1-2017

Phenology, Habitat Use, and the Impacts of Wetland Management on Autumn Migrating Rails in Missouri

Auriel M.V. Fournier
University of Arkansas, Fayetteville

Recommended Citation

Fournier, Auriel M.V., "Phenology, Habitat Use, and the Impacts of Wetland Management on Autumn Migrating Rails in Missouri" (2017). *Theses and Dissertations*. 1932.
http://scholarworks.uark.edu/etd/1932

Phenology, Habitat Use, and the Impacts of Wetland Management on Autumn Migrating Rails in Missouri

A dissertation in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in Biology

by

Auriel Maria VanDerLaar Fournier
Michigan Technological University
Bachelor of Science in Wildlife Ecology and Management, 2011

May 2017
University of Arkansas

This dissertation is approved for recommendation to the Graduate Council

Dr. David G. Krementz
Dissertation Director

Dr. Daniel D. Magoulick
Committee Member

Dr. Fred M. Stephen
Committee Member

Dr. John David Willson
Committee Member

ABSTRACT

Rails (Family: Rallidae) are among the least studied birds in North America, in large part due to their elusive nature. As a wetland-dependent species, understanding the timing of their migration and their habitat needs during migration is especially important since management needs to be timed to balance the needs of many species. I developed and verified a new distance sampling-based nocturnal ATV spotlight survey because traditional call-broadcast surveys are not effective during autumn migration because of the drop off in call rate after the breeding season. These surveys allow us to ask point-level questions about what habitats rails select during migration and how it changes over time. Through these standardized surveys from 2012-2016 across 11 public properties in Missouri, USA, I documented the migratory timing and habitat use of migratory rails. Sora (*Porzana carolina*) have a wide migratory window, beginning in early August and continuing through the end of October with a peak in late September. Virginia Rail (*Rallus limicola*) and Yellow Rails (*Coturnicops noveboracensis*) have shorter migratory periods, from late September through the end of October. Rails, especially Sora, migrate earlier than waterfowl, which can create a mismatch of habitat needs. We performed a 3 year experiment to examine the response of Sora and waterfowl to early autumn wetland flooding. Sora responded positively without a negative impact on waterfowl. I used monitoring data to create species distribution models to inform estimates of migratory connectivity for all three species using stable hydrogen isotopes. Sora and Yellow Rails were estimated to migrate generally north-south, with Virginia Rails coming from a wider east-west range. Through better understanding the migratory connectivity, timing and habitat use of rails in the autumn I provide a foundation to inform conservation and management of these fascinating and elusive birds. We provide a description of all variables used (Appendix II), GPS data of survey tracks and detection

points (Appendix III), data sets of bird observation points, survey data, and vegetation information (Appendix IV), data sets of stable hydrogen isotope data (Appendix V), data sets of species distribution models (Appendix VI).

DEDICATION

To my dad, Jim Van Der Laar, who told me how he liked to brag to his friends about his "outdoorsy scientist daughter" (even when she tried to prove him wrong) and let me play in the dirt as much as I wanted. This one's for you Dad.

To my Opa, John Van Der Laar, a giant among men, who taught me to love the outdoors, that everyone had value, and to fight for the things I loved. This is one step towards trying to fill your giant shoes.

ACKNOWLEDGMENTS

Thanks to my advisor, Dr. David G. Krementz, for constantly challenging me and helping me become a better scientist. To my committee, Dr. Dan Magoulick, Dr. J.D. Willson and Dr. Fred Stephens, for supporting me in every step.

To the Missouri Department of Conservation and U.S. Fish and Wildlife staff including Kenny Ackley, Cody Alger, Ron Bell, Alicia Burke, Matt Bowyer, Kevin Brunke, Gary Calvert, Candy Chambers, Keith Cordell, Craig Crisler, Chris Freeman, Mike Flaspohler, Ryan Kelly, Lindsey Landowski, Josh Hager, Mick Hanan, Marty Marks, Frank Nelson, Brad Pendley, Darrin Welchert, Steve Whitson, and Jason Wilson for their help planning logistics. You have all inspired me with your love for your work and the wetlands you care for. Thank you for sharing your knowledge and expertise with me, I am forever grateful.

Special thanks to Doreen Mengel who put in so much time and effort into making my field work possible and was so invested in helping guide it so that our results would have on the ground value. You are a huge reason this project was a success.

Thanks to the Arkansas Audubon Society Trust, Garden Club of American, U.S. Fish and Wildlife Service, Missouri Department of Conservation, University of Arkansas, Department of Biological Sciences and Arkansas Cooperative Fish and Wildlife Research Unit for funding my research and myself.

My thanks to the members of the Arkansas Cooperative Fish and Wildlife Research Unit for their camaraderie, patience and assistance. Special thanks to Diane Moler, for saving my butt more times than I can possibly recount. Thanks to my labmates (and their wonderful spouses), Chris Reddin, Eliese Ronke, Tyler Pittman, Cari Sebright (and Jeremy), John Herbert (and

Kristin), Joe Moore (and Liz), Phillip Stephenson (and Sarah), Jacob McClain (and Jennifer) for sharing their knowledge and keeping me grounded. Thanks to my fellow grad students, Matthew ’Skippy’ Jennings, Brad Austin, Katherine Crocker, Janet Ng, Allyn Dodd, Katey Duffey, Derek Hennen, Jordan Rutter, Nicole Wood, Gabe Foley, Kathryn and Nathan Haydon, Hal Halvorson, Marla Steele, Kaitlin Stack-Whitney, Kathleen Farley, Allison Barner, Asia Murphy, Anne Hillborn, Catherine Scott, Sean McCann, Desiree Narango, Morgan Jackson, Andrew MacDonald, Lizz Waring, Jen Ro, Robert Fournier, Chris Middaugh, Colin Carlson, Charlotte Chang, David Shiffman, Emily Rollinson, Chelsea Kross, Nick Caruso, Melissa Welch and Addison McCarver, for sharing in my love of science as we wandered along this path together.

Thanks to my technicians, Matt Boone, Leslie Brinkman, Dan Datlof, Justin Lehman, Hailee Pavisich, and Nick Seeger, without whom I probably would have died in a wetland somewhere. You should all probably regret working for my ridiculous project, hopefully the brownies and rails made up for it. You have all made my life and my science better.

Thanks to Alex Bond, Christi Bahlai, Beth Ross, Wayne Thogmartin, Terry McGlynn, Joshua Drew, Jeff Hollister, David Steen, Noam Ross, Holly Jones, Terry Wheeler, Eric Lawton, Ed Morris, Jacquelyn Gill, Jenny Bryan, Oliver Keyes, Stephen Heard, Julia Silge and countless others for their advice with my research and my career. You have kicked me in the butt, encouraged and lifted me up when I needed it most.

Mechanic’s daughters from rural Ohio aren’t supposed to grow up to gets PhDs and I am so thankful for the many people who helped me along the way. Kimberly and Kenn Kaufman, Mark Shieldcastle and Tom Kashmer, I blame and thank you for my love of all things bird and thank you for the countless hours you have given me. Thanks to the many the wonderful professors I had in the School of Forest Resources and Environmental Science at Michigan Tech during my undergrad who challenged me and helped me become a scientist, especially Joseph Bump, and Amber Roth your mentorship and friendship are a great treasure to me.

Deepest thanks to my brothers, Hank, Quin, Billy and Mike, for putting up with my ramblings, running around out in the woods with me and supporting me always. To my extended family who were always interested to hear about my work, or were at least good at pretending that they were. Special thanks to my mom, who has been the wind under my wings at every turn and is always up for whatever adventure I bring her along for.

Last, to my husband Jon, the first five years of our marriage are wrapped up in these pages, and for that I will continue to apologize. Thank you for following me here, for holding me up, from near and far while we did the long distance marriage dance and for letting me get WAY too excited about rails. I look forward to our next step together.

TABLE OF CONTENTS

INTRODUCTION 1

Literature Cited 4

CHAPTER 1 - THE TIMING OF AUTUMN SORA (*PORZANA CAROLINA*) MIGRATION IN MISSOURI 6

Abstract 7

Introduction 8

Methods 9

Results 11

Discussion 12

Literature Cited 15

Tables 18

Figures 19

Dissertation Authorization Letter 22

IACUC Approval Letters 23

CHAPTER 2 - SORA HABITAT USE DURING AUTUMN MIGRATION IN MISSOURI 25

Abstract 26

Introduction 27

Methods 29

Results 31

Discussion 31

Literature Cited 35

Tables 37

Figures 43

Dissertation Authorization Letter 49

IACUC Approval Letters 50

CHAPTER 3 - THE USE OF REGIONAL MONITORING DATA IN SPECIES DISTRIBUTION MODELS TO INFORM THE MIGRATORY CONNECTIVITY Of WETLAND BIRDS 52

Abstract 53

Introduction 54

Methods 57

Results 62

Discussion 63

Literature Cited 68

Figures 73

Supplementary Material 76

Dissertation Authorization Letter 81

IACUC Approval Letters 82

CHAPTER 4 - VIRGINIA AND YELLOW RAIL AUTUMN MIGRATION PHENOLOGY AND HABITAT USE: SUMMARY AND SYNTHESIS USING MULTIPLE DATA SETS 85

Abstract 86

Introduction 87

Methods 88

Results 91

Discussion 92

Literature Cited 96

Tables 98

Figures 100

Supplementary Materials 103

Dissertation Authorization Letter 104

IACUC Approval Letters 105

CHAPTER 5 - NOCTURNAL DISTANCE SAMPLING ALL-TERRAIN VEHICLE SURVEYS FOR NON-BREEDING RAILS 107

Abstract 108

Introduction 109

Methods 111

Results 114

Discussion 116

Literature Cited 120

Tables 123

Figures 125

Dissertation Authorization Letter 136

IACUC Approval Letters 127

CONCLUSION 129

SUPPLEMENTARY MATERIAL

Appendix I: Table of all wetland impoundments surveyed each year 134

Appendix II: Description of variables used in all analysis Electronic

Appendix III: GPS data of survey tracks and detection points Electronic

Appendix IV: Bird observation point data, survey data, vegetation data Electronic

Appendix V: Stable hydrogen isotope data Electronic

Appendix VI: Species distribution models Electronic

LIST OF PUBLISHED PAPERS

Chapter 1

Fournier, A.M.V., Mengel, D.C., Gbur, E.E., Krementz, D.G. In Press THE TIMING OF AUTUMN SORA (PORZANA CAROLINA) MIGRATION IN MISSOURI Wilson Journal of Ornithology

Chapter 3

Fournier, A.M.V., Drake, K.L. Tozer, D.C. Accepted THE USE OF MONITORING DATA IN SPECIES DISTRIBUTION MODELS TO INFORM MIGRATORY CONNECTIVITY OF WETLAND BIRDS Journal of Avian Biology

Chapter 5

Fournier, A.M.V., Krementz D.G., In Press. NOCTURNAL DISTANCE SAMPLING ALL-TERRAIN VEHICLE SURVEYS FOR NON-BREEDING RAILS The Wildlife Society Bulletin. DOI: 10.1002/wbs.745

INTRODUCTION

Rails are among the least studied birds in North America, in large part due to their elusive nature, but members of the family Rallidae are diverse and adapted to their environment. Rails are novel study organisms for a variety of questions including the evolution of flightlessness, vagrancy, colonization and dispersal, since rails have been found to be among the first birds to colonize many pacific islands and are frequently found as vagrants the world over despite their elusive behavior. This dissertation focuses on the migration and habits of the Sora (*Porzana Carolina*), Virginia Rail (*Rallus limicola*) and Yellow Rail (*Coturnicops noveboracensis*).

Sora are medium sized rails which live in freshwater wetlands from the Northwest Territory to Nova Scotia south into Mexico. Sora are often found in dense vegetation. While Sora breeding ecology has been examined for decades (Mousley 1937, Billard 1948, Pospichal et al. 1954, Tanner and Hendrickson 1956, Horak 1970, Griese et al. 1980, Johnson and Dinsmore 1985, Kaufmann 1987, 1989; Reid 1989, Lor and Malecki 2006) their migration is much more poorly studied, especially in autumn (Kemper et al. 1966, Griese et al. 1980, Kearns et al. 1998, Haramis and Kearns 2007, Fournier et al. 2015) and work on the wintering grounds is all but absent. Sora are a game species in many states, though harvest rates are very low and likely do not impact populations (Raftovich et al. 2012).

Sora and Virginia Rail habitats often overlap during the breeding season, though there are behavioral differences and Virginia Rails are not as generalist as Sora (Conway 1995). Most previous work on Virginia Rails has also been done during the breeding season, often in tandem with the study of Sora breeding ecology. During migration, Virginia Rails select flooded annual grasses with shallow water for foraging (Sayre and Rundle 1984, Fredrickson and Reid 1986).

Migrating Virginia Rails select a variety of water depths along with dense vegetation and seed producing plants (Andrews 1973, Rundle and Fredrickson 1981).

Of the three rail species studied here, Yellow Rails are the most poorly studied throughout their range, with the bulk of historic work being done on their breeding grounds (Wood 1909, Terrill 1943, Elliot et al. 1976, Grimm 1991, Robert et al. 1997, 2004; Martin 2012). In the past decade, work focused on at their abundance and habitat use on the Gulf Coast and in Oklahoma, which was recently identified as the most northerly wintering population of Yellow Rails (Tomer 1958, Post 2008, Butler et al. 2010, 2014; Morris 2015). The Yellow Rail population east of the Rocky Mountains is thought to be separate from the largely non-migratory population in the pacific northwest (Miller et al. 2012). In Oklahoma, migrating Yellow Rails were associated with *Sporobolus* spp (Butler et al. 2010). Otherwise their migratory habitat needs are unknown.

This dissertation focuses on autumn migration because priority information needs established by the Upland Game Bird Task Force for Rails and Snipe (Case and McCool 2009). Case and McCool (2009) highlighted autumn migration as a time to study rails because of the reduced flooded area of wetlands due to precipitation patterns and moist soil management. Here I will focus on six questions, each its own chapter and prepared as a publication for a peer reviewed journal.

1 – What is the timing of Sora autumn migration? Does that timing vary among years?

2 – What habitats do Sora select during autumn migration? Is that habitat equally available across the entire migratory season?

3 – What is the migratory connectivity of stopover and wintering rails in the Central and Mississippi Flyways?

4 – How are Sora and waterfowl impacted by early autumn flooding of wetlands?

5 – What is the timing Virginia Rail and Yellow Rail autumn migration? What habitats do Virginia Rail and Yellow Rail use during that time?

6 – Can ATV surveys at night be used as an effective method for detecting rails during autumn migration?

Rails are fascinating birds which have specialized habitat requirements and use habitat that has been lost in large part since European Settlement. Here, I present a foundation for future examination of rail migration ecology to promote sound science based conservation and management. In addition I examine how rails select and use stopover habitat during migration to inform migration theory.

LITERATURE CITED

Andrews DA. 1973. Habitat Utilization by Sora, Virginia Rail and King Rail near Southwestern Lake Erie. The Ohio State University.

Billard RS. 1948. An Ecological Study of the Virginia Rail (Rallus limicola limicola) and the Sora (Porzana carolina) in Some Conneticut Swamps, 1947.

Butler CJ, Pham LH, Stinedurf JN, Roy CL, Judd EL, Burgess NJ, and Caddell GM. 2010. Yellow Rails Wintering in Oklahoma. The Wilson Journal of Ornithology 122:385–387.

Butler CJ, Wilson JK, Brower CR, and Frazee SR. 2014. Age ratios, sex ratios, and a population estimate of Yellow Rails at San Bernard National Wildlife Refuge, Texas. Southwestern Naturalist 59:319–324.

Case DJ, and McCool DD. 2009. Priority Information Needs for Rails and Snipe.

Conway CJ. 1995. Virginia Rail. In The Birds of North America. p. 173.

Elliot R, Morrison RIG, and Ellioet RD. 1976. The Incubation Period of the Yellow Rail. The Auk 96:422–423.

Fournier AMV, Shieldcastle MC, Kashmer T, and Mylecraine KA. 2015. Comparison of Arrival Dates of Rail Migration in the Southwest Lake Erie Marshes, Ohio, USA. Waterbirds 38:312–314.

Fredrickson LH, and Reid FA. 1986. Wetland and Riparian Habitats: A Nongame Management Overview. Pages 59–96 in. Management of NonGame Wildlife In the Midwest A Developing Art.

Griese HJ, Ryder RA, and Braun CE. 1980. Spatial and Temporal Distribution of Rails in Colorado. The Wilson Bulletin 92:96–102.

Grimm M. 1991. Northwest Wisconsin Yellow Rail Survey. The Passenger Pigeon 53:115–121.

Haramis GM, and Kearns GD. 2007. Soras in Tidal Marsh : Banding and Telemetry Studies on the Patuxent River, Maryland. Waterbirds 30:105–121.

Horak GJ. 1970. A comparative study of the foods of the Sora and virginia rail. The Wilson Bulletin 82:206–213. doi: 10.2307/4159954

Johnson RR, and Dinsmore FF. 1985. Brood-Rearing and Postbreeding Habitat Use by Virginia Rails and Soras. The Wilson Bulletin 97:551–554.

Kaufmann GW. 1987. Growth and Development of Sora and Virginia Rail Chicks. The Wilson Bulletin 99:432–440.

Kaufmann GW. 1989. Breeding Ecology of the Sora Porzana Carolina, and the Virginia Rail Rallus Limicola. Canadian Field Naturalist 3:270–282.

Kearns GD, Kwartin NB, Brinker DF, and Haramis GM. 1998. Digital Playback and Improved Trap Design Enhances Capture of Migrant Soras and Virginia Rail. Journal of Field Ornithology 69:466–473.

Kemper CA, Raveling DG, and Warner DW. 1966. A Comparison of the Species Composition of Two TV Tower Killed Samples From the Same Night of Migration. The Wilson Bulletin 78:26–30.

Lor S, and Malecki RA. 2006. Breeding ecology and nesting habitat associations of five marsh bird species in Western New York. Waterbirds 29:427–436.

Martin KA. 2012. Habitat suitability of the yellow rail in south-central Manitoba.

Miller MP, Haig SM, Mullins TD, Popper KJ, and Green M. 2012. Evidence for Population Bottlenecks and Subtle Genetic Structure in the Yellow Rail. The Condor 114:100–112. doi: 10.1525/cond.2012.110055

Morris KM. 2015. Ecology of Yellow Rail (Coturnicops noveboracensis) overwintering in coastal pine savannas of the northern Gulf of Mexico.

Mousley H. 1937. A Study of a Virginia Rail and Sora Rail at their Nests. The Wilson Bulletin:80–84.

Pospichal LB, Marshall WH, and Tester J. 1954. A field study of Sora Rail and Virginia Rail in central Minnesota. The Flicker 26:2-32.

Post W. 2008. Winter Ecology of Yellow Rails Based on South Carolina Specimens. The Wilson Journal of Ornithology 120:606–610.

Raftovich RV, Wilkins KA, Williams SS, and Spriggs HL. 2012. Migratory Bird Hunting Activity and Harvest for the 2010 and 2011 Hunting Seasons.

Reid FA. 1989. Differential Habitat Use by Waterbirds In A Managed Wetland Complex.

Robert M, Cloutier L, and Laporte P. 1997. The Summer Diet of the Yellow rail in Southern Quebec. The Wilson Bulletin 109:702–710.

Robert M, Jobin B, Shaffer F, Robillard L, Gagnon B, Obert MIR, Obin BEJ, and Haffer FRS. 2004. Yellow Rail Distribution and Numbers in Southern James Bay, Quebec, Canada. Waterbirds 27:282–288.

Rundle WD, and Fredrickson LH. 1981. Managing Seasonally Flooded Impoundments for Migrant Rails and Shorebirds. Wildlife Society Bulletin 9:80–87.

Sayre MW, and Rundle WD. 1984. Comparison of Habitat Use by Migrant Soras and Virginia Rails. The Journal of Wildlife Management 48:599–605.

Tanner WD, and Hendrickson G. 1956. Ecology of the Sora in Clay County, Iowa. Iowa Bird Life. 26:78-81.

Terrill LM. 1943. Nesting habits of the yellow rail in Gaspe County, Quebec. The Auk 6:171–180.

Tomer JS. 1958. An Oklahoma Record of the Yellow rail. The Auk 76:94–95.

Wood NA. 1909. Notes on the Occurence of the Yellow Rail in Michigan. The Auk 26:1–5.

CHAPTER 1

The Timing of Autumn Sora (*Porzana Carolina*) Migration In Missouri

Auriel M.V. Fournier

and

Doreen C. Mengel, Edward E. Gbur, and David G. Krementz

ABSTRACT. --- Monitoring and conserving waterbirds in Missouri, including Sora (*Porzana carolina*), is constrained by the lack of information on migration phenology. We performed nocturnal distance-sampling-based ATV surveys across 11 state and federal managed wetlands in Missouri, USA from 2012-2015 to compare the timing of autumn Sora migration among years. Sora migration in Missouri began in the first week of August, on average it peaked on 25 September, and continued through the last week of October. We detected Sora migration earlier in autumn than previous work. We found the start and end of migration did not vary annually in three of four years. With our results, wetland managers should be able to better time their management for rails in Missouri.

INTRODUCTION

Understanding the timing of a species' migration is as important as knowing the species' habitat needs and stopover ecology (Sheehy et al. 2011, Albanese and Davis 2015, Hostetler et al. 2015). Awareness regarding the time of year that habitat is needed is vital to inform habitat management, especially in highly ephemeral habitats such as palustrine emergent wetlands. Public wetlands across the central United States, including Missouri, are typically managed as migratory bird stopover habitat, with a focus on waterfowl; other wetland-dependent bird species, including Sora (*Porzana carolina*), also use these habitats although the timing of their need is less well known (Melvin and Gibbs 1994, Melvin and Gibbs 2012, Andersson et al. 2015). The timing of autumn migration varies annually in many species and may be related to habitat availability, weather, and other variables (Richardson 1978, Richardson 1990, Krementz et al. 2012, Aagaard et al. 2015). While there is evidence that the timing of waterfowl and passerine migration has changed in response to climate change, there is no information available for Sora migration timing, which makes it difficult to predict how, or if, climate change will affect Sora or when habitat is needed to support multi-species management (Sokolov et al. 1999, Lehikoinen and Jaatinen 2011).

Several small-scale studies have been conducted on Sora migration timing, but no projects have looked specifically at the timing of migration across multiple sites and years in the Mississippi Flyway. Missouri is centrally located in the Mississippi Flyway and is an important midway point of stopover habitat for migratory waterbirds (Case and McCool 2009, Soulliere et al. 2013). Previous small-scale studies indicate Sora migration peaks in Missouri in the last two weeks of September and ranges from the last week of August to the last week of October (Rundle and Fredrickson 1981, Clark-Schubert 2009). While Sora observations from eBird

(Sullivan et al. 2009) ranged from the first week of August through the last week of October in Missouri, these data may not be reliable to examine variation in migration phenology because of the low detection probability of Sora and the lack of consistent observer effort (Sullivan et al. 2009, Conway and Gibbs 2011, Conway 2011). Our objective was to document autumn Sora migration phenology in Missouri using a standardized method and compare migration phenology differences among years.

METHODS

Study Area.--- We selected 11 publicly managed wetland properties across Missouri, USA because of their historical importance for migrating waterbirds (Fig. 1). At each property, we surveyed moist soil wetland impoundments (wetlands surrounded by levees with water control structures and dominated by smartweeds [*Polygonum* spp.] and millets [*Echinochola* spp.]) (sample size by region by year Table 1, further detail Appendix I). We made impoundments the survey unit because this is the scale at which wetland management decisions are made. Wetland impoundments were usually managed on a multi-year rotation using water level manipulation and disturbance (discing, mowing and burning) to hinder invasion by undesirable plants and set back succession (Rundle and Fredrickson 1981, Fredrickson and Taylor 1982). In 2012, Missouri experienced an extreme drought throughout the summer and autumn while weather conditions were more typical in 2013, 2014, and 2015 (U.S Drought Monitor 2015).

Surveys.--- Fournier and Krementz (In Press) developed a method for surveying Sora outside of the breeding season, by driving transects at night on ATVs running parallel to a randomly-chosen side of each impoundment and spaced 30 m apart in a systematic pattern. These surveys are done under a distance sampling framework where the perpendicular distance from the transect line to the point where each Sora was first detected is recorded, which allows for estimation of detection probability and density using hierarchical models (Fiske and Chandler 2011, Denes et al. 2015). We conducted surveys beginning 30 minutes after sunset for two hours each night in 2012 and for 3 hours each night in 2013, 2014 and 2015 (Table 1).

We began surveys each year in the northwest region of Missouri and moved clockwise around the state (Fig. 1). Regions were visited 3-4 times a year and each visit involved multiple surveys of the same impoundment by different observers. Effort varied by year because of changes in the number of observers, closure of some properties in preparation for hunting seasons and, in 2013, because of the U.S. federal government shutdown (Table 1).

Density.---We estimated Sora density 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). Unmarked provides an approach to fit biological data collected through repeated measures techniques to hierarchical models that estimate density while accounting for imperfect detection (Royle et al. 2004). The repeated transects within each survey allowed us to better estimate detection probability (MacKenzie 2006, Chandler et al. 2011). We met the population closure assumption by estimating density for each impoundment during each visit separately. This resulted in three-four separate density estimates per impoundment each year. We truncated our observations to only include those within 5 meters of the line, which encompassed 96% of the detections because the small number of detections in the larger distance bins would add 'little information for the estimation of the detection function and could complicate model fitting" (Schmidt et al 2012).

We used the intercept-only model to estimate Sora density and detection for each impoundment at each survey. We treated each year's density estimates as a function of day of the year with a cubic smooth spline in R (smoothing parameter = 0.8, Fig. 2). We bootstrapped 95% confidence intervals around the density estimates. We estimated detection probability by comparing the expected value from 500 bootstrap simulations of the “getP” function within the ‘unmarked’ package. To compare the distribution of migration among years we used a Kolmogorov-Smirnoff non-parametric test.

RESULTS

We detected 6,283 Sora during 868 hours of surveying. Detection probability on the line was 17% (SE=15-19). The earliest Sora we detected was 11 August 2015 (Fig. 2) and study area managers reported seeing Sora in 2012 and 2015 before our surveys began (personal communications, 2012, Craig Crisler, Missouri Department of Conservation and 2015, Cody Alger, U.S. Fish and Wildlife Service). We found no significant differences among years in Sora densities (Sora/hectare) before 31 August or after 19 October (2012 data collection ended 7 October, Fig. 2). Densities in all years except 2014 peaked in late September, followed by a slow decline thereafter, whereas 2014 had no clear peak and a greater interquartile range, indicating a wider spread of Sora across the autumn in 2014 than during other years (Table 2). The peak in Sora densities in 2012 was higher than any other year. The distribution of Sora density was different between 2014 and 2013, and 2015 and 2013 (D=0.22, and 0.23, p-values <=0.001, Figure 3), but not between 2014 and 2015 (D=0.04, p=0.96, Figure 3). The differences in the distributions was a result of higher Sora densities in 2013 beginning around the end of August through the end of the first week in October as compared to the Sora densities in either 2014 or 2015 (Figure 3).

DISCUSSION

Sora migration began the week of August 10th in all years, with 2013's shape being different from 2014 and 2015. The reason for the differences in the shape of migration among years suggests weather can play a role in shifting the distribution of migration, while at the same time processes like photoperiod are consistently triggering the initiation of migration (Bellrose 1980). We did not compare 2012 with the other years because 2012 surveys ended two weeks earlier; however, we do note that in 2012 we had our highest peak Sora densities which may have been because of an exceptional drought in the state which reduced the number of flooded wetlands (U.S. Drought Monitor 2015).

Knowing when a species migrates has implications for habitat management, monitoring, and research since the population's needs may not be met during migration or the species could be missed during monitoring if those surveys are incorrectly timed. Previous research in the Mississippi Flyway missed the initiation of Sora migration by several weeks, which is not surprising since the difficulty of detecting rails can lead to the incorrect observation of the migration initiation (Fournier et al. 2015). Our work consistently shows migration beginning in early August, which is in line with eBird (Sullivan et al. 2009). This is especially important to consider when making wetland management decisions during autumn migration because habitat management will need to be timed with migration. Extreme weather events, such as flooding and drought are predicted to increase across Missouri with climate change. The increase in extreme weather will make active wetland management more challenging and understanding the needed timing of wetland habitat even more important.

The latest date we detected Sora was in line with the end of migration in Missouri observed by Clark-Schubert (2009), whereas eBird records from Missouri continued into

November. We were unable to extend our surveys beyond the end of October because of the initiation of waterfowl hunting seasons and chose not to initiate them earlier in August to prevent disrupting late nesting species. As a result, we failed to capture the true initiation and end of migration but our data encompass the majority of Sora migration and should be sufficient to inform future research and monitoring.

When attempting to manage for a suite of wetland species consideration should be given to potential mismatches that may occur between the timing of species' needs and resource availability. Early autumn could be the most limited time of year for flooded wetlands on the landscape in Missouri in part because of late summer drawdowns. This combined with the increase in extreme weather events, particularly droughts, predicted in climate change scenarios, could further decrease the amount of flooded wetlands during this important time for Sora. Future work should look to inform decisions that incorporate the needs of Sora into the wetland management process.

ACKNOWLEDGEMENTS

Our research was funded by the U.S. Fish and Wildlife Service, the Missouri Department of Conservation, the U.S. Geological Survey Arkansas Cooperative Fish and Wildlife Research Unit, and the University of Arkansas. We would like to thank K. Ackley, C. Alger, R. Bell, 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, A. Raedeke, D. Welchert, S. Whitson, and J. Wilson for help in coordinating field work and site access. 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 collecting data. Thanks to S. Lehnen, and the 'unmarked' Google Group for their help with analysis. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government. All work completed under Special Use Permits from Missouri Department of Conservation, U.S. Fish and Wildlife Service, IACUC proposal #13044 and #15023 from the University of Arkansas and Federal Bird Banding Permit #23002.

LITERATURE CITED

Aagaard, K. , S. M. Crimmins, W. E. Thogmartin, B. G. Tavernia, and J. E. Lyons. 2015. Evaluating predictors of local dabbling duck abundance during migration: managing the spectrum of conditions faced by migrants. Wildfowl 65:100–120.

Albanese, G. , and C. A. Davis. 2015. Characteristics within and around stopover wetlands used by migratory shorebirds: Is the neighborhood important? Condor 117:328–340. doi: 10.1650/CONDOR-14-166.1

Andersson, K., C. A. Davis, G. Harris, and D. A. Haukos. 2015. An assessment of non-breeding waterfowl surveys on National Wildlife Refuges in the Central Flyway. Wildlife Society Bulletin 39:79–86. doi: 10.1002/wsb.500

Bellrose, F. C. 1980. Ducks, geese and swans of North America. Stackpole, Mechanicsburg, Pennsylvania.

Butler, C. J., L. H. Pham, J. N. Stinedurf, C. L. Roy, E. L. Judd, N. I. Burgess, and G. M. Caddell. 2010. Yellow Rails wintering in Oklahoma. Wilson Journal of Ornithology 122:385–387. doi: 10.1676/09-099.1

Butler, C. J., J. K. Wilson, C. R. Brower, and S. R. Frazee. 2014. Age ratios, sex ratios, and a population estimate of Yellow Rails at San Bernard National Wildlife Refuge, Texas. Southwestern Naturalist 59:319–324. doi: 10.1894/MCG-02.1

Case, D. J., and D. D. McCool. 2009. Priority Information Needs for Rails and Snipe. https://www.fws.gov/migratorybirds/pdf/surveys-and-data/Info-Needs-Rails-Snipe.pdf

Chandler, R. B., J. A. Royle, and D. I. King. 2011. Inference about density and temporary emigration in unmarked populations. Ecology 92:1429–1435. doi: 10.1890/10-2433.1

Clark-Schubert, N. D. 2009. Fall migration ecology of the Sora (*Porzana carolina*) at Four Rivers Conservation Area in Missouri. M.S. Thesis. University of Arkansas

Conway, C. J. 2011. Standardized North American marsh bird monitoring protocol. Waterbirds 34:319–346. doi: 10.1675/063.034.0307

Conway, C. J., and J. P. Gibbs. 2011. Summary of intrinsic and extrinsic factors affecting detection probability of marsh birds. Wetlands 31:403–411. doi: 10.1007/s13157-011-0155-x

Denes, F. V., L. F. Silviera, and S. R. Beissinger. 2015. Estimating abundance of unmarked animal populations for imperfect detection and other sources of zero inflation. Methods in Ecology and Evolution 6:543–556. doi: 10.1111/2041-210X.12333

Fiske, I. J., and R. B. Chandler. 2011. unmarked: An R package for fitting hierarchical models of wildlife occurrence and abundance. Journal of Statistical Software 43:1–23. doi: 10.18637/jss.v043.i10

Fournier, A. M. V., M. C. Shieldcastle, T. Kashmer, and K. A. Mylecraine. 2015. Comparison of arrival dates of rail migration in the southwest Lake Erie marshes, Ohio, USA. Waterbirds 38:312–314. doi: 10.1675/063.038.0313

Fournier, A. M. V., and D. G. Krementz. 2017. Nocturnal distance sampling all-terrain vehicle surveys for non-breeding rails. The Wildlife Society Bulletin (In Press).

Fredrickson, L. H., and T. S. Taylor. 1982. Management of seasonally flooded impoundments for wildlife. U.S. Fish and Wildlife Service Resource Publication 148. Washington, D.C. doi: 10.3996/012014-JFWM-009.S2

Hostetler, J. A., T. S. Sillett, and P. P. Marra. 2015. Full-annual-cycle population models for migratory birds. Auk 132:433–449. doi: 10.1642/AUK-14-211.1

Krementz, D. G., K. Asante, and L. W. Naylor. 2012. Autumn migration of Mississippi Flyway mallards as determined by satellite telemetry. Journal of Fish and Wildlife Management 3:238–251. doi: 10.3996/022012-JFWM-019

Lehikoinen, A., and K. Jaatinen. 2011. Delayed autumn migration in northern European waterfowl. Journal of Ornithology 153:563–570. doi: 10.1007/s10336-011-0777-z

Mackenzie, D. I. 2006. Modeling the probability of resource use: the effect of, and dealing with, detecting a species imperfectly. Journal of Wildlife Management 70:367–374. doi: 10.2193/0022-541X(2006)70[367:MTPORU]2.0.CO;2

Melvin, S. M., and J. P. Gibbs. 1994. Sora (*Porzana carolina*). pp 209–217 *in*: Migratory shore and upland game bird management in North America. (Tacha, T. C., and Braun C. E. Editors) International Association of Fish and Wildlife Agencies, Washington, D.C.,

Melvin, S. M. and J. P. Gibbs. 2012. Sora (*Porzana carolina*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/250

R Core Team 2015. R: A language and environment for statistical computing.

Richardson, W. J. 1978. Timing and amount of bird migration in relation to weather: a review. Oikos 30:224–272.

Richardson, W. J. 1990. Timing of bird migration in relation to weather: updated review. In: Bird Migration: Physiology and Ecophysiology. (Gwinner E. Editor) Springer-Verlag, Berlin, Heidelberg, pp 78–101

Royle, J. A., D. K. Dawson, and S. Bates. 2004. Modeling abundance effects in distance sampling. Ecology 85:1591–1597. doi: 10.1890/03-3127

Rundle, W. D., and L. H. Fredrickson. 1981. Managing seasonally flooded impoundments for migrant rails and shorebirds. Wildlife Society Bulletin 9:80–87.

Schmidt, J. H., K. L. Rattenbury, J. P. Lawler, and M. C. Maccluskie. 2012. Using distance sampling and hierarchical models to improve estimates of Dall's sheep abundance. The Journal of Wildlife Management, 76: 317–327. doi:10.1002/jwmg.216

Sheehy, J., C. M. Taylor, and D. R. Norris. 2011. The importance of stopover habitat for developing effective conservation strategies for migratory animals. Journal of Ornithology 152:161–168. doi: 10.1007/s10336-011-0682-5

Sokolov, L. V., M. Y. Markovets, and Y. G. Morozov. 1999. Long-term dynamics of the mean date of autumn migration in passerines on the Courish Spit of the Baltic Sea. Avian Ecology and Behaviour 2:1–18.

Soulliere, G. J., B. M. Loges, E. M. Dunton, D. R. Luukkonen, and M. W. Eichholz. 2013. Monitoring waterfowl in the midwest during the non-breeding period: challenges, priorities, and recommendations. Journal of Fish Wildlife Management 4:395-405 doi: 10.3996/062012-JFWM-054

Sullivan, B. L., C. L. Wood, M. J. Iliff, R. E. Bonney, D. Fink, and S. Kelling. 2009. eBird: a citizen-based bird observation network in the biological sciences. Biological Conservation 142:2282–2292. doi: 10.1016/j.biocon.2009.05.006

U.S. Drought Monitor 2015. United States Drought Monitor. National Drought Mitigation Center, U.S. Department of Agriculture and the National Oceanic and Atmospheric Administration. http://droughtmonitor.unl.edu/. Accessed 1 Oct 2015

Table 1. Survey start and end dates, visits per property type and sample size of wetland impoundments surveyed by region for each year of autumn rail surveys in Missouri, USA.

Year	**Observers**	**Start Date**	**End Date**	**Visits per Property**		**Number of Impoundments Surveyed by Region**				
				State	Federal	NW	NC	NE	SE	Total
2012	4	17 Aug	7 Oct	3	3	5	7	11	17	40
2013	4	11 Aug	27 Oct	3	4	7	10	7	15	39
2014	2	12 Aug	22 Oct	4	4	7	6	11	9	33
2015	2	12 Aug	23 Oct	4	4	7	6	11	9	33

Table 2. Distribution of Sora densities by date in Missouri, USA. IQR is the Inner Quartile Range – the number of days between Quantile 1 and Quantile 3.

Year	**Minimum**	**Quantile 1**	**Median**	**Quantile 3**	**Maximum**	**IQR**
2012	17 Aug	13 Sept	22 Sept	27 Sept	7 Oct	14
2013	11 Aug	14 Sept	26 Sept	3 Oct	27 Oct	19
2014	12 Aug	5 Sept	23 Sept	5 Oct	22 Oct	30
2015	12 Aug	14 Sept	29 Sept	3 Oct	23 Oct	19

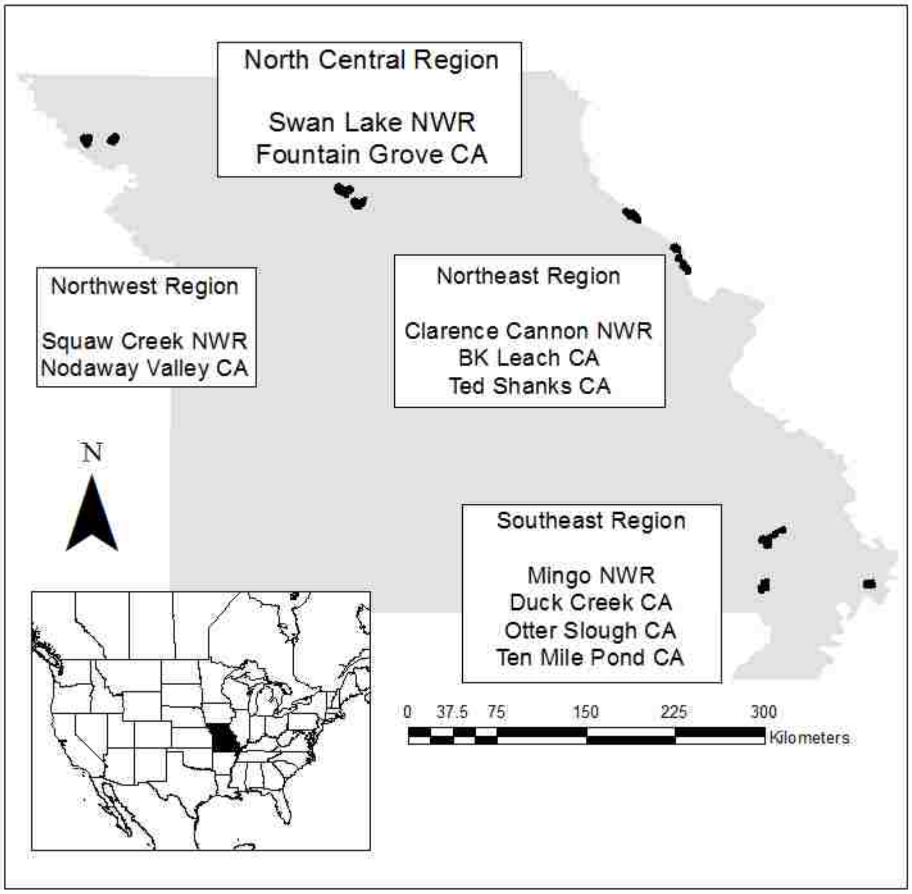


Figure. 1 - Eleven study sites in Missouri USA where Sora (*Porzana carolina*) were surveyed during autumn migration in 2012-2015.

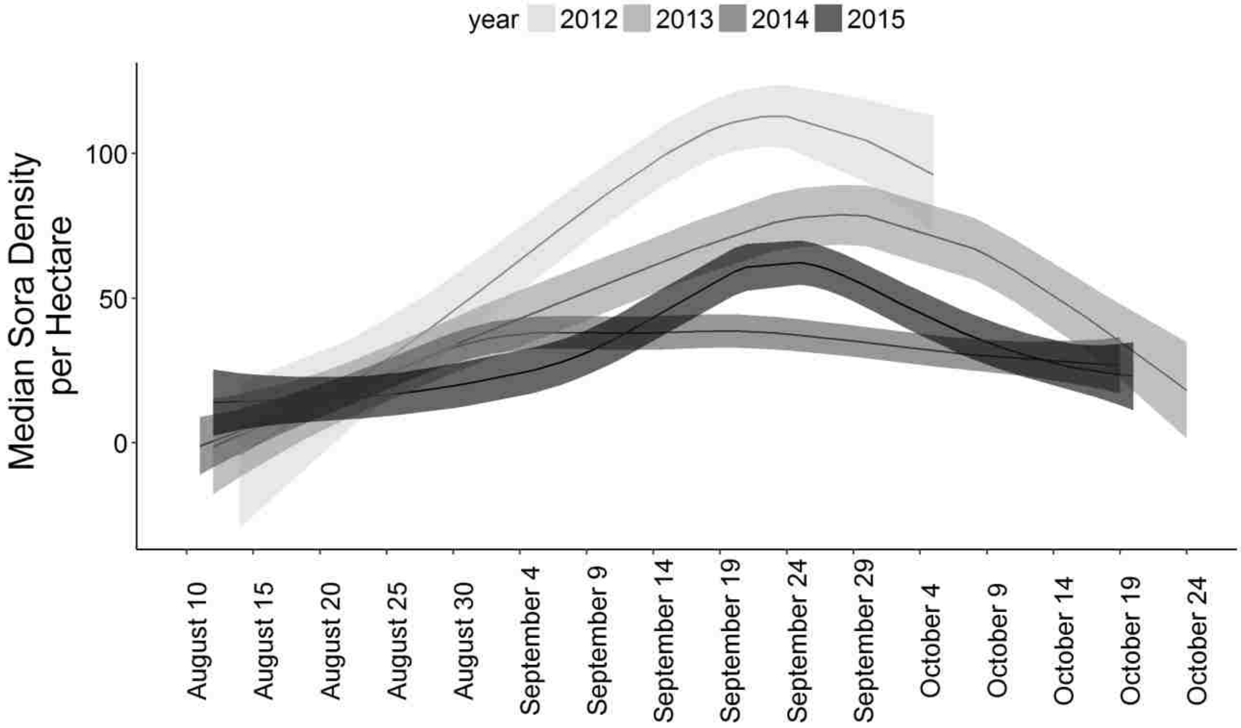


Figure. 2 – Smoothed splines of Sora (*Porzana carolina*) density from surveys across Missouri, USA from 2012-2015. Splines do not extrapolate beyond the survey periods, which differed among years.

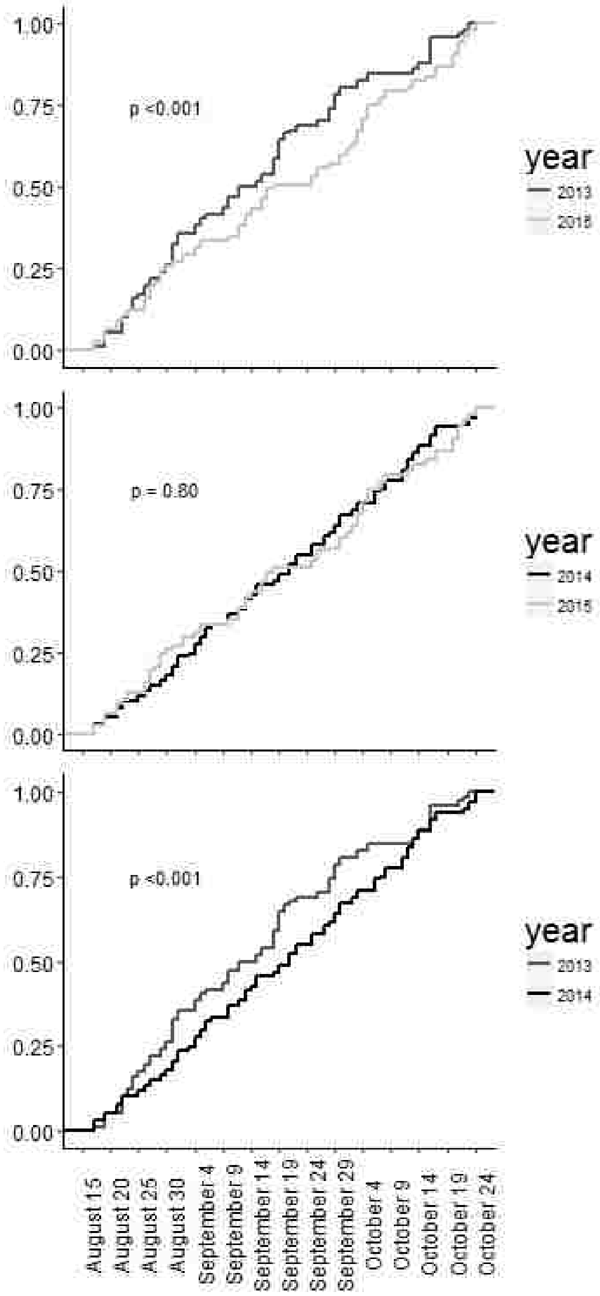


Figure. 3 – Comparison of cumulative distributions of Sora (*Porzana carolina*) density between years. The first year, 2012, was not compared to other years because the survey period that year ended earlier than the other years.

Chapter 1, "THE TIMING OF AUTUMN SORA (PORZANA CAROLINA) MIGRATION IN MISSOURI" of A.M.V. Fournier's dissertation is accepted for publication in the Wilson Journal of Ornithology with three coauthors, D.C. Mengel, E.E. Gbur, and D.G. Krementz.

I, Dr. David G. Krementz, advisor of Auriel M.V. Fournier, confirm Auriel M.V. Fournier will be first author and completed at least 51% of the work for this manuscript.

David G Krementz 16 March 2017

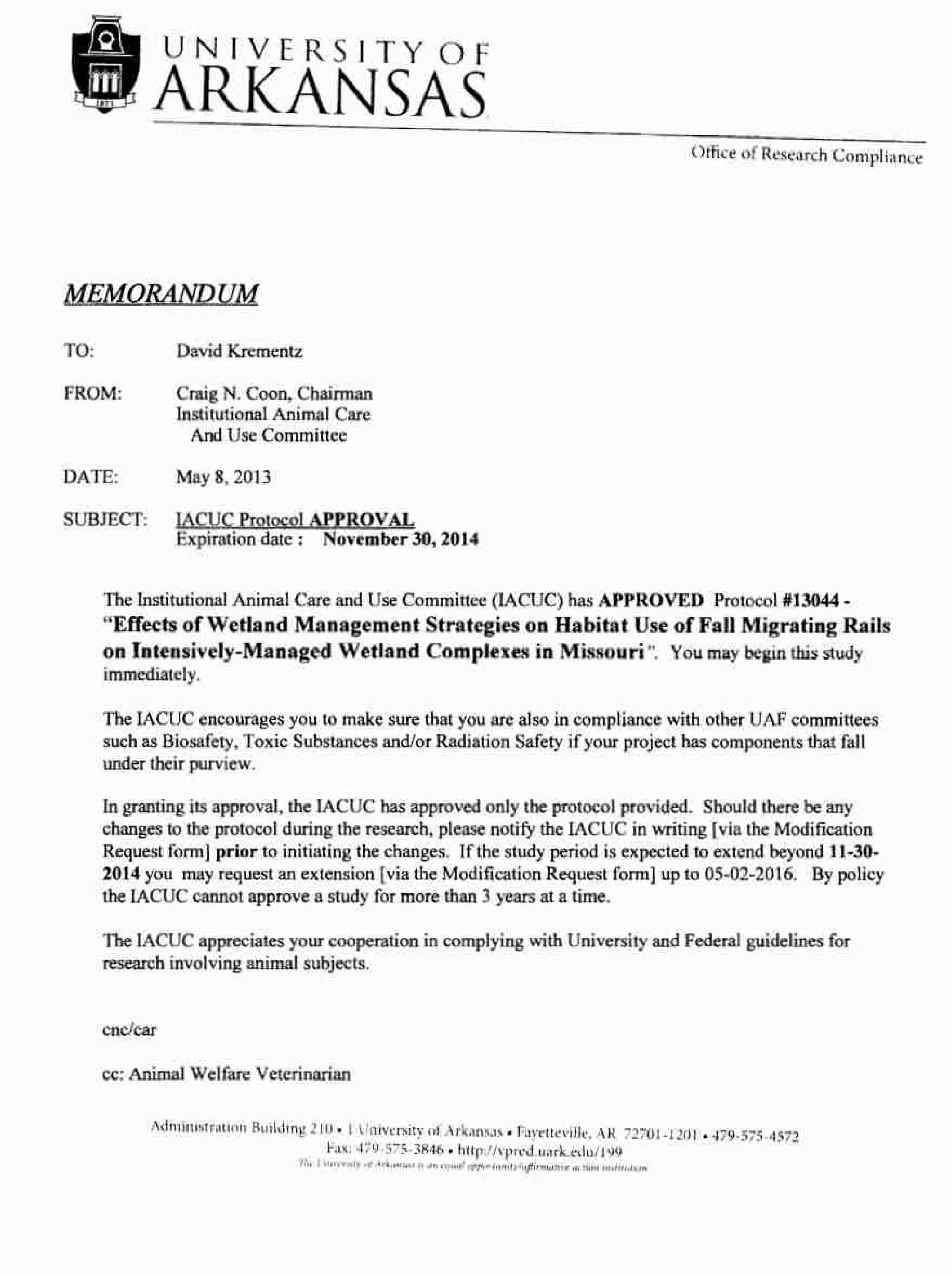
David G. Krementz Date

Unit Leader

U.S. Geological Survey

Arkansas Cooperative Fish and Wildlife

Research Unit



UNIVERSITY OF
ARKANSAS

Office of Research Compliance

MEMORANDUM

TO: David Krementz

FROM: Craig N. Coon, Chairman
Institutional Animal Care
And Use Committee

DATE: May 8, 2013

SUBJECT: IACUC Protocol **APPROVAL**
Expiration date : **November 30, 2014**

The Institutional Animal Care and Use Committee (IACUC) has **APPROVED** Protocol **#13044 - "Effects of Wetland Management Strategies on Habitat Use of Fall Migrating Rails on Intensively-Managed Wetland Complexes in Missouri**". You may begin this study immediately.

The IACUC encourages you to make sure that you are also in compliance with other UAF committees such as Biosafety, Toxic Substances and/or Radiation Safety if your project has components that fall under their purview.

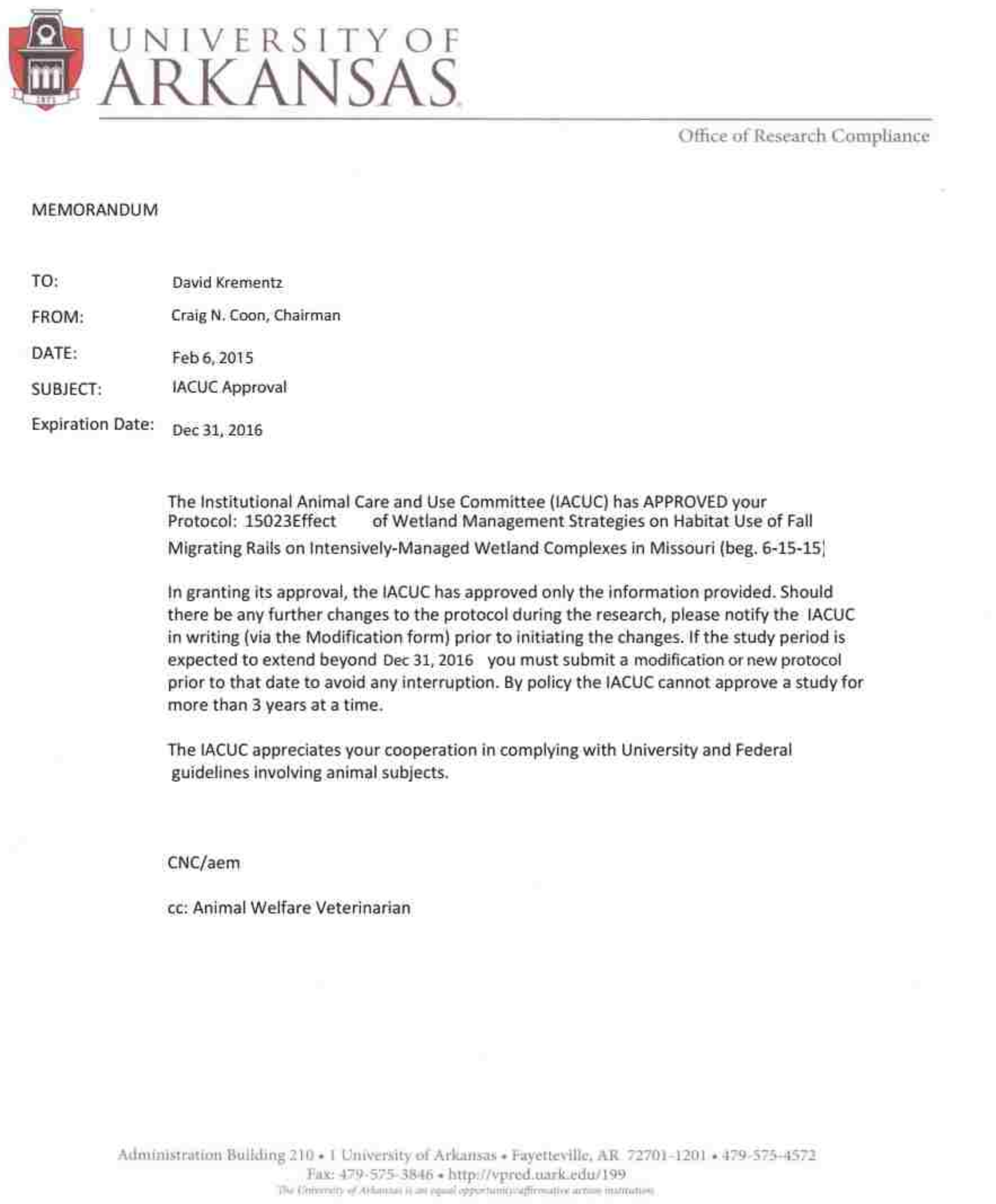
In granting its approval, the IACUC has approved only the protocol provided. Should there be any changes to the protocol during the research, please notify the IACUC in writing [via the Modification Request form] **prior** to initiating the changes. If the study period is expected to extend beyond **11-30-2014** you may request an extension [via the Modification Request form] up to 05-02-2016. By policy the IACUC cannot approve a study for more than 3 years at a time.

The IACUC appreciates your cooperation in complying with University and Federal guidelines for research involving animal subjects.

cnc/car

cc: Animal Welfare Veterinarian

Administration Building 210 • 1 University of Arkansas • Fayetteville, AR 72701-1201 • 479-575-4572
Fax: 479-575-3846 • http://vpred.uark.edu/199
The University of Arkansas is an equal opportunity/affirmative action institution



UNIVERSITY OF
ARKANSAS

Office of Research Compliance

MEMORANDUM

TO: David Krementz

FROM: Craig N. Coon, Chairman

DATE: Feb 6, 2015

SUBJECT: IACUC Approval

Expiration Date: Dec 31, 2016

The Institutional Animal Care and Use Committee (IACUC) has APPROVED your Protocol: 15023Effect of Wetland Management Strategies on Habitat Use of Fall Migrating Rails on Intensively-Managed Wetland Complexes in Missouri (beg. 6-15-15

In granting its approval, the IACUC has approved only the information provided. Should there be any further changes to the protocol during the research, please notify the IACUC in writing (via the Modification form) prior to initiating the changes. If the study period is expected to extend beyond Dec 31, 2016 you must submit a modification or new protocol prior to that date to avoid any interruption. By policy the IACUC cannot approve a study for more than 3 years at a time.

The IACUC appreciates your cooperation in complying with University and Federal guidelines involving animal subjects.

CNC/aem

cc: Animal Welfare Veterinarian

Administration Building 210 • 1 University of Arkansas • Fayetteville, AR 72701-1201 • 479-575-4572
Fax: 479-575-3846 • http://vpred.uark.edu/199
The University of Arkansas is an equal opportunity/affirmative action institution

CHAPTER 2

Sora habitat use during autumn migration in Missouri

Auriel M.V. Fournier

And

Doreen C. Mengel, And David G. Krementz

Abstract

Wetlands have been lost across the United States, especially among palustrine wetlands since European settlement. These remaining wetlands are very important and are managed to fulfill many needs. Palustrine wetland management across the central United States is often moist soil management which can limit the availability of flooded wetlands early in autumn migration because of an emphasis on water management to provide habitat for migratory waterfowl. Following this wetland management strategy could impact the distribution, stopover duration and survival of early migrating waterbirds, including rails, such as Sora (*Porzana carolina)*. We conducted nocturnal surveys on 11 state and federal properties in Missouri during autumn migration in 2012-2016 to examine Sora habitat selection in managed palustrine wetlands. Using binomial mixed models we examined Sora habitat selection. We found a strong positive second order relationship with mean water depth and first order annual moist soil vegetation, and a lesser positive relationship with perennial moist soil vegetation. We also found a change in mean water depth across the migration season, which highlights limitations of available wetland habitat early in migration for Sora. These results provide an informative foundation for multispecies management of palustrine wetlands and future research to inform the conservation and management of Sora.

Introduction

Wetlands have been greatly reduced across the United States since European settlement (Tiner 1984). Dramatic wetland loss increases the importance of remaining wetlands for providing habitat, mitigating flooding, cleaning water. While some wetland types have started to increase again, palustrine wetlands (non-tidal wetlands dominated by vegetation and having shallow water depths and low salinity, Cowardin et al. 1979) have continued to experience declines. To maintain palustrine emergent wetlands on an increasingly altered landscape which often disrupts natural hydrology, wetlands are often impounded. Impounded wetlands are managed under moist soil management regimes to promote conditions and plant communities that favor waterfowl habitat by mimicking natural flooding and disturbance patterns using a combination of soil disturbance and flooding (Fredrickson and Taylor 1982). Palustrine wetlands provide habitat for a wide suite of plant and animal species, including migratory waterbirds, such as waterfowl, shorebirds, and rails.

Promoting habitat for migratory waterfowl is often a high priority, but can result in limited flooded habitat early in autumn migration - before waterfowl arrive. Moist soil wetlands are dried out in late summer to encourage germination of seed producing plants (Rundle and Fredrickson 1981). Moist soil wetlands are managed on a multiple-year rotation using water level manipulation and soil disturbance to reduce invasive and woody plant succession as well as promote vegetation structure and food resources for migratory wetland birds (Fredrickson and Taylor 1982; Anderson and Smith 2000; Kross et al. 2008). The timing of wetland flooding relative to the timing of autumn migration of non-waterfowl waterbirds significantly affects available habitat and could affect waterbird distribution and habitat use, which in turn could influence their survival and migratory stopover ecology (Reid 1989; Case and McCool 2009).

Sora (*Porzana carolina*) are rails, and are one of many migratory waterbirds, though how Sora use habitats during autumn migration is poorly known (Case and McCool 2009). In late summer, Sora are often found in shallow flooded wetlands dominated by short emergent wetland plants (Gries et al. 1980), particularly *Echinochloa* and *Polygonum* spp. (Meanley 1965). Sora forage primarily on seeds during autumn migration, and this may explain why Sora are found in high densities in dense moist soil vegetation in the autumn (Rundle and Sayre 1983).

Much of the previous Sora autumn migration research has been conducted in Missouri, a state representative of the strictly migratory habitat (Melvin and Gibbs 2012). Previous work was completed on single sites and was based on opportunistic observations which found that during autumn migration, Sora flushed from shallow flooded (<11-14 cm) habitats dominated by annual wetland vegetation, including *Panicum, Echinochloa* and *Bidens* spp. (Reid 1989, Rundle & Frederickson 1981, Sayre & Rundle 1984). Sora have been founded in high densities around wetlands which were flooded during the late summer and early part of autumn migration in Missouri and Colorado (Gries et al. 1980, Rundle and Fredrickson 1981). In Missouri, Sora migration begins in early August and continues through late October, with the peak of migration occurring in late September while migratory waterfowl begin arriving in October and continue to migrate into the area throughout the following months (Fournier et al. In Press). Our objective was to examine Sora habitat selection during the entire span of their autumn migration, by surveying five years on multiple sites, under a standardized protocol, to inform wetland managers interested in Sora conservation and management.

Methods

Study Site

We selected 7 publicly managed wetlands across Missouri because of their active moist soil management and historic importance for migrating waterfowl (further detail Appendix I). At each property, we surveyed moist soil wetland impoundments (a wetland surrounded by a levee, with manual water level manipulation; 4.5-300 ha in size; mean = 26.5 ha; annual sample sizes in Table 1).

Surveys

We used the nocturnal survey method of Fournier and Krementz (In Press) and drove systematic nocturnal transects on ATVs spaced 30 m apart. We used a spotlight to scan for flushing, walking or swimming Sora and took a GPS location at the point where the individual was first detected. We surveyed each year from August through October (Figure 1, Table 1, Appendix I). We visited each region four times a year, with a few exceptions, with at least two surveys being completed in each impoundment during each visit (Table 1).

Vegetation Data

We recorded available habitat measurements at 20 randomly placed 25 m diameter plots in each impoundment and we resampled them on each visit. We recorded used habitat measurements at up to 20 points in each where Sora were observed during surveys the previous night. We measured water depth (cm) at the center of the plot, and 5 m from the center in the four cardinal directions; we used the mean value of these five measurements to characterize water depth in each plot. We visually estimated the percent cover of plant groups in the plot in the following categories: annual and perennial moist soil plants, upland plants, woody vegetation, and open (non-vegetated) areas (Darrah and Krementz 2009, 2010). We also measured percent cover of crops and man-made structures, but these two cover types occurred so infrequently we did not include them in the analysis.

Annual moist soil plants included wetland plant species that fall below the water surface at the end of the growing season, smartweeds (Polygonum spp.) and millets (Echinochloa spp.; Cowardin et al. 1979). Perennial moist soil plants include wetland plant species which stay above the water surface at the end of the growing season, cattail (Typha spp.) and burreed (Sparganium spp.). Woody vegetation was predominantly willow (Salix spp.) and buttonbush (Cephalanthus occidentalis). Upland vegetation was composed of a wide suite of terrestrial annual plants, including upland grasses, goldenrods (Solidago spp.), milkweeds (Asclepias spp.), sunflowers (Helianthus spp.).

Analysis

Based on Haramis and Kearns et al. (2007) who found stopover of 40+ days for Sora during autumn migration we do not believe our observations of rails among visits to be independent. Because of this, we are modeling habitat selection for each visit separately (so 4 separate models). We examined habitat selection by Sora using binomial mixed models in R with the ‘lme4’ package (Bates et al. 2015, version 1.1-12). All analysis took place in R (R Core Team 2016. R Version 3.3.2).

We included mean water depth^2, annual moist soil vegetation percent cover, woody vegetation percent cover, open ground percent cover, upland vegetation percent cover and perennial moist soil vegetation percent cover as covariates with random effects of visit nested with year . All numeric covariates were scaled for analysis. Based on previous work (Sayre and

Rundle 1984, Reid 1989) and our observations in the field, where more birds were found in shallowly flooded wetlands and less were found in dry or deeply flooded wetlands we included a second order term for our mean water depth variable.

Results

We detected 7905 Sora during August-October 2012-2016 (per year sample size Table 1). Initial comparison of mean used and available data suggested some patterns (Table 2). Visit 1 models show differences in 2014 and 2015 compared to 2013, and negative selection for Woody Vegetation percent cover (Table 3, Figure 1). Visit 2 models show differences among all years compared to 2012, with positive selection for annual moist soil percent cover and negative selection for open area and perennial moist soil percent cover (Table 4, Figure 2). We also found a significant interaction between mean water depth and 2014 (Table 4, Figure 3). In Visit 3 we found significant differences between 2013, 2015, and 2016 compared to 2012 (Table 5). In visit 3 we found positive selection for mean water depth^2 and annual moist soil percent cover (Table 5, Figure 4). In visit 3 we found negative selection for all other variables and all combinations of mean water depth^2 and years (Table 5, Figure 4 and 5). In Visit 4 we found positive selection for annual moist soil percent cover, upland percent cover, and perennial moist soil percent cover (Table 6, Figure 6).

Discussion

We found the peak of Sora selection for average water depth was deeper than previous work (11-14 cm; Rundle and Fredrickson 1981; Fredrickson and Taylor 1982; Sayre and Rundle 1984; Ried 1989). Our peak water depths are more similar to the breeding season (38cm +/- 16cm, Johnson and Dinsmore 1986). Sora are often discussed as a generalist among the rails

(Melvin and Gibbs 2012) and we found them using water depths from dry to over 50cm in depth which speaks to their adaptability, especially through their ability to dive and swim under water.

We found Sora selected for higher percent cover of annual and perennial moist soil vegetation, though the relationship with perennial moist soil cover is weak, which is in line with previous work which found Sora using dense stands of short seed producing plants in combination with tall dense cover (Meanley 1969, Andrews 1973, Gries et al. 1980, Rundle and Fredrickson 1981, Sayre and Rundle 1984, Reid 1989). While perennial emergent vegetation, such as cattail and bulrush were found to be important predictors of nest density during the breeding season (Walkinshaw 1940, Pospichal and Marshall 1954, Tanner and Henderson 1956, Gries et al. 1980, Johnson and Disnmore 1985, 1986, Gibbs and Melvin 1990, Gibbs 1991, Crowley 1994) we found stronger selection for annual moist soil plants such as smartweeds and annual grass than we did for perennial moist soil plants (Meanley 1965, Rundle and Sayre 1983, Sayre and Rundle 1984). This lack of strong selection for perennial emergents may be two fold; first, perennial moist soil plants are not widely available on the wetlands we surveyed, and second the needs of individuals are different during migration. During the breeding season plant structure and cover for nesting and raising young may be more important, while during migration plant species which provide the greatest food resources are needed.

Frequently, the timing of management-driven wetland flooding is directed at migratory waterfowl (Bellrose 1980). During our first visits to wetland sites each year, in August, many wetlands were largely dry (Figure 3), and Sora were concentrated around available water. Gries et al. (1980) and Rundle and Fredrickson (1981) also found Sora congregated around flooded areas early in autumn migration. Sora migrate earlier in autumn than waterfowl (Sora: August - October, Fournier et al. In Press; waterfowl: October - January). Therefore the timing of flooding, directed at providing habitat for waterfowl, may not provide abundant habitat early in autumn migration for Sora. When the length of time a species migrates through an area lasts several months, managers must consider what habitat is available for the entire period and how this fits in with management or conservation interventions directed at other species. Early flooding could have drawbacks for other species, especially if it results in changes to the vegetation later in the season, such as vegetation falling below the waters surface earlier in the year. The limited area of flooded wetlands early in migration may affect the ability of Sora to survive and obtain resources to continue migrating, which needs to be considered as part of multispecies management in palustrine wetlands during the autumn season.

We have shown Sora select for dense stands of annual moist soil plant communities in shallowly flooded wetlands, though the depths Sora select for are not always available to them during autumn migration. The timing of management actions is critical to provide suitable habitat when it is needed by multiple species, including rails, waterfowl, other waterbirds, reptiles and amphibians and many others (Rundle and Fredrickson 1981; Kross and Richter 2016). With large scale loss of palustrine wetlands, science based management of remaining wetlands is of special concern. Public agencies especially are concerned about science based management to serve a wide suite of ecosystem services including habitat for migrating Sora. Here we present a solid foundation to support future management and research to better understand, conserve and manage Sora.

Acknowledgements

Funding provided by the U.S. Fish and Wildlife, the Missouri Department of Conservation, the U.S. Geological Survey Arkansas Cooperative Fish and Wildlife Research Unit, and the University of Arkansas for funding our study. We 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. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government. 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.

Literature Cited

Anderson JT, Smith LM. 2000. Invertebrate response to moist-soil management of playa wetlands. Ecological Applications 10:550–558. doi: 10.1890/1051-0761(2000)010[0550:IRTMSM]2.0.CO;2

Bates D, Maechler M, Bolker B, Walker S. 2015. Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software, 67:1-48. doi:10.18637/jss.v067.i01.

Bellrose FC. 1980. Ducks, geese and swans of North America. Stackpole, Mechanicsburg, Pennsylvania.

Case DJ, McCool DD. 2009. Priority Information Needs for Rails and Snipe. https://www.fws.gov/migratorybirds/pdf/surveys-and-data/Info-Needs-Rails-Snipe.pdf (July 2016)

Chandler RB, Royle JA, King DI. 2011. Inference about density and temporary emigration in unmarked populations. Ecology 92:1429–1435. doi: 10.1890/10-2433.1

Cowardin LM, Carter V, Golet FC, Laroe ET. 1979. Classification of wetlands and deepwater habitats of the United States. https://www.fws.gov/wetlands/documents/classification-of-wetlands-and-deepwater-habitats-of-the-united-states.pdf (July 2016)

Crowley SK. 1994. Habitat use and population monitoring of secretive waterbirds in Massachusetts. Master's Thesis, University of Massachusetts, Amherst.

Darrah AJ, and Krementz DG. 2009. Distribution and habitat use of King Rails in the Illinois and Upper Mississippi River Valleys. Journal of Wildlife Management 73:1380–1386.

Darrah AJ, and Krementz DG. 2010. Occupancy and Habitat use of the Least Bittern and Pied-Billed Grebe in the Illinois and Upper Mississippi River Valleys. Waterbirds 33:367–375.

Fournier AMV, Mengel DC, Gbur EE, and Krementz DG. In Press. The Timing of Autumn Sora (Porzana carolina) Migration in Missouri. Wilson Journal of Ornithology.

Fournier AMV, and Krementz DG. In Press. Nocturnal Distance Sampling All-Terrain Vehicle Surveys for Non-Breeding Rails. The Wildlife Society Bulletin.

Fournier AMV, and Krementz DG. In Review. Confirmation of diving and swimming behavior in the Sora (*Porzana carolina*).

Fredrickson LH, Taylor TS. 1982. Management of Seasonally Flooded Impoundments for Wildlife. http://www.fwspubs.org/doi/suppl/10.3996/012014-JFWM-009/suppl_file/012014-jfwm-009.s2.pdf (July 2016)

Gibbs JP, and Melvin SM. 1990. An assessment of wading birds and other wetlands avifauna and their habitat in Maine. Bangor, ME: Final Report, Maine Dep. Inland Fish. Wildl.

Gibbs JP, Longcore JR, McAuley DG and Ringelman JK. 1991. Use of wetland habitats by selected nongame waterbirds in Maine. U.S. Fish and Wildlife Service, Fish and Wildlife

Research no. 9.

Griese HJ, Ryder RA, Braun CE. 1980. Spatial and Temporal Distribution of Rails in Colorado. The Wilson Bulletin 92:96–102.

Johnson RR, and Dinsmore JJ. 1985. Brood-rearing and postbreeding habitat use by Virginia Rails and Soras. The Wilson Bulletin 97:551-554.

Johnson RR, and Dinsmore JJ. 1986. Habitat use by breeding Virginia Rails and Soras. Journal of Wildlife Management 50:387-392.

Kross CS, Richter SC. 2016. Species Interactions in Constructed Wetlands Result in Population Sinks for Wood Frogs (Lithobates sylvaticus) while Benefitting Eastern Newts (Notophthalmus viridescens). Wetlands. doi: 10.1007/s13157-016-0751-x

Kross J, Kaminski RM, Reinecke KJ, Penny EJ, Pearse AT. 2008. Moist-soil seed abundance in managed wetlands in the Mississippi Alluvial Valley. Journal of Wildlife Management 72:707–714. doi: 10.2193/2007-100

Meanley, B. 1965. Early-fall food and habitat of the Sora in the Patuxent River marsh. Chesapeake Science 6:235-237.

Melvin SM, and Gibbs JP. 2012. Sora (Porzana carolina), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/250

Pospichal LB, and Marshall WH. 1954. A field study of Sora Rail and Virginia Rail in central Minnesota. Flicker 26:2-32.

R Core Team. 2016. R: A language and environment for statistical computing.

Reid FA. 1989. Differential Habitat Use by Waterbirds In a Managed Wetland Complex. Dissertation - University of Missouri-Columbia

Rundle WD, and Fredrickson LH. 1981. Managing Seasonally Flooded Impoundments for Migrant Rails and Shorebirds. Wildlife Society Bulletin 9:80–87.

Rundle WD, and Sayre MW. 1983. Feeding Ecology of Migrant Sora in Southeastern Missouri. The Journal of Wildlife Management 47:1153–1159.

Sayre MW, and Rundle WD. 1984. Comparison of Habitat Use by Migrant Soras and Virginia Rails. The Journal of Wildlife Management 48:599–605.

Tanner WD, and Hendrickson GO. 1956b. Ecology of the Sora in Clay County, Iowa. Iowa Bird Life 26:78-81.

Walkinshaw LH. 1940. Summer life of the Sora Rail. Auk 57:153-168

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

Year	Start date	End date	Visits per state property	Visits per federal property	Number of Impoundments	Number of Sora detected	Number of Sora vegetation points	Number of available vegetation points
2012	17 August	7 October	3	3	40	1895	900	909
2013	11 August	27 October	3	4	39	1876	1890	624
2014	12 August	22 October	4	4	33	1268	2268	589
2015	12 August	23 October	4	4	33	1063	1710	522
2016	10 August	20 October	4	4	33	1803	2124	664

Table 2. Summary of available habitat mean, minimum and maximum values across and by year for wetland impoundments in Missouri, USA surveyed for Sora (*Porzana carolina*) from 2012-2016.

Variable	**Year**	**Mean Available**	**SD Available**	**Min Available**	**Max Available**	**Mean Sora Selected**	**SD Sora Selected**	**Min Sora Selected**	**Max Sora Selected**
Annual Moist Soil Vegetation (%)	2012	29.0	24.2	0.0	85.0	34.2	27.9	0.0	95.0
	2013	17.8	17.8	0.0	65.0	21.7	22.5	0.0	85.0
	2014	18.2	23.1	0.0	82.5	24.4	25.9	0.0	95.0
	2015	53.2	18.8	10.0	90.0	70.5	17.5	25.0	100.0
	2016	43.9	23.1	0.0	90.0	49.4	26.8	0.0	100.0
	all	28.2	19.1	0.0	75.0	37.0	26.6	0.0	95.0
Mean Water Depth (cm)	2012	4.4	6.5	0.0	25.2	11.1	9.6	0.0	35.4
	2013	3.0	5.2	0.0	20.3	1.5	3.0	0.0	12.2
	2014	8.7	10.5	0.0	34.9	19.1	11.7	0.0	41.8
	2015	3.8	5.5	0.0	22.0	14.9	8.9	0.0	32.6
	2016	5.3	8.2	0.0	22.6	14.1	8.9	0.0	32.0
	all	3.2	5.1	0.0	18.9	12.0	9.2	0.0	32.5

(Table 2 Continued)

Variable	Year	Mean Available	SD Available	Min Available	Max Available	Mean Sora Selected	SD Sora Selected	Min Sora Selected	Max Sora Selected
Open Area (%)	2012	15.6	15.5	0.0	47.5	16.0	14.4	0.0	52.5
	2013	3.5	7.9	0.0	40.0	7.3	10.6	0.0	35.0
	2014	12.6	19.3	0.0	70.0	5.6	11.4	0.0	50.0
	2015	10.6	17.6	0.0	60.0	5.9	8.5	0.0	32.5
	2016	9.9	17.5	0.0	60.0	4.4	9.0	0.0	30.0
	all	7.3	12.2	0.0	47.5	9.7	14.2	0.0	52.5
Perennial Moist Soil Vegetation (%)	2012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2014	0.0	0.0	0.0	0.0	24.4	25.2	0.0	80.0
	2015	0.2	1.3	0.0	7.5	12.1	14.5	0.0	50.0
	2016	0.0	0.0	0.0	0.0	13.0	20.6	0.0	85.0
	all	0.0	0.0	0.0	0.0	6.2	13.9	0.0	50.0

(Table 2 Continued)

Variable	**Year**	**Mean Available**	**SD Available**	**Min Available**	**Max Available**	**Mean Sora Selected**	**SD Sora Selected**	**Min Sora Selected**	**Max Sora Selected**
Upland Vegetation (%)	2012	13.0	22.6	0.0	98.5	8.0	13.7	0.0	57.5
	2013	3.4	9.2	0.0	40.0	7.1	12.8	0.0	50.0
	2014	11.8	23.7	0.0	95.0	14.8	19.8	0.0	65.0
	2015	9.3	18.6	0.0	85.0	1.3	6.3	0.0	32.5
	2016	11.8	14.3	0.0	52.5	12.9	20.8	0.0	77.5
	all	5.7	11.6	0.0	65.0	7.2	13.6	0.0	57.5
Woody Vegetation (%)	2012	2.1	5.0	0.0	22.0	1.3	3.6	0.0	16.0
	2013	1.5	4.0	0.0	22.5	1.4	5.5	0.0	25.0
	2014	0.5	1.3	0.0	5.0	0.3	1.2	0.0	5.0
	2015	4.0	6.5	0.0	25.0	0.7	3.0	0.0	15.0
	2016	0.9	2.6	0.0	10.0	1.0	2.2	0.0	7.5
	all	1.3	3.4	0.0	22.0	0.9	3.8	0.0	25.0

Table 3. Beta estimates from binomial mixed model of Sora (*Porzana carolina)* habitat selection in Visit 1.

	Estimate	Std. Error	p-value
(Intercept)	-2.94	0.64	<0.001
2014	-2.03	0.70	<0.001
2015	1.19	0.42	0.01
2016	0.25	0.44	0.57
Mean Water Depth^2	-6.05	4.69	0.20
Annual Moist Soil % Cover	0.67	0.39	0.09
Wood % Cover	-0.69	0.33	0.04
Open Area % Cover	-0.06	0.23	0.79
Upland % Cover	0.13	0.23	0.57
Perennial Moist Soil % Cover	0.33	0.23	0.15
2014 x Mean Water Depth^2	6.35	4.70	0.18
2015 x Mean Water Depth^2	5.98	4.70	0.20
2016 x Mean Water Depth^2	6.63	4.70	0.16

Table 4. Beta estimates from binomial mixed model of Sora (*Porzana carolina)* habitat selection in Visit 2.

	Estimate	Std. Error	p-value
(Intercept)	-0.91	0.28	<0.001
2013	-1.00	0.18	<0.001
2014	-0.49	0.19	0.01
2015	-1.25	0.22	<0.001
2016	-1.00	0.20	<0.001
Mean Water Depth^2	0.17	0.09	0.05
Annual Moist Soil % Cover	0.56	0.12	<0.001
Wood % Cover	-0.14	0.08	0.08
Open Area % Cover	-0.27	0.09	<0.001
Upland % Cover	-0.07	0.08	0.39
Perennial Moist Soil % Cover	0.24	0.08	<0.001
2013 x Mean Water Depth^2	-0.56	0.30	0.06
2014 x Mean Water Depth^2	-0.22	0.10	0.03
2015 x Mean Water Depth^2	0.25	0.14	0.08
2016 x Mean Water Depth^2	-0.21	0.13	0.12

Table 5. Beta estimates from binomial mixed model of Sora (*Porzana carolina)* habitat selection in Visit 3.

	Estimate	Std. Error	p-value
(Intercept)	0.41	0.23	0.08
2013	-1.97	0.17	<0.001
2014	0.03	0.17	0.87
2015	-1.02	0.2	<0.001
2016	-0.48	0.16	<0.001
Mean Water Depth^2	0.53	0.07	<0.001
Annual Moist Soil % Cover	0.26	0.09	<0.001
Wood % Cover	-0.43	0.06	<0.001
Open Area % Cover	-0.58	0.07	<0.001
Upland % Cover	-0.51	0.07	<0.001
Perennial Moist Soil % Cover	-0.33	0.07	<0.001
2013 x Mean Water Depth^2	-0.32	0.09	<0.001
2014 x Mean Water Depth^2	-0.56	0.07	<0.001
2015 x Mean Water Depth^2	-0.46	0.09	<0.001
2016 x Mean Water Depth^2	-0.38	0.09	<0.001

Table 6. Beta estimates from binomial mixed model of Sora (*Porzana carolina)* habitat selection in Visit 4.

	Estimate	Std. Error	p-value
(Intercept)	-3.48	0.41	<0.001
2014	0.02	0.30	0.95
2015	-0.20	0.29	0.48
2016	-0.29	0.29	0.31
Mean Water Depth^2	0.03	0.17	0.85
Annual Moist Soil % Cover	1.71	0.23	<0.001
Upland % Cover	0.75	0.14	<0.001
Perennial Moist Soil % Cover	0.89	0.13	<0.001
Wood % Cover	0.04	0.10	0.69
Open Area % Cover	0.36	0.13	0.01
2014 x Mean Water Depth^2	-0.08	0.17	0.64
2015 x Mean Water Depth^2	-0.19	0.18	0.31
2016 x Mean Water Depth^2	-0.05	0.18	0.80

Figure 1. Probability of Sora (*Porzana carolina*) selecting habitat variables across the range of available habitat from wetland impoundments surveyed during the first visit of surveys from 2012-2016 in Missouri, USA. Shaded area represents the 95% confidence interval around the estimate.

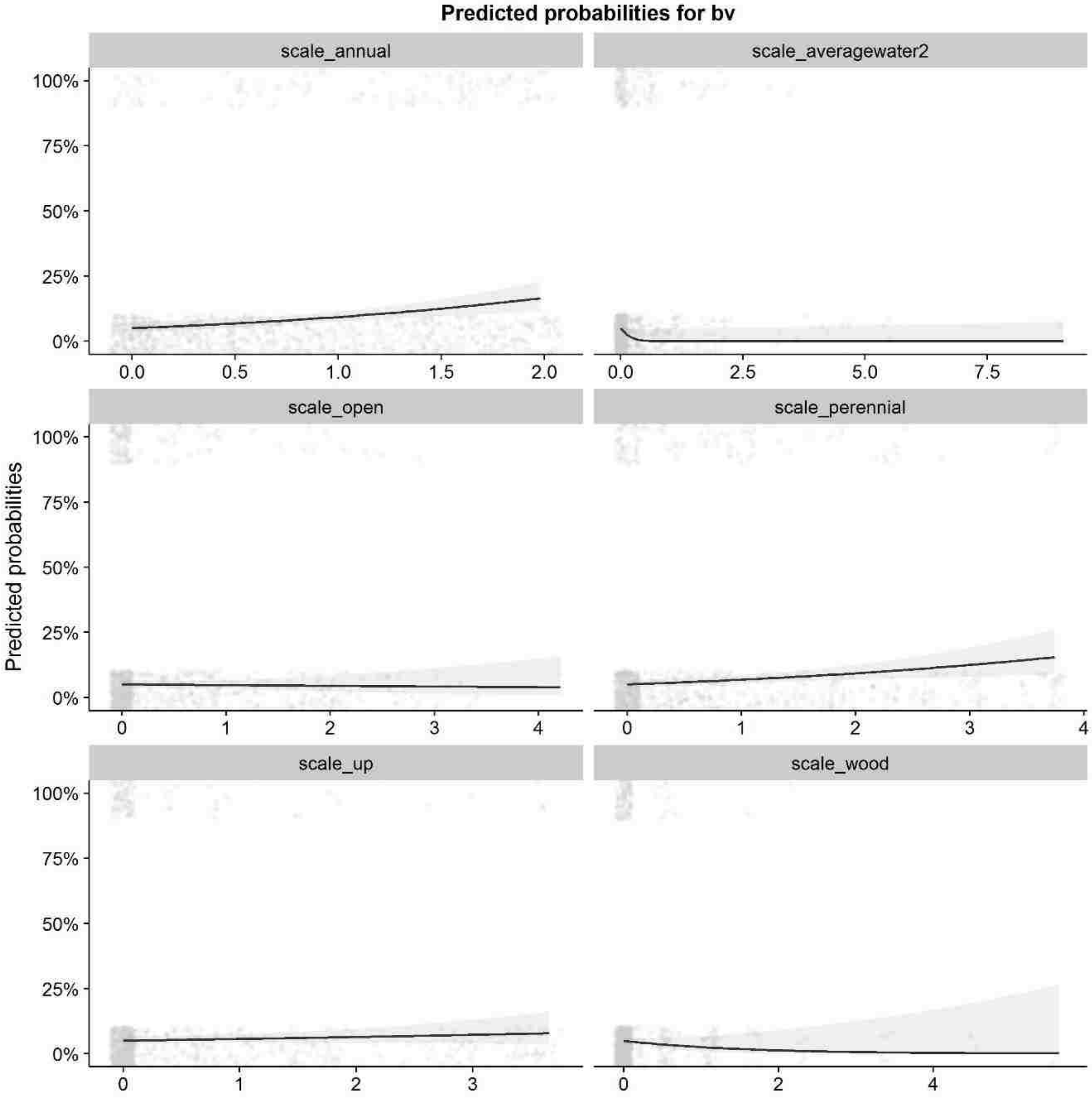


Figure 2. Probability of Sora (*Porzana carolina*) selecting habitat variables across the range of available habitat from wetland impoundments surveyed during the second visit of surveys from 2012-2016 in Missouri, USA. Shaded area represents the 95% confidence interval around the estimate.

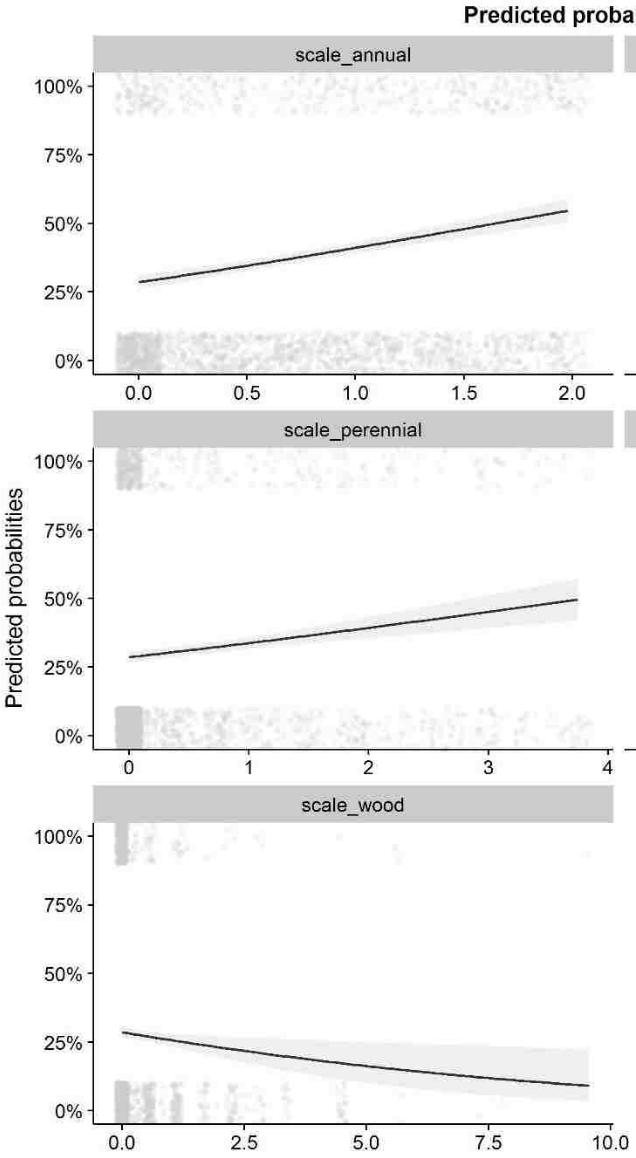


Figure 3. Probability of Sora (*Porzana carolina*) selecting mean water depth among years during the second visit of surveys from 2012-2016 in Missouri, USA. Shaded area represents the 95% confidence interval around the estimate.

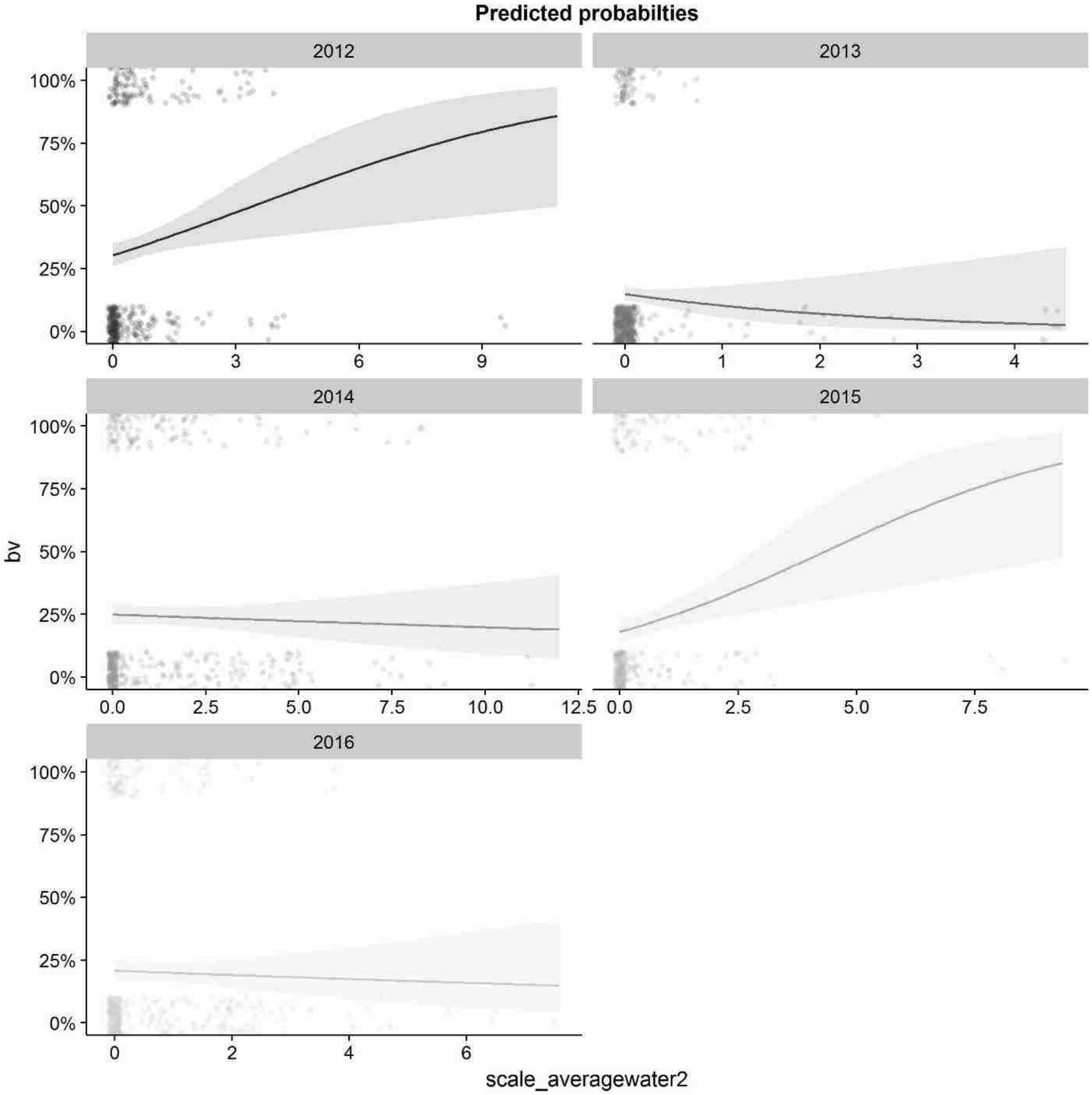


Figure 4. Probability of Sora (*Porzana carolina*) selecting habitat variables across the range of available habitat from wetland impoundments surveyed during the third visit of surveys from 2012-2016 in Missouri, USA. Shaded area represents the 95% confidence interval around the estimate.

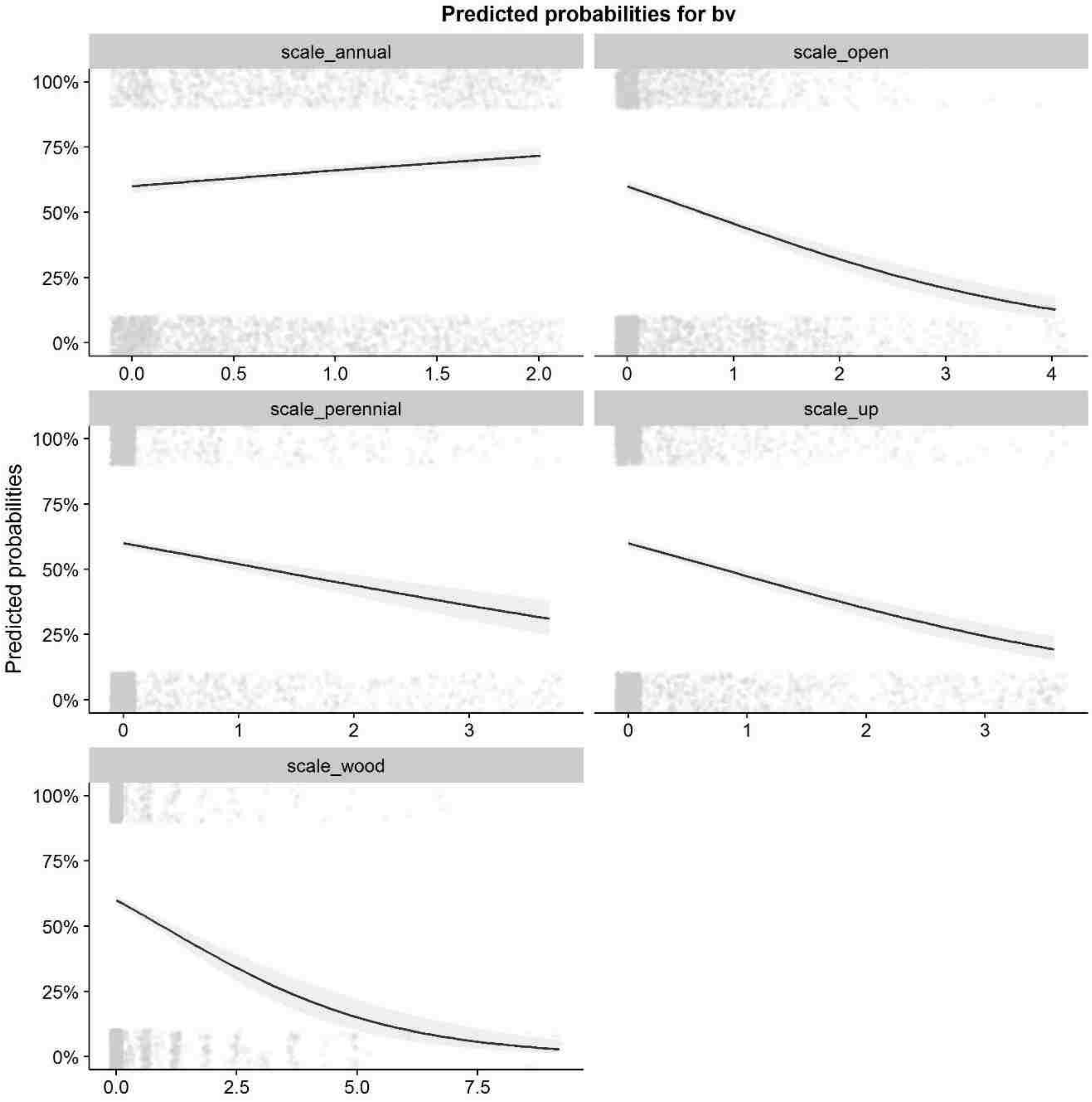


Figure 5. Probability of Sora (*Porzana carolina*) selecting mean water depth among years during the third visit of surveys from 2012-2016 in Missouri, USA. Shaded area represents the 95% confidence interval around the estimate.

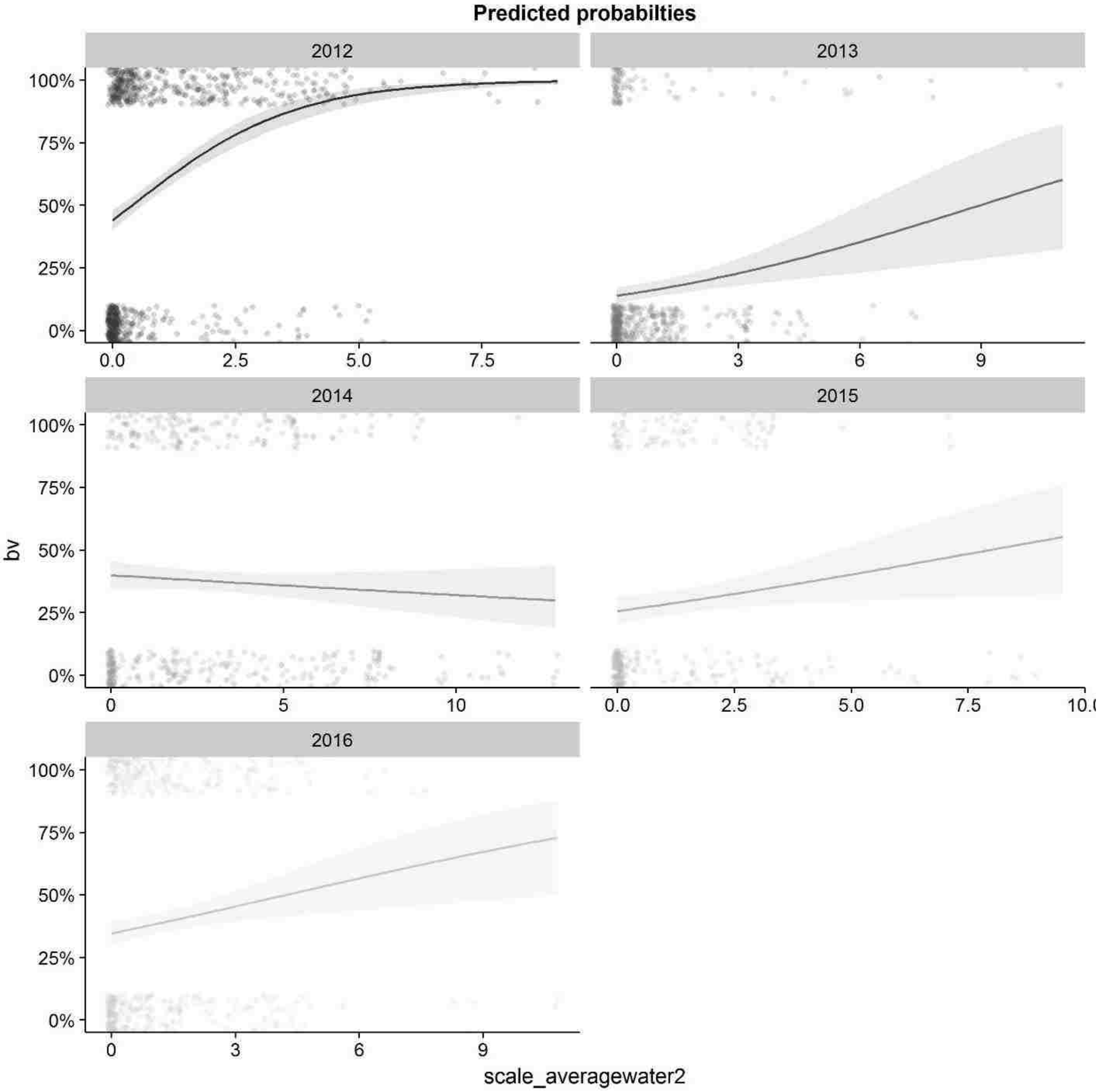
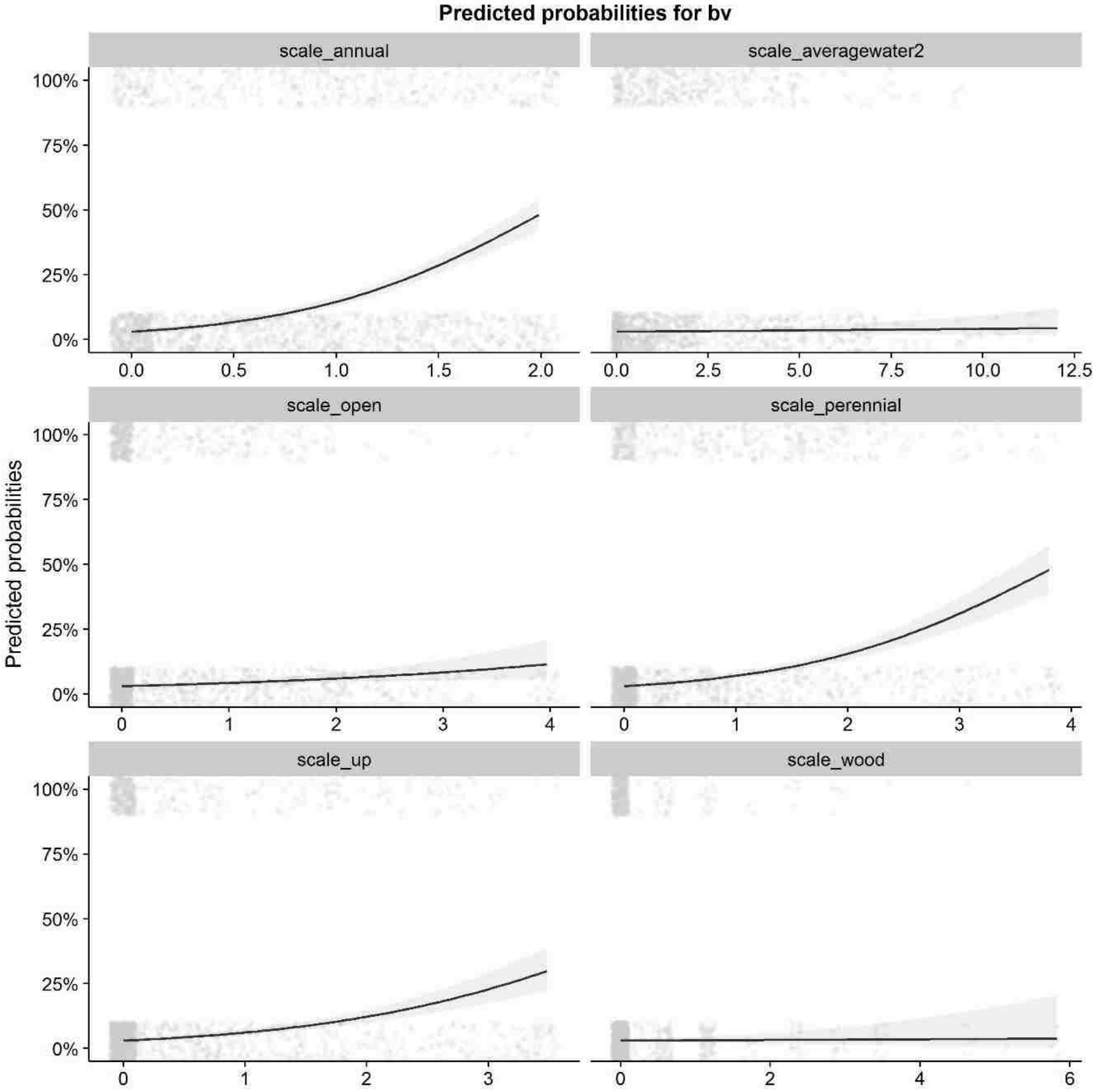


Figure 6. Probability of Sora (*Porzana carolina*) selecting habitat variables across the range of available habitat from wetland impoundments surveyed during the fourth visit of surveys from 2012-2016 in Missouri, USA. Shaded area represents the 95% confidence interval around the estimate.



Chapter 2, "Sora Habitat Use during Autumn Migration in Missouri" of A.M.V. Fournier's dissertation is intended for submission for publication with two coauthors, D.C. Mengel, and D.G. Krementz.

I, Dr. David G. Krementz, advisor of Auriel M.V. Fournier, confirm Auriel M.V. Fournier will be first author and completed at least 51% of the work for this manuscript.

David G Krementz   16 March 2017

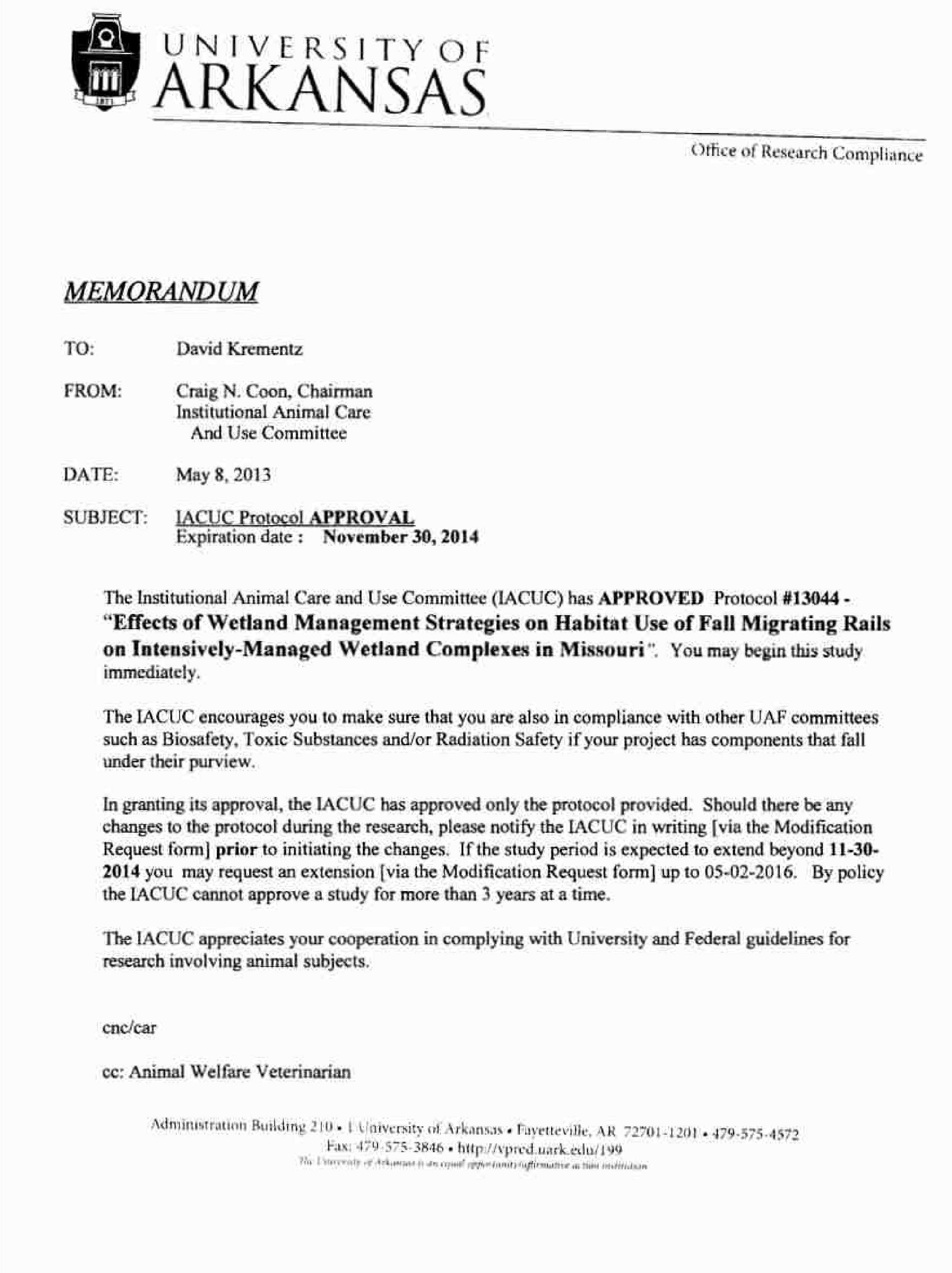
David G. Krementz   Date

Unit Leader

U.S. Geological Survey

Arkansas Cooperative Fish and Wildlife

Research Unit



UNIVERSITY OF
ARKANSAS

Office of Research Compliance

MEMORANDUM

TO: David Krementz

FROM: Craig N. Coon, Chairman
Institutional Animal Care
And Use Committee

DATE: May 8, 2013

SUBJECT: IACUC Protocol **APPROVAL**
Expiration date : **November 30, 2014**

The Institutional Animal Care and Use Committee (IACUC) has **APPROVED** Protocol **#13044 - "Effects of Wetland Management Strategies on Habitat Use of Fall Migrating Rails on Intensively-Managed Wetland Complexes in Missouri"**. You may begin this study immediately.

The IACUC encourages you to make sure that you are also in compliance with other UAF committees such as Biosafety, Toxic Substances and/or Radiation Safety if your project has components that fall under their purview.

In granting its approval, the IACUC has approved only the protocol provided. Should there be any changes to the protocol during the research, please notify the IACUC in writing [via the Modification Request form] **prior** to initiating the changes. If the study period is expected to extend beyond **11-30-2014** you may request an extension [via the Modification Request form] up to 05-02-2016. By policy the IACUC cannot approve a study for more than 3 years at a time.

The IACUC appreciates your cooperation in complying with University and Federal guidelines for research involving animal subjects.

cnc/car

cc: Animal Welfare Veterinarian

Administration Building 210 • 1 University of Arkansas • Fayetteville, AR 72701-1201 • 479-575-4572
Fax: 479-575-3846 • http://vpred.uark.edu/199

UNIVERSITY OF
ARKANSAS
Office of Research Compliance

MEMORANDUM

TO: David Krementz
FROM: Craig N. Coon, Chairman
DATE: Feb 6, 2015
SUBJECT: IACUC Approval
Expiration Date: Dec 31, 2016

The Institutional Animal Care and Use Committee (IACUC) has APPROVED your Protocol: 15023Effect of Wetland Management Strategies on Habitat Use of Fall Migrating Rails on Intensively-Managed Wetland Complexes in Missouri (beg. 6-15-15|

In granting its approval, the IACUC has approved only the information provided. Should there be any further changes to the protocol during the research, please notify the IACUC in writing (via the Modification form) prior to initiating the changes. If the study period is expected to extend beyond Dec 31, 2016 you must submit a modification or new protocol prior to that date to avoid any interruption. By policy the IACUC cannot approve a study for more than 3 years at a time.

The IACUC appreciates your cooperation in complying with University and Federal guidelines involving animal subjects.

CNC/aem

cc: Animal Welfare Veterinarian

Administration Building 210 • 1 University of Arkansas • Fayetteville, AR 72701-1201 • 479-575-4572
Fax: 479-575-3846 • http://vpred.uark.edu/199
The University of Arkansas is an equal opportunity/affirmative action institution.

CHAPTER 3

The use of monitoring data in species distribution models to inform the migratory connectivity of wetland birds

Auriel M.V. Fournier

and

Kiel L. Drake, Douglas C. Tozer

Abstract

Stable isotopes have been used to estimate migratory connectivity in many species. Estimates are often greatly improved when coupled with species distribution models (SDMs), which temper estimates in relation to the distribution of the population across space. Powerful SDMs can be constructed using extensive monitoring data typically collected by citizen scientists. A previous demonstration used extensive haphazard presence-only data from eBird, which provided large sample sizes, but came with challenges due to sampling bias. To avoid the challenges, we demonstrate the approach using SDMs based on marsh bird monitoring program data collected by citizen scientists and other participants following protocols specifically designed to maximize detections of species of interest at locations representative of larger areas of inference. We then used the SDMs to refine isotopic assignments of breeding areas of autumn-migrating and wintering Sora (*Porzana carolina*), Virginia Rails (*Rallus limicola*), and Yellow Rails (*Coturnicops noveboracensis*) based on feathers collected from individuals caught at various locations in the United States from Minnesota south to Louisiana and South Carolina. Sora were assigned to an area that included much of the western U.S. and prairie Canada, covering parts of the Pacific, Central, and Mississippi Flyways. Yellow Rails were assigned to a broad area along Hudson and James Bay in northern Manitoba and Ontario, as well as smaller parts of Quebec, Minnesota, Wisconsin, and Michigan, including parts of the Mississippi and Atlantic Flyways. Virginia Rails were from several discrete areas, including parts of Colorado, New Mexico, the central valley of California, and southern Saskatchewan and Manitoba in the Pacific and Central Flyways. Our study demonstrates extensive data from organized citizen science monitoring programs are especially useful for improving isotopic assignments of migratory connectivity in birds, which will ultimately lead to better management and conservation of species.

Introduction

Determining connections among breeding, migratory stopover, and wintering areas for different populations of migratory birds (hereafter ‘migratory connectivity’) is critically important for conserving species throughout their annual cycle (Webster et al. 2002). Quantifying migratory connectivity informs conservation by associating populations with limiting factors which allows more effective management of threats, such as habitat loss and climate change, because efforts can be directed to the populations and parts of the annual cycle that are affected the most (Norris and Taylor 2006, Taylor and Norris 2010, Rushing et al. 2016). Most studies examine migratory connectivity between wintering and breeding areas, but connectivity with stopover habitat during migration is also important in understanding potential limiting factors and other characteristics of populations throughout the annual cycle (e.g., Hobson et al. 2015).

There are a variety of effective methods for estimating migratory connectivity of birds including mark-recapture (Ryder et al. 2011), archival biologgers (Ryder et al. 2011, Salewski et al. 2013, Hallworth et al. 2013), collaborative radio tracking networks (Francis et al. 2016, Bird Studies Canada 2017b), and satellite transmitters (Krementz et al. 2011). Unfortunately, these methods do not work with all species. When a transmitter is too heavy relative to the weight of the species it is unsafe to attach the device. When a species has low site fidelity among years it becomes impractical to relocate and recapture individuals to retrieve the devices and the data the devices contain. In addition, collaborative radio-tracking networks, although extremely promising in the near-future for broad scale studies, are currently unavailable in key areas. In situations when the above approaches are ineffective, isotopes can be used because individuals need to be captured only once to obtain samples (e.g., feathers, toenails, blood), and no tracking devices need to be attached to the birds. In North America, the ratio of hydrogen isotopes (δ^2H) follows a spatial gradient from northwest to southeast and has been widely used to examine migratory connectivity of many species (Hobson and Wassenar 2008, Guillemain et al. 2014a, Butler et al. 2016). One disadvantage of stable hydrogen isotopes is the resulting coarse geographic assignments, which can limit the level of inference, but even limited inference can inform conservation if it's the only information available (Hobson and Wassenaar 2008). The incorporation of additional data, such as environmental variables, genetic information, band recovery data, and predictions from species distribution models (SDMs), can improve geographic assignment because populations are not equally spread over space (Royle and Rubenstein 2004, Hobson et al. 2013, Rushing et al. 2014, Ruegg et al. 2016). The results of these refinements often lead to assignments that are more informative for conservation and management purposes (Haig et al. 1998, Webster et al. 2002, Hobson 2005).

Of the many options for refining isotopic assignments of migratory connectivty, SDMs show excellent utility. The models can be used to predict species occurrence or abundance across vast unsampled areas, often with reasonable precision and accuracy based on existing data (Elith and Leathwick 2009). This information can then be coupled with isotopic assignments to produce refinements in relation to species occurrence or abundance. The most powerful SDMs for this purpose are ones based on extensive representative datasets through space and time.

Species abundance data at broad scales are most-easily obtained from citizen science monitoring programs. These programs operate by engaging volunteers and training them to follow standardized field survey protocols to collect reliable monitoring data. Due to the volunteer nature of the programs combined with widespread engagement of participants, citizen sciencetists often produce remarkably large sample sizes suitable for powerful SDM development. For instance, Fournier et al (2016) used haphazard presence-only citizen science data from eBird (Sullivan et al. 2009) to refine stable isotope assignments of migratory connectivity in the Virginia Rail (*Rallus limicola*). The approach was successful and substaintially improved the refinment of isotopic assignments. However, the authors noted challenges due to potential biases caused by factors driving where and how observers conduct surveys.

One way to overcome perceived bias associated with haphazard presence-only data is to use data collected by formal monitoring programs. In these programs, participants collect data at locations regardless of whether certain species were detected or not, following established protocols designed to maximize detections of species of interest (Conway 2011). Organized monitoring programs typically collect data at pre-determined randomly-chosen survey locations, making the data representative of entire populations. Therefore, data from organized bird monitoring programs is more suitable for developing SDMs to refine istopic assignments of migratory conenctivity.

In this paper, we demonstrate the use the SDMs, based on data collected by citizen scientists and other participants in organized marsh bird monitoring programs, to refine isotopic assignments of Sora (Porzana carolina), Virginia Rail, and Yellow Rail (Coturnicops noveboracensis) based on feathers collected from individuals caught at various autumn migration and wintering locations in the United States ranging from Minnesota to Louisiana and South Carolina. We chose these three rail species, in part, because they are elusive wetland birds that breed across a wide swath of North America, but are poorly studied (Eddleman et al. 1988). The species are of concern because they stopover in highly modified landscapes where wetland loss ranges 60-90%, and their populations are thought to be declining, but are not clearly understood (Reid 1989, Case and McCool 2009, Ducks Unlimited Canada 2010, Dahl 2011). In addition, Sora and Virginia

Rail are game bird species in some jurisdictions (Tacha and Braun 1994), while the Yellow Rail is a species of special concern in Canada (Alvo and Robert 2009). Knowledge of migratory connectivity in these three rail species is only now beginning to emerge (Butler et al. 2016, Fournier et al. 2016), and is needed to inform conservation and management efforts. Studying broad scale migratory connectivity in the three species is also currently unsuitable with any of the methods listed above, except for isotopes. Together, these characteristics made the species worthy candidates with which to demonstrate the method and approach.

Methods

Field

Migrating and Wintering Individuals

Sora, Yellow Rail, and Virginia Rail were captured using dipnets from all-terrain vehicles during autumn migration (August- October) 2015 at 10 sites in Missouri, USA (Perkins et al. 2010). Sora, Virginia Rail and Yellow Rail feathers from other migratory locations (Minnesota, Michigan, South Carolina, Ohio, and Arkansas, USA) and wintering locations (Louisiana and Mississippi, USA) were collected opportunistically by hunters and researchers from August through December 2015 (Table S2). The first primary feather, which is grown on the breeding grounds (Pyle 2008) and therefore has the isotopic signature of that location (Hobson et al. 2012a), was removed from each individual. Previously collected Yellow Rail feathers from another project were included to increase sample size and these feathers were collected in Missouri during autumn migration in 2013 and 2014.

Breeding Individuals

Sora, Yellow Rail and Virginia Rail were captured on foot during night using call broadcast lures and a dipnet in late-June and July 2015 near Foam Lake, Saskatchewan, Canada (51.6601, -

103.5538). Captures began at dusk and ran until dawn. Similar to migrants, the first primary feather was removed from each individual.

Laboratory

Feathers were cleaned with phosphate-free detergent and 2:1 chloroform methanol solution, rinsed in deionized water, and dried them at 50 °C for 24 hours. A total of 0.350 mg of material was weighed into silver capsules (Elemental Microanalysis, part# d2302) and analyzed by coupled pyrolysis/isotope-ratio mass spectrometry using a thermo-chemical elemental analyzer (TC/EA) (Thermo Scientific) interfaced to a Thermo Scientific Delta V Plus configured through a CONFLO IV for automated continuous flow gas-isotope ratio mass spectrometer (CF-IRMS) at the Colorado Plateau Stable Isotope Laboratory at Northern Arizona University.

Given that ~20% of the δ^2H in feathers exchanges freely with ambient water vapor (Wassenaar & Hobson 2003), we analyzed feathers concurrently with three calibrated keratin standards (Keratin – SC Lot SJ (powdered) mean = –120.7 ± 1.1 ‰, expected = –121.6 ‰, n=32; CBS – caribou hoof (powdered) mean= –198.5 ± 1.1 ‰, expected = –197.0 ‰, n=10; KHS – Kudo horn (powdered) mean= –55.1 ± 1.0 ‰, expected = –54.1 ‰, n=10) to allow for future comparison across laboratories (Wassenaar & Hobson 2003). We report the non-exchangeable δ^2H fraction in parts per mil (‰) normalized to the Vienna Standard Mean Ocean Water-Standard Light Antarctic Precipitation (VSMOW-SLAP) standard.

Species Distribution Models

We used count data from 7,146 100-m-radius plots surveyed largely by citizen scientists and other participants in Bird Studies Canada’s Great Lakes, Québec, and Prairie marsh monitoring programs (Bird Studies Canada 2017a; Tozer 2013, 2016) available through Nature Counts (Bird Studies Canada 2017c), and by observers in the North American Marsh Bird Monitoring

Program at various National Wildlife Refuges available from the Midwest Avian Data Center (Figure 1; Koch et al. 2010) to construct SDMs. These data spanned 1995-2015 and were collected under a slightly modified version of the Standardized North American Marsh Bird Monitoring Protocol (e.g., Tozer et al. 2016), which included the use of standardized call broadcasts of Sora, Yellow Rail, and Virginia Rail during point counts to increase detection probability (Conway 2011). We collapsed the dataset to include the highest count at a point across all the years the point was surveyed, which adjusted and controlled to a certain extent for potential differences in detection probability. We found this approach more attractive than the potential pitfalls associated with formally taking detection probability into account during modeling (Welsh et al. 2013, Guillera-Arroita et al. 2014b). Collapsing the data this way yielded 929 Sora, 695 Virginia Rail, 39 Yellow Rail points where at least one individual was detected and 4,056 Sora, 4,290 Virginia Rail, and 4,946 Yellow Rail points were each species was not detected in any year.

We created species distribution models describing Sora, Yellow Rail and Virginia Rail abundance using 11 raster layers (1 km^2 resolution) representing land cover (Latifovic et al. 2002), wetland presence (Lehner & Döll 2004), and bioclimatic parameters. We chose these layers because they likely influence precipitation, and thus stable isotope ratios across North America, as well as the distribution and abundance of the species we considered. We removed variables which were correlated (Pearson's correlation coefficient >=75%, See Table S1). We constrained predictions based on isotopes from each model to each species' summer range (BirdLife International & NatureServe 2015). Within each species' summer range, our goal, similar to Fournier et al. (2016), was to generate a SDM with the greatest predictive accuracy (see details below), but not necessarily informative for inferring environmental relationships

(Merow, Smith and Silander 2013). We included all 11 environmental covariates in the analysis and used leave-one-out jackknifing to identify covariates that reduced the predictive power of the model, which were then removed. All modeling took place in R (R Core Team 2016, version 3.3.2).

Spatially explicit assignment of geographic origins

We used the methods and code of Van Wilgenburg and Hobson 2011 to perform our spatially explicit isotopic assignments for each individual. Below is a summary of those methods. We used a likelihood-based assignment that incorporated estimates of uncertainty (Royle and Rubenstein 2004). Expected $\delta^2H_{feather}$ values were calculated by regressing raw δ^2H feather values of sampled feathers on mean annual growing season δ^2H in precipitation at the site of collection. This calibration was necessary to account for systematic differences between the δ^2H of sampled feathers and δ^2H in precipitation. Because we only had feathers from one breeding ground location, we included data from other projects in our linear regression of δ^2H of flight feathers to mean annual growing season δ^2H across North America (~37 × 37 km resolution; Bowen et al. 2005). This known-origin dataset included feathers from Foam Lake Saskatchewan (45 Sora feathers, 30 Yellow Rail Feathers and 4 Virginia Rail), and 10 Virginia Rail feathers from one location from Fournier et al. (2016), along with 44 King Rail feathers from Perkins (2007), including 13 museum specimens from 11 different localities and 31 live captured King Rail specimens. In total we had 133 feathers from 14 different localities (for additional detail on the feathers from locations outside of Saskatchewan see Appendix S1 in Fournier et al. (2016)). Because of small sample size for Yellow Rails in 2015, we also included feathers from autumn migration in 2013 and 2014. We did not find a significant difference between the median δ^2H values in Yellow Rails among years (ANOVA $F = 0.11$, $df = 21$, $p = 0.91$; Figure 2), suggesting that inter-annual variability in feather δ^2H was unlikely to be a significant source of variation for our analysis so we combined annual samples. We regressed our data of known-origin feathers against δ^2H precipitation to derive the calibration equation ($\delta^2H_{corrected} = -52.36 + 0.83[\delta^2H_{precipitation}]$).

For each feather we assessed the probability that any cell within the expected values was the origin of that individual using a normal probability density function as follows:

$$f(y*|\mu_c\sigma_c) = \left(\frac{1}{\sqrt{2\pi\sigma_c}}\right)\exp\left[-\frac{1}{2\pi\sigma_c^2}(y*-\mu_c)^2\right]$$

Where $f(y*|\mu_c\sigma_c)$ represents the probability that a given cell (c) within the δ^2HF isoscape represents a potential origin for an individual of unknown origin (y*), given the expected mean δ^2HF for that cell (μ_c) from the calibrated δ^2HF isoscape and the expected standard deviation (σ_c) of δ^2HF between individuals growing their feathers at the same locality. To assign probable breeding areas to samples within a particular state, we summed the assignments from each feather sample in units of the number of rails with origins consistent with a given pixel and converted to proportions to enable comparisons with other states, which we report only in the supplementary material. For each individual we produced a surface of spatially explicit probability densities (i.e., one surface per bird in a sample). We then incorporated the prior probabilities from our SDM by applying Bayes's Rule (Van Wilgenburg and Hobson 2011). To depict these origins across the entire sample size we assigned each feather to the base map individually by determining the odds that any given assigned origin was correct relative to the odds it was incorrect. Based on 3:1 odds that a given bird had originated from within the range we recorded the set of raster cells that defined the upper 75% of estimated origins and coded them as 1, all others as 0. We choose 3:1 odds based on Van Wilgenburg and Hobson (2011) where this ratio provided a compromise between the possibility of being incorrect and the bird assignment geographic resolution. The results of the individual assignments were then summed over all individuals, by addition of the surfaces. We facilitated this step by rescaling the posterior probabilities (f_x) relative to the maximum value within the posterior probability surface prior to applying the odds-ratio-based reclassification.

We made assignments using functions within the R statistical computing environment (R Core Team 2016, version 3.3.2) using the 'raster' package (Hijmans 2016, version 2.5-8). To make our results even more relevant for conservation, we also visually inspected assignments to determine broad overlap with traditional flyways used as administrative units by migratory game bird managers (US Fish and Wildlife Service 2017).

Results

Captures

We captured 142 southbound autumn migrating and wintering rails across the southern U.S., and 79 breeding rails at a wetland complex in Saskatchewan, Canada. Sora comprised the bulk of migrant and wintering samples (88%; 117 individuals; 8 states) followed by Virginia Rails (7%; 9 individuals; 2 states) and Yellow Rails (5%; 11 individuals; 2 states). Sora also comprised the bulk of breeder samples (57%; 45 individuals) followed by Yellow Rails (38%; 30 individuals) and Virginia Rails (5%, 4 individuals). See Table S2 for more details.

Species Distribution Models

All three species distribution models fit the data (Homer-Lemeshow Goodness of Fit Test, Sora $\chi2 = 4.7$, df = 8, p = 0.7; Virginia Rail $\chi2= 4.7$, df = 8, p = 0.7; Yellow Rail $\chi2= 4.4$, df = 8 p = 0.8). The top species distribution model for Yellow Rail contained mean temperature of driest quarter (β = -0.30, SE = 0.09, p = 0.002), mean temperature of warmest quarter (β = 0.28, SE = 0.14, p = 0.008), mean diurnal range (mean of monthly (max temp-min temp)) (β = 0.60, SE = 0.16, p <0.001) and a significant interaction between latitude and longitude (β = 2.09, SE = 0.59, p <0.001). The top species distribution model for Virginia Rail contained temperature seasonality (β = -0.002, SE = 0.0007, p = 0.002). The top species distribution model for Sora included annual mean temperature (β = 0.07, SE = 0.02, p=0.003), mean temperature of the warmest quarter (β = -0.09, SE = 0.02, p<0.001) and temperature seasonality (β = 0.001, SE = 0.0002, p <0.001).

Isotopic Assignments

Sora were assigned to an area that included much of the western U.S. and prairie Canada, covering parts of the Pacific, Central, and Mississippi flyways (Figure 3). Yellow Rails were assigned to a broad area along Hudson and James Bay in northern Manitoba and Ontario, as well as smaller parts of Quebec, Minnesota, Wisconsin, and Michigan, including parts of the Mississippi and Atlantic flyways (Figure 3). Virginia Rails were from several discrete areas, including the southern part of their breeding range in parts of Colorado, New Mexico, the central valley of California, and southern Saskatchewan and Manitoba in the Pacific and Central flyways (Figure 3). Due to small sample size (Table S2), we do not include breeding ground assignments broken down by state, although for the interested reader we include maps of these assignments in the supplementary material (Figure S2, S3, S4).

Discussion

We demonstrated the use of SDMs to inform isotopic assignments of migratory connectivity in wetland birds, based on organized marsh bird monitoring program data collected by citizen scientists and other participants. We found these data to be especially useful for this purpose for reasons related to sample size, search effort, detection probability, and ease of obtaining data, which we elaborate further below.

Powerful SDMs to refine isotopic assignments of migratory connectivity should be based on extensive datasets through space and time. Such data are most easily obtained by researchers from citizen science monitoring programs. These programs normally involve careful training of participants to follow well-established and tested field protocols that produce reliable data. Citizen science programs also typically engage impressive numbers of participants to survey numerous locations throughout large portions of the range of occurrence of species of interest. These characteristics produce datasets with large sample sizes that are powerful for capturing the range of conditions and circumstances under which species occur, leading to better predictions based on SDMs for refining isotopic assignments of migratory connectivity.

Various extensive citizen science datasets suitable for powerful bird SDM deveopment are freely-available to researchers, such as from the Christmas Bird Count (National Audubon Society 2010), eBird (Sullivan et al. 2009), Breeding Bird Survey (Link and Saur 1998, Price et al. 1995), breeding bird atlases (North American Ornithological Atlas Committee 2016), Project FeederWatch (Bird Studies Canada and Cornell Lab of Ornithology 2017), Nocturnal Owl Survey (Takats et al. 2001), and the North American Marsh Bird Monitoring Program (Conway 2011). Most of these and other useful sources of data are easily obtained through the various information nodes of the Avian Knowledge Network (2017), such as the ones used to obtain data for this paper: Nature Counts (Bird Studies Canada 2017a) and Midwest Avian Data Center (Koch et al. 2010).

Some of these datasets, however, are more useful or easier to implement than others for developing SDMs. Like the programs that produced data for this paper, some monitoring programs pre-select survey locations so the points are representative of larger areas of inference, typically by using various randomization procedures (e.g., Johnson et al. 2009). Many of these programs also record data regardless of whether certain species were detected or not, following protocols specifically designed to maximize detections of species of interest (e.g., Conway 2011). Such protocols include restrictions on the time of day and season, type of weather, and the amount of background noise that is acceptable during surveys (e.g., Tozer et al. 2016). Protocols also include requirements on the minimum number of visits per survey location, and the total duration of each survey, plus some use standardized call broadcasts to increase the probability of detection of especially elusive species. All of these characteristics provide more reliable information on the presence or absence or abundance of species of interest. These programs, which are dedicated to generating reliable, representative data on occurrences or counts of species may be the best choice, when available, for developing SDMs to refine isotopic assignments of migratory connectivity.

By contrast, monitoring programs that lack the standardized restrictions and guidelines noted above can pose challenges for SDM development. This was shown by the additional bias-correction analysis that Fournier et al. (2016) were required to perform during their use of SDMs based on eBird data to refine isotopic assignments of migratory connectivity in the Virginia Rail. The bias was thought to occur because there are no restrictions on where and how eBird participants survey for rails or other species. While this flexibility is a major advantage of eBird and other programs like it for numerous other applications, the lack of organized standardization of surveys causes challenges for SDM development (Yackulic et al 2012).

Our SDMs might have provided better assignment resolution if finer-scale habitat covariates, especially wetland cover, were available in a consistent format across Canada and the U.S. Our analysis might also have been improved by simultaneously considering another isotope, such as Sulphur ($\delta^{34}S$). Some rails use brackish or saline habitats during the breeding season, and this would be reflected in their $\delta^{34}S$ feather signatures, potentially helping to further refine assignments (Hobson et al. 2012b, Butler et al. 2016). The incorporation of genetic information might also have been beneficial, though currently, to our knowledge, such information is not available for rails.

We combined isotopic signatures of the largest sample of autumn-migrating and wintering rails with SDMs based on organized marsh bird monitoring data to produce the most extensive estimates of migratory connectivity of three rail species currently available. We found that the migratory connectivity of the three species included wide-ranging breeding areas, including more than one migratory game bird flyway in the two hunted species—results useful for improving conservation of these poorly-studied species—although additional work is needed to fully establish patterns. Extensive data from organized citizen science monitoring programs are especially useful for improving isotopic assignments of migratory connectivity in birds, which will ultimately lead to better management and conservation of species.

Acknowledgements

Funding provided through the Arkansas Cooperative Fish and Wildlife Research Unit, Bird Studies Canada’s Long Point Waterfowl and Wetlands Research Program, Garden Club of America’s Frances M. Peacock Scholarship for Native Bird Habitat, SC Johnson, and The Bluff's Hunting Club. A special thank you goes to the many volunteers and employees who have contributed to provincial and state marsh bird monitoring programs. Thanks to Matt Boone, Nick Seeger, Dan Datlof, Dan Holm, Hailee Pavisich, Patrick Turgeon, David Anderson, Erik Johnson, Christine Hand, John Simpson and LeeAnn Latremouille who helped capture birds and collect feathers for this project. Special thanks go to Alex Bond and David Krementz for comments that greatly improved an earlier version of the manuscript. Feathers were collected in Canada under federal bird banding permit #10842, #10842C, #10842D, and #10842F, and in the U.S. under federal bird banding permit #23002. University of Arkansas IACUC protocols #15049, #15023, and #13044 covered this project.

Literature Cited

Alvo, R. and Robert, M. 1999. COSEWIC status report on the Yellow Rail *Coturnicops noveboracensis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-62 pp. http://www.registrelep-sararegistry.gc.ca/ virtual_sara/files/cosewic/sr_Yellow%20Rail_0810_e.pdf (Accessed 13 September 2016)

Bird Studies Canada. 2017a. Marsh Monitoring Program. http://www.birdscanada.org/volunteer/ natmmp/index.jsp?lang=EN (Accessed 25 January 2017).

Bird Studies Canada. 2017b. Motus Wildlife Tracking System. http://www.birdscanada.org/ research/motus/index.jsp?lang=EN (Accessed 25 January 2017).

Bird Studies Canada. 2017c. Nature Counts. http://www.birdscanada.org/birdmon/default/main.jsp (Accessed 25 January 2017).

Bird Studies Canada and Cornel Lab of Ornithology. 2017. Project FeederWatch. http://feederwatch.org/ (Accessed 25 January 2017).

BirdLife International and NatureServe. 2015. Bird species distribution maps of the world. BirdLife International, Cambridge, UK and NatureServe, Arlington, USA.

Butler, C. J., Wilson, J.K., Frazee, S. R., and Kelly, J. F. 2016. A comparison of the origins of yellow rails (Coturnicops noveboracensis) wintering in Oklahoma and Texas, USA. – Waterbirds. 39: 156–164.

Bowen, G.J. 2008. Spatial analysis of the intra-annual variation of precipitation isotope ratios and its climatological corollaries - J. Geophys. Res. Atmos. 113: D05113. doi:10.1029/2007JD009295

Bowen, G. J., Wassenaar, L.I. and Hobson, K.A. 2005. Global application of stable hydrogen and oxygen isotopes to wildlife forensics. - Oecologia. 143: 337–348

Case, D. J., and McCool, D. D. 2009. Priority information needs for rails and snipe.

Conway, C. J. 2011. Standardized North American marsh bird monitoring protocol. – Waterbirds. 34: 319–346.

Dahl, T. E. 2011. Status and trends of wetlands in the conterminous United States 2004 to 2009. US Department of the Interior, US Fish and Wildlife Service, Fisheries and Habitat Conservation.

Ducks Unlimited Canada. 2010. Southern Ontario wetland conversion analysis. Final report, March 2010. Published by Ducks Unlimited Canada, Barrie, ON. http://www.ducks.ca/assets/2010/10/duc_ontariowca_optimized.pdf (Accessed 5 June 2015).

Eddleman, W. R., F. L. Knopf, B. Meanley, F. A. Reid, and R. Zembal. 1988. Conservation of North American Rallids. - The Wilson Bulletin 100:458–475.

Elith, J., and Leathwick, J. R. 2009. Species Distribution Models: Ecological Explanation and Prediction across Space and Time.

Fournier, A. M. V., Sullivan, A. R., Bump, J. K., Perkins, M., Shieldcastle, M. C. and King, S. L. 2016. Combining citizen science species distribution models and stable isotopes reveals migratory connectivity in the secretive Virginia rail. J Appl Ecol. doi:10.1111/1365-2664.12723

Francis, C., Taylor, P. D., and Crysler Z. J. 2016. BOU Proceedings – Birds in time and space: avian tracking and remote sensing. Proceedings of the BOU's 2015 Annual Conference

Guillemain, M., Van Wilgenburg, S. L., Legagneaux, P. and Hobson, K. A. 2014a. Assessing geographic origins of Teal (Anas crecca) through stable-hydrogen isotope analyses of feathers and ring-recoveries. - J. Ornithol. 155: 165–172.

Guillera-Arroita, G., Lahoz-Monfort, J.J., MacKenzie, D.I., Wintle, B.A., McCarthy, M.A. 2014b. Ignoring Imperfect Detection in Biological Surveys Is Dangerous: A Response to 'Fitting and Interpreting Occupancy Models'. PLoS ONE 9: e99571.

Haig, S. M., Mehlman, D. W. and Oring, L. W. 1998. Avian movements and wetland connectivity in landscape conservation. - Conserv. Biol. 12: 749–758.

Hallworth, M. T., Studds, C. E., Sillett, T. S. and Marra, P. P. 2013. Do archival light-level geolocators and stable hydrogen isotopes provide comparable estimates of breeding-ground origin? – Auk. 130: 273–282.

Hijmans, R.J. 2016. raster: Geographic Data Analysis and Modeling. R package version 2.5-8. https://CRAN.R-project.org/package=raster

Hobson, K. A. 2005. Using stable isotopes to trace long distance dispersal in birds and other taxa. - Divers. Distrib. 11: 157–164.

Hobson, K. A., and Wassenaar, L. I. 2008. Tracking animal migration with stable isotopes. Elsevier.

Hobson, K. A., S. L. Van Wilgenburg, L. I. Wassenaar, and K. Larson 2012a. Linking hydrogen (^{2}H) isotopes in feathers and precipitation: Sources of variance and consequences for assignment to isoscapes. PLoS ONE 7:1–9. doi: 10.1371/journal.pone.0035137

Hobson, K. A., Van Wilgenburg, S. L., Wassenaar, L. I., Powell, R. L., Still, C. J., and Craine, J. M. 2012b. A multi-isotope (δ^2H , δ^{13}C , δ^{15}N) approach to establishing migratory connectivity in Palearctic Afrotropical migrants : An example using Wood Warblers Phylloscopus sibilatrix. - Ecosphere, 3: 44.

Hobson, K. A., Van Wilgenburg, S. L., Ferrand, Y., Gossman, F. and Bastat, C. 2013. A stable isotope (^{2}H) approach to deriving origins of harvested woodcock taken in France. - Eur. J. Wildl. Res. 59: 881–892.

Hobson, K. A., Van Wilgenburg, S. L. , Dunn, E. H., Hussell, D. J. T., Taylor, P. D., and Collister, D. M. 2015. Predicting origins of passerines migrating through Canadian migration monitoring stations using stable hydrogen isotope analyses of feathers: a new tool for bird conservation. Avian Conservation and Ecology 10(1): 3. http://dx.doi.org/10.5751/ACE-00719-100103.

Johnson, D.J., Gibbs, J.P., Herzog, M., Lor, S., Niemuth, N. D., Ribic, C. A., Seamans, M., Shaffer, T.L., Shriver, W. G., Stehman, S. V., and Thompson, W. L. 2009. A Sampling Design Framework for Monitoring Secretive Marshbirds. Waterbirds 32:203-215

Koch, K., D. Moody, S. Michaile, M. Magana, M. Fitzgibbon, G. Rowell, T. Will, and G. Ballard. 2010. The Midwest Avian Data Center. [web application]. Petaluma, California. http://data.pointblue.org/partners/mwadc.

Krementz, D. G., Asante, K. and Naylor, L. W. 2011. Spring migration of mallards from Arkansas as determined by satellite telemetry. - J. Fish Wildl. Manag. 2: 156–168.

Latifovic, R., Zhu, Z.-L., Cihlar, J. & Giri, C. 2002. Land cover of North America 2000. Natural Resources Canada, Canada Center for Remote Sensing, US Geological Service EROS Data Center

Lehner, B. and Döll, P. 2004. Development and validation of a global database of lakes, reservoirs and wetlands. - J. Hydro. 296: 1-22.

Link, W.A. & Sauer, J.R. 1998. Estimating population change from count data: Application to the North American Breeding Bird Survey. Ecological Applications, 8, 258–268.

Merow, C., Smith, M. J. and Silander, J. A. 2013. A practical guide to MaxEnt for modeling species’ distributions: what it does, and why inputs and settings matter. Ecography, 36: 1058–1069. doi:10.1111/j.1600-0587.2013.07872.x

National Audubon Society 2010. The Christmas Bird Count Historical Results [Online]. Available http://www.christmasbirdcount.org

Norris, D. R. and Taylor, C. M. 2006. Predicting the consequences of carry-over effects for migratory populations. – Biol. Letters 22:148-151

North American Ornithological Atlas Committee. 2016. Handbook for atlasing North American breeding birds. http://www.bsc-eoc.org/norac (Accessed 1 February 2017).

Perkins, M. 2007. The Use of Stable Isotopes To Determine The Ratio Of Resident to Migrant King Rails In Southern Louisana and Texas. Louisana State University.

Perkins, M., King, S. L. and Linscombe, J. 2010. Effectiveness of capture techniques for rails in emergent marsh and agricultural wetlands. - Waterbirds 33: 376–380.

Price, J.T., Droege, S. & Price, A. 1995. Summer atlas of North American birds. Academic Press, London.

Pyle, P. 2008. Identification Guide to North American Birds Part II (First Edit). Point Reyes Station, California: Slate Creek Press.

R Core Team. 2016. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Version 3.3.2

Reid, F. A. 1989. Differential habitat use by waterbirds in a managed wetland complex. University of Missouri-Columbia.

Royle, J. A., and Rubenstein, D. R. 2004. The role of species abundance in determining breeding origins of migratory birds with stable isotopes. – Eco. Apps. 14: 1780–1788.

Ruegg K.C. , Anderson E., Harrigan R. J., Paxton K. L., Kelly J., Moore F., Smith T. B. 2016. bioRxiv 085456; doi: 10.1101/085456

Rushing, C. S., Ryder, T. B., Saracco, J. F. and Marra, P. P. 2014. Assessing migratory connectivity for a long-distance migratory bird using multiple intrinsic markers. Ecological Applications, 24: 445–456. doi:10.1890/13-1091.1

Rushing, C. S., Ryder, T. B., Mara, P. P. 2016. Quantifying drivers of population dynamics for a migratory bird throughout the annual cycle. - Proc. R. Soc. B 283:20152846.

Ryder, T. B., J. W. Fox, and P. P. Marra. 2011. Estimating Migratory Connectivity of Gray Catbirds (Dumetella carolinensis) using Geolocator and Mark—Recapture Data. The Auk 128:448–453.

Salewski, V., Flade, M., Poluda, A., Kiljan, G., Liechti, F., Lisovski, S. and Hahn, S. 2013. An unknown migration route of the "globally threatened" Aquatic Warbler revealed by geolocators. - J. Ornithol. 154: 549–552.

Sullivan, B.L., C.L. Wood, M.J. Iliff, R.E. Bonney, D. Fink, and S. Kelling. 2009. eBird: a citizen-based bird observation network in the biological sciences. Biological Conservation 142: 2282-2292.

Tacha, T.C., and Braun, C.E., editors. 1994. Migratory Shore and Upland Game Bird Management in North America. International Association of Fish and Wildlife Agencies, Washington, D.C.

Takats, D. L., Francis, C. M., Holroyd, G. L., Duncan, J. R., Mazur, K. M., Cannings, R. J., Harris, W., Holt, D. 2001. Guidelines for Nocturnal Owl Monitoring in North America. Beaverhill Bird Observatory and Bird Studies Canada, Edmonton, Alberta. 32 pp. http://www.birdscanada.org/download/owlguidelines.pdf.

Tozer, D. C. 2013. The Great Lakes Marsh Monitoring Program 1995-2012, 18 years of surveying birds and frogs as indicators of ecosystem health. Published by Bird Studies Canada, Port Rowan, ON. http://www.birdscanada.org/download/GLMMPreport.pdf.

Tozer, D. C. 2016. Marsh bird occupancy dynamics, trends, and conservation in the southern Great Lakes basin: 1996 to 2013. Journal of Great Lakes Research 42:136-145.

Tozer, D. C., Drake, K. L., Falconer, C. M. 2016. Modeling detection probability to improve marsh bird surveys in souther canada and the great lakes states. - Avian. Cons. Ecol. 11:3.

Taylor, C. M., and Norris, D. R. 2010. Population dynamics in migratory networks. - Theor. Eco. 3: 65–73.

US Fish and Wildlife Service. 2017. Waterfowl hunting management in North America Flyways.US: A collaborative effort of waterfowl managers across the continent. US Fish and Wildlife Service. http://flyways.us/ (Accessed 25 January 2017).

Van Wilgenburg, S. L., and Hobson, K. A. 2011. Combining stable-isotope (deltaD) and band recovery data to improve probabilistic assignment of migratory birds to origin. - Ecol. Appl. 21: 1340–51.

Wassenaar, L. I., and Hobson, K. A. 2003. Comparative equilibration and online technique for determination of non-exchangable hydrogen of keratins for use in animal migration studies. - Isot. Environ. Healt. S. 39: 211–217.

Webster, M. S., Marra, P. P., Haig, S. M., Bensch, S. and Holmes, R. T. 2002. Links between worlds: unraveling migratory connectivity. - Trends Ecol. Evol. 17: 76–83.

Welsh, A.H., Lindenmayer, B.D., Donnelly, C.F. 2013. Fitting and Interpreting Occupancy Models. PLoS ONE 8: e52015.

Yackulic, C.B., Chandler, R., Zipkin, E.F., Royle, J.A., James, D., Grant, E. H. C. & Veran, S. 2012. Presence-only modeling using MAXENT: when can we trust the inferences? - Meth. Eco. Evol. 4: 236-243

Figure 1. Locations of marsh bird monitoring program survey points used to develop species distribution models, and states where autumn-migrating and wintering rails were captured and sampled or isotopic analysis.

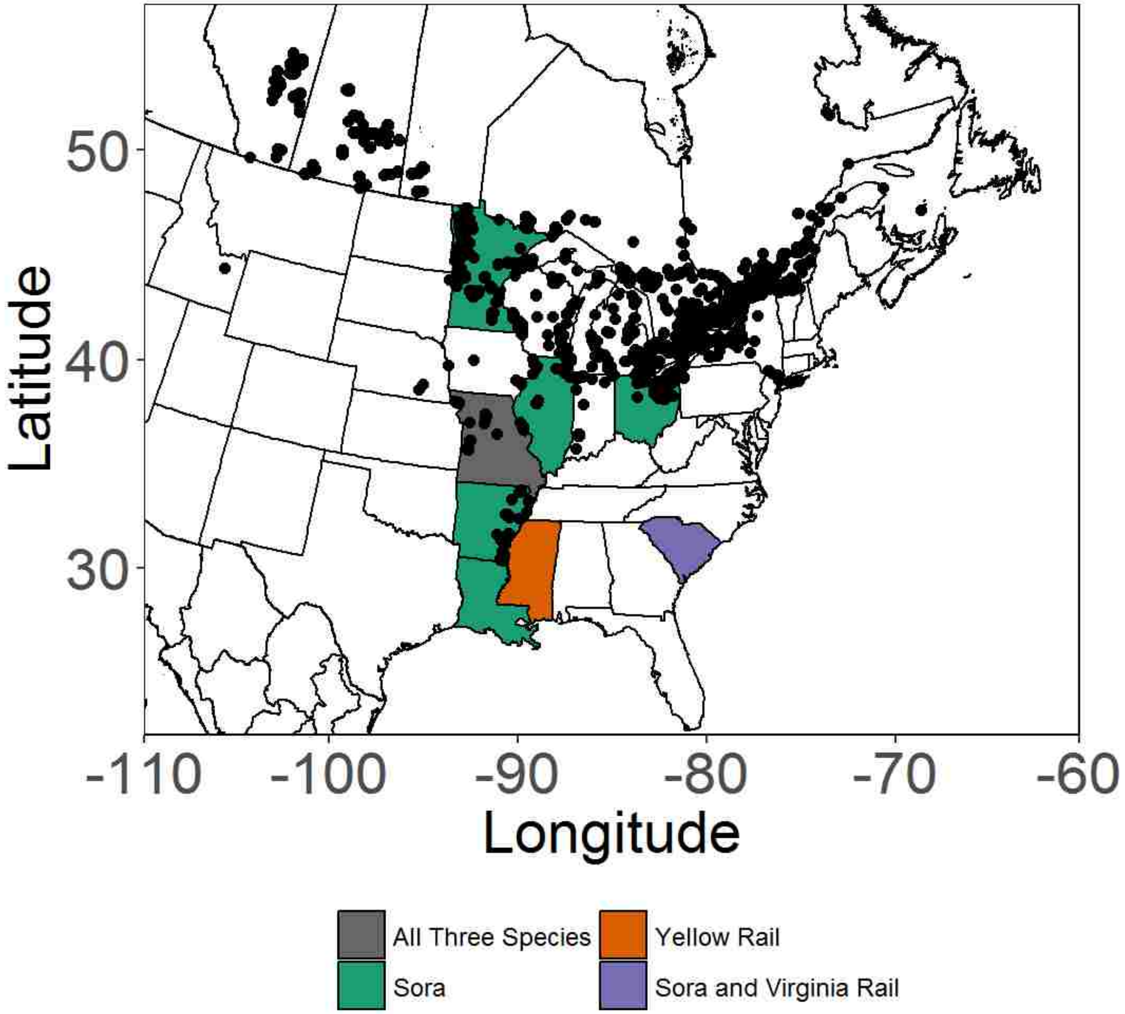


Figure 2 – Distribution of δ^2H values of feathers from rails caught at Foam Lake, Saskatchewan, Canada. The horizontal line represents δ^2H in precipitation from Bowen et al. (2005).

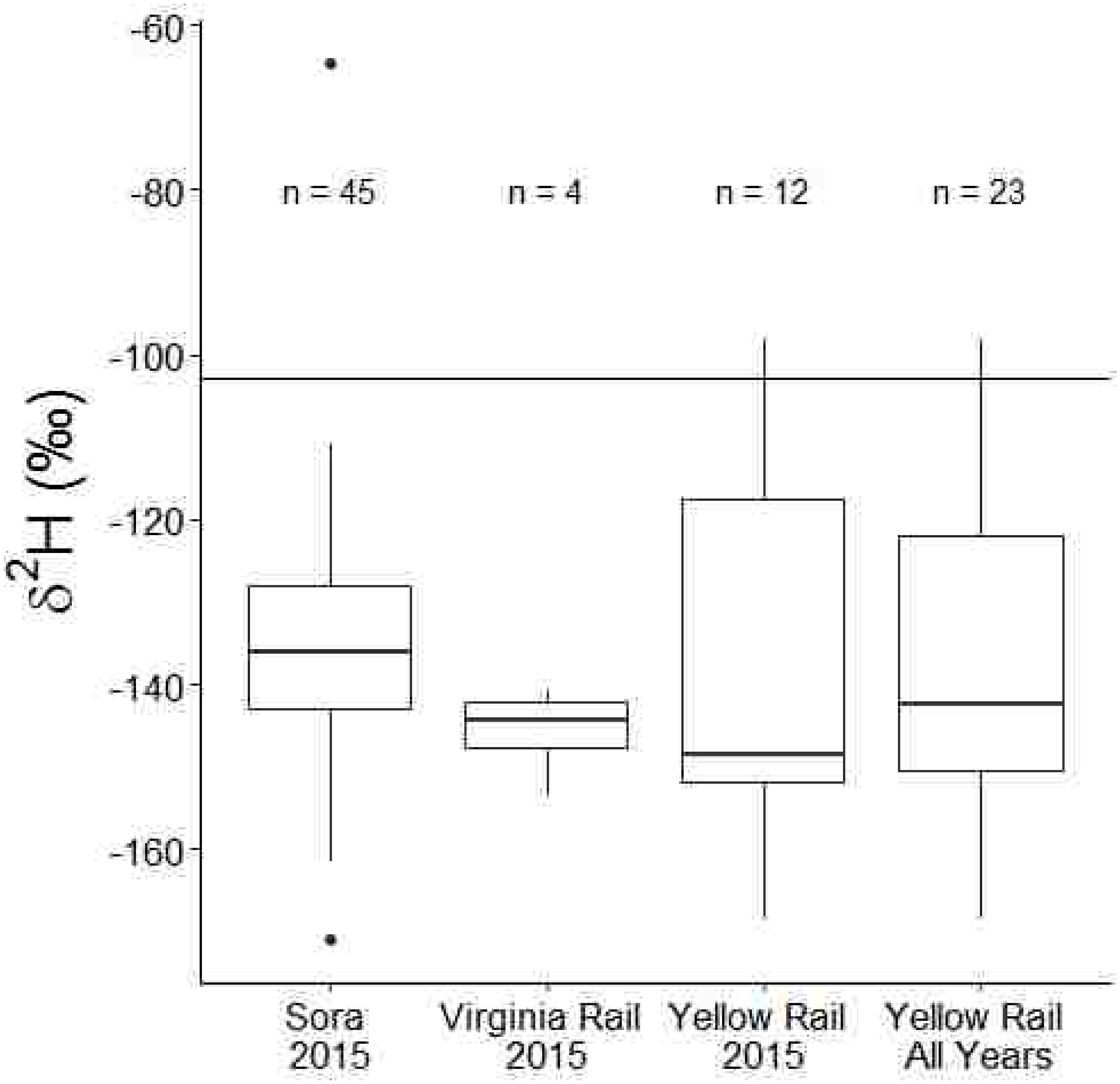
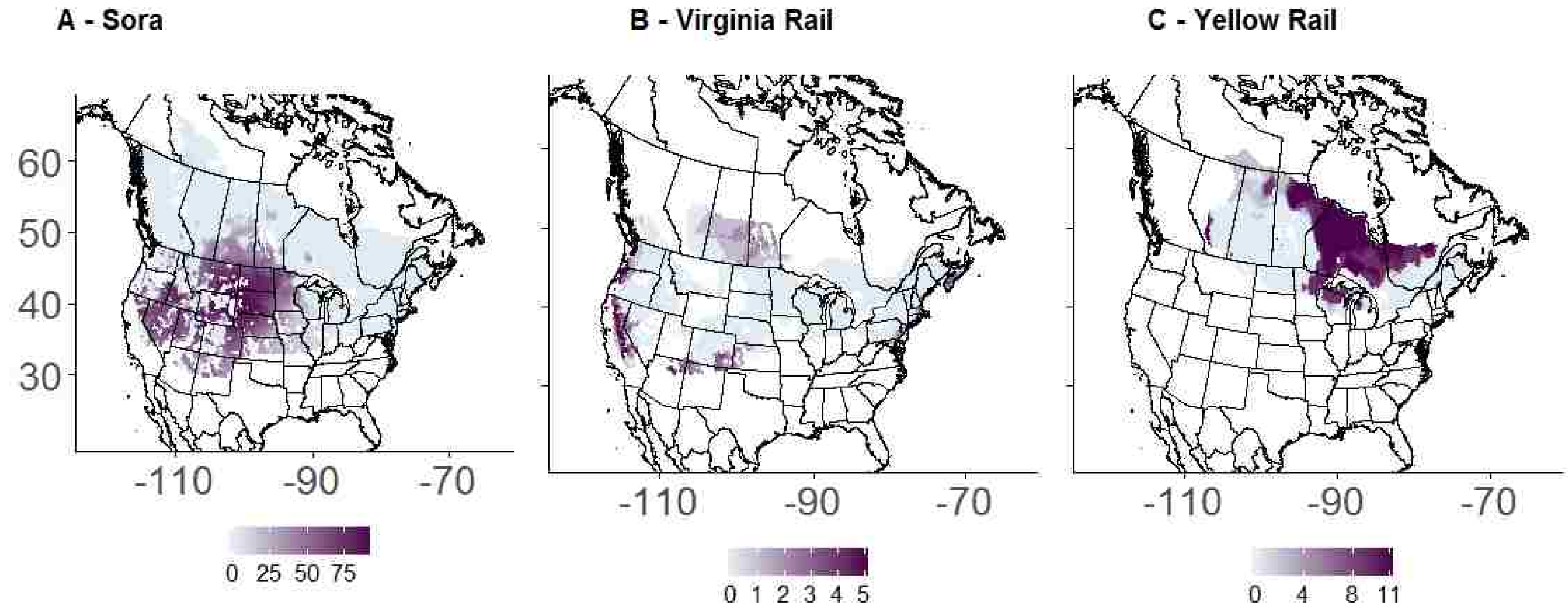


Figure 3 – Cumulative assignment of breeding areas of autumn migrating and wintering Sora (*Porzana carolina*), Virginia Rails (*Rallus limicola*) and Yellow Rails (*Corturnicops noveboracensis*) based on expected $\delta^2H_{feather}$ values using regional monitoring data in a species distribution model as an informative prior. Each individual bird's assignment surface represents the area where the bird is like from with 3:1 odds and then those surfaces are summed to form the cumulative assignment for all individuals from that species.



[redacted]

Table S1. Variables included as environmental predictors for the breeding habitat of rails. BIO variables were constructed by Hijmans *et al.* (2006) and downloaded from < http://www.worldclim.org/>. Wetland presence and type were developed and validated by Lehner & Döll (2004) and converted to binary presence/absence rasters. North American land cover was interpolated from SPOT VEGETATION satellite data (Latifovic *et al.* 2002).

Model Name	**Description**
BIO1	Annual Mean Temperature
BIO2	Mean Diurnal Range (Mean of monthly (max temp – min temp))
BIO5	Max Temperature of Warmest Month
BIO8	Mean Temperature of Wettest Quarter
BIO9	Mean Temperature of Driest Quarter
BIO12	Annual Precipitation
BIO13	Precipitation of Wettest Month
BIO15	Precipitation Seasonality (Coefficient of Variation)
BIO19	Precipitation of Coldest Quarter
GLWD	Wetland Presence
GLC2000	Land Cover

Table S2. The number of individuals caught and sampled for isotopic feather analysis by species, year, and location. All birds in Saskatchewan were captured in June and July. All other birds were captured between August and November.

Species	**Year**	**Arkansas**	**Illinois**	**Louisiana**	**Minnesota**	**Mississippi**	**Missouri**	**Ohio**	**Saskatchewan**	**South Carolina**	**Total**
Sora	2015	2	6	38	6		53	10	45	2	162
Virginia Rail	2015						8		4	1	13
Yellow Rail	2013						4				4
	2014								17		17
	2015					2	5		13		13
All	Total	2	6	38	6	2	75	10	79	3	221

Figure S1 - Corrected δ^2H of Sora (*Porzana carolina*), Virginia Rail (*Rallus limicola*) and Yellow Rail (*Corturnicops novebrancis*) as a function of location. Individuals from Saskatchewan were captured on the breeding grounds. All others were captured during autumn migration.

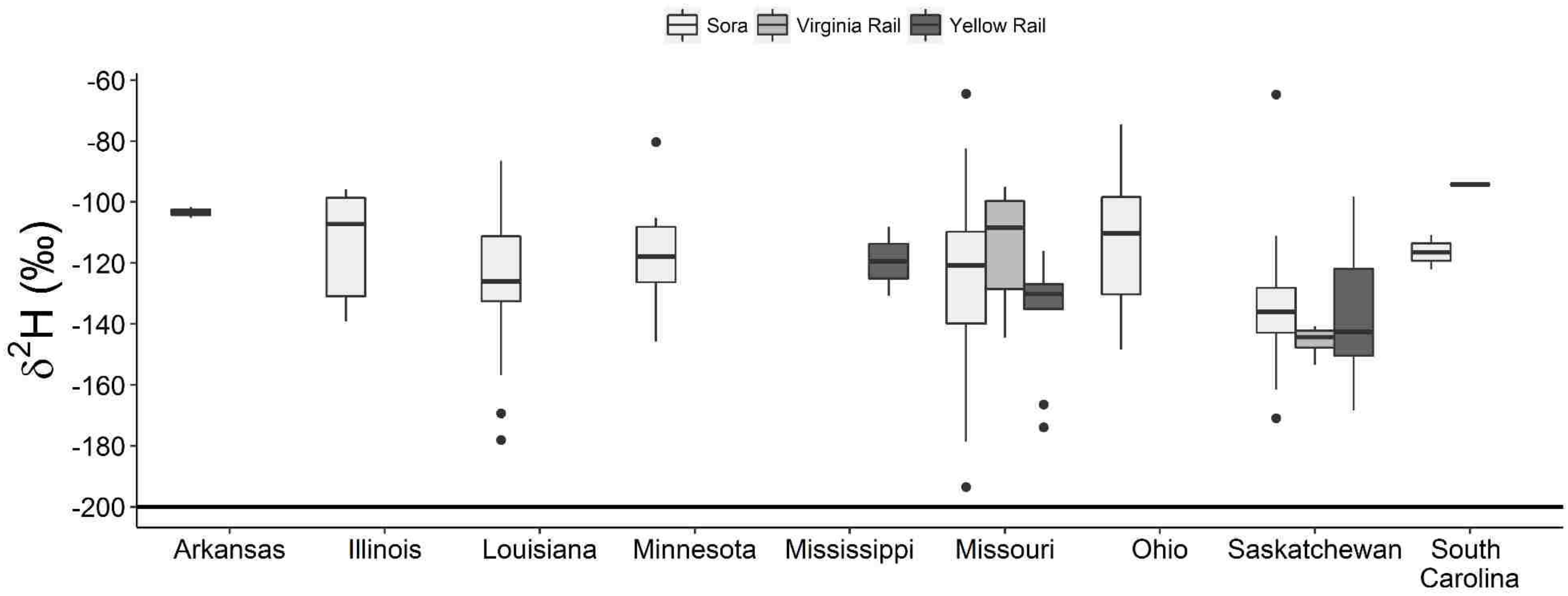


Figure S2 - Assignment of breeding areas of Virginia Rail (*Rallus limicola*). Each map depicts individuals captured within that particular state.

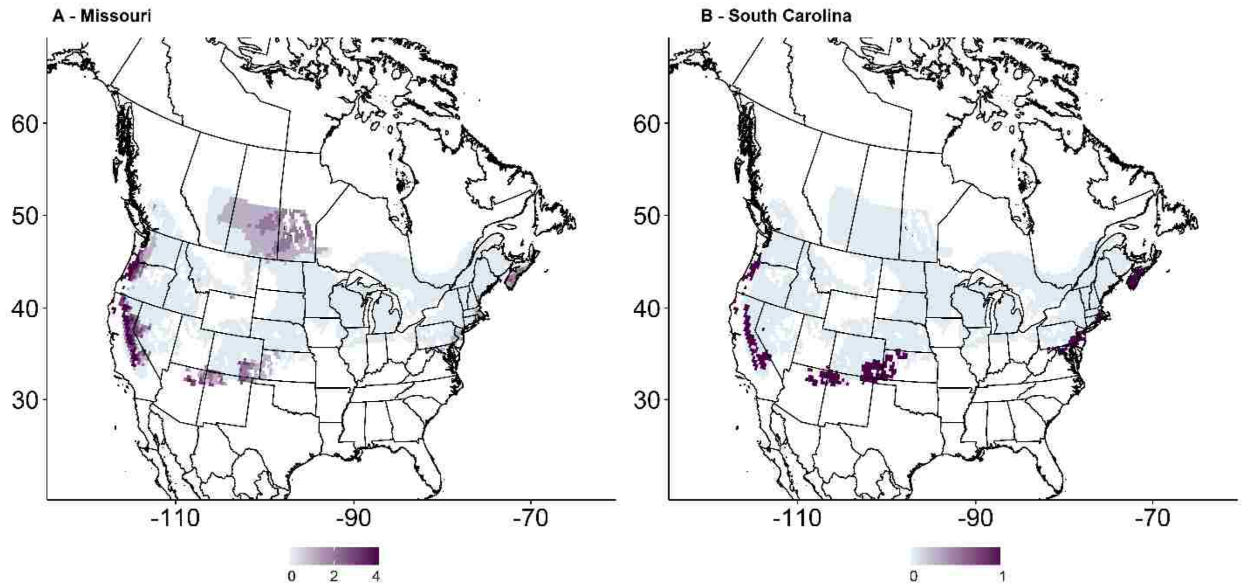


Figure S3 - Assignment of breeding areas of Yellow Rail (*Coturnicops noveboracensis*). Each map depicts individuals captured within that particular state.

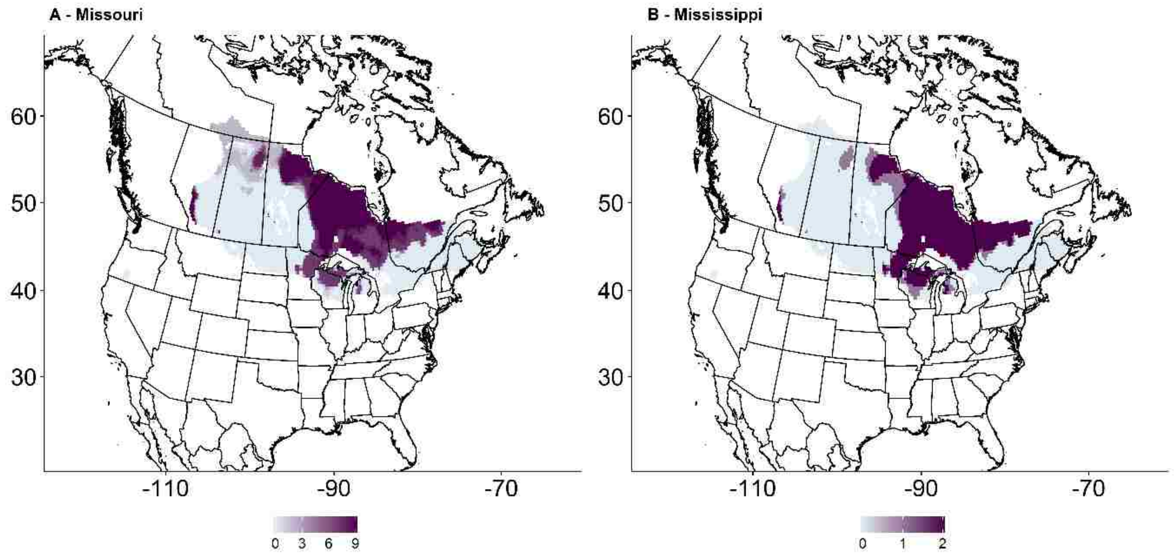
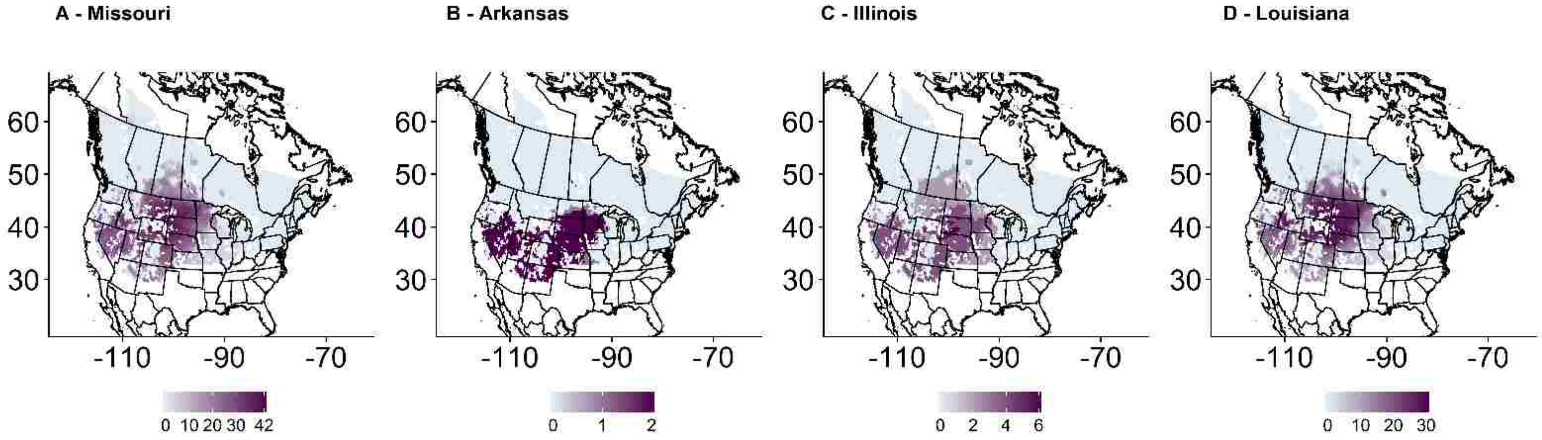
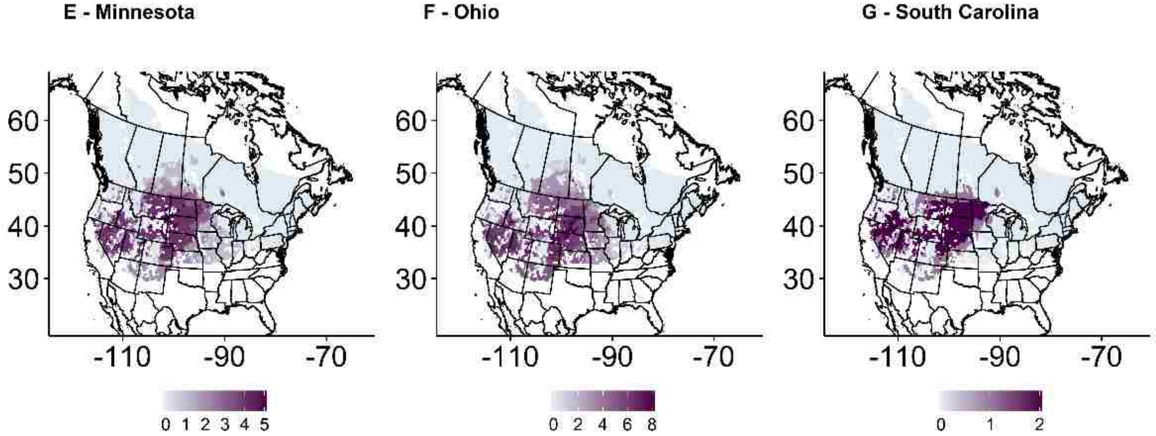


Figure S4 - Assignment of breeding areas of Sora (*Porzana carolina*). Each map depicts individuals captured within that particular state.





Chapter 3, "The Use Of Regional Monitoring Data In Species Distribution Models To Inform The Migratory Connectivity Of Two Wetland Bird Species" of A.M.V. Fournier's dissertation is accepted for publication in the Journal of Avian Biology with two coauthors, K.L. Drake, D.C. Tozer.

I, Dr. David G. Krementz, advisor of Auriel M.V. Fournier, confirm Auriel M.V. Fournier will be first author and completed at least 51% of the work for this manuscript.

David G Krementz

16 March 2017

David G. Krementz

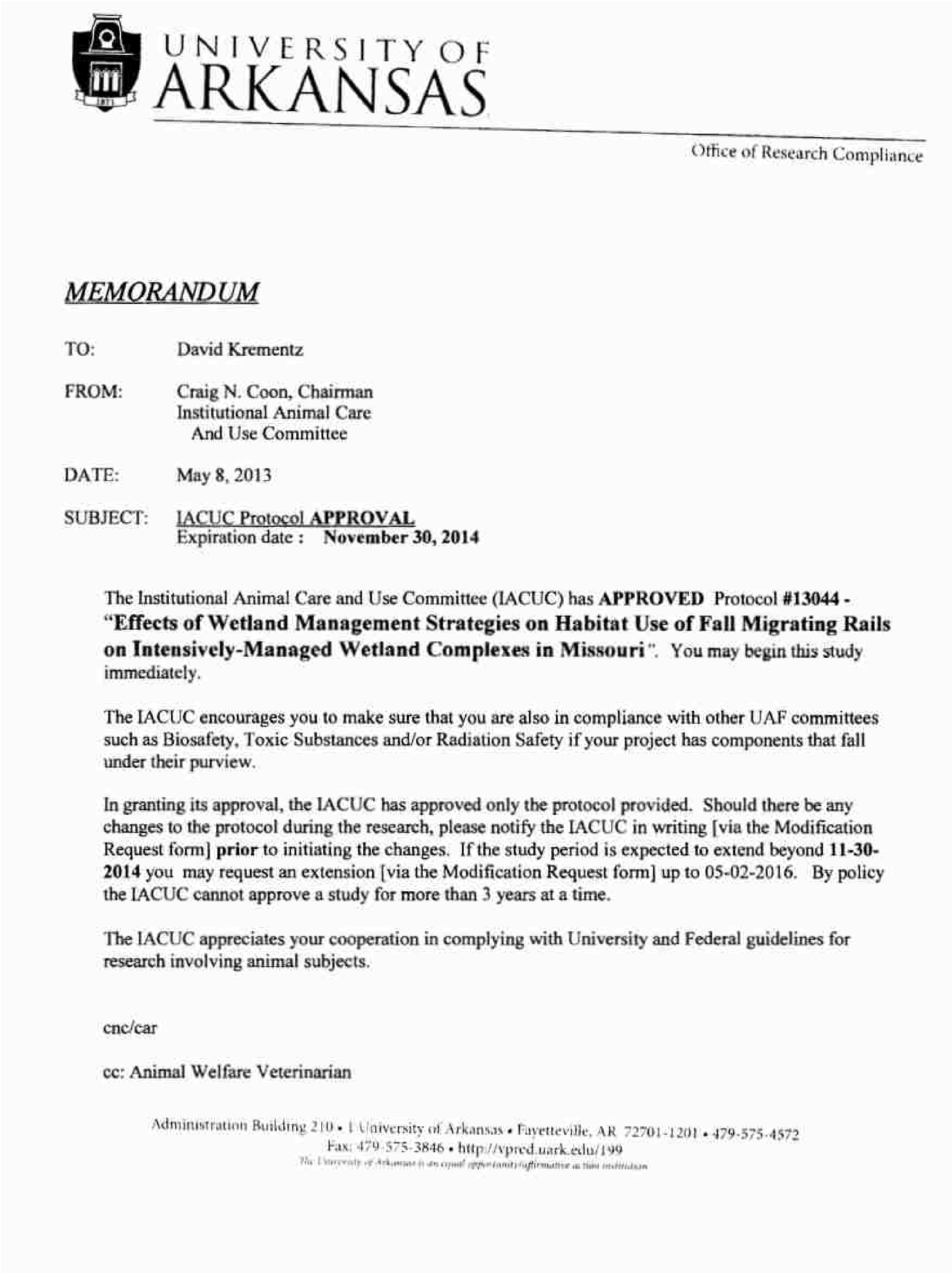
Unit Leader

U.S. Geological Survey

Arkansas Cooperative Fish and Wildlife

Research Unit

Date



UNIVERSITY OF
ARKANSAS

Office of Research Compliance

MEMORANDUM

TO: David Krementz

FROM: Craig N. Coon, Chairman
Institutional Animal Care
And Use Committee

DATE: May 8, 2013

SUBJECT: IACUC Protocol **APPROVAL**
Expiration date : **November 30, 2014**

The Institutional Animal Care and Use Committee (IACUC) has **APPROVED** Protocol **#13044 - "Effects of Wetland Management Strategies on Habitat Use of Fall Migrating Rails on Intensively-Managed Wetland Complexes in Missouri**". You may begin this study immediately.

The IACUC encourages you to make sure that you are also in compliance with other UAF committees such as Biosafety, Toxic Substances and/or Radiation Safety if your project has components that fall under their purview.

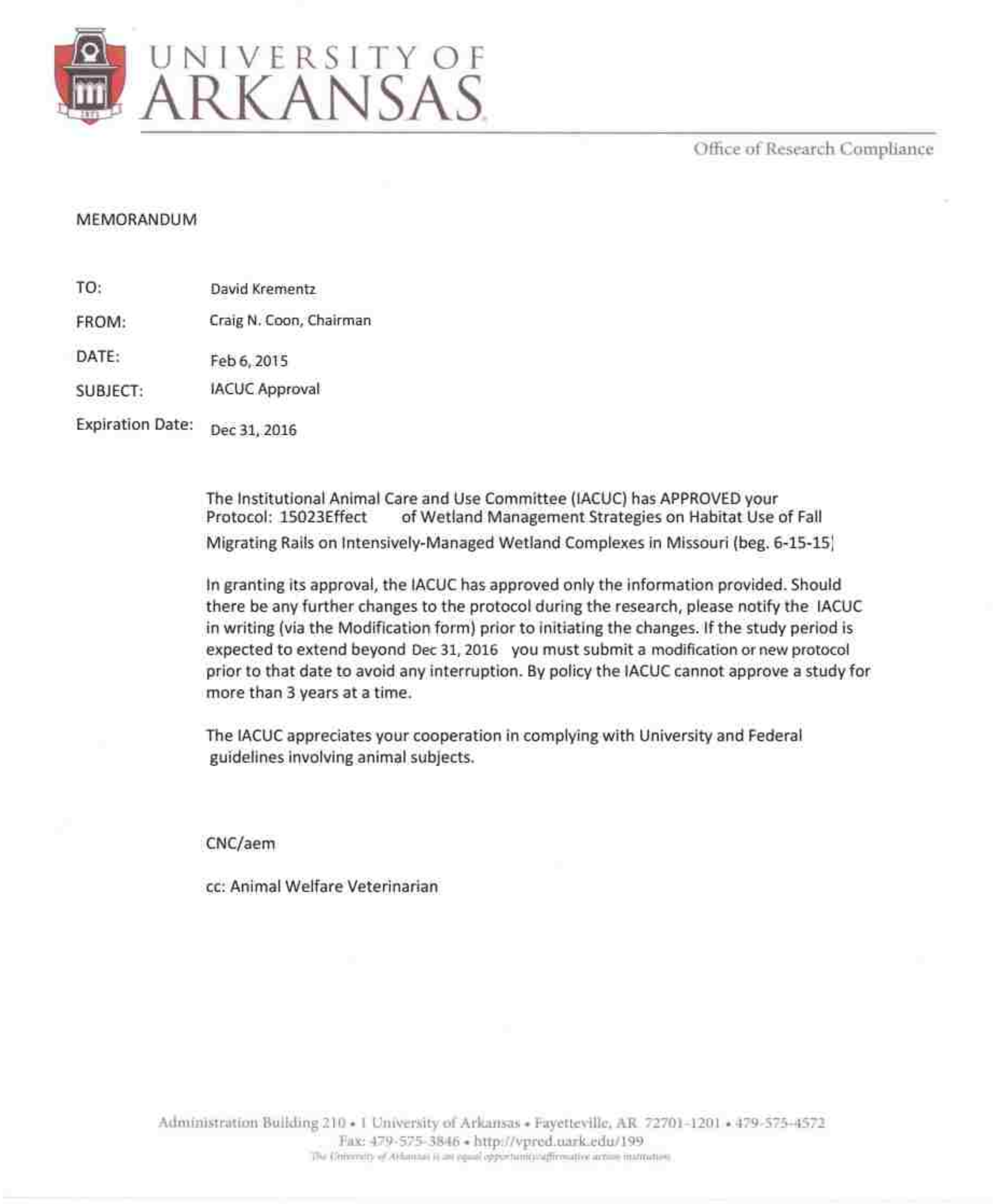
In granting its approval, the IACUC has approved only the protocol provided. Should there be any changes to the protocol during the research, please notify the IACUC in writing [via the Modification Request form] **prior** to initiating the changes. If the study period is expected to extend beyond **11-30-2014** you may request an extension [via the Modification Request form] up to 05-02-2016. By policy the IACUC cannot approve a study for more than 3 years at a time.

The IACUC appreciates your cooperation in complying with University and Federal guidelines for research involving animal subjects.

cnc/car

cc: Animal Welfare Veterinarian

Administration Building 210 • 1 University of Arkansas • Fayetteville, AR 72701-1201 • 479-575-4572
Fax: 479-575-3846 • http://vpred.uark.edu/199
The University of Arkansas is an equal opportunity/affirmative action institution



UNIVERSITY OF ARKANSAS

Office of Research Compliance

MEMORANDUM

TO: David Krementz

FROM: Craig N. Coon, Chairman

DATE: Feb 6, 2015

SUBJECT: IACUC Approval

Expiration Date: Dec 31, 2016

The Institutional Animal Care and Use Committee (IACUC) has APPROVED your Protocol: 15023Effect of Wetland Management Strategies on Habitat Use of Fall Migrating Rails on Intensively-Managed Wetland Complexes in Missouri (beg. 6-15-15

In granting its approval, the IACUC has approved only the information provided. Should there be any further changes to the protocol during the research, please notify the IACUC in writing (via the Modification form) prior to initiating the changes. If the study period is expected to extend beyond Dec 31, 2016 you must submit a modification or new protocol prior to that date to avoid any interruption. By policy the IACUC cannot approve a study for more than 3 years at a time.

The IACUC appreciates your cooperation in complying with University and Federal guidelines involving animal subjects.

CNC/aem

cc: Animal Welfare Veterinarian

Administration Building 210 • 1 University of Arkansas • Fayetteville, AR 72701-1201 • 479-575-4572
Fax: 479-575-3846 • http://vpred.uark.edu/199

UNIVERSITY OF
ARKANSAS

Office of Research Compliance

MEMORANDUM

TO: David Krementz

FROM: Craig N. Coon, Chairman

DATE: 5/11/15

SUBJECT: IACUC Approval

Expiration Date: Dec 31, 2016

The Institutional Animal Care and Use Committee (IACUC) has APPROVED your Protocol 15049 : "The use of stable isotopes, eBird and species distirbution models to assess migratory connectivity of fall migrating rails" to begin June 1, 2015.

In granting its approval, the IACUC has approved only the information provided. Should there be any further changes to the protocol during the research, please notify the IACUC in writing (via the Modification form) prior to initiating the changes. If the study period is expected to extend beyond Dec 31, 2016 you must submit a modification or new protocol prior to that date to avoid any interruption. By policy the IACUC cannot approve a study for more than 3 years at a time.

The IACUC appreciates your cooperation in complying with University and Federal guidelines involving animal subjects.

CNC/aem

cc: Animal Welfare Veterinarian

Administration Building 210 • 1 University of Arkansas • Fayetteville, AR 72701-1201 • 479-575-4572
Fax: 479-575-3846 • http://vpred.uark.edu/199
The University of Arkansas is an equal opportunity/affirmative action institution.

CHAPTER 4

Virginia and Yellow Rail Autumn Migration Phenology and Habitat Use: Summary and Synthesis Using Multiple Data Sets

Auriel M.V. Fournier

And

Doreen C. Mengel, And David G. Krementz

Abstract. - Virginia and Yellow Rails are among the least studied birds in North America, with a specific lack of information about their autumn migration ecology and migratory habitat use. We conducted nocturnal surveys across 11 public wetlands in Missouri, USA from 2012-2016, and compared the timing of autumn migration from our surveys with three opportunistic datasets: 1) eBird records, 2) building strikes, and 3) state ornithological records. The timing of Virginia Rail autumn migration varied between the opportunistic data and our surveys. Opportunistic data was bimodal, while our surveys had a single peak the second week in October. Yellow Rail autumn migration through Missouri peaked earlier in our surveys than opportunistic datasets which peaked during the second week in October. Both rails were found in moist soil habitats, however Virginia Rails selected perennial species more than was available, while Yellow Rails selected annual species. Both species showed no selection for water depth and used shallowly flooded wetlands. Understanding the autumn migration period and habitat requirements will allow wetland managers to better manage lands for autumn migrating Virginia and Yellow Rails.

INTRODUCTION

Migration is a critical period of the annual cycle for many species, yet it is often overlooked because it is difficult to study, and often only represents a small portion of the year (Webster et al. 2002, Webster and Marra 2005). Migratory species are exposed to a wide range pressures and conditions throughout their annual cycle, including during migration, which makes understanding and conserving their habitat even more important (Hostetler et al. 2015). To conserve migratory species, threats and pressures that operate in all parts of their annual cycle must be studied, including what may limit the habitats the species uses during migration, and consequently affect survival (Marra et al. 2015). Study species that have low detection rates, such as rails, which are among the least studied birds in North America, is especially difficult (Conway 1995, Bookhout 2015). Among the rails of North America, the Virginia Rail (*Rallus limicola*) and Yellow Rail (*Coturnicops noveboracensis*) are among the least abundant, and consequently two of the most poorly known (Conway 1995, Bookhout 2015). An understanding of rails' habitat selection during migration, including when they use those habitats, is needed before conservation and management efforts can be successful. Rails' secretive behavior makes them challenging to survey (Nadeau et al. 2008, Conway and Nadeau 2010). As a result, combining multiple data sources could provide us with a better assessment of rails' migratory phenology (Bond and Lavers 2015).

Opportunistic accounts, rather than formal surveys, provide most of the information on the phenology of rail autumn migration (Rundle and Fredrickson 1981, Conway 1995). Virginia Rail migration has been described as variable, occurring between late-August and late-October, peaking around 1 October (Conway 1995, Haramis and Kearns 2007). Similarly, Yellow Rails has been recorded from the last week of August through the first week of November with the peak in late September (Bookhout 2015). Opportunistic observations are important sources of information but not sufficient for informing conservation decisions, especially for cryptic species where specific methods are needed to increase odds of detecting an individual when it is present.

Virginia and Yellow Rails use managed wetlands [wetlands surrounded by levees and actively managed to promote a certain plant community and habitat conditions] as autumn migration stopover habitat, but our knowledge of both species is incomplete. Virginia Rail stopover habitat includes dense perennial moist soil plant cover, flooded with 5-10 cm of water (Rundle and Fredrickson 1981, Sayre and Rundle 1984, Reid 1989, Conway 1995). Yellow Rail habitat is less well understood, Butler et al. (2010) found Yellow Rails used sites dominated by perennial wetland cover, while Jacobs (2001) described Yellow Rail habitat as wet prairie and pastures, and Reid (1989) found Yellow Rail used shallowly flooded emergent wetlands. Our objectives were to document the migratory timing and habitat use of Virginia and Yellow Rails through the central portion of the Mississippi Flyway using a synthesis of our surveys and opportunistic migratory records.

METHODS

Migratory phenology

We surveyed managed moist soil wetlands (Strader and Stinson 2005) in Missouri, USA from August-October in 2012-2016 with ATV-based surveys (Fournier and Krementz In Press, Appendix I). We synthesized three additional datasets with our own to characterize Virginia and Yellow Rail migration phenology. These additional datasets included observations collected by the Audubon Society of Missouri (Fournier 2016), eBird citizen science observations (Sullivan et al. 2009), and published data from building strikes (Loss et al. 2014). We used observations from these datasets from 1 August and 30 November and 36.5 - 40.5°N in the Mississippi Flyway because these areas represent primarily migratory habitat for both species (Conway 1995, Bookhout 2015, Figure 1, Table 1). Similar data sets have been used in combination with other data sources to infer migration phenology of other bird species (e.g. Bond and Lavers 2015). Each data set used has inherent biases, in that the bluebird and eBird data represent presence only collected by birders, who are not evenly spread over space, or time. Building strike data could also be biased if it attracts or detracts rails during migration, but whether either is the case is not known. While we recognize these biases, they are our only source of comparison for our own data, which should be less biased because they are done under a standardized protocol on the same sites over several years. We compiled records into one data set, which we refer to from here on as opportunistic observations. We compared median date of migration between our surveys and the opportunistic observations with a Mann-Whitney test. We compared the distribution of observations using a Kolmogorov-Smirnoff non-parametric test.

Habitat selection

We collected habitat data at 5 random plots for every one plot where a Virginia or Yellow Rail was detected during our standardized surveys. The random plots were within the same impoundment where the Virginia or Yellow Rail was detected. We used a ratio of 5 to 1 available to used points because this is considered adequate to reduce bias and ensure convergence of parameter estimates (Northrup et al. 2013). In each 25 m-diameter plot, we recorded the mean of five water depths (cm) measured at the center of each plot and 5 m from the center in each cardinal direction. We visually estimated the percent cover of annual moist soil plants, perennial moist soil plants, and upland vegetation in the plot (Darrah and Krementz 2010, 2011). Annual moist soil plants include species that fall below the water surface at the end of the growing season such as annual smartweeds (*Polygonum* spp.) and millets (*Echinochloa* spp.; Cowardin et al. 1979). Perennial moist soil plant species persist above the water surface at the end of the growing season, and include perennial smartweeds (*Polygonum* spp.), bulrush (*Scirpus* spp.) and cattails (*Typha* spp) (Cowardin et al. 1979). We measured these variables because they have been found to be important to migrating rails (Rundle and Fredrickson 1981, Sayre and Rundle 1984, Reid 1989, Conway 1995, Butler et al. 2010, Bookhout 2015).

We had too few detections for distance sampling or occupancy modelling to be effective for Virginia and Yellow Rails, so we used counts of individuals. While this approach does not take into account detection probability we simply do not have sufficient data to do so. We analyzed the differences in habitat variables between used and available points for each species separately using resource selection functions in the R package ‘ResourceSelection’ (Lele et al. 2016, version 0.2-6, R Core Team 2016, version 3.3.1), which followed the functions described in Lele and Keim (2006) and Lele (2009). For Virginia Rails, we included annual moist soil vegetation, perennial moist soil vegetation and average water depth in our model. For Yellow Rails, we included the same covariates as Virginia Rail as well as upland vegetation because Yellow Rails are often characterized as a wet prairie species (Jacobs 2001). We assessed model fit using the Hosmer and Lemeshow goodness of fit test (Hosmer and Lemeshow 2013).

RESULTS

Migratory phenology

We detected 114 Virginia Rails during 1049 hours of surveying from 2012-2016 (range: 16 August-23 October). Opportunistic observations of Virginia Rails occurred between 1 August-26 November (n=284, Table 1). Our observations overlapped with the Birds of North America account but have a slightly wider window of migration (Conway 1995, Figure 2). The mediate date of opportunistic observations of Virginia Rails during autumn were different than our surveys (Mann Whitney, W = 12692, p<0.001) as the opportunistic observations suggested that there were two peaks during migration as compared to our single peak (Figure 2). The distribution of opportunistic observations of Virginia Rails were different than our surveys (Kolmogrov-Smirnoff Test, D = 0.37, p<0.001).

We detected 77 Yellow Rails during 1049 hours of surveying from 2012-2016 (range: 22 August-23 October). Yellow Rails were reported in opportunistic observations between 27 August 27 and 6 November (n=74, Table 1). Our surveys and the opportunistic observations were coincident with the Birds of North America account range of migration (Bookhout 2015, Figure 2). Our surveys and the opportunistic detections mediate date were different (W = 3808.5, p<0.001) as our surveys peaked earlier. The distribution of opportunistic observations of Yellow Rails were different than our surveys (Kolmogrov-Smirnoff Test, D = 0.35, p<0.001).

Habitat selection

Virginia Rails selected sites with greater perennial moist soil vegetation cover than were available whereas Virginia Rails did not select sites with water depths or percent annual moist soil vegetation cover different than available (Table 2, Supplementary Table S1, Fig 3). Yellow Rails selected sites with greater annual moist soil vegetation than were available whereas Yellow Rails did not select sites with water depths different or percent cover of upland or perennial moist soil vegetation than were available (Table 2, Supplementary Table S1, Fig 3). The Virginia Rail model fit the data (χ^2 = 7.336, df = 8, p = 0.50) as did the Yellow Rail model (χ^2 = 11.2, df = 8, p = 0.19).

DISCUSSION

Our survey results for Virginia Rail showed a singular later peak when compared to the two peaked wider distribution of opportunistic records. Virginia Rails' migration was over a shorter period than Sora and Virginia Rails were less abundant (~8000 Sora and 97 Virginia Rails during concurrent surveys (Fournier et al. In Press)). These differences in abundance led us to speculate as to the effectiveness of our survey method at detecting Virginia Rails. Haramis and Kearns (2007) found walk-in traps captured ~10% as many Virginia Rails as Sora, and hypothesized traps were positioned where the mean water level was too deep for Virginia Rails. We surveyed wetlands that spanned from dry to 50 cm water depth, so we doubt water depth influenced our ability to detect Virginia Rails. We assessed this concern using radio-tagged Sora, and found that marked Sora did not run away from the approaching ATV (Fournier and Krementz In Press) but future work is needed to understand the behavioral reaction of Virginia Rails to approaching ATVs at night using radio-marked birds. Because there are no formal population estimates for Virginia Rails and Sora we are unable to further infer differences between species abundances in our counts.

Our survey results for Yellow Rails showed an earlier peak in migration than opportunistic records, though the range of both were in line with the published literature (Bookhout 2015). Yellow Rails have broad migratory period, which is shorter than Sora (Fournier et al. In Press). We observed many fewer individual Yellow Rails than Sora, though again the lack of formal population estimates limits our comparisons of these counts estimates for either species and additional work is needed to understand how Yellow Rails react to our survey method. More importantly both Yellow and Virginia Rails are migrating earlier than some waterfowl species, suggesting traditional waterfowl management may not cover their needs.

We found Virginia Rails selected for perennial moist soil plant habitat, including perennial *Polygonum* and *Eleocharis* spp, which is in line with previous work (Reid 1989). Virginia Rail water depth selection has varied in previous work, with median values ranging from 2.4 to 19cm (Rundle and Fredrickson 1981, Sayre and Rundle 1984, Reid 1989). We did not find Virginia Rails select for water depths different than was available, but available water depths were similar to the range of values found in previous work since water availability within the surveyed impoundments was shallow.

We found Yellow Rails in shallowly flooded stands of annual moist soil plants, which may differ from previous work since perennial moist soil plants were less abundant within the wetlands we surveyed. Previous work found Yellow Rails in shallowly flooded (~4cm, range 0-11cm) wetlands with high percent cover of perennial moist soil plants such as *Panicum* and *Cyperus* spp (Reid 1989, Butler et al. 2010). Overall our results are similar to previous work which characterized Yellow Rails habitat as shallowly flooded densely vegetated wetlands and wet prairies, the results just differ in the plant community making up the dense vegetation (Robert et al. 1997, 2004, Jacobs 2001). Rundle and Fredrickson (1981) suggested “rails probably selected habitat because of water conditions and vegetation structure rather than species composition” which would support these findings as well.

Understanding species’ habitat selection during autumn migration is vital to understanding how migration impacts demography (Sheehy 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 (Brown and Dinsmore 1986, Albanese and Davis 2015). This study provides missing information that can be used to implement direct conservation and management actions, namely the active flooding of wetlands, in a way that maximizes the benefit to migratory waterbirds, including rails. While closely related species are often described as having similar characteristics, we show here that these two rails have different migratory timing and habitat needs than Sora. Understanding these differences is vital to the conservation and management of all rails as well as their wetland communities.

ACKNOWLEDGEMENTS

Our research was funded by the U.S. Fish and Wildlife Service, the Missouri Department of Conservation, the U.S. Geological Survey Arkansas Cooperative Fish and Wildlife Research Unit, and the University of Arkansas. We would like to thank K. Ackley, C. Alger, R. Bell, 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, A. Raedeke, D. Welchert, S. Whitson, and J. Wilson for help in coordinating field work and site access. 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 collecting data. Research completed under University of Arkansas IACUC #15049 and #15023 and state and federal property special use permits. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

LITERATURE CITED

Albanese, G., and C. A. Davis. 2015. Characteristics within and around stopover wetlands used by migratory shorebirds: Is the neighborhood important? The Condor 117:328–340.

Bond, A. L., and J. A. Lavers. 2015. Flesh-footed Shearwaters (Puffinus carneipes) in the Northeastern Pacific Ocean: Summary and Synthesis of Records from Canada and Alaska. Canadian Field Naturalist 129:263–267.

Bookhout, T. A. 2015. Yellow Rail. Page 139 *in*. The Birds of North America.

Brown, M., and J. J. Dinsmore. 1986. Implications of Marsh Size and Isolation for Marsh Bird Management. The Journal of Wildlife Management 50:392–397.

Butler, C. J., L. H. Pham, J. N. Stinedurf, C. L. Roy, E. L. Judd, N. J. Burgess, and G. M. Caddell. 2010. Yellow Rails Wintering in Oklahoma. The Wilson Journal of Ornithology 122:385–387.

Conway, C. J. 1995. Virginia Rail. Page 173 *in*. The Birds of North America.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. Laroe. 1979. Classification of wetlands and deepwater habitats of the United States. Biological services program. <http://www.charttiff.com/pub/WetlandMaps/Cowardin.pdf>.

Darrah, A. J., and D. G. Krementz. 2010. Occupancy and Habitat use of the Least Bittern and Pied- Billed Grebe in the Illinois and Upper Mississippi River Valleys. Waterbirds 33:367–375.

Darrah, A. J., and D. G. Krementz. 2011. Habitat Use of Nesting and Brood-rearing King Rails in the Illinois and Upper Mississippi River Valleys. Waterbirds 34:160–167.

Fournier, A. M. V. 2016. The Bluebird Rail Data. figshare.

Fournier, A. M. V., and D. G. Krementz. n.d. Nocturnal Distance Sampling All-Terrain Vehicle Surveys for Non-Breeding Rails. The Wildlife Society Bulletin.

Fournier, A. M. V., D. C. Mengel, E. E. Gbur, and D. G. Krementz. n.d. The Timing of Autumn Sora (Porzana carolina) Migration. Wilson Journal of Ornithology.

Haramis, G. M., and G. D. Kearns. 2007. Soras in Tidal Marsh : Banding and Telemetry Studies on the Patuxent River , Maryland. Waterbirds 30:105–121.

Hosmer, D. W., and S. Lemeshow. 2013. Applied Logistic Regression. Wiley, New York, USA.

Hostetler, J. A., T. S. Sillett, and P. P. Marra. 2015. Full-annual-cycle population models for migratory birds. The Auk 132:433–449. <http://dx.doi.org/10.1642/AUK-14-211.1>.

Jacobs, B. 2001. Birds of Missouri. Jefferson City, MO.

Lele, S. R. 2009. A new method for estimation of resource selection probability function. The Journal of Wildlife Management 73:122–127.

Lele, S. R., and J. L. Keim. 2006. Weighted distributions and estimation of resources selection probability functions. Ecology 87:3021–3028.

Lele, S. R., J. L. Keim, and P. Solymos. 2016. ResourceSelection: Resource Selection (Probability) Functions for Use-Availability Data.

Loss, S. R. S. S., T. Will, P. P. Marra, S. R. S. S. Loss, and P. P. Marra. 2014. Bird–building collisions in the United States: Estimates of annual mortality and species vulnerability. Condor 116:8–23.

Marra, P. P., E. B. Cohen, S. R. Loss, J. E. Rutter, and C. M. Tonra. 2015. A call for full annual cycle research in animal ecology. Biology letters 11:2015.0552.

Reid, F. A. 1989. Differential Habitat Use by Waterbirds In a Managed Wetland Complex. University of Missouri-Columbia.

Robert, M., L. Cloutier, and P. Laporte. 1997. The Summer Diet of the Yellow rail in Southern Quebec. The Wilson Bulletin 109:702–710.

Robert, M., B. Jobin, F. Shaffer, L. Robillard, B. Gagnon, M. I. R. Obert, B. E. J. Obin, and F. R. S. Haffer. 2004. Yellow Rail Distribution and Numbers in Southern James Bay, Quebec, Canada. Waterbirds 27:282–288.

Rundle, W. D., and L. H. Fredrickson. 1981. Managing Seasonally Flooded Impoundments for Migrant Rails and Shorebirds. Wildlife Society Bulletin 9:80–87.

Sayre, M. W., and W. D. Rundle. 1984. Comparison of Habitat Use by Migrant Soras and Virginia Rails. The Journal of Wildlife Management 48:599–605.

Sheehy, J., C. M. Taylor, and D. R. Norris. 2011. The importance of stopover habitat for developing effective conservation strategies for migratory animals. Journal of Ornithology 152:161–168.

Sullivan, B. L., C. L. Wood, M. J. Iliff, R. E. Bonney, D. Fink, and S. Kelling. 2009. eBird: A Citizen-based Bird Observation Network in the Biological Sciences. Biological Conservation 142:2282–2292.

Webster, M. S., and Marra. 2005. The importance of understanding migratory connectivity and seasonal interactions. Pages 199–209 *in* R. Greenberg and Marra, editors. Birds in Two Worlds : The Ecology and Evolution of Migration. The Johns Hopkins University Press, Baltimore, Maryland.

Webster, M. S., P. P. Marra, S. M. Haig, S. Bensch, and R. T. Holmes. 2002. Links between worlds: unraveling migratory connectivity. Trends in Ecology & Evolution 17:76–83.

Table 1 – Sample sizes from opportunistic data sources used to characterize Virginia Rail (*Rallus limicola*) and Yellow Rail (*Coturnicops noveboracensis)* migration in Missouri, USA. The Bluebird is the journal of the Audubon Society of Missouri. eBird is a citizen science database of birding checklists. Building Strikes are records of either species from building strike monitoring programs.

Data Source	**Yellow Rail**	**Virginia Rail**	**Citation**	**Years Represented**
The Bluebird	20	20	(Fournier 2016)	1963-2016
eBird	53	261	(Sullivan et al. 2009)	2000-2015
Building Strikes	1	3	(Loss et al. 2014)	1973-2010

Table 2 – Beta estimates and p-values from resource selection functions to explain habitat selection of Virginia Rail (*Rallus limicola*) and Yellow Rail (*Coturnicops noveboracensis)* during migration in Missouri, USA.

Species	**Variable**	**β Estimate**	**Standard Error**	**P-value**
Virginia Rail	Annual Moist Soil Vegetation	0.008	.004	0.08
	Perennial Moist Soil Vegetation	0.01	0.006	<0.001
	Mean Water Depth	0.008	0.01	0.44
Yellow Rail	Annual Moist Soil Vegetation	0.02	0.005	<0.001
	Perennial Moist Soil Vegetation	0.006	0.01	0.65
	Mean Water Depth	-0.02	0.01	0.08
	Upland Vegetation	0.01	0.007	0.06

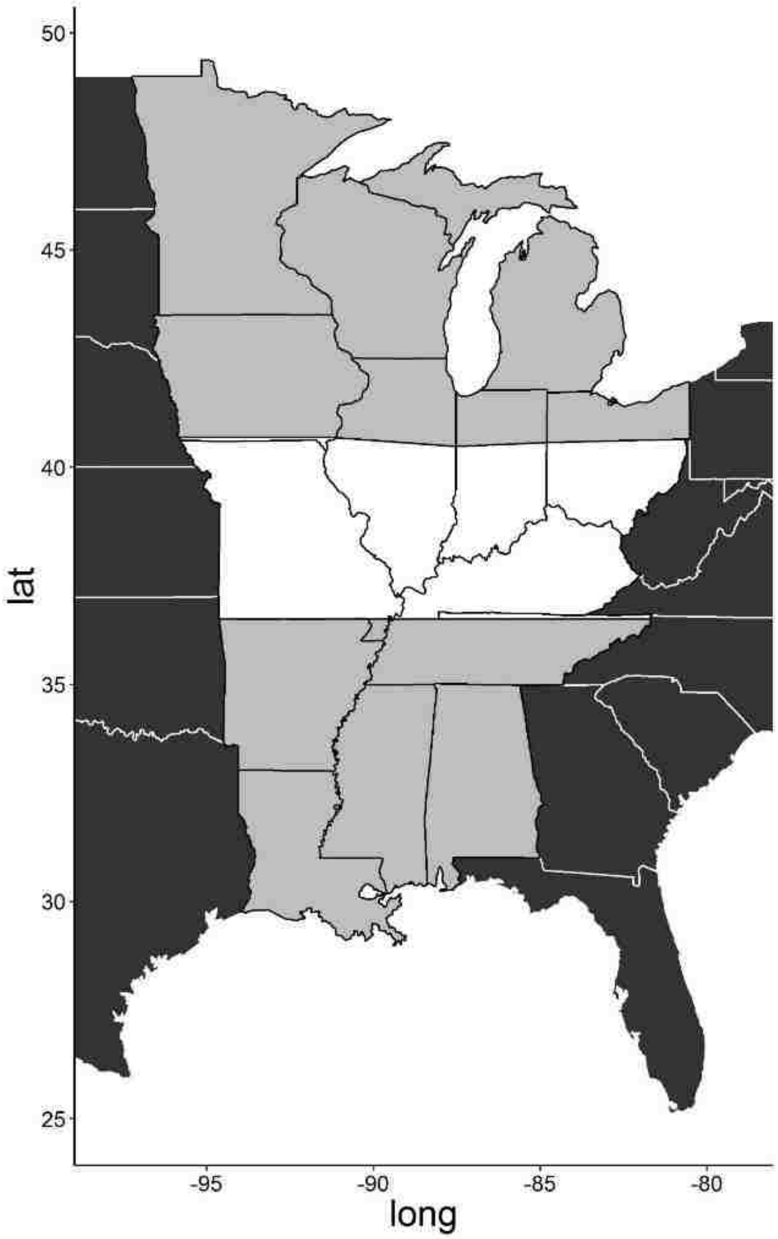


Fig. 1 – Area of the Mississippi Flyway (light grey) where opportunistic observations of Yellow Rail (*Coturnicops noveboracensis)* and Virginia Rail (*Rallus limicola*) during autumn migration were collected (white).

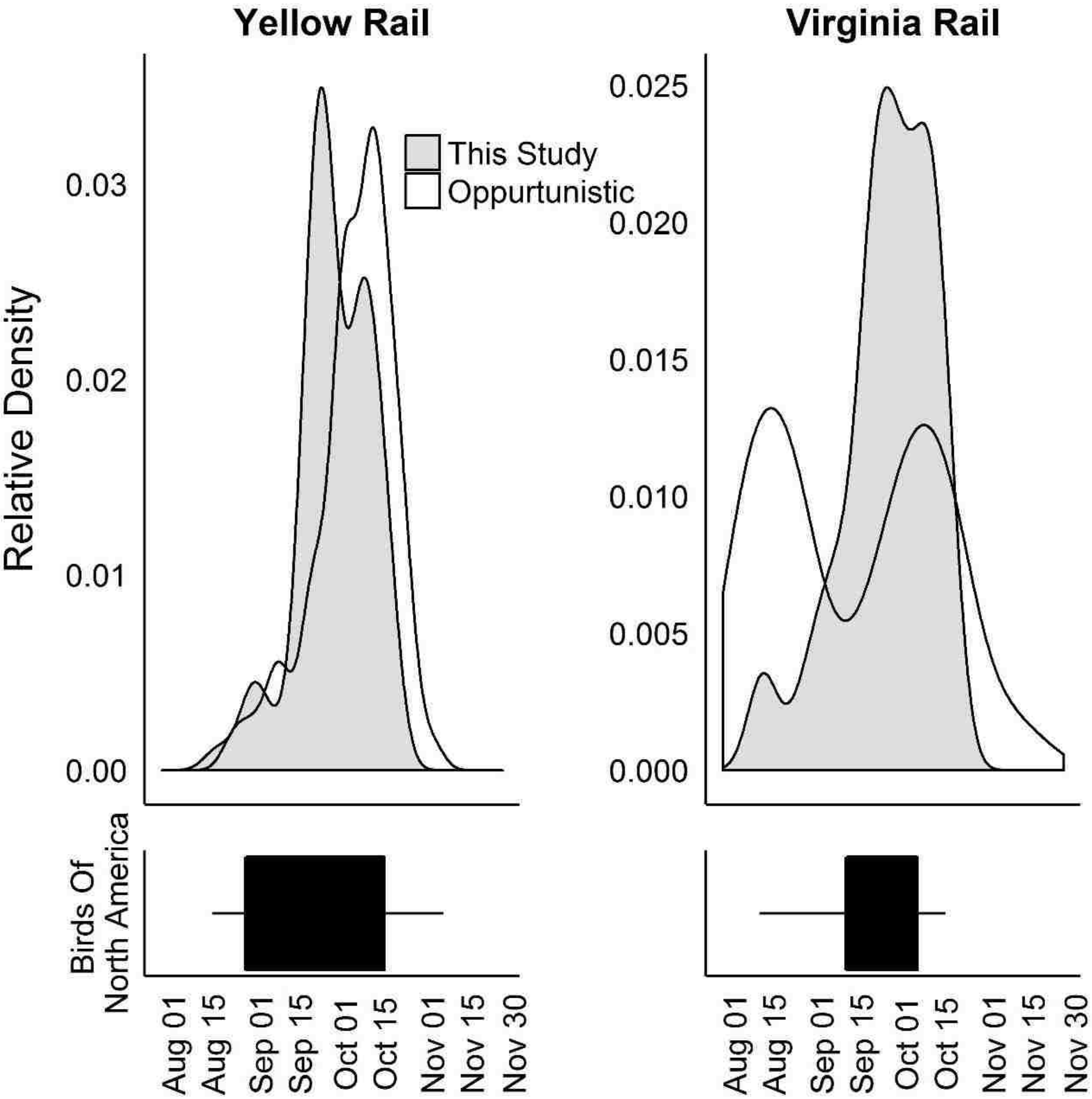


Fig. 2 – Distribution of observations of Yellow Rail (*Coturnicops noveboracensis)* and Virginia Rail (*Rallus limicola*) during autumn migration comparing our data, opportunistic data points and the range reported in Birds of North America.

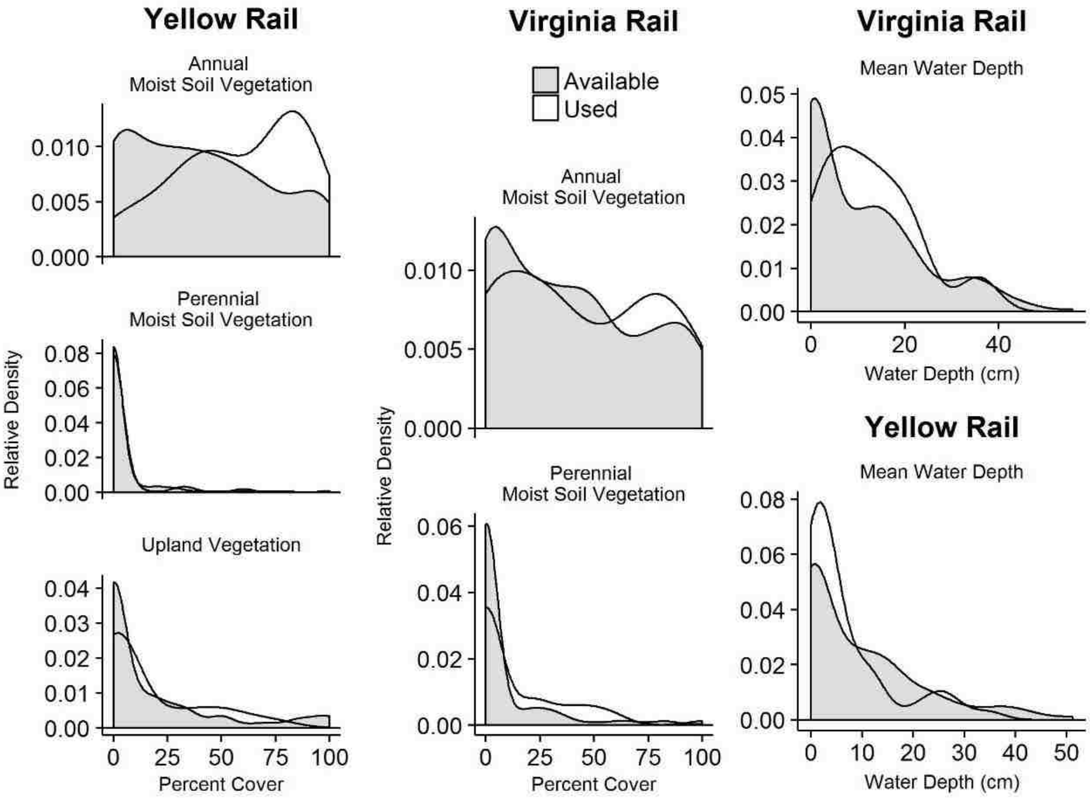


Fig. 3 – Distribution of used vs available habitat variables for Yellow Rail (*Coturnicops noveboracensis)* and Virginia Rail (*Rallus limicola*) during autumn migration in Missouri, USA

Supplementary Table S1 – Habitat Used vs Available Data Summary Data

Category	Species	Minimum	First Quantile	Median	Third Quantile	Maximum
Average Water Depth (cm)	Available	0.0	0.0	0.0	16.0	69.4
	Yellow Rail	0.0	0.0	3.2	9.9	34.8
Annual Moist Soil Vegetation (% cover)	Available	0.0	0.0	30.0	60.0	100.0
	Virginia Rail	0.0	13.8	37.5	76.3	100.0
	Yellow Rail	0.0	40.0	62.5	84.3	100.0
Perennial Moist Soil Vegetation (% cover)	Available	0.0	0.0	0.0	0.0	100.0
	Virginia Rail	0.0	0.0	0.0	23.5	100.0
	Yellow Rail	0.0	0.0	0.0	0.0	60.0
Upland (% cover)	Available	0.0	0.0	0.0	20.0	100.0
	Yellow Rail	0.0	0.0	2.5	30.0	80.0

Chapter 4, "Virginia And Yellow Rail Autumn Migration Phenology And Habitat Use: Summary And Synthesis Using Multiple Data Sets" of A.M.V. Fournier's dissertation is intended for submission for publication with two coauthors, D.C. Mengel, and D.G. Krementz.

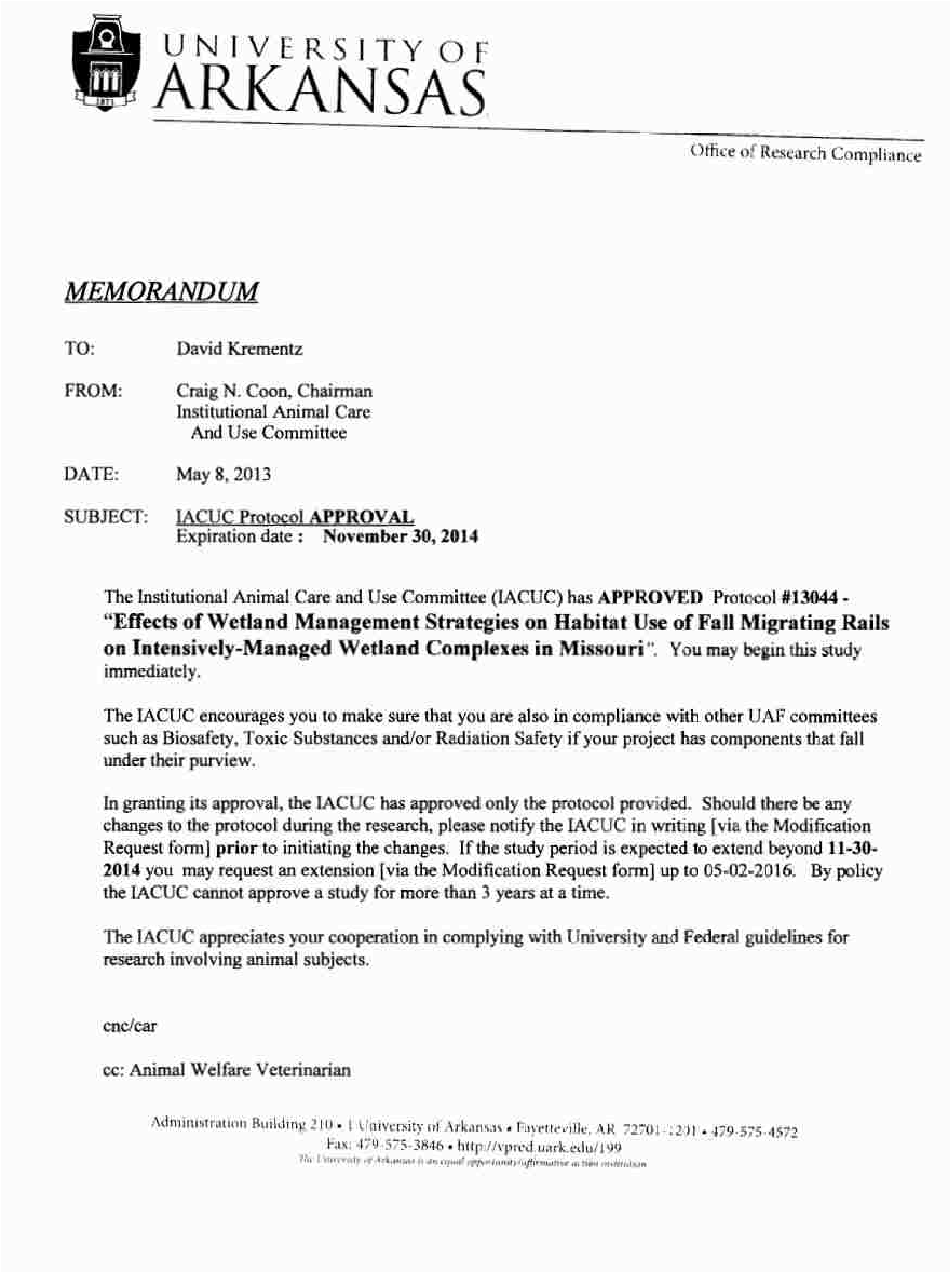
I, Dr. David G. Krementz, advisor of Auriel M.V. Fournier, confirm Auriel M.V. Fournier will be first author and completed at least 51% of the work for this manuscript.

David G Krementz

16 March 2017

David G. Krementz
Unit Leader
U.S. Geological Survey
Arkansas Cooperative Fish and Wildlife
Research Unit

Date



UNIVERSITY OF
ARKANSAS

Office of Research Compliance

MEMORANDUM

TO: David Krementz

FROM: Craig N. Coon, Chairman
Institutional Animal Care
And Use Committee

DATE: May 8, 2013

SUBJECT: IACUC Protocol **APPROVAL**
Expiration date : **November 30, 2014**

The Institutional Animal Care and Use Committee (IACUC) has **APPROVED** Protocol **#13044 - "Effects of Wetland Management Strategies on Habitat Use of Fall Migrating Rails on Intensively-Managed Wetland Complexes in Missouri**". You may begin this study immediately.

The IACUC encourages you to make sure that you are also in compliance with other UAF committees such as Biosafety, Toxic Substances and/or Radiation Safety if your project has components that fall under their purview.

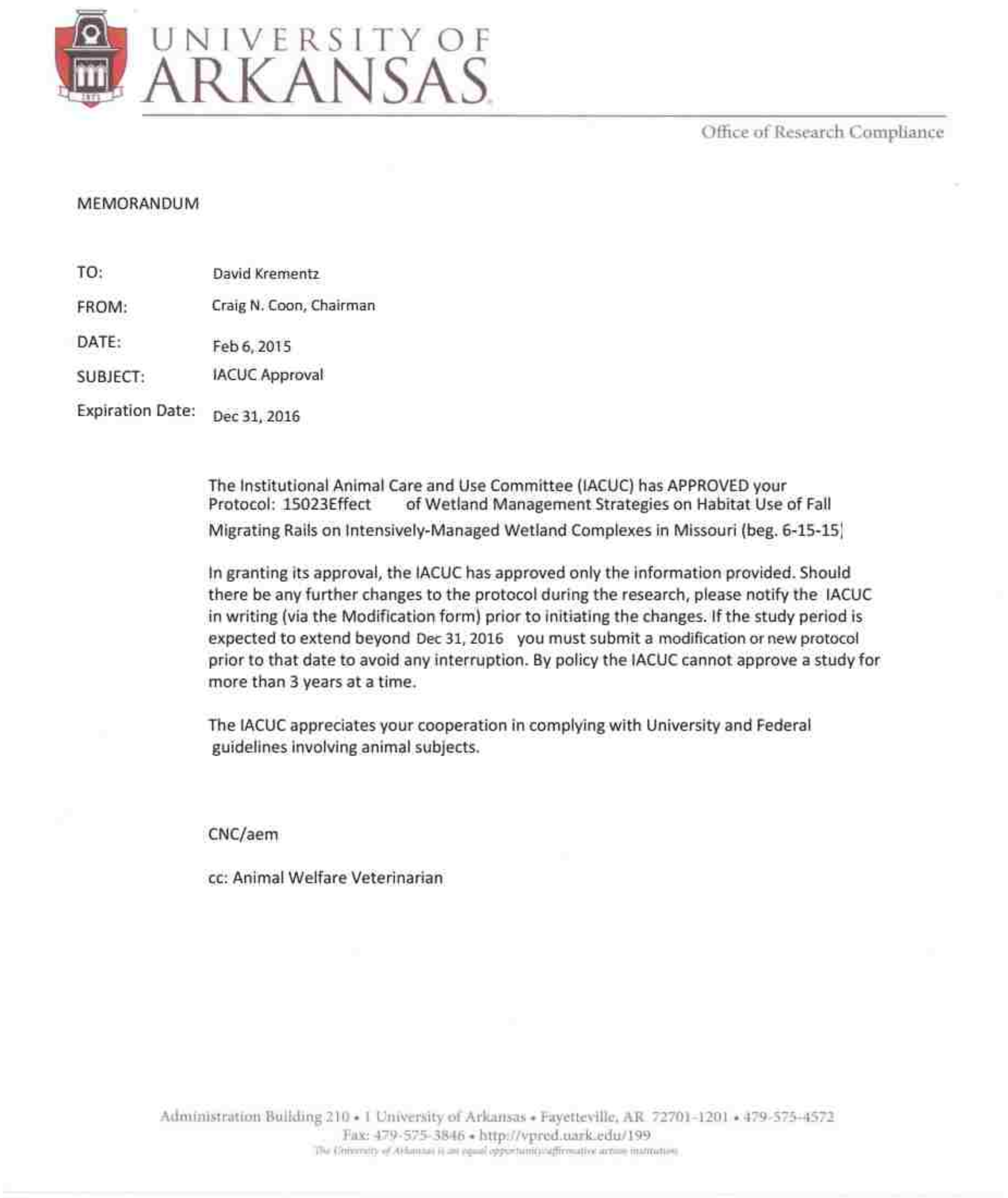
In granting its approval, the IACUC has approved only the protocol provided. Should there be any changes to the protocol during the research, please notify the IACUC in writing [via the Modification Request form] **prior** to initiating the changes. If the study period is expected to extend beyond **11-30-2014** you may request an extension [via the Modification Request form] up to 05-02-2016. By policy the IACUC cannot approve a study for more than 3 years at a time.

The IACUC appreciates your cooperation in complying with University and Federal guidelines for research involving animal subjects.

cnc/car

cc: Animal Welfare Veterinarian

Administration Building 210 • 1 University of Arkansas • Fayetteville, AR 72701-1201 • 479-575-4572
Fax: 479-575-3846 • http://vpred.uark.edu/199
The University of Arkansas is an equal opportunity/affirmative action institution



UNIVERSITY OF
ARKANSAS

Office of Research Compliance

MEMORANDUM

TO: David Krementz

FROM: Craig N. Coon, Chairman

DATE: Feb 6, 2015

SUBJECT: IACUC Approval

Expiration Date: Dec 31, 2016

The Institutional Animal Care and Use Committee (IACUC) has APPROVED your Protocol: 15023Effect of Wetland Management Strategies on Habitat Use of Fall Migrating Rails on Intensively-Managed Wetland Complexes in Missouri (beg. 6-15-15)

In granting its approval, the IACUC has approved only the information provided. Should there be any further changes to the protocol during the research, please notify the IACUC in writing (via the Modification form) prior to initiating the changes. If the study period is expected to extend beyond Dec 31, 2016 you must submit a modification or new protocol prior to that date to avoid any interruption. By policy the IACUC cannot approve a study for more than 3 years at a time.

The IACUC appreciates your cooperation in complying with University and Federal guidelines involving animal subjects.

CNC/aem

cc: Animal Welfare Veterinarian

Administration Building 210 • 1 University of Arkansas • Fayetteville, AR 72701-1201 • 479-575-4572
Fax: 479-575-3846 • http://vpred.uark.edu/199
The University of Arkansas is an equal opportunity/affirmative action institution

CHAPTER 5

Nocturnal Distance Sampling All-Terrain Vehicle Surveys for Non-Breeding Rails

Auriel M.V. Fournier

And

David G. Krementz

ABSTRACT

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

INTRODUCTION

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

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

STUDY AREA

We developed this protocol on public managed wetland properties across Missouri, USA, including 7 Missouri Department of Conservation's Conservation Areas and 4 U.S. Fish and Wildlife Service's National Wildlife Refuges. At each property, we surveyed moist-soil wetland impoundments (wetlands surrounded by levees with water control structures) (*n* of impoundments, 2012 = 40, 2013 = 39, 2014 = 33, 2015 = 33; Supplementary Table 1). We selected impoundments as the survey unit because they were the scale at which wetland management decisions are made. Moist-soil wetland impoundments were managed on a multi-year rotation (~1-3 year) using water-level manipulation and disturbance (discing, mowing and burning) to reduce invasion by undesirable plant species and set back succession (Rundle and Fredrickson 1981, Fredrickson and Taylor 1982). We only examined this method in moist-soil wetlands dominated by palustrine emergent vegetation. These wetlands rarely had vegetation >2 m and with the exception of borrow ditches rarely had large areas of water deeper than 50 cm.

METHODS

Surveys

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

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

Verification

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

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

To examine survey repeatability, we compared effort-corrected counts (sora/hr of survey) in first and second surveys of the night using a 2x2 crossover design with impoundment and time period as the 2 variables and observer crossed between them (Quinn and Keough 2011). Based on our field observations of sora behavior, we do not believe there were any carryover effects. We assessed the difference between the 2 nightly surveys using a Mann-Whitney test because effort-corrected counts were not normally distributed.

Density

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

To estimate sora density in a wetland impoundment over repeated surveys in a distance-sampling framework, we had to assume geographic closure (no emigration or immigration). We met the closure assumption within each impoundment by estimating density separately for each night and impoundment. We had 4 separate density estimates per impoundment, per year; one for each of the 4 nights we surveyed there in that year. We used the 2 survey occasions each night to estimate detection probability. Two survey occasions is less than the typical 3-5 used in many n-mixture models. However, Royle (2004b) and Ross et al. (2016a,b) found that 2 repeat surveys were sufficient to estimate detection probability. To assess differences in the detection among observers (2012 had 4 observers, J, L, M, and AMVF; 2013 had 4 observers, N, D, M and

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

RESULTS

We detected 6,010 sora during 1229.20 of surveying across August-October 2013-2016. We also detected 30 yellow rails, 64 Virginia rails and 1 king rail. In addition to rails we observed other species including waterfowl (Family Anatidae), sparrows (Family Emberizidae), wrens (Family Troglodytidae), meadowlarks (*Sturnella* spp.), shorebirds (including frequent sightings of Wilson's snipe ([*Gallinago delicata*] and American woodcock [*Scolopax minor*]), and raccoons (*Procyon lotor*). Although we did not record other detected animals, we believe that our survey method could be used for other species. The number of detections of nonsora rails (yellow, Virginia and king) were too low to estimate density under a distance sampling framework, although other analysis approaches, such as occupancy modeling, could possibly be used.

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

The global model adequately fit the data and was the top model ($\chi^2 = 5181$, $P = 0.95$). Sora detected during surveys rarely flew more than 10 m when flushed by an ATV. We never detected a sora flushing >13 m from the transect line. Because 96% of our detections occurred $\leq$5 m from the line, we truncated our data to include only those detections. This truncation and our observations of sora behavior minimized double-counting. In 2015, we recorded whether individuals were first observed flushing or on the ground and 51% were detected flushing while 49% were first detected on the ground, often walking in front of the ATV. They then flew when the ATV approached them. The exception to this was if the sora was swimming.

There was no difference in the number of sora detected between the 2 surveys conducted by 2 different observers in the same impoundment on the same night ($W_{104} = 1479.5$, $P = 0.62$). Average detection probability of an individual, assuming it was available to be detected, in the first transect bin was 0.17 (Fig. 2). We did not include observer as a covariate for detection because the model with observer as a covariate received no support (>300 ΔAIC from the top ranked model). Estimates of density derived from hierarchical distance sampling models incorporating habitat covariates to explain sora density produced estimates from 1 (1.4 - 2.1 95% CI) to 18 (16.6 - 19.8) sora per ha (Table 1).

DISCUSSION

Rails are elusive, yet to answer questions about the effects of management on rails, we require an understanding of how detection might affect the observation process because the probability of detecting an individual, assuming that it is present, is not the same in all circumstances or for all species (Conway 1995, Thompson 2002). The National Marshbird Monitoring Protocol was designed to optimize detection probability during the breeding season, because detection is so low for many rails and other marshbirds (Conway 2011). Many factors can affect wetland bird detection, including ambient temperature, wind speed, cloud cover, moon phase, and observer and often these factors go untested in new survey methods (Anderson 2001, Conway and Gibbs 2011, Bolenbaugh et al. 2011, Budd and Krementz 2011, Glisson et al. 2015). When working with rails that are difficult to detect, understanding how individuals react to the survey methodology and estimating detection probability is important.

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

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

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

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

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

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

ACKNOWLEDGMENTS

This research was funded by the U.S. Fish and Wildlife Service, the Missouri Department of Conservation, the Arkansas Audubon Society Trust, the U.S. Geological Survey Arkansas Cooperative Fish and Wildlife Research Unit, and the University of Arkansas. We would like to thank K. Ackley, C. Alger, R. Bell, 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, A. Raedeke, D. Welchert, S. Whitson, and J. Wilson for help in coordinating field work and site access. Special thanks to M. Boone, L. Brinkman, D. Datlof, J. Fournier, J. Lehman, H. Pasivich and N. Seeger for their diligent work in the field collecting data. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government. Thanks to the Associate Editor and reviewers for their comments which improved this manuscript.

LITERATURE CITED

Anderson, D. R. 2001. The need to get the basics right in wildlife field studies. Wildlife Society Bulletin 29:1294–1297.

Bolenbaugh, J. R., D. G. Krementz, and S. E. Lehnen. 2011. Secretive marsh bird species co-occurrences and habitat associations across the Midwest, USA. Journal of Fish and Wildlife Management 2:49–60. DOI: 10.3996/ 012011-JFWM-001

Budd, M. J., and D. G. Krementz. 2011. Status and distribution of breeding secretive marshbirds in the Delta of Arkansas. Southeastern Naturalist 10:687–702.

Butler, C. J., J. K. Wilson, C. R. Brower, and S. R. Frazee. 2014. Age ratios, sex ratios, and a population estimate of yellow rails at San Bernard National Wildlife Refuge, Texas. Southwestern Naturalist 59:319–324. DOI: 10.1894/MCG-02.1

Chandler, R. B., J. A. Royle, and D. I. King. 2011. Inference about density and temproary emigration in unmarked populations. Ecology 92:1429–1435. DOI: 10.1890/10-2433.1

Conway, C. J., W. R. Eddleman, S. H. Anderson, and L. R. Hanebury. 1993. Season changes in Yuma clapper rail vocalization rate and habitat use. Journal of Wildlife Management 57:282–290. DOI: 10.2307/3809425

Conway, C. J., and J. P. Gibbs. 2011. Summary of intrinsic and extrinsic factors affecting detection probability of marsh birds. Wetlands 31:403–411. DOI: 10.1007/s13157-011-0155-x

Conway, C. J., and C. P. Nadeau. 2010. Effects of broadcasting conspecific and heterospecific calls on detection of marsh birds in North America. Wetlands 30:358–368. DOI: 10.1007/s13157-010-0030-1

Conway, C. J. 2011. Standardized North American marsh bird monitoring protocol. Waterbirds 34:319–346. DOI: 10.1675/063.034.0307

Denes, F. V., L. F. Silviera, and S. R. Beissinger. 2015. Estimating abudance of unmarked animal populations for imperfect detection and other sources of zero inflation. Methods in Ecology and Evolution 6:543–556. DOI: 10.1111/2041-210X.12333

Diefenbach, D. R., D. W. Brauning, and J. A. Mattice. 2003. Variability in grassland bird counts related to observer differences and species detection rates. Auk 120:1168–1179. DOI: 10.1642/0004-8038(2003)120[1168:VIGBCR]2.0.CO;2

Fiske, I. J., and R. B. Chandler. 2011. unmarked: An R Package for fitting hierarchical models of wildlife occurence and abundance. Journal of Statistical Software 43:1–23. DOI: 10.18637/jss.v043.i10

Fournier, A. M. V., M. C. Shieldcastle, T. Kashmer, and K. A. Mylecraine. 2015. Comparison of arrival dates of rail migration in the Southwest Lake Erie marshes, Ohio, USA. Waterbirds 38:312–314. DOI: 10.1675/063.038.0313

Fredrickson, L. H., and T. S. Taylor. 1982. Management of seasonally flooded impoundments for wildlife. <https://pubs.er.usgs.gov/publication/rp148>.

Glisson, W.J., R. S. Brady, A. T. Paulios, S. K. Jacobi, and D. J. Larkin. 2015. Sensitivity of secretive marsh birds to vegetation condition in natural and restored wetlands in Wisconsin. Journal of Wildlife Management 79:1101–1116. DOI: 10.1002/jwmg.937

Hostetler, J. A., T. S. Sillett, and P. P. Marra. 2015. Full-annual-cycle population models for migratory birds. Auk 132:433–449. DOI: 10.1642/AUK-14-211.1

Kearns, G. D., N. B. Kwartin, D. F. Brinker, and G. M. Haramis. 1998. Digital playback and improved trap design enhances capture of migrant soras and Virginia rail. Journal of Field Ornithology 69:466–473.

Marra, P. P., E. B. Cohen, S. R. Loss, J. E. Rutter, and C. M. Tonra. 2015. A call for full annual cycle research in animal ecology. Biology Letters 11:2015.0552. DOI: 10.1098/rsbl.2015.0552

Melvin, S. M., and J. P. Gibbs. 2012. Sora. A. F. Poole and F. Gill, editors. The Birds of North America. The Academy of Natural Sciences, Philadelphia, PA and The American Ornithologists Union, Washington, D.C. DOI:10.2173/bna.250

Nadeau, C. P., C. J. Conway, B. S. Smith, and T. E. Lewis. 2008. Maximizing detection probability of wetland-dependent birds during point-count surveys in northwestern Florida. Wilson Journal of Ornithology 120:513–518. DOI: 10.1676/07-041.1

Newton, I. 2006. Can conditions experienced during migration limit the population levels of birds? Journal of Ornithology 147:146–166. DOI: 10.1007/s10336-006-0058-4

Olinde, M.W., F.G. Kimmel, and R.M. Pace, III. 2000. Direct recoveries from in-season banding of American woodcock in south-central Louisiana. Pages 77-83 in McAulery, D. G., J. G. Bruggink, and G. F. Sepik (eds.) Proceedings of the ninth American woodcock symposium. U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD/ITR-2000-0009, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Perkins, M., S. L. King, and J. Linscombe. 2010. Effectiveness of capture techniques for rails in emergent marsh and agricultural wetlands. Waterbirds 33:376–380.

Quinn, G. P., and M. Keough. 2011. Experimental design and data analysis for biologists. Second Edition. University Press, Cambridge, England, United Kingdom.

R Core Team. 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <http://www.r-project.org/>.Rappole, J. H., and A. R. Tipton. 1991. A new harness design for attachment of radio transmitters to small passerines. Journal of Field Ornithology 62:335–337.

Ross, B. E., D. Haukos, C. Hagen, and J. Pitman. 2016a. The relative contribution of climate to changes in lesser prairie-chicken abundance. Ecosphere 7:1–11. Doi: 10.1002/ecs2.1323

Ross, B. E., D. A. Haukos, C. A. Hagen, and J. C. Pitman. 2016b. Landscape composition creates a threshold influencing lesser prairie-chicken population resilience to extreme drought. Global Ecology and Conservation 6:179–188. Doi: 10.1016/j.gecco.2016.03.003

Royle, J. A. 2004a. N-mixture models for estimating population size from spatially replicated counts. Biometrics 60:108–15. <http://www.ncbi.nlm.nih.gov/pubmed/15032780>.

Royle, J. A. 2004b. Generalized estimators of avian abundance from count survey data. Animal Biodiversity and Conservation 27:375–386.

Royle, J. A., D. K. Dawson, and S. Bates. 2004. Modeling abundance effects in distance sampling. Ecology 85:1591–1597. Doi: 10.1111/j.0006-341X.2004.00142.x

Rundle, W. D., and L. H. Fredrickson. 1981. Managing seasonally flooded impoundments for migrant rails and shorebirds. Wildlife Society Bulletin 9:80–87.

Sillett, T. S., R. B. Chandler, J. A. Royle, M. Kery, and S. A. Morrison. 2012. Hierarchical distance-sampling models to estimate population size and habitat-specific abundance of an island endemic. Ecological Applications 22:1997–2006. Doi: 10.1890/11-1400.1

Thompson, W.L. 2002. Towards reliable bird surveys: accounting for individuals present but not detected. Auk 119:18–25.

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

Area	**Impoundment**	**Visit 1 estimate**	**upper CI**	**lower CI**	**Visit 2 estimate**	**upper CI**	**lower CI**	**Visit 3 estimate**	**upper CI**	**lower CI**	**Visit 4 estimate**	**upper CI**	**lower CI**
Duck Creek Conservation Area	Unit A 14	13.8	14.9	12.8	14.3	15.4	13.2	13.2	15.1	11.5	13.3	14.4	12.3
	Unit A 18				8.1	8.8	7.6	13.5	15.1	12	14.1	15.3	13.1
	Unit A 22										5.4	5.9	5
B.K Leach Conservation Area	Kings Tract 2	5.2	5.7	4.8	6.8	7.3	6.3	5.8	6.2	5.3	9.1	9.9	8.5
	Kings Tract 5	7	7.5	6.5	9.9	10.7	9.2	10.8	11.6	10	9.2	9.9	8.5
	Kings Tract 6				5.6	6.1	5.1						
	Kings Tract 9	7.6	8.3	7	5.6	6.1	5.2						
Swan Lake National Wildlife Refuge	m10	14.6	15.9	13.5	13.2	14.3	12.2	7	7.7	6.5	7	7.7	6.5
	m11	6.6	7.2	6.1	9.9	10.6	9.2	13.6	14.7	12.5	13.1	14.2	12.2
	m13	3.9	4.3	3.5	4.5	4.9	4.1	8.4	9.1	7.7	8	8.7	7.4
Otter Slough Cons. Area	21	7.4	8	6.9	8.2	8.8	7.6	7	7.5	6.5	8.5	9.1	7.9
	23							5.6	6.2	5.1	7.1	7.7	6.4

(Table 1 Continued)

Area	Impoundment	Visit 1 estimate	upper CI	lower CI	Visit 2 estimate	upper CI	lower CI	Visit 3 estimate	upper CI	lower CI	Visit 4 estimate	upper CI	lower CI
Fountain Grove Cons. Area	pool2	6.4	6.9	5.9	12.4	13.4	11.4				12.1	13	11.2
	Pool 2 walk In	6.6	7.1	6	6.3	6.8	5.8	7	7.5	6.4	13.3	14.3	12.3
Ten Mile Pond Cons. Area	Pool C	6.3	6.8	5.8	7.8	8.4	7.2	6.3	6.8	5.8	10.3	11.1	9.6
	Pool E	16.3	17.8	14.9	15.8	17.3	14.5	19.8	21.8	18	13.8	15	12.6
	Pool I				5.9	6.4	5.4				8.5	9.1	7.9
Nodaway Valley Cons.Area	rail	6.3	6.8	5.8	11.7	12.7	10.9	7.2	7.8	6.7	12.6	13.6	11.6
	sanctuary	5.9	6.4	5.4	8.9	9.5	8.3	10.3	11.1	9.6	12.7	13.7	11.8
Squaw Creek National Wildlife Refuge	Snow Goose B				5.7	6.2	5.3	12.7	13.8	11.7	12	13	11.2
	Snow Goose D	6.3	6.8	5.8	6.3	6.8	5.8	13.9	15.1	12.8	10.6	11.5	9.9
Ted Shanks Cons.Area	2a	5.6	6.1	5.1	5.6	6.1	5.1	6.8	7.4	6.3	9.3	10	8.6
	4a	4.9	5.4	4.5	4.9	5.4	4.5						
	6a	6.1	6.6	5.6	6.1	6.6	5.6	13.4	14.5	12.4	13.5	14.6	12.5
	8a	5.6	6.1	5.1	6.4	6.9	6	11.9	13.2	10.8	11.9	13.2	10.8

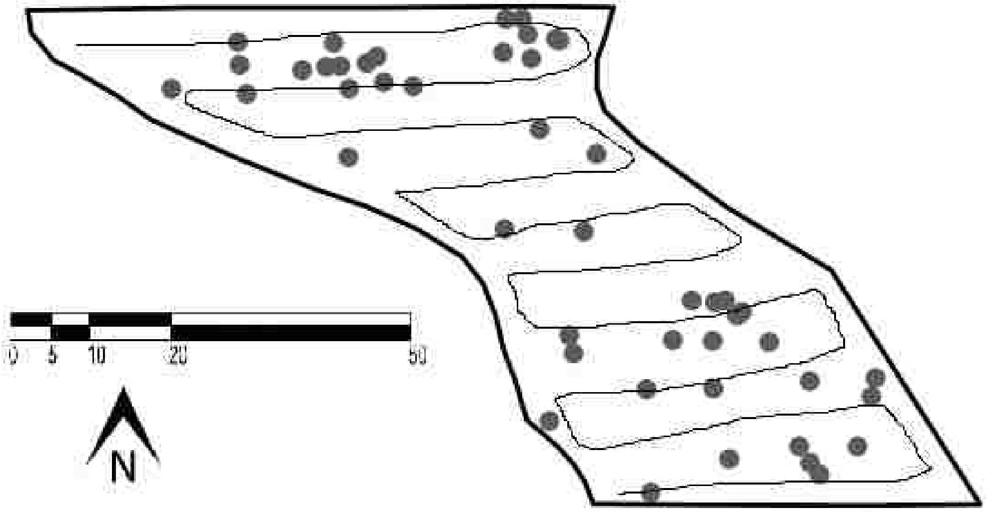


Figure 1 - Example of a Survey Transect (line) and observed Sora (dots) in a wetland impoundment at Swan Lake National Wildlife Refuge, Missouri, USA

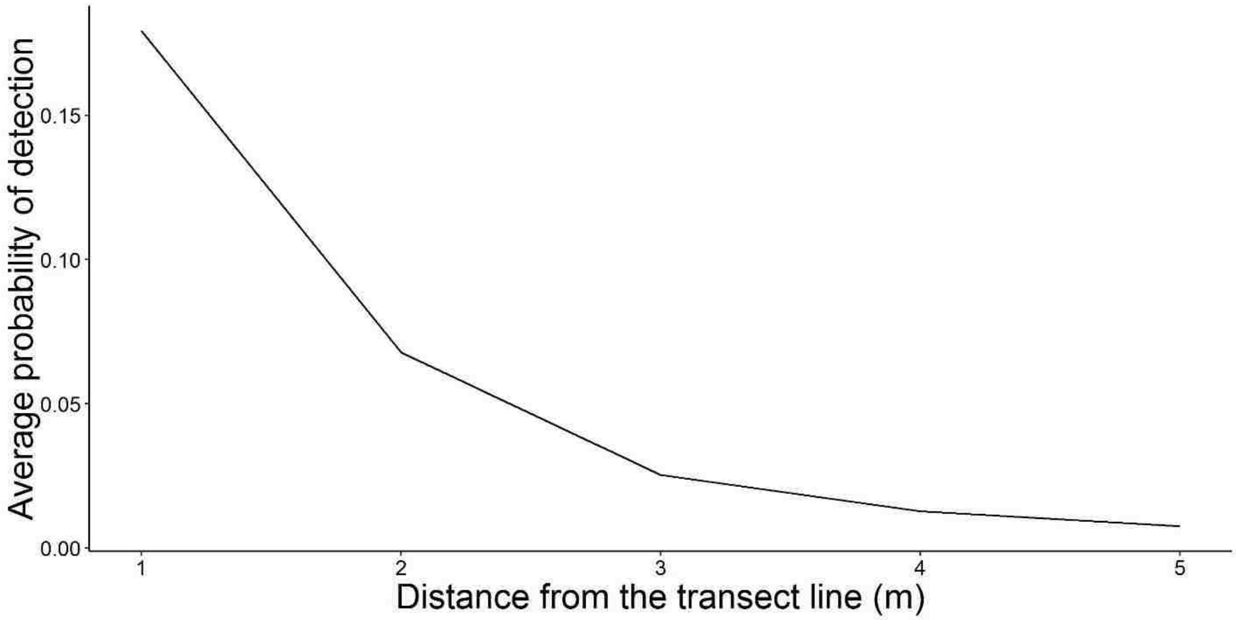


Figure 2 - Relationship between distance from the transect line and average probability of detecting an individual assuming the individual is available to be detected

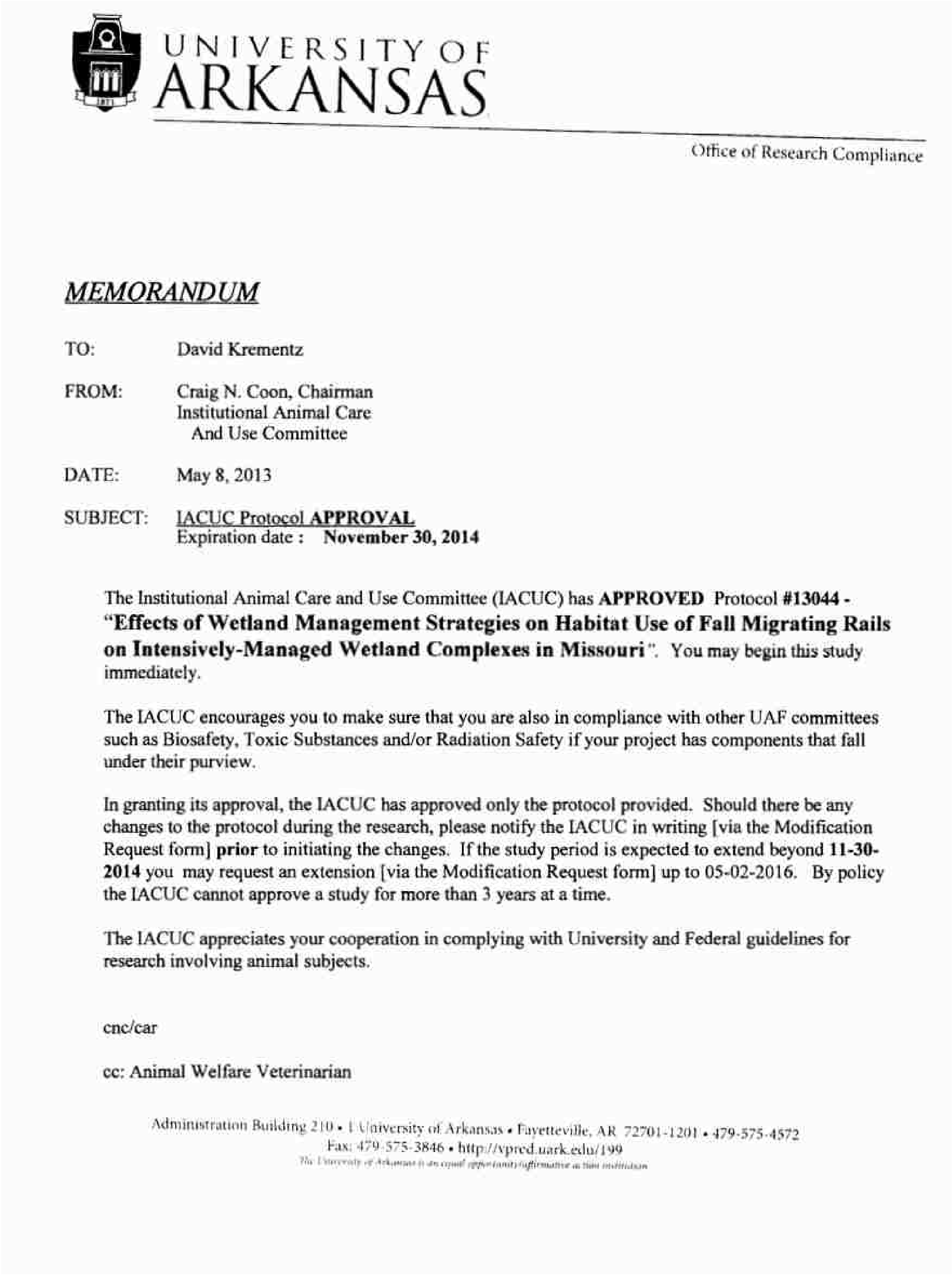
Chapter 5, "Nocturnal Distance Sampling All-Terrain Vehicle Surveys for Non-Breeding Rails" of A.M.V. Fournier's dissertation accepted for publication in the Wildlife Society Bulletin with one coauthor, D.G. Krementz.

I, Dr. David G. Krementz, advisor of Auriel M.V. Fournier, confirm Auriel M.V. Fournier will be first author and completed at least 51% of the work for this manuscript.

David G Krementz ______ 16 March 2017 ______

David G. Krementz
Unit Leader
U.S. Geological Survey
Arkansas Cooperative Fish and Wildlife
Research Unit

Date



UNIVERSITY OF
ARKANSAS

Office of Research Compliance

MEMORANDUM

TO: David Krementz

FROM: Craig N. Coon, Chairman
Institutional Animal Care
And Use Committee

DATE: May 8, 2013

SUBJECT: IACUC Protocol **APPROVAL**
Expiration date : **November 30, 2014**

The Institutional Animal Care and Use Committee (IACUC) has **APPROVED** Protocol **#13044 - "Effects of Wetland Management Strategies on Habitat Use of Fall Migrating Rails on Intensively-Managed Wetland Complexes in Missouri**". You may begin this study immediately.

The IACUC encourages you to make sure that you are also in compliance with other UAF committees such as Biosafety, Toxic Substances and/or Radiation Safety if your project has components that fall under their purview.

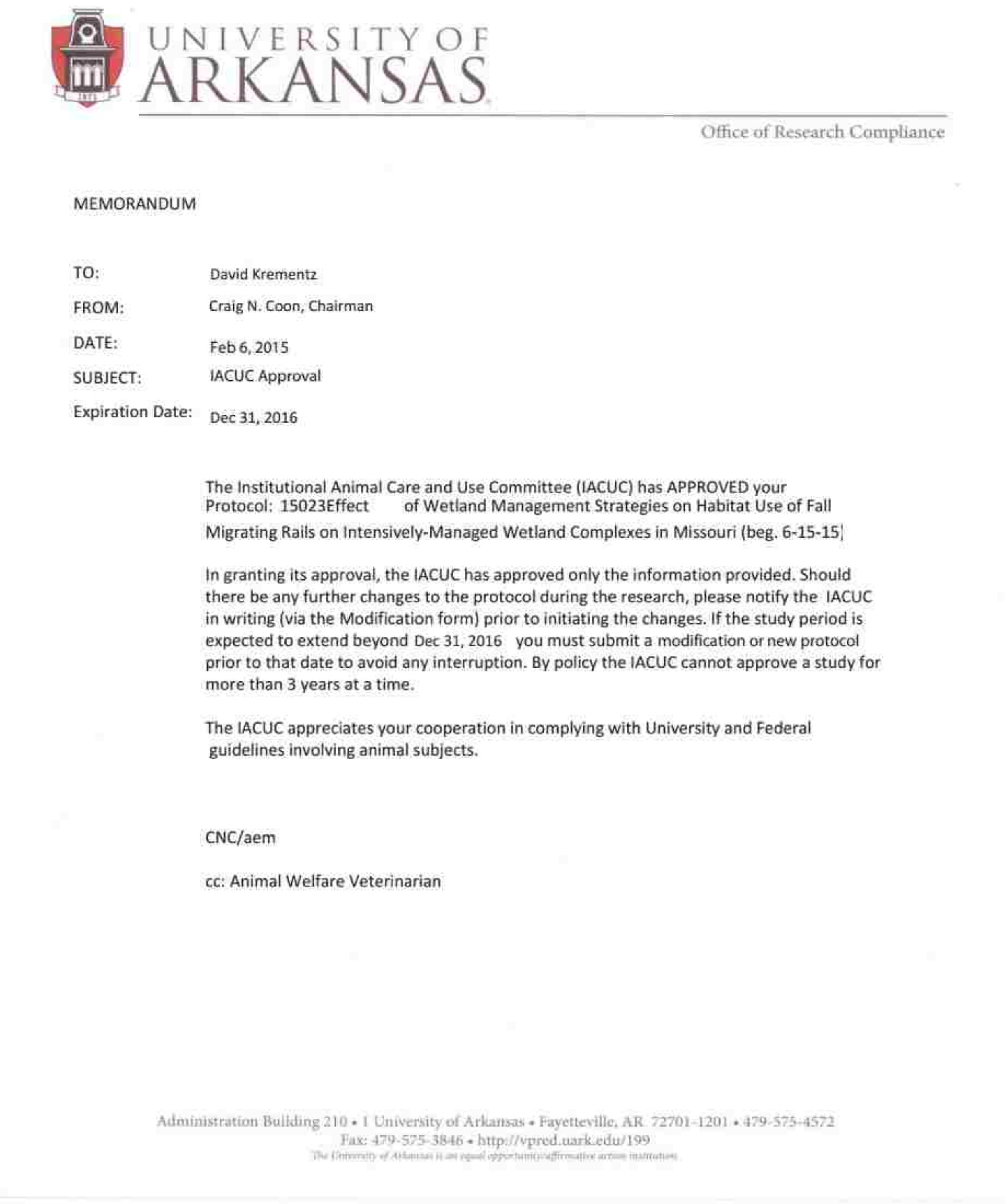
In granting its approval, the IACUC has approved only the protocol provided. Should there be any changes to the protocol during the research, please notify the IACUC in writing [via the Modification Request form] **prior** to initiating the changes. If the study period is expected to extend beyond **11-30-2014** you may request an extension [via the Modification Request form] up to 05-02-2016. By policy the IACUC cannot approve a study for more than 3 years at a time.

The IACUC appreciates your cooperation in complying with University and Federal guidelines for research involving animal subjects.

cnc/car

cc: Animal Welfare Veterinarian

Administration Building 210 • 1 University of Arkansas • Fayetteville, AR 72701-1201 • 479-575-4572
Fax: 479-575-3846 • http://vpred.uark.edu/199



UNIVERSITY OF
ARKANSAS

Office of Research Compliance

MEMORANDUM

TO: David Krementz

FROM: Craig N. Coon, Chairman

DATE: Feb 6, 2015

SUBJECT: IACUC Approval

Expiration Date: Dec 31, 2016

The Institutional Animal Care and Use Committee (IACUC) has APPROVED your Protocol: 15023Effect of Wetland Management Strategies on Habitat Use of Fall Migrating Rails on Intensively-Managed Wetland Complexes in Missouri (beg. 6-15-15)

In granting its approval, the IACUC has approved only the information provided. Should there be any further changes to the protocol during the research, please notify the IACUC in writing (via the Modification form) prior to initiating the changes. If the study period is expected to extend beyond Dec 31, 2016 you must submit a modification or new protocol prior to that date to avoid any interruption. By policy the IACUC cannot approve a study for more than 3 years at a time.

The IACUC appreciates your cooperation in complying with University and Federal guidelines involving animal subjects.

CNC/aem

cc: Animal Welfare Veterinarian

Administration Building 210 • 1 University of Arkansas • Fayetteville, AR 72701-1201 • 479-575-4572
Fax: 479-575-3846 • http://vpred.uark.edu/199
The University of Arkansas is an equal opportunity/affirmative action institution

CONCLUSION

To manage migratory bird populations in an effective way, decisions need to be based on an understanding of the drivers of that species population, and migration is an often overlooked time of year. Before the advent of many new technological tools for studying migratory birds studying migration on anything but the small scale was very difficult. The constant challenges of studying migration, coupled with the elusive nature of rails, has left their migration largely understudied which limits our ability to assess how migration may impact their populations and how current management could be improved to better suit rails and other species at the same time. In this dissertation, I have presented a foundation for understanding the migration ecology of three rail species to promote sound, science-based, conservation and management of them and their habitats.

Rails are difficult to detect because of their elusive behavior, including infrequent vocalization and spending most of their time in dense vegetation while also rarely flying. Although methods have been developed to optimize detection during the breeding season, there was no survey method for the non-breeding season. Low detection of rails and lack of suitable methods limits monitoring efforts and examination of important questions related to rail conservation and habitat management during the non-breeding season. I created and verified a new survey method along with suggestions for its effective use in moist-soil wetlands. I conducted nocturnal surveys during the autumn to detect Sora (*Porzana carolina)* using hierarchical generalized distance sampling along transects that I traveled while riding all-terrain vehicles at night. I evaluated assumptions of our survey method by examining the response by radio-marked Sora to survey vehicles and comparing survey counts between surveys on the same night. These surveys produced Sora density estimates that can be used to address conservation and management questions, such as habitat use and migratory timing.

Understanding what habitat is needed during migration by rails required us to tackle two questions simultaneously, when are rails migrating, and what habitats are rails using. I found Sora migration in Missouri began in the first week of August, on average it peaked on 25 September, and continued through the last week of October. I detected Sora migration earlier in autumn than previous work. I found the start and end of migration did not vary annually in three of four years. In addition I found a strong positive second order relationship between the presence of Sora at a point and with mean water depth and first order annual moist soil vegetation, and a lesser first order positive relationship with perennial moist soil vegetation. I also found a change in mean water depth across the migration season, which highlights limitations of available wetland habitat early in migration for Sora. These results provide an informative foundation for multispecies management of palustrine wetlands and future research to inform the conservation and management of Sora.

Based on these results, I hypothesized if wetlands were flooded earlier in autumn migration I would observe more Sora. Our initial observations supported this but could have been confounded by other variables, such as the surrounding landscape, so I designed an experiment to explicitly test two flooding treatments. Rails are not the only birds using these habitats, waterfowl are also of interest and I looked at the impacts of two flooding treatments, one early in the migration, one later on rails and waterfowl. Initially I planned this to be a 2x2 crossover, but because of factors, such as extreme flooding, outside of my control many of the treatments were confounded and so I extended the experiment to a third year and assigned treatments post hoc using quantitative rules. Taking into account the random effect of visit, I found a positive effect of early flooding on Sora count across all years. Waterfowl were counted weekly from October till January, and I looked at change in maximum count every two weeks and did not find a negative impact of the early flooding treatment, which had been hypothesized because the earlier flooding could have negatively impacted the vegetation community. To manage wetlands to fill the wide suite of wildlife, plant, ecosystem service, and human (recreational and cultural needs) I need science based management that allows us to make informed decisions about the consequences of management, especially in the face of additional challenges like climate change.

While I detected fewer Virginia and Yellow Rails than Sora during this project, I were still able to ask some interesting questions about them and their stopover ecology. I compared our survey data to the timing of autumn migration from three opportunistic datasets: 1) eBird records, 2) building strikes, and 3) state ornithological records. The timing of Virginia Rail autumn migration varied between the opportunistic data and our surveys. Opportunistic data had two peaks, while our surveys had a single peak the second week in October. Yellow Rail autumn migration through Missouri peaked earlier in our surveys than opportunistic datasets, which peaked during the second week in October. Both rail species were found in moist soil habitats, however Virginia Rails selected perennial species more than was available, while Yellow Rails selected annual species. Both species showed no selection for water depth and used shallowly flooded wetlands. Understanding the autumn migration period and habitat requirements will allow wetland managers to better manage lands for autumn migrating Virginia and Yellow Rails.

When a species' needs during migration, are discussed the focus is often on the individual stopovers, but those stopover locations and events are part of the larger annual cycle of a species and that larger context, also needs to be considered. When the connections between parts of a migratory animal's annual cycle we are discussed their migratory connectivity, or how connected, or not connected, a given part of the breeding range is with a given part of the wintering range are typically the primary focus. What is often missing from conversations about migratory connectivity is the role of migratory stopover locations. Including stopover locations is valuable for informing management and conservation, and when using stable isotopes to quantify connectivity, the incorporation of additional information can help. I used data from marsh bird monitoring programs to create species distribution models for Sora (*Porzana carolina*), Virginia Rail (*Rallus limicola*), and Yellow Rail (*Coturnicops noveboracensis*). I then used the species distribution models to refine assignments of breeding areas of autumn-migrating and wintering birds based on isotope analysis of feathers collected at various locations across the southern United States. Sora were assigned to an area that included the central part of the U.S. and the central portion of southern Canada, covering parts of the Mississippi, Central and Pacific migratory flyways. Yellow Rails were assigned from James Bay through northern Manitoba, through Ontario and southern Quebec and down into northern Minnesota, Wisconsin and Michigan. Virginia Rails were primarily from several discrete areas, including the southern part of their breeding range in Colorado, and New Mexico, the central valley of California, and southern Saskatchewan and Manitoba. Monitoring data could be used to improve the isotopic assignment of a wide suite of birds, which in turn contributes to better management and conservation of those species.

Rails are often spoken of as one homogenous group, largely because in the past all species have been studied in tandem and also because each individual species is so poorly studied discussing the nuance between species is difficult. While some of the things documented in this dissertation are not particularly surprising, I have tried to provide some of that nuance, showing the differences between Sora, Yellow Rail and Virginia Rail migration timing, and their habitat selection during autumn migration. The harder I look at rails, the more intriguing behavior I have found, the more questions I am left with. In this project, I observed novel behaviors, including documenting Sora diving and swimming under water on video and the earliest autumn migrating yellow rail, and highest number of yellow rails in one day during autumn migration, in Missouri. The challenge of studying these birds, and their wetlands has been rewarding, rails are fascinating, frustrating, intriguing and endearing little birds about which I am grateful to have learned slightly more than the little we knew before.

APPENDIX I

Table 1 - Impoundments Surveyed from 2012-2016. The first time an impoundment is mentioned the latitude, longitude of the center of the impoundment is given.

Property	**Year**	**Region**	**Wetland Impoundments**
Nodaway Valley Conservation Area	2012	northwest	Sanctuary (40.093070, -95.047479), Ash Grove (40.085344, -95.047671)
	2013		Sanctuary, Ash Grove
	2014, 2015, 2016		Sanctuary, Ash Grove, Rail Marsh (40.100918, -95.052288)
Squaw Creek National Wildlife Refuge	2012		Snow Goose B (40.090428, -95.265754), North Mallard (40.102608, -95.278374), North Pintail (40.090984, -95.271568)
	2013		Snow Goose B, C (40.085930, -95.264500), D (40.081784, -95.264433) & E (40.078820, -95.263299), North Mallard
	2014, 2015, 2016		Snow Goose B & D, MSU 2 (40.104765, -95.237954) and 3 (40.100912, -95.236862)
Fountain Grove Conservation Area	2012	north central	Pool 2 (39.701420, -93.312018), Pool 3 (39.693605, -93.296458), Boardwalk (39.734499, -93.347640)

(Appendix 1 Table 1 Cont.)

Property	**Year**	**Region**	**Wetland Impoundments**
	2013		Pool 1 (39.707164, -93.330787) & 2, Pool 2 Walk-in (39.692044, -93.313637), Pool 3 Walk-in (39.690647, -93.303875)
	2014, 2015, 2016		Pool 2, Pool 2 Walk-in, Pool 3 Walk-in
Swan Lake National Wildlife Refuge	2012		M4 (39.613125, -93.204565), M5 (39.614682, -93.199878), M10 (39.592252, -93.194279), M11 (39.592024, -93.189795)
	2013		M3 (39.614832, -93.196389), M4, M5, M10, M11, M14 (39.612200, -93.211902)
	2014, 2015, 2016		M10, M11, M13
Ted Shanks Conservation Area	2012	northeast	4a (39.541458, -91.162459), 11a (39.525066, -91.140947), Nose Slough (39.512751, -91.118386)
	2013		Nose Slough
B.K. Leach Conservation Area	2012		Bittern Basin 1 (39.207272, -90.767368), 2 (39.198068, -90.771326), & 3 9 39.200561, -90.762914), Kings Tract 2 (39.144996, -90.728693) & 6 (39.134015, -90.738947)

(Appendix 1 Table 1 Cont.)

Property	Year	Region	Wetland Impoundments
	2013		Bittern Basin 1, 2, & 3, Kings Tract 2 & 6
	2014, 2015, 2016		Kings Tract 2, 5 (39.133427, -90.733879), 6, & 9 (39.141516, -90.743086)
Clarence Cannon National Wildlife Refuge	2012		MSU 1 (39.258810, -90.783929), 2 (39.264733, -90.785253) & 7 (39.272534, -90.797022)
	2013		MSU 7
	2014, 2015, 2016		MSU 1, 2, & 12 (39.261315, -90.776206)
Duck Creek Conservation Area	2012	southeast	Unit A 13 (37.060825, -90.118003), 14 (37.061443, -90.123525), 15 (37.054538, -90.122279), 18 (37.056687, -90.129754), 20 (37.060556, -90.128913), & 21 (37.061818, -90.134228), ditch (37.059858, -90.126318)
	2013		Unit A 11 (37.054806, -90.118070), 13, 14, 15, 16 (37.052252, -90.129720), 18, 20, ditch

(Appendix 1 Table 1 Cont.)

Property	Year	Region	Wetland Impoundments
	2014, 2015, 2016		Unit A 14, 18, 20, 22 (37.057224, -90.137459)
Otter Slough Conservation Area	2012		21 9 36.690744, -90.131168), 25 (36.702304, -90.127952), R3 (36.695699, -90.119714), R4/5 (36.699405, -90.111673), R7 (36.690704, -90.120517), R8 (36.692557, -90.115546), R9 (36.691951, -90.108107)
	2013		21, 25, R4/5, R7
	2014, 2015, 2016		21, 23 (36.696303, -90.130061)
Mingo National Wildlife Refuge	2012		2w (37.013013, -90.127367), 2 (37.004314, -90.122802) & 3 (37.009989, -90.122180)
	2013		2w, 2 & 3
Ten Mile Pond Conservation Area	2014, 2015, 2016		Pool C (36.713699, -89.340489), E (36.706395, -89.335239) and I (36.740863, -89.330972)