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Community congruence of plants, invertebrates and birds in natural and constructed shallow open-water wetlands: Do we need to monitor multiple assemblages?

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A B S T R A C T

Biomonitoring is a common means of evaluating wetlands. It is based on the premise that the community composition of one taxonomic group is indicative of overall biology and the underlying environmental conditions at a wetland. To be a good bioindicator, there must be adequate concordance between the indicator group and other biotic assemblages. Otherwise, multi-assemblage monitoring is necessary to glean a complete picture of wetland condition. In 32 sites ranging from reference wetlands to stormwater retention ponds, we evaluated concordance in community composition among the six most commonly monitored wetland assemblages: waterfowl, wetland dependent songbirds, aquatic macroinvertebrates, and plants in the wet meadow, emergent, and open-water vegetation zones. We also assessed agreement in environmental correlates among these six assemblages and investigated the impact of human disturbance on cross-assemblage concordance. We found that cross-assemblage concordance was positive ($p < 0.03$ in 14 of 15 pair-wise comparisons, $p = 0.06$ in 15th case), but relatively low (Mantel R values 0.11–0.37), suggesting that the assemblages are mediocre surrogates for one another. Yet, we found very strong agreement among environmental correlates of the six assemblages, especially along the first axis of assemblage-specific ordinations (mean Spearman rho = 0.923), indicating that despite low concordance, the six assemblages are likely responding to the same environmental gradients. Thus, while a single assemblage may not serve as a surrogate for the other assemblages, it should yield an adequate estimate of underlying environmental conditions and the degree of disturbance. Most important among the environmental correlates were sediment and water nutrient levels, shoreline slope, and the size of wet meadow and emergent vegetation zones. Perhaps most interestingly, we found that the strength of cross-assemblage concordance was greatest in reference wetlands and was lower ($p \leq 0.05$) in constructed wetlands. This implies that cross-assemblage concordance present in undisturbed sites may not persist in disturbed wetlands where several of these cross-assemblage relationships deteriorate. Furthermore, a general change in cross-assemblage concordance may itself be indicative of human disturbance in wetlands.

1. Introduction

Biological monitoring is promoted as a means to evaluate wetland condition by both the U.S. Environmental Protection Agency (USEPA, 2011) and Environment Canada (EC, 2011). In biological monitoring, bioindicators are used as surrogates that indicate overall biotic or environmental conditions (e.g., Bilton et al., 2006; Heino, 2010; Mykra et al., 2008). In other words, we assume that the community composition of the indicator assemblage is representative of the composition patterns in other taxonomic groups and of the underlying environmental conditions. Efforts to test this assumption have been made in rivers (Heino et al., 2005; Mykra et al., 2008; Paavola et al., 2006), lakes (Allen et al., 1999; Jackson and Harvey, 1993; Paszkowski and Tonn, 2000), and ponds (Bilton et al., 2006; Gioria et al., 2010), but to the best of our knowledge, no such attempts have been made in wetlands.

Many different biota have served as bioindicators in wetlands, but the most popular assemblages include aquatic macroinvertebrates (e.g., Balcombe et al., 2005; Gernes and Helgen, 1999), plants (Hargiss et al., 2008; Rooney and Bayley, 2011a) from the open-water, emergent, or wet meadow vegetation zones, and birds (e.g., Brazner et al., 2007; Veselka et al., 2010), namely waterfowl and wetland dependent songbirds. As bioindicators, each of these assemblages possess advantages and disadvantages, but generally, all meet most of the criteria outlined by Cairns et al. (1993): they are all sensitive to environmental change, biologically relevant,

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capable of being monitored over time using standardized procedures, and information derived from their composition is interpretable and can be used to diagnose a wetland's condition. To varying degrees the different assemblages are capable of being anticipatory, broadly applicable, and integrative, and they range in terms of cost-effectiveness, seasonal restrictions, and time requirements for sample collection, processing, and analysis. Thus, there is some debate over whether certain assemblages make better bioindicators than others. Arguments have been made that favour particular taxa (e.g., Beyene et al., 2009; Griffith et al., 2005). Alternatively, some authors argue that multiple assemblages should be monitored (e.g., Brazner et al., 2007; Diffendorfer et al., 2007; Johnson et al., 2006).

Incorporating multiple assemblages may improve wetland monitoring and assessment if each assemblage provides unique information about environmental conditions, but one of the criteria outlined by Cairns et al. (1993) is that bioindicators should not be redundant. If there is a high degree of concordance among the various assemblages, either because environmental conditions affect the assemblages in a comparable manner (e.g., Allen et al., 1999) or because one of the assemblages has a structuring effect on others (e.g., Jackson and Harvey, 1993), then one might be used as a surrogate measure of the others (e.g., Gioria et al., 2010). This is especially true where the concordant assemblages are found to be correlated with the same environmental variables. In such a case, using a single assemblage lowers the costs associated with monitoring and assessment without losing important information about wetland condition.

Reliance on a single indicator assemblage is only advisable if the pattern of concordance persists across the entire human disturbance gradient. If human disturbance causes the concordance among assemblages to decline, then even if measurement of multiple-assemblages is redundant in relatively pristine wetlands, it may be necessary to ensure accurate evaluation of disturbed wetlands. The converse may also occur (e.g., Mykra et al., 2008), and wetlands that would be classified differently by different assemblages were they healthy may be lumped together when disturbed.

Our objectives were (1) to assess cross-assemblage concordance among wetland plants, aquatic macroinvertebrates, and birds, (2) to evaluate cross-assemblage similarity in terms of important environmental correlates, and (3) to determine whether the degree of human disturbance influences the degree of concordance among the different assemblages.

2. Materials and methods

2.1. Study region

The wetlands selected for sampling are situated the Central Parkland Subregion of Alberta, Canada (Fig. 1). Surficial soil deposits are regionally variable, including intermediate-textured moraine, fine-textured glaciolacustrine deposits, coarse outwash kame moraine, and dune field materials. Vegetation transitions from grassland with groves of aspen in the south to closed aspen forest in the north. The region is generally flat and drainage is poor. Most natural wetlands are isolated with no surface water outlets and drainage is primarily via groundwater recharge (Holden, 1993).

We selected 32 shallow open-water wetlands from within this region by stratified random sampling, choosing eight sites from each of four classes: reference wetlands, agriculturally impacted wetlands, stormwater ponds, and naturalized constructed wetlands (Fig. 1). Wetland areas by class are listed in Table 1. Wetlands were selected from a list of candidates within 60 km of the City of Edmonton that were identified from 2007 aerial photography. Criteria for candidacy included that area range between 1 and 10 ha, open water be present, and age >3 years for constructed sites.

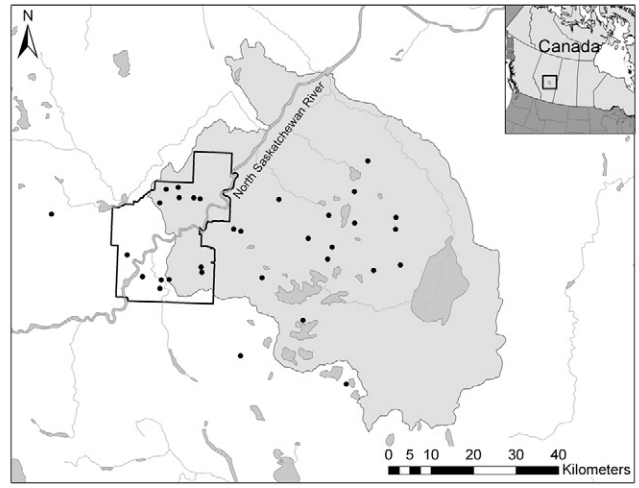

Fig. 1. Map of the study region depicting the 32 study sites (dots) all within 60 km of the City of Edmonton (black outline), mainly within the Beaverhills Subwatershed (grey shading) of the North Saskachewan River.

Table 1
Variation in wetland area (ha) among the four wetland classes.

Type	Mean	Standard deviation	Minimum	Maximum
Reference	4.95	2.51	1.30	9.87
Agricultural	3.82	2.56	1.72	9.41
Naturalized	2.45	1.44	1.06	5.42
Stormwater	2.60	1.15	1.33	5.16

Agricultural wetlands are the most common category in the study area and are the most at risk from development pressure. At least 50% of the landscape within a 500 m radius of each agricultural wetland was comprised of cultivated or pasture land. In contrast, the 500 m landscape surrounding each reference wetland contained <10% cultivated or pasture land; most were located within protected parks. Stormwater ponds are constructed to temporarily store overflow from the local storm sewer system and represent the most disturbed class of wetlands that we sampled. Naturalized constructed wetlands are stormwater ponds that have been designed to mimic natural wetlands. Plants growing in naturalized constructed wetlands help improve water quality and increase water retention time, allowing more fine particles to settle.

2.2. Sampling

Aquatic macroinvertebrates (hereafter invertebrates) were sampled by sweep-netting with a 500 μm D-net within a 1 m square quadrat in July 2008. Eight samples were collected from each wetland: four from equidistant locations along the transition between the emergent and open-water zones and another four from adjacent positions within the open-water. Samples were preserved in 99% ethanol in the field, before transport to the lab where samples were cleaned and sorted under a dissecting microscope. Sorted invertebrates were identified (mainly to the family-level) using recent keys (Merritt and Cummins, 1996; Thorp and Covich, 2001). We use the general term taxa in reference to invertebrates because the level of effort required to identify some taxa beyond order exceeded our resources. Exceptions to family-level identifications included the orders Ostracoda, Cyclopoida, Calanoida, Nematoda, and Nematomorpha. The eight sweep samples were composited to provide relative abundance numbers based on counts.