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Population ecology and monitoring of secretive marsh-birds in Iowa

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Population ecology and monitoring of secretive marsh-birds in Iowa

by

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A thesis submitted to the graduate faculty

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Major: Wildlife Ecology

Program of Study Committee:
Stephen J. Dinsmore, Major Professor
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CHAPTER I. GENERAL INTRODUCTION

Population monitoring is crucial to the effective conservation and management of a species because it identifies declining population trends before the species is at risk of extinction (Hagan 1992). In addition, knowing how different populations respond to changes in habitat is an important aspect of species conservation (Soulé 1985).

According to the Breeding Bird Survey (BBS; Sauer et al. 2008), populations of marsh-birds are declining across North America. As a result, several species are of heightened conservation status at the regional and local levels. For example, the American bittern (*Botaurus lentiginosis*), king rail (*Rallus elegans*), Virginia rail (*Rallus limicola*), and sora (*Porzana carolina*) are listed as priority species in one of the two Bird Conservation Regions (BCR) in Iowa (NABCI 2011). The American bittern and king rail are also listed as species of conservation concern by the U.S. Fish and Wildlife Service and the National Audubon Society, respectively. In Iowa, four species of marsh-birds (American bittern, least bittern [*Ixobrychus exilis*], king rail, and common moorhen [*Gallinula chloropus*] are currently listed as species of greatest conservation need (SGCN) by the Iowa Wildlife Action Plan (Zohrer 2006). The overall population decline of marsh-birds illustrates the need for regular monitoring and future research.

Little is known about the population status and distribution of marsh-birds in Iowa. This is due largely to lack of an effective monitoring program for these birds. Marsh-birds are secretive in nature, occupy habitats with dense emergent vegetation, and vocalize infrequently, making them difficult to detect using conventional survey techniques (Lor and

Malecki 2002). The concern about declining populations and the lack of effective survey methodology prompted the development of the North American Marsh Bird Monitoring Program (see < http://ag.arizona.edu/research/azfwru/NationalMarshBird/azfwru/NationalMarshBird/>). The main goal of this program was to evaluate the efficacy of call-broadcast surveys for monitoring secretive marsh-birds. Call-broadcast surveys are effective at increasing detection probability of marsh-birds (Conway and Nadeau 2006); however, other factors should also be considered when implementing this methodology. For instance, response rates of marsh-birds to call-broadcasts can vary temporally, both by season and time of day (Rehm and Baldassarre 2007, Nadeau et al. 2008). Therefore, further research is needed to establish optimal times for conducting marsh-bird surveys at different locations.

Evaluating habitat associations of secretive marsh-birds in conjunction with continuous population monitoring allows researchers and managers to assess the impacts of habitat restoration and management activities on populations. Habitat associations of secretive marsh-birds relative to wetland characteristics have been well studied (Brown and Dinsmore 1986, Craig and Beal 1992, Lor and Malecki 2006). However, few studies have examined the probability of marsh-birds to occupy a particular wetland based on habitat characteristics (Darrah and Krementz 2010). Site occupancy provides valuable information on species occurrence and can be used as an index of abundance for territorial species such as rails (Mackenzie et al. 2002, 2003, 2005). Knowing habitat associations of secretive marsh-birds in Iowa will allow us to provide guidance on wetland restoration and management decisions that will aid in the conservation of these birds.

The overall goal of our project was to understand distribution, abundance, and habitat associations of secretive marsh-birds, as well as refine national protocols for future monitoring in Iowa. To assess distribution and abundance, we modeled detection probability and obtained density estimates of four species of marsh-birds (pied-billed grebe [*Podilymbus podiceps*], least bittern, Virginia rail, and sora) in three different regions of Iowa (Chapter 2). We evaluated wetland occupancy of the same four species of marsh-birds relative to wetland characteristics (Chapter 3) to investigate habitat associations. Lastly, to refine survey protocols, we compared response rates to call-broadcasts of secretive marsh-birds between morning and evening survey periods and between early and late in the survey season (Chapter 4). We hope that this study will provide information on the population status and habitat requirements of secretive marsh-birds in Iowa to guide conservation and management efforts.

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CHAPTER II. DENSITY AND ABUNDANCE OF SECRETIVE MARSH-BIRDS IN IOWA

A paper to be submitted to *Waterbirds*

Tyler M. Harms and Stephen J. Dinsmore

ABSTRACT: Populations of marsh-birds are believed to be declining throughout North America in response to a decrease in wetland habitats. As a result, several species of marsh-birds are of heightened conservation status at the local and regional levels and the need to monitor populations of these birds is critical to effective conservation and management. Our objective was to estimate population densities and abundances of secretive marsh-birds in Iowa. We conducted call-broadcast surveys in conjunction with distance sampling for eight species of marsh-birds at wetlands in Iowa during 2009 and 2010. We divided Iowa into three regions based on our observations of microhabitat differences and to improve precision of our density estimates. We used Program Distance to model detection probability and obtain region-specific density estimates for four species of marsh-birds for which we had sufficient detections (pied-billed grebe, least bittern, Virginia rail, and sora). Density estimates ranged from 0.019 birds/ha (95% CI = 0.014-0.024) for least bittern to 0.12 birds/ha (95% CI = 0.11-0.14) for pied-billed grebe. Density estimates were different in all regions for three of the four species (pied-billed grebe, Virginia rail, and sora). Least bittern density was not different between regions 1 and 2, but was lower in region 3. Estimates of density are a reliable metric of population status because they consider the amount of suitable

habitat in the study area rather than all available habitats, thus allowing researchers to consider the effects of suitable habitat on bird populations.

KEY WORDS: bittern, call-broadcast, density, distance sampling, grebe, marsh-bird, point count, rail

INTRODUCTION

The evaluation of population status and trends is a common theme in avian research. Ongoing projects such as the Breeding Bird Survey (BBS; Sauer et al. 2008) and Audubon Christmas Bird Count (CBC; National Audubon Society 2011) have been in place for decades and are intended to measure long-term population trends of North American birds. In recent years, studies have evolved to using estimates such as population density and abundance as indicators of overall population size (Rosenstock et al. 2002). Researchers have used such estimates to establish baseline information on the population status of birds, evaluate the response of bird populations to both habitat characteristics and environmental change, and aid in the conservation and management of species of conservation concern (Rosenstock et al. 2002). The increasing importance of population monitoring (Bart 2005) makes it critical for researchers and managers to understand population sizes and those estimates that can be used as indicators of population status.

Populations of marsh birds are believed to be declining throughout North America since the 1970s and several species are of heightened conservation status at the local and regional levels (Eddleman et al. 1988, Gibbs et al. 1991, Conway and Gibbs 2005). Data from the BBS showed declining trends for American bittern (*Botaurus lentiginosis*) and king rail (*Rallus elegans*) from 1966 – 2007 (Sauer et al. 2008). Trends for other species such as

Virginia rail (*Rallus limicola*) and least bittern (*Ixobrychus exilis*) were also possibly declining during this period but were poorly estimated due to small sample sizes (Bystrak 1981, Robbins et al. 1986). According to the North American Bird Conservation Initiative (NABCI 2011), the American bittern, Virginia rail (*Rallus limicola*), and sora (*Porzana carolina*) are priority species for Bird Conservation Region (BCR) 11 (Prairie Pothole Region), which encompasses the portion of Iowa containing a majority of the wetland habitats (Miller et al. 2009). The king rail is a priority species for BCR 23 (Prairie Hardwood Transition Region; NABCI 2011) and is listed on the National Audubon Society Yellow WatchList (National Audubon Society 2007).   In Iowa, four species (American bittern, least bittern [*Ixobrychus exilis*], king rail, and common moorhen [*Gallinula chloropus*]) are listed as species of greatest conservation need (SGCN) by the Iowa Wildlife Action Plan (Zohrer 2006) and the king rail is also an Endangered Species in Iowa (Cooper 2008). In contrast, three species (Virginia rail, sora, and American coot [*Fulica americana*] are game species in Iowa. This wide range of conservation and management statuses indicates a need for population monitoring at both the state and regional levels.

The need for monitoring marsh-bird populations is amplified by the decline in wetland habitats across the U.S. Since the late 1800s, >90% of wetlands have been lost (Dahl 1990). This decline was almost exclusively related to agricultural development and the majority of these losses occurred in the Midwest and in California (Dahl 1990). By 1980, <1% of the historical wetland habitat in Iowa remained (Bishop et al. 1998). Many of the aforementioned declines in marsh-bird populations can be attributed to loss of suitable habitat (Eddleman et al. 1988, Conway et al. 1994, and Conway 2008). As wetland habitats

continue to be threatened by agricultural expansion and climate change (Zedler and Kercher 2005), it is crucial that researchers and managers evaluate population trends of marsh-birds to understand their resilience to habitat change and loss.

Marsh-birds are secretive, typically occupy habitats with dense emergent vegetation, and vocalize infrequently (Lor and Malecki 2002). This makes them difficult to detect using conventional survey techniques (Gibbs and Melvin 1993, 1997, Lor and Malecki 2002). Marsh-birds are frequently undersampled by large-scale monitoring programs such as the BBS, which can lead to biased population trends (Gibbs and Melvin 1993). Other limitations of BBS data exist because surveys are conducted from roadways, which are typically located away from suitable marsh-bird habitat (Bystrak 1981, Robbins et al. 1986, Conway and Gibbs 2001). In addition, the BBS does not permit the use of methods to elicit responses from secretive birds (marsh-birds, owls, nightjars), so detections of these birds are mostly opportunistic (Bystrak 1981, Conway et al. 1994). The uncertainty about the population status of these birds and lack of an effective survey methodology prompted the creation of the North American Marsh Bird Monitoring Program (see <http://ag.arizona.edu/research/azfwru/NationalMarshBird/index.htm>). The primary goal of this program is to develop and field-test the use of call-broadcast surveys for monitoring secretive marsh-birds. A central database was also established through this program to collect count data from researchers across the U.S. to establish nation-wide population trends of these species.

Population monitoring is crucial to the effective conservation and management of a species because it identifies declining population trends before the species is at risk of

extinction (Hagan 1992). Our objective was to estimate population densities and abundances of secretive marsh-birds in Iowa. To do this, we utilized distance sampling in conjunction with call-broadcast surveys at wetlands across Iowa. Findings from this study will form baseline population estimates of secretive marsh-birds in Iowa that can be combined with future studies to establish long-term population trends.

STUDY AREA

We surveyed marsh-birds at wetlands throughout Iowa in 2009 and 2010. We used the National Wetlands Inventory (NWI; USFWS 2009) as a base from which to select our sites. Wetlands in the NWI are located using aerial photointerpretation and are subsequently classified into systems, subsystems, and classes based on wetland characteristics (USFWS 2009). We considered wetlands from the Aquatic Bed (AB), Emergent (EM), and Unconsolidated Bottom (UB) classes of the Palustrine system (Wilen and Bates 1995). Wetlands within these classes fit one or more of the following general habitat criteria required by our target species: 1) shallow water (less than 1m deep), 2) closed basins (no inflow or outflow), 3) surrounded by few or no trees, and 4) the presence of emergent vegetation. We considered both natural and constructed wetlands for selection. Most wetlands were permanent or semi-permanent, although some temporary or seasonal wetlands were also selected (Stewart and Kantrud 1971). Wetlands contained a mix of emergent vegetation that included cattail (*Typha* spp.), sedge (*Carus* spp.), river bulrush (*Scirpus fluviatilis*), soft-stem bulrush (*Schoenoplectus tabernaemontani*), and reed canary grass (*Phalaris arundinacea*). Mean water depth at survey points within wetlands was 30 cm (± 1 cm) ranging from 0 to 115 cm.

METHODS

Site selection

Using Hawth's Analysis Tools for ArcGIS (Beyer 2004), we randomly selected wetlands from the NWI database. We stratified wetlands into six size classes based on area (ha) (≤5 ha, >5 to 10 ha, >10 to 20 ha, >20 to 30 ha, >30 to 40 ha, and >40 ha) to facilitate an equal representation of wetlands of different sizes and to ensure that potential area-dependent species were sampled. We randomly selected 10 wetlands from each size class (Brown and Dinsmore 1986) except that only 6 wetlands of 30-40 ha were selected due to the small number of wetlands within that class. To facilitate access for surveys, we selected only wetlands that were on public lands. We randomly assigned a fixed number of survey points 400 m apart to wetlands within each size class to allow for maximum coverage of each wetland and to minimize double-counting birds (Conway 2008). We assigned 1 point to both the <5 ha and >5 to 10 ha size classes, 2 points to the >10 to 20 ha size class, 3 points to the >20 to 30 ha size class, 4 points to the >30 to 40 ha size class, and 5 points to the >40 ha size class.

To improve precision of our density estimates, we divided Iowa into three post hoc regions based on our observations of microhabitat differences in wetlands (Figure 1). We defined region 1 as the Des Moines Lobe (Prior 1991). This region contained the majority of surveyed wetlands (n = 247) and consisted of those wetlands characterized as shallow potholes with shallow-marsh emergents (sedges [*Carex* spp.] and cattail [*Typha* spp.]) surrounded by upland prairie (Stewart and Kantrud 1971). We defined region 2 as western Iowa and it consisted mainly of wetlands in the Missouri River floodplain plus some

wetlands in northwest Iowa that were outside the boundaries of the Des Moines Lobe. These wetlands typically consisted of deeper water (>40 cm) and deep-water emergents (cattail and bulrush [*Scirpus fluviatilis* or *Schoenoplectus tabernaemontani*]; T.M. Harms, personal observation). Region 3 contained widely scattered wetlands in eastern and southern Iowa that included a variety of wetland types. Many of these wetlands were either isolated, man-made, or surrounded by forested uplands, all of which set them apart from most wetlands in the first two regions. The boundary between regions 2 and 3 is arbitrary, although we attempted to draw the line to best reflect differences in wetland characteristics as described above. Based on species-specific microhabitat preferences, we presumed that density estimates would differ between regions. For example, we expected Virginia rail density to be greatest in region 1 because these wetlands are natural potholes with requisite emergent vegetation, whereas we expected the density of least bitterns to be greatest in region 2 because those wetlands contain deeper water (>40cm) and taller (>1m) over-water emergent vegetation (cattail and river bulrush).

Bird surveys

We conducted unlimited-radius point counts with call-broadcast surveys from 16 May to 15 July 2009 and from 20 April to 10 July 2010. We conducted surveys for eight focal species of marsh-birds in accordance with the North American Marsh Bird Monitoring Protocol (Conway 2008). The eight focal species included pied-billed grebe (*Podilymbus podiceps*), American bittern, least bittern, king rail, Virginia rail, sora, common moorhen, and American coot (*Fulica americana*). Using an MP3 player (SanDisk Sansa Clip 1GB, SanDisk Corporation, Milpitas, CA, USA) attached to a pair of amplified speakers

(Panasonic Model RPSPT70, Panasonic Corporation, Secaucus, NJ, USA), we broadcast the call sequence at 90 dB 1 m from the source (Conway 2008). We placed the speakers 0.5 m from the substrate (ground or water surface) and pointed them towards the interior of the wetland. The call-broadcast sequence was obtained from the North American Marsh Bird Monitoring Program coordinator (Conway 2008) and consisted of a 5-minute passive listening period followed by 8 minutes of vocalizations. Each minute of the 8-minute call-broadcast period corresponded to one species and consisted of 30 seconds of vocalizations and 30 seconds of silence. Vocalizations were ordered by species dominance to minimize scaring birds prior to their respective sequence (Conway 2008). We recorded all visual and aural detections of all species at each survey point. Using a laser rangefinder (Nikon Prostaff 550, Nikon Incorporated, Melville, NY, USA), we measured the radial distance (m) to each bird detected. We recorded the distance to an individual bird only once regardless of any subsequent detections because distance sampling assumes that birds were detected at the location of first detection. Prior to conducting surveys, we measured wind speed (Beaufort; bft) and temperature (˚C) using a Weather Kestrel 4000 handheld weather meter (Nielsen Kellerman, Boothwyn, PA, USA). We also visually estimated the amount of cloud cover and assigned in to one of four classes (0 – few or no clouds, 1 – partly cloudy, 2 – cloudy or overcast, 4 – fog). We refrained from conducting surveys during periods of rain or when wind speeds exceeded 12 km/hr. Most survey points were accessed by foot, although we used a canoe to reach points on some larger wetlands.

Distance analyses

We used Program Distance (ver 6.2; Thomas et al. 2010) to model detection probability and obtain region-specific density estimates for four species of marsh-birds for which we had sufficient detections. These species were pied-billed grebe, least bittern, Virginia rail, and sora. Our densities are of breeding birds for three species (pied-billed grebe, least bittern, and Virginia rail) and spring migrants for the sora only. Our survey protocol nicely spanned the breeding season for two species (least bittern and Virginia rail), included the breeding season and perhaps some spring migrants for pied-billed grebe, and was truncated on 31 May to include only spring migrants for sora. Most of the migrant pied-billed grebes had already passed through by the start of our survey season. In addition, Darrah and Krementz (2010) started surveys for pied-billed grebes in mid-April and assumed that no individuals were immigrating or emigrating from a wetland. We included three covariates in models, all of which we believed could have affected detection probability. Those covariates were cloud cover (CLOUD), wind speed (WIND), and temperature (TEMP). We did not include observer as an effect because observers were familiar with vocalizations of target species and highly trained at detecting birds at varying distances. We assumed that detection of birds did not differ by year because we surveyed the same habitat types during both seasons and because the length of our survey seasons accounted for any seasonal variation in detectability. Subsequently, we pooled data from both years for analysis. For models without covariates, we estimated the detection function using the conventional distance sampling (CDS) engine (Thomas et al. 2010). We utilized four models suggested by Buckland et al. (2001:155) that are best suited for detection functions and meet

the distance sampling assumption that detection probability decreases as distance from the observer increases. These models were 1) uniform key function with a cosine expansion, 2) uniform key function with a simple polynomial expansion, 3) half-normal key function with a Hermite polynomial expansion, and 4) hazard-rate key function with a cosine expansion. For models that included covariates, we modeled the detection function using the multiple covariate distance sampling (MCDS) engine (Marques and Buckland 2003, 2004). This engine limits the choices of models for the detection function, so we utilized only the half-normal key function with Hermite polynomial expansion and hazard-rate key function with cosine expansion. We assigned the raw distances for three species (pied-billed grebe, Virginia rail, and sora) into distance bins to minimize variation in distance measures (Buckland et al. 2001:15) and to reduce effects of potential movement of birds prior to detection. We assessed the raw distances recorded for each species and assigned them to bins to meet assumptions about the detection function for each analysis. We did not bin the raw distances for least bittern because this species does not move in response to call-broadcasts (Conway and Gibbs 2001). We compared models using Akaike's Information Criterion corrected for small sample sizes (AIC_c) and considered models with $\Delta AIC_c \leq 2$ to have strong support (Burnham and Anderson 2002).

Using the number of detections from each year and a detection probability estimated from all detections, we calculated year-specific density estimates using the density equation for point transects (Buckland et al. 2001:39). We also calculated the variance of the year-specific density estimates, and then subsequently calculated the standard error of the year-specific density estimates (Buckland et al. 2001:76).

Using density estimates from the best-supported model for each species, we extrapolated breeding numbers of each species for each year by multiplying the overall density estimate for each year by total area of wetlands in Iowa, except that we estimated the number of migrants for Sora only. Using ArcGIS (ver. 10; ESRI 2010), we calculated the total area of wetlands in the NWI database from which we drew our sample by taking the sum of the area of all wetland polygons. We used the wetlands from which we drew our sample because these wetlands consist of habitat characteristics suitable for marsh-birds. We report total abundance (SE) for each species.

RESULTS

We surveyed 326 points at 130 wetlands during 2009 and 429 points at 177 wetlands during 2010 (Table 1). Of the species used in the analyses, we detected 406 birds during 2009 and 704 birds during 2010. The total area of wetlands in Iowa from which we drew our sample was 29,783 ha.

For pied-billed grebe, we assigned raw distances to bins of 0 – 100 m, 101 – 300 m, and 301 – 400 m. The best-supported model for pied-billed grebe was the uniform key function with a simple polynomial expansion and included no covariates on detection (Table 2). The single competitive model ($\Delta AIC_c = 0.92$) was the half-normal key function with Hermite polynomial expansion and included the covariate TEMP on detection (Table 3). However, temperature had no effect on detection probability because the confidence interval for this effect overlapped zero. According to the best-supported model, the density of pied-billed grebes was greatest in region 2 (0.16 birds/ha, 95% CI = 0.14 - 0.18, 6.10% CV) and we surmised that density was different in each region because the respective 95% confidence

intervals did not overlap. We estimated there was a total of 3,724 (± 232) breeding pied-

billed grebes in Iowa in 2009 and 2,839 (± 172) in 2010.

For least bittern, we used the raw distances to estimate density and detection

probability. The best-supported model for least bittern was the half-normal key function with

Hermite polynomial expansion and included the covariate WIND on detection (Table 3).

The best-supported model estimated that density of least bitterns was greatest in region 2

(0.030 birds/ha, 95% CI = 0.019 – 0.045, 19.55% CV). There was no difference in least

bittern density between region 1 and region 2 (95% confidence intervals overlapped), but

region 3 had a lower density than the other two regions (0.003 birds/ha, 95% CI = 0.001 –

0.008, 38.10% CV). For least bitterns, we estimated a total of 512 (± 122) and 474 (± 67)

breeding birds in Iowa in 2009 and 2010, respectively.

We assigned raw distances of Virginia rails to bins of 0 – 40 m, 40 – 125 m, 125 –

300 m, and 300 – 500 m. The best-supported model for Virginia rail was the half-normal key

function with no expansion and included the covariate CLOUD on detection (Table 3). The

single competitive model (ΔAIC$_c$ = 1.67) was the half-normal key function with no

expansion and no covariates on detection (Table 3). The best-supported model estimated that

density of Virginia rail was greatest in region 1 (0.10 birds/ha, 95% CI = 0.088 – 0.11, 5.81%

CV). All regions were different in terms of the density estimates because none of the 95%

confidence intervals overlapped. We estimated total number of breeding Virginia rails to be

1,656 birds (± 147) in 2009 and 2,073 birds (± 135) in 2010.

For sora, we assigned raw distances to bins of 0 – 100 m, 100 – 300 m, and 300 – 400

m. The best-supported model for this species was the uniform key function with simple

polynomial expansion and included no covariates on detection (Table 3). The single

competitive model (ΔAIC_c = 1.83) was the half-normal key function with no expansion and

included the covariate TEMP on detection (Table 3). The best-supported model estimated

sora density to be greatest in region 3 (0.16 birds/ha, 95% CI = 0.14 – 0.18, 6.55% CV).

Density estimates were different for all regions. We estimated total number of spring

migrant soras to be 827 birds (± 178) in 2009 and 3,608 birds (± 242) in 2010.

DISCUSSION

To make valid inferences concerning our density estimates, distance sampling

requires that researchers adhere to three main assumptions. These assumptions are: 1)

objects on the line or point are detected with certainty, 2) objects are detected at their initial

location, and 3) distance measurements are exact (Buckland et al. 2001:29-37). The use of

distance sampling in conjunction with call-broadcast surveys for surveying marsh-birds has

been questioned because some marsh-birds may move in response to the observer or to the

broadcasted calls, thus violating the second assumption of distance sampling (Conway and

Gibbs 2001). This potential movement towards the observer prior to detection is problematic

because it leads to overestimates of local density (Buckland et al. 2001:264). However, this

responsive movement is only problematic if birds move prior to being detected by the

observer (Conway and Gibbs 2001). Evidence of responsive movement towards the call-

broadcast exists for pied-billed grebes (Gibbs and Melvin 1993), Virginia rails (Baird 1974,

Tacha 1975), and soras (Baird 1974), although the frequency and propensity of movement in

these species has not been further studied. Legare et al. (1999) found that black rails

(*Laterallus jamaicensis*) move towards the tape prior to vocalizing. Weske (1969) found that

black rails moved towards the call-broadcast prior to vocalizing in 58% of trials, moved away from the call-broadcast in 4% of trials, and stayed in the same location during 38% of trials. Little research has addressed the distance of responsive movement, but Legare et al. (1999) found that male and female black rails moved mean distances of 9.5 m and 4.9 m towards the call-broadcast, respectively. Therefore, placing raw distances in bins *a posteriori*, that are wide enough to account for such movements, may reduce potential biases. Although we did not measure potential movement, we argue that by placing our raw distances into bins wide enough to account for any potential movement by each species improves the precision of our density estimates.

Although bias may exist in implementing call-broadcast surveys in conjunction with distance sampling, the realized benefits of this methodology may outweigh the potential bias. Conway and Nadeau (2006), while recognizing the potential bias associated with estimating distance to birds that are heard only, stressed three benefits of distance sampling for marsh-birds: 1) it allows researchers to rigorously assess detection probability of marsh-birds, 2) it better allows researchers to distinguish between multiple individuals at a single survey point, and 3) it provides researchers the option to control for observer bias by limiting detections to a certain distance from the observer. The importance of having a robust method for estimating detection probability for secretive species allows for the assessment of different survey methodologies for future monitoring. Call-broadcast surveys are effective at increasing detection probability when compared to passive surveys (Gibbs and Melvin 1993, Erwin et al. 2002, Conway and Gibbs 2005), and utilizing these methods along with distance sampling could better allow researchers to monitor population trends.

To our knowledge, no studies have utilized distance sampling to model detection and obtain density estimates of secretive marsh-birds. Because of the wide array of conservation statuses of marsh-birds in Iowa and throughout the Midwest, obtaining density and abundance metrics is an important first step to effective conservation and future monitoring. Many conservation decisions and actions rely on population estimates to assess the current status of the population and as a baseline comparison for future studies to establish population trends. Our study provides density and abundance estimates for four species of marsh-birds in Iowa, two of which are game species and one a SGCN species. The estimates of density and abundance found in our study were considerably lower than those found by Manci and Rusch (1988). However, we caution that our population estimates may be conservative because there may be more suitable habitat for marsh-birds in Iowa than what we considered for our extrapolation.

Our annual abundance estimates for soras illustrate that these species are abundant migrants from mid-April to mid-May. In 2009 we started surveys on 16 May, causing us to miss peak migration of this species and leading to a low estimate of abundance. However, our estimate of the number of migrant soras in 2010 was also lower than we expected. This is likely because the large number of birds detected during the narrow migration window was offset by the few birds detected during the remainder of the survey season. This illustrates the need to focus survey efforts for migrant species to a narrow migration window to obtain accurate abundance estimates. In contrast, our annual abundance estimates for the three breeding species were similar to what we expected. This demonstrates the utility of

conducting call-broadcast surveys and distance sampling throughout the breeding season to obtain estimates of breeding populations.

Density estimates were different in all regions except for least bitterns, which had similar densities in regions 1 and 2, but considerably lower density in region 3. We expected densities for all species to be different between regions because of microhabitat differences in wetlands within each region. Density of pied-billed grebes was greatest in region 2. Because pied-billed grebes frequently utilize wetlands with deep water for foraging and nesting (mean depth = 55.6cm ± 1.5cm; Lor and Malecki 2006), we were not surprised by this result because wetlands in region 2 contain deeper water (>40 cm; T.M. Harms, personal observation). Least bitterns prefer wetlands with tall emergent vegetation and deep water (Lor and Malecki 2006, Poole et al. 2009). We expected least bittern density to be greatest in region 2 because wetlands within this region are characterized by tall (>1m), robust stands of emergent vegetation and typically contain deeper water (>40cm; T.M. Harms, personal observation). Density was greatest in region 2, however it was not significantly different from that of region 1. The Iowa Breeding Bird Atlas Project (Jackson et al. 1996) found more evidence of breeding in the Des Moines Lobe than in western Iowa, although there are far more wetlands in the Des Moines Lobe than in other parts of Iowa. Density of Virginia rails was highest in region 1. The Iowa Breeding Bird Atlas Project (Jackson et al. 1996) found the most evidence of breeding for this species within the Des Moines Lobe. Virginia rails prefer shallow water (<15cm) and emergent cover (Sayre and Rundle 1984), and typically place nests in drier areas near the edges of marshes (Tanner and Hendrickson 1954). Wetlands in region 1 are characterized by shallow water (<40cm) and emergent vegetation

and are likely preferred by Virginia rails for nesting. Lastly, we found density of soras was greatest in region 3. We expected density of soras to be greatest in region 1 because they require similar habitat characteristics to the Virginia rail (Johnson and Dinsmore 1986b). Soras migrate through Iowa during a narrow window (mid-April – early May). Therefore, this finding could be the result of the timing of surveys in stratum 3.

Considering detection probability when estimating density and abundance of secretive species greatly improves precision of the estimates. Studies have used BBS data to evaluate population trends of marsh-birds (Conway et al. 1994, Lor and Malecki 2002). However, these studies recognize the drawbacks of using BBS data for these birds because they are typically undersampled. Other studies have simply used the number of birds encountered during surveys as an index of relative abundance (Johnson and Dinsmore 1986a, Frederick et al. 1990). Our study indicated that detection probability was low for all species, ranging from 0.076 (95% CI = 0.068 – 0.085) for Virginia rail to 0.27 (95% CI = 0.22 – 0.34) for least bittern. These estimates of detection probability are lower than those from other studies (Gibbs and Melvin 1993, Allen et al. 2004), but not surprising given this group's secretive behavior and potential geographic variation in detection probability (Nadeau et al. 2008). This difference in detection probabilities illustrates the need to consider this parameter when estimating density and abundance of secretive marsh-birds.

MANAGEMENT IMPLICATIONS

The importance of population monitoring is crucial to the effective conservation of any species (Hagan 1992). We argue that estimates of density are a reliable metric of population status because they consider the amount of suitable habitat in the study area rather

than all available habitats. This is important because researchers can assess the effects of suitable habitat on density and because considering all available habitats may cause density to be overestimated because birds will not occupy non-suitable habitats. Researchers can use density estimates as a baseline to establish population trends with information from future studies. We suggest that detection probability be considered when estimating population density and abundance of secretive marsh-birds because detection can vary geographically and because detection probability can be low for secretive species. If detection probability is not considered, density and abundance could be overestimated.

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TABLE 2.1. Number of wetlands visited and points surveyed for marsh-birds in each size

class in Iowa, 2009-2010.

Size class (ha)	No. of wetlands visited		No. of points surveyed	
	2009	2010	2009	2010
<5	20	30	20	30
>5 – 10	21	35	21	35
>10 – 20	28	39	56	78
>20 – 30	20	28	55	83
>30 – 40	11	11	39	44
>40	30	34	135	159
Total	130	177	326	429

TABLE 2.2. Model selection results and respective density estimates (with 95% confidence intervals) of four species of secretive marsh-birds in Iowa, 2009-2010. Density estimates are reported as birds/ha and by stratum. K is the number of parameters estimated by the model, ΔAIC_c is the difference in AIC units from the top model, and CV is the percent coefficient of variation. SP is the simple polynomial expansion and HP is the Hermite polynomial expansion.

Model	K	ΔAIC_c	Stratum 1 Density	CV	Stratum 2 Density	CV	Stratum 3 Density	CV
Pied-billed grebe								
Uniform(SP) + No Cov	1	0.00[1]	0.12 (0.11-0.14)	5.68	0.16 (0.14-0.18)	6.10	0.043 (0.039-0.048)	5.71
Half-normal(HP) + TEMP	2	0.92	0.15 (0.14-0.17)	4.77	0.19 (0.17-0.21)	5.26	0.053 (0.048-0.058)	4.81
Least bittern								
Half-normal(HP) + WIND	4	0.00[2]	0.019 (0.014-0.024)	13.62	0.030 (0.020-0.045)	19.55	0.003 (0.001-0.008)	38.10
Virginia rail								
Half-normal(HP) + CLOUD	4	0.00[3]	0.10 (0.088-0.11)	5.81	0.014 (0.012-0.016)	6.32	0.050 (0.045-0.056)	5.87
Half-normal(HP) + No Cov	1	1.67	0.095 (0.082-0.11)	7.10	0.013 (0.011-0.015)	7.51	0.048 (0.042-0.055)	7.14
Sora								
Uniform(SP) + No Cov	1	0.00[4]	0.064 (0.056-0.073)	6.45	0.038 (0.033-0.044)	6.79	0.16 (0.14-0.18)	6.55
Half-normal(HP) + TEMP	2	1.83	0.078 (0.066-0.092)	8.52	0.048 (0.029-0.078)	23.63	0.20 (0.17-0.24)	8.42

[1]AIC_c value for top model for pied-billed grebe is 578.82

[2]AIC_c value for top model for least bittern is 1,015.62

[3]AIC_c value for top model for Virginia rail is 735.00

[4]AIC_c value for top model for sora is 387.
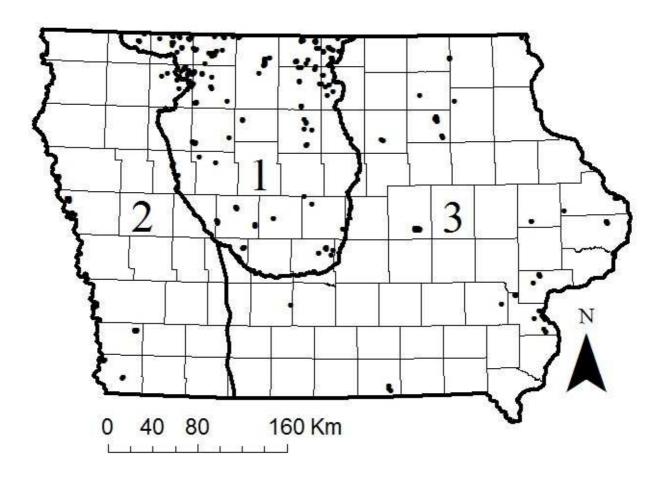
FIGURE 2.1. Location of wetlands surveyed for secretive marsh-birds within three strata in

Iowa, 2009-2010. Each dot represents a surveyed wetland, which could have included from

1 to 5 point counts.
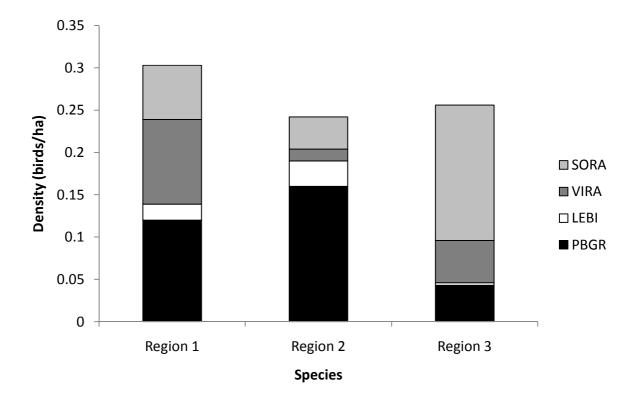
FIGURE 2.2. Density estimates for each species by region at wetlands in Iowa, 2009-2010.
Estimates from the best-supported model for each species are shown. PBGR is pied-billed
grebe, LEBI is least bittern, VIRA is Virginia rail, and SORA is sora. Region 1 was defined
as the Des Moines Lobe and contained wetlands characterized as shallow potholes with
shallow-marsh emergents (sedges [*Carex* spp.] and cattail [*Typha* spp.]) surrounded by
upland prairie. Region 2 was defined as western Iowa and consisted of wetlands with deeper
water (>40 cm) and deep-water emergent (cattail and bulrush [*Scirpus* spp.]). Region 3
contained widely scattered wetlands in eastern and southern Iowa that included a variety of
wetland types, many of which were isolated, man-made, or surrounded by forested uplands.

CHAPTER III. HABITAT ASSOCIATIONS OF SECRETIVE MARSH-BIRDS IN IOWA

A paper to be submitted to *The Condor*

Tyler M. Harms and Stephen J. Dinsmore

ABSTRACT: Drastic losses of wetland habitats across North America over the past century have resulted in population declines of many marsh-birds. This illustrates the need for proper management of remaining wetlands for the conservation of marsh-birds. The objective of our study was to evaluate the probability of site occupancy of secretive marsh-birds in Iowa in response to habitat variables at multiple scales. We conducted call-broadcast surveys for eight species of marsh-birds at wetlands in Iowa from 16 May – 15 July 2009 and from 20 April – 10 July 2010. We utilized occupancy models in Program MARK to estimate site occupancy probability based on habitat covariates for four species with the most detections (pied-billed grebe, least bittern, Virginia rail, and sora). Wetland size had a positive effect on site occupancy for three species (pied-billed grebe [$\beta = 0.03$, 95% CI = 0.006-0.054], least bittern [$\beta = 0.03$, 95% CI = 0.001-0.054], and Virginia rail [$\beta = 0.03$, 95% CI = 0.004-0.061]). Water depth positively affected site occupancy for pied-billed grebes ($\beta = 0.06$, 95% CI = 0.026-0.099) and least bitterns ($\beta = 0.06$, 95% CI = 0.025-0.095), and percent cover of cattail positively affected site occupancy for Virginia rails ($\beta = 0.05$, 95% CI = 0.025-0.085). We were unable to model site occupancy for soras because they are migrants in Iowa and violated the closure assumption of occupancy modeling. Site occupancy probabilities estimated by the top models ranged from 0.28 (95% CI = 0.173-0.419) for least bitterns to 0.69 (95% CI = 0.522-0.819) for Virginia rails. Detection probability ranged

from 0.54 (95% CI = 0.407-0.677) for least bitterns to 0.71 (95% CI = 0.608-0.799) for Virginia rails. Knowing habitat associations of secretive marsh-birds in Iowa will allow us to provide guidance on wetland restoration and management decisions that will aid the conservation of these birds.

KEY WORDS: bittern, call-broadcast, detection, grebe, Iowa, MARK, marsh-bird, occupancy, rail

INTRODUCTION

Drastic losses of wetland habitats across North America over the past century have resulted in declines of many populations of marsh-birds (Eddleman et al. 1988, Conway et al. 1994, Conway 2008). Since 1970, >90% of wetlands have been lost across the United States with the greatest losses occurring in the Midwest and California (Dahl 1990). In Iowa, many wetlands have been drained for agricultural purposes since settlement, leaving < 30,000 acres of the original 7.6 million acres of wetland habitat by 1980 (Bishop 1981). In response to these wetland losses, several species of marsh-birds are of heightened conservation at the state and regional levels (Lor and Malecki 2002, Conway and Gibbs 2005). This loss of wetlands and its corresponding effects illustrate the need for proper management of remaining wetlands for conservation of marsh-birds and other wetland-dependent birds (Lor and Malecki 2006, Rehm and Baldassarre 2007, Darrah and Krementz 2010).

Until recently, little was known about secretive marsh-birds across the United States and, in Iowa, they are arguably some of the least understood birds. Their secretive nature and tendency to occupy habitats with dense emergent vegetation makes monitoring these

birds very difficult (Lor and Malecki 2002). This lack of information and evidence of population declines prompted the development of the North American Marsh Bird Monitoring Program (see http://ag.arizona.edu/research/azfwru/NationalMarshBird/). The goal of this program was to develop a standardized set of survey protocols that could be implemented across the U.S. as a long-term monitoring tool with hopes to gain more information on secretive marsh-birds in the U.S. including status and population trends, habitat associations, and the effectiveness of targeted survey methodologies (Conway 2008).

Several studies have examined habitat associations of marsh-birds relative to different wetland characteristics. For example, some studies have examined the effects of different landscape-level variables such as degree of isolation (Brown and Dinsmore 1986, 1988, Craig and Beal 1992, Fairbairn and Dinsmore 2001), wetland size (Brown and Dinsmore 1986, 1988, Craig and Beal 1992,Craig 2008), and adjacent land use (Smith and Chow-Fraser 2010). Other studies have evaluated the effects of local-scale characteristics such as water-vegetation interspersion (Lor and Malecki 2006, Rehm and Baldassarre 2007), vegetation density and height (Sayre and Rundle 1984, Lor and Malecki 2006, Darrah and Krementz 2010), and water level and fluctuation (Gonzalez-Gajardo et al. 2009). Little research, however, has evaluated how these different habitat characteristics affect the probability of marsh-birds to occupy particular wetlands (Darrah and Krementz 2010).

Estimating population parameters can be relatively difficult with rare or secretive species because detection probability is imperfect ($< 100\%$; Mackenzie et al. 2002, 2003, Royle et al. 2005). However, site occupancy can provide valuable information on species occurrence and, for territorial species such as some rails, can be directly linked to species

abundance (MacKenzie et al. 2002, 2003, 2005). In addition, models have been developed to evaluate the effects of habitat variables on the probability of a species to occupy a particular habitat patch (MacKenzie et al. 2002, 2003). The use of such models for secretive species is particularly appealing because they also consider the probability of detection when estimating occupancy.

By determining habitat associations and linking such associations to life history characteristics, researchers can better understand the influence of different habitat attributes on the probability a species will occupy a particular patch. The goal of our study was to evaluate the probability of site occupancy by secretive marsh-birds in Iowa in response to habitat variables at multiple spatial scales.

STUDY AREA

We surveyed marsh-birds at wetlands throughout Iowa in 2009 and 2010. We used the National Wetlands Inventory (NWI; USFWS 2009) as a base from which to select our sites. The NWI classifies wetlands into systems, subsystems, and classes based on wetland characteristics (USFWS 2009). We considered wetlands from the Aquatic Bed (AB), Emergent (EM), and Unconsolidated Bottom (UB) classes of the Palustrine system (Wilen and Bates 1995). Wetlands within these classes fit one or more of the following general habitat criteria required by our target species: 1) shallow water (less than 1m deep), 2) closed basins (no inflow or outflow), 3) surrounded by few or no trees, and 4) the presence of emergent vegetation. We considered both natural and constructed wetlands for selection. Most wetlands were permanent or semi-permanent, although some temporary or seasonal wetlands were also selected (Stewart and Kantrud 1971). Wetlands contained a mix of

emergent vegetation that included cattail (*Typha* spp.), sedge (*Carus* spp.), river bulrush (*Scirpus fluviatilis*), soft-stem bulrush (*Schoenoplectus tabernaemontani*), and reed canary grass (*Phalaris arundinacea*). Mean water depth at survey points within wetlands was 30 cm (± 1 cm) ranging from 0 to 115 cm.

METHODS

Site selection

Using the NWI database, we stratified wetlands into six size classes based on area (ha) (≤5 ha, >5-10 ha, >10-20 ha, >20-30 ha, >30-40 ha, and >40 ha). We randomly selected wetlands from each size class using Hawth's Analysis Tools for ArcGIS (Beyer 2004). This allowed for an equal representation of both large and small wetlands and ensured that potential area-dependent species were sampled (Brown and Dinsmore 1986). To facilitate access for surveys, we only selected wetlands that were on public lands. We randomly assigned a fixed number of survey points 400 m apart to wetlands within each size class to allow for maximum coverage of each wetland and to minimize double-counting birds (Conway 2008). We assigned 1 point to both the ≤5 ha and >5-10 ha size classes, 2 points to the >10-20 ha size class, 3 points to the >20-30 ha size class, 4 points to the >30-40 ha size class, and 5 points to the >40 ha size class.

Bird surveys

We conducted unlimited-radius point counts in conjunction with call-broadcast surveys from 16 May to 15 July 2009 and from 20 April to 10 July 2010 during the early-morning (one-half hour before sunrise to three hours after sunrise) and late-evening (three

hours before sunset to one-half hour after sunset).In accordance with the North American

Marsh Bird Monitoring Protocol (Conway 2008), we conducted surveys for eight species of

secretive marsh-birds: pied-billed grebe (*Podilymbus podiceps*), American bittern (*Botaurus*

lentiginosis), least bittern (*Ixobrychus exilis*), king rail (*Rallus elegans*), Virginia rail (*Rallus*

limicola), sora (*Porzana carolina*), common moorhen (*Gallinula chloropus*), and American

coot (*Fulica americana*). We surveyed 56 wetlands up to four times during 2010 to create

the encounter history necessary to estimate site occupancy probability and detection

probability (MacKenzie et al. 2002). We also included data from single surveys conducted at

253 wetlands during 2009 and 2010. Using an mP3 player (SanDisk Sansa Clip 1GB,

SanDisk Corporation, Milpitas, California, USA) attached to a pair of amplified speakers

(Panasonic Model RPSPT70, Panasonic Corporation, Secaucus, New Jersey, USA), we

broadcast the call sequence at 90 dB 1 m from the source (Conway 2008). We placed the

speakers 0.5 m from the substrate (ground or water surface) and pointed them towards the

interior of the wetland. The call-broadcast sequence was obtained from the North American

Marsh Bird Monitoring Program coordinator (Conway 2008) and consisted of a 5-minute

passive listening period followed by 8 minutes of vocalizations. Each minute of the 8-minute

call-broadcast period corresponded to one species and consisted of 30 seconds of

vocalizations and 30 seconds of silence. Vocalizations were ordered by species dominance

to minimize scaring birds prior to their respective sequence (Conway 2008). We recorded all

visual and aural detections of all species at each survey point. We also recorded the distance

(m) to each bird and the minute of the sequence during which each vocalization was heard to

be used in other studies. Using a Weather Kestrel 4000 (Nielsen Kellerman, Boothwyn,

Pennsylvania, USA), we measured wind speed (Beaufort; bft) and temperature (˚C). We

visually estimated the amount of cloud cover and assigned it to one of four categories (0 – few or no clouds, 1 – partly cloudy, 2 – cloudy or overcast, 4 – fog). We refrained from conducting surveys during periods of rain or when wind speeds exceeded 12 km/hr. Most survey points were accessed by foot, although we used a canoe to reach points on some larger wetlands.

Habitat measurements

Prior to conducting surveys, we measured habitat variables at each survey point within each wetland. We conducted measurements at both the survey point and within a 50-m radius of the survey point to assess local habitat characteristics (Conway 2008). We measured water depth (cm; WATERDEP) and vegetation height (m; VEGSIZE) at the survey point. Vegetation height was assigned to one of three size classes (1 = 0.0-0.5 m, 2 = 0.5-1.0 m, 3 = >1.0 m). Within a 50-m radius of the survey point, we visually estimated percent coverage of the major types of emergent vegetation (Conway 2008). These vegetation types included cattail (*Typha* spp.; CATTAIL), bulrush (*Schoenoplectus* spp.; BULRUSH), sedge (*Carus* spp.; SEDGE), reed canary grass (*Phalaris arundinacea*; REEDCAN), and woody vegetation (WOOD). We took the sum of all vegetation cover estimates to obtain the total percent coverage of emergent vegetation (TOTVEG). We also visually estimated the percent coverage of water (WATER) and bare ground (GROUND). Percent coverage was estimated in 5% increments.

Using ArcGIS (v. 9.3; ESRI 2009), we measured five landscape level variables of interest. We obtained wetland size (ha; WETSIZE) from the NWI database from which we selected our survey wetlands. Wetland size was an important variable because studies have

shown that larger wetlands host greater avian diversity (Brown and Dinsmore 1986, 1988) and because some of our study species are potentially area-dependent. Those species are pied-billed grebe (Brown and Dinsmore 1986, Naugle et al. 1999), American bittern (Brown and Dinsmore 1986), and least bittern (Brown and Dinsmore 1986), king rail (Craig 1990), and common moorhen (Chabot 1996). Using ET Geo Wizards extension for ArcGIS (Tchoukanski 2011), we measured distance to the nearest wetland (m; DIST). We calculated the area of wetland habitat within a 1 km (ONEKM), 3 km (THREEKM), and 5 km (FIVEKM) buffer of the surveyed wetland to assess the degree of isolation of the surveyed wetland (Brown and Dinsmore 1986).

Occupancy models

We used the site occupancy model (MacKenzie et al. 2002) in Program MARK (White and Burnham 1999) to evaluate the effects of habitat variables on site occupancy of marsh-birds. This model generates estimates of the probability that marsh-birds occupy a particular wetland (ψ) and the probability of detecting marsh-birds given that they are present (p). We modeled site occupancy for four species that had the greatest number of detections. Those species were pied-billed grebe (*P. podiceps*), least bittern (*I. exilis*), Virginia rail (*R. limicola*), and sora (*P. carolina*). The site occupancy model in Program MARK estimates the above mentioned parameters from encounter histories generated from repeated surveys of sites (MacKenzie et al. 2002, White and Burnham 1999). We assumed that each wetland was independent and was closed to changes in occupancy state by marsh-birds throughout the survey season. This was a reasonable assumption because our surveys were restricted to a portion of the marsh-bird nesting season, a time when each focal species was unlikely to be

immigrating or emigrating from a wetland (Darrah and Krementz 2010). We also assumed that the mean of all local habitat variables measured at survey points within each wetland were representative of habitat characteristics in the entire wetland (Darrah and Krementz 2010).

Based on an extensive literature review and our own observations pertaining to habitat associations of secretive marsh-birds, we developed species-specific predictions about the effects of different habitat variables on site occupancy probability (ψ). We also considered the life history characteristics of each species when developing hypotheses. Below, we discuss hypotheses for each species in further detail.

Pied-billed grebe. - Pied-billed grebes are open-water nesters and typically build nests on floating platforms of vegetation (Muller and Storer 1999). Therefore, we predicted that the percent cover of open water would have a positive effect on site occupancy probability. We expected water depth to have a positive effect on site occupancy probability because this species forages primarily by diving (Muller and Storer 1999). Because pied-billed grebes utilize emergent vegetation in the construction of their nests (Glover 1953, Muller and Storer 1999), we surmised that percent cover of emergent vegetation would also have a positive effect on site occupancy probability. However, we were unable to specifically predict which type of emergent vegetation would yield this effect. At the landscape level, we expected wetland size to have a positive effect on site occupancy probability of pied-billed grebes because studies have found them to be area-dependent (Brown and Dinsmore 1986, Naugle et al. 1999). We also expected that a greater proximity to other wetlands would positively affect site occupancy (Rehm and Baldassarre 2007).

Least bittern. - We expected vegetation height to have a positive effect on site occupancy probability for this species because they construct nests suspended in tall emergent vegetation (Weller 1961, Lor and Malecki 2006, Poole et al. 2009). We also expected percent cover of bulrush to have a positive effect on site occupancy probability because least bitterns prefer this type of vegetation for nesting in Iowa (Kent 1951). However, other studies have shown that least bitterns associate more with percent cover of cattail (Frederick et al. 1990, Bogner and Baldassarre 2002), so we also expected percent cover of cattail to have a positive effect on site occupancy. We hypothesized that percent cover of water would have a similar positive effect to those of percent cover of the aforementioned vegetation types because several studies have shown that least bitterns prefer wetlands with near equal proportions of water and emergent vegetation (Bogner and Baldassarre 2002, Winstead and King 2006). We included wetland size in candidate models of site occupancy probability for least bitterns because they have been found to possibly be area-dependent (Brown and Dinsmore 1986). We did not find any evidence in the literature that least bitterns respond to the degree of isolation of wetlands.

Virginia Rail. - Lor and Malecki (2006) found that Virginia rails build nests in shallow water and others have shown that Virginia Rails are commonly found in wetlands with shallow water (Johnson and Dinsmore 1986, Conway 1995). Therefore, we expected water depth to have a negative effect on the site occupancy probability by this species.Lor and Malecki (2006) also found that Virginia rails build nests in wetlands with shorter vegetation, so we expected vegetation height to have a negative effect on site occupancy probability. We predicted percent cover of cattail would have a positive effect on site

occupancy probability because studies have found that Virginia rails used habitats with high amounts of cattail (Johnson and Dinsmore 1986, Manci and Rusch 1988). Virginia rails have been found to be area-independent (Brown and Dinsmore 1986, Benoit and Askins 2002, Craig 2008) and we found no evidence in the literature that they respond to the degree of isolation of wetlands, so we hypothesized that none of the landscape variables would affect site occupancy probability.

Sora. - Studies have shown that soras use several types of emergent vegetation (Tanner and Hendrickson 1956, Brown and Dinsmore 1986, Manci and Rusch 1988, Melvin and Gibbs 1996). We predicted that total percent cover of emergent vegetation would have a positive effect on site occupancy probability. Similar to Virginia rails, we expected water depth to have a negative effect on site occupancy probability because soras typically associate with shallow water (Johnson and Dinsmore 1986, Lor and Malecki 2006). Soras also associate towards shorter vegetation, so we expected vegetation height would have a negative effect on site occupancy probability (Lor and Malecki 2006). We did not predict wetland size would have an effect on site occupancy probability of this species because they have been found to be area-independent (Brown and Dinsmore 1986, Melvin and Gibbs 1996). There is no evidence that the degree of isolation affects occurrence of soras at wetlands so we did not predict an effect of these variables.

Detection probability (p). - We included variables wind speed (WIND), temperature (TEMP), and cloud cover (CLOUD) as factors affecting detection probability. We modeled detection probability as a time-varying parameter by day to account for both seasonal differences in vocalization frequencies of the target species (T.M. Harms, pers. obs.) and

daily variation in weather conditions that may affect detectability. Because observers were familiar with vocalizations of target species and highly trained at detecting birds at varying distances, we did not include observer as a covariate on detection probability.

Modeling process. - We utilized a two-step modeling process by which covariates on p were modeled first while keeping ψ constant; the top model for p was then included in the models for ψ (Olsen et al. 2005, Kroll et al. 2010). When modeling ψ, we envisioned a hierarchical model selection framework similar to that described by Johnson (1980) in which birds are first selecting for broad-scale, landscape variables to establish home ranges and then select for microhabitat variables to establish feeding and nesting sites. When building models, we first included landscape-level variables (WETSIZE, DIST, ONEKM, THREEKM, FIVEKM) and then added microhabitat variables. We compared models using Akaike's Information Criterion (AIC) adjusted for small sample sizes (AIC_c) and considered models with $\Delta AIC_c \le 2$ to have strong support (Burnham and Anderson 2002). There is currently no test for overdispersion in these data because the occupancy model in Program MARK does not currently have a goodness-of-fit test. We assessed correlation amongst the site-specific covariates by constructing a correlation matrix. Variables with $r \ge 0.80$ were considered highly correlated (Lor and Malecki 2006). Pairs of highly correlated variables included TOTVEG and WATER ($r = -0.98$), ONEKM and THREEKM ($r = 0.85$), and THREEKM and FIVEKM ($r = 0.96$). Therefore, we did not include these pairs of variables as additive effects in the models.

Model predictions. - We obtained model-based predictions of site occupancy probability by utilizing the user-specified covariate values option in Program MARK. We

used the best model for each species and specified a range of values for the covariate of

interest while setting values for all other covariates in the model to the mean. This allowed

us to obtain a set of occupancy predictions for species based on a range of values for

biologically-relevant covariates. We predicted site occupancy for all three species at

wetlands 0.1 – 40.0 ha in size. For pied-billed grebes and least bitterns, we also predicted

site occupancy at wetlands with varying water depths (10 -100 cm) because this covariate

was included in the best-supported model for both species. Lastly, we predicted site

occupancy for Virginia rails at wetlands with varying ranging from 10-90% because we

assumed that wetlands with either 0% or 100% were not suitable habitat for this species.

RESULTS

Pied-billed grebe

We detected pied-billed grebes at 127 sites during both years of surveys with the

greatest percentage of sites occupied occurring in the >30-40 ha size class (77.2%; Table 1).

The best-supported model for pied-billed grebe included the covariate CLOUD on detection

probability and the covariates WETSIZE, WATER, WOOD, and WATERDEP on site

occupancy probability (Table 2). The single competitive model ($\Delta AIC_c = 1.05$) included the

covariate CLOUD on detection probability and the covariates WETSIZE, TOTVEG,

WOOD, and WATERDEP on site occupancy probability (Table 2). Detection probability

was not affected by CLOUD ($\beta = -0.31$, 95% CI = -0.636-0.021) because the 95% confidence

interval included zero. Site occupancy probability was positively affected by WETSIZE ($\beta = $

0.03, 95% CI = 0.006-0.054), WATER ($\beta = 0.03$, 95% CI = 0.001-0.055), and WATERDEP

($\beta = 0.06$, 95% CI = 0.026-0.099) and was negatively affected by WOOD ($\beta = -0.06$, 95% CI

= -0.099 - -0.027). TOTVEG did not have an effect on site occupancy probability because

the 95% confidence interval included zero (β = -0.02, 95% CI = -0.049-0.003).

Least bittern

We detected least bitterns at 60 sites during both years of surveys with the greatest

percentage of sites occupied occurring in the >30-40 ha size class (36.3%; Table 1). The

best-supported model for least bitterns included the covariate CLOUD on detection

probability and the covariates WETSIZE, VEGSIZE, and WATERDEP on site occupancy

probability (Table 2). The single competitive model (ΔAIC_c = 0.61) included the covariate

WIND on detection probability and the covariates WETSIZE, VEGSIZE, and WATERDEP

on site occupancy probability (Table 2). Detection probability was not affected by CLOUD

(β = -0.33, 95% CI = -0.744-0.085) or WIND (β = 0.33, 95% CI = -0.147-0.809) because the

95% confidence intervals included zero. Site occupancy probability was positively affected

by WETSIZE (β = 0.03, 95% CI = 0.001-0.054), VEGSIZE (β = 1.41, 95% CI = 0.485-

2.325), and WATERDEP (β = 0.06, 95% CI = 0.025-0.095).

Virginia rail

We detected Virginia rails at 123 sites during both years with the greatest percentage

of sites occupied occurring in the >40 ha size class (56.4%; Table 1). The best-supported

model for Virginia rails included the covariate CLOUD on detection probability and the

covariates WETSIZE, CATTAIL, and REEDCAN on site occupancy probability (Table 2).

Competitive models ($\Delta AIC_c \leq$ 2) also included the covariates VEGSIZE, WATERDEP, and

DIST on site occupancy probability in addition to those covariates included in the top model.

Detection probability was negatively affected by CLOUD (β = -0.39, 95% CI = -0.708 - -0.067). Site occupancy probability was positively affected by WETSIZE (β = 0.03, 95% CI = 0.004-0.061) and CATTAIL (β = 0.05, 95% CI = 0.025-0.085). All other covariates mentioned above had little or no effect on site occupancy probability because the 95% confidence intervals included zero.

Sora

We detected soras at 98 sites during both years of surveys with the greatest percentage of sites occupied occurring in both the >30-40 ha and >40 ha size classes (50.0% in each; Table 1). Soras are abundant in Iowa during migration and are a rare breeder (Kent and Dinsmore 1996). We presumed that this violated the closure assumption because individuals were not available for detection throughout the duration of the survey season (MacKenzie et al. 2002). To satisfy this assumption, we truncated detections to the breeding season only (1– 30 June) and eliminated the possibility of migrants through late May (Melvin and Gibbs 1996). Truncation of the data in this manner resulted in too few detections (n = 48) to model site occupancy for this species.

Parameter estimates and model predictions

Site occupancy probability for pied-billed grebes ranged from 0.47 – 0.74 (SE = 0.08 and 0.07, respectively) across wetland sizes (Figure 2). For least bitterns, site occupancy probability ranged from 0.15 – 0.36 (SE = 0.05 and 0.10, respectively) across wetland sizes (Figure 2). Site occupancy ranged from 0.49 – 0.78 (SE = 0.10 and 0.08, respectively) across wetland sizes for Virginia rails (Figure 2).

We used the best model for each species to make predictions about site occupancy as a function of important covariates. Site occupancy for pied-billed grebes ranged from 0.53 (SE = 0.07) at 10-cm depths to >0.99 (SE = 0.01) at 100-cm depths (Figure 3). For least bitterns, site occupancy was 0.18 (SE = 0.05) at 10-cm depths and 0.98 (SE = 0.03) at 100-cm depths (Figure 3). Site occupancy for Virginia rails across varying percent cover of cattail ranged from 0.39 – 0.98 (SE = 0.07 and 0.02, respectively; Figure 4).

DISCUSSION

Wetland size had a positive effect on site occupancy probability for all species in this study. Several studies have shown that larger wetlands support the greatest avian species diversity (Brown and Dinsmore 1986, Craig and Beal 1992, Fairbairn and Dinsmore 2001, Craig 2008). Studies have found evidence of area-dependency in both pied-billed grebes (Brown and Dinsmore 1986, Naugle et al. 1999) and least bitterns (Brown and Dinsmore 1986, Moore et al. 2009), whereas Virginia rails have been found to be area-independent (Brown and Dinsmore 1986). Pied-billed grebes typically occupy wetlands with large expanses of open water (Muller and Storer 1999, Osnas 2003, Darrah and Krementz 2010). Least bitterns are believed to occupy larger wetlands to increase distance (>123 m) between breeding territories and avoid aggressive interactions between conspecifics (Bogner and Baldassarre 2002) and prefer larger wetlands for nesting (Lor and Malecki 2006). Wetland size has not been shown to be a factor influencing site occupancy of Virginia rails. However, Kantrud and Stewart (1984) found that larger semi-permanent and permanent wetlands typically possess tall, robust stands of emergent vegetation which are preferred by Virginia rails during the breeding season (Johnson and Dinsmore 1986, Lor and Malecki 2006).

Water depth positively affected site occupancy probability for pied-billed grebes and least bitterns. Published literature suggests that pied-billed grebes prefer wetlands with deeper water (Lor and Malecki 2006), although we found no evidence of this for least bitterns. Pied-billed grebes forage by diving and studies have shown that other diving species (e.g., diving ducks) occupy wetlands with deeper water (Murkin et al. 1997, Webb et al. 2010). This could be because wetlands with deeper water possess larger invertebrates, such as salamanders and small fish, which are preferred prey items of pied-billed grebes (Muller and Storer 1999, Osnas 2003). In addition, pied-billed grebes build nests over deeper water (Lor and Malecki 2006) and have higher reproductive success in deep wetlands (Osnas 2003). Deep water may result in increased foraging efficiency and may eliminate access to nests by potential mammalian predators. Although we found no evidence for least bittern preference of deep-water wetlands, studies have shown that low water levels can cause population declines (Weller 1961, DesGranges et al. 2006). Least bitterns utilize tall emergent vegetation for a variety of purposes including nesting (Bogner and Baldassarre 2002, Lor and Malecki 2006, Poole et al. 2009) and foraging (Poole et al. 2009). Kantrud and Stewart (1984) found that deeper water increases water permanence in wetlands, thus allowing establishment of robust emergent vegetation communities. Therefore, the observed effect of water depth on site occupancy of least bitterns could be indirect.

Site occupancy probability for pied-billed grebes was negatively affected by percent cover of woody vegetation. Darrah and Krementz (2010) also found that site occupancy decreased with increased cover of woody vegetation. Woody plants are not common in prairie pothole wetlands (Galatowitsch and Van Der Valk 1996) and are frequently found in

wetlands with little or no emergent vegetation (pers. obs.). Pied-billed grebes require some component of emergent vegetation for nesting (Muller and Storer 1999, Osnas 2003), which may explain why site occupancy decreased at wetlands with increased cover of woody vegetation and decreased cover of emergent vegetation. Darrah and Krementz (2010) also suggest the pied-billed grebes may avoid wetlands with increased woody vegetation to avoid risk of predations by hawks and mammals.

We found no effect of degree of wetland isolation on site occupancy probability for any species. This was a surprising result because other studies have shown that marsh-birds prefer wetlands within a complex in favor of isolated wetlands (Brown and Dinsmore 1986, Fairbairn and Dinsmore 2001, Smith and Chow-Fraser 2010). Iowa has lost nearly 90% of its original wetland habitat since the development of agriculture and European settlement (Dahl 1990) and those wetlands remaining are isolated on the landscape (Brown and Dinsmore 1986). Birds may be occupying isolated wetlands because they still produce microhabitat characteristics preferred for nesting and foraging. In addition, Johnson (1980) explains that habitat selection is based on usage and availability. If few wetland complexes are available on the landscape, birds may focus their selection on alternative habitats (e.g., isolated wetlands) that they can still use and are more readily available on the landscape.

MANAGEMENT IMPLICATIONS

Although some habitat characteristics will be suitable for all species, managers should consider species-specific habitat needs for effective conservation. We found that large wetlands (>26 ha) with deep water (>19 cm) benefited three focal species of marsh-birds in Iowa because they provided suitable areas for foraging, enough area for birds to establish

breeding territories, and minimized interactions with conspecifics. In addition, pied-billed grebes occupied wetlands with little surrounding woody cover and greater cover of open water for foraging and nesting. Least bitterns occupied wetlands with tall, robust stands emergent vegetation for building nests and perching while foraging. Virginia rails occupied wetlands with greater cover of cattail for placement and construction of nests, cover from predators, and foraging habitats. We suggest that land managers focus efforts to restoring and managing wetlands for deep water and tall emergent vegetation communities. Also, managers should attempt to acquire larger wetlands, although most species will use smaller wetlands when available. Knowing habitat associations of secretive marsh-birds relative to wetland characteristics in Iowa will help land managers to make informed decisions when managing and restoring wetlands for multiple species of marsh-birds.

ACKNOWLEDGMENTS

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TABLE 3.1. Number of wetlands surveyed in each size class in Iowa, 2009-2010 and the percent of wetlands in which each species was detected.

Species	Wetland size (ha)					
	≥5	>5-10	>10-20	>20-30	>30-40	>40
Number	n =52	n =54	n =70	n =49	n =22	n =62
Pied-billed grebe	31	31	37	33	77	56
Least bittern	12	11	10	29	36	31
Virginia rail	37	19	36	45	55	56
Sora	21	13	33	31	50	50

TABLE 3.2. Model selection results for site occupancy (ψ) and detection probability (p) of three species of marsh-birds in Iowa, 2009-2010. ΔAIC_c is the difference in Akaike's Information Criterion relative the smallest value, K is the number of parameters in the model, w_i is the AIC_c weight, and Dev is the model deviance. Time-varying covariates on detection probability are as follows: CLOUD is the amount of cloud cover (0, 1, 2, 4) and WIND is the wind speed (Bft). Site-specific covariates on site occupancy probability (ψ) are as follows: WETSIZE is wetland size (ha), WATER is percent cover of open water, WOOD is percent cover of woody vegetation, WATERDEP is water depth (cm), TOTVEG is percent cover of all emergent vegetation, VEGSIZE is the height of vegetation, CATTAIL is the percent cover of cattail (*Typha* spp.), REEDCAN is the percent cover of reed canary grass (*Phalaris arundinacea*), and DIST is the distance to the nearest wetland (m).

Model	ΔAIC_c	K	w_i	Dev
Pied-billed grebe				
p(CLOUD) ψ(WETSIZE+WATER+WOOD+WATERDEP)	0.00[1]	7	0.51	531.21
p(CLOUD) ψ(WETSIZE+TOTVEG+WOOD+WATERDEP)	1.05	7	0.30	532.26
Least bittern				
p(CLOUD) ψ(WETSIZE+VEGSIZE+WATERDEP)	0.00[2]	6	0.39	371.47
p(WIND) ψ(WETSIZE+VEGSIZE+WATERDEP)	0.61	6	0.28	372.08
Virginia rail				
p(CLOUD) ψ(WETSIZE+CATTAIL+REEDCAN)	0.00[3]	6	0.25	544.47
p(CLOUD) ψ(WETSIZE+CATTAIL+REEDCAN+VEGSIZE)	0.51	7	0.19	542.89
p(CLOUD)ψ(WETSIZE+CATTAIL+REEDCAN+WATERDEP)	0.65	7	0.18	543.03
p(CLOUD) ψ(WETSIZE+DIST+CATTAIL)	1.58	6	0.11	546.05
p(CLOUD) ψ(WETSIZE+CATTAIL+VEGSIZE)	2.00	6	0.09	546.48

[1] AIC_c value for top model for pied-billed grebe is 545.58

[2] AIC_c value for top model for least bittern is 383.75

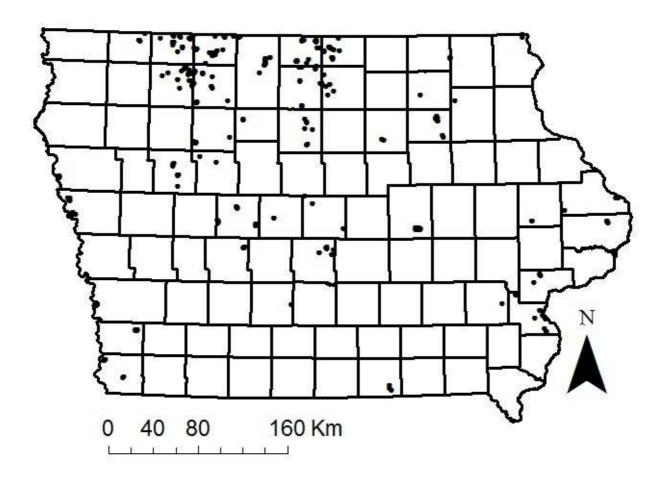[3] AIC_c value for top model for Virginia rail is 556.75

FIGURE 3.1. Location of wetlands surveyed for marsh-birds in Iowa, 2009-2010. Each dot represents a surveyed wetland, which could have included from 1 to 5 point counts.
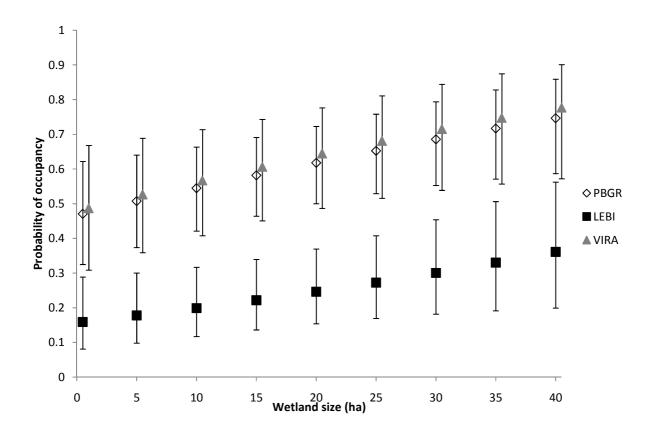
FIGURE 3.2. Predicted probability of site occupancy (±95% confidence limits) for pied-billed grebe, least bittern, and Virginia rail at wetlands ranging from 0.1 to 40 ha in Iowa, 2009-2010.
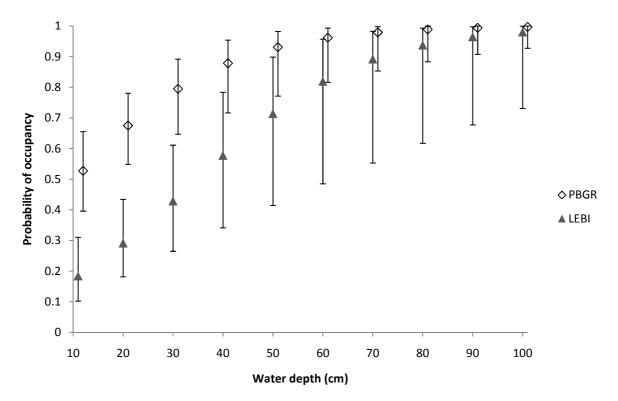
FIGURE 3.3. Predicted probability of site occupancy (±95% confidence limits) for pied-billed grebe and least bittern at wetlands with water depths ranging from 10 to 100 cm in Iowa, 2009-2010.
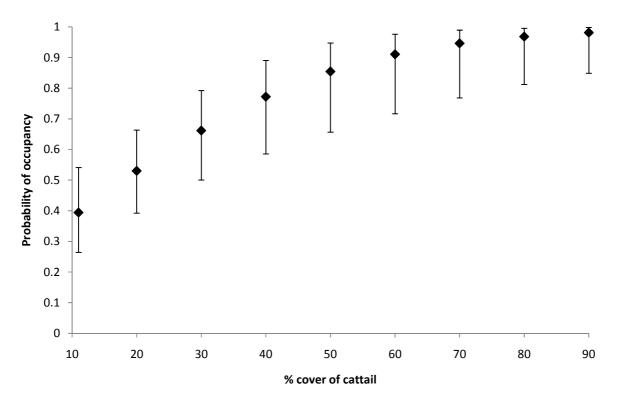
FIGURE 3.4. Predicted probability of site occupancy (±95% confidence limits) for Virginia rail at wetlands with 10 to 90 percent cattail cover in Iowa, 2009-2010.

CHAPTER IV: RESPONSE RATES OF SECRETIVE MARSH-BIRDS IN IOWA

A paper submitted to *Wildlife Society Bulletin*

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ABSTRACT: Call-broadcast surveys are frequently used to elicit responses of secretive marsh-birds and produce greater detection rates than passive surveys. However, little is known about how detection rates of birds from these surveys differ by season and time of day. We conducted call-broadcast surveys for eight focal species at wetlands throughout Iowa from 15 May – 13 June 2010 (early season) and from 15 June – 10 July 2010 (late season). Surveys were conducted in the early morning (one-half hour before sunrise to three hours after sunrise) and late evening (three hours before sunset to one-half hour after sunset) in accordance with the North American Marsh Bird Monitoring Protocol. We evaluated response rates to call-broadcast surveys as a function of a) time of day (morning and evening survey periods), b) season (early and late in the breeding season), and c) wetland size for four species with the greatest detection rate (pied-billed grebe, least bittern, Virginia rail, and sora). We also evaluated the above effects for all eight species pooled and all rails pooled. We found strong ($P < 0.05$) effects on the number of detections for pied-billed grebe in response to time of day, time of season, and wetland size; sora, Virginia rail, all rails, and all species had an effect of time of season only. Understanding seasonal and time-of-day differences in detection rates, as well as area dependence of secretive marsh-birds, will refine existing monitoring protocols by allowing researchers to maximize detection probabilities of target species.

KEY WORDS: bittern, call-broadcast, coot, detection, Iowa, marsh-bird, moorhen, rail

INTRODUCTION

Secretive marsh-birds (e.g., bitterns and rails) are some of the most inconspicuous birds in North America. These birds are difficult to monitor using conventional survey techniques because they vocalize infrequently and tend to occupy habitats that are densely covered by emergent vegetation (Lor and Malecki 2002). In addition, their crepuscular habits require sampling to occur in the early-morning and late-evening hours. The North American Marsh Bird Monitoring Protocol (Conway 2008) was established to aid researchers in the development of standardized surveys to effectively monitor these birds. Call-broadcast surveys have been implemented in several studies to elicit responses from marsh-birds (Johnson and Dinsmore 1986, Manci and Rusch 1988, Gibbs and Melvin 1993, Lor and Malecki 2002) and produce higher detection rates when compared to passive surveys (Gibbs and Melvin 1993, Erwin et al. 2002, Allen et al. 2004, Conway and Gibbs 2005 DesRochers et al. 2008). However, the effectiveness of call-broadcast surveys can vary temporally (Conway and Gibbs 2001, Rehm and Baldassarre 2007, Nadeau et al. 2008) and by species (Manci and Rusch 1988, Gibbs and Melvin 1993, Lor and Malecki 2002, Soehren et al. 2009). There is a need for additional information on seasonal variation in response rates and whether responses vary between morning and evening periods.

The North American Marsh Bird Monitoring Protocol (Conway 2008) instructs researchers to conduct call-broadcast surveys in the morning or evening depending on when birds are most vocal in the study area. A single study found that vocalization probabilities of marsh-birds are greater during morning surveys (Nadeau et al. 2008); other studies have shown that such probabilities are greater during evening surveys (Johnson and Dinsmore

1986, Conway et al. 2004). Several environmental factors such as temperature, wind speed, and cloud cover may differ during morning and evening survey periods, potentially affecting the vocalization frequency of marsh-birds (Nadeau et al. 2008). Vocalization frequencies of marsh-birds may also vary by time of day due to activity levels and other behavioral characteristics of the birds (Palmeirim and Rabaça 1994). No research has been done to determine the best time of day for surveying marsh-birds in the Midwestern United States. This information is critical to maximize detection probabilities of target species.

Another important consideration when conducting call-broadcast surveys for marsh-birds is that temporal variation in detection probability is minimized (Conway and Gibbs 2001, 2005). The national monitoring protocol states that optimal timing of surveys should overlap with the breeding seasons of focal marsh-bird species in the study area and suggests that surveys be conducted during a 45-day window that varies regionally based on average minimum temperatures in May. However, research has found that these survey windows may not be long enough to include peak detection periods for all focal species (Rehm and Baldassarre 2007). In Iowa, for example, the American bittern (*Botaurus lentiginosis*) and sora (*Porzana carolina*) arrive and initiate breeding in mid- to late April (Kent and Dinsmore 1996), whereas the least bittern (*Ixobrychus exilis*) arrives in mid-May and initiates breeding in late May or early June (Weller 1961). Therefore, the suggested survey window for Iowa (15 April to 30 May) may not include peak detection periods for all species of marsh-birds, especially late breeders like the least bittern. An adjustment of survey timing at the regional level may be necessary to account for seasonal differences in detection of target species.

Our objective was to examine the effects of 1) time of day, 2) time of season, and 3) wetland size on the detection rates of secretive marsh-birds in Iowa. This information will help refine survey timing for secretive marsh-birds in Iowa and whether detection rates vary with wetland size.

STUDY AREA

We surveyed marsh-birds at wetlands in the Des Moines Lobe of north-central and northwestern Iowa (Prior 1991; Figure 1). We used the National Wetlands Inventory (NWI; USFWS 2009) as a base from which to select our sites. The NWI classifies wetlands into systems, subsystems, and classes based upon wetland characteristics (USFWS 2009). We considered wetlands from the Aquatic Bed (AB), Emergent (EM), and Unconsolidated Bottom (UB) classes of the Palustrine system (Wilen and Bates 1995). Wetlands within these classes fit one or more of the following general habitat criteria required by our target species: 1) shallow water (< 1m deep), 2) closed basins (no inflow or outflow), 3) surrounded by few or no trees, or 4) the presence of emergent vegetation. We considered both natural and constructed wetlands for selection. Most wetlands were permanent or semi-permanent, although some temporary or seasonal wetlands were also selected (Stewart and Kantrud 1971). Most wetlands contained a mix of emergent vegetation that included cattail (*Typha* spp.), sedge (*Carex* spp.), river bulrush (*Scirpus fluviatilis*), soft-stem bulrush (*Schoenoplectus tabernaemontani*), or reed canary grass (*Phalaris arundinacea*). Mean water depth at survey points within wetlands was 30 cm ($\pm$ 1 cm) ranging from 0 to 115 cm.

METHODS

Site selection and surveys

Using Hawth's Analysis Tools for ArcGIS (Beyer 2004), we randomly selected wetlands from the NWI database. We stratified wetlands into six size classes based on area (ha) (≤5 ha, >5 to 10 ha, >10 to 20 ha, >20 to 30 ha, >30 to 40 ha, and >40 ha) to facilitate an equal representation of wetlands of different sizes and to ensure that potential area-dependent species were sampled. We randomly selected 10 wetlands from each size class (Brown and Dinsmore 1986) except that only 6 wetlands of 30-40 ha were selected due to the small number of wetlands within that class. To facilitate access for surveys, we selected only wetlands that were on public lands. We randomly assigned a fixed number of survey points 400 m apart to wetlands within each size class to allow for maximum coverage of each wetland and to minimize double-counting birds (Conway 2007). We assigned 1 point to both the <5 ha and >5 to 10 ha size classes, 2 points to the >10 to 20 ha size class, 3 points to the >20 to 30 ha size class, 4 points to the >30 to 40 ha size class, and 5 points to the >40 ha size class.

We conducted unlimited-radius point counts with call-broadcast surveys from 15 May to 10 July 2010. We conducted surveys for eight focal species of marsh-birds in accordance with the North American Marsh Bird Monitoring Protocol (Conway 2008). The eight focal species included pied-billed grebe (*Podilymbus podiceps*), American bittern, least bittern, king rail (*Rallus elegans*), Virginia rail (*Rallus limicola*), sora, common moorhen (*Gallinula chloropus*), and American coot (*Fulica americana*). Using an MP3 player (SanDisk Sansa Clip 1GB, SanDisk Corporation, Milpitas, CA, USA) attached to a pair of amplified speakers

(Panasonic Model RPSPT70, Panasonic Corporation, Secaucus, NJ, USA) we broadcast the call sequence at 90 dB 1 m from the source (Conway 2008). We placed the speakers 0.5 m from the substrate (ground or water surface) and pointed them towards the interior of the wetland. The call-broadcast sequence was obtained from the North American Marsh Bird Monitoring Program coordinator (Conway 2008) and consisted of a 5-minute passive listening period followed by 8 minutes of vocalizations. Each minute of the 8-minute call-broadcast period corresponded to one species and consisted of 30 seconds of vocalizations and 30 seconds of silence. Vocalizations were ordered by species dominance to minimize scaring birds prior to their respective sequence (Conway 2008). We recorded all visual and aural detections of all species at each survey point. We also recorded the distance (m) to each bird and the minute of the sequence during which each vocalization was heard to be used in other studies. We refrained from conducting surveys during periods of rain or when wind speeds exceeded 12 km/hr. Most survey points were accessed by foot, although we used a canoe to reach points on some larger wetlands.

To assess time-of-day differences in response rates, we conducted paired surveys at each wetland during both morning (30 minutes before sunrise to 3 hours after sunrise) and evening (3 hours before sunset to 30 minutes after sunset) survey periods. We conducted surveys during consecutive survey periods (morning-evening or evening-morning) to minimize any daily variation in responses of birds (Nadeau et al. 2008) and the order in which we conducted morning and evening surveys was varied so that one survey was not always conducted prior to the other (Conway et al. 2004). We split the survey season into early season (15 May to 14 June) and late season (15 June to 14 July) and conducted paired

surveys at each wetland during both seasons. To standardize the time between surveys, we conducted late-season surveys about a month (within 3 days) after early-season surveys. For example, if surveys were conducted on 25 May during early season, surveys of the same wetland were conducted within 3 days of 25 June during late season. We randomized the order in which points were surveyed at each visit. We hypothesized that all species would be more vocal in the morning survey period than evening survey period during both early and late in the survey season. We also hypothesized that pied-billed grebes, Virginia rails, and soras would be more vocal early in the survey season than late in the survey season, whereas least bitterns would be more vocal late in the survey season than early in the survey season.

Statistical analyses

Using generalized linear mixed-effects models (PROC GLIMMIX; SAS Institute 2002) we examined the effects of time of day, time of season, and wetland size on the number of detections at each survey point. Because our data were over-dispersed counts, we fit models using a Poisson-log normal probability distribution and a log (ln) link function (P.M. Dixon, Iowa State University, pers. comm.). Also known as mixed Poisson regression models, these models assume that the conditional distribution of the response is Poisson distributed with a random mean, which is dependent on the normally-distributed random effects (Weems and Smith 2004). The inclusion of random effects accounts for over-dispersion in the response variable. We considered effects significant at $P \leq 0.05$. For those models that yielded a significant interaction between time of season and time of day, we conducted further analyses to examine time-of-day effects by season.

We used the total number of birds detected at each survey point as the number of detections. We assumed that detection probability was increased in our study by the use of call-broadcast surveys (Gibbs and Melvin 1993, Conway and Gibbs 2005). We also assumed constant detection probability across survey sites because sites contained similar habitat and because habitats were open with little to inhibit bird detections. Time of day and time of season were categorical variables (1 or 2) corresponding to morning and evening survey periods and early and late in the survey season, respectively. We included wetland size in the models because we assumed that larger wetlands would harbor more marsh-birds and make the number of detections area-dependent (Conway and Gibbs 2001).

To account for over-dispersion in the response variable, we included a random effect on each individual visit to each wetland (WETLAND*TIME OF DAY*TIME OF SEASON). We also included random effects on wetland, survey point, the interaction of wetland and time of day (WETLAND*TIME OF DAY), and the interaction of wetland and time of season (WETLAND*TIME OF SEASON) to further account for variation in the model. We modeled the number of detections versus fixed effects for four of our focal species. We chose these species to compare results between three breeding species (pied-billed grebe, least bittern, and Virginia rail) and a migrant (sora). Due to the low number of detections (<10), we could not model the number of detections for American bittern, king rail, or common moorhen. We chose not to include American coot because many individuals were visually detected and their response to call-broadcasts was problematic. We also modeled the number of detections for all rails combined (king rail, Virginia rail, sora, and common moorhen) and for all eight species pooled. Survey points at which no birds were detected

during all four visits (n = 406) were not included because these points did not contribute any information to the analyses.

RESULTS

We surveyed a total of 56 wetlands (136 points) from both 15 May - 14 June (early season) and 15 June - 10 July (late season) 2010 (Figure 1). The number of detections was greater during the early season ($n = 379$) than during the late season ($n = 217$) and we detected more birds during morning survey periods ($n = 306$) than during evening survey periods ($n = 290$; Table 1).

We found significant ($P < 0.05$) effects of time of season on the number of detections for three species (pied-billed grebe, Virginia rail, and sora) and both groups (Table 2). Birds were more vocal early in the survey season than late in the survey season. For pied-billed grebes, we also found significant effects of wetland size ($F_{1, 14.01} = 10.30$, $P = 0.006$), and the interaction of time of season and time of day ($F_{1, 219} = 6.04$, $P = 0.015$) on the number of detections. The number of detections for pied-billed grebes was greater at larger wetlands. Upon further analysis of the interaction term, we found a significant effect of time of day late in the survey season ($F_{1, 19.47} = 7.85$, $P = 0.011$), thus illustrating that pied-billed grebes were vocal at all hours early in the survey season but were more vocal during morning hours late in the survey season. For least bitterns, we found no effects of the variables on the number of detections.

DISCUSSION

Seasonal differences in detection rates have been observed for several species of marsh-birds (Spear et al. 1999, Rehm and Baldassarre 2007). These differences, however, can vary geographically (Rehm and Baldassarre 2007). In this study, birds vocalized more frequently early in the survey season than late in the survey season. The explanation for this finding varies by species. Pied-billed grebes and Virginia rails are regular breeders in Iowa and their peak breeding seasons overlap with the early portion of the survey period. Virginia rails frequently vocalize during the breeding season (Glahn 1974, Conway 1995), but are mostly silent during migration (Griese 1980, Kaufmann 1989). Similarly, pied-billed grebes frequently vocalize during the breeding season when establishing territories and during courtship (Glover 1953, Muller 1999), but vocalize less frequently outside the breeding season depending on geographic location (Palmer 1962, Muller 1999). We expected the distribution of detections of both pied-billed grebes and Virginia rails to be non-linear. That is, birds vocalize frequently during the breeding season, infrequently when on the nest or with young, and more often again later in the survey season at the potential start of a second nesting attempt. Gibbs and Melvin (1993) found that the probability of response for both pied-billed grebes and Virginia rails peaked from 16 May – 31 May, decreased from 1 June – 30 June, and then increased again from 1 July – 15 July. If a similar pattern occurs in Iowa, it could diminish our ability to find differences in the detection rate between early and late in the survey season. Detections for both pied-billed grebes and Virginia rails peaked early in the survey season and decreased over time with no evidence of an increase late in the survey season.

Soras are common migrants in Iowa and are infrequent breeders in the northern half of Iowa (Melvin and Gibbs 1996). Soras commonly vocalize during migration (Kaufmann 1983, 1989, Johnson and Dinsmore 1986). Therefore, we expected strong seasonal variation in detections of this species with a peak early in the survey season and a steady decline thereafter. This explains why the detection rate of soras was greater early in the survey season than late in the survey season.

Our data indicate that time of day did not affect the detection rate of most species of marsh-birds in Iowa. We were surprised by this result because other studies have found that vocalization frequencies of marsh-birds vary by time of day (Johnson and Dinsmore 1986, Conway et al. 2004, Nadeau et al. 2008). Variation in vocalization frequency of marsh-birds is often attributed to temperature (Spear et al. 1999, Nadeau et al. 2008) because higher temperatures during the evening survey period may decrease activity levels of birds (Robbins 1981). We found a time-of-day effect on the number of detections for pied-billed grebes only, but this effect was significant only late in the survey season. As expected, the number of detections of pied-billed grebes was greater during the morning survey period than the evening survey period during late season. Gibbs and Melvin (1993) also observed that detection probabilities of pied-billed grebes were relatively high during morning surveys, although no previous studies have compared detection probabilities of pied-billed grebes between morning and evening survey periods. We attribute increased detections of pied-billed grebes during the morning survey period to weather conditions. Late in the survey season, temperatures ranged from 12.3 – 25.4˚ C during morning survey periods and 19.4 – 33.0˚ C during evening survey periods with a mean difference of 6.6˚ C. This suggests that

pied-billed grebes are most active and vocal during cooler times of the day (e.g. morning hours) late in the season because of generally warmer temperatures during this time of year. It is difficult to ascertain why higher evening temperatures affect the detection rate of pied-billed grebes and not other species. Pied-billed grebes spend a majority of their time on open water, whereas bitterns and rails spend their time in dense, tall stands of emergent vegetation (T.M. Harms, personal observation). Perhaps pied-billed grebes are most active during cooler, morning hours because they are more exposed to direct sunlight. Rails and bitterns are protected from the sun by tall vegetation, and therefore can remain active during the warmer hours of the day.

We did not find effects of time of season or time of day on the detection rate for least bitterns. Least bitterns vocalize infrequently (Bogner and Baldassarre 2002) and it is debatable whether call-broadcast surveys are effective at increasing detection probabilities of these birds. Some studies have shown that call-broadcasts are effective at eliciting responses of least bitterns (Swift et al. 1988, Gibbs and Melvin 1993, Bogner and Baldassarre 2002), whereas other studies have shown call-broadcasts to be ineffective (Manci and Rusch 1988, Tozer et al. 2007). Although we did not address the effectiveness of call-broadcasts at increasing detections of least bitterns in this study, the number of detections (n=80) was relatively low compared to other species. In addition, Bogner and Baldassarre (2002) suggested that call-broadcast sequences consist of >1 minute of least bittern calls to effectively stimulate birds to respond. Our call sequence contained 30 seconds of least bittern calls. The unknown effectiveness of call-broadcast surveys and our small sample size

could explain why we did not find any seasonal or time-of-day effects on the number of detections of least bitterns.

The North American Marsh Bird Monitoring Protocol (Conway 2007) suggests a survey window of 15 April – 30 May for Iowa based on average minimum temperatures in May. We extended our survey season to 10 July to determine if there was a justification for extending the survey window for Iowa. As a result, we detected nearly half of the total number of birds (n=296) after 30 May, illustrating that the survey window for Iowa can be extended to increase detections of target species. Rehm and Baldassarre (2007) found similar results in a New York study and also suggested that the survey window be extended to incorporate peak detection periods for all species.

MANAGEMENT IMPLICATIONS

Interspecific seasonal variation of peak detection periods should be considered when conducting call-broadcast surveys, especially when surveying for both breeding species and migrants. If time is a limiting factor, surveys should be conducted early in the survey season because this is when marsh-birds are most vocal, thus increasing detections of target species. Surveys for pied-billed grebes should also be limited to the morning survey period. In Iowa, we suggest extending the survey window past that recommended by the North American Marsh Bird Monitoring Protocol to increase the number of detections of marsh-birds. Minimally, this period should be extended to 15 June, although the exact date will depend on the species being surveyed and the time available for conducting surveys.

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TABLE 4.1. Number of detections of marsh-bird species and group by survey period during

call-broadcast surveys in Iowa, 2010.

Species	Early/Morn	Early/Eve	Late/Morn	Late/Eve	Total
Pied-billed grebe	48	54	49	10	161
Least bittern	22	17	13	28	80
Virginia rail	54	55	40	36	185
Sora	35	23	5	1	64
Rails	95	80	51	38	264
All species	180	199	126	91	596

TABLE 4.2. Model estimates (SE) for each fixed effect for models to predict site occupancy by marsh-bird species and group from call-broadcast surveys in Iowa, 2010. Significant effects ($P \leq 0.05$) are italicized

Species	Time of season	Time of day	Wetland size	Season/Day
Pied-billed grebe	*0.91 (0.25)*	*0.79 (0.25)*	*0.0084 (0.0026)*	*-0.72 (0.29)*[1]
Least bittern	-0.51 (0.34)	-0.45 (0.30)	-0.0641 (0.0855)	0.29 (0.44)
Virginia rail	*0.45 (0.19)*	-0.06 (0.20)	-0.0027 (0.0018)	-0.20 (0.27)
Sora	*1.98 (0.54)*	0.55 (0.63)	0.0004 (0.0033)	-0.36 (0.69)
Rails	*0.63 (0.19)*	0.04 (0.20)	-0.0020 (0.0020)	-0.14 (0.24)
All species	*0.66 (0.14)*	0.21 (0.15)	0.0016 (0.0023)	-0.29 (0.18)

[1]The time-of-day effect differed between early season (15 May to 14 June; -0.01 [0.17], $P = 0.954$) and late season (15 June to 15 July; 0.76 [0.27], $P = 0.011$) for this species.
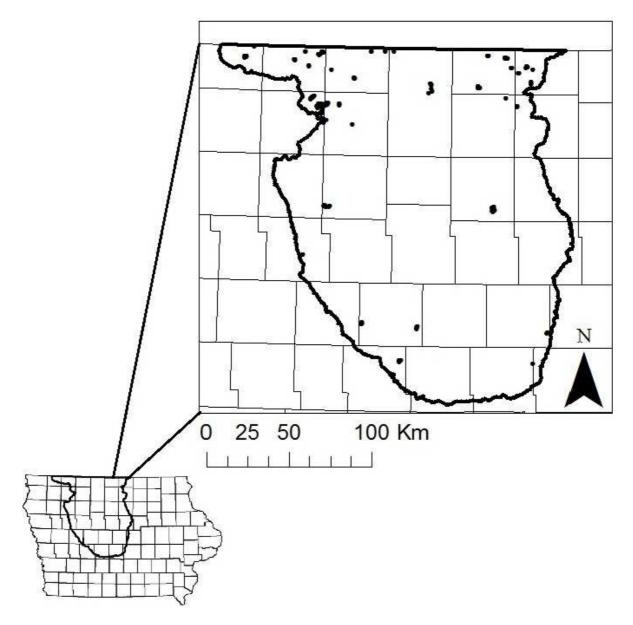
FIGURE 4.1. Location of surveyed wetlands (points) within the Des Moines Lobe (bold

line) region of Iowa, 2010.

CHAPTER V. GENERAL CONCLUSIONS

The North American Marsh Bird Monitoring Program has prompted several research projects examining population and habitat ecology of secretive marsh-birds, as well as ongoing research evaluating the efficacy of call-broadcast surveys for monitoring these birds across the U.S. My study aimed to provide information on the population status and habitat associations of secretive marsh-birds in Iowa. I estimated population density ranged from 0.019 birds/ha for least bitterns to 0.12 birds/ha for pied-billed grebes. I concluded that density of each species was different in different areas of the state due to contrasting microhabitat characteristics. I argue that distance sampling is a rigorous method that provides a precise population estimate, although the potential exists for violating the second assumption that birds are detected at their initial location.

I found that wetland size was the single habitat characteristic that positively affected probability of occupancy of all species. I also concluded that water depth and percent coverage and height of emergent vegetation (specifically cattail) were important characteristics affecting wetland occupancy by marsh-birds. These findings provide valuable information about habitat associations of marsh-birds in Iowa and offer guidance to land managers regarding wetland restoration and management.

Lastly, I determined that response rates of secretive marsh-birds vary between early and late in the survey season. Response rates varied by time of day for pied-billed grebes only, although this variation was only evident late in the survey season. I suggest that marsh-bird surveys in Iowa be conducted from 15 May to 15 June during both morning and evening

to obtain adequate detections for estimating site occupancy and density. This

recommendation deviates from currently accepted recommendations to complete marsh-bird

surveys in Iowa between 15 April and 31 May.

Overall, this study increased our general knowledge about population status and

habitat associations of secretive marsh-birds in Iowa. Findings from this study will also be

contributed to the national database to establish large-scale population trends of these birds.

I hope that information from this study will guide future marsh-bird research and monitoring,

as well as wetland restoration and management decisions.