



Great Lakes Environmental Indicators (GLEI)

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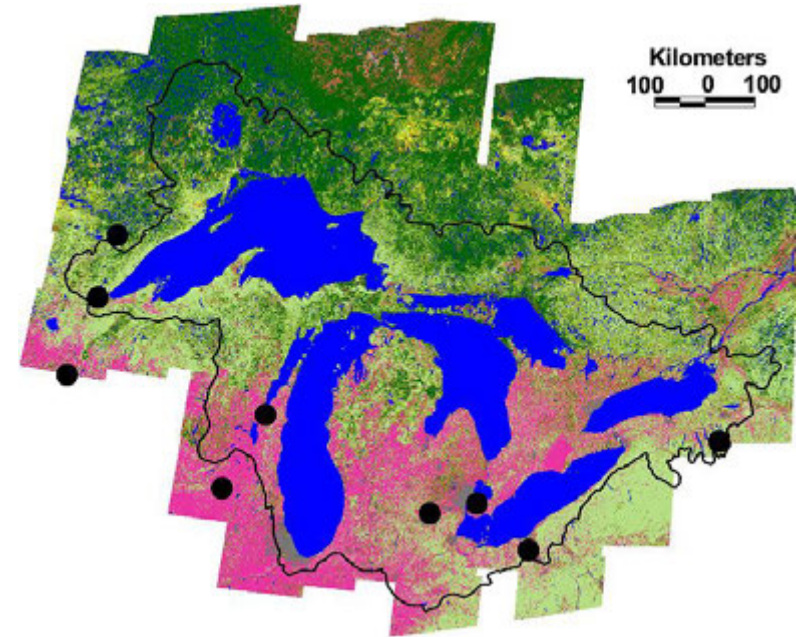
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Project Emphasis

- **Develop indicators that assess the ecological condition of the US Great Lakes coastal region **AND** point to causes of impairment**
- **Indicators examined**
 - Birds & Amphibians
 - Diatoms
 - Contaminants
 - Fish & Macroinvertebrates
 - Wetland Vegetation
 - Land use and landscapes – NASA
- **Basic questions – how are these biological communities related with human disturbances across the Great Lakes coastal region?**



Hydrogeomorphic Types

High energy



Embayment



Protected wetland



Coastal wetland



Riverine wetland



Stress Data Used

- Over 200 variables from 19 data layers were available as GIS coverages
- Required substantial processing effort
- Used to characterize stress regime for segments and watersheds
- Used to identify sample sites over the gradient



Envirofacts



National Atmospheric Deposition Program



GLEI Stress Categories: (212 georeferenced variables)



Land cover

Agriculture



Population density



Atmospheric deposition



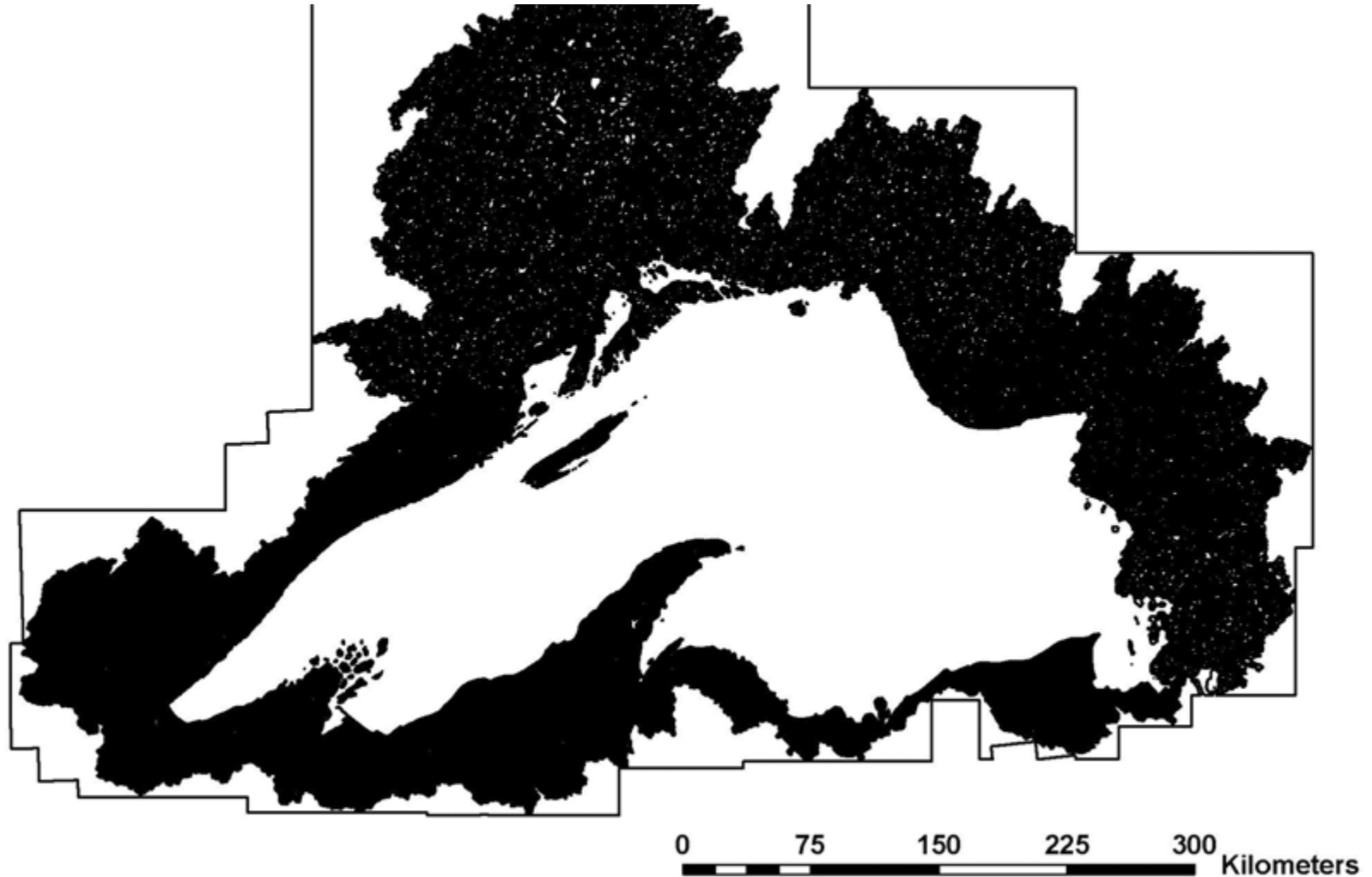
Point source discharge



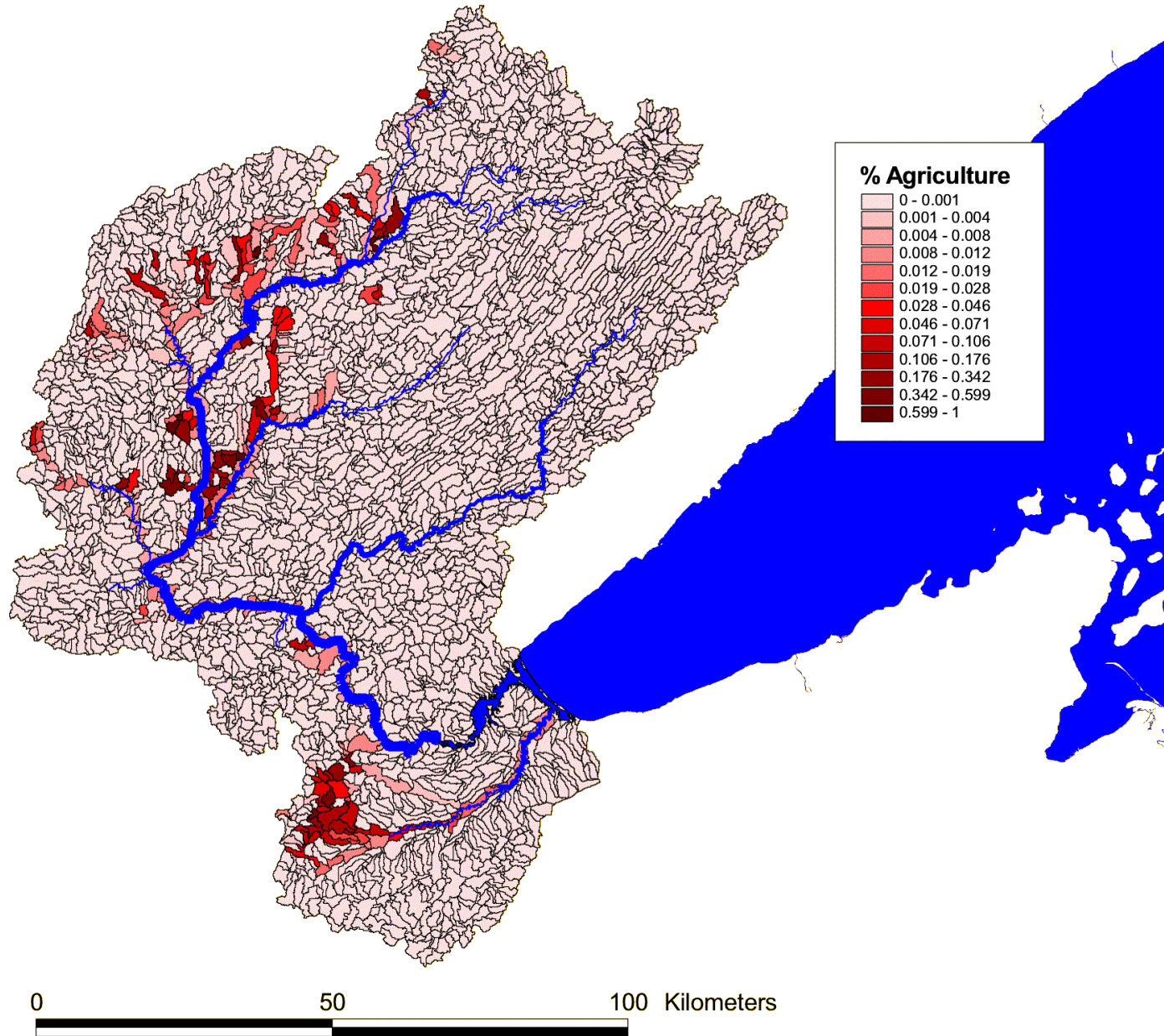
Shoreline modification



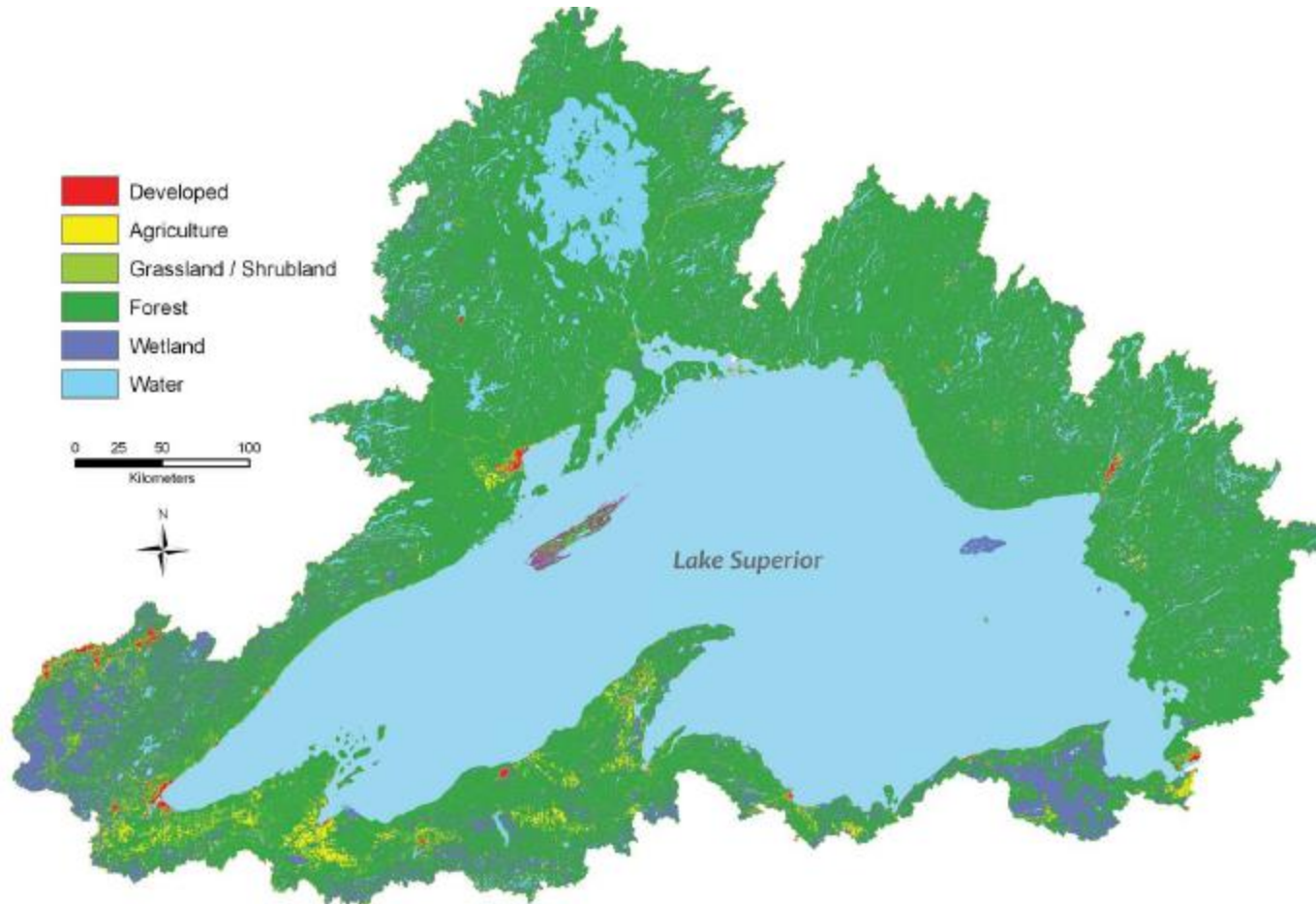
High resolution watersheds for the Lake Superior basin to calculate cumulative, and spatially explicit stressors. 6,993 watersheds that flow to coast; 130,921 sub-catchments.



Spatially-explicit land use (% Agriculture)



Landscape Characteristics & Stressors



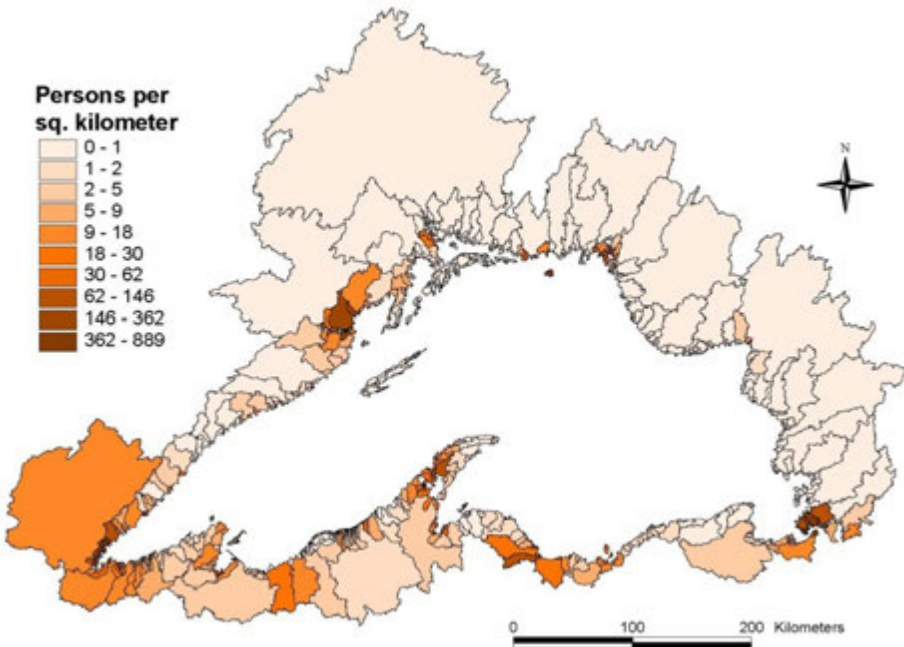
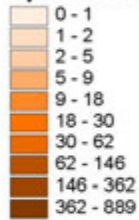
Canada - 2000 Provincial Land Cover Dataset
U.S. - 2001 National Land Cover Dataset

Map created by:
Natural Resources Research Institute
Geographic Information Systems Laboratory
University of Minnesota Duluth



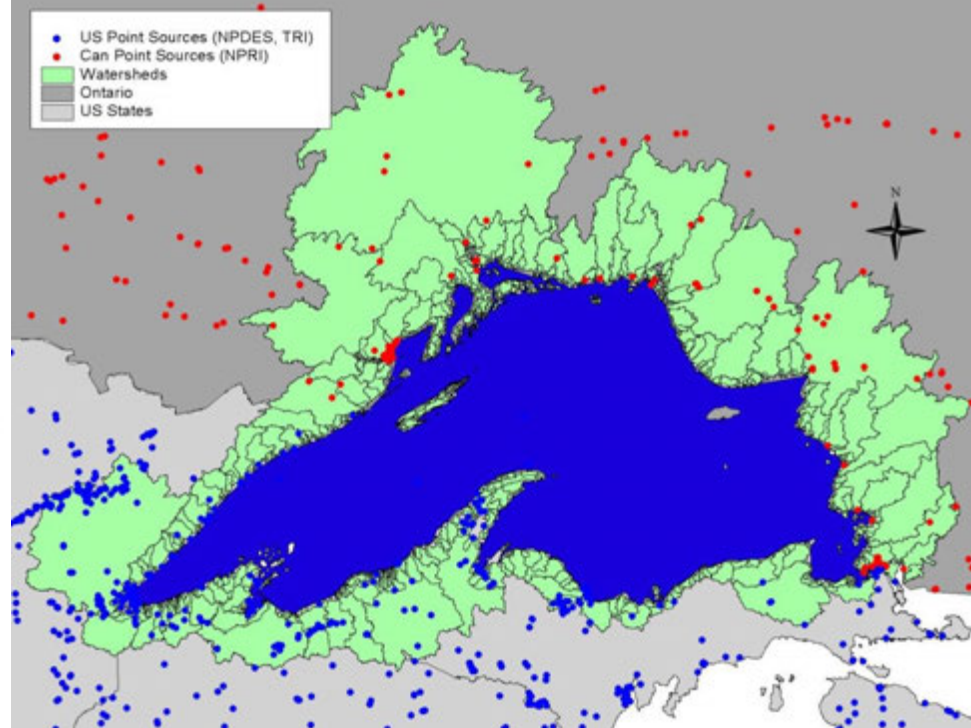
Lake Superior Basin Stressors

Persons per sq. kilometer

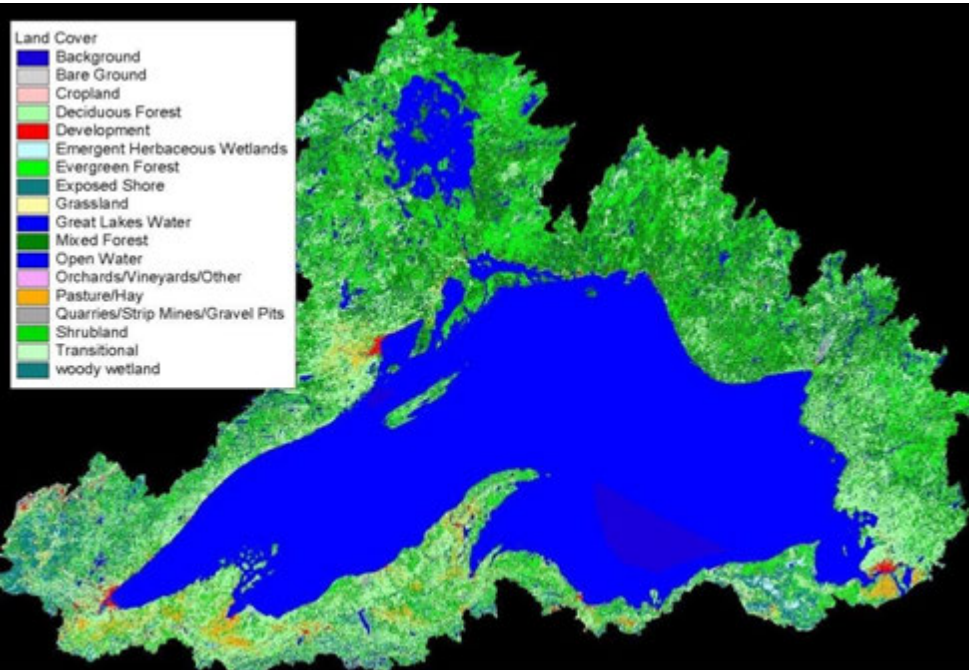


- US Point Sources (NPDES, TRI)
- Can Point Sources (NPRI)

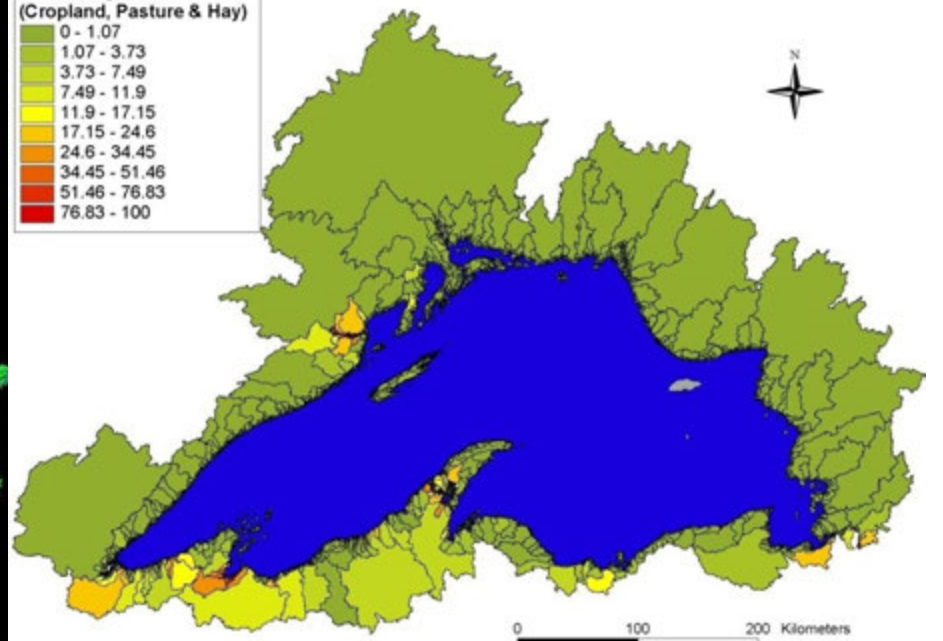
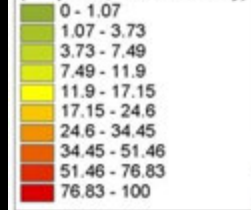
- Watersheds
- Ontario
- US States



- ### Land Cover
- Background
 - Bare Ground
 - Cropland
 - Deciduous Forest
 - Development
 - Emergent Herbaceous Wetlands
 - Evergreen Forest
 - Exposed Shore
 - Grassland
 - Great Lakes Water
 - Mixed Forest
 - Open Water
 - Orchards/Vineyards/Other
 - Pasture/Hay
 - Quarries/Strip Mines/Gravel Pits
 - Shrubland
 - Transitional
 - woody wetland



Percent Agriculture (Cropland, Pasture & Hay)



CONDITION
Land Cover

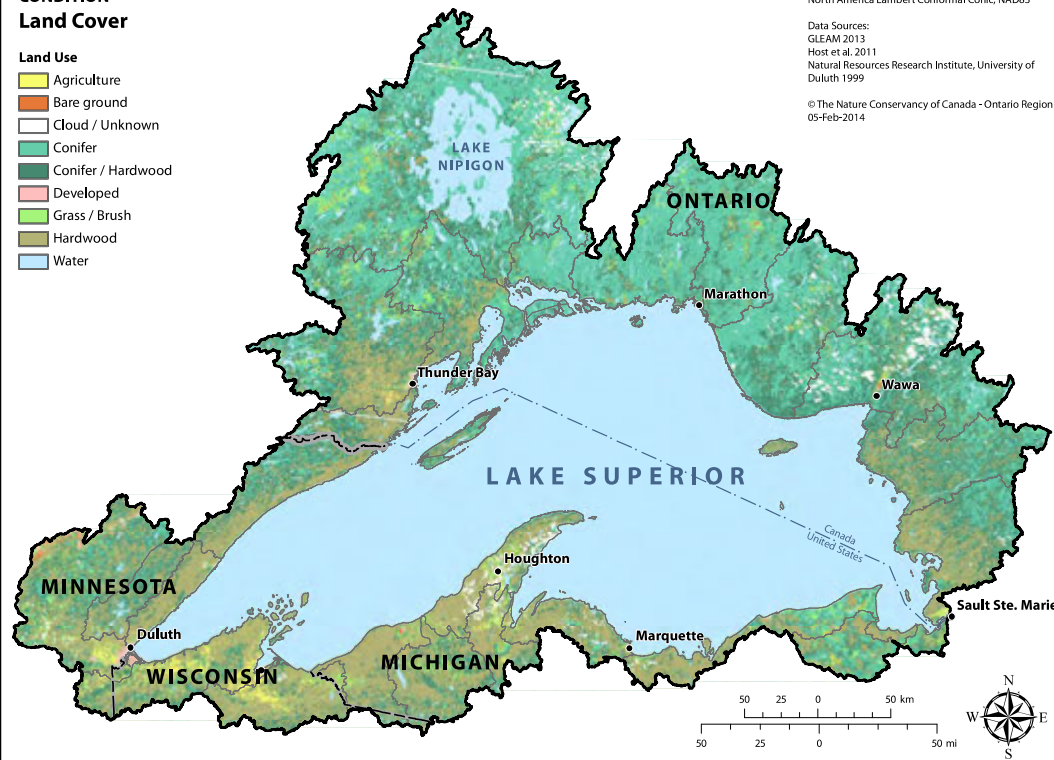
Land Use

- Agriculture
- Bare ground
- Cloud / Unknown
- Conifer
- Conifer / Hardwood
- Developed
- Grass / Brush
- Hardwood
- Water

Data Projection:
North America Lambert Conformal Conic, NAD83

Data Sources:
GLEAM 2013
Host et al. 2011
Natural Resources Research Institute, University of
Duluth 1999

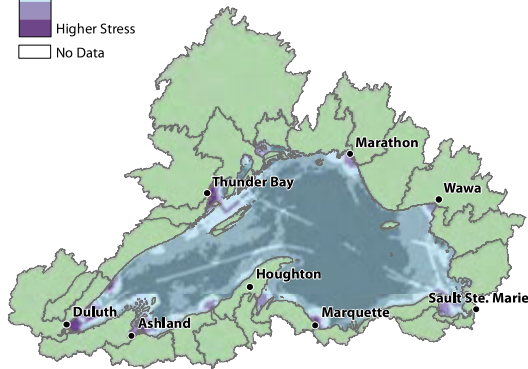
© The Nature Conservancy of Canada - Ontario Region
05-Feb-2014



Lake Superior Biodiversity Conservation Strategy

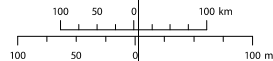
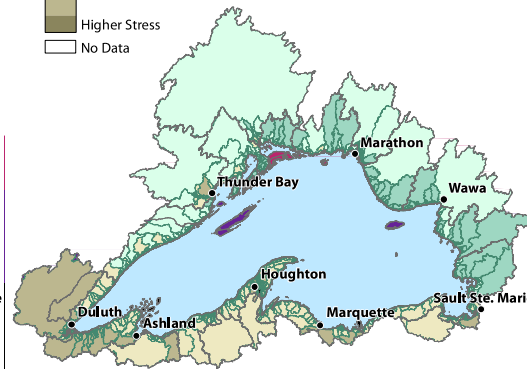
BIODIVERSITY TARGET
GLEAM Great Lakes Stress Index

- Lower Stress
- Higher Stress
- No Data



BIODIVERSITY TARGET
GLEI Watershed Stress Index

- Lower Stress
- Higher Stress
- No Data



GLEI-I Stress Gradient: A site selection tool

Selecting Sites

Great Lakes Environmental Indicators

- Cluster segment sheds based on similarities in stress level
- Select sample sites randomly from each cluster

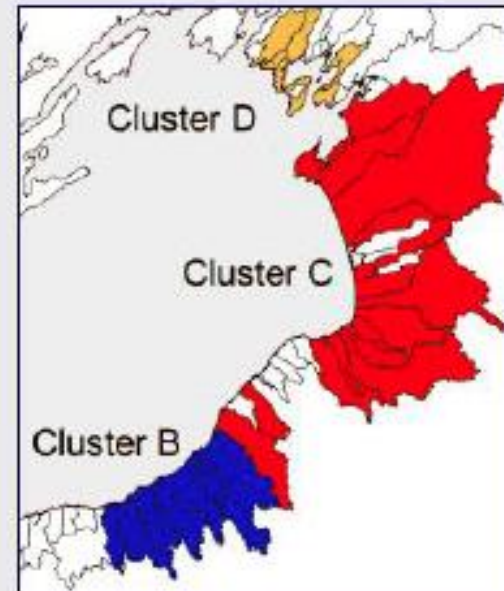
Open-coast Wetland



Riverine Wetland

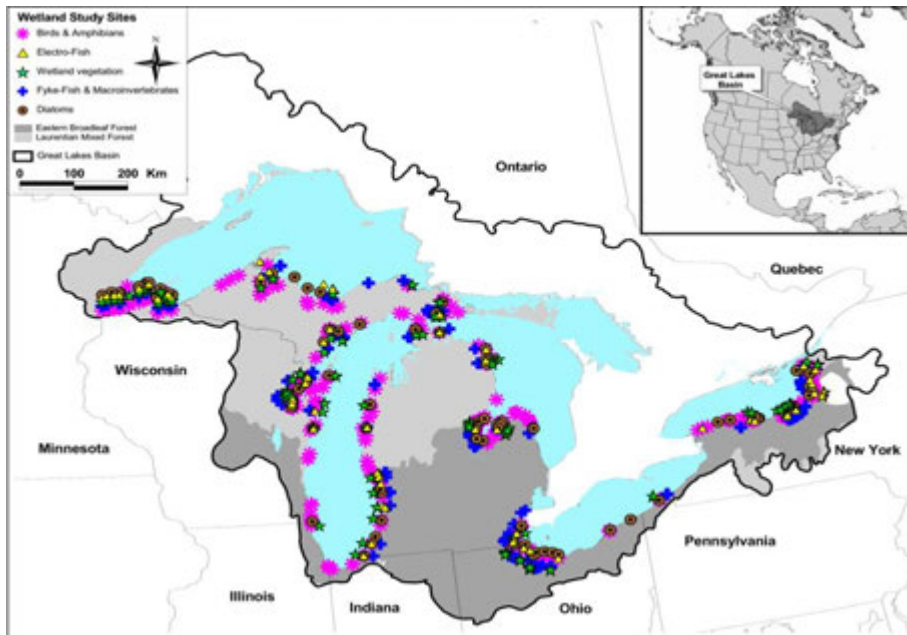


Protected Wetland / High Energy Shoreline



Applications: Sampling design

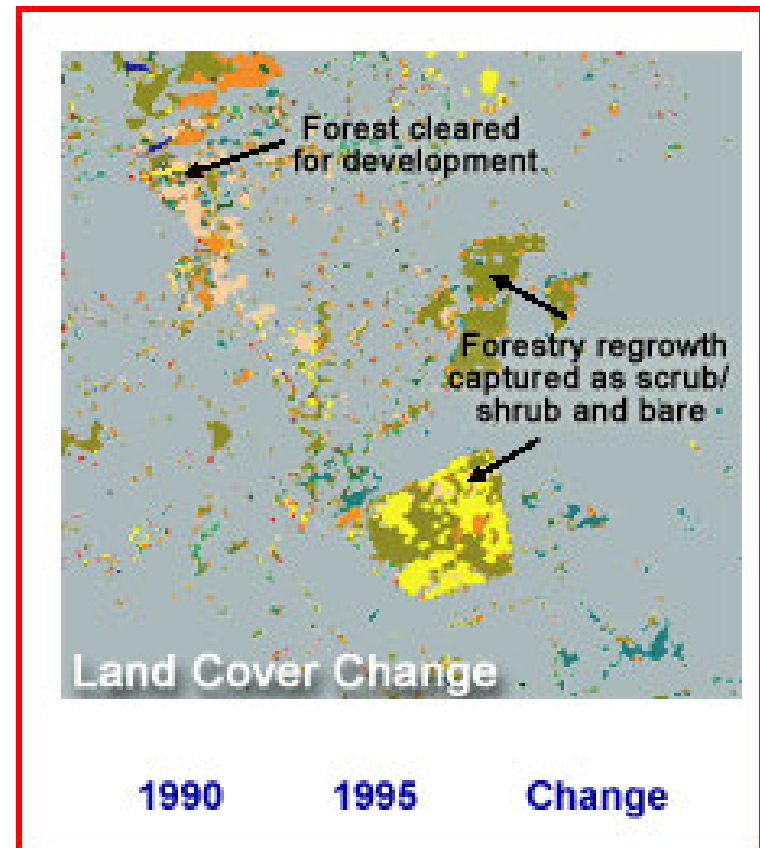
- Framework for stratified sampling of coastal ecosystems
 - The variation in environmental variables can be used to allocate samples along a disturbance gradient
 - Useful for predictive modeling of response variables
 - More efficient use of field effort



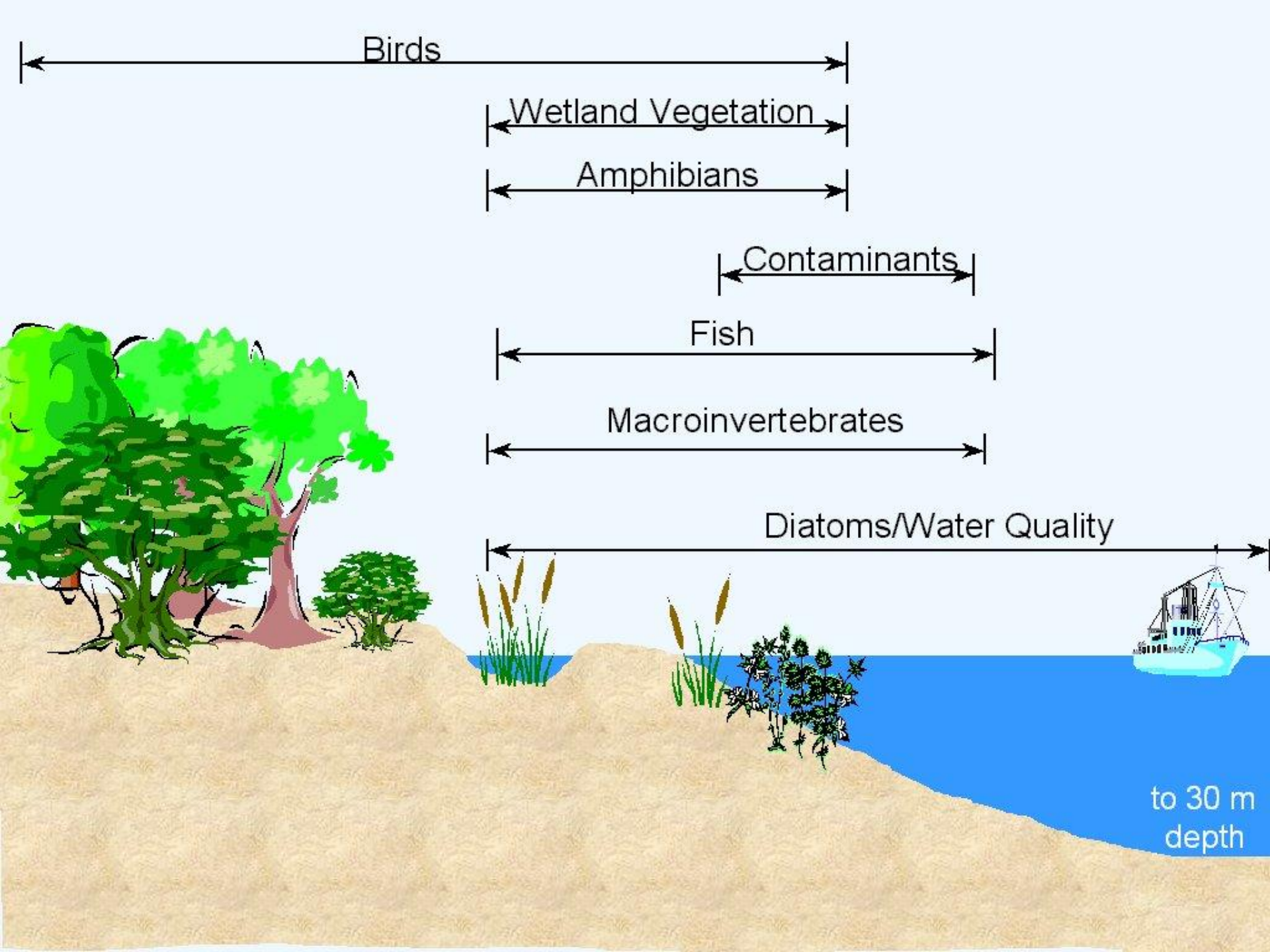
Danz, N. P., R. R. Regal, G. J. Niemi, V. Brady, T. Hollenhorst, L. B. Johnson, G. E. Host, J. M. Hanowski, C. A. Johnston, T. Brown, J. Kingston, and J. Kelly R. 2005. Environmentally stratified sampling design for the development of Great Lakes environmental indicators. *Environmental Monitoring & Assessment* 102:41-65.

Applications: Landscape monitoring

- Framework for detecting long term changes at watershed scale (land use, point sources, demographics)



From NOAA C-CAP Program



Environmental Variables



Physicochemical -

- Temperature
- pH
- Dissolved Oxygen
- Conductivity
- ORP



Habitat –

- Shoreline
- Landuse
- Vegetation (density/cover)

Water Clarity -

- Secchi depth
- Turbidity tube depth



Sediment -

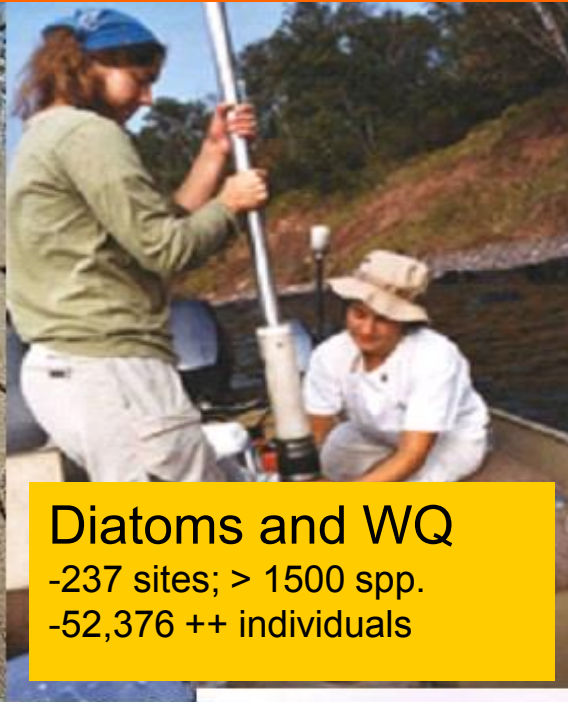
- Particle size
- LOI
- Depth of fines

GLEI components – Biological Constituents



Contaminants

-49 Sites



Diatoms and WQ

-237 sites; > 1500 spp.
-52,376 ++ individuals



Birds and amphibians

- >3,000 points; >250 sites;
-195 bird spp;
-120,909 individual birds
-12 spp. amphibians;



Wetland vegetation

-91 complexes
-526 taxa
-20,560 observations



Fish & Bugs – 145 sites

- 104 fish spp, 104,476 individuals
- 337 bug taxa, 240,334++ individuals

In addition to raw data there are

Data Summaries & Indicators

- Community metrics based on individual assemblages (fish, amphibians, invertebrates, vegetation, diatoms).
- Threshold responses of assemblages based on landscape stressors.
- Assemblage specific models predicting environmental conditions, e.g., Weighted Averaging; Index of Ecological Condition.

GLEI - I & GLEI - II

- Lacustrine Wetland
- Embayment
- ▲ High Energy Coast
- ⊕ Protected Wetland
- ✱ Riverine Wetland
- ▲ Wetland
- Upland Bird Site



Application of GLEI Biological Indicators and Assemblage Data

- Indicators were derived to assess condition relative to an anthropogenic stressor gradient derived at the scale of watersheds.
- Indicators are scaled to the site level (e.g., entire wetland) within a watershed context.
- Assemblages respond coherently to individual stressors, e.g., development, agriculture.

Acknowledgements

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**Environnement
Canada**

