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

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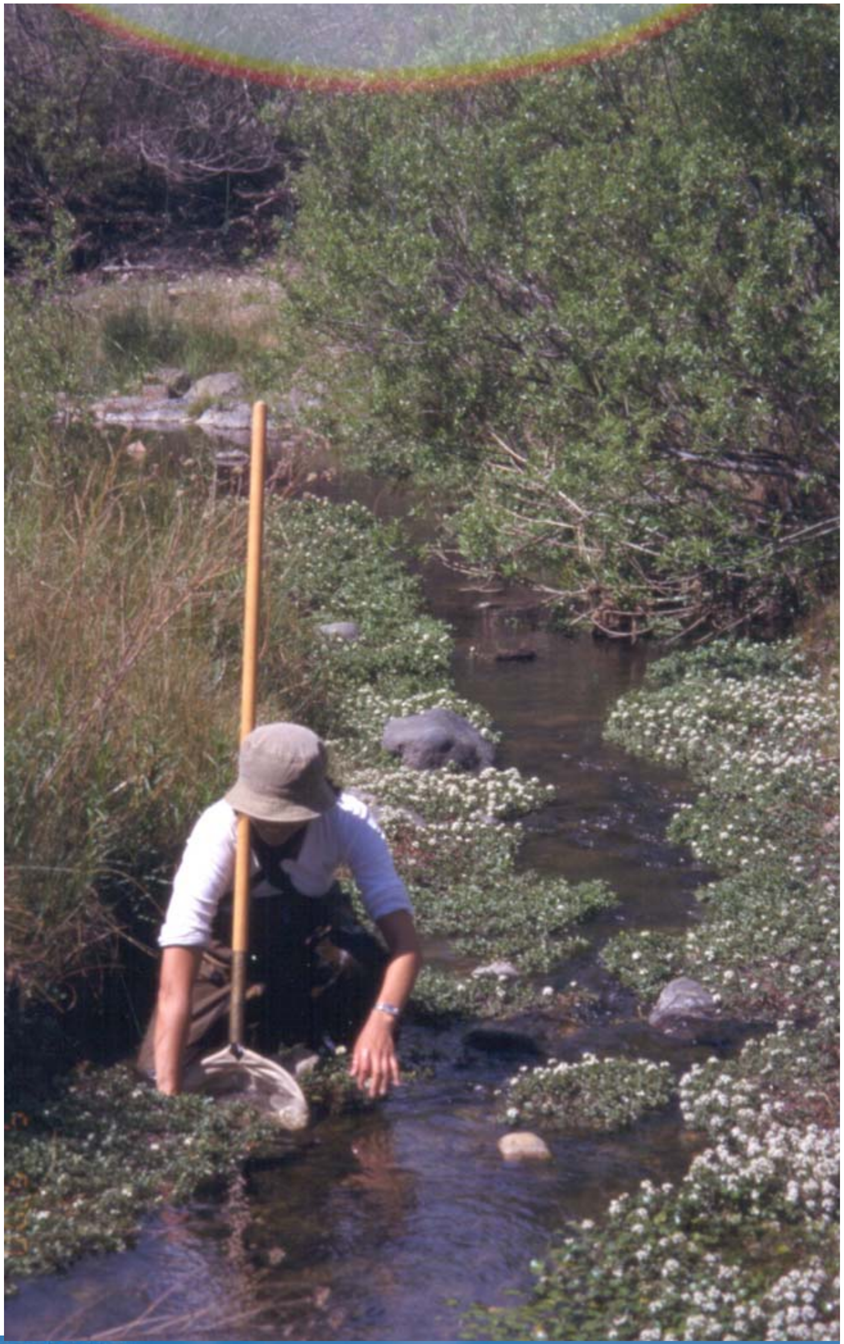
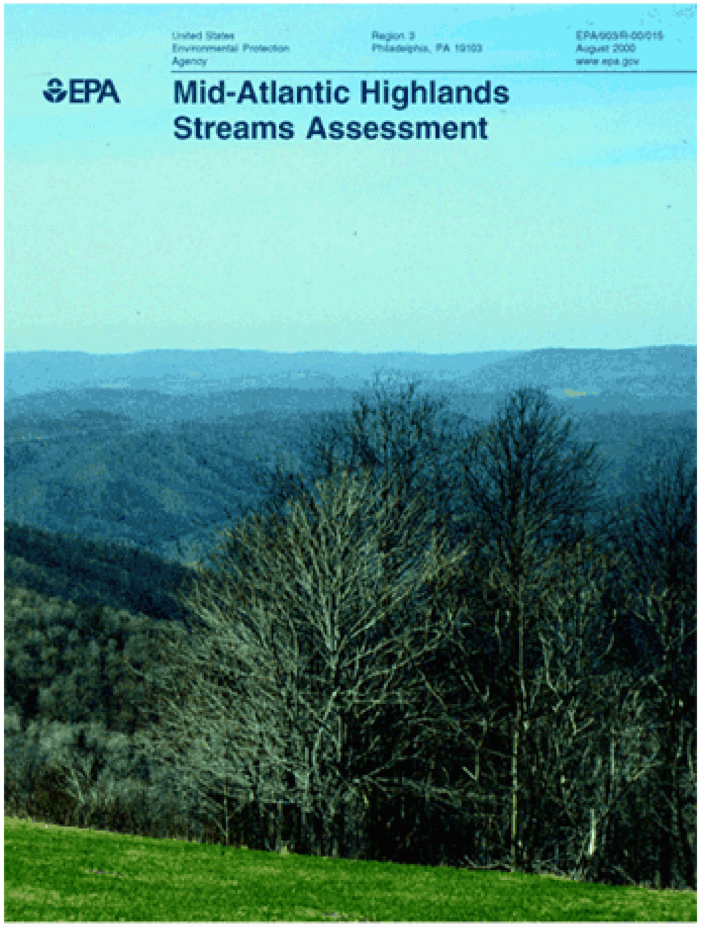


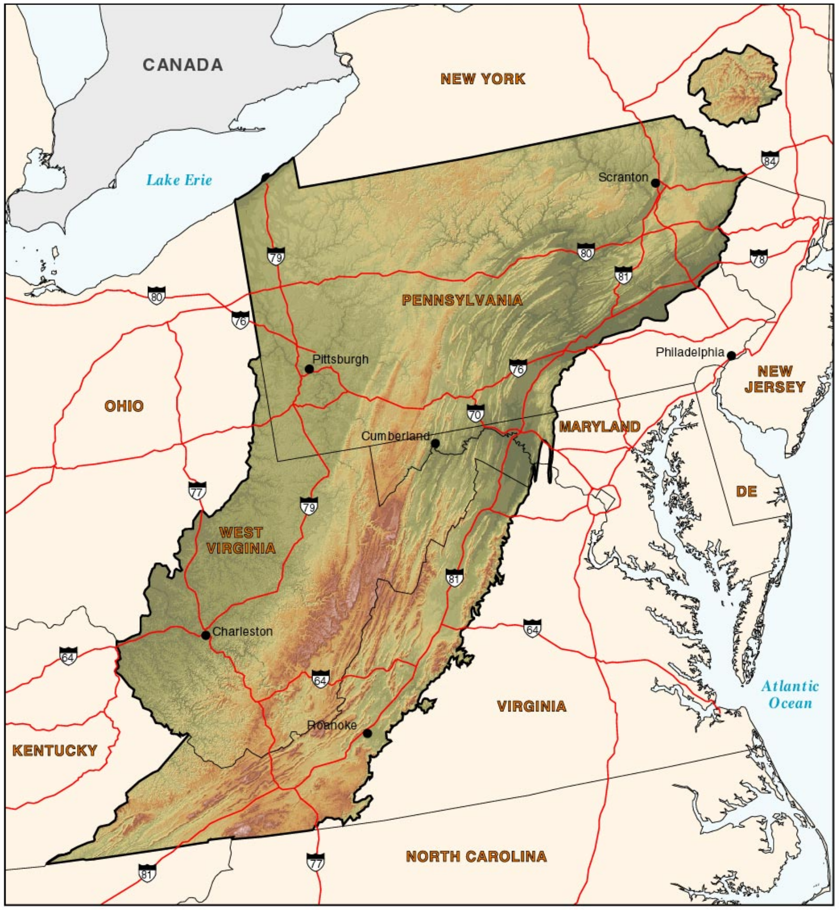
# Elements of EMAP Streams

- 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)



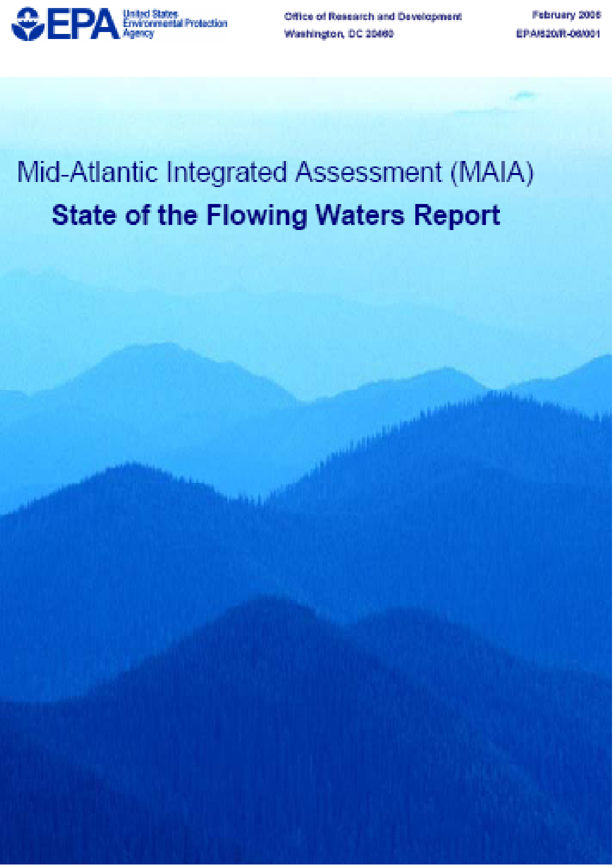

Wadeable streams
(1st through 3rd order)




79,000 $mi^2$

Portion of Region III, portions of 5 states

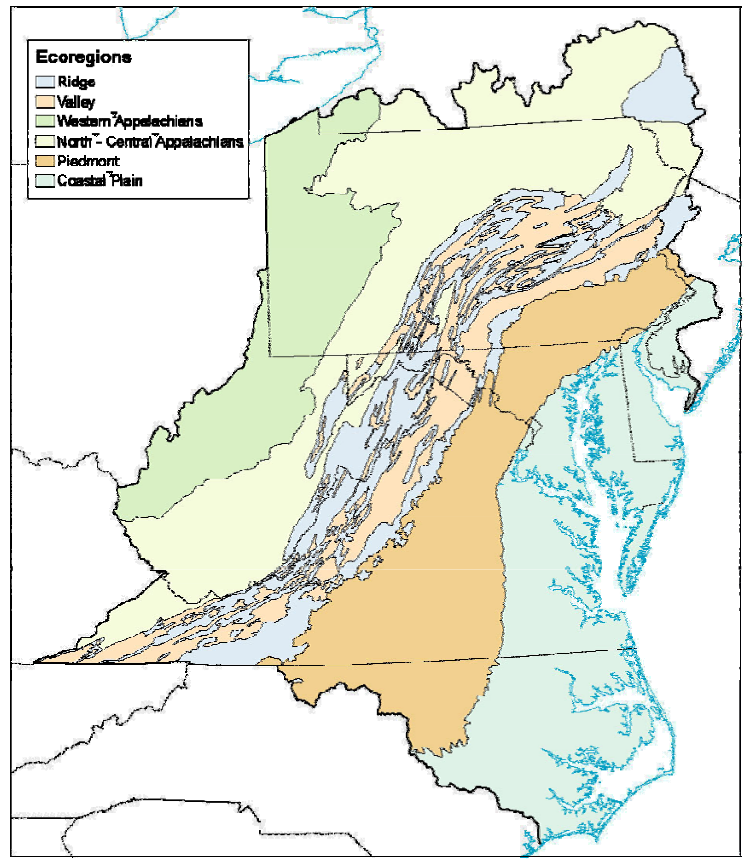
# Mid Atlantic Integrated Assessment (MAIA – 1997-98)




180,000 mi$^2$

Region 3, all or part of 8 states

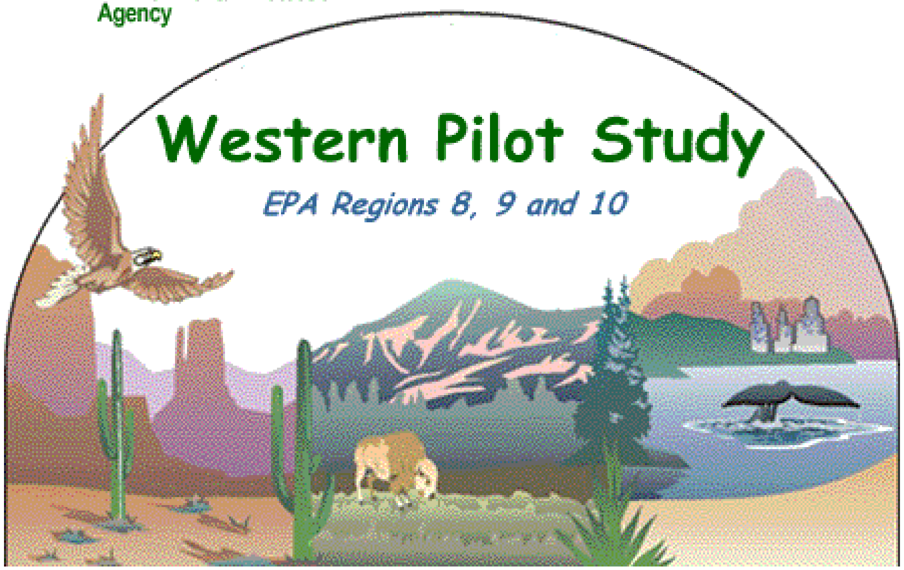
All perennial flowing waters



# EMAP Western Pilot
# (EMAP-W 2000-04)

All perennial flowing waters, except "Great Rivers"

EPA
United States
Environmental Protection
Agency

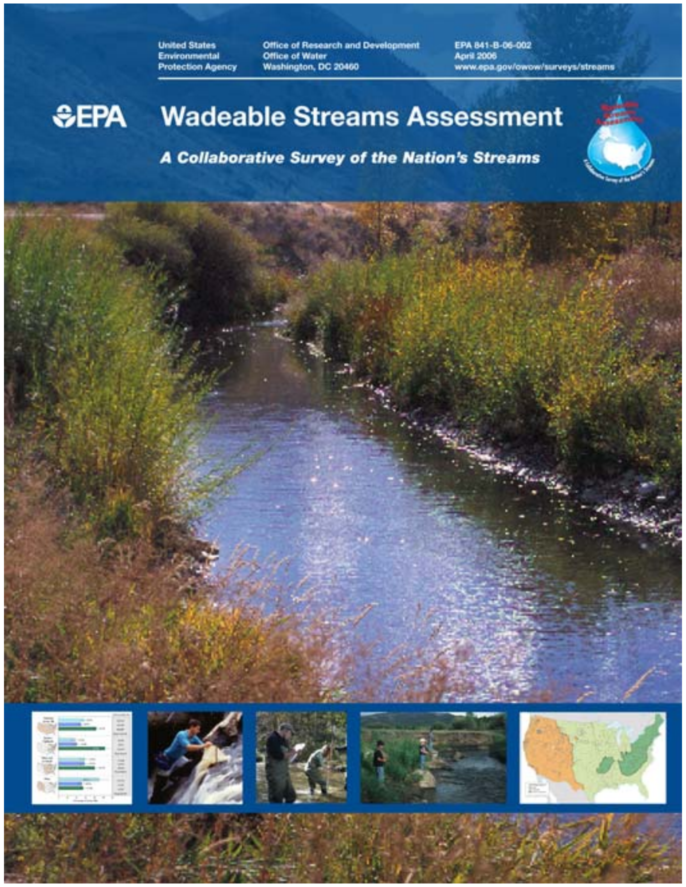




1,223,000 mi$^2$

12 States; Regions 8, 9 and 10

# Wadeable Streams Assessment (WSA - 2005)

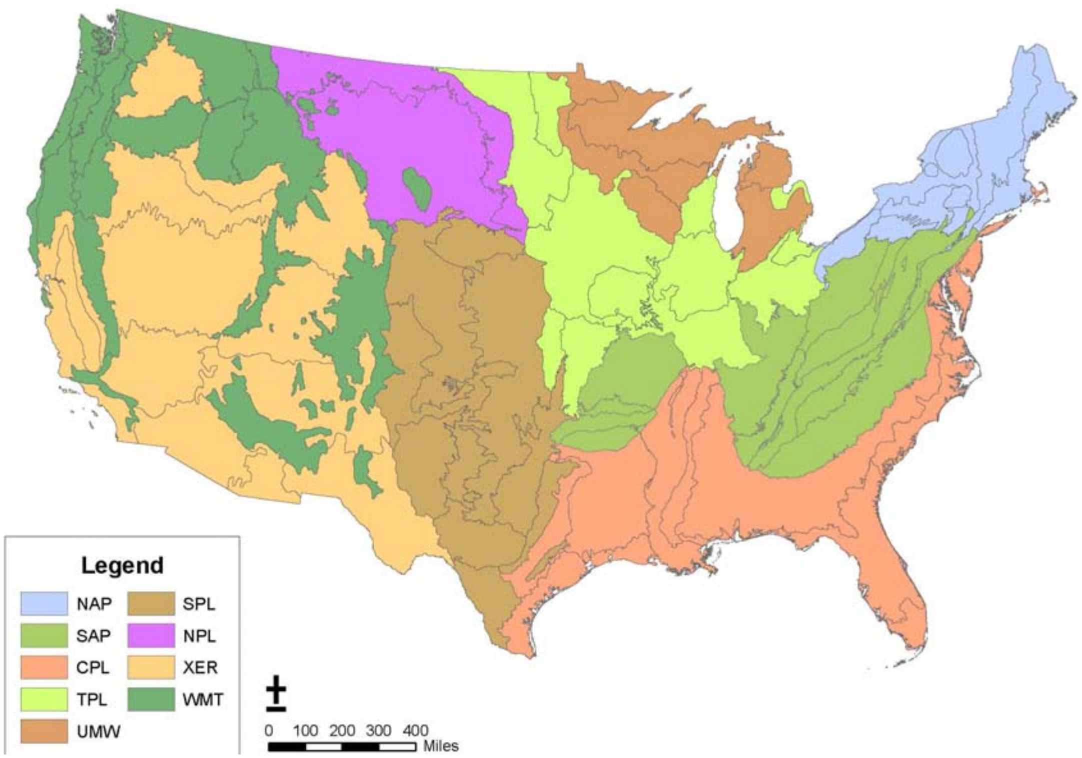



3,100,000 mi$^2$

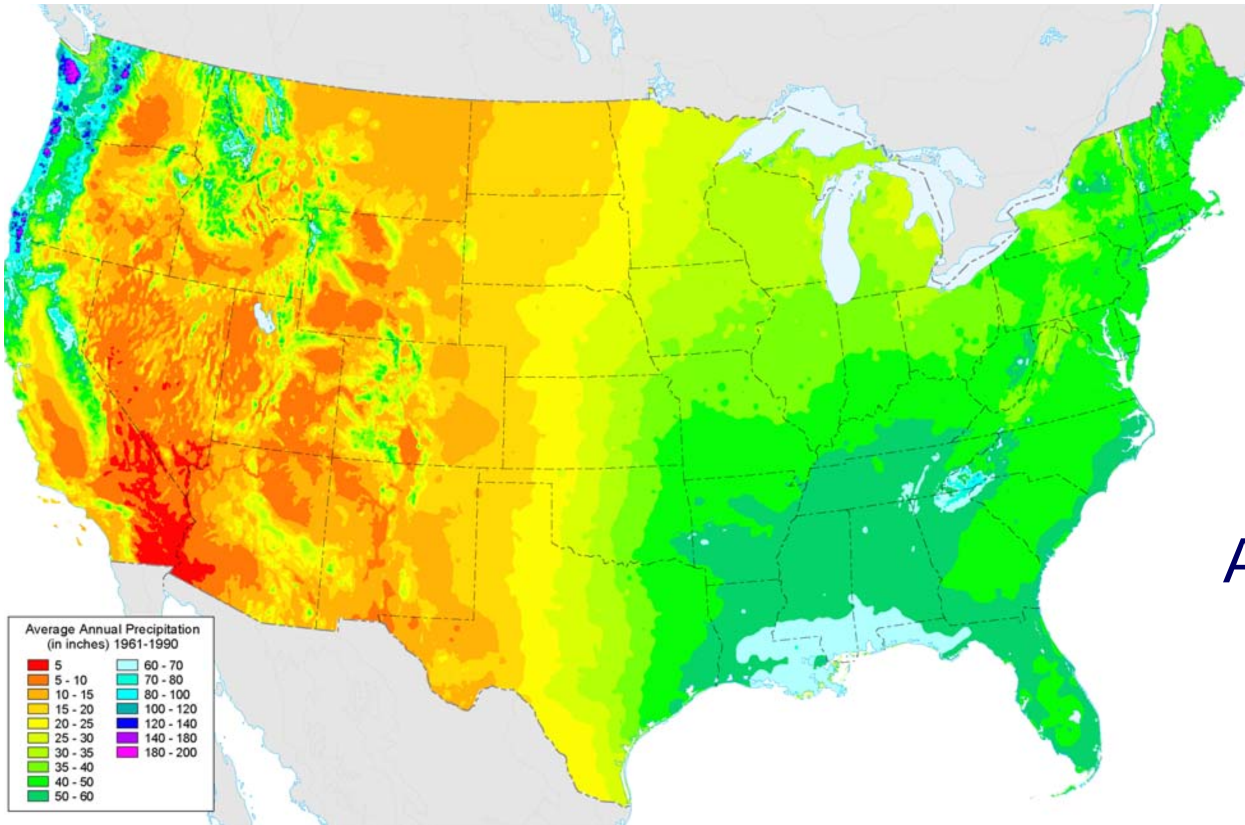
10 Regions, 48 states

Wadeable streams

(1st through 3rd order)



# National River and Stream Assessment (2008-09)



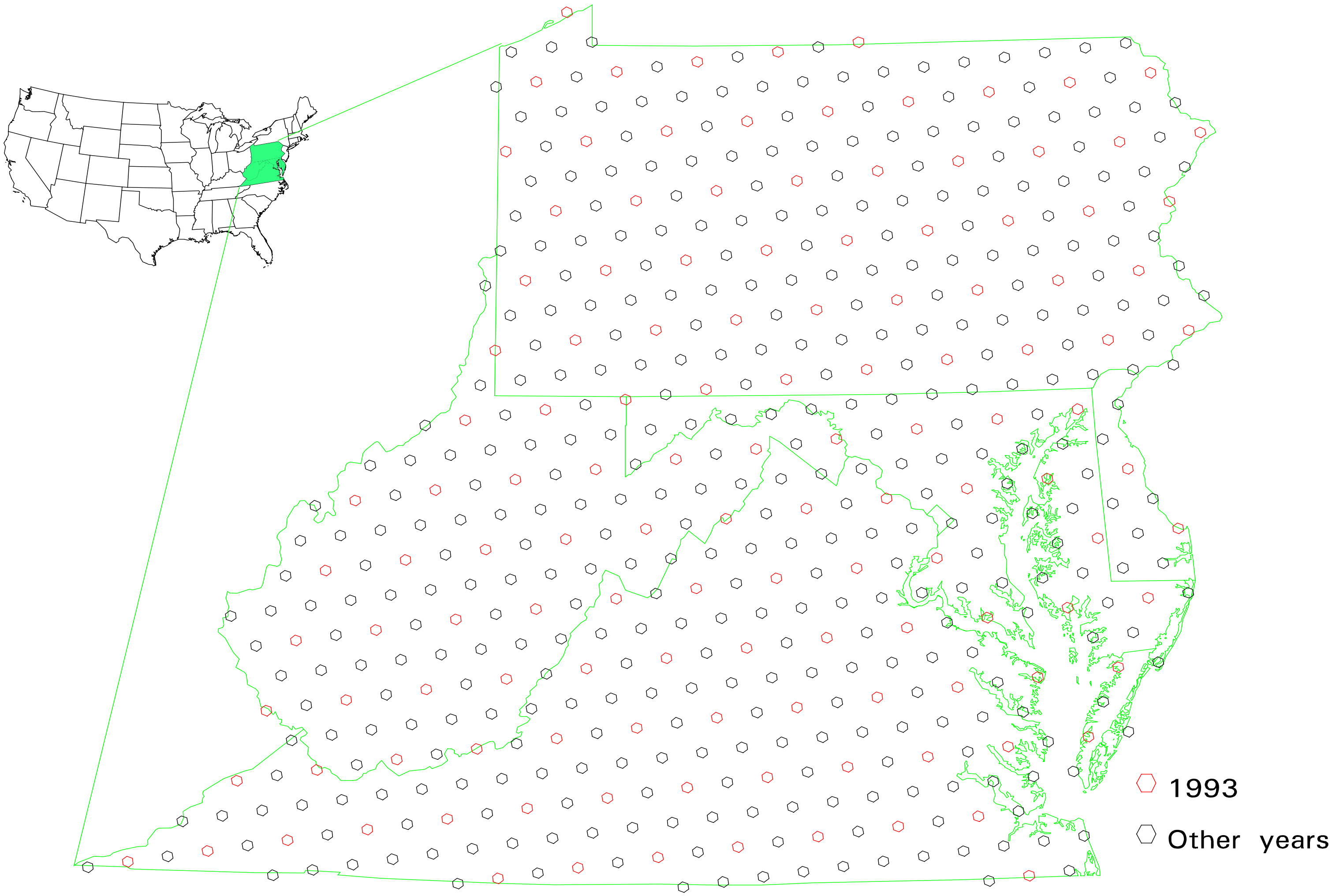

All perennial flowing waters, *including* "Great Rivers"

3,100,000 $mi^2$

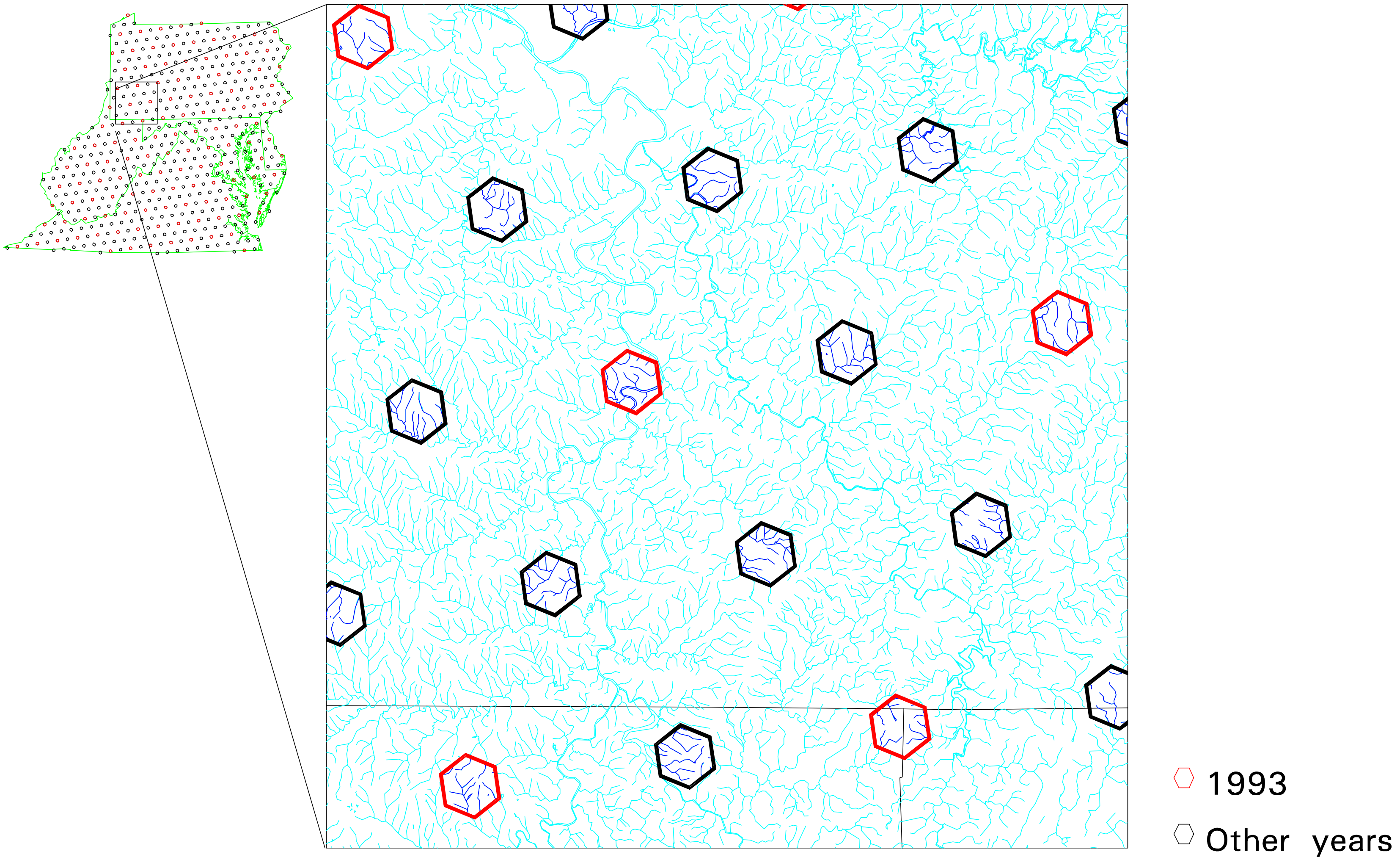
10 Regions, 48 states

# Design

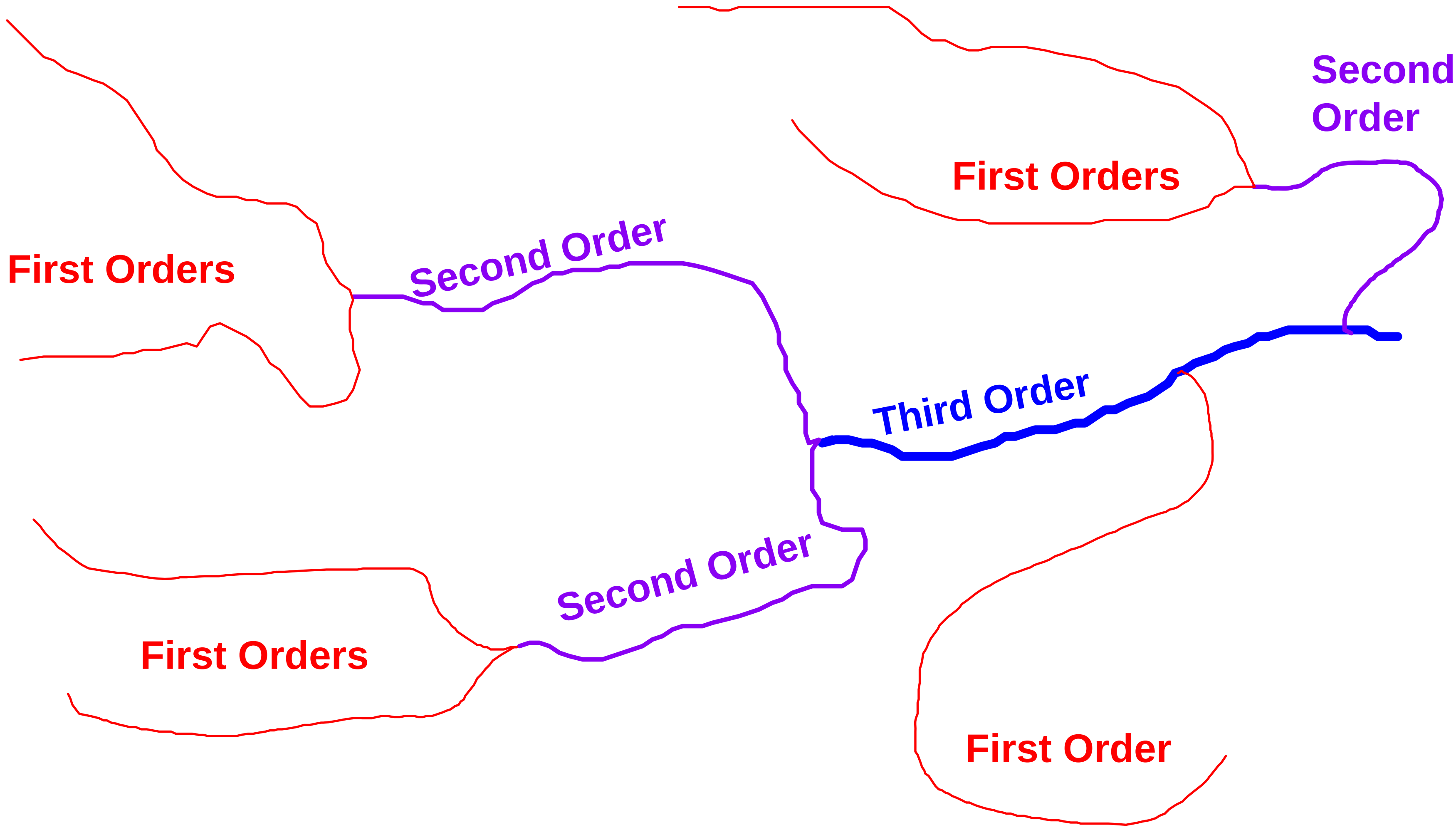
# Design - MAHA Site Selection



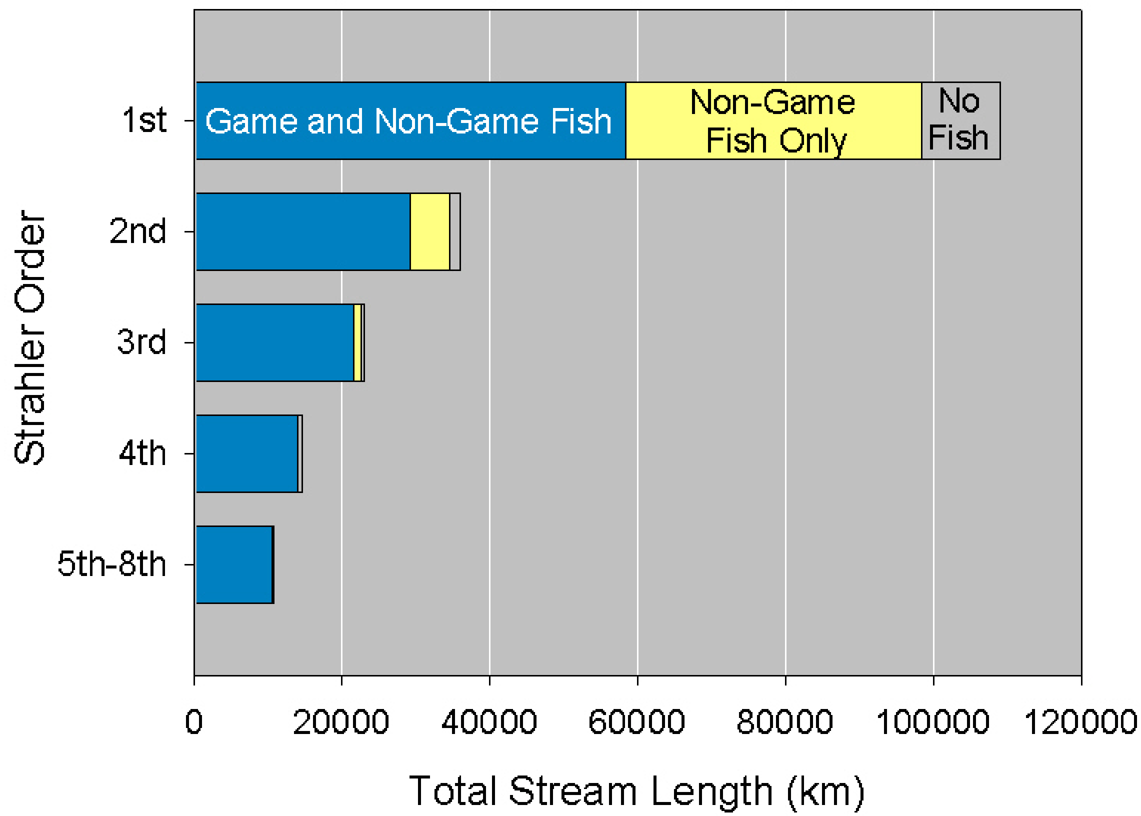
# Design - MAHA Site Selection



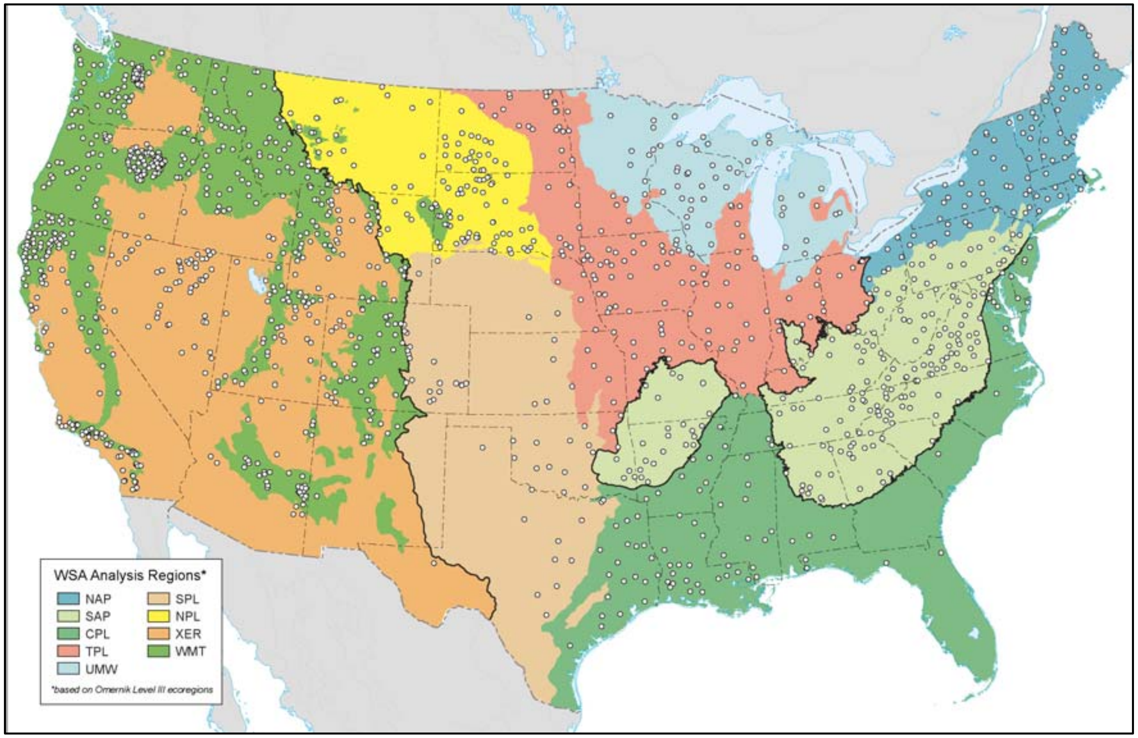
# Strahler Orders



# Strahler Orders



# Design – GRTS
## Eastern portion of WSA




Spatially-balanced

Unequal probabilities based on:

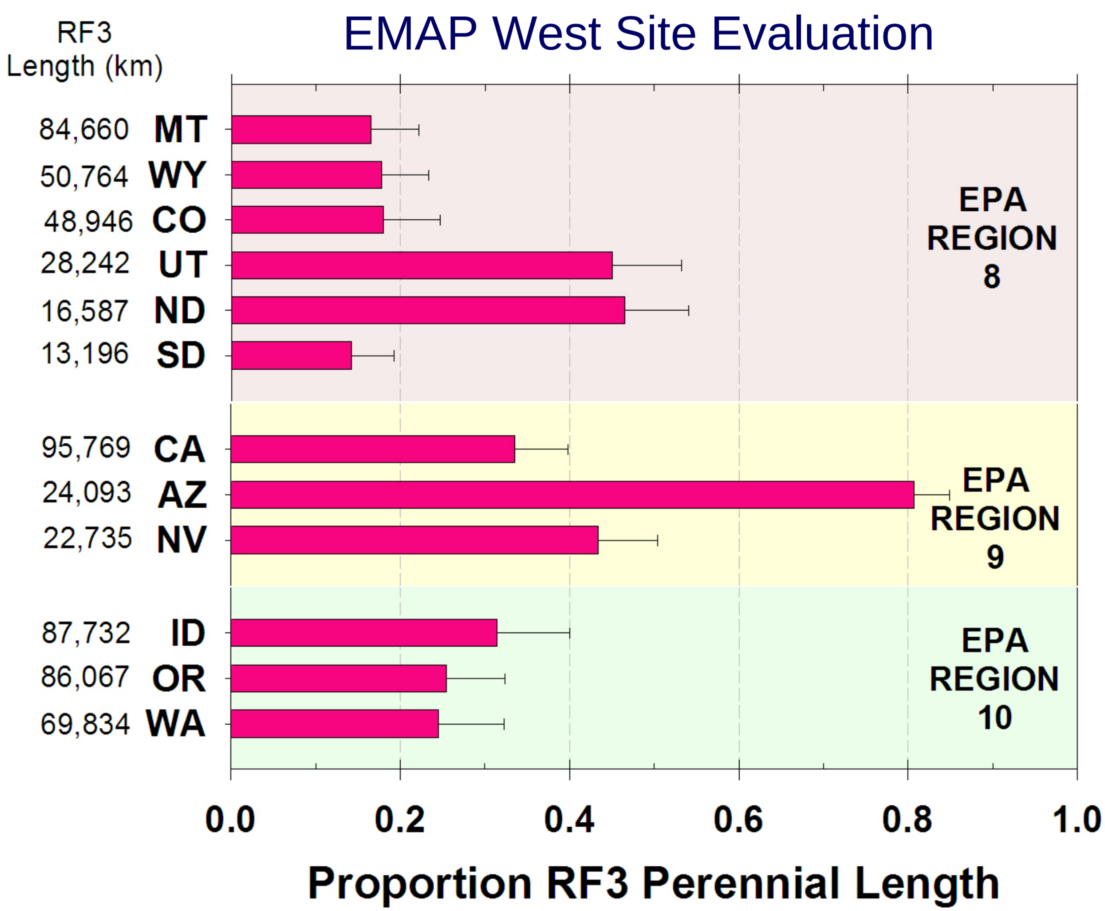
- Omernik ecoregion
- USEPA region
- Strahler order categories:

Expected sample size 500 sites

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

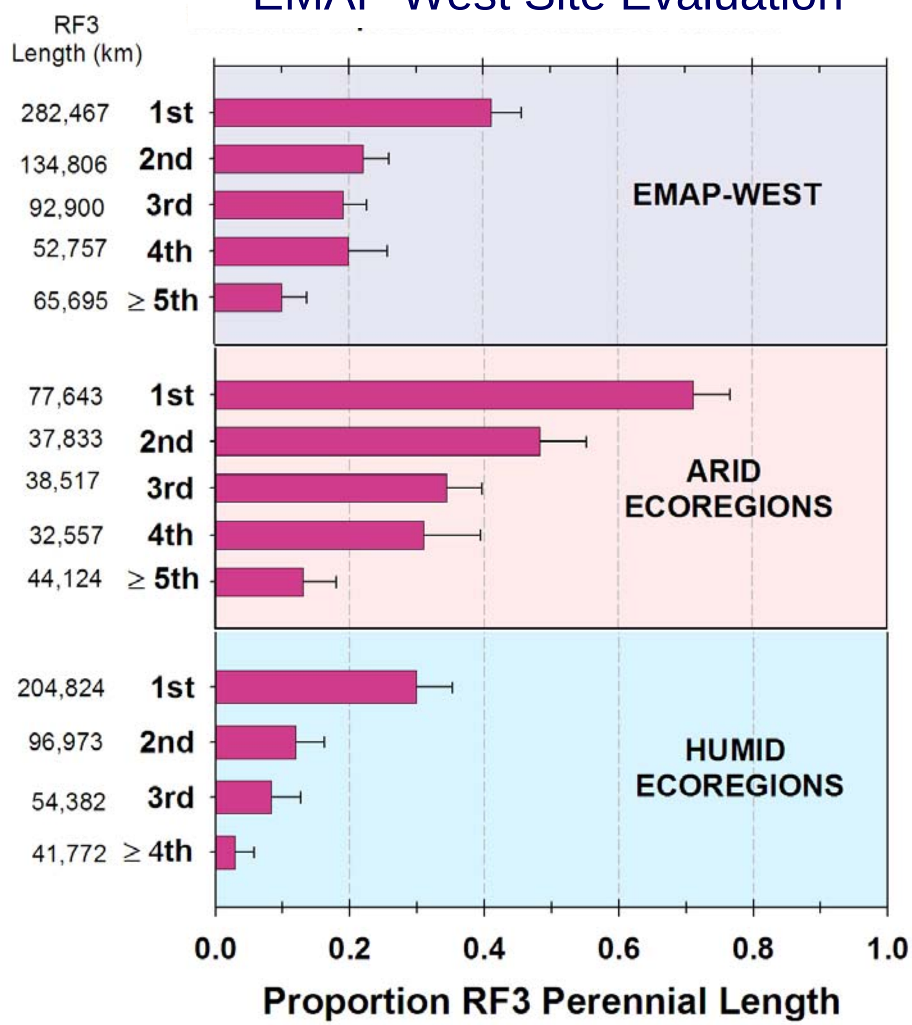
- Non-wadeable stream
- Landowner access denial
- Physically inaccessible

# Design
## Dealing with an Imperfect Frame

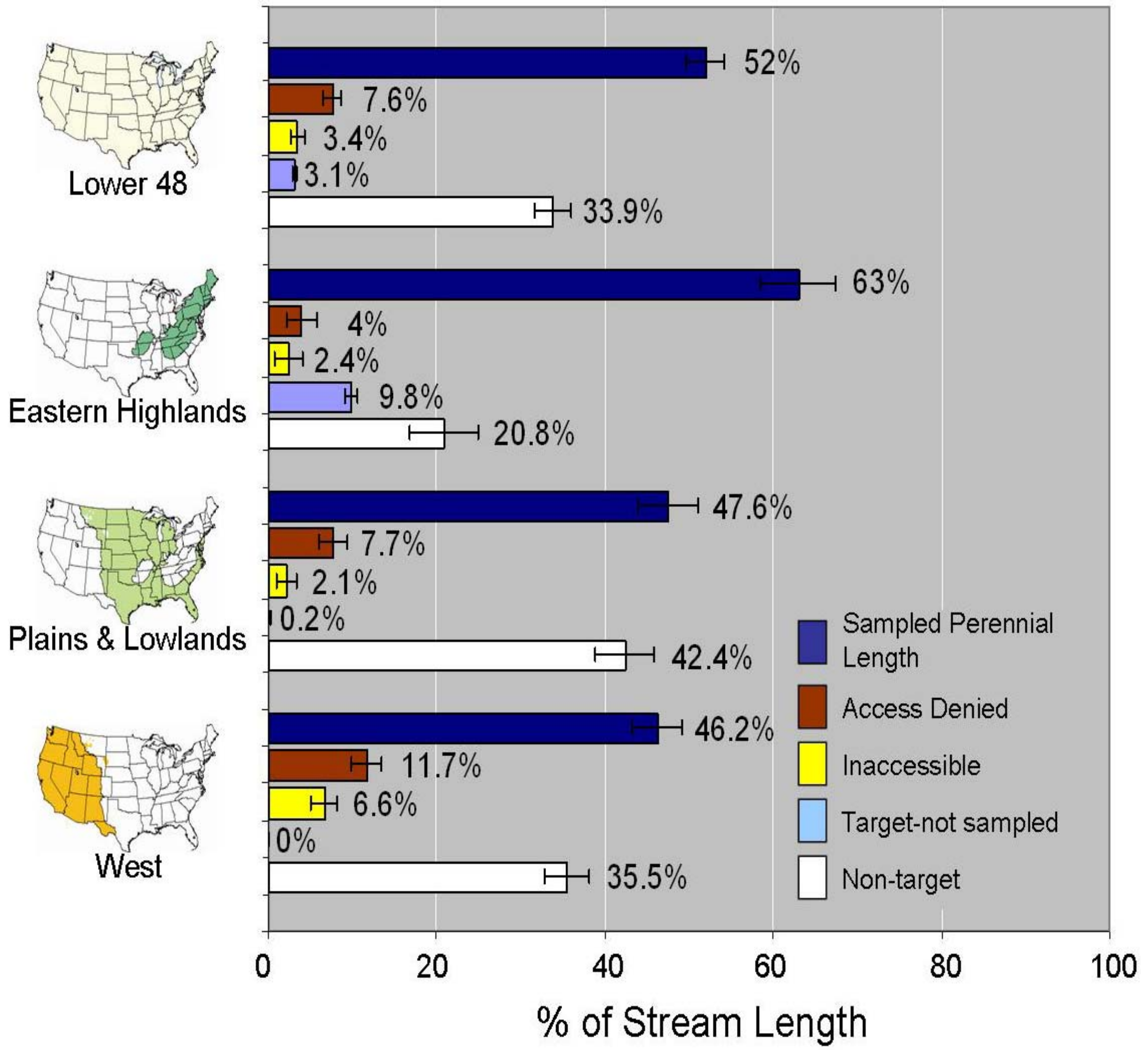



# Design
# Dealing with an Imperfect Frame - EMAPW

EMAP West Site Evaluation

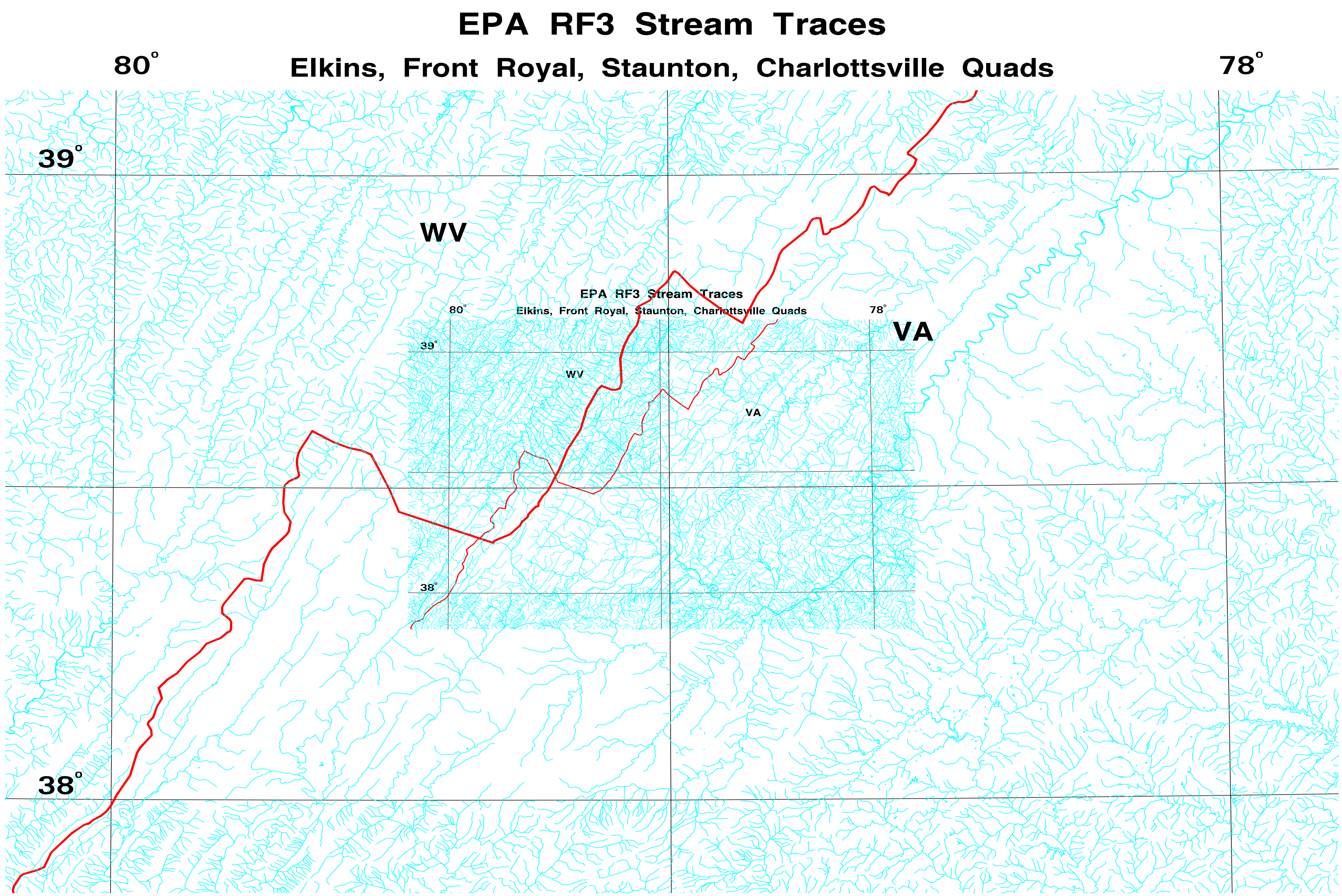


# Design
## Dealing with an Imperfect Frame - WSA




Based on office and field evaluation of sites in sample.

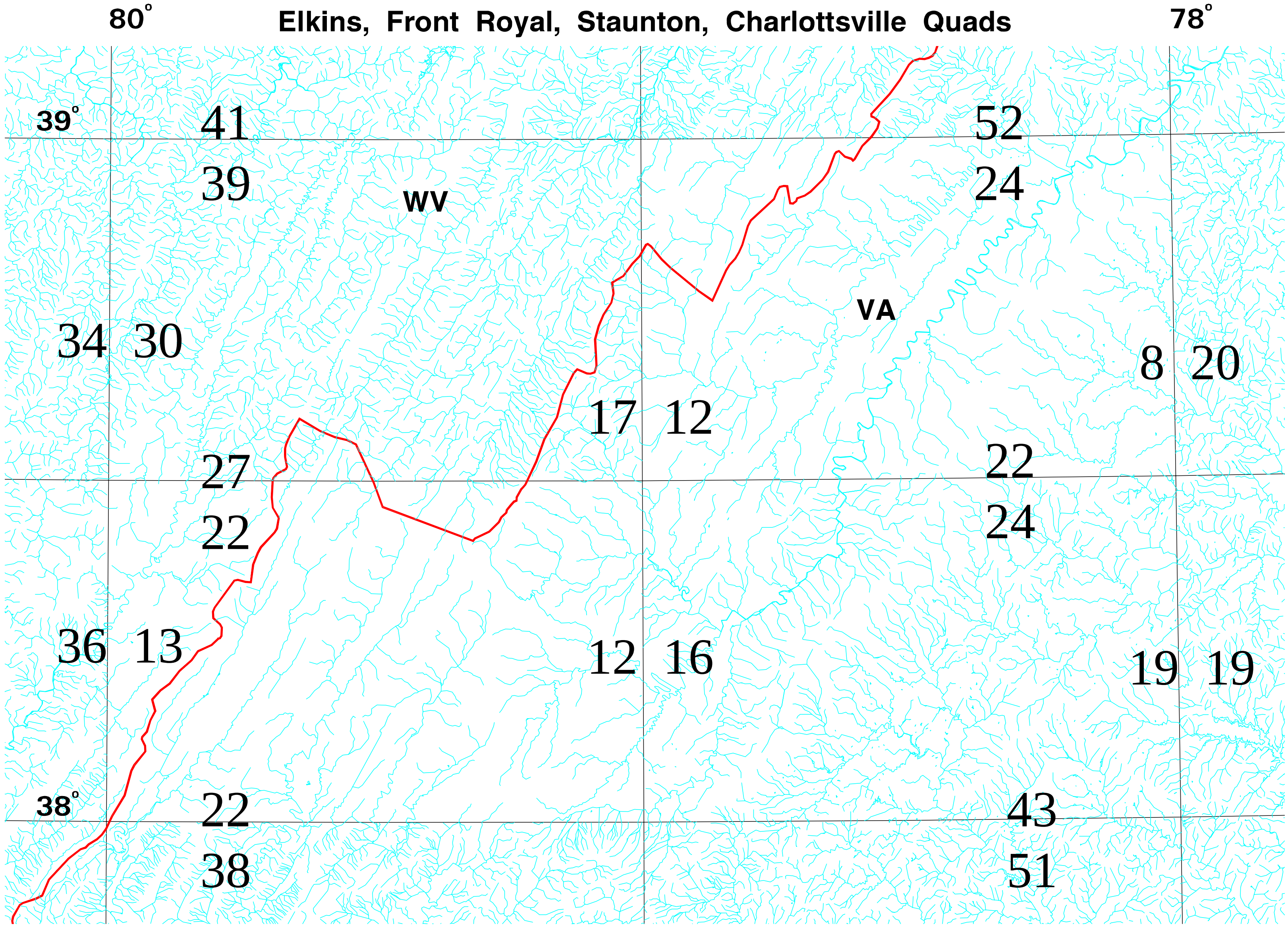
In each region, percentages are percent of NHD length in the region



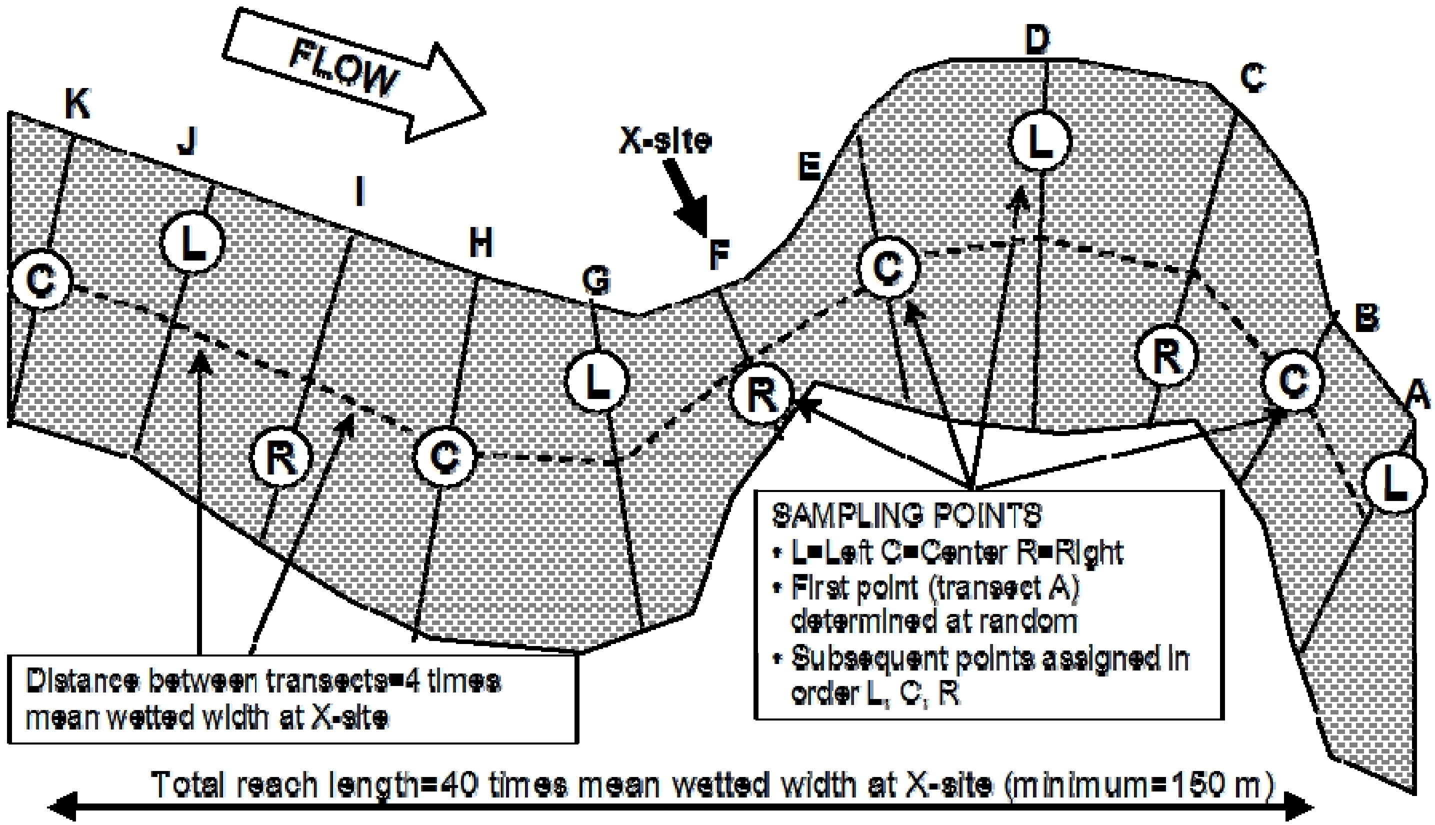
EPA RF3 Stream Traces
Elkins, Front Royal, Staunton, Charlottsville Quads
80°
78°
39°
38°
WV
VA
EPA RF3 Stream Traces
Elkins, Front Royal, Staunton, Charlottsville Quads
80°
78°
39°
38°
WV
VA

# EPA RF3 Stream Traces

Elkins, Front Royal, Staunton, Charlottsville Quads

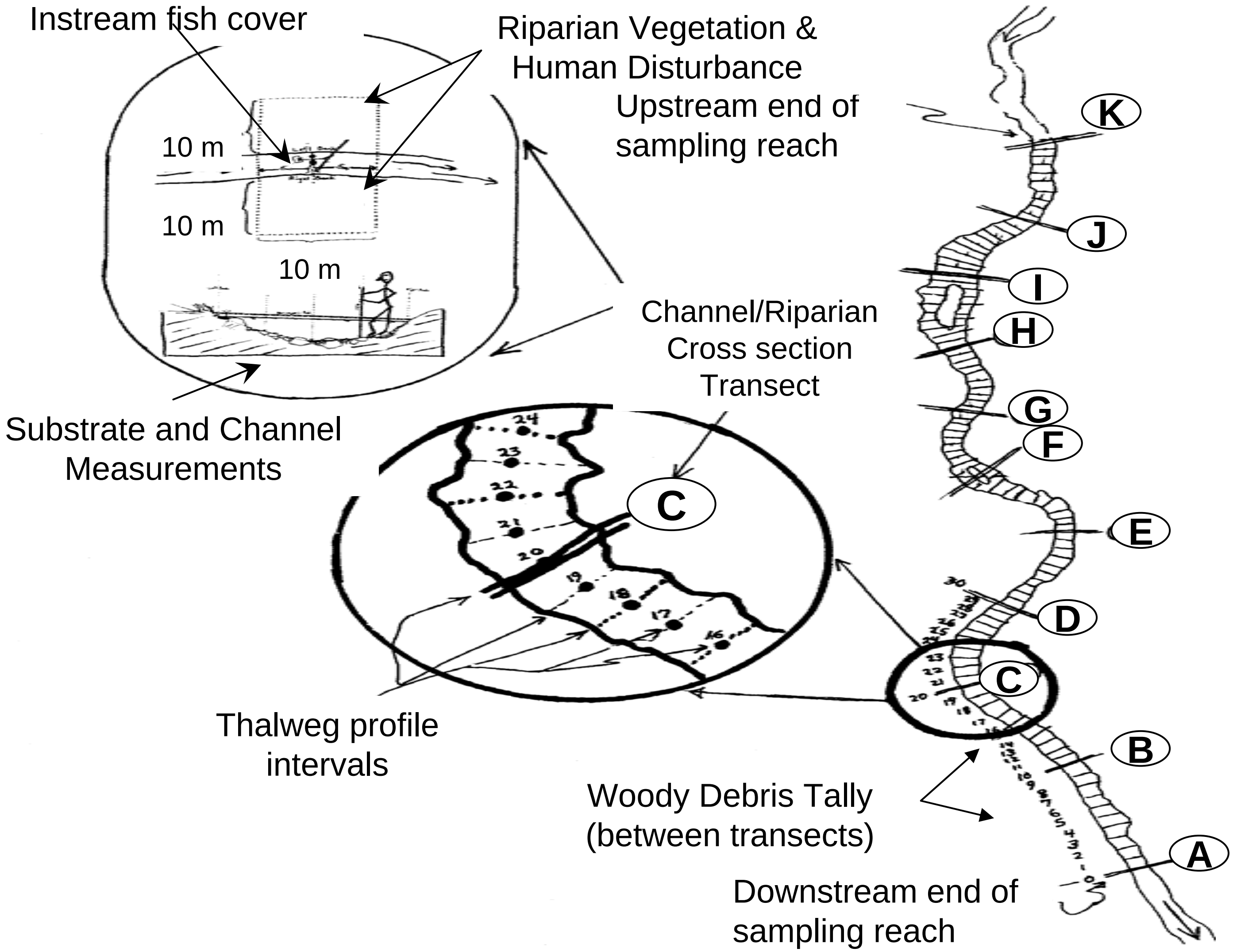


# Plot Design

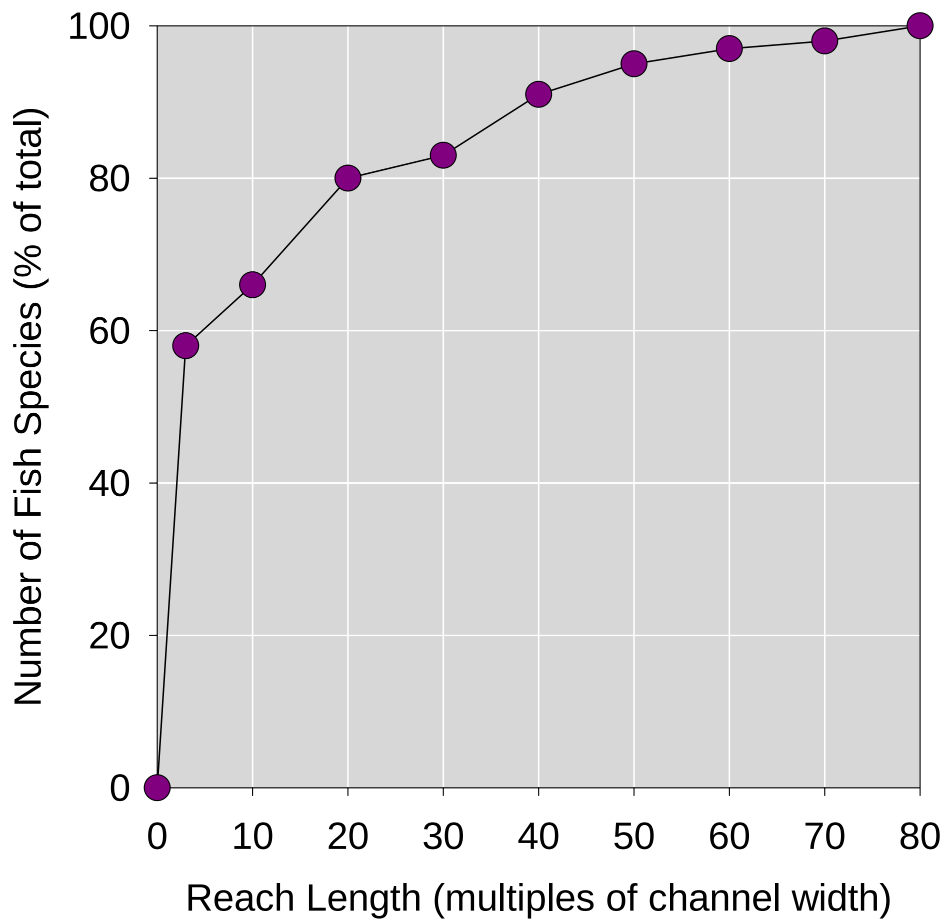


FLOW
K
J
I
H
G
F
E
D
C
B
A
X-site
C
L
R
C
L
R
C
L
R
C
L
Distance between transects=4 times
mean wetted width at X-site
SAMPLING POINTS
• L=Left C=Center R=Right
• First point (transect A)
determined at random
• Subsequent points assigned in
order L, C, R
Total reach length=40 times mean wetted width at X-site (minimum=150 m)

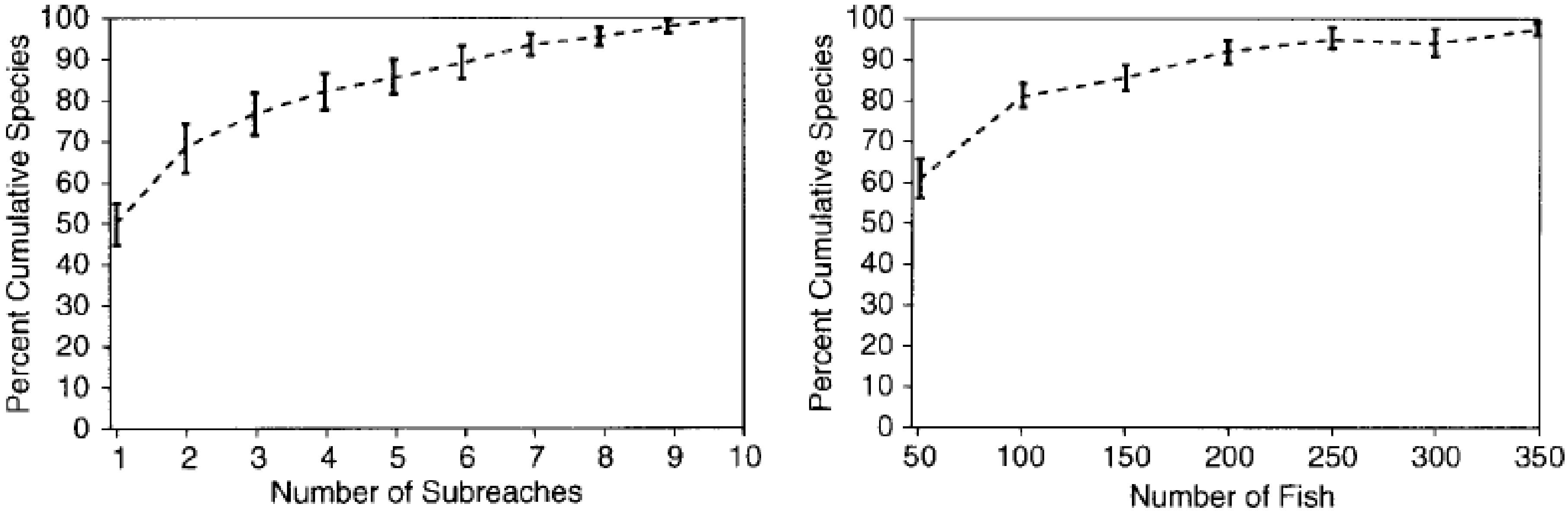
# Plot Design


Instream fish cover
Riparian Vegetation & Human Disturbance
Upstream end of sampling reach
10 m
10 m
10 m
K
J
I
H
G
F
E
D
C
B
A
Channel/Riparian Cross section Transect
Substrate and Channel Measurements
C
Thalweg profile intervals
Woody Debris Tally (between transects)
Downstream end of sampling reach

# Plot Design – Sample Sufficiency for Streams



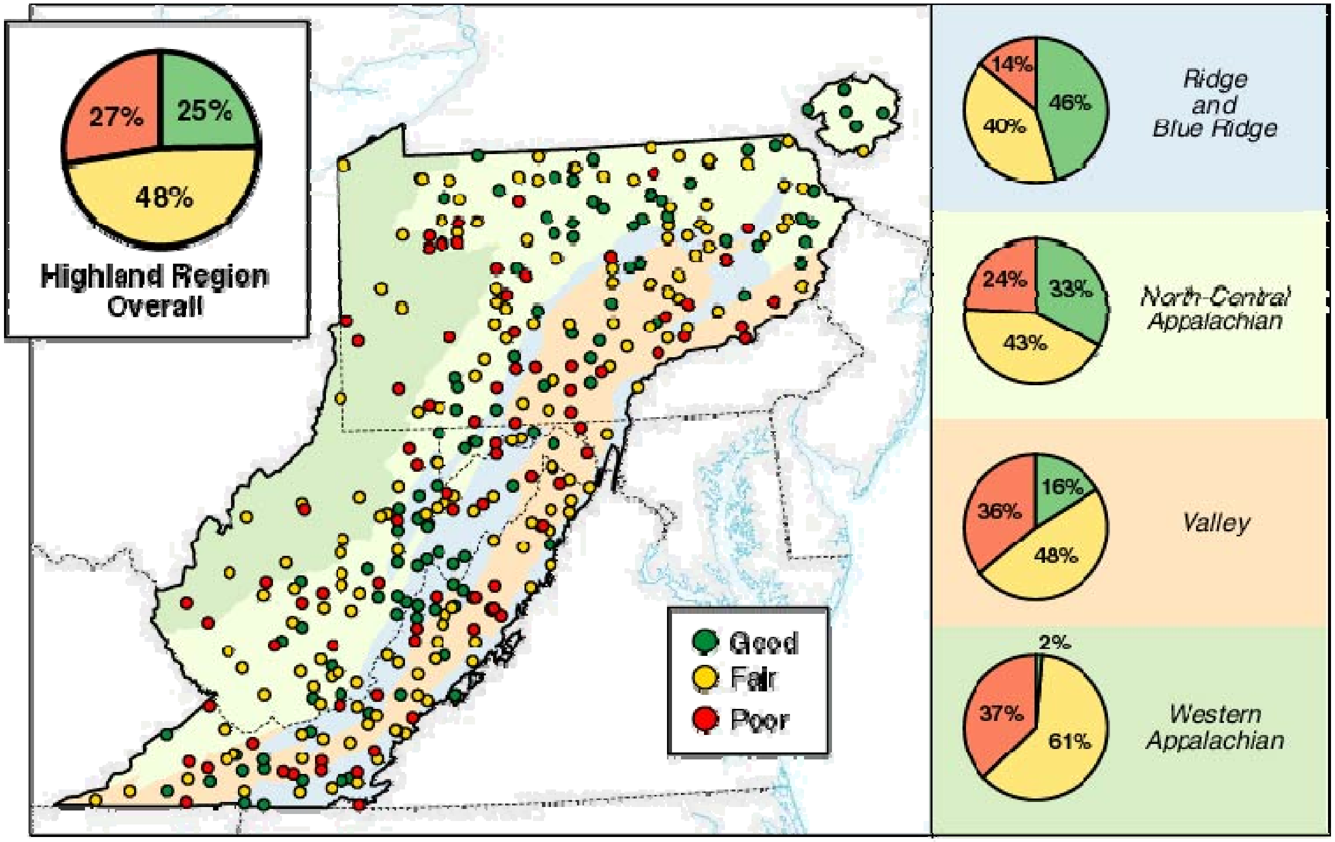
# Plot Design – Sample Sufficiency for Rivers



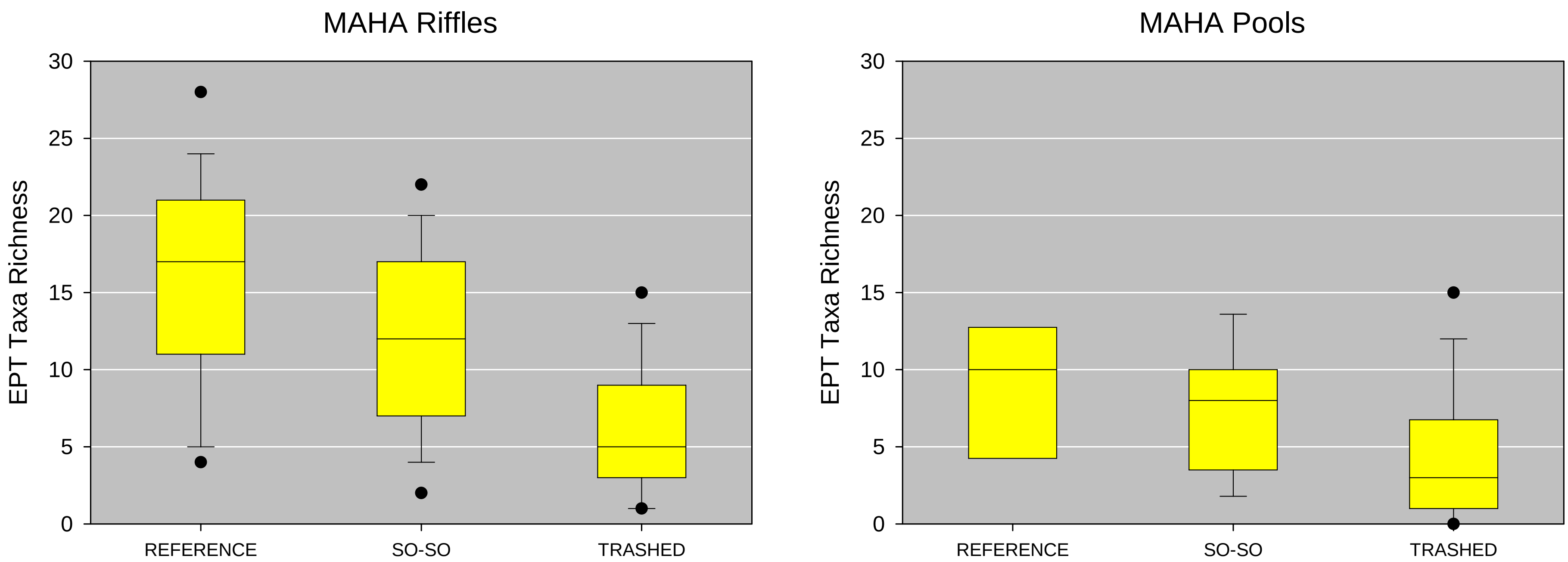
# Biological Indicators

# MAHA Macroinvertebrate Results

## Number of EPT Taxa



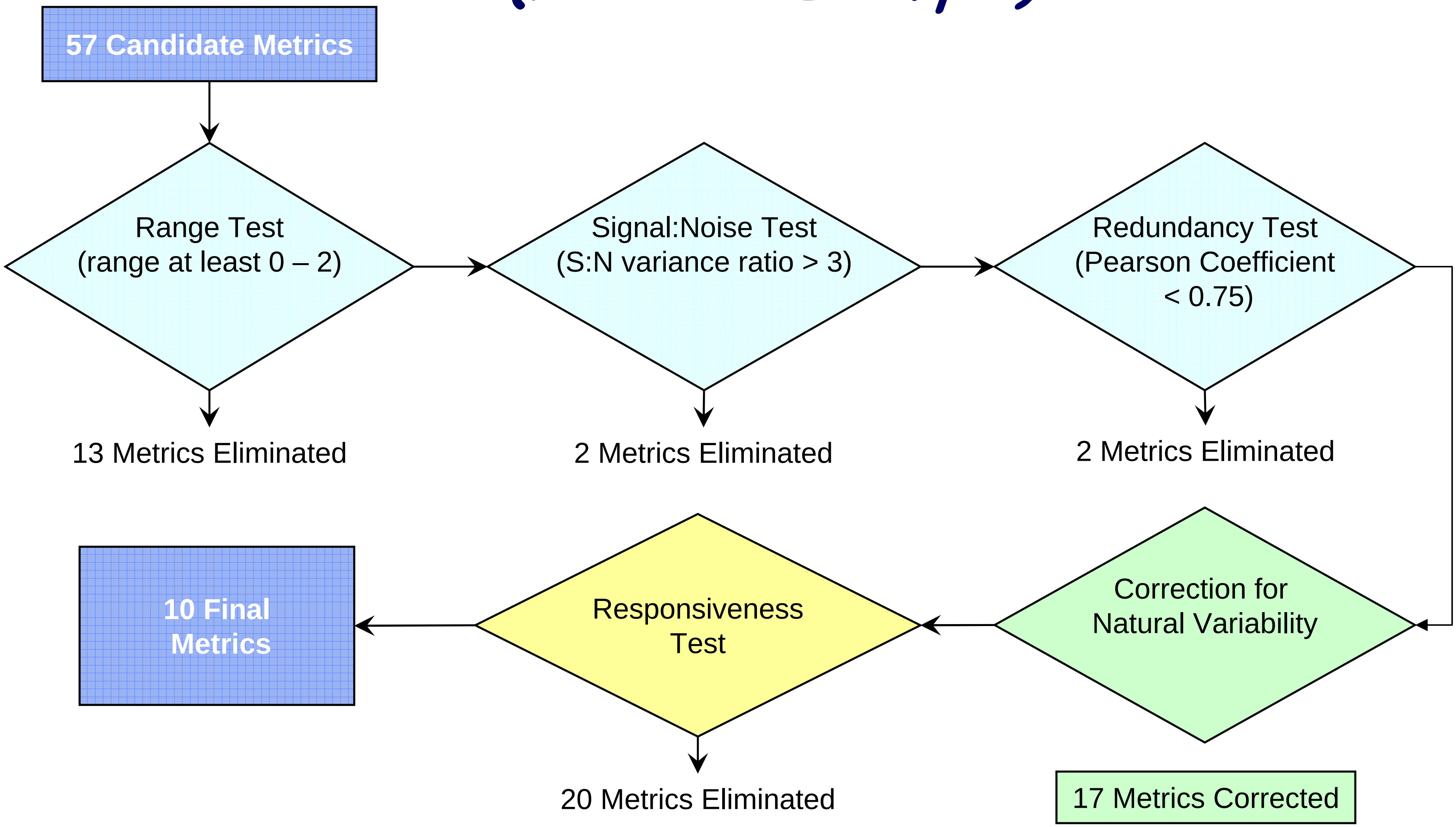
# EPT Results in Riffles and Pools



# Index Development Approach
## Example Fish Metrics

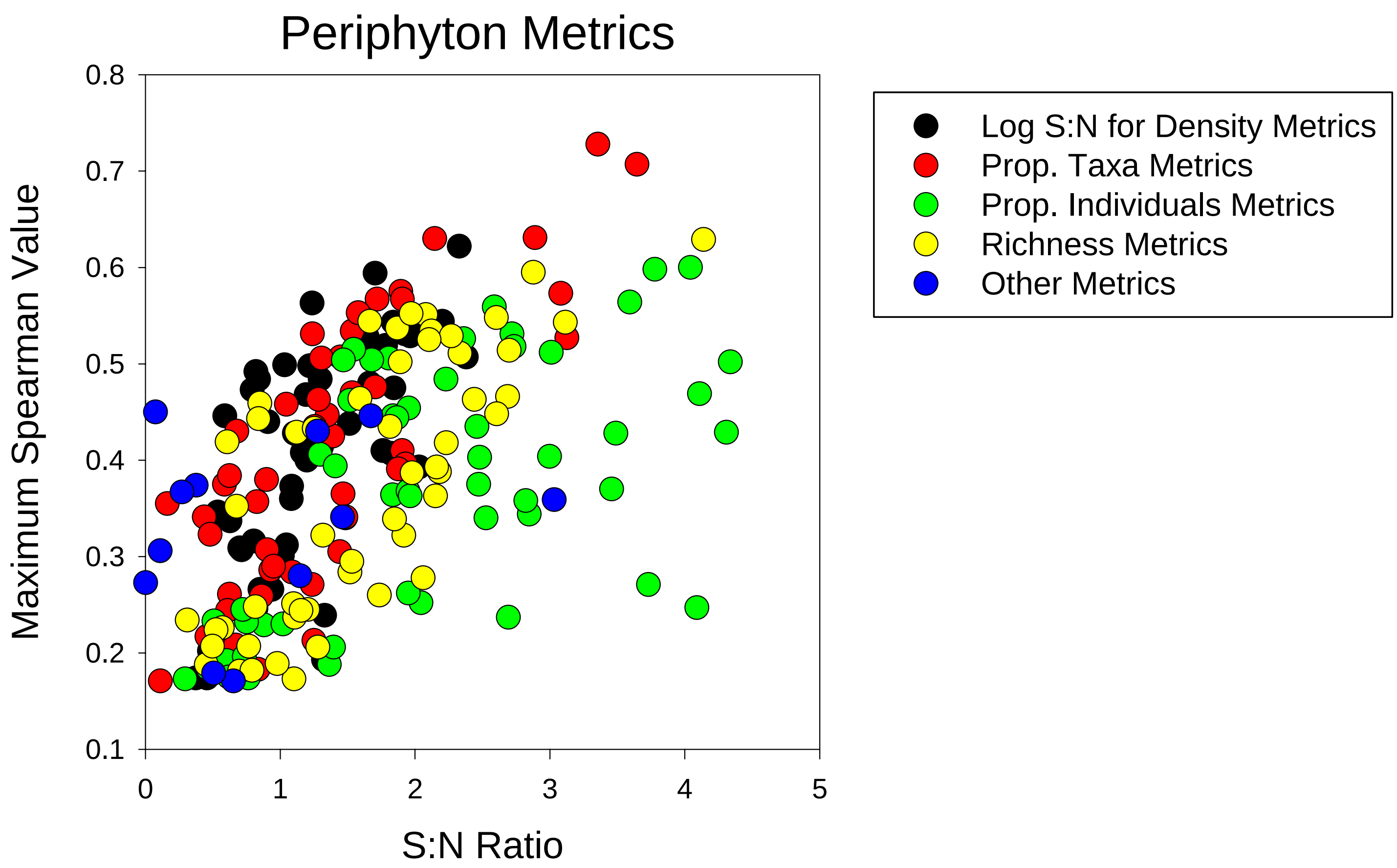
| | | | |
|---|---|---|---|
| NATIVFAM | Number of families represented | PBCLN | prop. of indiv. as bc spwn clear substr. |
| NREPROS | Number of reproductive guilds | PBCST | prop. of indiv. as broadcast spawners |
| NSANGU | Number of anguilla species | PBENT | prop. of fish as benthic insectivores |
| 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. 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 | | |

# Index Development Approach
## (Fish IBI Example)

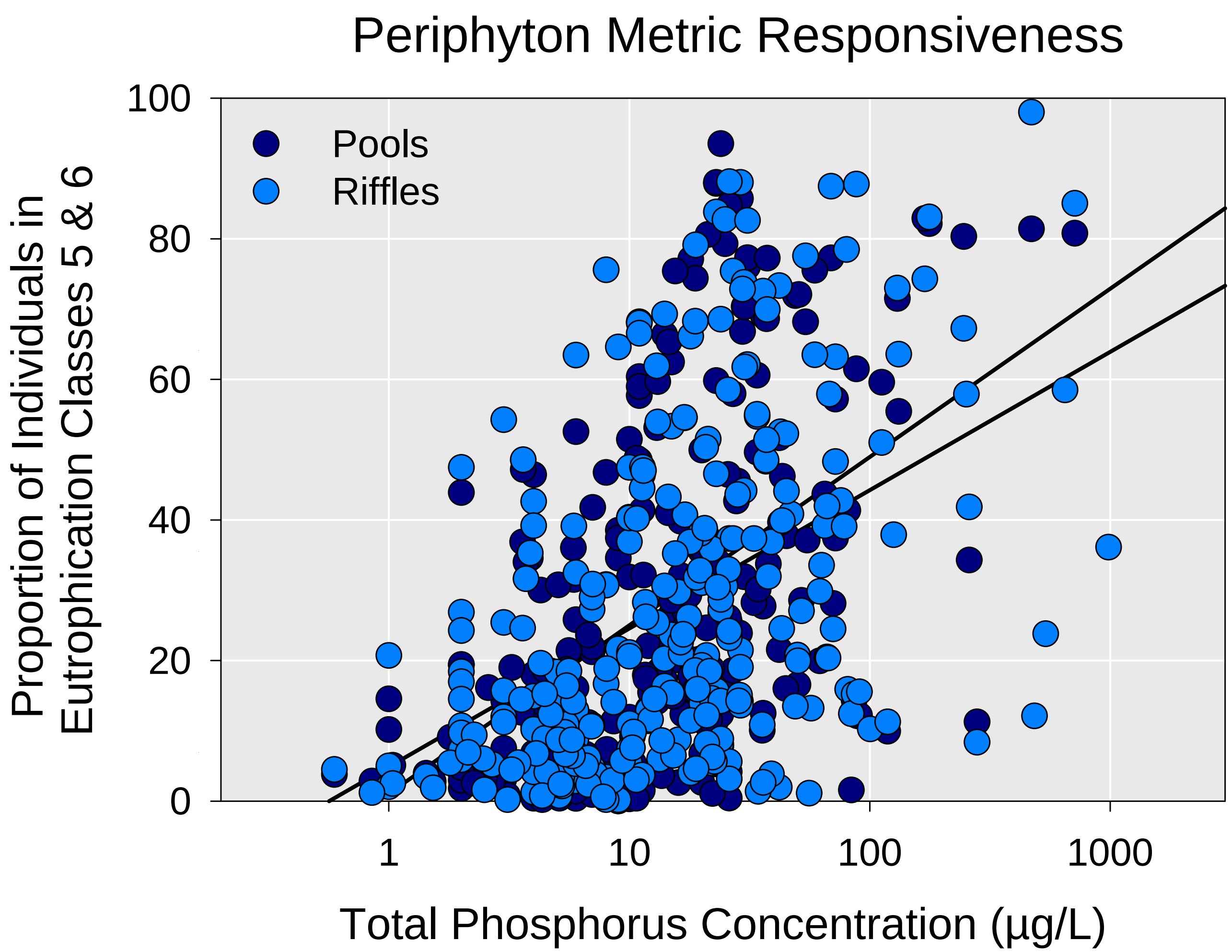


# Index Development Approach
## (Signal:Noise Test)

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

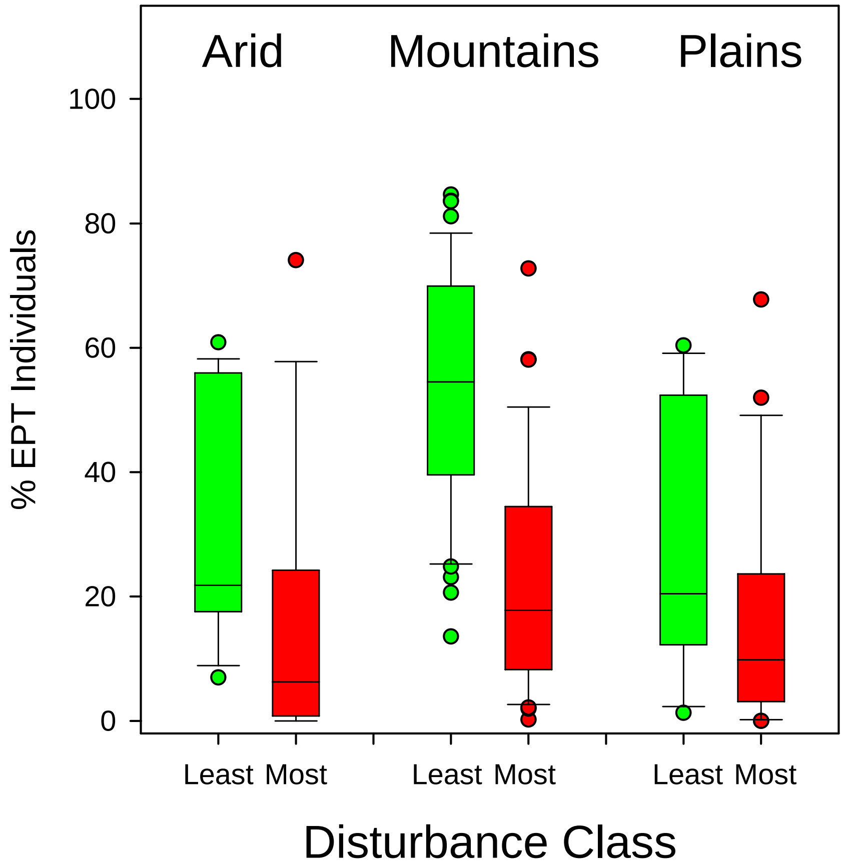


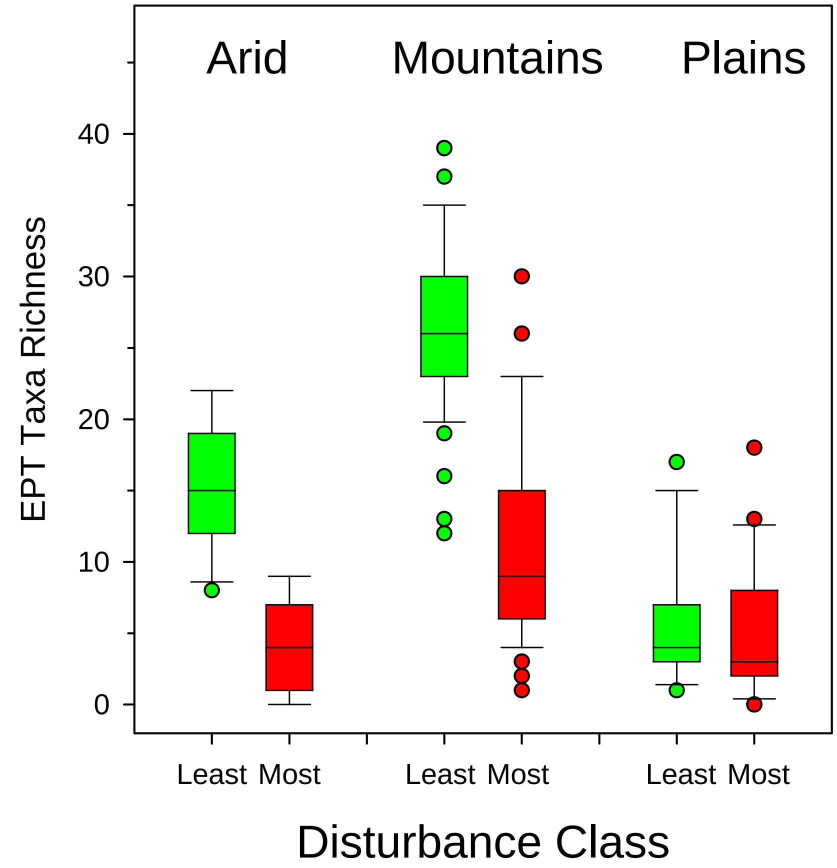
# Index Development Approach
## (Example of Periphyton Responsiveness)



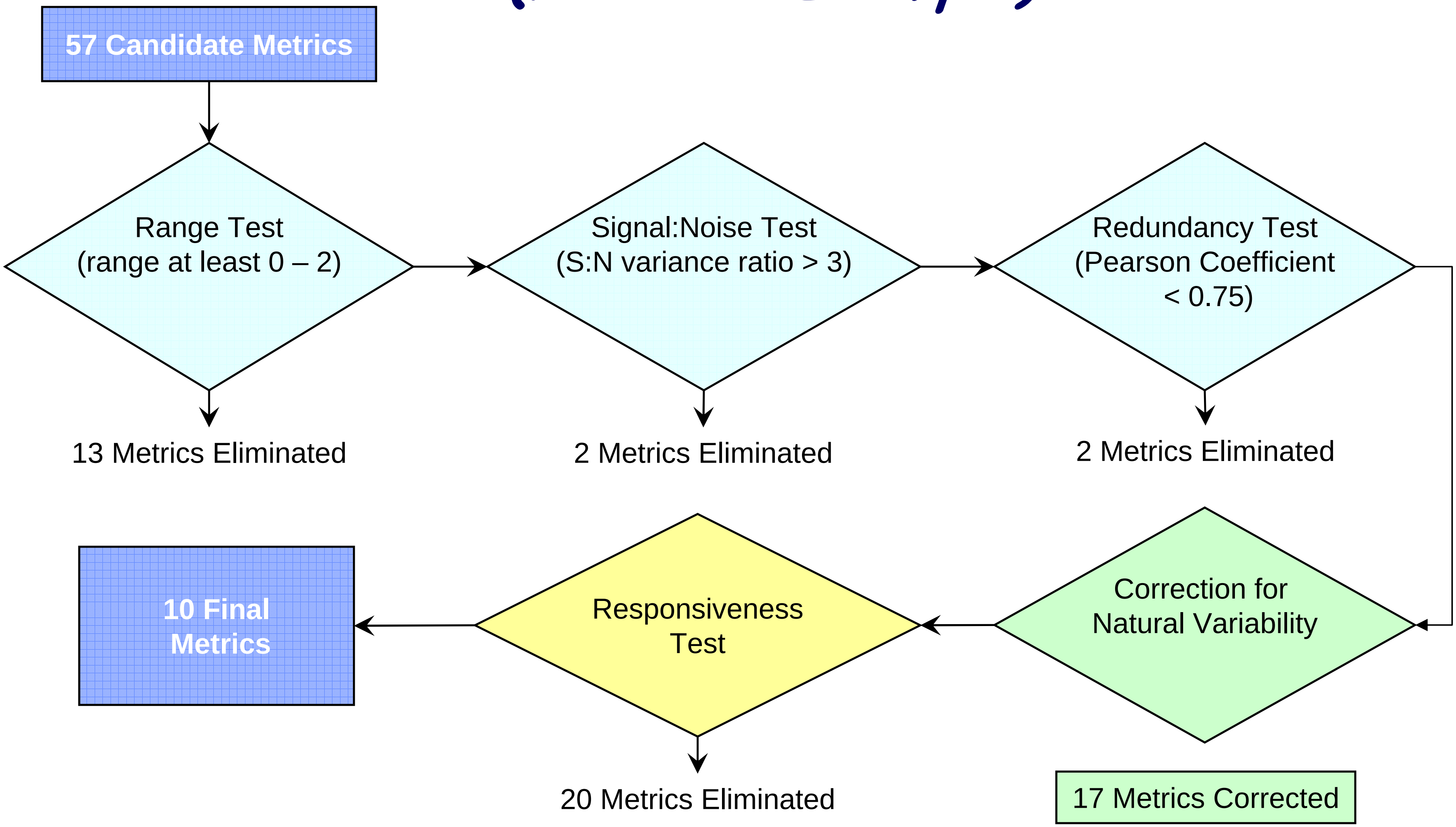
# Index Development Approach

## Responsiveness Quick and Dirty Screen

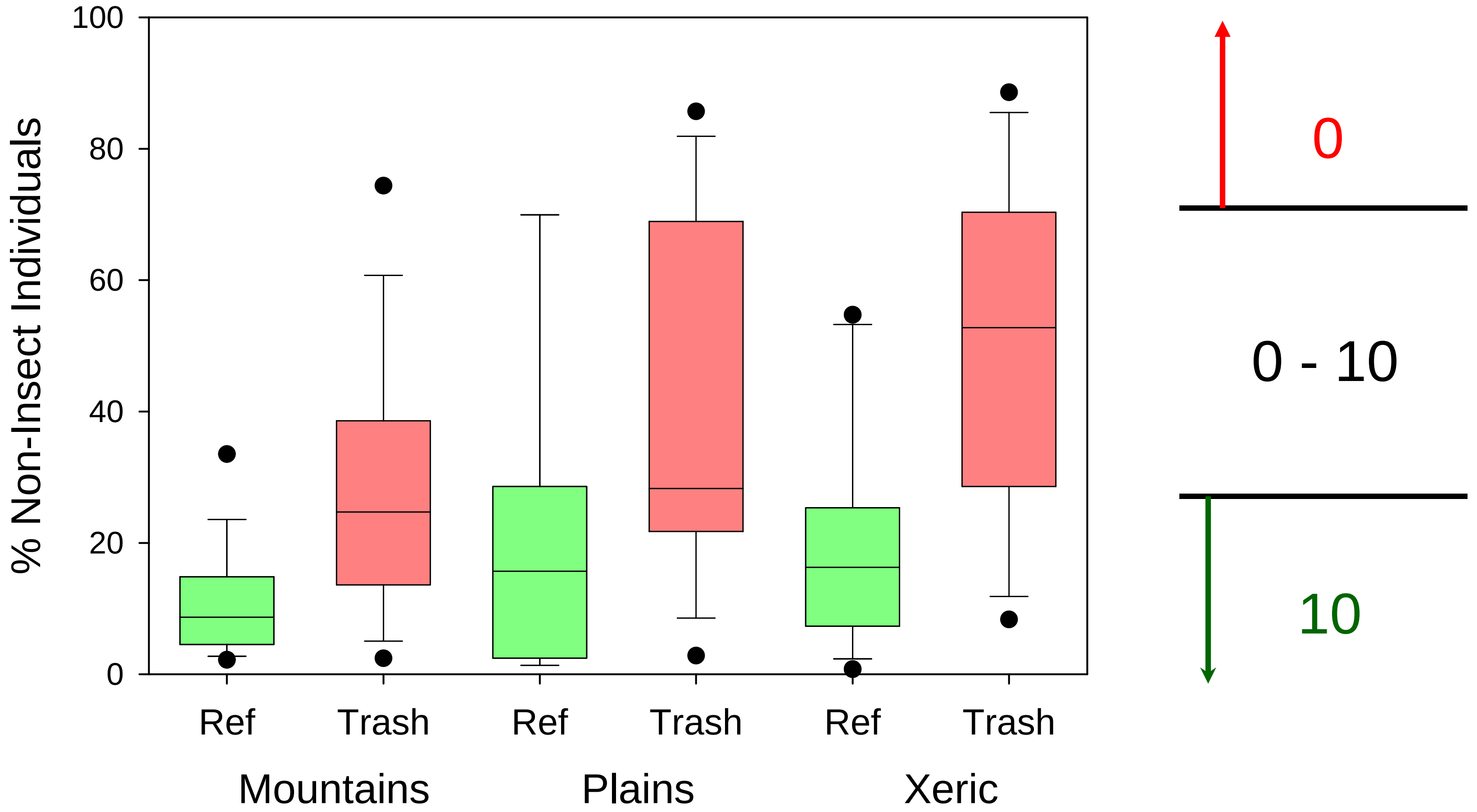


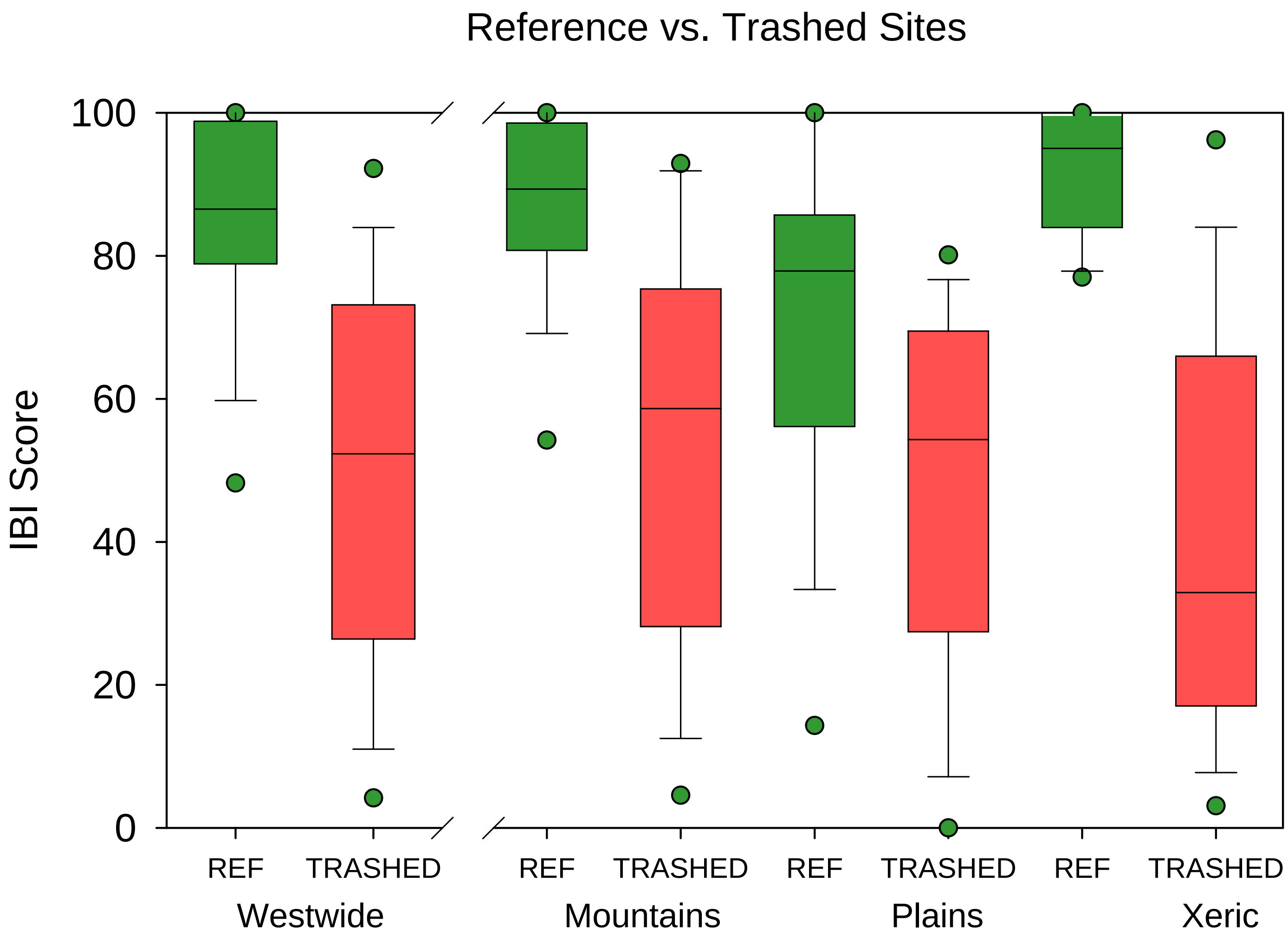
# Index Development Approach
## (Fish IBI Example)



# Metric Scoring



# Responsiveness of Final Index
## EMAP West Fish IBI

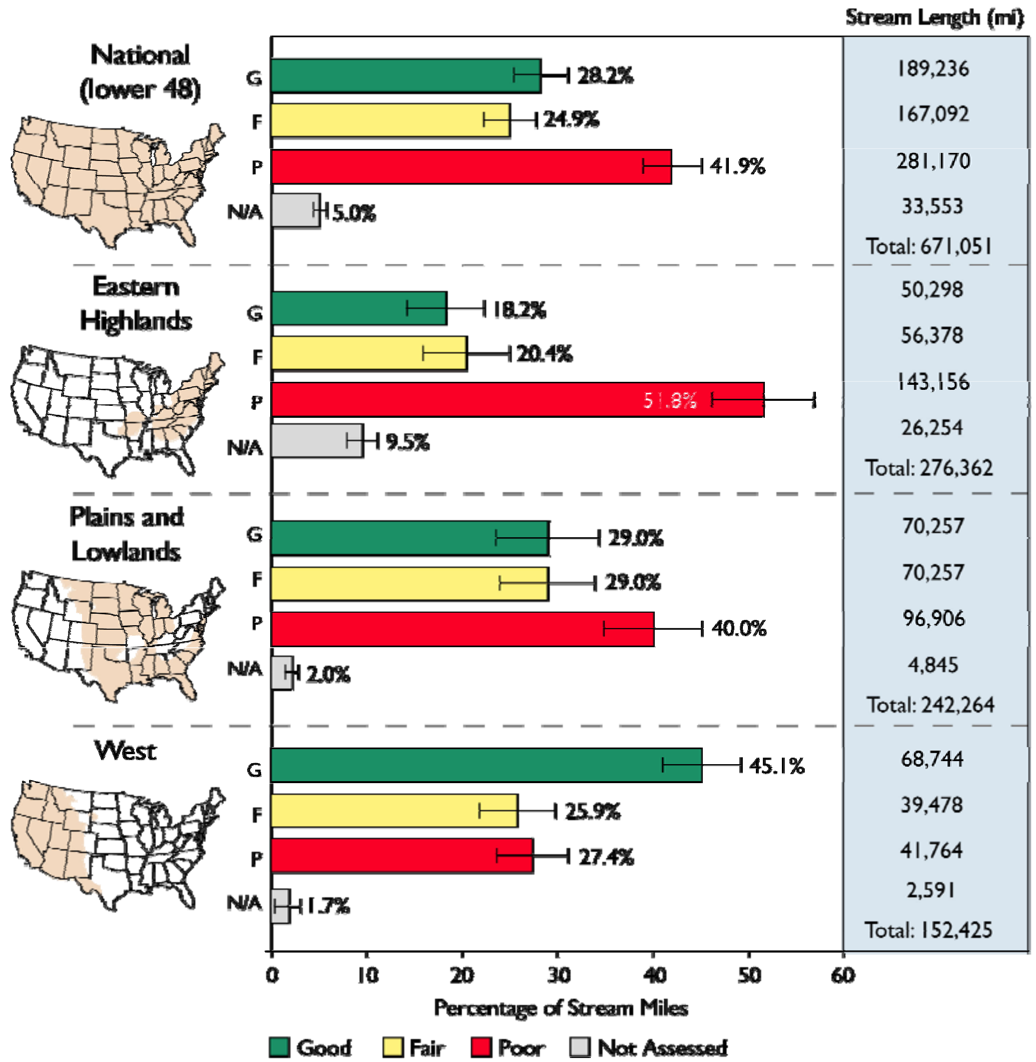


# Wadeable Streams Assessment

## 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



# Predictive Modeling
## An Alternative to IBIs?

REFERENCE TAXA LIST

(hypothetical example with 5 reference sites in region)

| | Taxa Name | # of Ref Sites | Probability |
|---|---|---|---|
| 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?

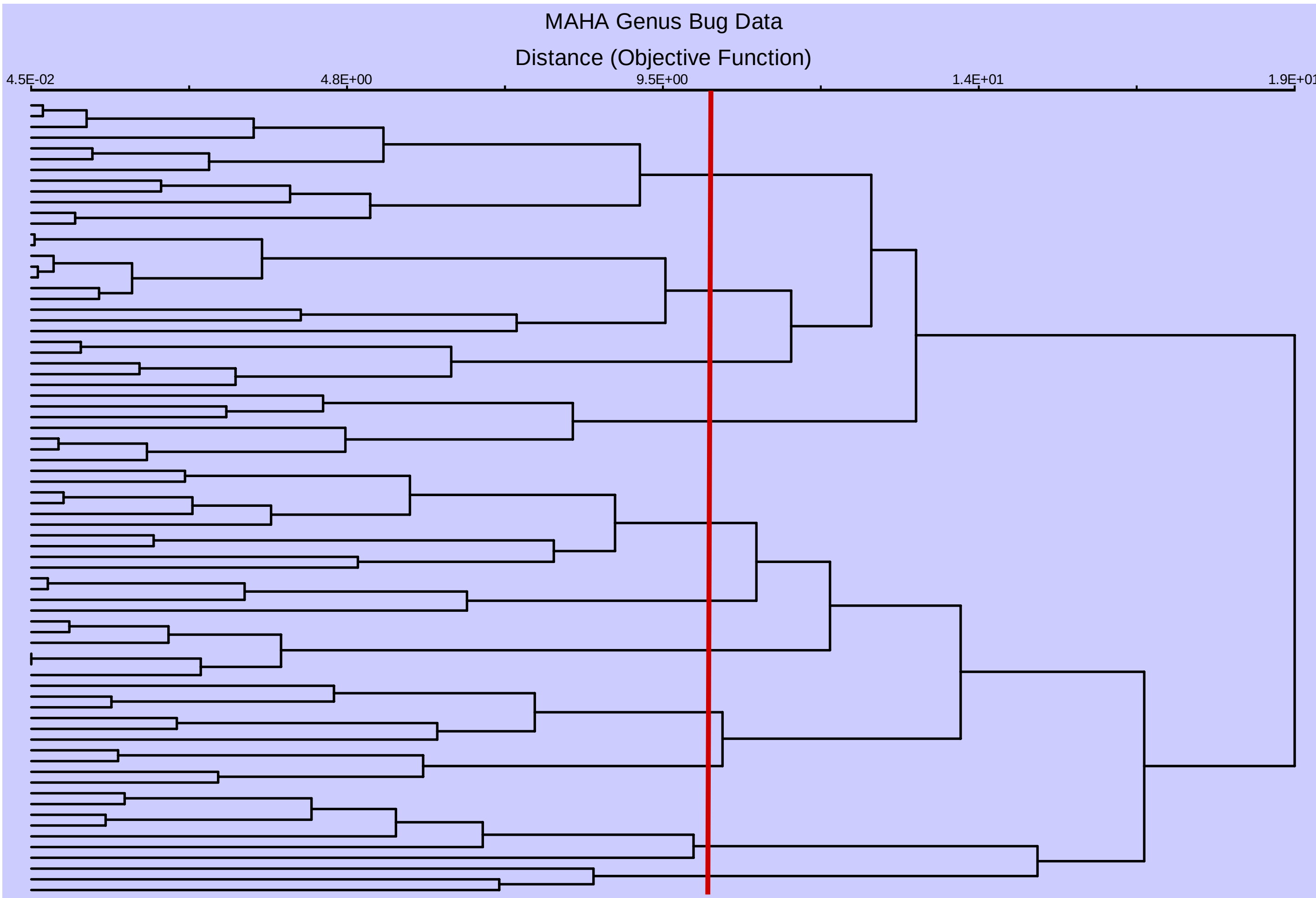
SITE AR08-04

| Reference Taxa | Non-Reference Taxa |
|---|---|
| 1. BAETLABI | 14. AMEAMEL |
| 2. CERACERA | 15. COLLSP. |
| 3. CHIRCHIR | 16. CORYNEOH |
| 4. CHIRORTH | 17. EMPICLIN |
| 5. CHIRTPOD | 18. EPHESERR |
| 6. CHIRTTAR | 19. HEPTCGMA |
| 7. CHLOSWEL | 20. PLANSP. |
| 8. EMPICHEL | |
| 9. LEPILEPI | |
| 10. LEPTPARA | |
| 11. NEMASP. | |
| 12. OLIGSP. | |
| 13. TIPUDICR | |

**O = 13** **E=26.4** **O/E=0.492**

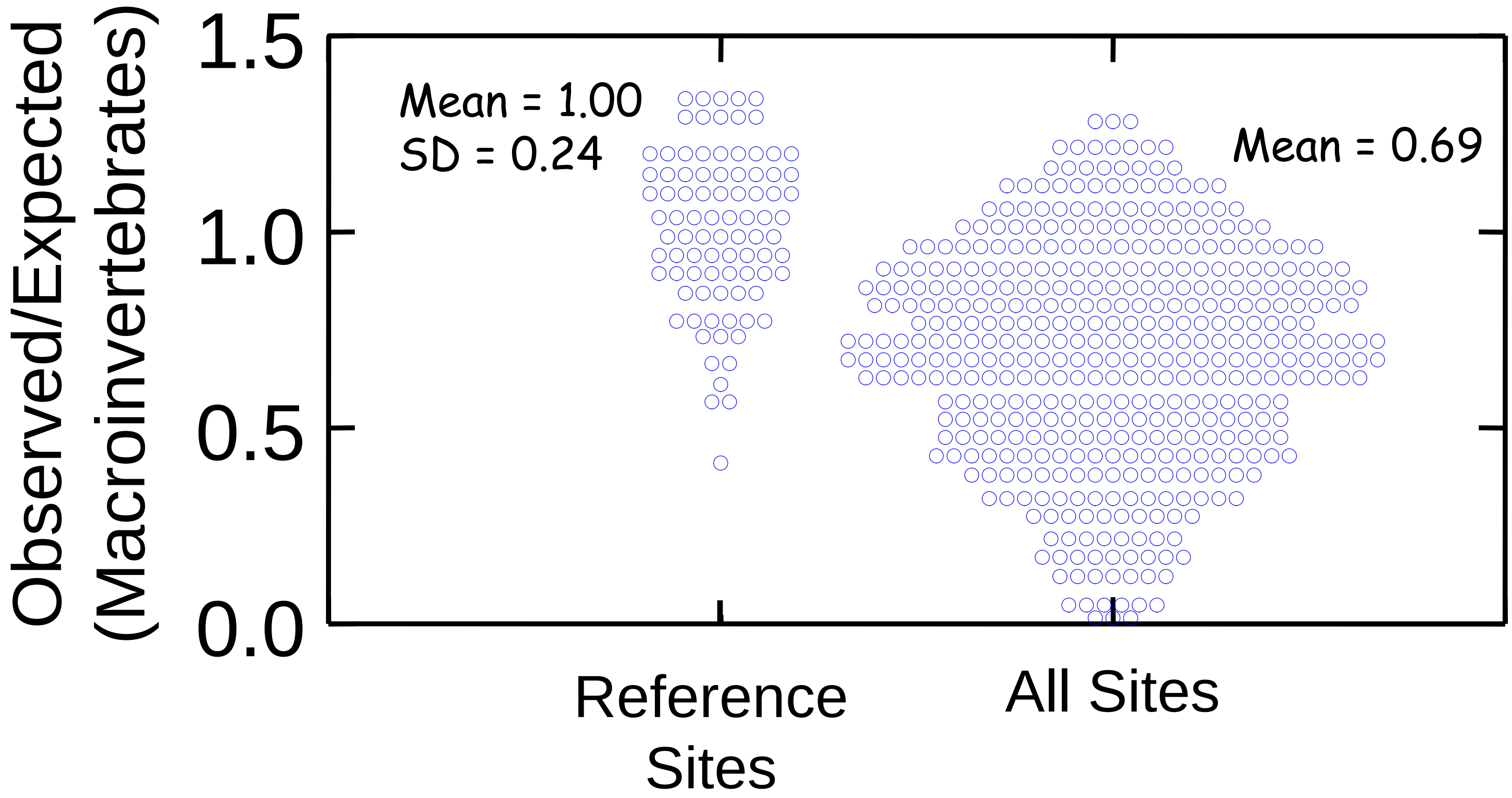
# Predictive Modeling

## Full Model Includes Multiple Site Clusters

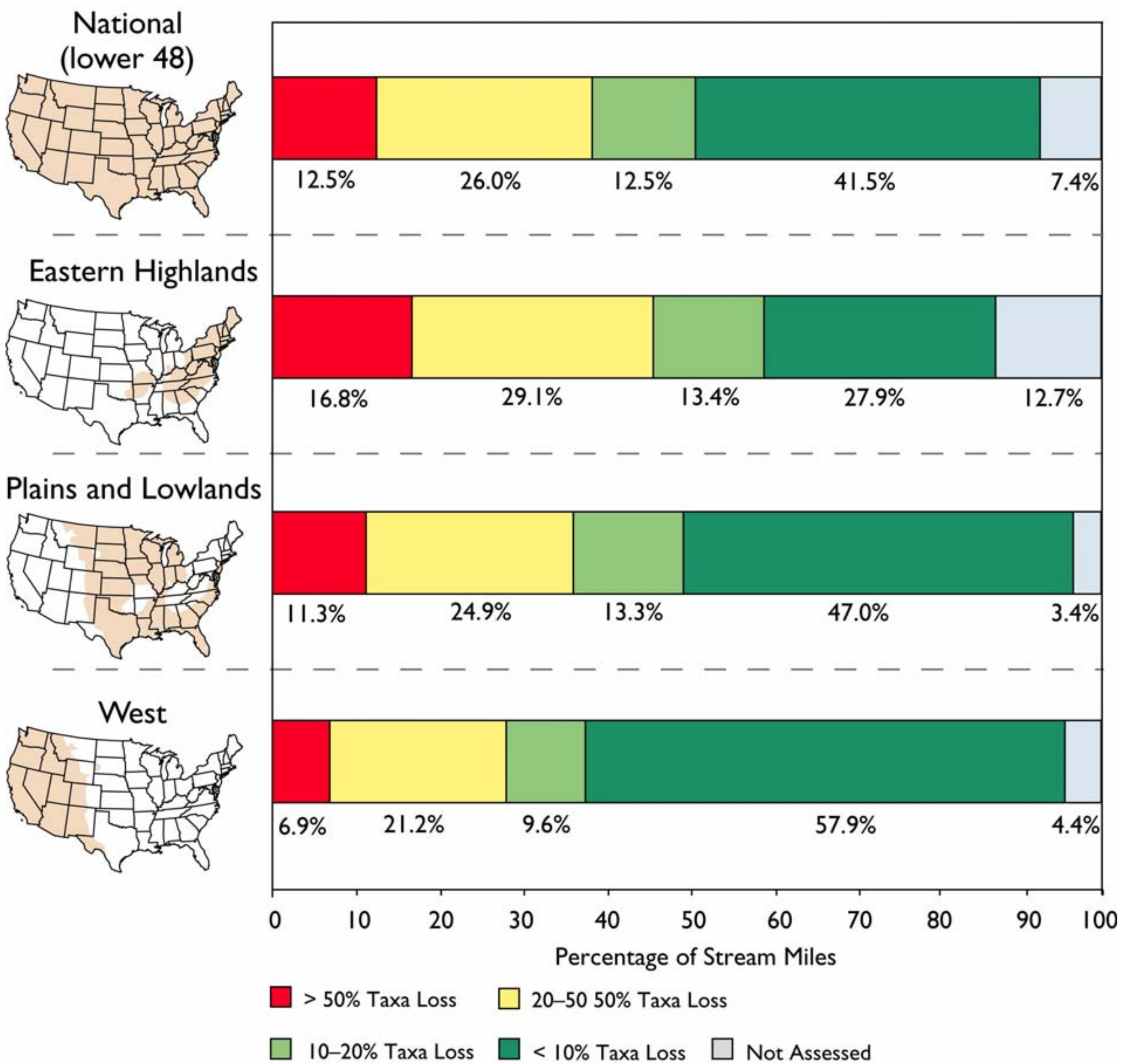


# Predictive Modeling

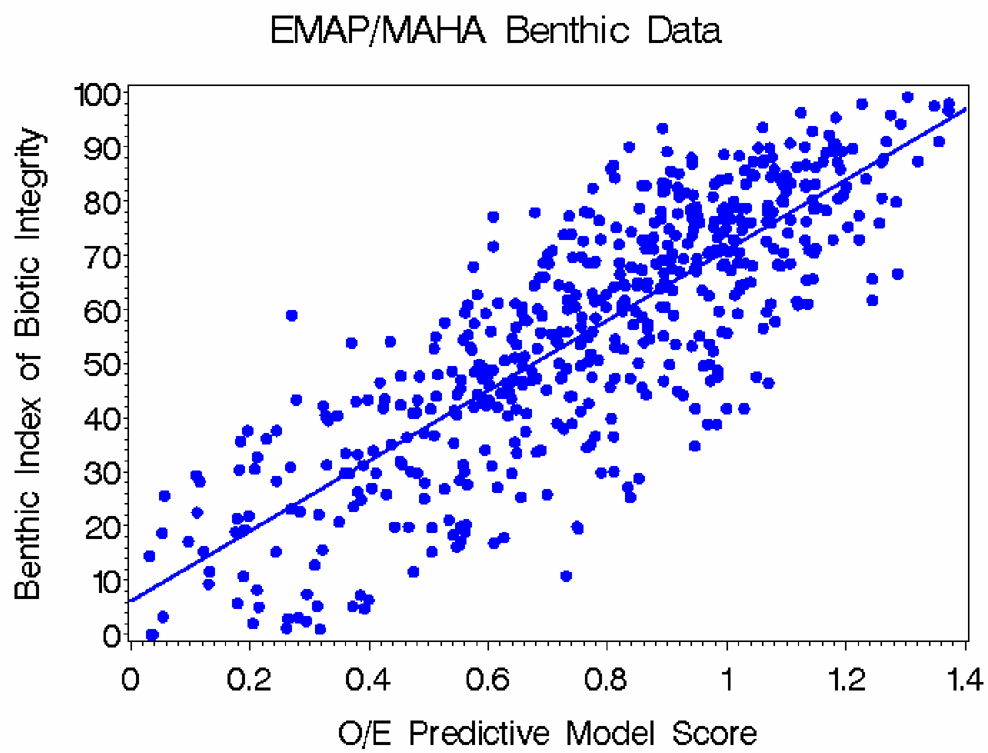
## Example for MAHA Bugs

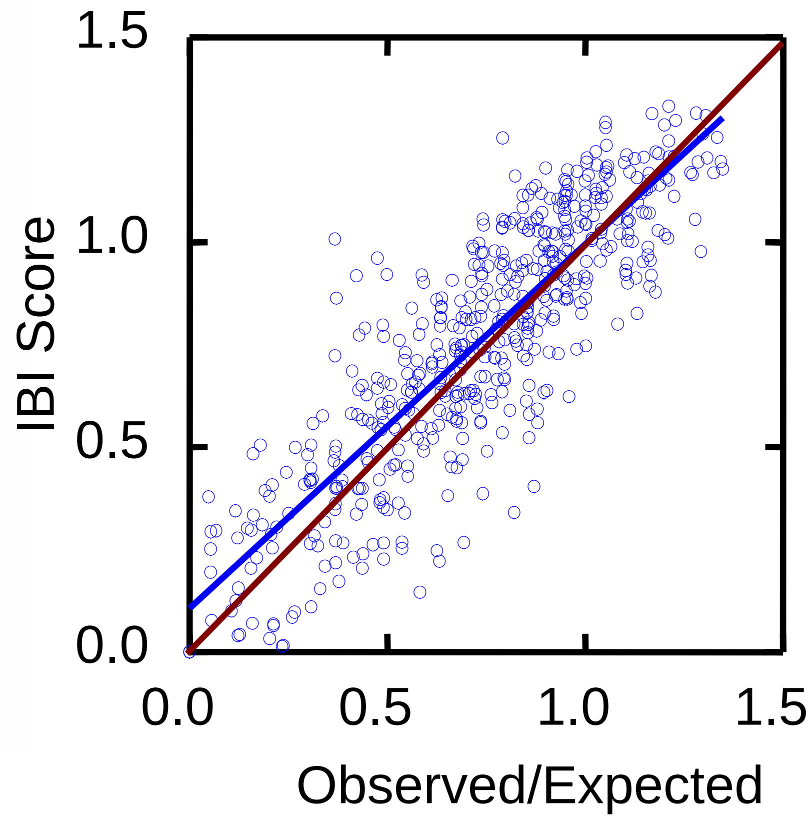


# Wadeable Streams Assessment – O/E

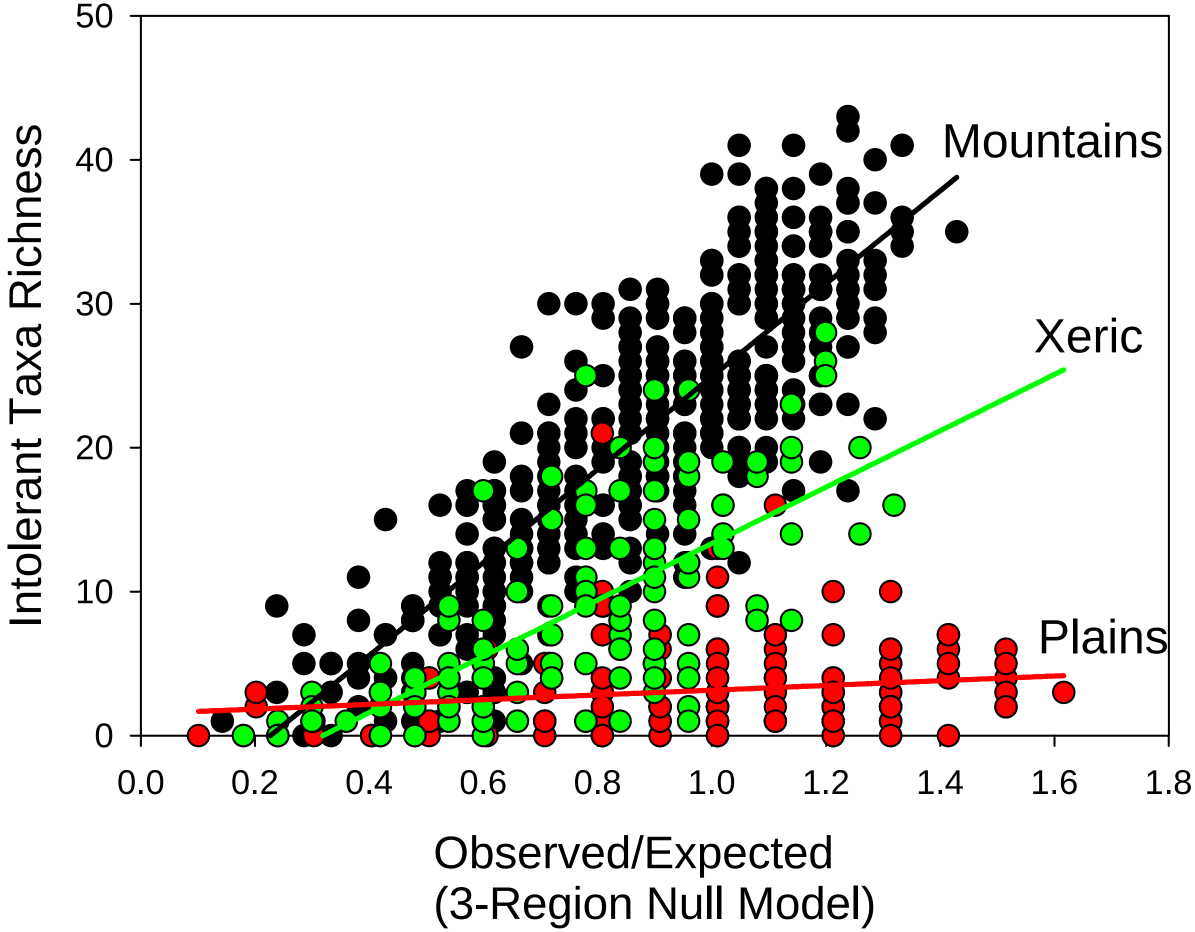


# Comparing IBI and O/E Scores



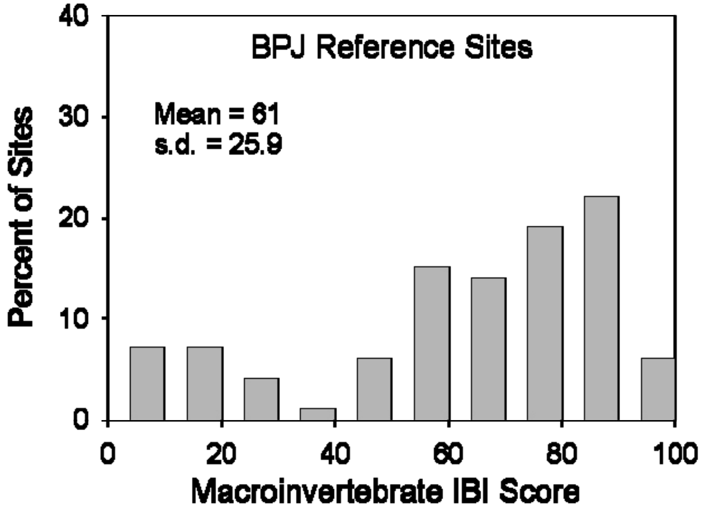
# Comparing O/E Scores with IBI Metrics

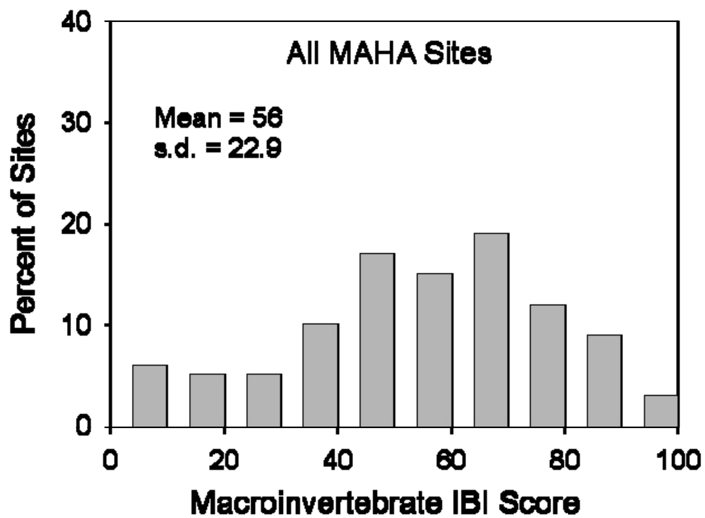


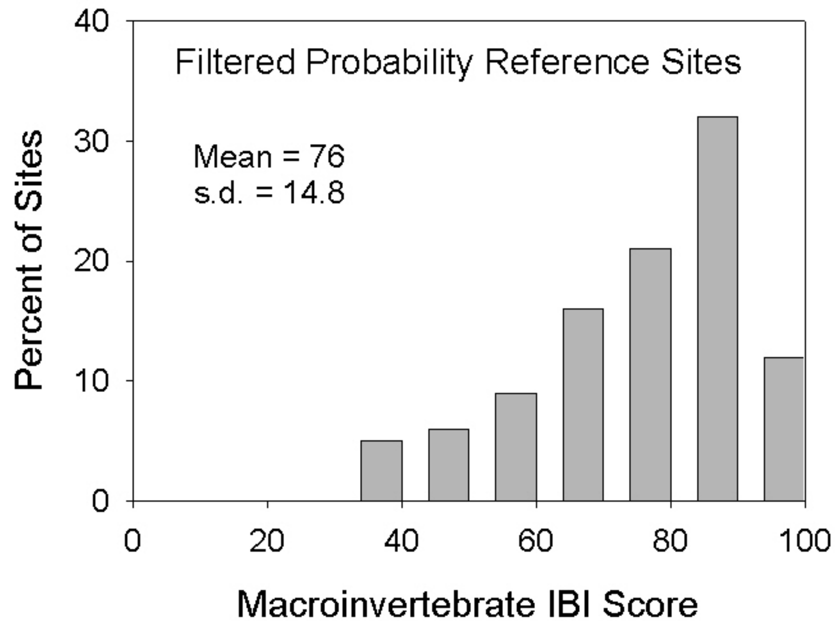
# Reference Condition

# MAHA Approach to Reference Condition

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

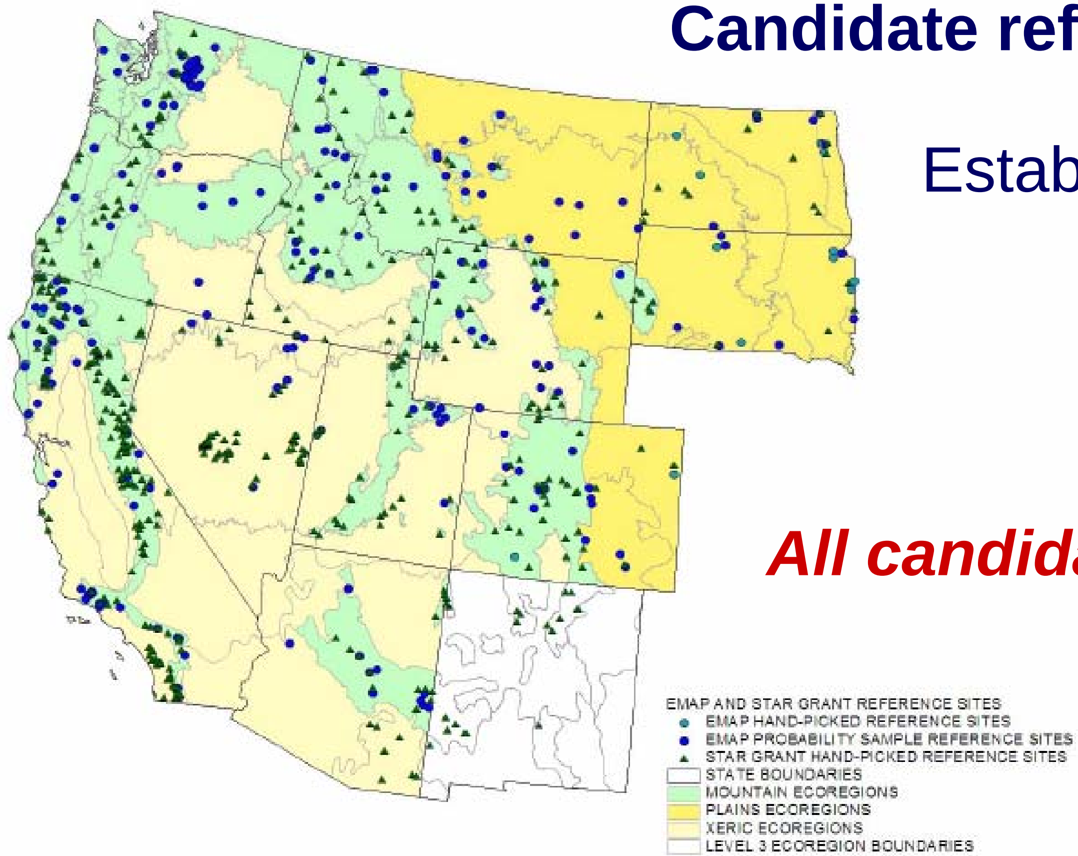


# EMAP-W Approach to Reference Condition

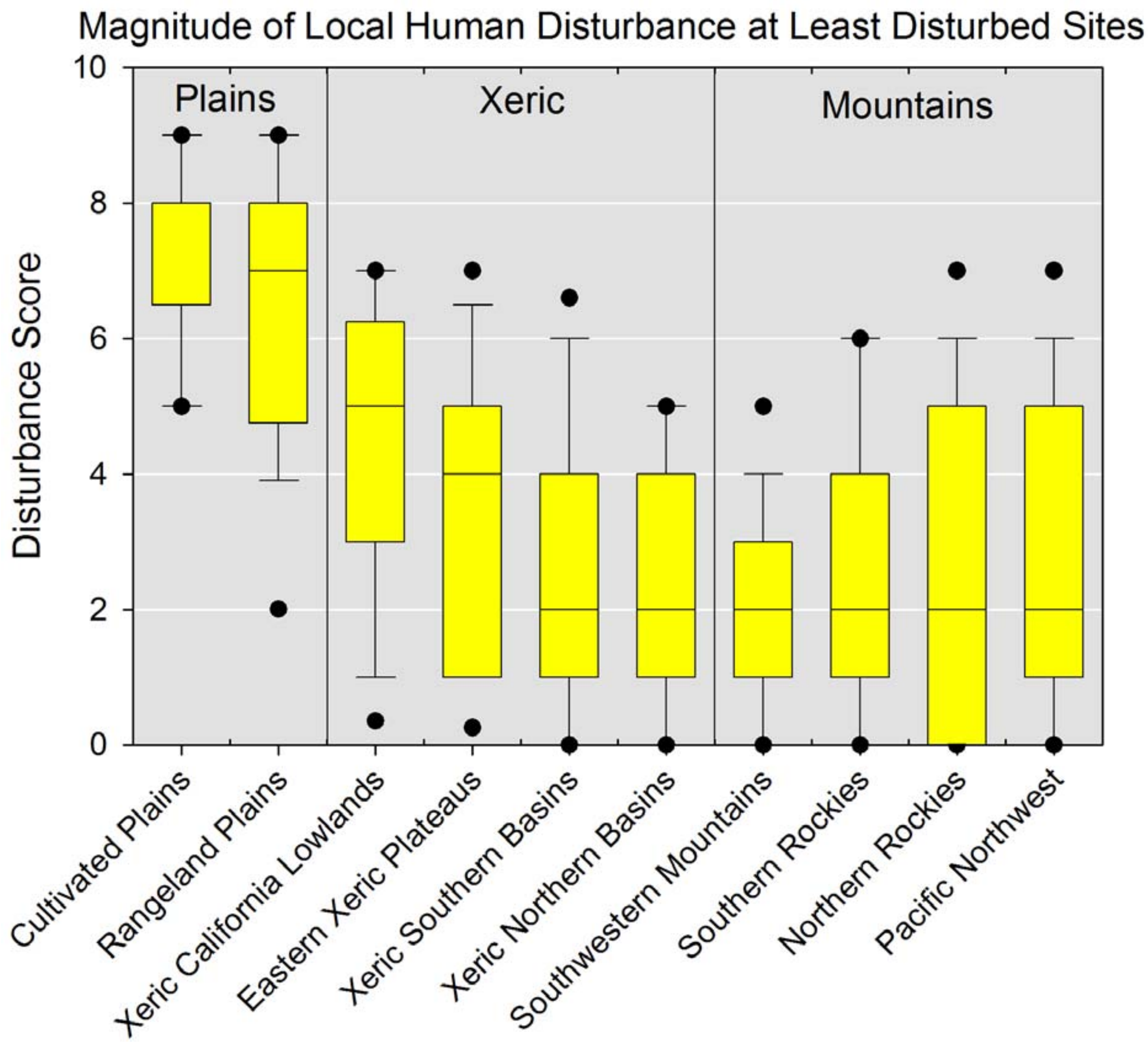
***730 Reference Sites; 965 Probability Sites***




**Candidate reference sites selected by:**

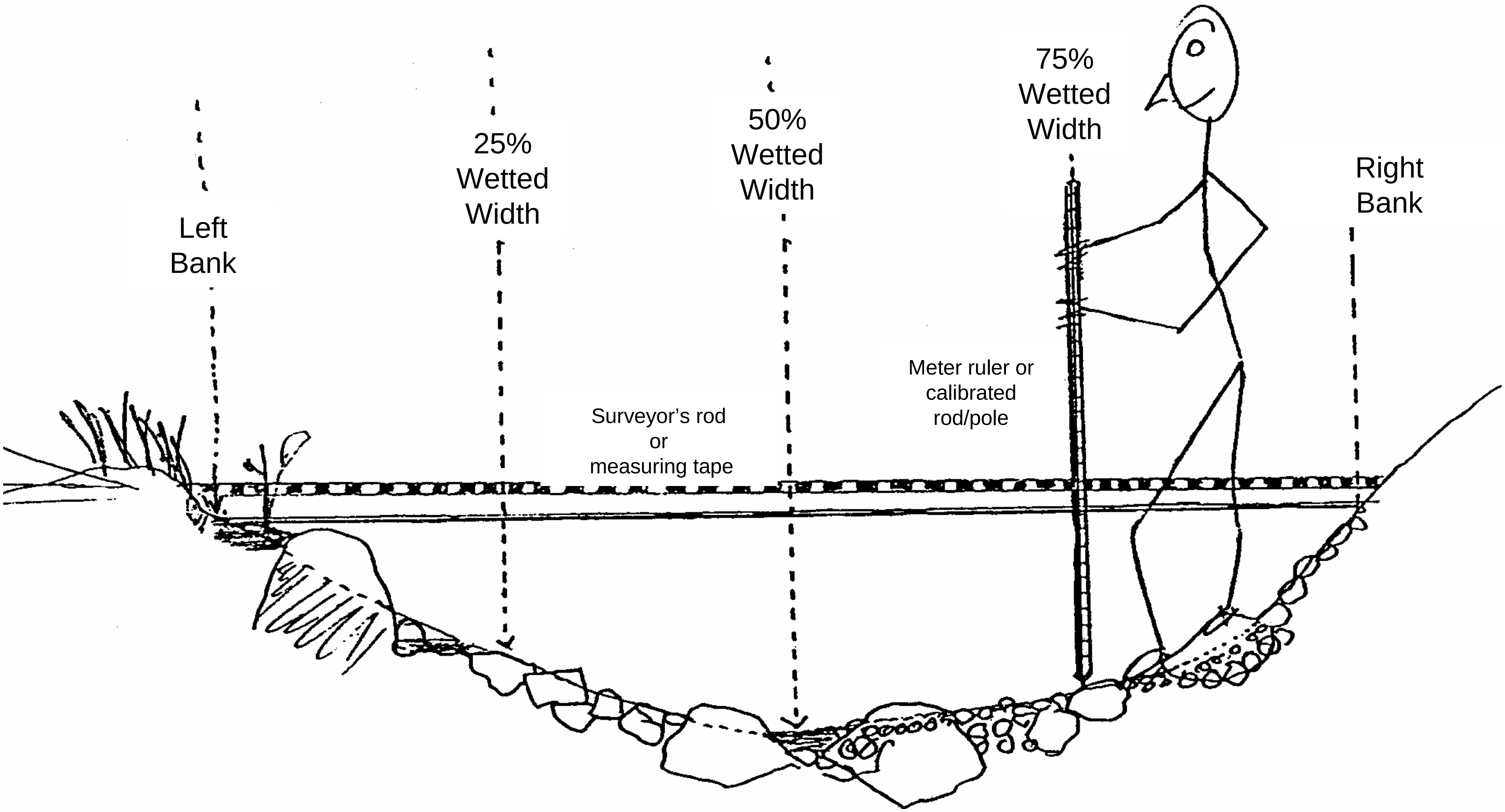
Established state reference sites
State BPJ suggestions
STAR (Hawkins) BPJ sites
EMAP GIS top-down sites
Filtered probability sites
***All candidates subjected to filtering***

# EMAP-W Approach to Reference Condition

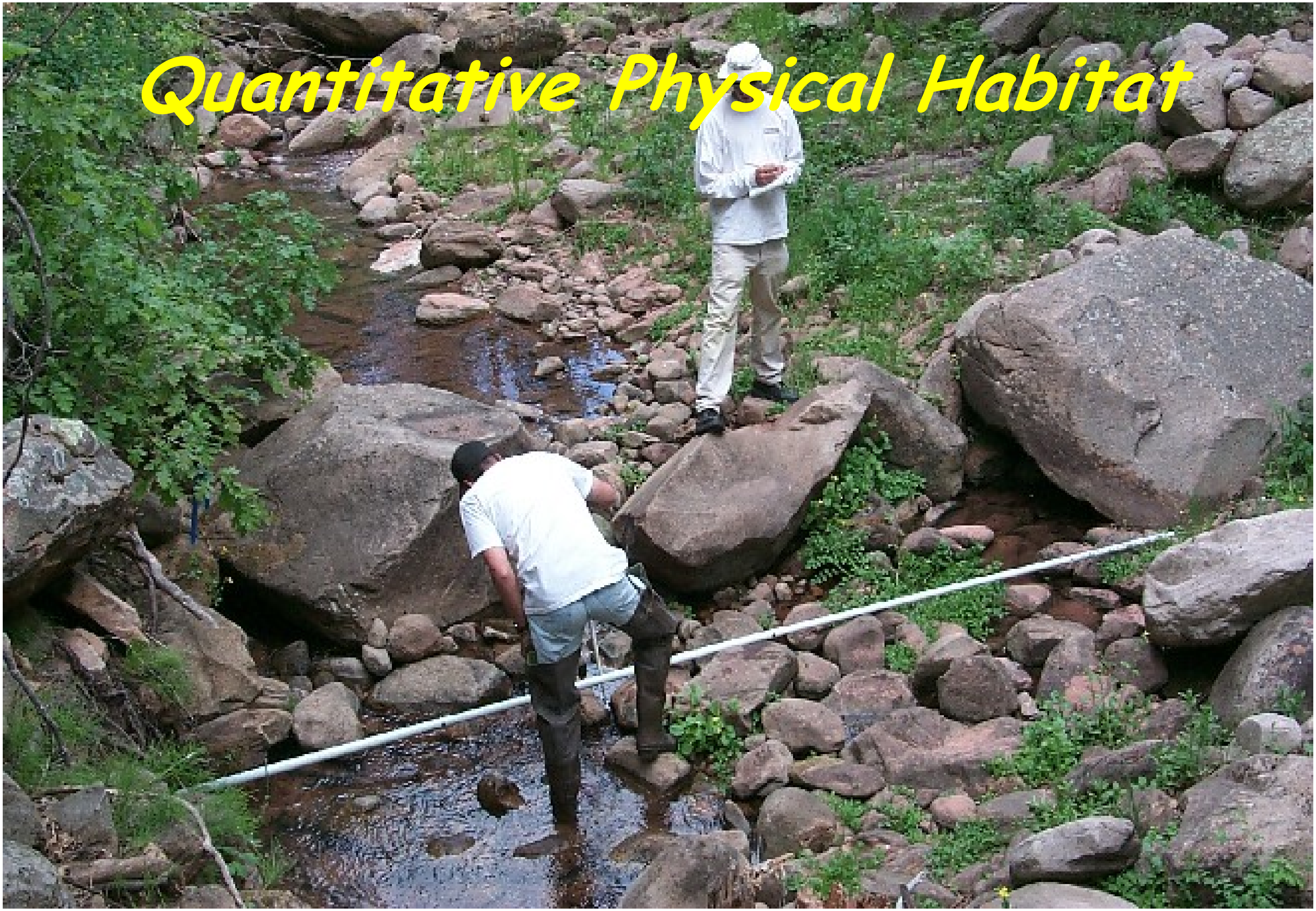


# Stressor Indicators

# Quantitative Physical Habitat



# Quantitative Physical Habitat



# Quantitative Physical Habitat

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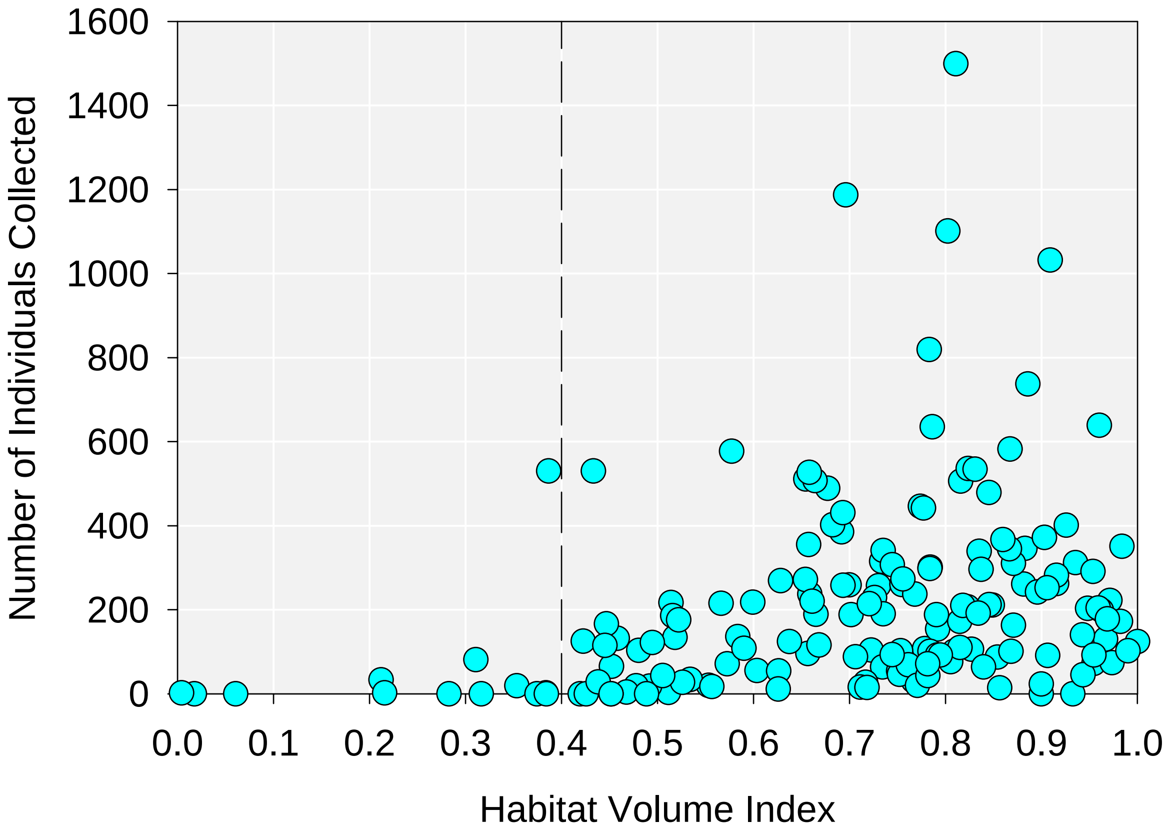
Did you know? 24 of 32 EMAP Stream forms are for Physical Habitat

# Quantitative Physical Habitat

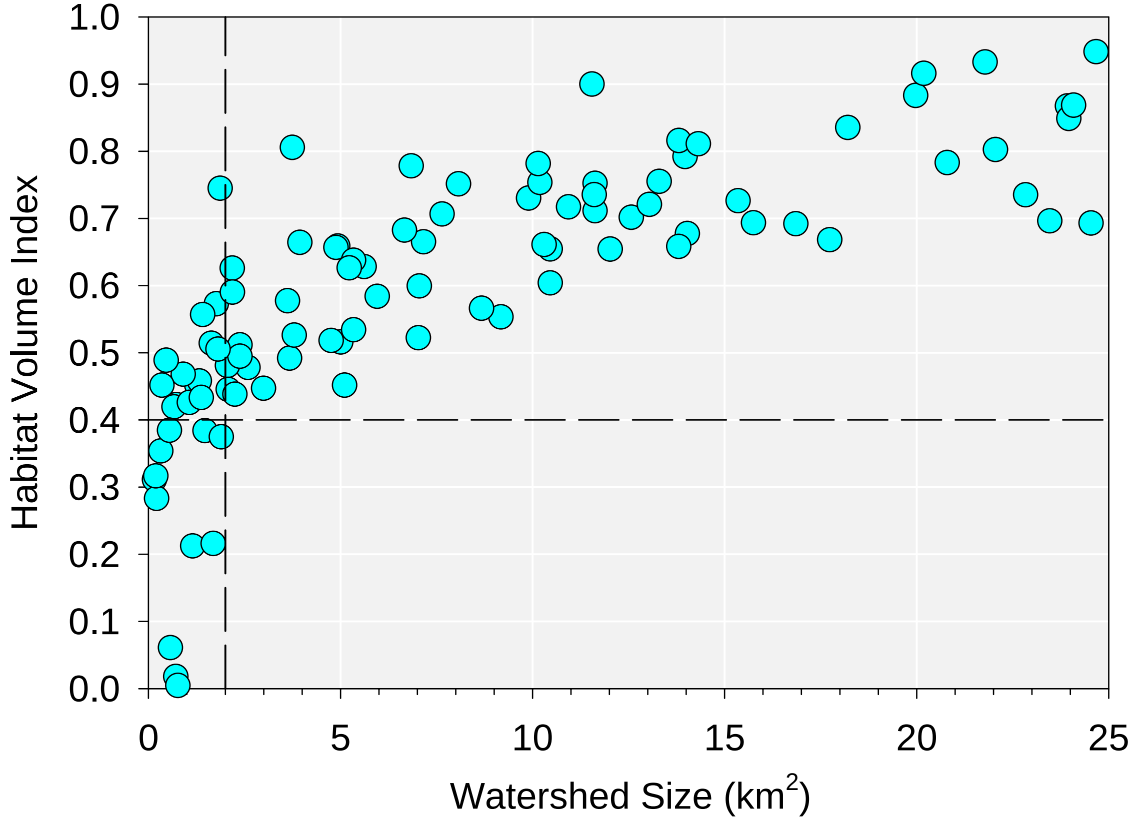
## Helps determine how to assign IBI values to fishless lakes




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

# 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

**$LRBS=Log(D_{gm}/D^*_{cbf})$**

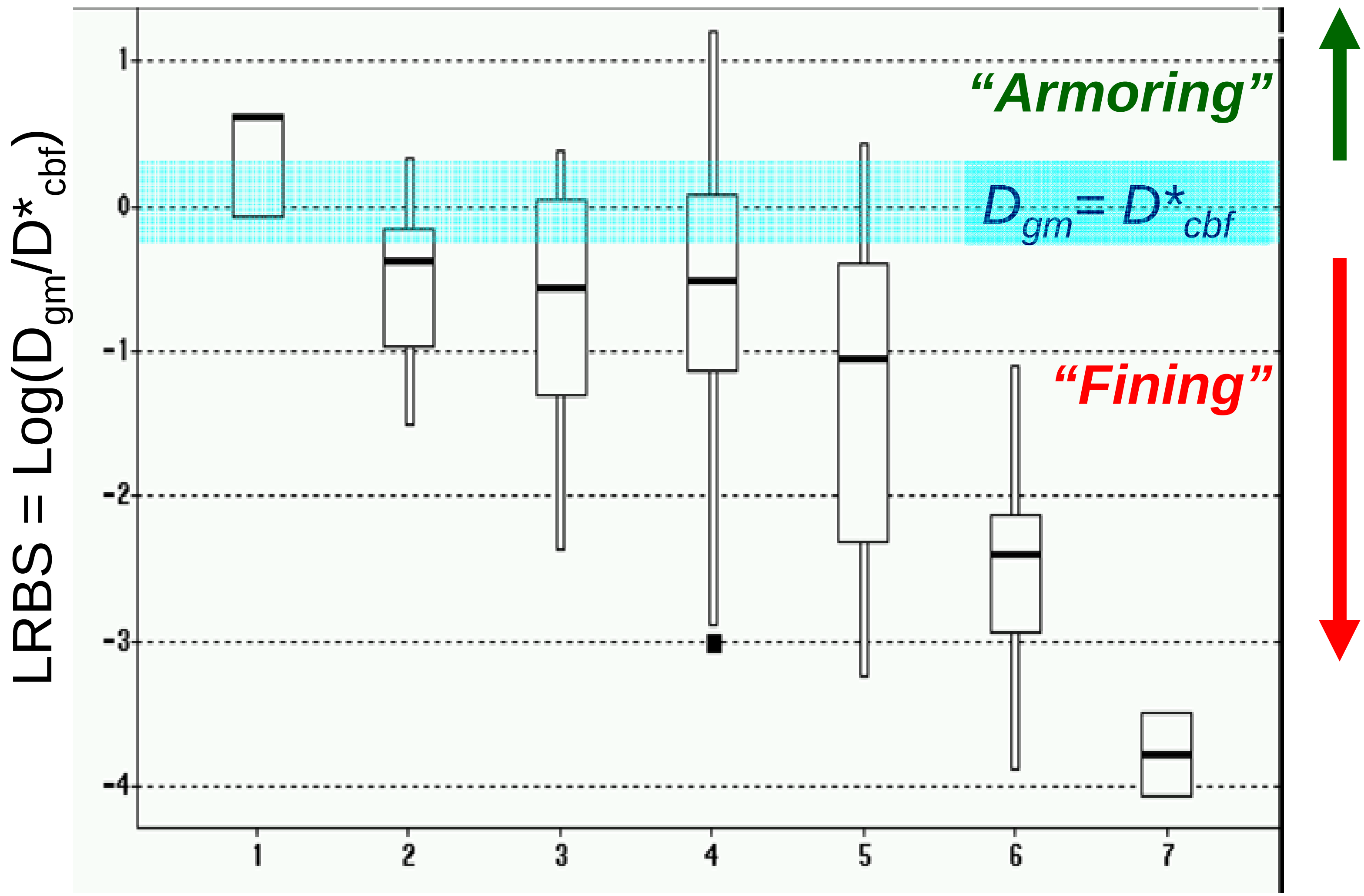
**$D_{gm}$** --- observed geometric mean diameter from field "pebble count".

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

<u>Bankfull Bed Shear Stress ($\rho g R^*_{bf} S$), controlled by</u>:
+ Channel slope (S)
+ Adjusted Bankfull Hydraulic Radius ($R^*_{bf}$ )
  + Bankfull Depth,
  - Residual pool depth, - Form roughness,- Large wood volume

<u>Critical Shear Stress $\theta(\rho_s-\rho)gD$, influenced by</u>:
+ Particle Diameter (D)
+ mass density of particles in water ($\rho_s$-$\rho$)
. shape, exposure, size variance, turbulence, relative submergence (θ)

# Relative Bed Stability




Basin + Riparian Disturbance Index

# Relative Bed Stability and Excess Fines

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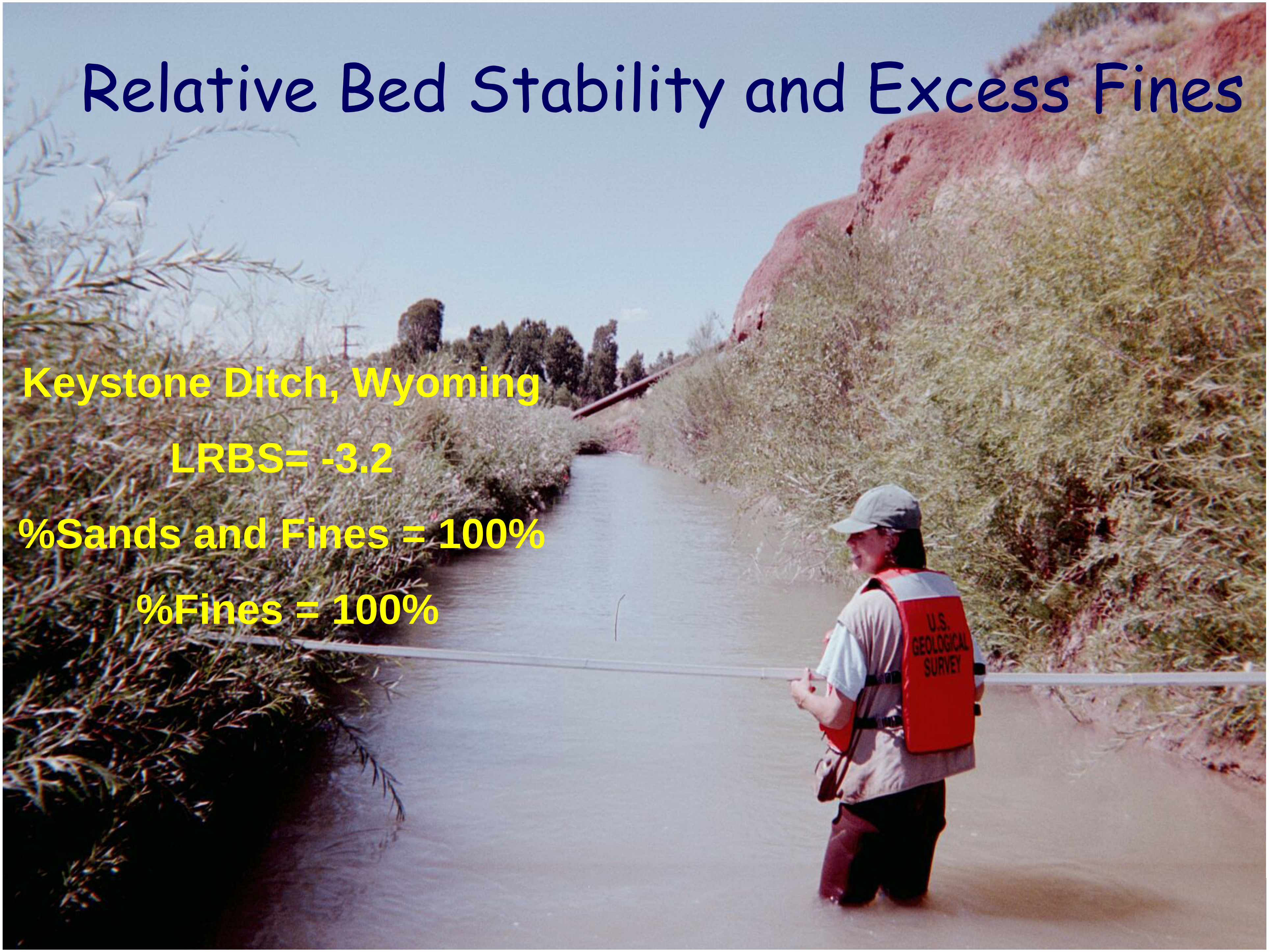
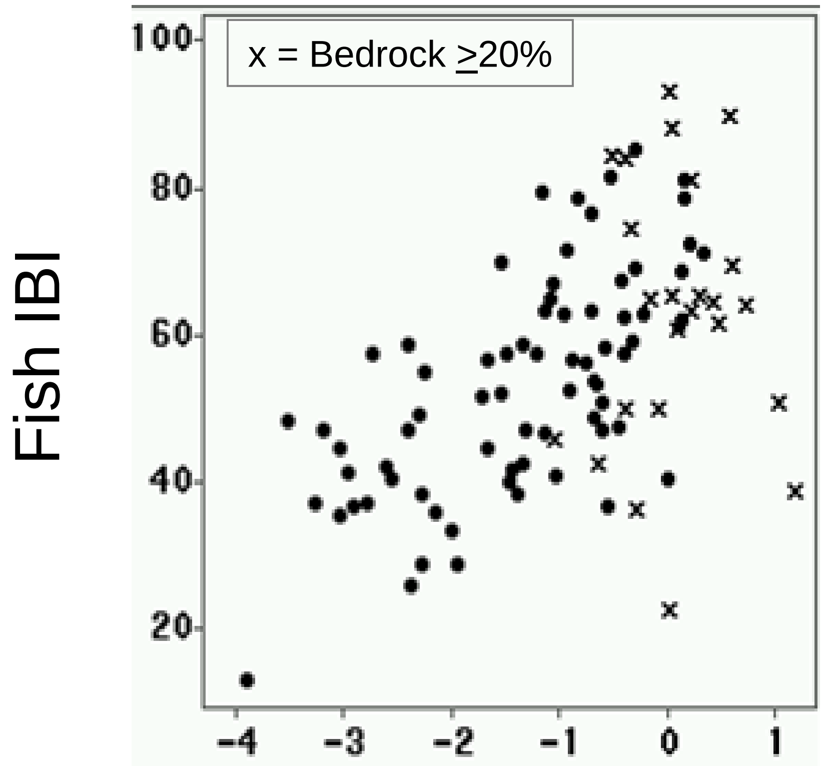
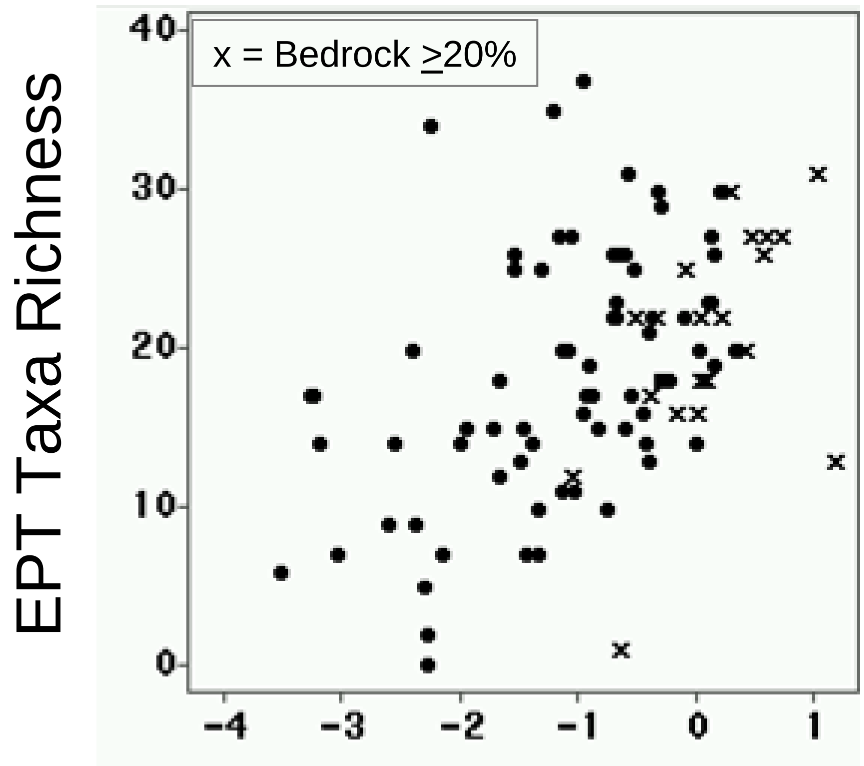


# Relative Bed Stability

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

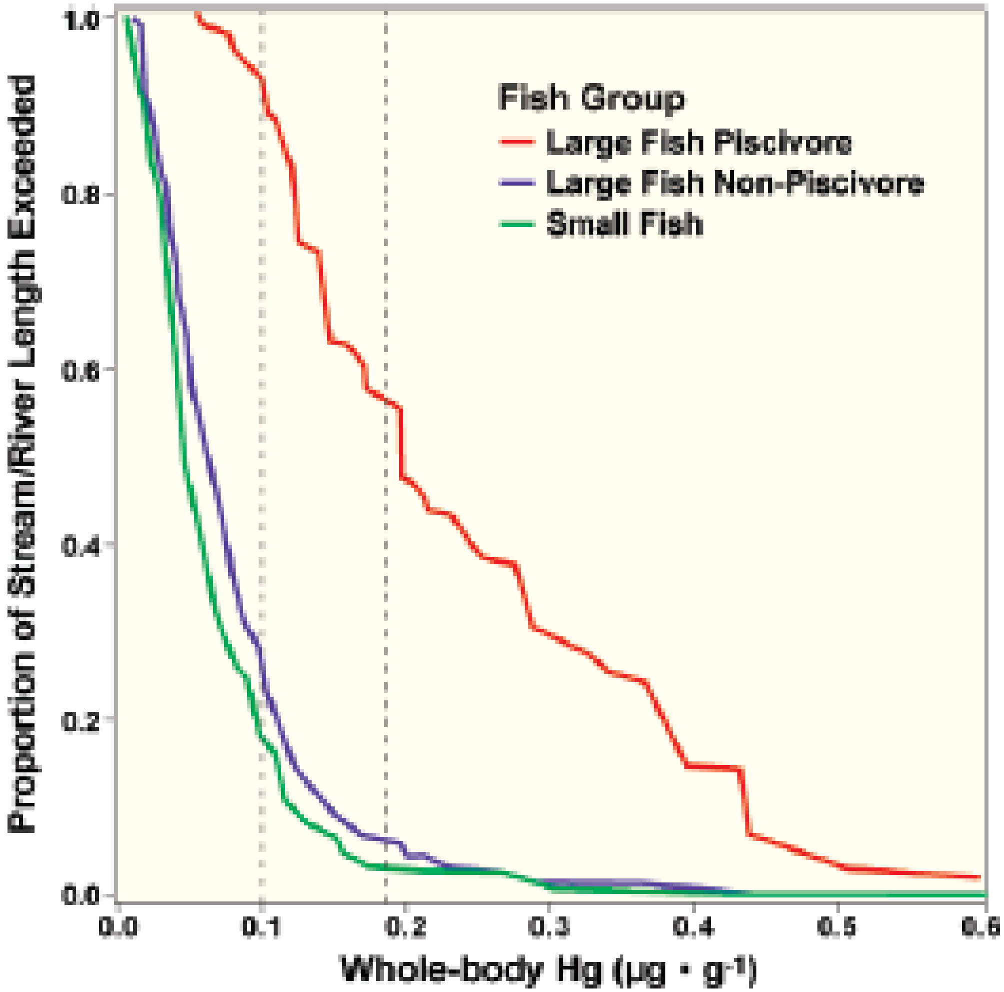



LRBS: $\text{Log}(D_{gm}/D^*_{cbf})$

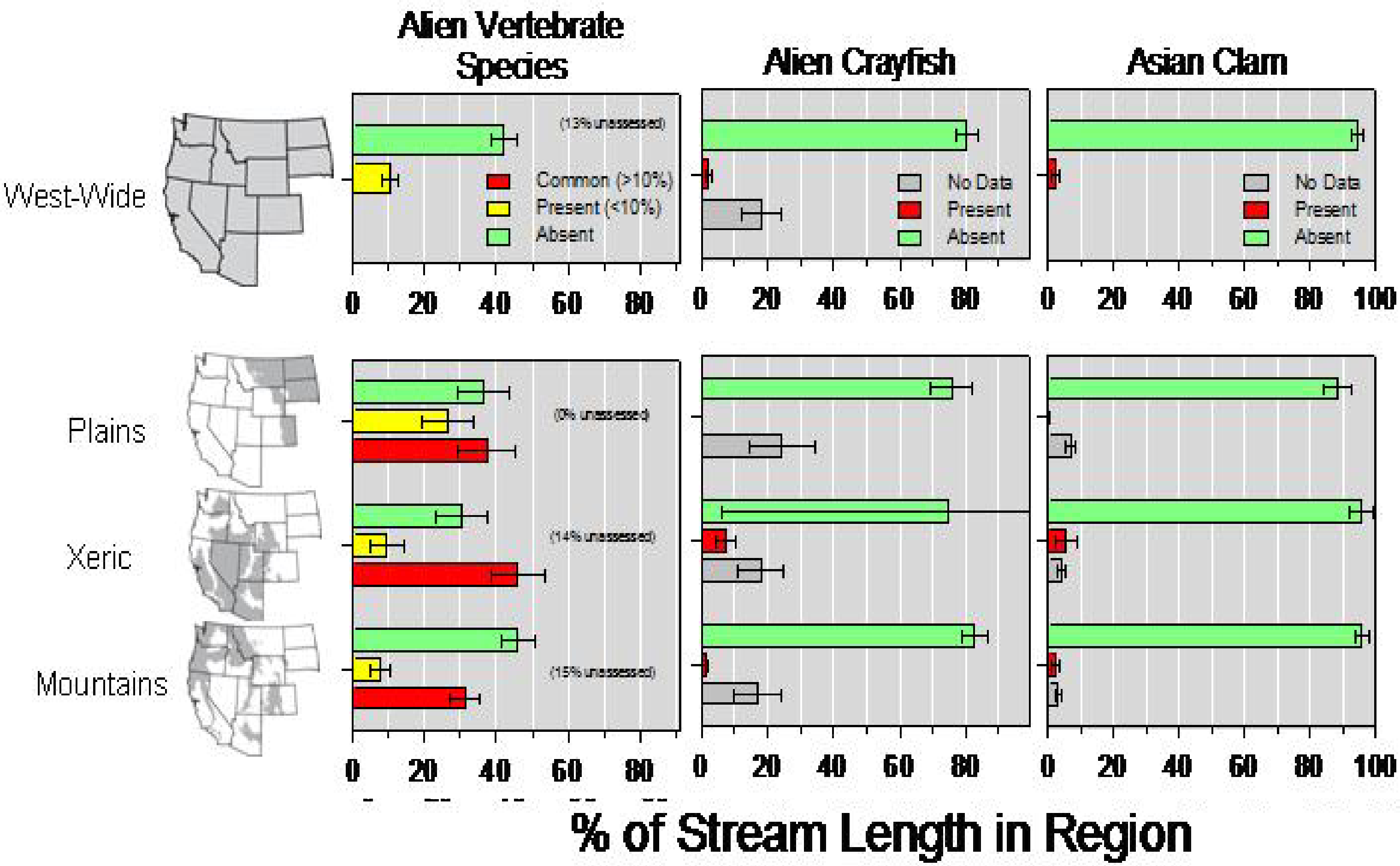
# Chemical Stressors

## Mercury in EMAP West



# Biological Stressors

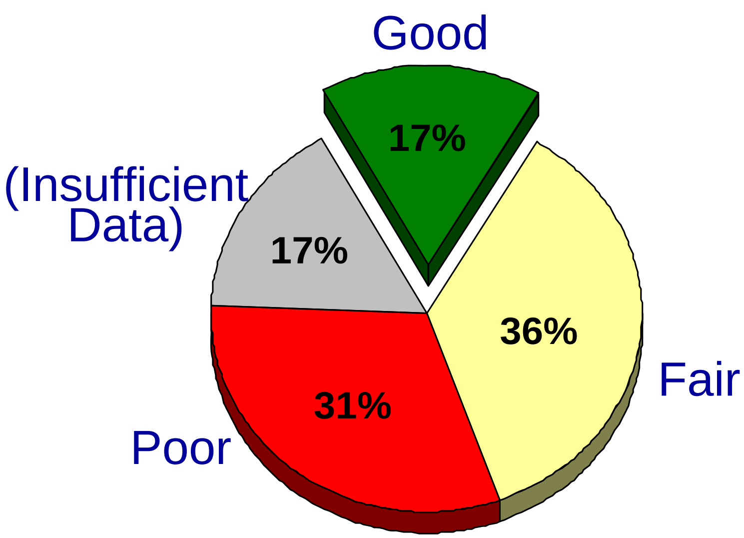
## Alien Species



# Assessment

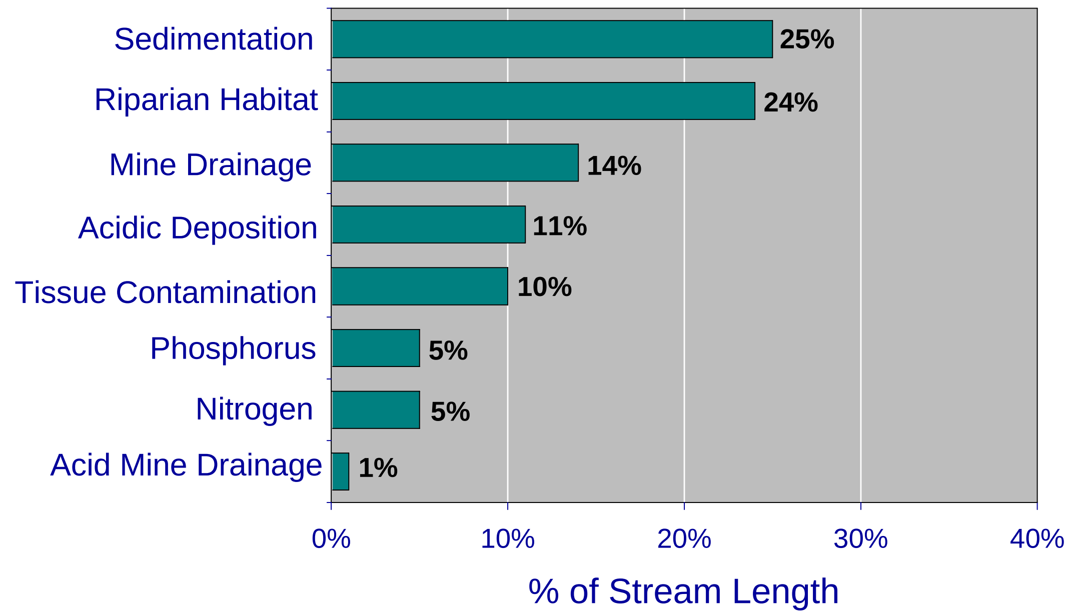
# Assessment - MAHA

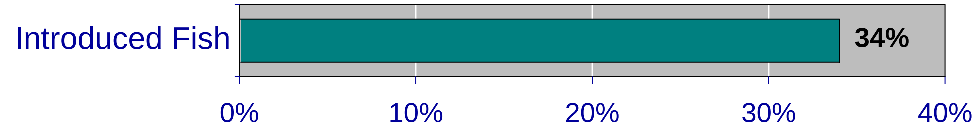
Fish Index of Biotic Integrity




Proportion of Stream Length

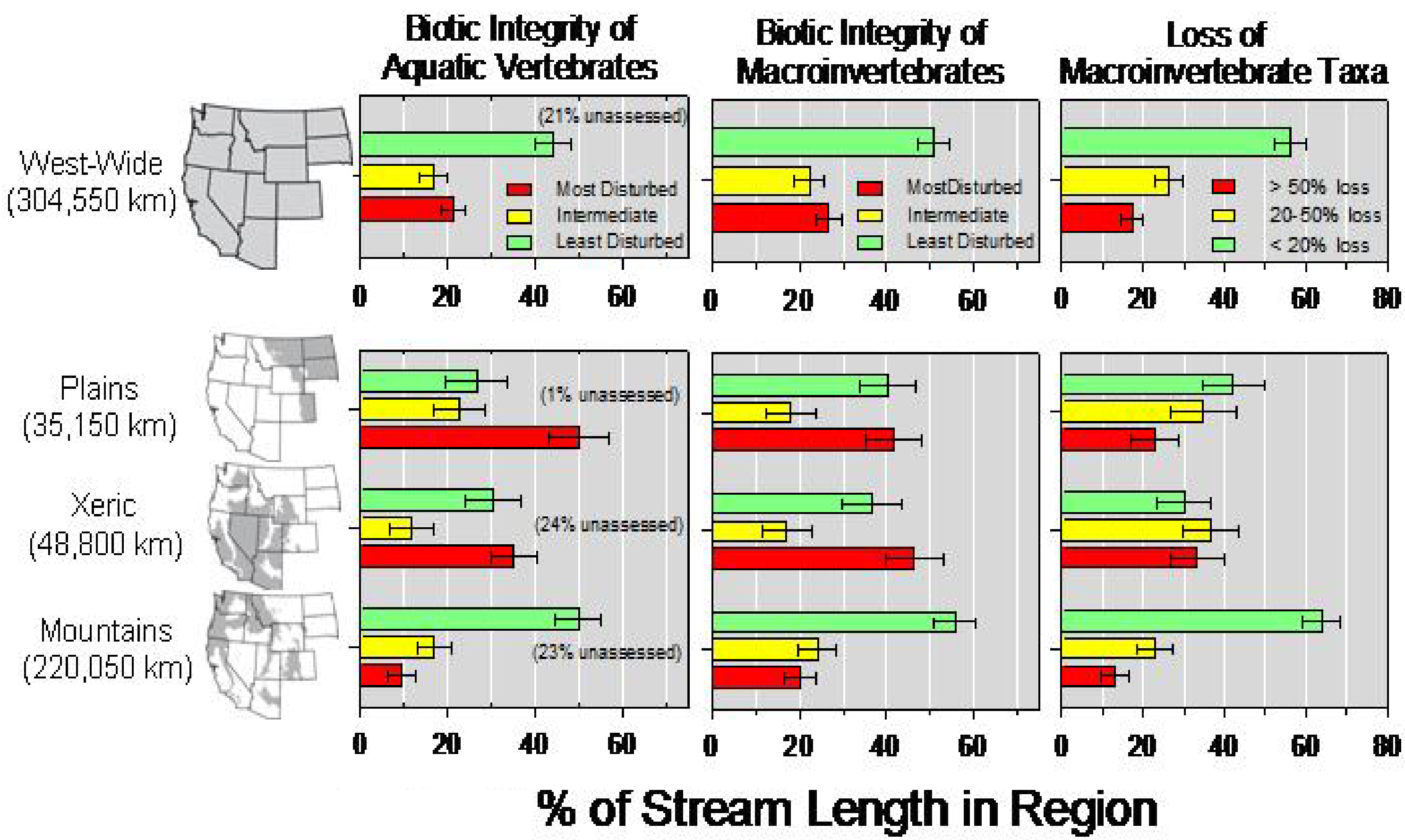
Relative Ranking of Stressors



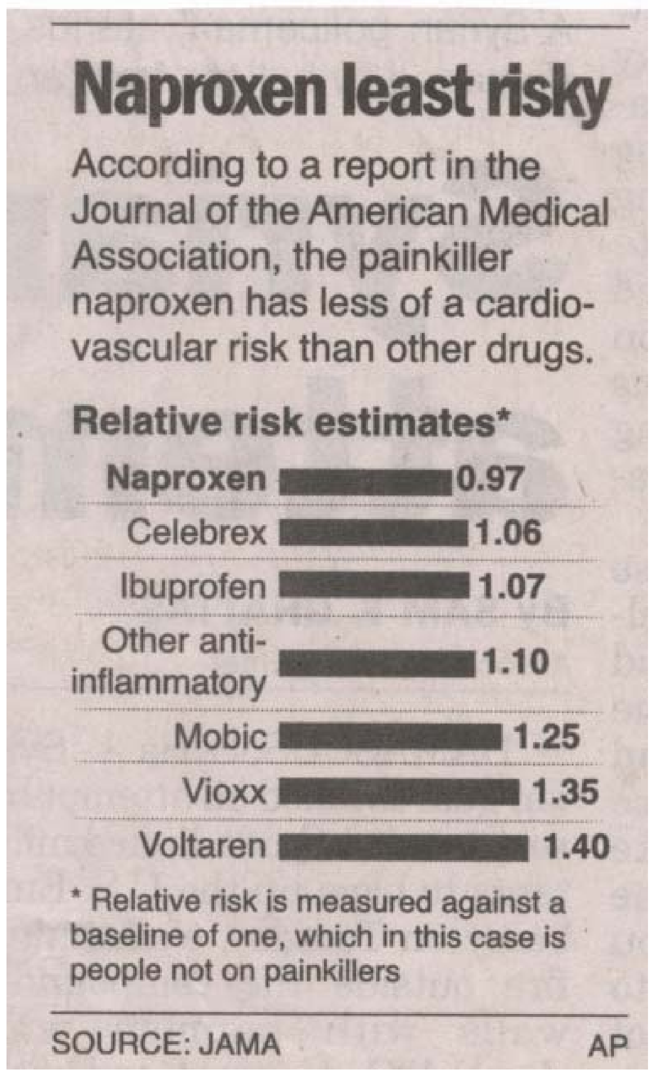



# Assessment – EMAP West

## Multiple Indices, Multiple Assemblages



# 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 cardio-vascular risk than other drugs.

**Relative risk estimates***

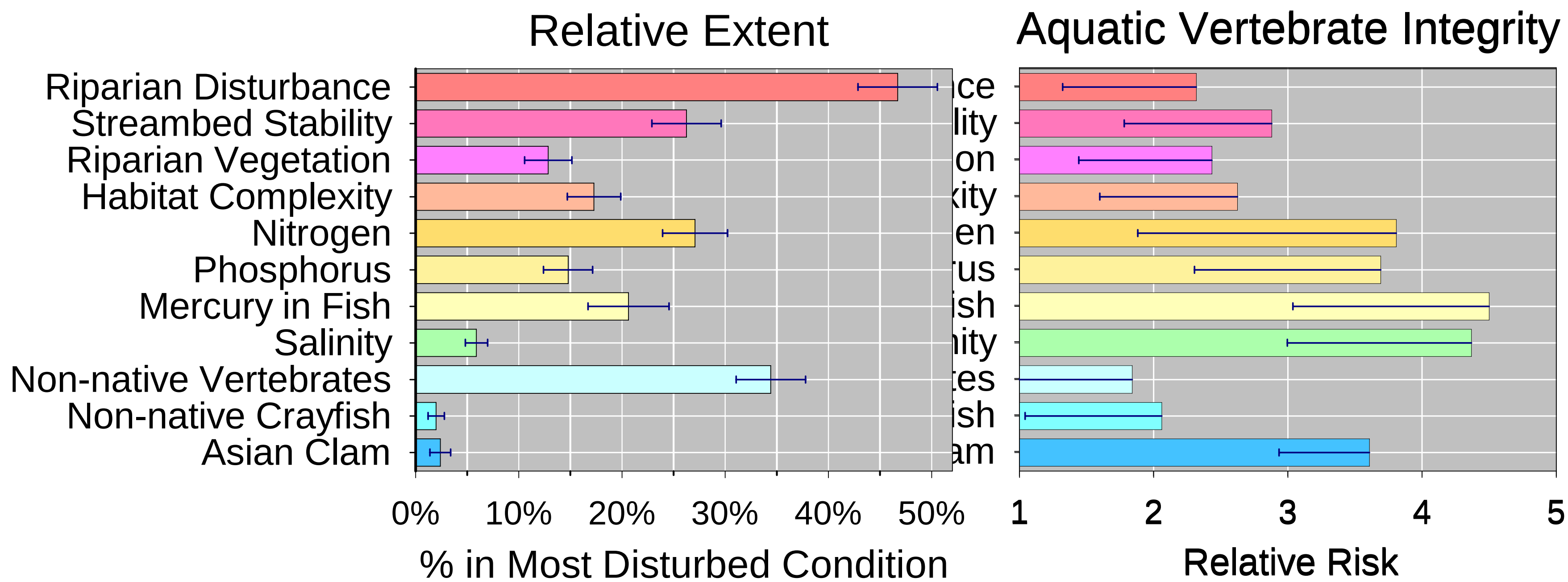
| | |
|---|---|
| **Naproxen** | 0.97 |
| Celebrex | 1.06 |
| Ibuprofen | 1.07 |
| Other anti-inflammatory | 1.10 |
| Mobic | 1.25 |
| Vioxx | 1.35 |
| Voltaren | 1.40 |

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

SOURCE: JAMA AP

# Assessment - Relative Risk

## EMAP West

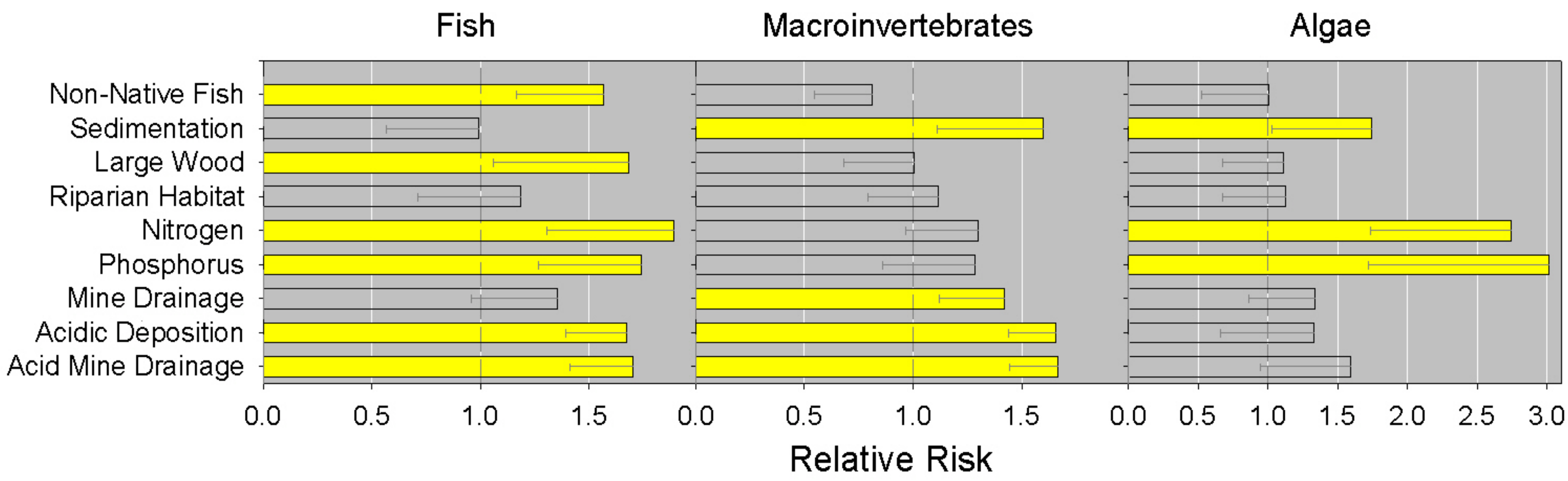



Relative importance of stressors is a function of both their relative extent and their relative risk

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