Presented at

Great Rivers Reference Condition Workshop

January 10-11, Cincinnati, OH

Sponsored by

The U.S. Environmental Protection Agency and The Council of State Governments

U.S. EPA Office of Research and Development

Environmental Monitoring and Assessment Program

Identifying Reference Sites in Great Lakes Coastal Areas

Lucinda Johnson, George Host, Jan Ciborowski, Valerie Brady, Dan Breneman, Jeff Schuldt, Carl Richards, Yakuta Bhagat

EPA STAR EaGLe

Great Lakes Environmental Indicators

Acknowledgements

EaGLe

This research has been supported by a grant from the US Environmental Protection Agency's Science to Achieve Results (STAR) Estuarine and Great Lakes (EaGLe) Coastal Initiative through funding to the Great Lakes Environmental Indicators (GLEI) Project, US EPA Agreement EPA/R-8286750 & EPA/R-82877701.

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # EPA/R-8286750

EPA STAR EaGLe

Defining Reference Conditions

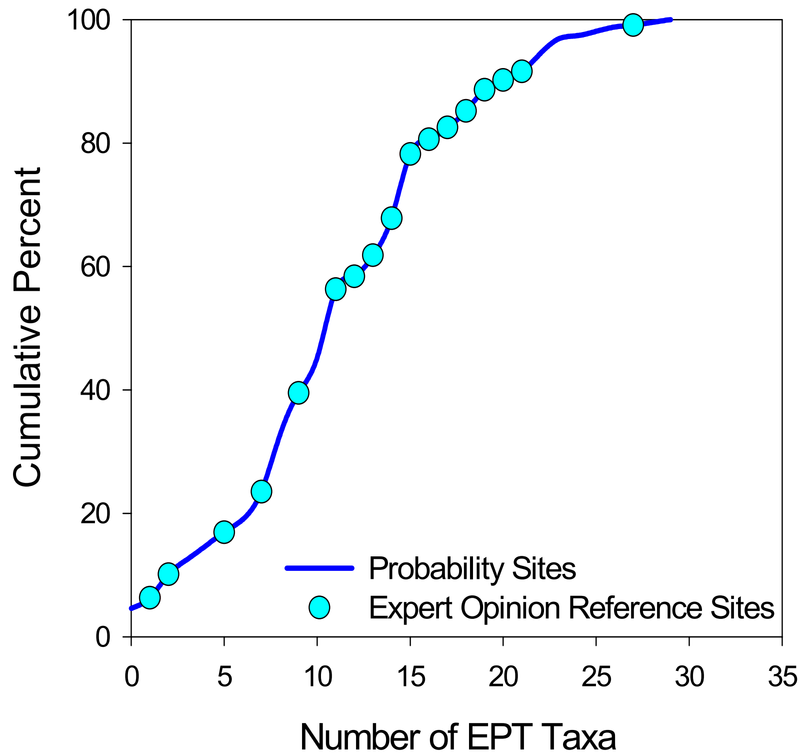
- Minimally disturbed- absence of anthropogenic disturbance;
- Least disturbed- best available given current condition;***
- Best attainable (theoretical)- equivalent to hypothetical least disturbed sites under BMP (Stoddard et al.)

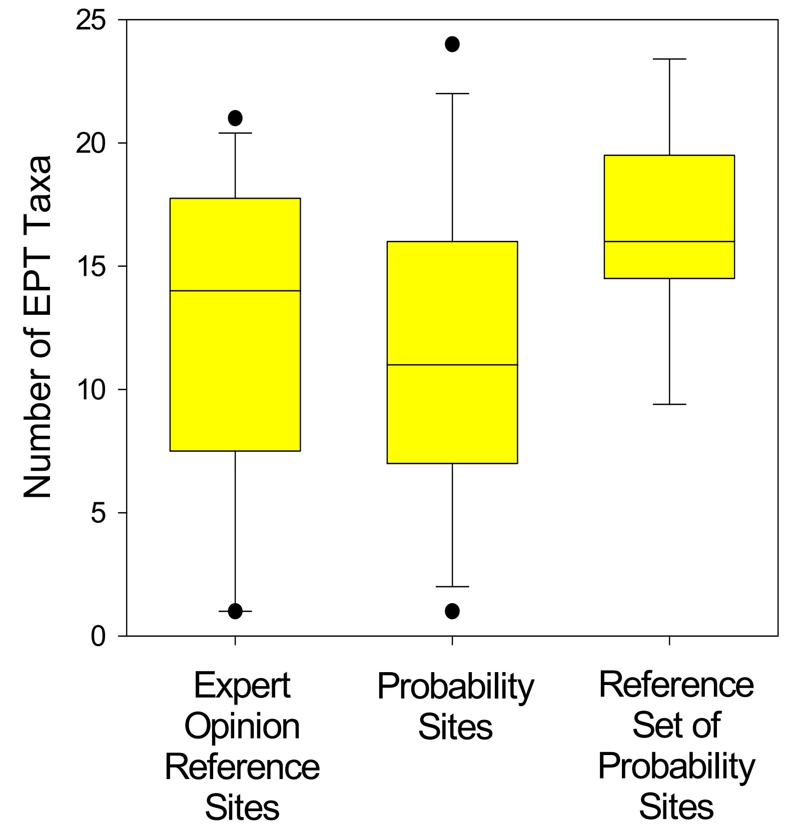
*** working definition for the Reference Area project.

Selecting reference sites by committee

Expert opinion compared to a random sample

Mid Atlantic streams





Source: EMAP

Motivating issues:

- **The appropriate spatial scales for regionalizing reference conditions are not well understood**
  - Are the biota of Lake Superior reference wetlands similar to those of Lake Michigan? Erie?
  - Are riverine wetlands similar to protected wetlands?
- **Over large geographic areas (e.g. the Great Lakes), quantifying anthropogenic stress is challenging**

EPA/STAR Research Programs

Reference Condition

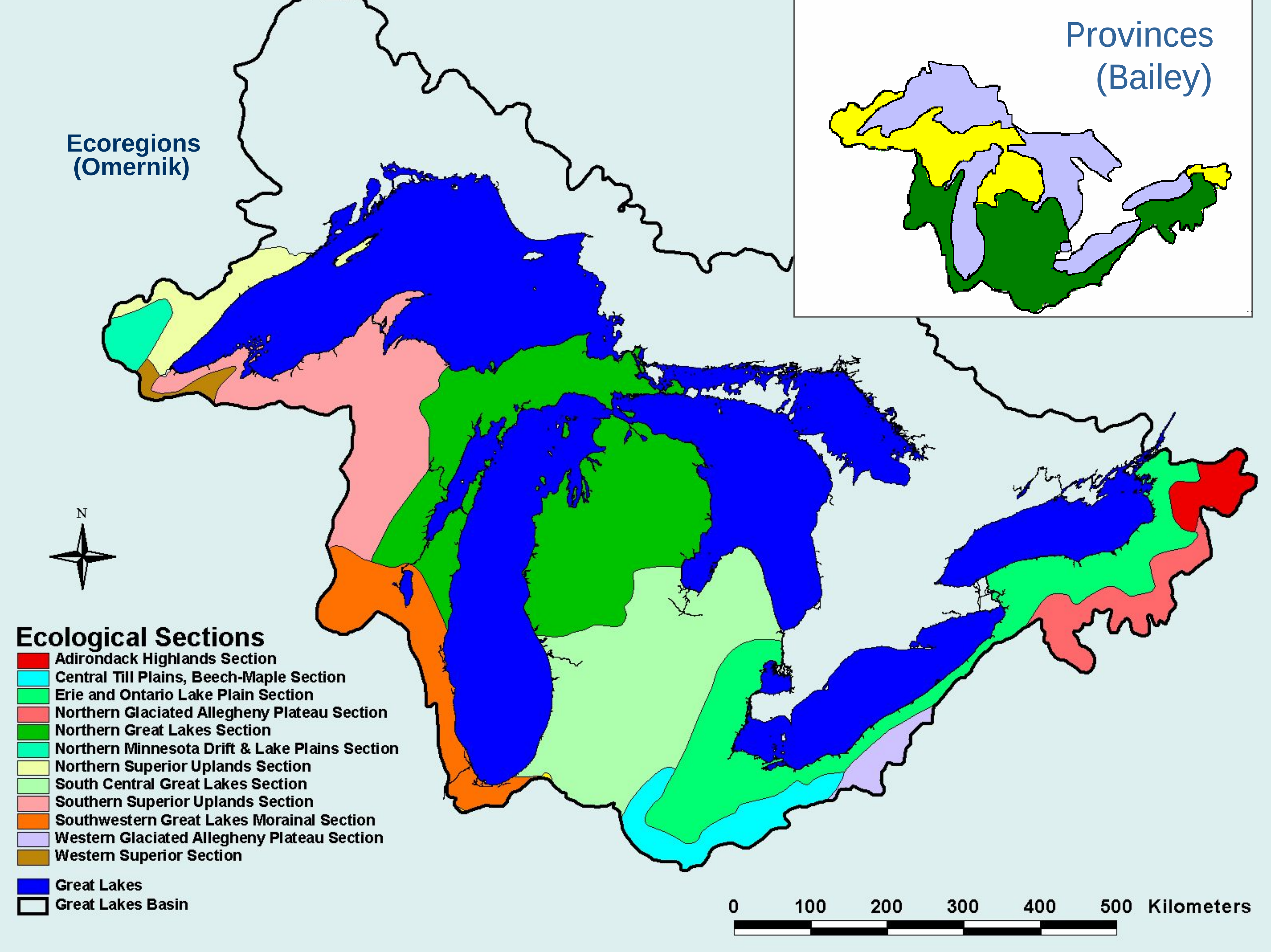
- Develop and apply an *a priori* classification system to Great Lakes coastal ecosystems
- Use spatial data to select reference sites
- Sample to define biological reference conditions
- Evaluate how biota respond to different levels of classification
  - Ecoregional
  - Hydrogeomorphic

Sample ‘pristine’ sites

Great Lakes Environmental Indicators

- Identify potential and useful environmental indicators
- Quantify relationships between stress and responses for diagnosis
- Recommend a suite of hierarchically-structured indicators that are useful for making informed management decisions

Sample across stress gradient



Provinces
(Bailey)
Ecoregions
(Omernik)
N
Ecological Sections
Adirondack Highlands Section
Central Till Plains, Beech-Maple Section
Erie and Ontario Lake Plain Section
Northern Glaciated Allegheny Plateau Section
Northern Great Lakes Section
Northern Minnesota Drift & Lake Plains Section
Northern Superior Uplands Section
South Central Great Lakes Section
Southern Superior Uplands Section
Southwestern Great Lakes Morainal Section
Western Glaciated Allegheny Plateau Section
Western Superior Section
Great Lakes
Great Lakes Basin
0 100 200 300 400 500 Kilometers

Hydrogeomorphic Classification of Coastal Ecosystems

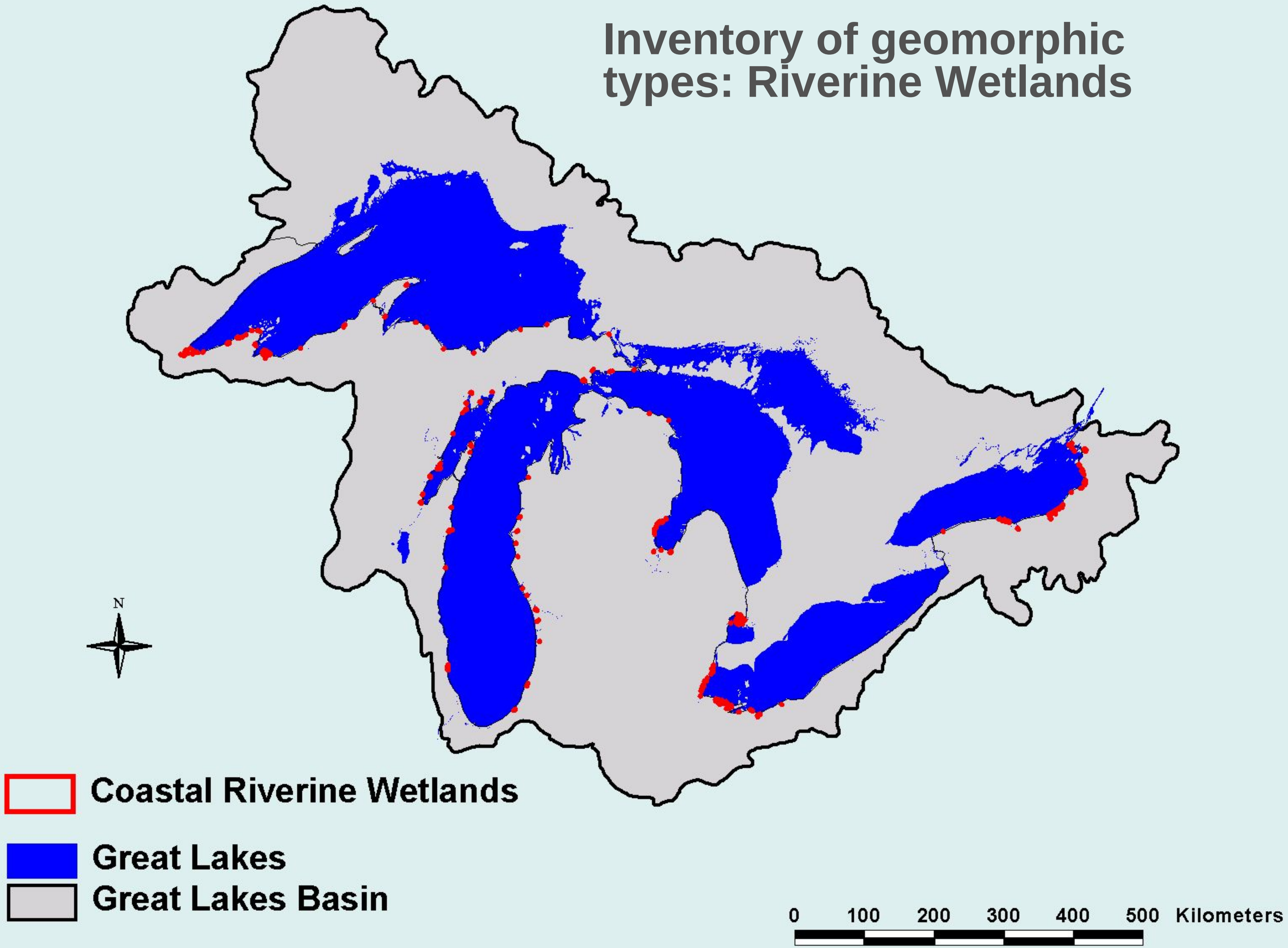
Open-coast Wetland

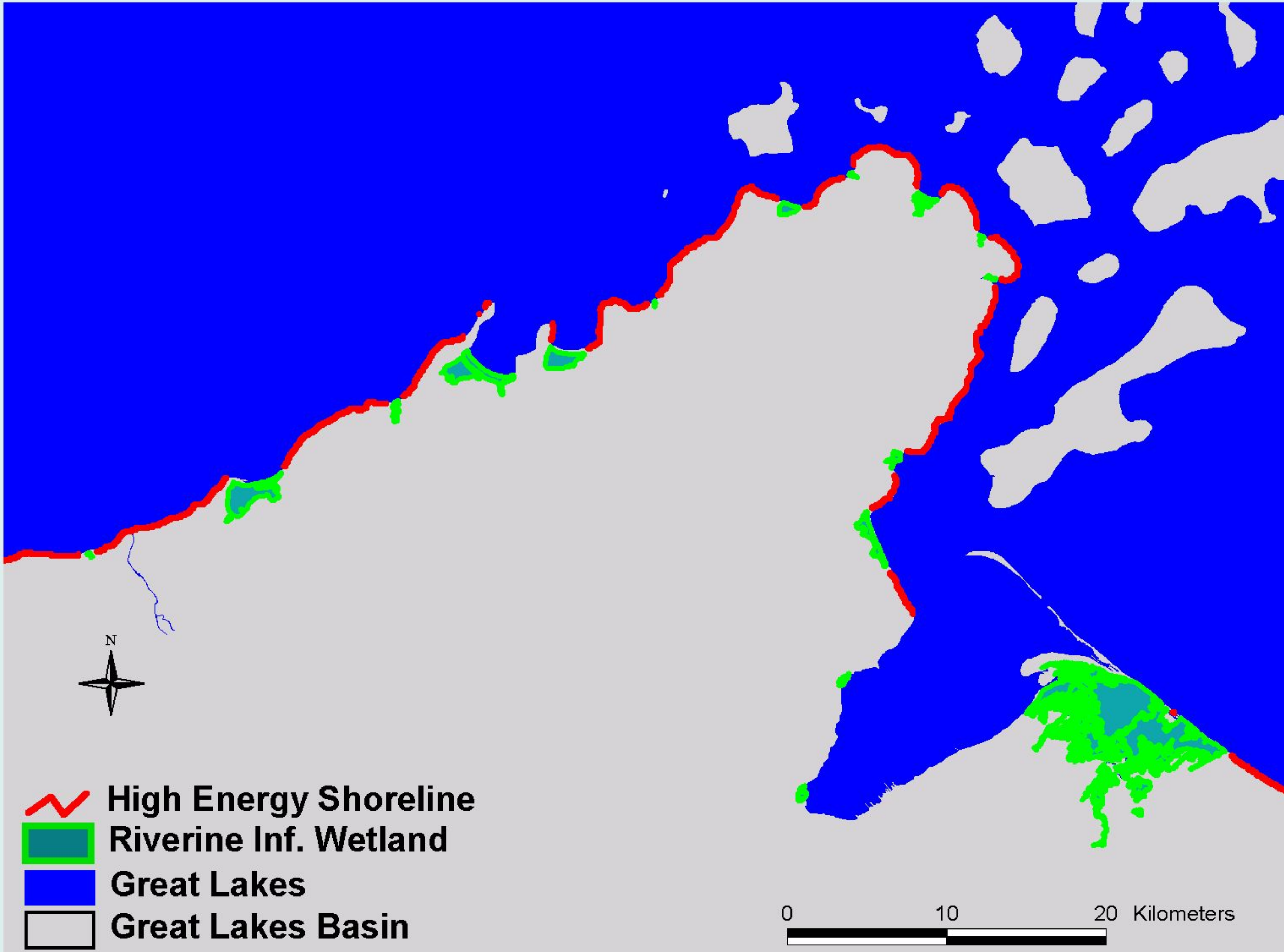
Protected Wetland behind High Energy Shoreline

Embayment

Riverine Wetland

Inventory of geomorphic types: Riverine Wetlands



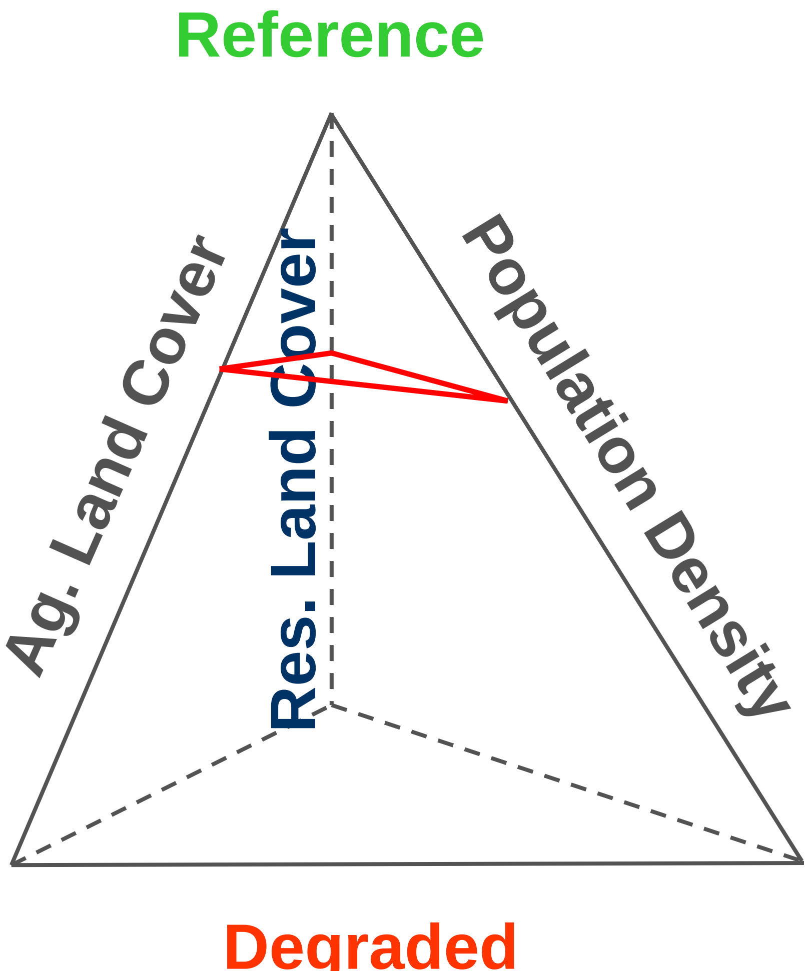

N
High Energy Shoreline
Riverine Inf. Wetland
Great Lakes
Great Lakes Basin
0
10
20 Kilometers

Hydrogeomorphic Inventory for the Great Lakes

Ecosection	High Energy Shoreline	Embayment	River Influenced Wetland	Protected Wetland	Coastal Marsh
EOL	1613 km	18	77	45	38
NGL	2687 km	34	53	95	188
NSU	389 km	0	16	3	0
SCG	592 km	2	12	6	33
SGL	520 km	0	2	10	0
SSU	920 km	10	39	29	27

- Sampled wetland systems (n > 30)

Anthropogenic stress model



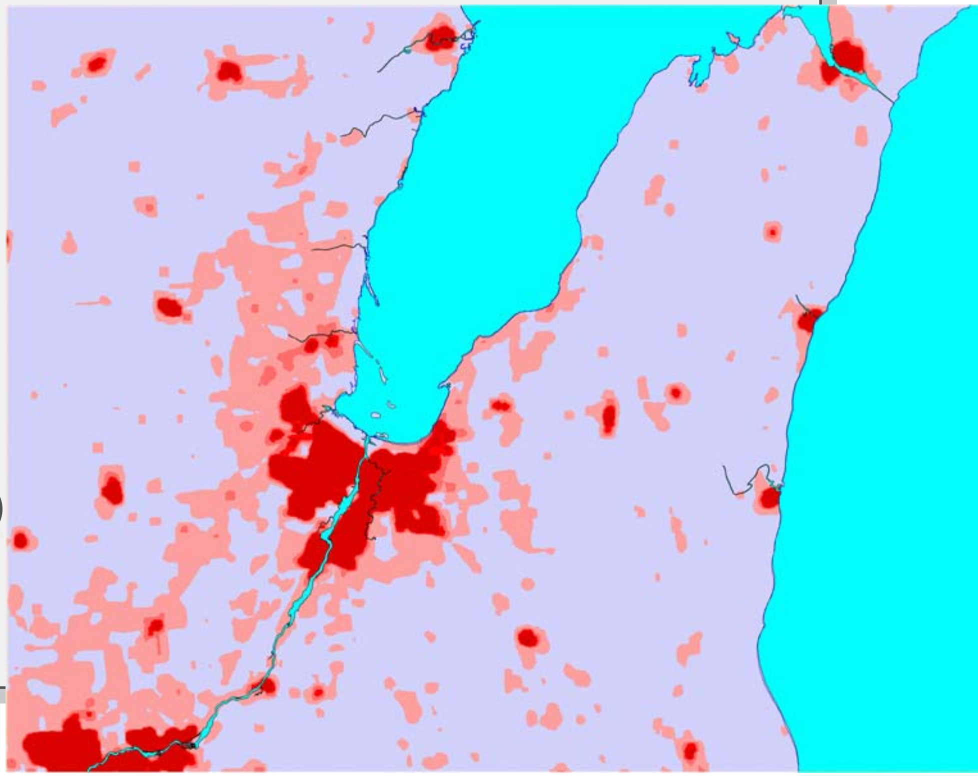
How to identify wetlands with minimum anthropogenic pressure values across multiple stress axes

Host et al., Intl. J. Remote Sensing 2005.

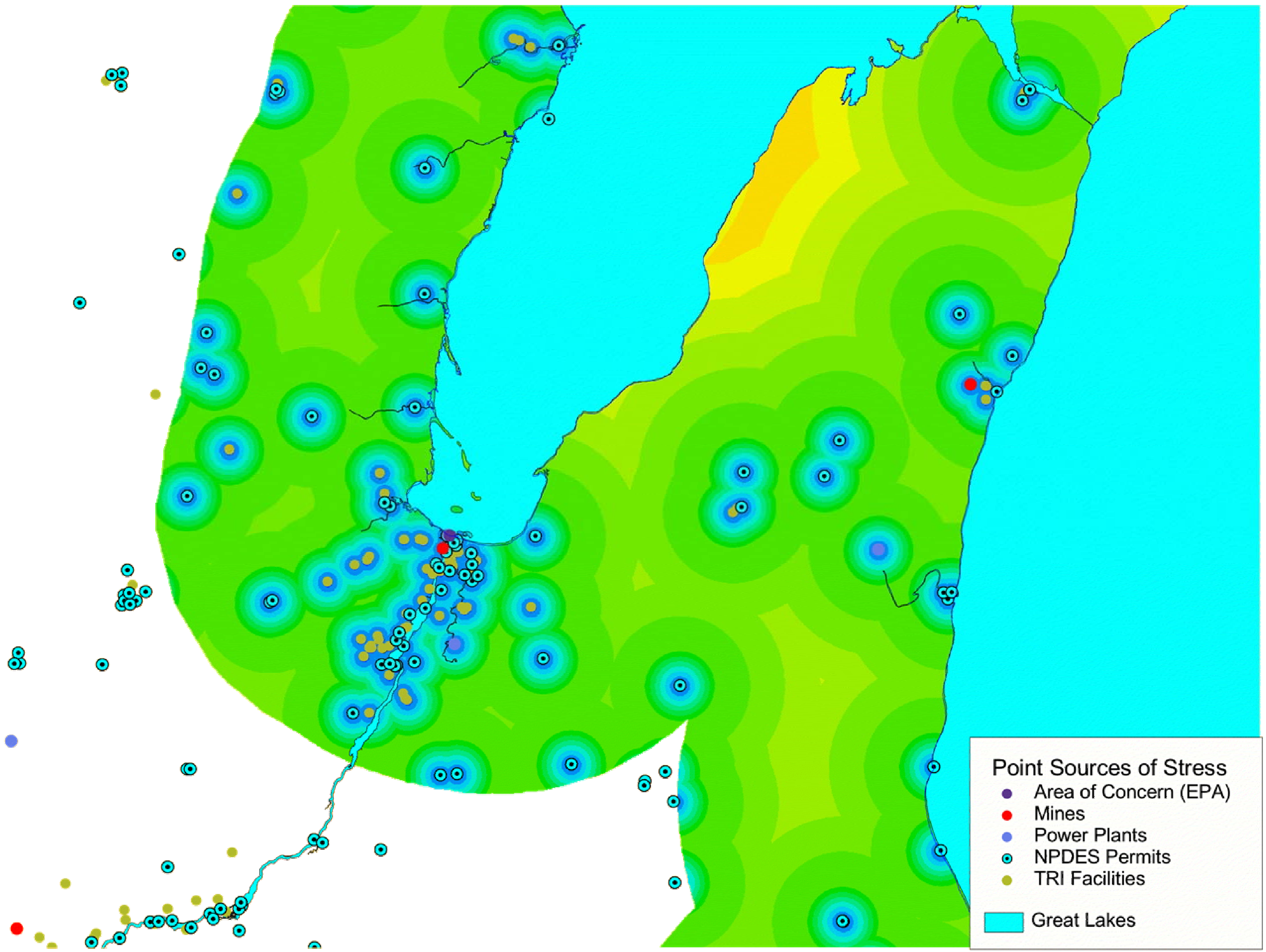
Ciborowski et al., *in prep.*

Quantifying Anthropogenic Stress: Data

- **Publicly available spatial data (raster/polygon)**
  - Agricultural land cover
    - (USGS-NLCD – 30 m)
  - Residential land use
    - (USGS-NLCD – 30 m)
  - Population density
    - (2000 Census Block)
  - Road density
    - (TIGER)
- **Point source data**
  - NPDES permits (EPA)
  - Toxic Release Inventory (EPA)
  - Areas of Concern (AOC)
  - Mines and power plants



Population density (people/pixel)

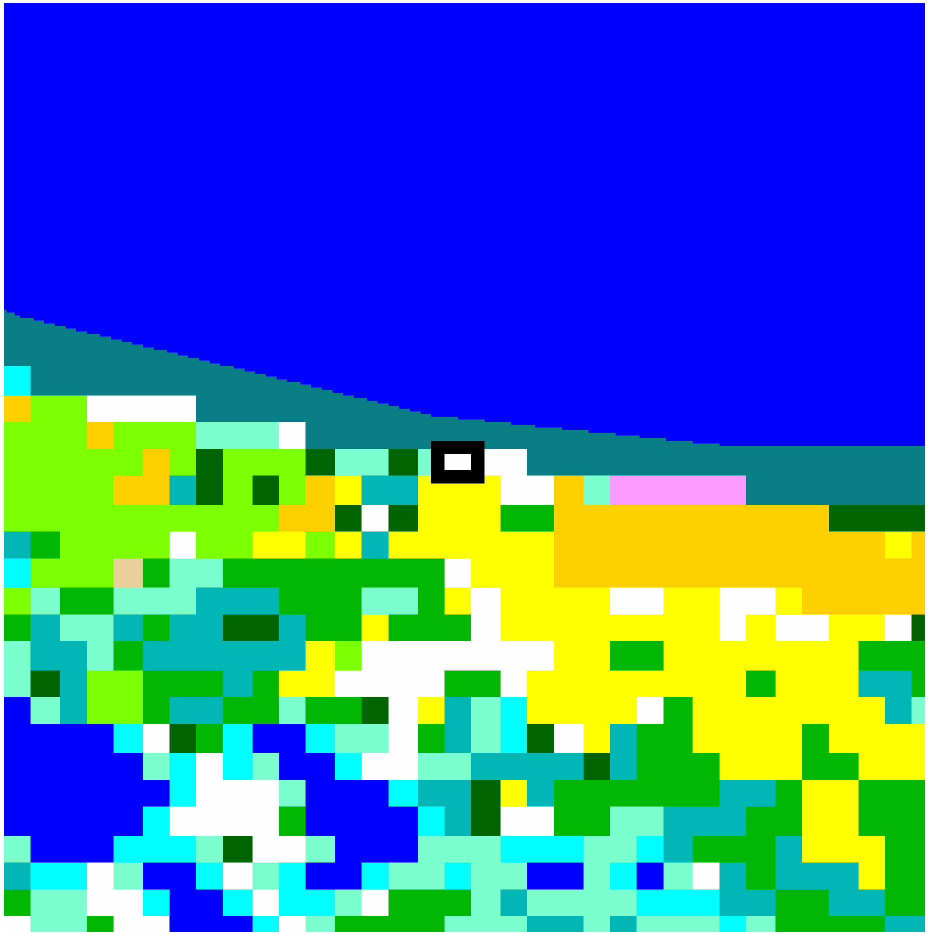

Point Sources of Stress
Area of Concern (EPA)
Mines
Power Plants
NPDES Permits
TRI Facilities
Great Lakes

Contributing areas

- **Watersheds**
  - River influenced wetlands
  - Protected wetlands
  - Coastal wetlands
- **“Moving Window” approach**
  - High energy shorelines
  - Embayments

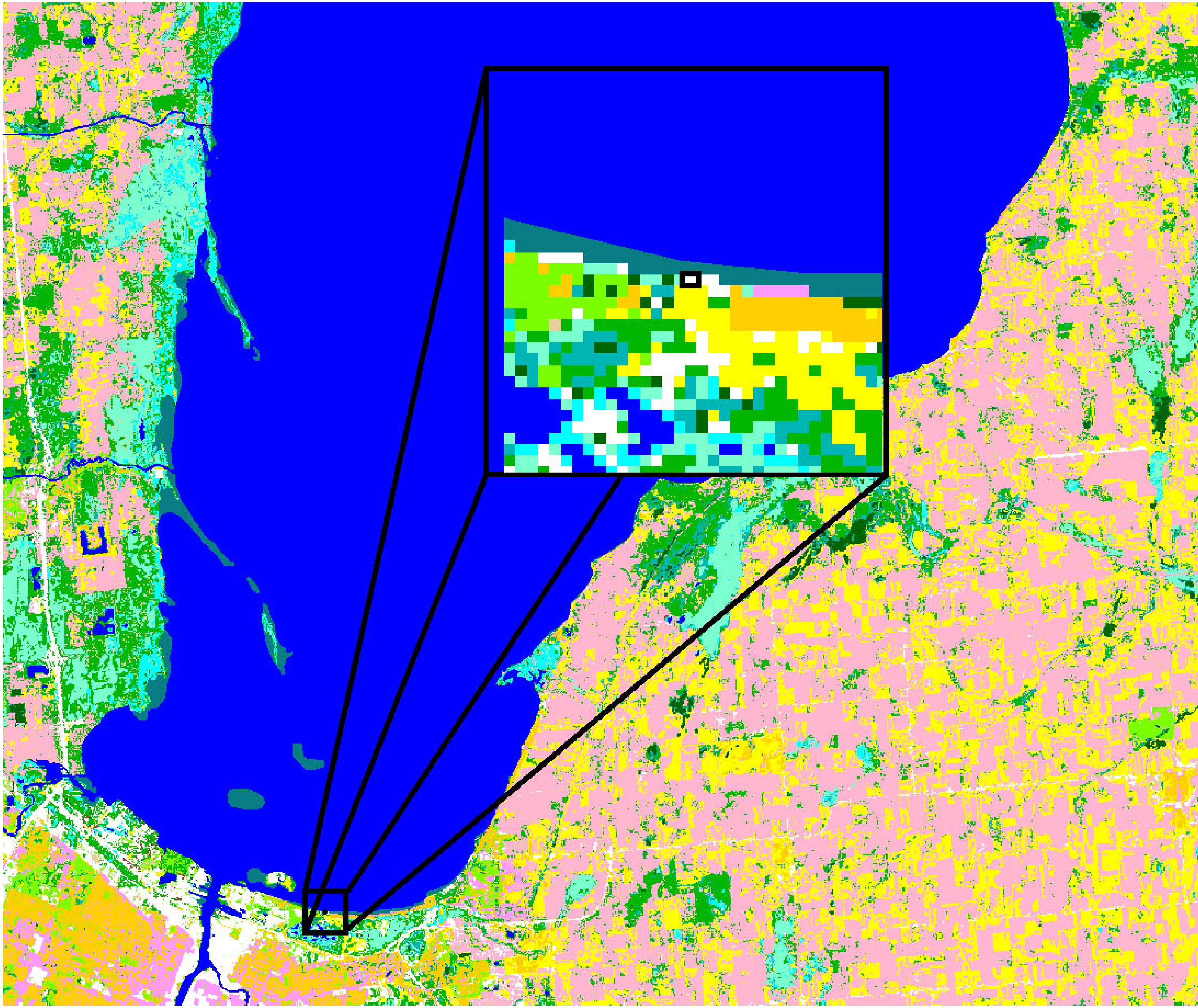
Moving window analysis

Summarize stressor attributes (e.g. # Ag pixels) in a 1 km^2 window around each shoreline pixel



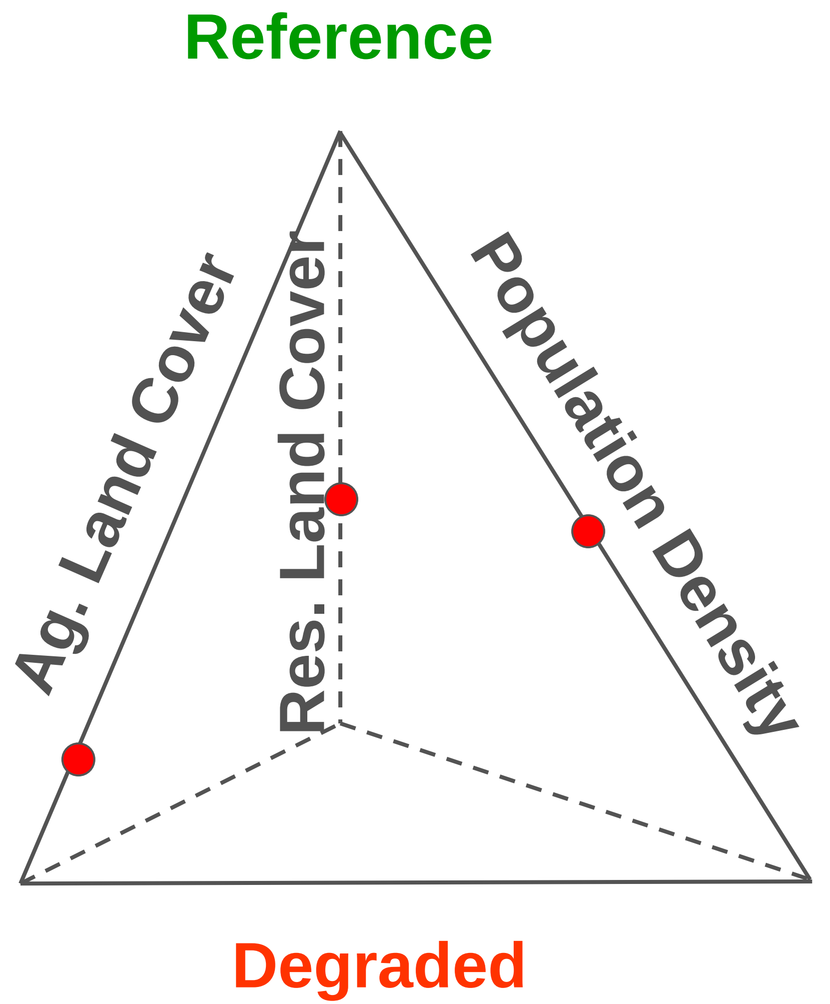
Window Summary

Ag	125
Res	96
Pop	.306
AOC	5159



Axes of Evil

Select pixels with minimum stressor values across all axes



Defining the Axes of Evil:

Step 1: Standardize data by axis

Scale each stressor axis from 0-1 based on the maximum value within that Type/Ecosection

Window Summary		Scaled Value
Ag	125	0.352
Res	96	0.254
Pop	.306	0.156
AOC	5159	0.089

Defining the Axes of Evil:
Step 2: Select maximum across axes

Calculate maximum across each of 5 stressor axes

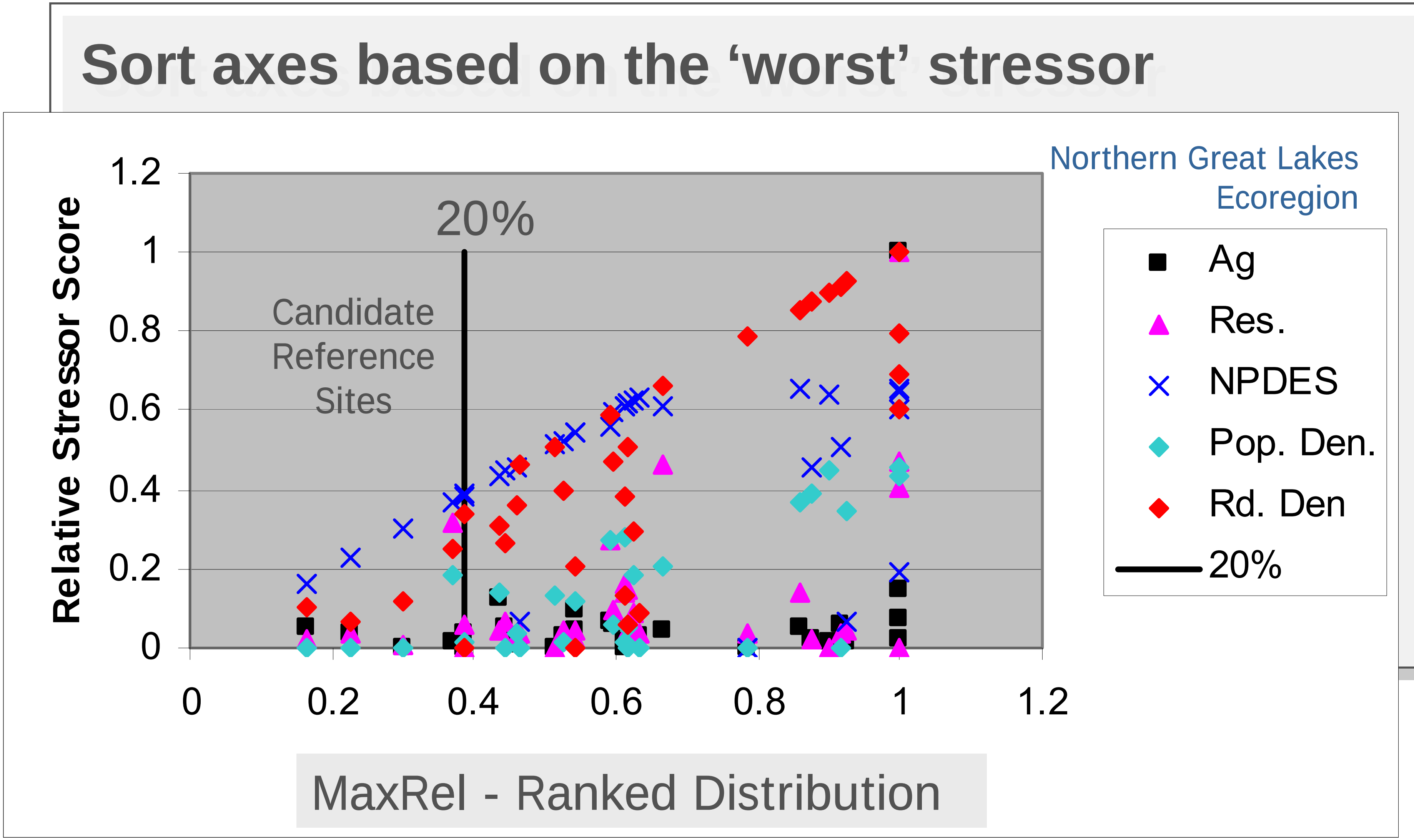
- Max{Agriculture, Residential, Population, Roads, NPDES}

Window Summary		Scaled Value		Score for Pixel/Polygon
Ag	125	0.352	→	0.352
Res	96	0.254		
Pop	206	0.156		
Point	5159	0.089		

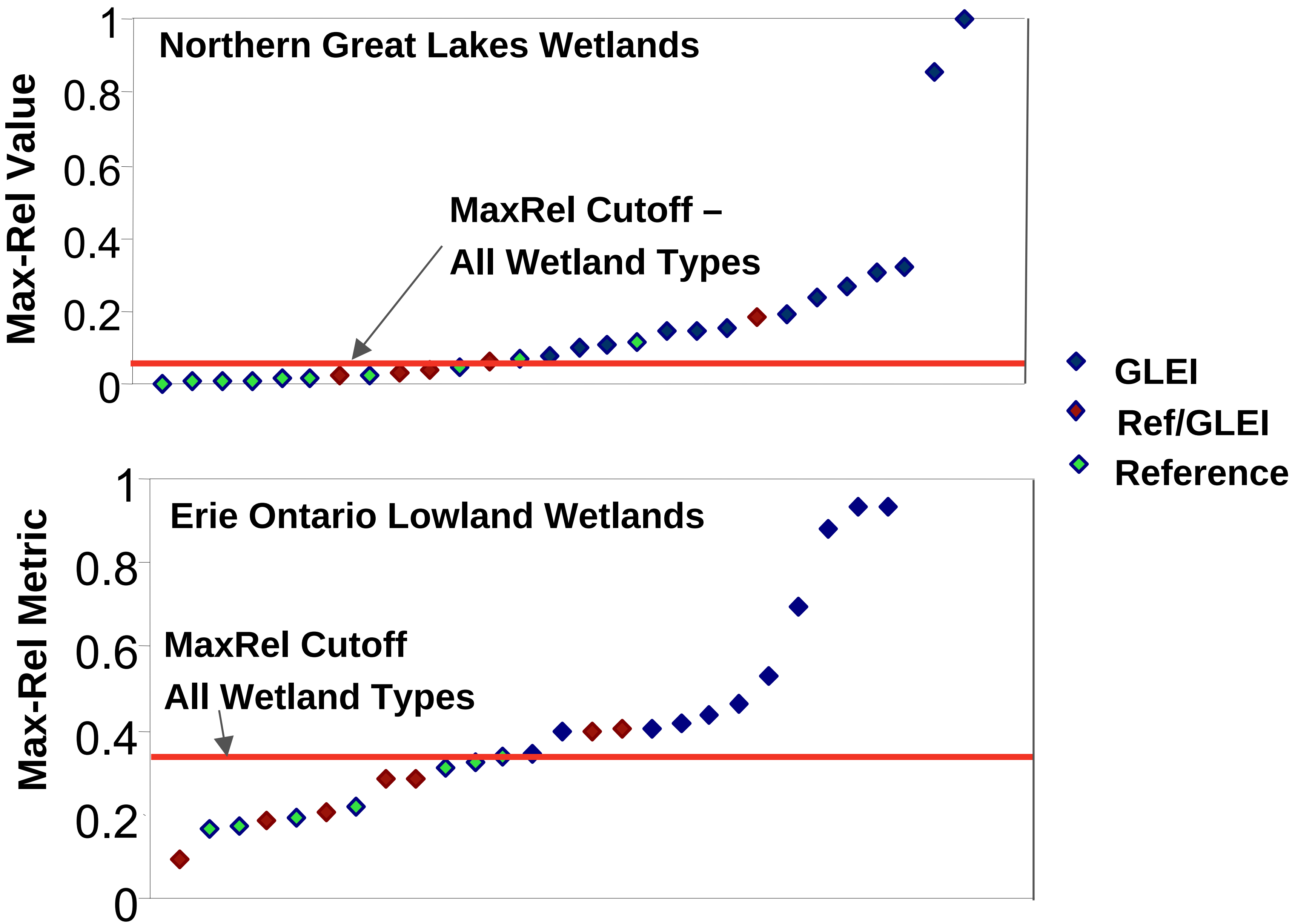
Assumption: biotic communities are limited by the "worst" stressor

Identifying reference wetlands

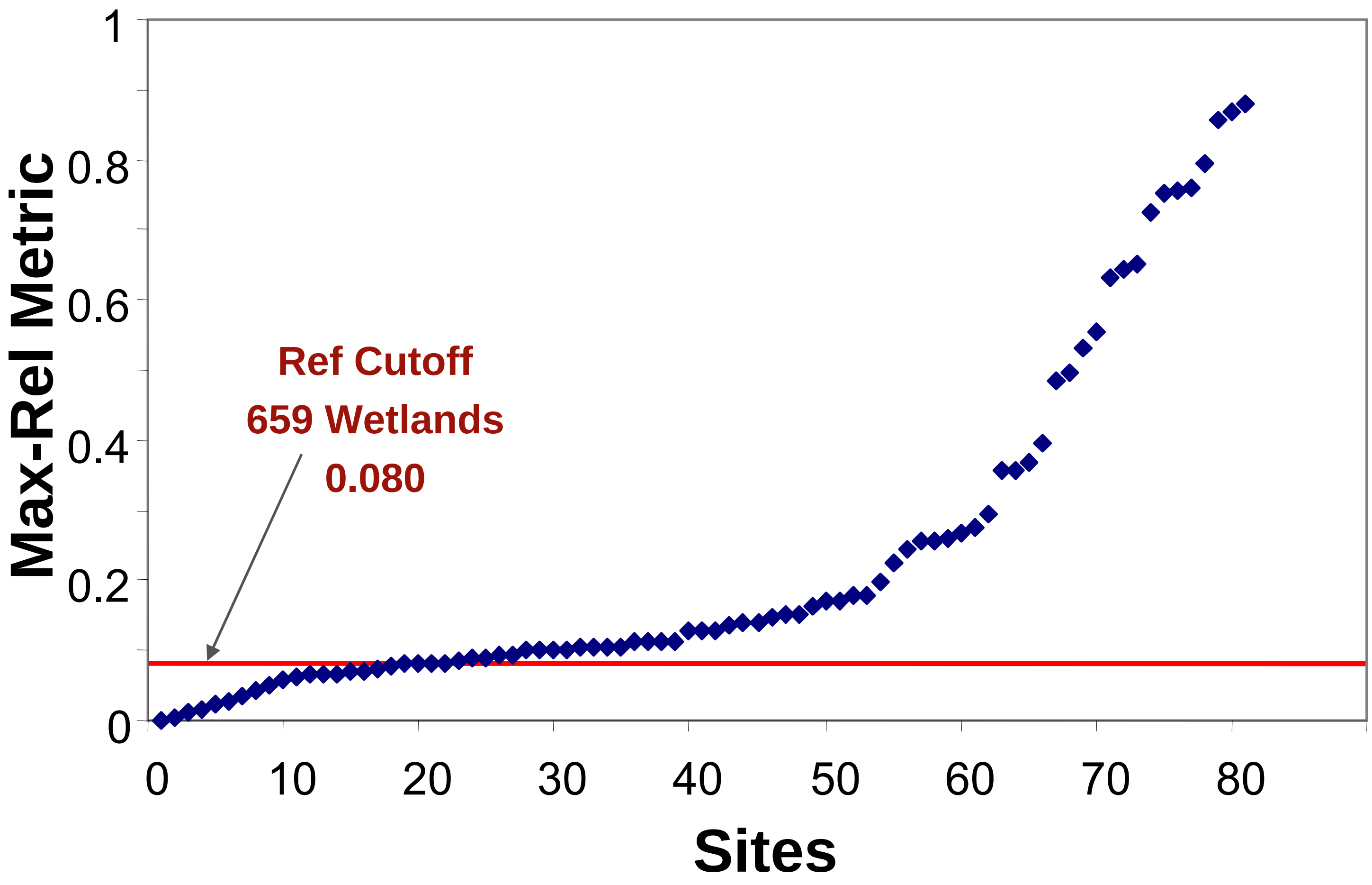
Step 3: Rank pixels by stressor type, select top 20%



Distribution of sites by “Max-Rel” Score



Distribution of sites by Max-Rel Score
US Side Great Lakes Basin



Sum of Stressors- an alternate approach

- Max {Agriculture, Residential, Population, Roads, Pt Sources}
- Reference = lowest 20th percentile Rel-Max scores

- Σ { Agriculture, Residential, Population, Roads, Pt Sources}
- References = lowest 20th percentile Sum-Rel scores

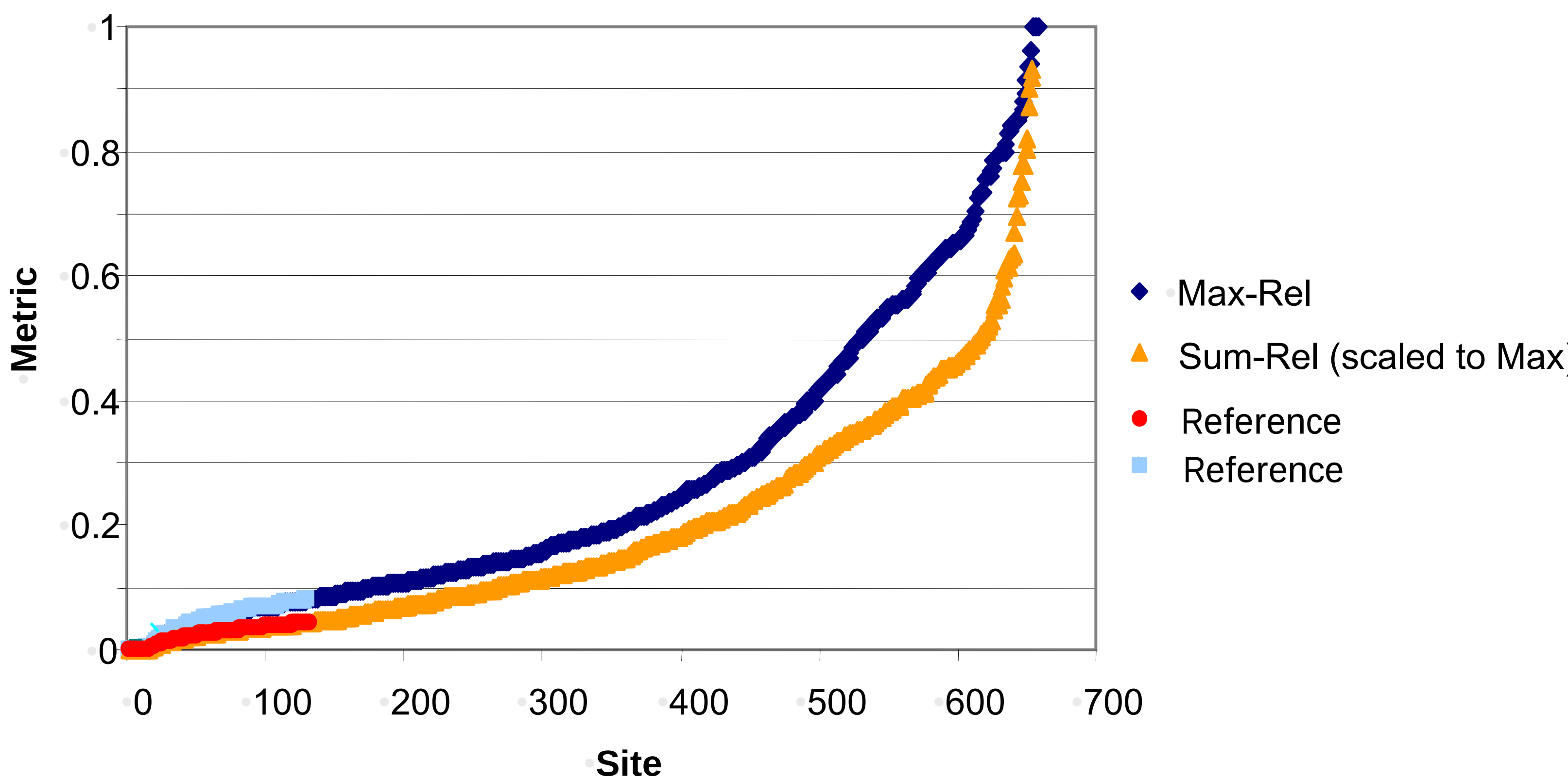
Max-Rel and Sum-Rel

	Raw Ag.	Raw Res.	Raw Pop. Den	Scaled Ag.	Scaled Res.	Scaled Pop. Den	Max-Rel Metric
	10	4	1.19	0.20	0.40	0.34	0.40
	20	1	1.91	0.40	0.10	0.54	0.54
	50	5	3.51	1.00	0.50	1.00	1.00
	30	10	3.21	0.60	1.00	0.91	1.00
Max.	50	10	3.51				

	Raw Ag.	Raw Res.	Raw Pop. Den	Scaled Ag.	Scaled Res.	Scaled Pop. Den	Sum-Rel Metric
	10	4	1.19	0.20	0.40	0.34	0.94
	20	1	1.91	0.40	0.10	0.54	1.04
	50	5	3.51	1.00	0.50	1.00	2.50
	30	10	3.21	0.60	1.00	0.91	2.51
Max.	50	10	3.51				

Distribution of Sites by Max-Rel and Sum-Rel

US Side Great Lakes Basin- 659 wetlands



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Great Lakes Environmental Indicators

Summary

- The '*a priori*" approach based on spatial data effectively identifies reference areas
- Reference cutoffs (defining what is 'good') vary greatly among ecoregions
- Max-Rel and Sum-Rel behave similarly, especially at the reference end of the scale.
- Province and ecoregional stratifications account for biogeographic variability that could confound reference area interpretations (results not shown)

EPA/STAR Research Programs

Reference Condition

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- Use spatial data to select reference sites
- Sample to define biological reference conditions
- Evaluate how biota respond to different levels of classification
  - Ecoregional
  - Hydrogeomorphic

Sample ‘pristine’ sites

Great Lakes Environmental Indicators

- Identify potential and useful environmental indicators
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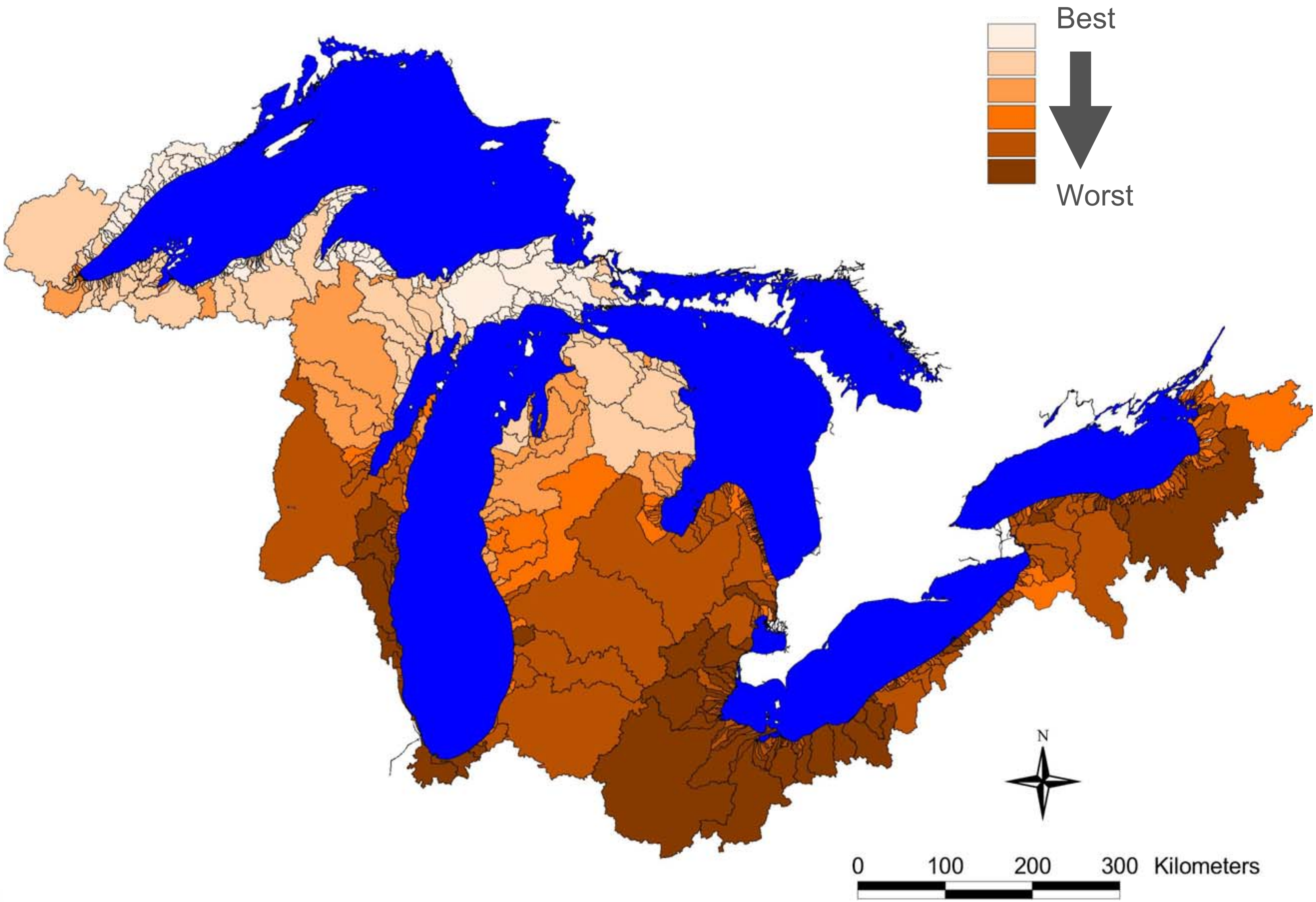
Sample across stress gradient

Great Lakes Basin Disturbance Index



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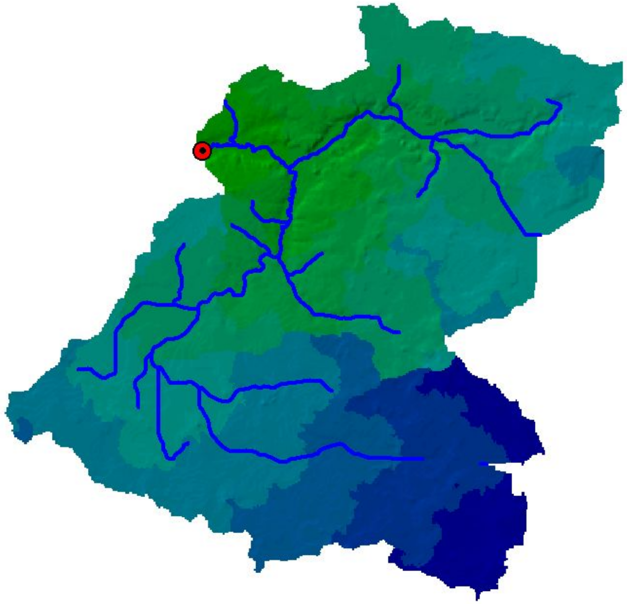
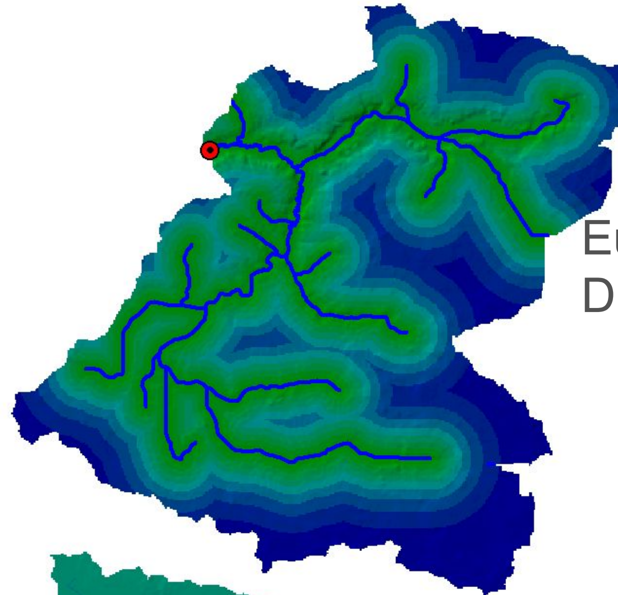
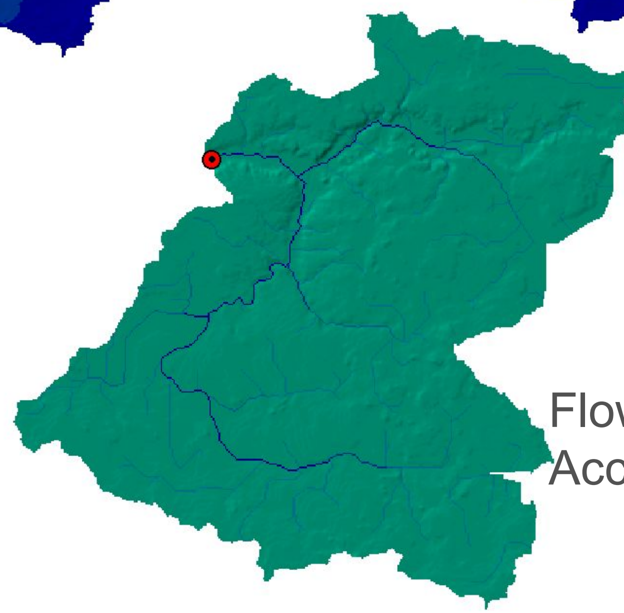
Great Lakes Environmental Indicators

Flow
Distance





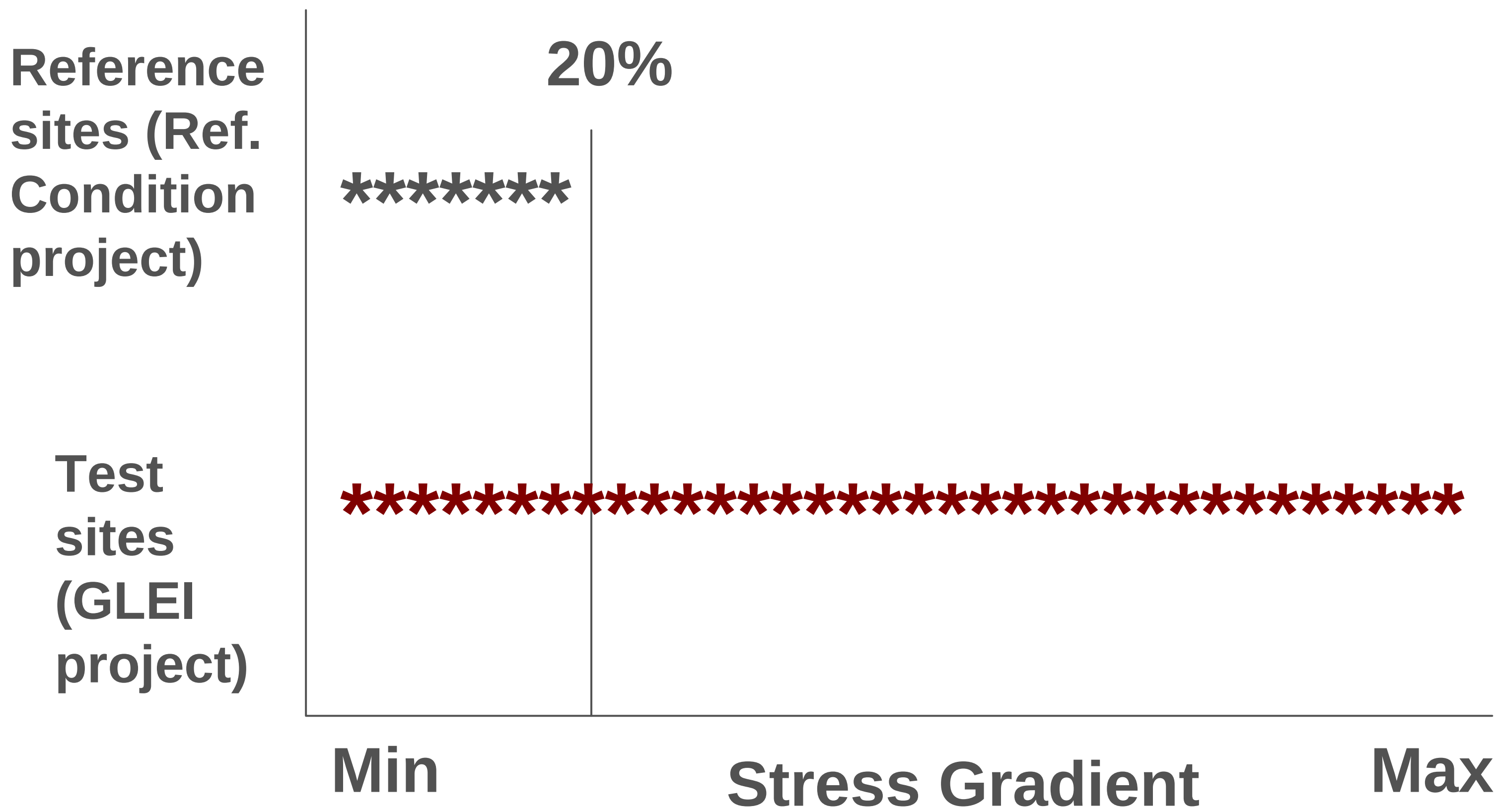
Euclidean
Distance

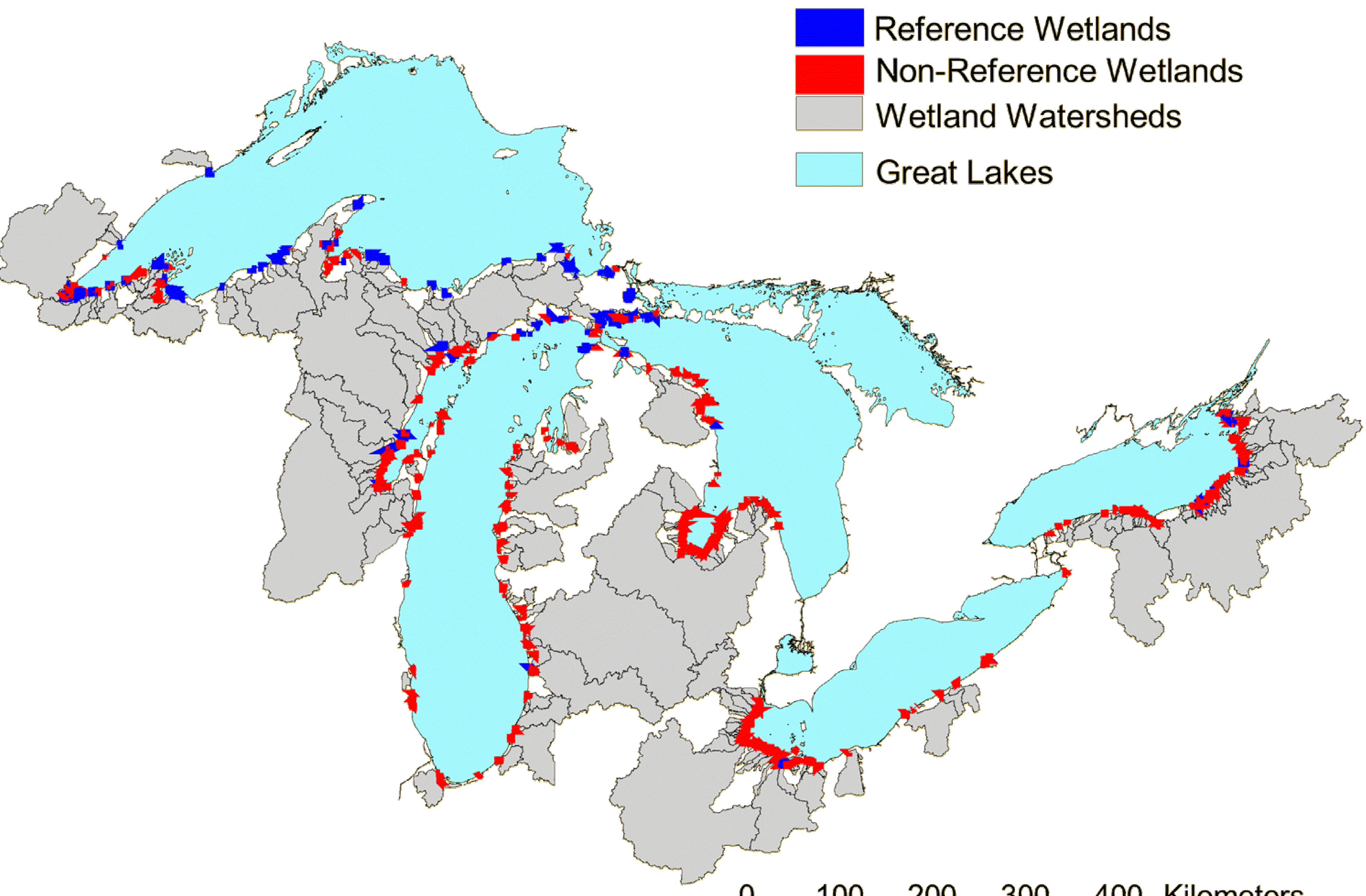


Flow
Accumulation

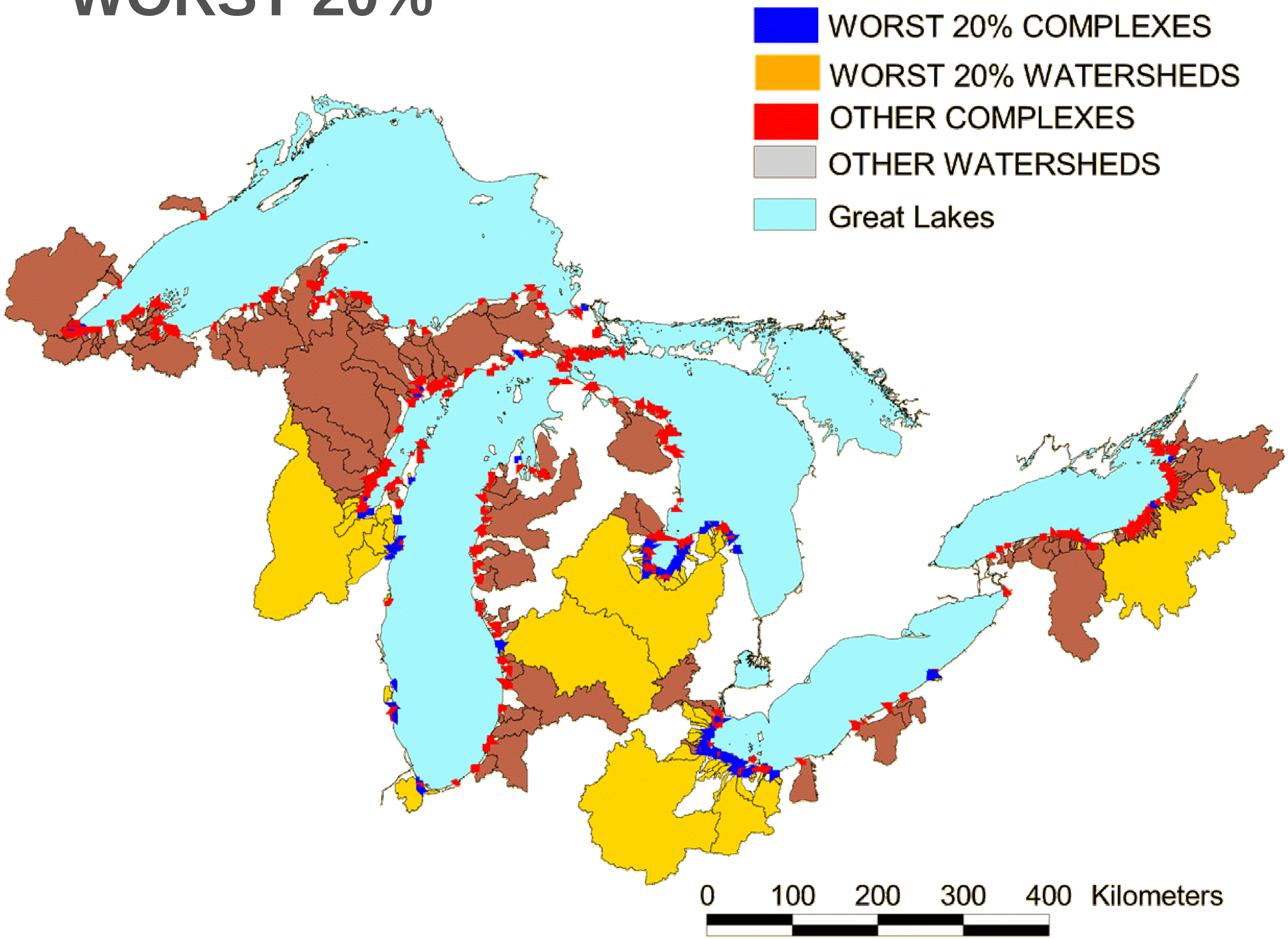
Summarizing land use within a watershed

Reference and GLEI sites



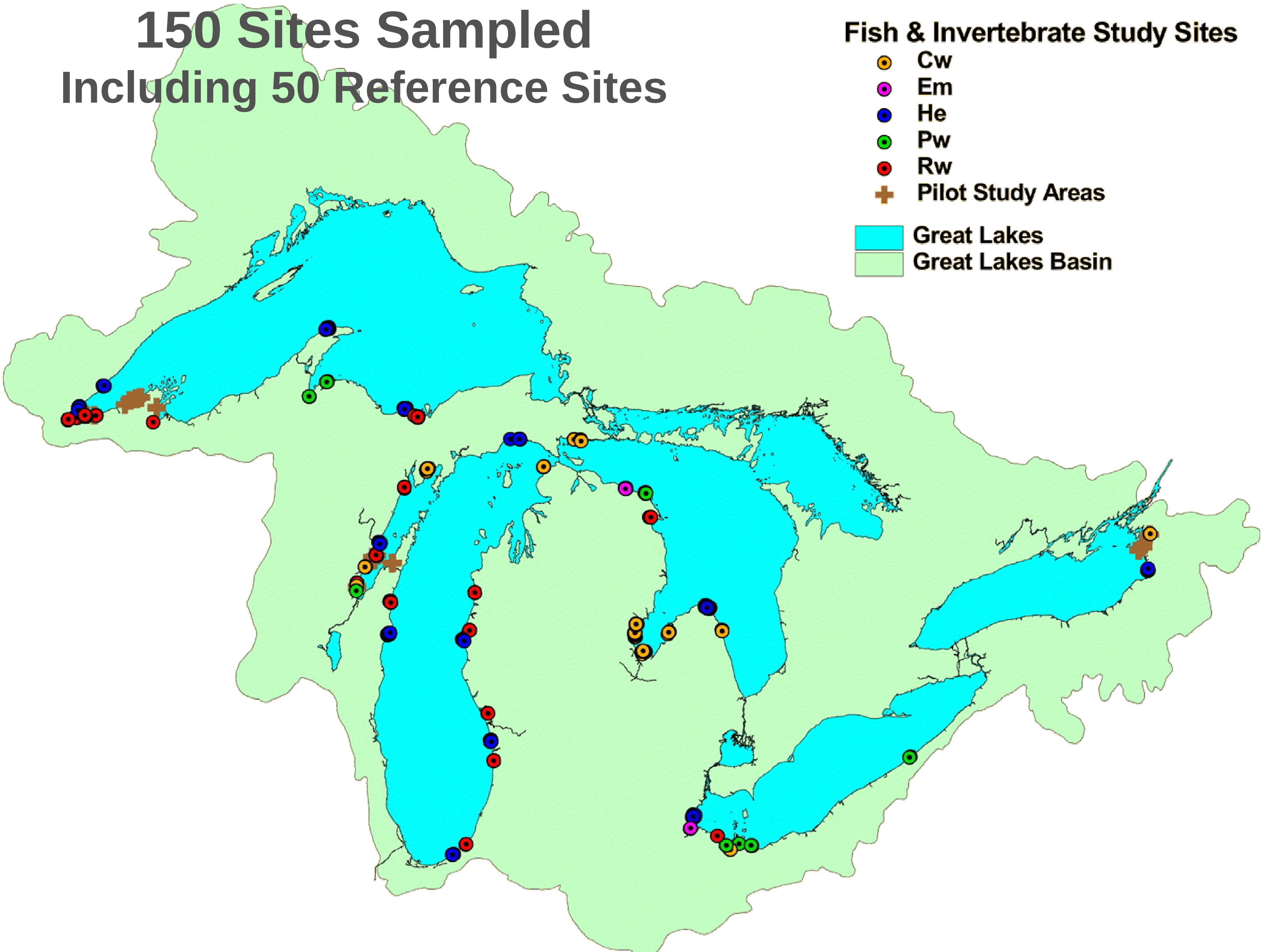

Reference Wetlands
Non-Reference Wetlands
Wetland Watersheds
Great Lakes
0 100 200 300 400 Kilometers

WORST 20%



WORST 20% COMPLEXES
WORST 20% WATERSHEDS
OTHER COMPLEXES
OTHER WATERSHEDS
Great Lakes
0
100
200
300
400
Kilometers

150 Sites Sampled
Including 50 Reference Sites



Fish & Macroinvertebrate community sampling

Emergent | Submergent | Coastal Margin

0.3-0.5 m | 0.5-1.0 m | 5.0 m | 10.0 m

Fyke Net Arrays
D-frame; cores

Ponar

Environmental Variables

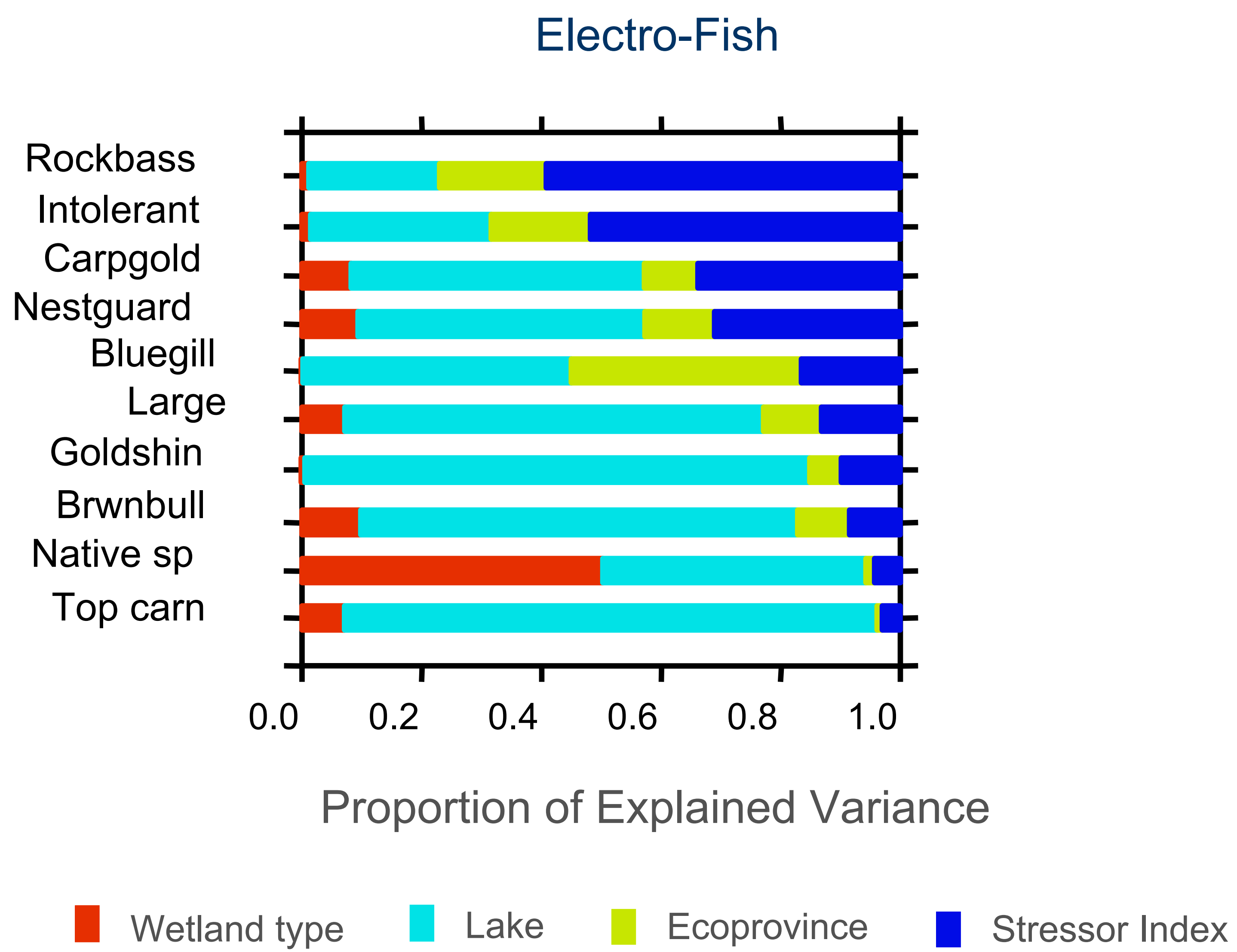
Physicochemical -
- Temperature
- pH
- Dissolved Oxygen
- Conductivity
- ORP

Habitat –
- Shoreline
- Landuse
- Vegetation (density/cover)

Water Clarity -
- Secchi depth
- Turbidity tube depth

Sediment -
- Particle size
- Organics %
- Depth of fines

Hierarchical Partitioning – Independent Effects



From: Brazner, et al., *in review*

Indicator Development

- Development indicators of stress for Great Lakes coastal margins using multivariate techniques and fish assemblages.

Approach

Cluster Analysis:
Identify reference sites with similar species composition

Identify set of environmental variables that best separate clusters of reference sites (DFA)

Use DFA model to determine the clustering for test sites

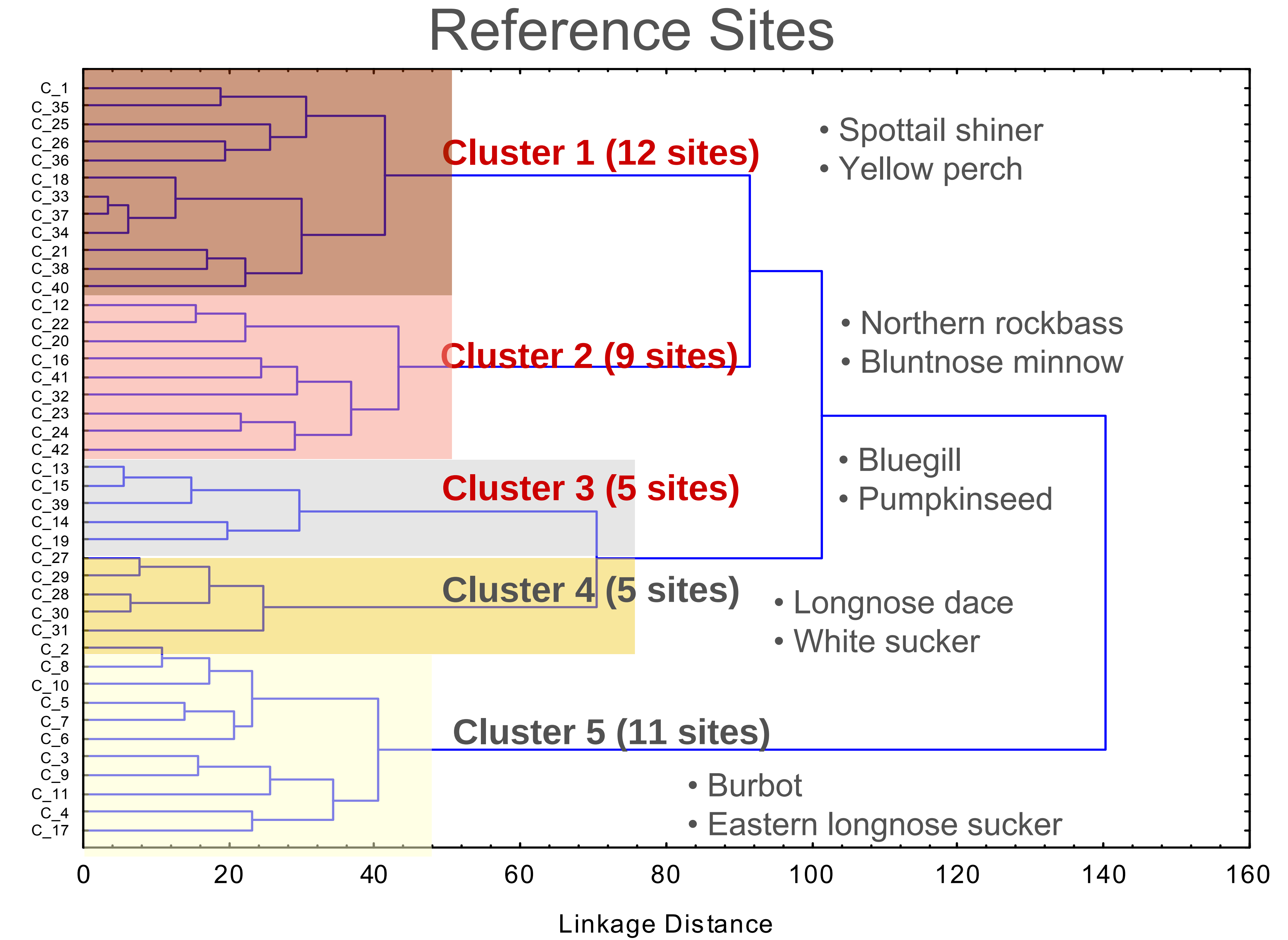
Ordinate clusters of sites along stressor axes

Test site within reference cluster

Reference

Test site outside of reference cluster

Non-reference


Reference Sites
Cluster 1 (12 sites)
Cluster 2 (9 sites)
Cluster 3 (5 sites)
Cluster 4 (5 sites)
Cluster 5 (11 sites)
• Spottail shiner
• Yellow perch
• Northern rockbass
• Bluntnose minnow
• Bluegill
• Pumpkinseed
• Longnose dace
• White sucker
• Burbot
• Eastern longnose sucker
C_1
C_35
C_25
C_26
C_36
C_18
C_33
C_37
C_34
C_21
C_38
C_40
C_12
C_22
C_20
C_16
C_41
C_32
C_23
C_24
C_42
C_13
C_15
C_39
C_14
C_19
C_27
C_29
C_28
C_30
C_31
C_2
C_8
C_10
C_5
C_7
C_6
C_3
C_9
C_11
C_4
C_17
0
20
40
60
80
100
120
140
160
Linkage Distance

DFA Model - Variables

- EOL $p < 0.05$
- SSU $p < 0.001$
- NGL $p < 0.001$
- SCG $p < 0.05$
- Latitude $p < 0.001$
- Julian Day $p < 0.05$
- Protected wetland $p < 0.05$
- Mean EM cover $p < 0.01$

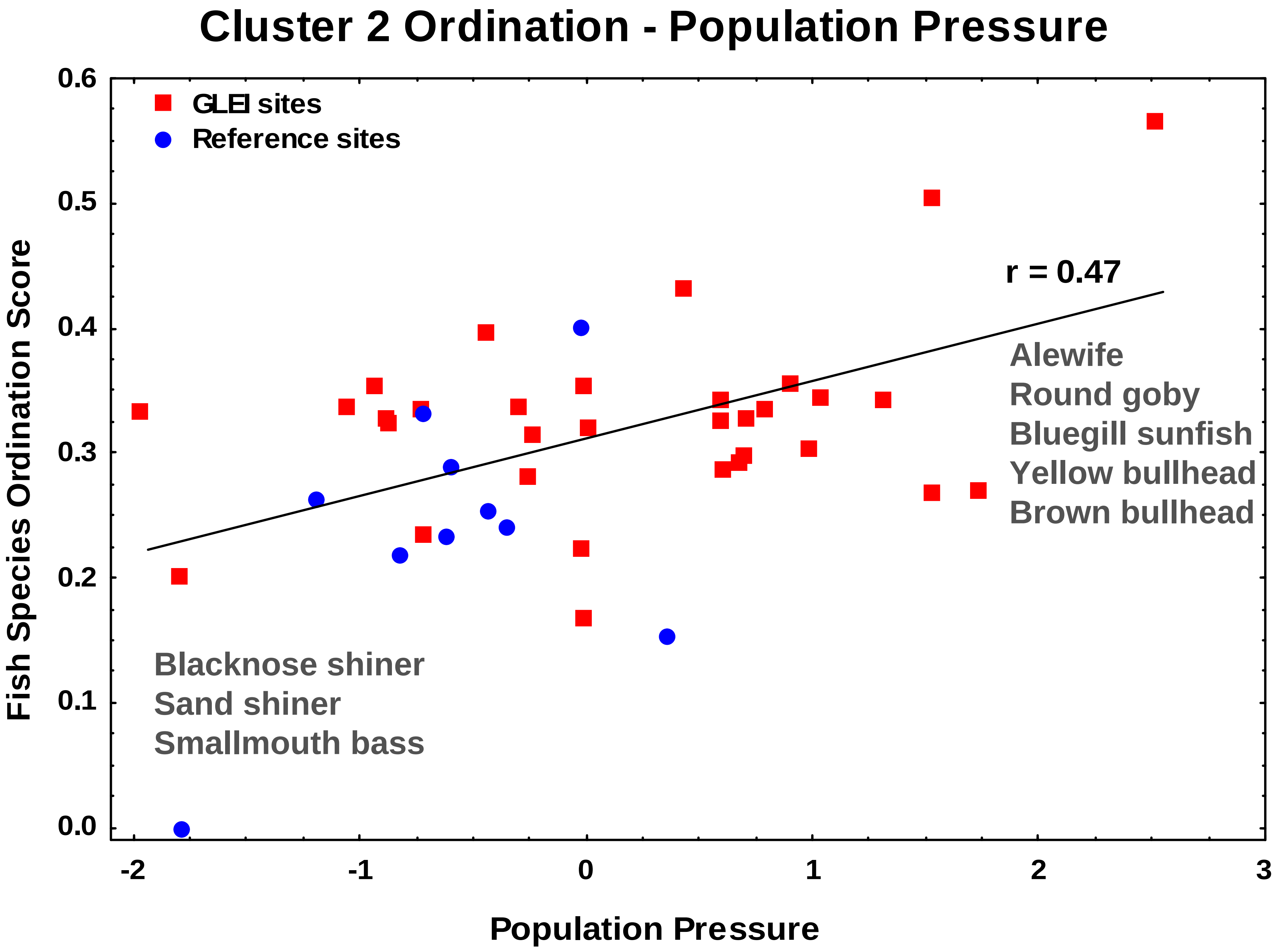
DFA – Classification of Reference sites

	Percent Correct	Ecoregion	Latitude	Julian Day	Pw	Em cover
Group 1	100	SCG/SGL	Low	Early	No	Low
Group 2	100	NGL/SSU	Low-High	Mid	No	Low
Group 3	80.0	NGL/SSU	High	Mid	No	Low
Group 4	100	NSU	High	Late	No	No
Group 5	100	EOL	Low	Mid	Yes	High
Total	91.6					

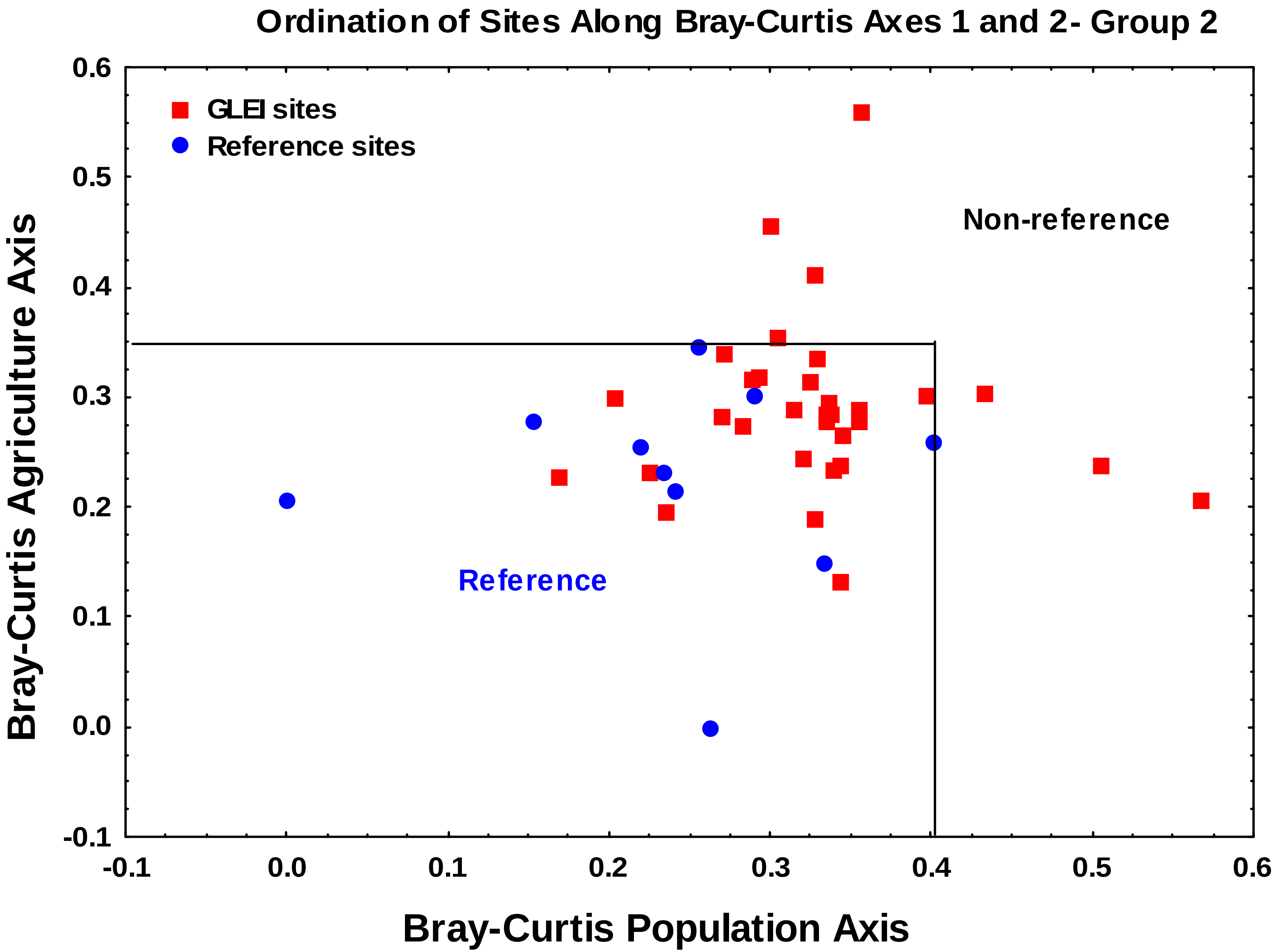
Ordinations

- **Bray-Curtis Ordination**
  - Subjective endpoint selection

- **PCA of stressor axes**
  - Population pressure
  - Agricultural pressure



Cluster 2 Ordination - Population Pressure
GLEI sites
Reference sites
r = 0.47
Alewife
Round goby
Bluegill sunfish
Yellow bullhead
Brown bullhead
Blacknose shiner
Sand shiner
Smallmouth bass
Fish Species Ordination Score
Population Pressure
0.0
0.1
0.2
0.3
0.4
0.5
0.6
-2
-1
0
1
2
3



Ordination of Sites Along Bray-Curtis Axes 1 and 2- Group 2
GLEI sites
Reference sites
Non-reference
Reference
Bray-Curtis Agriculture Axis
Bray-Curtis Population Axis
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6

Summary

- **Cluster Analysis** - clear separation of sites
- **DFA model**
  - good classification of sites
  - 8 main variables (48 total)
- **Ordinations**
  - Separate indicator assemblages at reference and non-reference sites.
  - Establish criteria for identifying condition at test sites.

Acknowledgements

Research supported by a grant from the US EPA's Science to Achieve Results (STAR) Estuarine and Great Lakes (EaGLe) Coastal Initiative through funding to the Great Lakes Environmental Indicators (GLEI) and Reference Area Projects

US EPA Agreements EPA/R-8286750 & STAR EPA/R-82877701.

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