Student
April11th, 2010
Proposal Draft 2

A comparison of survey methods to evaluate macrophyte index of biotic integrity performance in Minnesota lakes

Introduction

Aquatic plants, or macrophytes, are an important component of a healthy aquatic ecosystem. Macrophyte communities intricately shape trophic web dynamics by providing oxygen, food, and shelter to macroinvertebrates, fish, and waterfowl. Additionally, aquatic vegetation contributes substantially to nutrient retention, sediment stabilization, and water clarity (Valley et al. 2004). Given the influence of macrophytes on the structure and function of aquatic ecosystems, aquatic plant assemblages should not be overlooked by water resource managers.

In the United States, the restoration and maintenance of the chemical, physical, and biological integrity of the nation's waters is mandated by the Clean Water Act of 1972 (33 U.S.C. 1251). The specific legal requirement to maintain the biological integrity of aquatic systems cannot be fulfilled without directly assessing the biota. Current methods of evaluating the health of water resources largely ignore this requirement and instead rely heavily on proxies such as trophic state indices and point-source pollution protocols such as Total Maximum Daily Load standards (Beck and Hatch 2009). Minnesota is in an ideal position to expand upon these traditional methods of ecosystem health assessment by adopting the use of macrophytes as bioindicators. The recent development of a macrophyte-based index of biotic integrity (Beck et al, in press) and the passage of a 2008 Minnesota constitutional amendment (H.F. 2285) that created funding for the restoration, protection, and enhancement of aquatic habitats could facilitate a step forward in biological assessment methods.

Indices of biotic integrity (IBIs) are useful because they incorporate several indicators of ecosystem degradation into a single index (Karr 1991). In Minnesota, the utility of standardized multimetric measurements has been recognized and the implementation of IBIs in water resources management has been mandated by law (7050.0150). Since macrophytes are immobile, relatively easy to sample and identify, and respond to environmental stressors on an ecological time scale, they are well-suited as indicators of ecological health (Nichols 2000, Clayton and Edwards 2006, Beck and Hatch 2009). Using Wisconsin's established aquatic macrophyte community index as a template (Nichols 2000), Beck et al. (in press) developed a macrophyte-based IBI for Minnesota lakes. In order to measure biological condition, multiple attributes of macrophyte communities (relative frequencies of submersed, sensitive, and tolerant species, number of native plant taxa, number of species with relative frequency over 10%, percentage of the littoral area vegetated, and depth at which 95% of macrophyte growth occurs) were examined in relation to natural and anthropogenic disturbances (Beck et al., in press).

In order for widespread adoption of the Minnesota macrophyte-based IBI to be efficient, it should be integrated into existing macrophyte survey protocols. Currently, macrophyte surveys are carried out by both the Ecological Services division and the division of Fish and Wildlife within the Minnesota Department of Natural Resources (DNR). DNR Ecological Services staff have completed over 200 surveys since 1999 using a grid-based point-intercept (PI) method, while DNR Fisheries staff have completed over 1500 surveys since 1992 primarily using a modified belt-transect method (Reshke et al. 2006). In the former method, a predefined grid of evenly spaced points is overlaid across the entire lake area, and each point that falls within the littoral zone is navigated to by boat and sampled using a double-headed rake. Plant species are indentified and their presence or absence at each point is recorded (Madsen 1999). The belt-transect survey method is similar to this, except sample points are instead arranged along transects at set intervals. The number of transects is determined by lake surface area, and transects are positioned parallel to the shoreline at equal distances around the lake's perimeter (Anonymous 1993).

Although PI survey methods provide quality data across the entire littoral area of a lake, they are labor intensive and may work best for specific objectives such as monitoring macrophyte communities before and after herbicide treatment. Transect surveys do not represent whole-lake macrophyte communities as accurately, but do require less sample effort. The Minnesota macrophyte-based IBI was developed from PI surveys and its performance has not yet been evaluated using other survey methods. However the potential effects of decreasing sample effort on survey data have been investigated (Beck et al., in press, Mikulyuk et al. 2010). Mikulyuk et al. (2010) reported that estimations of species richness responded significantly to a reduction in sampling effort, but other attributes such as the relative frequency of dominant species, maximum depth of plant growth, and percentage of littoral area vegetated were less dependent on sampling intensity. Additionally, although species richness estimates based on lowered sample effort significantly underestimated actual measures of richness, estimations were reported to differ in a predictable manner (Mikulyuk et al. 2010). If actual estimates of indicators of biological integrity can be accurately predicted by measures made at a reduced sampling intensity, there is potential to increase the efficiency of widespread assessment of aquatic ecological health using macrophytes.

Developing an understanding of the performance of the Minnesota macrophyte-based IBI across PI and belt-transect survey methods will reveal how the IBI behaves at reduced sampling effort. This is important for (1) informing the most efficient and accurate wide-spread implementation of the macrophyte-based IBI, (2) evaluating the feasibility of incorporating the IBI into existing DNR Fisheries macrophyte surveys, and (3) assessing the possibility of calculating meaningful IBI scores from historical data to better document natural and anthropogenic changes in ecosystem integrity.

Proposed Research

Research Question:

Can the Minnesota macrophyte-based IBI provide accurate and precise results using data from belt-transect surveys?

Hypotheses:

- Measures of biological condition calculated from transect survey data will be less accurate than those calculated from PI survey data because of reduced sampling intensity.
- Given that PI surveys are composed of multiple transects spanning the entire lake area, there will be a threshold where a reduced number of transects will yield predictable IBI scores.
- Individual IBI metrics will respond differently to reduced sampling effort because of unique data requirements.
    - IBI metrics that measure the relative frequency of sensitive species and richness will increase as sampling effort increases because the likelihood of sampling rare macrophytes increases with sampling effort.
    - IBI metrics that measure the relative frequency of submersed species and the depth at which 95% of macrophyte growth occurs will increase as sampling

effort increases because the likelihood of sampling macrophytes growing under specific conditions increases with sampling effort.

  - IBI metrics that measure the relative frequency of tolerant species, the number of species with relative frequency over 10%, and the percentage of littoral area vegetated will decline as sampling intensity increases past a certain level because these metrics will be overrepresented at reduced sampling effort.

Objectives:

- Simulate transect surveys at multiple levels of sampling effort and calculate respective IBI scores and scores of individual IBI metrics
- Compare IBI scores calculated from lake-wide PI surveys to those calculated from simulated transects
- Determine the level of sampling effort where IBI scores from both survey methods are comparable at a known level of confidence
- Establish if accurate lake-wide IBI scores can be calculated from standard MN DNR fisheries transect surveys

Tentative Methods:

- Obtain macrophyte survey data from the MN DNR
  - Abide by any data handling requirements
  - Use the same 97 lakes which were used in the development of the Minnesota macrophyte-based IBI (Beck et al., in press)
  - I have already received point intercept survey data for all 97 lakes and GIS shapefiles for 3 lakes from Marcus Beck (U. Minnesota), but still need to obtain shapefiles for the remaining 94 lakes
- Simulate belt-transect surveys from grid-based point-intercept survey data using ArcGIS
  - Generate transects that are parallel to shoreline whose starting points are equally spaced around the perimeter of the lake; the starting point of the first transect will be randomly placed along the shoreline
  - Overlay simulated transects on PI data; extract data from each point that is intersected by transects to represent a simulated modified belt-transect survey

- Simulate transect surveys over a range of sampling effort depending on lake size (10%, 50%, 100%, 150%, and 200% of the recommended number of transects for a particular lake size as outlined in Madsen (1999))
- Perform 5 replicates of the simulated transect surveys at each level of sampling effort (25 per lake) by shifting the starting point of the first transect X meters clockwise depending on distance between transects

- Calculate IBI scores and raw IBI metric scores from each simulated transect survey using a program written by Marcus Beck (U. Minnesota) in R
- Compare IBI metrics and scores calculated from simulated transect surveys at different levels of effort to those calculated from PI surveys using Monte Carlo or bootstrapping methods of resampling a sample

Literature Cited

Anonymous. 1993. Lake Survey Manual. Saint Paul (MN): Minnesota Department of Natural Resources, Section of Fisheries, Special Publication 147.

Beck MW, Hatch LK. 2009. A review of research on the development of lake indices of biotic integrity. Environ Rev. 17:21–44.

Beck MW, Hatch LK, Vondracek B, Valley RD. In press. Development of a macrophyte-based index of biotic integrity for Minnesota lakes. Ecol Indicat.

Clayton J, Edwards T. 2006. Aquatic plants as environmental indicators of ecological condition in New Zealand lakes. Hydrobiologia 570:147-151.

Karr JR. 1991. Biological integrity: a long-neglected aspect of water resource management. Ecol Appl. 1:66-84.

Madsen JD. 1999. Point intercept and line intercept methods for aquatic plant management. Aquatic Plant Control Technical Note MI-02, U.S. Vicksburg (MS): Army Engineer Waterways Experiment Station.

Mikulyuk A, Hauxwell J, Rasmussen P, Knight S, Wagner KI, Nault ME, Ridgely D. 2010. Testing a methodology for assessing plant communities in temperate inland lakes. Lake Reserv Manage. 26(1):54-62.

Nichols S, Weber S, Shaw B. 2000. A proposed aquatic plant community biotic index for Wisconsin lakes. Environ Manage. 26:491-502.

Reshke C, Host GE, Johnson LB. 2006. Evaluation of DNR aquatic vegetation surveys: data summaries and comparative analysis. Natural Resources Research Institute, Duluth (MN): unpubl.

Valley RD, Cross TK, Radomski P. 2004. The role of submersed aquatic vegetation as habitat for fish in Minnesota lakes, including the implications of non-native plant invasions and their management. Saint Paul (MN): Minnesota Department of Natural Resources Special Publication.

General Thesis Information

Thesis Committee:

1) Joel Carlin, assistant professor of biology, Gustavus Adolphus College (Committee Chair)
2) Carolyn Dobler, professor and chair of mathematics and computer science department, Gustavus Adolphus College
3) Marcus Beck, PhD student, conservation biology graduate program, University of Minnesota

Background:

Since the summer of 2008, I have been working as an aquatic herbicide applicator for Lake Management Inc. and have become increasingly interested in aquatic ecosystem health. Last fall, I took Bio 383 Aquatic Biology with Dr. Carlin and was acquainted with Marcus Beck's work on developing a macrophyte-based IBI for Minnesota Lakes. I contacted Marcus and inquired about possible research questions I could investigate that would help to support his work, and he agreed to meet with me and discuss possible projects. In early March 2010, I attended the Minnesota joint meeting of the American Fisheries Society, Society for Conservation Biology, The Wildlife Society, and the American Society of Foresters. I met with Joel and Marcus at this meeting to come to an agreement on a feasible research topic. Recently I met with Marcus and his advisor (Bruce Vondracek) at the U of Minnesota and acquired further guidance, background literature, and macrophyte survey data.

Potential Deadlines*:

Oct 20, 2010	Oral data review & data backup (first round to committee chair)
Nov 1, 2010	Literature review (first draft to committee chair)
Dec 1, 2010	Literature review (second draft to entire committee)
Mar 1, 2011	Oral data review & data backup (second round to committee chair)
Mar 3, 2011	Complete thesis outline (first draft to committee chair)
Mar 7, 2011	Complete thesis outline (second draft to entire committee)
Mar 16, 2011	Complete thesis (first draft to committee chair)
Apr 4, 2011	Complete thesis (second draft to committee chair)
Apr 11, 2011	Complete thesis (third draft to entire committee)
May 2, 2011	Oral exam (entire committee must be present)
May 4, 2011	Complete thesis *revised* (fourth draft to entire committee)
May 4, 2011	Thesis summary (to biology department secretary)

*These deadlines must be agreed upon by the entire committee and can be changed with permission of the committee and two weeks' prior notice.

To be written in the style of a publishable manuscript for a specific journal:

Journal	Lake and Reservoir Management
Style	As stated by the Instructions for Authors of Lake and Reservoir Management, otherwise in CSE- 7th edition
Spacing, Margins, Font	Double, 1 inch, 12 pt Times New Roman
Electronic or Hardcopy	Electronic
Total thesis length (including references, figures, tables, and appendices)	Approximately 25 pages
Introduction length	No set requirements
Location of Figures and Tables	After body and references
Appendices of data required	No, but accepted for online version

Time commitment:

Over the course of fall semester, January term, and spring semester (2010-2011), I will dedicate an average of 10 hours per week to relevant research, writing a thesis, and preparing for presentations and the oral examination. Depending on the reliability and speed of my analyses, I will further my research by calculating IBI scores from historical vegetation survey data. These historical estimates will be used to explore additional issues, such as long-term macrophyte community changes in lakes subject to differing management practices.

Presentation of work:

At the very least, I will present my research at the Gustavus Adolphus College Celebration of Creative Inquiry (April 2011) and at a monthly Tri Beta meeting. Additionally, depending on my results, I would also like to present at a professional venue such as the 2011 annual MN chapter meeting of the American Fisheries Society meeting or the 2011 Minnesota Shallow Lakes Forum (dates TBA).

Authorship and Acknowledgment:

Advising in research ethics will be provided by Dr. Carlin, including the handling of data and the dissemination of results. As part of this effort, credit for committee members, myself, and others will be discussed and agreed upon by the entire committee.