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U.S. EPA Office of Research and Development

Environmental Monitoring and Assessment Program

Identifying Reference Sites in Great Lakes Coastal Areas

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EPA STAR EaGLe

Great Lakes Environmental Indicators

Acknowledgements

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Great Lakes Environmental Indicators

Defining Reference Conditions

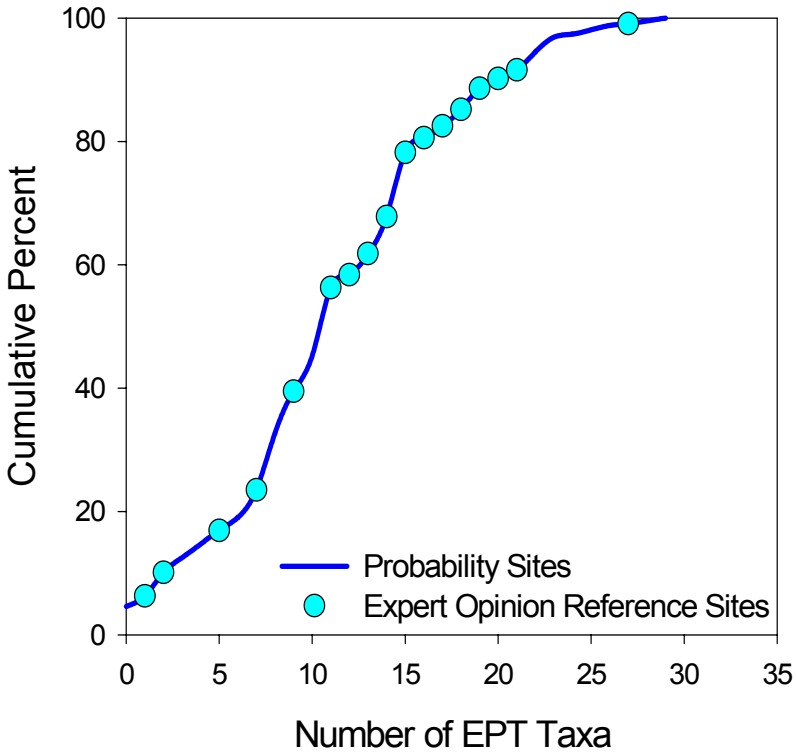
- Minimally disturbed- absence of anthropogenic disturbance;
- Least disturbed- best available given current condition;***
- Best attainable (theoretical)- equivalent to hypothetical least disturbed sites under BMP (Stoddard et al.)

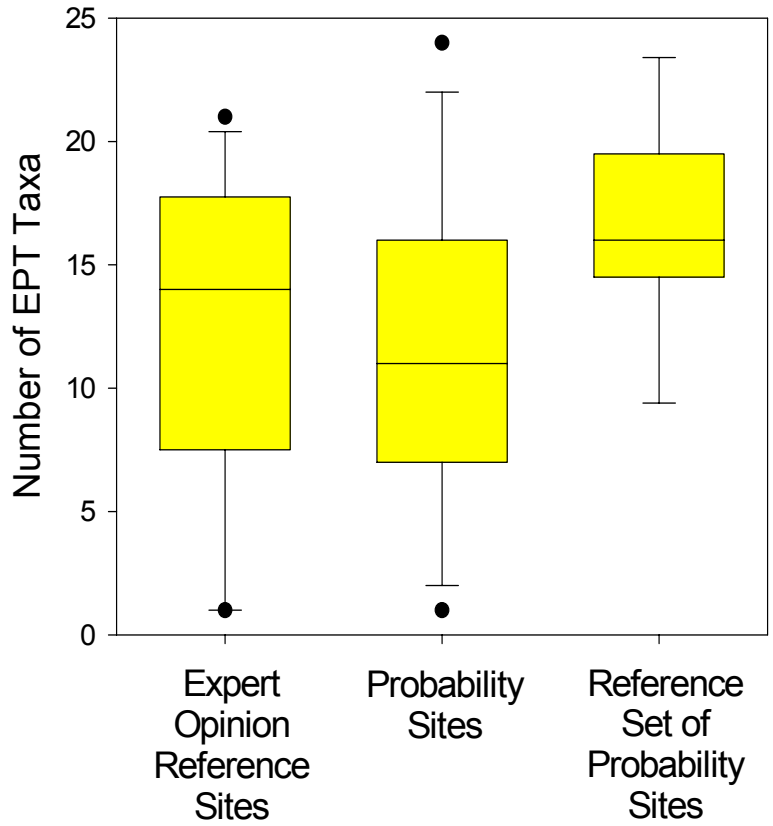
*** working definition for the Reference Area project.

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

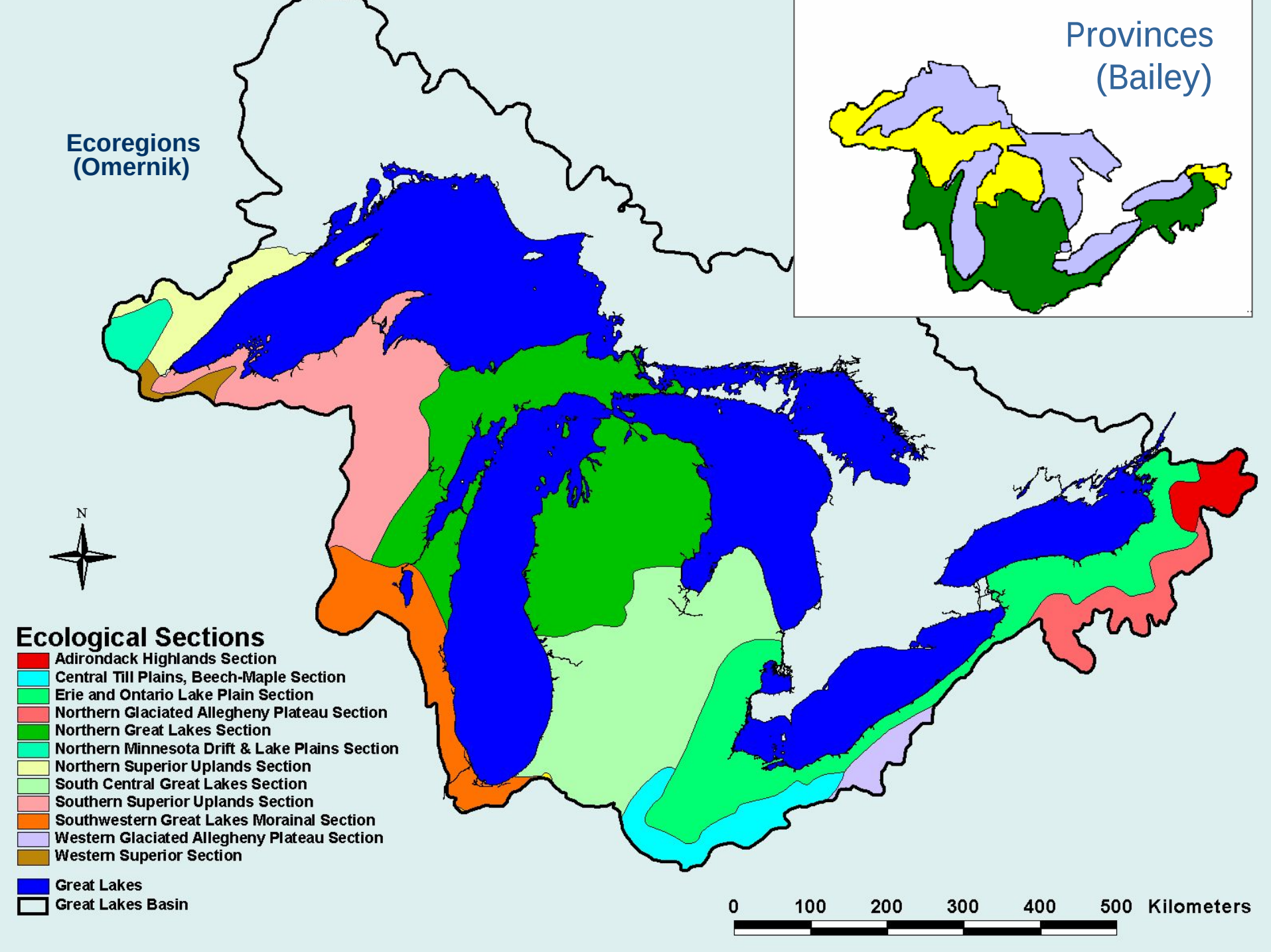
- Develop and apply an *a priori* classification system to Great Lakes coastal ecosystems
- Use spatial data to select reference sites
- Sample to define biological reference conditions
- Evaluate how biota respond to different levels of classification
  - Ecoregional
  - Hydrogeomorphic

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


Ecoregions
(Omernik)
Provinces
(Bailey)
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

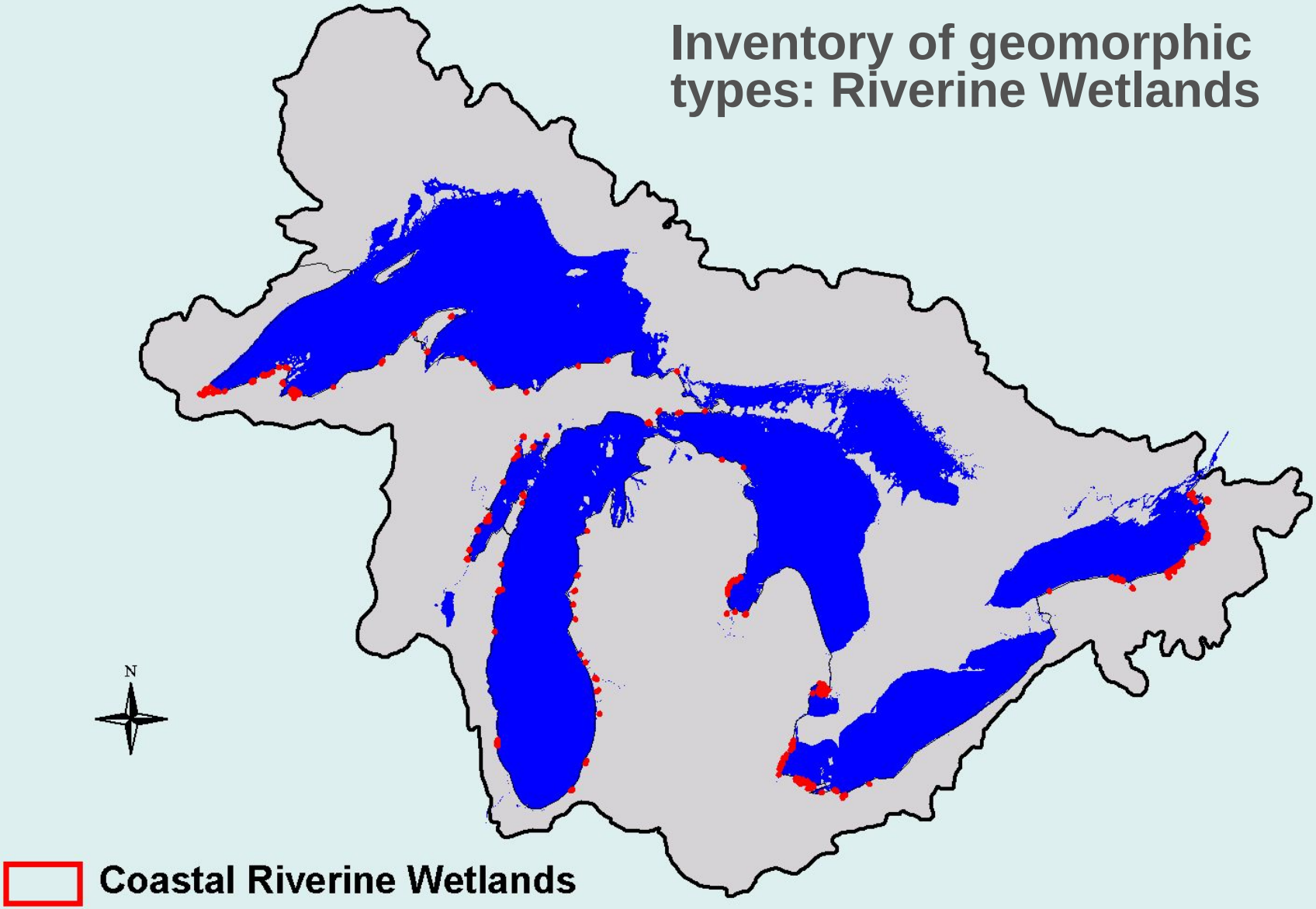
Open-coast Wetland

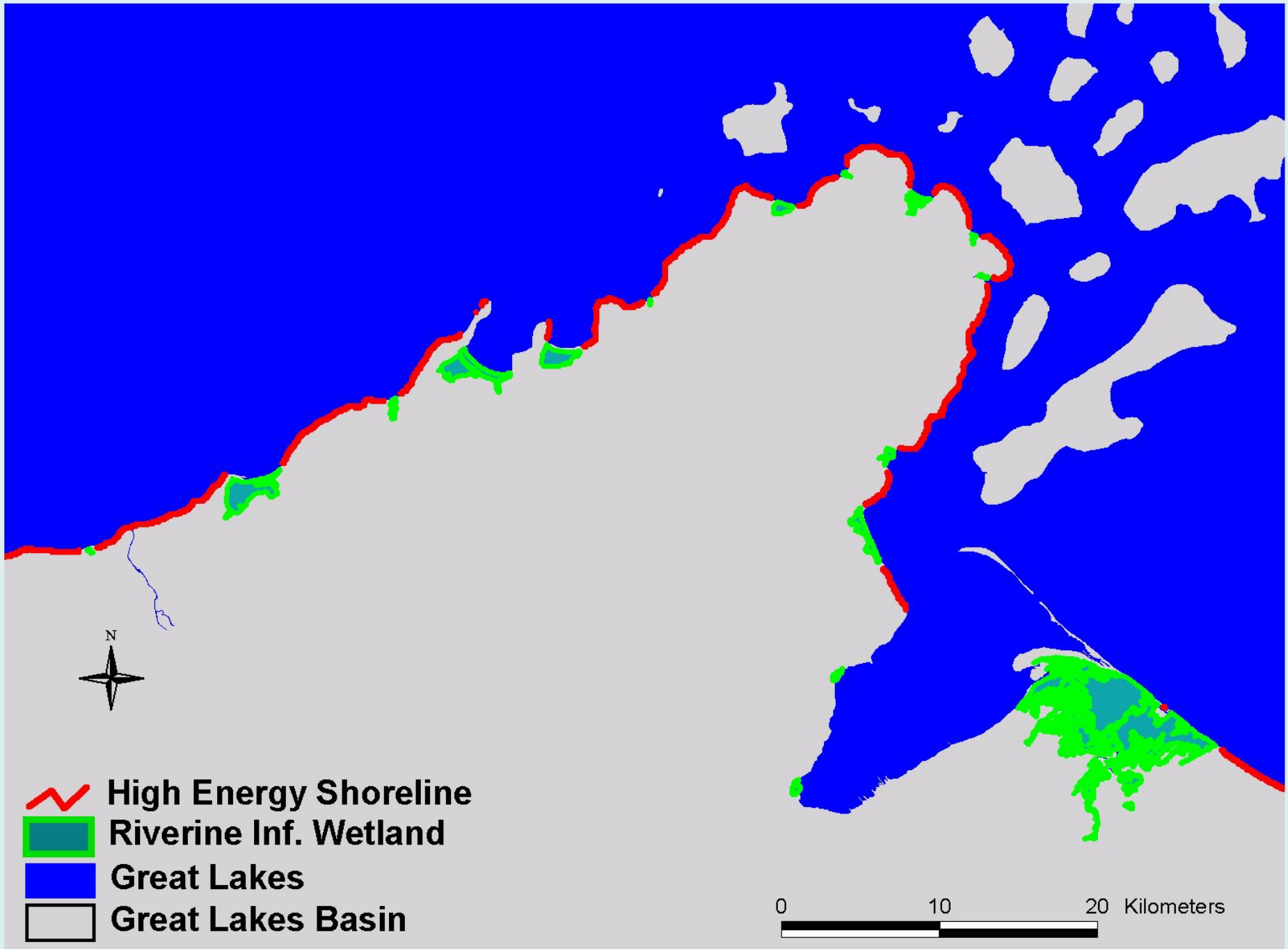
Protected Wetland behind High Energy Shoreline

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)

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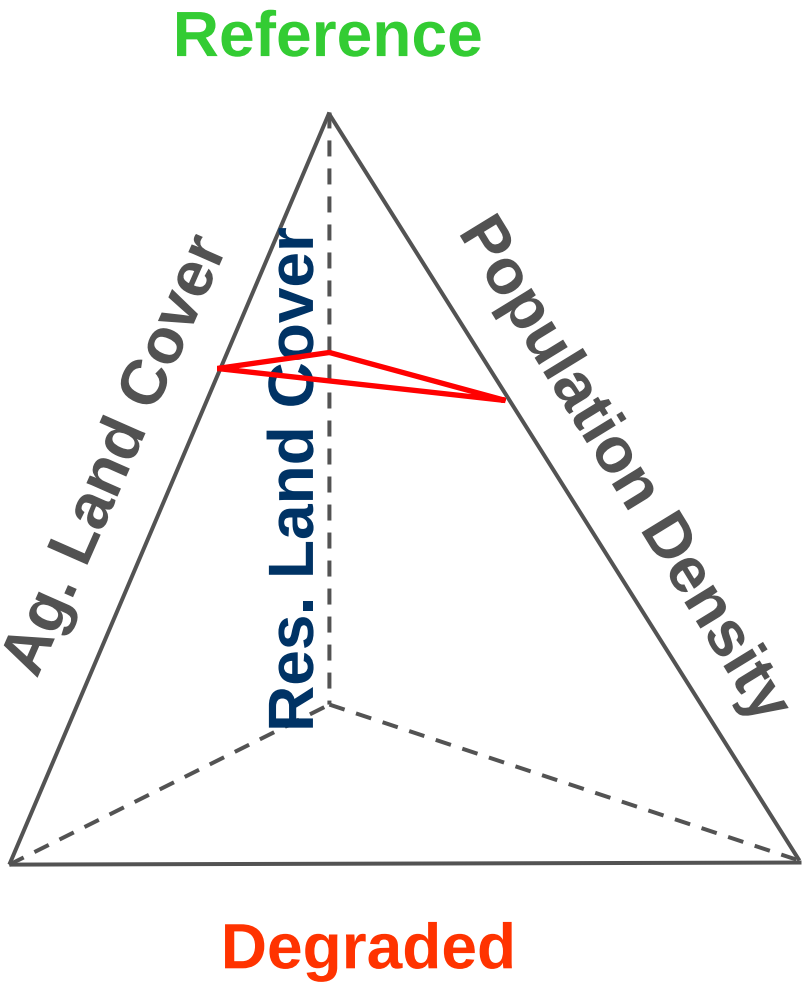
Great Lakes Environmental Indicators

Anthropogenic stress model



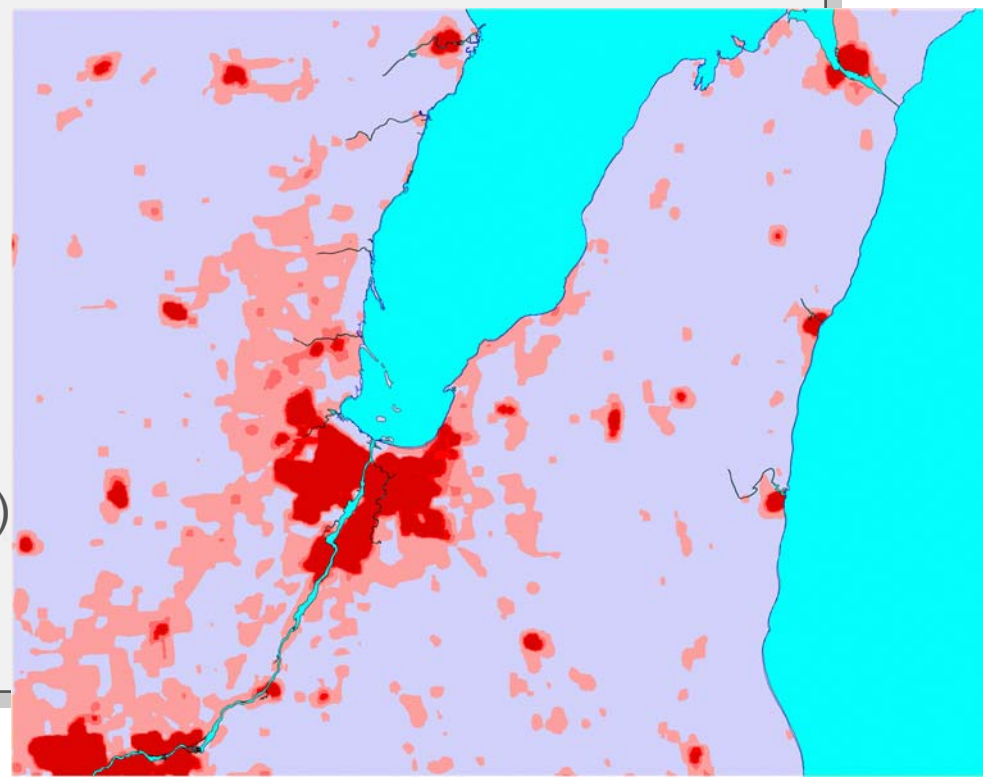
How to identify wetlands with minimum anthropogenic pressure values across multiple stress axes

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

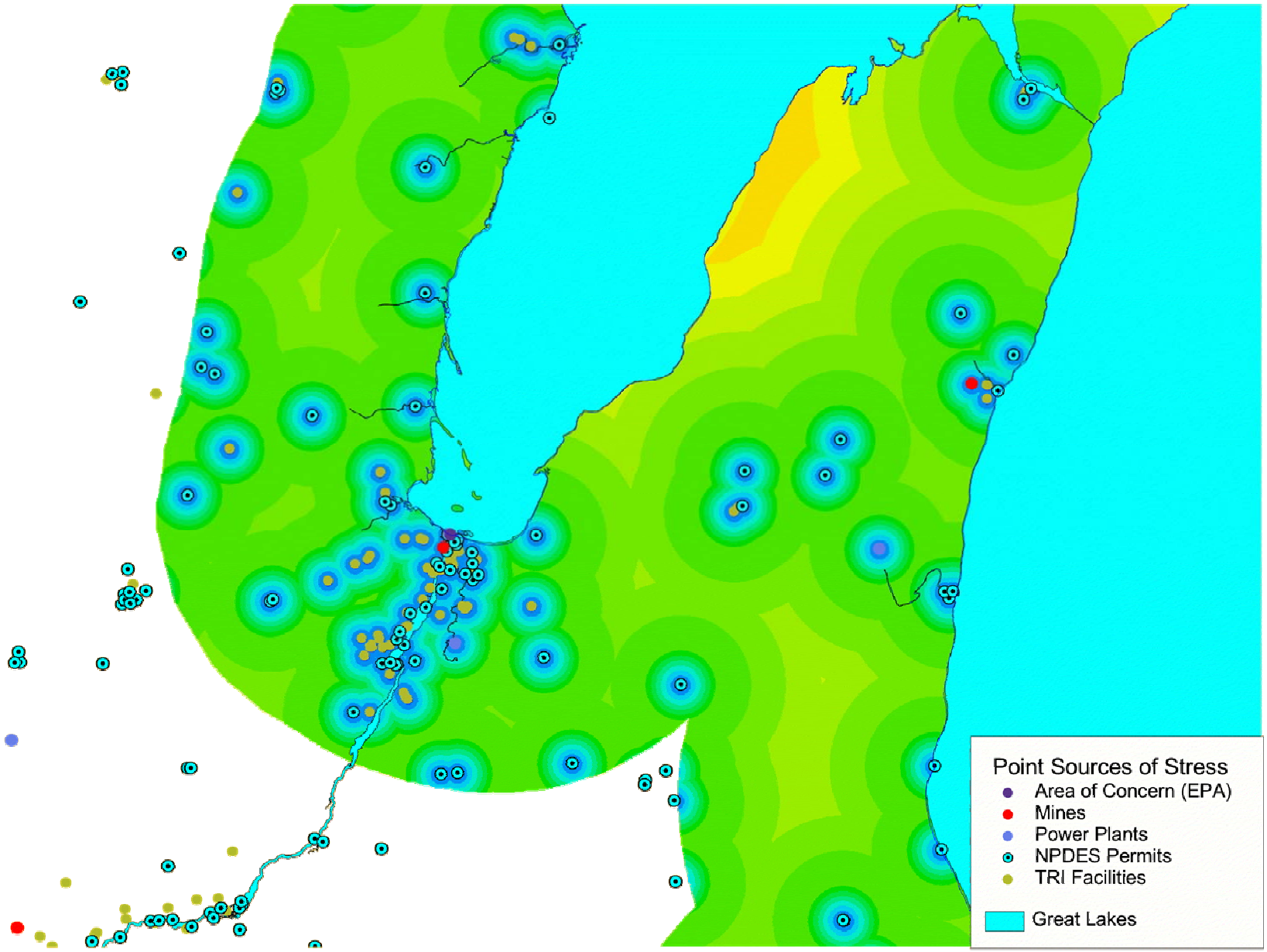
Ciborowski et al., *in prep.*

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)

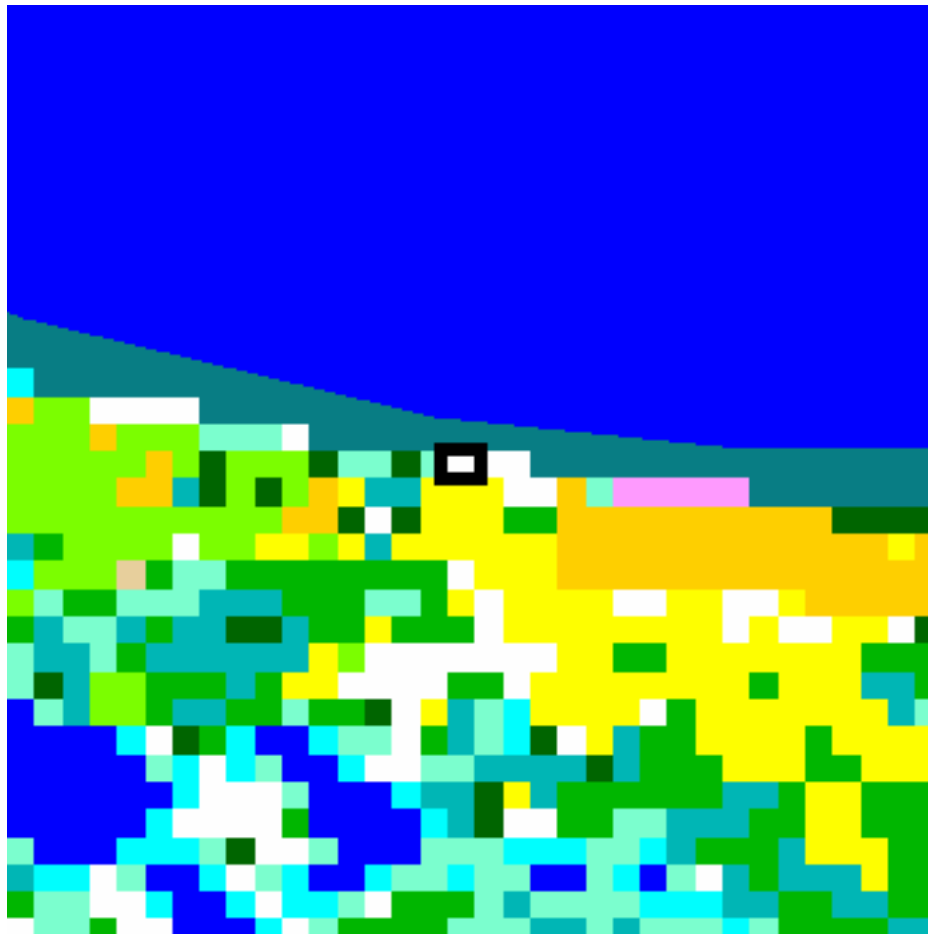

Point Sources of Stress
Area of Concern (EPA)
Mines
Power Plants
NPDES Permits
TRI Facilities
Great Lakes

Contributing areas

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

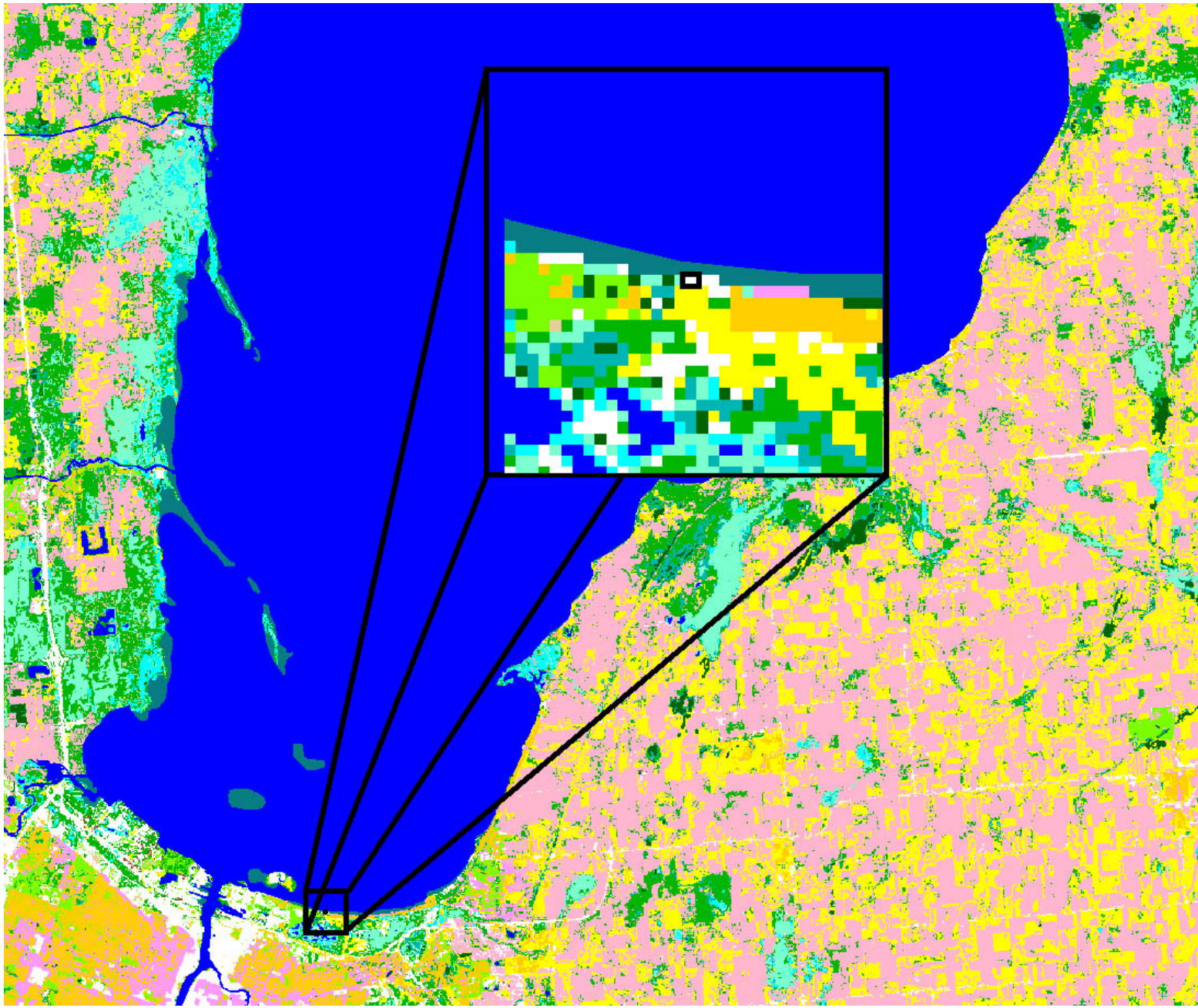
Moving window analysis

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



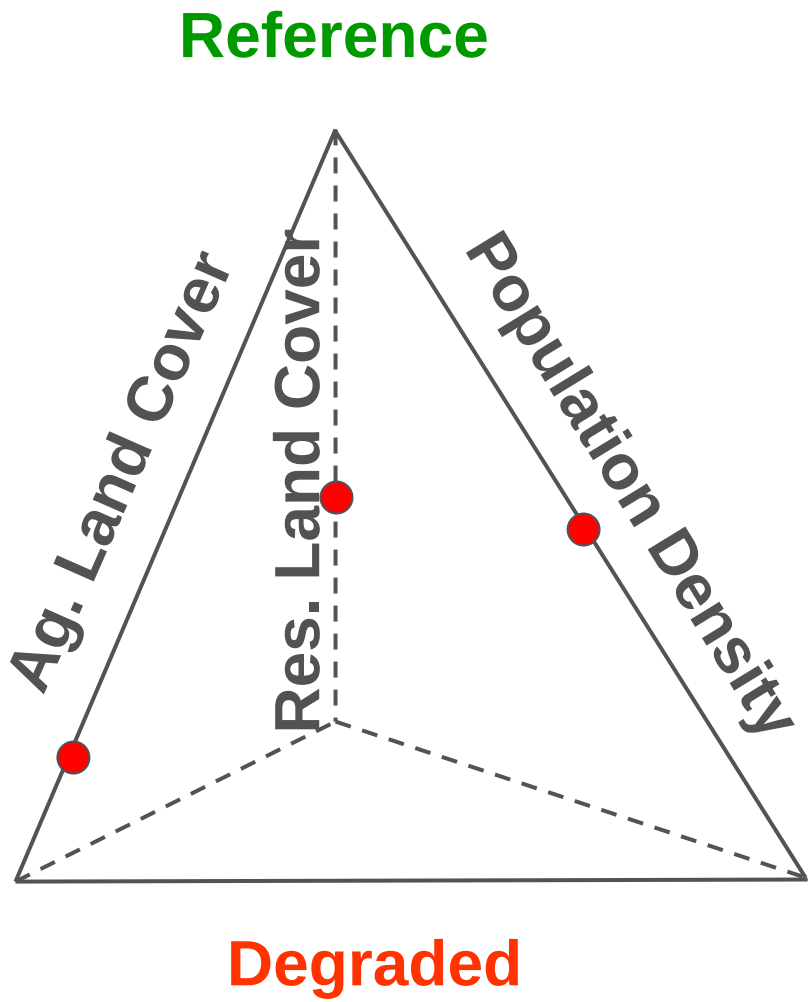
Window Summary

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}

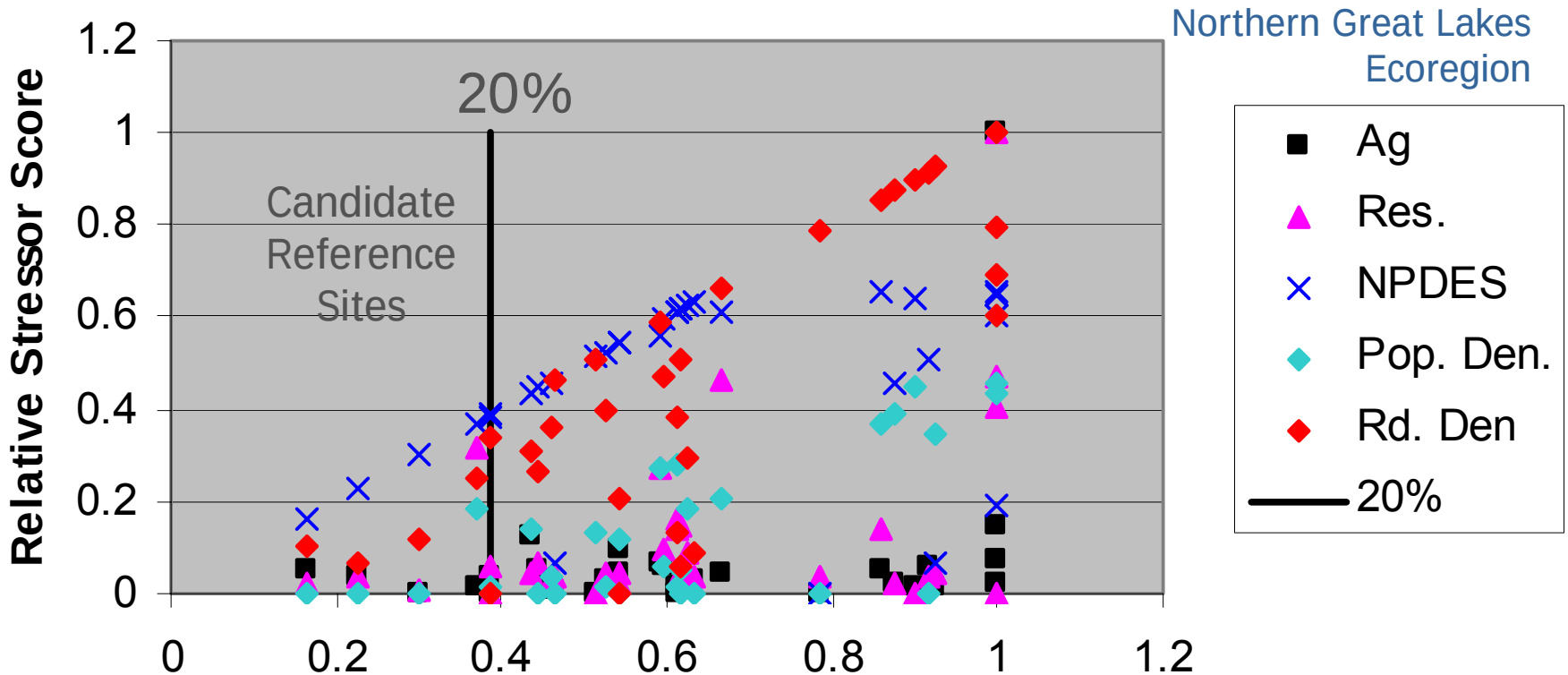
Summary		Scaled Value	Score for Pixel/Polygon
Ag	125	0.352	0.352
Res	96	0.254	
Point	5159	0.089	

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

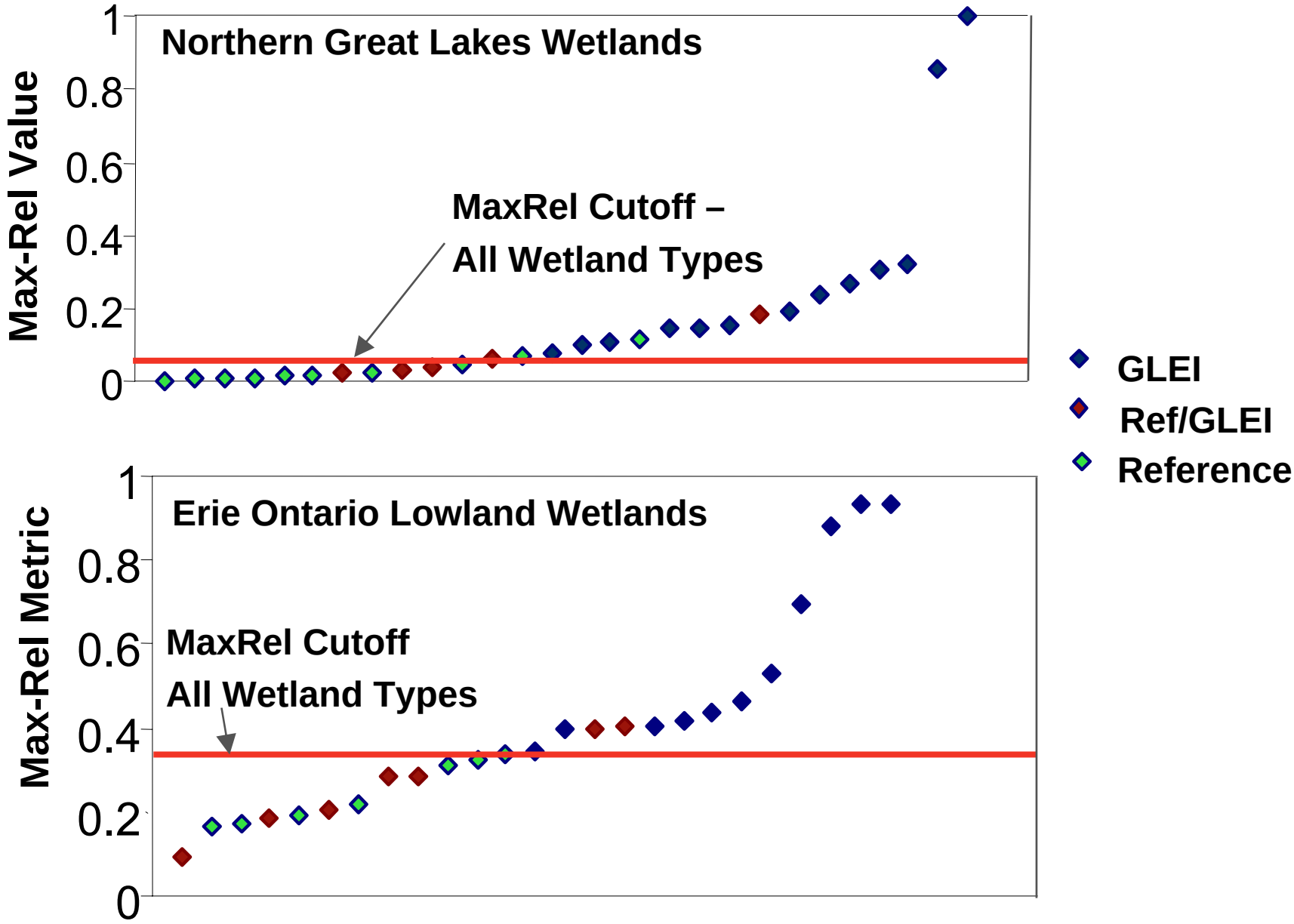
Identifying reference wetlands

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

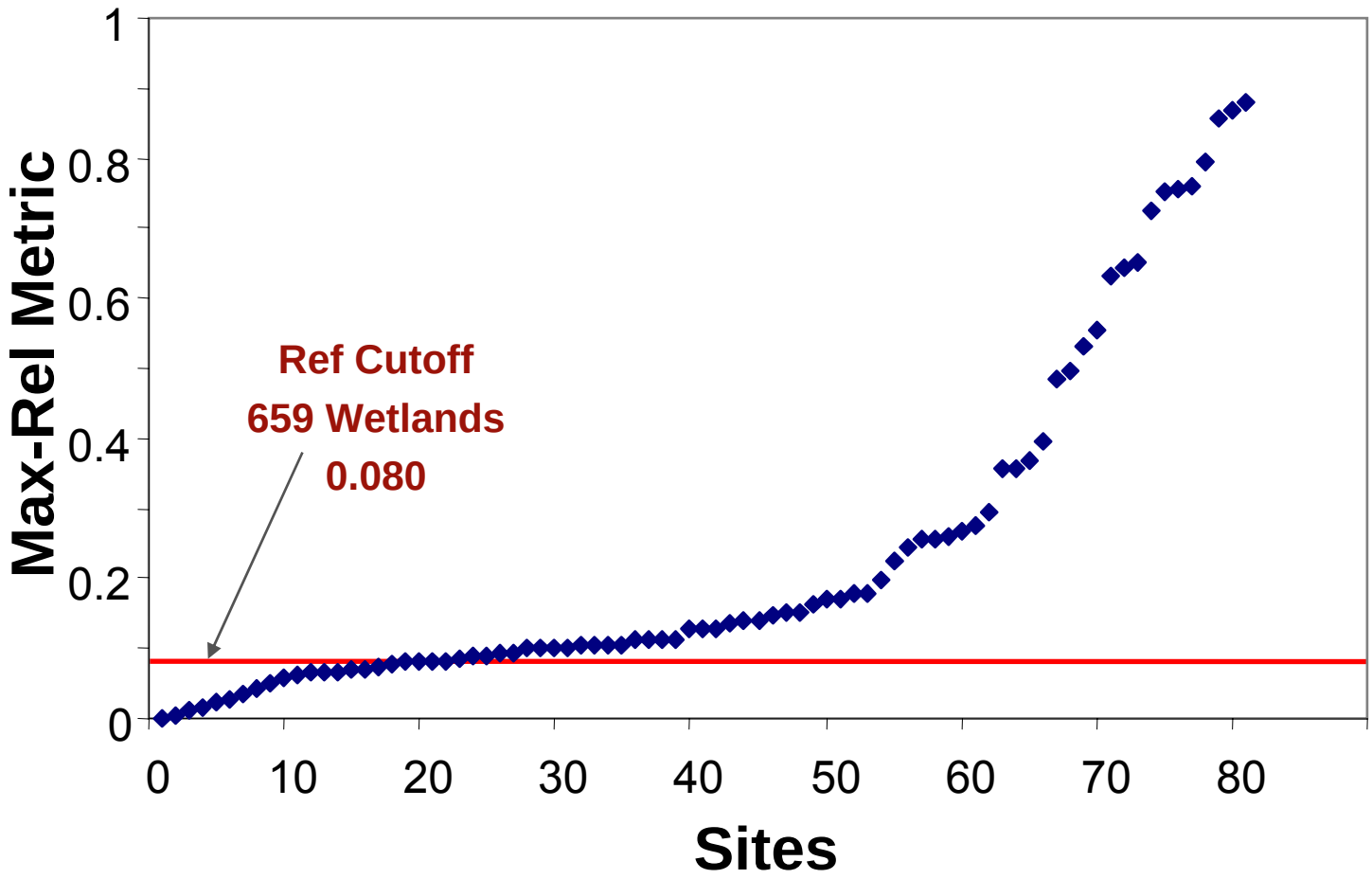
Sort axes based on the 'worst' stressor



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

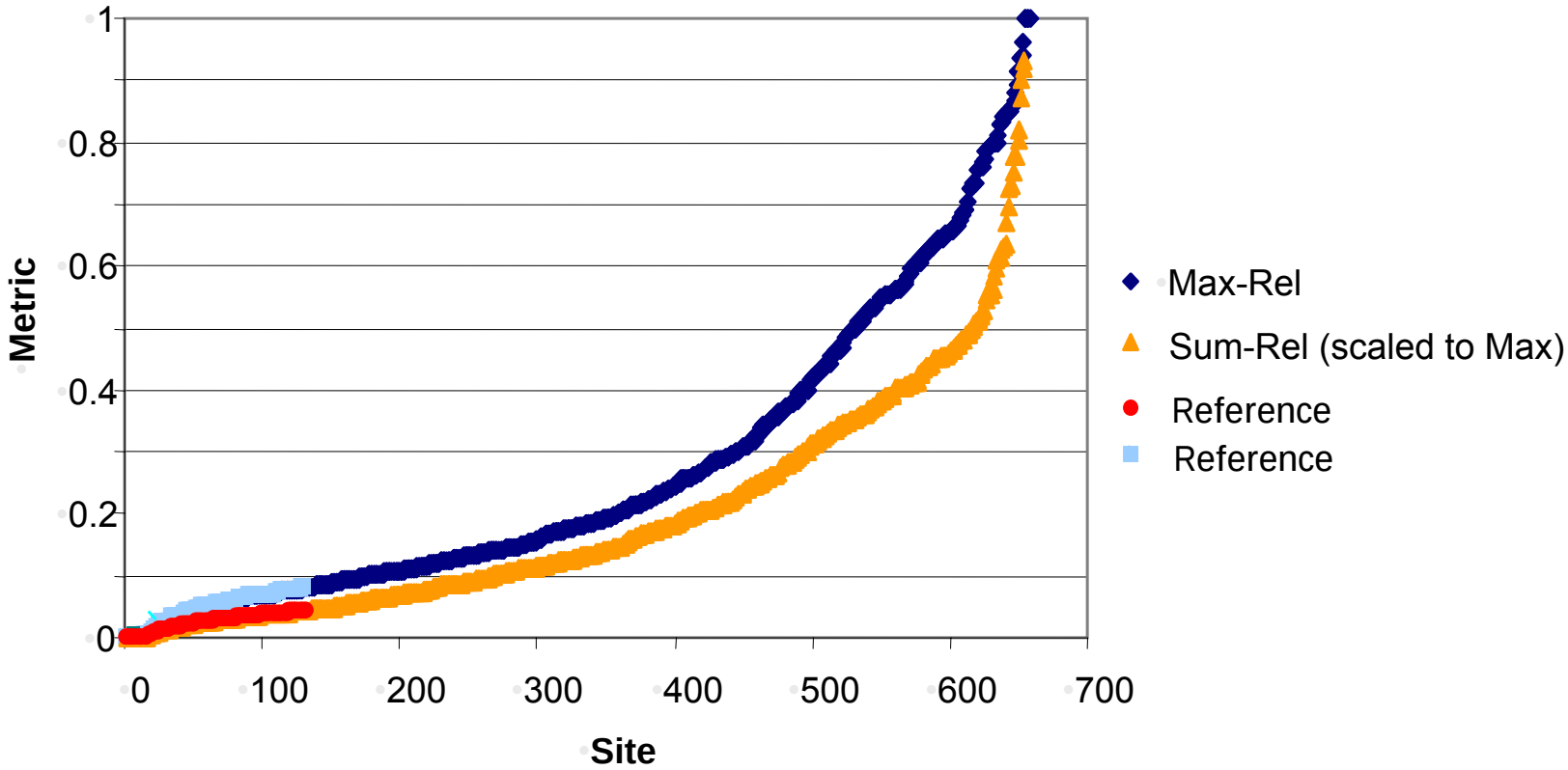
Max-Rel and Sum-Rel

	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

- 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

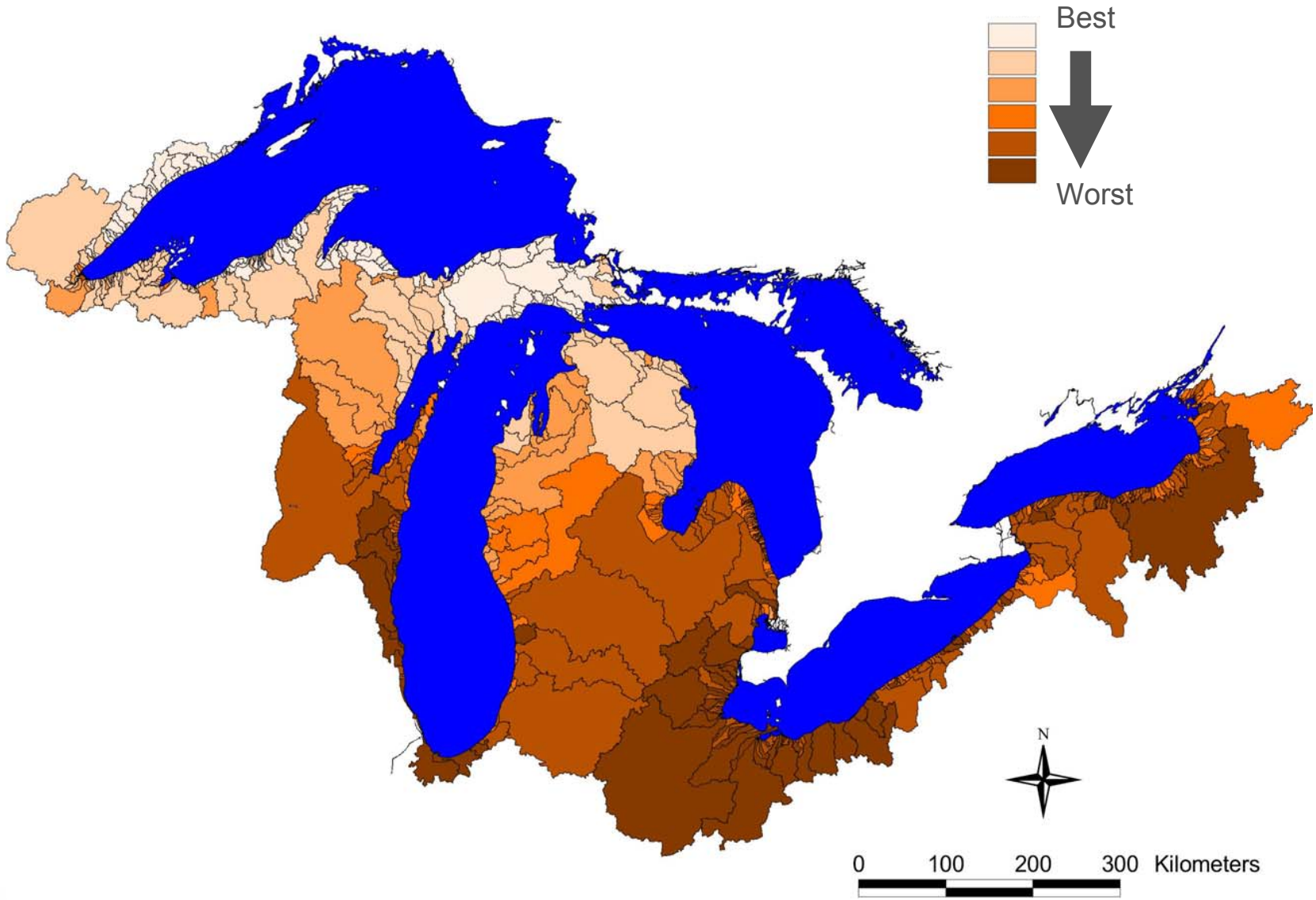
Sample ‘pristine’ sites

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

Great Lakes Basin Disturbance Index



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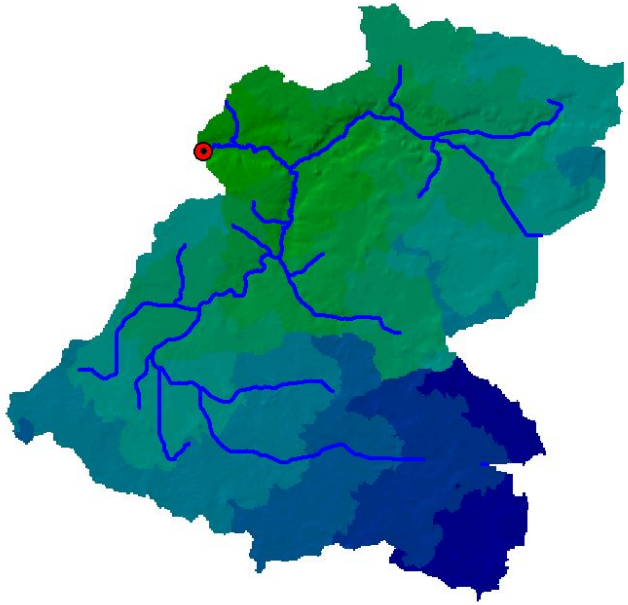
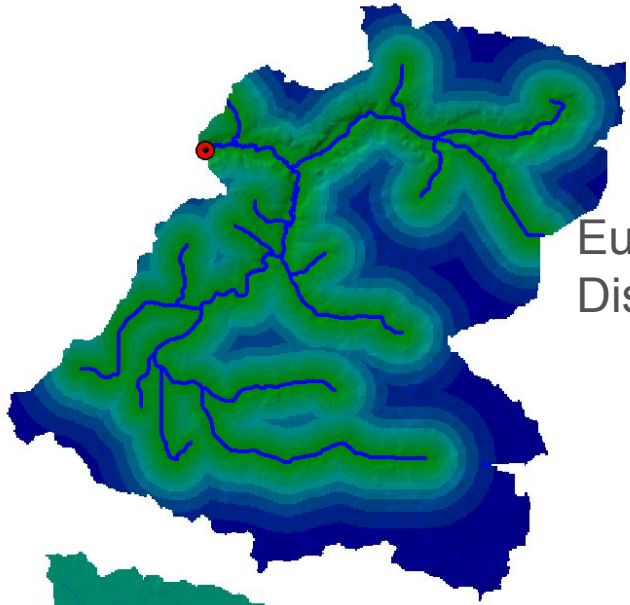
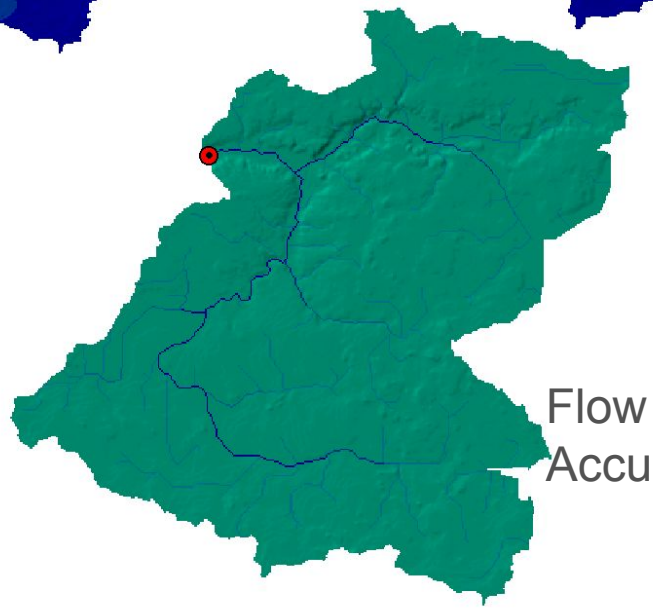
Great Lakes Environmental Indicators

Flow
Distance





Euclidean
Distance



Flow
Accumulation

Summarizing land use within a watershed

Reference and GLEI sites

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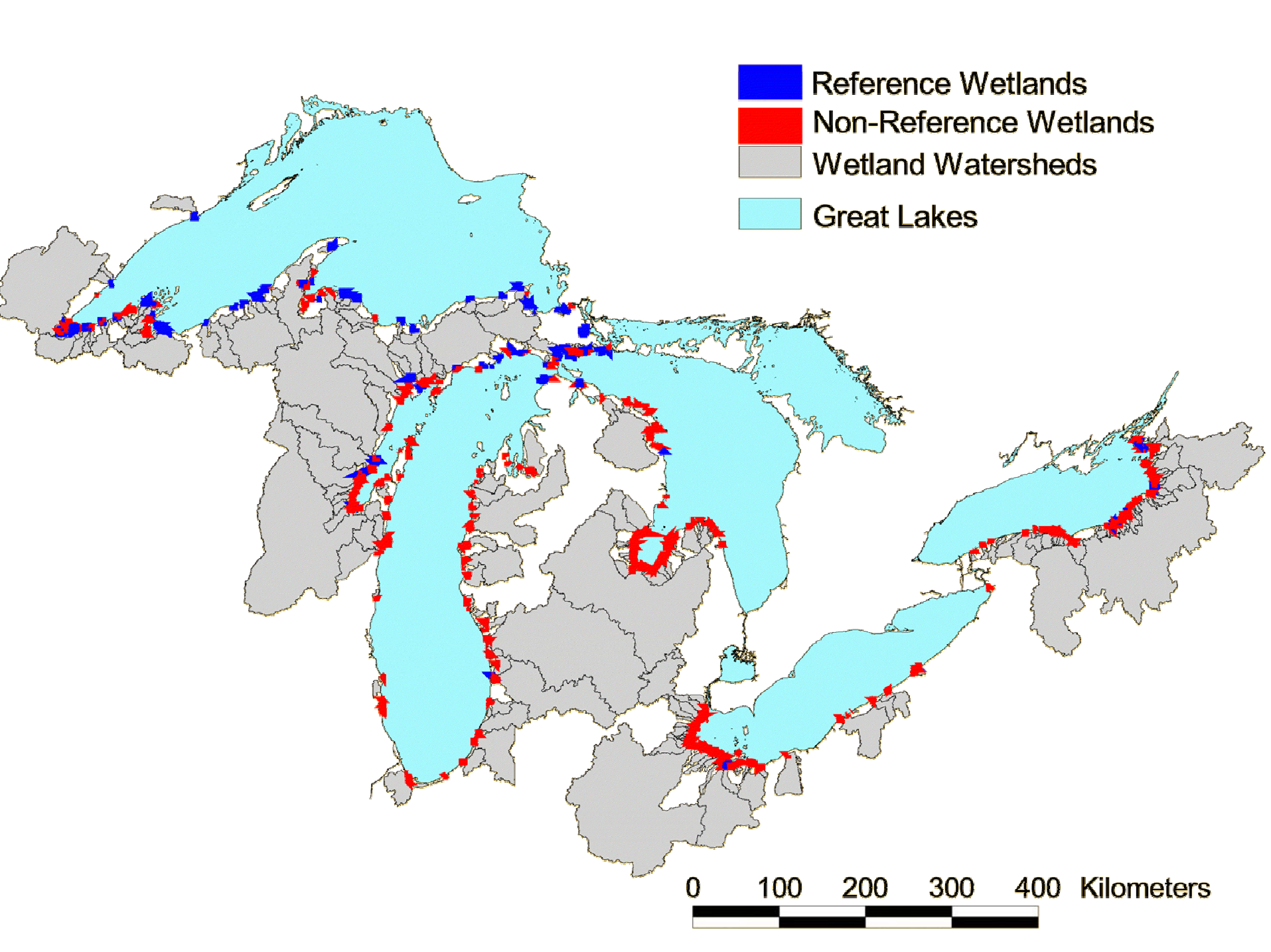
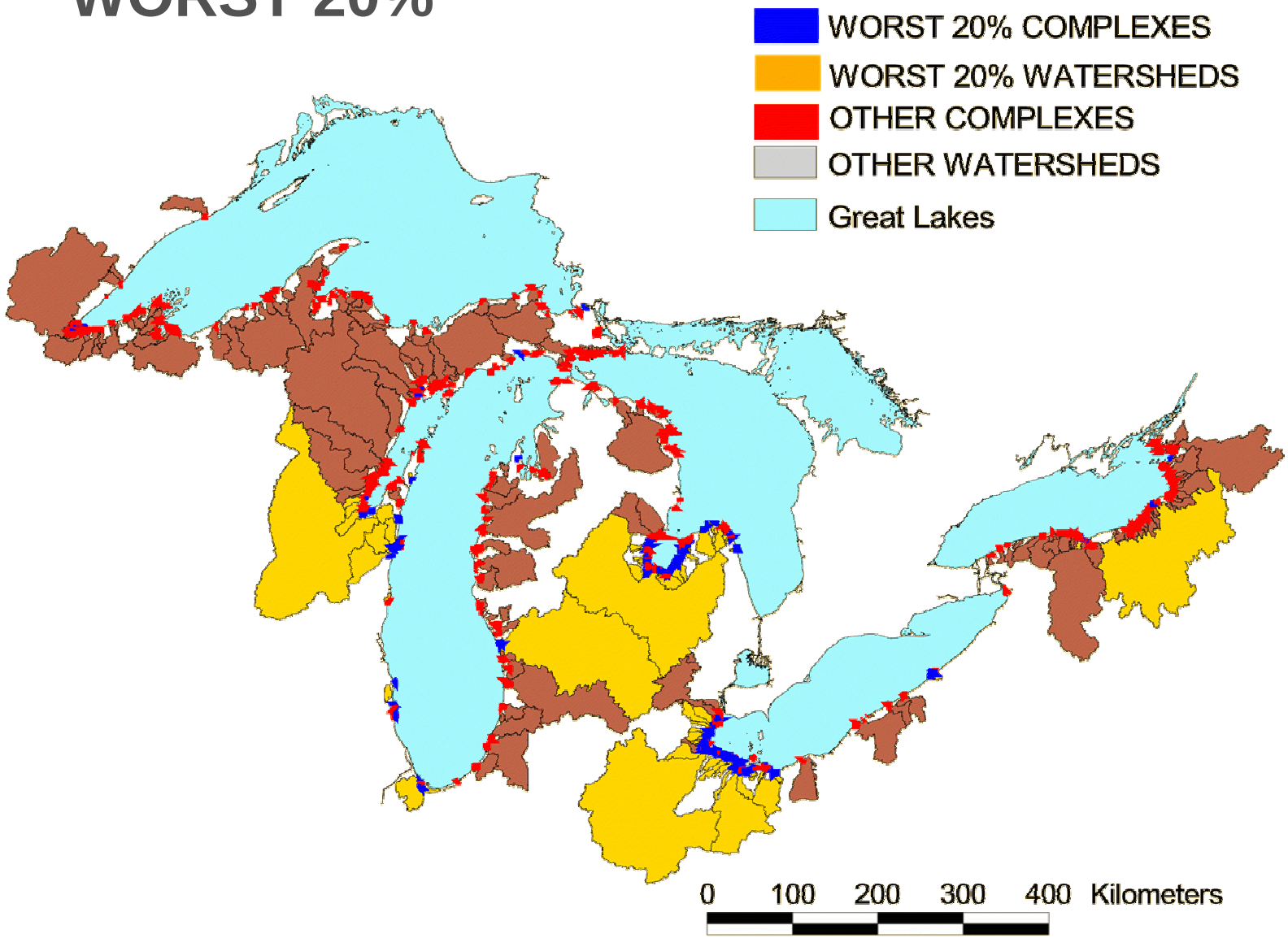
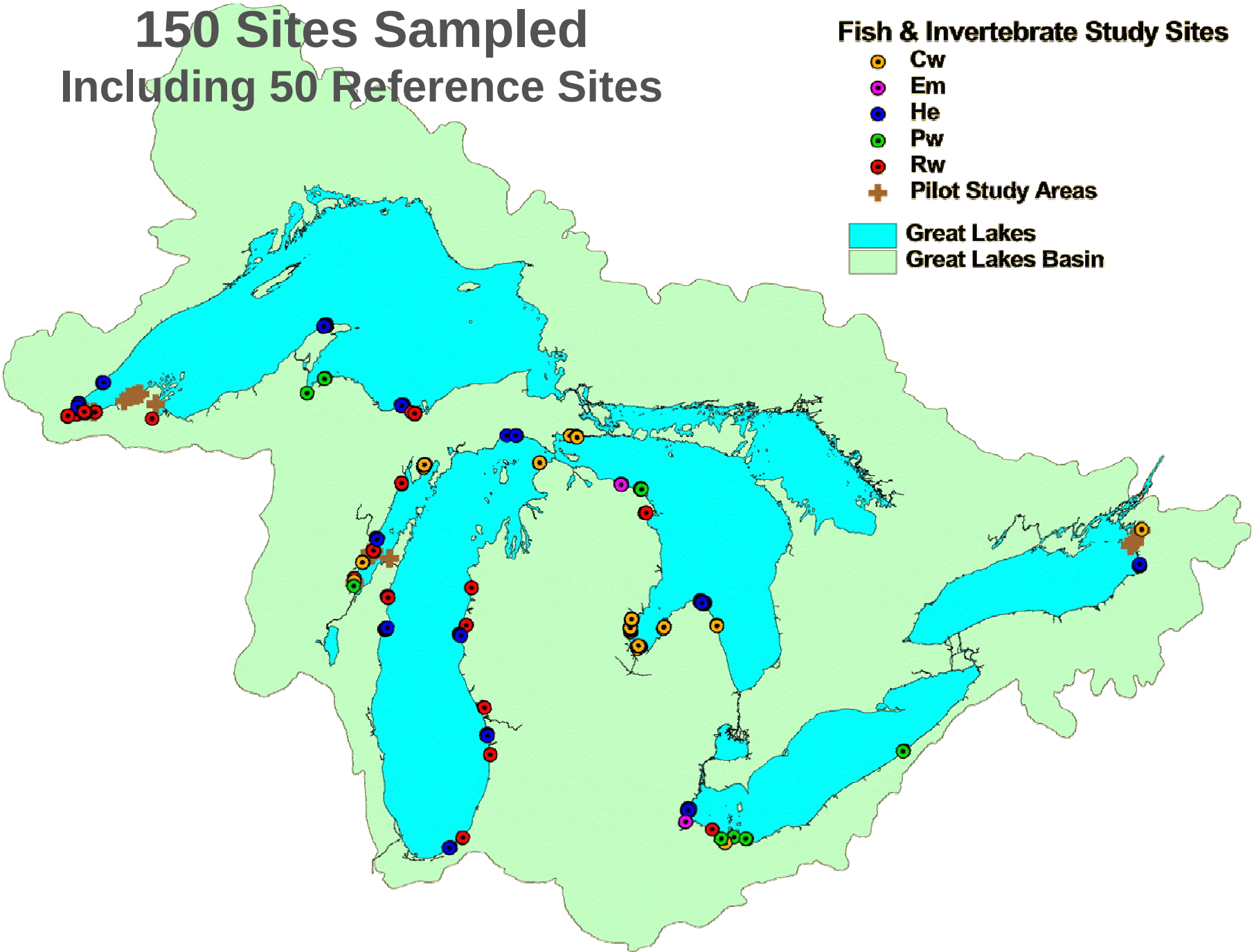
Great Lakes Environmental Indicators


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

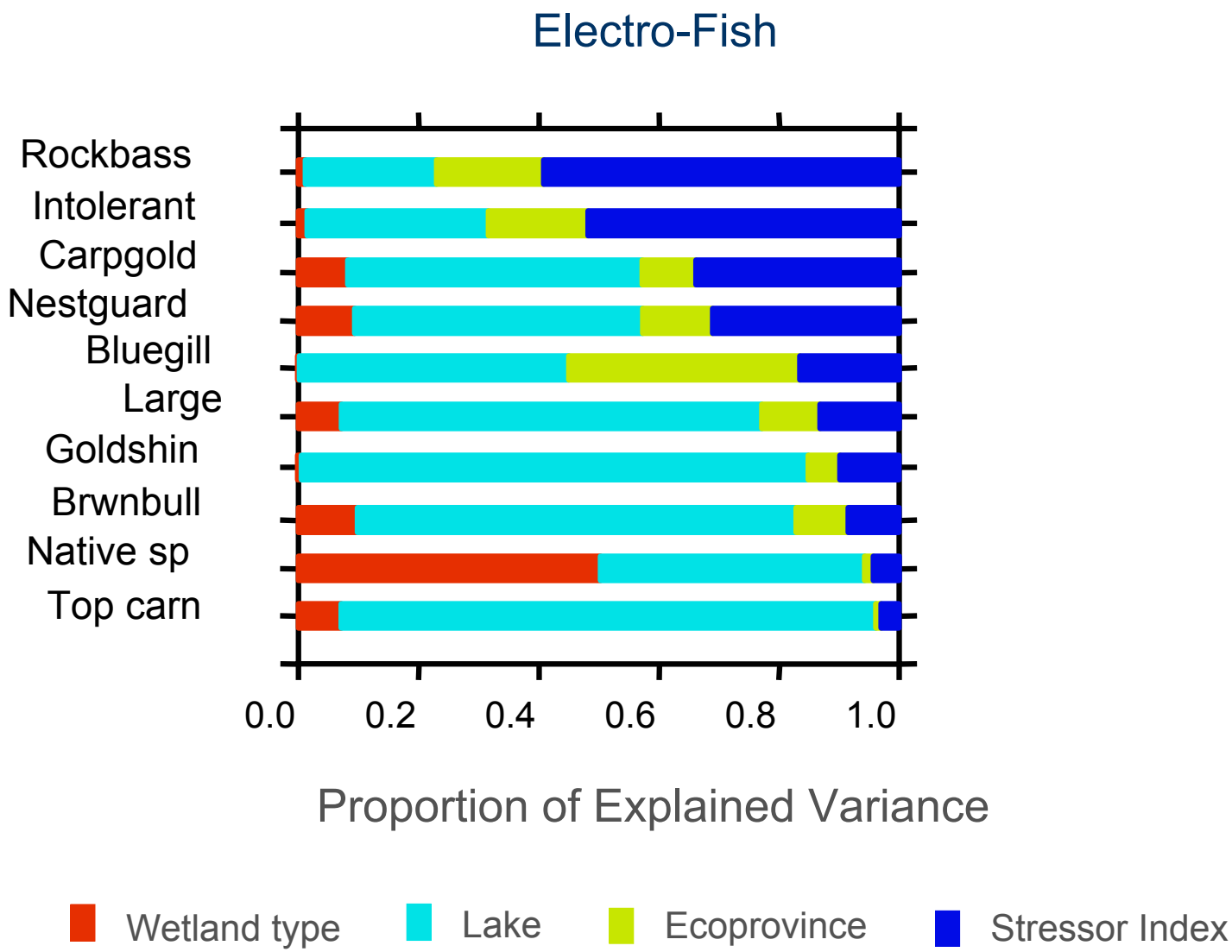
Physicochemical -
- **Temperature**
- **pH**
- **Dissolved Oxygen**
- **Conductivity**
- **ORP**

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

Water Clarity -
- **Secchi depth**
- **Turbidity tube depth**

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

Hierarchical Partitioning – Independent Effects

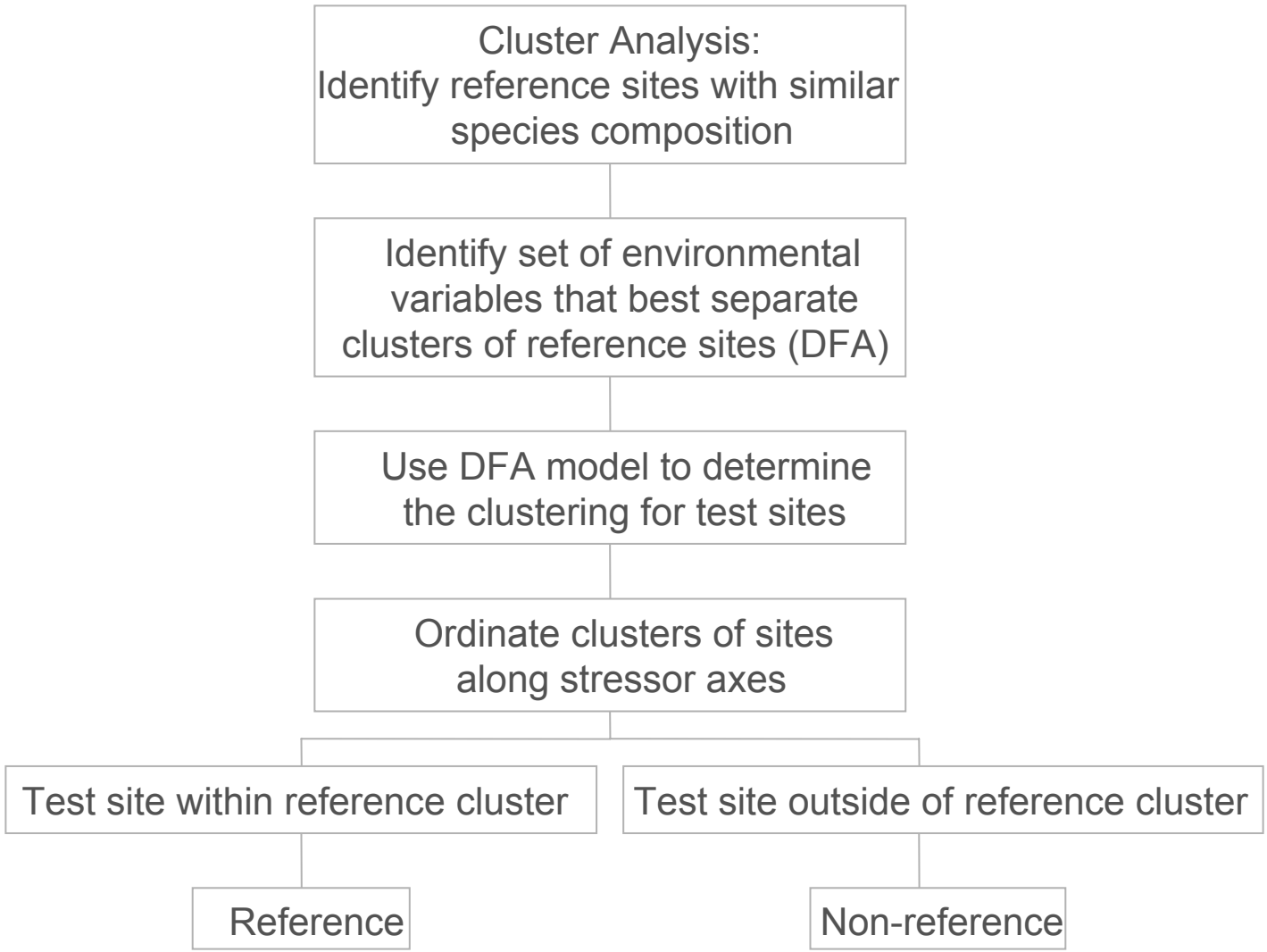


From: Brazner, et al., *in review*

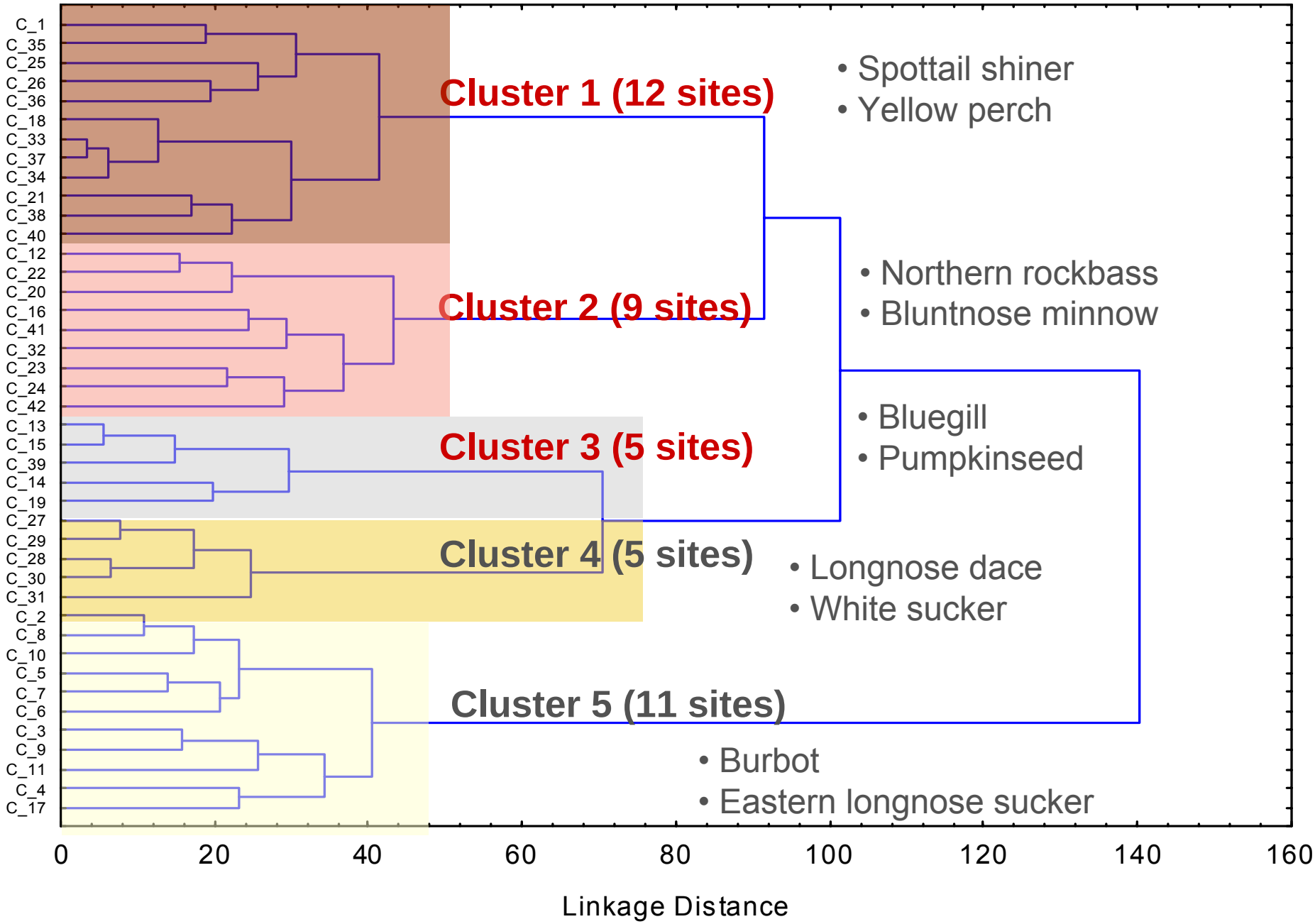
Indicator Development

- 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
Test site outside of reference cluster
Reference
Non-reference

Reference Sites



DFA Model - Variables

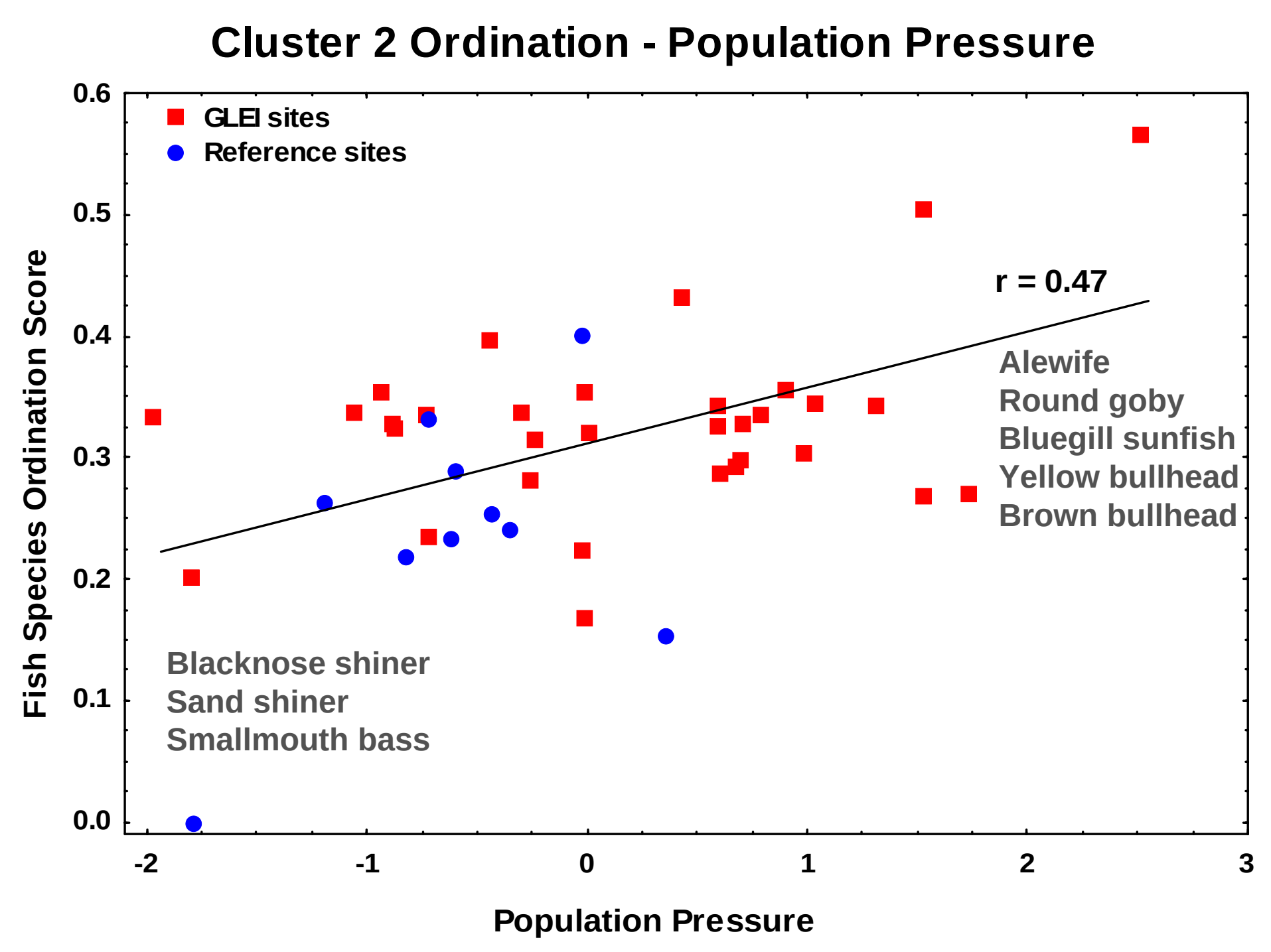
➢ EOL	p < 0.05
➢ SSU	p < 0.001
➢ NGL	p < 0.001
➢ SCG	p < 0.05
➢ Latitude	p < 0.001
• Julian Day	p < 0.05
• Protected wetland	p < 0.05
• Mean EM cover	p < 0.01

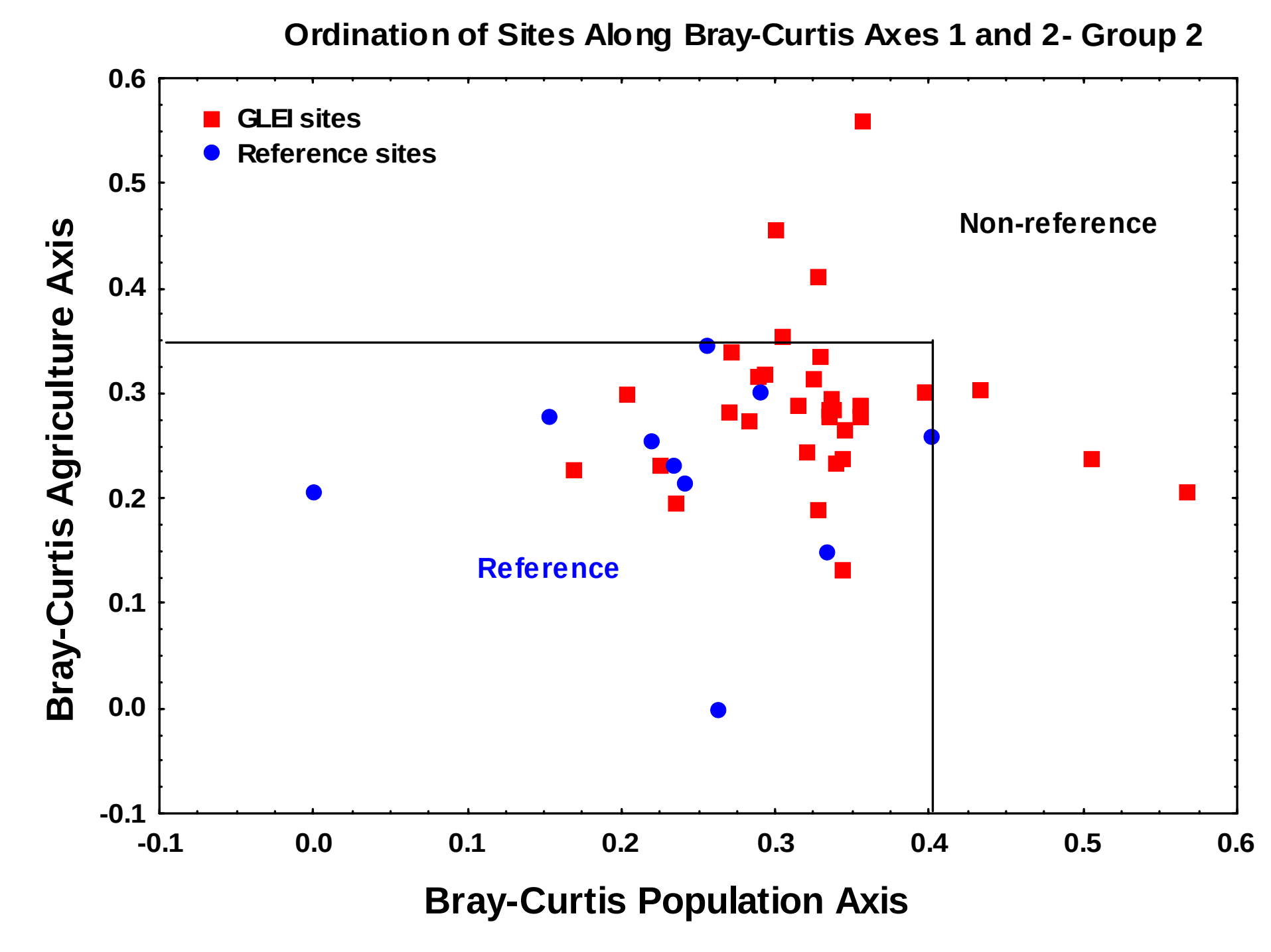
DFA – Classification of Reference sites

	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
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-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

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

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