Journal of Great Lakes Research xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Journal of Great Lakes Research

journal homepage: www.elsevier.com/locate/jglr

Hydrology influences generalist–specialist bird-based indices of biotic integrity in Great Lakes coastal wetlands

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ARTICLE INFO

Article history:
Received 21 July 2013
Accepted 22 January 2014
Available online xxxx

Communicated by Craig Hebert

Keywords:
Bird
Coastal wetland
Index of biotic integrity
Lake Erie
Lake Ontario
Water level

ABSTRACT

Marsh bird habitats are influenced by water levels which may pose challenges for interpreting bird-based indices of wetland health. We determined how much fluctuating water levels and associated changes in emergent vegetation influence the Index of Marsh Bird Community Integrity (IMBCI) using data collected in Great Lakes coastal wetlands by participants in Bird Studies Canada's Great Lakes Marsh Monitoring Program. IMBCI scores for 90 wetlands in Lake Erie and 131 wetlands in Lake Ontario decreased with decreasing water levels due to decreasing number of marsh-dependent species in Lake Erie and perhaps also in Lake Ontario. The average magnitude of the decrease in scores between extremely high and low water periods for wetlands with sufficient data was 15% in Lake Erie where water dropped 0.9 m on average ($n = 11$ wetlands) and 18% in Lake Ontario where water dropped 0.5 m ($n = 7$). Scores in Lake Erie increased with increasing *Typha* due to increasing numbers of marsh-dependent species and decreased with increasing *Phragmites* due to increasing numbers of generalist species. The opposite was observed in Lake Ontario, perhaps due to denser *Typha* and sparser *Phragmites*. Scores were explained by the naturally fluctuating water levels of Lake Erie, which favored *Phragmites* expansion and the regulated water levels of Lake Ontario which promoted *Typha* expansion. Scores were influenced by fluctuating water levels and associated changes in emergent vegetation. Inter-annual water level fluctuations should be considered when interpreting any indicator of wetland health that is based on marsh-dependent bird species.

Introduction

Naturally fluctuating water levels are important for maintaining biological diversity in coastal wetlands of the Great Lakes basin (Keddy, 2000; Wilcox and Nichols, 2008). Periods of high water limit the lakeward expansion of dominant species and certain trees and shrubs; whereas, periods of low water promote germination from the seed bank (Keddy and Reznicek, 1986). As such, the long-term inter-annual ebbs and flows associated with variable water levels help produce and maintain structurally complex wetlands with diverse vegetation (Wilcox and Meeker, 1991; Wilcox et al., 2002). In marshes throughout North America, black tern (*Chlidonias niger*), pied-billed grebe (*Podilymbus podiceps*), and American coot (*Fulica americana*) prefer open water patches within emergent vegetation (Dunn, 1979; Forbes et al., 1989; Sutherland and Maher, 1987); whereas, swamp sparrow (*Melospiza georgiana*), American bittern (*Botaurus lentiginosus*), least bittern (*Ixobrychus exilis*), marsh wren (*Cistothorus palustris*), and Virginia rail (*Rallus limicola*) prefer more extensive coverage of emergent vegetation (Frederick et al., 1990; Gibbs et al., 1991; Lor and Malecki, 2006; Willson, 1967). As a result, diversity is highest where interspersion of emergent vegetation with open water is greatest (Rehm and Baldassarre, 2007). Diversity is also higher when and where emergent vegetation is inundated because dense dry patches are avoided by most marsh-dependent species (Gibbs et al., 1991; Manci and Rusch, 1988). Thus, water levels alter the abundance and quality of wetland habitats, which in turn alter the distribution and abundance of marsh-dependent species of birds (Timmermans et al., 2008).

Indices of biotic integrity (IBIs) are intended to evaluate the health of ecosystems based on the abundance or occurrence of species in communities (Karr, 1981). Anthropogenic stressors such as pollution and habitat degradation are reflected in IBIs by the presence or absence of disturbance-sensitive species (Karr, 1981). Many IBIs applied to Great Lakes coastal marshes incorporate the occurrence of marsh-dependent breeding bird species in their scores (e.g., Index of Biotic Integrity: Crewe and Timmermans, 2005; Macecek and Grabas, 2011; Index of Ecological Condition: Howe et al., 2007; Index of Marsh Bird Community Integrity [IMBCI]: DeLuca et al., 2004; Smith and Chow-Fraser, 2010; Smith-Cartwright and Chow-Fraser, 2011). These obligate marsh-nesting species are considered *specialists*, in part, due to their relatively narrow habitat requirements, whereas facultative marsh-nesting species are considered *generalists*, in part, because they nest in marsh and upland habitats. As urbanization, pesticide inputs, or other localized

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http://dx.doi.org/10.1016/j.jglr.2014.02.006
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wetland stressors intensify, IBI-based scores of wetland health decline because the occurrence of specialists decreases (DeLuca et al., 2004). However, similar declines in scores may be realized when the proportion of inundated emergent vegetation declines or the species composition or amount of emergent vegetation changes temporarily due to changes in water levels, because marsh-dependent species relocate to higher-quality sites (e.g., least bittern (Winstead and King, 2006), marsh wren (Verner and Engelsen, 1970),Virginia rail (Manci and Rusch, 1988)). Given that the rate of vegetation change or extent of vegetation inundation varies from site to site, there is potentially a large amount of variability in IBI wetland scores caused by changing water levels that may be independent of overall wetland health based on presence/absence of avian species (Wilcox et al., 2002). This may be especially true because factors such as climate warming and anthropogenic water level regulation operate at broad regional scales (e.g., Angel and Kunkel, 2010; Wilcox and Xie, 2007, 2008); whereas bird-based IBIs are meant to reflect wetland health largely as a function of local- or watershed-level stressors.

Specialist richness in coastal wetlands may decline during low water due to invasion by non-native common reed (*Phragmites australis* subsp. *australis*; hereinafter "*Phragmites*") because *Phragmites* germinates from the seed bank during low water (Hudon et al., 2005; Wilcox, 2012) and some marsh-dependent breeding birds avoid *Phragmites* stands (Benoit and Askins, 1999; Meyer et al., 2010). Specialist richness may also decline during stable water levels due to dense growth of aggressive cattails (*Typha angustifolia*, *Typha* x *glauca*), which readily spread in the absence of water level fluctuations through vegetative reproduction (Wilcox et al., 2008), because most marsh-dependent breeding birds avoid dense cattail stands (e.g., Rehm and Baldassarre, 2007). Furthermore, increasing coverage of emergent vegetation reduces coverage of submergent vegetation, which influences the foraging behavior and reduces the abundance of certain specialist species (Steen et al., 2006). However, these water level-related vegetation changes typically require at least one or more growing seasons before changes in vegetation are realized (e.g., Gathman et al., 2005; Tulbure et al., 2007; Wilcox et al., 2003). By contrast, specialist richness may decline more rapidly during low water because drying of existing emergent vegetation patches leads to specialists abandoning previously inundated breeding sites and relocating to higher quality sites within the same breeding season if water levels fall soon after the birds have settled (Timmermans et al., 2008). Thus, IBI scores could be biased if they are based on data collected during temporary periods of low water or periods of associated growth of dense emergent vegetation due to factors that may be largely unrelated to localized wetland stressors and the overall health of the wetlands that IBIs are meant to measure.

Given these potential sources of variation, our objective was to determine whether, and how much, fluctuating water levels and associated changes in emergent vegetation influence IMBCI scores, using data collected by participants in Bird Studies Canada's Great Lakes Marsh Monitoring Program (GLMMP). We predicted that numbers of marsh-dependent species would track water level changes; therefore, IMBCI scores would fluctuate according to water levels (e.g., Timmermans et al., 2008). We also predicted that numbers of marsh-dependent species and associated IMBCI scores would be lower in locations dominated by dense stands of *Phragmites* or cattail (e.g., Meyer et al., 2010; Rehm and Baldassarre, 2007).

Materials and methods

Study sites

Data were collected in coastal wetlands throughout Lake Erie ($n = 90$) and Lake Ontario ($n = 131$; Fig. 1). Wetlands were defined as being coastal based on a hydrogeomorphic classification system (Albert et al., 2005; Great Lakes Coastal Wetlands Consortium, 2003). Twenty wetlands considered for analysis as being in Lake Erie were actually in adjacent Lake St. Clair, which we justified based on the observation that during our study period the water levels of Lake St. Clair were explained by 96% of the variance in Lake Erie water levels.

Water levels

Water level data measured in meters referenced to the 1985 International Great Lakes Datum (IGLD85) were obtained from the Canadian Hydrographic Service (2012). The monthly mean reported by the Canadian Hydrographic Service represents the average from a network of water level gauging stations throughout each lake. For each year from 1995 to 2011, we averaged the monthly means of the water levels from April to July (i.e., an average of four averages) to derive a single average per year (hereinafter "water levels") to coincide with the breeding season of most bird species detected in the surveys.

Birds and vegetation

All data were collected by Bird Studies Canada's GLMMP participants within one to eight 100-m-radius semicircular stations in each wetland between 1995 and 2011 for birds and between 1996 and 2011 for vegetation. A subsample of wetlands was surveyed each year (Lake Erie average: 18 wetlands; Lake Ontario average: 30 wetlands). Participants recorded the occurrence of all bird species detected by sight or sound within each station during each of the two or three visits between 20 May and 5 July. Broadcasts of secretive marsh-dependent species were used during each 15-min bird survey, and bird surveys were only performed between 30 min before sunrise and 10:00 or between 18:00 and 30 min after sunset under ideal weather conditions, to increase detections. Stations were separated by more than 250 m to avoid double-counting birds. During one of the visits later in the season, when emergent vegetation was well-established, participants recorded the percentage of each station covered by cattails (*Typha* spp.; hereinafter "*Typha*"), reeds (*Phragmites* spp.; hereinafter "*Phragmites*"), grasses (Poaceae family), and sedges (*Carex* spp.). However, the sample size and range of coverage of grasses and sedges within the two lakes prevented robust analysis, so we did not consider grasses and sedges. The bird and vegetation survey protocol is described in greater detail elsewhere (Bird Studies Canada, 2009a, 2009b).

Index of Marsh Bird Community Integrity

The IMBCI score for each wetland was derived using the following formula:

$$W_{IMBCI} = [(\sum S_{IMBCI}/S_N) + MO_N] - 4,$$

where S_{IMBCI} is the individual IMBCI score for a species, S_N is the total number of species detected for a wetland, and MO_N is the total number of marsh obligate species detected for a wetland (see DeLuca et al., 2004). To determine S_{IMBCI} scores, four attribute categories of species were summed according to generalist–specialist characteristics (Table 1). A species was considered to have a breeding range in the Great Lakes basin if there were at least isolated populations present. We classified species with S_{IMBCI} scores < 10 as generalists and ≥ 10 as specialists. From 1995 to 2011, a total of 181 bird species were detected and scored using the S_{IMBCI} (Supplemental information Table S1).

Statistical analyses

During our study the water levels of Lake Erie were unregulated, but the water levels of Lake Ontario were regulated (Quinn, 2002) which likely resulted in more extensive *Phragmites* cover in Lake Erie and more extensive *Typha* cover in Lake Ontario (e.g., Wilcox et al., 2008; see also the Results section). Therefore, we analyzed data from each lake separately. Given that stations within the same wetland were