

2003 Progress Report: Testing Indicators of Coastal Ecosystem Integrity Using Fish and Macroinvertebrates

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Center: [Great Lakes Environmental Indicators Project](#)

Center Director: [Gerald J. Niemi](#)

Title: Testing Indicators of Coastal Ecosystem Integrity Using Fish and Macroinvertebrates

Investigators: Lucinda B. Johnson¹, Jan Ciborowski⁴, Thomas Hrabik², Valerie Brady¹, Jeffrey Schuldt⁵, Carl Richards³, Dan Breneman¹

Cooperators: John Brazner⁵, John Kelly⁵, John Morrice⁵, Jill Scharold⁵, Michael Sierszen⁵, Dan Tanner⁵, Anett Trebitz⁵, Peder Yurista⁵

Institutions: ¹Center for Water and the Environment, Natural Resources Research Institute, University of Minnesota Duluth; ²University of Minnesota Duluth; ³Minnesota Sea Grant College Program; ⁴University of Windsor; ⁵US EPA Mid-Continent Ecological Division, Duluth; ⁶University of Wisconsin, Superior

EPA Project Officer: Barbara Levinson

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Project Amount: \$6,000,000

RFA: [Environmental Indicators in the Estuarine Environment Research Program \(2002\)](#)

Research Category: [Ecological Indicators/Assessment/Restoration](#)

Description:

Objective: Evaluate and integrate indicators across multiple spatial scales, by employing a multi-tiered sampling and modeling strategy, integrating data collected at a regional scale via satellite imagery, with the local scales, and at a site scales via field sampling. These data will be used to identify indicators at each scale that reflect critical ecosystem processes or state variables related to the integrity and sustainability of those ecosystems. We will test indicators representing fundamental processes at multiple spatial scales, and integrate them into a procedure for identifying the health of Great Lakes coastal margins. The goals of our project are to:

1. Evaluate the applicability of SOLEC-derived and complementary indicators in the context of the ecosystem types making up the Great Lakes coastal region;
2. Rigorously test the efficacy of a suite of indicators across the range of habitats that make up the Great Lakes coastal system;
3. Recommend indicators of specific ecological conditions keyed to assessment endpoints and stressors in the Great Lakes coastal region.

Progress Summary:

The combined sampling effort during the 2002 and 2003 field seasons has resulted in a total of 112 sites sampled at 101 unique locations across the basin. Fifteen sites sampled previously were revisited to quantify temporal variation (Table 1). In addition, 56 Reference Condition sites were sampled (**EPA grant R-8386750**) as part of a parallel study to define reference condition in nearshore coastal waters of the Great Lakes. The 2003 field season was characterized by

extremely low lake levels in lakes Huron and Michigan; protected and coastal wetlands were most severely impacted, resulting in many rejected sites.

More than 4,000 benthic samples were collected in 2002 - 2003 at the combined GLEI and Reference Condition project sites. Approximately 1,100 fyke net sets (of 24h duration) were fished, resulting in over 103,000 fish captured; 108 fish taxa were identified. Habitat data were recorded from more than 1,800 benthos points, 800 net locations, and about 2,000 habitat points. Water quality was measured at approximately 2,000 locations.

To date, we have completed data entry and have QC'ed approximately 100% of the 2002 and 2003 fish data; 100% of the habitat data have been entered and QC is ongoing. All benthic samples collected in 2002 have been processed, and with the exception of Chironomidae (Diptera) larvae, all other taxa have been identified to the lowest practical taxonomic unit. Final verification and validation of suspect materials is about 1/3 complete (UW). Approximately 25% of benthic samples from 2003 have been processed. Analysis of sediment for organic content and particle size distribution is approximately 90% complete.

Activities this winter are focusing on analysis of fish and habitat data, along with sediment and benthic sample processing. We also are assessing different methods for identifying reference conditions, and comparing the multimetric and multivariate approaches to indicator development:

Multimetric Approach (issues to address):

Finalize list of metrics to test;

1. Quantify the variance structure for individual metrics (Fore 2003);
2. Quantify metric responses to gradients of human disturbance (HDG)
3. Test signal to noise ratio (Kaufmann et al.1999) for fish, invertebrate, and habitat metrics;
4. Test metrics for: a) biological relevance, b) range of values, c) consistency of response to HDG; d) uniqueness of response (relative to other metrics); e) reliability; f) cost to acquire and process data.;
5. Develop and test a set of integrated metrics (fish, habitat, invertebrates, water quality) using approach of Wiley, et al. (2003); assess above for integrated metrics.

Table 1. Sites sampled for GLEI and Reference Condition projects, 2002-2003.

Hydrogeomorphic type	CW	PW	RW	EB	HE	Total
GLEI						
# Sampled	24	20	25	23	24	116
# Unique	21	18	22	20	20	101
Reference Condition						
# Sampled	9	6	14	-	27	56

Results to Date

Distribution of Invading Species - Aquatic Invertebrates

Our extensive, basin-wide sampling program has been particularly effective in permitting us to delineate the spatial extent, relative dominance, and associations among nonindigenous invading species, especially invertebrates. For example, work by GLEI research student MiSun Kang (M.Sc. 2003) demonstrated that an invading amphipod species, *Echinogammarus*, has only been found where exotic zebra mussels have previously colonized. This association suggests that the invasion of one exotic species is entirely dependent on the presence of a previous invader. This species-level indicator also provides clues on the concern for declining populations of *Gammarus*; the native amphipod in the Great Lakes which is critical to fish populations. MiSun has begun a PhD program designed to investigate the effects of establishment order on the invasion success of subsequent new species.

A small population of the Asiatic clam, *Corbicula*, has been found in Saginaw Bay; a first record of occurrence in the upper Great Lakes. *Gammarus tigrinum*, native to the Atlantic coast, has also been identified at a site on Lake Huron - another first record in the Great Lakes. This species has extensively invaded many locations in Europe. New records of several species of snails have also been found throughout the Great Lakes, many likely native species, but previously not known from the region. The sampling framework and resulting inventory of many taxa in the Great Lakes Environmental Indicators project has added immensely to the knowledge of the biota and will result in further linkages among multiple stressors in the coastal region.

Fish Community Distributions:

Preliminary analyses of 2002 and 2003 fish data confirm our hypothesis that high energy shorelines have significantly different fish communities than are found in Great Lakes wetlands and embayments (multi-response permutation parameter $p < 0.0001$). Nonmetric multidimensional scaling (NMDS) ordination analysis of the high energy sites also indicated that the types of stressors influencing the northern sites were quite different from those influencing the southern sites, confirming another of our hypotheses. For example, community differences among southern sites were strongly correlated with the stressors phosphorus fertilizer, row crop agriculture, number of pollution point sources, amount of disturbed land use, and stream sedimentation. Northern sites had greater taxonomic richness of piscivores, a potential indicator for high energy sites.

NMDS and MRPP analyses showed a clear separation between northern and southern sites ($p < 0.0001$) for wetland and embayment sites, as well as high energy sites. Consequently, the northern and southern sites were analyzed separately. For both datasets, sites grouped by exposure - the more open types (embayments and fringing coastal wetlands) grouped somewhat distinctly from more protected site types (protected and riverine coastal wetlands). There were also some distinct fish community characteristics within each lake ($p = 0.05$). Although stressors at the landscape level did not show strong correlations with the ordination axes, several potential fish indicators were identified for further analysis (taxa richness and proportional abundance of exotic species, proportional abundance of small-bodied fish, proportional abundance of medium-bodied fish, taxa richness of large-bodied fish, proportional abundance of larval and juvenile zoobenthivores, taxa richness of juvenile zoobenthivores, taxa richness of larval phytoplanktivores).

Fish Community Responses

Preliminary analyses show that fish community data collected independently by GLEI and EPA exhibited similar response trends with respect to stressors across ecoprovinces. In general, Province 212 has smaller numbers of exotic species, and more native species and individuals, while piscivore richness was greater (Table 2). This pattern was reversed in Province 222. Spearman rank correlations with selected stressors indicate that in Province 212, the main stressors influencing fish communities are related to human population and urban development features (Table 3). In contrast, stressors related to agricultural activities are most highly correlated with fish metrics in the southern ecoprovince.

Table 2. Summary statistics for fish data sampled via electrofishing and fyke nets at wetland and embayment locations.

Group	Province	# Sites	Exotic		Native		Piscivore	
			Richness	SD	Richness	SD	Richness	SD
EPA	212	18	1.67	0.82	14.17	2.86	5.50	2.74
GLEI	212	48	0.20	0.42	11.60	2.67	1.90	1.20
EPA	222	19	1.60	0.89	14.00	3.16	7.60	0.55
GLEI	222	28	1.15	1.68	10.62	2.18	1.23	0.73
Group	Province	# Sites	Piscivore		Exotic		% Exotic	
			e Individ	SD	Indiv	SD	Sp	SD
EPA	212	18	0.09	0.06	0.04	0.08	0.10	0.04
GLEI	212	48	0.07	0.07	0.00	0.00	0.01	0.03
EPA	222	19	0.20	0.09	0.01	0.01	0.11	0.08
GLEI	222	28	0.05	0.05	0.02	0.04	0.08	0.09

Table 3. Spearman rank correlations between normalized fish metrics (Wiley et al. 2003) and a subset of stressors. Metrics were normalized using the standard deviation of the metric from reference sites. Only correlation coefficients > 0.5 are shown.

Group	Province	Metric	Ag	Pop	Phosphoru	Stream	Develope	Row	Disturbe
			Chem	/Dev	s	Sediment	d	Crop	d
			PCA	PCA	Fertilizer			Clay	
EPA	212	Exotic		0.52					
EPA	212	Native							
EPA	212	Piscivore							
EPA	212	%		-0.72		-0.56	-0.60	-	-0.60
EPA	212	% Exotic		0.57			0.53		0.54
EPA	212	% Exotic							
EPA	212	%		0.55					
EPA	222	Exotic	0.57		0.58	0.73			0.50
EPA	222	Native	-0.17						
EPA	222	Piscivore	-0.61			-0.53			-0.55
EPA	222	%	-0.69		-0.63	-0.71		-	-0.73
EPA	222	% Exotic							
EPA	222	% Exotic	0.56		0.56	0.59			0.62 0.50
EPA	222	%	0.68		0.63	0.81		0.69 0.67	0.65
GLEI	212	Exotic							

GLEI	212	Native						
GLEI	212	Piscivore						
GLEI	212	%		-0.58				
GLEI	212	% Exotic						
GLEI	212	% Exo Sp						
GLEI	212	%		0.45				
GLEI	222	Exotic			0.63		0.64	0.59
GLEI	222	Native						
GLEI	222	Pisc Rich						
GLEI	222	%	-0.62			-0.53		-0.51
GLEI	222	% Exot	0.56		0.67	0.57	0.71	0.56
GLEI	222	% Exotic			0.55		0.61	0.58
GLEI	222	%						

Future Activities

This summer we will have a limited sampling effort to finish up a few sites where weather created sampling problems last year. Most of our effort will focus on finishing the macroinvertebrate sample processing, data entry and QA, and data analyses for indicator development and testing. We will be working on several manuscripts, and will be giving a number of presentations at scientific meetings.

Publications and Presentations

Type	Citation
Journal	Ciborowski, J.J.H., J. Schuldt, L.B. Johnson, G.E. Host, C. Richards, N. Danz, T. Hollenhorst. Reference conditions and axes of environmental stress - developing, integrating, and evaluating indicators of environmental conditions at Great Lakes coastal margins. For submission to <i>Ecological Applications</i> . In prep.
Journal	Grigorovich, I., E. Mills, C. Richards, D. Breneman, J. Ciborowski. European valve snail <i>Valvata piscinalis</i> (Müller) in the Great Lakes basin: Cryptic occurrence and spread. For submission to <i>Journal of Great Lakes Research</i> . In prep.
Journal	Kang, M., Ciborowski, J. J. H., Johnson, L. B., Hrabik, T.R., Richards, C., Schuldt, J. The relationship between anthropogenic disturbance and the distribution of a nonindigenous species, <i>Echinogammarus ischnus</i> Stebbing, 1898 (Amphipoda: Gammaridae), at Great Lakes coastal margins. For submission to <i>Biological Invasions</i> . In prep.
Presentation	Brady, V. J. Johnson, L. B., Breneman, D. H., Ciborowski, J. J. H., Hrabik, T. R., Richards, C. Schuldt, J. relative influence of landscape characteristics and anthropogenic stress on fish communities in Great Lakes coastal wetlands. International Association of Great Lakes Research. June 2003.
Presentation	Brazner, J.C., et al., Fish Assemblages as Indicators of Lake Superior Coastal Wetland Condition. International Association of Great Lakes Research. June 2003.
Presentation	Ciborowski, J.J.H., et al., Reference conditions, degraded areas, stressors, and impaired beneficial uses: conceptual integration of approaches to evaluating human-related environment pressures. International Association of Great Lakes

- Research. June 2003.
- Presentation Ciborowski, J.J.H., et al., Reference conditions, degraded areas, stressors, and impaired beneficial uses: conceptual integration of approaches to evaluating human-related environment pressures. 30th Annual Aquatic Toxicity Workshop, Ottawa, ON. September 2003.
- Presentation Hrabik, T.R., Brady, V.J., Breneman, D.H., Ciborowski, J., Richards, C. Quantifying the influence of landscape characteristics on fish communities in coastal riverine wetlands for use as indicators. American Association of Limnology and Oceanography, April 2003.
- Publication Kang, M. 2004. The invasibility of stressed sites by exotic benthic macroinvertebrates in the Great Lakes: a test of hypotheses using *Echinogammarus ischnus*. M.S. thesis. University of Windsor, Windsor, Ontario, CA.

Postdoctoral Fellows and Research Activities

- Grigorovich, I. 2003. Great Lakes Environmental Indicators - distribution and implications of nonindigenous invading species at Great Lakes coastal margins.
- Gathman, J. 2003-2004. Great Lakes Environmental Indicators - multivariate analysis of zoobenthic distribution at Great Lakes coastal margins.
- Holland, J. 2003-2004. Great Lakes Environmental Indicators - role of scale in indicator sensitivity.

Graduate Student Participation

- Bhagat, Y. In progress. Classifying fish communities to assess environmental condition at Great Lakes shorelines: a comparison of multimetric and multivariate approaches. M.Sc. thesis, University of Windsor.
- Kang, M. In progress. The influence of entry sequence on invasion success and the importance of scale for biotic resistance to biological invasion. Ph.D. thesis, University of Windsor.

Undergraduate Thesis Students

- Foley, C. In progress. The associations between larval Odonata and habitat structure as indicators of anthropogenic stress in great lakes coastal margin wetlands. Hon. B.Sc. thesis, University of Windsor.

Undergraduate Interns 2003

University of Minnesota Duluth

David Branstat, Darin Gossett, Robert Hell, Chris Palvere, Megan Warner, Lynn Wright, David Chapman, Joseph Verdegan

University of Windsor

Katherine Andriash, Leanne Baker, Lucas Bryk, Rebecca Danard, Justin Duncan, Carolyn Foley, Marilynn Kullman, Angela Sabelli, Daisaki Sasaki Paige Short, Jennifer Stanley, Laura St. John, Rana Youseff

Supplemental Keywords: *Great Lakes, coastal wetlands, environmental indicators, community, fish, macroinvertebrate, high energy shorelines, embayment*

Relevant Web Sites: <http://glei.nrri.umn.edu>

