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Tools and Technology

Nocturnal Distance Sampling All-Terrain Vehicle Surveys for Nonbreeding Rails

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ABSTRACT Rails (Family: Rallidae) are among the most difficult birds to detect. Although methods have been developed to optimize detection during the breeding season, there is no current suitable survey method for the nonbreeding season. Low detection of rails and lack of suitable methods limit monitoring efforts and examination of important questions related to rail conservation and habitat management during the nonbreeding season. We present a new survey method along with suggestions for its effective use in moist-soil wetlands. We conducted nocturnal surveys during the autumns 2012–2015 in Missouri, USA, to detect sora (*Porzana carolina*) using hierarchical generalized distance sampling along transects that we traveled while riding all-terrain vehicles at night. We evaluated assumptions of our survey method by examining the response by radiomarked sora to survey vehicles and comparing survey counts between surveys on the same night. These surveys produced sora density estimates with error that can be used to address conservation and management questions such as habitat use and migratory timing. Published 2017. This article is a U.S. Government work and is in the public domain in the USA.

KEY WORDS all-terrain vehicle, autumn migration, Missouri, *Porzana carolina*, rail, sora, survey.

The elusive habits of rails (Family: Rallidae), namely that they are small in body size, rarely vocalize during the nonbreeding season, and live in dense vegetation, make them difficult birds to detect (Nadeau et al. 2008, Conway and Nadeau 2010, Conway 2011, Conway and Gibbs 2011). Extensive work has been done to optimize survey methods for rails during the breeding season by maximizing detection using a broadcast call to elicit a response at the time of day when call rates are thought to be greatest (Conway 2011). The effectiveness of this protocol has never been reported for autumn migration, but is likely not effective because of the decrease in rail call rate after the breeding season (Conway et al. 1993, Conway and Gibbs 2001).

Developing monitoring methods for rails outside of the breeding season is important because migration can be a time of high rates of mortality and physiological stress (Newton 2006, Hostetler et al. 2015, Marra et al. 2015). Although walk-in traps can capture many individuals for the purposes of monitoring, walk-in traps are not appropriate for addressing questions about habitat use because the broadcast call used in the traps may draw rails out of the habitat they originally selected (Kearns et al. 1998, Fournier et al. 2015). To address the absence of a method that would allow for the examination of habitat and conservation questions during the nonbreeding season, we built upon the work of Perkins et al. (2010), who compared rail capture techniques among all-terrain vehicles (ATVs), airboats, and traps. Use of ATVs was most effective for capturing rails in shallow-water moist-soil wetlands, such as those in the mid-latitude states of the central United States (Perkins et al. 2010). Perkins et al. (2010) found ATVs were effective for capturing rails (1.8 rails/hr of ATV operation) in shallow-water (<50 cm) situations; therefore, we speculated that using ATVs would be an effective platform for developing a nonbreeding survey for rails. We designed our survey method using ATVs under a hierarchical distance sampling framework, where we recorded distance from the transect line to account for detection probability and allow us to estimate density using hierarchical models (Fiske and Chandler 2011, Sillett et al. 2012, Denes et al. 2015). We tested a nocturnal ATV flushing survey for autumn migrating rails. We focused our analysis on sora (*Porzana carolina*) because they were the most frequently detected species at our sites (>95% of detections), but we also detected small numbers of Virginia rail (*Rallus limicola*), yellow rail (*Coturnicops noveboracensis*), and king rail (*R. elegans*).

STUDY AREA

We developed this protocol on public-managed wetland properties across Missouri, USA, including 7 Missouri Department of Conservation's Conservation Areas and 4 U.S. Fish and Wildlife Service's National Wildlife Refuges. At each property, we surveyed moist-soil wetland impoundments (wetlands surrounded by levees with water control

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structures; n of impoundments: 2012 = 40, 2013 = 39, 2014 = 33, 2015 = 33; Supporting Information, Table 1). We selected impoundments as the survey unit because they were the scale at which wetland management decisions are made. Moist-soil wetland impoundments were managed on a multiyear rotation (~1–3 yr) using water-level manipulation and disturbance (discing, mowing, and burning) to reduce invasion by undesirable plant species and set back succession (Rundle and Fredrickson 1981, Fredrickson and Taylor 1982). We only examined this method in moist-soil wetlands dominated by palustrine emergent vegetation. These wetlands rarely had vegetation >2 m in height and, with the exception of borrow ditches, rarely had large areas of water deeper than 50 cm.

METHODS

Surveys

Before nightly surveys, we scouted impoundments to identify any potential hazards (deep water, downed trees). We started in a random corner of the impoundment and drove transects running parallel to the impoundment side and spaced 30 m apart (this width was to prevent double-counting and based on our observed flushing behavior of sora) to cover the entire impoundment in a standardized fashion. We only counted rails on parallel transects, not on short drives between transects (Fig. 1). We slowly drove ATVs (<3 km/hr) with the driver standing to allow for maximum distance observation in front of the ATV. When a rail was detected, the surveyor took a global position system (GPS) point at the location where the rail was first detected and recorded the perpendicular distance from the point to the transect line to the nearest m. A handlebar-mounted GPS unit recorded the track driven to record distance for each survey. This also allowed for the observer to navigate around hazard points (recorded on the GPS during scouting earlier in the day) during surveys. We used the ATV's headlights, a handheld spotlight, and a strong headlamp for maximum illumination.

We surveyed for 3 hr each night, beginning 30 min after sunset. We chose nocturnal surveys because based on the work of Perkins et al. (2010) and our observations that sora readily flushed at night when approached on ATVs, but not during the day. We divided the 3-hr time block into 2 1.5-hr survey periods. Observers switched impoundments in the second survey period, allowing for 2 surveys in each impoundment on the same night by 2 different observers. We incorporated the 2 survey periods by switching observers to investigate observer bias and increase opportunities to observe rarer rail species. We did not survey when it was raining more than a light drizzle, when fog prevented us from seeing >20 m, or under high wind conditions. Each impoundment was surveyed every 2.5 weeks from August 10 to October 23 2013–2015. Doing so allowed us to survey wetlands throughout the state and examine changes in sora density across time and habitats.

Verification

We investigated how sora behaved in response to ATVs by deploying very-high-frequency (VHF) transmitters on 20 sora at 5 sites across Missouri. We captured sora at night using a hand net and attached a transmitter on the synsacrum using a modified thigh harness (Rappole and Tipton 1991). Using VHF transmitters to track individual bird behavior allowed us to test the concern that sora were being pushed away from the transect line, which would violate the assumption that individuals are detected before they move.

We practiced locating transmitters in the wetland and found that from a distance of 30 m, we could locate them within 4 m. We allowed the marked rails to wear the transmitter for 48 hr; then after sunset, 2 people triangulated the rail's location from 30 m away while the rail was approached by an ATV. We did our best to direct the ATV to pass as close to the marked sora as possible. We recorded the distance each marked bird moved when approached by the ATV and whether or not the observer on the ATV detected the sora. After the experiment, we recaptured the marked sora and removed the transmitter. All work was completed under Special Use Permits from Missouri Department of Conservation and U.S. Fish and Wildlife Service, along with Institutional Animal Care and Use Committees proposals #13044 and #15023 from the University of Arkansas and Federal Bird Banding Permit #23002.

To examine survey repeatability, we compared effort-corrected counts (sora/hr of survey) in first and second surveys of the night using a 2×2 crossover design with impoundment and time period as the 2 variables and observer crossed between them (Quinn and Keough 2011). Based on our field observations of sora behavior, we do not believe there were any carryover effects. We assessed the difference between the 2 nightly surveys using a Mann–Whitney test because effort-corrected counts were not normally distributed.

Density

We estimated sora density using the generalized distance sampling model of Chandler et al. (2011) in the R package "unmarked" function gdistsamp() using a hazard key function (R version 3.2.3; "unmarked" version 0.11-0; Fiske and Chandler 2011, R Core Team 2015). We observed from 0 to 130 individuals in a night of surveys in a single impoundment, with a mean of 26 (SE = 0.59). "Unmarked" provides an approach where count data from replicate visits are examined in n-mixture models that estimate density while relaxing the assumption of traditional distance sampling such that we do not assume probability of detection on the line to be 1 and detection probability is estimated for each distance bin of our input data (Royle 2004*a*, *b*; Chandler et al. 2011).

To estimate sora density in a wetland impoundment over repeated surveys in a distance-sampling framework, we had to assume geographic closure (no emigration or immigration). We met the closure assumption within each impoundment by estimating density separately for each night and impoundment. We had 4 separate density estimates per impoundment, per year; 1 for each of the 4 nights we surveyed there in that year. We used the 2 survey occasions each night to estimate detection probability. Two survey occasions is less than the typical 3–5 used in many n-mixture models. However, Royle

Table 1. Impoundment-specific estimates of sora density (sora/ha) based on the habitat covariate hierarchical distance sampling model for 2015 in Missouri, USA (visit 1 = 10 Aug–30 Aug, visit 2 = 31 Aug–21 Sep, visit 3 = 20 Sep–8 Oct, visit 4 = 9 Oct–25 Oct).

Area	Impoundment	Visit 1 estimate	Upper CI	Lower CI	Visit 2 estimate	Upper CI	Lower CI	Visit 3 estimate	Upper CI	Lower CI	Visit 4 estimate	Upper CI	Lower CI
Duck Creek	Unit A 14	13.8	14.9	12.8	14.3	15.4	13.2	13.2	15.1	11.5	13.3	14.4	12.3
Conservation Area	Unit A 18				8.1	8.8	7.6	13.5	15.1	12.0	14.1	15.3	13.1
	Unit A 22										5.4	5.9	5.0
B.K Leach	Kings Tract 2	5.2	5.7	4.8	6.8	7.3	6.3	5.8	6.2	5.3	9.1	9.9	8.5
Conservation Area	Kings Tract 5	7.0	7.5	6.5	9.9	10.7	9.2	10.8	11.6	10.0	9.2	9.9	8.5
	Kings Tract 6				5.6	6.1	5.1						
	Kings Tract 9	7.6	8.3	7.0	5.6	6.1	5.2						
Swan Lake	m10	14.6	15.9	13.5	13.2	14.3	12.2	7.0	7.7	6.5	7.0	7.7	6.5
National Wildlife Refuge	m11	6.6	7.2	6.1	9.9	10.6	9.2	13.6	14.7	12.5	13.1	14.2	12.2
	m13	3.9	4.3	3.5	4.5	4.9	4.1	8.4	9.1	7.7	8.0	8.7	7.4
Otter Slough	21	7.4	8.0	6.9	8.2	8.8	7.6	7.0	7.5	6.5	8.5	9.1	7.9
Conservation Area	23							5.6	6.2	5.1	7.1	7.7	6.4
Fountain Grove	Pool2	6.4	6.9	5.9	12.4	13.4	11.4				12.1	13.0	11.2
Conservation Area	Pool 2 walk in	6.6	7.1	6.0	6.3	6.8	5.8	7.0	7.5	6.4	13.3	14.3	12.3
Ten Mile Pond	Pool C	6.3	6.8	5.8	7.8	8.4	7.2	6.3	6.8	5.8	10.3	11.1	9.6
Conservation Area	Pool E	16.3	17.8	14.9	15.8	17.3	14.5	19.8	21.8	18.0	13.8	15.0	12.6
	Pool I				5.9	6.4	5.4				8.5	9.1	7.9
Nodaway Valley	rail	6.3	6.8	5.8	11.7	12.7	10.9	7.2	7.8	6.7	12.6	13.6	11.6
Conservation Area	sanctuary	5.9	6.4	5.4	8.9	9.5	8.3	10.3	11.1	9.6	12.7	13.7	11.8
Squaw Creek	Snow Goose B				5.7	6.2	5.3	12.7	13.8	11.7	12.0	13.0	11.2
National Wildlife Refuge	Snow Goose D	6.3	6.8	5.8	6.3	6.8	5.8	13.9	15.1	12.8	10.6	11.5	9.9
Ted Shanks	2a	5.6	6.1	5.1	5.6	6.1	5.1	6.8	7.4	6.3	9.3	10.0	8.6
Conservation Area	4a	4.9	5.4	4.5	4.9	5.4	4.5						
	6a	6.1	6.6	5.6	6.1	6.6	5.6	13.4	14.5	12.4	13.5	14.6	12.5
	8a	5.6	6.1	5.1	6.4	6.9	6.0	11.9	13.2	10.8	11.9	13.2	10.8

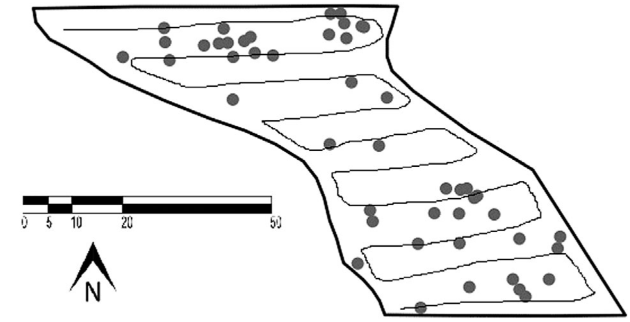

Figure 1. Example of a survey transect (line) and observed sora (dots) in a wetland impoundment at Swan Lake National Wildlife Refuge, Missouri, USA, from surveys conducted in 2015.

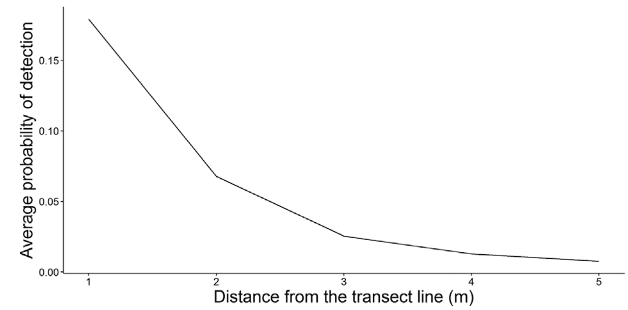

Figure 2. Relationship between distance from the transect line and average probability of detecting an individual sora assuming the individual is available to be detected, based on the generalized hierarchical distance sampling model in wetlands of Missouri, USA, from 2012 and 2015.

(2004*b*) and Ross et al. (2016*a*, *b*) found that 2 repeat surveys were sufficient to estimate detection probability. To assess differences in the detection among observers (2012 had 4 observers: J, L, M, and AMVF; 2013 had 4 observers: N, D, M and AMVF; 2014 had 2 observers: N and AMVF; 2015 had 2 observers: H and AMVF), we compared the null model for density and detection to a model using observer as a covariate to explain detection. We did not consider any variables to predict availability in our model. Based on the model with the lowest Akaike's Information Criterion (AIC), we used that covariate for detection in our model to estimate density. We evaluated the goodness-of-fit of the global model (the model with all density covariates included) by calculating the chi-squared statistic for the observed data and comparing it with expected values in 500 simulations of parametric bootstrapping in the parboot() function in R (Kéry et al. 2005). To estimate density, we included several habitat covariates in the hierarchical distance sampling models, but because we focused on describing the sampling method not habitat relationships, we will not detail those habitat relationships here. We estimated sora density using the top-ranked model.

RESULTS

We detected 4,207 sora during 689.8 hr of surveying across August–October 2013–2015. We also detected 17 yellow rails, 47 Virginia rails, and 1 king rail. In addition to rails, we observed other species including waterfowl (Family: Anatidae), sparrows, wrens (Family: Passeridae), meadowlarks (Family: Icterid), shorebirds (including frequent sightings of Wilson's snipe [*Gallinago delicata*] and American woodcock [*Scolopax minor*]), and raccoons (*Procyon lotor*). Although we did not record other detected animals, we believe that our survey method could be used for other species. The number of detections of non-sora rails (yellow, Virginia, and king) were too low to estimate density under a distance sampling framework, although other analysis approaches, such as occupancy modeling, could possibly be used.

Based on our experience across the 4 years, vegetation in these disturbed wetlands quickly (within 2 days) recovered from our ATV survey activity. The track of the ATV was not visible when we returned 2 weeks later. We found 80% of radiotagged sora did not move in response to the ATV; the other 20% moved $\leq$10 m. Of those that did not move, all were located within 5 m of the transect line after the ATV passed, none were on the transect line; however, none of the radiomarked sora were detected by the observer on the ATV. Because we monitored the radio-tagged sora, we know that they did not flush. Sora with transmitters were readily able to fly, and did so when approached on foot for recapture. Incidentally, we noted that sora responded differently to being approached on foot versus on the ATV. When approached on foot they would run away from the person and then fly long distances (>50 m) several times before being captured. When approached on the ATV, we could get within approximately 3 m without the bird moving, possibly because of the "background noise" of the ATV engine (Olinde et al. 2000, Diefenbach et al. 2003).

The global model adequately fit the data and was the top model ($\chi^2 P = 0.98$). Sora detected during surveys rarely flew >10 m when flushed by an ATV. We never detected a sora flushing >13 m from the transect line. Ninety-six percent of our detections occurred $\leq$5 m from the line, so we truncated our data to include only those detections. This truncation and our observations of sora behavior minimized double-counting. In 2015, we recorded whether individuals were first observed flushing or on the ground and 51% were detected flushing, whereas 49% were first detected on the ground, often walking in front of the ATV. They then flew when the ATV approached them. The exception to this was if the sora was swimming.

There was no difference in the number of sora detected between the 2 surveys conducted by 2 different observers in the same impoundment on the same night ($W_{104} = 1{,}479.5$, $P = 0.62$). Average detection probability of an individual, assuming it was available to be detected, in the first transect bin was 0.17 (Fig. 2). We did not include observer as a covariate for detection because the model with observer as a covariate received no support (>300 ΔAIC from the top-ranked model). Estimates of density derived from hierarchical distance sampling models incorporating habitat covariates to explain sora density produced estimates from 1 (95% CI = 1.4–2.1) to 18 (95% CI = 16.6–19.8) sora per ha (Table 1).

DISCUSSION

Rails are elusive, yet to answer questions about the effects of management on rails, we require an understanding of how detection might affect the observation process because the probability of detecting an individual, assuming that it is present, is not the same in all circumstances or for all species (Conway et al. 1993, Thompson 2002). The National Marshbird Monitoring Protocol was designed to optimize detection probability during the breeding season because detection is so low for many rails and other marshbirds (Conway 2011). Many factors can affect wetland bird detection, including ambient temperature, wind speed, cloud cover, moon phase, and observer, and often these factors go untested in new survey methods (Anderson 2001, Bolenbaugh et al. 2011, Budd and Krementz 2011, Conway and Gibbs 2011, Glisson et al. 2015). When working with rails that are difficult to detect, understanding how individuals react to the survey methodology and estimating detection probability is important.

Data from ATV-based nocturnal surveys in a hierarchical distance sampling framework allowed us to estimate detection probability, while incorporating variables to explain density into a model that can then be used in a predictive manner to understand how density changes with habitat or management (Royle 2004*a*, *b*; Royle et al. 2004). Our model estimated detection probability at 17%, which illustrates the challenge of working with rails. This low detection was reinforced by our lack of detections during our mock surveys. Although we have detected thousands of sora over 4 years, these detections represent a small percentage of sora using palustrine wetlands during autumn migration. The generalized distance sampling framework offered in "unmarked" allowed us to relax the assumption of perfect detection on the transect line that is common in traditional distance sampling and still estimate density based on our 2-occasion surveys (Royle 2004*b*, Chandler et al. 2011).

One question raised about this survey method centers on the potential for disturbance to the wetland vegetation. In our sampling scheme, we did not return to the same impoundment for $\geq$2 weeks, which gave the vegetation time to recover. Use of this method on a more frequent basis would be inappropriate because the vegetation would not have time to recover and use of this method during the breeding season would be unwise because of disturbance of nests and nesting species. Butler et al. (2014) used ATVs on the Gulf of Mexico coast during the winter to capture rails. This method has the potential to be effective on the wintering grounds as well because it will not damage nests.

Running ATVs through wetlands is disruptive to birds and vegetation, but it allows researchers to address questions relating habitat and management to density that cannot be answered in an occupancy framework. Because of the large number of sora in these wetlands, occupancy modeling would not be sufficient because naïve occupancy is so large, it would not be able to inform what habitat has greater densities of sora and what habitat is only being used by a few individuals. By surveying sora within a framework that accounts for detection probability and allows for the estimation of density in relation to habitat, we can answer questions about how sora density differs in relation to management and habitat conditions to inform future management. Additional questions related to the stopover duration of individuals would also be informative to better understand the habitat requirements of these species during migration, but this survey methodology cannot address those questions because individuals are not identifiable.

It was unclear whether our detection rate of non-sora rails (Virginia, yellow, king) corresponded to their true prevalence on the landscape, or if other factors (e.g., behavioral response to the ATV, such moving away from the ATV) were influencing our ability to detect them. All-terrain-vehicle–based surveys have been used to locate these species (Perkins et al. 2010), but for some unknown reason, our approach did not work well for non-sora rails during autumn. We were unable to find any examples of nocturnal distance sampling surveys for birds, likely because most birds can be better surveyed at other times of day or with other methods.

Herein, we have shown that our ATV-based survey method can be used to detect large numbers of sora during the autumn in a repeatable way. Working in wetlands at night can be hazardous and caution should always be used. Time should be spent before each survey identifying and mapping potential hazards in wetland impoundments. We recommend working in pairs for safety and convenience in the event that ATVs become stuck or break down. We recommend using a manual, drive-shaft driven, light-weight ATV to reduce the chances of getting stuck and minimize overheating and mechanical issues that arise from driving ATVs through mud and water. These surveys can be conducted in water depths up to 50 cm, though ATVs can handle deeper water. The addition of an air intake snorkel may also be appropriate when working in wetlands with deeper water levels.

Surveying for rails during the nonbreeding season is challenging. Our survey method would likely be less effective in vegetation that is taller than a standing observer because it will obstruct the ability of the observer to detect rails. Although this survey method could be used through the night, we found after 3 hr, fatigue reduced observer attention. This method provides researchers and managers with a tool to produce reliable density estimates of sora during the nonbreeding season to address important management and conservation questions.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's website.

Table S1. List of impoundments surveyed for sora from 2012 to 2015 in Missouri, USA.