Development of Dual Fish-Indices of Biotic Integrity (IBI) for Connecticut Streams

Yoichiro Kanno and Jason Vokoun
University of Connecticut

Mike Beauchene
Connecticut Department of Environmental Protection

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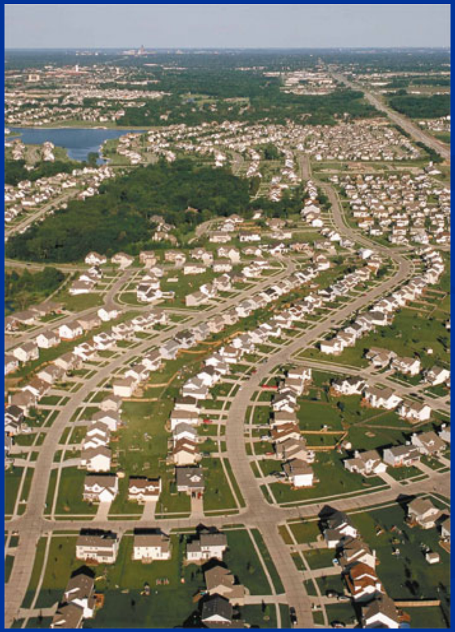
US Clean Water Act

- The objective of the Act is:

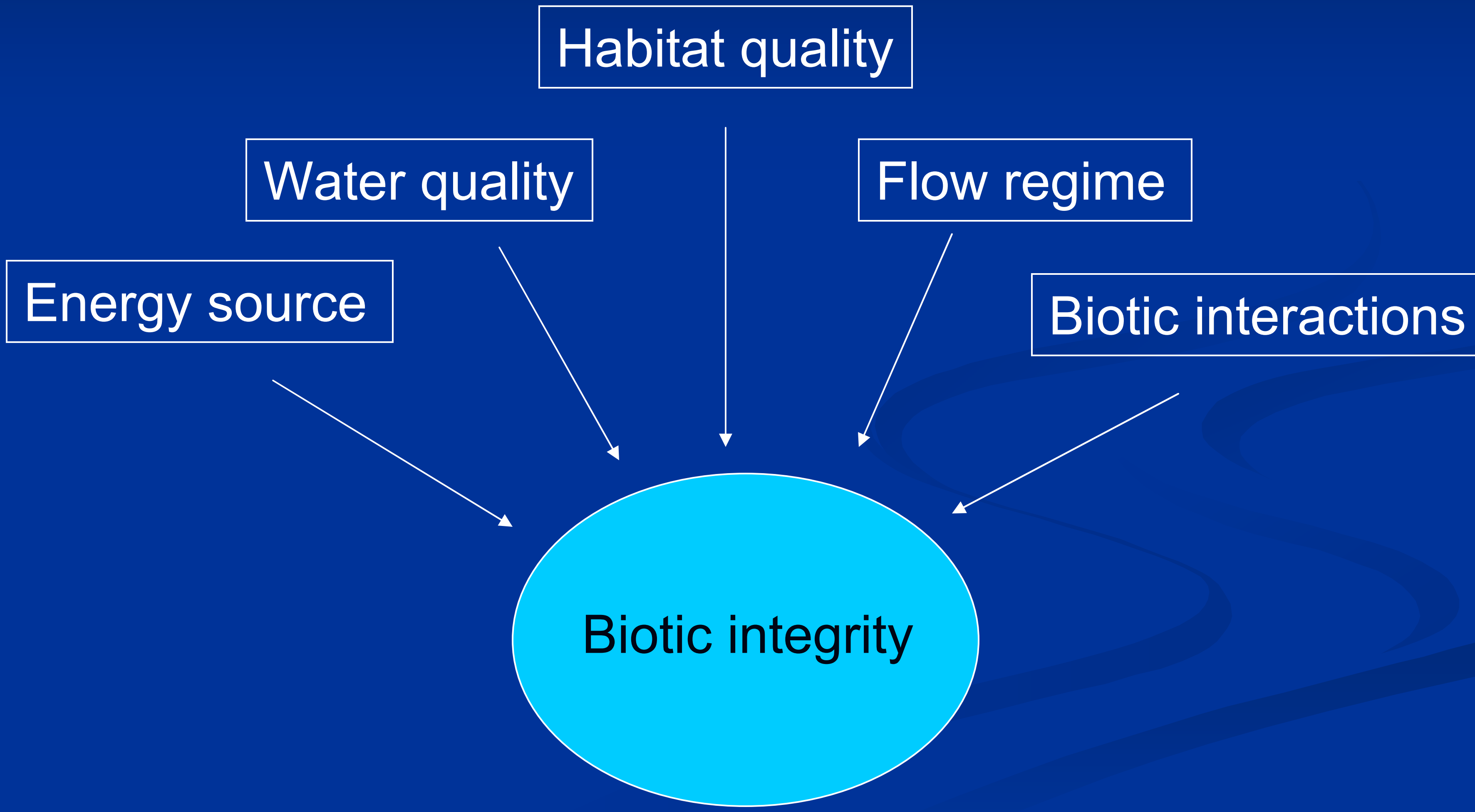
“to restore and maintain the chemical, physical, and **biological integrity** of the nation's waters.”



Fish as indicators of stream environment

- Advantages of using fish;
  - ubiquitous where there is water
  - fish are a diverse group
  - fish ecology is relatively well known
  - fish are relatively easy to identify
  - the general public can relate better

Factors affecting biological integrity
(Karr et al. 1986)



Index of Biotic Integrity (IBI)

Stream environment

- Species richness
- Composition
- Trophic groups
- Abundance

Economy

- GDP
- Unemployment rate
- Housing market
- Trade balance

Human health

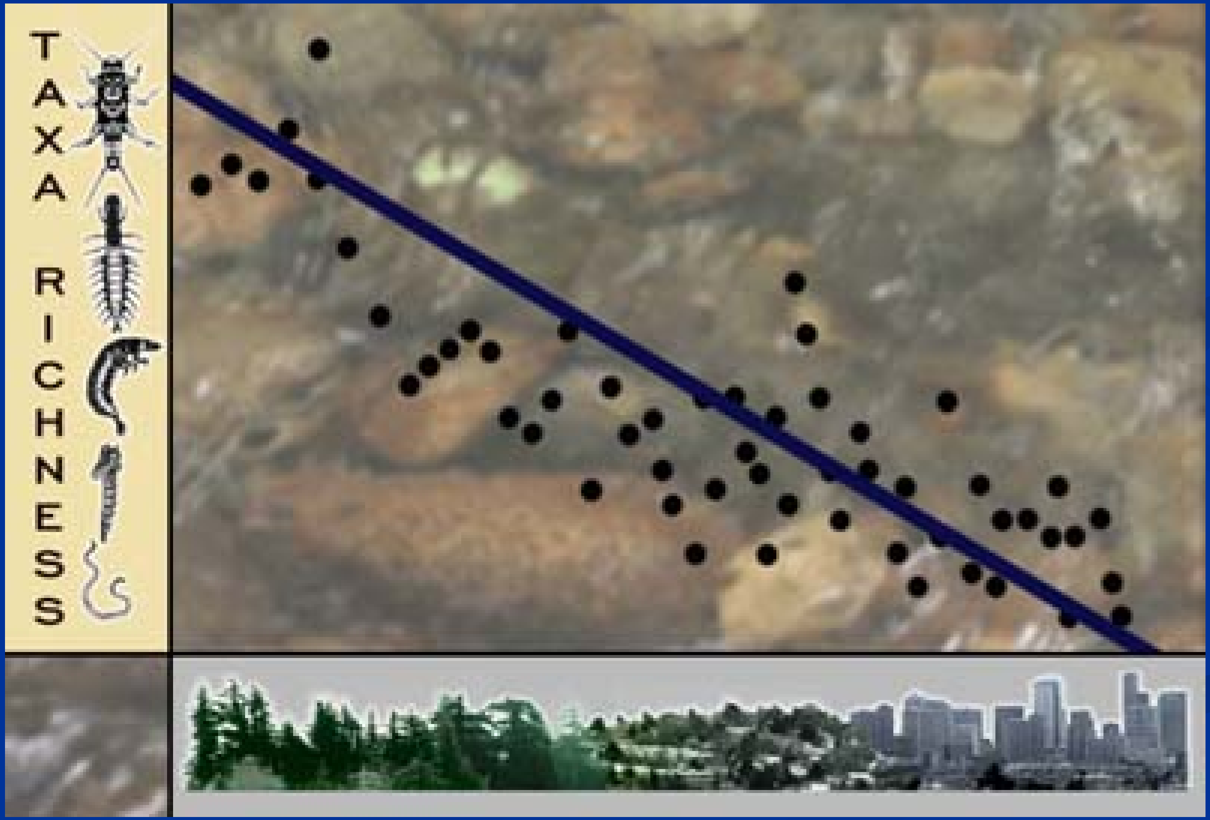
- Cholesterol
- Blood pressure
- Heart rate
- Infection

Challenges of using fish in CT

- Naturally low species richness
- Very few sensitive species
- Extensive management/stocking

Goal: develop an IBI for wadeable streams in CT

1. Quantify human disturbance levels in watersheds
2. Identify fish assemblage attributes which respond to human disturbance levels



Factors shaping today's fish distributions

Natural history

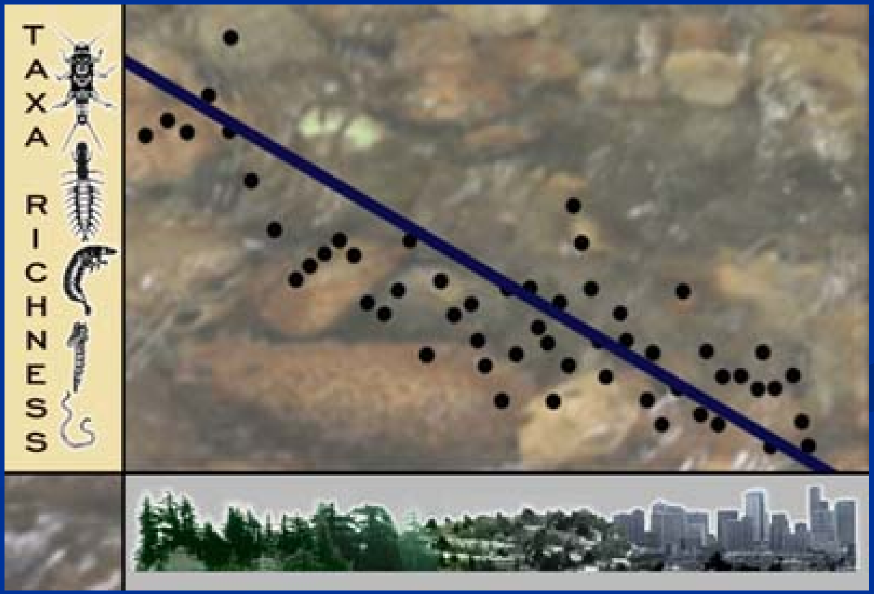
(colonization, climate)

Human impacts

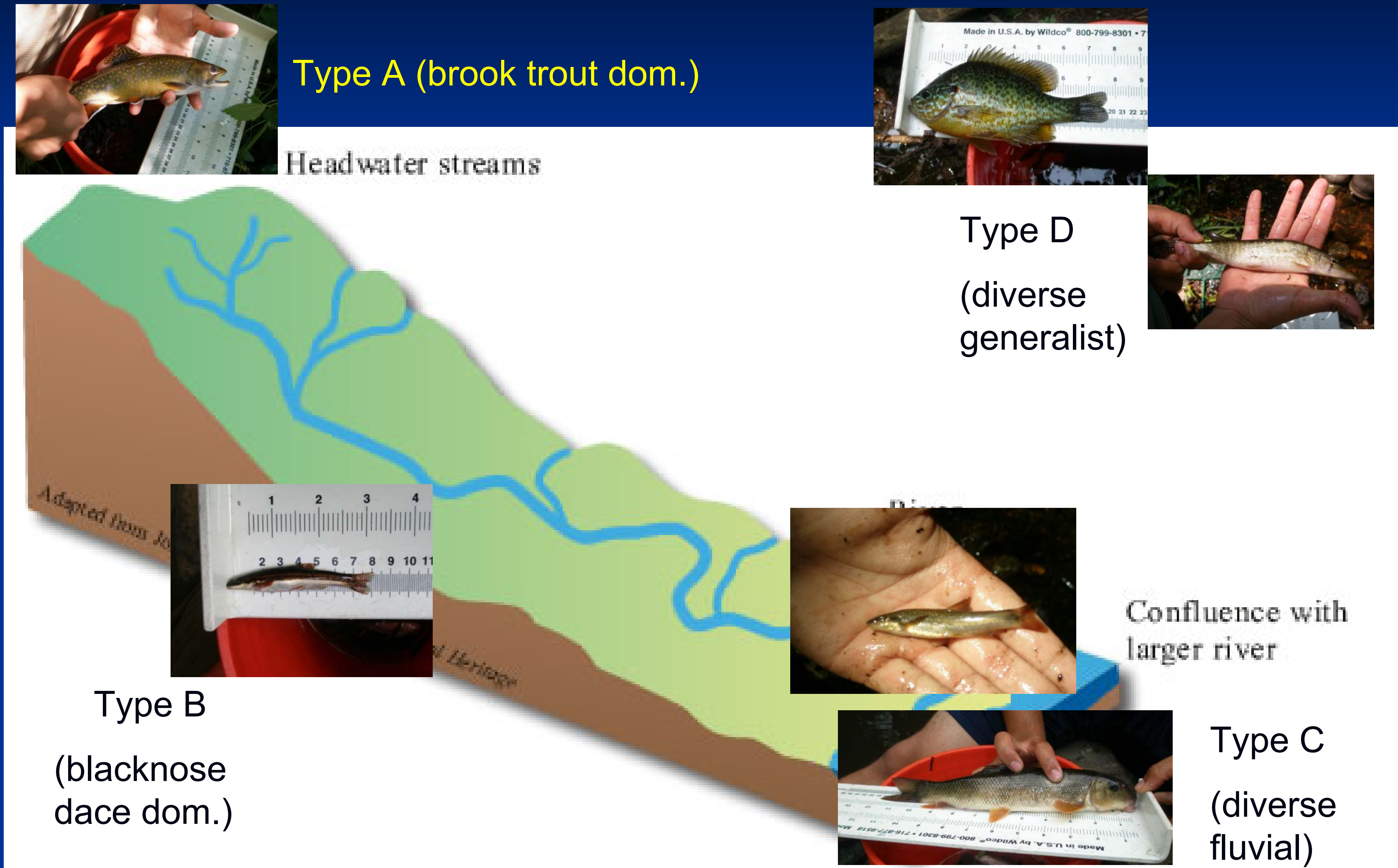
(habitat degradation, species introductions)

Current stream

fish distributions



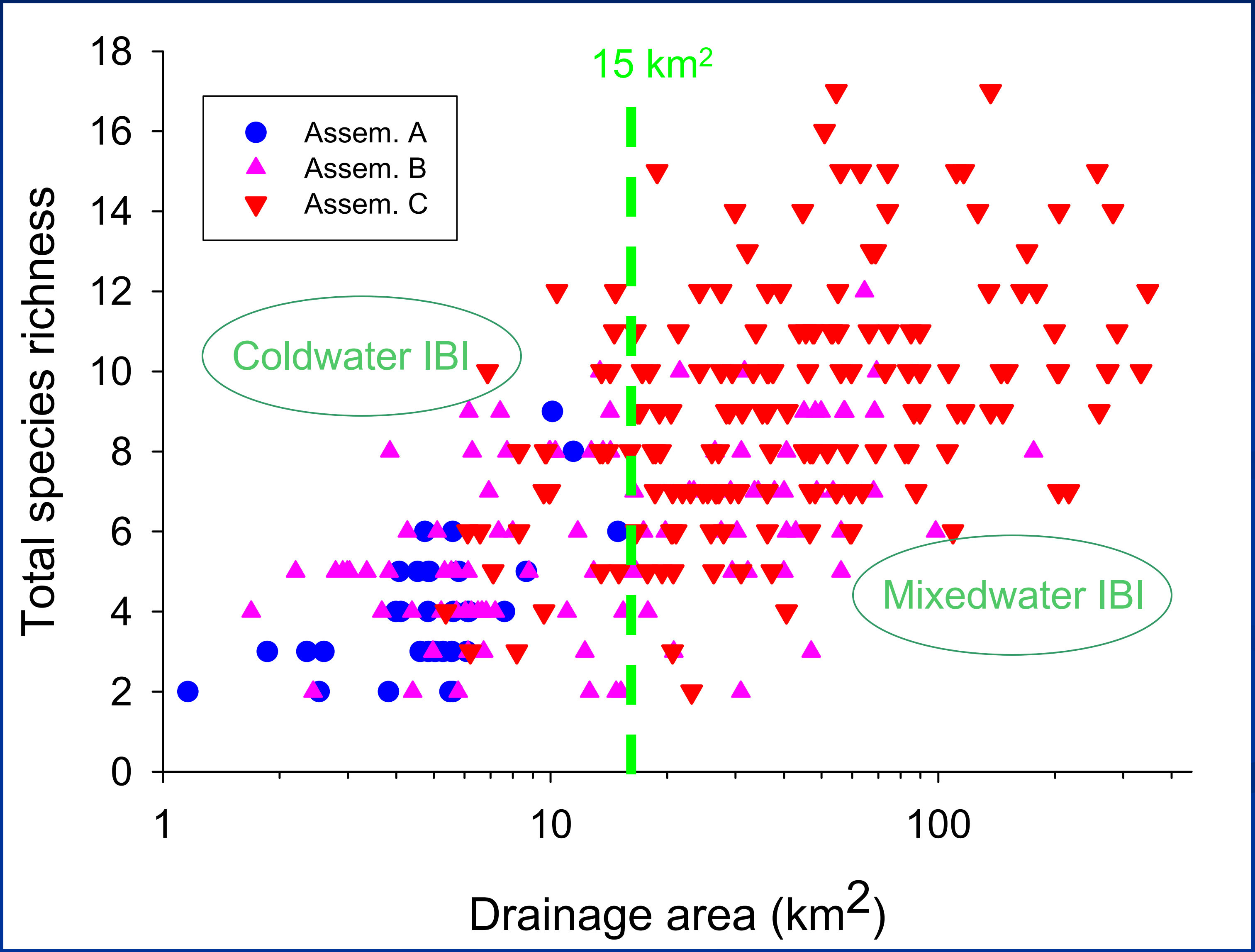
Longitudinal assemblage distributions
(Kanno and Vokoun 2008)



Longitudinal assemblage distributions (Indicator species analysis)

Western faunal region in CT			Eastern faunal region in CT		
Assemblage	**Indicator Species**	**Indicator values %**	**Assemblage**	**Indicator Species**	**Indicator values %**
Type A	Brook trout	72.9	Type A	Brook trout	62.8
Type B_W	Blacknose dace	53.3	Type B_E	Blacknose dace	66.1
	Creek chub	38.5			
Type C_W	White sucker	47.0	Type C_E	Fallfish	54.7
	Longnose dace	38.3		Redbreast sunfish	42.1
	Common shiner	34.5		Tessellated darter	39.1
Type D_W	Pumpkinseed	70.8	Type D_E	Brown bullhead	38.5
	Brown bullhead	40.5		Chain pickerel	33.1
	Golden shiner	36.1		Pumpkinseed	21.6

Longitudinal assemblage distributions

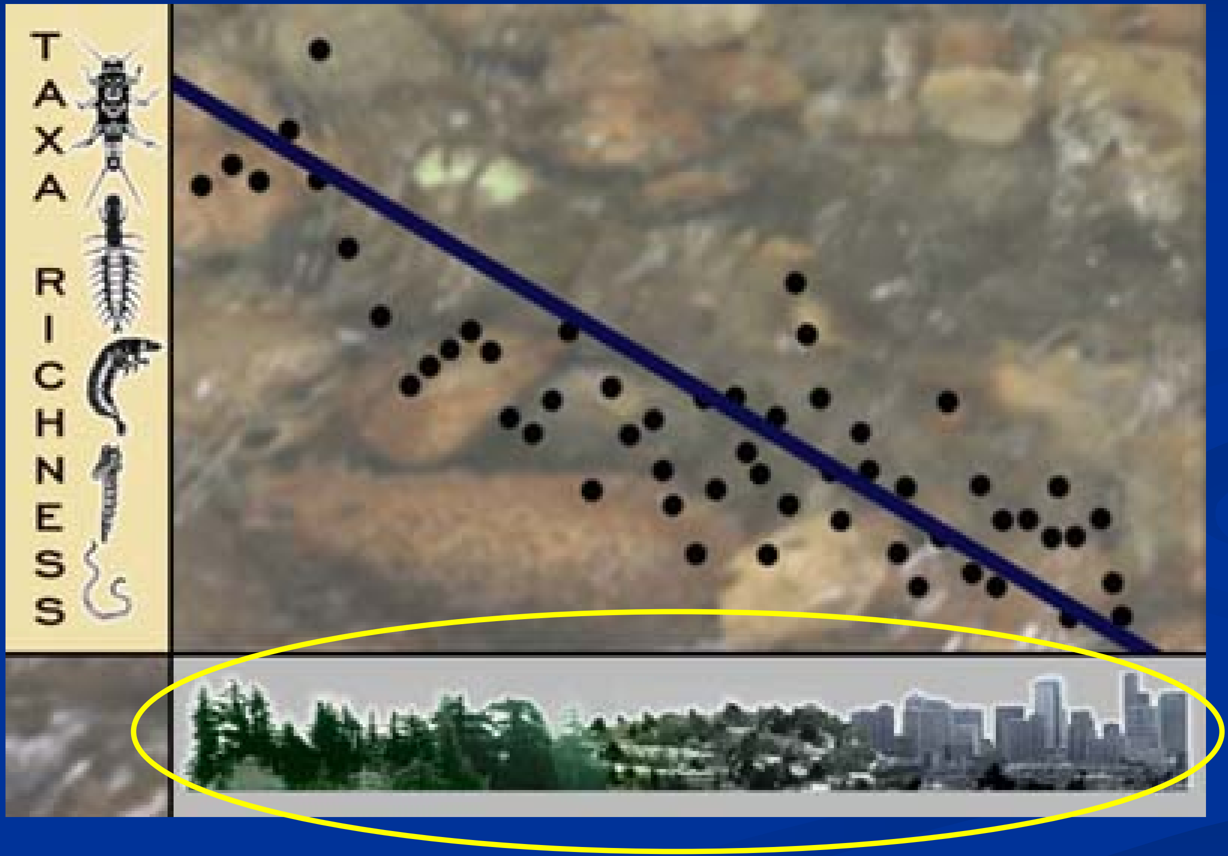


IBI development in CT: Fish data

- DEP electrofishing survey:
  - Mostly 1^{st} to 4^{th} order streams
  - Sampled during summer base flow
  - High to moderate gradient streams

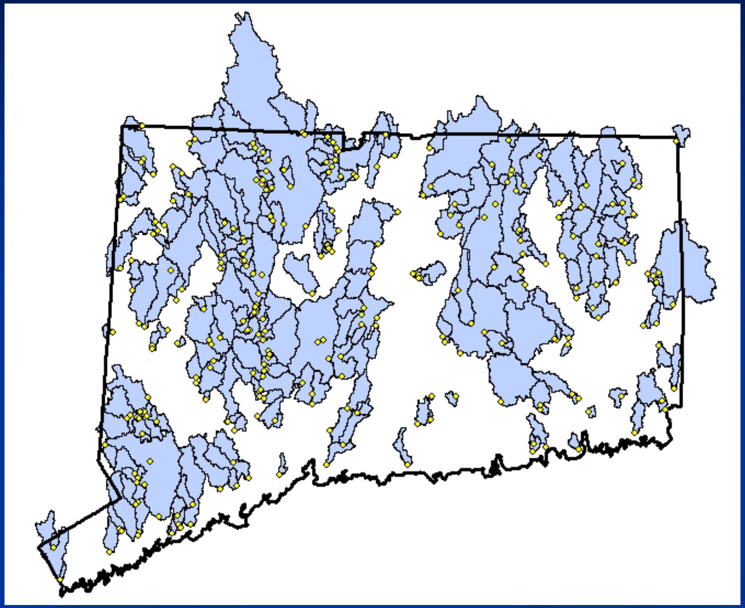
- Data screening:
  - Stocked salmonids deleted
    - Atlantic Salmon, Brook, Brown, Rainbow Trout
  - Stream sites with ≥ 30 fish individuals
  - 348 stream sites (1.16 – 347.20 km^2)

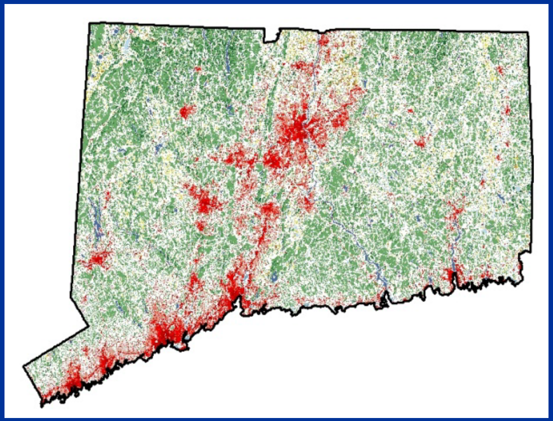
Quantifying human disturbances

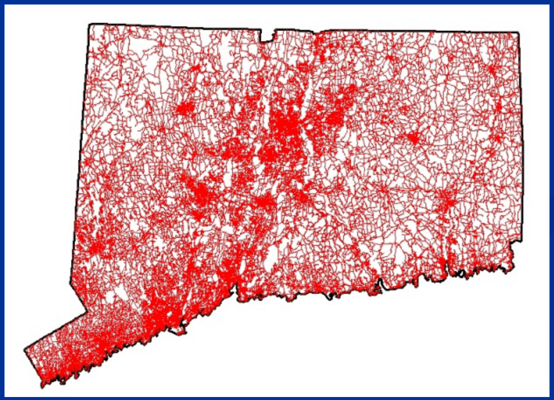


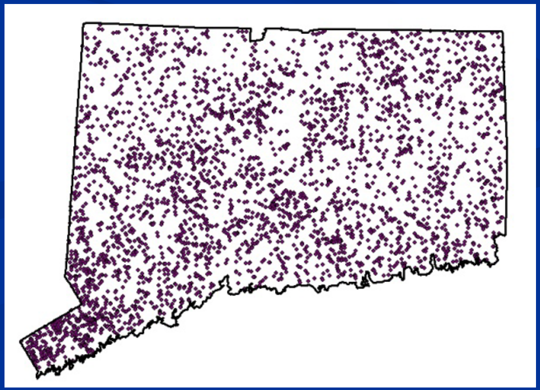
Landscape variables

1. Percent of impervious surface
2. Percent of forested land
3. Road density
4. Road crossing density
5. Population density
6. Dam density
7. Density of known water quality issues (e.g., discharge permits and leachate reports)









Human disturbances at the landscape scale

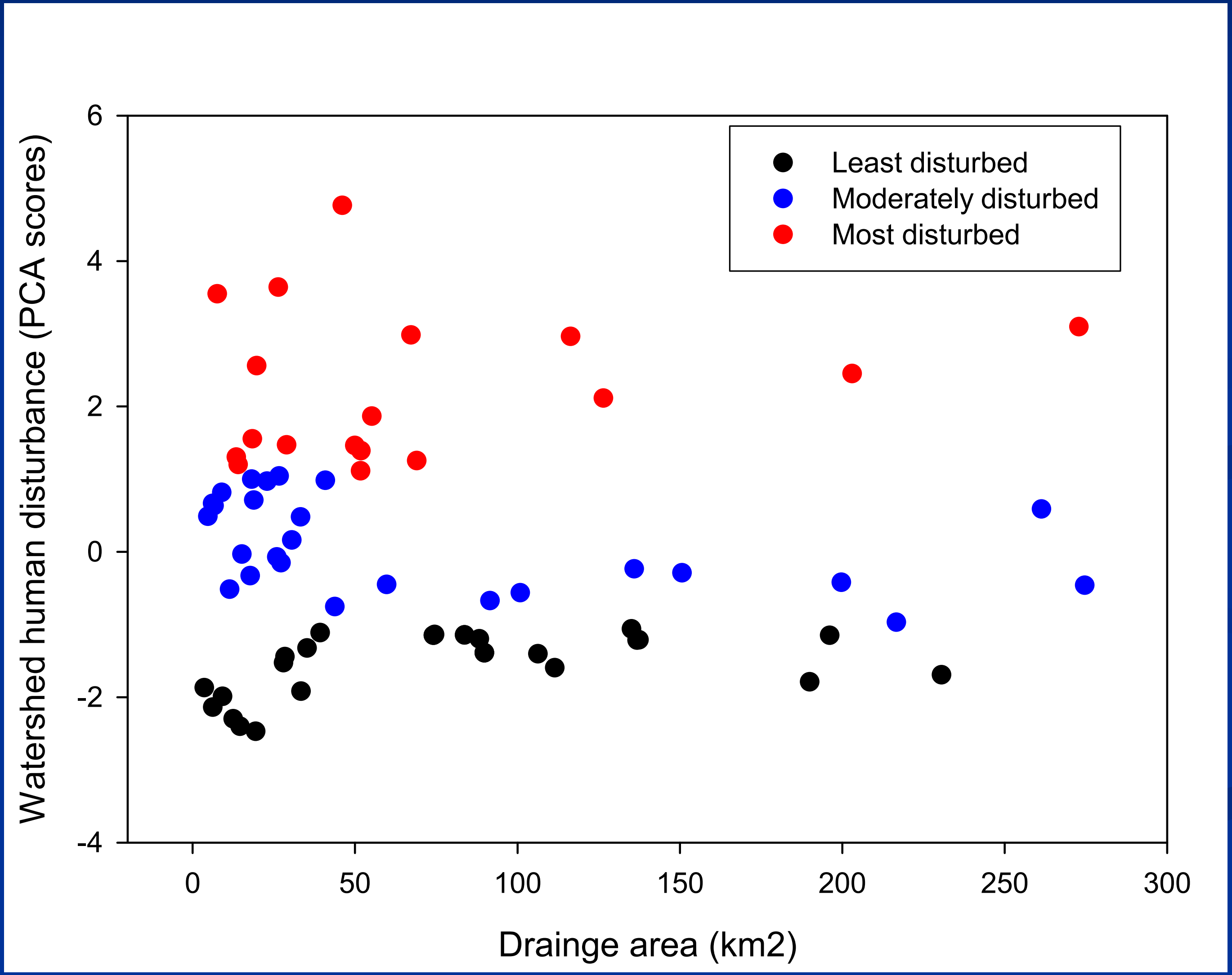
- Principle Component Analysis (PCA) of the 7 landscape variables;

  - Purpose: reduce dimensionality of data

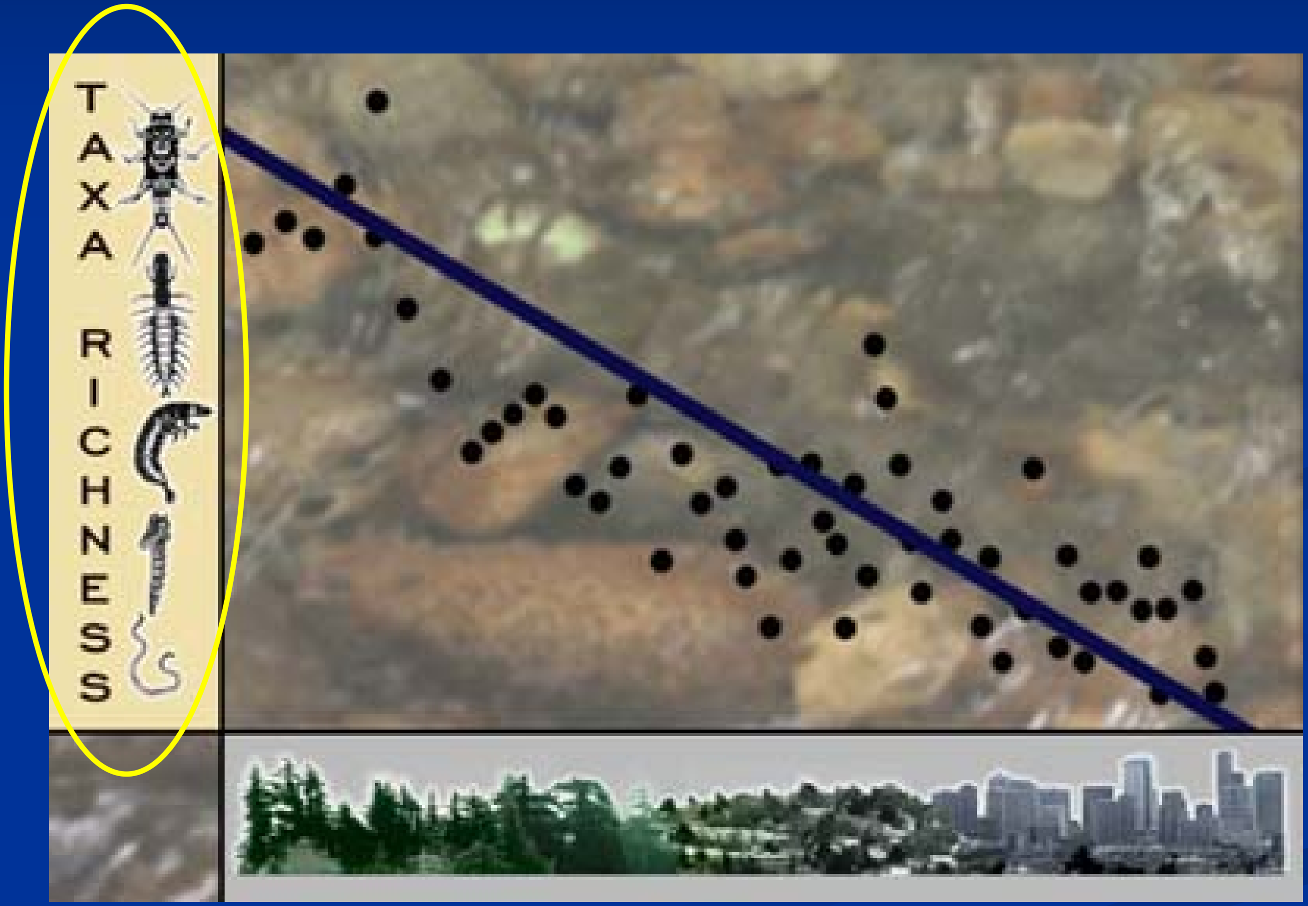
  - Result: Only the first PCA axis statistically significant (Monte Carlo randomization test, *P* = 0.001)

  - Scores of the first PCA axis used to classify stream sites into 3 categories of human disturbances
    1. least-disturbed sites
    2. moderately-disturbed sites
    3. most-disturbed sites

Classifications of streams based on human disturbances



Selecting IBI metrics



Candidate IBI metrics

- # total species
- # native species
- # coldwater species
- # warmwater species
- # tolerant species
- # top carnivore species
- # fluvial specialist species

- % native indiv.
- % coldwater indiv.
- % warmwater indiv.
- % intolerant indiv.
- % general feeder indiv.
- % fluvial dependent indiv.
- % brook trout indiv.

40 candidate metrics for coldwater IBI
55 candidate metrics for mixedwater IBI

Structured approach (Whittier et al 2007)

Grouping metrics by ecological class

- Coldwater IBI
  - taxonomic richness
  - thermal
  - trophic
  - tolerance
  - stream flow
  - non-native
  - indicator species
  - brook trout population

- Mixedwater IBI
  - taxonomic richness
  - thermal
  - trophic
  - tolerance
  - stream flow
  - non-native
  - indicator species
  - composition

Structured approach (Whittier et al. 2007)

- Select single best metric from each ecological class

- 5 sequential steps
    1. Range
    2. Signal-to-noise (within-year-precision)
    3. Correlation with stream size
    4. Responsiveness to human disturbances
    5. Redundancy

Step 1: Range test

- Metrics with small ranges have a low discriminatory power;

  - Failed if:
    (1) > 70% sites were 0.
    (2) taxonomic richness metrics with <= 3 spp.

  - Results
    (1) 3 metrics failed for coldwater IBI
    (2) 4 metrics failed for mixedwater IBI

Step 2: Signal to Noise ratio test

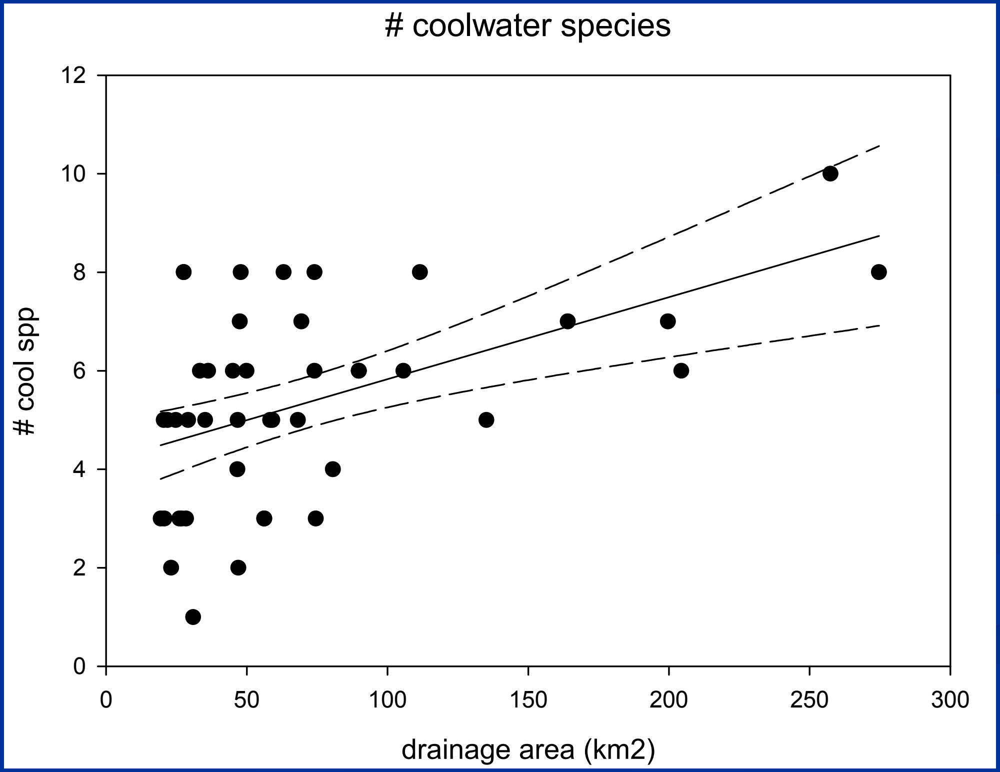
- Good metrics possess repeatability of results;
  signal: among-stream variability
  noise: temporal variability at the same streams

- Failed if S:N ratio < 2

- Results (applied only in mixedwater IBI)
  4 metrics failed for mixedwater IBI

Step 3: Correlation with stream size

- Stream size greatly influences fish assemblages;
  - used only least-disturbed streams
  - regression between each metric and drainage area
  - used regression residuals as corrected metrics



Step 3: Correlation with stream size

- Results

  (1) 6 metrics corrected in coldwater IBI

  (2) 10 metrics corrected in mixedwater IBI

  (mostly taxonomic richness metrics)

Step 4: Responsiveness test

- Good metrics respond to human disturbances;
  - ANOVA between least- and most-disturbed sites
  - Selected one metric from each ecological class with the highest F-scores

5. Redundancy test

- Redundant metrics add little new information;

  - calculated correlation matrices of all metrics

  - two metrics were considered redundant if $r > 0.70$;
    the metric with the higher F-value retained;
    the other metric replaced with the next best
    metric from its class

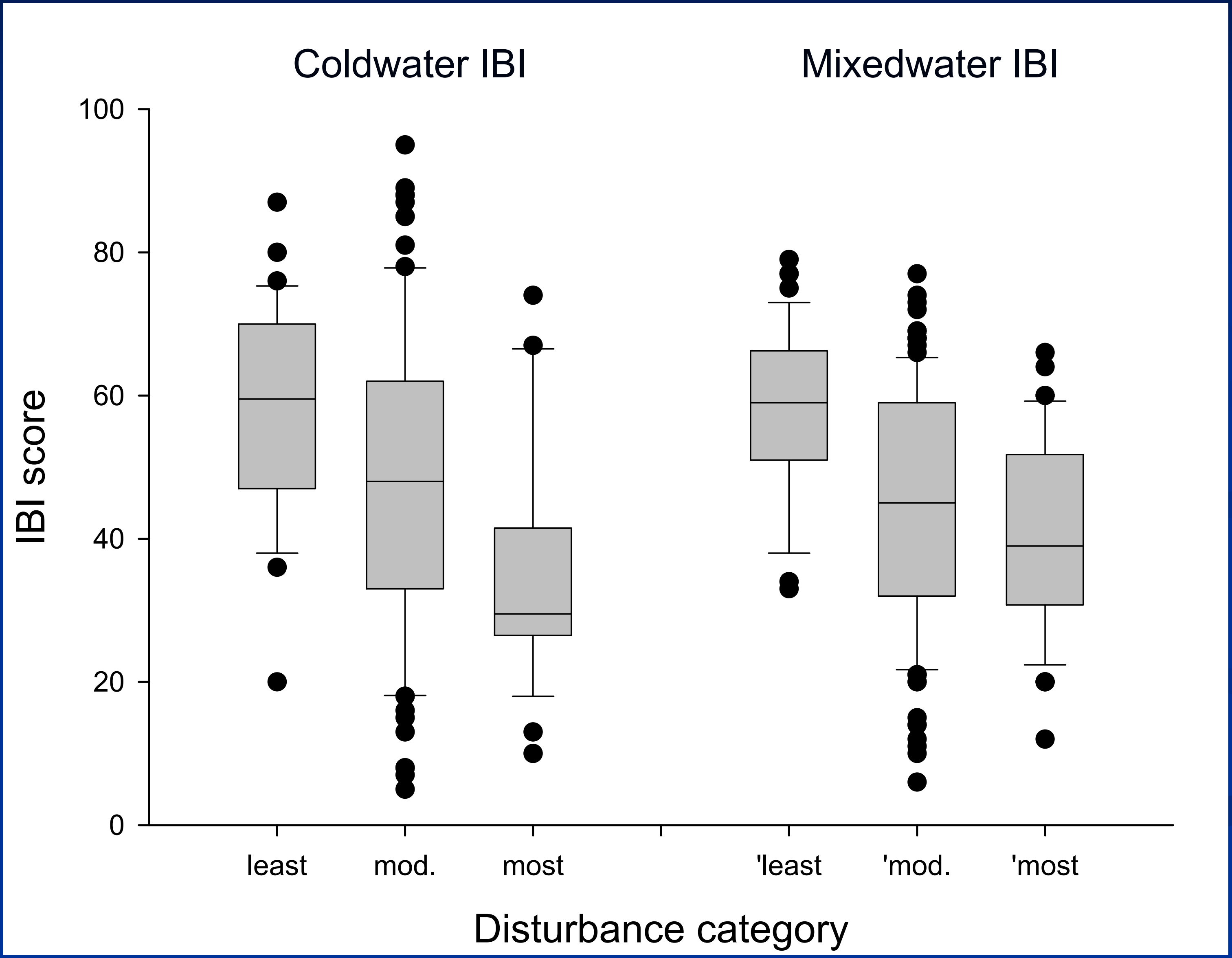
Result: Mixedwater IBI

Metrics	Ecological class	Increase or decrease with degradation?
% white sucker indiv.	Indicator species	Increase
% Cyprinidae indiv.	Composition	Decrease
% fluvial specialist indiv., except blacknose dace	Stream flow	Decrease
% non-tolerant general feeder indiv.	Trophic	Decrease
% native warmwater indiv.	Thermal	Increase
% intolerant indiv.	Tolerance	Decrease
# fluvial specialist spp.	Taxonomic richness	Decrease

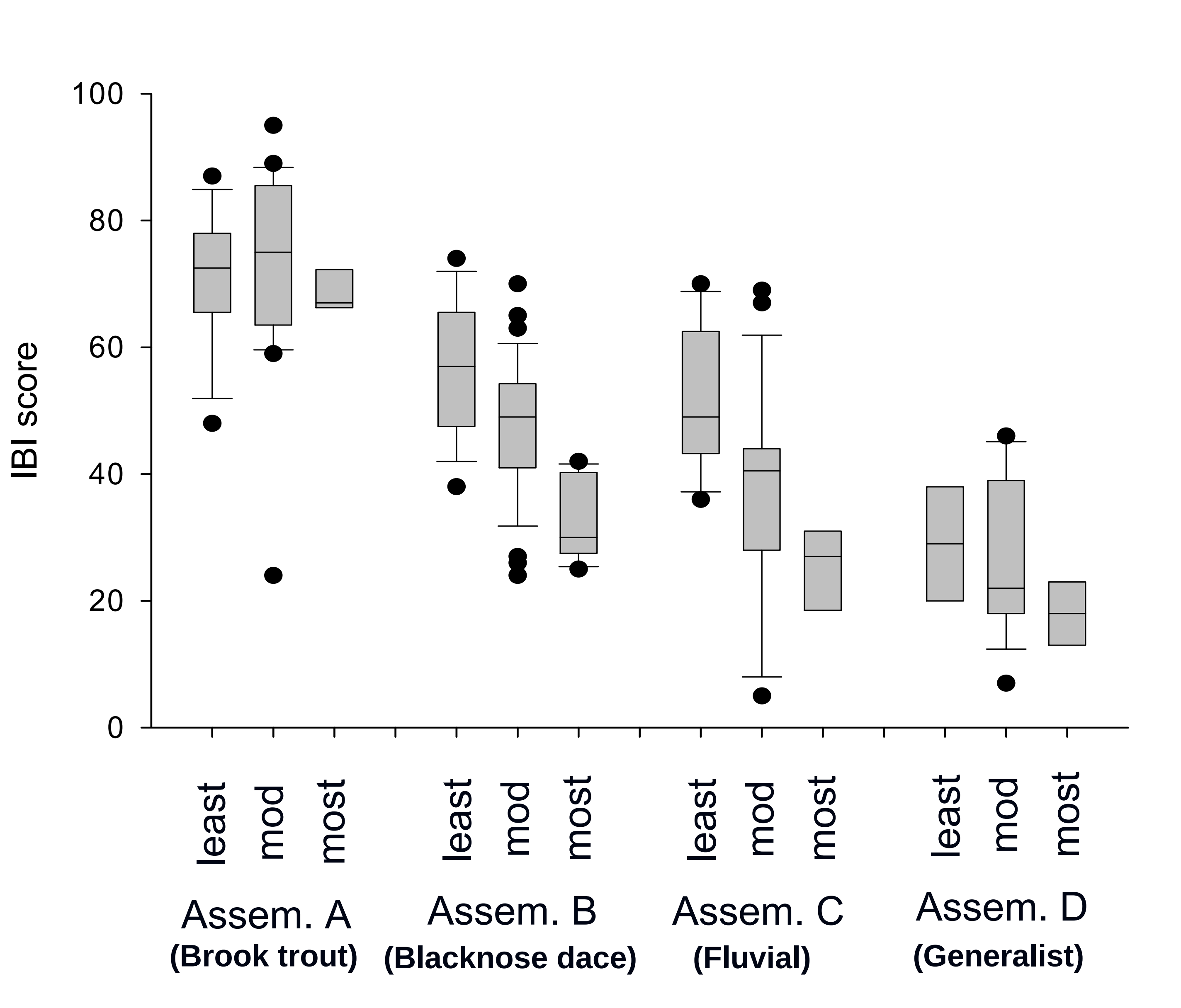
Result: Coldwater IBI

Metrics	Ecological class	Increase or decrease with degradation?
# brook trout indiv. per $100m^2$	Brook trout population	Decrease
% fluvial dependent indiv.	Stream flow	Increase
# warmwater species (stream size corrected)	Taxonomic richness	Increase
% warmwater indiv.	Thermal	Increase
% brook trout indiv.	Indicator species	Decrease

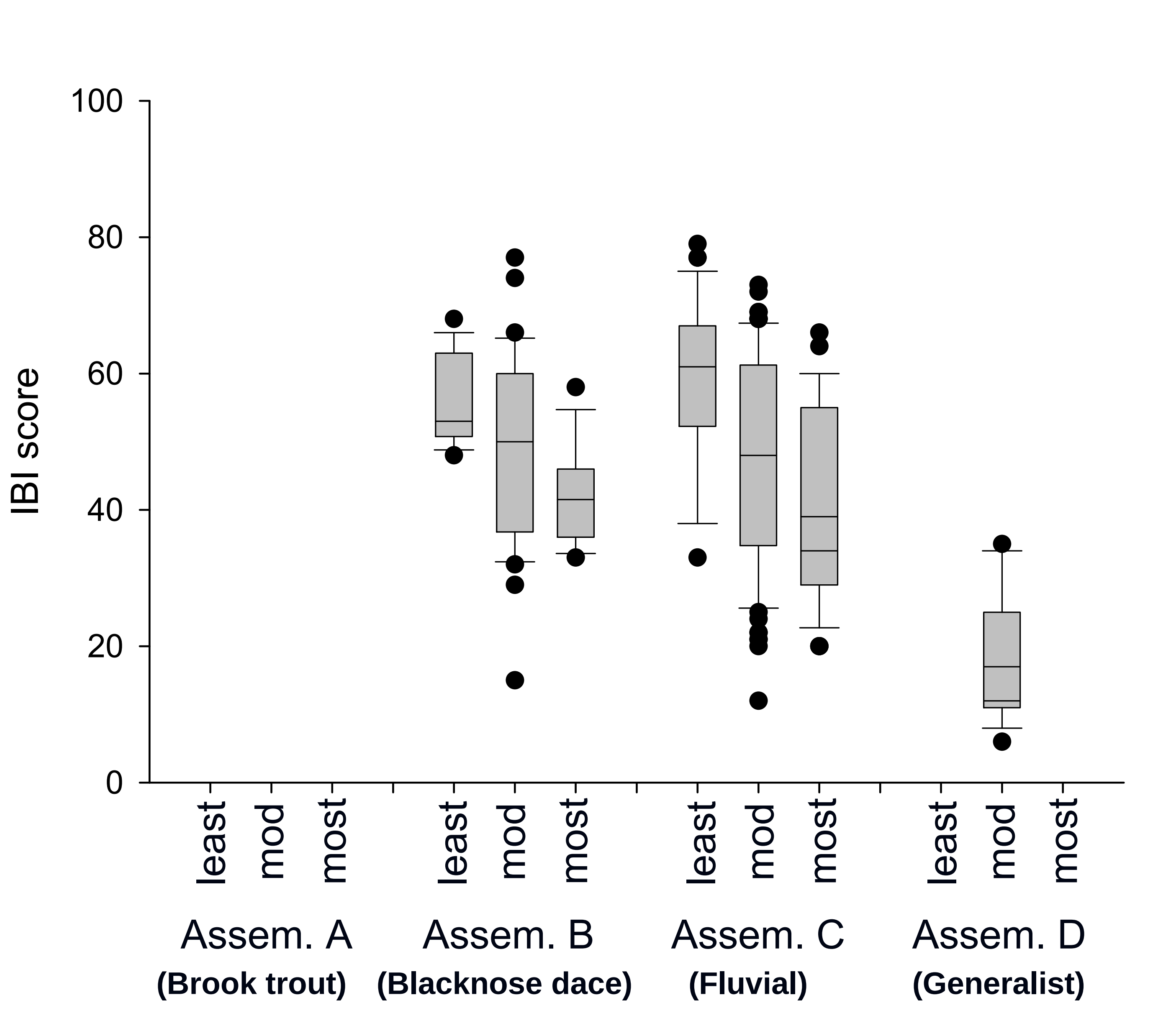
IBI scores across disturbance categories



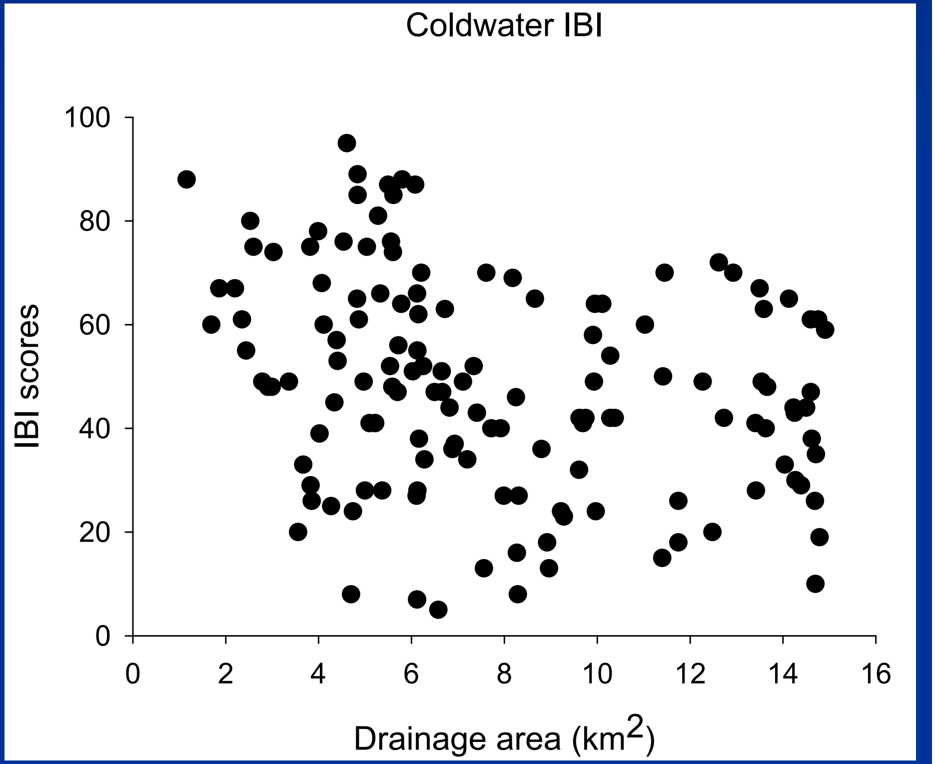
Coldwater IBI and assemblage types

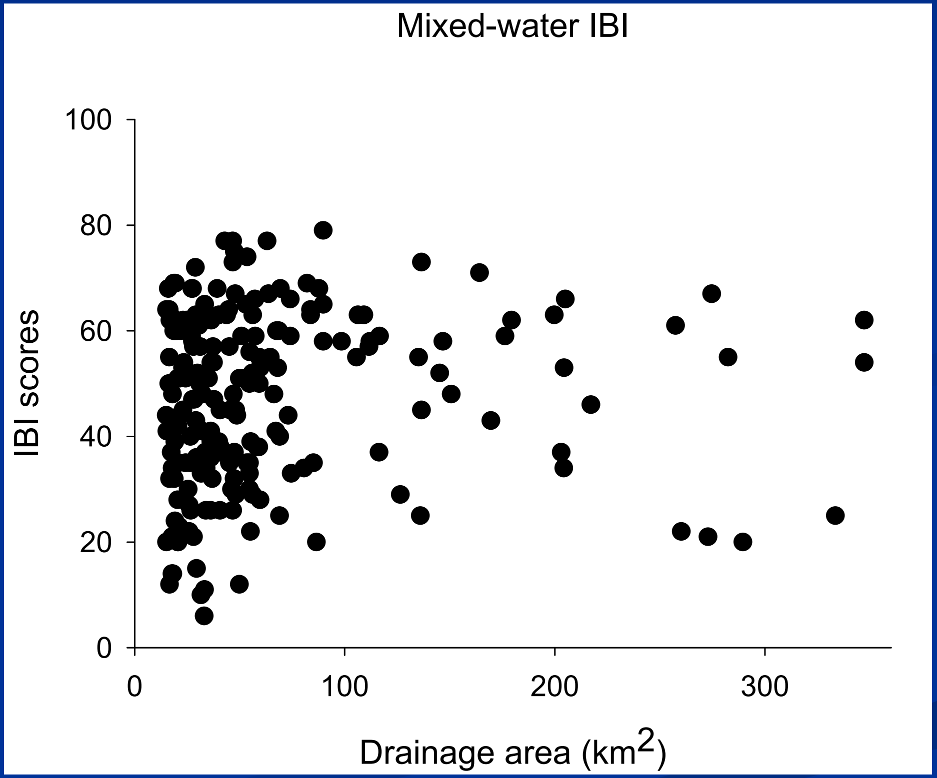


Mixedwater IBI and assemblage types

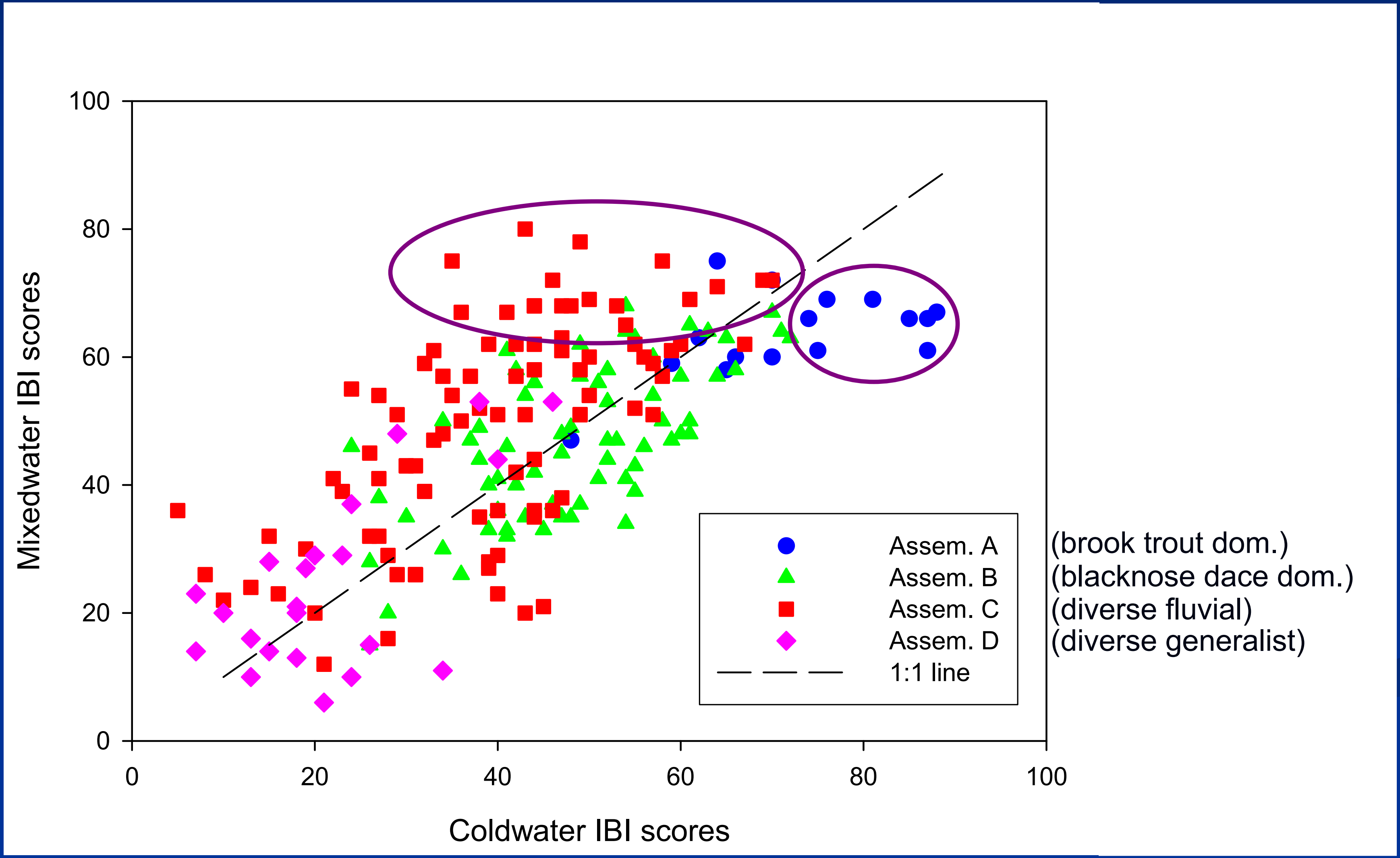


IBI scores and stream size





Application of both IBIs to transitional sites (5 – 40 km²)



Conclusions

- IBIs in Connecticut
  - dual IBIs to account for natural variability
  - structured approach useful
  - state-wide application: Clean Water Act
  - transitional streams: which IBI is more appropriate?

Acknowledgments

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Questions?