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Effects of taxonomic group, spatial scale and descriptor on the relationship between human activity and stream biota

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ABSTRACT

Using human activity and stream biota data collected from 160 small (600–3000 ha) watersheds in rural southwestern Ontario, we determined the relative ability of three commonly used methods of describing fish and benthic macroinvertebrate assemblages (i.e., metrics, presence/absence, and relative abundance) to assess the biological effects of reach and basin scale human activity. Analyses indicated that benthic macroinvertebrate presence/absence was more strongly correlated with human activity at both reach and basin scales than fish presence/absence, benthic macroinvertebrate or fish relative abundance, and metrics derived from benthic macroinvertebrates or fish data. However, sites exhibiting lower levels of human activity were, in some cases, better differentiated by relative abundance. The use of metrics did not provide any additional information regarding the effects of human activities and regularly appeared to underestimate differences between moderately exposed sites and sites exposed to low or very high levels of human activity. Tests for redundancy between fish and benthic macroinvertebrates indicated that they respond differently to the same type and extent of human activity suggesting that the assemblages are sensitive to different stressors emanating from the same activities. There was also a disparity between assemblages with regards to which scale they were most strongly associated as fish were more associated with human activities at the basin scale whereas benthic invertebrates were most strongly associated with the activities at the reach scale. Finally, there was no apparent advantage to describing human activities at multiple scales as predicted basin scores were highly correlated among scales, a finding that may be attributable to the homogeneity of rural environments. Similar studies need to be conducted for a broader spectrum of human activities across a larger geographic extent to determine if these findings are widely applicable.

1. Introduction

In aquatic environments, bioassessments are commonly conducted using one or more aquatic taxa, such as benthic macroinvertebrates (BMI) or fish (Rosenberg and Resh, 1993; Simon, 1999a,b). Biotic communities can be described using a wide variety of attributes, including the number of species present, their relative abundance, or other ecological attributes (Ricklefs and Miller, 1999). Indeed, the choice of method to describe the biota is one of the fundamental differences between multivariate and multi-metric approaches commonly used in aquatic bioassessment studies.

Multivariate approaches (e.g., RIVPACS [Wright, 2000] and BEAST [Reynoldson et al., 2000]) typically use either presence/absence or relative abundance data that describe the taxonomic composition of the community. The multi-metric approach (e.g., IBI [Karr, 1981] and B-IBI [Kerans and Karr, 1994]) uses a large number of indices or metrics that describe ecological attributes thought to be sensitive to the effects of human activities, followed by selection of a subset of indices that are most correlated to stressor gradients of interest (Gerritsen, 1995; Fore et al., 1996). Despite several studies comparing the ability of different approaches to evaluate ecological condition (e.g., Fore et al., 1996; Zamora-Muñoz and Alba-Tercedor, 1996; Reynoldson et al., 1997), there have been mixed results as to which is most effective, perhaps because of differences in how the biota are described rather than the assessment method itself. Given that change in ecological assemblages depends on the type and extent of human activity to which the ecosystem is exposed (Allan, 2004), the "best" way of describing the biota may depend on the combination of stressors present. Using both metrics and compositional descriptions of the biota may therefore add significant informa-

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tion and decision-making power to assessment and monitoring studies.

The taxonomic group(s) used in a bioassessment also affects the results (Mazor et al., 2006; Feio et al., 2007; Hughes et al., 2009). BMI are commonly used in both multivariate and multi-metric assessments of freshwater ecosystems around the globe (e.g., Barbour et al., 1999; Davies, 2000; Wright, 2000; Reynoldson et al., 2000). Fish have also been widely used for assessments with the multimetric approach, especially in the United States (e.g., McCormick et al., 2001; Hughes et al., 2004; Lyons, 2006), and more recently in Europe (e.g., Breine et al., 2004; Magalhaes et al., 2008), as well as other parts of the world (e.g., Ganasan and Hughes, 1998; Bozzetti and Schulz, 2004; Joy and Death, 2004). Fish are also commonly used in multivariate based assessments, particularly within Australia and New Zealand (Joy and Death, 2002, 2003; deZwart et al., 2006; Kennard et al., 2006a; Chessman et al., 2008). Other biota, such as periphyton and macrophytes, are also used (e.g., Winter et al., 2003; Walker and Pan, 2006; Kelly et al., 2008), but less frequently than BMI or fish. The effect of the taxon used on the outcome of an assessment is important to determine because different taxonomic groups have been shown to vary in sensitivity to different stressors (Johnson et al., 2006) as have individual taxa and ecological characteristics within biotic groups (Compin and Cereghino, 2007; Wenger et al., 2008; Hutchens et al., 2009). Using a single group of organisms may therefore constrain the effectiveness of an assessment of the condition of freshwater ecosystems and as such the use of multiple assemblages has become common in some jurisdictions (e.g., European Union Water Framework Directive, European Commission, 2000).

The effectiveness of a taxon and the method with which it is described may also be influenced by the spatial scale at which the human activity being assessed is occurring. BMI and fish have been found to be most strongly associated to different scales (i.e., BMI to reach scale and fish to basin scale [Lammert and Allan, 1999; Freund and Petty, 2007]). As such, variation in assessment results may also be attributable, at least in part, to where in an ecosystem human activity is occurring.

The purpose of this study was to measure the relationship between three methods of describing biota (i.e., metrics, presence/absence, and relative abundance) of two taxa (i.e., BMI and fish) with gradients of human activity at both the reach and basin scales. We answered three related questions after quantifying the strength and nature of these relationships.

- How are the strength and nature of associations between the biota and human activity gradients affected by choice of the descriptors of the biota (metric, presence/absence, relative abundance)?
- How are the strength and nature of associations between the biota and human activity gradients affected by choice of taxon (BMI, fish)?
- How are the strength and nature of association between the biota and human activity gradients affected by the geographic scale (reach, basin) of the analysis?

The results of this study will clarify how and how much the choice of descriptor(s) and taxon used add value to the assessment of the effects of human activity on aquatic ecosystems.

2. Methods

2.1. Study area

Southwestern Ontario is the southernmost part of Canada. It is almost completely encircled by the North American Great Lakes (Fig. 1), creating a warmer and more humid environment unique in Canada, with conditions and biota similar to areas much

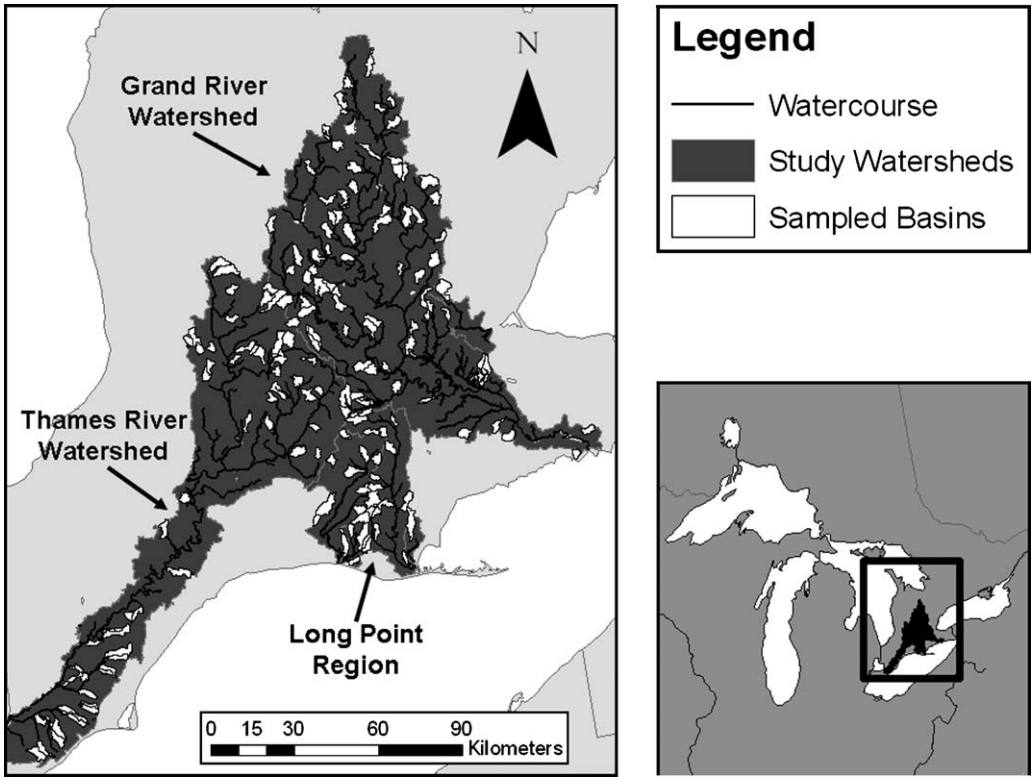

Fig. 1. Location of study area in Great Lakes Region, North America (lower right) and position of sampled rural headwater basins in their respective southwestern Ontario drainage basins (main).