Response Design

Inland Aquatics Stream Example

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Purpose

- Describe elements of response design
- Examples and considerations
- Indicator development and evaluation example
- Focus on process rather than specific examples
- What would you need to think about for your own monitoring program?

Response Design - What Is It?

- Once you have selected a site to visit, how do you sample it for the selected indicators?
- Response design can have both a temporal and a spatial dimension.
- Requires defining the “target population” for which the design is applicable.
- Ultimately, it includes how you collapse the measurements into an “indicator”
- Integrated into a daily operational scenario that can be consistently implemented by a field crew at a lot of different stream types and still provide comparable data

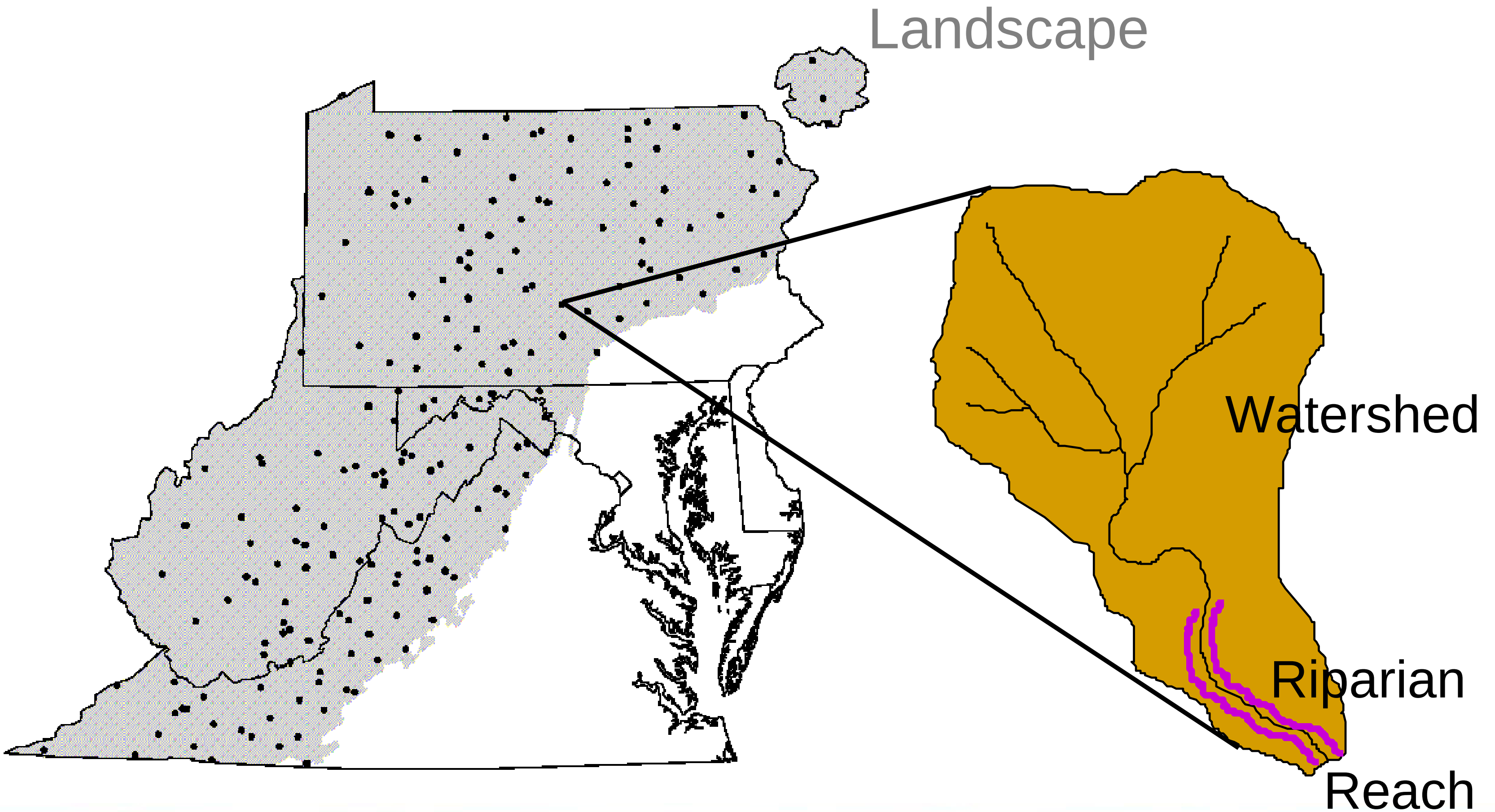
Target Population

- The portion of the systems about which you want information
  - e.g. All 1st - 3rd order streams, all streams and rivers on non-private land, all streams and rivers as defined by 1:100,000 map scale, all lakes > 1 ha., emergent palustrine wetlands.
- Response design might vary with subpopulations within the target population
  - e.g., wadeable streams versus large rivers.

Response Design: Indicators

- Indicators of Condition:
  - Vertebrate Assemblage
  - Macro-invertebrate Assemblage
  - Periphyton Assemblage
- Indicators of Stress:
  - Physical Habitat (in-stream and near-stream)
  - Ambient Chemistry (nutrients, major ions)
  - Fish Tissue Contamination (mercury, organic contaminants)
  - Watershed/Landscape Characteristics
- Indicator can be derived as:
  - Direct measure
  - Metrics representing structural or functional attributes

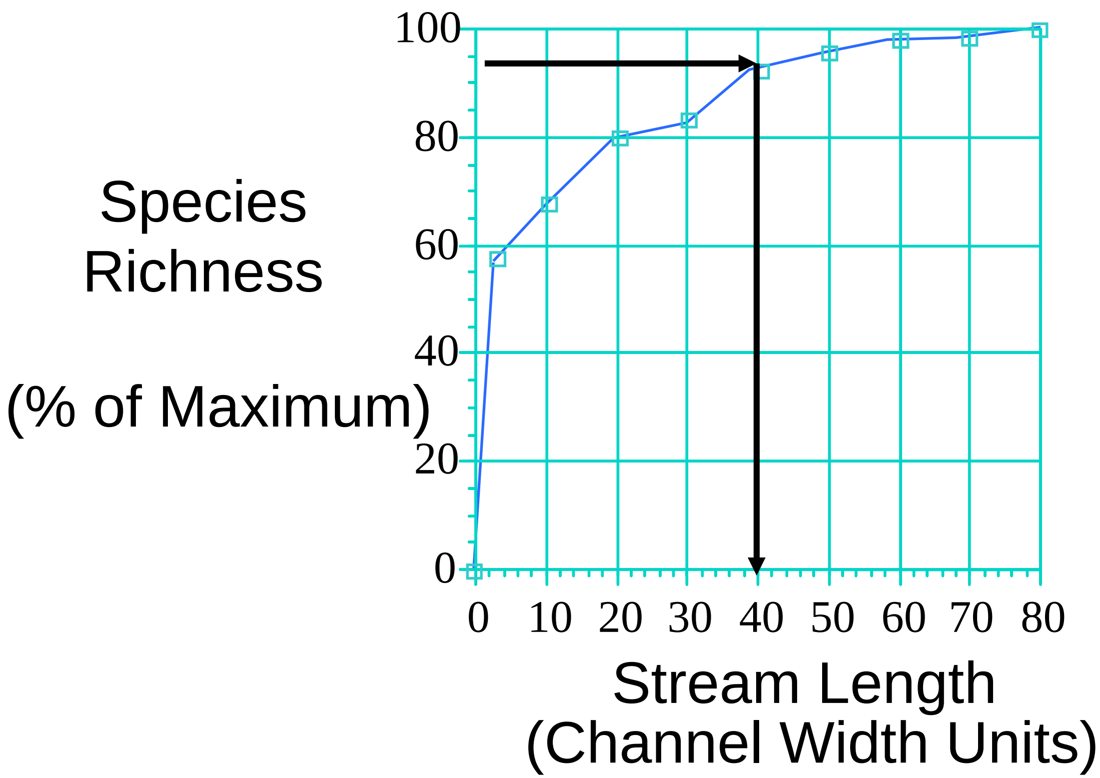
Response Design Scales



Response Design: Index Period

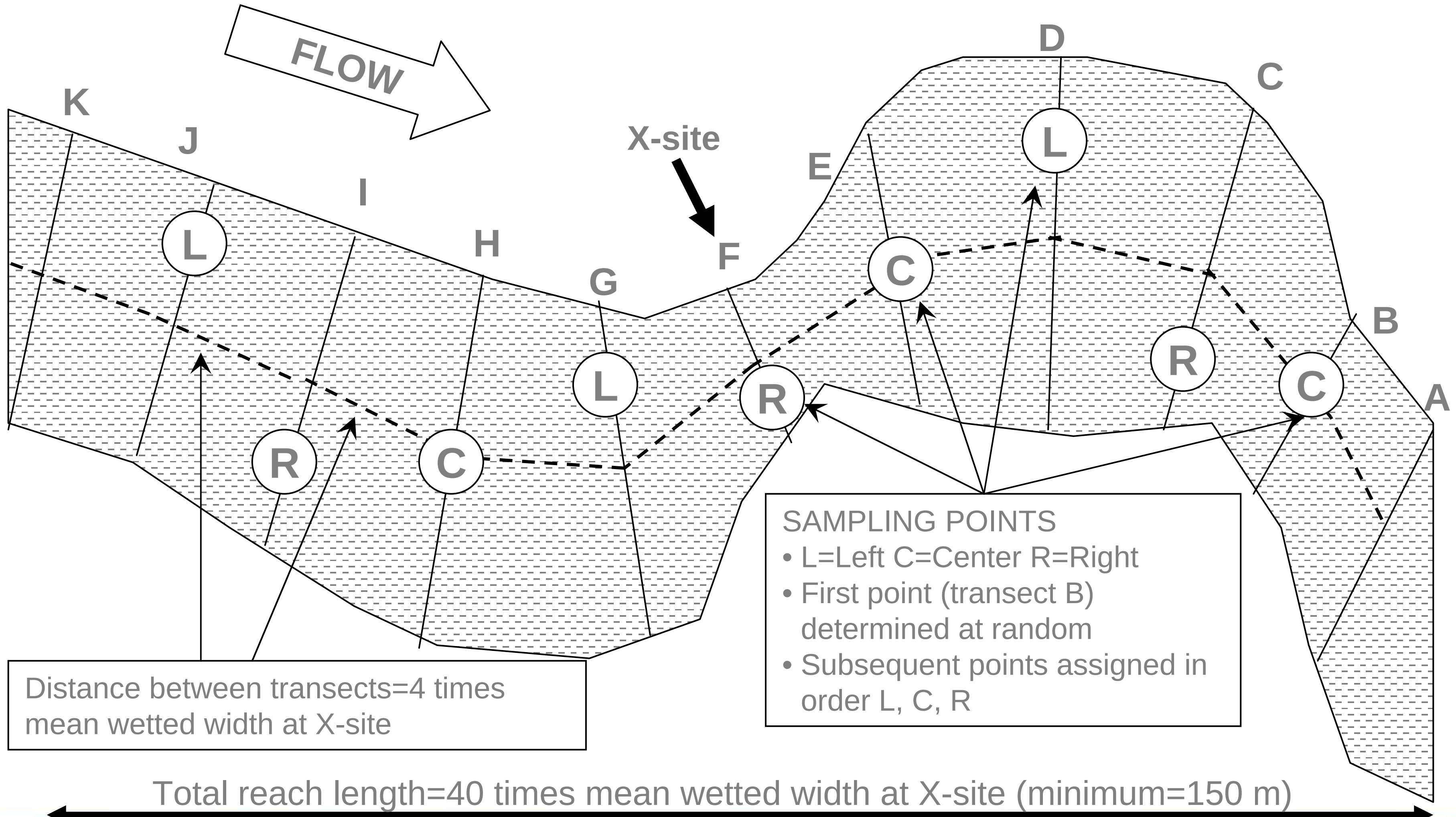
- When to sample
- Desirable qualities
  - Stable conditions
    - Maximize among-site variability, minimize within-site variability of all indicators
  - Biota present and amenable to collection
- May require compromises for multiple indicators
- Influenced by logistics
  - Number of sites (or sampling trips)
  - Number of field crews
  - When are they available and for how long?

Response Design - Fish



- 1-pass sampling
- Spread effort throughout reach
- Get "common" species in approx. relative abundance

Response Design: Benthos and Periphyton



Response Design: Benthos

- Composite sample from samples collected throughout reach
  - Many small better than a few large
    - 1 ft^2 kick or sweep samples
- Sufficient material to enumerate 500 individuals
  - 11 samples
- Obtain sample from every stream
  - Sample at each transect
- Comparability with reference site study
  - 500 µ mesh net
  - 8 samples from riffles
- Minimize equipment
  - 1 net for all samples

Response Design: Periphyton

- Composite sample from samples collected throughout reach
  - Many small better than a few large
    - 12 cm^2 scrub or slurp samples
- Sufficient material to enumerate 500 diatom valves, filter 50 mL for chlorophyll and biomass
  - 11 samples
- Obtain sample from every stream
  - Sample at each transect
- Minimize effort
  - Sample at same points as for benthos

Essential Stream Physical Habitat Elements

- Channel Dimensions: Nothing may be more important than space
  - Without it-- other elements do not matter
- Gradient: hydraulic "energy" of a stream
  - used with size to determine stream power and shear stress
- Substrate Size and Type: important for fish, benthos, periphyton
- Complexity & Cover: Niche diversity, protection from predation

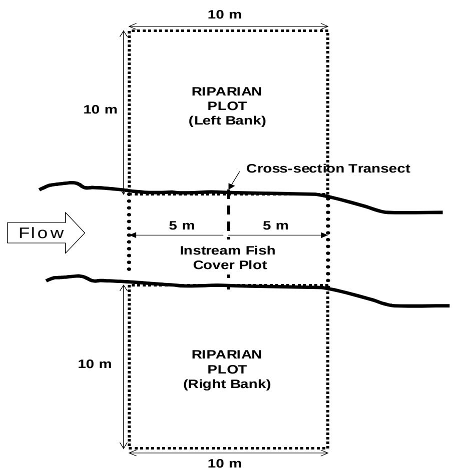
Essential Stream Physical Habitat Elements

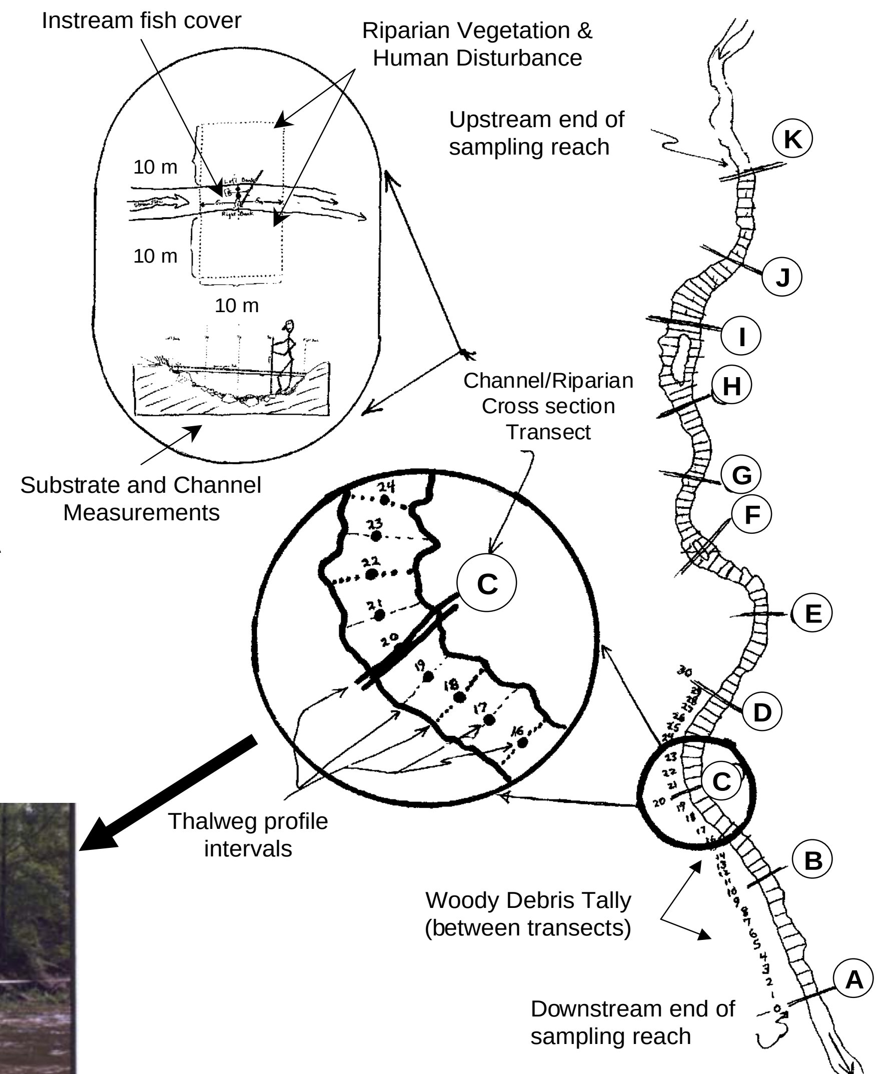
- Riparian Vegetation Cover and Structure: Temperature, organic inputs, channel morphology
- Channel-Riparian Interaction: Channel Characteristics altered by riparian and catchment land use, which in turn influence terrestrial-aquatic interactions
- Anthropogenic Alterations: diagnose stream disturbance and "reference condition"
- Note: Chemistry, Nutrients, Temperature:
  - Also need other physical and chemical data to interpret biological data

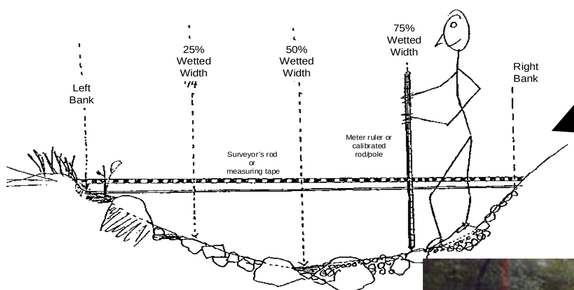
Physical Habitat Characterization
(40 channel width study reach)

- Long. Profile at 100 equidistant points:
  - Thalweg Depth, Surficial fines, Habitat Class
- Woody Debris Tally (continuous)
- 21 Equidistant Cross-Sections:
  - Width, Substrate
- 11 Equidistant Cross-Sections & Plots:
  - Channel Measures: Slope, Bearing, Channel Dimensions, Fish Cover, Canopy Cover, Substrate Embeddedness
  - Riparian Measures: Bank Characteristics, Human Disturbance, Riparian Vegetation Type, Structure and Cover
- Whole Reach: Channel Constraint, Flood/Torrent Evidence
- Near X-Site: Discharge

Response Design: Physical Habitat



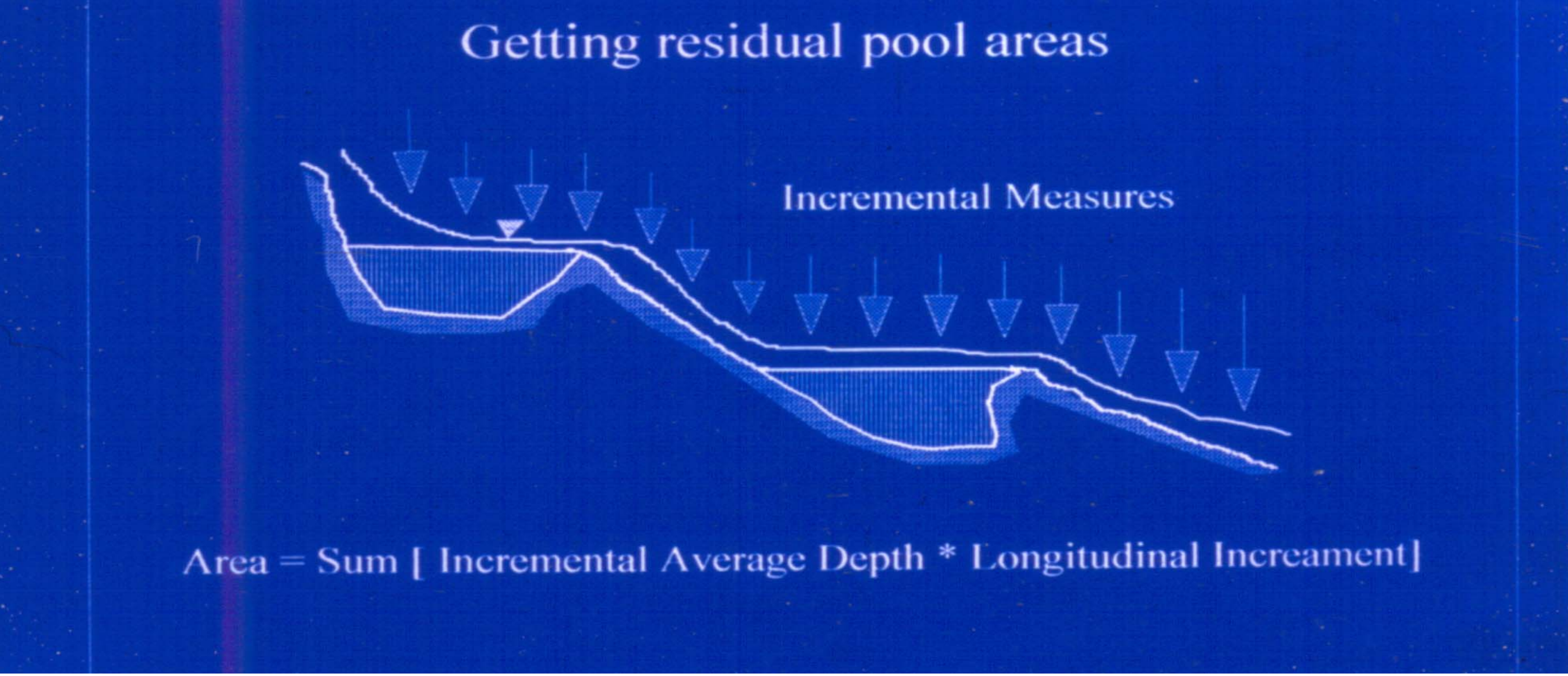




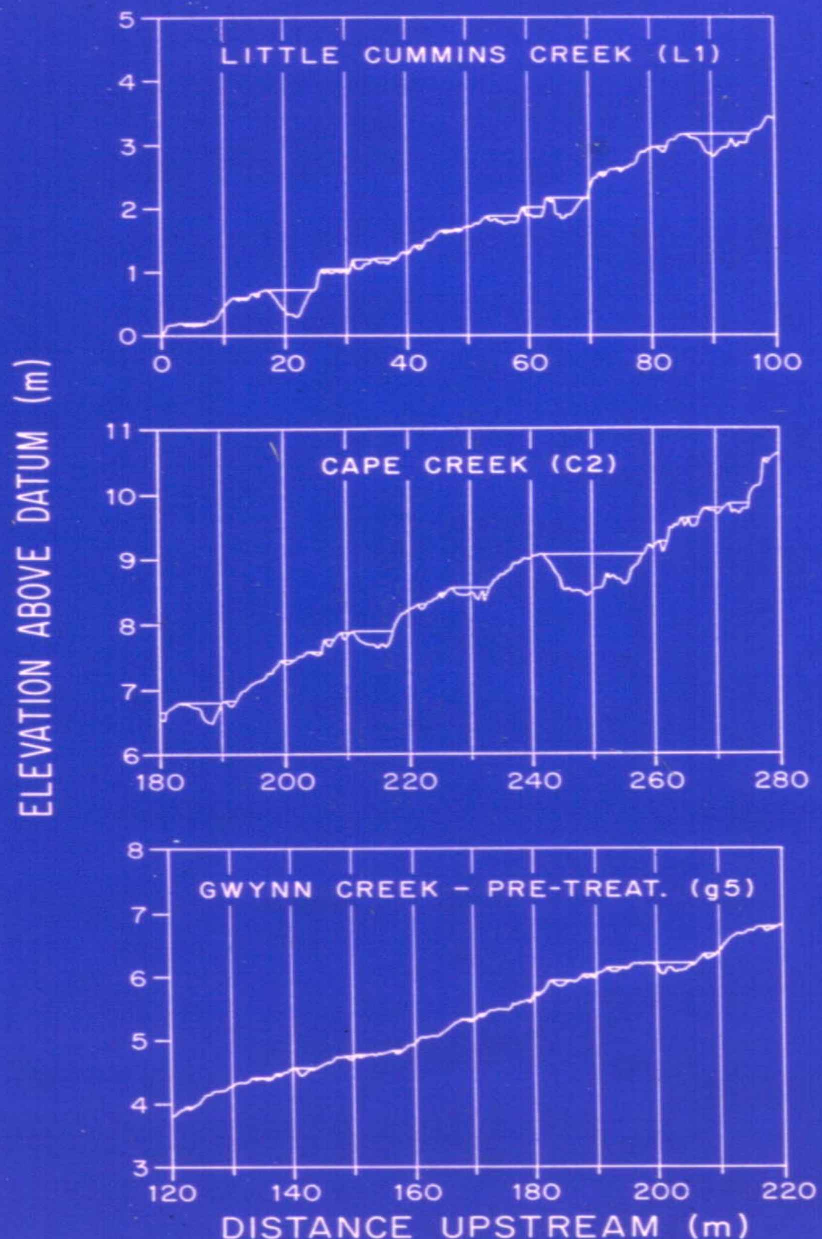
Physical Habitat "Quality" Metrics

- Riparian Vegetation: Complexity, Cover
- Riparian Disturbance: Proximity-Weighted Tally
- Substrate: Fines, Embeddedness, Bedrock, Macrophytes
  Algae
- Channel Alts: Pipes, Revetment, Rel. Bed Stability,
  Deviation in Resid. Pool Vol
- Volume : Width, Cross-Sectional Area, Residual Pool, %Dry
- Complexity: CV Depth, Sinuosity
- Cover: Separate and Sum of 6 Cover Types
- Velocity: Slope, Shear Stress

Quantifying Pools Using Residual Pool Concept



- "Residual Pool Area": Depths, slopes used to estimate volume of water remaining at zero flow
- Independent of discharge, sensitive to activities that alter LWD, sediment inputs



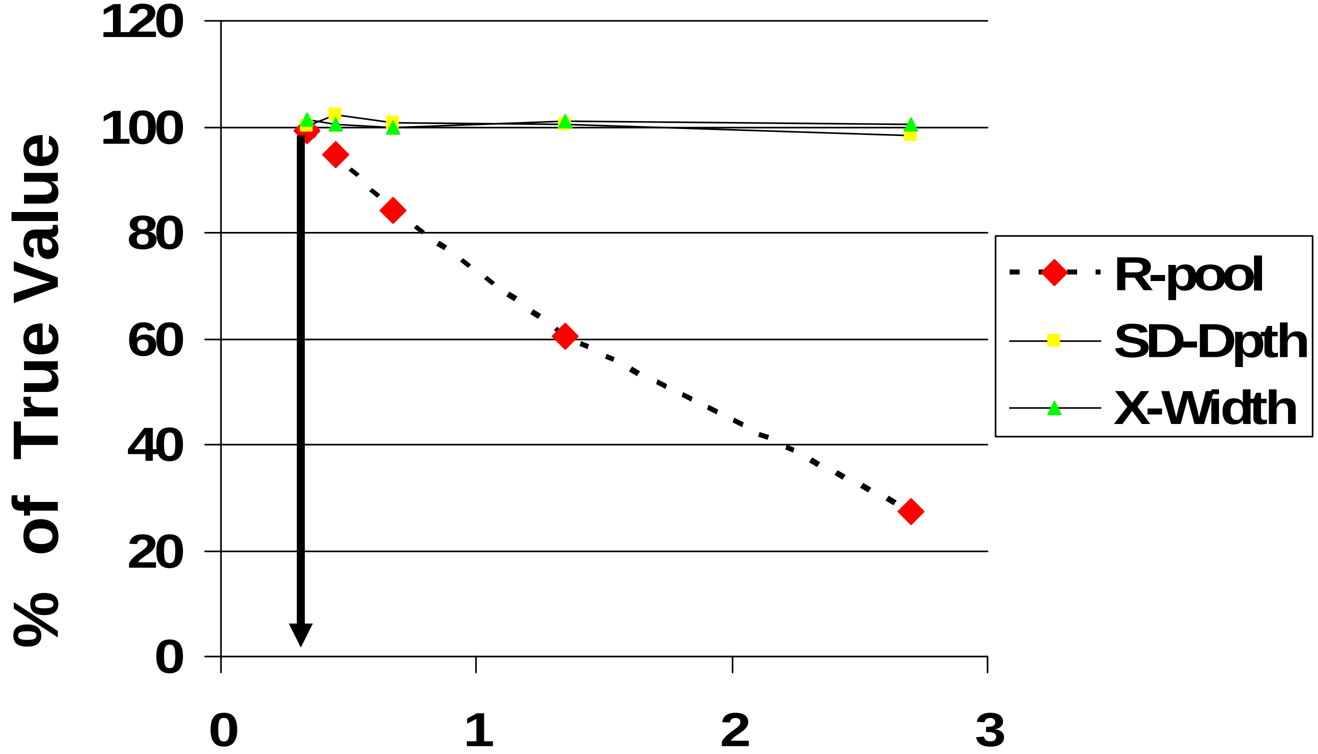
"Old growth" 120 yr after torrent

15 yr after torrent that deposited LWD, gravel

1 yr after torrent that severely scoured channel

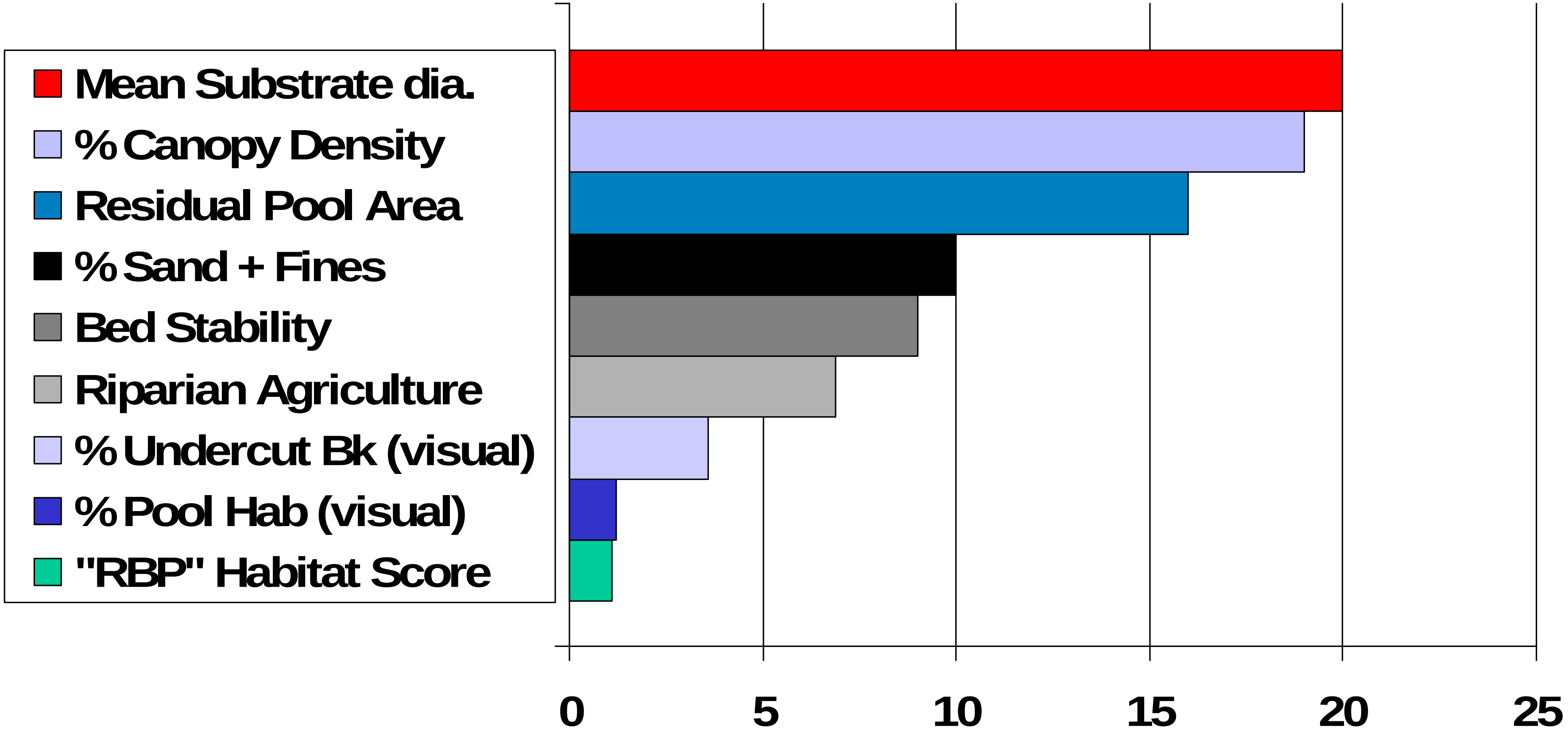
Effect of Measurement Spacing

(from Robison, 1998)



Spacing (ChW's)
on 40 ChW Reach

Signal to Noise Variance Ratio (MAHA 93-96) Streams : Replicates



The Long and Winding Road…

Data Generation

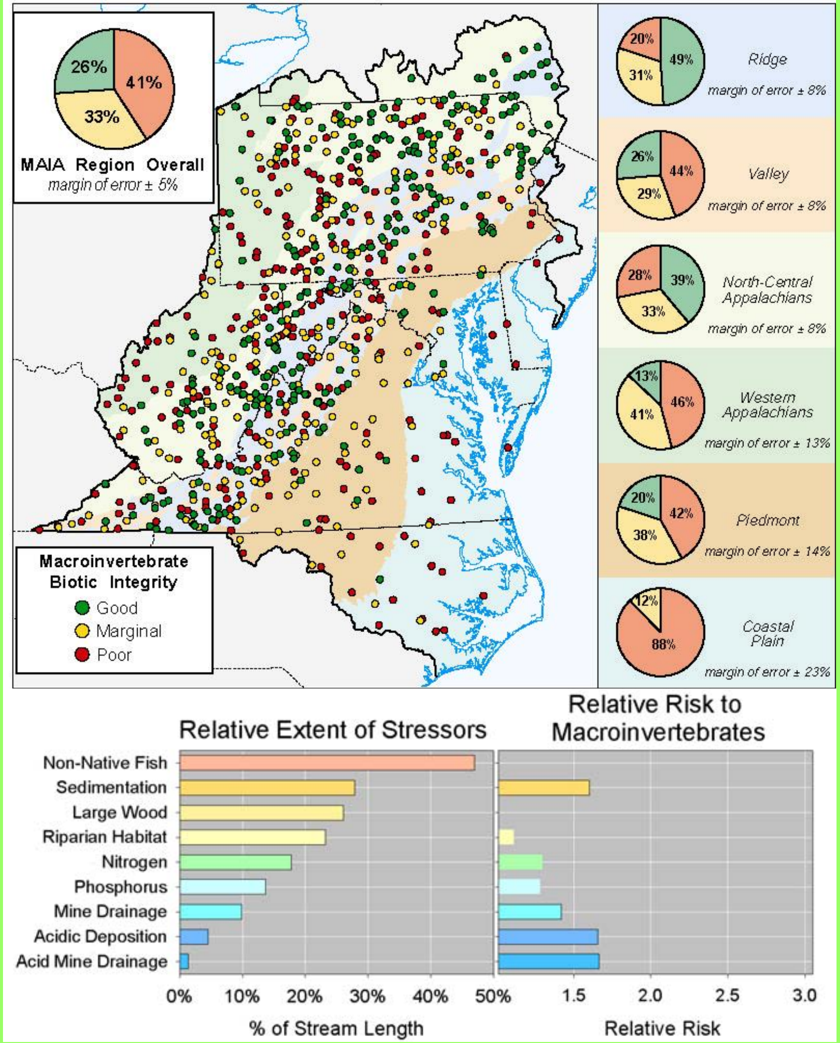
Data Entry & Verification

Validation

Metric/ Indicator Development & Evaluation

Survey Analysis

Interpretation & Assessment



An Index - Bringing It All Together

- Eliminate metrics with insufficient range (raw scores 0-2 or less) - 15 metrics fail this test
- Eliminate metrics with high variability (signal:noise ratio < 3) - 2 metrics fail this test
- Correct remaining metrics for watershed size if necessary (n = 15) - these metrics normalized for 100 km^2 watershed
- Eliminate redundant metrics (Pearson $r > 0.75$) - 2 metrics fail this test
- Analyze metric responsiveness to disturbance - 10 most responsive metrics retained
- Score metrics using reference/test sites in calibration data (1 metric could not be calibrated)
- 9 remaining metrics combined in final IBI
- IBI tested for ability to discriminate known disturbance gradients using test data set

The Process - Data Sets

- **Agreement on data - Mid-Atlantic EMAP streams data, 1993-96 (excluding only Coastal Plain sites)**
- **Calibration data to include all sites with quantitative physical habitat data (n = 177)**
- **Validation data (set aside, and not used in IBI development) includes all remaining sites (n = 119)**
- **57 candidate metrics calculated**

Candidate Metrics

NATIVFAM	Number of families represented	PBCLN	prop. of indiv. as bc spwn clear substr.
NREPROS	Number of reproductive guilds	PBCST	prop. of indiv. as broadcast spawners
NSANGU	number of anguilla species	PBENT	prop. of fish as benthic insectivores
NSATHER	number of atherin species	PBENTSP	prop. of benthic hab. sp. in native sp.
NSBENT2	Number of native bent_inv species minus 3 taxa	PCARN	prop. piscivore-invert.(piscinv+pisciv)
NSCATO	number of sucker species	PCGBU	prop. of indiv. as clear gravel buryers
NSCATO2	Num. of native intolerant Catostomids	PCOLD1	Prop. of cold water individuals
NSCENT	Sunfish Species Richness	PCOLD2	Prop. of cold & cool water individuals
NSCOLU	number of water column species	PCOLSP	prop. of column sp. in native sp.
NSCOTT	number of sculpin species	PCOTTID	prop. of individuals as cottids
NSCYPR2	number of intolerant cyprinid species	PCYPTL	prop. of ind. as tolerant cyprinids
NSDART	number of darter species	PEXOT	prop. of individuals as introduced
NSDRUMX	number of drum species	PGRAVEL	prop. of simple lithophils
NSESOXX	number of esox species	PHERB	prop. of individuals as herbivores
NSFUND	number of fundelis species	PINSE	prop. of indiv. as native insectivores
NSGAMB	number of gambusia species	PINVERT	prop. of invertivores
NSICTA	number of ictalurid species	PMACRO	prop. of macro-omnivores
NSINTOL	number of intolerant species	PMICRO	prop. of micro-omnivores
NSLAMP	number of lamprey species	PMICRO2	Prop. of micro-omnivores minus RHINATRO
NSPERCO	number of percopsis species	PNEST	prop. of indiv. as nest associates
NSPPER	number of perch species	PNTGU	prop. of indiv. as nester guarder
NSSALM	Trout Species Richness	POMNI	prop. Omninore individuals (pmicro+pmacro)
NSUMBR	number of umbridae species	POMNI_H	prop. omni-herbiv.(pmicro+pmacro+herbiv)
NTROPH	number of trophic guilds	PPISC	prop. of individuals as carnivores
NUMFISH	number of individuals in sample	PPISCIN2	Prop. of piscivore-insectiv. minus SEMOATRO
NUMNATSP	number of native species	PPISCINV	prop. of piscivore-insectivores
NUMSPEC	Total number of fish species	PTOLE	prop. of individuals as tolerant
PANOM	Proportion of individuals with anomolies	PTREPRO	prop. tolerant reproductive guild individuals
PATNG	prop. of indiv. as attacher non-guarder		

Range Test

Question: Do all metrics have enough of a range that they will contribute useful information to an IBI?

Answer: No. Several metrics have values (only) of 0, 1 or 2. These metrics were dropped from the candidate list:

NSANGU	NSATHER
NSCATO2	NSDRUMX
NSESOXX	NSFUND
NSGAMB	NSICTA
NSLAMP	NSPERCO
NSPPER	NSSALM
NSUMBR	

Signal:Noise Test

Question: Are all metrics sampled reliably, i.e., do repeated measurements at a single site yield the same results?

Answer: No. Two metrics have signal:noise ratios (ratio of within site variance to between site variance) less than 3. These metrics were dropped from the candidate list:

NTROPH
PNEST

Watershed Correction

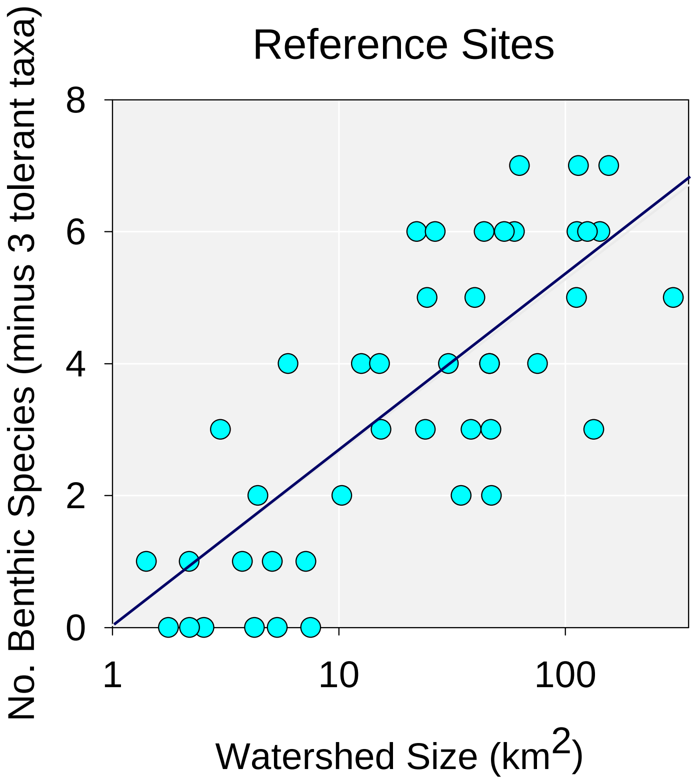
Question: Do metrics show strong correlations with watershed size, so that their scores need to be normalized (watershed size effect removed?)

Answer: Yes. These metrics need to be corrected for watershed size effects:

NATIVFAM	NUMFISH
NREPROS	NUMNATSP
NSBENT2	NUMSPEC
NSCATO	PATNG
NSCENT	PBENT
NSCOLU	PCARN
NSCYPR2	PINSE
NSDART	PINVERT
NSINTOL	

Watershed Correction

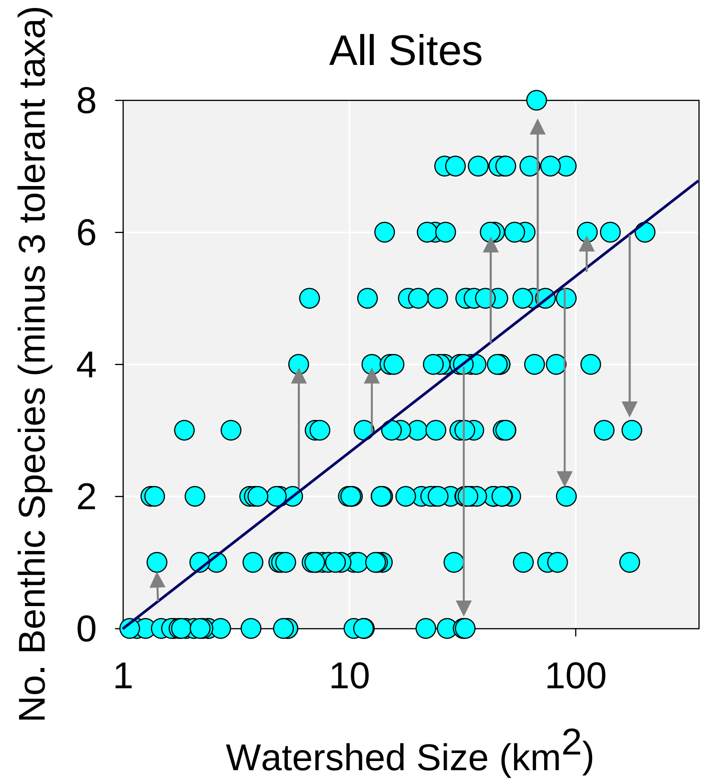
Approach: Use relationships observed at reference sites to define 'natural' element of watershed size effect



1. Calculate regression for reference sites

2. Apply reference regression to all sites.

3. Calculate 'residuals' for all sites.



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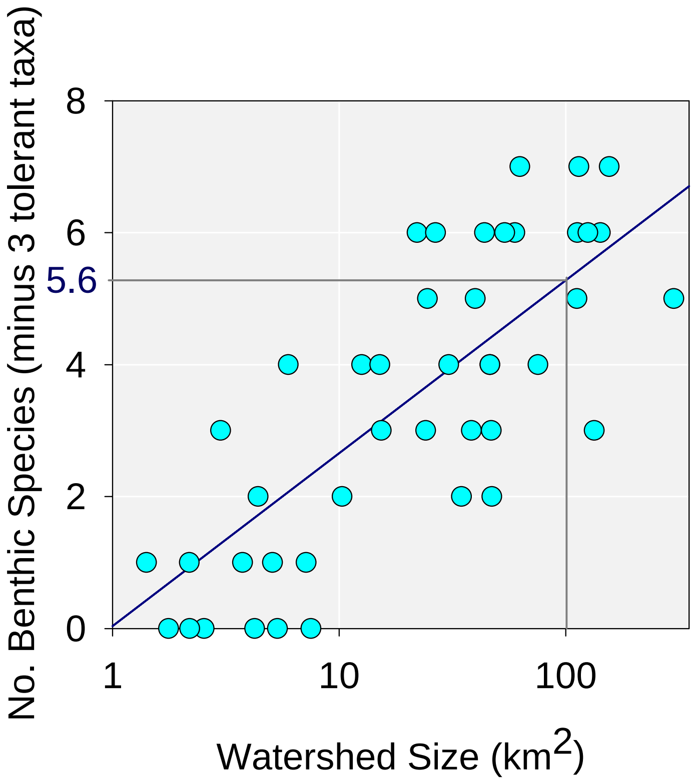
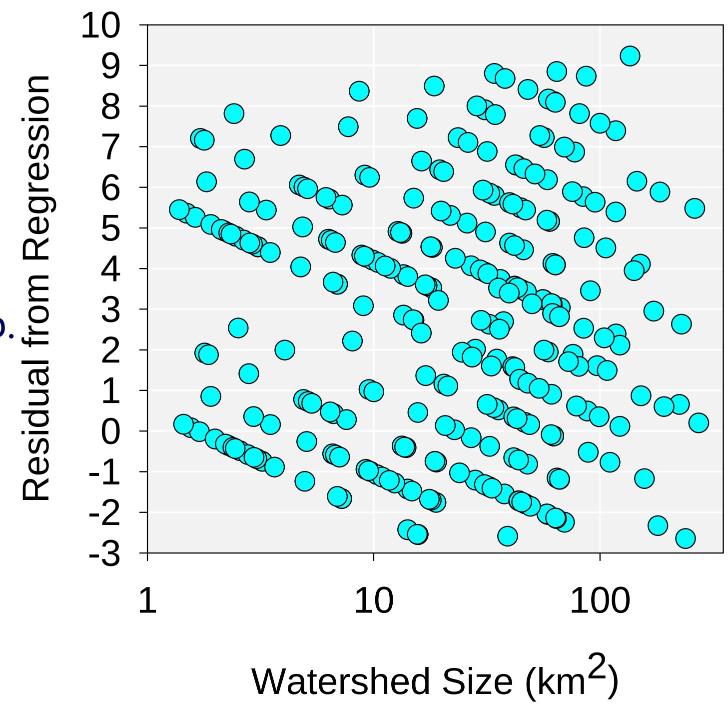


1. Calculate expected value for reference data set at 100 km^2

2. Take residuals from previous step.

3. Add 100 km^2 expected value to residuals to create all positive metric, corrected for watershed size.



Result: Each metric scored against its expected value in a reference site with watershed area = 100 km^2

Redundancy Test

Question: Are all metrics independent?

Answer: No. Two pairs of metrics have Pearson $r > 0.75$.
Only one of each pair can be used in final IBI.
These metrics were dropped from the candidate list:

NCOLD1 (redundant with PCOLD2)
PBCLN (redundant with PMACRO)

Responsiveness Disturbance Metrics

(each metric evaluated for response to each of 18 disturbance gradients)

Chemical:

- •pH
- •sulfate concentration
- •total nitrogen concentration
- •total phosphorus concentration
- •chloride concentration

Integrated Measures:

- •Disturbance Class
  (Mine Drainage, Acid Rain, Nutrients, etc.)
- •Watershed Condition Class
  (Bryce et al., 1999)

Habitat:

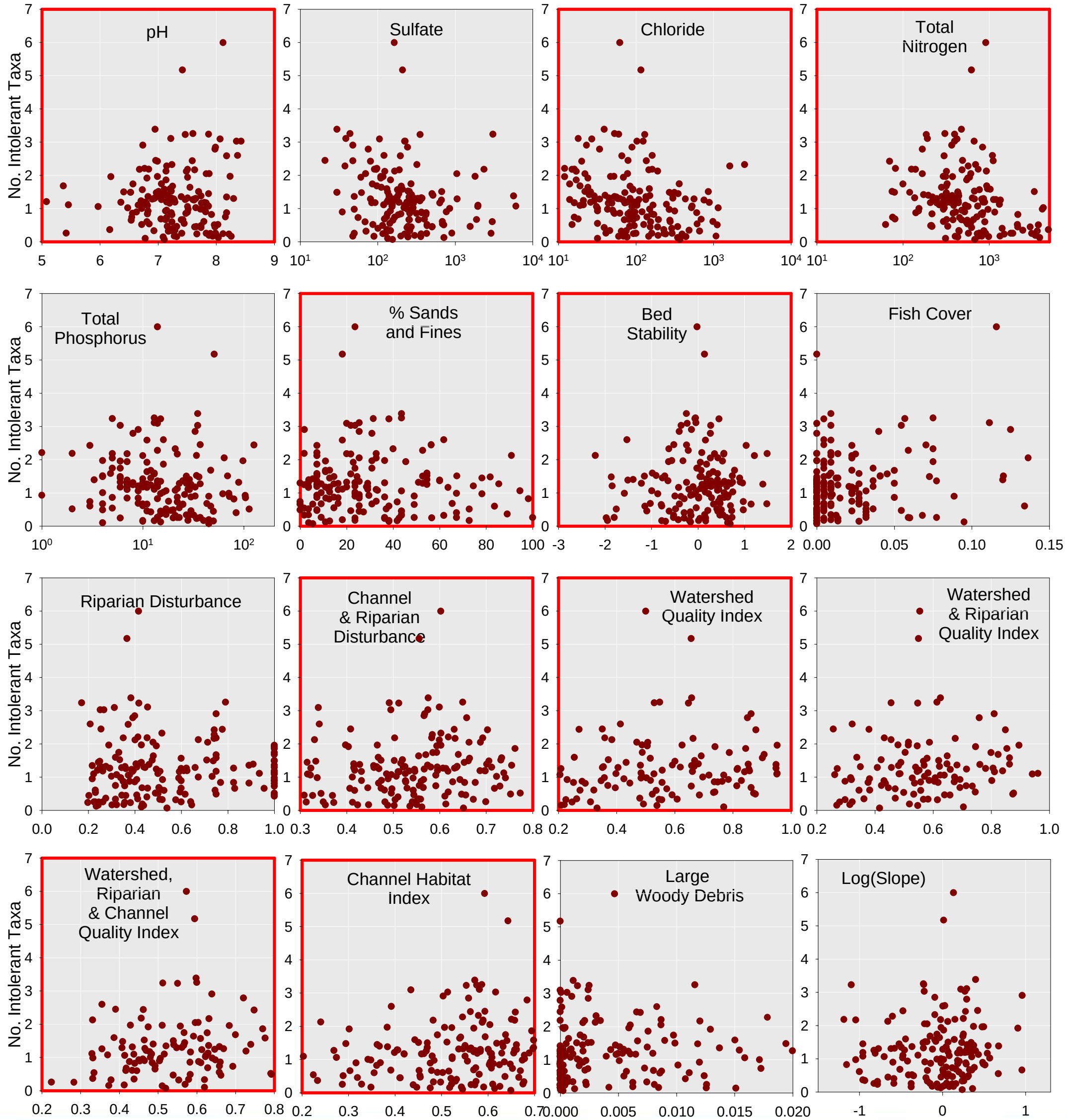
- •Percent Sands and Fines
- •Bed Stability
- •Density of Large Woody Debris
- •Fish Cover
- •Riparian Disturbance
- •Channel and Riparian Disturbance Index
- •Watershed Quality Index
- •Watershed & Riparian Quality Index
- •Watershed, Riparian & Channel Habitat Quality Index
- •Channel Habitat Quality Index

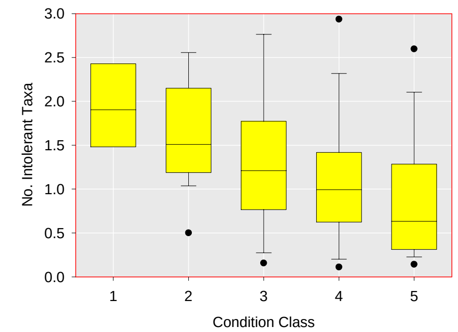
Natural drivers (included as a check):

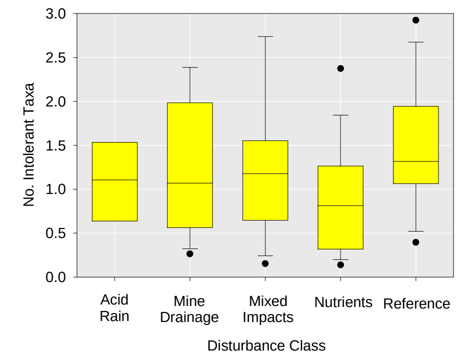
- •Reach Slope

Responsiveness - Example

Number of Intolerant Taxa (Adjusted for Watershed Size)

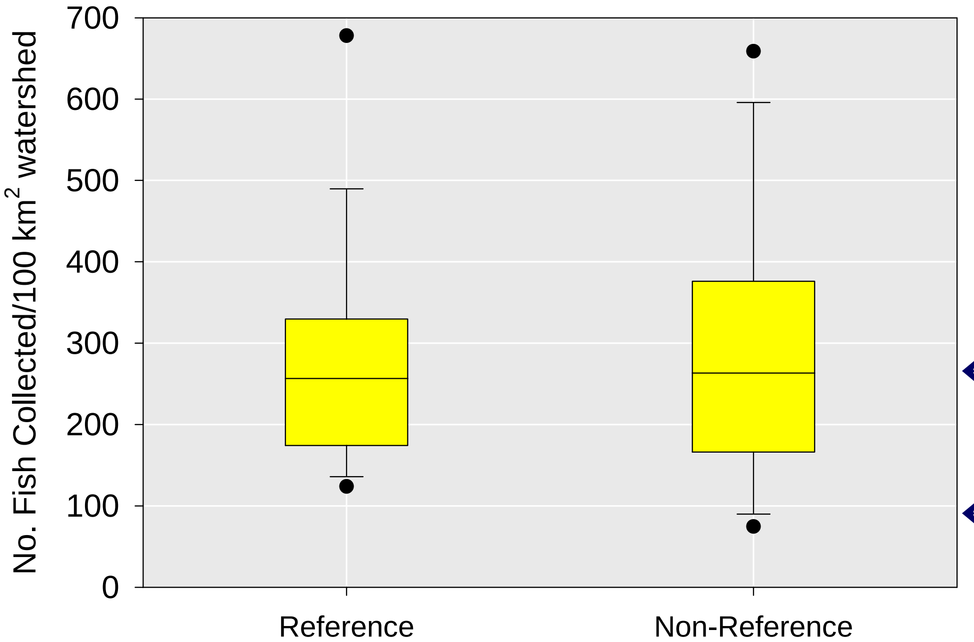






(Plots outlined in red illustrate good metric response)

Special Case #1
Number of Fish Metric



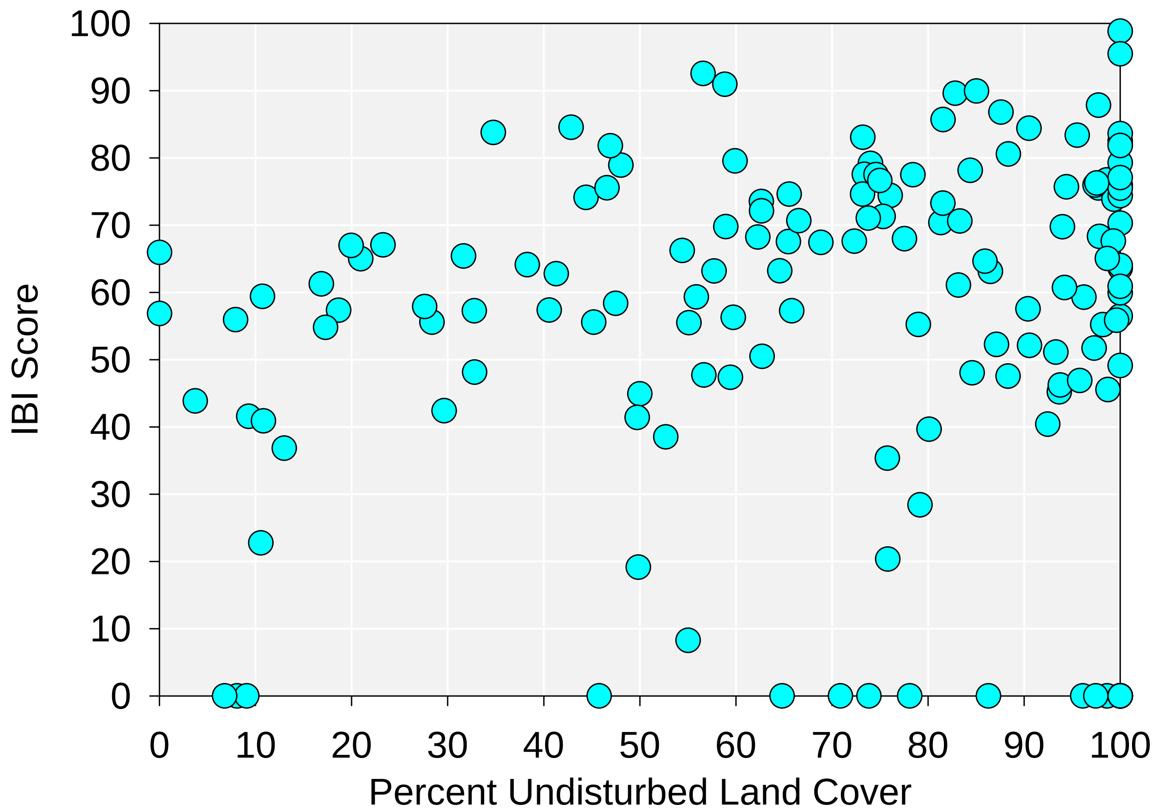
Median from reference sites = 10

10th Percentile from test sites = 0

Result: While this metric passed all of our tests, if scored like all other metrics, more than half of sites would score 10. The amount of information gained by its use is too small to include it in final IBI

Special Case #2 - 'Fishless' Sites

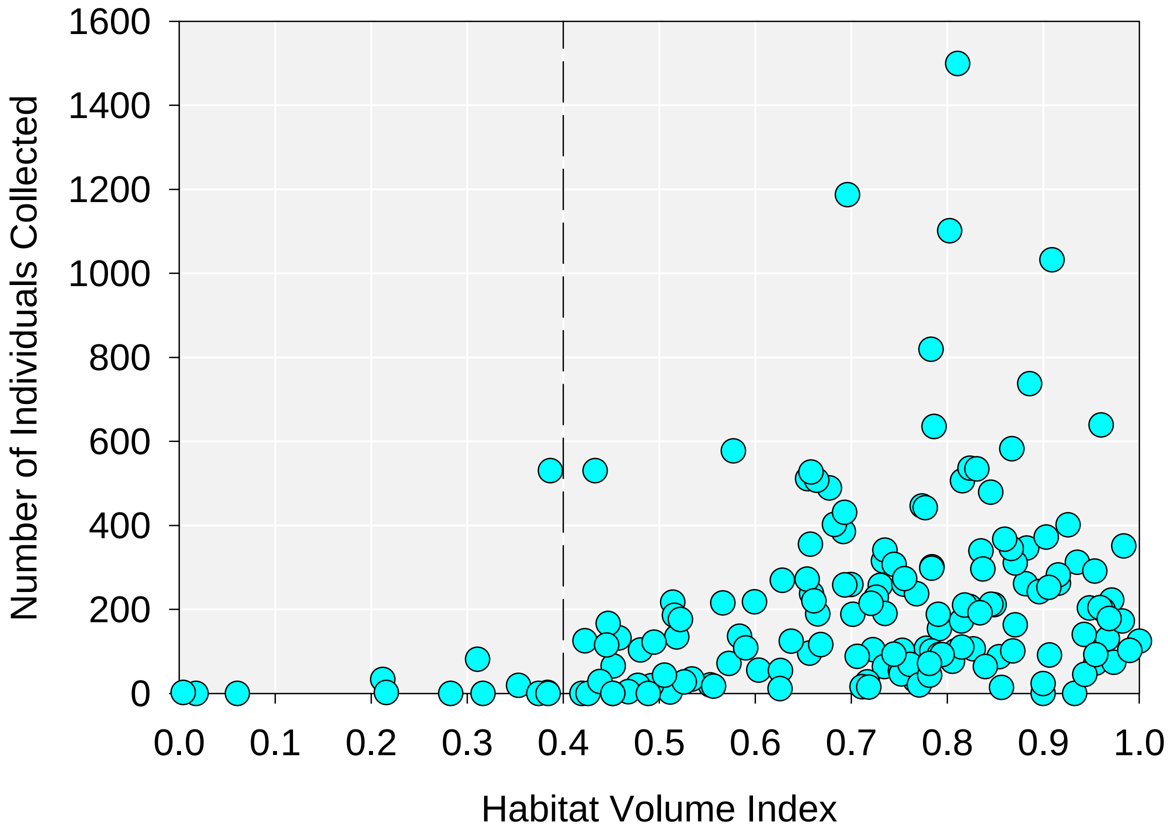
If fishless sites are scored as IBI=0



These zero values may be reasonable

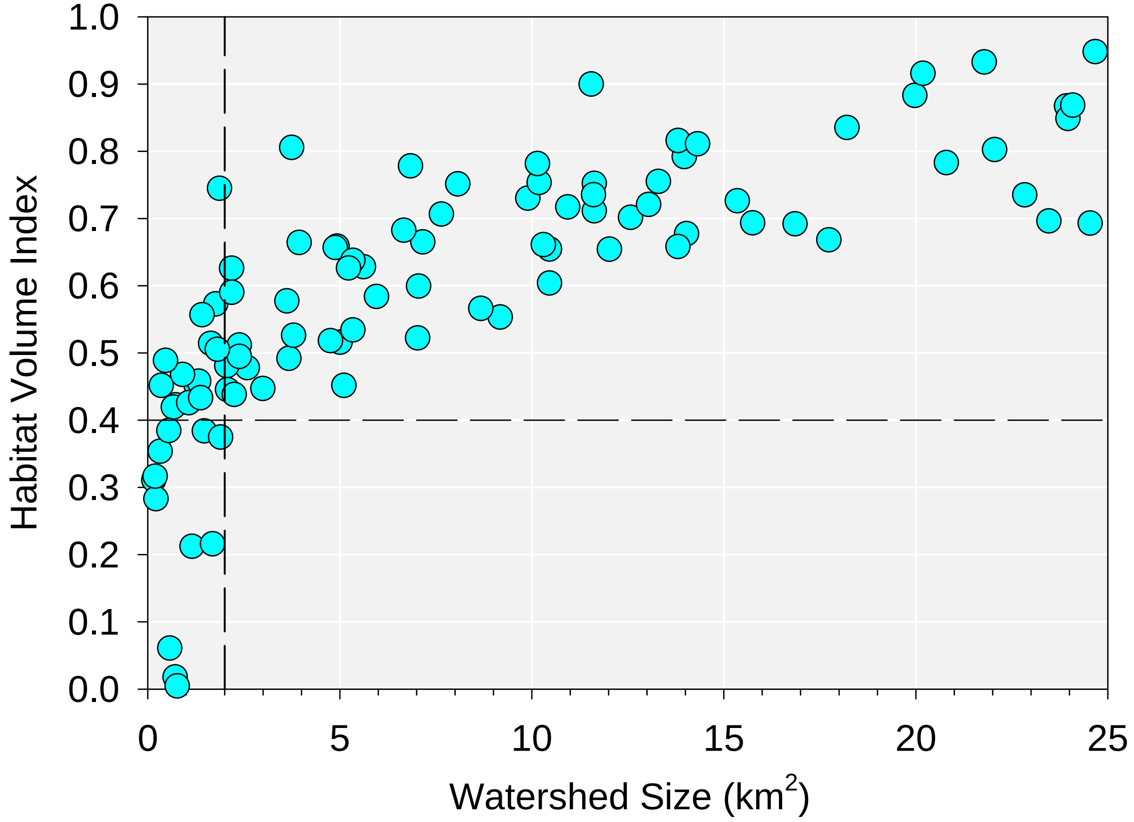
But what about these?

Habitat Volume



Conclusion: High probability of 'fishless' streams when Habitat Volume Index falls below 0.4

Minimum Watershed Size



Conclusion: Habitat Volume Index Values < 0.4 common in watersheds less than 2 km^2. Below this threshold, we cannot confidently expect to encounter fish - set IBI to missing when number of fish is < 10.

Final Metrics

Class of Metric	Metric Name	Description	Responds to:
Tolerance Metrics	NSINTOL4	No. Intolerant Taxa	Chemistry, Channel Habitat, Watershed Condition
	PTOLE	Proportion of Tolerant Taxa	Chemistry, Channel Habitat, Watershed Condition
Count Metrics	NUMFISH	Number of Fish Collected	Nutrients (positive response)
Reproductive Metrics	PGRAVEL	Proportion of Simple Lithophils	Channel Habitat
Habitat Metrics	PCOTTID	Proportion of Cottids	Nutrients, All Habitat measures
	NSBENT23	Number of Benthic Species	Disturbance Classes
	NSCYPR3	Number of Cyprinid Species	Condition Classes
Alien Metrics	PEXOT	Proportion of Introduced Individuals	Introduced Species
Trophic Metrics	PMACRO	Proportion of Macro-omnivores	Nutrients
	PPISCIN2	Proportion of Piscivore/Insectivores	All Habitat measures

Metric Scoring

- All metrics scored on continuous scale, from 0 to 10
- Scoring based on distributions of reference and test site scores in calibration data
- Upper limit (10 set by 50th percentile score in the reference distribution
- Lower limit (0) set by 10th percentile score in the non-reference distribution

IBI Thresholds

How to set thresholds for IBI assessment?

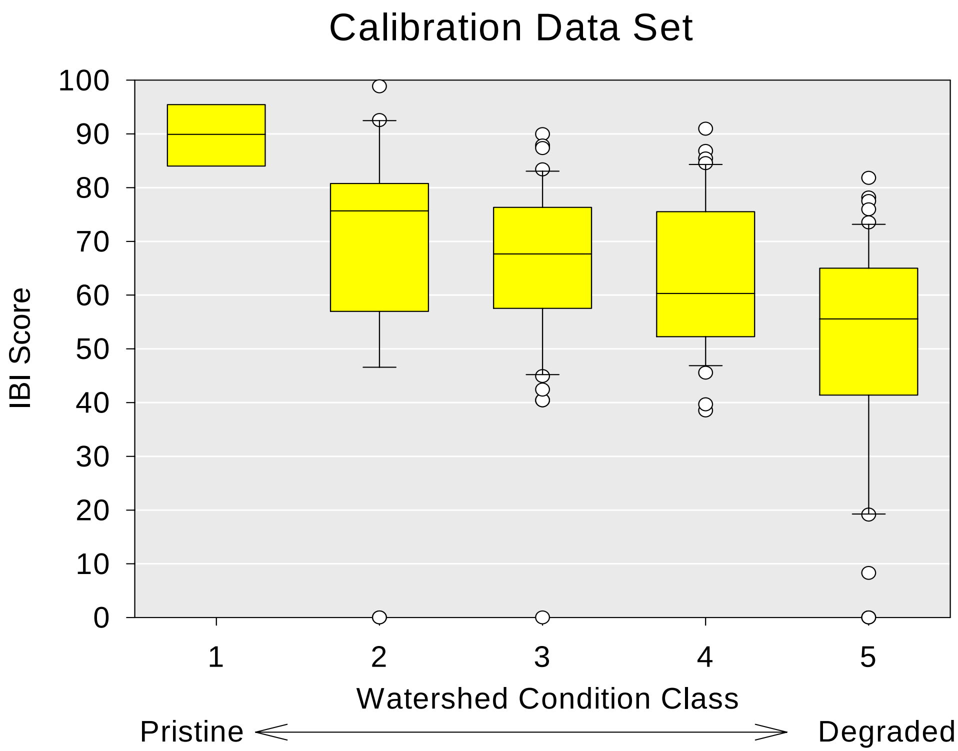
Goal: Use the distribution of IBI scores in reference sites to set thresholds between good, fair and poor IBI scores:

IBI > 25th reference percentile = good
5th < IBI < 25th reference percentile = fair
IBI < 5th reference percentile = poor

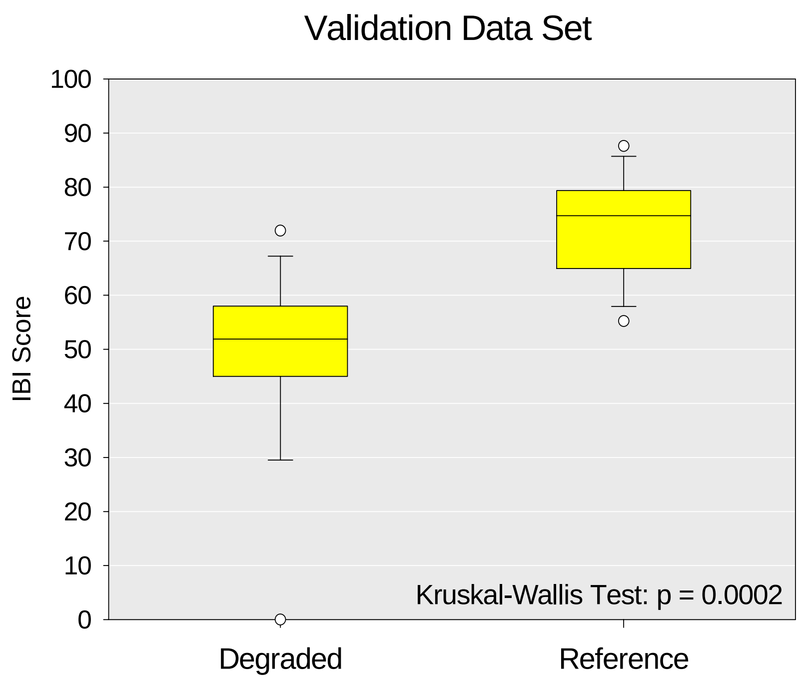
One difficulty: There are multiple ways to define reference, and each gives a different reference distribution:

- least restrictive: based on chemical and RBP habitat filters
  (n = 27, good geographic coverage)
- moderately restrictive: adds quantitative habitat filters
  (n = 23, good geographic coverage)
- most restrictive: adds watershed condition class (1 or 2)
  (n =12, restricted geographic coverage)

Final IBI Responsiveness



Watershed Condition Classes
from Bryce et al., 1999, JAWRA



Using Reference and Test Site "Filters"

IBI Thresholds

How to set thresholds for IBI assessment?

Goal: Use the distribution of IBI scores in reference sites to set thresholds between good, fair and poor IBI scores:

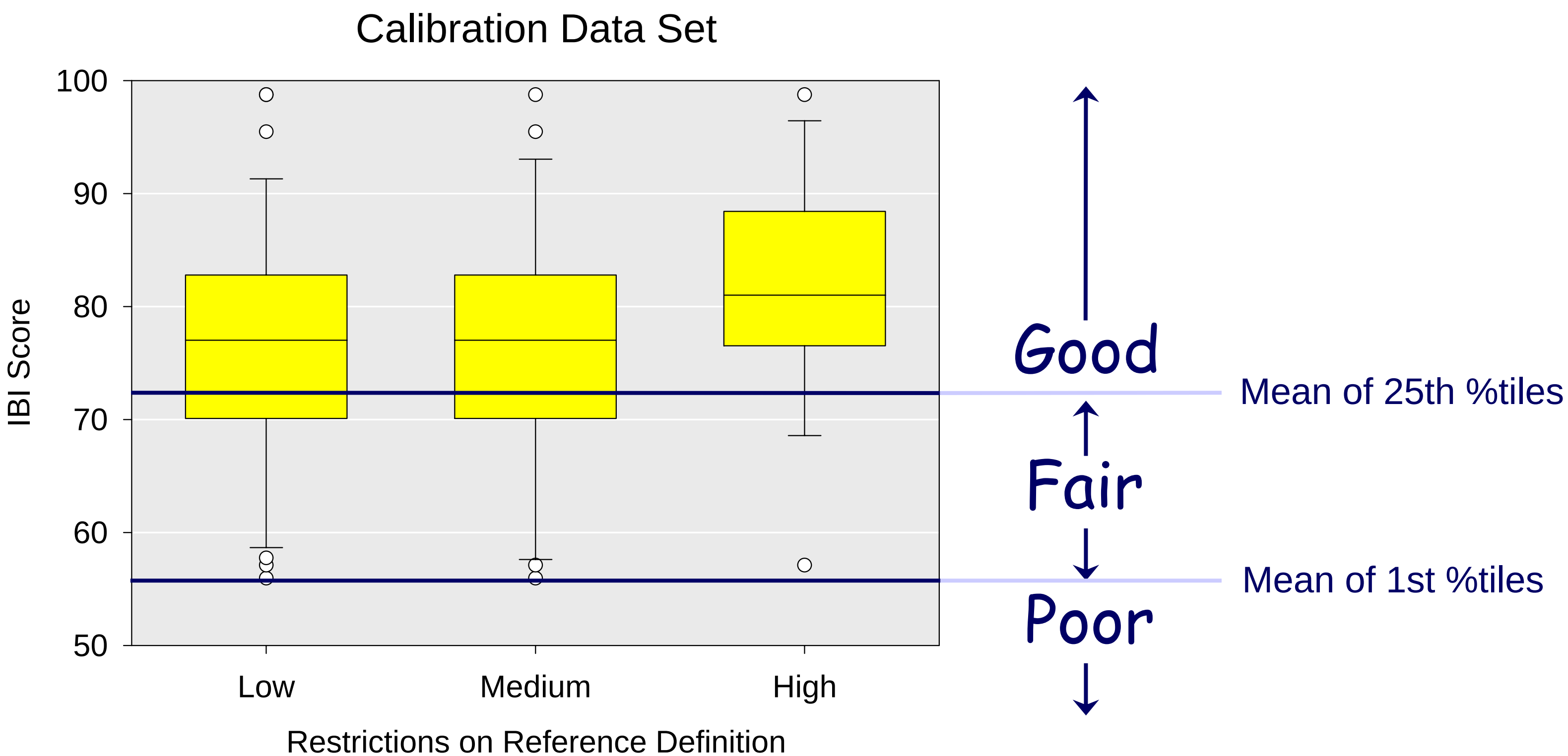
IBI > 25th reference percentile = good
1st < IBI< 25th reference percentile = fair
IBI < 1st reference percentile = poor

One difficulty: There are multiple ways to define reference, and each gives a different reference distribution:

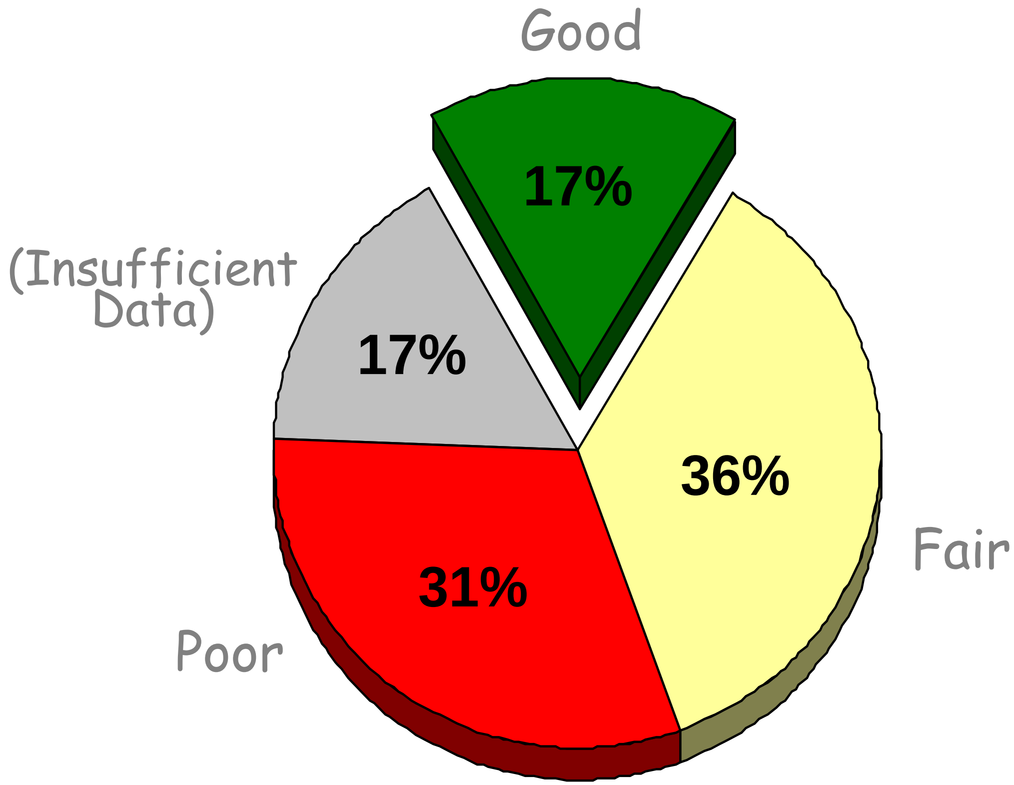
- least restrictive: based on chemical and RBP habitat filters (n = 27, good geographic coverage)
- moderately restrictive: adds quantitative habitat filters (n = 23, good geographic coverage)
- most restrictive: adds watershed condition class (1 or 2) (n =12, restricted geographic coverage)

IBI Thresholds

Solution? Use information from all 3 reference definitions to set thresholds - acknowledge uncertainty involved in any one definition

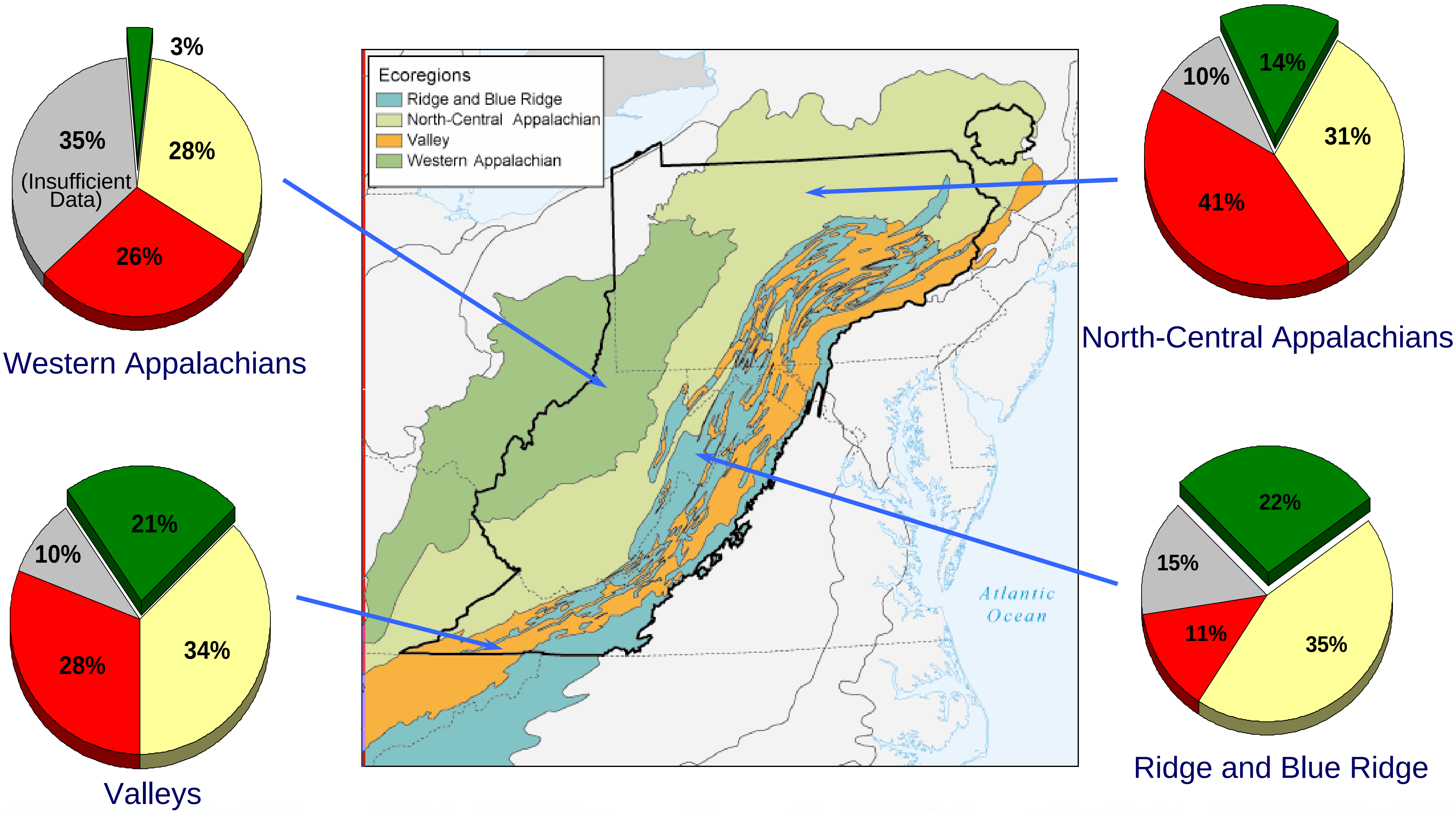


Fish IBI Results



Proportion of Stream Length

IBI Results
Geographic Distribution



Response Design Summary

- Involves entire process from obtaining measurements at a site through calculation of indicators for the site.
- Field plot design has both spatial and temporal dimensions
  - Size of the support for the plot
  - Sampling restricted to index period during the year
- Integrated to provide cost-effective, consistent data when implemented by multiple field crews
- Metrics and Indicators are calculated with respect to the elements of the target population
- Indicators must be calibrated so that their scores have the same meaning for any element in the target population
- Assessment decisions are categorical indicators.