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Aquatic macroinvertebrates are poor indicators of agricultural activity in northern prairie pothole wetlands

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ABSTRACT

The Northern Prairie Pothole Region (NPPR) of Alberta, Canada, contains numerous shallow marshes that serve as important habitat for wildlife and provide essential ecosystem services. Many of these wetlands have been destroyed or degraded by human activity and the majority of remaining wetlands occur in landscapes affected by crop and cattle production. Alberta has implemented a conservation policy which requires the creation of wetland assessment tools. Aquatic macroinvertebrates are frequently used as indicators of environmental condition in rivers, but their effectiveness as indicators in prairie pothole wetlands is not clear. To evaluate the capacity of aquatic macroinvertebrates identified to family-level resolution to serve as regional bioindicators of agricultural disturbance in NPPR wetlands, we sampled macroinvertebrates at 64 fishless wetlands. The wetlands spanned a gradient in the extent of agriculture from 0 to 100% cover within a 500 m buffer around each wetland. We discovered that, contrary to our predictions, macroinvertebrate family richness and community composition could not predict agricultural disturbance (cropping or cattle grazing). We conclude that efforts to develop bioindicators for NPPR wetlands should be redirected to other taxa that are less costly to identify to species and that exhibit sensitivity to agricultural disturbance.

1. Introduction

Aquatic macroinvertebrates are the most commonly used bioindicator of environmental condition in both lakes and rivers (Bonada et al., 2006; Environment Canada, 2014; Jones et al., 2007; Resh et al., 1995). They have numerous traits that make them excellent bioindicators in many aquatic ecosystems. For example, macroinvertebrates are sensitive to multiple environmental stressors and can be indicators of the overall condition of an ecosystem (e.g., Jones et al., 2007), although they are most often used to diagnose nutrient pollution (e.g., Johnson et al., 2013). Despite their popularity in river assessments, macroinvertebrates are not as well represented in wetland biomonitoring. This is especially true of prairie pothole marshes, many of which are subject to seasonal drawdown and rewetting (Hayashi et al., 2016). The sensitivities of wetland macroinvertebrates to environmental stressors are relatively poorly studied and the published literature offers conflicting results on their potential to serve as bioindicators in wetland ecosystems (review in Batzer, 2013). However, research into the concordance between macroinvertebrate families and other useful wetland bioindicator taxa (e.g., wetland birds and aquatic macrophytes) in shallow open water marshes of the Northern Prairie Pothole Region (NPPR) of Alberta concluded that all the bioindicators were correlated with variation in the same subset of environmental variables (Rooney and Bayley, 2012). This suggests that aquatic macroinvertebrates could be as useful in wetland monitoring as they are in other freshwater habitats.

Macroinvertebrates in lentic ecosystems appear strongly influenced by the abundance and nature of top predators and the permanence of ponded water (review in Wellborn et al., 1996); however, studies of temporary, seasonal and semi-permanent marshes (i.e., non-permanent wetlands; Table 1) in both Canada and the United States are often in contradiction about the relative importance of other factors, such as surrounding land use. In the NPPR, researchers have suggested that wetland macroinvertebrates are sensitive to surrounding land use practices. For example, both adult odonate species and larval odonate genera were useful indicators of grazing intensity (Foote and Rice Hornung, 2005; Hornung and Rice, 2003) and the abundance and richness of macroinvertebrate genera decreased with increased grazing pressure (Silver and Vamosi, 2012) in non-permanent wetlands. It is not clear whether these relationships to land use should be evident at a coarser taxonomic resolution, though several studies suggest that even family-level identifications are adequate to discriminate between healthy and impaired aquatic ecosystems (e.g., Bowman and Bailey, 1997; King and Richardson, 2002; Waite et al., 2004).

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Table 1
Permanence classes of prairie pothole wetlands and their typical water retention periods after the spring snow melt as described in Stewart and Kantrud (1971). The vegetation zone that characterizes the most saturated part of the wetland classes is listed, although higher permanence classes typically also contain patches or borders of vegetation types characterizing less saturated zones. In our study, we sampled wetlands from class II to IV.

Class	Name	Water retention period	Vegetation zone in most saturated part of wetland	Typical plants in wettest vegetation zone
I	Ephemeral	Water or saturated soil for first week or two of spring	Wetland-low prairie zone	Grasses
II	Temporary	First month of spring	Wet meadow	Grasses and sedges
III	Seasonal	Surface water present in spring and early summer	Shallow marsh	Emergent plants (sedges, cattails, rushes)
IV	Semi-Permanent	Only draw down completely in drought years	Deep marsh	Submerged and floating aquatic vegetation
V	Permanent	Contains open water though out entire year	Deep marsh and open water	Submerged and floating aquatic vegetation

Macroinvertebrates were used to monitor wetland condition in newly constructed temporary and permanent wetlands in Iowa, and their diversity decreased with turbidity (Stewart and Downing, 2008), which can be related to human activities in the surrounding landscape (e.g. Bayley et al., 2013). In coastal marshes of the Laurentian Great Lakes, aquatic macroinvertebrates responded reliably to the amount of anthropogenic disturbance in the contributing watershed (Kovalenko et al., 2014). Yet not all researchers find evidence in support of using macroinvertebrate bioindicators in wetlands. In the semi-permanent wetlands of Minnesota, the presence of fathead minnows was the primary driver of aquatic invertebrate community composition and diversity (Zimmer et al., 2000). Similarly, the presence of fish was the only significant factor in structuring invertebrate communities in the semi-permanent wetlands of North Dakota, with land use having no discernable effect on invertebrate communities (Tangen et al., 2003). In Oklahoma, surrounding land use was also unrelated to the composition of invertebrate communities (Meyer et al., 2015).

Globally, there have been successful invertebrate indexes created for distinguishing between high and low quality wetlands in the flatland ponds of Spain (Trigal et al., 2009) and the everglades (King and Richardson, 2002), even when restricted to coarser taxonomic resolution. Yet disagreement remains over the reliability of aquatic macroinvertebrates as indicators of human disturbance in wetland ecosystems (review in Batzer, 2013).

We are particularly interested in the effects of agricultural disturbance on the fishless, shallow, non-permanent marshes characteristic of the NPPR because agricultural expansion in this region has resulted in high rates wetland loss (Bartzen et al., 2010; Dahl, 1990; Martin and Hartman, 1987). The estimates of percentage of wetlands lost in the Canadian prairies reach as high as 70% (Alberta Wilderness Association, 2014), and it is estimated that 80% of wetlands lost from Alberta's NPPR in the past ten years were drained without permission from the provincial government (Clare and Creed, 2014). NPPR marshes that remain are largely located in agricultural landscapes, where they are exposed to soil compaction through livestock activity and farming equipment (Wrubleski and Ross, 2011), increased sedimentation and nutrient loading, (Bayley et al., 2013), pesticide contamination (Main et al., 2014), altered vegetation communities (Mushet et al., 2002), increased exposure to invasive species (Green and Galatowitsch, 2001), and changes to their water budget (Hayashi et al., 2016). In addition to degrading the ecological integrity of prairie potholes, the environmental changes associated with agriculture likely affect wetland macroinvertebrate communities as aquatic macroinvertebrates are highly sensitive to changes in water and sediment quality (Baker et al., 2014; Foote and Rice Hornung, 2005; Silver and Vamosi, 2012).

The province of Alberta recently passed a new provincial wetland policy that will require wetland evaluation and monitoring tools to support its implementation (Government of Alberta, 2013). Since aquatic macroinvertebrates are effective bioindicators in other aquatic systems and are known to be sensitive to the environmental stressors associated with agriculture, they may serve as bioindicators in temporary, seasonal, and semi-permanent marshes in the NPPR. In order to be a useful bioindicators, the macroinvertebrate community must be sensitive to the extent of surrounding agriculture. Additionally, that sensitivity must be detectable at a taxonomic resolution achievable given the resource and time constraints that many management programs face. To justify selecting wetland macroinvertebrates as the basis of wetland biomonitoring, the expense must be comparable to the costs of sampling and identifying other potential bioindicators that have already proven sensitive indicators of agricultural disturbance in the NPPR, such as wetland birds (Anderson, 2017; Polan, 2016) or vegetation (Wilson et al., 2013). Thus, we tested the family-level sensitivity of wetland macroinvertebrates to the extent of agricultural disturbance surrounding marshes of Alberta's NPPR. If aquatic macroinvertebrate families are sensitive indicators of agricultural disturbance in the NPPR, this would justify further analysis of taxonomic sufficiency and development of a biomonitoring tool.

2. Methods

2.1. Field collection and sample preparation

We collected aquatic macroinvertebrates from 64 wetlands in Alberta's NPPR (Fig. 1), which covered the temporary to semi-permanent permanence classes (*sensu* Stewart and Kantrud, 1971; Table 1). In addition, our selected wetlands spanned a statistically independent gradient in the extent of agricultural disturbance (i.e., crops and cattle pasture) within a 500 m radius buffer around the perimeter of each wetland. Land cover was based on the Agriculture and Agri-food Canada crop inventory dataset from 2014 (AAFC, 2015), which discriminates between natural grassland and pasture, as well as a variety of crop types. We categorized the marshes as either low disturbance (< 25% agricultural land cover; n = 28), medium disturbance (25–75% agricultural land cover; n = 14), or high disturbance (> 75% agricultural land cover; n = 22).

At each marsh, we employed the quadrat-column-core (Q-C-C) sampling method as described in Meyer et al. (2013), which, compared with D-netting, can yield higher estimates of abundance and biomass for most invertebrate taxa and has the advantage of being quantitative (Meyer et al., 2013). In brief, this method involves collecting three subsamples. First, a vegetation sample is obtained using a 0.25 m^2 floating quadrat to gather emergent or submerged vegetation and captured macroinvertebrates are sorted from the plant material. Second, macroinvertebrates in the water column are collected with a 10 cm diameter tube submerged to just above the sediment. Third, a benthic core is taken with a 4.9 cm diameter suction corer inserted into the sediment to a depth of 10 cm. All samples were rinsed using a 500 μm mesh sieve. Where wetlands possessed an open water zone (i.e., an area of ponded water where no emergent vegetation protruded but where submersed and floating vegetation may grow), we collected and composited three replicate quadrat-column-core samples from each of the open water and emergent vegetation zones separately, as different macroinvertebrate species could reside in these different microhabitats (Merrit et al., 2008). In wetlands lacking an open water zone, we collected and composited three replicate samples from the emergent vegetation. Each wetland was sampled twice between May and June, with visits separated by about three weeks.

Our macroinvertebrate sorting, identification and data quality