

US EPA ARCHIVE DOCUMENT



***Fifteen Years of Stream Monitoring
in EMAP: The Evolution of Design,
Indicators and Assessment***

RESEARCH & DEVELOPMENT

Building a scientific foundation for sound environmental decisions

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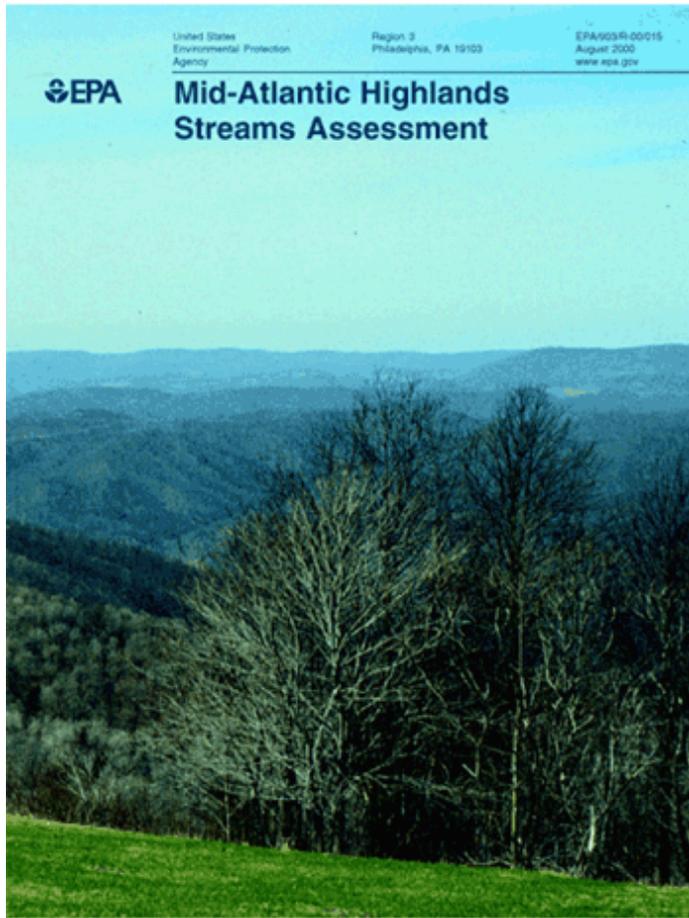
F.H. McCormick



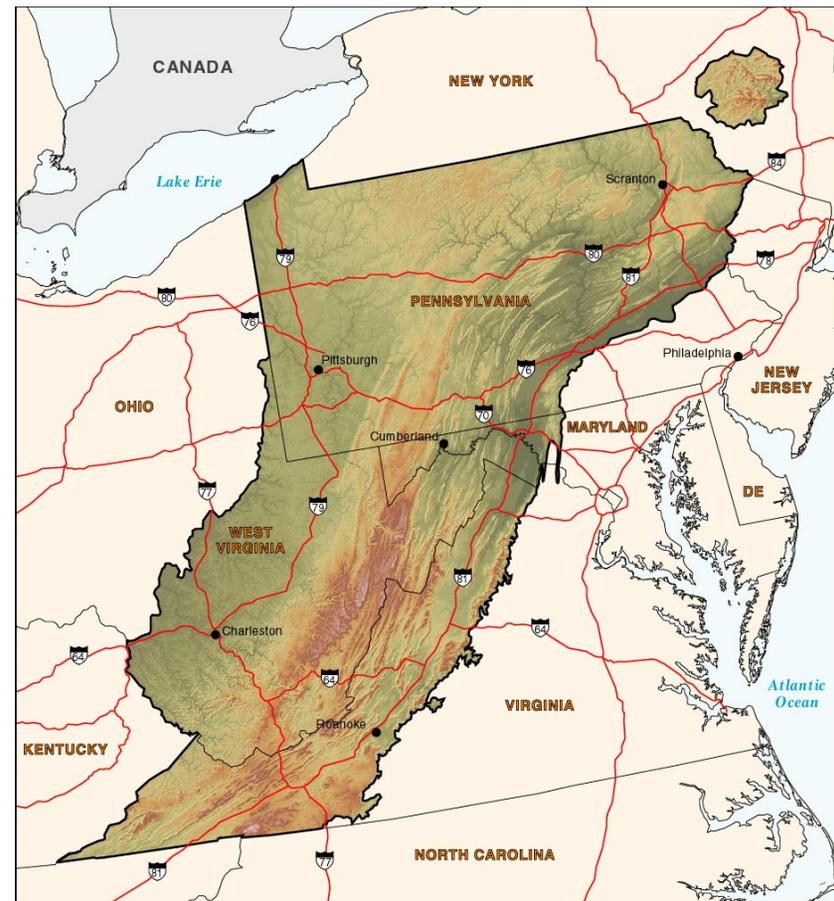
Elements of EMAP Streams

- Design
 - Probability designs - extrapolated to a target population with known confidence
 - Plot-scale design – consistent and sufficient sampling effort in all stream types
- Indicators
 - Focus on biological indicators and indices (ecological condition)
 - Extensive indicators of physical, chemical and biological habitat (relative importance of stressors)
 - Reference condition (setting expectations)
- Assessment tools
- Regional demonstrations

Mid Atlantic Highlands Assessment (MAHA - 1993-94)



Wadeable streams
(1st through 3rd order)



79,000 mi²

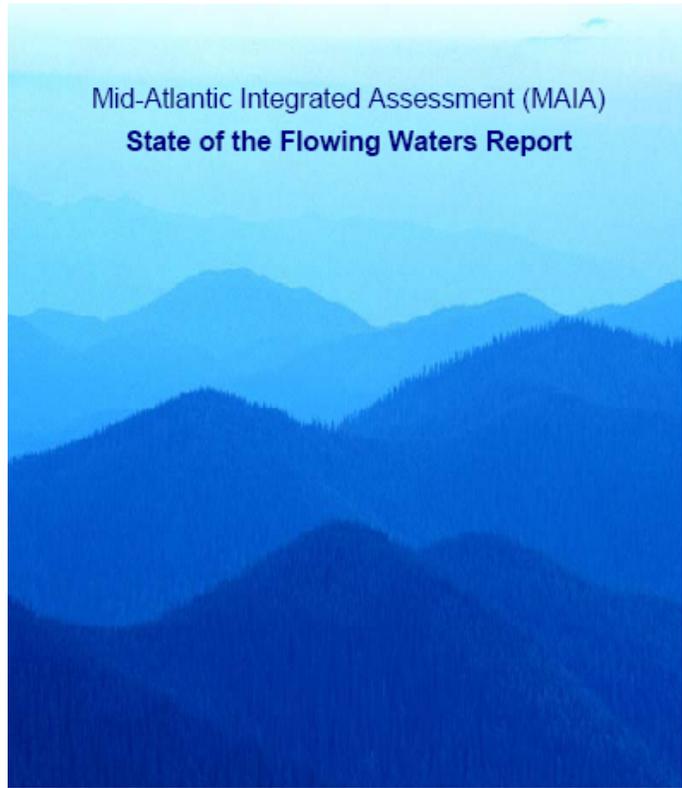
Portion of Region III, portions of 5 states

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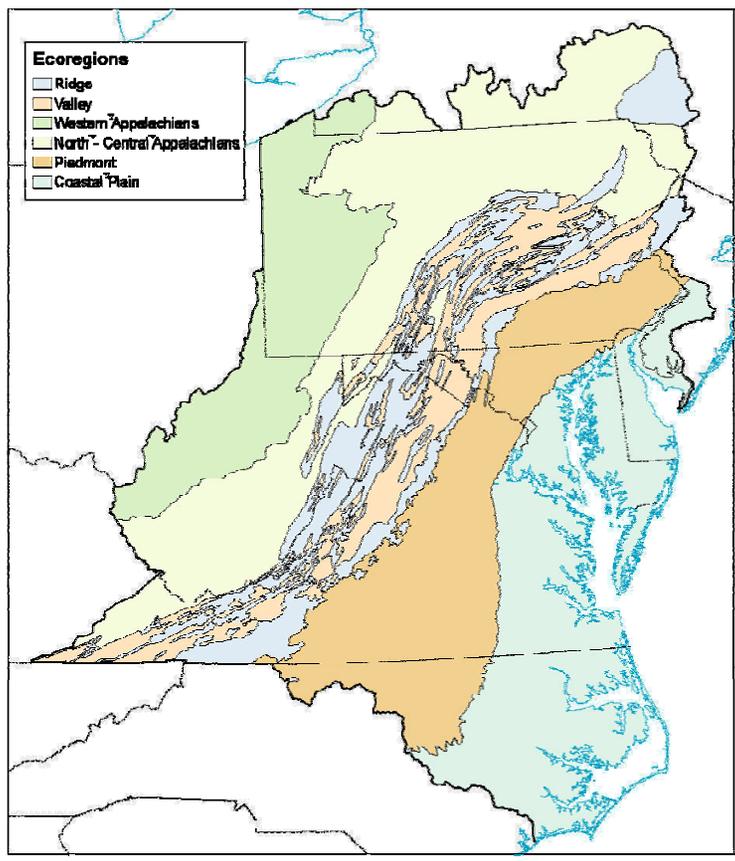
Mid Atlantic Integrated Assessment (MAIA - 1997-98)

EPA United States Environmental Protection Agency
Office of Research and Development
Washington, DC 20460
February 2008
EPA/620/R-08/001



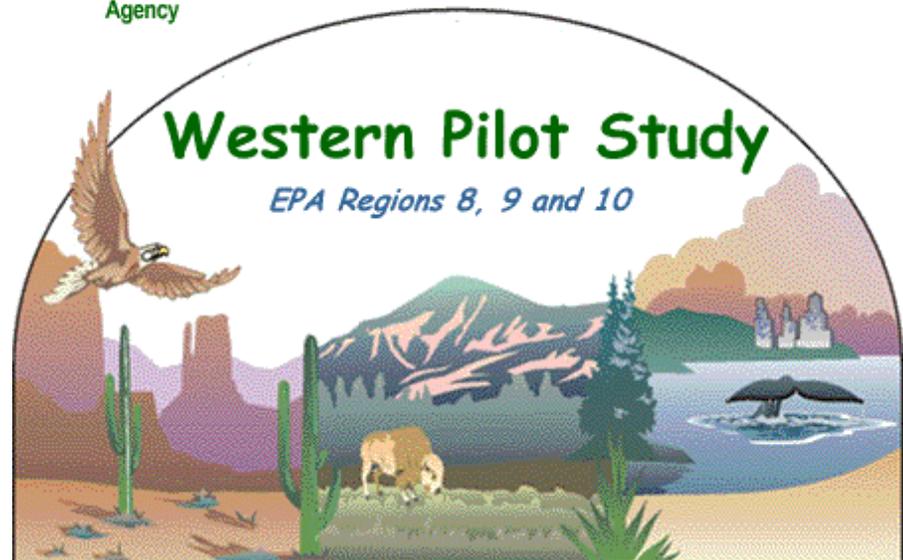
180,000 mi²
Region 3, all or part of 8 states

All perennial flowing waters



EMAP Western Pilot (EMAP-W 2000-04)

All perennial flowing waters,
except "Great Rivers"

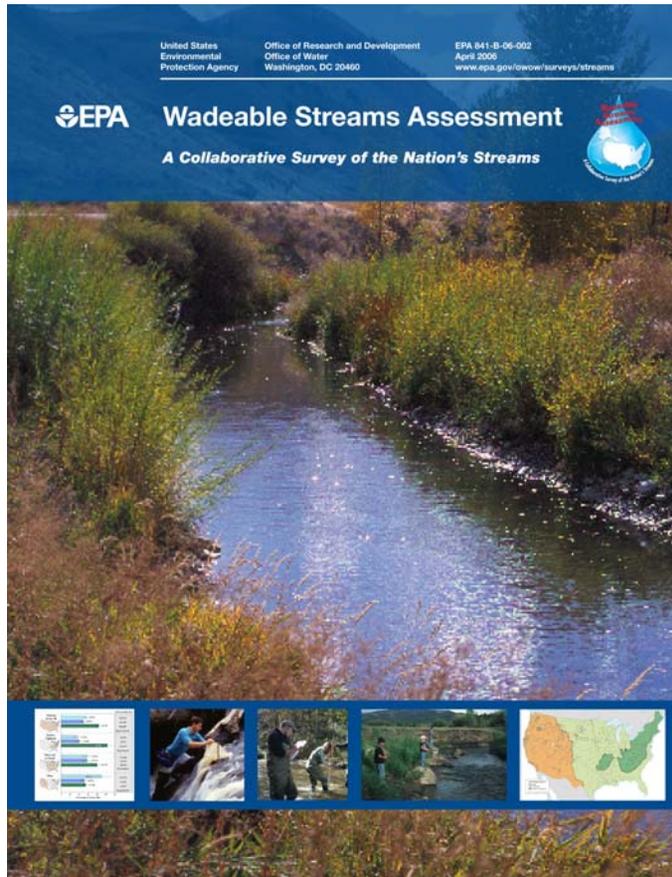


1,223,000 mi²

12 States; Regions 8, 9 and 10

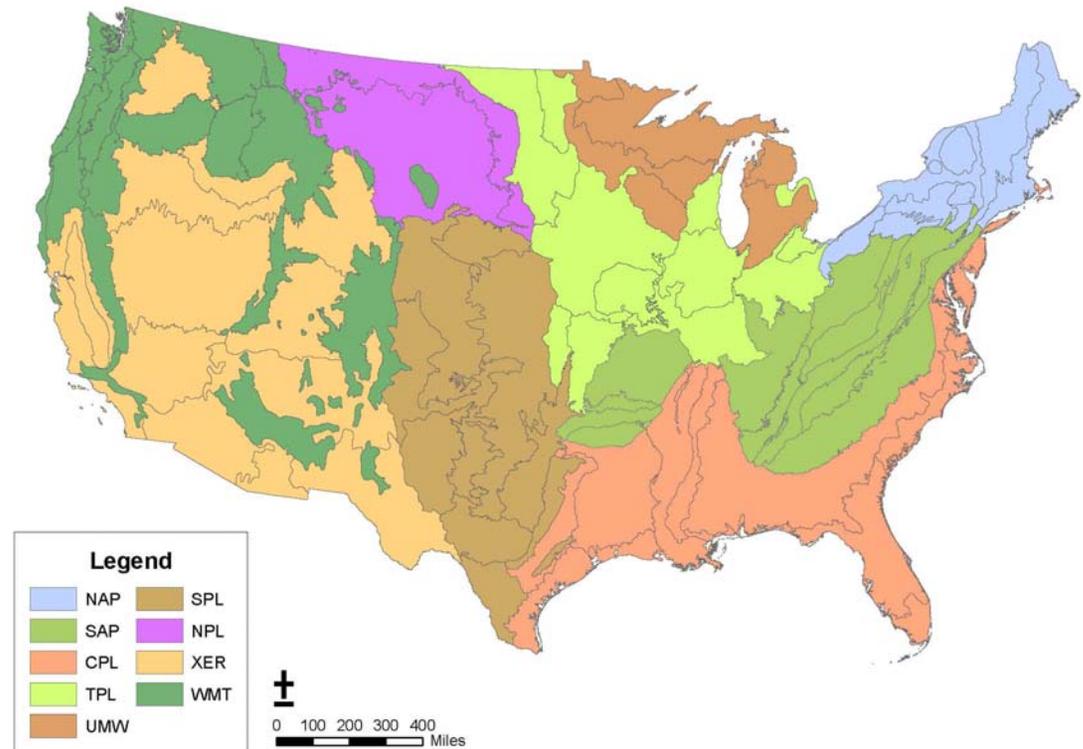


Wadeable Streams Assessment (WSA - 2005)



3,100,000 mi²
10 Regions, 48 states

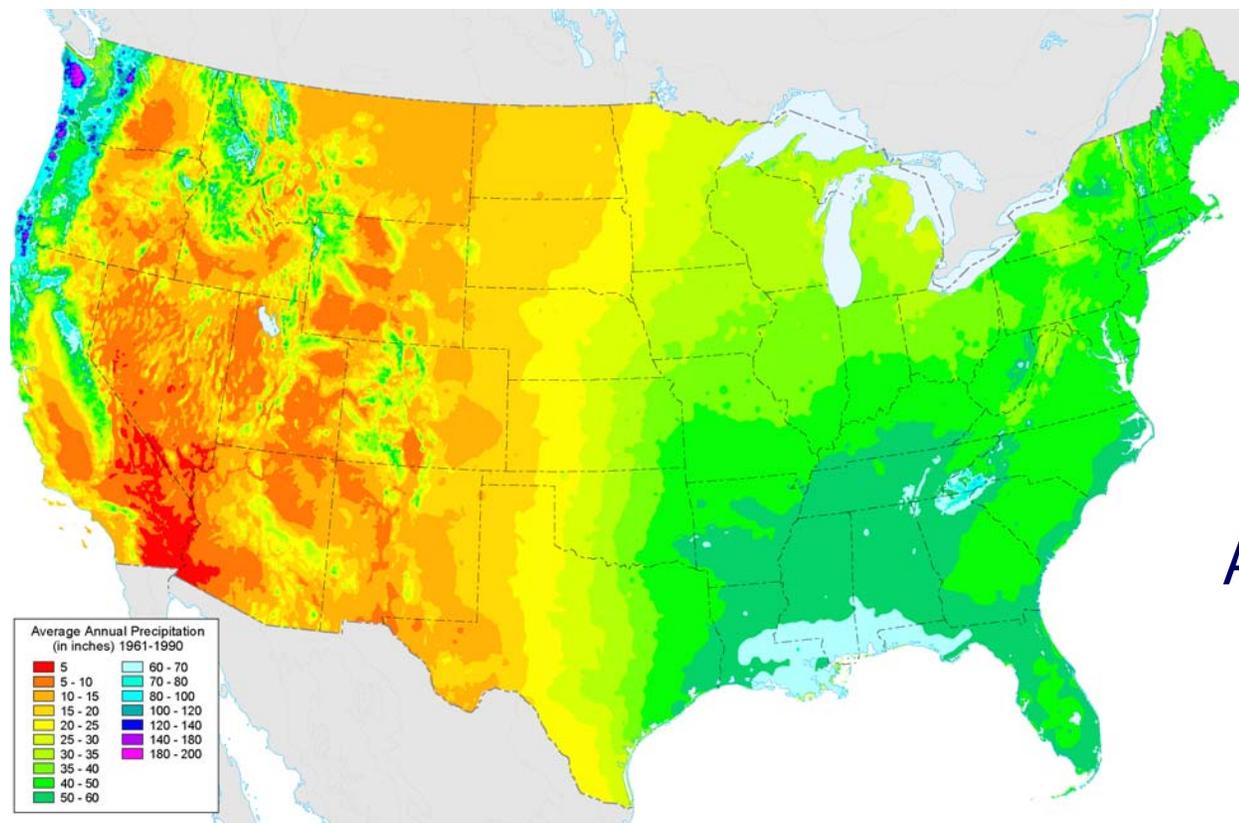
Wadeable streams
(1st through 3rd order)



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National River and Stream Assessment (2008-09)



3,100,000 mi²
10 Regions, 48 states

All perennial flowing
waters, *including*
“Great Rivers”

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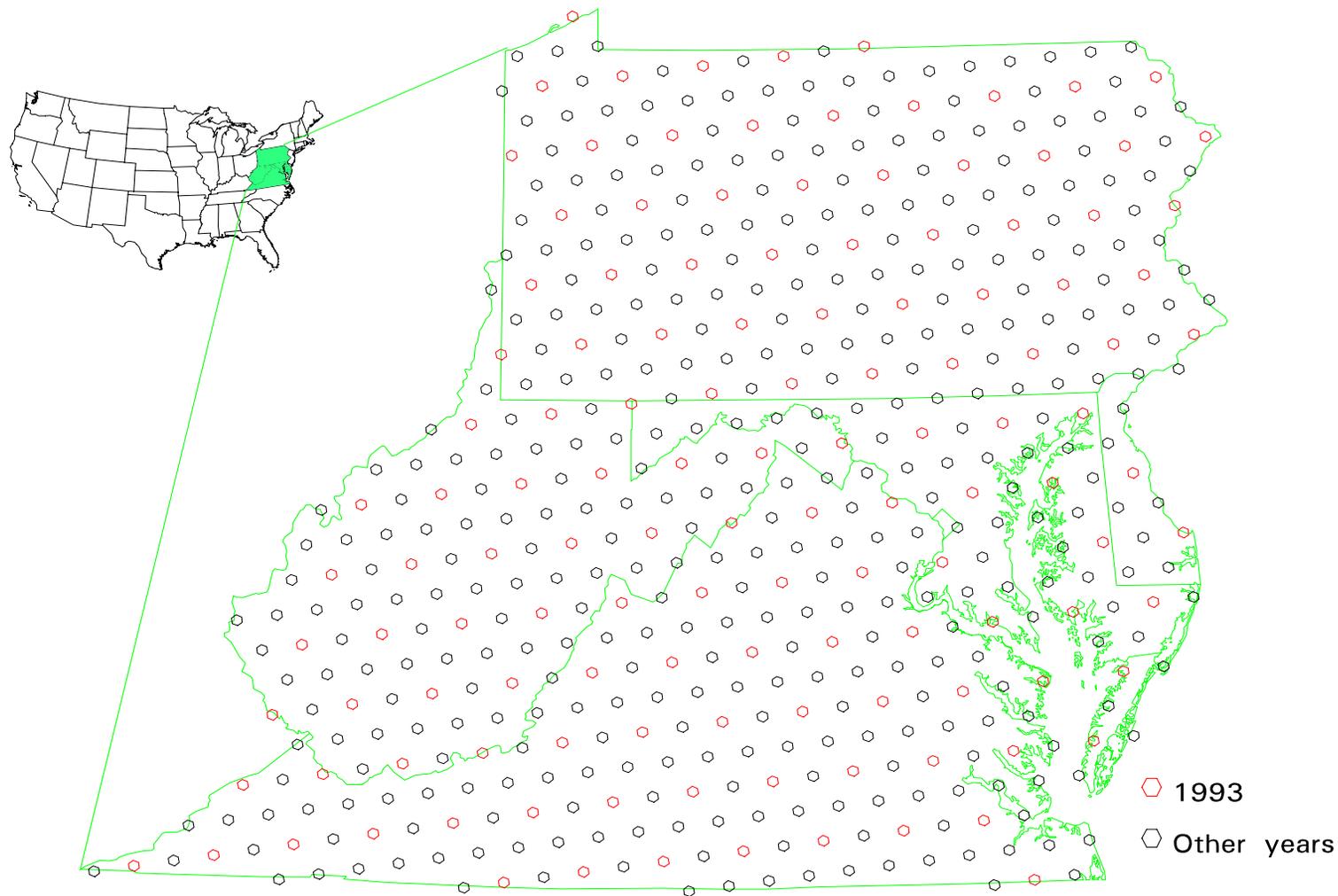
Design



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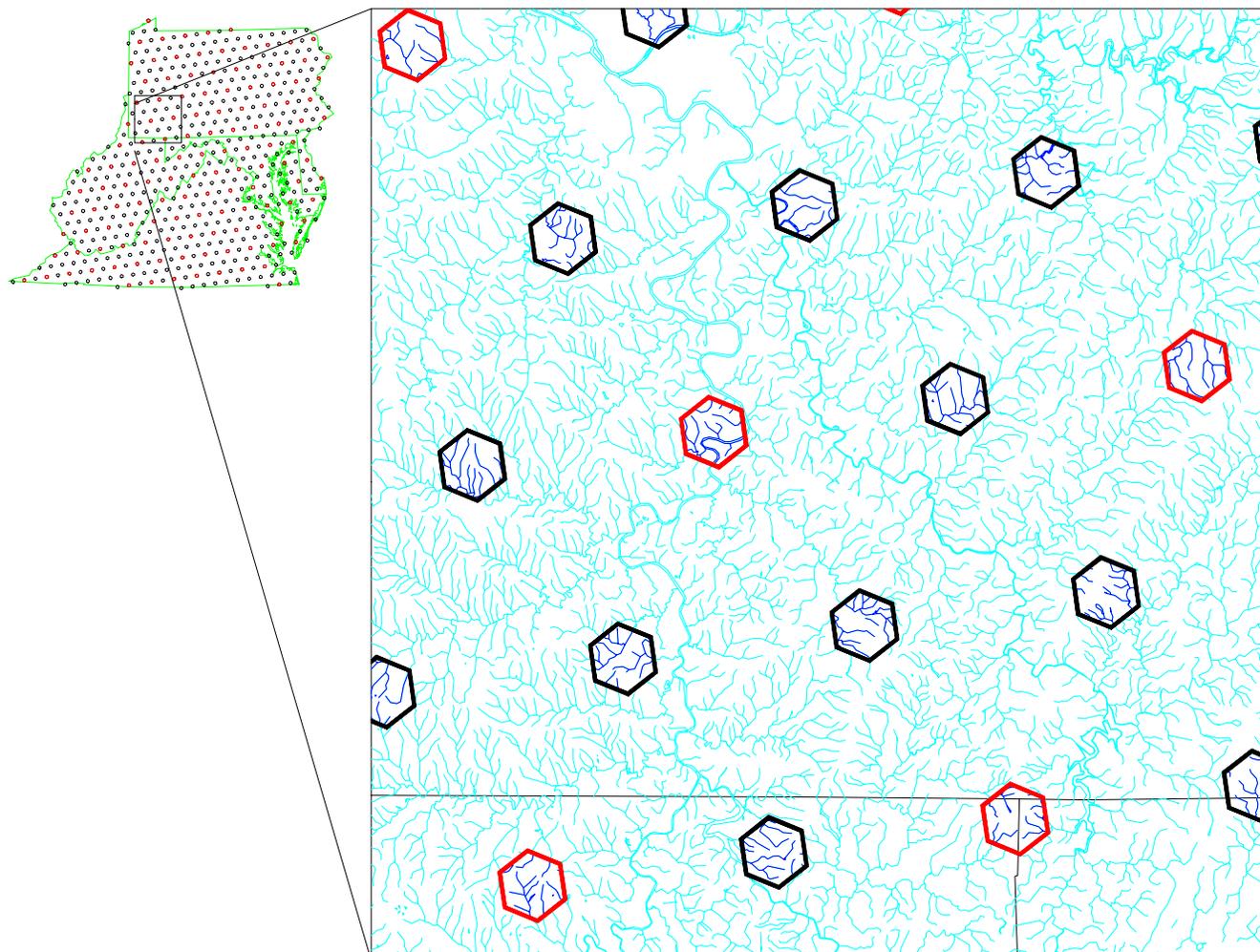
Design - MAHA Site Selection



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Design - MAHA Site Selection

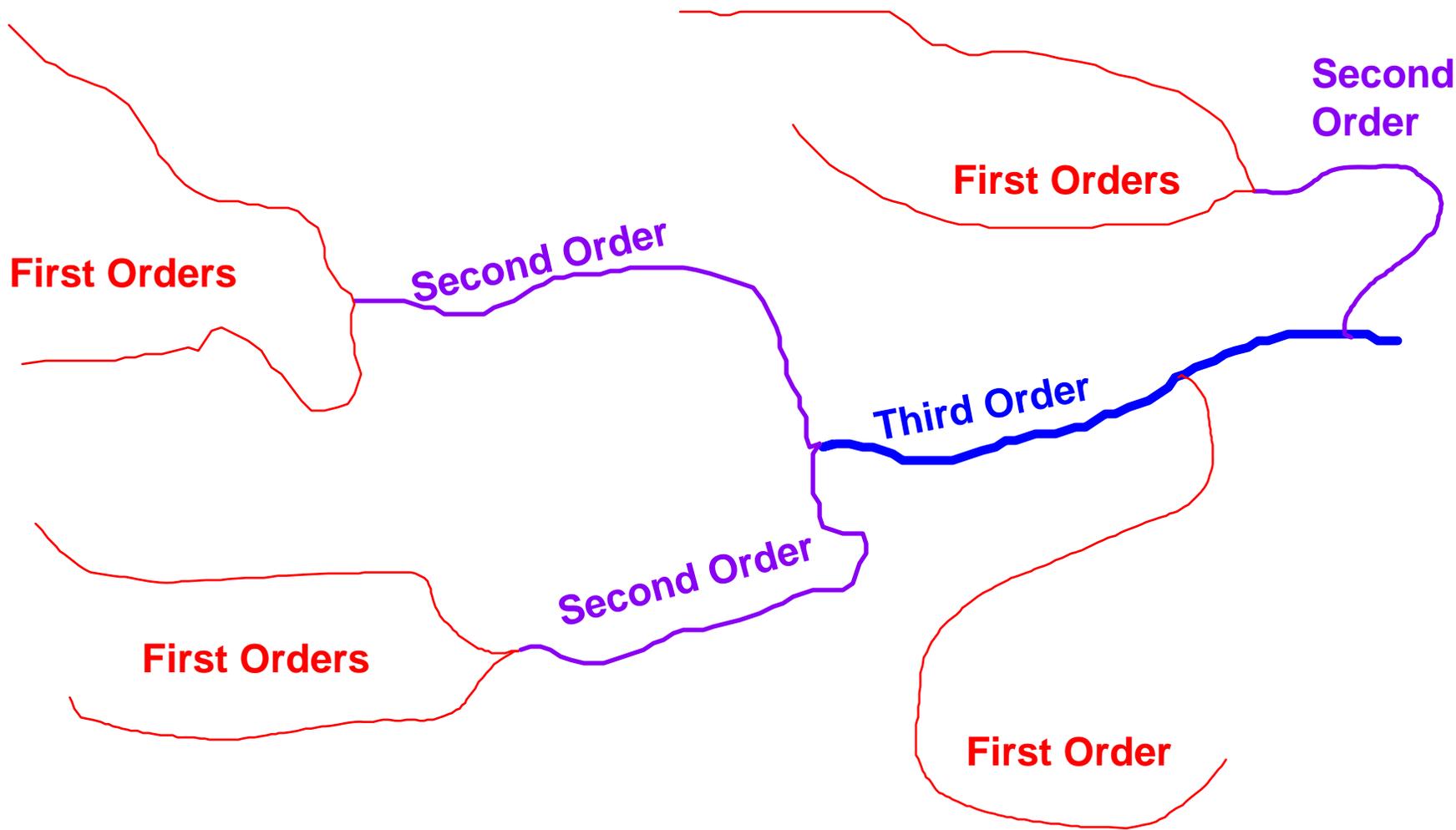


- 1993
- Other years

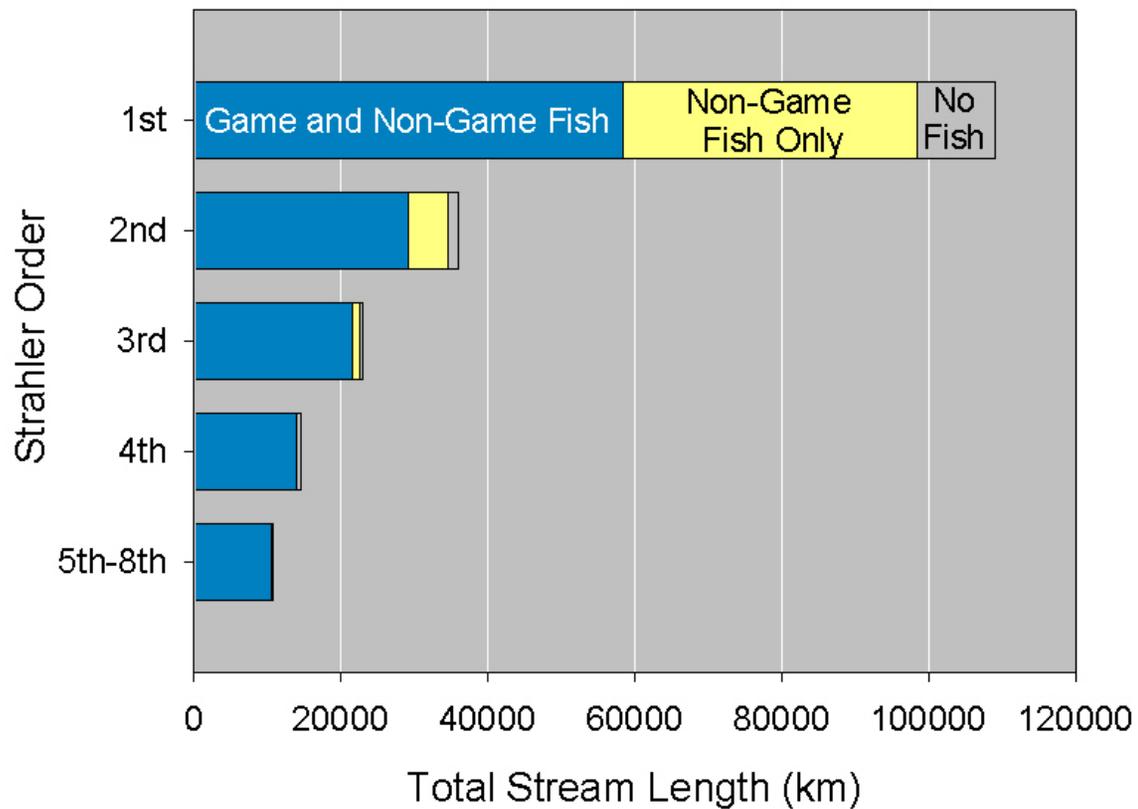
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Strahler Orders

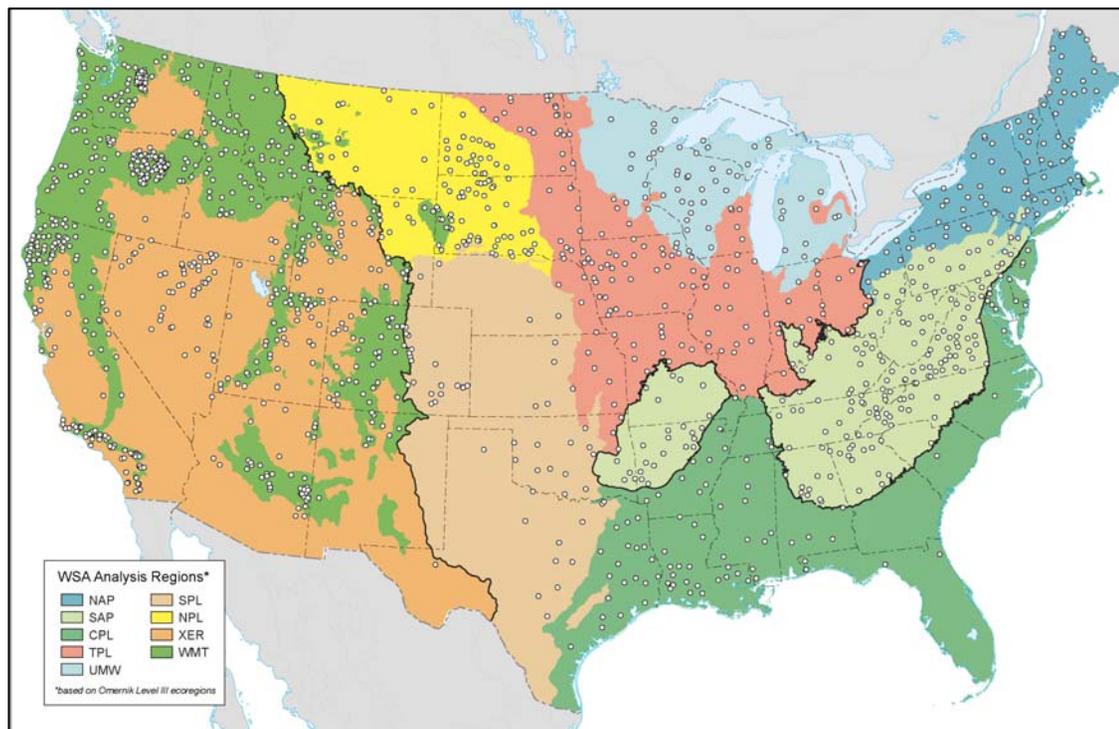


Strahler Orders



Design - GRTS

Eastern portion of WSA



Spatially-balanced

Unequal probabilities based on:

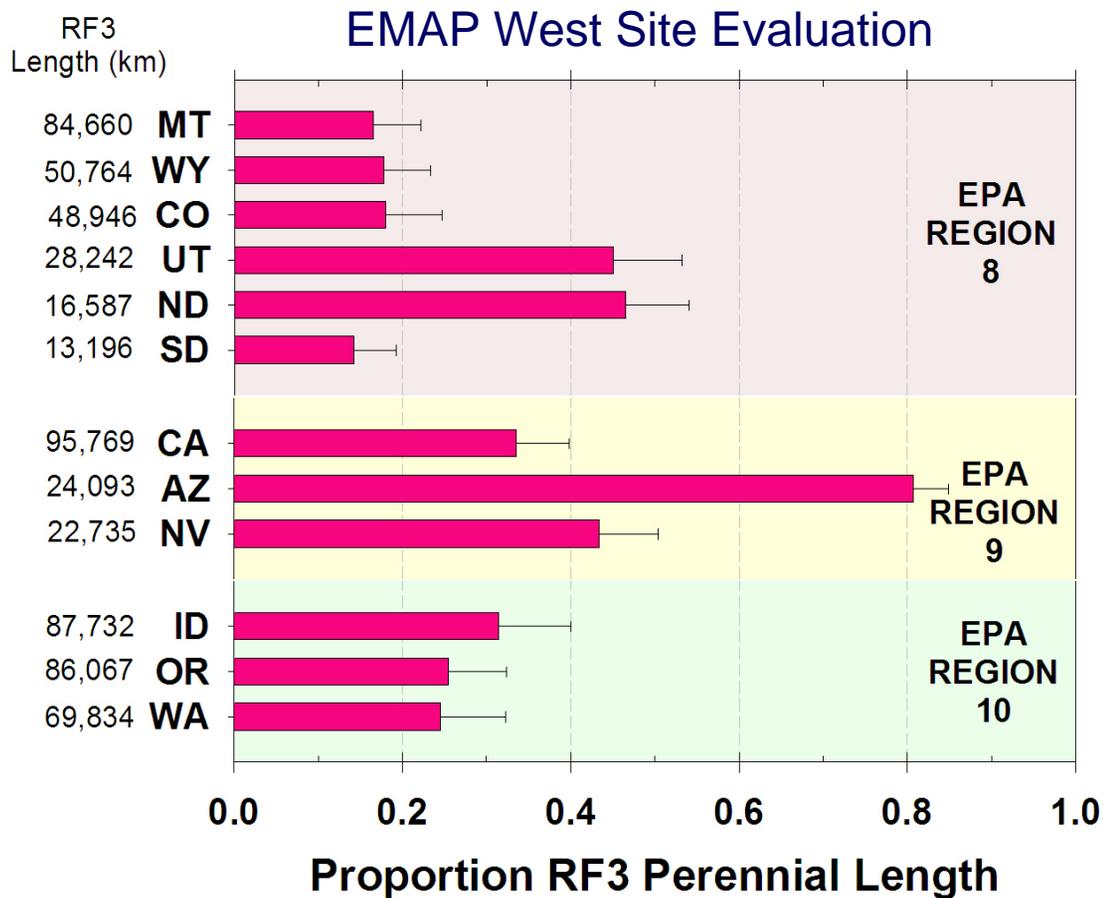
- Omernik ecoregion
- USEPA region
- Strahler order categories:

Expected sample size 500 sites

Additional sites selected to be used when initial sites can not be sampled

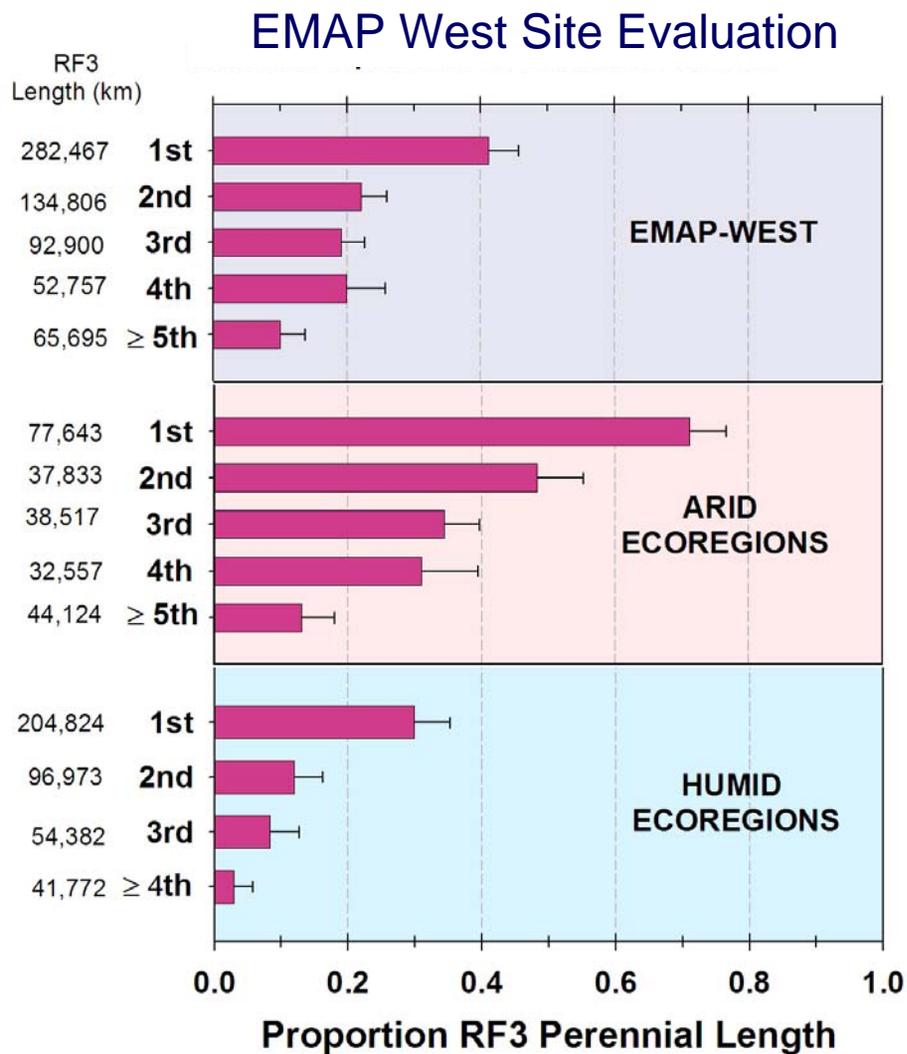
- Non-wadeable stream
- Landowner access denial
- Physically inaccessible

Design Dealing with an Imperfect Frame



Design

Dealing with an Imperfect Frame - EMAPW

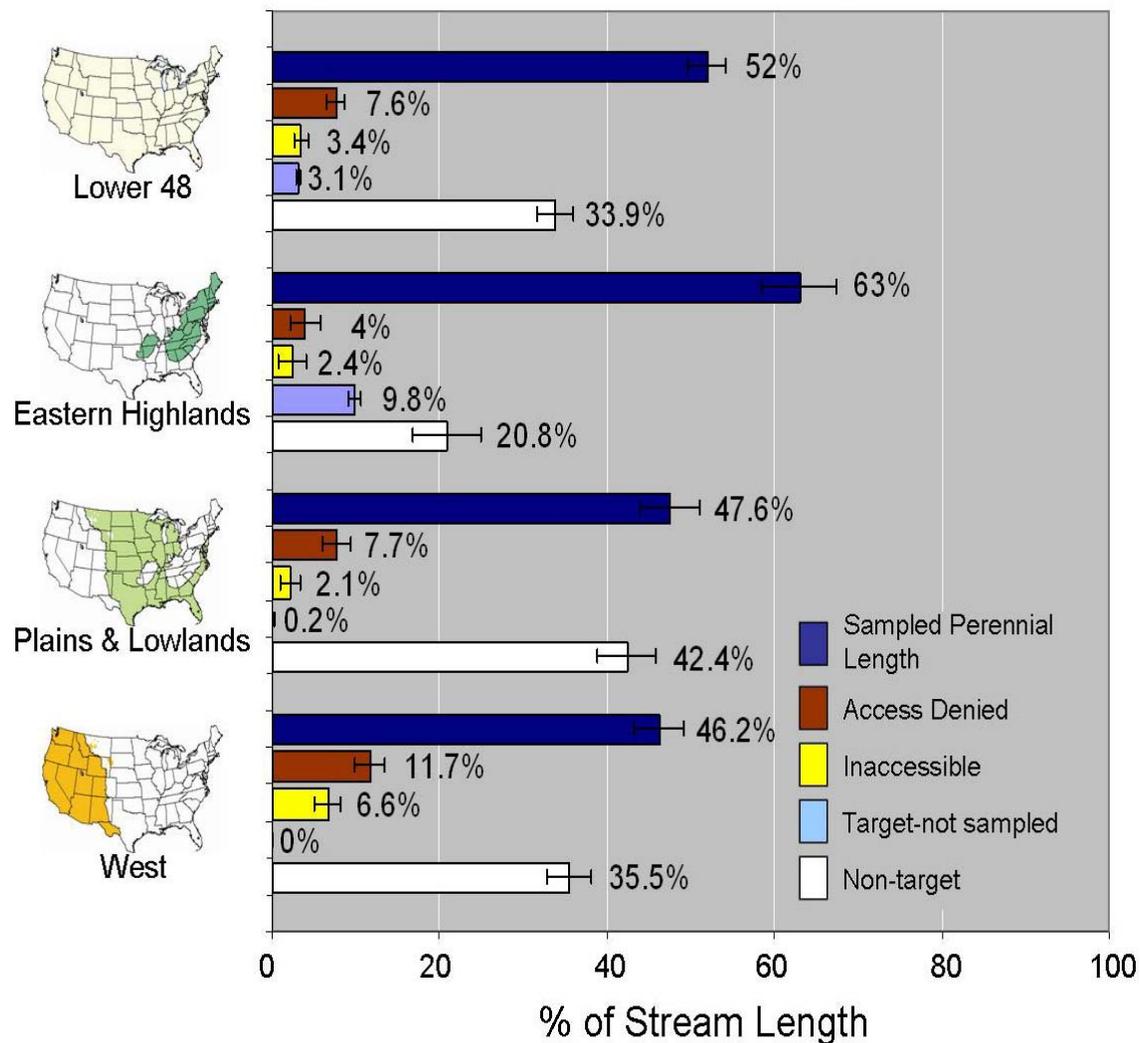


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Design

Dealing with an Imperfect Frame - WSA



Based on office and field evaluation of sites in sample.

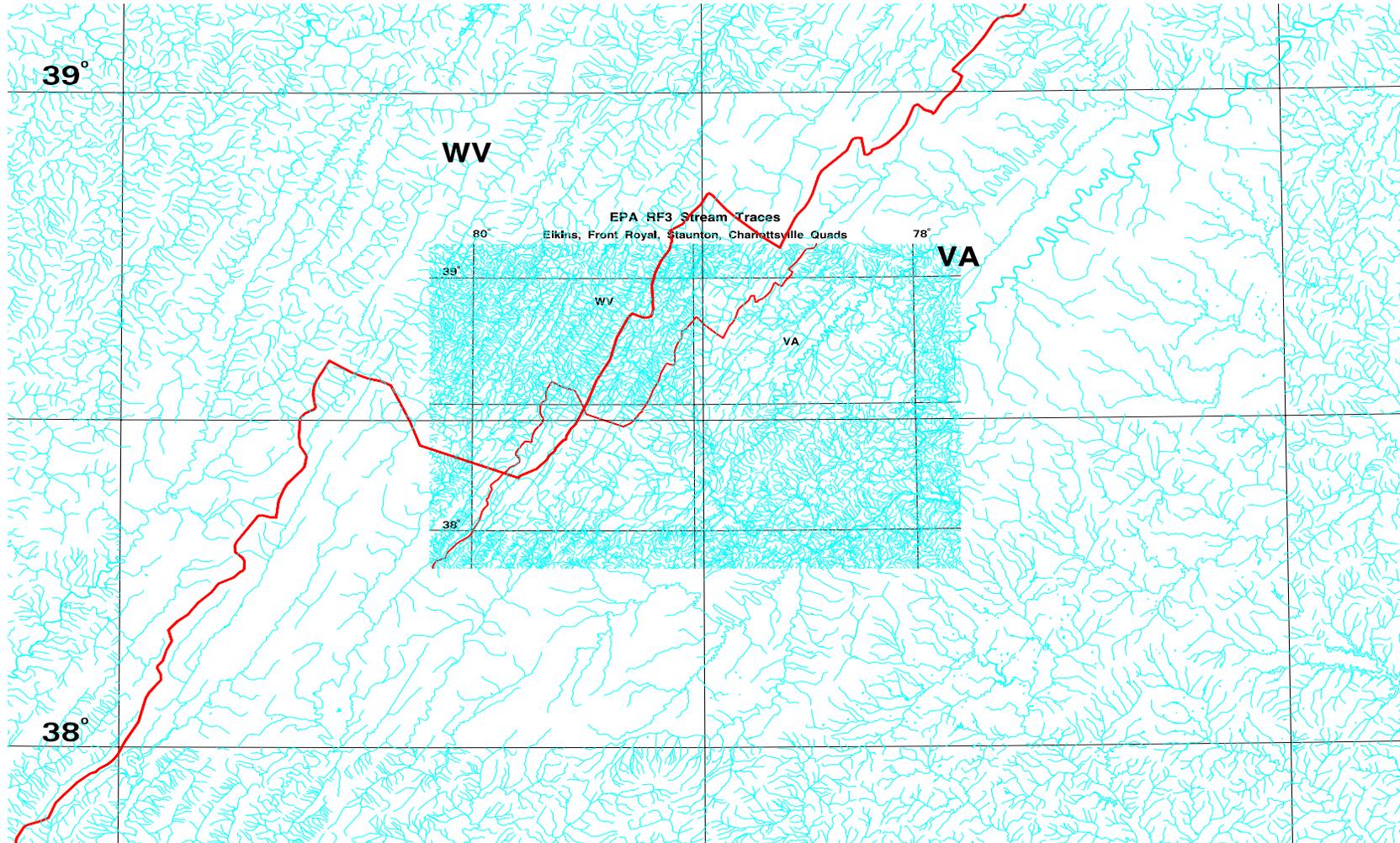
In each region, percentages are percent of NHD length in the region

EPA RF3 Stream Traces

80°

Elkins, Front Royal, Staunton, Charlottesville Quads

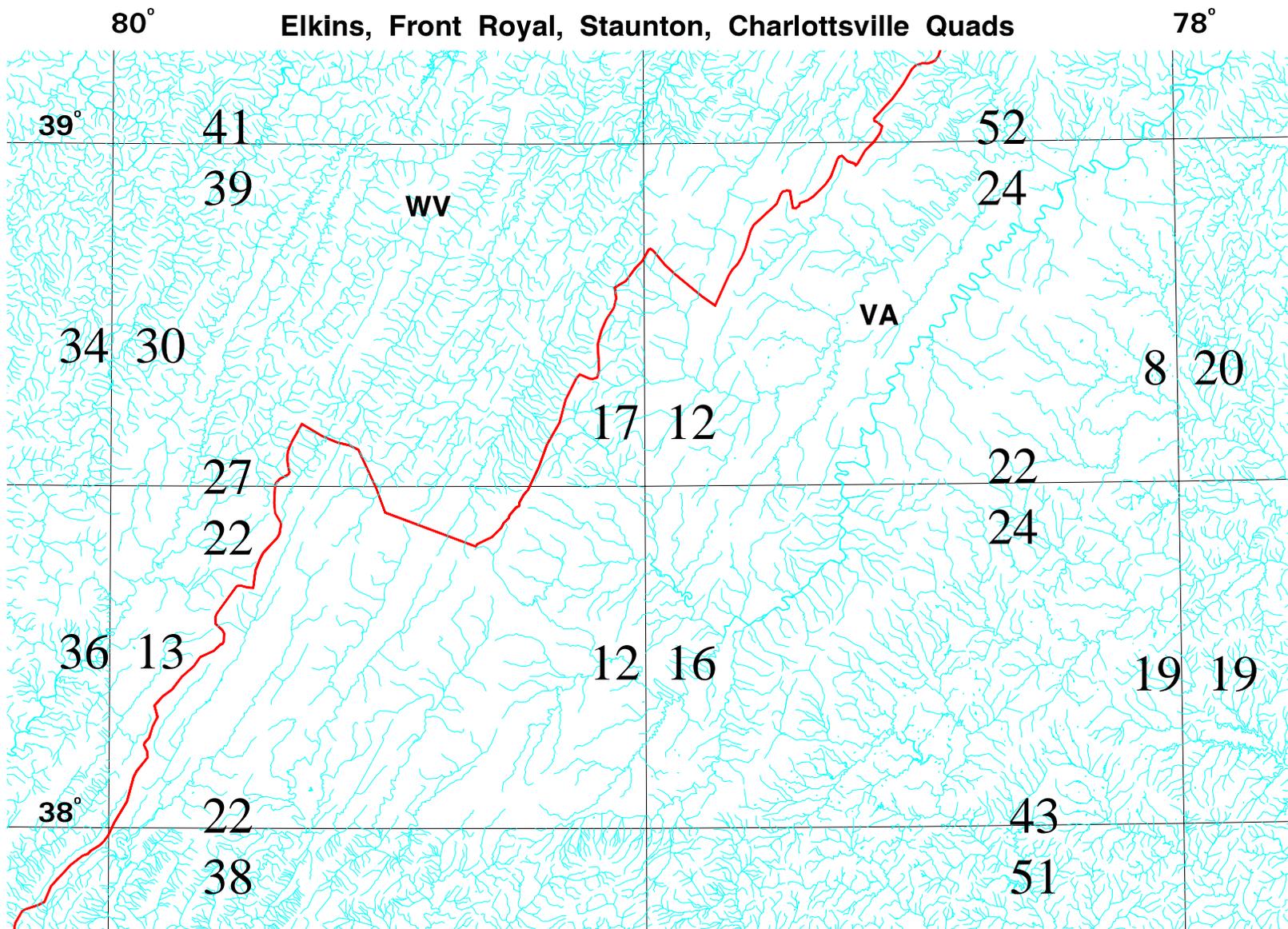
78°



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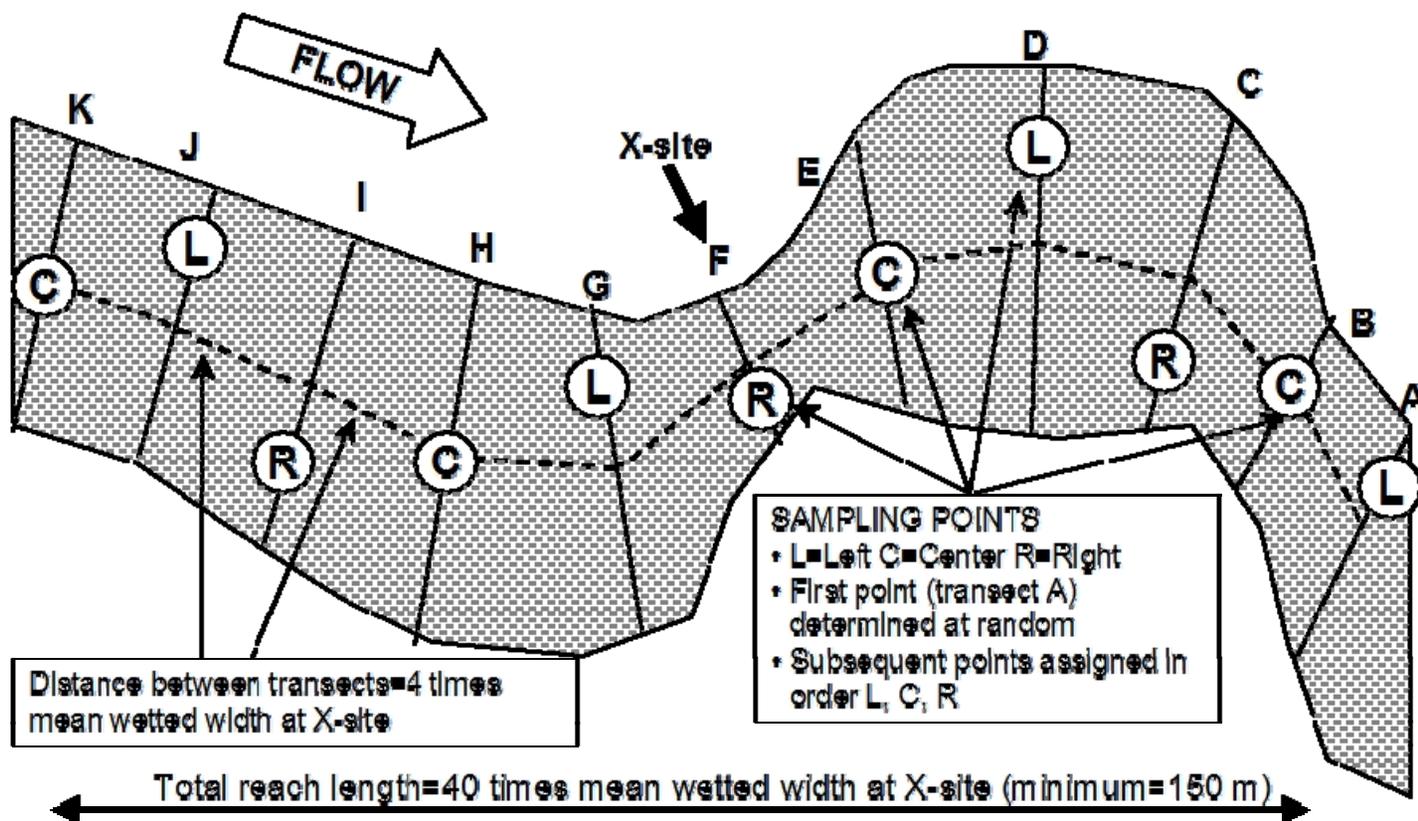
EPA RF3 Stream Traces



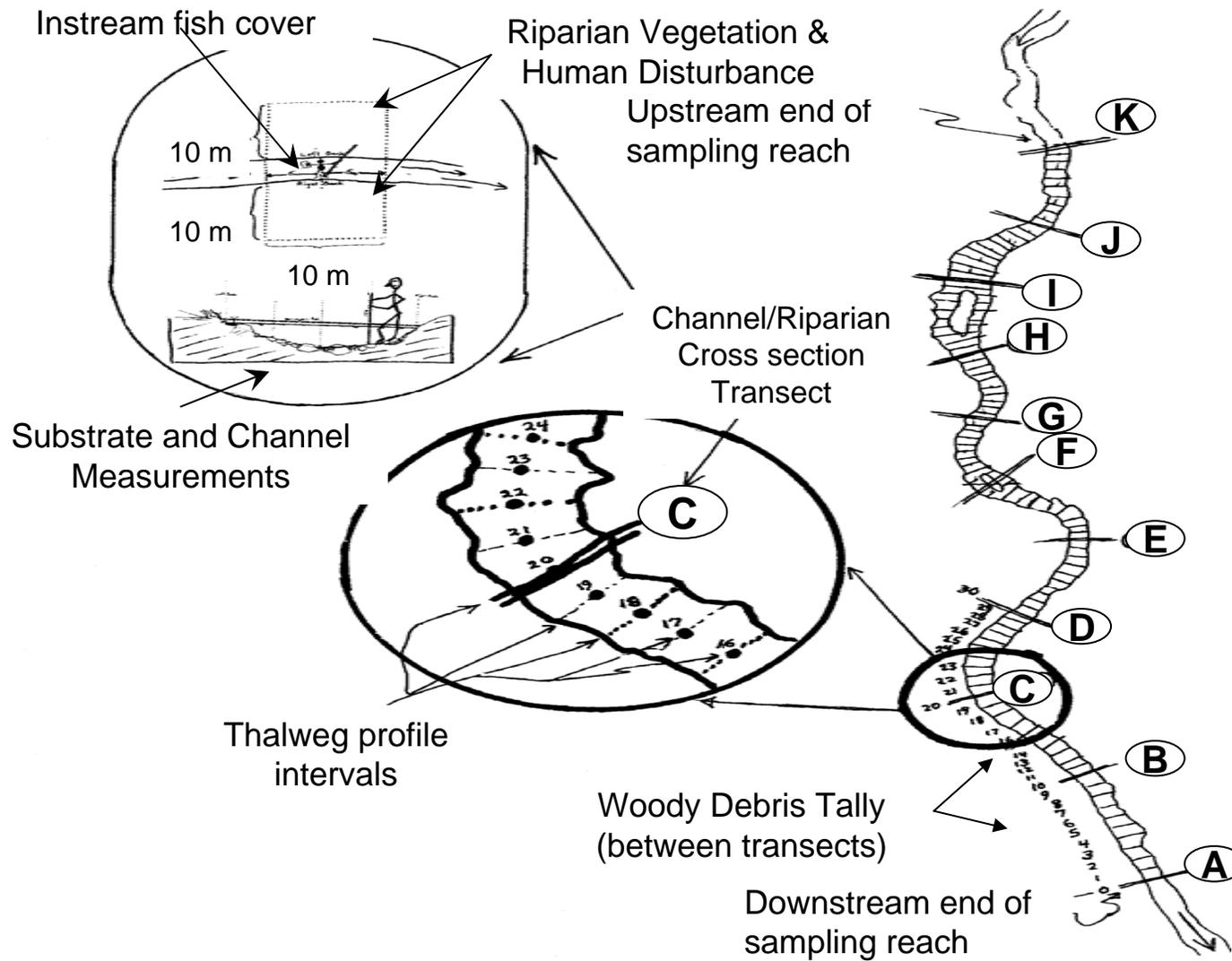
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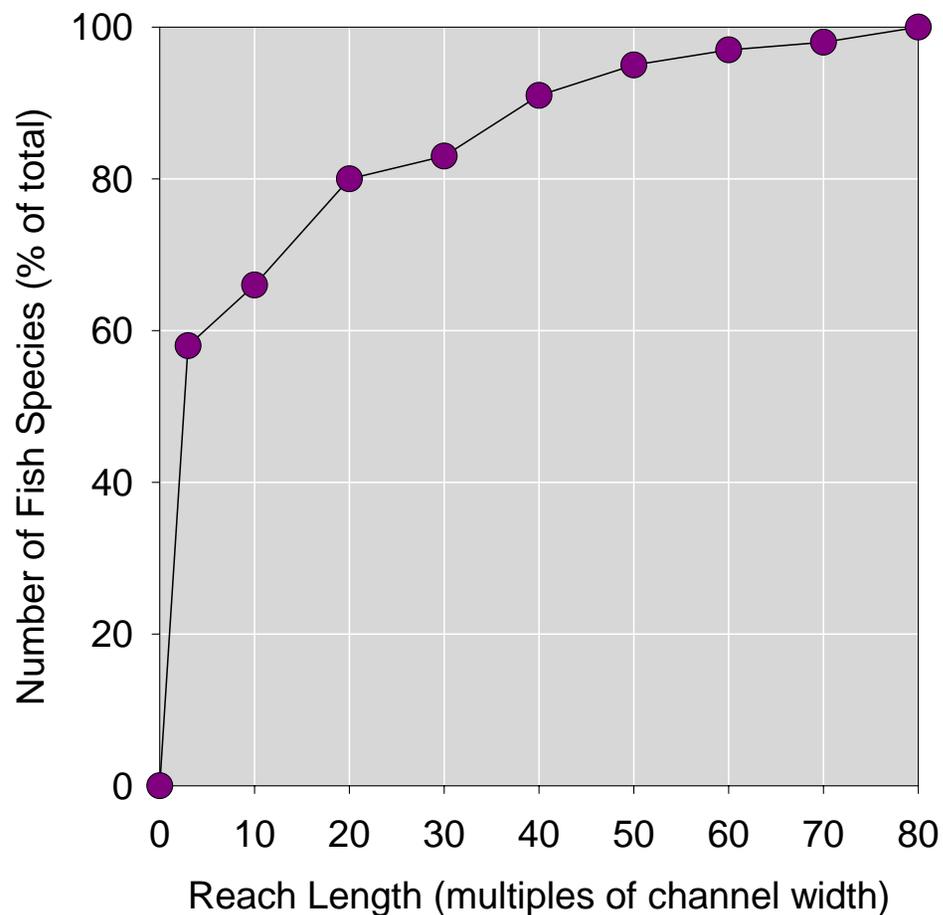
Plot Design



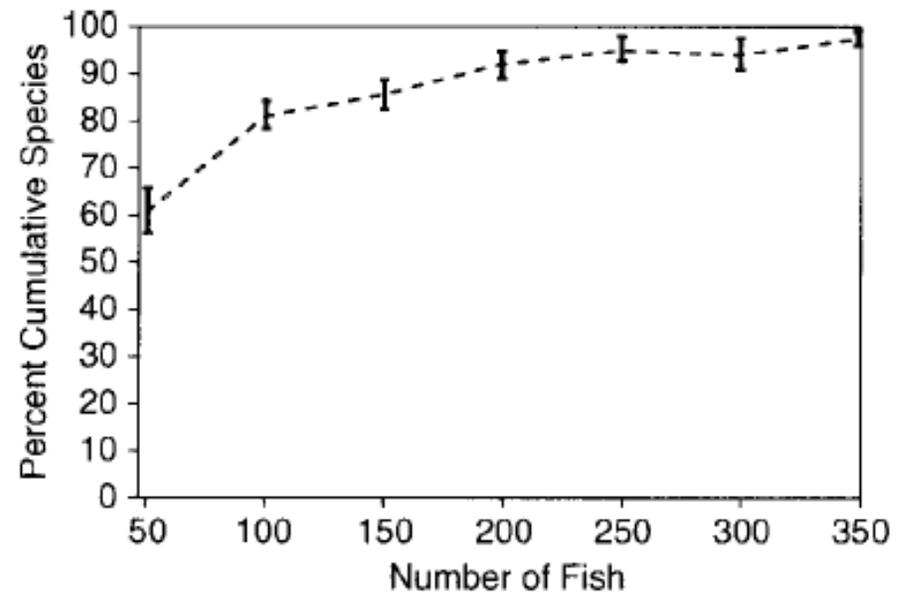
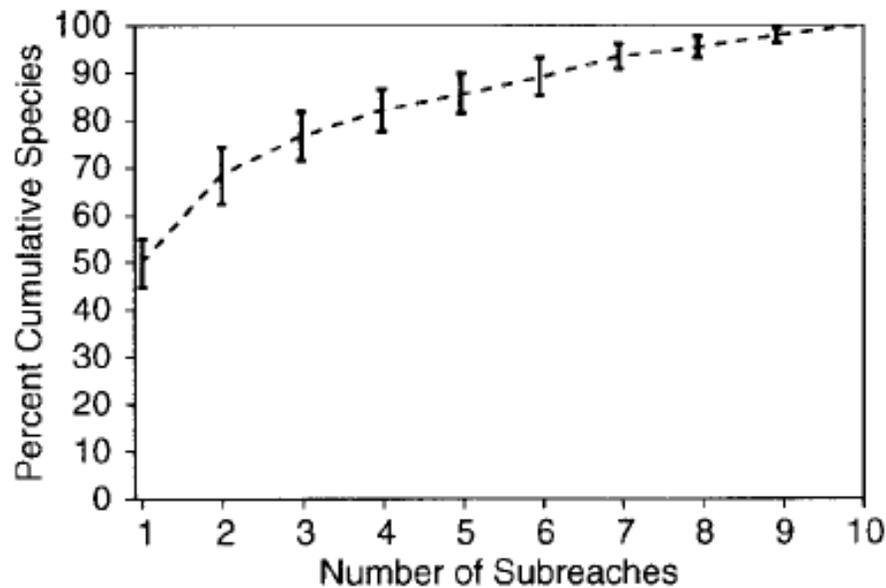
Plot Design



Plot Design - Sample Sufficiency for Streams



Plot Design - Sample Sufficiency for Rivers



Biological Indicators

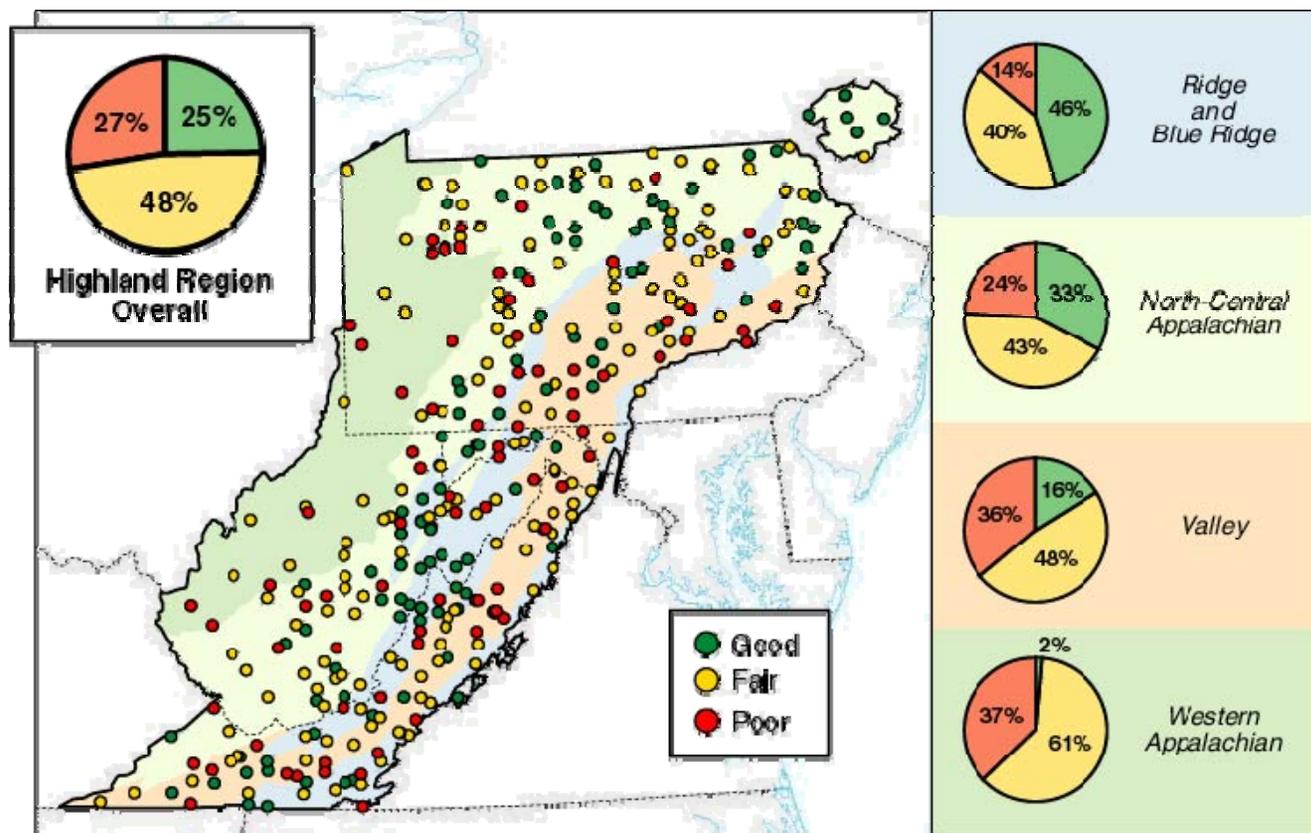


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MAHA Macroinvertebrate Results

Number of EPT Taxa

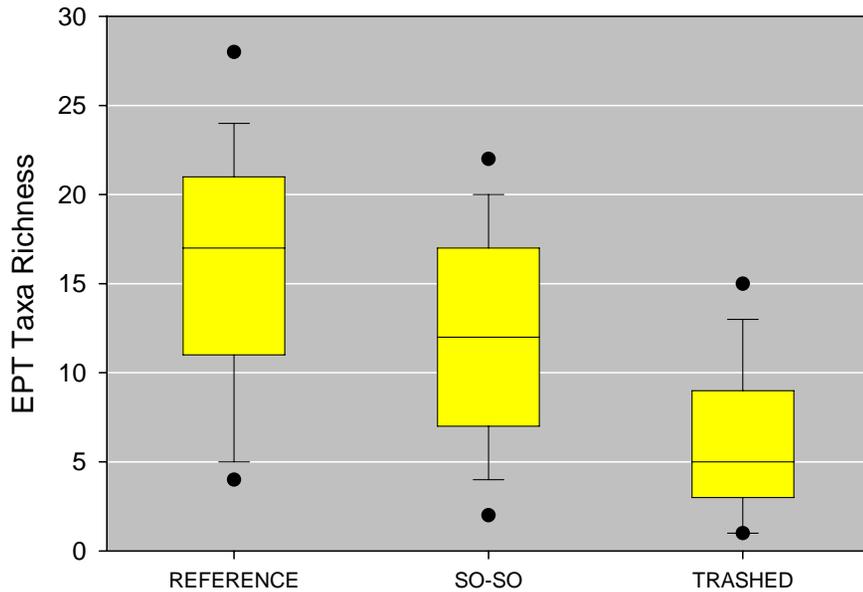


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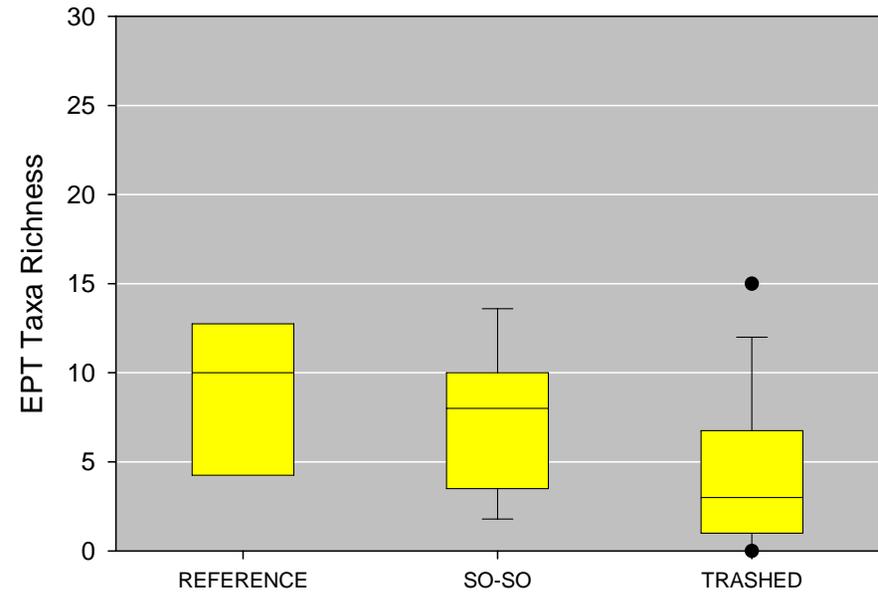
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EPT Results in Riffles and Pools

MAHA Riffles



MAHA Pools

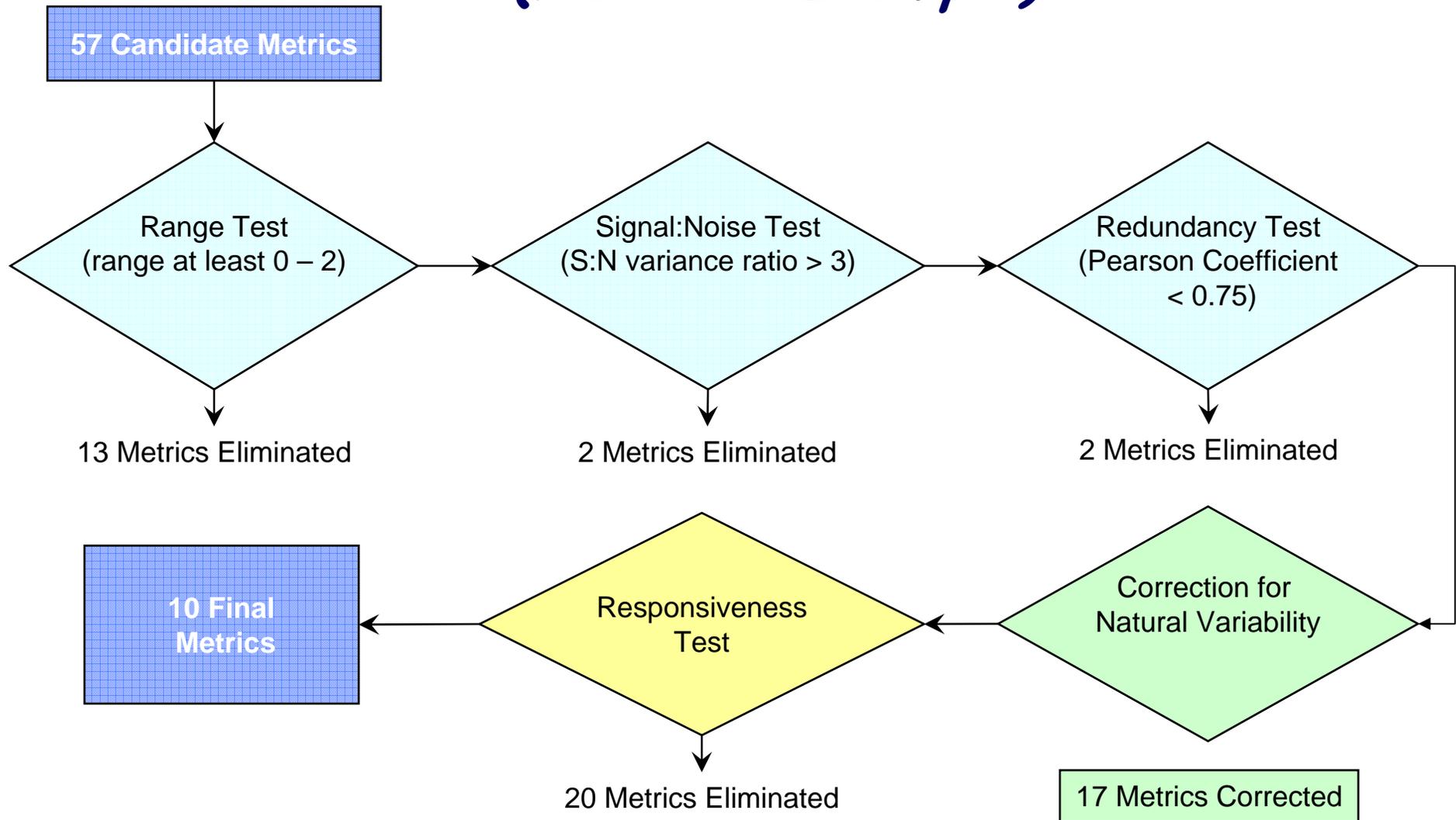


Index Development Approach

Example Fish 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 benthic species	PCARN	prop. piscivore-invert.(piscinv+pisciv)
NSCATO	Number of sucker species	PCGBU	prop. of indiv. as clear gravel buryers
NSCATO2	Number 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. Omnivore 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		

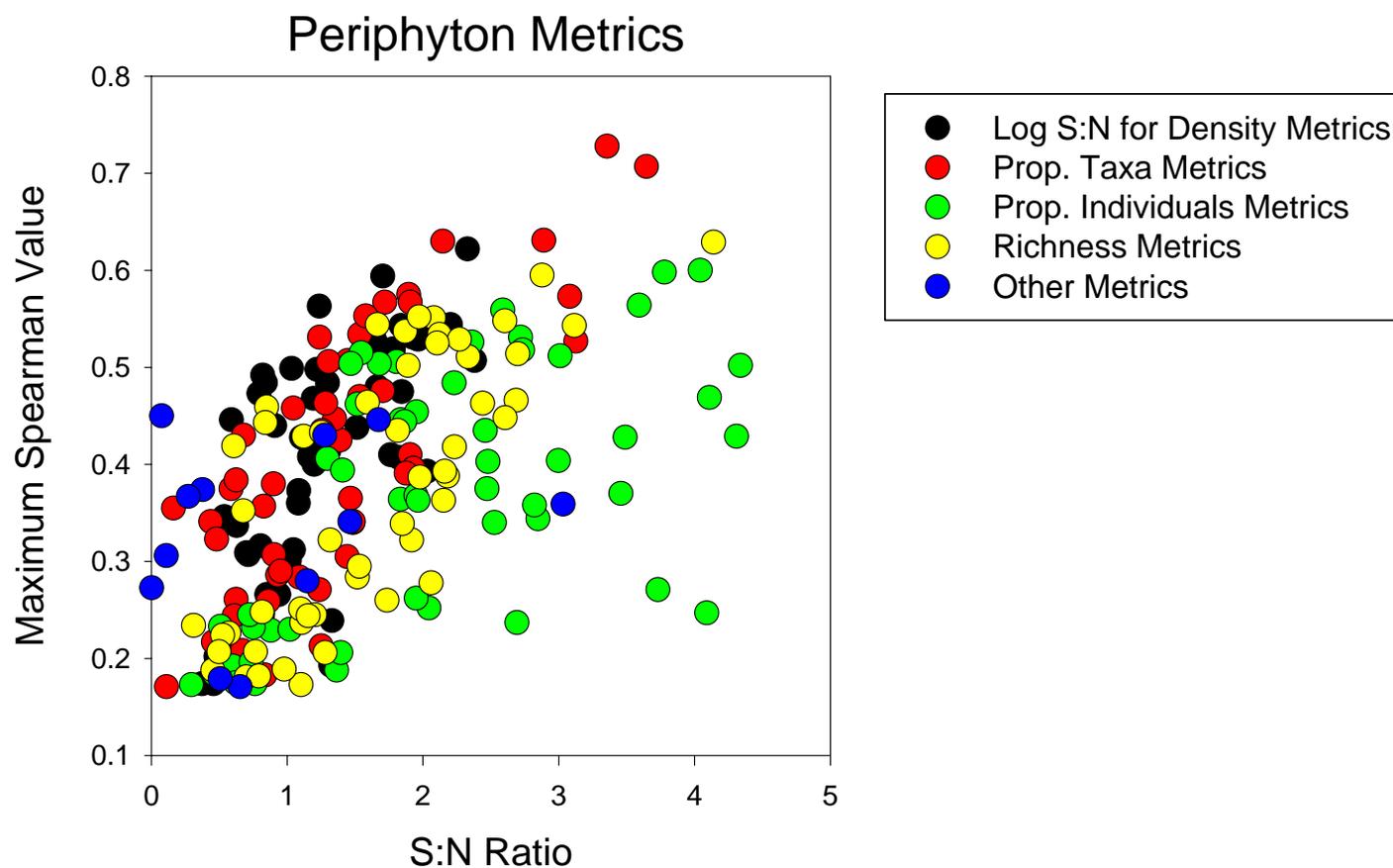
Index Development Approach (Fish IBI Example)



Index Development Approach

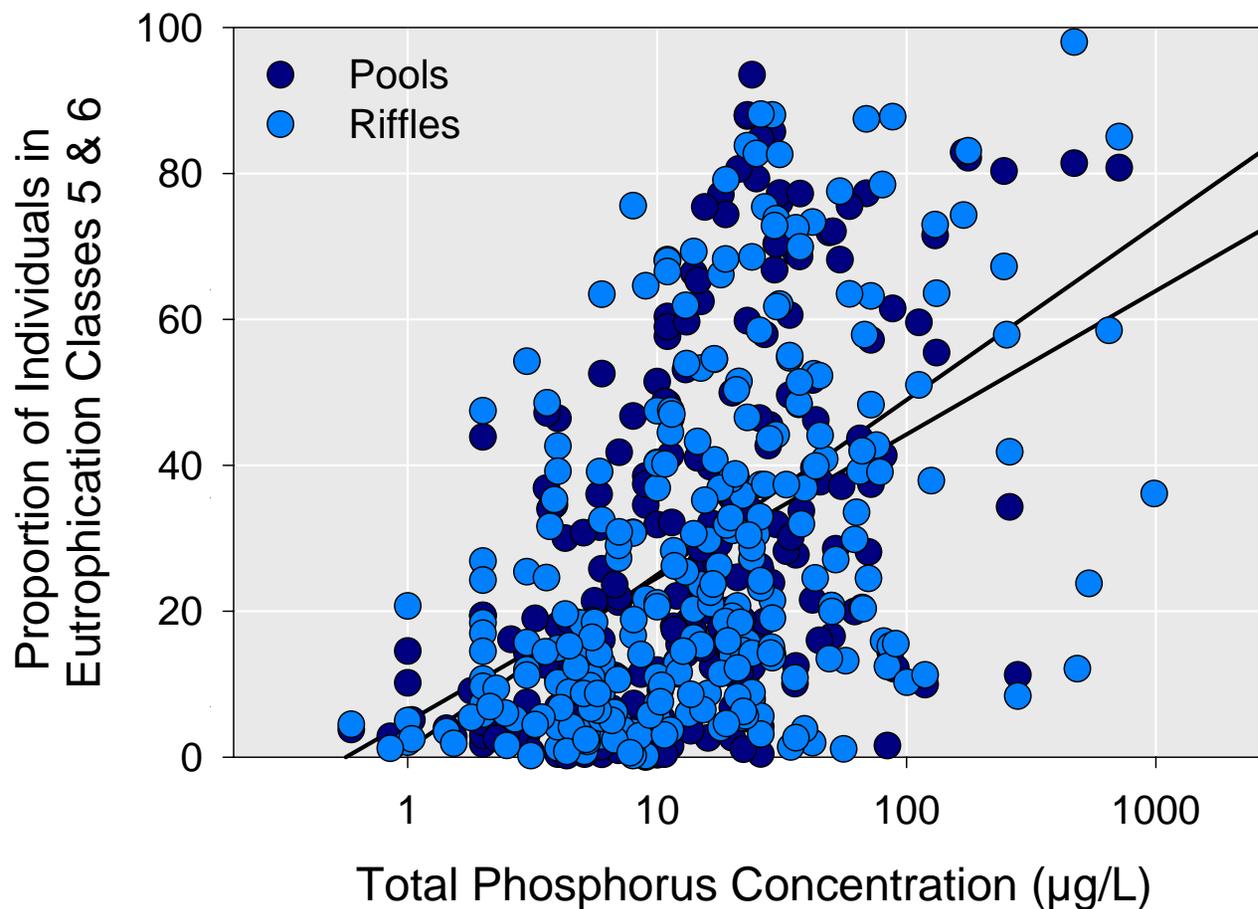
(Signal:Noise Test)

Signal:Noise = ratio of between-site variance and within-site variance (based on repeat samples)



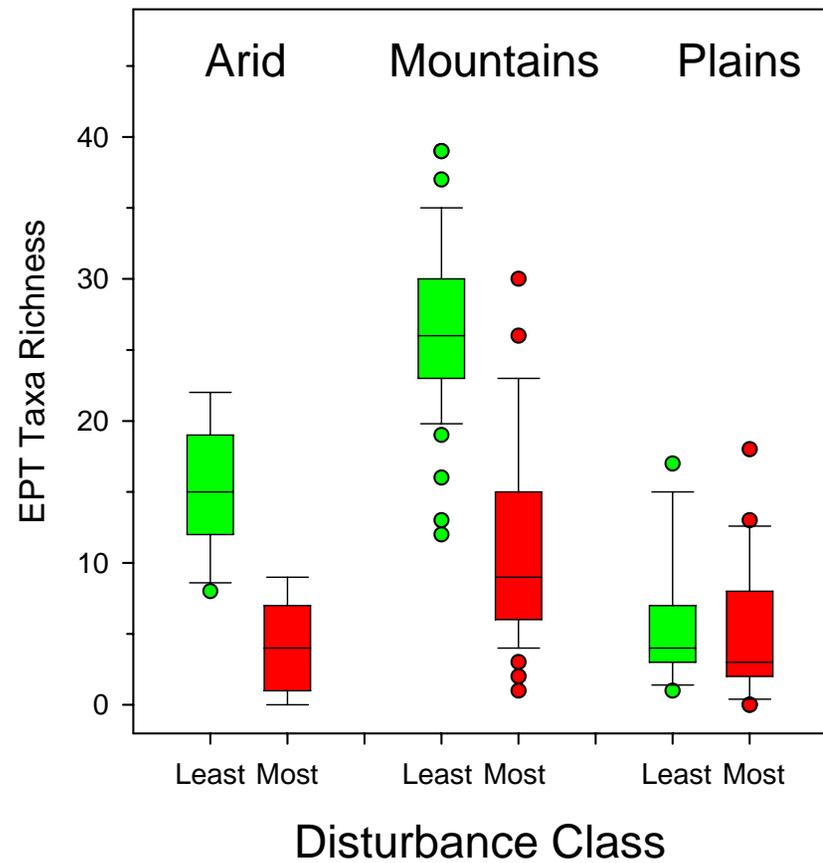
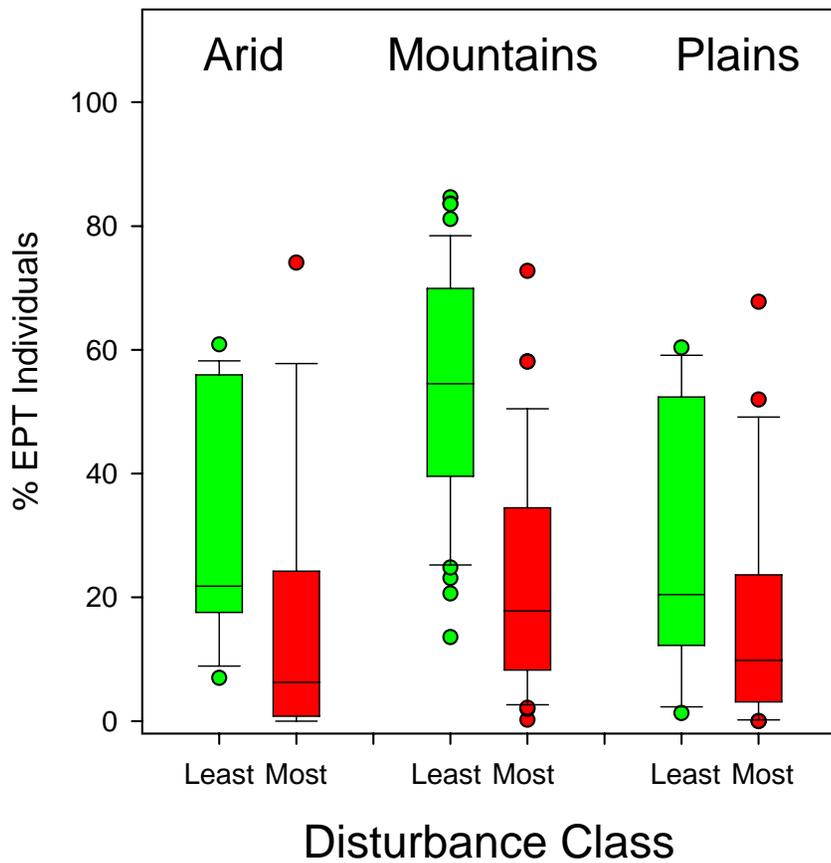
Index Development Approach (Example of Periphyton Responsiveness)

Periphyton Metric Responsiveness

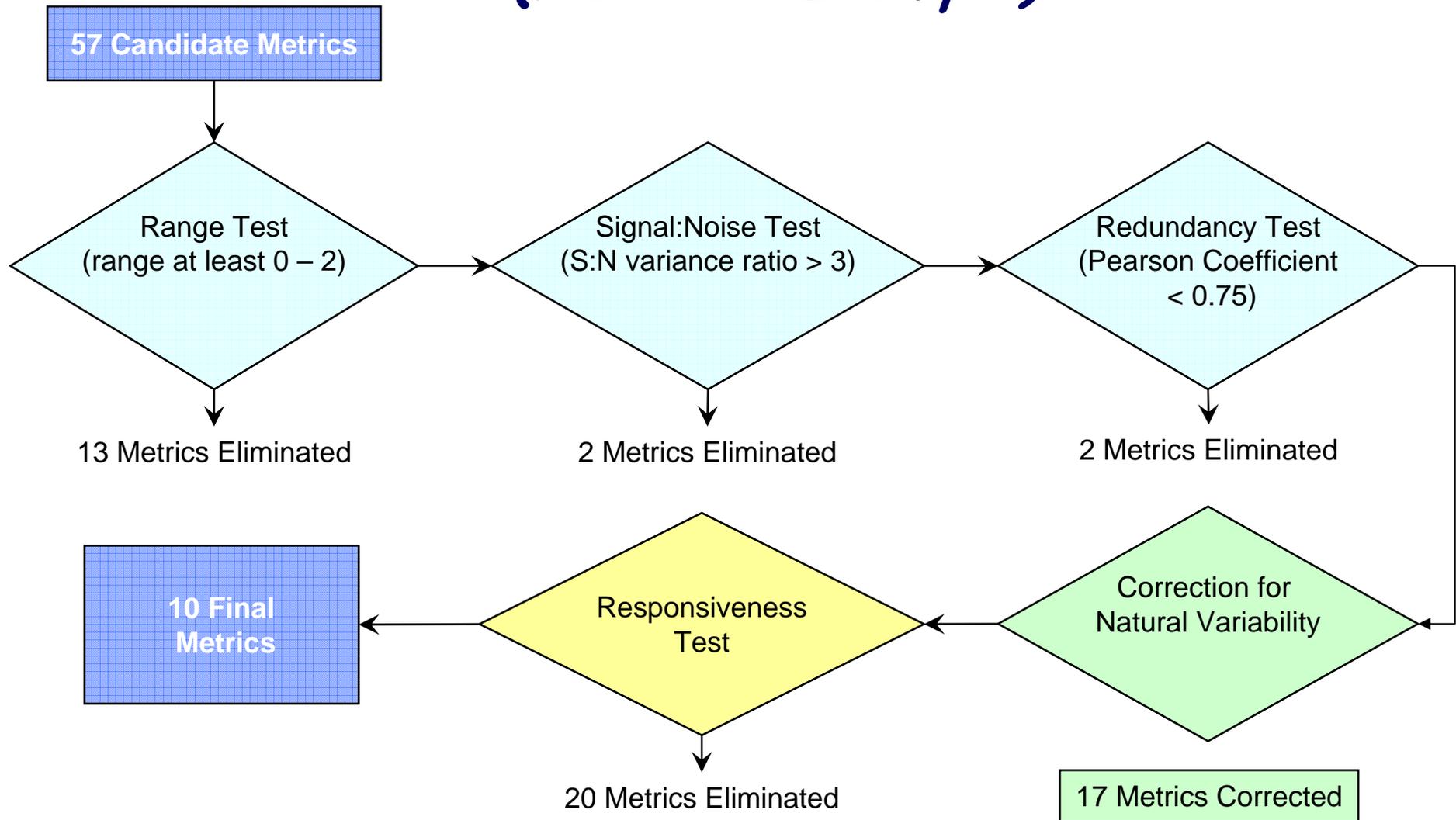


Index Development Approach

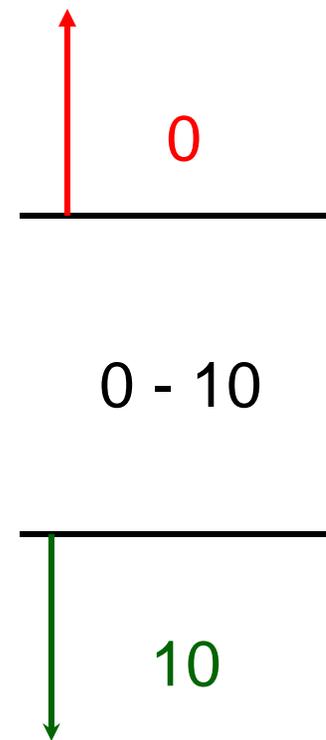
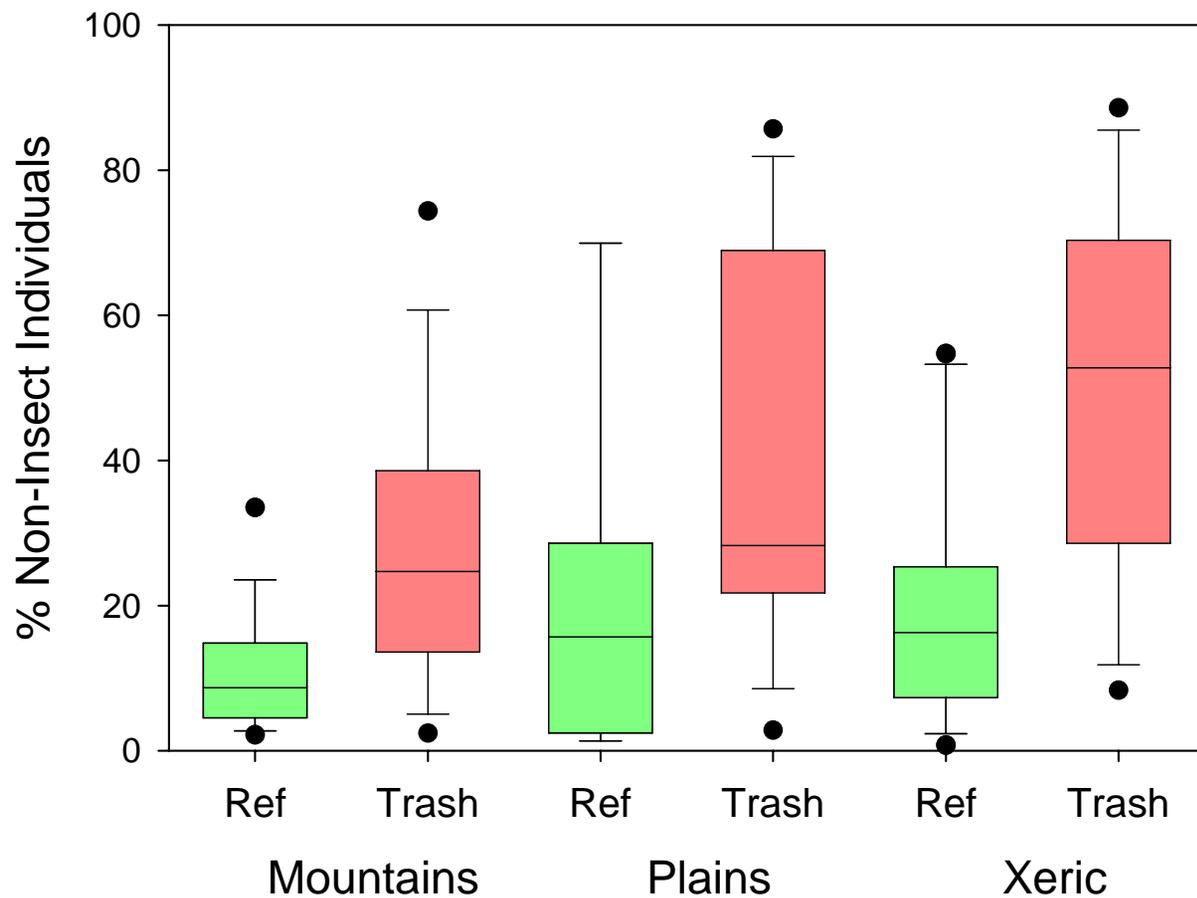
Responsiveness Quick and Dirty Screen



Index Development Approach (Fish IBI Example)



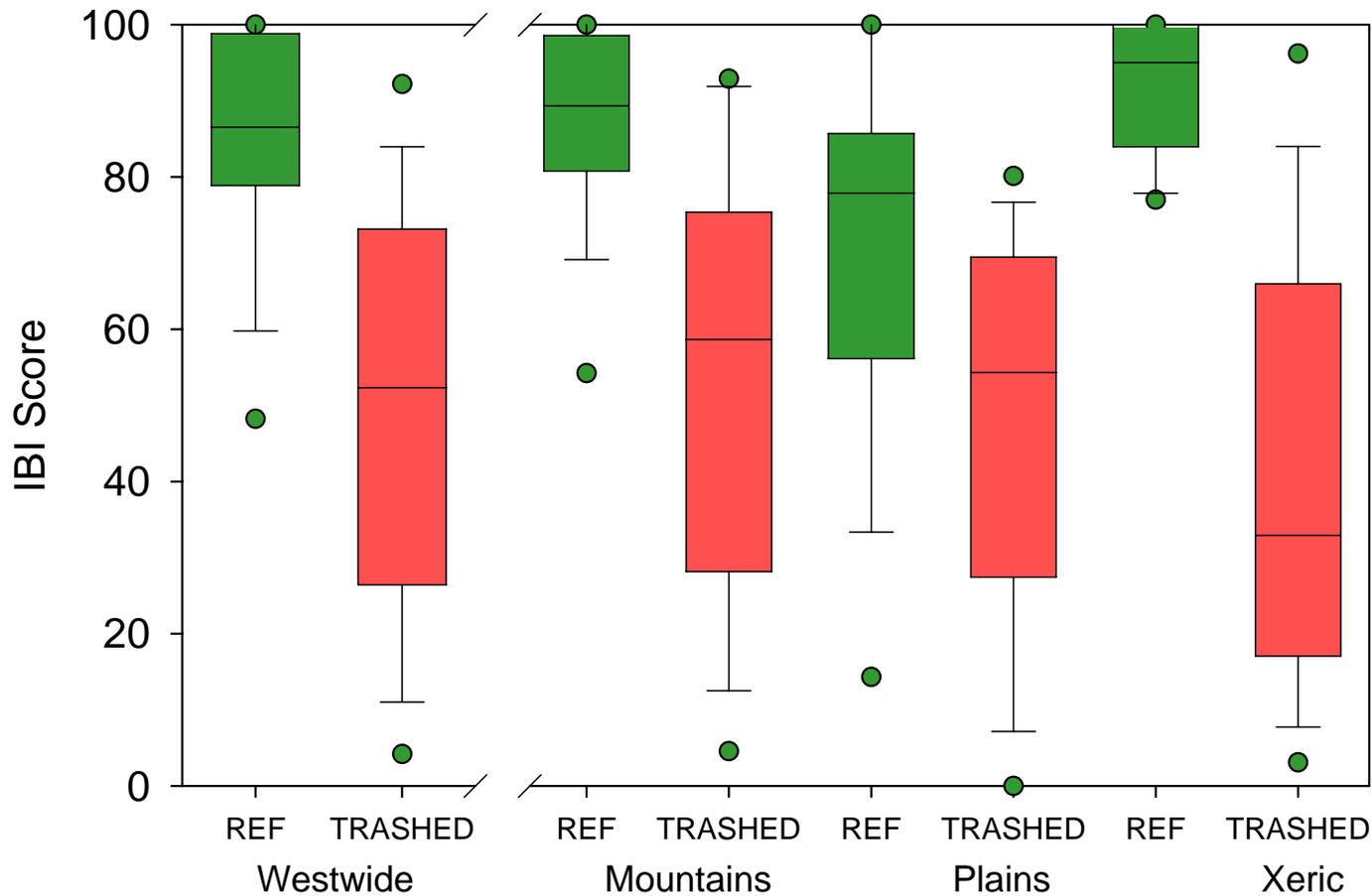
Metric Scoring



Responsiveness of Final Index

EMAP West Fish IBI

Reference vs. Trashed Sites

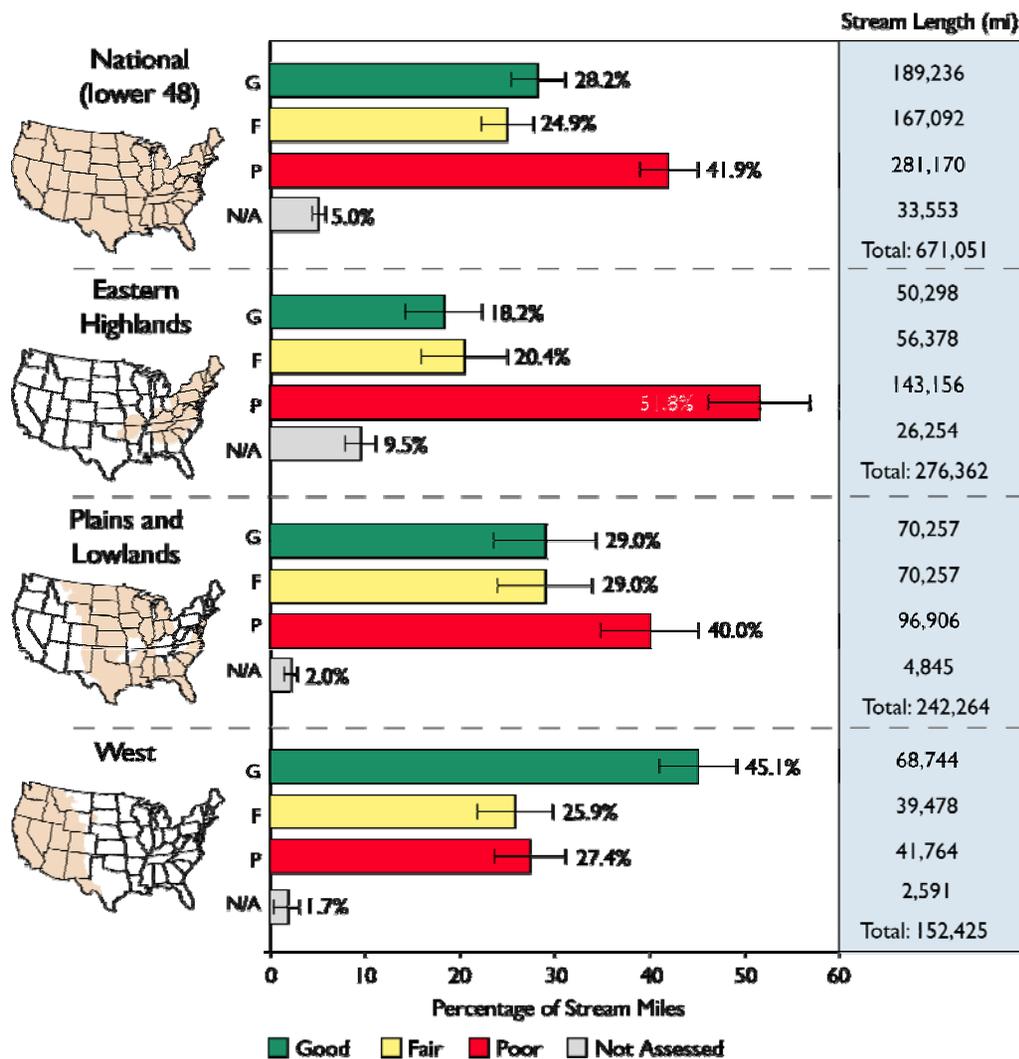


Wadeable Streams Assessment

Regional IBI Metrics

	NAP	SAP	CPL	UMW	TPL	NPL	SPL	WMT	XER	ALL
% EPT Taxa	X					X		X		X
% EPT Individuals					X		X			
% Non-Insect Taxa									X	
% Non-Insect Individuals			X							
% Ephemeroptera Taxa		X								
% Chironomid Taxa				X						
Shannon Diversity		X	X	X	X		X			X
% Individuals in top 5 taxa	X							X	X	
% Individuals in top 3 taxa						X				
Scraper Richness	X	X			X	X	X	X	X	X
Shredder Richness			X	X						
% Burrower Taxa		X		X		X	X			X
% Clinger Taxa	X		X					X	X	
Clinger Taxa Richness					X					
Ephemeroptera Taxa Richness	X	X	X	X			X	X	X	X
EPT Taxa Richness					X					
Total Taxa Richness						X				
Intolerant Richness						X	X			X
% Tolerant Individuals		X	X					X	X	

Wadeable Streams Assessment Macroinvertebrate IBI Results



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Predictive Modeling

An Alternative to IBIs?

REFERENCE TAXA LIST

(hypothetical example with 5 reference sites in region)

	<u>Taxa Name</u>	<u># of Ref Sites</u>	<u>Probability</u>
1.	CHIRCHIR	5	1.0
2.	HYDRSP.	5	1.0
3.	OLIGSP.	5	1.0
4	PLEUJUGA	5	1.0
5	CHIRORTH	4	0.8
6	CHIRTPOD	4	0.8
7	CHIRTTAR	4	0.8
8	CHLOSWEL	4	0.8
9	ELMIOPTI	4	0.8
10.	HEPTEPEO	4	0.8
.
36.	NEMASP.	2	0.4
37.	PLODSKWA	2	0.4
38.	PTYCPTYC	2	0.4
39.	SIALSIAL	2	0.4
40.	TIPUDICR	2	0.4
41.	TIPUTIPU	2	0.4

===

Sum of Probability Values = E = 26.4

Predictive Modeling

An Alternative to IBIs?

SITE AR08-04

Reference Taxa

1. BAETLABI
2. CERACERA
3. CHIRCHIR
4. CHIRORTH
5. CHIRTPOD
6. CHIRTTAR
7. CHLOSWEL
8. EMPICHEL
9. LEPILEPI
10. LEPTPARA
11. NEMASP.
12. OLIGSP.
13. TIPUDICR

O = 13

Non-Reference Taxa

14. AMEAMEL
15. COLLSP.
16. CORYNEOH
17. EMPICLIN
18. EPHESERR
19. HEPTCGMA
20. PLANSP.

E=26.4

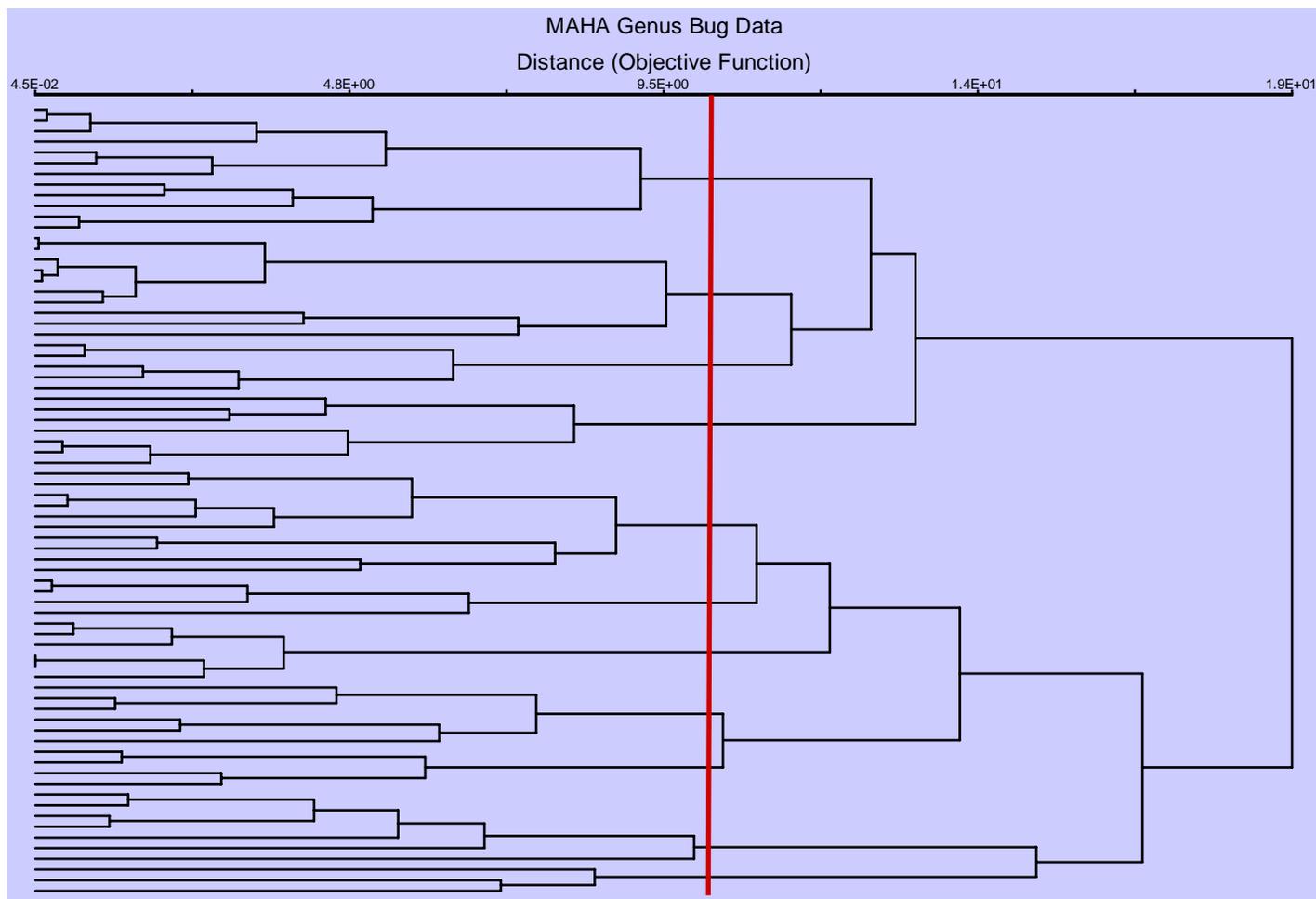
O/E=0.492

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Predictive Modeling

Full Model Includes Multiple Site Clusters

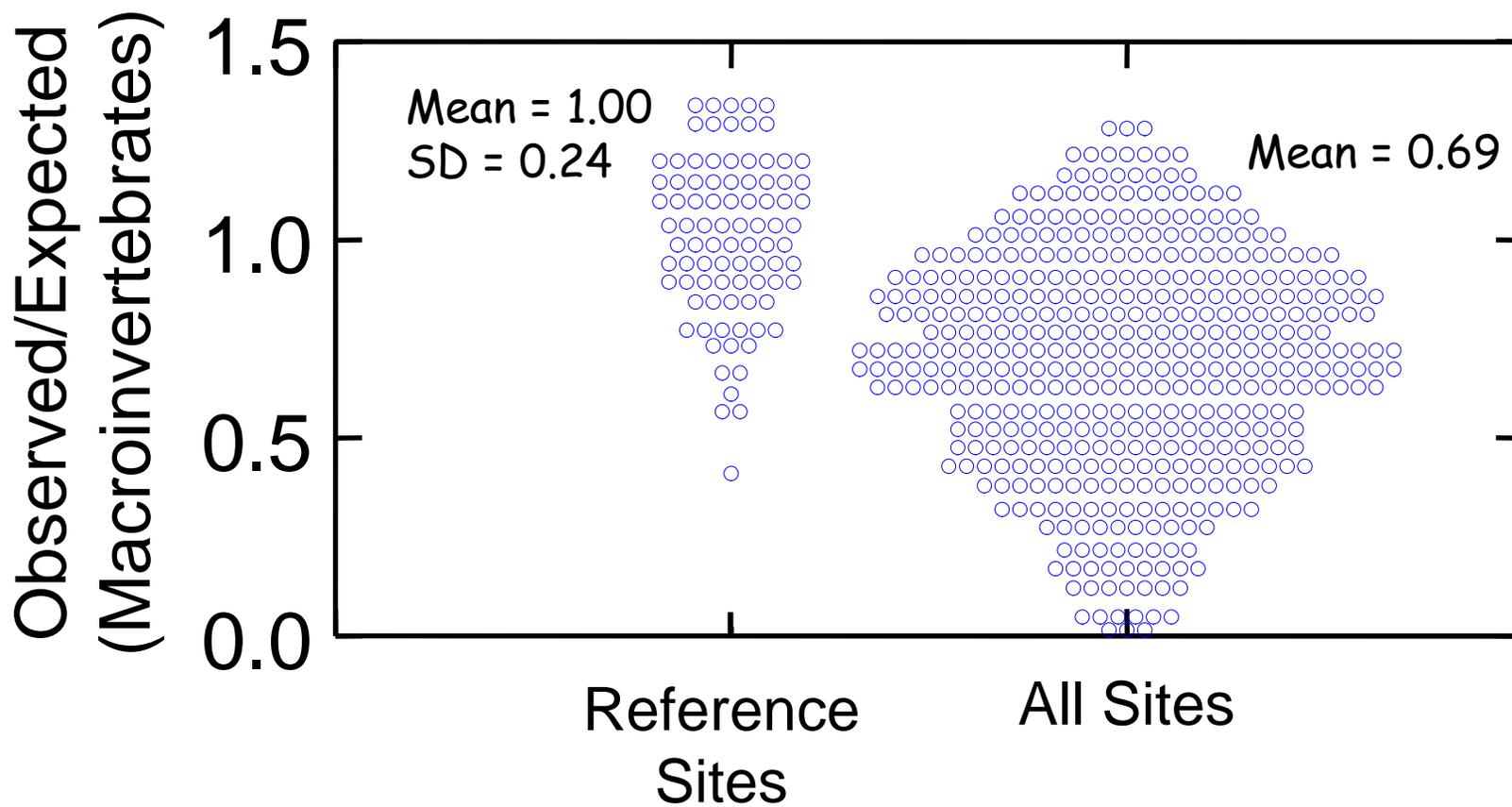


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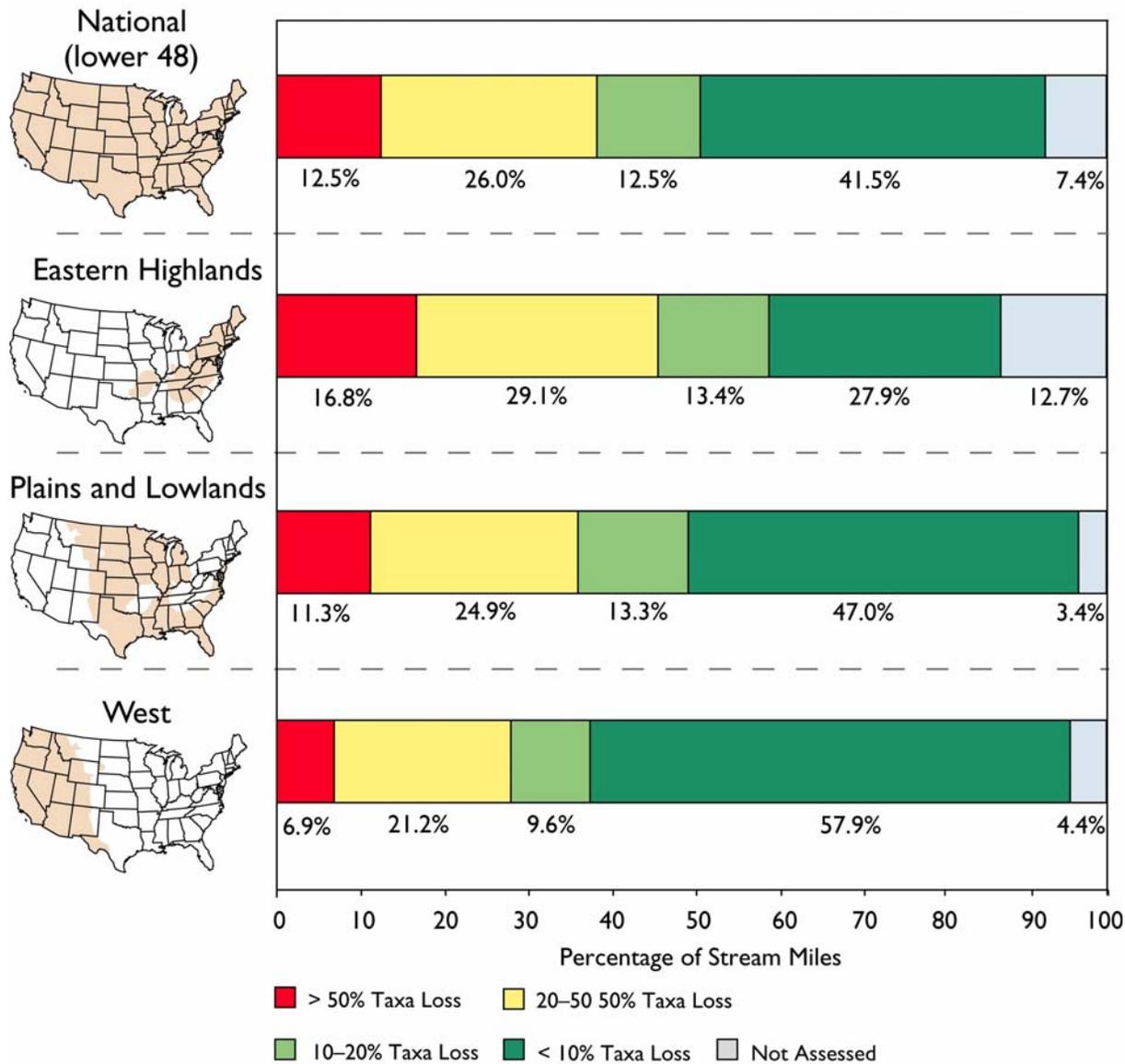
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Predictive Modeling

Example for MAHA Bugs



Wadeable Streams Assessment - O/E

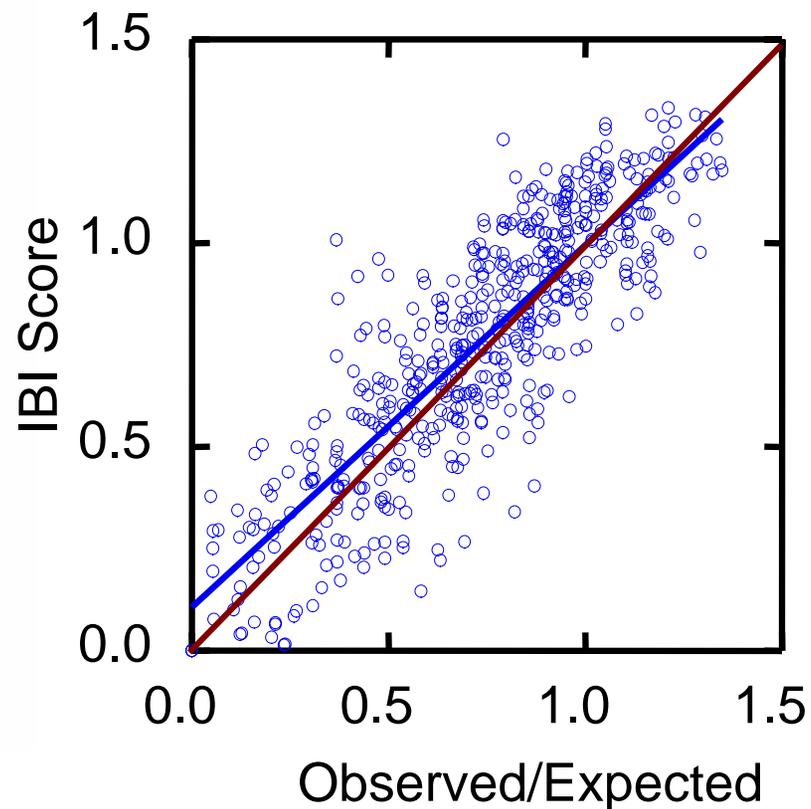
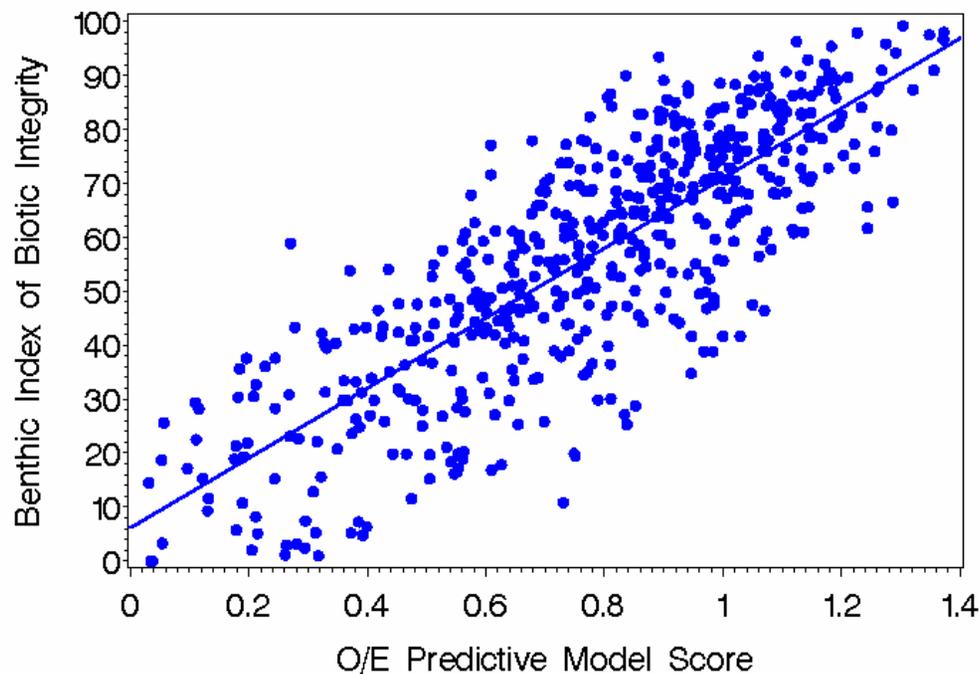


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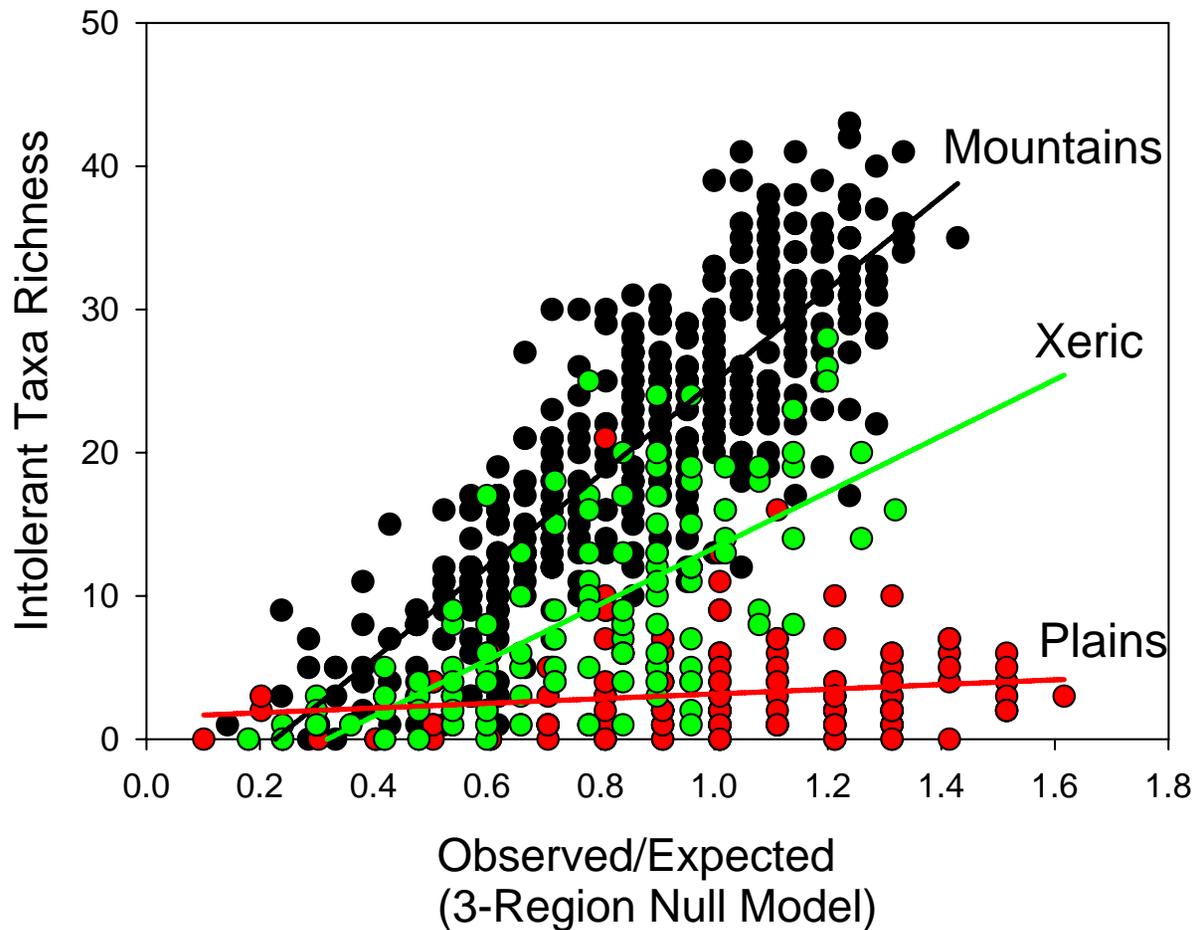
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Comparing IBI and O/E Scores

EMAP/MAHA Benthic Data



Comparing O/E Scores with IBI Metrics



Reference Condition

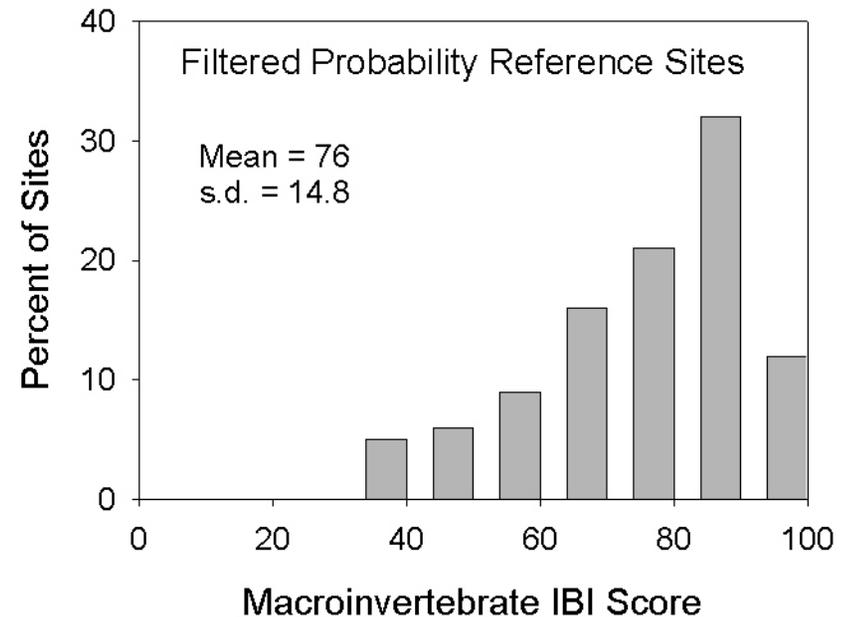
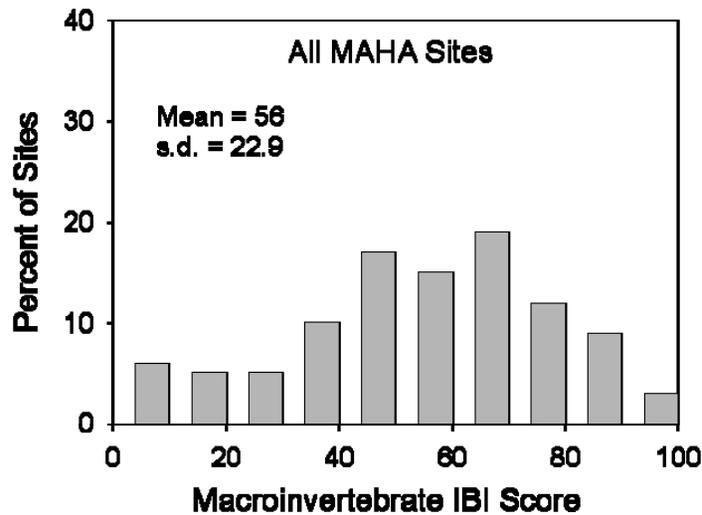
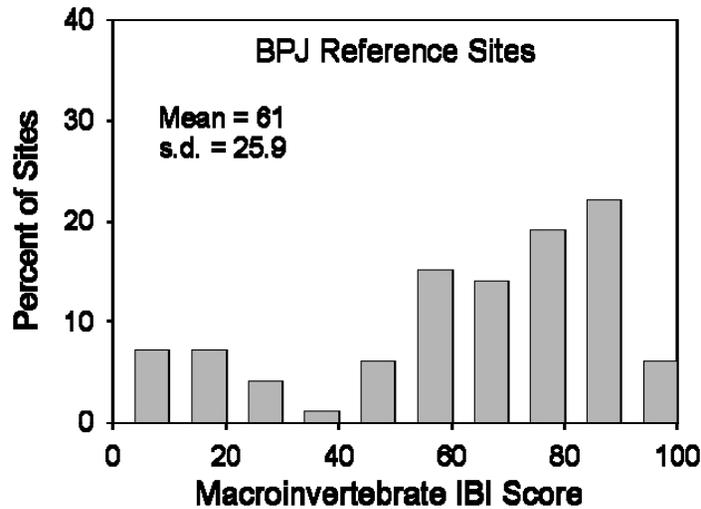


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MAHA Approach to Reference Condition

61 hand-picked (BPJ) Reference Sites; 380 Probability Sites



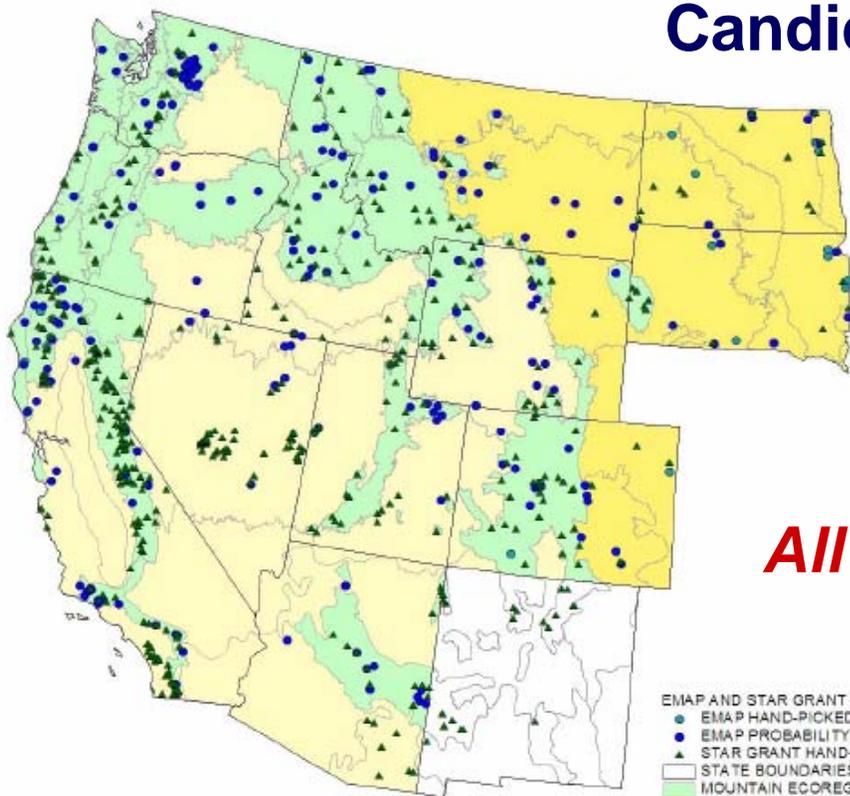
EMAP-W Approach to Reference Condition

730 Reference Sites; 965 Probability Sites

Candidate reference sites selected by:

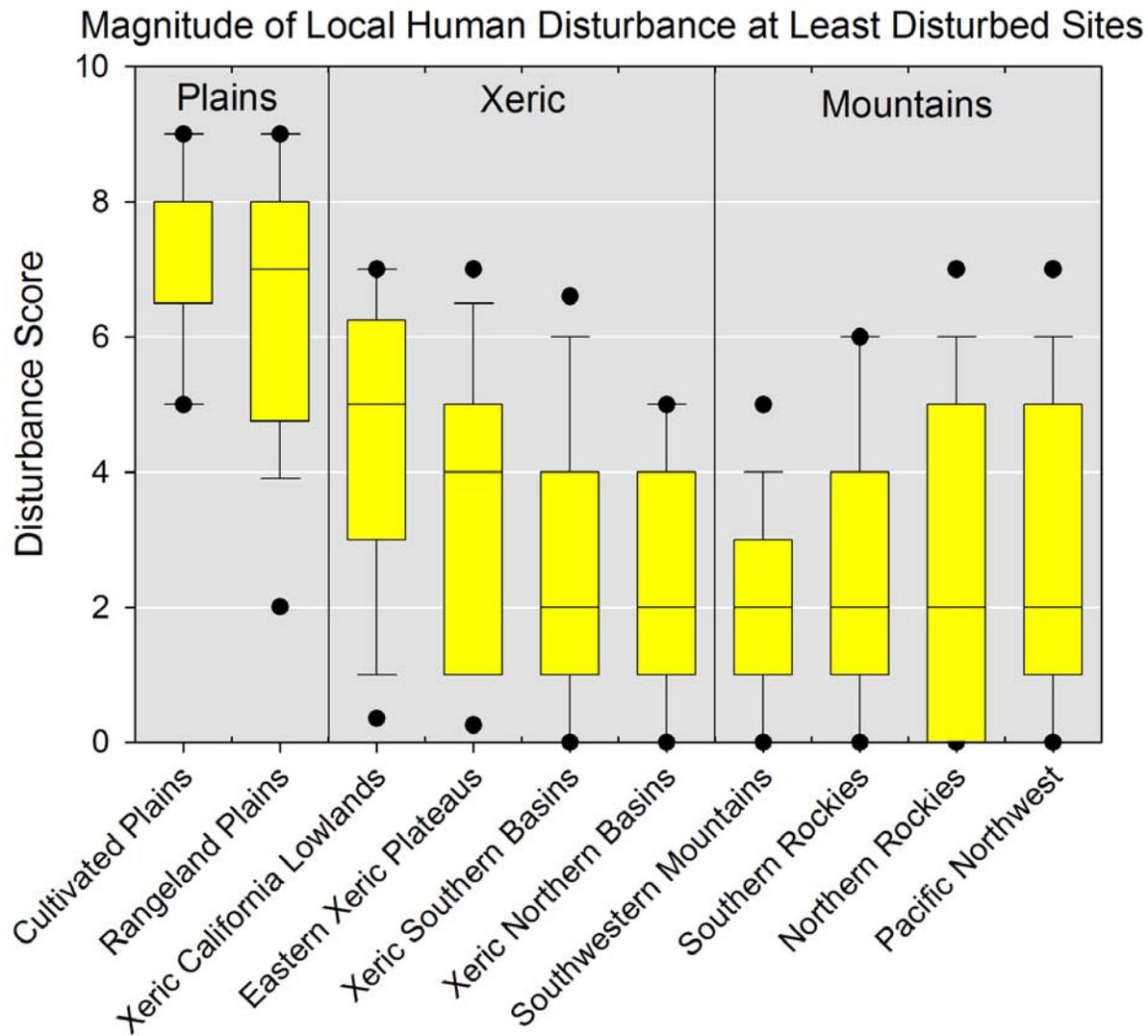
- Established state reference sites
- State BPJ suggestions
- STAR (Hawkins) BPJ sites
- EMAP GIS top-down sites
- Filtered probability sites

All candidates subjected to filtering



EMAP AND STAR GRANT REFERENCE SITES
 ● EMAP HAND-PICKED REFERENCE SITES
 ■ EMAP PROBABILITY SAMPLE REFERENCE SITES
 ▲ STAR GRANT HAND-PICKED REFERENCE SITES
 — STATE BOUNDARIES
 — MOUNTAIN ECOREGIONS
 — PLAINS ECOREGIONS
 — XERIC ECOREGIONS
 — LEVEL 3 ECOREGION BOUNDARIES

EMAP-W Approach to Reference Condition



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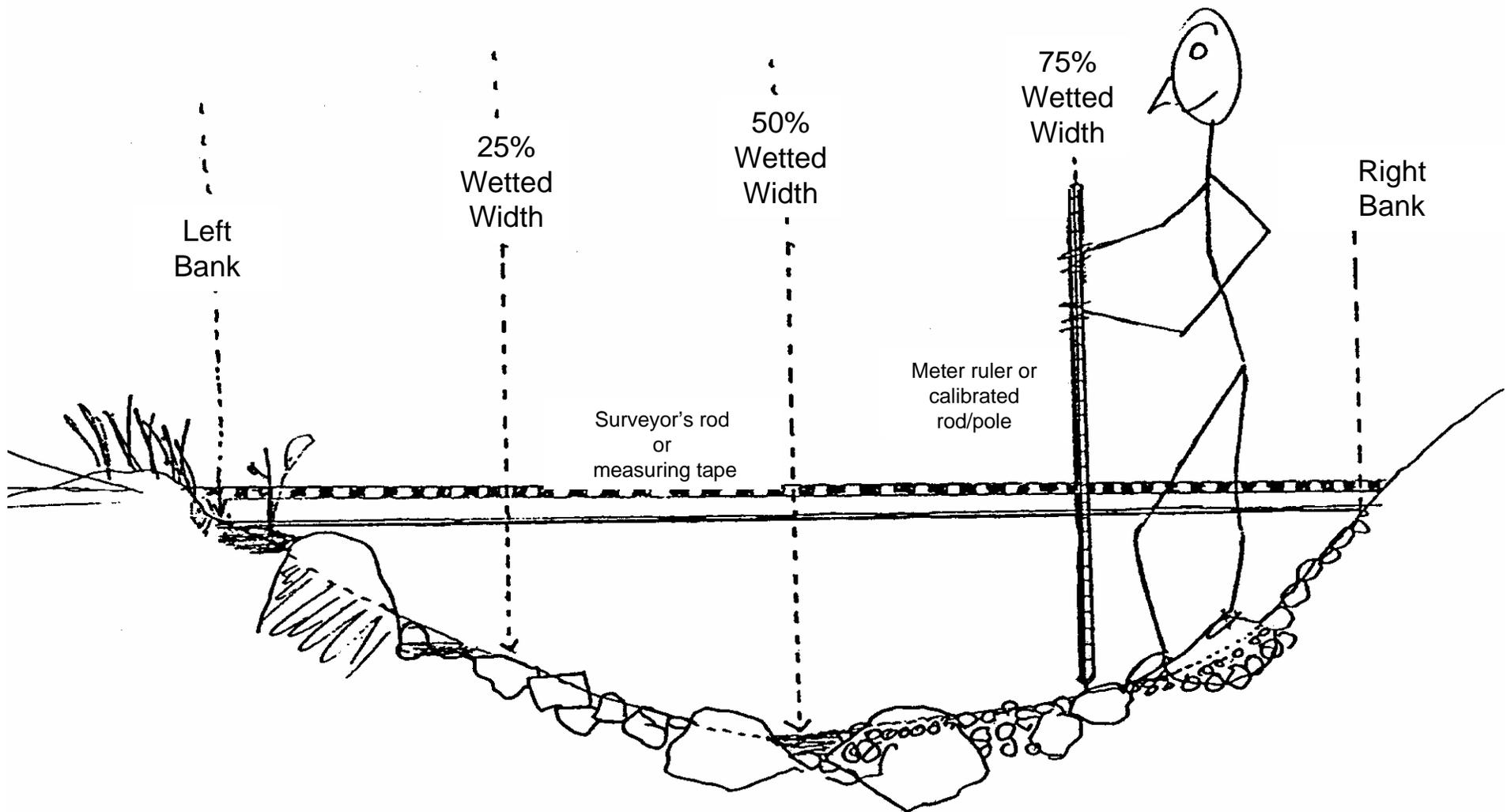
Stressor Indicators



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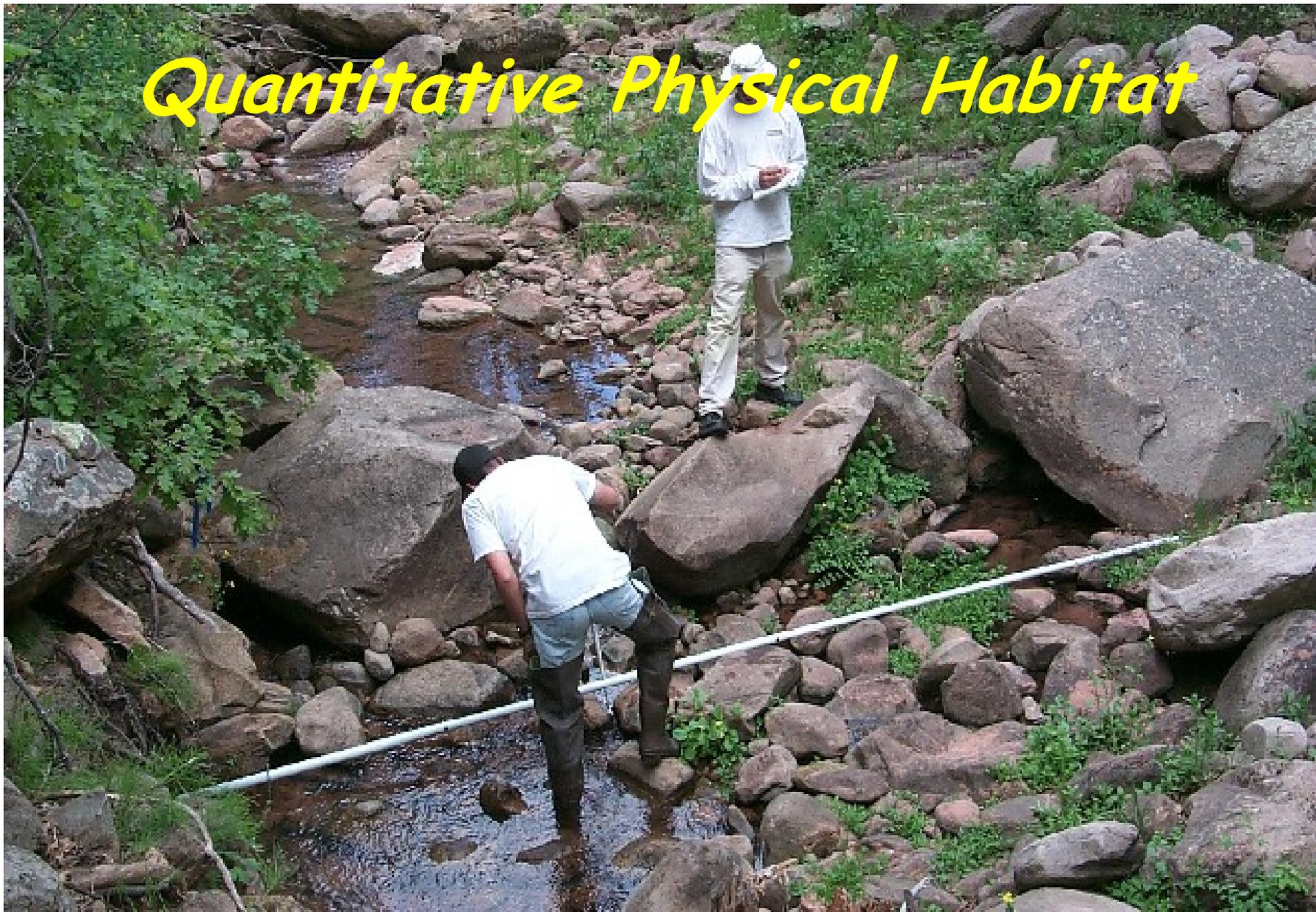
Quantitative Physical Habitat



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Quantitative Physical Habitat



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Quantitative Physical Habitat



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Quantitative Physical Habitat



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Quantitative Physical Habitat



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Quantitative Physical Habitat



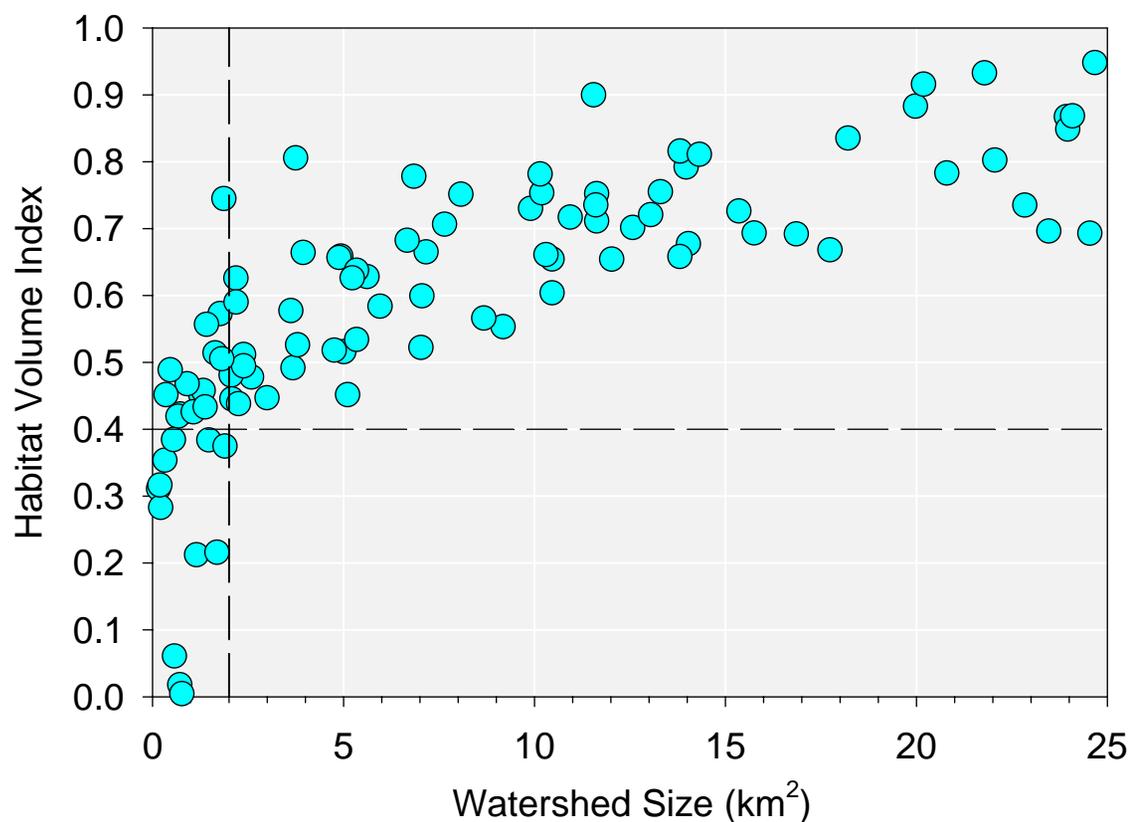
Did you know? 24 of 32 EMAP Stream forms are for Physical Habitat

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Quantitative Physical Habitat

Helps determine how to assign IBI values to fishless lakes



But only 100 MAHA sites were sampled quantitatively for physical habitat, so we were forced to use a surrogate for habitat volume (watershed size)

Relative Bed Stability and Excess Fines

based on mean particle diameter ratio: Observed/Mobile

$$LRBS = \text{Log}(D_{gm}/D_{cbf}^*)$$

D_{gm} --- observed geometric mean diameter from field "pebble count".

D_{cbf}^* : max mobile D "Critical D" at bankfull --- by equating bankfull and critical shear stress:

Bankfull Bed Shear Stress ($\rho g R_{bf}^* S$), controlled by:

+ Channel slope (S)

+ Adjusted Bankfull Hydraulic Radius (R_{bf}^*)

+ Bankfull Depth,

- Residual pool depth, - Form roughness, - Large wood volume

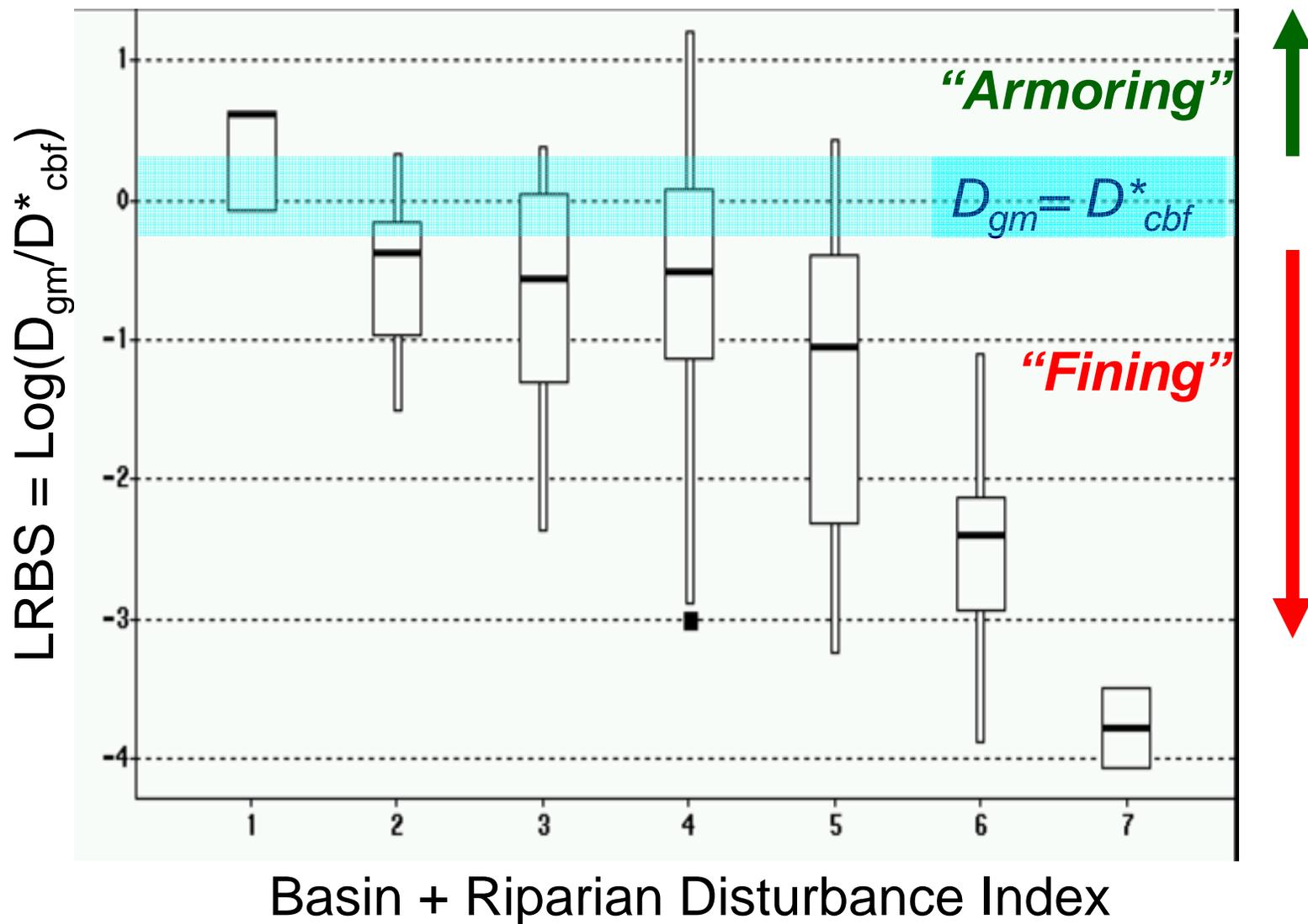
Critical Shear Stress $\theta(\rho_s - \rho)gD$, influenced by:

+ Particle Diameter (D)

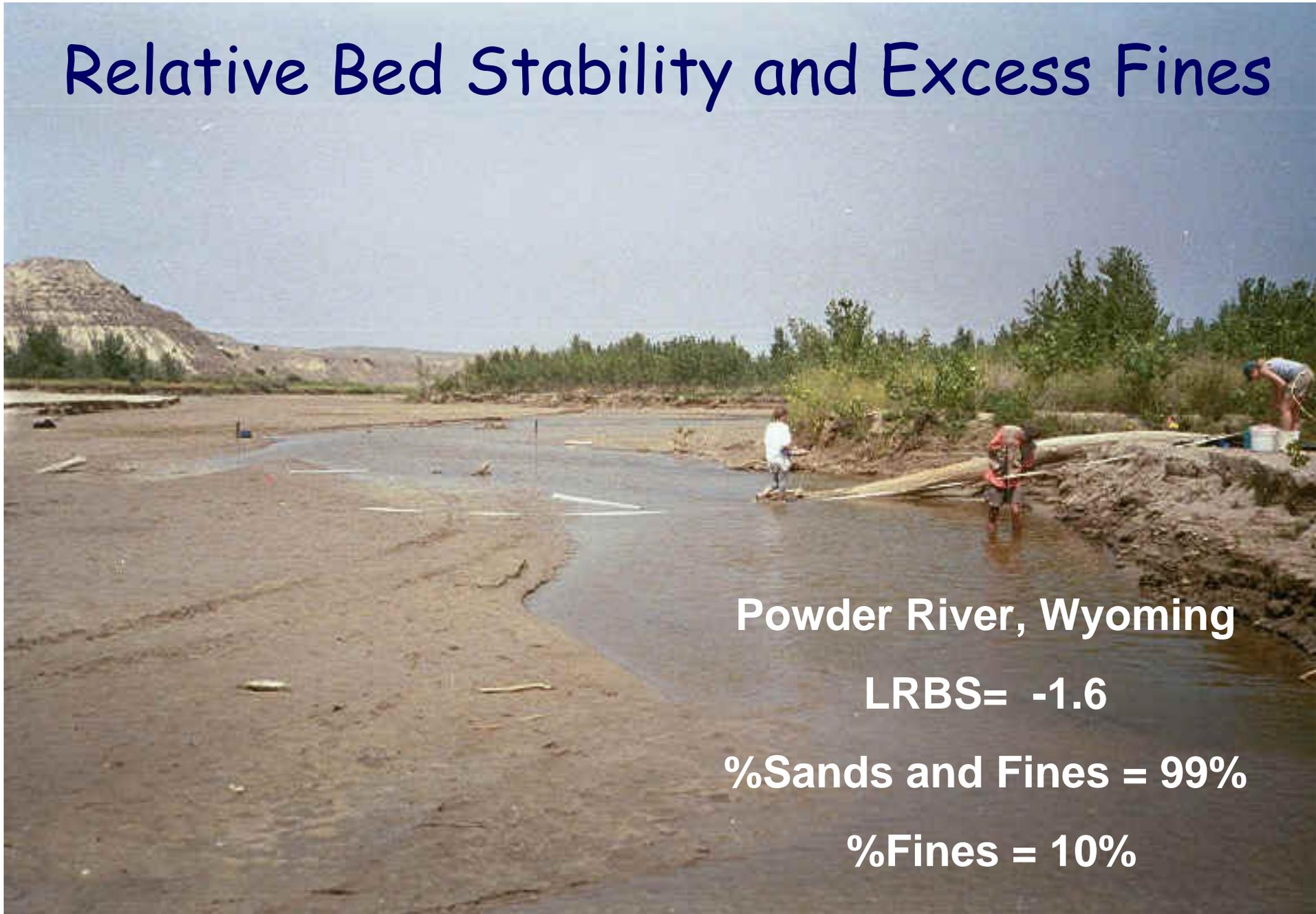
+ mass density of particles in water ($\rho_s - \rho$)

. shape, exposure, size variance, turbulence, relative submergence (θ)

Relative Bed Stability



Relative Bed Stability and Excess Fines



Powder River, Wyoming

LRBS= -1.6

%Sands and Fines = 99%

%Fines = 10%

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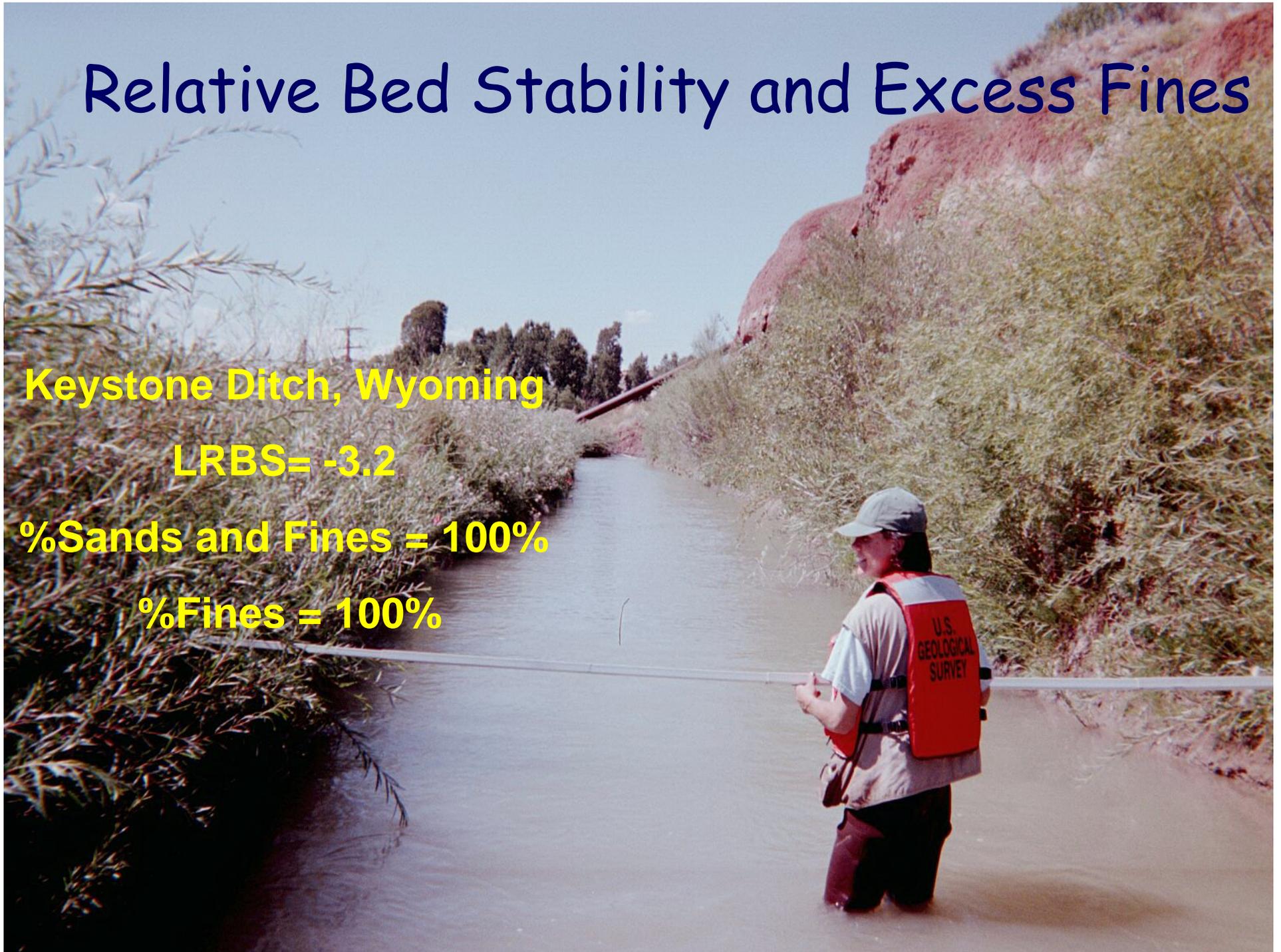
Relative Bed Stability and Excess Fines

Keystone Ditch, Wyoming

LRBS= -3.2

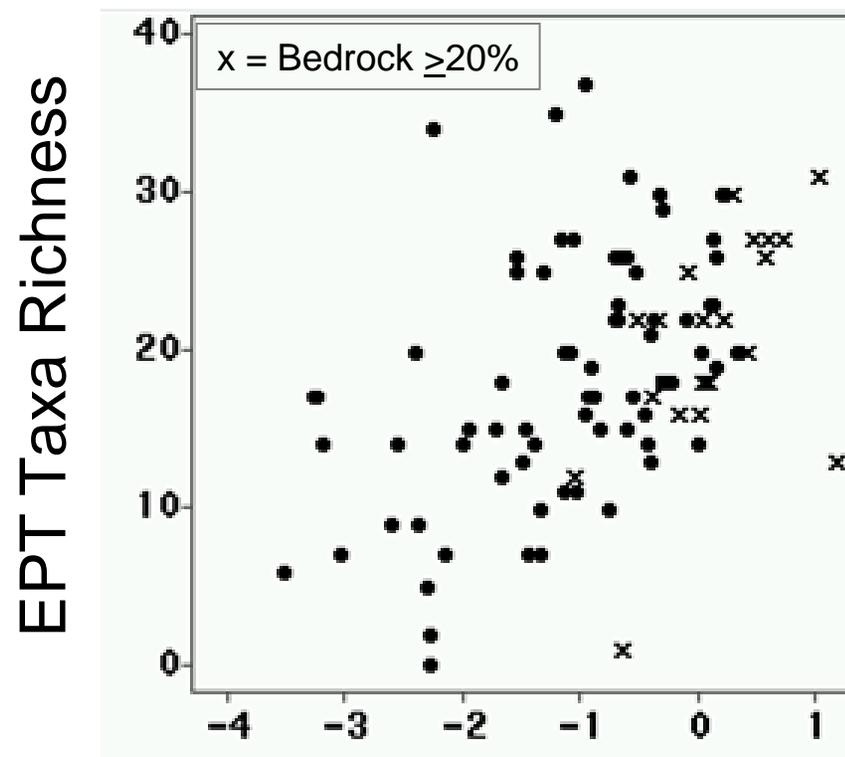
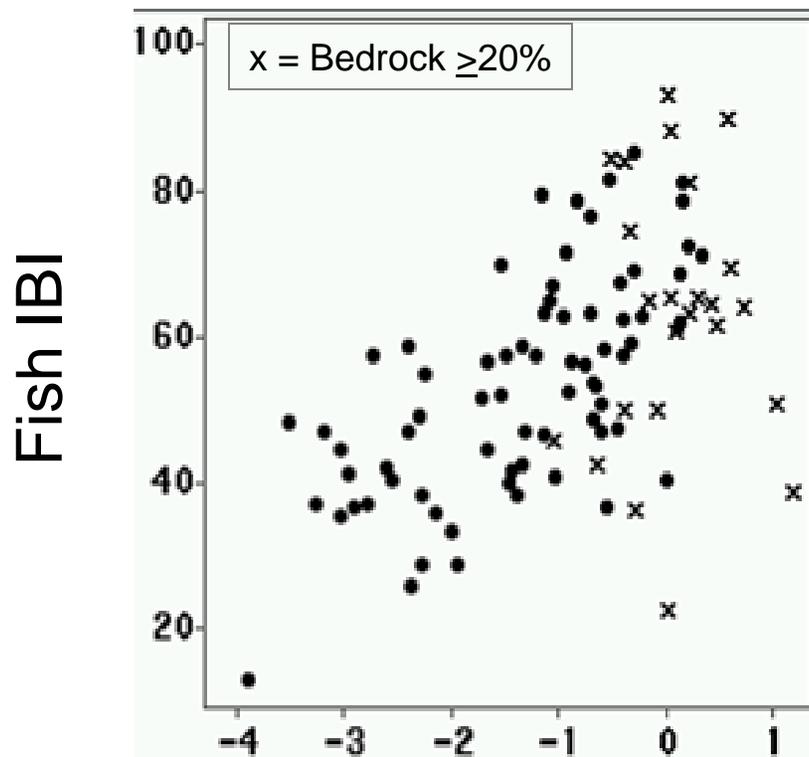
%Sands and Fines = 100%

%Fines = 100%



Relative Bed Stability

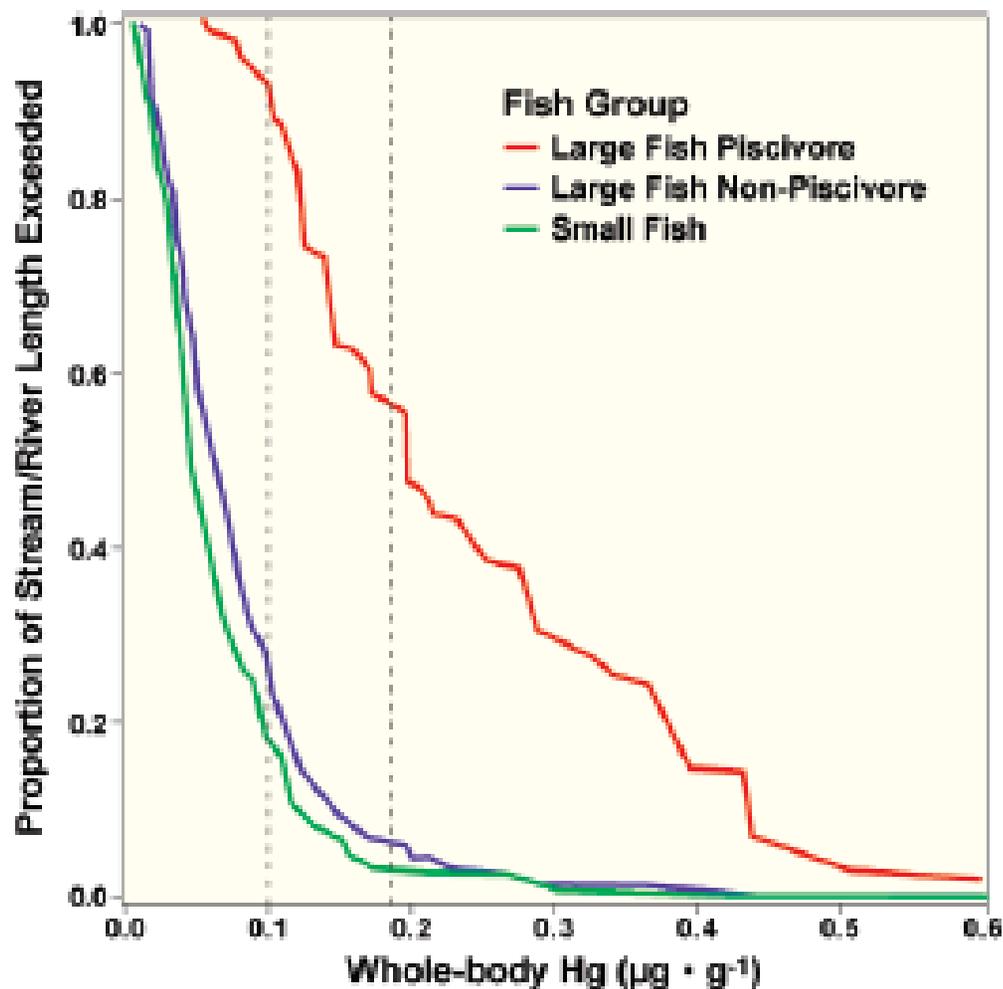
(Data from OR/WA Coast Range REMAP '94-'95)



LRBS: $\text{Log}(D_{gm}/D_{cbf}^*)$

Chemical Stressors

Mercury in EMAP West

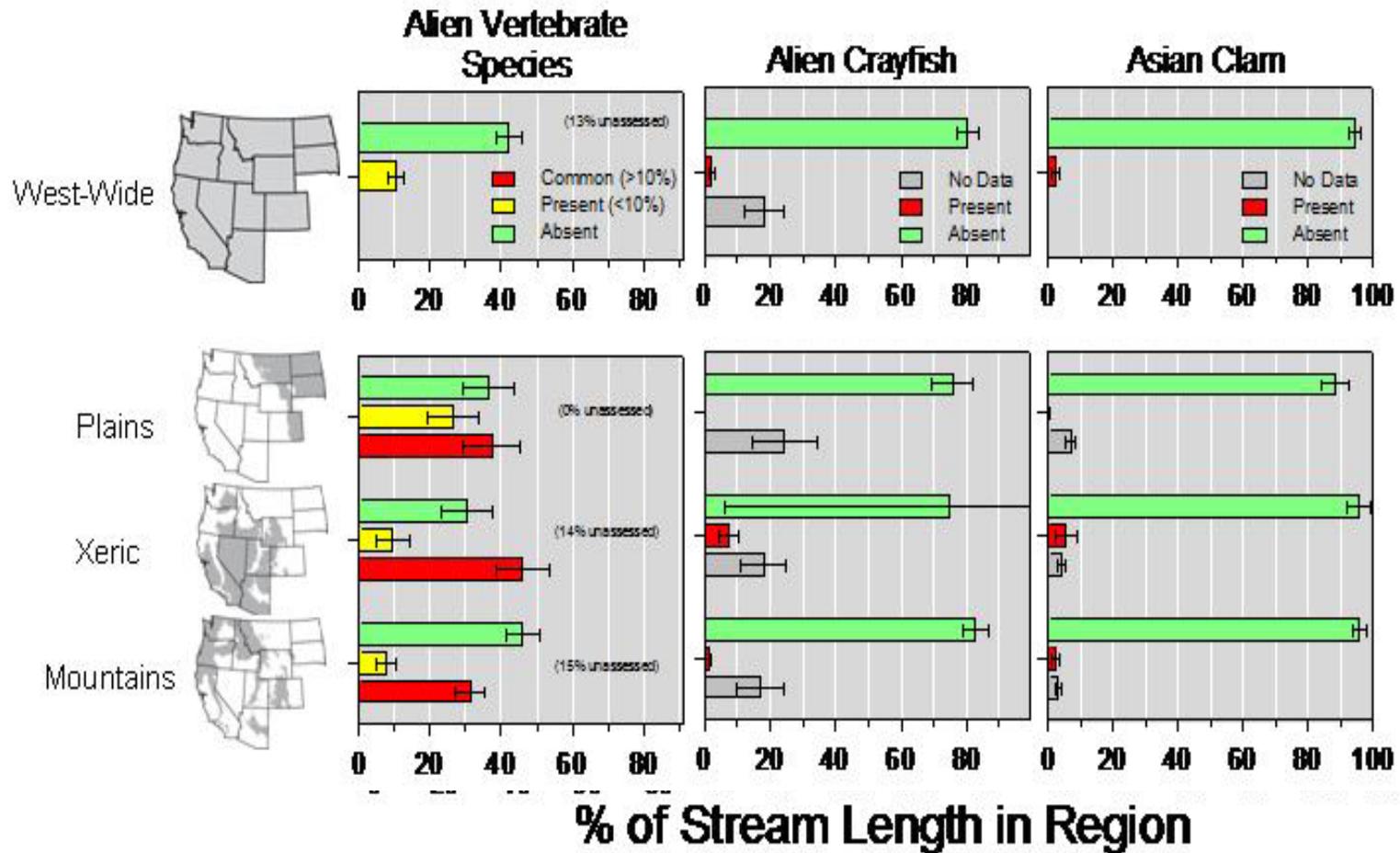


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Biological Stressors

Alien Species



Assessment

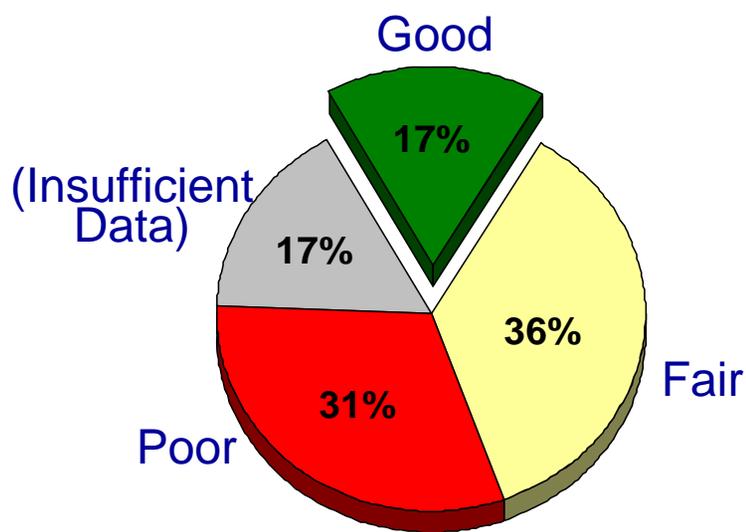


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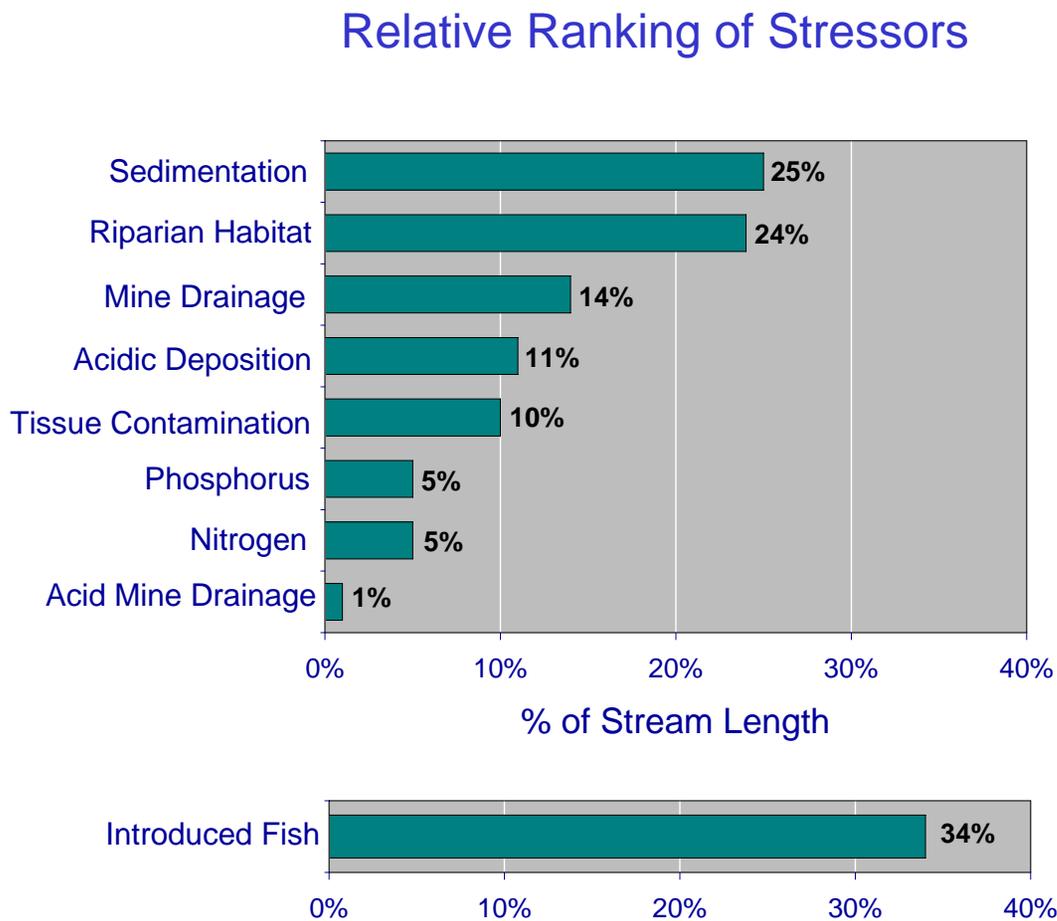
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Assessment - MAHA

Fish Index of Biotic Integrity

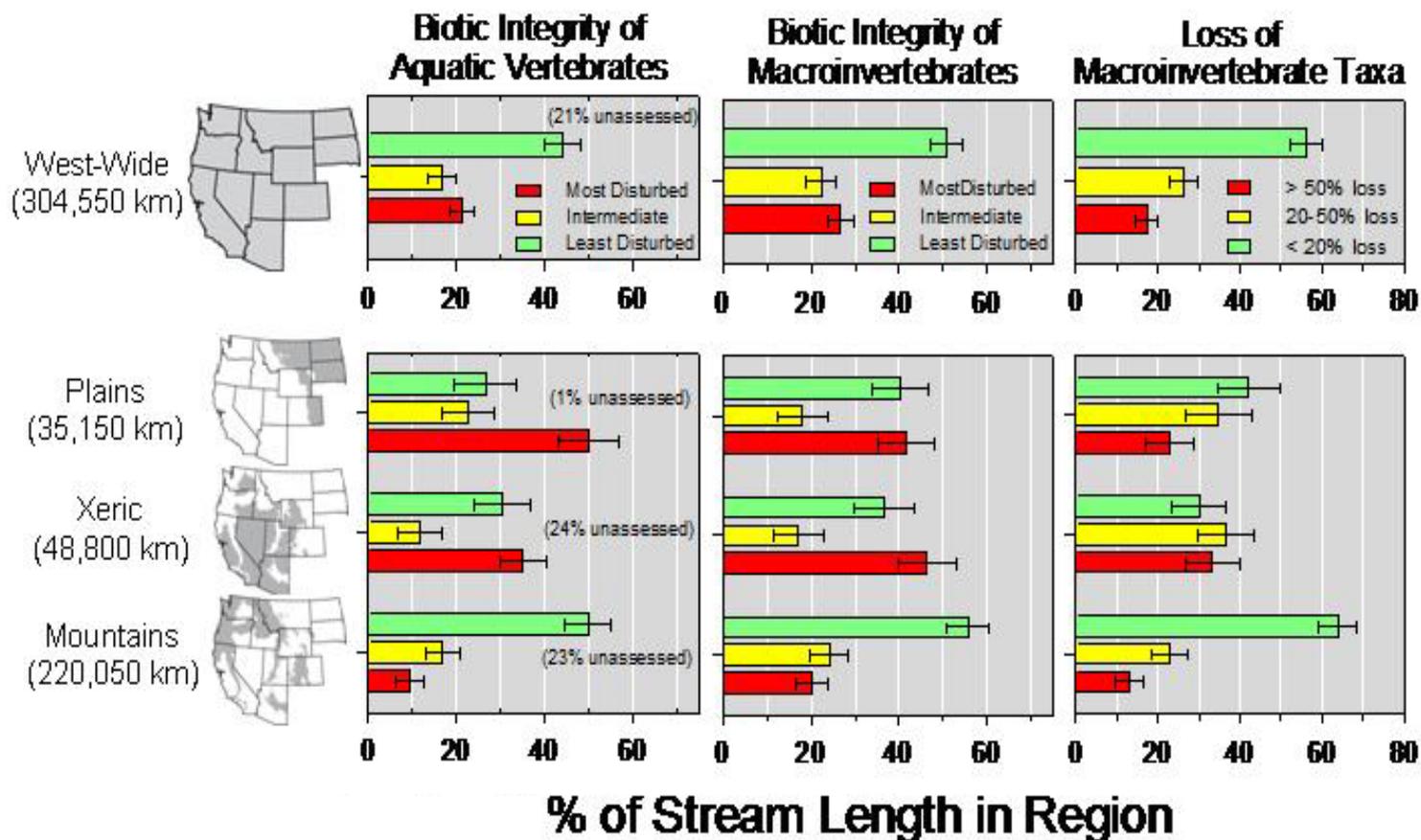


Proportion of Stream Length



Assessment - EMAP West

Multiple Indices, Multiple Assemblages



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Assessment - Relative Risk

Naproxen least risky

According to a report in the Journal of the American Medical Association, the painkiller naproxen has less of a cardiovascular risk than other drugs.

Relative risk estimates*

Naproxen	0.97
Celebrex	1.06
Ibuprofen	1.07
Other anti-inflammatory	1.10
Mobic	1.25
Vioxx	1.35
Voltaren	1.40

* Relative risk is measured against a baseline of one, which in this case is people not on painkillers

SOURCE: JAMA

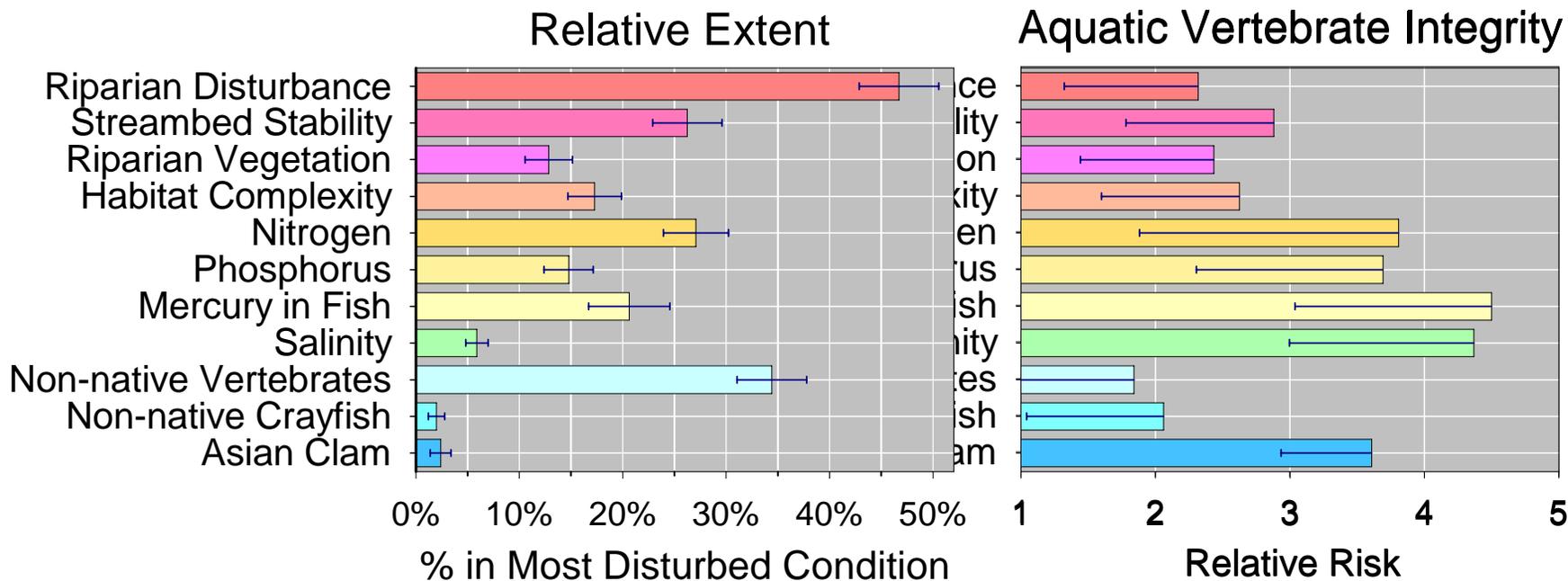
AP

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Assessment - Relative Risk

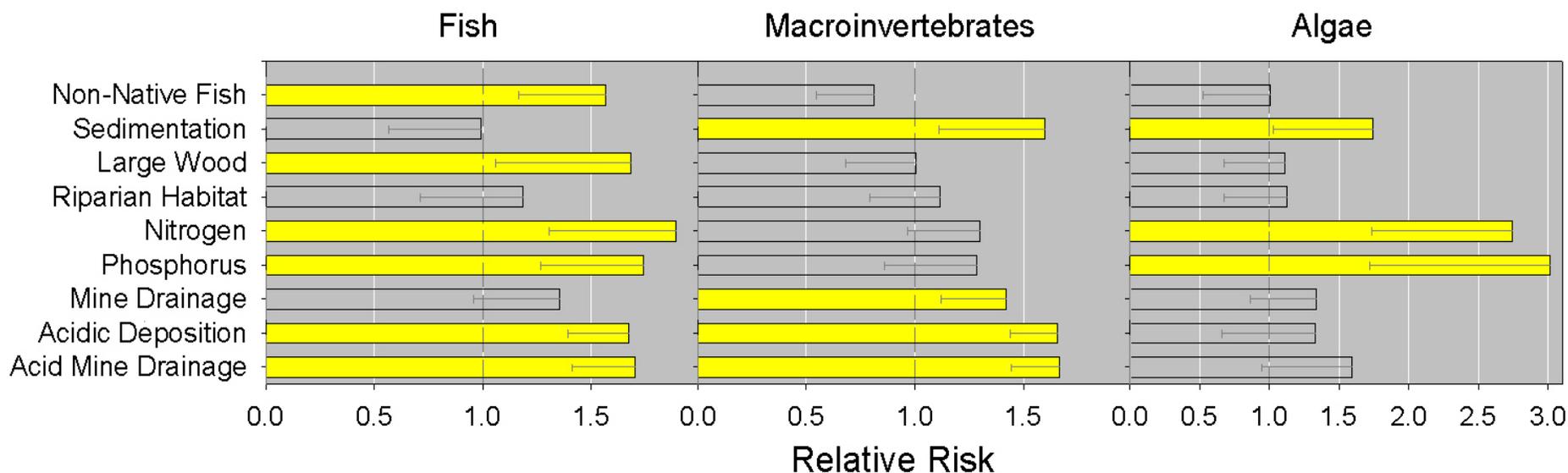
EMAP West



Relative importance of stressors is a function of both their relative extent and their Relative Risk. Increased likelihood of poor biotic condition when stressor is present, relative to when stressor is absent

Assessment - Relative Risk

MAIA



Multiple assemblage assessment confirms that different stressors affect fish, macroinvertebrates and periphyton

Next Steps in EMAP (Streams) Evolution

- Design
 - Site selection: continued improvement in GRTS designs
 - Plot design: harmonizing of wadeable/non-wadeable protocols
- Biological Indicators
 - Settling the IBI/O:E debate
- Stressor Indicators
 - Modeling flashy stressors (pesticides, nutrients)
 - Incorporating natural gradients into IBIs
- Reference Condition
 - Modeling approaches to deal with sliding scale issue
- Assessment
 - Melding relative extent and relative risk