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Keywords

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

Disciplines

Natural Resources Management and Policy | Ornithology | Population Biology | Poultry or Avian Science

Comments

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Density and Abundance of Secretive Marsh Birds in Iowa

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Abstract.—A decrease in wetland habitats throughout North America has caused a decline in populations of marsh birds. The objective of this study was to estimate population densities and abundances of secretive marsh birds in Iowa. Call-broadcast surveys were conducted in conjunction with distance sampling for eight species of marsh birds at wetlands in three regions of Iowa during 2009 and 2010. Regions were defined by observed microhabitat characteristics which also corresponded to physiographic regions. Region-specific density estimates were obtained using Program Distance for four species of marsh birds for which sufficient detections existed (Pied-billed Grebe [*Podilymbus podiceps*], Least Bittern [*Ixobrychus exilis*], Virginia Rail [*Rallus limicola*] and Sora [*Porzana carolina*]). The range of density estimates was 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 highest in Region 2 for Pied-billed Grebe, Region 1 for Virginia Rail, and Region 3 for Sora. Least Bittern density was similar between Regions 1 and 2, but was 0.027 birds/ha lower in Region 3. The need to focus conservation efforts on areas of the state where large amounts of suitable habitat exist and marsh bird densities are highest is illustrated by the observed differences in species' densities across regions. Information on the current population status of marsh birds in Iowa and regions where conservation efforts can be directed are provided by these density estimates. *Received 31 May 2011, accepted 19 November 2011.*

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Populations of many marsh birds are believed to have been declining throughout North America since the 1970s in response to a loss of wetland habitat (Eddleman *et al.* 1988; Conway *et al.* 1994; Conway 2008). Since the late 1800s, >90% of wetlands have been lost almost exclusively to agricultural development with the majority of these losses occurring in the Midwest and in California (Dahl 1990). As a result, several species of wetland-dependent birds are of heightened conservation status at local and regional levels (Eddleman *et al.* 1988; Gibbs *et al.* 1991; Conway and Gibbs 2005). Data from the North American Breeding Bird Survey (BBS) showed declining trends for American Bittern (*Botaurus lentiginosis*) and King Rail (*Rallus elegans*) from 1966 - 2007 (Sauer *et al.* 2008) and possibly Virginia Rail (*Rallus limicola*) and Least Bittern (*Ixobrychus exilis*) (Bystrak 1981; Robbins *et al.* 1986). The North American Bird Conservation Initiative (NABCI 2011) lists the American Bittern, Virginia Rail (*Rallus limicola*) and Sora (*Porzana carolina*) as priority species for Bird Conservation Region (BCR) 11 (Prairie Pothole Region), which encompasses the Des Moines Lobe that contains the majority (1.4 million ha) of wetland habitats in Iowa (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. The wide array of conservation statuses above necessitates further research to evaluate the population statuses of secretive marsh bird species at both the state and regional levels.

Marsh birds are secretive, typically occupy habitats with dense emergent vegetation, and vocalize infrequently making them difficult to detect using conventional survey techniques (Gibbs and Melvin 1993; 1997; Lor and Malecki 2002). Consequently, little information exists on the population status and trend of many species of marsh birds (Gibbs and Melvin 1993; Conway 2011). 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).

Density estimates of marsh birds provide information on current population statuses and a baseline comparison for future studies to establish population trends. Estimates of density are dependent on estimates of detection probability because surveys rarely count all individuals present in the study area. When surveying marsh birds, all individuals present in the study area are rarely counted due to the low detectability associated with their inconspicuousness and secretive nature (Lor and Malecki 2002). The Standardized North American Marsh Bird Monitoring Protocol (Conway 2008; 2011) suggests the use of methods to estimate detection probability to obtain reliable density estimates. The use of distance sampling methods when surveying marsh birds allows researchers to estimate population densities of marsh birds while also acknowledging that detection probability is imperfect (Conway 2011).

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

Methods

Study Area

Our study included surveys of marsh birds at wetlands throughout Iowa from 16 May to 7 July 2009 and 20 April to 15 July 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). Our selection 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 (*Carex* 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.

Site Selection

Using Hawth's Analysis Tools for ArcGIS (Beyer 2004), we randomly selected wetlands from the NWI database. Prior to selection, 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 ten wetlands from each size class (Brown and Dinsmore 1986) except that only six wetlands of 30-40 ha were selected due to the small number of wetlands within that class. To facilitate access for surveys, only wetlands on public lands were considered. Our procedure included random assignment of 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 one point to both the <5 ha and >5 to 10 ha size classes, two points to the >10 to 20 ha size class, three points to the >20 to 30 ha size class, four points to the >30 to 40 ha size class, and five 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 (Fig. 1). We defined Region 1 as the Des Moines Lobe (Prior 1991). Region 1 contained the majority of surveyed wetlands (n = 247) and consisted of those wetlands characterized as shallow potholes with shallow-marsh emergents (sedge and cattail) surrounded by upland prairie (Stewart and Kantrud 1971). Region 2 encompassed western Iowa and 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, Soft-stem bulrush, and River Bulrush; T. M. Harms, personal observation). Region 3 contained widely scattered wetlands in eastern

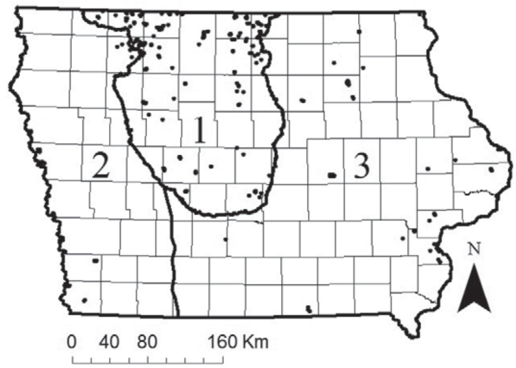

Figure 1. Location of wetlands surveyed for secretive marsh birds within three regions in Iowa, 2009-2010. Each dot represents a surveyed wetland, which could have included from one to five point counts.

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 of all species would differ between regions. For example, we expected Virginia Rail density to be greatest in Region 1 because those 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. Surveys were conducted for eight focal species of marsh birds in accordance with the Standardized 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. Our approach included conducting surveys 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) hours. Using an MP3 player (SanDisk Sansa Clip 1GB, SanDisk Corporation, Milpitas, California) attached to a pair of amplified speakers (Panasonic Model RP-SPT70, Panasonic Corporation, Secaucus, New Jersey), 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 five-minute passive listening period followed by eight minutes of vocalizations. Each minute of the eight-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, New York), we measured the radial distance (m) to each bird detected. Distance sampling assumes that birds are detected at the location of first detection (Buckland *et al.* 2001; 29-37), so the distance to an individual bird was recorded only once regardless of any subsequent detections. Prior to conducting surveys, our approach included measuring wind speed (Beaufort; bft) and temperature (°C) at each survey point using a Weather Kestrel 4000 handheld weather meter (Nielsen Kellerman, Boothwyn, Pennsylvania). Also, we visually estimated the amount of cloud cover at each survey point and assigned our estimate to one of four classes (0 - few or no clouds, 1 - partly cloudy, 2 - cloudy or overcast, 4 - fog). Surveys were not conducted 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.

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 overlapped 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. We included three covariates in models, all of which could have affected detection probability (Conway and Gibbs 2011). Those covariates were cloud cover (CLOUD), wind speed (WIND), and temperature (TEMP). Observer effect was not included in the models because observers were familiar with vocalizations of target species and highly trained at detecting birds at varying distances. Training included repeated exposure to all calls of each species, then placing the call-broadcast system in wetlands and blindly positioning observers at distances varying from 10-500 m. Training was conducted for each species at wetlands with different vegetative conditions (vegetation density and height) and during various weather conditions. 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, the detection function was modeled using the conventional distance sampling (CDS) engine (Thomas *et al.* 2010). Our analyses included 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, the detection function was modeled using the multiple covariate distance sampling (MCDS) engine (Marques and Buckland 2003, 2004). The MCDS 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. Our modeling procedure included assigning 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. Raw distances for Least Bittern were not assigned to distance bins 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 density estimates from the best-supported model for each species, we extrapolated breeding numbers of each species for each region by multiplying the density estimate for each region by total area of wetlands in the respective region, except that we estimated the number of migrants for Sora only. Our models provided species-specific density estimates for each region. Using ArcGIS (ver. 10; ESRI 2010), we calculated the total area of wetlands in each region using the NWI database from which we drew our sample by taking the sum of the area of all wetland polygons. Only wetlands from which we drew our sample were considered because these wetlands consisted of habitat characteristics suitable for marsh birds. We assumed that habitat characteristics were similar across wetlands in each region because we selected from one of three sub-classifications in the NWI database. Also, we assumed that, because wetlands were similar in habitat characteristics in each region, bird densities also remained consistent across wetlands in each region. Total abundance (95% CI) is reported 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. We surveyed 247 wetlands in Region 1, 32 wetlands in Region 2, and 75 wetlands in Region 3. The number of wetlands surveyed in each region is not equal because of the distribution of wetlands in Iowa and because we divided Iowa into three regions based on microhabitat regions post hoc.

Table 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

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 2). We found that TEMP had no effect on detection probability because the confidence interval for this effect included zero. According to the best-supported model, the density of Pied-billed Grebes was greatest in Region 2 (Fig. 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 2,392 (95% CI = 2,135 - 2,685) breeding Pied-billed Grebes in Iowa.

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 2). WIND

Table 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 region. 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.

			Region 1		Region 2		Region 3	
Model	K	ΔAIC_c	Density	CV	Density	CV	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.

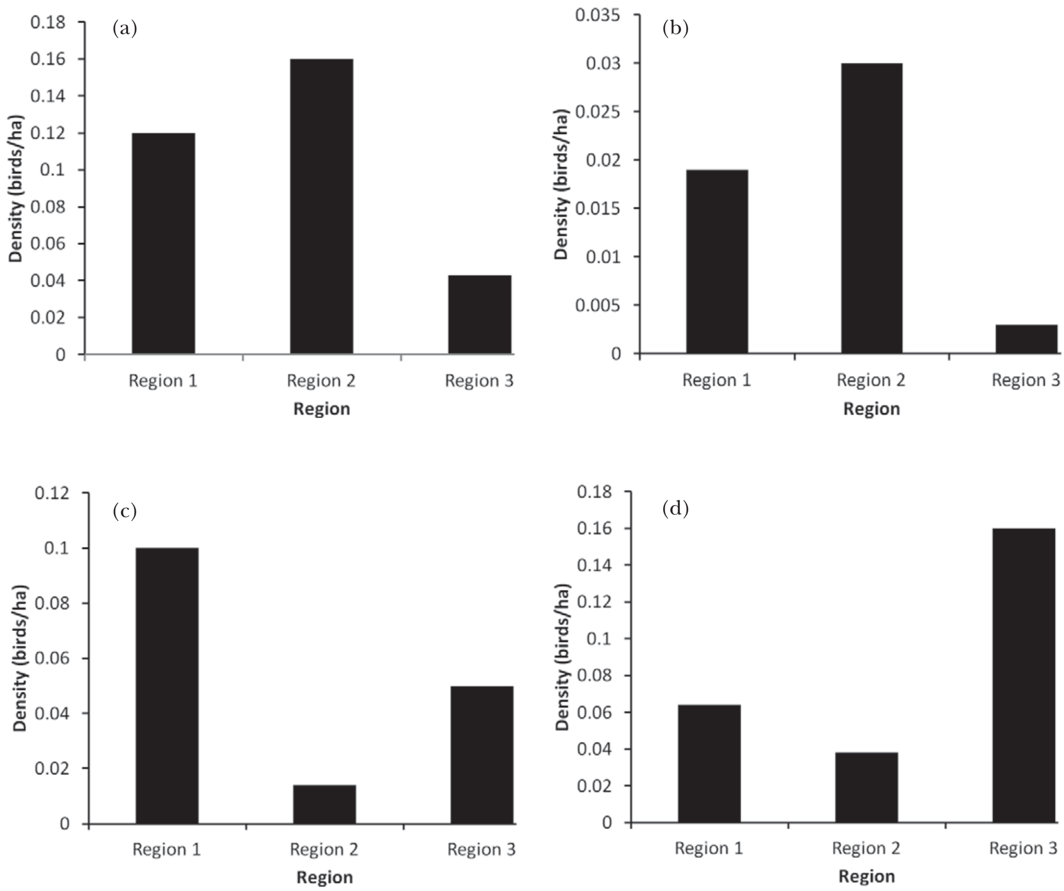

Figure 2. Density estimates for Pied-billed Grebe (a), Least Bittern (b), Virginia Rail (c) and Sora (d) by region at wetlands in Iowa, 2009-2010. Region 1 was defined as the Des Moines Lobe and contained wetlands characterized as shallow potholes with shallow-marsh emergents (sedge and cattail) surrounded by upland prairie. Region 2 was defined as western Iowa and consisted of wetlands with deeper water (>40 cm) and deep-water emergent (cattail, Softstem Bulrush, and River Bulrush). 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.

had a strong negative effect on the detection probability of this species. The best-supported model estimated that density of Least Bitterns was greatest in Region 2 (Fig. 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 319 (95% CI = 214 - 504) birds in Iowa.

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 2). The single competitive model ($\Delta AIC_c = 1.67$) was the half-normal key function with no expansion and no covariates on detection (Table 2). CLOUD had a strong negative effect on the detection probability of Virginia Rails. The best-supported model estimated that density of Virginia Rails was greatest in Region 1 (Fig. 2; 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 1,797 birds (95% CI = 1,604 - 2,015).

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 2). 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 2). TEMP did not have an effect on detection probability because the confidence interval for this effect included zero. The best-supported model estimated Sora density to be greatest in Region 3 (Fig. 2; 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 3,514 birds (95% CI = 3,081 - 3,995).

DISCUSSION

To our knowledge, only a single study has utilized distance sampling to model detection and obtain density estimates of secretive marsh birds (Beadell *et al.* 2003). 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. In regions with the greatest densities, estimates in this study ranged from 0.030 birds/ha (95% CI = 0.019 - 0.045) for Least Bittern to 0.16 birds/ha (95% CI = 0.14 - 0.18) for both Pied-billed Grebe and Sora. Overall abundance estimates in Iowa ranged from 319 (95% CI = 214 - 504) breeding Least Bitterns to 3,514 (95% CI = 3,081 - 3,995) migrant Soras. The estimates of density for Virginia Rails and Soras found in our study were 1.14 - 1.30 birds/ha lower than those estimates for Virginia Rails and Soras found by Manci and Rusch (1988). We caution that our extrapolation approach could have resulted in conservative population estimates because more suitable habitat for marsh birds may exist in Iowa.

Considering detection probability when estimating density and abundance of secretive marsh birds improves precision of the estimates (Conway and Gibbs 2011). Our study indicated that detection probability was low for all species, ranging from 0.076 for Virginia Rail to 0.27 for Least Bittern. Estimates of detection probability for all four species were lower than those estimates found by Gibbs and Melvin (1993). The observed difference is not surprising given the secretive behavior of marsh birds and potential geographic variation in detection probability (Nadeau *et al.* 2008). The effects of various weather covariates on detection probability were mixed for all species, which coincides with the findings of Conway and Gibbs (2011). We found that wind speed had a strong negative effect on the detection probability of Least Bitterns. Wind speed has been found to affect vocalization probability of rails (Tacha 1975) and has also been found to affect observers' ability to detect vocalizing birds (Bart *et al.* 1984). Least Bitterns have a subtle and less-dominant call than other species (Least Bittern is least dominant in the call-broadcast sequence; Conway 2008) suggesting that high winds reduce the detectability of these birds. Percent cloud cover had a strong negative effect on detection probability of Virginia Rails. The effect of cloud cover on detection probability of marsh birds is unclear and has not been found in other studies (Conway and Gibbs 2011). However, we found a negative effect of cloud cover on detection probability of Virginia Rails in a different portion of this study (Harms 2011).

Density estimates were different in all regions of Iowa for all study species except the Least Bittern. Least Bittern density was similar in Regions 1 and 2, but was 0.027 birds/ha lower 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, which was expected because Pied-billed Grebes frequently utilize wetlands with deep water for foraging and nesting (mean depth = 55 cm ± 1 cm; Lor and Malecki 2006) and wetlands in this region contain deeper water (>40 cm; T. M. Harms, personal observation). 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 deeper water (>40cm; T.

M. Harms, personal observation), two characteristics preferred by Least Bitterns (Lor and Malecki 2006; Poole *et al.* 2009). Density was greatest in Region 2, however it was not significantly different from that of Region 1. Density of Virginia Rails was highest in Region 1. Wetlands in Region 1 are characterized by shallow water (<40cm) and emergent vegetation, two characteristics preferred by Virginia Rails for nesting (Sayre and Rundle 1984). 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 1986). Soras migrate through Iowa during a narrow window (mid-April - early May). Therefore, our finding of Sora density to be highest in Region 3 could be the result of the timing of surveys.

Many conservation decisions and actions rely on density estimates to assess the current statuses of the populations. 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. These estimates provide much-needed information on current population status of these species and serve as a baseline comparison for future monitoring efforts to establish population trends. In addition, our estimates contribute to the ongoing monitoring efforts of these birds nationwide as part of the North American Marsh Bird Monitoring Program.

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