

2004 Progress Report: Development of Environmental Indicators of Condition, Integrity, and Sustainability in the U.S. Great Lakes Basin

EPA Grant Number: R828675

Title: Development of Environmental Indicators of Condition, Integrity, and Sustainability in the U.S. Great Lakes Basin

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

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

Investigators: Richard P. Axler¹, JoAnn M. Hanowski¹, George E. Host¹, Robert W. Howe², Lucinda B. Johnson¹, Carol A. Johnston¹, John C. Kingston¹, Euan D. Reavie¹, Ronald R. Regal³, Carl Richards⁴, Deborah L. Swackhamer⁵

Cooperators: John R. Kelly⁶, Janet Keough⁶, David Mount⁶, Paul Bertram⁷, John Schneider⁷

Institutions: ¹Center for Water and the Environment, Natural Resources Research Institute, University of Minnesota Duluth; ²University of Wisconsin, Green Bay; ³University of Minnesota Duluth; ⁴Minnesota Sea Grant College Program; ⁵University of Minnesota Twin Cities; ⁶U.S. EPA Mid-Continent Ecology Division, Duluth; ⁷ U.S. EPA Region 5, Chicago, IL

EPA Project Officer: Barbara Levinson

Project Period: January 10, 2001 to January 9, 2005 (Extended to January 9, 2006)

Project Period Covered by this Report: January 11, 2004 to January 9, 2005

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

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

Description:

Objective: The major question being addressed is “What environmental indicators can be developed to efficiently, economically, and effectively measure and monitor the condition, integrity, and long-term sustainability of the coastal region?”

Our specific objectives include:

- identification of environmental indicators that will be useful to define the condition, integrity, and change of the ecosystems within the coastal region,
- testing these indicators with a rigorous combination of existing data and field data to link stressors of the coastal region with environmental responses, and
- recommendation of a suite of hierarchically structured indicators to guide managers toward informed management decisions.

The final product will provide information for managers to communicate with the public on the condition and integrity of the coastal region, to guide development of monitoring programs to measure change, to identify areas in need of restoration or conservation strategies, and to use as key indicators for input into modeling efforts to predict the future of the coastal region.

Approach: The primary focus during the past year has been to complete the processing of field samples, data compilation, data analysis, and the preparation of publications resulting from these efforts. The bird and amphibian group sampled over 600 sites in 2002 and 2003. The fish and macroinvertebrate group sampled 112 sites in 2002 and 2003. The diatom and water quality team has sampled 240 sites from 2001 to 2003. The wetland vegetation group has sampled 86 sites from 2001 to 2003. The contaminants group has sampled 22 sites across the Great Lakes basin. In addition, over 40 sites were visited by each of four project components: fish and

macroinvertebrates, wetland vegetation, bird and amphibian, and diatom groups. Most of the sites sampled by the contaminant group were also sampled by the remaining four groups.

The compilation of data for each subcomponent has been developed through central administration of the project to insure data compatibility and ease of analysis among the study components. In addition, all study components have documented points of sampling using current geopositioning (GPS) instruments to insure spatial integrity and allow visualization of sample sites and overlap. Over 12,000 GPS points have been recorded during field sampling within the coastal region of the Great Lakes.

This co-operative agreement with U.S. EPA Office of Research and Development includes regular conference calls and individual face-to-face meetings on an as-needed basis for each subcomponent. This generally has occurred on a monthly basis and more frequently during the field sampling period (April to September). U.S. EPA Mid-Continent Ecology Division has also coordinating their sampling of the Great Lakes to overlap with our study design. Their primary focus, however, was to examine nutrient gradients in the coastal region of the Great Lakes.

Additional Information: The investigators have given a host of presentations which collectively totals more than 50 this past year. In particular, GLEI investigators made presentations at four major national/international science meetings. These included meetings of the American Society of Limnology and Oceanography, International Association of Great Lakes Research, North American Benthological Society, and the Society of Environmental Toxicology and Chemistry. PI Niemi in collaboration with Dr. Hans Paerl of ACE INC (U of North Carolina) were successful in having an Organized Oral Discussion accepted for the upcoming International Ecological Society and Ecological Society of America meeting in Montreal, Quebec in August 2005. This was a highly competitive process. In addition, about ten presentations were made to managers or the general public.

A major emphasis of current efforts is the preparation of peer-reviewed publications. To date, GLEI investigators have published or have in press 12 papers in peer-reviewed journals and 24 manuscripts are in preparation. In particular, PI Niemi coordinated the publication among all EaGLE lead investigators on a "Rationale for a new generation of ecological indicators for coastal waters (*Environmental Health Perspectives* 112: 979-986, 2004. In addition, PI Niemi was invited to complete a review paper on the "Application of ecological indicators" for *Annual Review of Ecology, Evolution, and Systematics* 35:89-111, 2004. These reviews are among the most-cited papers in ecology in the world. Seventeen graduate students have been involved in GLEI-associated research and nine of these have successfully defended.

Each of the components has been adhering to and refining its quality assurance and quality control objectives. We have requested and have been granted a one-year no-cost extension to the project to January 9, 2006. Budget targets for women and minority owned businesses are also being met.

Progress Summary: The primary focus of the fourth year in what is now a five year effort has been the data compilation, analysis, and summarization of the results to test the hypotheses of stress and response relationships. Field data have continued to verify many of the stress gradients (e.g., nutrients) that we had identified *a priori* with our experimental design. The results of this experimental design was recently published in the journal *Environmental Monitoring and*

Assessment (Vol. 102:41-65, 2005). The details of these efforts are described under each subproject included in this report.

Among the major activities that we have been involved with during the past 6 months is the integration of data among the GLEI subprojects. We have been using a procedure known as hierarchical partitioning to identify the variance explained for several dependent variables (potential ecological indicators) by ecotype (e.g., habitat), lake (e.g., one of the five Great Lakes), ecoprovince (2 in our region), stressors (a combination of land use, pollution, and human population density), and basinwide. We have been exploring this partitioning for each of the subcomponents from the perspective of amphibians, birds, diatoms, fish, insects, and wetland vegetation. We also have incorporated indicators at the species level, compositional level, and function-based indicators. These analyses are critical for a variety of reasons, including the following: 1) to identify the relative merit of using different types of ecological indicators, 2) what is the scale upon which these indicators can be applied such as basinwide or lake-specific, or 3) are these indicators related to stress and at what scale. The preliminary analyses indicate that lake is very important to consider when applying an indicator and ecotype has not been as important as we would have expected.

An all-investigators EaGLE meeting was hosted by the GLEI group this past fall on September 30 to October 2, 2004 in Duluth. An all-investigators meeting of the GLEI investigators was held in September 2004 and another meeting is planned for June 2-3, 2005 in Duluth, MN.

Future Activities: The primary emphases over the next year will include the following 1) complete the compilation and synthesis of the data gathered, 2) continue with the analysis of hierarchical partitioning and other integration analysis among the subcomponents, and 3) prepare presentations and manuscripts for peer-reviewed publications. GLEI investigators will be making presentations at several national/international science meetings this year. These include the Ecological Society of America, the Estuarine Research Federation, International Association of Great Lakes Research, the Society of Environmental Toxicology and Chemistry, and North American Benthological Society.

Publications and Presentations: Total count: 12 published or accepted, 24 submitted or in preparation; presentations; over 102.

Published, in press, and accepted

<u>Type</u>	<u>Citation</u>
Journal	Danz, N.P., R.R. Regal, G.J. Niemi, V.J. Brady, T. Hollenhorst, L.B. Johnson, G.E. Host, J.M. Hanowski, C.A. Johnston, T. Brown, J. Kingston, J.R. Kelly. 2005. Environmentally stratified sampling design for the development of Great Lakes environmental indicators. <i>Environmental Monitoring and Assessment</i> 102:41-65.
Proceeding	Ector L., J.C. Kingston, D.F. Charles, L. Denys, M.S.V. Douglas, K. Manoylov, N. Michelutti, F. Rimet, J.P. Smol, R.J. Stevenson, J.G. 2004. Workshop report. Freshwater diatoms and their roles as ecological indicators. Proceedings of the 17 th International Diatom Symposium 2002, Ottawa, Canada (M. Poulin, ed.), pp.469-480, Biopress Limited, Bristol.
Journal	Grigorovich, I., E. Mills, C. Richards, D. Breneman, J. Ciborowski. 2005. European valve snail <i>Valvata piscinalis</i> (Müller) in the Great Lakes basin. <i>Journal of Great Lakes Research</i> 31:135-143.

- Journal Grigorovich, I.A., M. Kang, and J.J.H. Ciborowski. 2005. Establishment of the invasive amphipod *Gammarus tigrinus* Sexton in Saginaw Bay, Lake Huron. *Journal of Great Lakes Research*. Accepted with minor revisions.
- Journal Johnston, C.A. 2003. Shrub species as indicators of wetland sedimentation. *Wetlands* 23:911-920. (Funded by completed EPA Grant No. R804823, but related to the current research)
- Journal Johnston, CA, P Meysembourg. 2002. Comparison of the Wisconsin and National Wetlands Inventories. *Wetlands* 22:386-405.
- Journal Kercher, Suzanne M., Christin B. Frieswyk, and Joy B. Zedler. 2003. Quality control approaches reveal effects of sampling teams and estimation methods for assessing plant cover in temperate herbaceous wetlands. *Journal of Vegetation Science* 14:899-906.
- Journal Niemi, G.J., D. Wardrop, R. Brooks, S. Anderson, V. Brady, H. Paerl, C. Rakocinski, M. Brouwer, B. Levinson, M. McDonald. Rationale for a new generation of ecological indicators for coastal waters. *Environmental Health Perspectives* 112(9):979-986.
- Book Chapter Niemi, G.J., J.M. Hanowski, N. Danz, R. Howe, M. Jones, J. Lind, D. Mladenoff. 2004. Hierarchical scales in landscape responses by forest birds. In *Landscape Ecology and Wildlife Habitat Evaluation: Critical Information for Ecological Risk Assessment, Land-Use Management Activities, and Biodiversity Enhancement Practices, ASTM STP 1458*, L.A. Kapustka, H. Gilbraith, M. Luxon, and G.R. Biddinger, Eds., American Society for Testing and Materials, West Conshohocken, PA.
- Journal Niemi, G.J., M. McDonald. Application of ecological indicators. *Annual Review of Ecology, Evolution, and Systematics* 35:89-111.
- Journal Price, S.J., D.R. Marks, R.W. Howe, J. Hanowski, G.J. Niemi. The importance of spatial scale for conservation and assessment of anuran populations in coastal wetlands of the western Great Lakes. *Landscape Ecology*. In press.
- Journal Sgro G.V., Ketterer M.E., Johansen J.R. 2005. Ecology and assessment of the diatom communities of four Lake Erie estuaries using lange-Bertalot Tolerance Values. *Hydrobiologia* (accepted).
- Book Chapter Zedler, J.B. and K.W. Potter. 2005. Southern Wisconsin herbaceous wetlands. In Don Waller and Tom Rooney. *Vanishing present*. University of Wisconsin Press.

Submitted and in preparation

- Journal Adams, A. D.; Lehr, R. A.; Swackhamer D. L.; Diamond, S. A.; Mount D. R.; Simcik, M. F. Measuring attenuation of ultraviolet-A radiation in Great Lakes coastal ecosystems: implications for photo activation of polycyclic aromatic hydrocarbons. *Journal of Great Lakes Research*. Submitted.
- Journal Axler, R., J. Henneck, A. Kireta, J. Sgro, J. Kingston. Surrogate water quality indicators for use in monitoring the Great Lakes coastal zone. *Environmental Monitoring and Assessment*. In preparation.
- Journal Bhagat, Y., J.J.H.Ciborowski, L.B. Johnson, V. Brady, D. Breneman, J. Schuldt, T. Hrabik, C. Richards, D. Uzarski, T. Burton. Testing a fish index of biotic integrity for Great Lakes coastal wetlands: stratification by plant zones. In preparation for submission to *Canadian Journal of Fisheries and Aquatic Sciences*, summer 2005.
- Journal Brady, V., J. Ciborowski, J. Holland, N. Danz, L. Johnson, D. Breneman, J. Gathman, T. Hrabik, J. Schuldt. Optimizing fishing time: One vs. two night fyke

- net sets in Great Lakes coastal systems. In preparation for submission to *Transactions of the American Fisheries Society*, May 2005.
- Journal Brazner, J.C., N.P. Danz, G.J. Niemi, R.R. Regal, J.M. Hanowski, C.A. Johnston, E.D. Reavie, A.S. Trebitz, L.B. Johnson, R.W. Howe 2005. Assessing the condition of Great Lakes coastal wetlands using multiple taxonomic groups: geographic and geomorphic influences. In preparation for submission to *Ecological Applications*, June 2005..
- Journal Breneman, D.B., T. Hrabik, J. Schuldt, L.B. Johnson. Effects of landscape-scale stressors on size class distribution of Great Lakes nearshore fish communities. In preparation for submission to *Canadian Journal of Fisheries and Aquatic Sciences*, August 2005.
- 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 *Ecological Applications*.
- Journal Danz, N.P., G.J. Niemi, R.R. Regal, V.J. Brady, L.B. Johnson, T. Hollenhorst et al. Human disturbance gradients in the U.S. Great Lakes. In preparation.
- Journal Foley, C., D. Breneman, J.J.H. Ciborowski, J.P. Gathman, V.J. Brady, L.B. Johnson., C. Richards. The associations between larval Odonata and habitat structure as indicators of anthropogenic stress in great lakes coastal margin wetlands. In preparation for submission to *Freshwater Biology*, summer 2005.
- Journal Frieswyk, C.B., C.A. Johnston, J.B. Zedler. In revision. Measuring dominance among co-occurring plants. Submitted to *Ecological Applications*.
- Journal Grandmaison, D.D., G.J. Niemi. Landscape influence on Red-winged Blackbird (*Agelaius phoeniceus*) nest success in Great Lakes coastal wetlands. *The Auk*. Submitted.
- Journal Foley, C., D. Breneman, J.J.H. Ciborowski, J.P. Gathman, V.J. Brady, L.B. Johnson., C. Richards. The associations between larval Odonata and habitat structure as indicators of anthropogenic stress in great lakes coastal margin wetlands. In preparation for submission to *Freshwater Biology*, Summer 2005.
- Journal Hanowski, J., R. Howe, G. Niemi. Sampling effectiveness of calling anuran surveys. In preparation.
- Journal Hanowski, J., R. Howe, R. Regal, G. Niemi, N. Danz. Quantifying sources of variability in wetland breeding bird surveys; effects on sampling design. In preparation.
- Journal Hanowski et al. Consideration of geography and wetland geomorphic type in the development of Great Lakes coastal wetland bird indicators. In review in *Ecohealth*
- Journal Hanowski et al. Species-specific sampling effectiveness of calling anuran surveys in Lake Superior wetlands. In review in *Copeia*
- Journal Holland, J., J.J.H. Ciborowski, L.B. Johnson, T. Hollenhorst. The spatial scale of fish indicator responses in Great Lakes coastal regions. In preparation for submission to *Canadian Journal of Fisheries and Aquatic Sciences*, June 2005.
- Journal Howe, R.W., R.R. Regal, G.J. Niemi, N.P. Danz, J. M. Hanowski. A probability-based indicator of ecological condition. In preparation.
- Journal Hrabik, T.R., D.B. Breneman, L.B. Johnson, J. Schuldt, C. Richards, J. Ciborowski, V. Brady, Y. Bhagat. Variability in the trophic structure and diversity of fish assemblages in Great Lakes wetlands: the influence of anthropogenic

- stressors and land use information. In preparation for submission to *Journal of Great Lakes Research* or *Canadian Journal of Fisheries and Aquatic Sciences*.
- Journal Johnson, L.B., T. Hollenhorst, G. Host, C. Richards. Scale effects in mapping riparian zones. In preparation for submission to *Landscape Ecology*.
- Journal Johnson, L.B., J.A. Schuldt, V. Brady, D. Breneman, G.E. Host, C. Richards. Comparison of fish communities in reference and non-reference coastal Great Lakes wetlands. In preparation for submission to *Canadian Journal of Fisheries and Aquatic Sciences*, August 2005.
- Journal Kang, M., J.J.H. Ciborowski, L.B. Johnson, T. Hrabik, C. Richards, J. Schuldt. The relationship between anthropogenic disturbance and the distribution of a nonindigenous species, *Echinogammarus ischnus* Stebbing, 1898 (Amphipoda: Gammaridae), at Great Lakes coastal margins. In revision for submission to *Oecologia*, June 2005.
- Journal Lehr, R.A., Adams, A., Simcik, M., Ankley, G., Swackhamer, D.L. Effects of carrier solvent selection on the Vitellogenin (Vtg) mRNA response in male fathead minnows (*Pimephales promelas*). Draft completed.
- Journal Lehr, R.A., Adams, A., Simcik, M., Ankley, G., Swackhamer, D.L. Linking exposure and effect for environmental estrogens: the exposure-effect paradox. Draft completed.
- Journal Lehr, R.A., Adams, A., Simcik, M., Ankley, G., Swackhamer, D.L. Managing environmental estrogens in aquatic ecosystems. Draft completed.
- Journal Miller, C.M., G.J. Niemi, J.M. Hanowski, R.R. Regal. Effects of anthropogenic development on breeding bird abundance and communities. *The Auk*. In preparation.
- Journal Trebitz, A., J. Brazner, V. Brady. Turbidity tolerances of Great Lakes wetland fishes. In preparation for submission to *Canadian Journal of Fisheries and Aquatic Sciences*, May 2005.
- Journal Stoermer, E.F., J.L. Pappas. Atypical *Tabularia* in coastal Lake Erie. For submission to *Diatom Research*. In preparation.

Training Future Scientists (to date)

Undergraduate interns: 48

Undergraduate honors theses: 3

Graduate students: 36

Graduate student projects: 17

Graduates defended: 9

Undergraduate Theses Students

Andriash, K. Contrasting zoobenthic community composition in riverine vs. protected wetlands of the Great Lakes coastal margins. GLEI Hon BSc thesis. In preparation.

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

Ladwig, L. 2004. *Typha x glauca* and *Phragmites australis* expansion in Peter's Marsh, Wisconsin. Senior thesis. Department of Botany, University of Wisconsin-Madison.

Master's Theses Students

Adams, A. Photo-enhanced toxicity of polycyclic aromatic hydrocarbons to larval fish in the coastal Great Lakes. GLEI MS thesis. In preparation.

Bhagat, Y. Classifying fish communities to assess environmental condition at Great Lakes shorelines: a comparison of multimetric and multivariate approaches. MS thesis, University of Windsor. In preparation.

Bourdagh, M. 2004. Properties and Performance of the Floristic Quality Index in Great Lakes Coastal Wetlands. GLEI MS thesis. Current position: Works for the Minnesota Pollution Control Agency.

Ferguson, M. Analysis of the benthic diatom flora in variable habitat regions of the Laurentian Great Lakes. MS thesis. John Carroll University, Cleveland, Ohio. In preparation.

Grandmaison, D. 2003. Landscape factors affecting productivity of breeding birds in Great Lakes coastal wetlands. MS thesis. University of Minnesota Duluth.

Johnson, C. 2003. Predicting the vegetational composition of a wetland created from dredged material in Duluth-Superior Harbor. MS thesis. University of Minnesota Duluth

Kang, M. 2004. The invasibility of stressed sites by exotic benthic macroinvertebrates in the Great Lakes: a test of hypotheses using *Echinogammarus ischnus*. MS thesis. University of Windsor, Ontario, CA.

Marks, D. 2003. Habitat and landscape associations of breeding birds in Great Lakes coastal wetlands. University of Wisconsin-Green Bay. 123 pp.

Miller, C. 2003. Effects of anthropogenic development on breeding bird abundance and communities. University of Minnesota Duluth.

Peterson, A. 2005. Evaluation of the Ohio rapid assessment methods on wetlands of the Great Lakes basin: a comparative analysis of bird assemblages and wetland quality. University of Minnesota Duluth. In preparation.

Price, S. Anuran-habitat associations in coastal wetlands of the western Great Lakes. University of Wisconsin-Green Bay. 2003. 85 pp.

Yanko, K. 2002. An analysis of the benthic diatom flora of the Laurentian Great Lakes, and their use as indicators of water quality. GLEI MS thesis. John Carroll University, Ohio, 156 pp.

PhD Dissertations

Boers, A. The effects of hydroperiod manipulation on wetland nutrient dynamics and invasion by *Typha x glauca*. GLEI PhD dissertation, University of Wisconsin-Madison. In preparation.

Frieswyk, C. Ecosystem resilience and the behavior of *Typha* species in Lake Michigan coastal wetlands. GLEI PhD dissertation. In preparation.

Iverson, K. GIS-derived indicators of wetland vegetation condition. GLEI PhD dissertation, South Dakota State University. In preparation.

Kang, M. The influence of entry sequence on invasion success and the importance of scale for biotic resistance to biological invasion. PhD thesis, University of Windsor. In preparation.

Lehr, Randy A. 2005. Assessment and Management of Environmental Estrogens. PhD thesis, Water Resources Science, University of Minnesota. 175 pp.

Vaccaro, Lynn. Understanding a wetland's vulnerability to invasion: A comparison of *Typha* production, nutrient use and decomposition in distinct hydrogeologic settings. GLEI PhD dissertation. In preparation.

Postdoctoral Fellows

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.

Supplemental Keywords: coastal, disturbance, indicators, Great Lakes, stress, water, landscapes, amphibians, birds, contaminants, diatoms, fish, insects, vegetation, wetlands, macrophytes

Relevant Websites: <http://glei.nrrl.umn.edu>