Migration and Breeding Ecology of King Rails (Rallus elegans) in Southeast Arkansas

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Movement and Breeding Ecology of King Rails (*Rallus elegans)* in Southeastern Arkansas

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Biology

by

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Delaware Valley University
Bachelor of Science in Wildlife Conservation and Management, 2015

May 2024
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

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ABSTRACT

King Rails (*Rallus elegans*) are a secretive marsh bird species of conservation concern in Arkansas. Freddie Black Choctaw West WMA in southeast Arkansas has multiple confirmed pairs of breeding King Rails and offered an opportunity to investigate King Rail migration ecology, as well as nesting ecology and nest site selection.

In Chapter 1, we determined migratory status (resident vs. migratory) and described seasonal movement. To do this, we captured and outfitted 23 birds with Argos GPS tags to track migration patterns throughout the season. We found that most of the population did not make long distance migrations but instead were residents year-round. We examined monthly movements on the landscape to determine how their movement changed seasonally to help understand how management impacts their use of habitat.

In Chapter 2, we investigated nest site selection relative to the habitat available across the Wildlife Management Area, in a used versus available habitat framework. To do this, we performed habitat surveys at confirmed nest sites and random points throughout the WMA to assess what characteristics are significant to King Rails. We ran generalized linear models to see what rails select for in a used versus available habitat framework. King Rails selected for nest sites that had higher average vegetation density and percent of rush cover.

From this research, we corroborated that heterogeneous habitat is important for both the breeding and movement ecology of this species and recommend management that promotes diverse habitats that support these birds year-round.

ACKNOWLEDGEMENTS

First and foremost, I'd like to thank my incredible advisors, Dr. Auriel Fournier and Dr. Caleb Roberts. I am so lucky they chose me to be the graduate student on a project studying a species close to my heart. They guided me through my master's with kindness and grace and helped me learn things in my own process without holding my hand. They are exceptional biologists and people, and I am indebted to them for helping with everything that made me a better scientist and human being, including edits, analysis, research questions and encouraging me to ask for help. I'd also like to thank my committee member Dr. Kusum Naithani for her thoughtful edits, questions, and support throughout my master's classwork and thesis writing.

There are so many research and funding partners involved in a project like this. It was great to be part of such a collaborative effort between multiple states and agencies, and this research gave me the opportunity to work with such wonderful people on this project. First, I'd like to thank Arkansas Game and Fish Commission (AGFC) as the major funding source with their State Wildlife Grant. This project would not have been possible without their financial support. I am also thankful for being the recipient of the AGFC Conservation Scholarship to support my research in conserving Arkansas's native wildlife and ecosystems. In addition, they provided so much logistical support and helped with the fieldwork component as well. I'd like to extend a special thank you to Karen Rowe and Jason McCallie, both for their kindness and willingness to help and learn more about King Rails. They brought so much logic and humor to my life and my fieldwork. This project, and even the success of these King Rails at Choctaw West WMA, would not be possible without them. I am grateful to consider them colleagues but also dear friends.

I’d also like to thank other AGFC folks who helped with permitting, catching birds, nest searching and completing vegetation surveys and drone flights. They represent the agency with such pride, confidence, joy, and unerring generosity that made them a pleasure to work with. Many thanks to these people, including Sarah Baxter, Clayton Whitaker, Allen Clawson, Blake Wooten, Michael Shepherd, Mark Barbee, David Luker, Mark Hooks, Matthew Warriner, Nick Goforth, Meredith Swartwout, Allison Fowler, Clint Johnson, and Ryan Farney. Another special thank you to Mark Hooks for allowing myself and my technician to stay at my field site; it saved us many hours of driving and provided a safe refuge as well.

I need to thank my three administrative angels for all their hard work and help in making my time as a master’s student so successful: Mindy Lowers, Diane Moler and Jan Warren. They went above and beyond to make sure I had a way to conferences and field work, and fiercely advocated for me. I am thankful for all their help and shared wisdom over coffee.

Many, many thank yous to the folks at Forbes Biological Station, part of the larger INHS Prairie Research Institute. I have worked with them in some capacity for several years and they’ve all been incredible, so to be able to continue to work with them has been an amazing experience. I enjoyed working alongside such wonderful people, including Josh Osborn, Chelsea Kross, Andy Gilbert, Therin Bradshaw, Abby Blake-Bradshaw, and countless technicians. They aided with permitting, helping me get field gear and transmitters, provide logistics from hundreds of miles away, sat through so many practice presentations and provided invaluable suggestions and support, as well as great humor and honesty.

Within my Forbes lab under the guidance of Dr. Fournier, I’d like to thank my other lab members, Nicole Pietrunti, Chad Cremer, Nora Hargett, Lauren Monopoli and Cheyenne Beach. I have an additional and heartfelt thank you to Cheyenne for helping me with my successful pilot season of rail captures and offering wisdom as a grad student, researcher, and friend. Being a part of two different labs at once meant I had double the resources for guidance, help, laughs and friendship. Whether that's luck or a blessing, I couldn't have done it without all of them.

I'd like to thank the USGS Cooperative Wildlife Research Unit at the University of Arkansas for giving me the space and support to help conduct this research. I am grateful to my former and current labmates and "Coop" unit members, especially Percival Marshall, Mike Shaw, Lauren Berry, Ken Wilson, Lindsey LaBrie, Michael Ferrara, Vinita Karki, Paul Akpejeluh, Leah Bayer, Kearstin Findley, Sarah Sorenson, Casey Davis, Ellery Lassiter, Emily Johannson, and Leah McTigue. They provided invaluable help with coding and life, and I am thankful to them for their company in the trenches as we all navigated our graduate school experience. They unwittingly became family and friends for life.

I owe a huge debt of gratitude to my friends and colleagues within the Biology Department at UArk. I'd especially like to thank Elliot Lassiter and Maddie Sudnick for their help with capturing birds and spending long weekends trapping birds with me in SE Arkansas. In no particular order, I want to also thank: Ethan Hollender, Elizabeth Hays, Ben Stratton, Mitchell Pruitt, Camryn Larson, Wade Boys, Gideon Long, Reilly Jackson, Isabella DeAnglis, Chris Wilson, Rachel Savage, Morgan Russell, Jenna Miladin, Braden Wojahn, Sarah Heissenberger and Will Kirkpatrick. Thank you for your friendship and shenanigans. I love y'all.

Thank you to my previous employers and coworkers who helped show me the ropes of wetlands research and the secret to working with rails. To Ashley Jackson, Tom Faughnan, and Marisa Martinez: Thank you for taking a chance on a totally green field worker and getting me started in wetlands work. To John O'Connell, for hiring me even though my cover letter was riddled with typos. To my Forbes crew, including Aaron Yetter, Chris Hine, Sam Klimas, Ryan

Askren: thank you for teaching me so much about waterfowl. To Brendan Shirkey and John Simpson at the Winous Point Marsh Conservancy, a huge thank you for honing my skills capturing birds and giving me my first taste of working with King Rails and beginning a lifelong obsession. To Elisa Elizondo and Haley Glasgow at the University of Delaware, for giving me the experience to catch and handle rails in a TOUGH environment. To my best friend Macayla Greider, for her incredible support, unrelenting sass and shared love of wetlands and birds and screaming. To my dear friend Kathleen Carey, for her gift of moral support and shared love of Wawa. Despite being younger than me, they gave me so much wisdom and love and taught me a lot about communication and friendship. Cheers to all of you for getting me to this point.

Above and beyond, I'd like to thank my field partner Jennifer Kay. Not one, but both seasons, she worked tirelessly to help catch birds, complete tedious surveys, and put up with my antics. She brought so much joy and awe every day and reminded me how lucky we are to be biologists. If she ever reads this: You're the best sister-daughter I could have asked for. I love you big.

I'd like to thank my partner, Gabe Schmit, for his unwavering support during my master's thesis, and the long years prior of holding down the fort while I travelled for fieldwork. Thank you for taking care of our sweet baby Mo and cheering me on no matter how far away I was for how long. Thank you for coming down to help me catch birds in a marsh even though you hate getting wet. I couldn't have done this without you, and I am eternally grateful.

And finally, a thank you to all the King Rails I've ever worked with, but especially my beloveds at Choctaw West WMA. Thank you for being the coolest, sneakiest birds ever, and for giving me the privilege to be challenged and fulfilled every day. Live long and prosper, and make sure to nest in dense habitat!

DEDICATION

I'd like to dedicate this thesis to all the wonderful librarians and public libraries that I spent time with during my time as a graduate student: McGehee Public Library, Dumas Public Library, Eureka Springs Carnegie Public Library, Madison County Public Library, Rogers Public Library, and especially the Fayetteville Public Library. They are the heart and soul of every community, and the warmth of the employees and fellow patrons gave me joy and support to write this thesis.

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INTRODUCTION

King Rails (*Rallus elegans*) are a large, reddish-brown bird in the family Rallidae, and belong to an avian cohort of secretive marsh birds—birds who are rarely seen but often heard in the marsh. King Rails are the largest rail in North America (Cooper 2008) and are distinguished from other rails by their size and harsh call. They are laterally compressed to help them maneuver through thick vegetation in their preferred emergent wetland habitats and have long toes to help them cross wet and muddy ground quickly. They are identified by a rufous breast, barred flanks, and have a well-streaked back, with a unique pattern of black centers to scapulars with olive edges (Pickens and Meanley 2020). Both sexes are similar in plumage, but the male is larger overall (Perkins 2007).

King Rails occupy freshwater habitat but can utilize some brackish habitat where they overlap with their salt-marsh relatives, the Clapper Rail (*Rallus crepitans*), especially in the Gulf Coast where both species occur (Perkins et al 2009). King Rails are indicative of high-quality wetland habitat that they occupy and are a great representative taxa for wetland ecosystems because the habitat they need provides resources for other species in addition to the rails themselves (MacPherson et al 2018). They eat invertebrates, especially crayfish, but also hunt frogs and small fish in shallower water. In addition to utilizing shallower water, King Rails prefer a hemi-marsh habitat with moderate interspersion between water and vegetation (Kaminski and Prince 1981, Darrah and Krementz 2009, Kane et al 2019)

Historically, these birds used to be abundant in the Mississippi Alluvial Valley of Arkansas, part of the larger Mississippi Flyway corridor. This corridor once formed important breeding and migratory habitat for King Rails (Meanley 1953, Reid 1989), but due to many factors their population dwindled. The greatest direct threat to King Rail habitats has been the large reduction in herbaceous floodplain wetlands through agricultural, urban, and industrial developments that impacted hydrology but also introduced toxicants through point and non-point pollution (Reid 1989). Brooke Meanley's extensive research on King Rails in Stuttgart, AR in the 1950s and 60s provided foundational information on the breeding ecology and some behavior of King Rails in rice fields. However, as practices changed, King Rails were no longer able to nest as successfully in rice, in addition to losing emergent wetlands across the state as well (Herring et al 2021).

In 2011, research from the Arkansas Cooperative Wildlife Research Unit identified locations with King Rails and documented their decline in Arkansas (Budd and Krementz 2011, Krementz 2017). In one location, private property known as the Wallace Trust, there were multiple pairs of breeding King Rails identified. It was an NRCS property with cypress swamp and emergent marsh habitat until 2013, when it was purchased by Arkansas Game and Fish and renamed Freddy Black Choctaw West Wildlife Management Area (WMA) (henceforth Choctaw West). Located in Desha County, southeast Arkansas, this 1200 acre property represents a dramatic wetland restoration success that is critical to learn from for King Rail habitat needs during migration and the breeding season. The Arkansas Game and Fish Commission's management at Choctaw West WMA provides an important refuge of habitat for waterfowl, King Rails and other wetland wildlife.

In 2020, the Arkansas Game and Fish Commission, as part of the Arkansas Wildlife Action Plan, listed King Rails as a priority species in Arkansas (Arkansas Game and Fish 2020). King Rails were given an S1B ranking: the 1 signifying that the species is vulnerable in Arkansas, and the B denoting that they breed here There were several questions that AGFC wanted to answer about King Rail breeding and movement ecology in Arkansas. Funded by the State Wildlife Grant, we designed the research project to answer some of the pressing questions. The first chapter of my thesis sought to investigate the breeding habitat and ecology of King Rails in southeastern Arkansas at Choctaw West WMA, and the second chapter aimed to determine the migratory status of Choctaw King Rails and describe seasonal movement.

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CHAPTER 1. NEST SITE SELECTION OF KING RAILS IN SOUTHEASTERN ARKANSAS

ABSTRACT

King Rails (*Rallus elegans*) are a secretive marsh bird species of conservation concern in Arkansas and throughout most of their range in the Mississippi Flyway and other parts of the US. Previous research from the Arkansas Cooperative Wildlife Research Unit identified Freddie Black Choctaw West WMA in southeast Arkansas as having multiple pairs of breeding King Rails. This presented researchers and Arkansas Game and Fish Commission biologists the opportunity to investigate King Rail nesting ecology and nest site selection at a restored wetland. Despite the possibility for differences in habitat availability throughout their range, understanding the characteristics driving King Rail nest site selection translates to each region and the ways that land managers can provide appropriate nesting habitat for these birds.

To investigate nest site selection, we searched for nests, and performed habitat surveys to assess what characteristics are significant to King Rails at confirmed nest sites and random points throughout the WMA. Over two field seasons, we found 26 nests and completed 679 habitat surveys looking at habitat characteristics important to King Rails. We ran generalized linear models to see what rails select for in a used versus available habitat framework. From the top two models, we model-averaged the coefficient estimates to capture a variable's overall effect on the probability of nest site selection by King Rails. We found that the probability of nest site selection by King Rails increased with higher percentages of cover by rush species and average vegetation density. This research contributes to knowledge of King Rail nesting ecology and confirms that dense, vegetative habitat cover of rushes is critical for breeding King Rails in Arkansas.

INTRODUCTION

Emergent wetlands are dynamic systems that can vary greatly over the course of a season, and species that rely on emergent wetlands must adapt in their behavioral strategies accordingly. For example, finding appropriate habitat for foraging, raising broods and nesting is difficult for birds in a changing habitat such as wetlands as both the habitat and species' needs shift seasonally (Murkin et al 1997). Like many species, wetland birds consider many different aspects of their environment when selecting suitable nesting habitat, including habitat characteristics, food, safety from predators, intraspecific competition with other birds, and conspecific relationships with other nesting birds (Hoi et. al 2012) but have the additional hurdle of selecting for these components in a shifting landscape that can vary greatly temporally.

Widespread loss of emergent wetland habitat presents an additional challenge for birds reliant on emergent wetlands. One such species is the King Rail (*Rallus elegans*). King Rails are species of conservation concern across much of their range and have been in decline over the last few decades (Cooper 2008, Darrah and Krementz 2011, Bolenbaugh et al 2012, Pickens and Meanley 2015, Krementz et al 2016). King Rails occupy freshwater emergent wetlands, but due to habitat loss and degradation are vulnerable in 12 of the states they occupy (Cooper 2008). The lack of large, contiguous habitat is suspected to be a cause of decline for these birds, as well as the loss of quality habitat (Darrah and Krementz 2009, Bolenbaugh et al 2012, Krementz et al 2016). Current literature suggests that having diverse, high-quality habitat and heterogeneity of water levels, vegetative cover, and lack of woody vegetation throughout their breeding season is critical for the success of King Rails, and the lack of quality habitat can be attributed as contributing to their decline (Darrah 2009; Bolenbaugh et al 2012; Budd and Krementz 2011). While King Rail populations are declining, they can serve as a representative taxa of multispecies wetlands management, due to their variable habitat needs throughout their life history (Meanley 1953, Darrah and Krementz 2009, Krementz et al 2016, MacPherson et al 2018), including their varied diet of amphibians, invertebrates and fish (Meanley 1956, Reid 1989) and the diversity of wetland habitats they use throughout the annual cycle (Carlisle et al 2018, Bradshaw et al 2020, Malone et al 2023).

In the 1950s and 60s when King Rails were a common breeding bird in Arkansas, they were found nesting in rice fields and in emergent wetland vegetation in fields and ditches (Meanley 1953). As humans have modified the landscape, changes in rice agriculture, and the reduction in emergent wetlands left King Rails with isolated patches of habitat in a landscape that is otherwise low quality (Fuller 2012, Xie et al 2018, Herring et al 2021) and could be contributing to King Rail population declines in Arkansas and elsewhere. King Rails are now a critically imperiled breeding species in Arkansas and learning about their nesting habitat will inform management decisions to continue to provide appropriate habitat (Arkansas Game and Fish Commission 2022). Choice of high-quality breeding sites can impact nest and fledging success (Martin 1995), and adult survival (Chalfoun and Martin 2007). Successful breeding, and subsequently successful nesting, has important impacts for contributing to population growth and is a critical component for improving inland King Rail populations (Krementz et al 2016).

King Rail (*Rallus elegans*) chicks are semi-precocial and can leave the nest within an hour of hatching but rely on their parents for food until they can forage on their own (Darrah and Krementz 2009, Johnson 2021). As a result, King Rail parents often travel great distances in their territory to find enough food to feed their large broods and keep them safe, which requires dense vegetation and variable water levels to provide food and protection of the chicks from predators (Bancroft et al 2002, Krementz et al 2016, Kolts and McRae 2017).

In dynamic habitats such as emergent wetlands, being able to see landcover changes in real-time can help biologists understand the shifting landscape and how it can impact wildlife. Previous work has looked at water depths at limited time steps, often once during a season, which is a useful baseline but does not fully represent the changes we see in emergent wetlands daily or weekly across the breeding season. Remotely sensed datasets can allow us to look at landcover and water inundation changes over time at scales that are not feasible to measure on the ground, allowing us to better assess habitat availability. Wetlands host an incredible amount of biodiversity, and given their significance, monitoring their land cover classifications is important to identify how that changes and subsequently what habitat is available for vulnerable species (Gxokwe and Mazvimavi 2023). Dynamic World is a dataset that uses Sentinel-2 satellite imagery at a 10m resolution taken on a roughly weekly (5-day) basis to classify landcover types (Venter et al 2022; Small and Sousa 2023). Dynamic World offers an opportunity to measure changing landscapes and map habitat suitability at many time steps across the breeding season, which in turn can help us better understand King Rail breeding ecology and inform management decisions during the breeding season.

We expect that a combination of factors is important for King Rails in selecting nest site locations. Previous work has shown water level can help provide protection from predators for nesting marsh birds (Picman 1993, Schmidt et al 2023) and that water level had a positive effect on nesting season survival of two rail species, and that variable water levels increased individual nest survival and mean site nest survival (Robertson 2015). Water less than 6 cm at the nest site is beneficial for chick survival and nest success as it can help deter terrestrial predators (Meanley 1953, Krementz et al 2016).

We also expect vegetation density to be a key component of nest site selection. Vegetation type may also be an influence based on density to provide good cover for nest sites (Winter et al 2005). Previous studies have shown that vegetation density is a critical component for King Rail breeding and nesting habitat selection (Kolts 2014; Darrah 2009; Krementz et al 2016, Kolts and McRae 2017) and that the amount of rush and other dense vegetation was positively associated with King Rails during the breeding season (Darrah and Krementz 2011, Bolenbaugh et al 2012, Krementz et al 2016, Brewer et al 2023). Physiognomy of nesting cover is important to evaluate for specific species, as this can vary throughout different regions (Weller 1965). Wetland management aimed at creating dense emergent wetlands with shallow water levels could maintain suitable habitat for King Rails, though more information is needed about how habitat influences nest site selection and success, especially given the dynamic nature of emergent wetlands throughout the breeding season (Bolenbaugh et al 2012). In other studies, the amount of rush and other dense vegetation was positively associated with King Rails during the breeding season (Darrah and Krementz 2011, Bolenbaugh et al 2012, Krementz et al 2016, Brewer et al 2023).

Our objective in this study is to evaluate the nest site selection of King Rails within emergent wetlands available at a restored wetland in southeastern Arkansas. Characteristics of different nesting cover and plant communities are important to evaluate for specific species, as this can vary throughout different regions (Weller 1965) but can also vary across natural and restored habitats. Understanding the habitat characteristics influencing King Rail nest site selection and breeding ecology in a restored emergent wetland will help land managers and biologists create, enhance and restore a habitat mosaic suitable for King Rails across their range in the Mississippi Alluvial Valley of Arkansas and potentially in other regions as well (Budd and Krementz 2011, Krementz et al 2016).

METHODS

Study Area

Freddie Black Choctaw West WMA (Choctaw West WMA) is a 1200-acre wildlife management area owned and managed by Arkansas Game and Fish located in Desha County in southeast Arkansas. Of the 1200 acres, 700 acres are emergent wetland. Choctaw West was selected as the study site for this research because previous marsh bird surveys revealed multiple pairs of King Rails (Budd and Krementz 2011, Krementz 2017) and juvenile rails were seen during the breeding season (Jason McCallie, personal communication; Hargrove and Osborne 2023).

Data Collection

Finding Nests

To find nests, we used three different methods. We searched for nests along transects around randomly generated points. We also searched for nests around locations GPS-tagged King Rails were known to have been. In addition, we searched for nests in areas where we heard or saw King Rails.

For the transect surveys around randomly generated points, we created the random points within the bounds of the wetland units at Choctaw West by using packages *'base'* (R Core Team 2023, R 4.4.0) and '*dplyr'* (Wickham et al 2023, version R 1.1.2). We searched habitat for a minimum of 20 randomly generated points each week. Transects were concentric circles 5 meters apart leading out from the random point with the further transect being 50 m from the central point.

When searching for nests at locations used by GPS-tagged birds, we used a similar circular transect as above but stopped at a maximum of 25m from the point.

When we were out on the WMA, we took GPS locations anywhere we saw or heard King Rails, and we later revisited these locations to look for nests, using the methods used for random points.

Nest Site Selection Habitat Surveys

To evaluate King Rail nest site selection, we compared sites that King Rails selected for nest sites and the areas that were available to them. We measured habitat variables at each nest and at 5 random points within 100 meters of each nest. We selected the 100 m radius (200 m diameter) circle as the area in which to generate random points because the estimated size of King Rail home ranges in Louisiana is 200 m in diameter (Pickens and King 2013). We randomly generated a degree to navigate in that direction and then determined a distance to within 100 m of the nest site, using a threshold of 25 degrees for distance between points to eliminate the potential for overlap of the 5m circles at the random points (Brewer et al 2023).

We selected covariates based on previous research describing habitat types and metrics found in wetland ecosystems selected by King Rails (Darrah and Krementz 2009, Budd and Krementz 2011, Bolenbaugh et al 2012, Brewer et al 2023). At each random nest searching point, we measured water depth, vegetation communities, and percentage of live and senesced vegetation cover, vegetation density, and plant types (Darrah 2009). To measure vegetation density, we used a Robel pole (Robel 1970). Robel pole vegetation density measurements were taken from 5 m away and 1 m height to provide a standardized measure of the height and density of vegetation (Robel 1970). Coverage of the pole was measured as the pole being 0-24% obscured, 25% obscurity, 50% obscurity, 75% obscurity, and 100% obscurity (completely hid the pole). We measured water depth at the center point, and 5m away in each of the cardinal directions (Krementz et. al 2016). To measure the vegetation community and determine if vegetation type impacts nest site selection, we recorded the dominant cover type, and the top five plant species and the percentage of their composition within a 5 m radius of the central point. Cover types included scrub shrub, forest, open water, mudflat, and emergent vegetation over and under 1 meter in height.

Remotely sensed data

For the remotely sensed data, we collected landscape data using Dynamic World (Venter 2022) and Google Earth Engine (Gorelick et al 2017). Dynamic World is software used to visualize landscape changes and habitat types over time. Though Dynamic World data is coarser than our field data, it enabled us to calculate the amount of water and flooded vegetation on the landscape over the nesting season before nest initiation. We calculated "number of five-day periods with water", "areas/pixels with water", "number of five-day periods with flooded vegetation" and "area/pixels with flooded vegetation" to examine how those cover types could play a role in selection of nesting habitat at the larger landscape scale of available habitat on the management area (Jedlikowski 2016, Smith et al 2022). We were interested in a count of the total number of weeks that pixels at the points had sufficient flooded vegetation or water, incorporating only weeks prior to survey completion or nest. To do this, we counted the number of 5-day periods in which at least 50% of each pixel was covered in flooded vegetation or water.

Data Analysis

Nest Site Selection Analysis

To evaluate nest site selection, we compared vegetation data from the nest site to vegetation data from random points representing what was available to be selected. We defined available habitat as emergent wetlands within the boundary of the Choctaw West WMA units, and we excluded forested areas on the WMA because King Rails are known to avoid woody vegetation (Darrah and Krementz 2009).

To evaluate nest site selection of King Rails, we used a generalized linear model to explain the binomial relationship between used and available nesting habitat (Jedlikowski 2016, Fournier et al, 2021). The response variable of the model was nest site presence/absence. Before creating models, we checked for pairwise correlation between habitat covariates and excluded covariates with $\geq$ 0.6 Pearson correlation coefficients. Percentages of live vegetation and senesced vegetation were strongly correlated, so we removed the percentage of dead vegetation and modeled only the percentage of live vegetation. After determining the top models, we ran model averaging of the coefficients. Model averaging of coefficients was performed using habitat covariates of the top three candidate models, with the intention of capturing a variable's overall effect on the probability of nest site selection (Dormann et al 2018).

The global model includes every variable we considered in the model set. Our vegetation density model incorporates the amount of rush and other dense vegetation, which is positively associated with King Rails during the breeding season (Winter et al 2005, Darrah and Krementz 2009, Darrah and Krementz 2011, Brewer et al 2023). Rushes favor wet areas, and water can be useful in deterring predators for marsh birds (Schmidt et al 2023), so we included a model with mean depth as well as percent rush and average vegetation density to encompass these other habitat characteristics. Our community model compared the percentage of live vegetation and vegetation shorter than 1 m in height (Darrah and Krementz 2009), and the water model examined the amount of open water, water availability based on satellite imagery, and the average water depth at each point (Darrah and Krementz 2009, 2011; Clauser and McRae 2016). The vegetation model examines the percentage of rush, amount of vegetation less than 1 meter in height and the amount of flooded vegetation available to examine another layer of the importance of vegetation characteristics that could be important to King Rails (Darrah and Krementz 2009,2011; Bolenbaugh et al 2012, Glisson et al 2015). Our model of available habitat used Dynamic World to provide coarser landscape data with the amount of flooded vegetation and water cover over 5-day periods, so we also included a model with the weeks of available habitat (water and flooded vegetation) on a landscape scale.

All variables were scaled (subtracted mean and divided by standard deviation) prior to analysis. Our models were run using the *glm* function from the '*stats'* package in R (R Core Team 2013; R 4.3.1.). The descriptions of the covariates used is found in Table 1.

RESULTS

From April-July 2022 and 2023 we found 26 total nests (18 in 2022 and 8 in 2023). We found 7 nests from randomly generated survey points and walking transects (5 in 2022 and 2 in 2023). We found 3 nests searching for areas used by GPS-tagged birds (2 in 2022 and 1 in 2023). We found 16 nests by searching locations where we had seen or heard King Rails (11 in 2022, and 5 in 2023).

During our two field seasons, we completed 523 random habitat surveys throughout the WMA to measure habitat characteristics. To compare nest site habitat to the surrounding landscape habitat, we generated 5 random points within 100 m of each nest (n=156), resulting in a total of 679 habitat surveys.

We found nests in soft rush (*Juncus effusus),* common spikerush (*Eleocharis palustris),* square-stem spikerush *(Eleocharis quadralangulata),* tall flatsedge (*Cyperus eragrostis),* cattail (*Typha sp.),* and ovate false-fiddleleaf (*Hydrolea ovata).* When considering all the habitat available, the mean percentage of coverage by rush species at each survey point was 20.21%, and 31.68% at nest sites. The top two species of rush we found King Rails using at nest sites in Arkansas were *Eleocharis quadralangulata* (n=10) and *Juncus effusus* (n=4). Over the entire WMA, the average vegetation density was 75.2 cm, while at nest sites the mean average vegetation density was 86.6 cm. The average water depth at survey points across the WMA was 8.3cm, while at nest sites and related territories, the average depth was 5.0cm,

There were two top models explaining the differences between used versus available nesting habitat: the vegetation density model (year + average vegetation density + percentage of rush species) and the density and water depth model (year + average water depth + average vegetation density + percentage of rush species) (Table 2).

We found positive selection for Percent Rush at 95% CI, and the other covariates did not show selection different from 0 (Figure 4 and 5). To pick up on any weaker signals, we also ran the models with an 80% confidence interval. The only change was that there was positive selection for Average Vegetation Density as well.

While not significant, we also found weak negative selection for periods of flooded vegetation cover, water cover, average water depth and percent of emergent vegetation under 1 m in height.

DISCUSSION

In a drastically restored wetland, King Rails selected nest site locations with higher vegetation density and rush cover when compared to available habitat. We also found weak evidence for avoidance of deeper water. Our results corroborate other research on King Rail nest site habitat selection that show emergent vegetation and vegetation density are important (Pierluissi and King 2008, Darrah and Krementz 2009,2011; Bolenbaugh et al 2012, Kane et al 2023). One difference between our results and previous research is we did not find selection for water depth, while previous work did (Darrah and Krementz 2009, Glisson et al 2015, Krementz et al 2016).

Based on previous research and available literature, we predicted that water levels and vegetation density would be the strongest covariates for King Rail nest site selection (Meanley 1953, Pierluissi and King 2008, Darrah and Krementz 2009, Bolenbaugh et al 2012, Krementz et al 2016). We found average vegetation density was 11 cm higher at nests than across the WMA,which is similar to previous work that found a positive association between vegetation density and King Rails during the breeding season (Darrah and Krementz 2009,2011; Bolenbaugh et al 2012, Brewer et al 2023). Additionally, waterbird species richness and abundance increase with increasing emergent vegetation cover and plant diversity in wetlands; vegetation is the food-web base for the entire ecosystem (Ma 2010). For King Rails this may be because crayfish, which are a major part of a King Rails diet, rely on dense vegetation for habitat and food (Anderson and Smith 2000). Dense vegetation can improve the viability of invertebrate eggs or diapausing invertebrates, which increases invertebrate density, biomass, and diversity (Rehfisch 1994; Anderson and Smith 2000, Ma 2010).

We found King Rail nest sites used six different plant species at their nest sites. *Eleocharis quadralangulata* and *Juncus effusus* were most used, similar to what was found by Krementz et al (2016) in Oklahoma. Based on those results, we investigated if the percentage of rush species cover at each point to see if King Rails selected for those species at Choctaw West WMA. We found that rails selected for areas with 11.5% more rush cover than over habitat available on the WMA, with *Eleocharis quadralangulata* and *Juncus effusus* most selected for by King Rails and other rail species, rushes have been identified as an important aspect of nesting habitat because of their vertical structure for nest building and protective cover (Meanley 1953, Darrah and Krementz 2009, 2011; Pickens and King 2014). Intermediate marshes in Louisiana were defined as wetlands dominated by *Spartina patens*, *Phragmitesaustralis*, *Schoenoplectus* spp., *Typha* spp., and *Paspalum vaginatum*, a diversity of rushes and other plants that rely on shallow but varied depths of water (Pickens and King 2014).

Previous work has shown water level can help provide nests with protection from mammalian predators (Picman 1993, Schmidt et al 2023) and that water level had a positive effect on nesting season survival of two rail species, and that variable water levels increased individual nest survival and mean site nest survival (Robertson 2015, Jedlikowski 2016). We did not find water depth to be a contributor to King Rail nest site selection. We found that King Rails in Arkansas select for shallower water at nest sites, compared to other research showing King Rails with broods using shallow areas (Krementz et al 2016). Our lack of selection for water depth may be due to the drought conditions Choctaw West WMA experienced in 2023, and the limited variation in water level depths across the WMA in both years. Rallids such as the Purple Gallinule, Virginia Rail, Sora, Clapper Rail and King Rail have a preferential gradient of habitat with shallow water to almost dry ground, but each are adaptable, and their precise nest site and feeding location in relation to vegetation structure seems subject to variation in water regime, vegetation density, food availability, season, and perhaps local population traditions (Weller 1999). While studying nesting King Rails in Stuttgart, AR, Brooke Meanley described birds nesting on dry ground as well as in the flooded rice fields.

While periods with flooded vegetation and water cover were not significant to King Rail nest site selection, we found weak negative selection for flooded vegetation cover from available habitat on the WMA, and no selection at the nest site. The limited representation of flooded cover types in the data in the results may be attributed to limited data during the early part of the pre-breeding season (March to April) of dry season images due to the unavailability of images with minimal cloud coverage during the wet season (Gxokwe and Mazvimavi, 2023). Especially in the early, rainy parts of the season, image availability was reduced, which could have had more weeks with days of wetland habitat cover but we could not definitively say. After utilizing satellite imagery for this research, it could work well in future investigations to examine the effects of water and flooded vegetation cover in just the week before nest initiation, or how much area of the pixel was covered in water several months prior, around when birds are selecting nest sites.

Using more frequent satellite imagery instead of on a sub annual scale has the potential to estimate dynamism of wetland habitats over a spatiotemporal scale. This new tool could make it possible to measure wetland areas and available habitat throughout the season. This has been done before with ground-truthing and satellite imagery to describe habitat availability for wetland birds over a breeding season (Shealer and Alexander 2013, Blake-Bradshaw et al 2020). At such a fine resolution, Dynamic World can be used to visualize and describe differences across geography to explore species-habitat relationships in a changing ecosystem and begin to map those changes over time (Brown et al 2022). There is a necessity to further determine how flooded vegetation cover shows up on the satellite imagery and whether it will be represented by the classification of “grass” or “flooded vegetation” depending on how much interspersion there is and if the satellite is picking up water. Darrah and Krementz (2009) identified interspersion as a key characteristic of habitat selection by King Rails, so it could be an important distinction to learn.

With a small sample size of nests (n=26), our statistical power is limited, especially given the heterogeneity of habitat across our study site and the range of King Rails. Without examination of nest site selection characteristics, we did not consider if the nests are successful; future work would help inform King Rail management by looking at habitat impacts on nest success. Due to our small number of nests found, we did not estimate nest success, but in other states and habitats (rice fields), King Rails had an approximate 50% nest success rate, but ranged from 48% to 67% (Pierlussi and King 2008, Pierlussi et al 2010). Other King Rail research has identified the need to understand nest success, and across different states and habitats such as emergent wetlands, this has become increasingly important to learn (Darrah and Krementz 2011, Clauser and McRae 2016).

Wetlands have an incredible array of species biodiversity, presumably because of their diverse food resources and structural opportunities of cover for different species and different functions during individual life cycles (Weller 1999). Wetland management could identify either a single species or a cohort of species whose habitat overlaps with many other species. King Rails make a great potential umbrella species for Arkansas wetlands because of our results showing their need for dense, heterogenous habitat, and other studies that highlight the diverse and changing habitat that rails require throughout their life cycle and including diet (Meanley 1956, Darrah and Krementz 2009, Bolenbaugh et al 2012, Stermin et al 2013, Krementz et al 2016). The habitat they require and utilize supports a wide variety of other species, including specialized plants, invertebrates, amphibians, reptiles, and fish (Parsons et al 2002, Kalinkat et al 2017). These results support the concept of managing emergent wetlands for multiple species, or one species whose life history coincides with many others (Olson 2002). Choctaw West WMA is an example of the success that comes with managing emergent wetlands for rails. Other species are not excluded with the management techniques employed, and future research would help verify and explain the relationship between habitat management and the success of breeding King Rails.

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APPENDIX

Tables and Figures

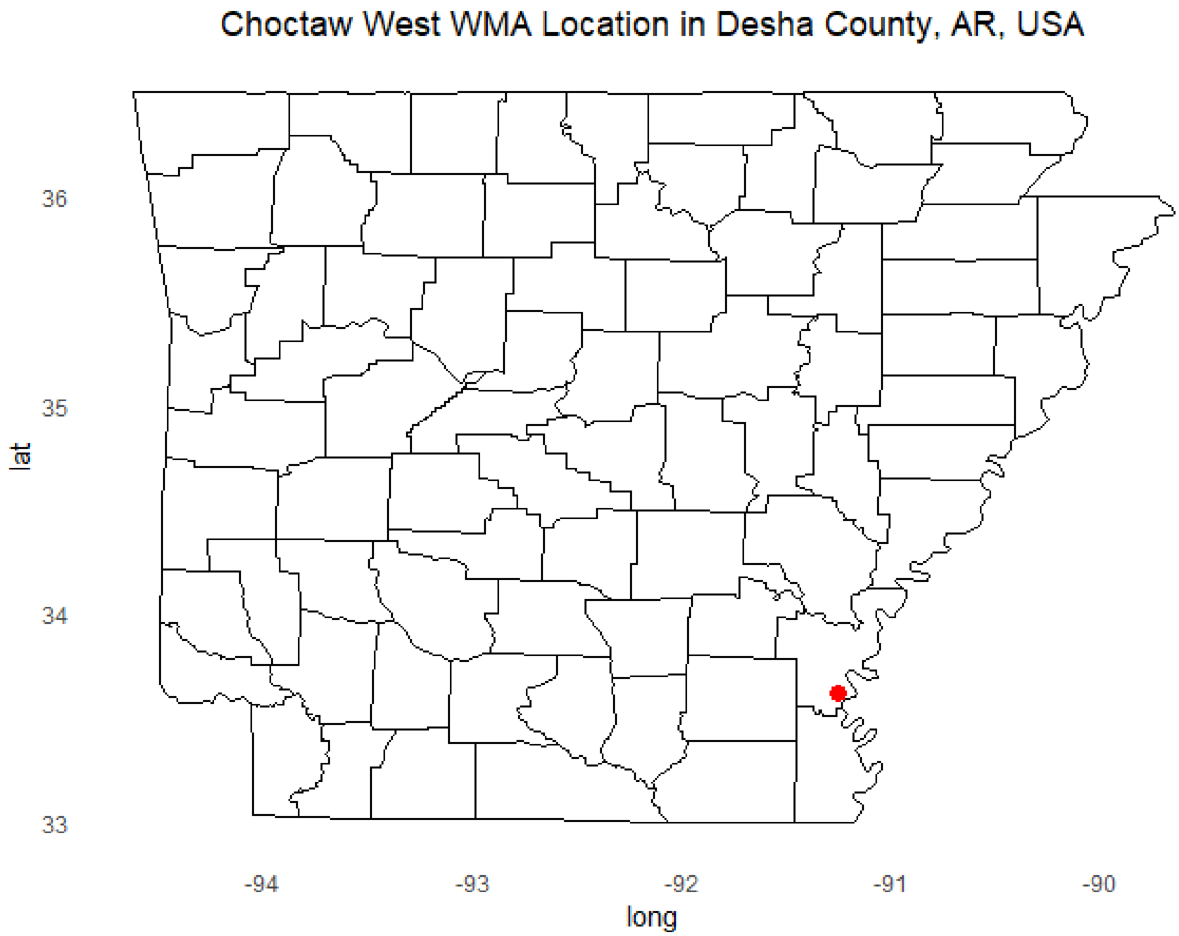

Figure 1**.** Map showing the location (red dot) of Choctaw West WMA in Desha County, AR, USA.

Table 1. Descriptions of the habitat covariates used in the model analysis of used versus available habitat.

		Available Habitat			**Nest Site**		
Covariate	**Description**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Percent emergent vegetation less than one meter in height	Percentage of vegetation in the survey area that was under 1 meter in height	0	100	35.99	0	100	43.62
Percent scrub shrub	Percentage of scrub shrub in the survey area	1	70	1.19	1	70	1.01
Percent forest	Percentage of forest in the survey area	0	100	0.67	0	100	1.62
Percent open water	Percentage of open water in the survey area	0	100	9.33	0	100	4.84
Percent mudflat	Percentage of mud flat or open bare ground in the survey area	0	75	2.23	0	20	0.28
Percent live vegetation	Percentage of live vegetation in the survey area	0	100	87.55	0	100	86.1
Percent rush	Percentage of plant species in the vegetation community classified as rushes	0	99	20.21	0	86	31.68
Total number of weeks with water coverage	Total number of weeks of water on the landscape covering 50% or more of the survey area	0	9	0.41	0	5	0.16
Total number of weeks with flooded vegetation	Total number of weeks of flooded vegetation on the landscape covering 50% or more of the survey area	0	6	1.38	0	4	1.4
Average water depths	Mean depth of water at each survey point, taken in the four cardinal directions and center	0	168.4	8.34	0	28.1	5.04
Average vegetation density	Average density taken from Robel measurements and averaged across four cardinal directions	5	200	75.23	7	200	86.6

Table 2. Table of AIC Values for measuring habitat models of King Rail nest site selection in a used versus available framework

	K	**Akaike Information Criterion (corrected)**	**Delta Akaike Information Criterion (corrected)**	**Akaike Information Criterion (corrected) Weight**
Nest Presence ~ Year + Average Vegetation Density + Percent Rush Species	4	172.55	0	0.61
Nest Presence ~ Year + Mean Water Depth + Average Vegetation Density + Percent Rush Species	5	173.64	1.09	0.35
Nest Presence ~ Year + Percentage of emergent vegetation less than 1 m in height + Percent Rush Species + Total number of 5-day weeks with flooded vegetation	5	179.16	6.61	0.02
Nest Presence ~ Year+ Percentage of emergent vegetation less than 1 m in height + Percent of open water + Percent Rush Species + Mean Water Depth + Average Vegetation Density+ Total number of 5-day weeks with flooded vegetation + Total number of 5-day weeks with water	9	179.65	7.1	0.02
Nest Presence ~ Year	2	213.38	40.83	0
Nest Presence ~ Year + Total number of 5-day weeks with flooded vegetation + Total number of 5-day weeks with water	4	214.02	41.47	0
Nest Presence ~ Year + Percentage of open water + Mean Water Depth + Total number of 5-day weeks with water	5	215.27	42.72	0
Nest Presence ~ 1 (null)	1	216.16	43.61	0
Nest Presence ~ Year + Percent live vegetation + Percentage of emergent vegetation less than 1 m in height	4	217.24	44.69	0

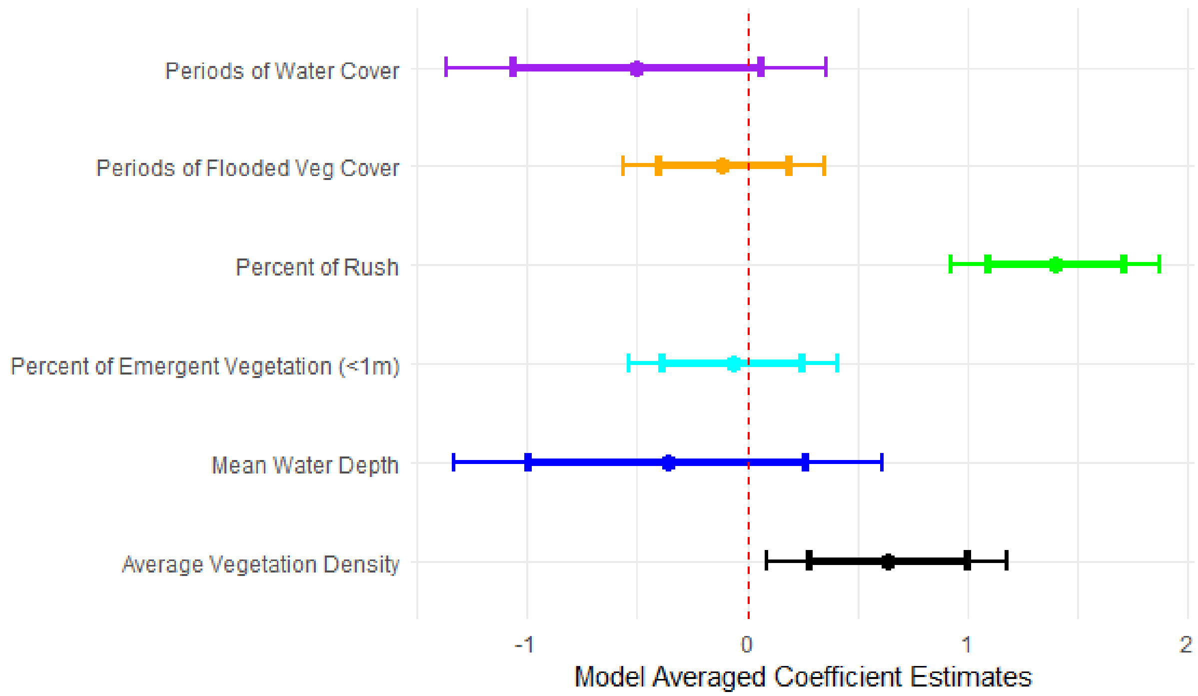

Figure 2. Model averaged coefficient estimates of habitat variables of available versus used habitat. The thin lines represent 95% confidence intervals, and the wide line represents 80% confidence intervals. .

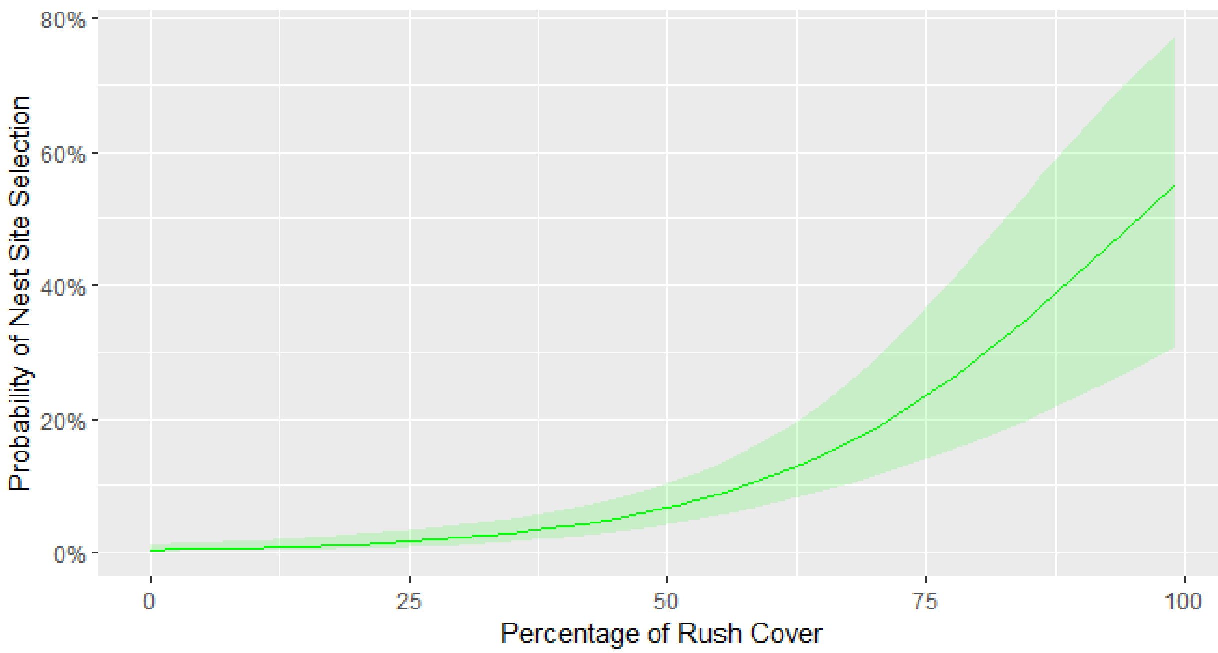

Figure 3. Marginal effects of the top model showing the relationship between probability of nest site selection and percent rush cover. Solid green line shows mean effect, and green ribbon shows 95% confidence intervals.

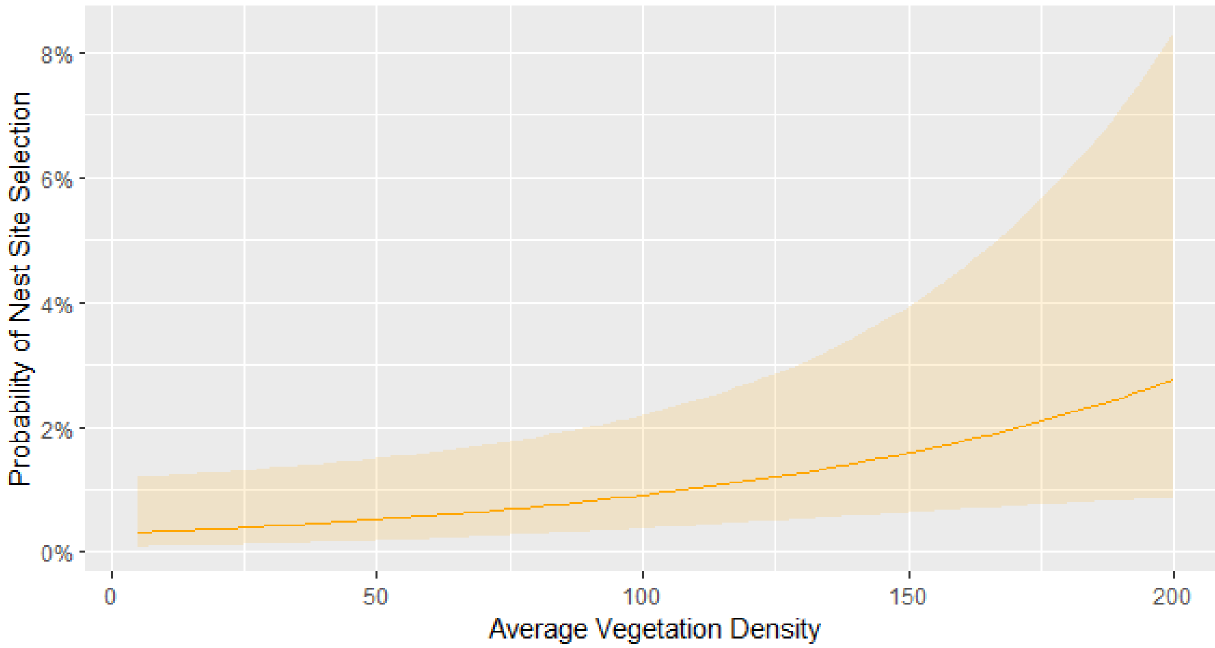

Figure 4. Marginal effects of the top model shows the relationship between probability of nest site selection and average vegetation density. Solid orange line shows mean effect, and the orange ribbon shows a 95% confidence interval.

CHAPTER 2: DESCRIBING THE MIGRATORY BEHAVIOR OF KING RAILS IN SOUTHEAST ARKANSAS

ABSTRACT

King Rails (*Rallus elegans*), a declining species of secretive marsh bird species throughout its range, have a mixed migratory strategy, with some individuals and populations being predominately migratory and some being mixed resident and migratory. Determining the migratory status of King Rails (residents vs migrants) is critical to guiding management decisions: should conservation areas be managed for birds year-round, or will targeted seasonal management suffice? Here, we examined the movement strategies of birds at Choctaw West WMA in southeastern Arkansas, a known breeding location with multiple pairs of birds. In order to learn their movement and assess migration status, we captured and outfitted 23 birds with Argos GPS tags to track migration patterns throughout the season. We found that 21 birds did not make long distance migrations and are residents year-round, and only two birds made long-distance movements to Louisiana. We examined monthly movements on the landscape to describe how their movement changed seasonally. As a vulnerable and threatened species both in Arkansas and the US, understanding their habitat needs and use throughout the year could have implications for biologists and land managers to provide more suitable habitat annually life cycle.

INTRODUCTION

The decision to migrate or not is critically important for survival and reproduction in many bird species (Webster and Marra 2005, Hedenström 2008, Newton 2023). Avian migration can take several forms including facultative or obligate migration, migratory timing driven by day length changes, or by weather, long or short-distance movements, and species where some individuals migrate, and some do not (Pulido et al 1996, Pulido and Berthold 2010, Newton 2012). Migration is risky and energetically expensive, resulting in some individuals and some species not migrating at all and instead remaining residents (Hedenström 2008). Movement strategies can be adjusted to habitat availability and quality, resulting in different strategies among individuals or populations using different migration routes and wintering areas (van Bemmelen et al 2019).

Some species of birds have individuals that do migrate and have different routes among different populations and some that don't migrate. For example, several rail species exhibit split migration strategies in different populations, including King Rails *(Rallus elegans)* (Perkins 2007, Bolenbaugh et al 2012, Kolts and McRae 2017, Kane et al 2019, Pickens and Meanley 2020) and Black Rails (*Laterallus jamaicensis*) (McGowan et al 2020). Different movement strategies are also employed by the same species in different populations, including Burrowing Owls (*Athene cunicularia*) (Korfanta et al 2005) and Blackcaps (*Sylvia atricapilla)* (Pulido and Berthold 2010). It is important to examine how environmental factors or geographical barriers can cause such varied behavior in populations of the same species, such as the different migration routes used by Red-necked Phalaropes (*Phalaropus lobatus)* (van Bemmelen et al 2019). These differences demonstrate the variability in how individuals make migratory decisions. It is important to investigate different strategies between migrating and resident birds because the existence of resident birds is indicative of suitable breeding habitat that meets the species' needs year-round (Kolts and McRae 2017).

The finer details of King Rail migration and movement are not well known and present a knowledge gap in understanding their behavior and consequently conservation needs (Pickens and Meanley 2020). In addition to knowing their migratory behavior and habitat locations they use, it is also important to explore their whole range during the winter and migration periods (Webster et al 2002) to identify what habitats are required, and what threats a species faces throughout the annual cycle. The first work on King Rail migration using Global Positioning System (GPS) transmitters was done by Kane et. al (2019) who investigated migratory timing in midwestern King Rails, showing when and where birds migrated, and they found King Rails made quick (<7 days) migrations from Ohio to their wintering grounds along the Gulf of Mexico coast with limited stopover events (Kane et al. 2019). The quick migrations could be attributed to lack of high-quality habitat at stopover locations in between wintering and breeding grounds, which could also influence movement patterns in birds (van Bemmelen 2019).

The severe population declines of King Rails highlight the need for conservation action and also the need for better information to inform those actions. Since King Rails are secretive and rare, starting to study them at a site where they are currently relatively abundant and successfully breeding can help inform future work and conservation actions at other sites. King Rails are known to have individuals that migrate and some that are fully resident, and understanding this split strategy in the population is important for informing the impacts of conservation actions on different parts of the population. It is crucial to determine migration status to sustain species at risk (Kolts and McRae 2017). While once a common breeding bird in the rice belt of Arkansas (Meanley 1953), King Rails are listed as a priority species in Arkansas, which identifies nongame species with the greatest need for protection and management (Arkansas Game and Fish Commission 2022). Currently there is only one known property in the state with multiple breeding pairs of King Rails, Freddy Black Choctaw West Wildlife Management Area (WMA), and the role this WMA plays in the distribution and abundance of the species in the state and region is unknown (Budd and Krementz 2011; Budd and Rowe 2013; Krementz 2017).

Currently we know there is a population of resident (non-migratory) King Rails along the Gulf of Mexico Coast (Perkins et al 2009) but it is not known how far north the ranges of resident King Rails extends. We assume King Rails who spend the breeding season in the Midwest migrate south in the fall and then overlap with full time resident birds on the Gulf Coast during the winter (Cooper 2008; Pickens and Meanley 2020, Kane et al. 2019). By determining King Rail migratory or non-migratory behavior at Choctaw West WMA, we can begin to understand how the King Rail population fits in with other populations across their range. To order to inform habitat restoration and management for King Rails in Arkansas, we need to understand if most individual King Rails are resident, like they are in the Gulf of Mexico States, or migratory, like they are in the Midwest states (Cooper 2008, Kane et al 2019, Pickens and Meanley 2020).

Our objective was to characterize average daily King Rail movement distances, with the aim of determining whether King Rails at Choctaw West WMA migrate or are year-round residents (Arkansas Game and Fish Commission 2022). We expected King Rails utilizing the WMA to do one of two things: migrate outside of Choctaw West after spending the winter there, or remain as a resident year-round.

METHODS

Capture

To capture birds, we used walk-in traps with an audio lure (modified from Shirkey 2017), lasso mats (Harrity and Conway 2020), and with a taxidermy Clapper Rail decoy and audio lure. To determine trapping locations, we played calls, solicited responses, and noted them with the GPS. We also used locations identified by WMA staff during standardized marsh bird surveys (Conway 2011). The audio lure was a FoxPro game caller attached to an Mp3 player within a dry bag. The MP3 players were pre-programmed with regional King Rail calls (Paul Driver, Dan Lane, Nathan Pieplow, J.R. Rigby, Andrew Spencer, Todd Wilson [XenoCanto Recordings]) and also calls recorded from local birds at Choctaw West WMA. We created call sequences of different types of calls, including territorial, breeding, and contact calls. Using a variety of calls helped eliminate any bias from using calls that would only elicit a response from males or female birds. We selected regional calls because rail dialect is suspected to vary by region (Schroder and McRae 2019). In 2022, traps were run from evening to dawn and calls were played throughout the night; we also ran traps later into the morning if we had pairs vocalizing nearby to try to attract them. In 2022, walk-in traps were checked as early as possible every morning and lasso mats were used opportunistically to capture actively calling birds. In 2023, traps were not run overnight but instead for 2.5 to three hours from predawn to mid-morning (6 am to 8:30 am in the early spring). In both seasons, we moved the traps after a successful capture to another location at least 200 m away to avoid recapturing the same bird in their territory. We ran traps for King Rails from March 21-April 29th, 2022. During 2023, traps were run during the breeding season from March 20th to April 28th, and then captured birds in the summer from June 26th to September 10th.

Banding

After capturing birds, we banded them with a United States Geological Survey (USGS) aluminum leg band. We weighed each bird and took morphometric measurements including tarsus, wing chord, culmen (bill length), total head, tail, body fat score, and brood patch.

All capture and handling procedures were approved through IACUC at University of Illinois Urbana Champaign (IACUC Protocol No. 19083) and under Federal Banding Permit #23923.

Transmitters

If rails weighed 300 g or more and were in good condition based on fat score and visual assessments, we equipped them with a 3.5-g Lotek Argos PTT satellite transmitter (Lotek Argos). Transmitters were attached using a modified Rappole-Tipton leg-loop harness (Haramis & Kearns 2000; Woolnough et al. 2003; Fair et al. 2010), and 0.7-mm diameter stretch magic cord and 2-mm Tygon tubes to build the harnesses (Stretch Magic Inc., Sonoma, California).

We expected birds captured at different time periods to be parts of different populations (residents or migrants). We expected birds captured in early March to be migrants moving through the region, and the birds captured later in the season (April onwards) to be classified as residents. These transmitters collected location data on a user-defined schedule and transferred data to an online server via the Argos satellite network, thus allowing remote access to location data (Harrity and Conway 2020; Scarpignato et. al 2021). For the birds captured in early March, we programmed transmitters to take data locations every 3 days for six weeks, then every 15 days for 4 months, every three days during the fall migration period (3 months), every 15 days for four months during the early winter, then back to recording points every 3 days in the spring of the following year to extend battery life and cover an annual cycle. For the birds captured in

April or May, we used a set fix schedules to collect location data every three days (starting on the capture date) for three months during the breeding season, then once a week for three months into the fall, every 15 days for three winter months into the following year, and then once a week from early spring to the fall (about 6 months).

For analysis purposes, we defined March, April and May as spring (Pickens and King 2013), June through August as summer, and September through November being fall, and December through February as winter.

From the migration data we receive from the tagged birds, we classified points based on time of year and the context of the consecutive points, we can also determine when birds are most active (local movements at Choctaw West). We looked at distances travelled during each period of their annual cycle to identify how far birds move seasonally and how that may change among seasons. We defined local movements as the bird remaining within the property boundaries of Choctaw West WMA, as well as any locations within a 20 km distance. We consider the movement a dispersal if the bird stayed at that particular location more than 20km from Choctaw West for longer than 14 days. We consider it a migration if the bird goes 30 km distance for over 30 days.

Analysis

We examined patterns in seasonal movement of King Rails on the WMA and to other sites in southeastern Arkansas. To compare movement patterns, we calculated average kilometers travelled/day per bird in R Version 4.3.1 (R Core Team 2023). To do this, we averaged the distance travelled in a month by dividing the total distance between GPS locations within a month over the number of days in that month for each individual bird . Using average distance traveled in a given month accounts for different numbers of fixes during each month since the tags had varying schedules across months.

RESULTS

We tagged 8 birds in 2022 and 15 birds in 2023. In 2022, of 8 satellite transmitters deployed on King Rails, four transmitters were still sending back fixes through the fall migration. In 2023, of the 15 transmitters deployed, 7 were still transmitting fixes through fall migration, and one of those tags stayed active into 2024 (as seen in Table 1). Only two birds made long-distance fall migrations. The migrating bird in 2022 left Choctaw West WMA on or around August 29th to go to a private flooded rice field 18 kilometers west of the WMA. It stayed there until October 10th, returned to Choctaw by the 31st of October, and then migrated to northern Louisiana to Delhi on November 7th (approximately 32.451, -91.502). Delhi is approximately 145 kilometers south of Choctaw and follows along the Bayou Bartholomew. According to Google Earth images (Google Earth 2022), the bird was using a small wetland near the town. The long-distance migrant in 2023 travelled across several units over the course of the summer. It migrated to Atchafalaya National Wildlife Refuge (approximately 29.558, -91.219) in southern Louisiana between June 28th and July 8th.

Excluding the one long distance migrant, tagged King Rails in 2022 largely stayed within the confines of Choctaw West WMA. Three King Rails in 2023 made movements on and off Choctaw West during the spring and summer (Figure 3). Often these movements were such that they spent several days off the WMA before returning.

Birds in 2022 travelled less per month than did birds in 2023 (Table 2). The only month that birds in 2022 travelled more in was March, moving 95.54 m monthly versus 76.77 m monthly by birds in 2023.

In addition to the movement data collected from tagged birds, we also successfully recaptured three banded birds from 2022 during the 2023 season. One female was captured in

Unit 2 both years, at trap sites approximately 15 m apart. Another banded bird was captured in 2022 in Unit 3 and recaptured about 300 m away in Unit 2 in 2023. A third individual was tagged in 2022, and recaptured in 2023 without the tag, the bird was then given a second tag, and it continues to spend time in the same unit of the WMA that it has since 2022.

DISCUSSION

Of the 23 tagged King Rails in our study, the vast majority were year-round residents, as 21 birds remained at Choctaw year-round, and only two birds migrated southward in the fall. The departure dates of the migratory individuals occurred in different parts of the annual cycle, with one bird migrating in the fall, and the other leaving Choctaw West at the end of the spring breeding season. Most resident birds remained on the conservation area in 2022, while in 2023 more individuals made local movements off the WMA and around southeastern Arkansas, mostly to agricultural fields.

We also observed differences in distance traveled by the resident King Rails between each year and overall in monthly distances travelled. We found King Rails at Choctaw West moved further distances in the late summer (June through August) compared with early spring (April through May). These seasonal changes may reflect different life stage needs of nesting, brood rearing for the adults and foraging with broods. Adults will need to travel further distances to obtain the necessary resources for young, including finding food and appropriate protection from predators (Darrah and Krementz 2011, Krementz et al 2016, Kolts and McRae 2017). Using stable isotope analysis, Perkins (2007) found that around 99% of individuals sampled in Texas and Louisiana during the winter months were residents, which corroborates with what we found with the resident population of King Rails at Choctaw West compared to the number of tagged birds that migrated. On the Atlantic Coast, Kolts and McRae (2017) used data from radio-tagged individuals during both the breeding and nonbreeding seasons to support that at least a small segment of the population of King Rails at their study sites were residents.

Our research raises the question of whether the resident and migrant King Rails in southeastern Arkansas are part of different populations or reflect the role that individual birds play in the same population. To understand the migratory and resident population of King Rails across their range, tagging or banding individuals across a wider geography would be informative. For resident King Rails, more research is needed to assess local seasonal movements and how habitat can best be managed for breeding and non-breeding needs in Arkansas. Longer-term tracking of individuals would help inform the impact of climate factors (drought, rain, temperature) on movement decisions. In addition, tagging of juveniles and tracking them across years would help inform whether the resident or migratory behavior of a juvenile matches its parents, or if they might make a different decision.

This study contributes to a base of knowledge about King Rail movement throughout the breeding season, and highlights more knowledge gaps, such as how environmental factors could influence bird movement and habitat use in a dynamic ecosystem. It also builds on previous studies of King Rail migration and movement and begins to uncover the veil of what different populations of King Rails do throughout the Mississippi Flyway.

By tracking the movements of King Rails in southeastern Arkansas, we have shown the amount of variation among individuals and among years in local movements for birds using Choctaw West. These results could be used to assess the impacts of land management decisions on populations and individuals in southeastern Arkansas which, based on our work, is on the edge of the resident vs migratory range. Whether the birds at a given property are mostly migratory or resident has implications for assessing how habitat management will impact them, since the timing of management has different impacts for migratory species, than for resident birds using the habitat year-round. While King Rails are not a game species in Arkansas, they are in Louisiana, and understanding that some King Rails that use Choctaw West migrate to Louisiana means that potential for harvest needs to be included when considering population dynamics and conservative actions. Despite increases in populations of waterfowl, waterbirds are in decline, and it is apparent that understanding bird movement and habitat use is critical to understanding their needs (Rosenberg 2019).

Our results come from a small sample size of tagged individuals, and need to be interpreted with care, especially given the large difference in environmental conditions the birds experienced between the two years. A drought in 2023 produced very dry conditions, which could have influenced individual King Rail movements. Kane et al (2019) suggested that sex may be an important factor in migration based on their tagged birds. Body condition may also play a role in a bird's decision to migrate or remain as a resident to take advantage of resources (Anderson et al 2019).

Given our study site is the only known location with multiple breeding pairs of King Rails in Arkansas, our results suggest that the population of King Rails in southeast Arkansas is mostly residential, which helps us inform management to best provide year-round habitat for rails. Wetland complexes can support a wide suite of wetland dependent wildlife and can provide critical connections to regional breeding areas (Haig et al 1998), or in the case of Choctaw West, provide year-round, critical habitat in a highly modified landscape that may not be suitable to wetlands species. Within the state and region, Choctaw West represents important breeding habitat (Krementz 2017), and our work shows it is also critical wintering habitat for resident King Rails as well. Knowing the movement patterns of this unique population of inland rails will address management and conservation concerns and provide critical information on how best to protect this threatened species and the habitat they utilize. Considering this residential population of King Rails requires considering year-round wetland management for appropriate habitat. Further research to understand management focused on increasing brood survival rates, as well as nesting habitat, is crucial for recovering the inland breeding King Rail population (Krementz et al 2016).

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APPENDIX

Tables and Figures

Table 1. Schedule showing first and last transmission from the transmitter, as well as total number of fixes, for each tagged bird.

Transmitter ID	First Transmission	Last Transmission	Number of Fixes
229440	2022-03-23	2022-10-22	27
229441	2023-07-28	2023-08-11	6
229442	2022-04-28	2022-11-7	36
229443	2022-04-27	2022-05-06	4
229444	2023-07-25	2023-09-15	16
229445	2022-04-04	2022-12-16	53
229446	2023-06-30	2023-10-31	18
229447	2022-04-25	2022-04-28	2
229449	2022-05-11	2022-05-26	4
229450	2022-03-26	2022-09-13	22
238180	2023-03-29	2023-06-30	18
238181	2023-03-23	2023-05-16	14
238182	2023-03-23	2023-05-31	18
238183	2023-03-31	2023-04-11	6
238184	2023-03-22	2023-04-30	14
238185	2023-04-05	2023-04-22	8
238186	2023-04-28	2023-07-15	12
238187	2023-04-02	2023-08-12	28
238188	2023-03-23	2023-05-25	20
238189	2023-04-13	2023-06-08	19
238190	2023-04-11	2023-08-05	30
238191	2023-04-06	2023-08-05	32

Table 2. Monthly average, minimum and maximum distances travelled by tagged King Rails in the 2022 and 2023 field seasons.

Year	Month	Minimum Distance	Maximum Distance	Average Distance	Standard Deviation
2022	March	44.13	123.6	95.54	44.59
2022	April	8.5	367.21	94.6	90.77
2022	May	13.42	377.4	198.31	123.55
2022	June	13.42	894.5	304.74	222.74
2022	July	21.93	917.5	504.1	357.49
2022	August	77.2	16754.1	2346.03	5415.25
2022	September	88.97	16781.9	3540.02	6821.99
2022	October	88.03	16861.24	3256.89	6375.35
2022	November	204.95	131357.41	105121.41	58650.1
2023	March	3.3	193.53	76.8	52.71
2023	April	2.13	24450.83	509.68	2339.27
2023	May	33.38	10845.84	1446.17	2761.76
2023	June	596.51	25911.3	3399.01	6804.16
2023	July	47.55	450966.86	39544.56	129712.29
2023	August	40.7	451043.12	15260.1	82306.97
2023	September	60.7	310.95	165.6	72.17
2023	October	3.64	239.64	160.94	89.99

Figure 1. Average daily distance travelled by all birds per year.

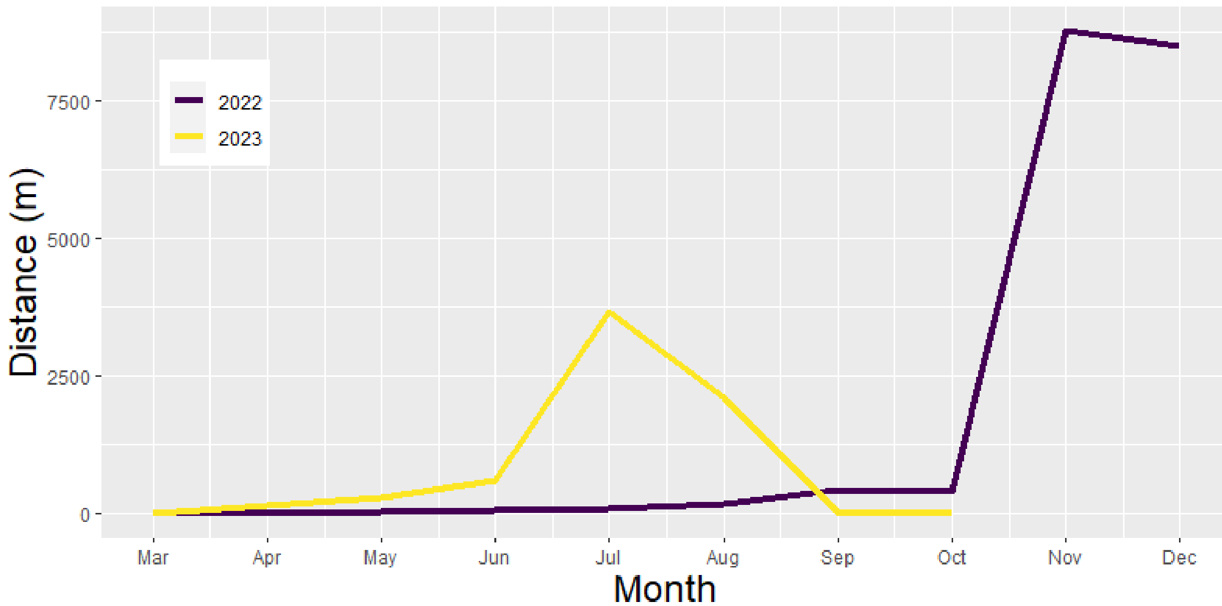


Figure 2. Average daily movement across all individuals. Six-digit numbers indicate tag identifier for each bird. Note: the y-axis scale for each bird is different.

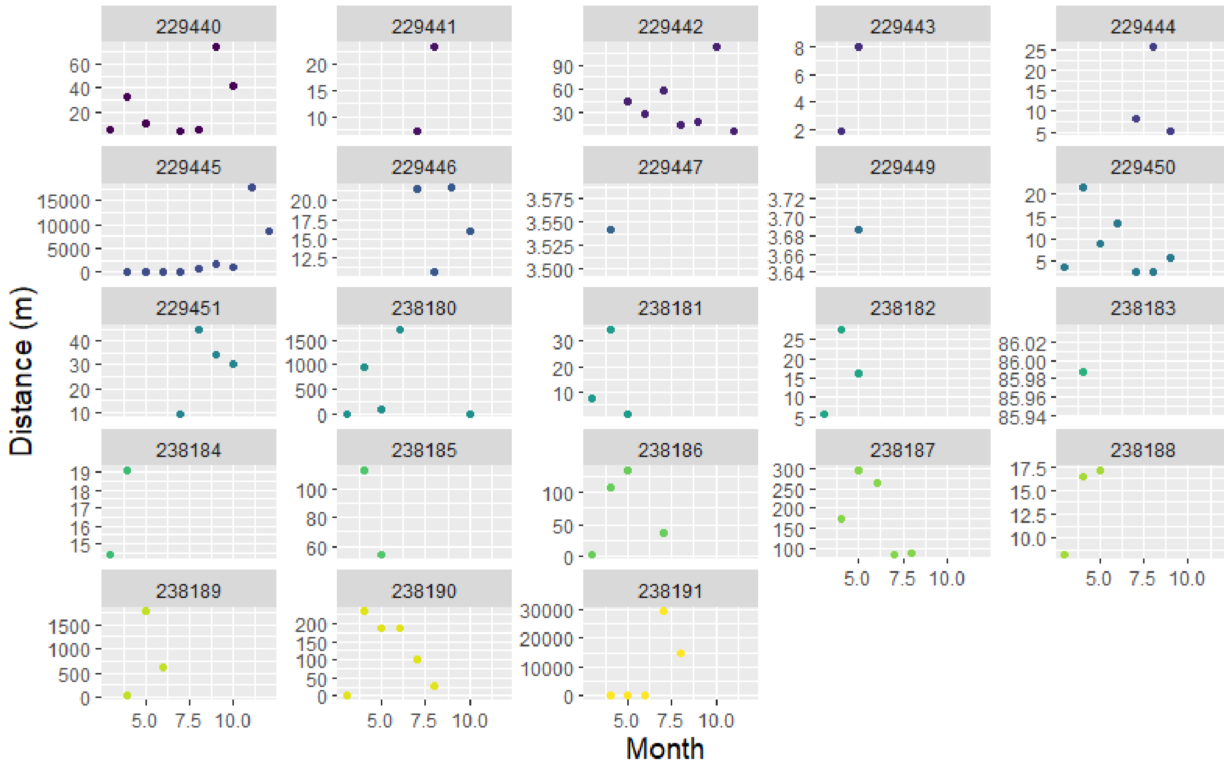
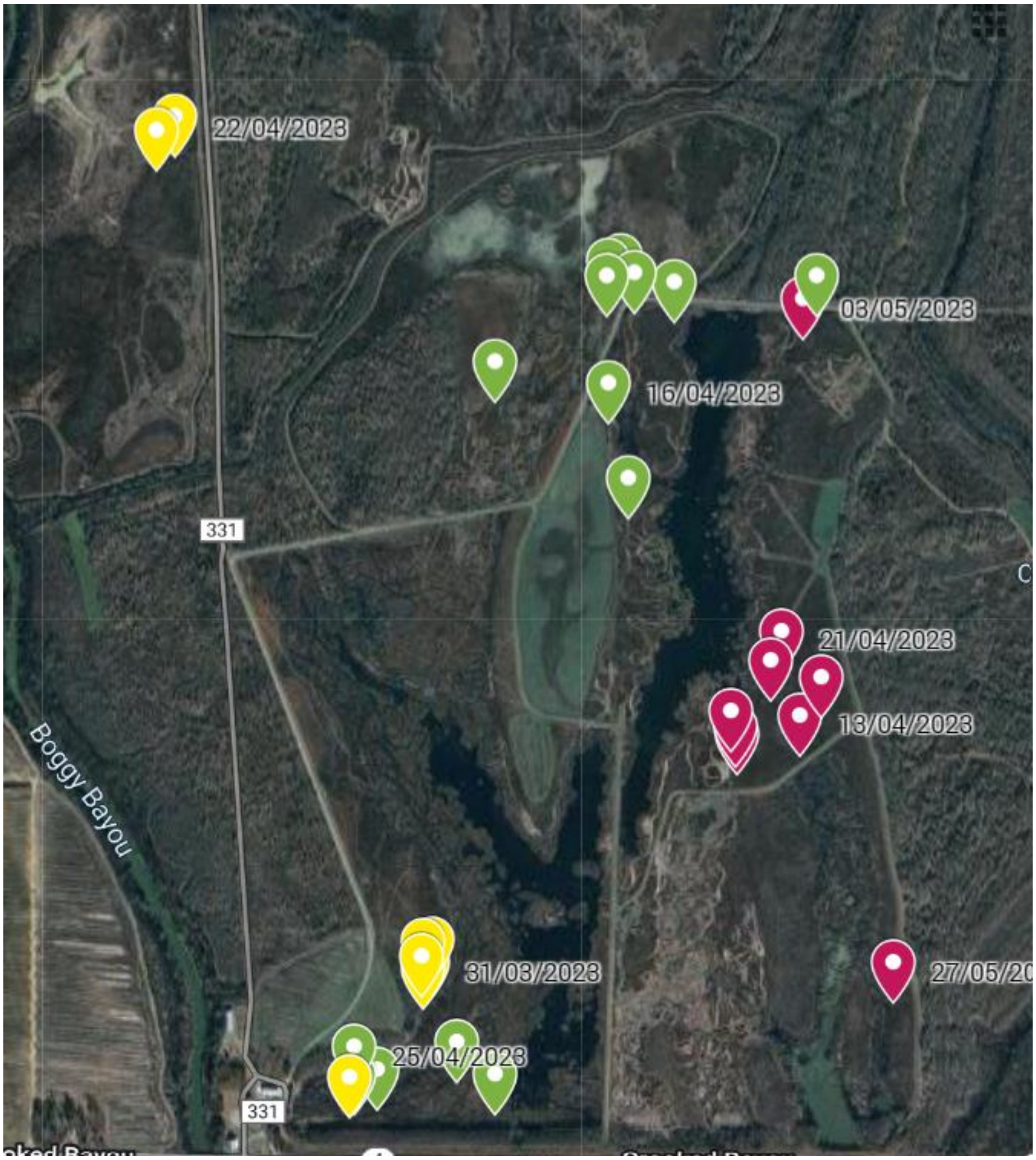


Figure 3. Map of movements at Choctaw West WMA of the dispersed birds that later left Choctaw West. At the WMA, they travelled to different wetland units over time and made different movements.



CONCLUSION

From the first chapter of my thesis and the research component, we learned that King Rails selected nest site locations with higher vegetation density and rush cover when compared to available habitat found across the WMA. We also found weak evidence for avoidance of deeper water. Our results corroborated with research on nest site habitat selection that show emergent vegetation and vegetation density are important to King Rails (Pierluissi and King 2008, Darrah and Krementz 2009,2011; Bolenbaugh et al 2012, Kane et al 2023). One major difference between our results and previous research is that we did not find positive selection for water depth, while previous work did (Darrah and Krementz 2009, Glisson et al 2015, Krementz et al 2016).

We found King Rails used six different plant species at their nest sites, with *Eleocharis quadralangulata* and *Juncus effusus* most used, similar to what was found by Krementz et al (2016) in Oklahoma. Rushes have been identified as an important aspect of nesting habitat because of their vertical structure for nest building and protective cover (Meanley 1953, Darrah and Krementz 2009, 2011; Pickens and King 2014). We did not consider the impacts of nest site selection on nesting success, but future work would help inform King Rail management by looking at habitat impacts on nest success. Other King Rail research has identified the need to understand nest success, and across different states and habitats such as emergent wetlands, this has become increasingly important to learn (Darrah and Krementz 2011, Clauser and McRae 2016).

For the second chapter of my thesis, we determined that King Rails at Choctaw West WMA are mostly residential, which has implications for management. Of the 23 tagged King Rails in our study, only two birds migrated southward in the fall. The departure dates of the migratory individuals occurred in different parts of the annual cycle, with one bird migrating in the fall, and the other leaving Choctaw West at the end of the spring breeding season. Most resident birds remained on the conservation area in 2022, while in 2023 more individuals made local movements off the WMA and around southeastern Arkansas, mostly to agricultural fields.

Our research raises the question of whether the resident and migrant King Rails at Choctaw West WMA are part of different populations or reflect the role that individual birds play in the same population. For resident King Rails, more work is needed to assess local seasonal movements and how habitat needs to be managed for breeding and non-breeding needs in Arkansas. Longer-term tracking of individuals would help inform the impact of climate factors (drought, rain, temperature) on movement decisions. In addition, tagging of juveniles and tracking them across years would help inform whether the resident or migratory behavior of a juvenile matches its parents, or if they might make a different decision.

Our results suggest that the population of King Rails in southeast Arkansas is mostly residential, which helps us inform management to best provide year-round habitat for rails. Wetland complexes can support a wide suite of wetland dependent wildlife and can provide critical connections to regional breeding areas (Haig et al 1998), or in the case of Choctaw West, provide year-round, critical habitat in a highly modified landscape that may not be suitable to wetlands species. Within the state and region, Choctaw West represents important breeding habitat (Krementz 2017), and our work shows it is also critical wintering habitat for resident King Rails as well. Knowing the movement patterns of this unique population of inland rails will address management and conservation concerns and provide critical information on how best to protect this threatened species and the habitat they utilize. This residential population of King Rails requires consideration for year-round wetland management for appropriate habitat. Further research to understand management focused on increasing brood survival rates, as well as nesting habitat, is crucial for recovering the inland breeding King Rail population (Krementz et al 2016).

Wetlands have an incredible array of species biodiversity, presumably because of their diverse food resources and structural opportunities of cover for different species and different functions during individual life cycles (Weller 1999). Wetland management could focus on either a single species or a cohort of species whose habitat overlaps with many other species. King Rails make a great potential umbrella species for Arkansas wetlands because of our results showing their need for dense, heterogenous habitat, and other studies that highlight the diverse and changing habitat that rails require throughout their life cycle and including diet (Meanley 1956, Darrah and Krementz 2009, Bolenbaugh et al 2012, Stermin et al 2013, Krementz et al 2016). The habitat they require and utilize supports a wide variety of other species, including specialized plants, invertebrates, amphibians, reptiles, and fish (Parsons et al 2002, Kalinkat et al 2017). These results support the concept of managing emergent wetlands for multiple species, or one species whose life history coincides with many others (Olson 2002). Choctaw West WMA is an example of the success that comes with managing emergent wetlands for rails. Other species are not excluded with the management techniques employed, and future research would help verify and explain the relationship between habitat management and the success of breeding King Rails.

A significant component of both of my thesis chapters is the need of heterogenous habitat for King Rails during their annual cycle for adults, and also during the breeding season. My research has compounded with other research to underline the impact that high quality habitat has on both King Rail breeding biology and their movement patterns, and the continued importance of understanding species-habitat relationships and how crucial it is to appropriately manage these habitats.

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