ARTICLE IN PRESS

JGLR-00995; No. of pages: 10; 4C:

Journal of Great Lakes Research xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Journal of Great Lakes Research

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

Marsh bird occupancy dynamics, trends, and conservation in the southern Great Lakes basin: 1996 to 2013

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ARTICLE INFO

Article history:
Received 7 November 2014
Accepted 15 October 2015
Available online xxxx

Communicated by Craig Hebert

Index words:
Citizen science
Coastal wetland
Great Lakes
Multi-scale
Marsh bird
Multi-season site occupancy model

ABSTRACT

Using data from 21,546 point counts conducted by volunteers in Bird Studies Canada's Great Lakes Marsh Monitoring Program, I assessed whether occupancy of 15 breeding marsh bird species increased or decreased throughout the southern portion of the Great Lakes basin between 1996 and 2013. I accounted for differences in detection probability, addressed spatial autocorrelation, and assessed whether initial occupancy in 1996 and subsequent colonization or extinction at a site within and across species was influenced by site, wetland, and landscape scale covariates. Occupancy of 9 of 15 (60%) species significantly decreased, whereas occupancy of only 1 (7%) species significantly increased. The results show the power of citizen science and suggest that the largest number of decreasing marsh-dependent breeding bird species will benefit from conserving, restoring, or creating large wetlands surrounded by limited urban land use, and from addressing issues within International Joint Commission Areas of Concern. Plus, individual or smaller groups of decreasing species will also benefit from conserving, restoring, or creating robust-emergent-dominated but interspersed, purple loosestrife (*Lythrum salicaria*)-free, *Phragmites*-free wetlands surrounded by higher proportions of wetland cover in the surrounding landscape, and from addressing issues within Great Lakes coastal wetlands. These actions will help promote colonization or reduce extinction and help slow or maybe even reverse declining trends in occupancy among decreasing species across the southern portion of the Great Lakes basin.

Introduction

Monitoring marsh dependent breeding birds can be challenging due to the birds' secretive behavior, low numbers, infrequent occurrence, and inaccessible habitat (Conway and Gibbs, 2011; Steidl et al., 2013). For instance, the Breeding Bird Survey (BBS), a passive, long-term, roadside monitoring program (Environment Canada, 2010), which is often considered the best source of information on North American bird population trends (e.g., North American Bird Conservation Initiative Canada, 2012), detected secretive marsh bird species on less than 5 of 91 (5%) survey routes per species per year on average throughout the Great Lakes-St. Lawrence lowlands between 1996 and 2013 (Pardieck et al., 2014). Such low numbers of annual detections require >30 years of data to achieve adequate statistical power for estimating linear population trends (Steidl et al., 2013). This is not effective for conservation and management because declines may be more subtle or rapid, and identification of problems needed more quickly.

To remedy the situation, Bird Studies Canada launched the Great Lakes Marsh Monitoring Program (GLMMP) in 1995, a volunteer citizen science program (Dickinson et al., 2010), which has operated every year since (Bird Studies Canada, 2014). To date, over 1500 trained participants have performed ~28,000 call broadcast surveys at targeted wetlands, resulting in detections of secretive marsh birds at greater than 50 of 232 (21%) survey routes per species per year on average in the Great Lakes basin, many times more detections than achieved by the BBS in the same region. Using standardized broadcasts of secretive species, visiting survey points at least two times per season, and surveying only in suitable emergent marsh habitat ensures that large sample sizes are achieved by the GLMMP each year for estimating population trends (Tozer, 2013). With the detection rates achieved by the GLMMP, it requires <15 years, or about half the time compared to the BBS, to achieve adequate statistical power for estimating population trends of most secretive marsh bird species in the Great Lakes basin (Steidl et al., 2013). However, in order to garner large numbers of volunteer participants to achieve such large sample sizes, the program has largely allowed participants to select sampling sites, which makes drawing inferences to larger un-sampled sets of sites less robust. Nonetheless, if one assumes that the GLMMP sites are approximately representative of wetlands in the region, the high precision of trends from the GLMMP make it the most suitable long-term dataset for guiding conservation of secretive marsh birds in the Great Lakes basin.

Previous analyses using the GLMMP dataset have identified numerous marsh bird population declines (e.g., Timmermans et al., 2008; Tozer, 2013, 2014). In a recent example, populations of 10 of 19 (53%) marsh breeding bird species declined between 1995 and 2012 across

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http://dx.doi.org/10.1016/j.jglr.2015.10.015
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the Great Lakes basin, including bitterns (e.g., *Botaurus*), shallow- (e.g., *Porzana*) and deep-water rails (e.g., *Gallinula*), and marsh-nesting terns (e.g., *Chlidonias*; Tozer, 2013). One study suggested that marsh bird trends were more negative within than outside Great Lakes International Joint Commission (IJC) areas of concern (Tozer, 2013), and another reported that declining marsh bird trends were steeper in coastal marshes in Lake Erie, Lake Huron, and Lake Michigan than in Lake Ontario (Timmermans et al., 2008). However, none of the previous studies above adjusted for differences in detection probability, addressed spatial autocorrelation, or explored influences of habitat covariates on occupancy dynamics. In this study, I report extended and updated annual occupancy estimates and trends of marsh-breeding birds in the southern portion of the Great Lakes basin based on GLMMP data. But I do so while addressing each of the three important items left unattended by the earlier studies listed above, which adds tremendous value to the results for conservation as elaborated on below.

The probability of detecting marsh birds during surveys varies with a number of factors including time of day, date, and weather (Conway and Gibbs, 2011). As a result, the probability of detecting marsh birds during surveys is almost never perfect (Mackenzie et al., 2003). Birds can be unavailable for detection for numerous reasons including being absent, or being present but never being visible or audible to the observer (Dénes et al., 2015). Birds can also be missed because observers fail to see or hear them, even though they were visible or audible, respectively (Dénes et al., 2015). Thus, detection probability must be accounted for in a way such as I accomplish in this study because if it varies systematically over time, unadjusted occupancy estimates may show trends where none exist, or fail to show trends where they do exist (Kéry and Schmidt, 2008).

Marsh bird survey points tend to be clustered at various scales, such as within wetlands or within wetland complexes (e.g., Conway, 2011). This often results in responses being more similar among clustered compared to unclustered points simply because they are closer together in space (Dormann et al., 2007). Referred to as spatial autocorrelation, this common feature of survey data violates independence assumptions required by statistical modeling (Dormann et al., 2007). Thus, spatial autocorrelation must be accounted for in a way such as I accomplish here because if certain spatially clustered points are assumed to be independent they may unduly influence parameter estimates and associated confidence limits and lead to unfounded recommendations for conservation.

Long-term marsh bird survey data provide important information on trends over time (e.g., Tozer, 2014). However, these data also harbor valuable information on habitat features associated with high colonization and low extinction (MacKenzie et al., 2003). This information then translates into conservation actions that will help promote colonization or reduce extinction, respectively, and in turn help slow or maybe even reverse declining trends. Thus, one should explore occupancy dynamics in a way such as accomplished here, particularly for species showing significantly decreasing occupancy over time (hereafter "decreasing species") versus those that do not (hereafter "increasing or stable species"), because it ultimately leads to more informed beneficial conservation actions for decreasing species.

My ultimate goal was to determine if occupancy for each of 15 marsh bird breeding species changed throughout the southern portion of the Great Lakes basin over the past two decades, and to generate conservation actions that will benefit decreasing species. In doing so, I was careful to account for differences in detection probability, address spatial autocorrelation, and assess whether initial occupancy and subsequent colonization or extinction at a site within and across species was influenced by site, wetland, and landscape scale covariates. Pursuing these outcomes seemed especially justified within the southern portion of the Great Lakes basin because intensive human land use and associated environmental stress has, and continues to have, a strong influence on remaining wetlands, in an area where up to 90% of wetlands have been converted to other land uses (e.g., Ducks Unlimited Canada, 2010; Wolter et al., 2006). I accomplished my goal using multi-season site occupancy models and an information theoretic approach to simultaneously evaluate variables potentially related to detection and occupancy dynamics using a large dataset consisting of ~21,000 GLMMP point counts conducted at ~2,100 sites over 18 years.

Methods

Study design

The GLMMP expanded throughout the Great Lakes basin in 1995, although coverage in the initial year and in the northern portion of the basin was never as extensive as subsequent years and in the southern portion of the basin (Fig. 1). I included only data from 1996 onward from the southern portion of the Great Lakes basin because, from that point and onward, there was reasonably good geographic coverage for birds throughout the area (~588 sites surveyed across ~181 routes per year on average; Fig. 2). I defined the southern portion of the Great Lakes basin as the part of the basin within Bird Conservation Regions 13, 14, 22–24, and 28 (Bird Studies Canada and NABCI, 2014). GLMMP participants selected survey marshes or they were randomly assigned. Participants conducted surveys within 1–8 semi-circular 100 m-radius plots (hereafter "sites") along survey routes within one marsh or across multiple marshes. Most sites (90%) were located on shore adjacent to marshes that were covered mostly by non-woody plants. Sites were >250 m apart to avoid double-counting individuals.

Bird surveys

Each site was surveyed for 10 min on 2–3 occasions at least 10 days apart between 20 May and 5 July in each year that the survey route was active. Surveys occurred in either the morning (30 min before local sunrise to 1000 local time) or evening (4 h before local sunset to dark) and only under weather conditions that were favorable for detecting all species and individuals present (no precipitation; wind: Beaufort 0–3, 0–19 km/h, recorded during each survey). Participants broadcasted calls during surveys to entice individuals of especially secretive species to reveal their presence by approaching or responding vocally. The calls occurred in the first 5 min of each 10-min survey and consisted of 30 s of vocalizations followed by 30 s of silence for each of least bittern (*Ixobrychus exilis*), sora (*Porzana carolina*), Virginia rail (*Rallus limicola*), a mixture of American coot (*Fulica americana*) and common gallinule (*Gallinula galeata*), and pied-billed grebe (*Podilymbus podiceps*), in that order. The GLMMP bird survey protocol is described in more detail in Bird Studies Canada (2009a). For each survey, I assigned day-of-year (e.g., 20 May = 140; hereafter "date"), morning versus evening (defined above; hereafter "time of day"), and a Beaufort wind scale value (hereafter "wind").

Site covariates

Visual estimates of percent areal coverage of major habitat and vegetation types were made annually within 100-m-radius semi-circular plots at each site. Multi-season site occupancy models can, in theory, incorporate these annual estimates directly into models, but as I describe under Analysis below, attempts to include these "yearly site covariates" (sensu Fiske et al., 2015) resulted in models that failed to converge. Instead, I took the first year value for each site to get coverage of open water (hereafter "% water"), robust emergent herbaceous vegetation (e.g., cattails [*Typha*], hereafter "% emergent"), common reed (*Phragmites* sp., hereafter "% *Phragmites*"), purple loosestrife (*Lythrum salicaria*; hereafter "% loosestrife"), and trees and shrubs (e.g., willows [*Salix*], hereafter "% trees and shrubs"), and I took the difference between the last-year value and the first-year value at each site to get overall change in coverage of open water (hereafter "change in % water"), robust emergent herbaceous vegetation (hereafter "change in

Please cite this article as: Tozer, D.C., Marsh bird occupancy dynamics, trends, and conservation in the southern Great Lakes basin: 1996 to 2013, J. Great Lakes Res. (2015), http://dx.doi.org/10.1016/j.jglr.2015.10.015