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An ecological assessment of Great Lakes tributaries in the Michigan Peninsulas

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ABSTRACT

Michigan stream fish and macroinvertebrate community data from multiple sources were combined to conduct a statewide assessment of riverine ecological condition. Using regionally normalized metrics to correct for methodological inconsistencies and natural variation and statistically based scoring criteria, about 50% of all sampled sites were in expected or better ecological condition, 30% were ecologically impaired, and 20% were marginal. Structural Equation Modeling with this regional assessment dataset indicated that land use effects were more important than effects of point-source discharges. Biological metrics appeared to be more sensitive to urban than agricultural land use, and riparian than basin-wide agricultural land use. Invertebrate communities were marginally more sensitive than fish communities to the suite of anthropogenic stressors examined. Using the observed assessment status from sampled sites, Classification and Regression Tree models were used to estimate ecological condition in the state's remaining unsampled river segments. Combining observed and estimated site scores, 25% of the state's river kms were estimated to be impaired, with the Erie and St. Clair basins having the highest degree of impairment (52% and 44% of total channel lengths, respectively) and lakes Superior, Michigan, and Huron basins had the lowest degree of impairment at 4%, 21% and 31%, respectively. We argue that correlations between the state of the Great Lakes and the ecological conditions of their tributary systems reflect both direct impact transmission from watershed to receiving waters, and also non-causal correlation due to shared anthropogenic stressors.

Introduction

Concern over the condition and future of the Laurentian Great Lakes continues (Great Lakes Coalition, www.iglc.org/; Great Lakes Initiative, www.epa.gov/waterscience/gli) despite decades of regional cooperation and international management efforts. Recent declines in *Diporeia hoyi* (Nalepa et al., 2007), the re-emergence of hypoxia in Lake Erie (Hawley et al., 2006), and continued food web disruptions in lakes Huron and Michigan (Dobiesz et al., 2005), among other issues, fuel a growing unease about the future of the Great Lakes.

Bold new initiatives aimed at system-wide restoration are currently being proposed (U.S. EPA, 2009) and yet much of our ecological diagnosis and restoration planning remains local in scale and spatially fragmented (e.g. Guidance for delisting Michigan's Great Lakes Areas of Concern, MDEQ 2006). Many scientists and managers have called for a larger-scale, more integrated ecosystem-based approach in which the entire Great Lakes watershed would be the focus of assessment and management activity (Cherwaty et al., 2004; EC and U.S. EPA, 2005; McKenzie, 1993, 1996; U.S. EPA, 2004). In particular, there is a growing recognition that tributary watersheds should be included in an assessment approach to the Great Lakes health (EC and U.S. EPA, 2005; Johengen et al., 2008). Nevertheless, almost all of the focus of Great Lakes ecosystem assessment to date remains on the open lakes, and a relatively narrowly defined coastal zone (EC and U.S. EPA, 2007).

The two Michigan peninsulas are both defined by Great Lakes shorelines, and together comprise about 30% of the total Laurentian system land catchment area (15.7% of Superior, 63.2% of Michigan, 31.5% of Huron, and 19.6% of St. Clair and Erie). Michigan has experienced rapid changes in land use and land cover over the past three decades (Pijanowski et al., 2002; Zang et al., 2005), and these changes have had substantial impacts on the hydrology and ecological integrity of its tributaries to the Great Lakes. This paper reports the results of an ecological assessment of Great Lakes tributaries in the Lower and Upper Michigan Peninsulas. Combining biological data from state agencies, and university, NGO, and federally funded-research projects, we have developed the most comprehensive analysis to date of the status of Michigan's Great Lakes tributary systems in relation to anthropogenic land use and permitted discharge stressors.

This study had three objectives. The first objective was to compile the currently available major datasets on stream fishes and benthic macroinvertebrates for the State of Michigan and then to conduct a

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statewide river and stream assessment of ecological condition. The second objective was to use correlation analyses and Covariance Structure Analysis (Structural Equation Modeling or SEM) to examine the sensitivity of biological metrics to key landscape-scale anthropogenic stressors (including urban land cover, agriculture, point-source impacts, and river fragmentation by impoundment). Finally, as a step towards a more holistic view of the Laurentian system, the cumulative status of Michigan's stream segments relative to those Great Lakes basins contiguous with its two peninsulas was explored.

Methods

Approach

Resource managers since the Clean Water Act of 1972 have relied on biological assessment of riverine systems to guide management and conservation activities (Higgins et al., 1999; Rabeni and Sowa, 1996; Seelbach et al., 2002). Since rivers are integrators of the landscape that they drain, biological assessments can provide indicators of ecological condition across broad spatial scales (Allan and Johnson, 1997; Hunsaker and Levine, 1995). Methods used in regional river assessment vary widely despite longstanding efforts at standardization (Barbour et al., 1999). Indicator variables, sampling methodology, and scoring criteria often vary among organizations and studies. But, the underlying concept of biological assessment is relatively stable and focuses on the measurable difference between the observed and reference condition of a resource. Reference condition is generally understood as the expected condition in the absence of anthropogenic impacts (Armitage et al., 1983; Bailey et al., 2004; Hughes, 1994; Karr et al., 1986; McCormick et al., 2001; Norris and Georges, 1993; Wright et al., 1984). The ubiquitous challenge has been to identify the reference condition, in the absence of historical data (Pont et al., 2006; Wiley et al., 2003). Ecological assessment methods that use statistically predicted reference conditions (Norris and Georges, 1993; Turak et al., 1999; Wright et al., 1984; see review by Seelbach et al. 2002) are particularly amenable to application in regional assessment where large spatial scale leads to wide variation in natural ecosystem structure and function and thus ecological expectations (Claessen et al., 1994; Gallant et al., 1989). A regional normalization approach (Wiley et al., 2003) was used to correct diverse data sets for both methodological inconsistencies and for variable properties of the regional landscape such as geology, topography, and climate and to develop assessment scores for sampled river reaches. These observed metric scores were used to build a Classification Regression Tree (CART) model (De'ath and Fabricius, 2000) and then estimate ecological condition at remaining unsampled river segments throughout the State. This analysis produced a region-wide biological assessment of the condition of Michigan rivers and streams.

Study area

This ecological assessment used combined biological data from a number of different survey data sets to provide the largest possible spatial coverage and resolution, and range of reference and impacted conditions. Fish assemblage data came from four studies and invertebrate assemblage data came from six studies (Fig. 1, Table 1). Fish assemblage data included sites from: 1) an intensive spatial sampling of the Muskegon River, a tributary of Lake Michigan (Muskegon Watershed Research Partnership (MWRP), 2001); 2) a regional data set compiled as part of the Michigan Rivers Inventory (MRI); 3) an EPA-funded survey of the northern lakes and forest (NLF) ecoregion of the northern Lower and Upper peninsulas of Michigan; and, 4) rapid assessment fish survey data from the Michigan Department of Environmental Quality (MDEQ). Land cover and drainage area were highly variable across the combined datasets resulting in a large range of combinations of land use, geology,

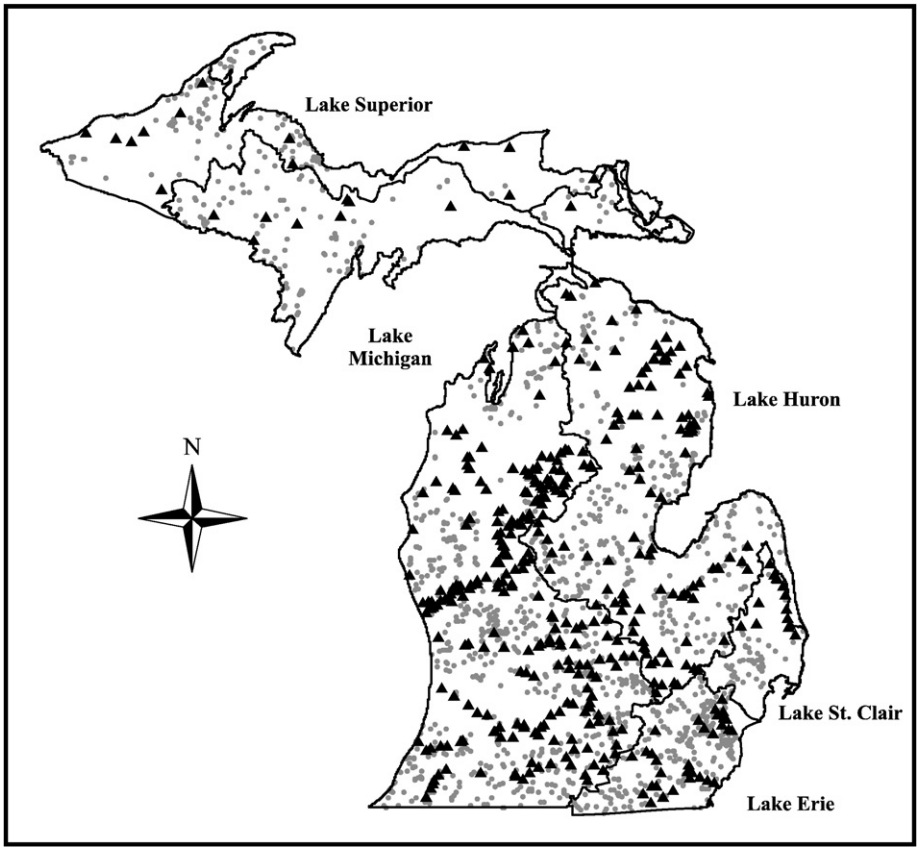

Fig. 1. Sample site locations for the fish assemblage data ($n = 754$); 1) circles indicate state rapid bioassessment sites ($n = 435$), and 2) triangles indicate research sites ($n = 319$). Great Lake basin boundaries are shown.