The Definition and Use of Least-Disturbed Reference Sites for Making National Assessments of Stream Ecological Condition

Alan Herlihy

Department of Fisheries and Wildlife, Oregon State University

Objectives Matter

- A host of reasons, methods and uses of reference sites

- "Reference Site" means different things to different people – usually related to objective of project

- What actually is a "Reference Site" is often in the eye of the beholder

- For this webinar: Examining the definition and selection of reference sites for making large-scale bioassessments of stream condition

A major challenge when conducting an assessment of natural resources, especially at a large scale, is determining the appropriate standard for comparison

EMAP and NARS Assessments National Scale Surveys

- Funded by US EPA to make national and regional assessments of aquatic condition
- Randomly selected sample sites using a probability design to estimate total population condition
  - Additional hand-picked potential reference sites
- Reference condition approach to making biological assessments
- All aquatic resources: NRSA, NLA, NWCA, NCCA

Assessments Needed Reference Sites for

- Biotic Index Development
  - Metric selection, scoring, and modeling
- Defining Good, Fair, Poor condition categories for
  - Biotic Integrity, Nutrients, and Physical Habitat condition
- Predictive (O/E) modeling
- Need a Population of Reference Sites
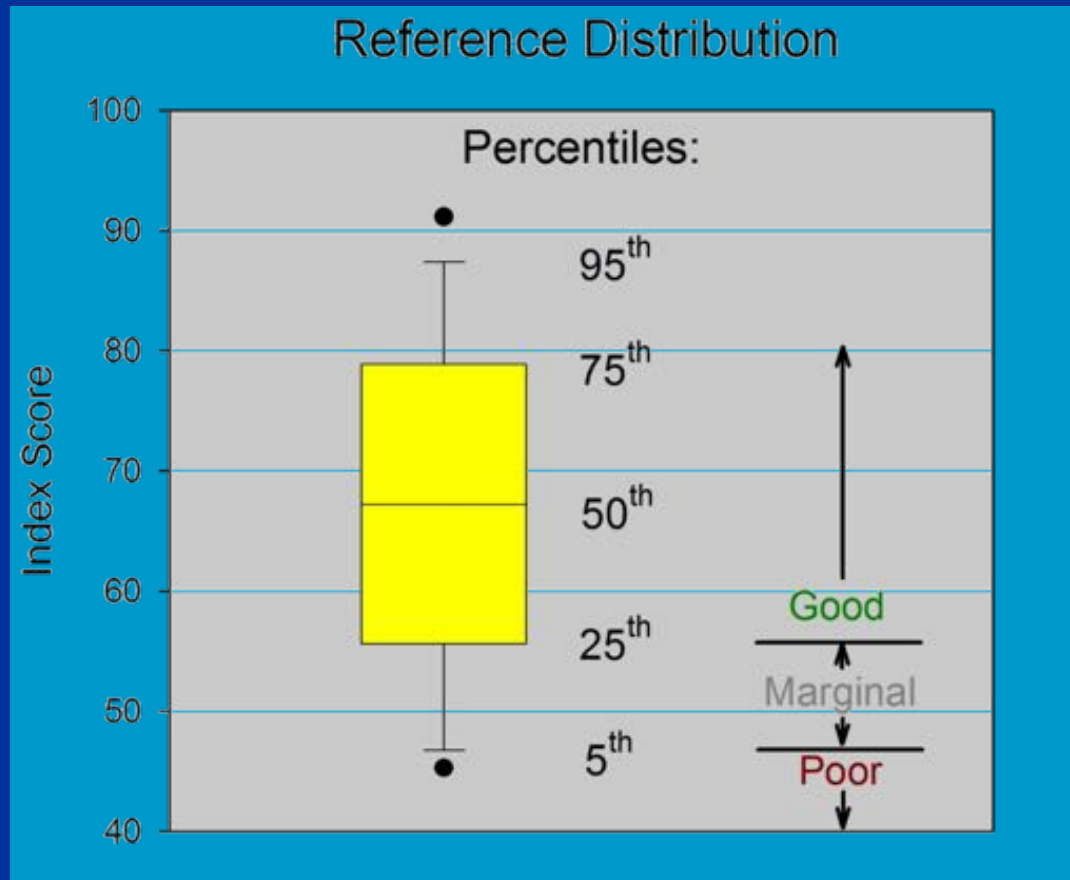 - ~30-50 per class

Metric Selection – Responsiveness
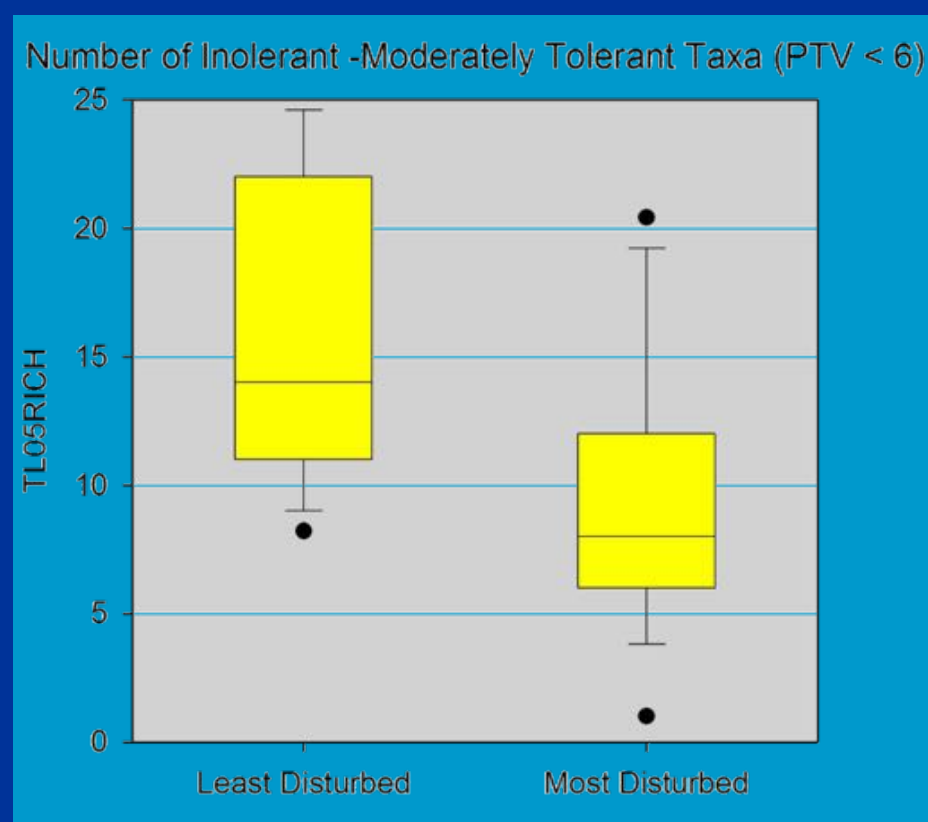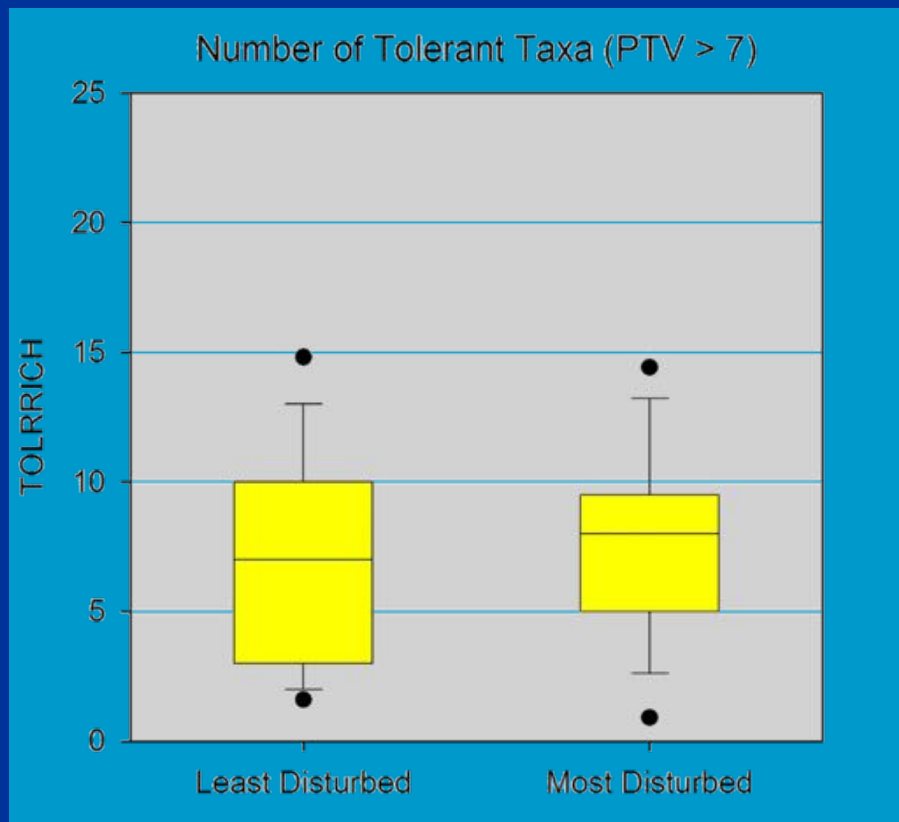
All metrics (by Region and by Class) ranked by their ability to differentiate least disturbed reference sites from most disturbed sites

Setting Condition Classes
Use Distribution of Biotic Index Scores at Least-Disturbed Reference Sites to Set Thresholds
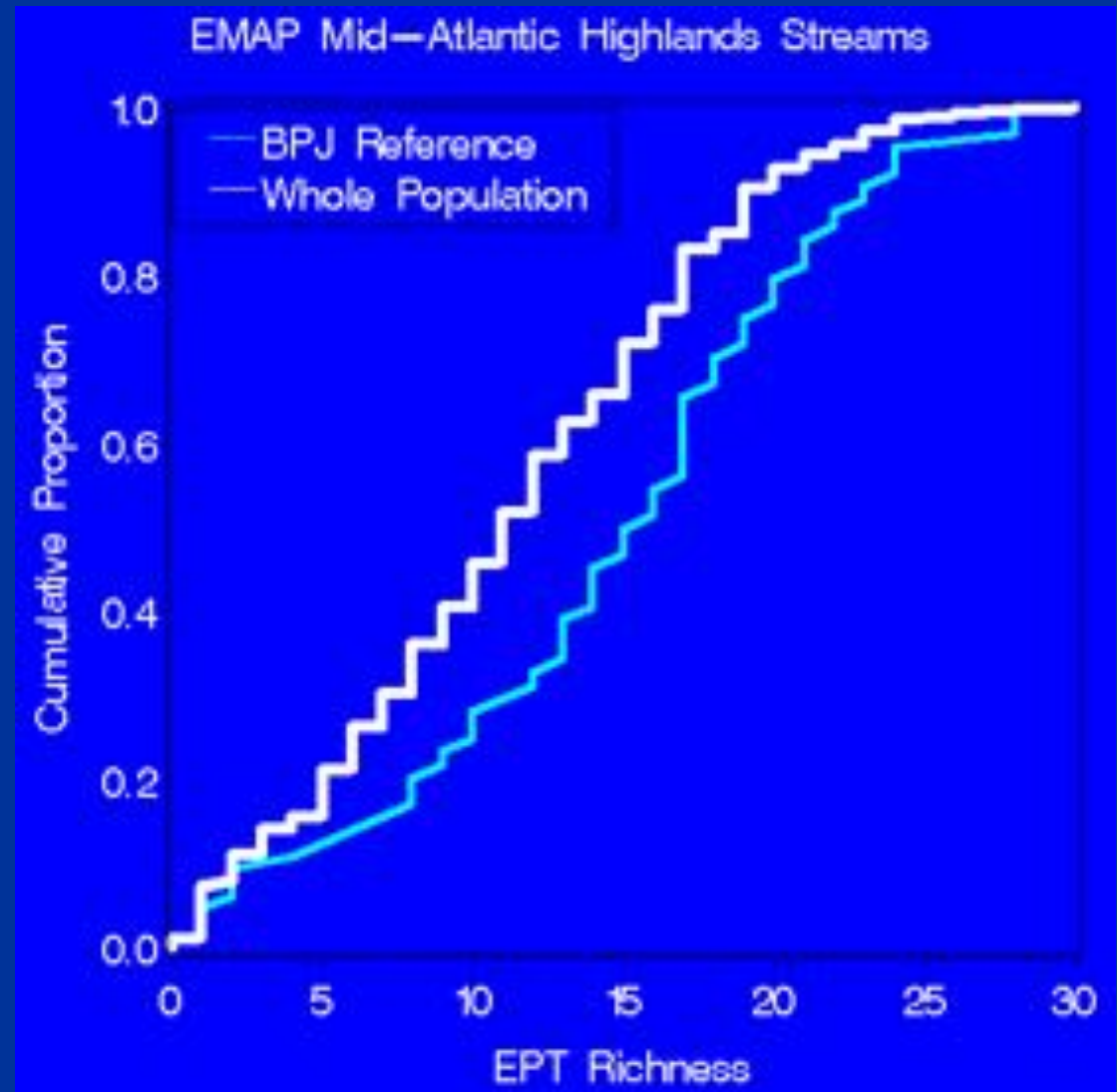
How to Pick Reference Sites?

- Commonly a compilation of BPJ lists of sites
  - Not a good history in USEPA NARS/EMAP surveys
  - Often a ~50% failure rate (hand-picked sites not being reference quality)
  - Why? -- Reference does not mean the same thing to everybody
    - Widely varying perspectives and objectives when multiple people pick sites
  - Pre-Screening sites helps some but not as much as you might think

Some Personal History

- First Attempt: 1993-1994 Mid-Atlantic Highlands Assessment Streams

- BPJ sites vary widely in terms of quality and lack a rigorous definition

- **Alternative:** Filter survey data for stressors to identify best sites

EMAP Mid—Atlantic Highlands Streams
- BPJ Reference
- Whole Population

(x-axis: EPT Richness, y-axis: Cumulative Proportion)

Mid-Atlantic Highlands EMAP Stream Example

- Screen all sites and remove those with:
  - Sulfate > 400 µeq/L (~20 mg/L)
  - Acid Neutralizing Capacity (ANC)< 50 µeq/L (~ 2.5 mg/L $CaCO_3$ or pH ~6)
  - Total phosphorus > 20 µg/L
  - Total nitrogen > 750 µg/L
  - Chloride > 100 µeq/L (~3.5 mg/L)
  - Mean RBP habitat score < 15

Contrary Creek, Virginia
pH=3, SO$_4$=5,000 μeq/L
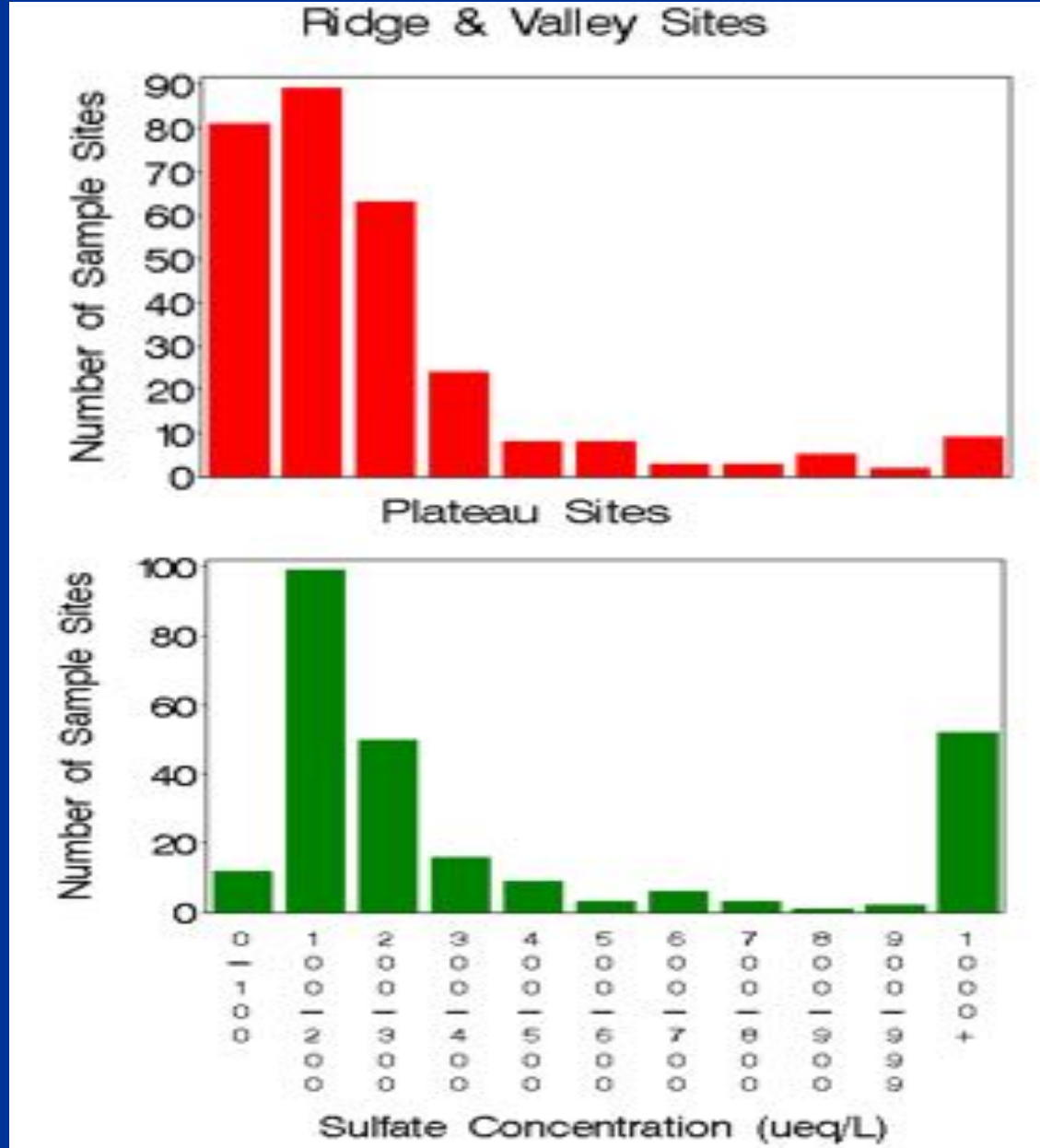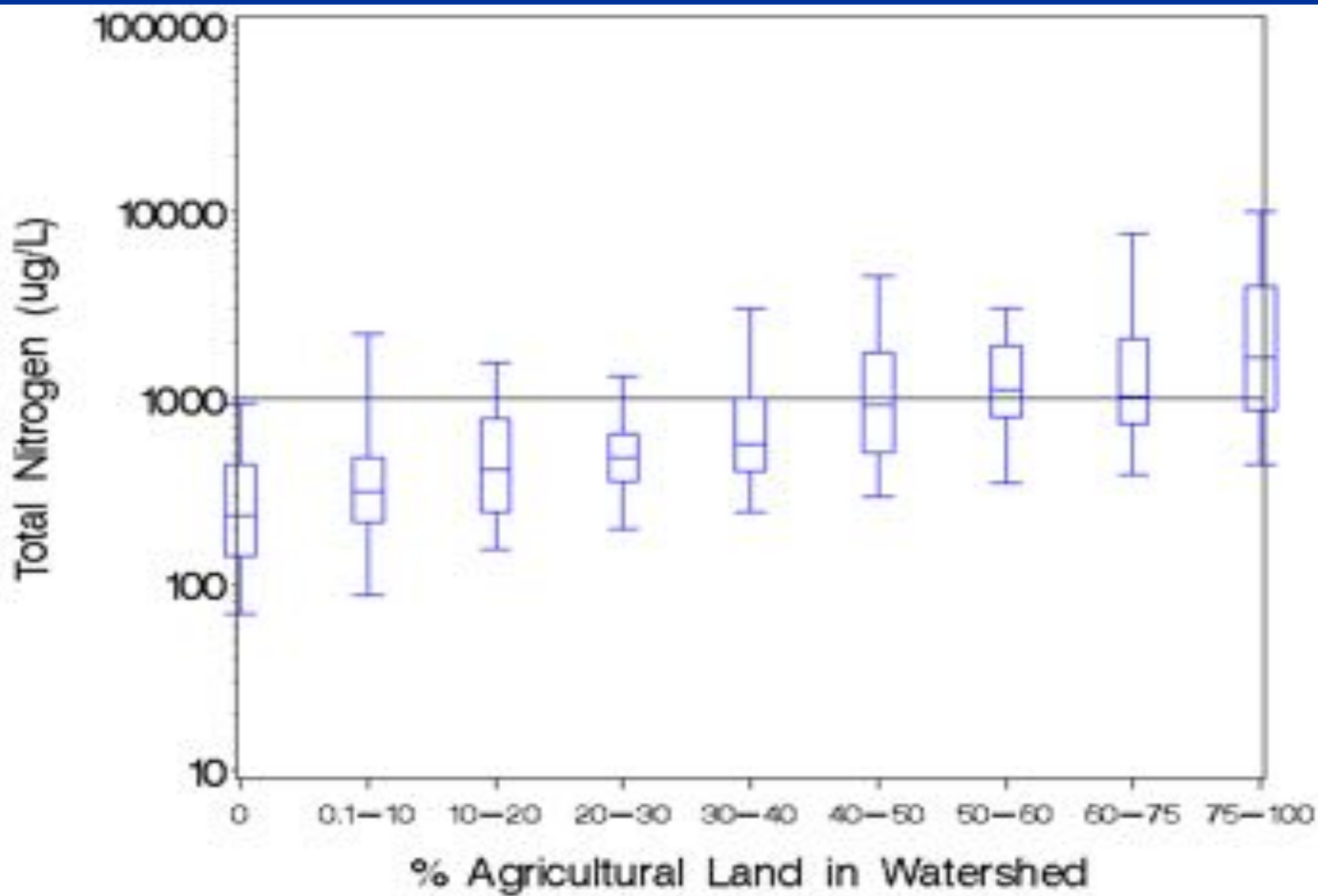
- Expected stream sulfate from deposition in this region is 100-300 μeq/L

- Bimodal sulfate histogram in Plateau. Mining not common in Ridge & Valley (except for Anthracite Belt)

- Sites with $SO_4 > 400$ μeq/L classified as non-reference

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Montgomery Creek, PA
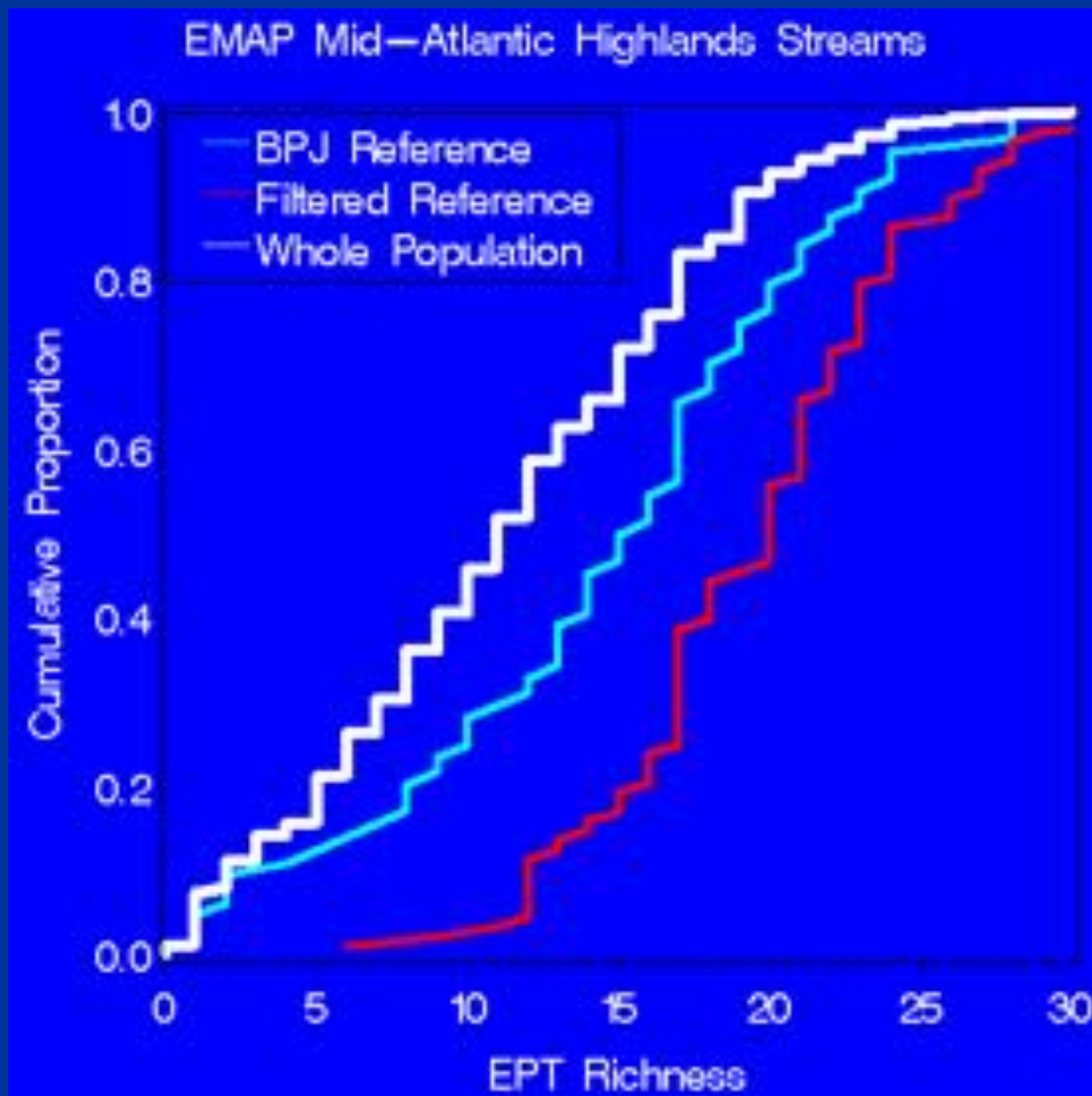## ANC=-5 ueq/L, pH=5.1, SO_4=175 μeq/L

Filtering produced a set of Reference Sites with higher EPT Richness scores than BPJ

Advantages of Filtered Sites

• Fewer poor biological condition sites

• Have a much more rigorous definition of "reference"

EMAP Mid—Atlantic Highlands Streams

- BPJ Reference
- Filtered Reference
- Whole Population

Cumulative Proportion vs EPT Richness

How do we apply a filtering process to the whole country?

- **<u>Primarily Done for Biological Assessment</u>**
- Classification Required
    - Can't apply exact same criteria everywhere
- What Screening (filter) Variables?
    - Chemical, Physical Habitat, and/or Landscape/GIS?
    - **Biological (Avoid due to CIRCULARITY)**
- Set Class Specific Screening Thresholds

What is Reference for NARS?

Least Disturbed Condition – sites with best available physical, chemical and biological condition given the current status of the landscape as defined by a set of explicit criteria to which all reference sites must adhere

SEE: Stoddard, J. L., D. P. Larsen, C. P. Hawkins, P. K. Johnson, and R. H. Norris. 2006. Setting expectations for the ecological condition of streams: the concept of reference condition. Ecological Applications **16:1267-1276.**

Process

- Used same set of filter screening variables in all ecoregions

- <u>Minimally Disturbed</u> versus <u>Least Disturbed</u>
  - Pristine? – don't exist

- For setting screening thresholds - start with minimally disturbed conceptual model for each ecoregion. If not enough sites, have to relax screening thresholds.
  - THIS VARIES AMONG ECOREGIONS

9 Aggregate Level III Ecoregions used to set filtering criteria
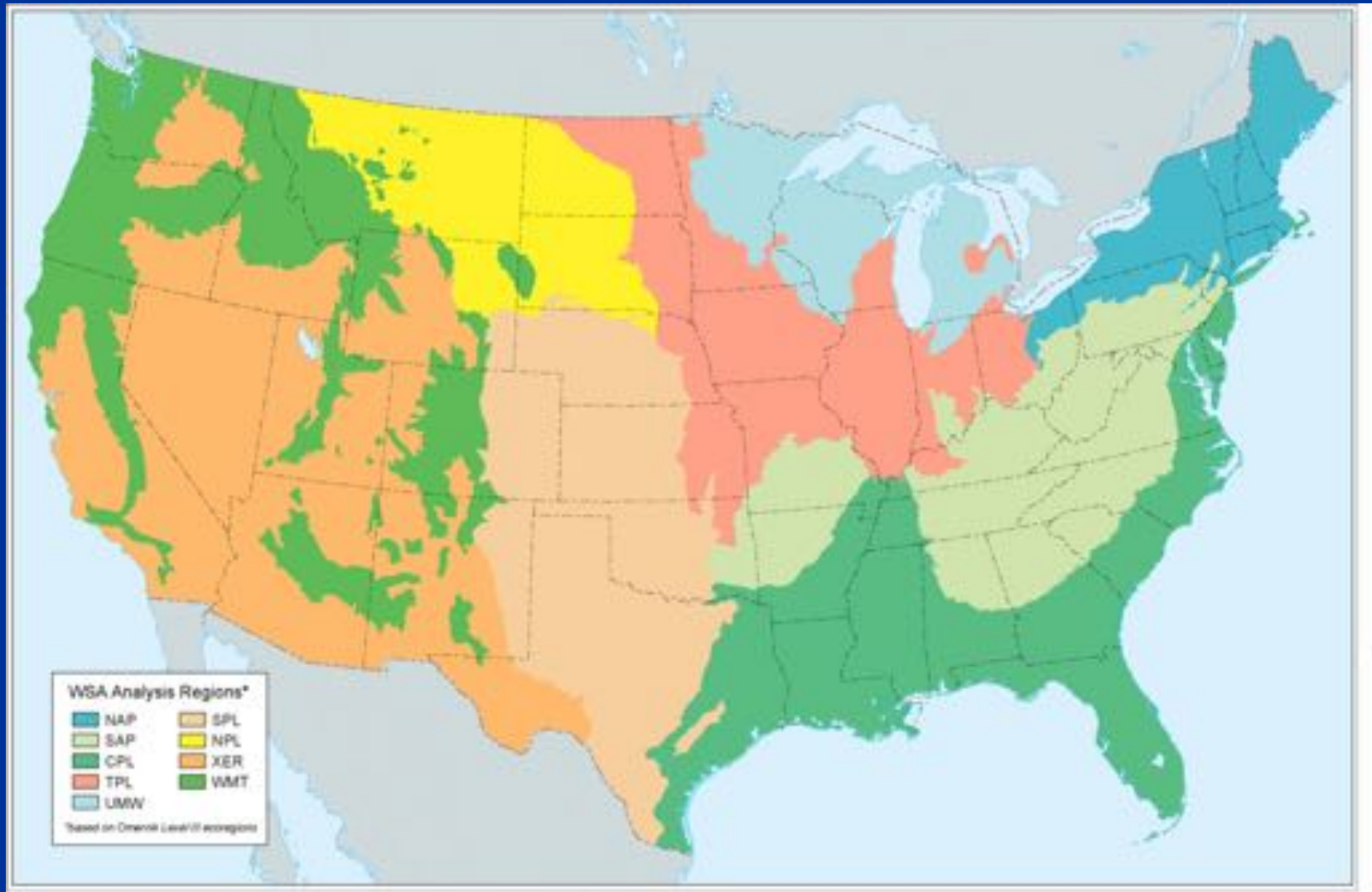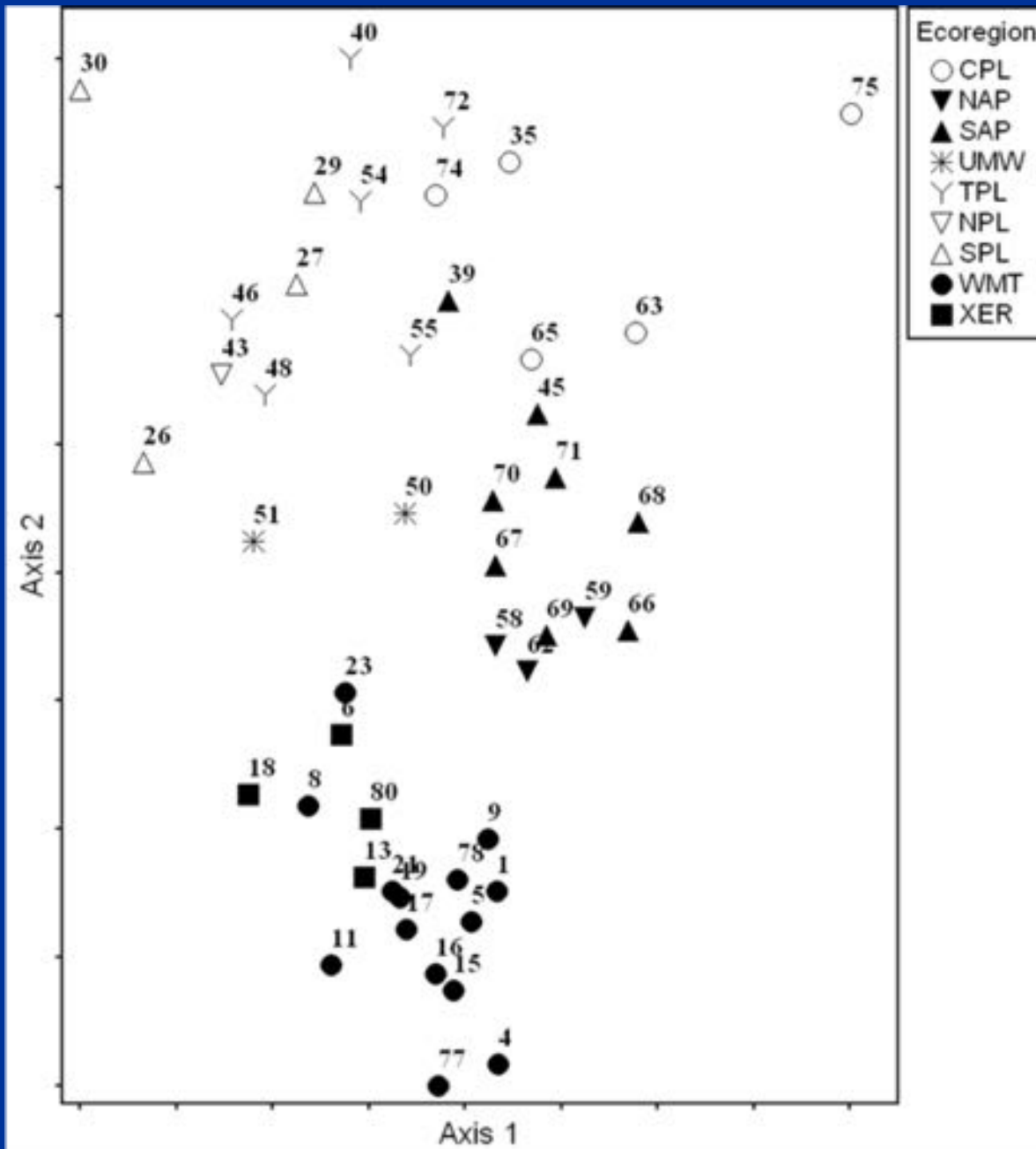
NMS Ordination of Omernik Level III Ecoregion Composite Macroinvertebrate Samples

Number=Omernik Level III ecoregion Code

Stream/River Screening Thresholds

Filter Variable	S. Appalachians	Southern Plains
Total P (μg/L)	> 20	> 150
Total N (μg/L)	> 750	> 4,500
Sulfate (μeq/L)	> 400	---
Chloride (μeq/L)	> 200	> 1,000
ANC&DOC (μeq/L, mg/L)	< 50 & < 5	< 50 & < 5
Turbidity (NTU)	> 5	> 50
Riparian Disturb. (W1_Hall)	> 2	> 2
% Fine Sediment	> 25	> 90

Field Data vs. GIS Screens

- Initially no Landscape/GIS screens involved
  - Landscape disturbance may have little/no relation to stream
    - GIS poor measure of intensity, accuracy?
  - Inherently defines a land use ("Agriculture") as "bad"
  - What matters is what's in the stream (BMP)
  - Existing filters do miss some disturbances (hydrologic)
    - Laugh Test
- For NARS streams, added 1 km circular buffer landscape screen and upstream dam influence screens

Concluding Thoughts

- Have Explicit Objectives
    - Use explicit criteria (definition) of what you mean by reference streams
    - GIGO
- Balance "strictness" of reference definition with desire to have streams spread out across the region of interest
    - Disturbance is not independent of size, ecoregion, hydrologic type, etc.
- I prefer Field data to GIS data when possible

Questions?

- **Pubs**

  - Herlihy, A.T., S.G. Paulsen, J. Van Sickle, J.L. Stoddard, C.P. Hawkins, and L.L. Yuan. 2008. Striving for consistency in a national assessment: the challenges of applying a reference condition approach at a continental scale. Journal of the North American Benthological Society 27:860-877.

  - Herlihy, A.T., M.E. Kentula, A.M. Nahlik, G.A. Lomnicky, T.K. Magee, and G. Serenbetz. 2019. Striving for consistency in the National Wetland Condition Assessment: developing a reference condition approach for assessing wetlands at a continental scale. Environmental Monitoring and Assessment In press. doi: 10.1007/s10661-019-7325-3.

Most Disturbed Sites

- For MMI metric selection and other testing, developed set of Most Disturbed Sites for NRSA, NLA, and NWCA

- Same classification and screening metrics

- Developed "Most Disturbed" thresholds for each metric in each class
  - Site exceeding any one threshold was considered most disturbed
  - In practice, the "most disturbed" 20-30% of the sites in each class
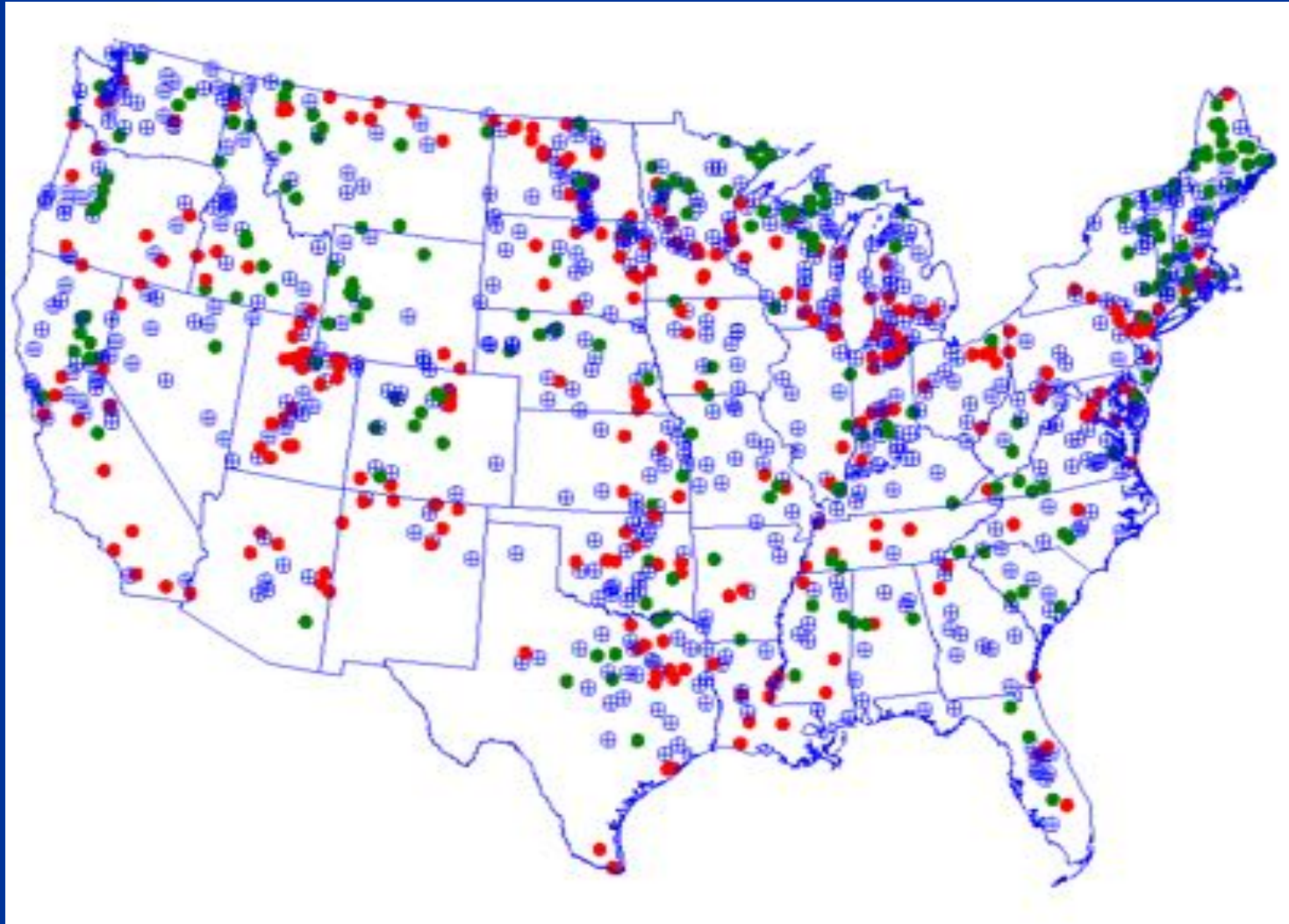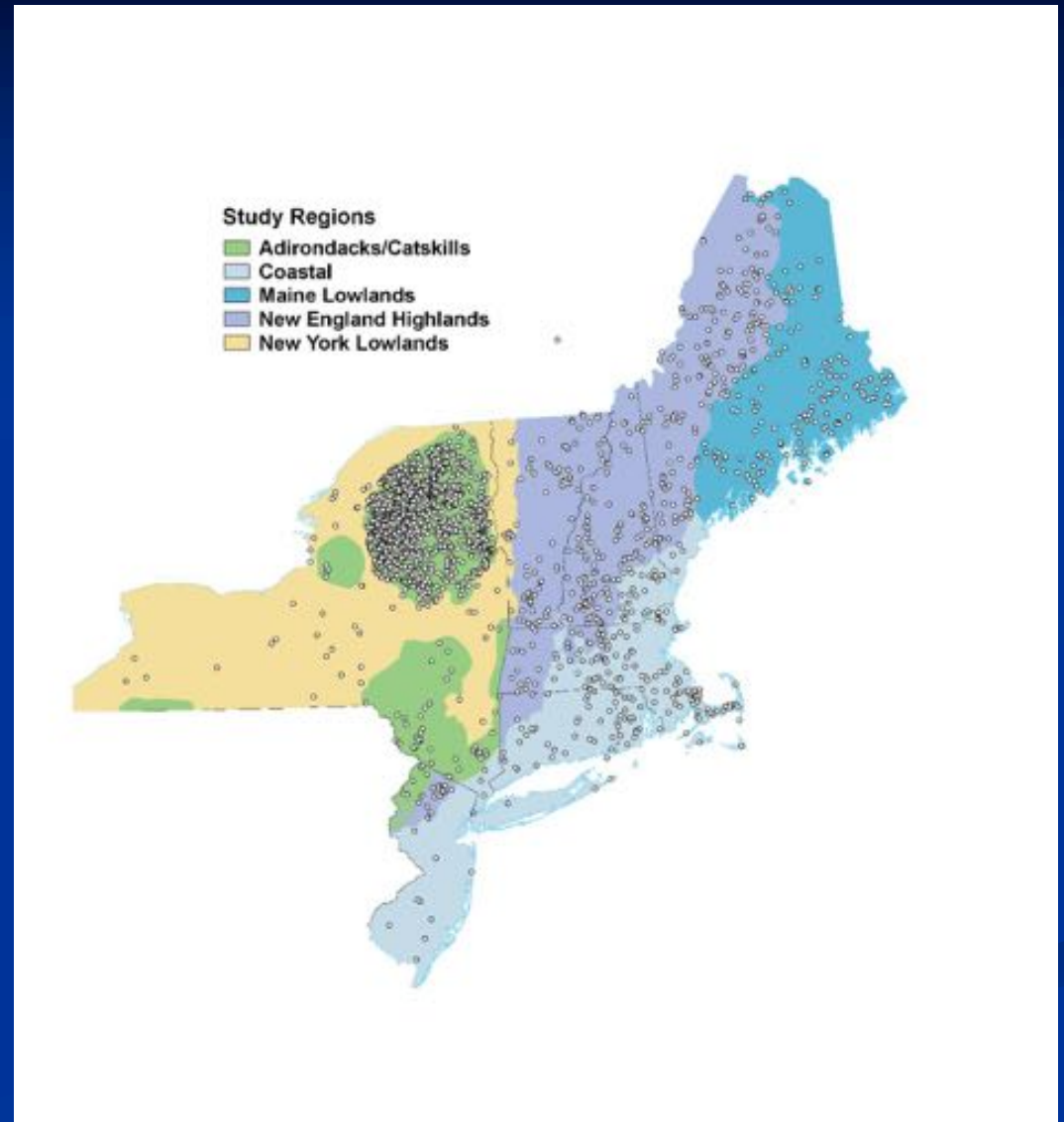
2012 NLA Sites

Green=Least Dist.

Red=Most Dist.

Blue=Intermed.

2007 National Lakes Assessment Pre-Sampling Reference Lake Selection

Wanted to increase the success rate for hand-picked reference sites

Pilot Study in Northeast

Study Regions
- Adirondacks/Catskills
- Coastal
- Maine Lowlands
- New England Highlands
- New York Lowlands

Three Stage Lake Screening Process

Stage 1
- 7350 target lakes in Northeast lake population
- 2109 lakes had data and were screened for water quality

Stage 2
- 369 lakes passed Stage 1 screening
- GIS land use and road data screening

Stage 3
- 149 lakes passed Stage 2 screening
- Aerial photograph screening
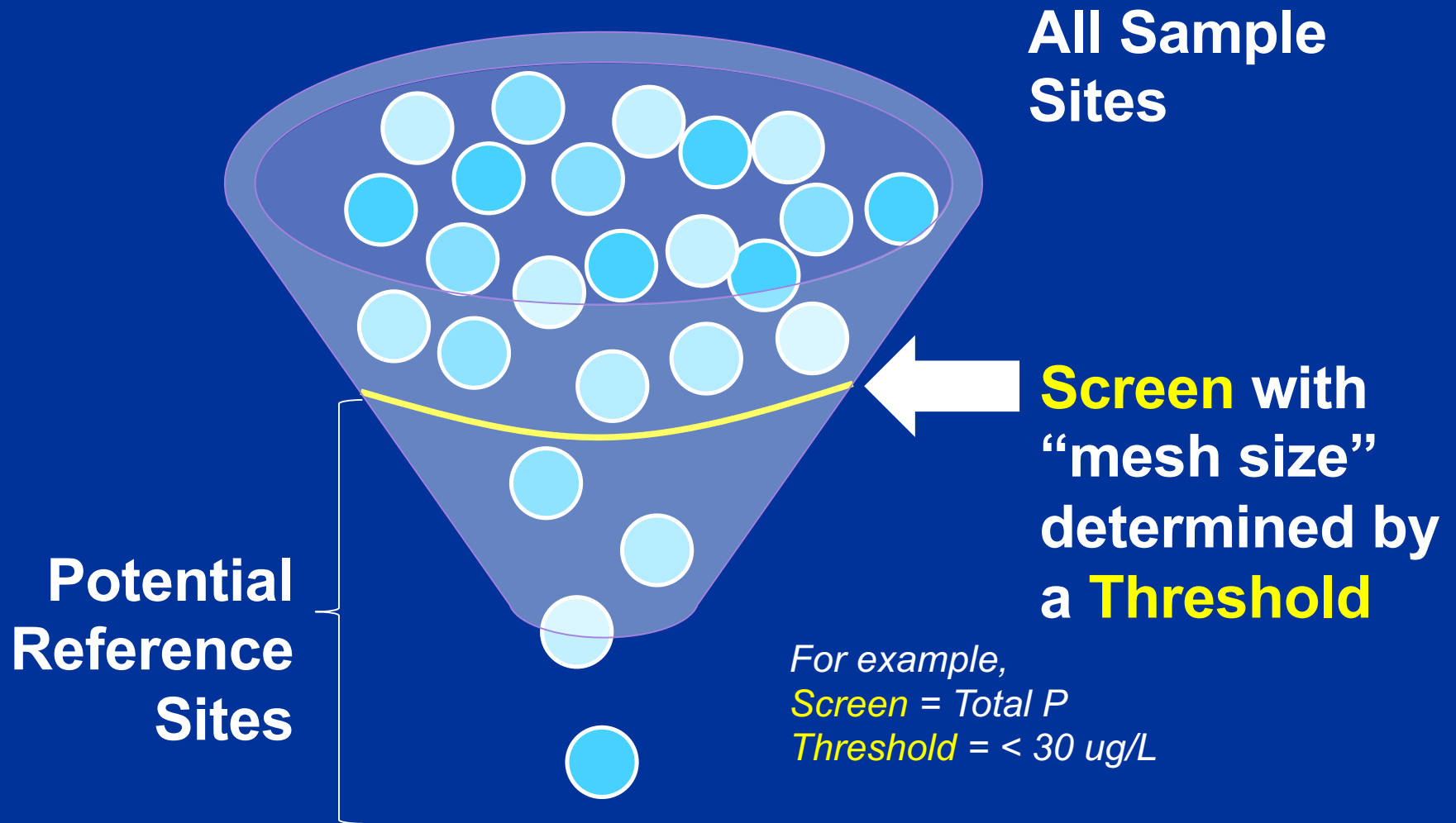- 89 lakes passed Stage 3 screening to make final candidate list

Field Sampling Results

- 20 of the 89 lakes were field sampled as potential reference lakes as part of the NLA probability sample
- Lakes screened along with probability lakes in NLA data analysis
- Most of the 20 lakes were in least-disturbed condition
    - 85-100% had least-disturbed water chemistry
    - 74-79% had least disturbed physical habitat
    - 68-78% had least-disturbed biology

NLA Reference Lake Pre-screening

- An efficient method for identification of good candidates for reference-lake sampling.

- Can be done in the office and relatively inexpensively.

- Useful for large-scale regional or national studies encompassing areas too large to census.

- Adds a level of consistency and quantification to the reference-site selection process

Screening Approach for Reference

All Sample Sites

Screen with "mesh size" determined by a **Threshold**

For example,
Screen = Total P
Threshold = < 30 ug/L

Potential Reference Sites

Definitions

- Following Stoddard et al. (2006) definitions of reference:
  - <u>Minimally Disturbed</u> sites have no evidence of significant human disturbance
  - <u>Least Disturbed</u> sites represent the best attainable conditions given the state of the landscape

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