Analysis of macrophyte indicator variation as a function of sampling, temporal, and stressor effects

Marcus W. Beck, Cynthia M. Tomcko, Ray D. Valley, David F. Staples

University of Minnesota, Minnesota Dept. of Natural Resources, St. Paul, MN

Abstract

Eight macrophyte indicators were estimated in 23 Minnesota (USA) lakes using four years of surveys to quantify sampling and temporal variation, response to development (phosphorus) and climate stress (growing degree days), and power to detect significant change at various annual sampling intervals. Indicators included a macrophyte index of biotic integrity, floristic quality index, maximum depth of growth, total species richness, common species richness, species per survey point, and frequency occurrence of rooted species and Chara sp. Regression and smoothed additive models indicated significant relationships of indicators to lake phosphorus and mean annual growing degree days. The macrophyte index of biotic integrity, floristic quality index, and the frequency rooted species had minimal sampling variation, were responsive to development or climate stress, and had low annual variation resulting in high to moderate power for detecting significant change. Results from these analyses will facilitate the use of precise and powerful indicators that respond to stressors that are of concern for the management of freshwater glacial lakes.

Objectives

- Quantify variation of indicators within and among lakes
- Identify patterns in variation related to total phosphorus and annual growing degrees days
- Quantify minimum sampling effort necessary for power to detect change over a finite period of observation

Data

Surveys were completed in 23 lakes each summer from 2008 to 2011, eight indicators were estimated

Figure: Locations of 23 survey lakes, sampled every four years.

Figure: Example of aquatic plant survey used to estimate indicators.

First Objective

Substantial variation of indicators was observed within and among the 23 lakes across four years

Figure: Estimated indicator values by lake for four years, colored by mean values between years and each indicator.

Figure: Spatial variation in mean indicator values in each lake for four years, colored and sized across the indicator range.

Second Objective

Indicators were responsive to spatial gradients in total phosphorus and mean growing degree days

Figure: Relationships of each indicator with total phosphorus and mean growing degrees days expressed with additive smoothing models. Points are colored and sized in relation to lake latitude.

Third Objective

Estimates of total uncertainty for each indicator were related to differing contributions of sampling and temporal uncertainty

Indicators had varying power to detect declines after twenty years at different annual sampling intervals

Figure: Estimated power for detecting indicator changes after twenty years at different sampling frequencies and rates of decline. Sampling frequencies were evaluated from once a year to every five years. Proportion decline indicates the change in the initial indicator value after twenty years.

Conclusions

- Biotic integrity, floristic quality, and frequency rooted were least variable and had the highest estimated power
- Species-specific indicators, such as Chara, were highly variable and had lower power
- All indicators were related to growing degree days, whereas total phosphorus was a significant predictor for maximum depth and frequency rooted

***Acknowledgments**: Thanks to Pete Jacobson for providing suggestions which improved earlier versions of the analysis. We also acknowledge the extensive efforts of area managers and field crews for obtaining the data used in our analyses. The contents are solely the views of the authors and do not represent endorsement by any state or federal agency.*

***Cite as**: Beck MW, Tomcko CM, Valley RD, Staples DF. In review. Analysis of macrophyte indicator variation as a function of sampling, temporal, and stressor effects. Ecological Indicators.*