insufficient data

4

Have data
Impaired
No TMDL needed

5

Have data
Impaired
Needs TMDL

End of Part 1

Questions –

Short break

Part 2
Advantages of the Trophic Index

- Avoid false positives
  - single measures can be misleading (in either direction)
  - redundancy builds confidence
- Reconciles weight-of-evidence with independent application
- Helps to position a waterbody on the enrichment gradient
  - reasonable potential
- Sets a *de facto* data quality standard for causal determination
  - must collect or model individual components
    - e.g., dissolved oxygen can be reliably modeled

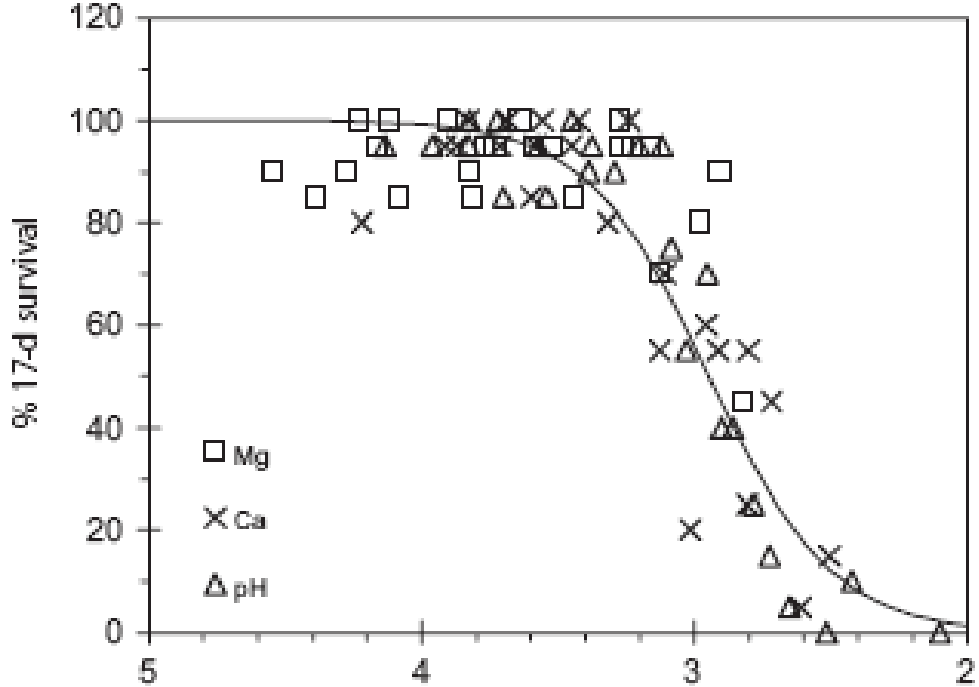
Numeric Nutrient Criteria

Challenges of Adoption and Implementation

Traditional Paradigm

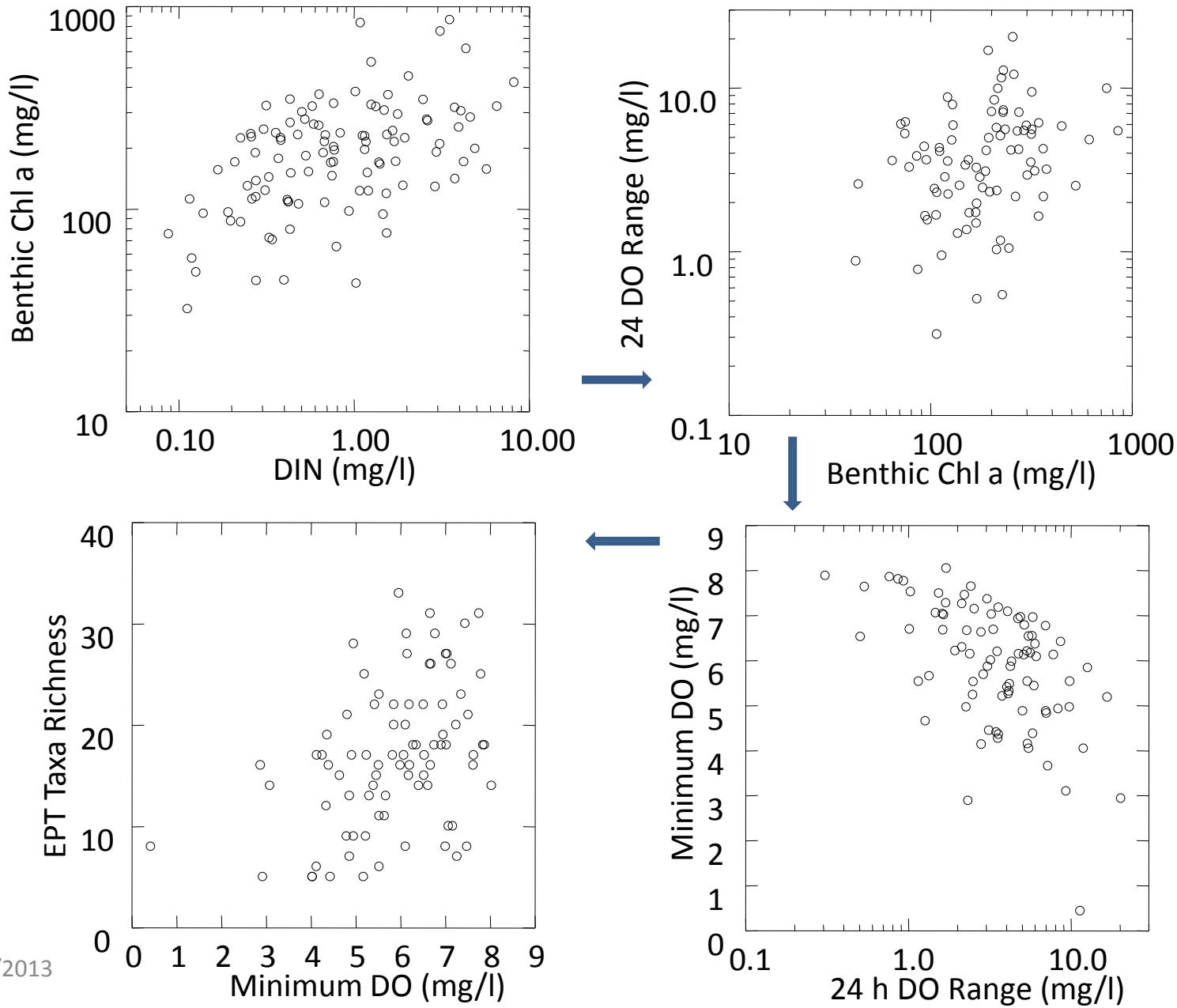
- Establish protective standard based on well-defined dose-response relationships
- Facilitates implementation
  - Reasonable Potential
  - Independent Application
- Generally amenable to single number or simple algorithmic standard

Survival Curve for Rainbow Trout Exposed to Ni

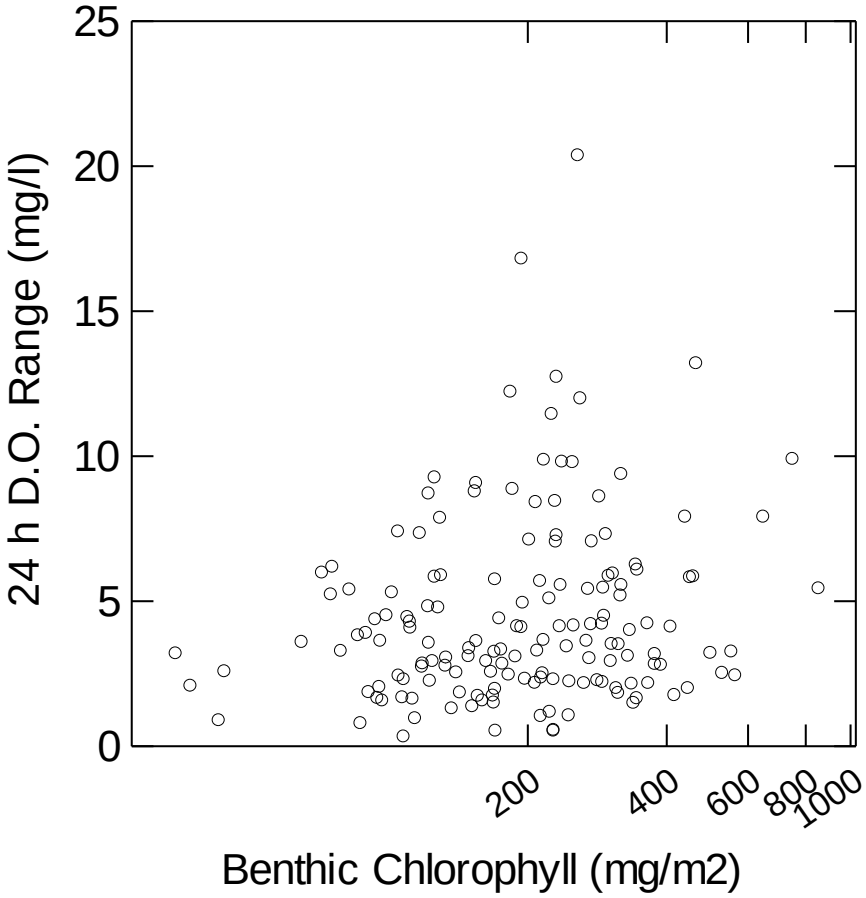


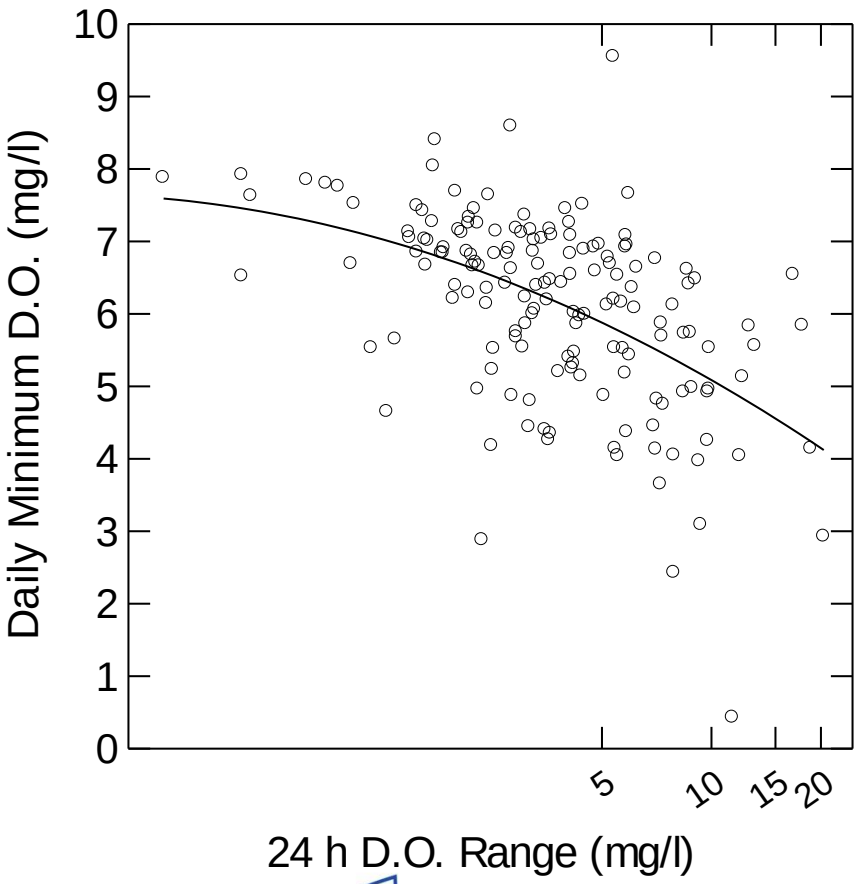
Deleebeeck et al. (2007) Ecotoxicology and Environmental Safety 67:1-13

Ohio Nutrient Study - Bivariate Representation



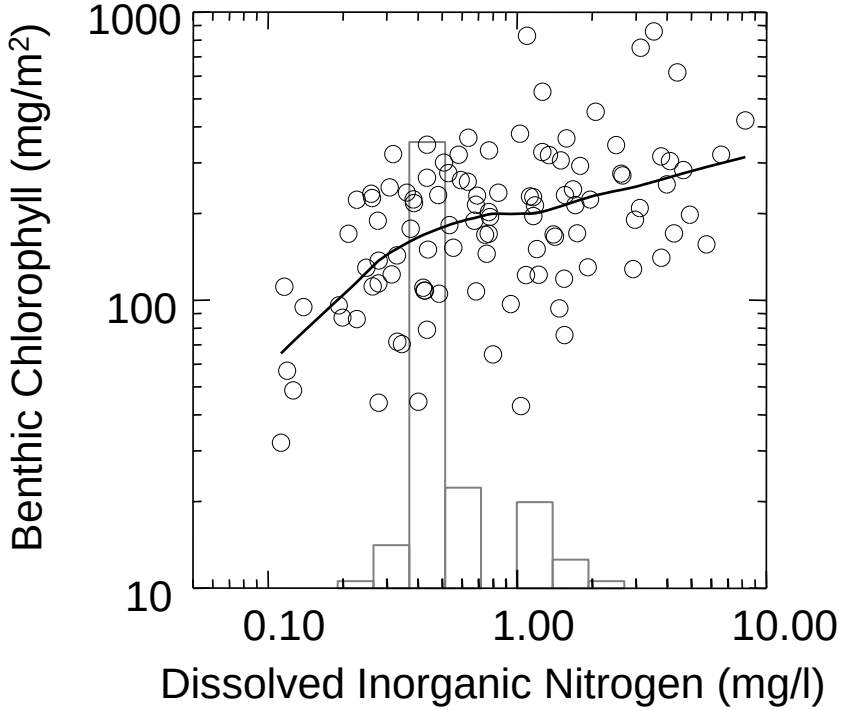
Enrichment and Dissolved Oxygen

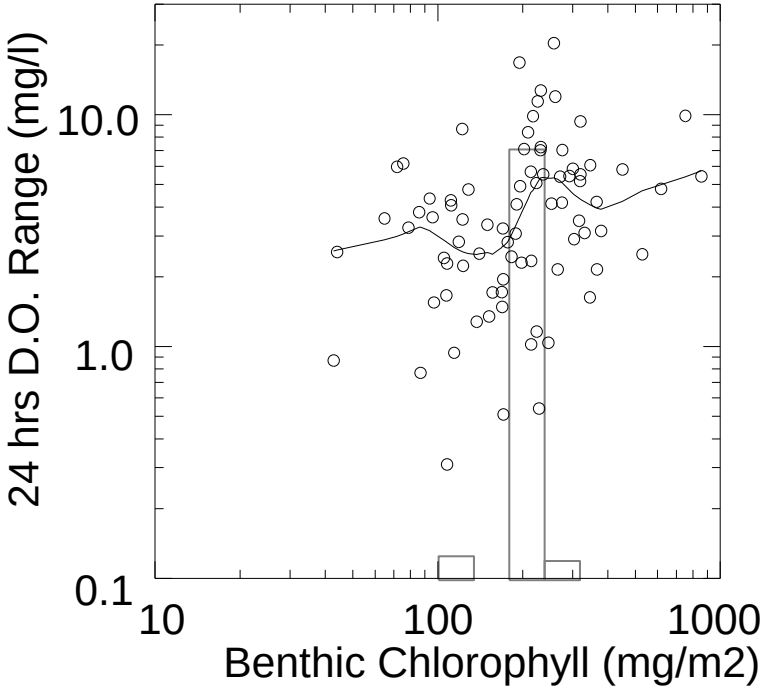




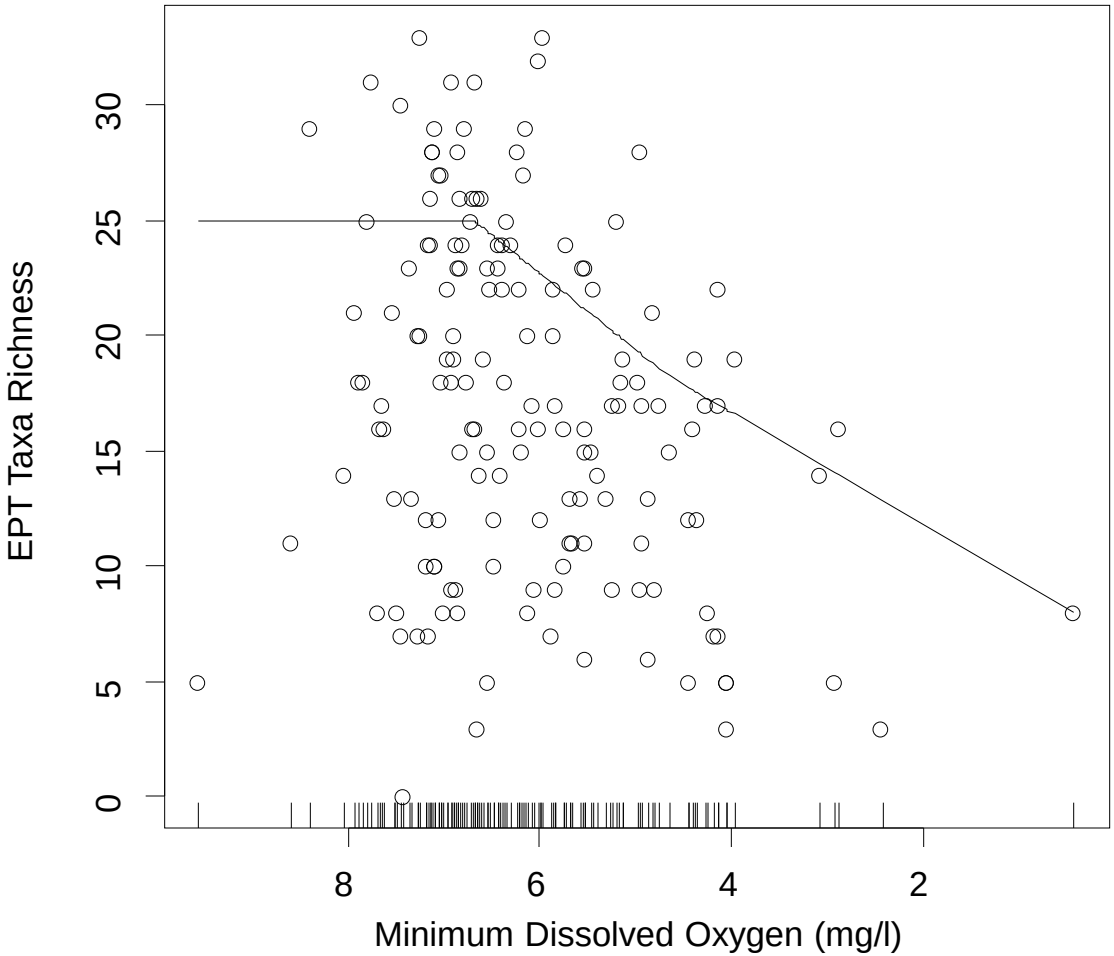
Developing Enrichment Indicators

- Step 1, Examine relationships between causal and response variables
- Step 2, Make sense of noisy, tenuous relationships
  - *no silver bullet, some BPJ is inevitable*
- Step 3, Use resulting information to set benchmarks & thresholds
- Step 4, Strive for parsimony





Dissolved Oxygen and Biological Quality



Change Points and Thresholds Identified in Nutrient Study and of Ohio Rivers and Streams

Drainage Areas < 1000 mi^2

DIN (mg/l)	TP (mg/l)	Benthic Chl a (mg/m2)	24 hour DO Range (mg/l)	DO Min (mg/l)
0.44	0.04	120	6	6
1.1	0.08	183	9	5

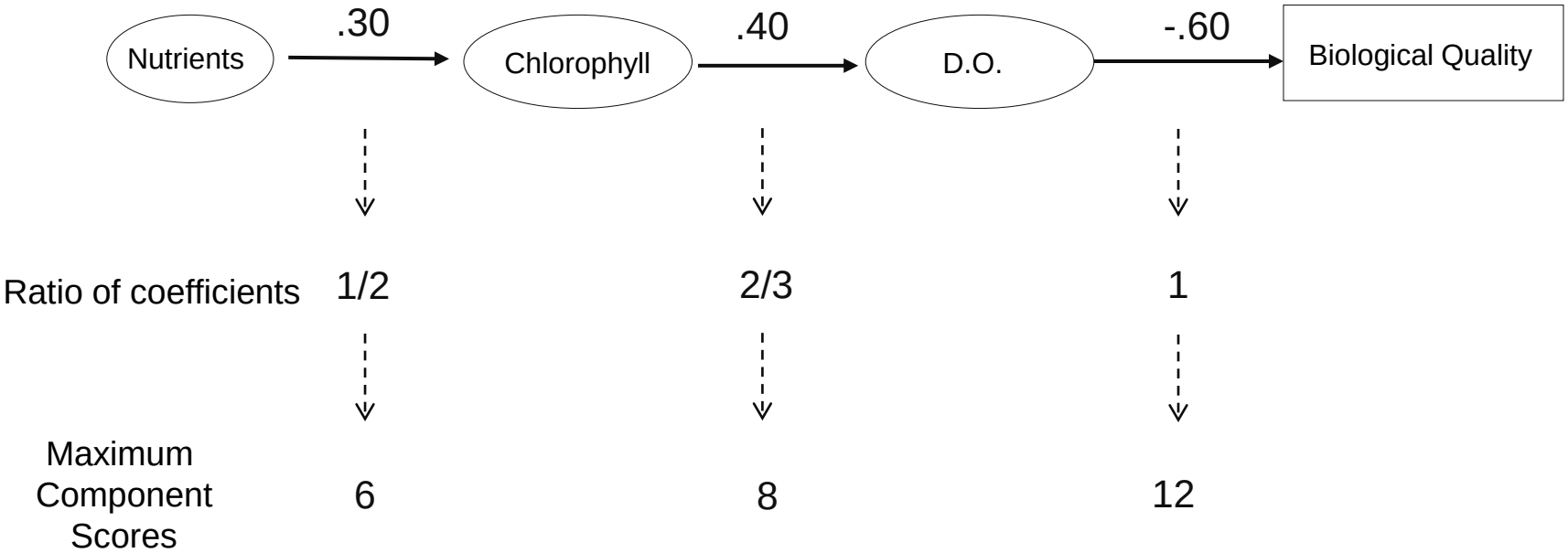
- Collective assessment of these measures plus information from biological communities position a water body along an enrichment gradient
- Rarefied as Trophic Index Criterion

Key Features in TIC Scoring

- Heavier weighting on biological indicators
  - Biological criteria (biocriteria) <u>already in rule</u>
  - Relative weighting derived from standardized regression coefficients
- Important interpretative conventions
  - Non-significant Departure
  - Partial Attainment

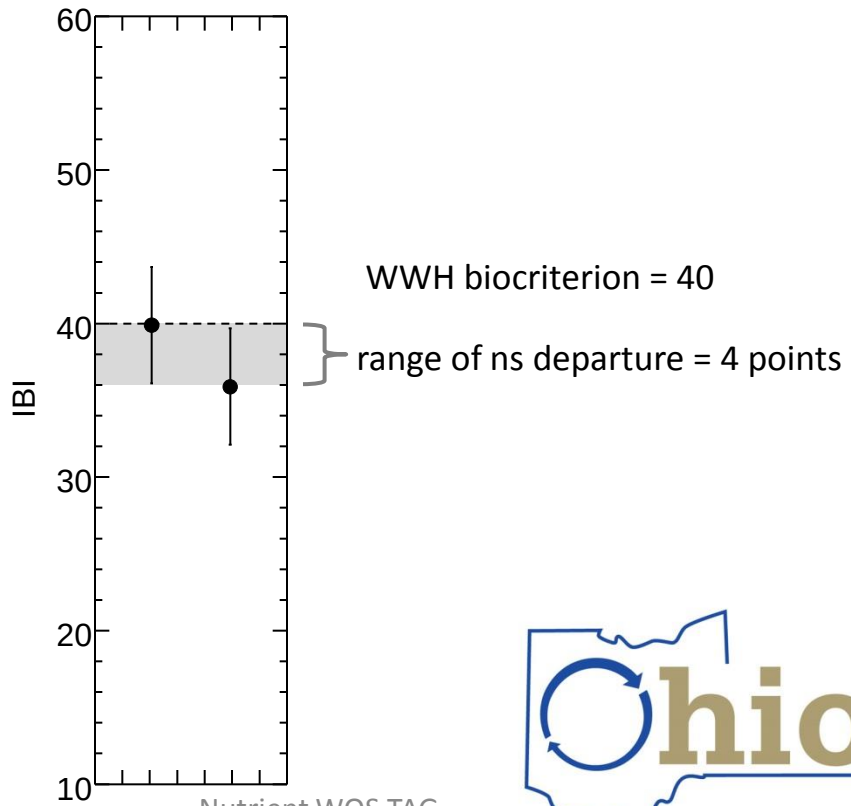
Linear Associations Inform TIC Weights

Standardized Regression Coefficients



What is Non-significant Departure?

Non-significant (ns) departure for a given biological index is the amount the index score can deviate from a respective biocriterion without being classed categorically as non-attaining. The ns departure range accounts for sampling error associated with a point estimate.



Biocriteria and Condition Status

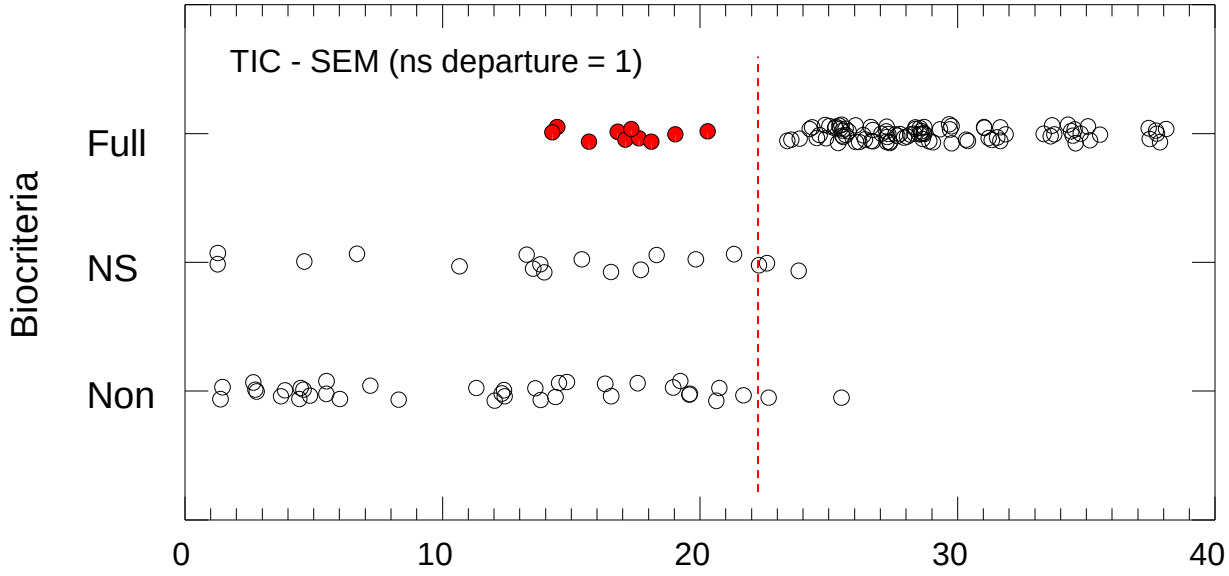
- Comparison of biological index scores to numeric water quality criteria (i.e., biocriteria) determine condition status
  - Full attainment: all biological index scores for a give site meet, or are within non-significant departure, of the numeric WQC
  - Partial attainment: One index score fails a respective biocriterion by more than the range of non-significant depature
  - Non attainment: At least one index score is rated as poor, or all index values are less than non-significant departure

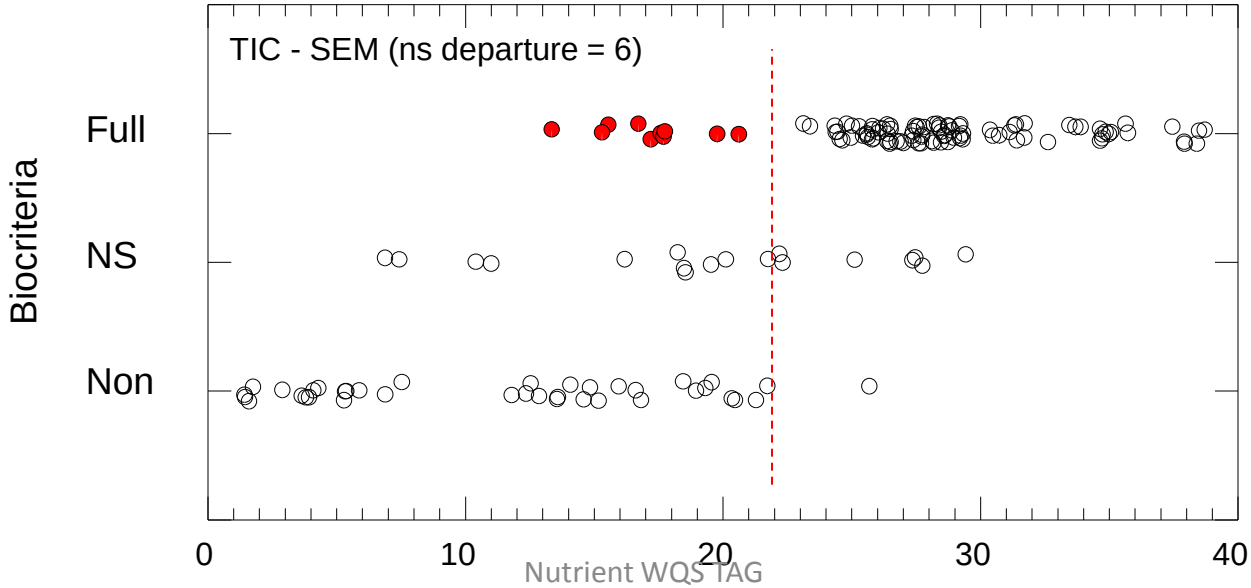
TIC Component Scores

	Biological Indicators	Dissolved Oxygen Regime	Benthic Chlorophyll	Nutrient Concentrations (see Table 4)
Highest Tier	12 biocriteria met	12 (24h range <6)	8 (<107)	6
Common Tier		6 (24 h range <7)	4 (107-183)	3
Elevated Tier	**6 or 1 ? ns departure**	1 (24 h range <9)	1 (184-320)	1
Over-Enriched	0 non/partial attainment	0 (24 h range >9; or min DO<WQS and 24 h range>6	0 (>320)	0

ns = non-significant departure from biocriteria

TIC Score Validation





Numeric Values Assigned to the Enrichment Continuum: The Trophic Index Criterion

	Biological Assemblages	Dissolved Oxygen	Benthic Algae	Nutrients	Trophic Index Criterion
Un-enriched	Meet applicable biocriteria (12)	Normal variation <6 mg/l (12)	<107 mg/m2 (8)	Concentrations typical of low disturbance (6)	**Acceptable (38-22)**
Typical waters		Modest swings >6 mg/ (6)	<183 mg/m2 (4)	Concentrations typical of working landscapes (3)	**Hold (21-20)**
Enriched	Within the range of non-significant departure (6)	Wide swings >7 mg/l (1)	<320 mg/m2 (1)	Exceeds ranges typically observed in reference sites (1)	**Threatened 19-14**
Over-enriched	Fail biological criteria (0)	Swings anomalously wide >9 mg/l or swings >7 mg/l and minimum D.O. <WQS (0)	>320 mg/m2 (0)	Exceeds concentrations associated with 50% chance of biological impairment (0)	**Impaired 13-0**

Nutrient Targets for TMDLs and TMDLs

Ambient concentrations in wadeable streams and small rivers

Aquatic Life Use and QHEI	TP (mg/l)	DIN (mg/l)
Exceptional warmwater habitat and all QHEI scores	0.060	3.0
Warmwater habitat and QHEI score = 12 to 64	0.13	3.0
All other aquatic life uses and QHEI scores	0.30	3.0

Nutrient Pollution Confirmed Now what?

- The general direction is known
  - We are short on the specifics of how

- Hopefully this will be the primary focus of future TAG work

Take Home

- Translating ambient concentration targets into TMDLs and NPDES permit limits is key
- Applicability of targets determined by
  - steam survey data, rigorous interpretation of results, and TIC scoring
  - First objective, resolve all TAG member questions
- Next, generate the implementation details
  - Ohio Nutrient Reduction Strategy provides a starting framework

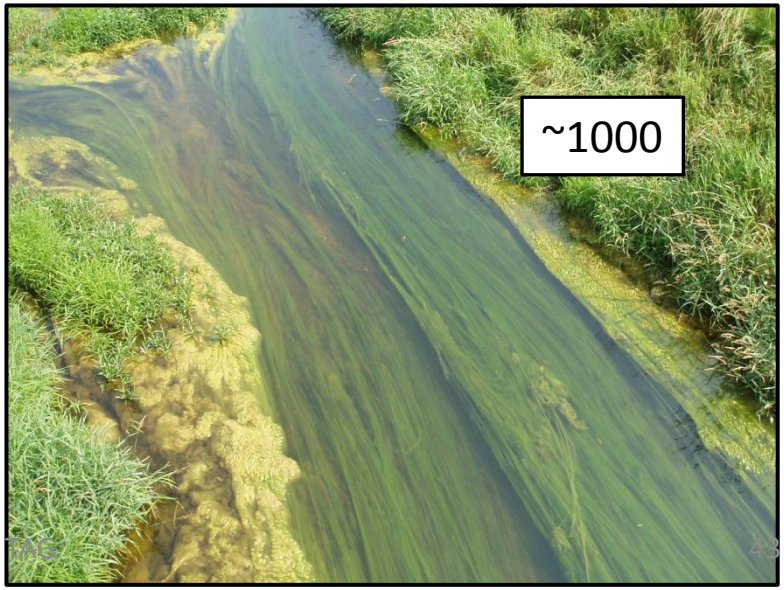
Strategy for Point Sources*

- **Phase in** water quality based effluent limits for phosphorus derived from TMDL/WLA calculations
  - In general, P limits imposed if receiving stream is impaired or threatened
    - Start with limit of 1 mg/l P or current load
    - allow exploration of trading or other options in lieu of achieving lower limits necessary to meet in-stream targets

* See Ohio Nutrient Reduction Strategy (6/28/13)

Questions?

Benthic Chlorophyll in Ohio Streams



LMR - Effluent Dominated Reach

Two Different Chlorophyll Levels, Same Aesthetics

Benthic Chlorophyll = 337 mg/m^2 RM 64.28

Benthic Chlorophyll = 167 mg/m^2 RM 60.84