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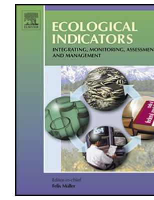

Mosses in Ohio wetlands respond to indices of disturbance and vascular plant integrity

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ABSTRACT

We examined the relationships between an index of wetland habitat quality and disturbance (ORAM score) and an index of vascular plant integrity (VIBI-FQ score) with moss species richness and a moss quality assessment index (MQAI) in 45 wetlands in three vegetation types in Ohio, USA. Species richness of mosses and MQAI were positively associated with ORAM and VIBI-FQ scores. VIBI-FQ score was a better predictor of both moss species richness and MQAI than was either ORAM score or vegetation type. This result was consistent with the strict microhabitat requirements for many moss species, which may be better assessed by VIBI-FQ than ORAM. Probability curves as a function of VIBI-FQ score were then generated for presence of groups of moss species having the same degree of fidelity to substrate and plant communities relative to other species in the moss flora (coefficients of conservatism, CCs). Species having an intermediate- or high degree of fidelity to substrate and plant communities (i.e., species with CC ≥ 5) had a 50% probability of presence (P_{50}) and 90% probability of presence (P_{90}) in wetlands with intermediate- and high VIBI-FQ scores, respectively. Although moss species richness, probability of presence of species based on CC, and MQAI may reflect wetland habitat quality, the 95% confidence intervals around P_{50} and P_{90} values may be too wide for regulatory use. Moss species richness, MQAI, and presence of groups of mosses may be more useful for evaluating moss habitat quality in wetlands than a set of "indicator species."

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1. Introduction

Indices of biological integrity (IBIs) have been used to evaluate the quality of wetland communities (Adamus et al., 2001). For example, IBIs for vascular plants (e.g., DeKeyser et al., 2003; Mack, 2004, 2007), amphibians (Micacchion, 2002, 2004; Micacchion et al., 2015; Stapanian et al., 2015), birds (e.g., Nosun and Hutto, 1995; Chin et al., 2014), and macroinvertebrates (Uzarski et al., 2004) in wetlands have been developed in many regions and states in the USA. In some states of the USA, IBIs are used to make important wetland management decisions, such as whether or not development can occur or setting goals for restoration projects (Stapanian et al., 2013a,b).

An underlying assumption of an IBI is that it responds to a gradient in disturbance (e.g., Gara and Stapanian, 2015). Methods for assessing habitat quality and disturbance levels of wetlands have been developed for several states and regions in the USA (e.g., Mack, 2001; Collins et al., 2008; Jacobs, 2010). The Ohio Rapid Assessment Method for Wetlands (ORAM: Mack, 2001) is used both to characterize a disturbance gradient and as a wetland classification tool. ORAM has been used to test the response of several indices to a disturbance gradient and wetland condition (Stapanian et al., 2013a; Gara and Stapanian, 2015; Micacchion et al., 2015).

Mosses (Division Bryophyta, Class Bryopsida) have numerous advantages as an indicator of environmental quality. The dominance of the gametophyte generation and lack of a leaf cuticle results in sensitivity to changes in humidity (Hallingbäck and Hodgetts, 2000). Thus, many moss species have comparatively strict habitat and microclimate requirements, particularly related to water levels, desiccation, and temperature (e.g., Glime and Vitt, 1987; Kimmerer and Allen, 1982; Arscott et al., 2000). Mosses are sensitive to pollution and disturbance and they are essential in nutrient recycling and carbon fixing (Kimmerer and Allen, 1982; Kimmerer, 1993; Hallingbäck and Hodgetts, 2000). There is evidence that mosses are useful indicators of climate change (Frahm and Klaus, 2001). Moss assemblages and growth forms were found to be useful for discerning hydrologic permanence of forested headwater streams (Fritz et al., 2009). In Poland, moss species richness was positively correlated with diversity of birds (both number of species and number of breeding pairs) and vascular plants (species

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richness and volume of trees and shrubs) in habitats adjacent to agriculture (Wierzcholska et al., 2008). Mosses have been used to define the boundaries of wetlands since the 1980s (Reed, 1998; Tiner, 1991; Gillrich and Bowman, 2010), and different species assemblages of mosses have been found in different wetland types (e.g., JNCC, 2005). Unlike vascular plants, most mosses can be collected at all times of the year without loss of key structures for reliable identification.

In spite of these attributes, mosses are often neglected or even omitted in ecological surveys, including vegetation surveys, despite an increasing number of available bryophyte species check-lists (Hallingbäck and Hodgetts, 2000; Mutke and Geffert, 2010). Although there are an estimated 14,000–15,000 moss species world-wide, comparatively few people can identify them (Hallingbäck and Hodgetts, 2000). However, increasingly there are groups that include both amateurs and professionals that survey mosses on a regular basis (e.g., American Bryological and Lichenological Society, 2015; Ohio Moss and Lichen Association, 2015). Studies of the responses of moss communities to habitat disturbance and environmental quality are, therefore, timely.

In this paper we examine data for mosses collected at 45 wetlands in Ohio, USA. We calculate three aspects of moss communities: number of species, a moss quality assessment index (Andreas et al., 2004); and probability of presence of groups of species with similar fidelities to substrates and plant communities. We test if these three variables respond to a disturbance gradient (ORAM) and if this response is the same in wetlands having different dominant vascular plant vegetation. For groups of moss species with similar fidelities to substrates and plant communities (Andreas et al., 2004), we calculate their respective probabilities of presence in our wetlands. Our objective is to make progress toward developing an IBI for mosses in wetlands, which may provide valuable ecological information on an often overlooked component in vegetation surveys. An IBI for mosses may provide a basis of comparison of the biological integrity of the moss communities among wetlands with different moss floras.

2. Materials and methods

2.1. Study areas and plot design

Data for this study were obtained from 45 wetlands in Ohio, USA (Fig. 1). These included 27 wetlands with emergent vegetation, 13 wetlands that were forested, and five wetlands in which shrubs were the dominant vegetation. Five additional wetlands were omitted because they were intensively managed or manipulated. Wetland area ranged from 0.004–86.1 ha ($\bar{x} = 20.6$ ha, $s = 20.0$ ha). Plot layout and assessment of vascular plants were conducted according to the 2011 National Wetland Condition Assessment (NWCA) protocols (U.S. EPA, 2011). In brief, transect lines were laid out in the four cardinal compass directions, with each line extending 45 m from the plot center. Five 10-m × 10-m subplots were established at fixed distances along these transect lines. Each subplot had one side on a cardinal line; one side parallel to, and 10 m from, that line; and two sides 10 m apart that were perpendicular to that same cardinal line. Two subplots were established on the South line, and one subplot was established on each of the remaining three lines. Aerial cover class for each vascular plant species found in the five subplots was estimated according to Peet et al. (1998).

2.2. Collection and identification of mosses

At each wetland, the five vegetation subplots were inspected to determine which was the most diverse with respect to substrates for bryophytes. We acknowledge that the effects of sampling scale on moss species diversity are unclear (e.g., Medina et al., 2014). However, by relegating our assessments to the five subplots our sampling scale was consistent for all wetlands. Once the most diverse subplot was selected, then the different substrates (Table 1) were identified and their approximate percentages with respect to cover were recorded. Substrate total cover may exceed 100% within a subplot. All moss species from each substrate were collected and put into small paper bags, each with an unique collection number. If we were not sure if a specimen belonged to a species that had already been collected, the specimen was collected in order to miss as few species as possible. The remaining subplots were subsequently inspected and any other moss species that had not already been collected on other subplots were then collected. Again, oversampling occurred by design to help ensure that as many moss species as possible were collected.

In the laboratory, the collected bryophytes were identified to the lowest possible taxonomic level according to taxonomic keys (Welch, 1957; Crum and Anderson, 1981; Ireland, 1982; Crum, 2004; Allen, 2006, 2014; Flora of North America Editorial Committee, 2007, 2014). Although both mosses and liverworts (Class Hepaticopsida) were collected and identified, we report only the results for mosses.

Table 1
Substrates examined for mosses. *Abbreviation*: dbh = diameter at breast height.

A. Soil
Soil
Hummock soil
Soil hollows (pit and mound)
B. Trees ≤30 cm dbh
Tree skirt
Skirt top to 33 cm height
Above 33 cm height
C. Trees >30 cm dbh
Tree skirt
Skirt top to 1 m height
Above 1 m
D. Dead trees
Tree skirt
Above skirt
E. Corticated log
F. Decorticated log
G. Shrubs
H. Tussock
I. Other (e.g., rocks, sticks)

2.3. Moss quality assessment index (MQAI)

The MQAI is a quality assessment index for mosses, developed by Andreas et al. (2004). Each moss species is assigned a coefficient of conservatism (CC) that ranges between 0 and 10 (Appendix B in Andreas et al., 2004). The CC describes a species' degree of fidelity to substrate and plant communities relative to other species in the moss flora. A CC of 0 is assigned to species with a wide range of ecological tolerances, including all non-native species and native species that are associated with ruderal, highly disturbed habitats. Species associated with anthropogenic disturbance and are found on a variety of substrates receive a CC of 1 (Andreas et al., 2004). Species commonly found in a variety of substrates and community types have CCs of 2 or 3. Species that are dependent on specific, natural substrate but are not associated with specific plant communities receive CCs of 4–6. Species with CCs of 7–8 are fairly substrate-specific and are associated with mature communities. CCs of 9 or 10 are reserved for species growing on specific substrates or in specific plant communities. The MQAI score is the sum of the CCs for all moss species divided by the square root of the total number of moss species recorded at the wetland (Andreas et al., 2004: equation 7). Thus, MQAI is "weighted" more for the presence of uncommon and obligate wetland moss species.