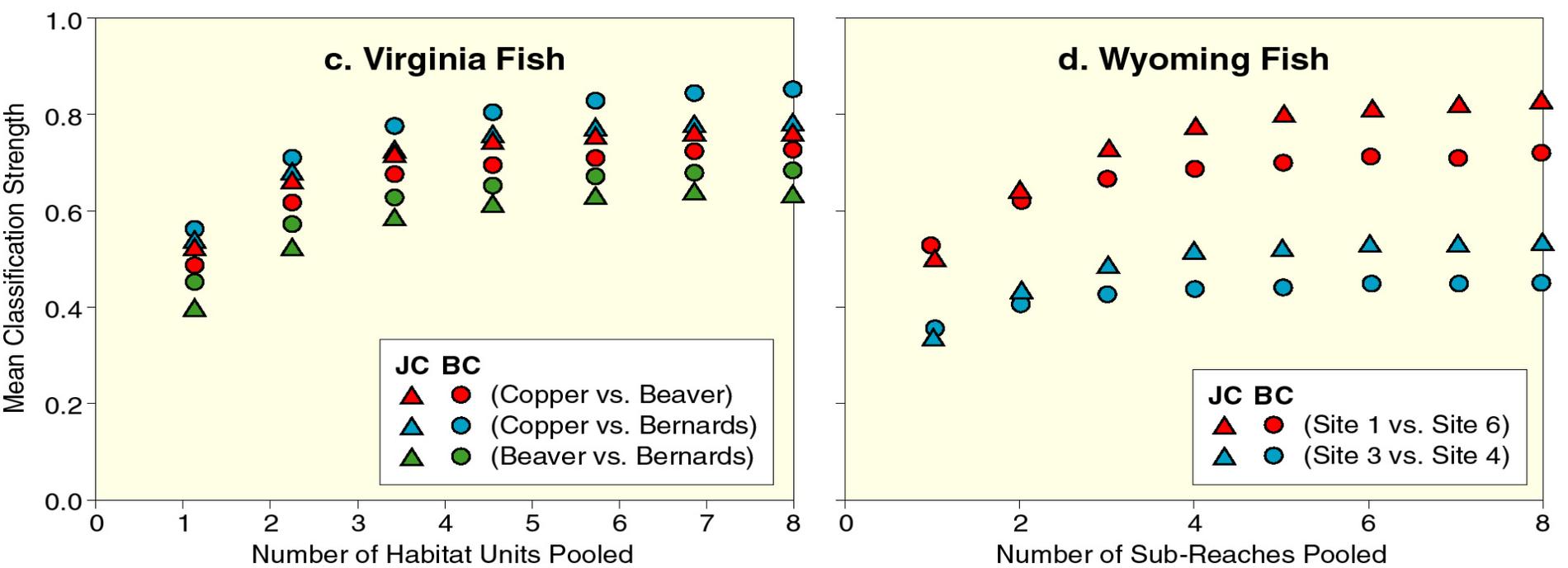
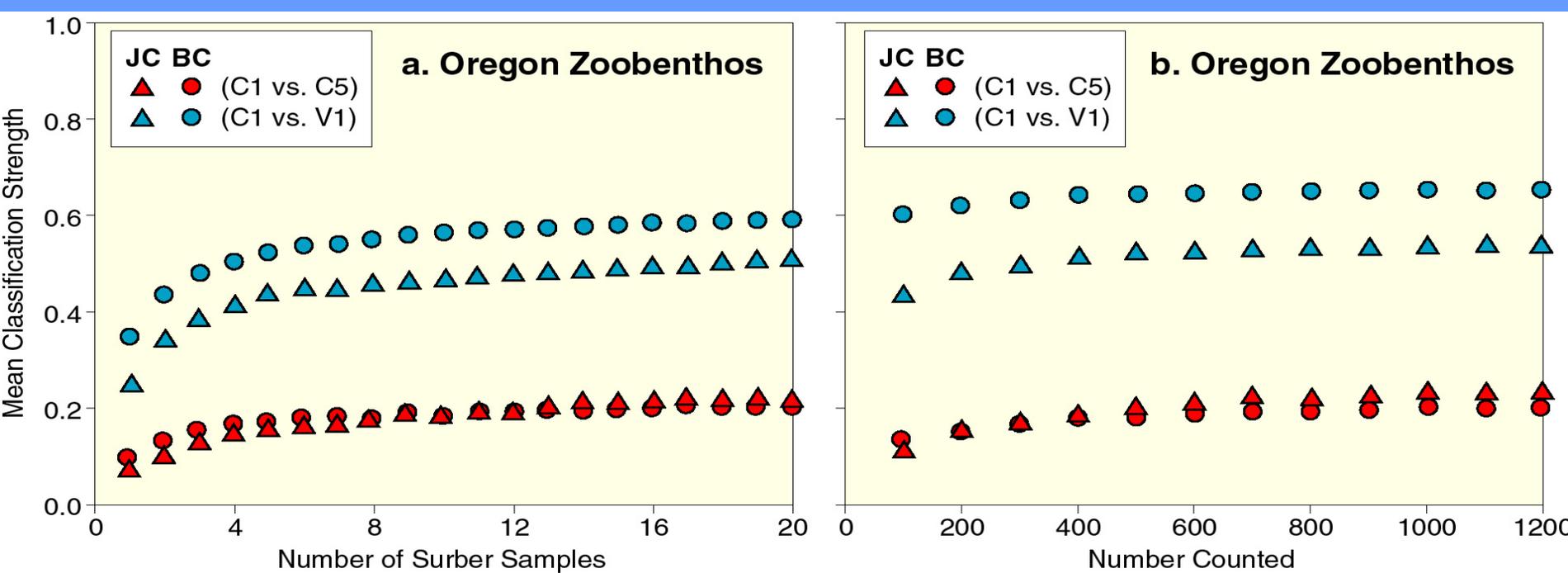
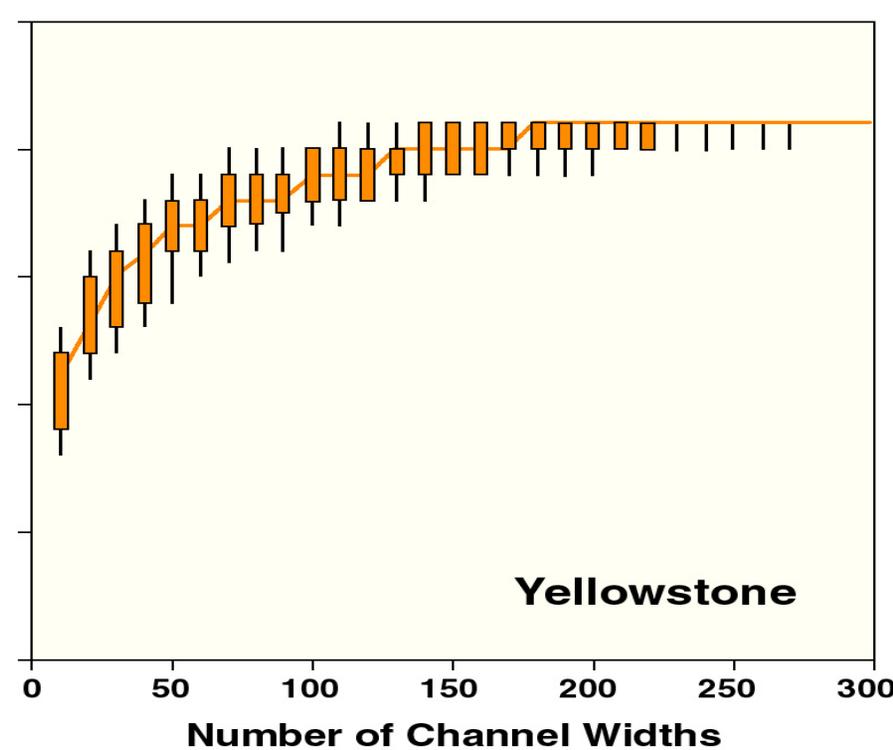
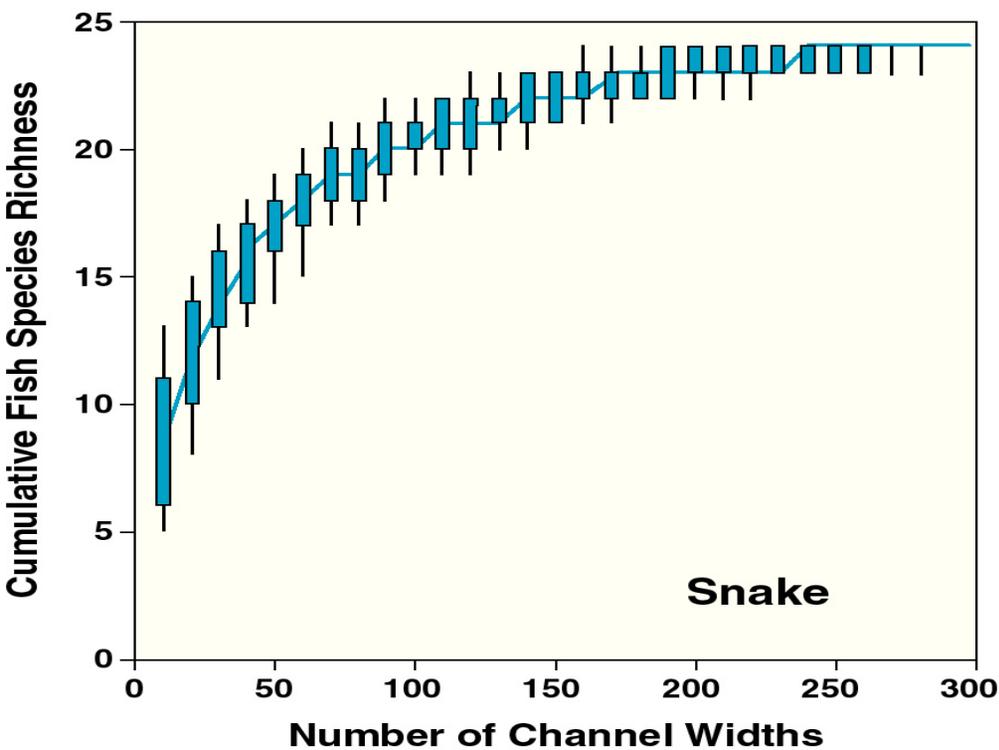
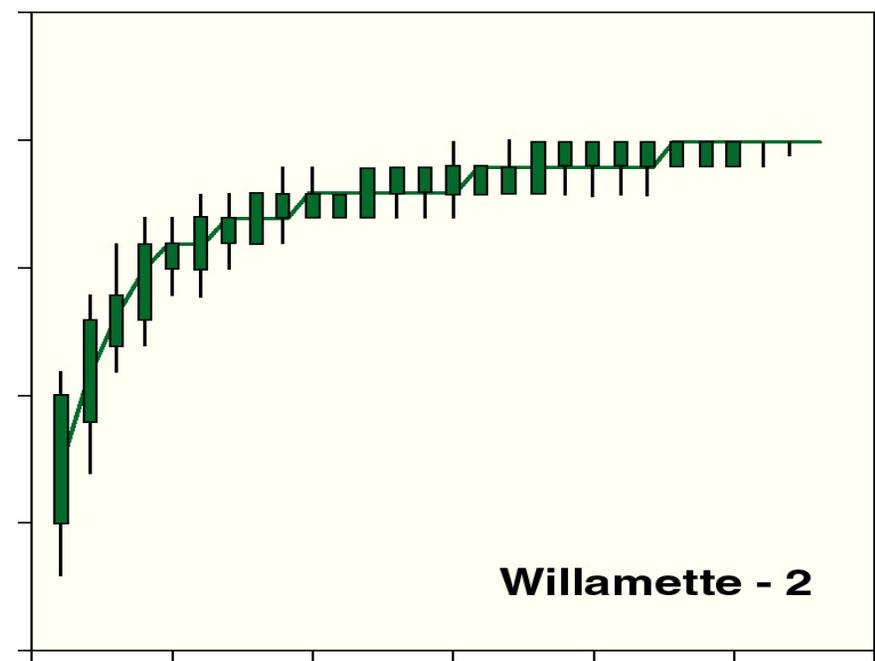
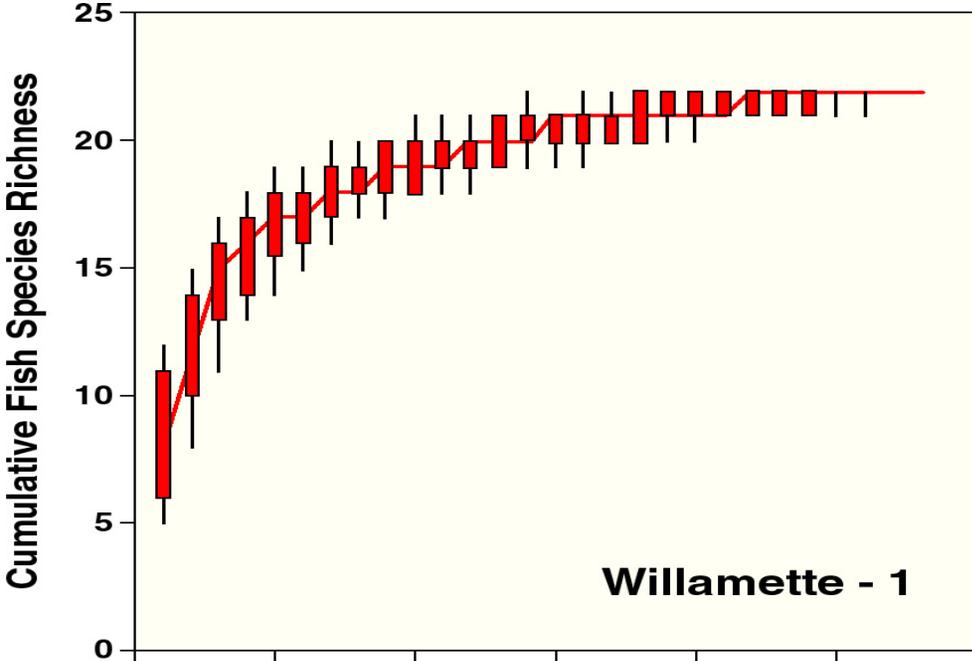


Assessing ecological condition in USA surface waters: EMAP's approach for fish assemblages







Karr's Original IBI Concept

- Species richness & composition
- Trophic composition
- Tolerance & sensitive composition
- Abundance & Anomalies
- No metric evaluation
- Metrics scored 1, 3, 5
- IBI scored 12-60

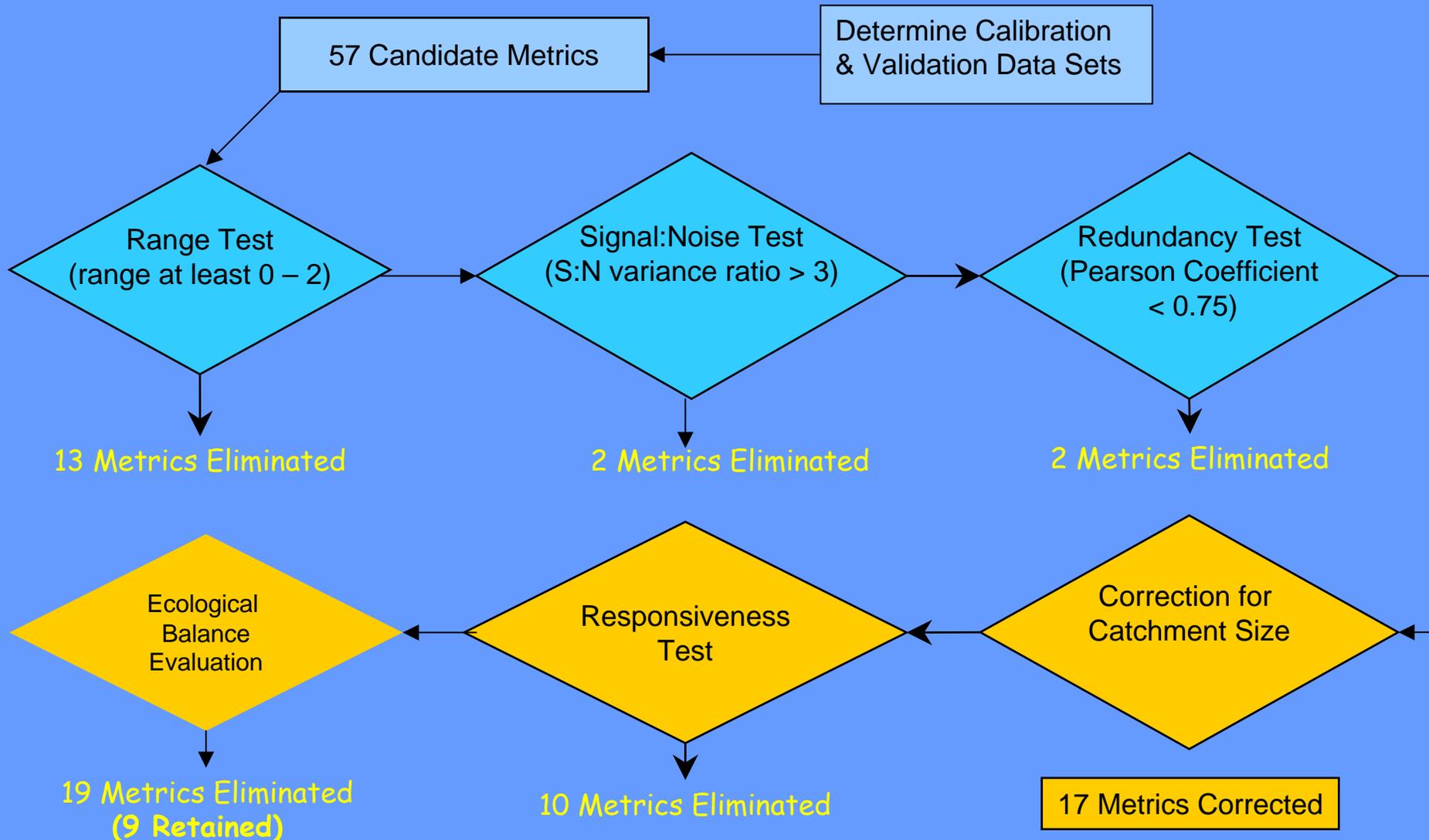
EMAP Adjustments to IBI

- Habitat guilds
- Reproductive guilds
- Life history guilds
- Aliens
- Size classes
- Rigorous metric evaluation
- Metric scoring based on reference sites
- Metrics scored 0-10; IBI scored 0-100
- Applied to fish, birds, benthos & algae

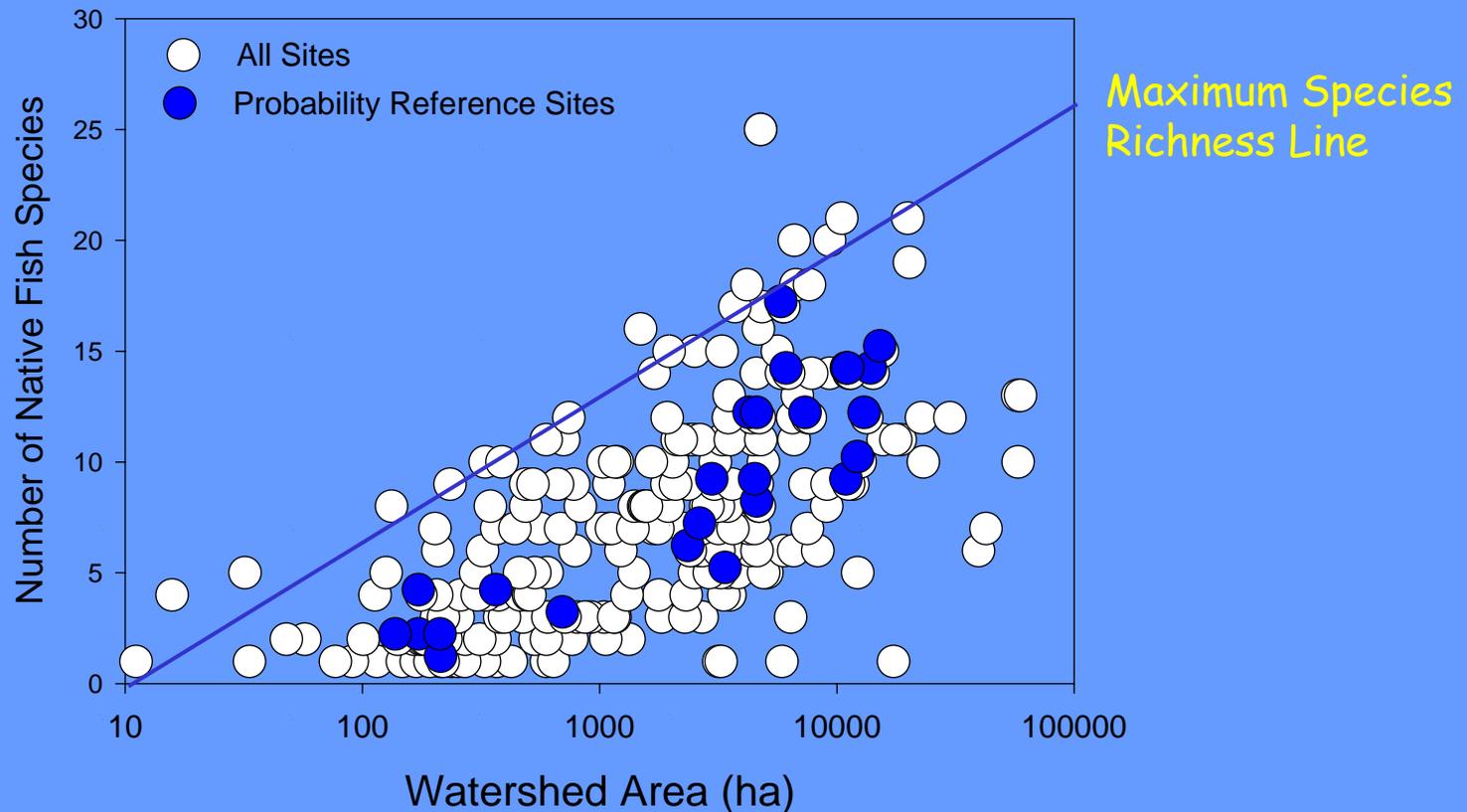
Metrics in USEPA's Tiered Aquatic Life Uses

- Sensitive, long-lived, endemic species
- Sensitive, rare taxa
- Sensitive, ubiquitous taxa
- Taxa of intermediate tolerance
- Tolerant taxa
- Alien species
- Proportion of individuals with anomalies
- Migratory species
- Ecosystem function
- Extent & duration of detrimental effects
- Ecosystem connectance

Fish IBI Development Approach

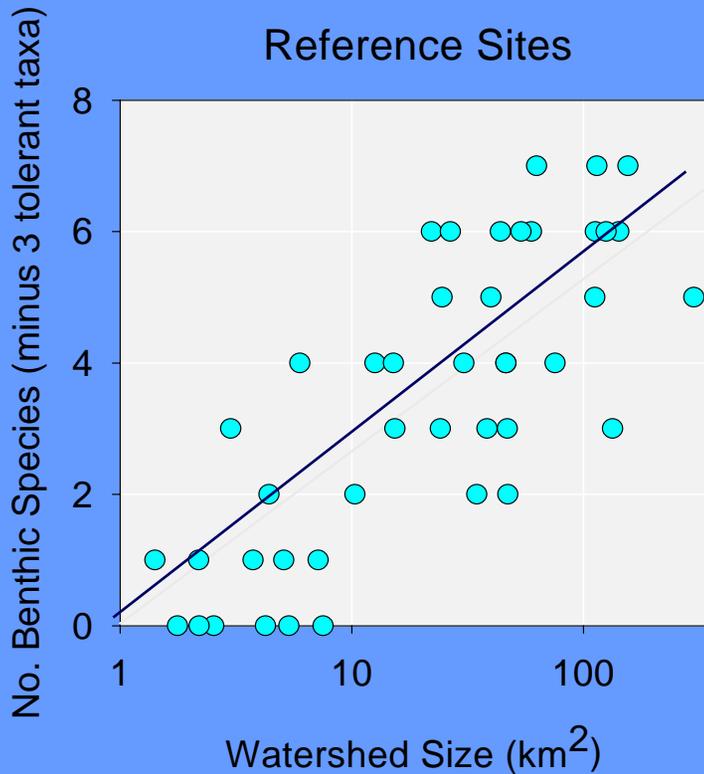


The Problem with Maximum Species Richness Lines (subsidy-stress gradient effect on species richness)



Watershed Correction

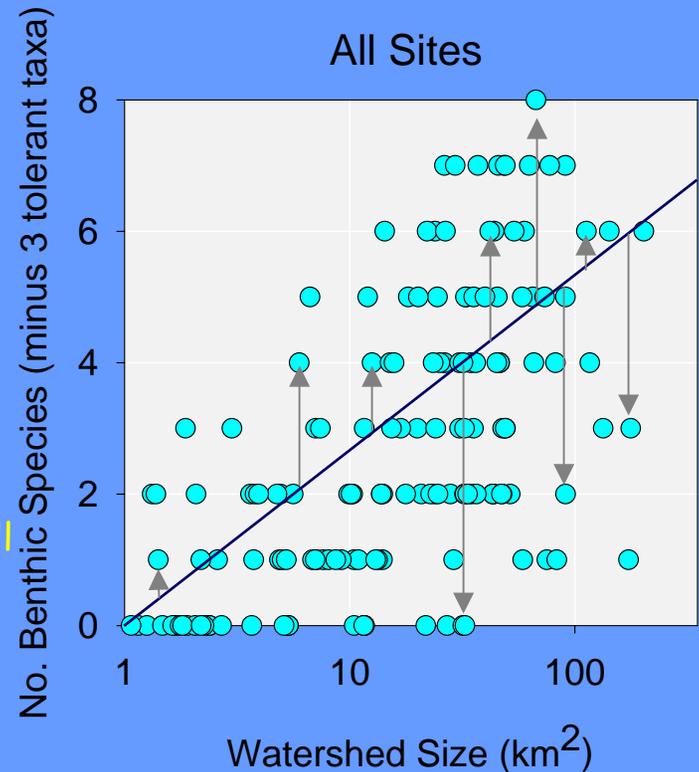
(Use relationships observed at reference sites to define 'natural' component of watershed size effect)



1. Calculate regression for reference sites

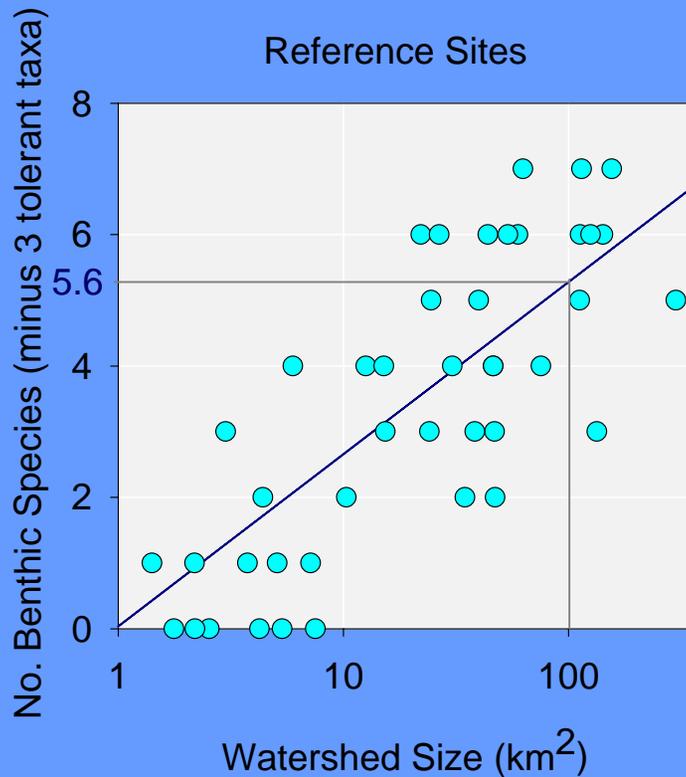
2. Apply reference regression to all sites.

3. Calculate 'residuals' for all sites.



Watershed Calibration

(Use relationships observed at reference sites to define 'natural' component of watershed size effect)

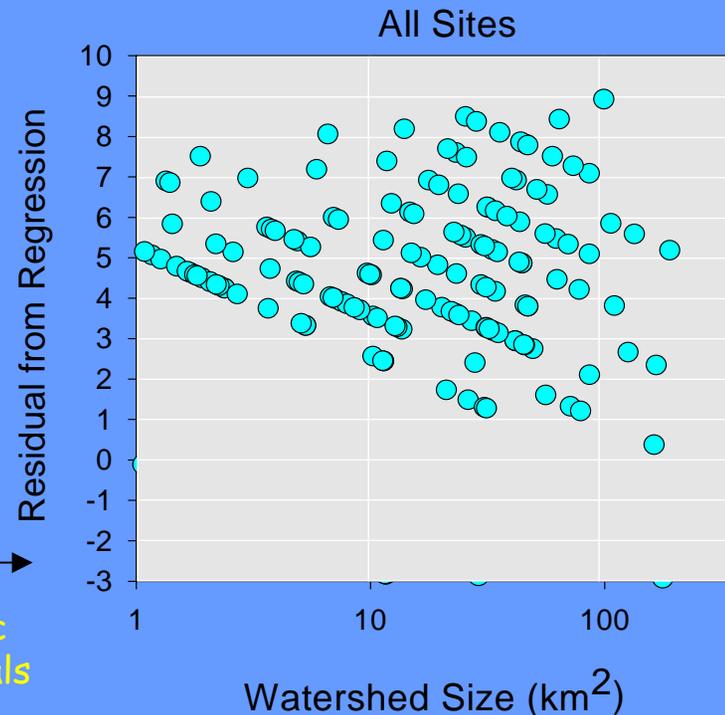


1. Start with residuals

2. Calculate expected value for reference data set at 100 km²

3. Apply constant to all residuals to create all non-zero values, standardized to 100 km² watershed size

4. Calculate metric value from residuals



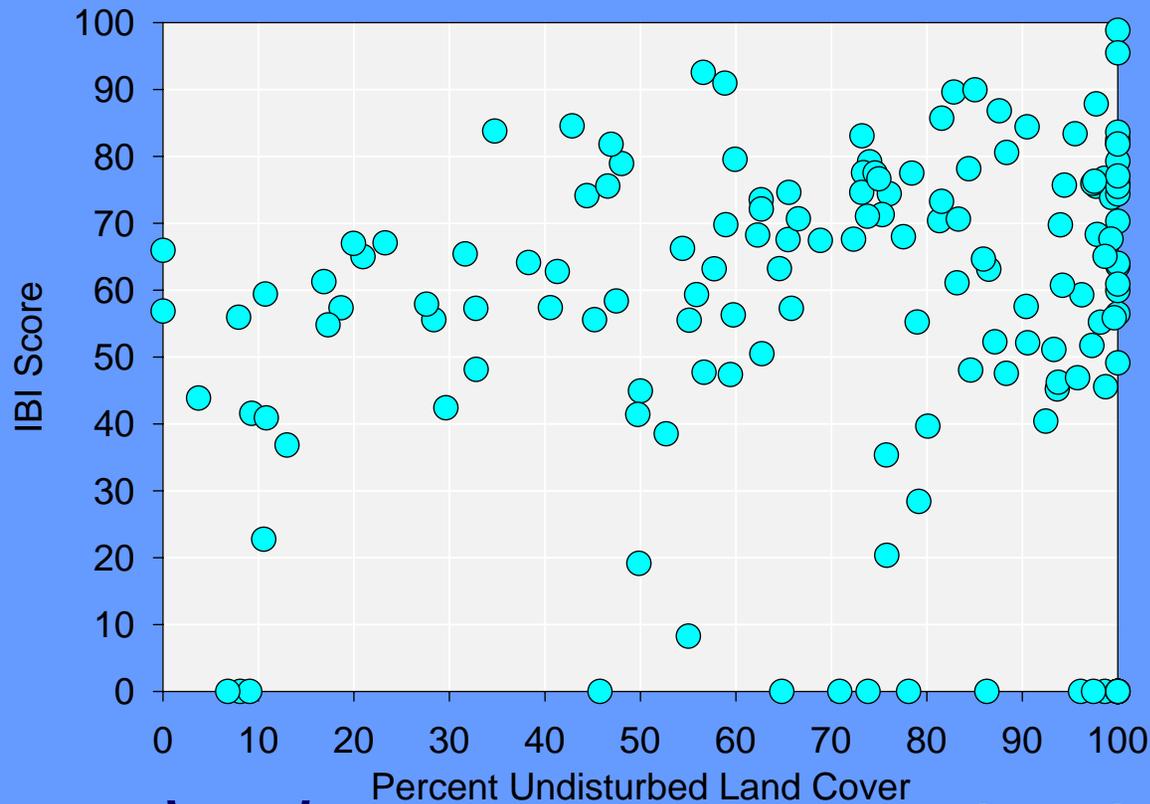
Result: Each metric scored against its expected value in a reference site with watershed area = 100 km²

Final Fish IBI Metrics

<u>Ecological Category</u>	<u>Metric Name</u>	<u>Responds to:</u>
Species Richness	No. Native Cyprinid Sp.	Watershed Condition
Tolerance Guilds	Number Intolerant Sp. Proportion Tolerant Ind.	Chem & Phys Hab, WS Cond. Chem & Phys Hab, WS Cond.
Habitat Guilds	No. Native Benthic Sp. Proportion Cottid Ind.	Watershed Disturbance Nutrients, Phys Hab
Trophic Guilds	Prop. Invert-Pisc Ind. Prop. Macro-Omnivore Ind.	Nutrients Physical Habitat
Reproductive Guilds	Prop. Gravel Spawners	Physical Habitat
Origin Guild	Prop. Alien Individuals	Species Introductions

Special Case - 'Fishless' Sites

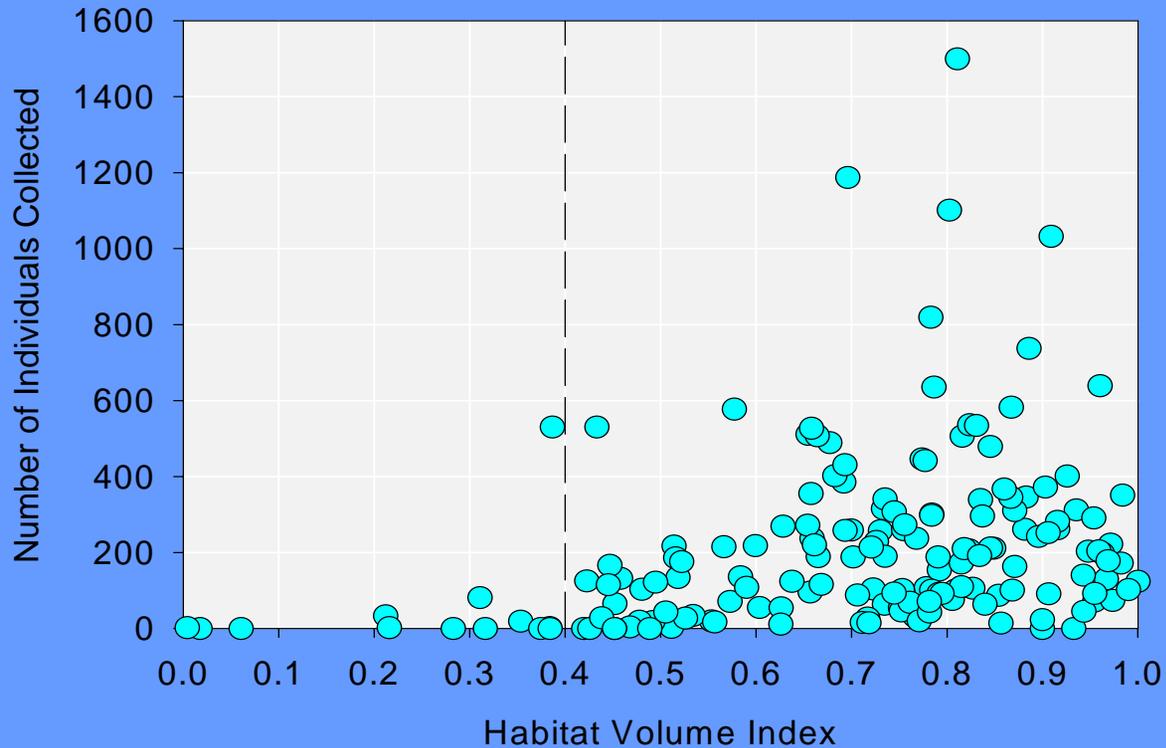
(If fishless sites are scored as IBI=0)



These zero values
may be reasonable

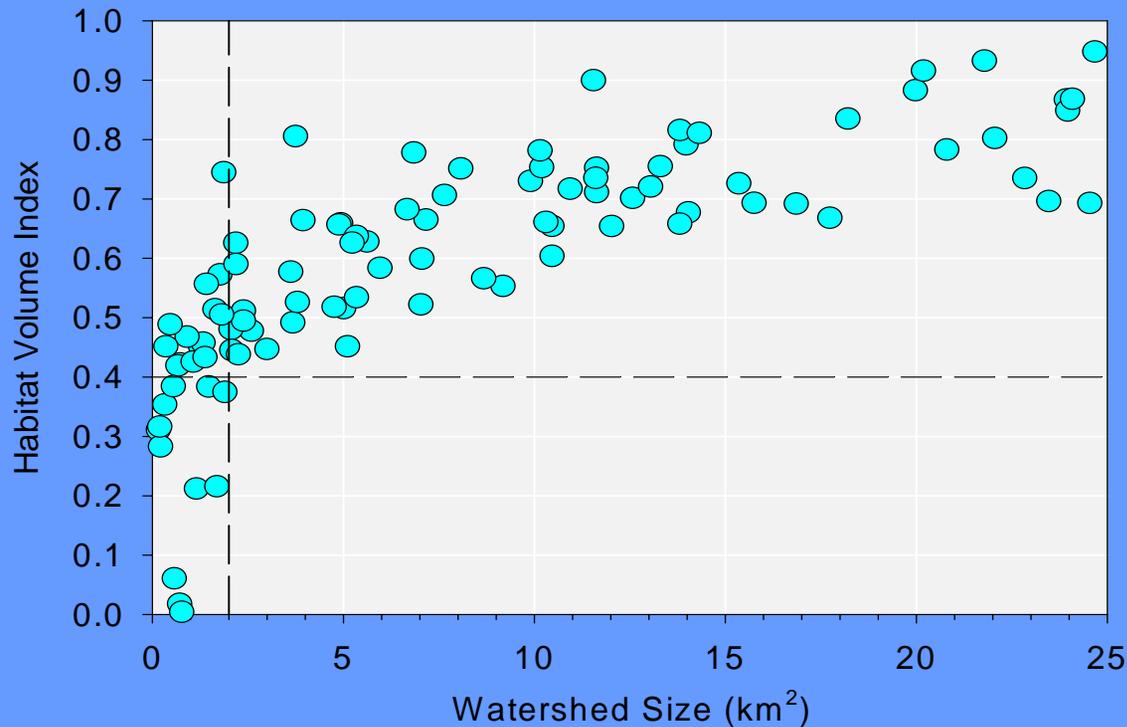
But what about
these?

Habitat Volume



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

Minimum Watershed Size

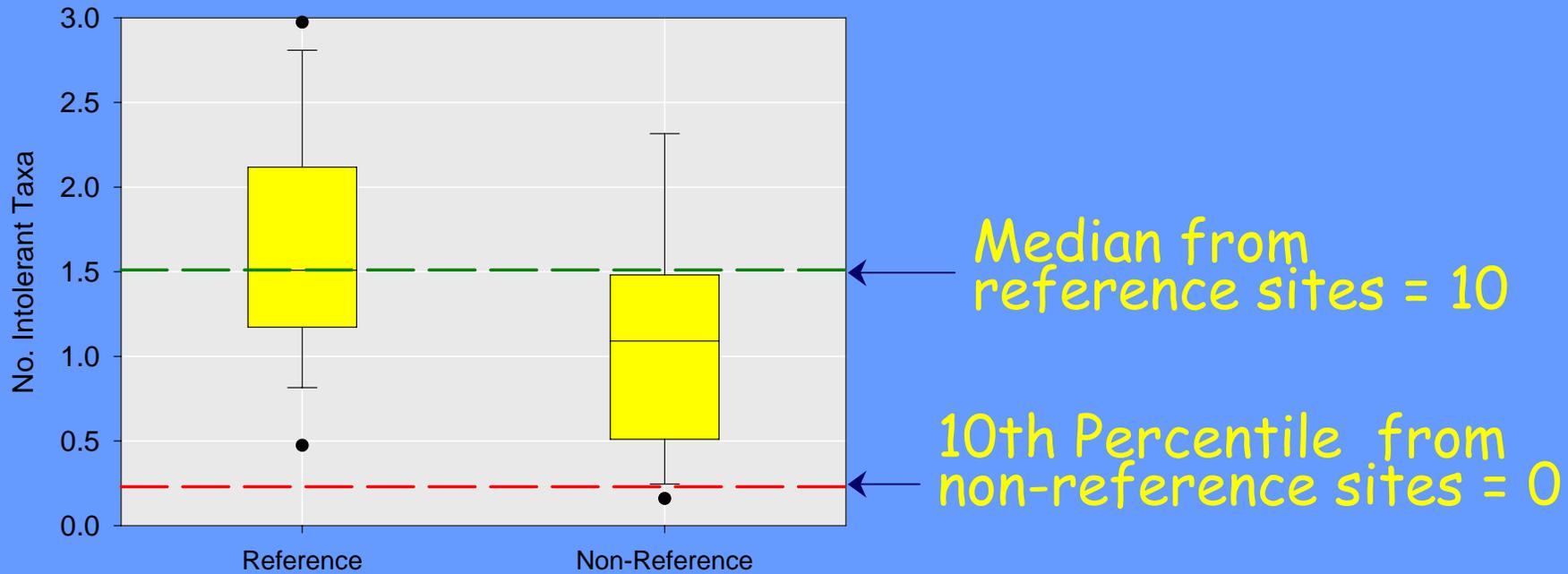


Conclusion: Habitat Volume Index Values < 0.4 common in watersheds less than 2 square kilometers. Below this watershed size, we cannot confidently expect to encounter fish - set IBI to missing when number of fish is < 10.

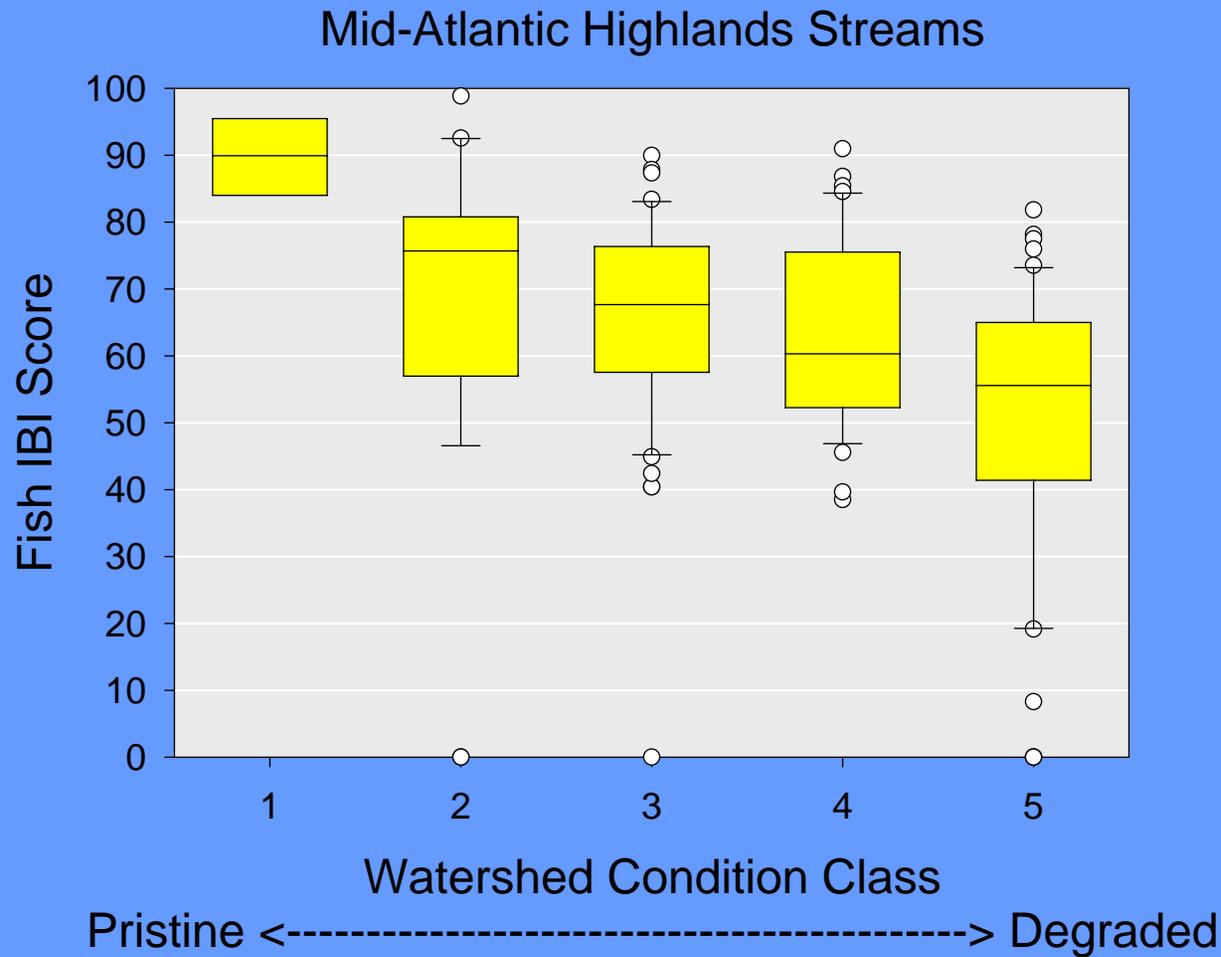
Metric Scoring

- 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 median score in the reference distribution
- Lower limit (0) set by 10th percentile score in the non-reference distribution
- Sum of metric scores (1.11) yields IBI from 0 to 100

Metric Scoring



Responsiveness of Final Index



Filtering Probability Sites to Yield Reference Sites

Excluded all sites with:

- sulfate over 400 $\mu\text{eq/L}$ (mine drainage)
- acid neutralizing capacity less than 50 $\mu\text{eq/L}$ (acid rain)
- average RBP habitat score less than 16 (physical habitat)
- total phosphorus over 20 $\mu\text{g/L}$ (nutrient enrichment)
- total nitrogen over 750 $\mu\text{g/L}$ (nutrient enrichment)
- chloride over 100 $\mu\text{eq/L}$ (general watershed disturbance)
- insufficient sample (watersheds < 2 sq. km.)

IBI Scoring Thresholds

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

But there are multiple ways to define reference, and each gives a different reference distribution:

Uncertain: based on best professional judgement, near roads (n = 38, good geographic coverage)

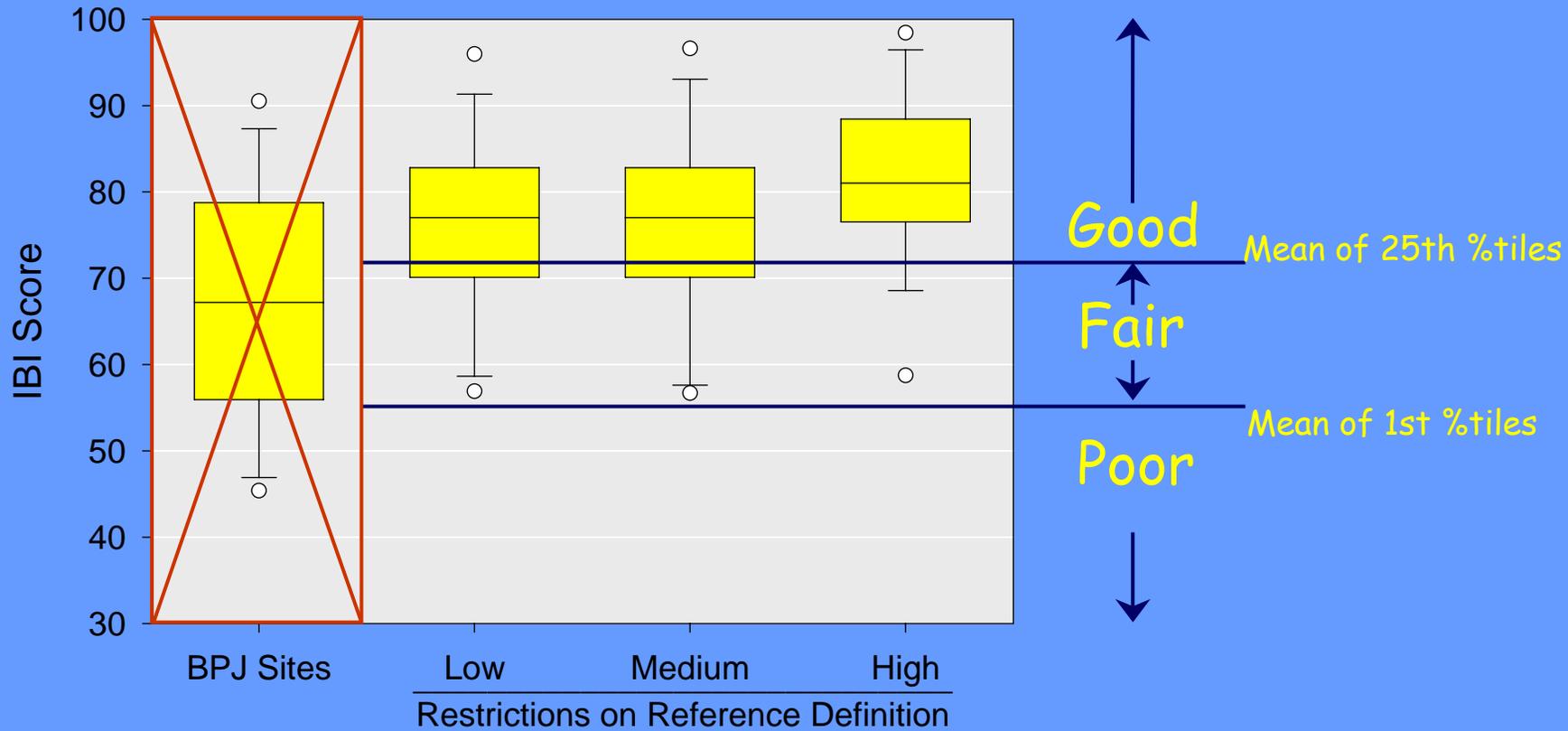
Least restrictive: based on chemical and qualitative physical habitat filters (n = 27, good geographic coverage)

Moderately restrictive: adds quantitative physical habitat filters (n = 23, good geographic coverage)

Most restrictive: adds watershed condition class (1 or 2) (n = 12, restricted geographic coverage)

Reference Condition

Mid-Atlantic Highlands Streams
Potential Reference Distributions



Reference and Trashed Sites

Reference site definition: (all calibration reference sites met all these criteria)

ANC > 50 $\mu\text{eq/L}$

Total Phosphorus < 20 $\mu\text{g/L}$

Total Nitrogen < 750 $\mu\text{g/L}$

Chloride < 100 $\mu\text{eq/L}$

Sulfate < 400 $\mu\text{eq/L}$

Mean RBP Score > 15

Habitat Quality Metrics > 0.5
(QTPH1, QCPH1, QW1, QWR1)

Trashed site definition: (all calibration trashed sites failed at least one of these criteria)

pH < 5

Total Phosphorus > 100 $\mu\text{g/L}$

Total Nitrogen > 5000 $\mu\text{g/L}$

Chloride > 1000 $\mu\text{eq/L}$

Sulfate > 1000 $\mu\text{eq/L}$

Mean RBP Habitat Score < 10

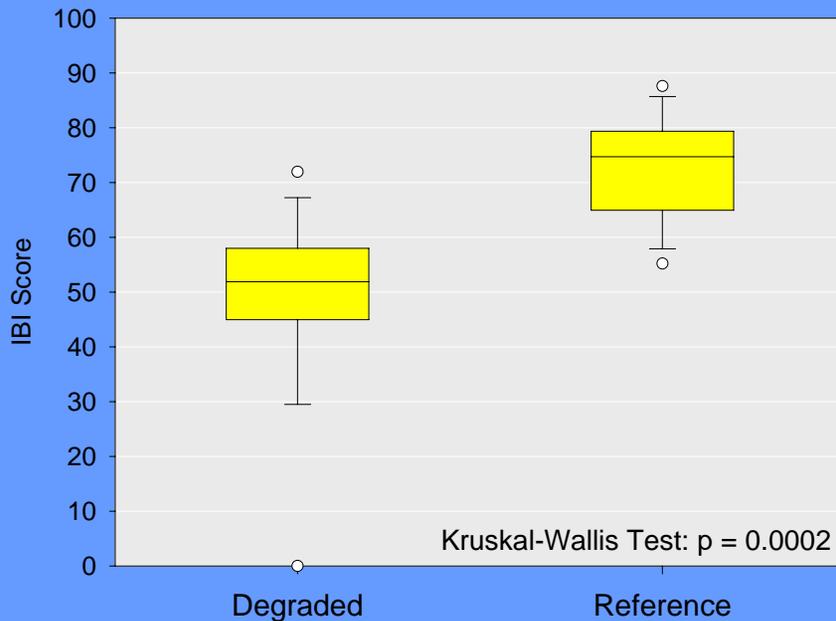
Habitat Quality Metrics < 0.3
(QTPH1, QCPH1, QW1, QWR1)

Watershed Condition Class = 5

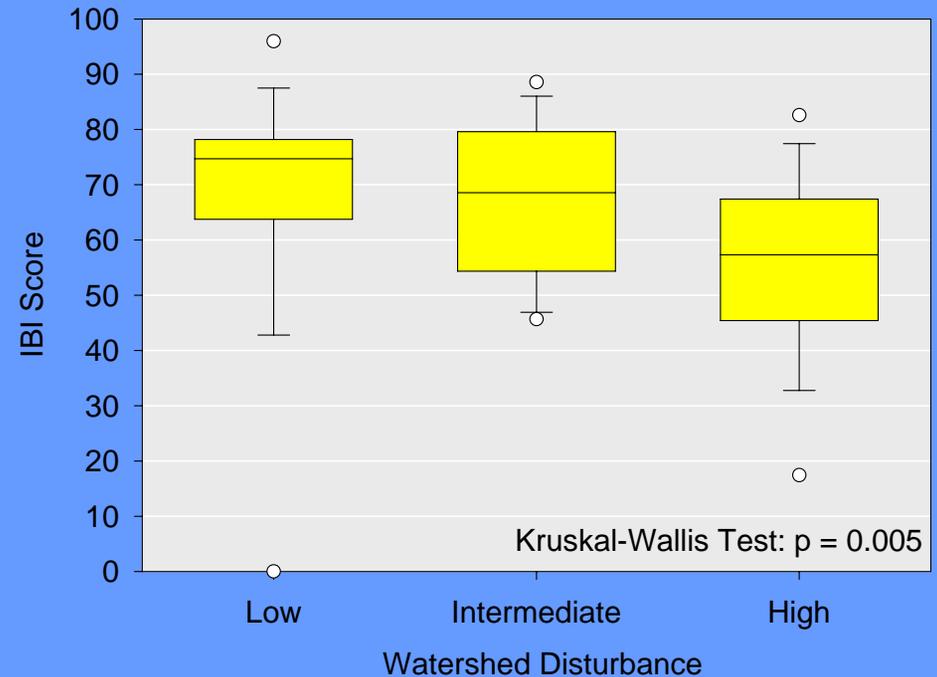
IBI Validation

Results from validation data set aside at start of process

Using Reference and Test Site 'Filters'



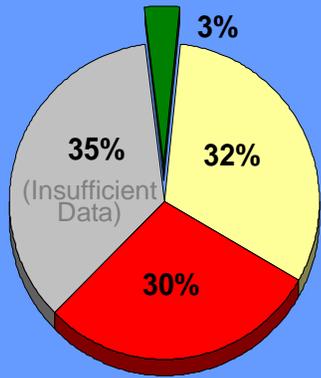
Using Watershed Disturbance Index



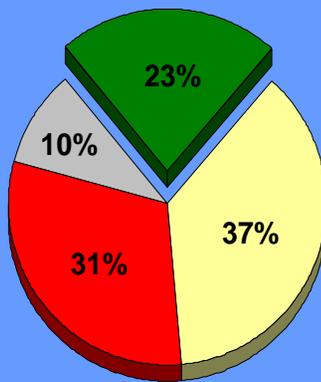
Conclusion: IBI can discriminate between disturbed and relatively undisturbed streams

IBI Results

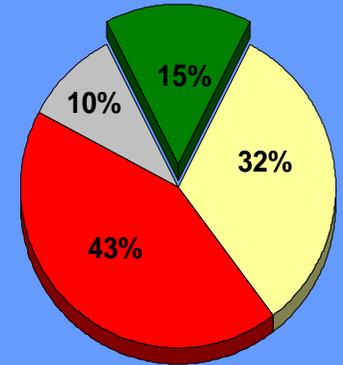
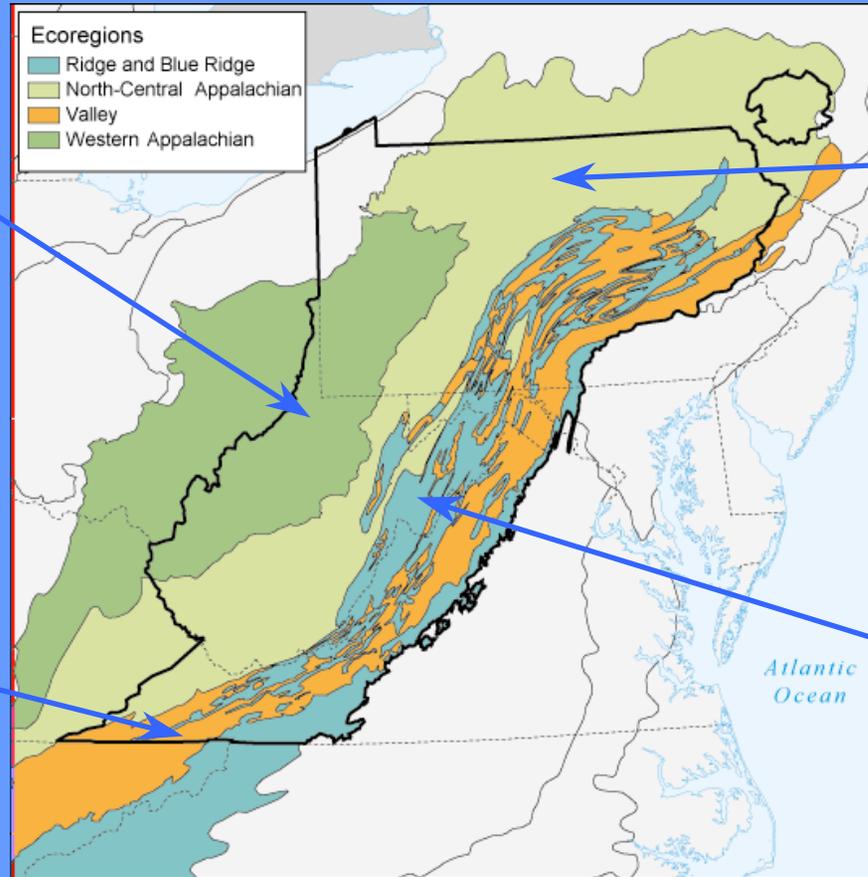
Geographic Distribution



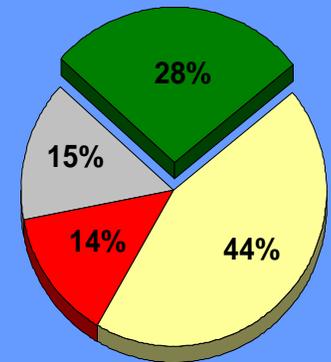
Western Appalachians



Valleys



North-Central Appalachian



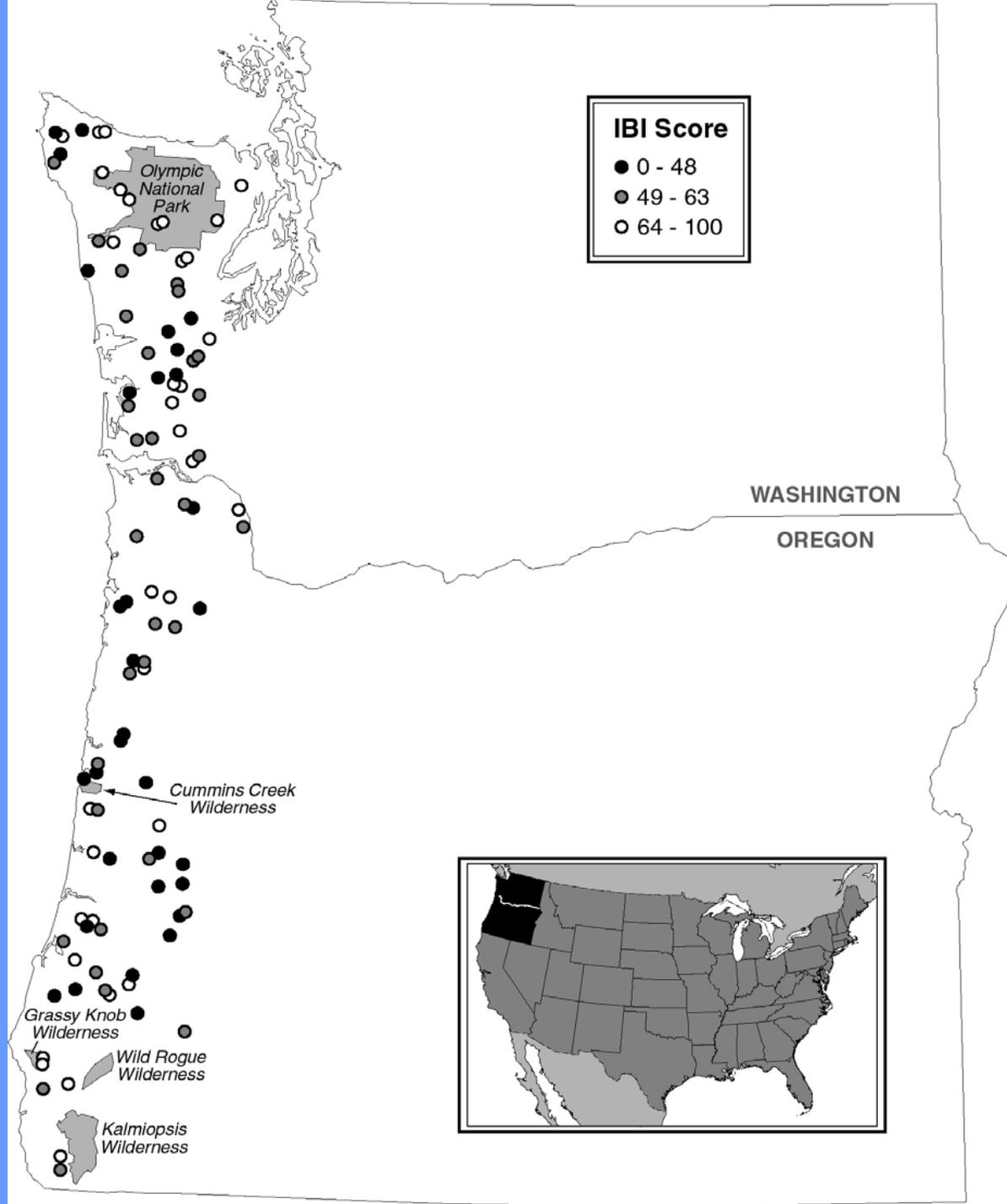
Ridge and Blue Ridge

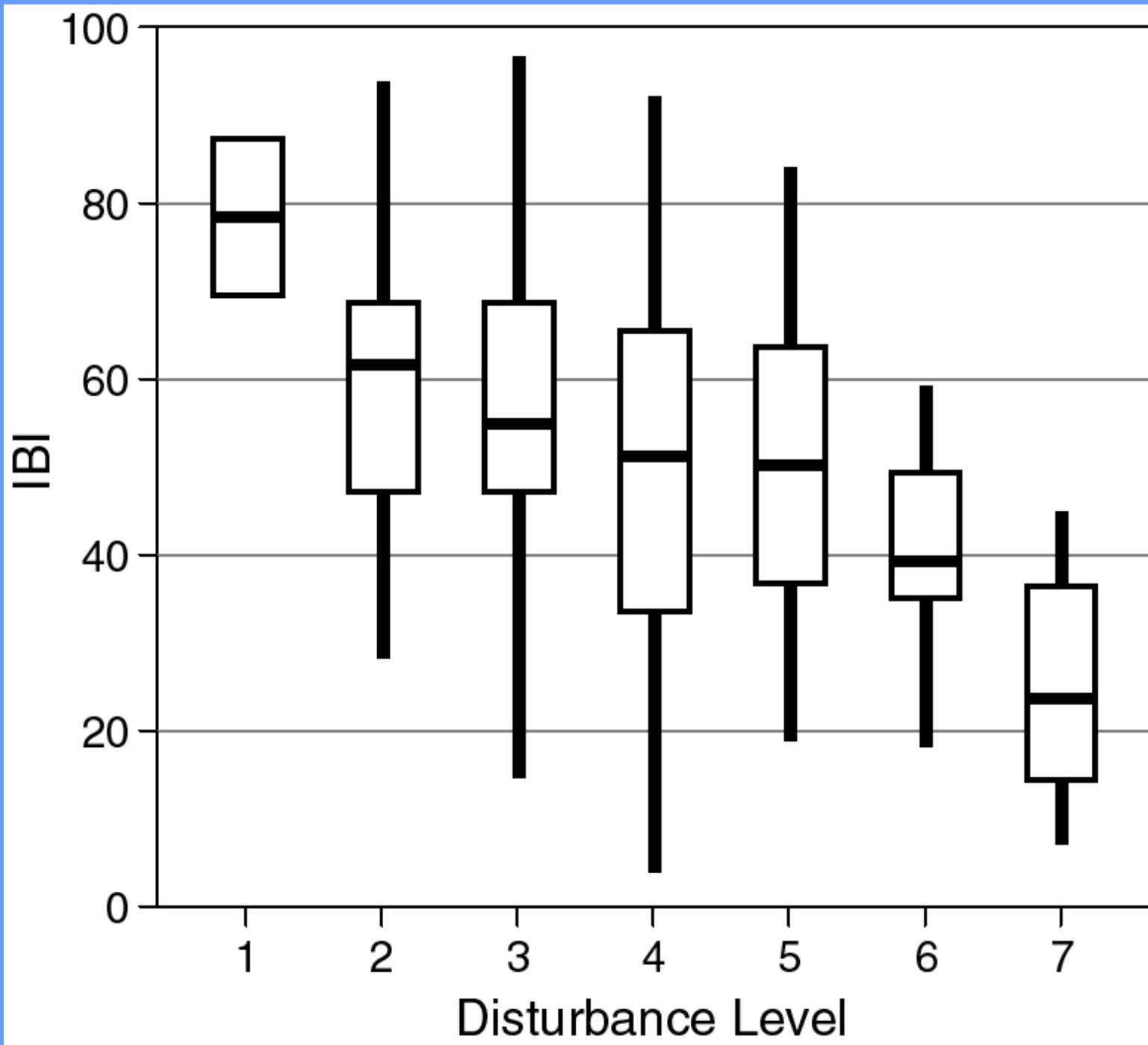
W-EMAP Fish IBI Challenges

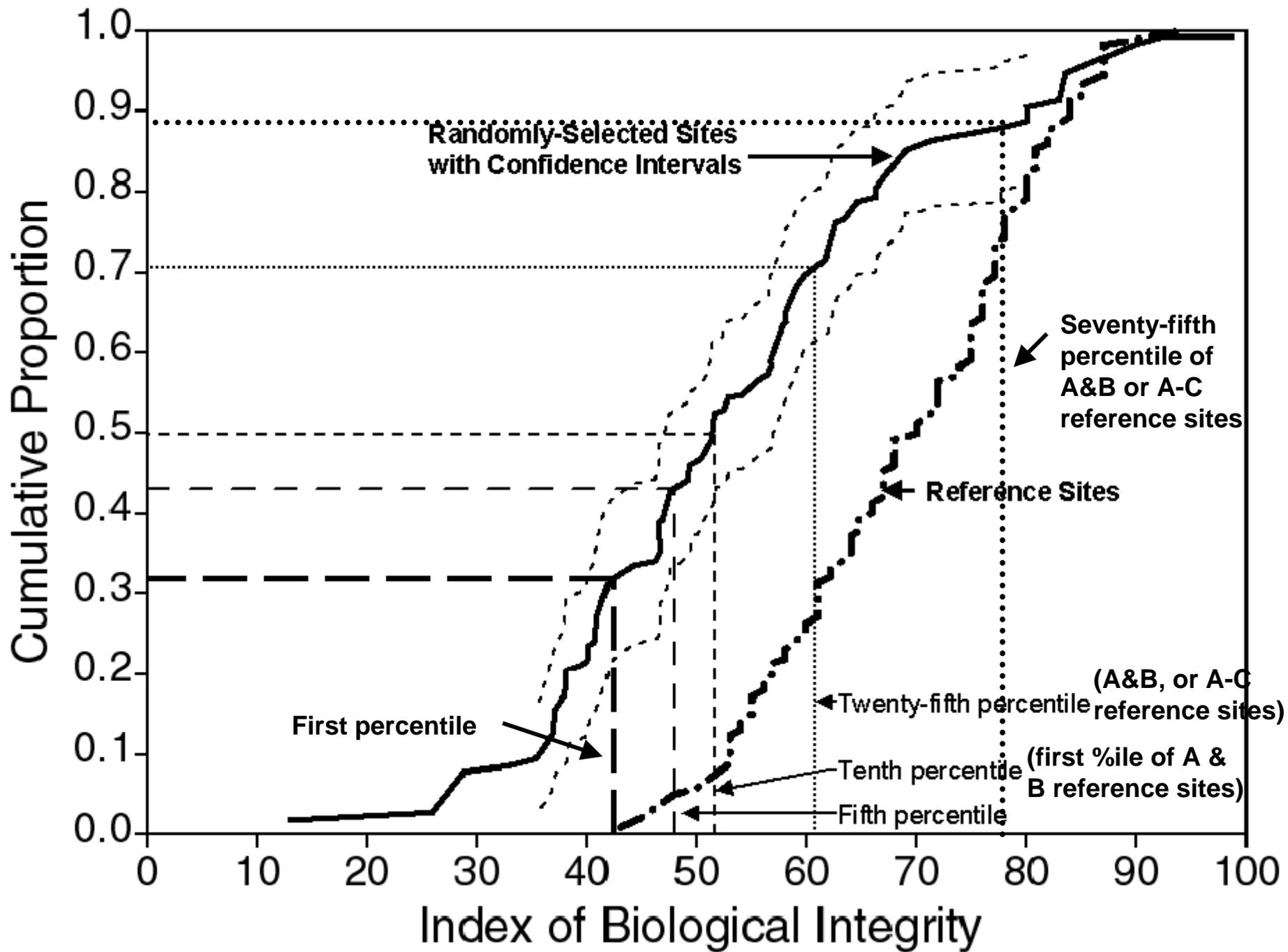
- Generally depauperate fauna
- Low species richness in streams
- Species with variable life histories
- Population abundance very important
- High % alien species & individuals
- Major natural gradients co-occur with human disturbance gradients

Coast Range Fish IBI Metrics

- % Alien species
- % Coolwater species
- % Anadromous species
- % Coldwater species
- No. tolerant individuals
- No. native coldwater species
- No. native coldwater individuals
- No. size classes

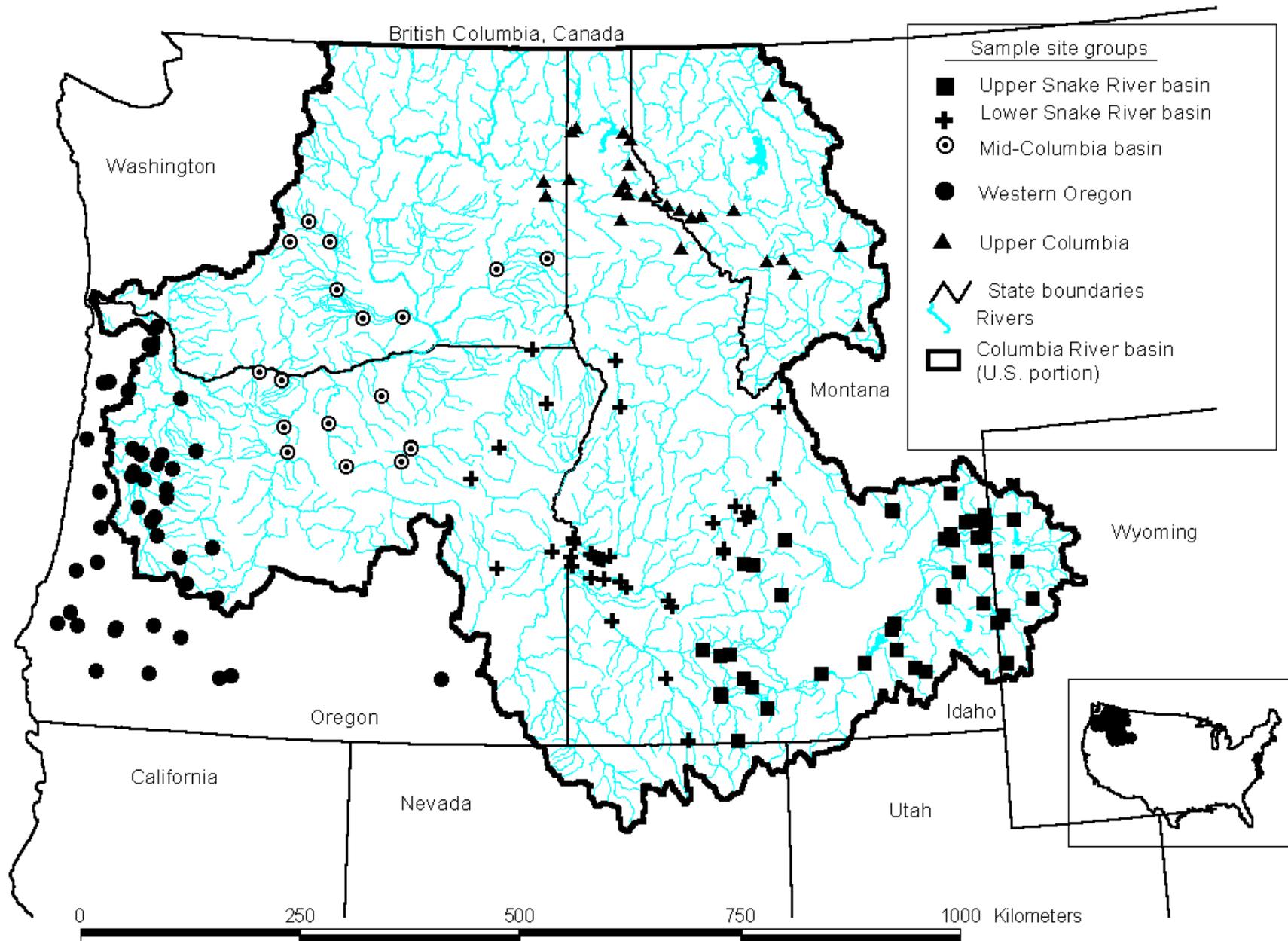






Cold Water River IBI Metrics

- % cold water individuals
- No. cold water native species
- % sensitive native individuals
- No. coldwater individuals/minute
- No. selected salmonid age classes
- No. sculpin age classes
- No. alien species
- % tolerant individuals
- % common carp
- % individuals with DELT anomalies



Willamette Valley IBI Metrics

- No. native families
- No. native species
- No. native benthic species
- No. native water column species
- No. hider species
- No. sensitive species
- No. native nonguarding lithophil nester species
- % tolerant individuals
- % filter feeding individuals
- % omnivores
- % native top carnivore individuals
- % target species with lunkers
- % individuals with anomalies

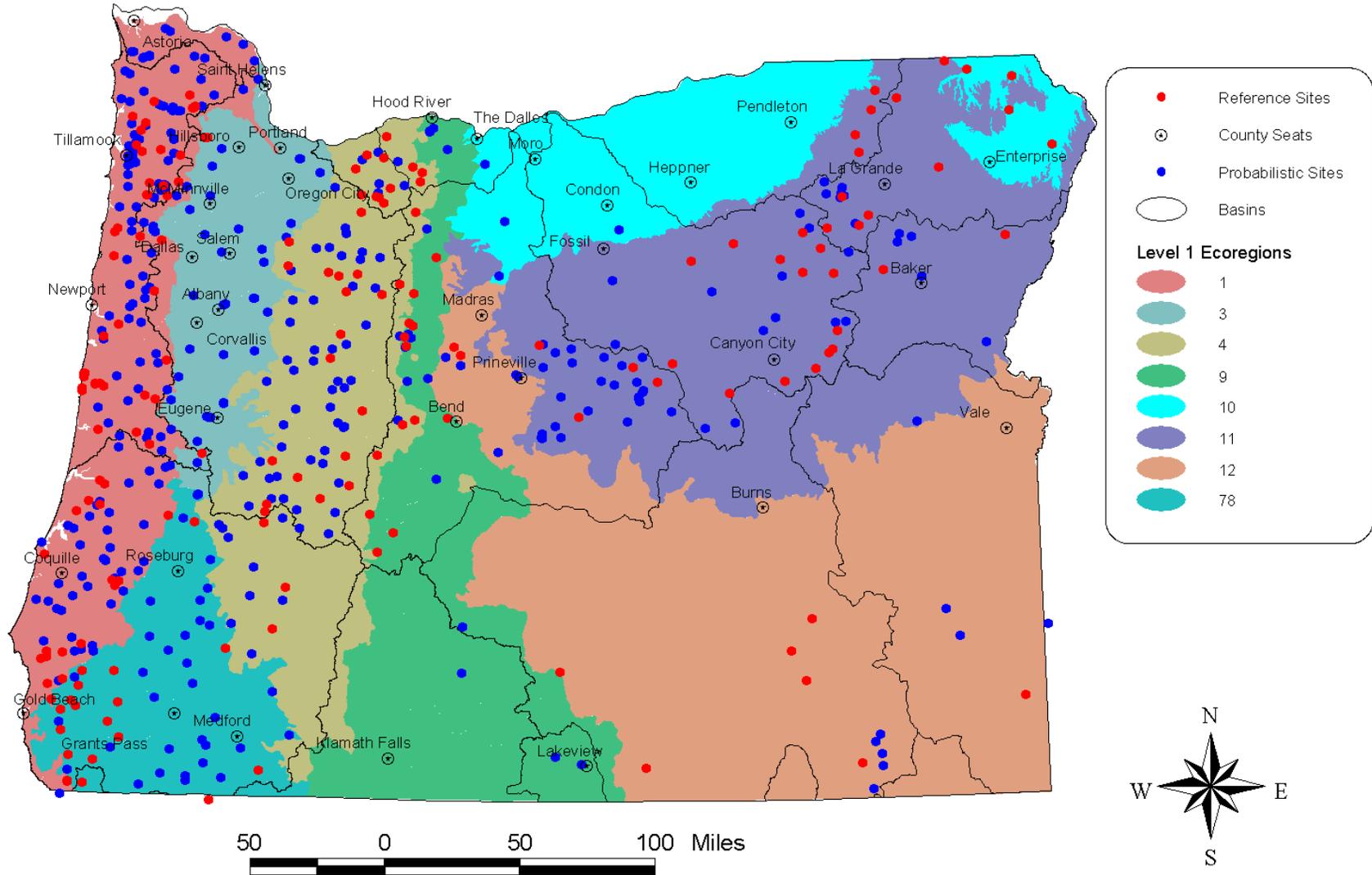
References

- Cao et al. 2001. *CJFAS* 58:1782-1793.
- Cao et al. 2002. *JNABS* 21:701-714.
- Hughes et al. 2002. *NAJFM* 22:1229-1240.
- Reynolds et al. 2003. *NAJFM* 23:450-461.

- Hughes & Gammon. 1987. *TAFS* 116:196-209.
- Hughes et al. 1998. *CJFAS* 55:1618-1631.
- Hughes et al. In Review. *TAFS*.
- McCormick et al. 2001. *TAFS* 130:857-877.
- Mebane et al. 2002. *TAFS* 132:239-261.

Oregon DEQ Biomonitoring Sites (from R. Hafele)

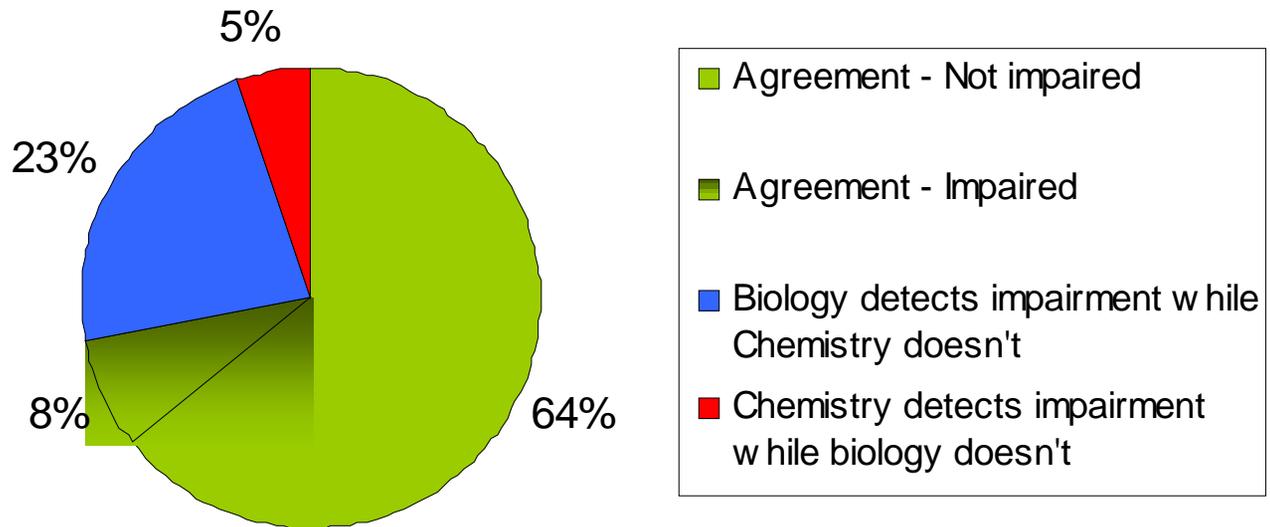
1996-2000



Biology Shows Greater Impairment than Chemistry

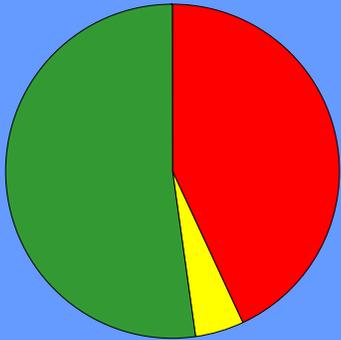
Oregon DEQ - April 2002

Chemical versus Biological Indicators of Aquatic Life Use Impairment - Macroinvertebrates & Vertebrates (n=150)

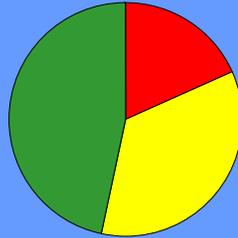


Willamette Basin

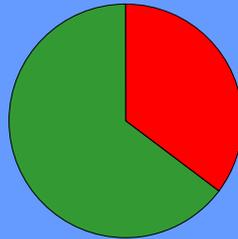
Macroinvertebrate Community



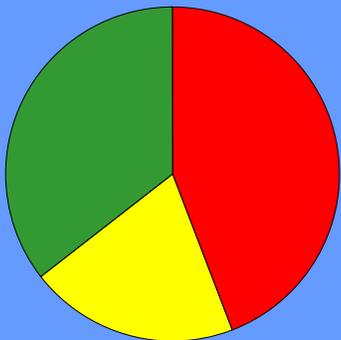
Water Quality



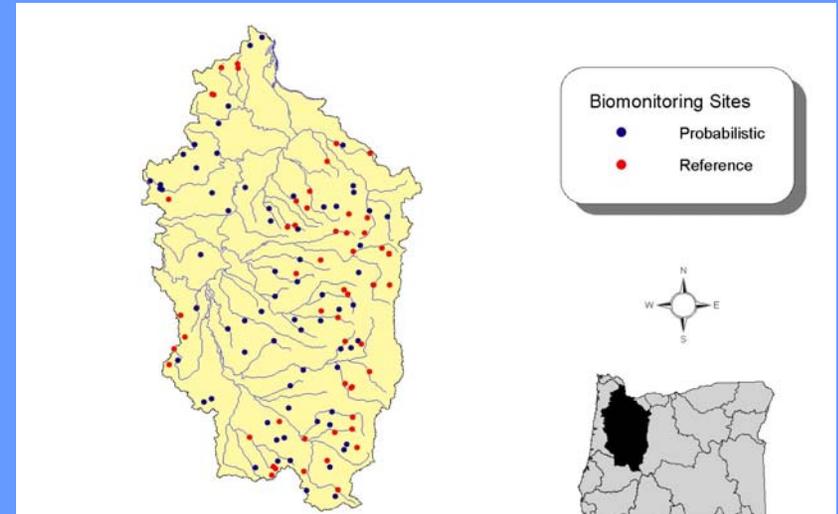
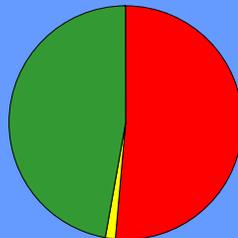
Temperature



Vertebrate Community

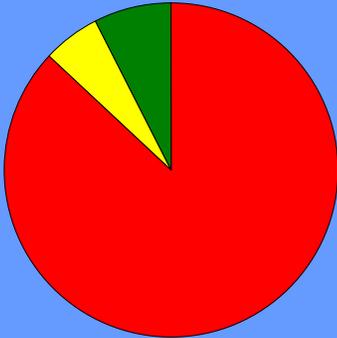


Fine Sediment

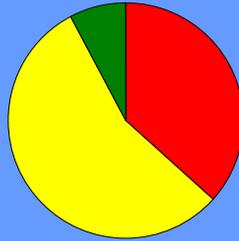


Willamette Valley Ecoregion

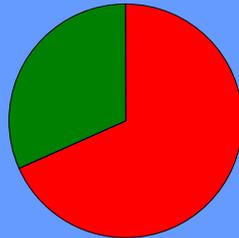
Macroinvertebrate Community



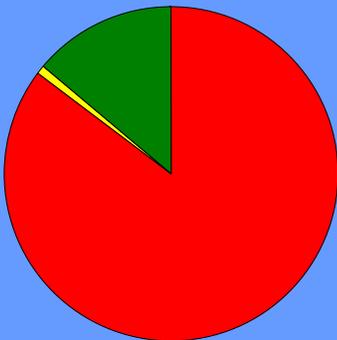
Water Quality



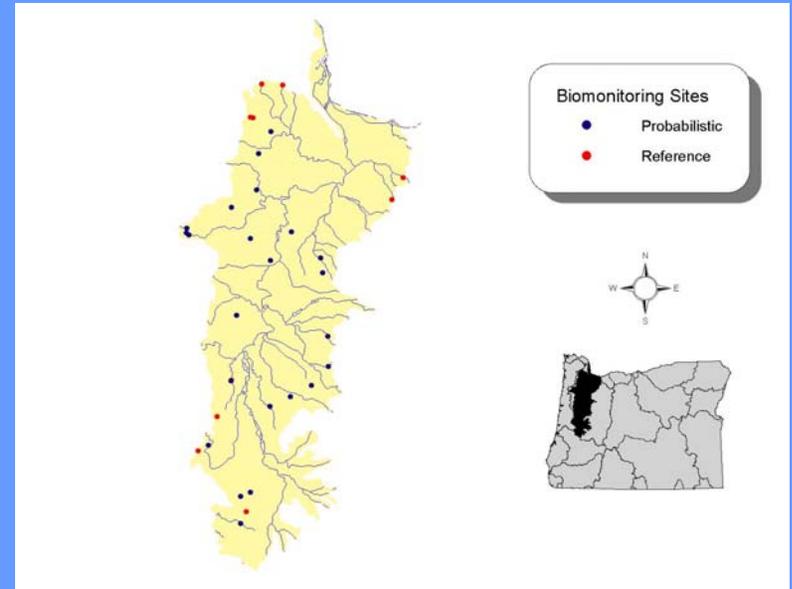
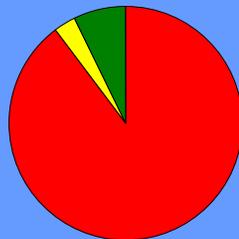
Temperature



Vertebrate Community



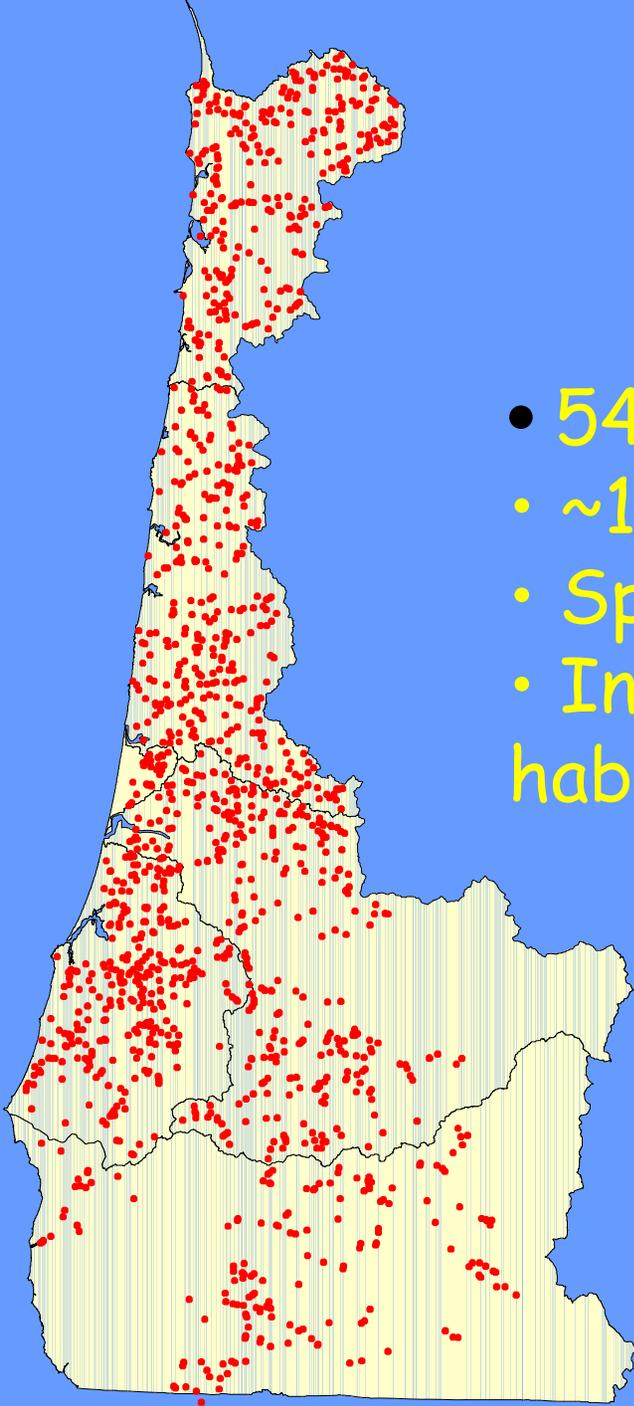
Fine Sediment



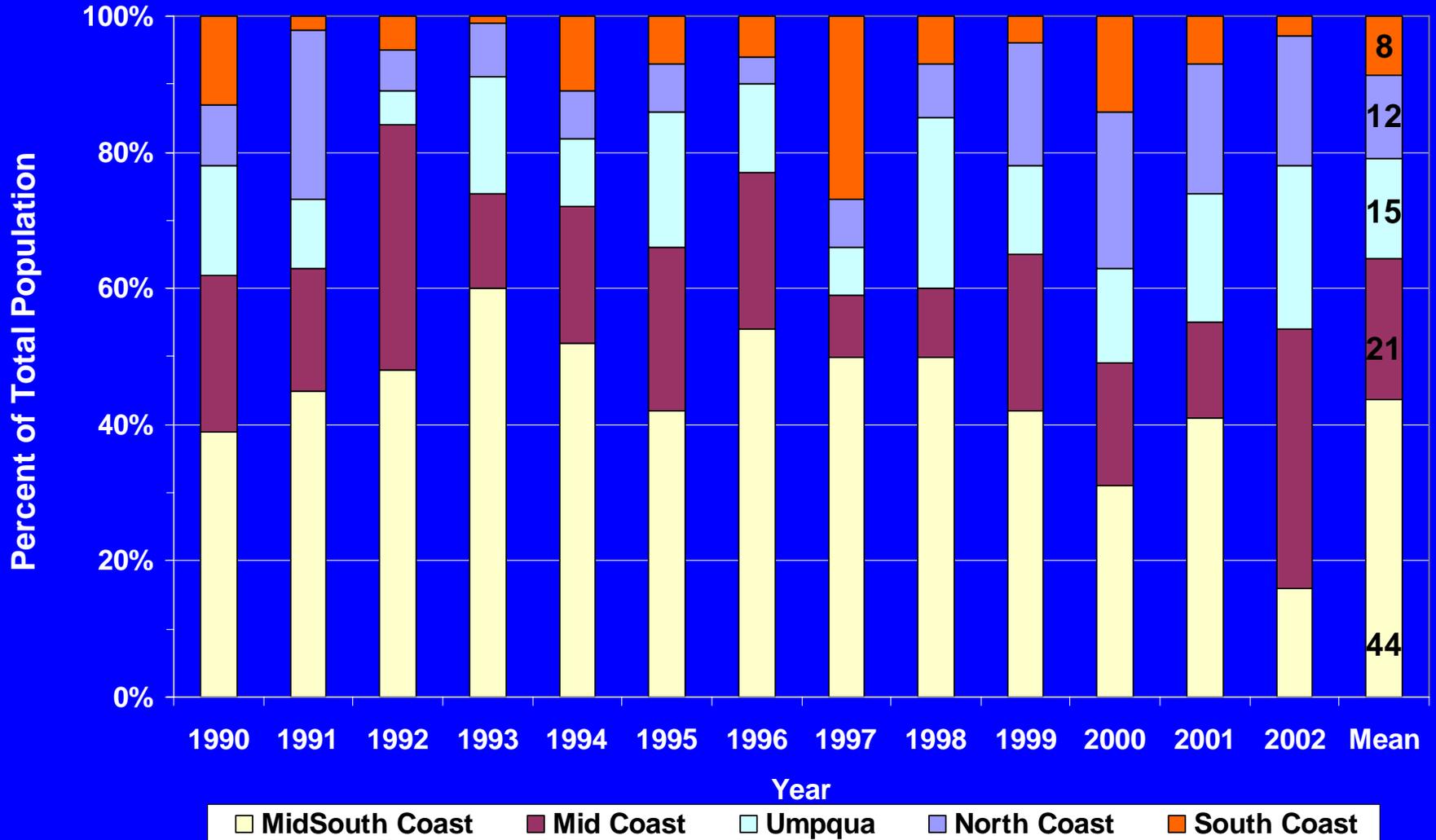
Random Adult Coho Surveys

(from S. Jacobs)

- 540 sites per year
- ~120 per GCA
- Spatially-balanced sample
- Integrated with juvenile and habitat sampling

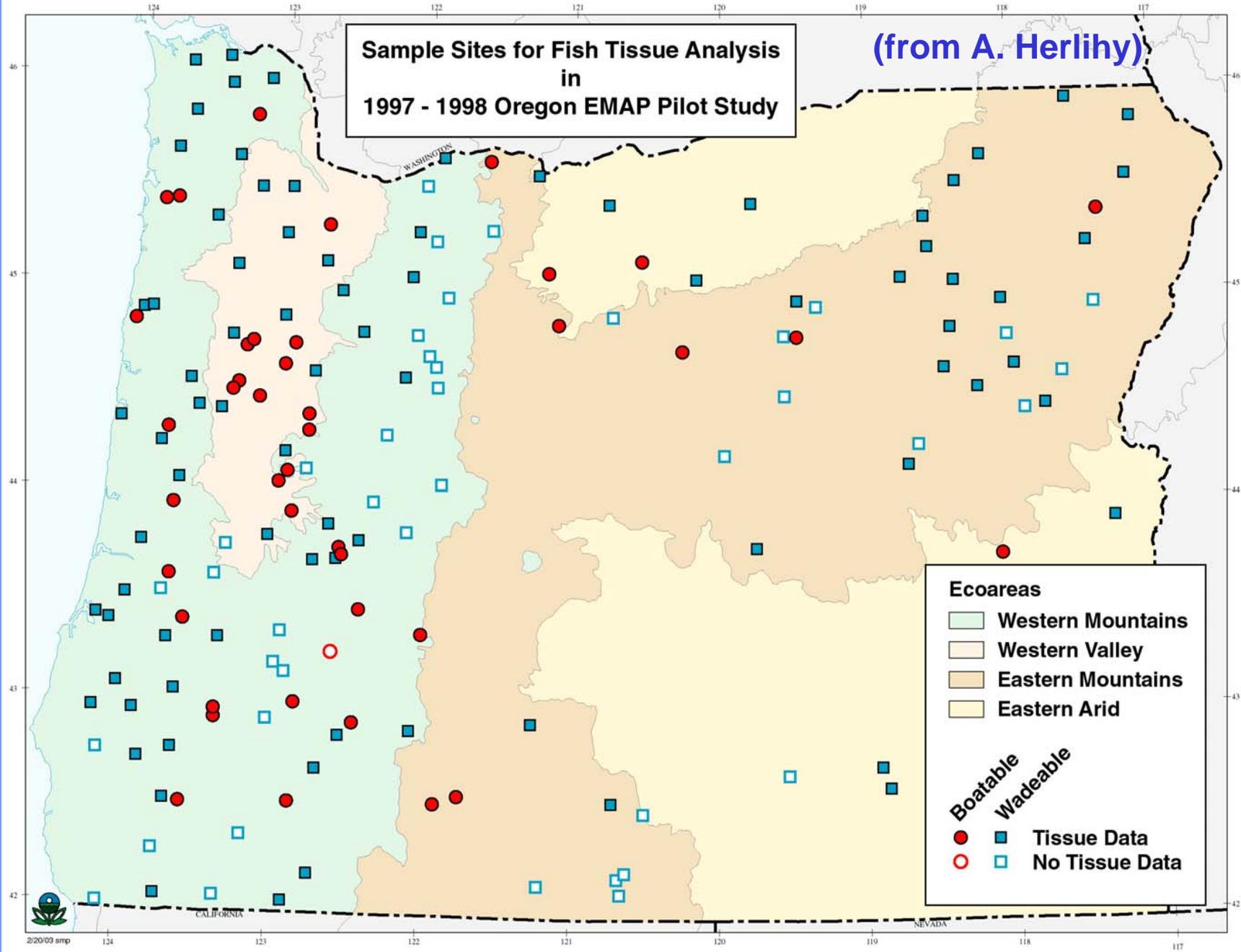


Coho Abundance By Monitoring Area

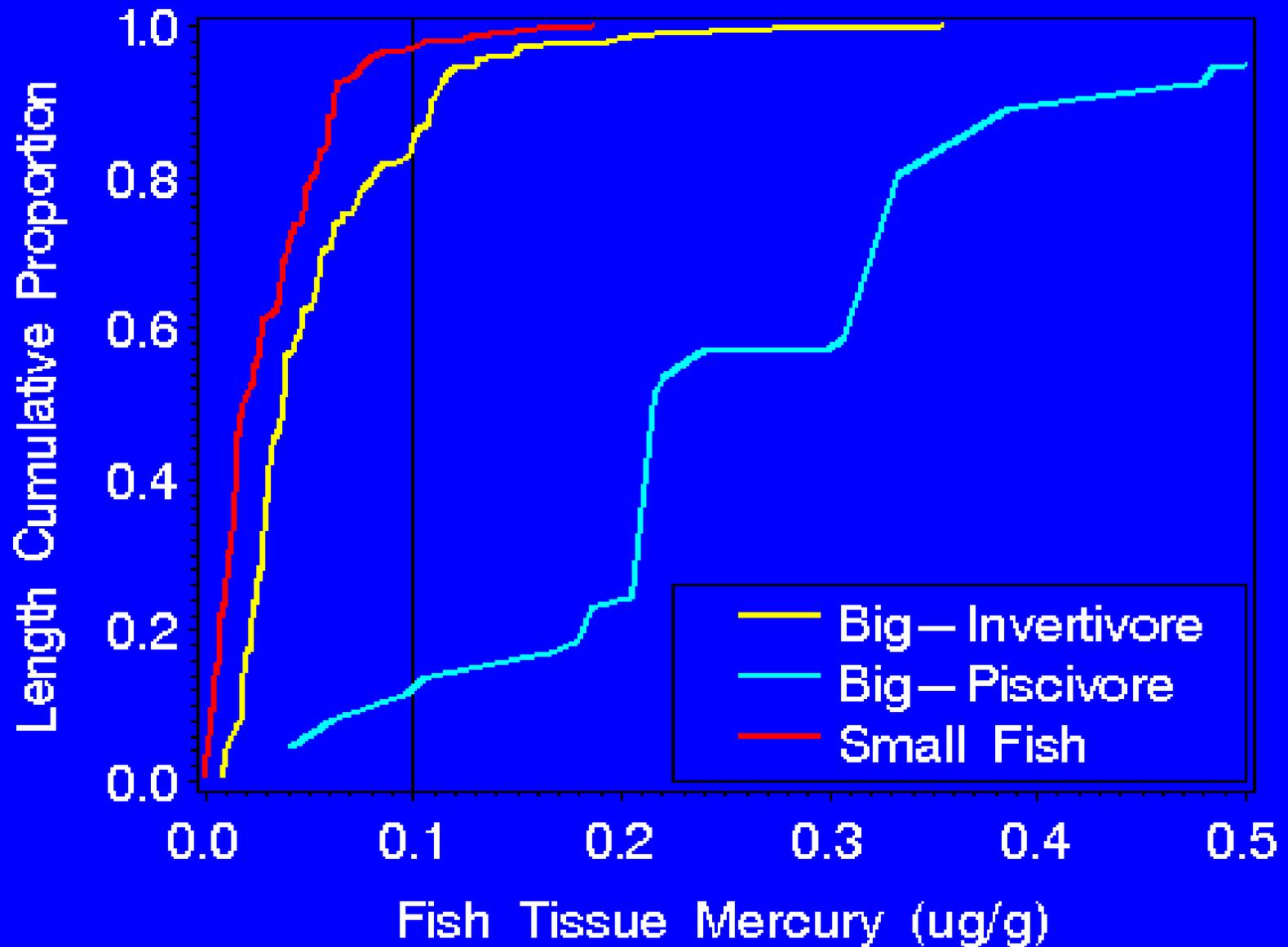


**Sample Sites for Fish Tissue Analysis
in
1997 - 1998 Oregon EMAP Pilot Study**

(from A. Herlihy)



Oregon Population Estimates



Fish Tissue Hg > 0.1 $\mu\text{g/g}$ by Taxon

