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Evaluation of suitability and comparability of stream assessment indices using macroinvertebrate data sets from the Northern Lakes and Forests Ecoregion

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ABSTRACT

Researchers and managers within the Upper Midwest currently use a variety of sampling methodologies and biological indices to assess ecological condition of stream systems. With multiple entities collecting bioassessment data it is important that we determine the comparability of data and the indices derived from these data for effective assessment of natural systems. In this study we assessed the similarity of data collected by different agencies and we focused on data from one watershed to examine the outputs of different indices for stream assessment, and the temporal variation of index score within sites. We compared duplicate macroinvertebrate community data collected by the Little River Band of Ottawa Indians and the Michigan Department of Environmental Quality for overall community composition and index scores derived from these data. Duplicate samples were similar in composition index scores. Taxonomic resolution was addressed and indicated that genus level resolution gives a more favorable score when using indices. We also evaluated the utility of currently available macroinvertebrate indices of biotic integrity to assess data from the Big Manistee River watershed. The indices evaluated were the Hilsenhoff biotic index, the benthic community index for the Northern Lakes and Forests (NLFBCI), the Great Lakes Environmental Assessment Survey (GLEAS) procedure 51 for macroinvertebrates and a biological condition gradient model for the Upper Midwest. Outputs from the indices were moderately correlated (Spearman rank order correlation, $r = 0.35–0.698$) though they indicated different assessments of overall site integrity. Compared with larger scale regional indices, locally calibrated indices generally classified sites as having better biological condition. Replicate samples collected within sites indicated the GLEAS had higher levels of variability (0–265%CV) within sites than the other indices (<10%CV). Data from long-term (10 year) monitoring stations were used to evaluate seasonal and long-term index performance. There were differences in index score classifications from spring and fall samples indicating that standardization of sampling time is necessary for comparative analysis. Temporal trends over 10 years reveal natural variation and set the baseline for evaluating the influence of anthropogenic effects. Overall, results indicate that choice of index can alter assessment of site condition. For bioassessment in the Big Manistee River watershed the NLFBCI performs well and accurately reflects site condition.

1. Introduction

Whether the goal is to protect a relatively pristine ecosystem, manage an actively used system, or restore a degraded one, the approach and success relies on our knowledge and assessment of the physical and biological condition of ecosystems. Aquatic biological monitoring has been recognized as the first step in protecting biological integrity (Karr and Chu, 1999). Assessing the ecological condition of a site may be approached through multiple methods, often with the estimated biological condition dependent on many factors, including the organisms selected for use in the interpretation (Carter and Resh, 2001), how data are interpreted (Cao et al., 2005), and methods used to collect the data (Hughes and Peck, 2008).

Numerous national, regional and local organizations have independently developed aquatic assessment programs producing many innovative technical approaches for data acquisition and interpretation (Davies and Jackson, 2006) but with little standardization; therefore, determining the comparability of data collected and resulting assessments is needed (Cao and Hawkins, 2011). The

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ability to utilize multiple sources of data could benefit programs by allowing for validation of assessments if they are shown to be comparable (Herbst and Silldorff, 2006; Gerth and Herlihy, 2006; Rehn et al., 2007).

Biotic indices have been developed to aid in the interpretation of biological assessment data. The product of a biotic index is a single site- and time-specific numeric score that can be interpreted within a regional gradient of condition (Karr and Chu, 1999). Assessment of the utility and applicability of these indices over spatial (Ode et al., 2008) and temporal scales is also necessary (Mazor et al., 2009). Determining comparability of this numeric score and inferences derived from these endpoints has become necessary to improve regulatory credibility, reduce redundancy, increase efficiency, improve long-term monitoring programs, expand assessments to a broader scale and generally increase sample size, which would improve assessment (Cao and Hawkins, 2011). In the Upper Midwest of the United States there are numerous indices available; however, determining the appropriate index and when to apply it is problematic. One biological data set can be interpreted in different ways and subsequently indicate different courses of action based on which index is applied.

Agencies within the Upper Midwest currently use disparate sampling methodologies and biological indices to assess stream systems. Often, management agencies use indices that are not directly comparable, having varying scales and different classification schemes. One of our goals for this study was to determine if indices developed for use at different spatial scales in the Upper Midwest (Fig. 1) would produce concordant index scores within and across sites. We used a nested approach to evaluate sites based on scores from indices developed with increasing geographic scope. By nested approach we mean that the data set from the Big Manistee River watershed is within the state of Michigan, which is within the Northern Lakes and Forests Ecoregion within the Upper Midwest. Scoring of sites is in comparison to reference condition or theoretical natural state utilized in the original development of the index. The natural variation across a larger region may limit discrimination of site specific differences in a regionally derived index. A locally derived index may be necessary for discrimination of smaller changes in biotic integrity (Ode et al., 2008). A nested approach to data interpretation may lead to better understanding of variation in ecological condition and the geographic scope appropriate for interpretation.

Evaluation of stream condition is also dependent on the temporal stability of a system (Milner et al., 2006). Temporal variation in community assemblage occurs both seasonally and annually. Seasonal variability has been shown by others to be dependent on the system evaluated (Linke et al., 1999; Morais et al., 2004; Maloney and Feminella, 2006; Callanan et al., 2008; Kappes et al., 2010). Annual variation has been less well studied (Jackson and Fureder, 2006) however; it has been shown that understanding annual variation is necessary to improve bioassessment when disturbance is subtle (Huttunen et al., 2012).

We evaluated the utility of currently available macroinvertebrate indices of biotic integrity to assess macroinvertebrate community data from the Big Manistee River watershed data set from the northwest Lower Peninsula of Michigan, USA. The five indices evaluated include the Hilsenhoff (HBI) (family and genus level) biotic indices (Hilsenhoff, 1987, 1988), the benthic community index for the Northern Lakes and Forests (NLFBCI) (Butcher et al., 2003), the Great Lakes Environmental Assessment Survey (GLEAS) procedure 51 for macroinvertebrates (Creel et al., 1998) and a Biological Condition Gradient model (BCG) for the Upper Midwest (Gerritesn and Stamp, 2012). The HBI was developed to evaluate organic stream pollution based on genus or family level tolerance values (G-HBI, F-HBI, respectively) for Wisconsin macroinvertebrates. Community-based indices are used to assess biological integrity using a combination of metrics such as native composition and relative sensitivity to environmental conditions. For example, the NLFBCI is a genus level assessment useful for delineating impaired sites from non-impaired sites in the Northern Lakes and Forests Ecoregion. The GLEAS was developed for use in Michigan with separate family level scoring for each ecoregion in the state resulting in a narrative classification of site scores as excellent, acceptable, or poor. The BCG, originally described by Davies and Jackson (2006), was calibrated for use in the Upper Midwest (Gerritesn and Stamp, 2012) and is based on the relationship between stressors in the environment and corresponding ecological response of the aquatic community indicated with a numeric value from one to six. In this study, macroinvertebrate community data collected through the Little River Band of Ottawa Indians (LRBOI) baseline monitoring and assessment program as well as State of Michigan Department of Environmental Quality (MI-DEQ) macroinvertebrate community data from the trend monitoring program were compiled and analyzed with available indices.

The objectives of this study were to (1) determine if data from multiple agencies could be effectively combined and integrated into a larger watershed dataset and (2) assess concordance of regional indices.

2. Methods

2.1. Study area

The Big Manistee River watershed (Fig. 1) is in the northern Lower Peninsula of Michigan, has an area of approximately 490,000 ha, spans 11 counties and includes the 1836 Reservation of the Little River Band of Ottawa Indians (LRBOI). The watershed is primarily forested (56%), with scrub/shrub and grassland covering 16% and wetlands comprising an additional 13%. There is some agricultural use in the form of grazing and row crops (9%) with developed land covering 6% of the watershed (NLCD, 2006). There are 3191 km of stream within the Big Manistee River watershed (NLCD, 2006). The lower portion of the Big Manistee River is federally recognized as a wild and scenic river with upper portions of the mainstem and sections of tributaries designated by the State of Michigan as Natural Rivers and Blue Ribbon Trout Streams.

2.2. Data acquisition

The LRBOI Natural Resources Department sampled benthic macroinvertebrates annually, beginning in 2002, using a multihabitat rapid bioassessment protocol (Barbour et al., 1999) to provide data for biological assessment of the watershed. Sampling occurred seasonally in the spring and fall of each year (2002–2011) at four long-term, fixed monitoring sites with reach lengths 40 × stream width. Habitat types (e.g., riffles and pools) were sampled in approximate proportion to their representation of surface area. Macroinvertebrates were preserved and identified in a laboratory. Additionally, three simultaneous replicate samples were collected from nine independent stream reaches in 2009. Three reaches were located on Sickle Creek, Bear Creek, and Pine Creek respectively ($n = 9$), and were separated by a distance of 40 × stream width. Macroinvertebrate data was also acquired from State of Michigan assessments. In 2009 the State of Michigan MI-DEQ conducted an assessment of 23 sites in the Big Manistee River Watershed as part of the state monitoring program, which is on a 5 year watershed rotation (Lipsey, 2010). Macroinvertebrate assessments conducted through this effort followed the Great Lakes and Environmental Assessment Section (GLEAS) Procedure 51 (Creel et al., 1998) protocols. This protocol is used by the State of Michigan for