2004 Progress Report: Great Lakes Diatom and Water Quality Indicators

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Center Director: Gerald J. Niemi
Title: Great Lakes Diatom and Water Quality Indicators
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EPA Project Officer: Barbara Levinson
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Research Category: Ecological Indicators/Assessment/Restoration

Description:

Objective: To quantify the extent to which pressure indicators influence diatom community structure in nearshore wetlands, estuaries, and reaches of the Laurentian Great Lakes including the following.

1. Develop predictive models through multivariate analyses of communities and ecosystems to:
   a. infer ecological status at local and regional scales, and
   b. describe pre-disturbance-to-recent baselines, trends, and magnitudes of change in restricted river-influenced and other wetlands.
2. Evaluate and modify existing diatom metrics, and devise and validate new diatom metrics, so that a number of state indicators for nutrient loading, siltation, and salinity in nearshore waters of the Great Lakes will be available to federal and state agencies.
3. Construct multimetric diatom indices from the best of these state or condition metrics.
4. Develop integrated indices of biotic integrity based on a combination of selected metrics developed in the diatom subprogram and by other teams in the larger program.
5. Develop a QA/QC infrastructure for the diatom subprogram and future assessment efforts.
6. Conduct a limited water quality survey (field and lab measurements) of nearshore sites contemporaneously with diatom sampling to:
   a. calibrate diatom indices,
   b. further characterize sampling sites for all GLEI subprojects and related EPA MED Great Lakes coastal wetlands projects,
   c. evaluate the efficacy of several relatively inexpensive, field-friendly measurements as surrogates for more expensive analytes typically used to characterize water quality.
Progress Summary: Our efforts in the past year have centered on three major tasks.

1. The assessment of all diatom samples was completed and data have been entered into a temporary (Excel) database for data analysis and formatting for eventual incorporation into the master GLEI database.

2. Several preliminary statistical evaluations of the diatom and environmental data were performed to provide guidance on upcoming indicator development. Initial diatom-environmental investigations show that the diatom indicators will yield robust models and multimetric indices for assessing environmental stress in coastal environments.

3. We completed the analysis, quality assurance and GLEI database entry for all field data documenting site characterization and condition. Several exploratory analyses have been completed relating water quality to segment shed stressors and for the development of surrogate, cost-effective water quality parameters.

Expected Results:
The research will develop and evaluate indicators by local habitat, by lake, by ecoregion, and by stressor activity/intensity. The diatom project will provide linkages from ecosystem function to water quality and to pressure indicators documented by other subproposals. We are confident that a suite of powerful diatom indicators can be developed for key pressure indicators for use throughout the Great Lakes basin.

Progress:
The PI of the diatom component of GLEI has transitioned to Euan Reavie. As a result of John Kingston’s illness and eventual passing away in June 2004, analytical effort was delayed on the diatom work, and Reavie’s primary goal for the year was to catch up and meet predefined goals in the GLEI agenda. For this reason, about 75% of our GLEI effort in 2004 was allocated to the identification and enumeration of remaining diatom samples. Despite setbacks, significant progress has been made in the last year.

Field work: All field work was completed in 2003. Diatom and water quality samples were collected from approximately 240 segment sheds of shoreline from 2001-2003 distributed across the U.S. shoreline of all 5 Great Lakes and 5 geomorphic units. The sampling effort generated >500 discrete water samples that were analyzed in the laboratory for nutrients, chlorophyll, suspended solids, DOC, chloride and several other parameters. At least 4 times that number of samples was also analyzed in the field for additional water quality characteristics.

Sample assessment: Diatom samples were processed at NRRI-Ely (upper lakes) and JCU (lower lakes mostly). Water quality analyses were performed at the NRRI – UMD Central Analytical Laboratory in Duluth, MN with the exception of DOC (dissolved organic carbon) which was graciously analyzed by EPA-MED in Duluth and certain field measurements. Databasing activities were coordinated at NRRI -UMD, and data entry via the Web has been developed to provide unified methods for entry and suitable quality control of the procedures.

As of March 2005 all diatom samples have been assessed for species composition and abundance, and data have been entered into a temporary Excel database for data analysis and formatting (for eventual incorporation into the master GLEI database). Taxonomic collaborations have been ongoing to ensure taxonomic harmony between researchers enumerating diatoms at the three universities.
All water samples have now been analyzed, quality assured and entered into the GLEI database. Field profiles of temperature, DO and specific electrical conductivity (EC25), secchi and transparency tube depth, pH, turbidity and soluble and particulate “chlorophyll”- fluorescence were also entered into the database. Metadata are being created for all parameters along with a set of queries to expedite retrieval of appropriate data sets for various statistical analyses. Field data (mostly temp, DO, and EC25) collected by the Fish-Invertebrate Subproject were added to the larger Diatom subproject dataset as well as EPA-MED field and lab water chemistry data from their 2002-2003 wetland and high energy sites. Since a common experimental unit, the “segment-shed” was used for all four subgroup studies, and similar methodology and QA/QC protocols, combining the data should provide us with better estimates of interannual and seasonal variation. Additional field and lab physical and chemical data is now being processed from the deepwater surveys collected in collaboration with EPA Great Lakes cruises in 2002 and 2003.

Diatom - stressor relationships - Significant relationships between surficial taxa and water chemistry (total phosphorus concentration) were found from the diatom samples analyzed as of September 2004. These preliminary results (Figures 2, 3, 4) reflect the strong indicator potential for the diatoms. At this time, these methods are being expanded to develop the diatoms as a more general indicator of pollution (i.e., an index providing a more holistic integration of stressors, including nutrients, salinity and water clarity). The same approach will also be evaluated using the diatom genera, to test the feasibility of an indicator-based tool that would provide more rapid and user-friendly assessments when a detailed, species-based approach is not feasible. These diatom-based tools will be developed and tested for the entire Great Lakes system and for particular habitats (wetlands, high energy shorelines, bays) so that the most appropriate model may be selected.

Water chemistry - stressor relationships - Exploratory analyses have begun to examine the relationship between GLEI-measured coastal zone water quality and segment shed stressors computed from the statistical analysis of 207 GIS data layers for the Great Lakes coastal zone (Figure 5). This analysis was conducted for determining the stressor gradients used for establishing the GLEI sampling design and so is being used for preliminary analyses until the final segment shed-specific stressors are calculated. Over the next few months results using the stressor value – WQ relationships computed from the segment shed analysis for the purpose of site selection will be compared to the “final” stressor values that are being computed based on hydrology/watershed analyses.

Surrogate water quality indicators - Lab water chemistry analyses are expensive and the coastal zones are extremely variable. The GLEI diatom water quality group is evaluating the efficacy of relatively inexpensive, field-friendly measurements as surrogates for more expensive analytes typically used to characterize coastal zone water quality (e.g., Figure 6). These include a new field-instrument for algal-fluorescence and turbidity, specific conductivity, optical color, and transparency tube clarity. All can be used in existing agency monitoring programs but also could easily be adapted to existing models for stream and lake volunteer monitoring programs. Such data should also be useful for ground-truthing (calibration) of satellite or aircraft remote sensing data. Several exemplary plots are included.

Future Activities: The project is now focused on
1. developing diatom-based models and multimetric indices;
2. quality assessment of diatom sampling and taxonomic methods;
3. integrating all available water quality data into the GLEI database (diatom, fish-invert, and EPA-MED collaborators) for all subprojects to use;
4. analysis of “surrogate” measures of water quality such as EC25, turbidity, color and particulate and filtrate fluorescence;
5. exploratory analysis of relationships between landscape-scale stressors and coastal zone water quality; and
6. drafting manuscripts based on results of the preceding goals.

**Publications and Presentations**

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<tr>
<td>Presentation</td>
<td>Stoermer, E.F. Importance of physical factors in determining diatom occurrence and distribution in large lakes. 18th International Diatom Symposium, Mięzyzdroje, Poland, 2-7 September 2004.</td>
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| Presentation  | Sgro G.V., Yanko, K.S., Johansen, J.R., Kingston, J.C., Kireta, A., Axler, R.A. A

Theses


Workshops
13-14 September 2004. GLEI data conference, NRRI. Attendees: All GLEI PIs.

Supplemental Keywords: diatoms, algae, water quality, metrics, multimetric indices, nutrients, salinity, siltation, Great Lakes, coastal wetlands, environmental indicators

Relevant Web Sites: http://glei.nrri.umn.edu
Figure 1. Diatom/chemical sample locations.
Figure 2. A multivariate analysis (canonical correspondence analysis (CCA) using forward selection and Monte Carlo permutation tests) was employed to determine which environmental variables explained variance in the diatom assemblages. Diatom assemblage composition exhibited strong responses across the gradients of eight of the measured variables. Selected environmental variables that can reflect “stress,” such as nutrients, are suited to diatom-based indicator approaches. The CCA biplot below illustrates the forward-selected variables that had strong relationships to patterns in the diatom assemblages. A reconstructive model was developed for total phosphorus to evaluate this approach.
Figure 3. Diatom responses to total phosphorus (TP). Weighted average regression was used to determine diatom species relationships to TP. The weighted average method assumes a unimodal response of the diatoms along the environmental gradient, so each species is assigned an optimum and a tolerance for TP. Subsequently these weighted average optima and tolerances could be used to infer TP concentrations for a study site with weighted average calibration.
Figure 4. diatom-TP model testing. By comparing measured to diatom-inferred TP concentrations, the power of the model can be tested. The root mean square error (RMSE) provides a measure of the model’s predictive ability. These results indicate a strong relationship between diatoms and stressor-related variables in Great Lakes coastlines, and that diatom assemblages may be used to infer environmental conditions. Although this evaluation focuses on total phosphorus, additional proxies of ecological stress are also being evaluated.
Figure 5. Statistically significant relationships for Great Lakes coastal wetlands between four water quality parameters and the first principal component of the agricultural variables. Increasing values on PC1 indicate increasing agriculture, especially nitrogen and phosphorous applications.
Figure 6. Preliminary regression analyses to evaluate cost-effective, field-friendly surrogates (e.g., transparency tube measurements) for more expensive analytes (e.g., suspended solids).