Effects of Wetland Management Strategies on Habitat Use of Fall Migrating Rails on Intensively-Managed Wetland Complexes in Missouri

Final Report

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Executive Summary

The impact of wetland loss and current wetland management on migratory rails during the autumn migration is unknown though encountering a largely dry landscape during the autumn season probably inhibits habitat use, density and survival. Little is known about habitat selection of Sora (*Porzana carolina*), Virginia Rail (*Rallus limicola*) and King Rails (*Rallus elegans*) in the Mississippi Flyway. Further, I know nothing about how flooding and habitat management affects migrating rails during autumn migration. To answer these questions and inform future research on rail survival, I conducted standardized distance sampling surveys across 10 state and federal wetland properties in Missouri, USA from 2012-2015 during autumn migration to estimate density and habitat selection for these three species.

Because I only detected 4 King Rails, I was unable to estimate density or habitat selection. I did not detect enough Virginia Rails to estimate their density but I was able to determine that they preferred shallowly flooded (11.5 cm, CI 8.08-14.91cm) wetlands dominated by millet (*Echinochloa* spp.) and spikerush (*Eleocharis* spp.) communities.

I detected over 6,000 Sora during my four years of surveys and estimated an average Sora density of 14.5 Sora/Hectare. Sora selected dense stands of annual moist soil vegetation dominated by smartweeds (*Polygonum* spp.) and millets (*Echinochloa* spp.) at a water depth of 27 cm.

I found that flooding impoundments earlier in the fall (early August) as compared to later in the fall (mid-September) resulted in higher abundances of Sora using those impoundments throughout autumn migration.

My work fills a vital gap in the natural history of rails. With this information, wetland managers can more effectively manage their properties for these rails and other similar wetland dependent birds that migrate through the central Mississippi Flyway during the autumn.

Introduction

Wetland cover, especially palustrine emergent wetlands, have been greatly reduced across the central United States (Tiner 1984). These emergent are often intensively managed under a moist soil management regime that promotes plant communities and conditions that favor waterfowl habitat (Fredrickson and Taylor 1982). Promoting habitat for waterfowl limits flooded wetland habitat during early autumn because wetlands are dried out in late summer to promote seed production (Rundle and Fredrickson 1981; Case and McCool 2009). Autumn is thought to be a critical time of year, especially in the central U.S. because habitat availability in the form of shallowly flooded wetland habitat is limited then (Reid 1989; Tacha and Braun 1994; Conway 1995). The timing of wetland flooding relative to the timing of autumn migration of non-waterfowl waterbirds (such as rails) affects their distribution and habitat use and could impact their survival (Reid 1989; Case and McCool 2009).

Virginia Rails (*Rallus limicola*) and King Rails (*Rallus elegans*) are among the least studied birds in North America, in part because of their elusive nature and the difficulty of detecting them (Conway 1995; Poole et al 2005; Conway 2011; Leston and Bookhout 2015). Rundle and Fredrickson (1981), Sayre and Rundle (1984) Reid (1989), and Conway (1995) described Virginia Rail autumn migration habitat as dominated by short dense annual cover with a water depth between 5 and 10 cm. Reid (1989) described King Rail autumn migration habitat as dominated by tall stands of perennial moist soil vegetation with similar water depths to Virginia Rails.

During autumn migration, Sora are often found in shallowly flooded wetlands dominated by short emergent wetland plants (Griese et al. 1980), particularly millets (*Echinochloa* spp.) and smartweeds (*Polygonum* spp.) (Meanley 1965). Among rails, Sora use the deepest water (between 10 and 20 cm) and have the longest autumn migration duration (Griese et al. 1980; Reid 1989). Sora may respond positively to early autumn flooding of wetlands, but these results were confounded by experimental design issues (Rundle & Frederickson 1981).

Project Objectives

Objective 1 – Estimate habitat selection by Virginia Rail, King Rail, and Sora during the autumn on four wetland complexes across Missouri.

Objective 2 - Estimate Virginia Rail, King Rail, and Sora density during the autumn and how these rails relate to water level management and wetland habitat management regimes during autumn migration.

Objective 3 - Determine timing, and location to conduct a telemetry study to evaluate survival during autumn migration.

Study Site

I selected 10 publicly managed properties across Missouri because of their active moist soil management and historic importance for migrating waterfowl. Properties, including Conservation Areas managed by Missouri Department of Conservation and National Wildlife Refuges managed by U.S. Fish and Wildlife Service, were grouped into four regions (northwest, north central, northeast and southeast; Fig. 1).

At each property, I surveyed moist soil wetland impoundments (a wetland surrounded by a levee, with manual water level manipulation; 4.5-300 hectares in size; median=26.5 hectares; per year sample size (*N*), 2012 *N* = 40; 2013 *N* = 39; 2014 *N* = 33; 2015 *N* = 33; Table S1). The impoundment was the unit of interest because management decisions were made at the scale of the impoundment. Moist soil wetlands were managed on a multiple-year rotation using water level manipulation and soil disturbance to reduce invasive, perennial and woody plant succession as well as promote vegetation structure and food resources for migratory waterbirds (Fredrickson and Taylor 1982; Anderson and Smith 2000; Kross et al. 2008). Note that wetland managers targeted annual wetland plant communities and tended to discourage perennial wetland plant communities. In 2012, Missouri experienced a severe to extreme drought throughout the summer and autumn (U.S Drought Monitor 2015). The following three years (2013-2015) experienced more normal precipitation levels.

Methods

Surveys

I developed a survey method based on Perkins et al. (2010), who found All-Terrain Vehicles (ATVs) were efficient for capturing rails in shallowly-flooded impounded wetlands. I used ATVs at night to detect rails with spotlights. I drove systematic transects in a serpentine transect running parallel to a random side of the impoundment, spaced 30 m apart. Because of the water depth limitations of ATVs, I was only able to survey areas of the impoundment with <50 cm of water. I estimated rail density by recording rail observations in a distance sampling framework where I measured the distance from the transect line to the point where a rail was first detected (Fiske and Chandler 2011; Sillett et al. 2012; Denes et al. 2015). I surveyed for two hours each night in 2012 and for 3 hours in 2013-2015, beginning 30 minutes after sunset. I surveyed only moist soil wetlands where vegetation could support heavy disturbance.

I began each year in the northwest region of Missouri and moved clockwise around the state, spending 4 nights in each region (Fig. 1). Each of these 4-night sessions was a ‘visit’.

Effort varied by year because of closure of some properties in preparation for hunting seasons and in 2013 because of the U.S. Federal Government shutdown (Table 1, Table S1).

Vegetation Data

I collected data on available habitat in 50 m-radius circular plots centered on 20 random points and at 20 points where rails were detected per impoundment. These random and used points were used to determine rail habitat selection. At each point, either available or used habitat, I measured water depth (cm) at the point and 5 m away in the four cardinal directions; these measurements were then averaged. I visually estimated the percent cover of annual moist soil plants in the 50m-radius plot. Annual moist soil plants were the dominant category of plants across all my sites and included species that fall below the water surface at the end of the growing season such as millets and annual smartweeds (Cowardin et al. 1979). I also recorded the three most dominant plant species, to genus, with the exception of grasses, within each circle. Water depth was recorded during each visit (4 times per autumn) while vegetation information was only collected

Habitat Use/Selection

As I detected few Virginia and King Rails, I opted to examine habitat use instead of habitat selection. For each metric (water depth, plant dominance, vegetation percent cover in each category) used by Virginia Rails, I calculated median percent of used and available points, with 95% confidence intervals, when each plant species was in the top three dominant plants. I considered non-overlapping 95% confidence intervals to indicate significantly different use for all comparisons. Because I detected only 4 King Rails, 3 in 2012 and 1 in 2013 during surveys, I did not analyze the data. I do present the King Rail habitat data that I collected in Supplementary Table 2.

For Sora detections, I calculated the Pearson correlation coefficient (r) for all combinations of habitat covariates and only included covariates with r > 0.6. Based on those correlations, I selected average water depth, and percent cover of annual moist soil vegetation because previous researchers including Meanley (1965), Griese et al. (1980), Rundle and Fredrickson (1981), Sayre and Rundle (1984) and Reid (1989) found these habitat variables important in explaining Sora habitat use.

I examined Sora habitat selection using logistic regression in R. I fit the logistic regression on the same set of candidate models as the density analysis (see below) while also adding a dominant plant category (which of the genera was dominant at that point, only include those genera that occurred at > 5% of points). I subset the data by visit since I felt habitat selection would change with changing conditions on the ground (visit 1 = 10 August – 30 August, visit 2 = 31 August – 21 September, visit 3 = 20 September – 8 October, visit 4 = 9 October – 25 October). I tested goodness of fit on the global model in each model set with the Hosmer and Lemeshow goodness of fit test (Hosmer and Lemeshow 2013).

Density

Because I detected few Virginia and King Rails, I was unable to estimate density for these species. I estimated Sora density (Sora/ha) using the generalized distance sampling model of Chandler et al. (2011) in the R package '*unmarked*' (R version 3.2.4, R Core Team 2015; unmarked version 0.11-0, Fiske and Chandler 2011). I used a Poisson distribution and hazard function based on preliminary model exploration where models with those qualities had the lowest AIC (Akaike Information Criterion). R package '*unmarked*' provides an approach to fit biological data collected through repeated surveys in hierarchical models that estimate density while accounting for imperfect detection (Royle et al. 2004). The repeated surveys within each visit allowed me to estimate detection probability (Royle et al. 2004, MacKenzie 2006).

To estimate density in a wetland impoundment over repeated surveys in a distance-sampling framework, I had to assume geographic closure (no immigration or emigration during the visit). I met the closure assumption by estimating density for each visit and impoundment separately.

I considered five candidate models to explain density of Sora: null (intercept only), global (all covariates), average water depth, average water depth^2, and percent annual moist soil vegetation; each model also included year as a fixed factor. I hypothesized a second order positive relationship with average water depth based on my observations in the field and the work of Sayre and Rundle (1984) and Reid (1989) that showed an optimum water depth of around 12 cm for Sora habitat. I hypothesized a positive relationship between annual moist soil plant percent cover and Sora density because of the dense cover and abundance of seed resources provided by these plant species. I ranked models using AICc (Akaike Information Criterion corrected for small sample size) and considered any model with ΔAICc < 2. I evaluated the goodness of fit of the global model by calculating the Freeman-Tukey fit statistic for the observed data and comparing it to expected values generated from 500 bootstrap simulations (Brooks et al. 2000; Kéry et al. 2005).

Water Level Treatment

I selected 18 wetland units on MDC conservation areas and USFWS national wildlife refuges (Figure 1) with relatively similar vegetative structure. I selected impoundments based on their plant community, disturbance level and their ability to be flooded in accordance with our two treatments. The two flooding treatments (early or late) were randomly assigned to each impoundment in a crossover design as described in Lyons et al. (2008). Early flooding began the week of August 1st and finished by the week of September 15th with the average water level of the impoundment being between 10 and 25 centimeters. Late flooding began the week of September 15th and finished by the week of October 31st with the average water level of the impoundment being between 10 and 25 centimeters. The pool that received early inundation the first year received late inundation in the second year and vice versa; this constituted the crossover experiment. The response variable was the total number of rails detected in each impoundment corrected for effort (number of hours surveyed) in year one minus the number of rails detected corrected for effort in that same impoundment in year two. I recognize that this variable does not formally account for detection. I determined using VHF transmitters that detection rates for marked sora were very low (~17% under ideal conditions) and further I suspect that new individuals were migrating through the study area over the course of the sampling period. These two issues are of concern but I have not developed a means of formally addressing them here. The predictive variable was the difference in the annual count between the treatment in year one to the treatment in year two, i.e., the count in early flooding first year minus the count in late flooding second year for that same impoundment. I predicted that the early flooded impoundments would be more attractive to migrating rails than late flooded impoundments. The analysis involved a student t-test examining the difference in the response variable given the treatment (early to late versus late to early), i.e., this is a test of whether the difference between the treatments was significantly different than zero.

Results

Virginia Rails selected deeper water on average than was available (Fig. 2). Virginia Rails consistently used points with higher percent cover of annual moist soil vegetation than was available on the landscape while they used perennial moist soil vegetation at lower percentages than was available on the landscape (Fig. 3). The available percent cover for the other four habitat variables was essentially zero. Virginia Rails used *Echinochloa, Eleocharis* spp., and *Poaceae* spp. more than they were available (Fig. 4).

For Sora, the global model fit the data ($\chi^2 = 10.626$, $p = 0.22$). Sora selected deeper water than was available in visits 2, 3 and 4 (Fig 5). There was a positive relationship between Sora selection and percent cover of annual moist soil vegetation (Fig. 5). There was no difference in Sora selection between the genera of dominant plants (Fig. 5).

I detected 5,341 Sora during August-October 2012-2015 (per year sample size (*N*), 2012 *N* = 1,456, 2013 *N* = 1,644, 2014 *N* = 1,219, 2015 *N* = 1,022). Percent vegetation cover and water depth varied among years (Table 2). The global model fit the data ($p = 0.98$). Virtually all of the model support was for the global model (Table 3). Average water depth was positively related to Sora density (β=0.44, SE = 0.025, $p < 0.001$, Fig. 6) with peak density occurring at a water depth of 27.8 cm. Annual moist soil vegetation cover was also positively related to Sora density (β=0.32, SE = 0.018, $p < 0.001$, Fig. 6). Average Sora density during autumn migration was 14.5 Sora/Hectare. I saw the highest average Sora density in 2012 (51.4 Sora/Hectare) followed by 2014 (14.1 Sora/Hectare), 2015 (12.7 Sora/Hectare) and the fewest in 2013 (7.69 Sora/Hectare).

I was unable to investigate the crossover effect of water level treatment on Virginia, Yellow or King Rails because we detected so few. The median difference between the Sora corrected annual counts per impoundment going from early to late flooding was 22.6 (95% CI: -16.63, 82.91) while for the other treatment direction, the difference was -45.6 (95% CI: -76.80, 11.68). There were three exceptions to the predicted results out of 18 impoundments (Table 4).

Two of the early to late flooded treatment impoundments had a negative difference, i.e., more Sora used the late flooded treatment, while one impoundment for the late to early treatment had a positive difference, e.g., more Sora used the late treatment. The t-test statistic for the treatment effect was -2.274 ($p = 0.019$) indicating that Sora were using early flooded impoundments at a higher abundance than late flooded impoundments regardless of year.

To address when and where to target capturing Sora in Missouri for future studies, the earliest Sora I detected was 11 August 2015 (Table 5) and study area managers reported seeing Sora in 2012 and 2015 before my surveys began (personal communications, 2012, Craig Crisler, Missouri Department of Conservation and 2015, Cody Alger, U.S. Fish and Wildlife Service). I found no significant difference in Sora density (Sora/hectare) before 31 August in all years or after 19 October in 2013-2015 (2012 data collection ended 7 October, Fig. 7). All years except 2014 had a similar trend with a peak in late September, followed by a slow decline thereafter, whereas 2014 had no clear peak and a greater interquartile range (Table 5). The peak in 2012 was higher than any other year.

According to both of my density estimates and my Sora/hour survey counts, the time of year to catch the largest number of Sora should be during visit 3; 20 September – 8 October (Fig. 8). Conservation Areas and National Wildlife Refuges in the northern part of Missouri generally had higher densities of Sora than southeastern Missouri (Fig. 9).

Discussion

I found Virginia Rails selected for shallowly flooded (<12 cm) annual moist soil plant communities that were similar, but deeper than found by Rundle and Fredrickson (1981), Sayre and Rundle (1984), and Reid (1989). I found Virginia Rails used millets and spikerushes just like Sayre and Rundle (1984) and Reid (1989) found.

Water depth was the most important habitat characteristics for explaining Sora during autumn migration. At the wetland level, I found peak Sora densities at 27 cm of water, deeper than previous work (11-14 cm) and greater than is recommended for teal during autumn and winter (Rundle and Fredrickson 1981; Fredrickson and Taylor 1982; Sayre and Rundle 1984; Reid 1989). Why I found Sora using deeper water than other researchers remains unclear.

My crossover experiment also demonstrated that Sora were using early flooded impoundments at a higher abundance than late flooded impoundments. I also found that this effect carried throughout the sampling period as early flooded impoundments consistently attracted more Sora despite late flooded impoundments having appropriate water levels by the third visit. I have no explanation for this temporal pattern as I might have argued that the new availability of food in late flooded impoundments would have attracted more Sora to those units later in the autumn.

The flooding of wetlands earlier in the autumn could impact other species, such as waterfowl that migrate later in the season, by causing plants to senesce more quickly and deplete food resources. Wetland loss is a concern on the landscape, making the management of remaining wetlands, especially those managed by public agencies, very important (Tiner 1984; Hagy et al. 2014). Manipulative experiments should be conducted to confirm my results and investigate whether there are unanticipated costs to earlier flooding on later migrating waterbirds.

While water depth was important, water depth was not the only consideration in making decisions on where to locate. I found that Sora were selecting habitat both on water depth and on plant cover, either habitat variable alone did not explain Sora use. I found the 27 cm water depth peak in Sora density when year and annual moist soil plant percent cover were held constant at median values (median values, annual moist soil plants = 33%, water depth = 9.22 cm, year = 2013). At the microhabitat level during visit 1, Sora did not select water depth. Early in the season little water was available on management areas and the lack of available water limited the Soras' ability to select flooded areas, i.e., Sora were forced to use what water was available. During visits 2, 3 and 4, Sora selected for deeper water than available. Griese et al. (1980) and Rundle and Fredrickson (1981) also found Sora around flooded areas early in migration. Sora migrate earlier in autumn than waterfowl (Sora, August – October; waterfowl, October – January). Usually the timing of wetland flooding on a management area is directed at migratory waterfowl (Bellrose 1980). The later timing of flooding during the autumn does not provide habitat early in autumn migration for Sora and other early migrating wetland birds. The paucity of floodwaters on the landscape early in migration may affect the ability of Sora to migrate during more optimal time periods and may also impact survival by forcing Sora to use suboptimal habitat types (Rundle and Fredrickson 1981; Fredrickson and Taylor 1982). When migratory windows last several months considering the entire breadth of that period is critical.

I found Sora density increased with greater percent cover of annual moist soil plants as it did for Meanley (1965), Rundle and Fredrickson (1981), Sayre and Rundle (1984), and Reid (1989). Annual moist soil vegetation provides dense cover to hide from predators and produces high densities of seed resources that are an important food resource during autumn migration (Rundle and Sayre 1983). Note that because perennial plant communites were generally managed against, I cannot remark on whether perennial or annual wetland plant communities were prefered during autumn migration by rails. Reid (1989) found that Sora and Yellow Rails were associated with annual wetland plants whereas Virginian and King Rails were associated with perennial wetland plants. Reid (1989) further noted that all rails were associated with moist-soil plants rather than robust emergents.

Efforts to capture and mark rails to inform questions about survival should target shallowly flooded dense stands of annual moist soil vegetation during the autumn. Based on my experience capturing Sora, following the ATV captures methods of Perkins et al (2010) works well, targeting areas with <50cm high vegetation. I captured many Sora in a few hours with an experienced crew. Capturing Virginia Rails is much more difficult using this method. My very limited attempts at catching King Rails were entirely unsuccessful.

Understanding the stopover ecology of a species is vital to understanding how migration impacts survival on an annual basis (Sheely *et al.* 2011; Hostetler *et al.* 2015). Future work should consider the landscape around each wetland, and wetland isolation on the landscape as these have been important during the breeding season for rails and during migration for shorebirds (Browns and Dinsmore 1986; Albanese and Davies 2015). My work fills a vital gap in the natural history literature for autumn migrating rails. With this information, wetland managers can more effectively manage their properties for these rails and other similar wetland dependent birds that migrate through the central Mississippi Flyway during the autumn.

Acknowledgements

Funding provided by the U.S. Fish and Wildlife Service Webless Migratory Game Bird Program, the Missouri Department of Conservation, the U.S. Geological Survey Arkansas

Cooperative Fish and Wildlife Research Unit, and the University of Arkansas. I would like to thank K. Ackley, C. Alger, R. Bell, A. Burke, M. Bowyer, K. Brunke, G. Calvert, C. Chambers, K. Cordell, C. Crisler, C. Freeman, M. Flaspohler, R. Kelly, L. Landowski, J. Hager, M. Hanan, M. Marks, F. Nelson, B. Pendley, D. Welchert, S. Whitson, and J. Wilson for their help planning logistics. Special thanks to M. Boone, L. Brinkman, D. Datlof, J. Fournier, J. Lehman, H. Pavisich and N. Seeger for their diligent work in the field. Thanks to E. Lawton, and A. Bond for their helpful comments on an earlier draft. All work completed under Special Use Permits from Missouri Department of Conservation, U.S. Fish and Wildlife Service and IACUC proposal #13044 and #15023 from the University of Arkansas and Federal Bird Banding Permit #23002.

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Table 1. Survey start and end dates for each year of autumn surveys of Sora (*Porzana carolina*) in Missouri, USA.

Year	Number of observers	Start date	End date	Visits per state property	Visits per federal property
2012	4	17 August	7 October	3	3
2013	4	11 August	27 October	3	4
2014	2	12 August	22 October	4	4
2015	2	12 August	23 October	4	4

Table 2. Summary of available habitat median, minimum and maximum values across and by year for wetland impoundments in Missouri, USA surveyed for Sora (*Porzana carolina*) density from 2012-2015.

Variable	Year	Median	Minimum	Maximum
Average Water Depth (cm)	2012	7.8	0	56.2
	2013	0	0	57
	2014	9.6	0	101.6
	2015	1.8	0	58.4
	all	5.1	0	101
Annual Moist Soil Vegetation Percent Cover	2012	30	0	100
	2013	10	0	100
	2014	15	0	100
	2015	60	0	100
	all	35	0	100

Table 3. Model selection results assessing those variables thought important in explaining Sora (*Porzana carolina)* density in Missouri, USA from 2012 – 2015. K (number of parameters), Akaike information criterion (AIC), ω (model weight),

Model name	**K**	**AICc**	**Delta AIC**	**ω**
Global	9	-11406	0.00	1
Average Water Depth^2	8	-11122	283	0
Average Water Depth	7	-11072	334	0
Annual Moist Soil Vegetation	7	-11006	400	0
Null	3	-10663	742	0

Table 4. Crossover experiment results for 18 impoundments surveyed for Sora (*Porzana carolina*) in Missouri, USA. Treatment was either switching from early flooded to late flooded, between 2014 and 2015 (0) or the reverse, switching from late flooded to early flooded (1). The measurement of response is the difference in the total count of Sora corrected for effort (number of survey hours) between early flooded and late flooded counts (e.g. total corrected Sora count in 2014 minus the total corrected Sora count in 2015 for the same impoundment) or the reverse.

Region	**Management Area**	**Impoundment Name**	**Treatment**	**Difference**
SE	Duck Creek CA	Unit A Pool 22	0	40
NE	BK Leach CA	Kings Tract Pool	0	17.4
NC	Swan Lake NWR	M10	0	38.9
SE	Otter Slough CA	Pool 23	0	22.6
NC	Fountain Grove CA	Pool 2 Walk In	0	-59.2
SE	Ten Mile Pond CA	Pool 1	0	21.3
NW	Nodaway Valley CA	Sanctuary	0	162.5
NW	Squaw Creek NWR	MSU 2	0	89.1
NE	Ted Shanks CA	Pool 2A	0	-34.4
SE	Duck Creek CA	Unit A Pool 14	1	-58.9
NE	BK Leach CA	Kings Tract Pool	1	98.3
NC	Swan Lake NWR	M13	1	-17.8
SE	Otter Slough CA	Pool 21	1	-10.6
NC	Fountain Grove CA	Pool 2	1	-37.3
SE	Ten Mile Pond	Pool E	1	-116.1

	CA			
NW	Nodaway Valley CA	Rail	1	-54.7
NW	Squaw Creek NWR	Snow Goose D	1	-50.3
NE	Ted Shanks CA	Pool 8A	1	-45.5

Table 5. Distribution of Sora densities across the survey period in Missouri, USA. IQR is the inner quartile range, or the number of days between Quantile 1 and Quantile 3.

Year	Minimum	Quantile 1	Median	Quantile 3	Maximum	IQR
2012	17 August	13 September	22 September	27 September	7 October	14
2013	11 August	14 September	26 September	3 October	27 October	19
2014	12 August	5 September	23 September	5 October	22 October	30
2015	12 August	14 September	29 September	3 October	23 October	19

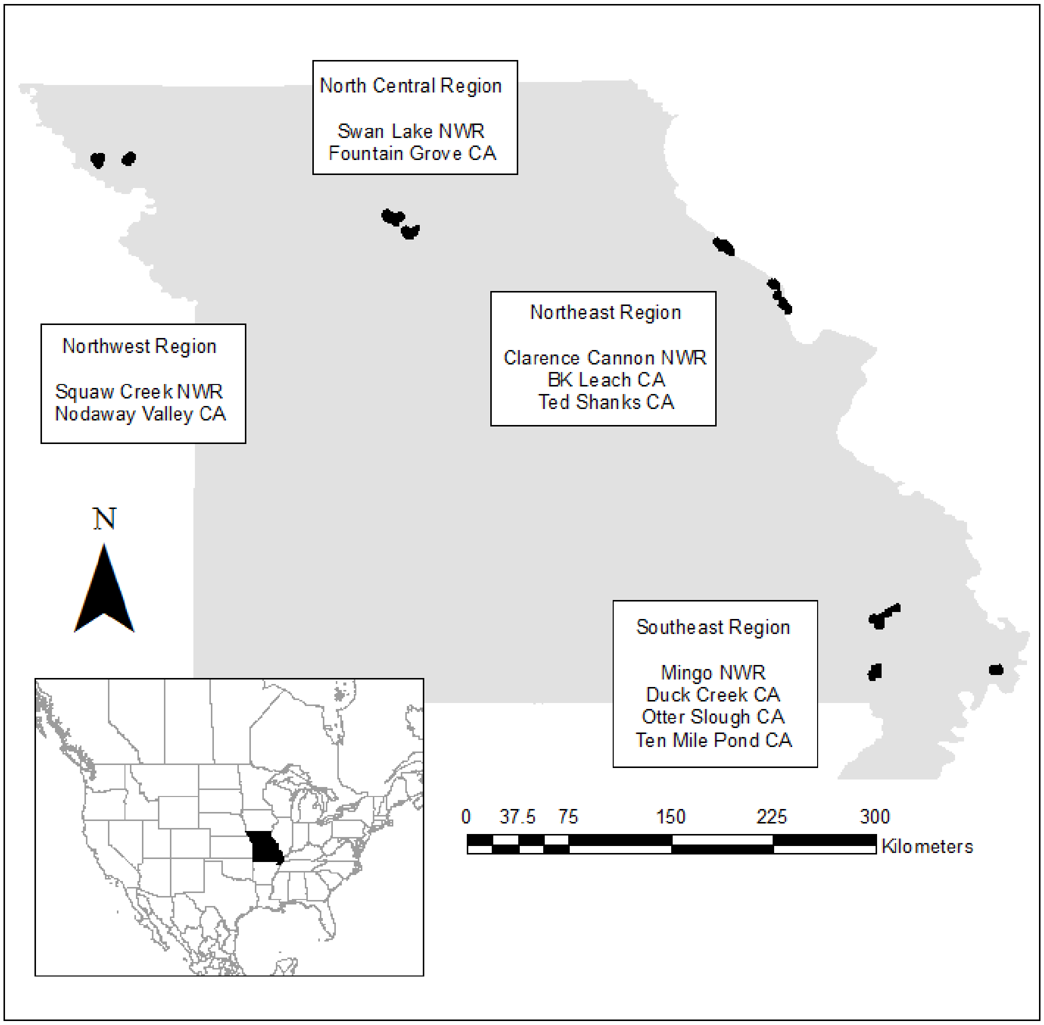

Figure 1 – National Wildlife Refuges and Conservation Areas I surveyed from autumn 2012-2015 for rails in Missouri, USA.

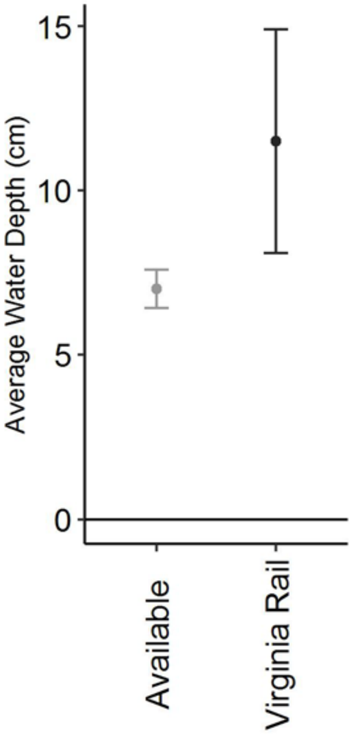

Figure 2 – Median (+/- 95% Confidence Intervals) average water depth of available, Virginia Rail (*Rallus limicola*) used points from 2012-2015 in Missouri, USA.

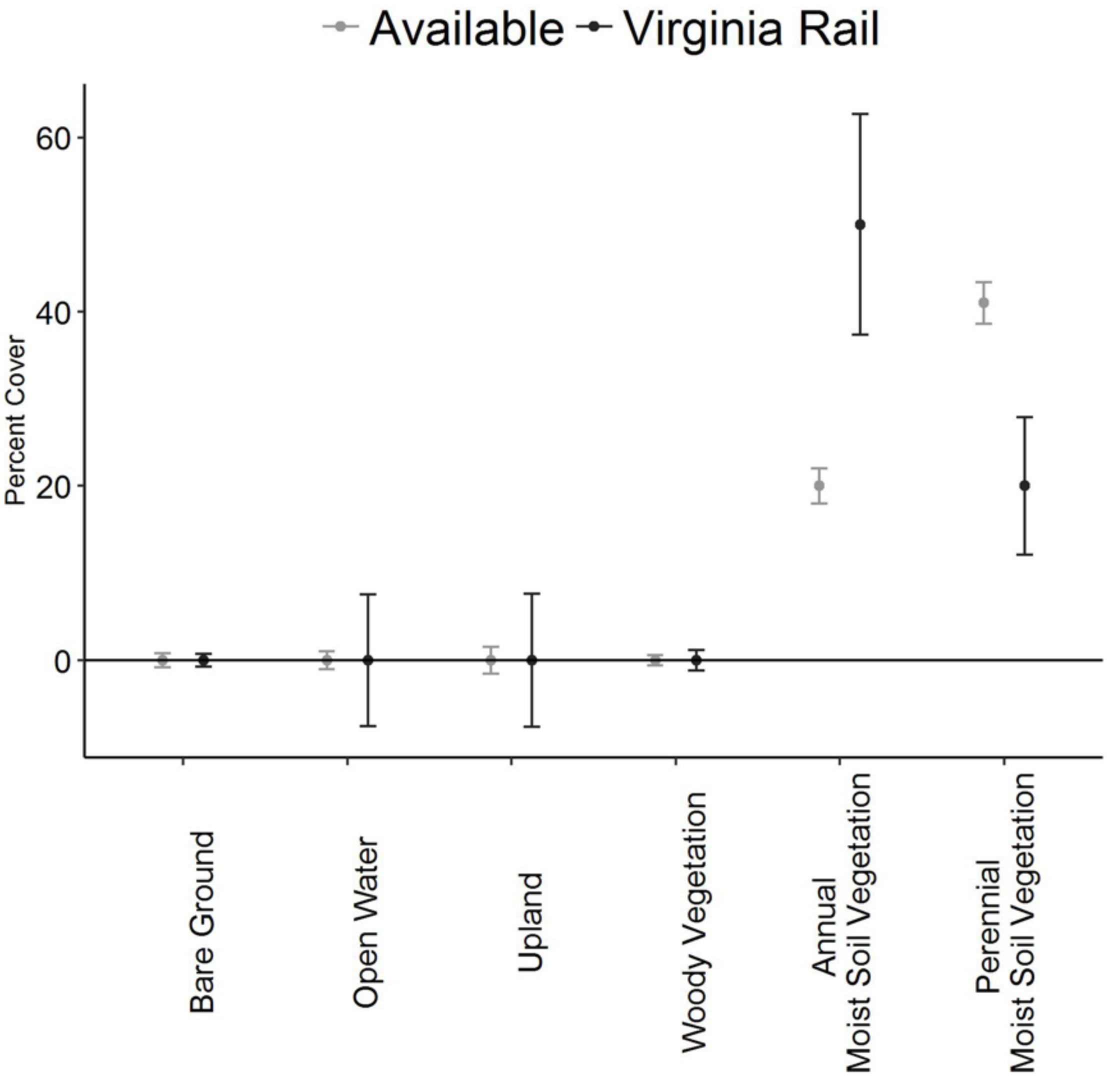

Figure 3 - Median (+/- 95% Confidence Intervals) of 6 categories of vegetation cover for available, Virginia Rail (*Rallus limicola*) used points from 2012-2015 in Missouri, USA.

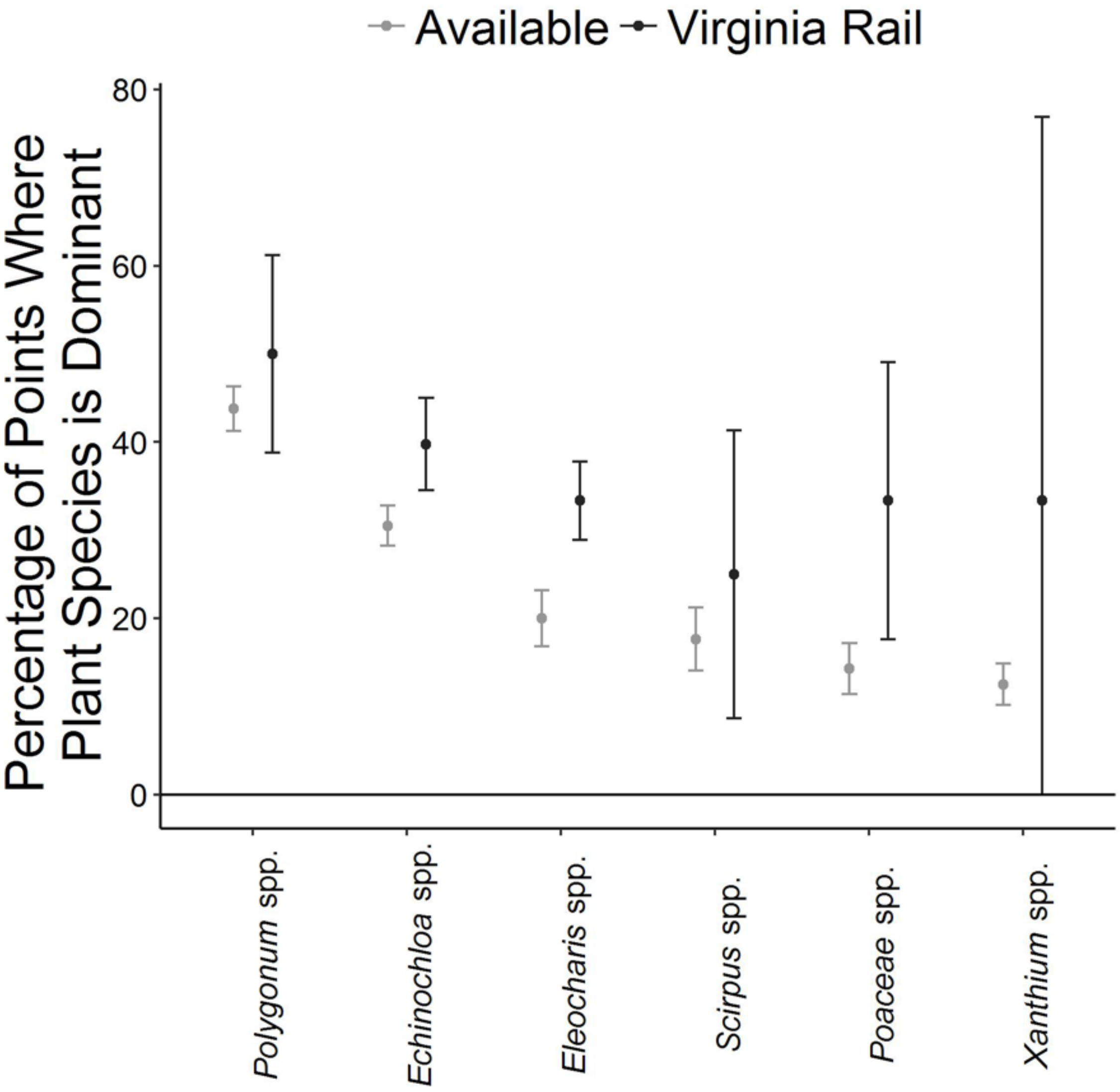

Figure 4 - Median (+/- 95% Confidence Intervals) of percentage of points where the 6 most dominant place species are present, Virginia Rail (*Rallus limicola*) used points from 2012-2015 in Missouri, USA.

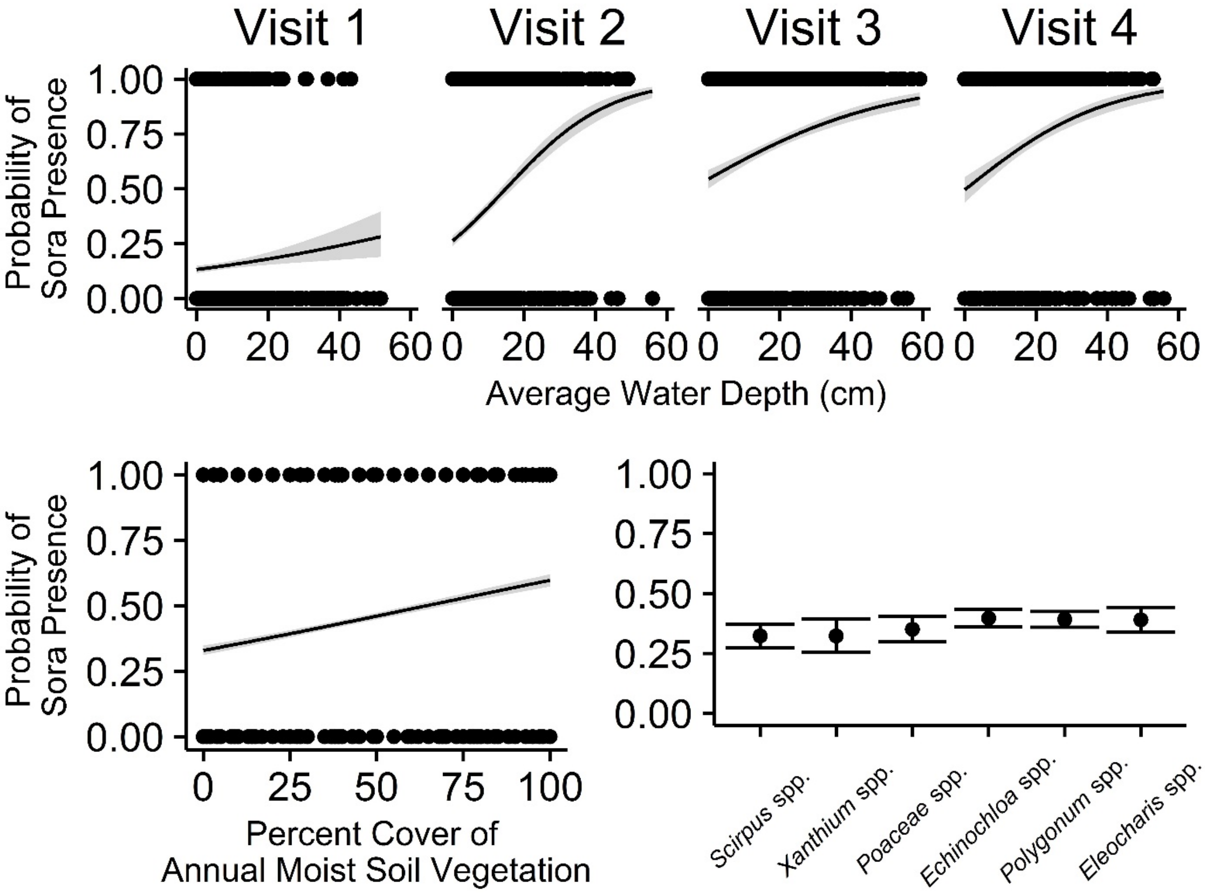

Figure 5 – Resource selection graphs for Sora (*Porzana carolina*) [top] Selection by visit of average water depth. [bottom left] Selection of Annual Moist Soil Vegetation Percent Cover [bottom right] Selection of six most dominant plant species.

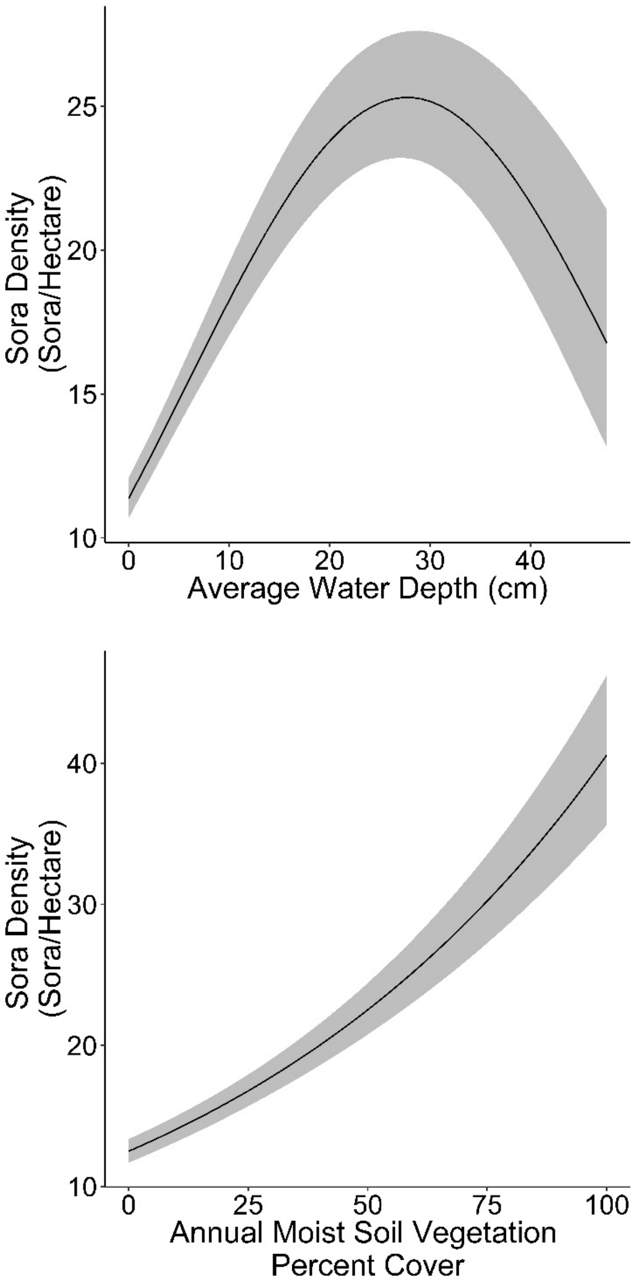

Figure 6 – Relationship between Sora density and habitat covariates in Missouri, USA 2012-2015.

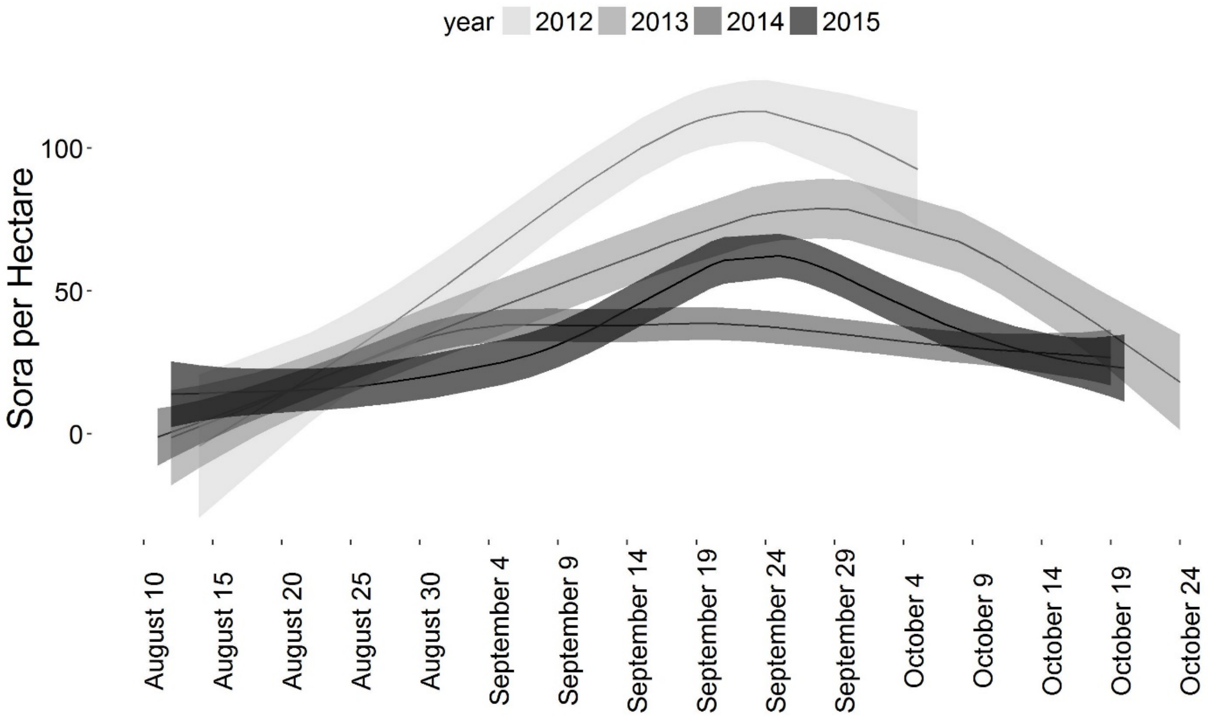

Figure 7 – Sora per hectare density estimates from generalized distance sampling models of rails from 2012-2015 in Missouri, USA.

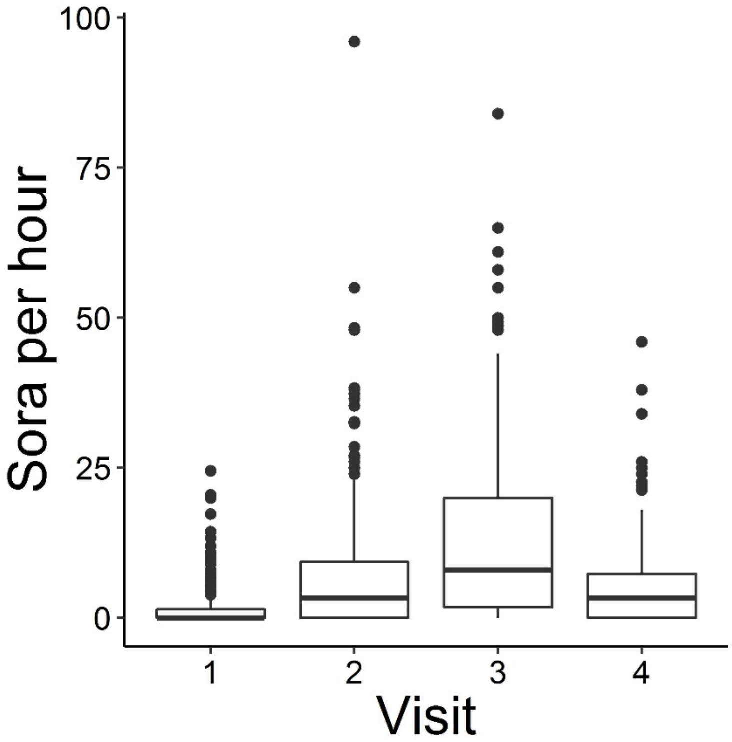

Figure 8 – Sora per survey hour by visit from 2012-2015. visit 1 = 10 August – 30 August, visit 2 = 31 August – 21 September, visit 3 = 20 September – 8 October, visit 4 = 9 October – 25 October

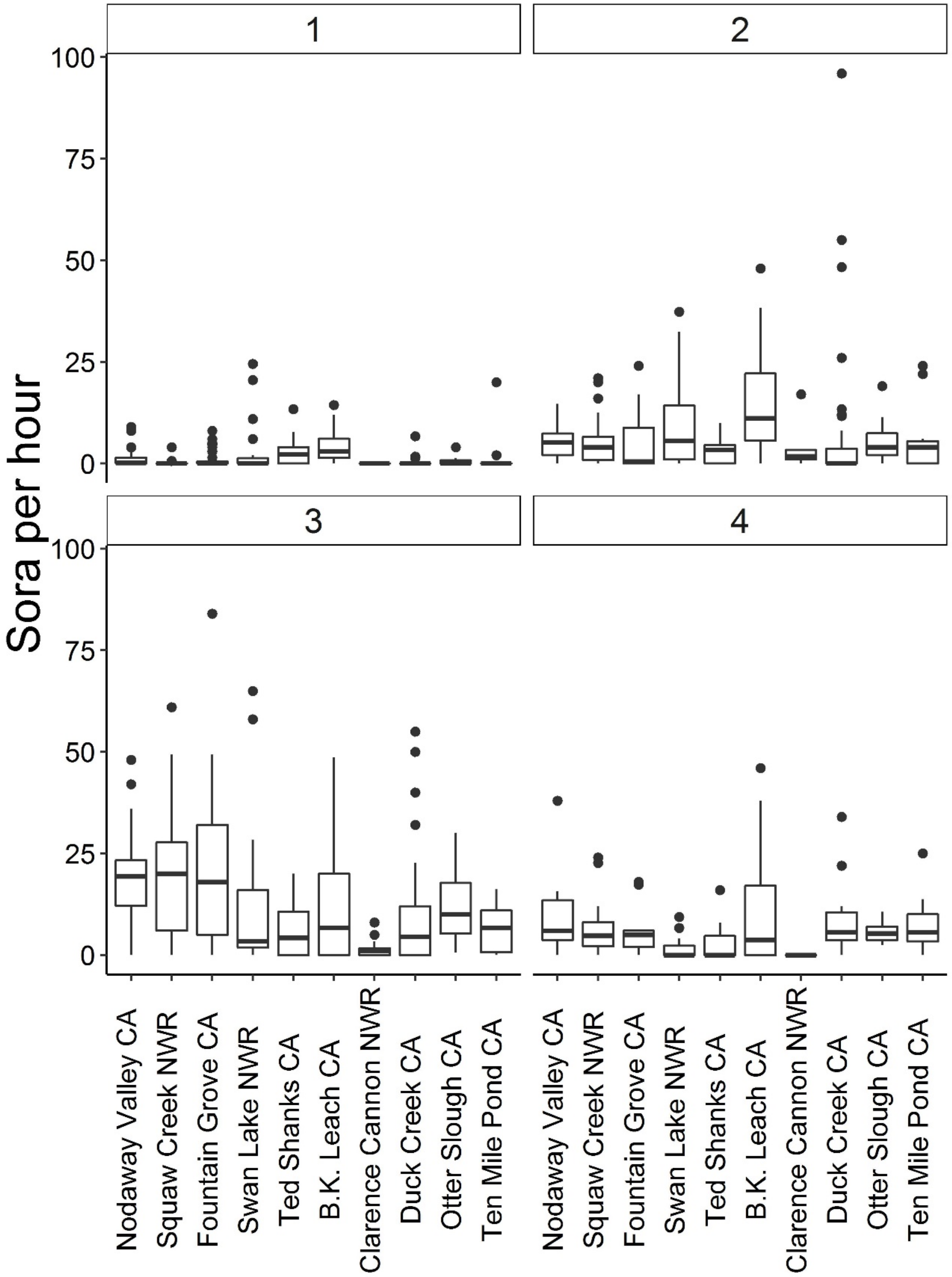

Figure 9 – Sora per hour by Conservation Area/National Wildlife Refuge in each visit from 2012-2015 in Missouri, USA. visit 1 = 10 August – 30 August, visit 2 = 31 August – 21 September, visit 3 = 20 September – 8 October, visit 4 = 9 October – 25 October

Supplementary Material

Supplementary Table 1. Impoundments surveyed each year

Property	**Year**	**Region**	**Wetland impoundments**
Nodaway Valley CA	2012	northwest	Sanctuary, Ash Grove
	2013		Sanctuary, Ash Grove
	2014 & 2015		Sanctuary, Ash Grove, Rail Marsh
Squaw Creek NWR	2012		Snow Goose B, North Mallard, North Pintail
	2013		Snow Goose B, C, D & E, North Mallard
	2014 & 2015		Snow Goose B & D, MSU 2 and 3
Fountain Grove CA	2012	north central	pool 2, pool 3, boardwalk
	2013		pool 1 & 2, pool 2 walk-in, pool 3 walk-in
	2014 & 2015		pool 2, pool 2 walk-in, pool 3 walk-in
Swan Lake NWR	2012		m4, m5, m10, m11
	2013		m3, m4, m5, m10, m11, m14
	2014 & 2015		m10, m11, m13
Ted Shanks CA	2012	northeast	4a, 11a, nose slough
	2013		nose slough
	2014 & 2015		2a, 4a, 6a, 8a
B.K. Leach CA	2012		bittern basin 1, 2, & 3, kings tract 2 & 6
	2013		bittern basin 1, 2, & 3, kings tract 2 & 6
	2014 & 2015		kings tract 2, 5, 6, & 9

Clarence Cannon NWR	2012		MSU 1, 2 & 7
	2013		MSU 7
	2014 & 2015		MSU 1, 2, & 12
Duck Creek CA	2012	southeast	Unit A 13, 14, 15, 18, 20, & 21, ditch
	2013		Unit A 11, 13, 14, 15, 16, 18, 20, ditch
	2014 & 2015		Unit A 14, 18, 20, 22
Otter Slough CA	2012		21, 25, R3, R4/5, R7, R8, R9
	2013		21, 25, R4/5, R7
	2014 & 2015		21, 23
Ten Mile Pond CA	2014 & 2015		Pool C, E and I
Mingo NWR	2012		2w, 2 & 3
	2013		2w, 2 & 3

Supplementary Table 2 – King Rail Data

Percent Interspersion	Annual Moist Soil Vegetation	Perennial Moist Soil Vegetation	Upland	Bare Ground	Open Water	Woody Vegetation	Other	Crop
5	85	0	0	0	5	0	10	0
4	97	0	0	0	3	0	0	0
14	99	0	0	0	1	0	0	0

Water	Water	Water	Water	Water	Average	Dominant Plant 1	Dominant Plant 2	Dominant Plant 3

Table 2a. Vegetation Data for King Rails (*Rallus elegans*) detected in Missouri, USA in 2012 and 2013.

Depth 1	Depth 2	Depth 3	Depth 4	Depth 5	Water			
36	35	35	39	23	33.6	smartweed	millet	willow
9	8	14	8	9.5	9.7	millet	smartweed	cocklebur
11	7	2	7	11	7.6	millet	smartweed	spikerush

Table 2b. King Rail (*Rallus elegans*) detected during surveys in Missouri, USA in 2012 and 2013.

Species	Impound	Area	Region	Latitude	Longitude	Month	Day	Year
King Rail	msu2	Clarence Cannon National Wildlife Refuge	ne	39.26161	-90.7814	8	25	2012
King Rail	m4	Swan Lake National Wildlife Refuge	nc	39.61302	-93.2026	9	9	2012
King Rail	r4/5	Otter Slough Conservation Area	se	36.7024	-90.1115	10	13	2013
King Rail	north mallard	Squaw Creek National Wildlife Refuge	nw	40.1016	-95.2737	9	3	2012