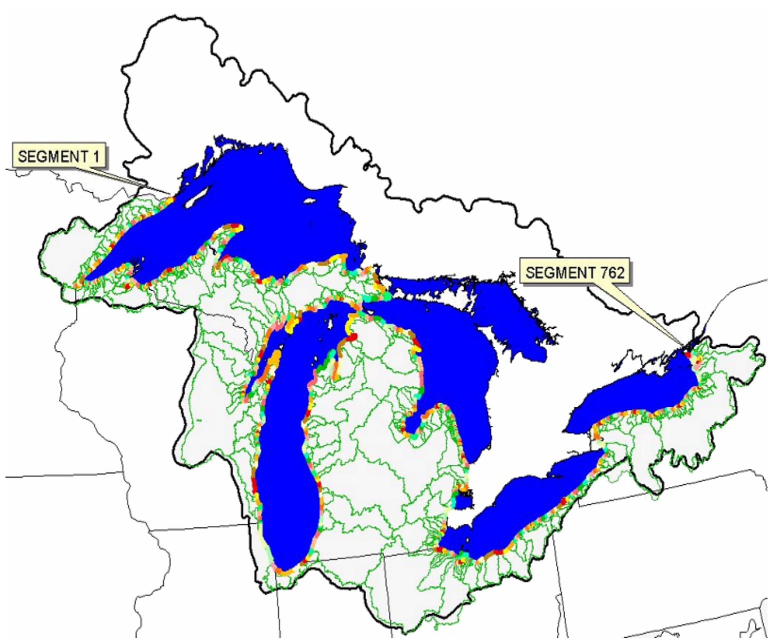
Great Lakes Environmental Indicators
EPA STAR EaGLe

Sampling Design for Linking Stress with Response in Great Lakes Coastal Ecosystems

Introduction

Understanding relationships between human disturbance and ecological response is essential to the process of indicator development. This understanding requires that sites are selected across gradients of human disturbance. For observational studies over large geographic regions 1) such gradients are often unknown for sites prior to site selection and field sampling, and 2) disturbances overlap in space and time, creating a complex multi-dimensional pattern of stress.
Our objective is to describe a sampling design for linking stress with ecological response that considers the complex nature of human disturbance in the US Great Lakes coastal region

Step 1. Divide basin into segment-sheds
The sampling frame consisted of coastal wetlands, embayments, and high-energy shoreline across the basin. Sampling units were too numerous to identify and delineate prior to site selection. We defined a manageable number of coastal units that contained sampling units using a geographic information system (GIS). The coastal units, named segment-sheds, were created to reflect the strong influence of land-based stressors on coastal ecosystem condition. Segment-sheds were created by first defining shoreline segments as beginning and ending halfway between each second order or higher stream entering one of the lakes. Drainage areas associated with these shoreline segments were then delineated, creating segment-sheds. There were 762 segment-sheds for the US Great Lakes basin.



762 segment sheds for the US Great Lakes basin

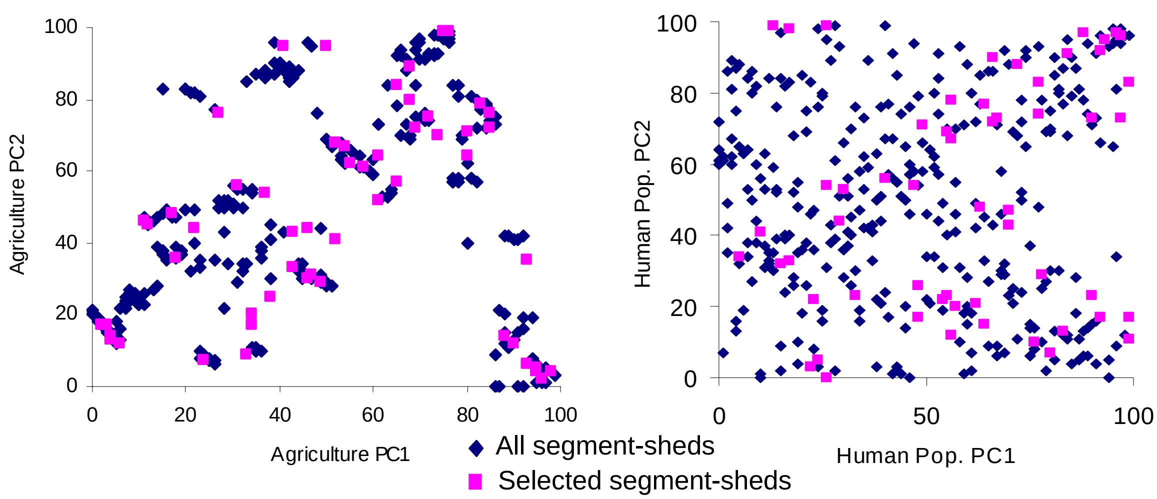
Step 2. Compute variables for segment-sheds
We collected 207 GIS variables representing six primary types of human disturbance (agriculture, atmospheric deposition, land cover, point source pollution, human population density, and shoreline alteration) and one type of environmental variation not related to disturbance (soils). The variables came in various original source units and resolutions. We used a variety of spatial data transformations (e.g. weighted averaging) to recompute the variables for the segment-sheds.

Step 3. PCA to remove redundancy
We used principal components analysis to reduce the number of variables in each category. Variables were kept in categories to retain information about particular types of stress. PCAs were run separately for the two ecoprovinces that comprise the basin. The first PC from each category represented an overall gradient in the amount of disturbance.

Step 4. Cluster analysis to develop strata
We used cluster analysis to create groups of segment-sheds with similar stress profiles. The PC scores that explained 90% of the variance within each category were used as input variables. PCs were rescaled so that the categories had overall equal influence on the clustering, but individual PCs had influence proportional to their variances. Clusters were created separately for segment-sheds containing each type of sampling unit with each ecoprovince.

Step 5. Site selection from strata
Within each cluster, segment-sheds were evaluated in random order using maps and aerial photos in a GIS to find sampling units that were accessible. Project subcomponents used different criteria to evaluate accessibility. Project subcomponents had different sample size requirements. At least one sampling unit was selected from each cluster.

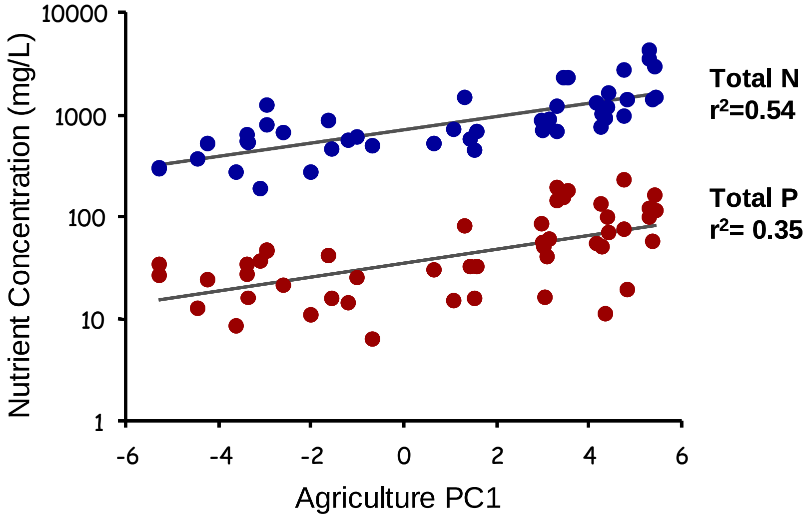
Step 6. Evaluate sample distribution
After site selection, the sample for each project subcomponent was shown to successfully span the potential range of variation in disturbance gradients.



Sites selected by the bird/amphibian subcomponent successfully spanned gradients of disturbance (blue diamonds represent the total potential range of variation; pink squares represent selected sites).

Conclusions

Data available from public sources can be used in a geographic information system (GIS) to partially characterize environmental conditions for large geographic areas without visiting sites. Random site selection from clusters of sites with a similar stress profile resulted in an unbiased sample across the range of conditions present in the disturbance variables. Although the disturbance PCs were created for the purpose of site selection, they also have applicability for understanding biological responses.



Relationships between the agriculture PC1 and total Nitrogen and Phosphorus from Great Lakes wetlands (data from Kelly *et al*., US EPA MED)

For more information

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.R. Kelly. Environmentally stratified sampling design for the development of Great Lakes environmental indicators. Environmental Monitoring and Assessment. *In press.*

Email: ndanz@nrri.umn.edu

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