USING MARSH BIRD NEST SURVIVAL AND POST-FLEDGING HABITAT USE AND SURVIVAL TO INFORM WETLAND MANAGEMENT

BY

STEPHANIE M. SCHMIDT

THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Natural Resources and Environmental Sciences
in the Graduate College of the
University of Illinois Urbana-Champaign, 2022

Urbana, Illinois

Master’s Committee:

Research Associate Professor Thomas J. Benson, Co-Advisor
Research Assistant Professor Auriel M. V. Fournier, Co-Advisor
Professor Michael P. Ward

ABSTRACT

Wetlands have become rare in the United States due to changing land-use practices, contributing to population declines of wetland-dependent birds. Many remaining wetlands are intensively managed through seasonal dewatering mimicking flood pulses in the spring and summer while marsh birds are nesting. However, water around nests may provide protection from predators, and lowering water levels during the breeding season of marsh birds may increase predation risk and exacerbate marsh bird losses. Additionally, the effects of dewatering may have negative implications for fledgling marsh birds who often face the highest risk of mortality due to their inexperience navigating, foraging, and avoiding predators. I studied spatial and temporal factors contributing to marsh bird nest loss and predation risk as a result of wetland dewatering at Least Bittern (*Ixobrychus exilis*), Common Gallinule (*Gallinula galeata*), Black-crowned Night-Heron (*Nycticorax nycticorax*), and American Coot (*Fulica americana*) nests at Emiquon Preserve in Fulton County, Illinois in 2020 and 2021. Additionally, I examined post-fledging Least Bittern habitat selection and mortality on a dewatered landscape. I found water below and around a nest and the timing and volume of dewatering influenced marsh bird nest survival, with greater survival of nests over deeper water, farther from the shoreline, and when dewatering was later, and less water volume was removed from the marsh. I also found predation risk by raccoons (*Procyon lotor)* and mink (*Neovision vision)*, and risk of nest abandonment increased as water was removed, suggesting mammalian predators have greater access to nests due to dewatering. I found fledgling habitat use was dependent on age and flight ability, and pre-flight fledging habitat decisions potentially maximized predator protection while post-flight fledgling decisions potentially maximized hunting efficiency. Fledgling mortality was dependent on age, with a bottleneck observed in the first few days following fledging.

ACKNOWLEDGEMENTS

First, I would like to thank my thesis co-advisors, Dr. Thomas J. Benson and Dr. Auriel M. V. Fournier, for taking me under their wing as a fledging scientist. I am forever grateful for your mentorship, expertise, and patience when guiding me through my master's degree. Next, I would like to thank my committee member Dr. Michael P. Ward, for his editorial guidance and advice when preparing for and writing my thesis. I also need to thank the staff at the Forbes Biological Station for going above and beyond to help me during my field seasons. Aaron, you fixed my boats countless times and made sure my team could safely head out on the water, and my data collection timeline was not hindered. Josh, you helped my project really take flight through your assistance with GIS mapping and banding permits and helping me catch birds in the field, no matter how many days were unsuccessful. Chelsea Kross, Andy Gilbert, and Therin Bradshaw I am very grateful for your help with nesting surveys and your shared knowledge of Emiquon Preserve, nesting marsh birds, and wetland predators. Mindy Lowers, I really put you through the wringer with my countless orders for supplies, travel reimbursements, and grant funds. You took it all in stride and were the unsung hero of my project. Thank you.

This work would not be possible without the help of my amazing technicians, Nora Hargett, Cheyenne Stephens, Nicole Pietrunti, and Cheyenne Beach. This project asked a lot out of you, and you all blew me away with your talent, dedication, and persistence. Nora Hargett, you really stepped up to the plate in my second field season as my lead technician. You are a great scientist and leader, and I am eternally thankful to have had you on my team. I would also like to thank members of the Ward, Hoover, and Benson labs (Ryan Askren, Wendy Dorman, Claire Johnson, Luke Malanchuk, Morgan Meador, Lauren Monopoli, Ian Souza-Cole, Sarah Stewart, and Sarah Winnicki-Smith) for their friendship, advice, and a shared love of

birds. I am grateful to The Nature Conservancy for access to Emiquon Preserve and Doug Blodgett and Sally McClure for their help with data collection. This research was made possible through a state wildlife grant (T-122-R) with the Illinois Department of Natural Resources, and individual research grants from the Illinois Ornithological Society, DuPage Birding Club, Chicago Audubon Society, American Ornithological Society, and Champaign County Audubon Society.

I would like to thank my family who has supported me every step of the way. Mom, Dad, Eva, and Anthony, you have watched my love for nature and birds grow with me and you never told me to stop dreaming big. Frank, Gaylee, Barb, and Wally, your support these past six years has meant everything to me. Brandon, your love, support, and encouragement have motivated me to keep going when the going gets tough. From the early mornings you joined me in the field as I learned how to identify birds to the late nights you gave me feedback on my writing, you have always been by my side and in my corner. Finally, I need to thank my undergraduate research advisor and mentor, Dr. Prashant Sharma and Dr. Connor Wood, respectively, for introducing me to research and continuing to push me to be a better scientist every step of the way.

TABLE OF CONTENTS

CHAPTER 1: LITERATURE REVIEW

Wetland loss and degradation from land-use practices that alter hydrology, increase sedimentation and eutrophication, introduce invasive species, and change the size and interspersion of habitat have contributed to the decline of wetland wildlife, including marsh birds (Eddleman et al. 1988, Newman et al. 2003, Zedler and Kercher 2005, Quesnelle et al. 2013, Soulliere et al. 2018, Rosenberg et al. 2019). In particular, obligate marsh birds have been negatively affected by marsh loss (Weller and Spatcher 1965, Lor and Malecki 2006). Marsh birds are biologically important indicators of wetland health, however, due to their dense habitat, cryptic plumage, and secretive behaviors they are often difficult to detect, which has hindered marsh bird research (Conway 2011).

The North American Breeding Bird Survey is a United States Geological Survey (USGS) roadside survey program developed to survey and obtain long-term population data for bird species (Lawler and O'Connor 2004, Gray et al. 2013). However, these roadside surveys are known to under-sample wetlands and are inadequate for monitoring marsh birds because of their secretive behavior and the inaccessibility of wetland sites (Lawler and O'Connor 2004, Gray et al. 2013). Alternative monitoring strategies have been proposed to gain further insight into marsh bird ecology (Conway 2011, Gray et al. 2013). Using these techniques and others to measure occupancy and abundance, research has demonstrated that management practices that alter the depth and extent of water, invertebrate communities, or the amount of emergent vegetation cover influence marsh bird communities (Conway 2011). In particular, studies have found that marsh bird occupancy tends to be greatest when accompanied with intermediate levels of active waterfowl management conducted outside of the breeding season and retain water on the landscape (Lane and Jensen 1999, Desgranges et al. 2006, Bradshaw et al. 2020).

Active dewatering is a management practice that is implemented to restore wetlands by manipulating wetland water levels to create a mosaic of wetland types for a diversity of plant and animal communities (Frederickson and Taylor 1982, Lane and Jensen 1999, Newman et al. 2003). Managed wetlands use water-level manipulations to reset wetland plant successional stages and create diverse configurations of emergent vegetation with highly productive seed-producing annuals (Bellrose 1941, Frederickson and Taylor 1982). This dynamic management technique constantly transitions habitat to accommodate a variety of species by controlling seasonal marsh flooding and drawdowns to expose new resources and habitats throughout the year (Lane and Jensen 1999).

Water level management is implemented primarily for the benefit of migrating waterfowl, though it has benefits beyond waterfowl, and has been shown to positively impact mammals, shorebirds, and marsh bird populations for some portion of their life cycle (Weller and Spatcher 1965, Rundle and Fredrickson 1981, Ma et al. 2010, Lemke et al. 2018, Bradshaw et al. 2020). Waterfowl and shorebirds primarily use Midwest wetlands as stopover sites during spring and fall migration, while marsh birds, defined as cryptically colored and secretive wetland-dependent birds who rely on emergent vegetation for nesting and hunting, use emergent wetlands (i.e., wetlands with persistent and non-persistent emergent vegetation) in this region for breeding (Bradshaw et al. 2020). However, water drawdowns implemented for wetland management during the breeding season may not provide conditions suitable for marsh birds and may have negative impacts on reproduction (Ricklefs 1969, Ma et al. 2010, Fournier et al. 2021). Water drawdowns and low water levels below a nest have been implicated with disrupting nest initiation, stranding nests over dry ground, increasing land-based predator access to nests, and increasing abandonment (Weller and Spatcher 1965, Eddleman et al. 1988, Post 1998, Desgranges et al. 2006, Hill 2015). For this reason, there is a need to evaluate the impact of water level manipulations on the breeding success of marsh birds to better understand the consequences of this dynamic wetland management technique on marsh bird populations.

Water-level management to mitigate wetland loss or degradation alters habitat structure and has been implicated with increasing predation risk at marsh bird nests following an increase in nest visibility and predator access. Predation accounts for 70% of reproductive failure in nesting birds, and temperate marsh nesting birds exhibit the highest mortality rates (Ricklefs 1969, Johnson 2001, Colombelli-Négrel and Kleindorfer 2005). Complex vegetated habitat of varied structure interspersed with open water is important to breeding and juvenile marsh birds because it provides protection from predators and space for waterbirds to forage (Bradshaw et al. 2020). Nest concealment (i.e., vegetation density) and nest location have varying effects on predation risk, predator access, and predator identity (Colombelli-Négrel and Kleindorfer 2005, Jedlikowski et al. 2015). Nests with greater concealment and height experience less loss from predators that use visual cues (Colombelli-Négrel and Kleindorfer 2005). Alternatively, predators that hunt using olfactory cues are not deterred by concealment, but rather access (i.e., water depth) (Colombelli-Négrel and Kleindorfer 2005, Hoover 2005). Multiple studies have shown that predation of waterbird nests increases as a result of decreasing water depth giving predators access to nests (Ma et al. 2010, Hill 2015) despite an increase in concealment from vegetation (Jobin and Picman 1997). On the other hand, deep water marshes have been shown to discourage predation attempts and decrease predator diversity due to the habitat conditions preventing effective nest searching by predators (Picman et al. 1993).

Additional studies have also found that edge effects and associated predation risk are substantial in habitats with pronounced productivity gradients between the habitat of interest and the surrounding areas. In wetlands, this effect has been found within 50 meters from an edge where predator communities are more diverse (Batáry and Báldi 2004). Predators such as snakes and mammals may reside or selectively hunt in these areas which can contribute to the heightened predation risk (Lee 2006, Barding and Nelson 2008). Parental activity at the nest may also deliver cues to predators that have access to nest habitat (Skutch 1949), and this activity increases in the nestling stage when there is a greater energetic demand from the juveniles (Martin et al. 2000). Both activity as well as odors associated with nests would be expected to increase with clutch size, potentially increasing predation risk (Colombelli-Négrel and Kleindorfer 2005).

Habitat management for birds often focuses on the breeding season, placing emphasis on the nesting period while giving very little attention to the post-fledging period. The post-fledging period, defined as the time between when a bird leaves the nest and when it migrates, is poorly understood for most bird species, despite it being a critical and challenging life-history stage (Small et al. 2015, Naef-Daenzer and Grüebler 2016, Jones et al. 2017). Young birds who have left their nest (i.e., fledglings), face the lowest chance of survival because of their inexperience foraging, navigating, and avoiding predators (Anders et al. 1997, Cox et al. 2014). Studies of passerines have revealed that food availability and vegetation cover for predator protection can influence habitat use and survival during the post-fledging period (Jones and Bock 2005, Small et al. 2015). For juvenile marsh birds, water depth is also likely to be important because water provides both protection from terrestrial predators and access to food resources for various birds who nest over water (Hoover 2005, Weller 1961).

This study set out to examine (1) spatial and temporal causes of marsh bird (Least Bittern, Common Gallinule, American Coot, Black-crowned Night-Heron) nest fate as a result of wetland dewatering, (2) predator-specific patterns of marsh bird nest predation risk, and (3) Least Bittern post-fledging survival and habitat use in response to water level manipulations. I used infrared video cameras on nests to identify predators because past studies have determined that tracks around nests or marks on eggs are relatively unreliable for identifying predators (Larivière 1999, Williams and Wood 2002). I radio-tagged and tracked juvenile Least Bitterns after leaving the nest to determine survival and habitat use. Overall, this focus on relationships between water-level management and habitat use and nest and fledging survival is intended to help guide conservation and management efforts for these and other wetland species of concern from incubation through fledging.

LITERATURE CITED

Anders, A. D., D. C. Dearborn, J. Faaborg, and F. R. Thompson III (1997). Juvenile survival in a population of neotropical migrant birds. Conservation Biology 11:698-707.

Barding, E. E., and T. A. Nelson (2008). Raccoons use habitat edges in northern Illinois. American Midland Naturalist 159:394-402.

Batáry, P., and A. Báldi (2004). Evidence of an edge effect on avian nest success. Conservation Biology 18:389-400.

Bellrose, F. C. (1941). Duck Food Plants of the Illinois River Valley. Illinois Natural History Survey Bulletin 21:237-280.

Bradshaw, T. M., A. G. Blake-Bradshaw, A. M. V. Fournier, J. D. Lancaster, J. O'Connell, M. W. Jacques, M. W. Eichholz, and H. M. Hagy (2020). Marsh bird occupancy of wetlands managed for waterfowl in the midwestern USA. PLoS ONE 15: 1-19.

Colombelli-Négrel, D., and S. Kleindorfer (2005). Nest height, nest concealment, and predator type predict nest predation in Superb Fairy-wrens (*Malurus cyaneus*). Ecological Society of Japan 24:921-928.

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

Cox, W. A., F. R. Thompson III, A. S. Cox, and J. Faaborg (2014). Post-fledging survival in passerine birds and the value of post-fledging studies to conservation. Journal of Wildlife Management 78:183-193.

Desgranges, J. L., J. Ingram, B. Drolet, J. Morin, C. Savage, and D. Borcard (2006). Modeling wetland bird response to water level changes in the Lake Ontario - St. Lawrence River hydrosystem. Environmental Monitoring and Assessment 113:329-365.

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

Fournier, A. M. V., J. D. Lancaster, A. P. Yetter, C. S. Hine, T. Beckerman, J. Figge, A. Gioe, M. Greider-Wagner, D. Jen, C. Johnson, M. R. Larreur, et al. (2021). Nest success and nest site selection of wetland birds in a restored wetland system. Avian Conservation and Ecology 16. https://doi.org/10.5751/ACE-01782-160106

Gray, M. J., M. J. Chamberlain, D. A. Buehler, and W. B. Sutton (2013). Wetland wildlife monitoring and assessment. In Wetland Techniques: Volume 2: Organisms (J. T. Anderson and C. A. Davis, Editors). Springer, Netherlands.

Hill, E. B. (2015). Linking wetland management decisions to secretive marsh bird habitat use during spring migration and summer breeding on public wetlands in Missouri. Master's thesis, University of Missouri-Columbia, Columbia, MO, USA.

Hoover, J. P. (2005). Water depth influences nest predation for a wetland-dependent bird in fragmented bottomland forests. Biological Conservation 127:37-45.

Jedlikowski, J., M. Brzeziński, and P. Chibowski (2015). Habitat variables affecting nest predation rates at small ponds: A case study of the Little Crake *Porzana parva* and Water Rail *Rallus aquaticus*. Bird Study 62:190-201.

Jobin, B., and J. Picman (1997). Factors affecting predation on artificial nests in marshes. Journal of Wildlife Management 61:792-800.

Johnson, D. H. (2001). Habitat fragmentation effects on birds in grasslands and wetlands: A critique of our knowledge. Great Plains Research: A Journal of Natural and Social Sciences 11:211-231.

Jones, T. M., J. D. Brawn, and M. P. Ward (2017). Post-fledging habitat use in the Dickcissel. Condor 119:497-504.

Jones, Z. F., and C. E. Bock (2005). The Botteri's Sparrow and exotic Arizona grasslands: An ecological trap or habitat regained? Condor 107:731-741.

Lane, J. J., and K. C. Jensen (1999). Moist soil impoundments for wetland wildlife. U.S. Army Corps of Engineers Technical Report EL-99-11.

Larivière, S. (1999). Reasons why predators cannot be inferred from nest remains. Condor 101:718-721.

Lawler, J. J., and R. J. O'Connor (2004). How well do consistently monitored breeding bird survey routes represent the environments of the conterminous United States? Condor 106:801-814.

Lee, Y. M. (2006). Monitoring of Eastern Fox Snakes (*Pantherophis gloydi*) in response to habitat restoration at Sterling State Park in southeast Michigan. Michigan Department of Natural Resources Report No. 2006-17.

Lemke, M. J., H. M. Hagy, A. F. Casper, and H. Chen, (2018). Floodplain wetland restoration along the Illinois river. In Ecological Restoration in the Midwest. (C. Lenhart, and P. C. Smiley, Editors). University of Iowa Press, IA, USA.

Lor, S., and R. A. Malecki (2006). Breeding ecology and nesting habitat associations of five marsh bird species in western New York. Waterbirds 29:427–436.

Ma, Z., Y. Cai, and J. Chen (2010). Managing wetland habitats for waterbirds: An international perspective. Wetlands 30:15-27.

Martin, T. E., J. Scott, and C. Menge (2000). Nest predation increases with parental activity: Separating nest site and parental activity effects. Proceedings of The Royal Society of London B 267:2287-2293.

Naef-Daenzer, B., and M. U. Grüebler (2016). Post-fledging survival of altricial birds: Ecological determinants and adaptation. Journal of Field Ornithology 87:227-250.

Newman, D. S., R. E. Warner, and P. C. Mankin (2003) Creating Habitats and Homes for Illinois Wildlife. Illinois Department of Natural Resources, IL, USA.

Picman, J., M. L. Milks, and M. Leptich (1993). Patterns of predation on passerine nests in marshes: Effects of water depth and distance from edge. Auk 110:89-94.

Post, W. (1998). Reproduction of Least Bitterns in a managed wetland. Colonial Waterbirds 21:268-273.

Quesnelle, P. E., L. Fahrig, L., and K. E. Lindsay (2013). Effects of habitat loss, habitat configuration and matrix composition on declining wetland species. Biological Conservation 160:200–208.

Ricklefs, R. E. (1969). An analysis of nesting mortality in birds. Smithsonian Contributions to Zoology 9:1-48.

Rosenberg, K. V., A. M. Dokter, P. J. Blancher, J. R. Sauer, A. C. Smith, P. A. Smith, J. C. Stanton, A. Panjabi, L. Helft, M. Parr, and P. P. Marra (2019). Decline of the North American avifauna. Science 366:120–124.

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

Skutch, A. F. (1949). Do tropical birds rear as many young as they can nourish? Ibis 91:430-455.

Small, D. M., P. J. Blank, and B. Lohr (2015). Habitat use and movement patterns by dependent and independent juvenile Grasshopper Sparrows during the post-fledging period. Journal of Field Ornithology 86:17-26.

Soulliere, G. J., M. A. Al-Saffar, R. L. Pierce, M. J. Monfils, L. R. Wires, B. W. Loges, B. T. Shirkey, N. S. Miller, R. D. Schultheis, F. A. Nelson, A. M. Sidie- Slettedahl, et al. (2018). Upper Mississippi River and Great Lakes Region Joint Venture waterbird habitat conservation strategy – 2018 Revision. U.S. Fish and Wildlife Service.

Weller, M. W. (1961). Breeding biology of the Least Bittern. Wilson Bulletin 73:11-35.

Weller, M. W., and C.S. Spatcher (1965). Role of habitat in the distribution and abundance of marsh birds. Iowa State University of Science and Technology Special Report No. 43.

Williams, G. E. and P. B. Wood (2002). Are traditional methods of determining nest predators and nest fates reliable? An experiment with Wood Thrushes (*Hylocichla mustelina*) using miniature video cameras. Auk 119:1126-1132.

Zedler, J. B. and S. Kercher (2005). Wetland resources: Status, trends, ecosystem services, and restorability. Annual Review of Environment and Resources 30:39–74.

CHAPTER 2: WETLAND DEWATERING INFLUENCES PREDATOR-SPECIFIC PATTERNS OF NEST LOSS IN FOUR SECRETIVE MARSH BIRD SPECIES

ABSTRACT

Wetlands have become rare in the United States, negatively influencing wetland-dependent birds, and many remaining wetlands are intensively managed through seasonal dewatering mimicking flood pulses in the spring and summer. However, water around nests may provide protection from predators, and lowering water levels during the breeding season of wetland birds may increase predation risk and exacerbate marsh bird losses. To better inform management strategies for emergent wetlands, we need to understand how the timing and extent of dewatering are impacting nesting marsh birds and whether it is facilitating nest predation. Between 2020 and 2021 we examined nest survival at 158 marsh bird nests (American Coot, *Fulica americana*; Black-crowned Night-Heron, *Nycticorax*; Common Gallinule, *Gallinula galleata*; Least Bittern; *Ixobrychus exilis*) and installed cameras at 80 nests to identify predators at a large wetland in Illinois managed through seasonal dewatering annually. We found Least Bittern and Common Gallinule nest predations and abandonments were related to shallower water, and early season, high volume dewatering. Least Bitterns nested more commonly along wetland edges and nests farther from the shore were more likely to survive. We also found mammalian predation and risk of abandonment decreased with deeper water around nests. Alternatively, snake predation risk increased with early-season emergent vegetation inundation. Our results demonstrate that water is important for deterring predation during the breeding season, particularly by mammals, and suggest managers should delay dewatering until after the nesting season at sites where management for conservation-priority marsh birds is a focus.

Keywords marsh bird, nest survival, nest predation, wetland management.

Lay Summary

- Active dewatering is used in managed wetlands in the spring and summer to create habitat for marsh birds, facilitate the germination of food for waterfowl, control the movement of invasive species, and reset wetland succession.
- The timing and intensity of active dewatering may have adverse effects on nesting marsh birds, because water can be important for limiting predator access to nests.
- We studied how dewatering impacts nest survival and predation risk at Least Bittern, Common Gallinule, American Coot, and Black-crowned Night-Heron nests.
- We found water below and around nests was critically important for facilitating nest survival, and that when large volumes of water were removed while marsh birds were nesting raccoons and mink depredated more nests.
- Our study suggests active dewatering should occur outside of peak nesting stages and at a lower intensity at wetlands where marsh bird nest survival is a concern.

INTRODUCTION

The United States has experienced substantial wetland loss, primarily due to drainage for agriculture or urban development (Dahl 1990, Holland et al. 1995). For many decades wetlands were viewed as a nuisance and by the 1980s, around 53% of the United States' colonial-era wetlands had been drained, mostly driven by heavily altered Midwestern states where most remaining wetlands are small and isolated (Dahl 1990, Havera et al. 1997). This conversion has led to altered hydrology, as well as changes in interspersion and size of emergent vegetation communities within wetlands (Havera et al. 1997). Floodplain wetlands, which historically relied on overbank flooding from the river to set back succession, have faced additional challenges as humans have channelized and added levees to rivers, resulting in increasing river flow rate, changes in flooding seasonality, and a hydrologic disconnection from the adjacent floodplain (Pierce and King 2013).

Wetland loss and degradation have significantly contributed to the decline of wetland wildlife, including marsh birds (Eddleman et al. 1988, Newman et al. 2003, Zedler and Kercher 2005, Quesnelle et al. 2013, Soulliere et al. 2018, Rosenberg et al. 2019). Secretive marsh birds (i.e., rails, bitterns, night-herons, grebes; hereafter marsh birds) are cryptic species that are associated with emergent wetlands (i.e. wetlands dominated by persistent and non-persistent non-woody vegetation) for all aspects of their life cycle (Darrah and Krementz 2010, Ward et al. 2010, Harms and Dinsmore 2013, Wilson et al. 2018, Bradshaw et al. 2020). To reverse the negative effects of marsh loss and protect at-risk species, wetland managers have actively restored and managed emergent wetlands to benefit a variety of wetland birds (waterfowl, marsh birds, shorebirds), and research has found that wetlands restored from agricultural fields were able to quickly provide habitat for breeding birds of conservation concern (Rundle and Fredrickson 1981, VanRees-Siewert and Dinsmore 1996, Fairbairn and Dinsmore 2001, Vanausdall and Dinsmore 2019, Fournier et al. 2021).

Wetlands may have infrastructure for managers to artificially manipulate water levels to mimic a wetland’s natural dynamic hydrology using pumps, weirs, and subsurface drainage structures (Guhin and Hayes 2015). Managers use periodic dewatering, or the active drawing down of water, to enhance natural wetland functions such as improving water quality, providing flood protection, recharging groundwater, and controlling nuisance species such as non-native fish and frogs (Guhin and Hayes 2015). Water-level management can also be used to create favorable habitat conditions for priority taxa, including spawning fish (Guhin and Hayes 2015, Lemke et al. 2017), mammals (Weller and Spatcher 1965, Lane and Jensen 1999), shorebirds

(Ma et al. 2010, Lemke et al. 2018), and marsh birds (Fournier et al. 2019). Active dewatering is widely used as an approach for creating moist-soil plant communities that feed migrating waterfowl (i.e. *Polygonum spp*., *Panicum spp.*; Bellrose 1941, Fredrickson and Taylor 1982), and while the benefits for waterfowl have been well documented, the impacts of active dewatering on marsh birds remain understudied.

Even though dewatering may be beneficial to a variety of species, the timing and volume of water removal may impact the suitability of conditions for breeding marsh birds and may expose nests to a larger predator community. Given that nest predation is the leading cause of nest failure, and marsh bird nests already experience relatively high mortality rates, water-level management during the breeding season may negatively impact marsh bird populations and increase predation risk by altering habitat structure and removing the barrier to depredation that water around a nest affords (Ricklefs 1969, Ma et al. 2010, Fournier et al. 2021). Past studies of nesting birds have found influences of nest concealment, distance from shore, and water depth on predator access, predator class, and overall predation risk (Post 1998, Batáry and Báldi 2004, Báldi and Batáry 2005, Colombelli-Négrel and Kleindorfer 2005, Jedlikowski et al. 2015). More specifically, nest concealment has been linked to risk from aerial predators and increased water depth and distance from edge has been associated with decreased risk from land-based predators, with Frederick and Collopy (1989) hypothesizing that as little as 5-10 cm of water can substantially restrict the movements of mammalian predators (Picman et al. 1993, Batáry and Báldi 2004, Báldi and Batáry 2005, Hoover 2005). Past research has suggested nest predation is not well explained by broad habitat generalizations, but can be better explained by predator identity, behavior, and activity (Benson et al. 2010, Lyons et al. 2015). However, we generally don’t know the identity of important nest predators in wetlands and have yet to elucidate the relationship between predator identity and habitat conditions because camera studies have not been used extensively in wetlands (DeGregorio et al. 2016).

Our objective was to evaluate the impact of predator communities on nesting marsh birds in the context of water level changes, to help inform wetland management decisions. In an effort to understand the influence of wetland management on conservation priority species, we examined links between water-level management and predator-specific patterns of nest predation of four obligate marsh birds, Least Bitterns (*Ixobrychus exilis*), Common Gallinules (*Gallinula galleata*), American Coots (*Fulica americana*), and Black-crowned Night-Herons (*Nycticorax nycticorax*). Three of these species, Least Bittern, Common Gallinule, and Black-crowned Night-Heron, are recognized as species of conservation concern across the U.S. (Soulliere et al. 2018, IESPB 2020). We expected increased predation following dewatering, particularly by mammals, and at nests with stronger activity cues to alert predators, such as nests with larger clutches.

METHODS

Study Area

Emiquon Preserve in Fulton County, Illinois is a 2723-ha floodplain Ramsar Wetland of International Importance managed by The Nature Conservancy and is one of the largest floodplain wetland restorations in Illinois (Chen et al. 2017). Emiquon Preserve consists of two lakes, Thompson Lake and Flag Lake (Figure 2.1), and these backwater lakes once supported the most productive floodplain ecosystem in Illinois before they were disconnected from the Illinois River in the early 1900s and a levee was constructed (Chen and Lemke 2009, vanMiddlesworth et al. 2015). Today, The Nature Conservancy uses a pump within its levee to practice cyclical dewatering with years of intense dewatering followed by years of moderate or minimal dewatering. This approach halts marsh succession to the lake-marsh phase, mimics a natural flood pulse that would occur prior to disconnection from the Illinois River, and increases habitat heterogeneity to benefit a variety of waterbird species (Ma et al. 2010).

Study Species

We selected American Coot, Common Gallinule, Least Bittern, and Black-crowned Night-Heron as our focal species because of their dependence on emergent wetlands, diversity of nest structures, and confirmed nesting at Emiquon Preserve in past research (Fournier et al. 2021). The American Coot is a native diving rail that nests in secured floating platforms on reedbed edges inundated by ≤ 76 cm of water (Bent 1963, Lane and Jensen 1999). The Least Bittern is a threatened species in Illinois as well as a regional species of conservation concern (Soulliere et al. 2018, IESPB 2020). This small wading bird builds suspended nests in dense growths of vegetation ≤ 1.2 m above 7-96 cm of water and typically within 10 m of open water (Bent 1963, Weller and Spatcher 1965). The Common Gallinule is morphologically similar to the coot and exhibits similar nest site selection; however, the Common Gallinule is rarer and is endangered in Illinois (Weller and Spatcher 1965, Fredrickson 1971, IESPB 2020). The Black-crowned Night-Heron is a state endangered colonial waterbird (IESPB 2020). It selects rookery sites in trees or in dense cattail over water or on islands (Noble et al. 1938, Hoefler 1980).

Survey Site Selection and Nest Searching

In 2020 we randomly selected 81 nest-searching plots in persistent emergent vegetation (*Typha* spp.), hemi-marsh (50:50 interspersed water-cover ratio; Weller and Spatcher 1965), and boundaries between the two habitats. Vegetation cover for Emiquon Preserve was determined using transect surveys conducted annually in autumn (Hine et al. 2017). Sampling locations and aerial photographs were used to delineate vegetation community boundaries and create a vegetation cover map in ArcGIS (ESRI, Redlands, California). In 2021, the vegetation cover map was not available, so nest-searching plots were randomly selected from persistent emergent vegetation and hemi-marsh conditions at Emiquon Preserve in May 2021. Plots were created using randomly selected distances (25-75 m) and directions from the vegetation edge at points that met the aforementioned vegetation and density criteria. The randomly selected point in both years defined the center of a survey plot.

Nest-searching plots were 50-m by 50-m squares and we searched for nests by systematically traversing these plots in teams of 1-3. Transects within plots were ≤ 2 m apart to minimize the risk of missing nests. We systematically searched plots from 05:00-13:00 (CDT) from May 12 through July 31, 2020, and May 16 through July 17, 2021. Each plot was searched 1-3 times throughout the season. We stopped visiting a plot if the current vegetation structure did not match the 2019 cover (i.e. persistent emergent, hemi-marsh), no nests were found after 2 visits, or focal species were absent. We also incidentally searched for nests between plots, in areas with ideal plant communities, and those with conspicuous activity of our focal species.

All nests were marked with a GPS point and flagging tape within the vicinity to facilitate relocation. We aged eggs using a field candler and photographs of incubation stages for representative eggs adjusted to fit the incubation length for our focal species (Hanson 1954, Hanson and Kossak 1957, Weller 1961, Young 1988). We categorized nest age based on the oldest egg. If the nest contained nestlings when first found, we did not assign an age. Nests were revisited every 3 to 5 days (range of 1-6 days) to determine fate and collect habitat measurements. We stopped visiting when nests were terminated (abandoned or depredated) or chicks had left the nest. A nest was determined to be abandoned if there was no evidence of an active incubator (i.e. eggs cold, eggs not aging, and incubator absent on camera), and a nest was determined to be depredated if all eggs or hatchlings were missing before reaching hatching or fledging age or a predator was seen on camera removing nest contents.

Video Cameras

We used miniature video cameras at a subset of nests to identify predators and examine predator-specific responses to habitat variables. Accordingly, we distributed cameras evenly among nests with different habitat conditions. The cameras were small (about 3 by 4 cm) and had infrared light-emitting diodes (LEDs) to facilitate recording in low-light conditions. Cameras were mounted on a dowel ~15 cm from nests with a clear view of nest contents from above. A cable from the camera ran to a waterproof box ≥ 5 m from the nest which included a digital video recorder (DVR), which recorded continuously at a rate of 8 frames per sec, and a 20-Amp-hour sealed lead acid battery (Cox et al. 2012). Unlike past studies of nest predators in terrestrial systems (DeGregorio et al. 2016), we had to develop a system that could adapt to changing water levels. Consequently, we mounted each waterproof box on a 0.6 by 0.9 m piece of 5-cm thick foam insulation anchored in place with a wooden or metal dowel to keep it from floating away. We exchanged SD cards and batteries every 3 days (range 1-4 days) adjusting camera angles if nest contents were out of frame until nests failed or young departed from the nest. We reviewed videos to determine hatch and depredation dates and to identify predators; nests were classified as abandoned if an incubating adult did not return within 24 hours, and cameras remained at nests until the nest failed or nestlings were unreliably on the nest.

Spatial and Temporal Measurements

We recorded nest-site variables during nest checks, including nest height (cm), water depth under the nest (cm), average height of emergent vegetation (cm), clutch size, nest stage (incubating or hatched), day of year, and nest fate. In 2021, we also measured vegetation density by recording the average number of stems within a 30 × 30-cm square adjacent to the nest at a randomly selected cardinal direction and 2 equidistant points 0.5m from the nest. We also estimated visibility above a nest (%), and percent cover by emergent vegetation to determine habitat openness (open, hemi-marsh, dense) and dominant vegetation type (persistent emergent, nonpersistent emergent, floating leaved) within a 2.5-m radius of the nest in 2021. We defined hemi-marsh as 40 to 60% vegetation to 60 to 40% water. We determined distance of each nest to a continuous shoreline using ArcGIS (ESRI, Redlands, California), daily water height above sea level recorded at Emiquon Preserve, and a 15.24-cm contour map of the preserve.

Statistical Analyses

We aimed to determine how spatial and temporal variables influenced overall predation risk as well as risk from specific classes of predators. Nest cameras were not expected to have a significant effect on nest success, but were disguised using paint and concealed by natural vegetation to minimize any impact they may have (Herranz et al. 2002, Cox et al. 2012, Chiavacci et al. 2018). To test the effects of cameras on predation risk, we compared survival rates at nests with and without cameras following the same 3-day re-visit schedule to reduce biases associated with human presence at the nest. We investigated the effects of visit frequency using only nests without cameras with longer and shorter intervals between nest visits. For both analyses we used a logistic exposure method with the *glm* function in R and we present our results as coefficient estimates (β) and 85% confidence intervals (Shaffer 2004, R Core Team 2013).

To address species-specific nest survival in conjunction with spatial and temporal variables, we grouped all causes of egg and chick loss together and investigated nest success, defined as at least one chick surviving to fledge. We included abandonment as a form of failure at nests where an incubator was confirmed. We developed a priori hypotheses from our spatial and temporal variables and excluded highly correlated variables ($|r|>0.7$) from occurring in models together. We ran separate spatial and temporal logistic exposure models for each species with (Shaffer 2004, R Core Team 2013).

In our spatial models, we analyzed the effects of water depth, distance to shore, nest height, stem density, nest visibility, habitat openness visually estimated within 2.5 m of the nest, average vegetation height, and year. We ranked all spatial models using an information-theoretic approach corrected for small sample sizes (AIC_c; Burnham and Anderson 2002). We classified models as competitive if they were within 2 ΔAIC_c units of the top model. In our temporal models we analyzed the effects of nest stage, clutch size, and day of the year (i.e., ordinal day). We ranked all temporal models against competitive spatial models using AIC_c (Burnham and Anderson 2002).

To address predator-specific nest losses as a function of spatial and temporal variables, we combined data from video-monitored nests of all 4 species to run a multinomial regression. We were interested in the influence of spatial and temporal variables on daily predation risk by mammals, snakes, birds, and other sources of failure (abandonment and unknown predators), and we divided our variables into 5 categories (mammal, snake, bird, other, and survive). We included all partial predation events because excluding them would underestimate the impact of some variables on predation risk (Báldi and Batáry 2005, Lyons et al. 2015). We ran models with the *multinom* function in the *nnet* package in R using daily intervals from our videos, and we evaluated support for these models using AIC_c (Burnham and Anderson 2002, R Core Team 2013). We considered models within 8 ΔAIC_c units of the top model to be competitive, as opposed to 2 ΔAIC_c units as a result of additional parameters in a multinomial analysis (i.e., each added variable results in 4 additional parameters). We ranked the spatial models using AIC_c and again ranked temporal models against competitive spatial models. We based inferences on coefficient estimates for variables in competitively ranked models and their corresponding 85% confidence intervals and determined variables to be meaningful for a predator class if the confidence interval did not overlap zero.

RESULTS

Dewatering Timing and Volume

In 2020, active dewatering was initiated on June 9 and lasted through August 6 and resulted in a net loss of ~1.37m of water, and in 2021 active dewatering occurred between July 8 and August 2 and resulted in a net loss of ~0.46 m of water. There was substantial overlap between peak nesting dates and active dewatering timing in 2020 but not in 2021 (Figure 2.2).

Nesting Phenology and Predators

Nesting Phenology. We monitored 158 nests in 2020 and 2021 (78 in 2020, 80 in 2021) and installed cameras at 80 of these nests (45 in 2020, 35 in 2021). Cameras remained at nests for 11.8 days on average (10.8 days in 2020, 13.1 days in 2021), and we found no effect of visit frequency on nest survival for Least Bitterns and Common Gallinules or cameras on nest survival for Least Bitterns or Black-crowned Night-Herons (Table 2.1). Cameras were found to impact Common Gallinule nest survival, likely due to greater sensitivity of nesting birds, resulting in 6 of the 9 observed abandonments (Table 2.1). Least Bitterns nested on average between June 18 and July 5 (±15 days [SD]; range: 3 June-20 July), Common Gallinules between June 14 and July 4 (±13 days; range: 1 June-17 July), and Black-crowned Night-Herons between May 31 (± 11 days) and June 27 (±12 days; range: 20 May-9 July). Black-crowned

Night-Herons nested colonially in 2020, and the one nest found in 2021 was not found in the same location as the previous year's colony.

Predators. We observed 39 predation events at 80 nests in 2020 and 2021 (Table 2.2). The largest group of predators was mammals (n=10, Table 2.2) and was comprised of Raccoons (*Procoyon lotor*), American Mink (*Neovision vision*), and unidentified mammals, which were a result of cameras only capturing fur or glowing eyes during a predation event. The second largest predator groups were snakes (n=5), all Eastern Fox Snakes (*Pantherophis vulpinus*), and birds (n=5), consisting of Black-crowned Night-Herons, Common Gallinules, Marsh Wrens (*Cistothorus palustris*), and Brown-headed Cowbirds (*Molothrus ater*). The final group defined as other, encompassed unknown losses (n=10) and abandonments (n=9). Unknown losses were recorded when a camera failed to identify a cause of nest loss either because cameras or nests were knocked down or cameras failed due to battery failure or damaged camera equipment. Raccoon predation resulted in complete nest loss four out of five times and the one partial predation event occurred at a nest where juveniles were force-fledged. The majority of Mink and Fox Snake events were partial predation events and often involved the same species, presumably, the same individual, returning to the nest later to consume the remaining eggs or nestlings. All avian events involved the individual breaking rather than consuming a few eggs. Successful nests that incurred a partial predation event were not common, and partially depredated nests generally failed later.

Species-specific Nest Survival

Our best-fit model for survival of Least Bittern nests (n=83) contained water depth, distance to shore, and year (w_i = 0.84, Table 2.3). There were no other competitive spatial or temporal models. Daily survival rates were lower for nests over shallower water, closer to shore, and in 2020 compared to 2021 (Figure 2.3). For Common Gallinules (n=64), the top model contained water depth and year with no other competitive models (w_i = 0.80, Table 2.4). Common Gallinule nest survival also declined over shallow water and in 2020 relative to 2021 (Figure 2.4). Daily survival rates for Least Bittern and Common Gallinule nests increased by 1.9% and 4.5% between 2020 and 2021, respectively (Table 2.5). Black-crowned Night-Heron (n=10) models showed survival increased at nests over shallower water and farther from shore (w_i = 0.41, Table 2.6) and later in the nesting period (w_i = 0.30, Table 2.6) (Figure 2.5).

We fit models for years combined as well as for 2021 alone, given some spatial variables were not collected in 2020. Our analyses of nest fate for Least Bittern and Common Gallinule nests in 2021 only revealed weak model support. Least Bittern models showed support for temporal variables day of year (w_i = 0.40) and nest stage (w_i = 0.21), as well as visibility (w_i = 0.23), and showed survival increased later in the nesting period, during the nestling stage, and when nests were less visible (Table 2.7). Common Gallinule models showed survival increased with increasing average emergent vegetation height (w_i = 0.28), increasing water depth and decreasing distance to shore (w_i = 0.19) increasing nest height (w_i = 0.18), and earlier in the nesting period (w_i = 0.27) (Table 2.8).

Predator-specific Nest Predation

Water depth and year (w_i = 0.72) was the best-fit model for predator-specific mortality, and competitive models included water depth (w_i = 0.21) and year (w_i = 0.06) (Table 2.9). For the best-fit model, daily predation rates at the mean water depth ($\bar{x}$ = 34.4 cm) for mammals, snakes, birds, and others in 2020 were 0.014, 0.012, 0.006, and 0.016, respectively and 0.007, <0.001, 0.005, and 0.025 in 2021. Confidence limits for coefficients from the best-fit and competitive models revealed that mammalian predation increased as water depth decreased

($\beta_{\text{water depth}}$= -0.0501; 85% CI: -0.0808 to -0.0195) and decreased from 2020 to 2021 (β_{year} = -2.1729; 85% CI: -3.6938 to -0.6520) (Table 2.10, Figure 2.6). Nest losses due to other causes (i.e. abandonment and unknown losses) also increased in shallower water ($\beta_{\text{water depth}}$ = -0.0271; 85% CI: -0.0456 to -0.0087) (Table 2.10, Figure 2.7). Predation by snakes only occurred in 2020 (β_{year} = -20.5543) (Table 2.10).

DISCUSSION

Active dewatering of emergent wetlands during the growing season creates a diverse habitat structure that is beneficial for a variety of wetland species (Lane and Jensen 1999). Dewatering can be used to produce vegetation with energy-rich seeds and tubers to feed migrating and wintering waterfowl, as well as creating emergent vegetation for marsh birds, mudflats for shorebirds, supporting diverse populations of invertebrates, and facilitating habitat use by furbearers typically deterred by deeper water (Bellrose 1941, Weller and Spatcher 1965, Fournier et al. 2019, Bradshaw et al. 2020). However, our study suggests that deep water below nests improves nest survival of vulnerable marsh birds and that intense dewatering during peak nesting removes the protection afforded by water, particularly by increasing access to nests by mammalian predators.

In past work at our site, Least Bitterns and Common Gallinules selected nest sites in dense inundated vegetation, avoiding dry areas (Fournier et al. 2021), possibly because of greater predation risk in shallow water or dry locations, although other benefits of this pattern include proximity to prey and protection from weather (Weller 1961, Holway 1991, Moore et al. 2009). Black-crowned Night-Herons, however, experienced greater nest failure in deeper water, also consistent with our results (Fournier et al. 2021). Although the relationships we observed with Black-crowned Night-Herons are from a small sample size and not useful for informing management decisions; we believe the relationship could be influenced by the colonial structure of Emiquon Preserve's nesting night-herons on centrally located cattail islands over dry substrate and surrounded by water, suggesting individuals towards the center of a colony are over dry ground or shallower water and exhibit higher nest survival rates (Olmos 2002, Uzun 2009).

In Least Bitterns and Black-crowned Night-Herons, the negative impact of shore proximity on nest survival may also be a factor of an enhanced edge effect in wetlands, the result of habitat fragmentation increasing the propensity of edge habitat resulting in marsh bird nests being closer to areas where nest predators are more abundant or active (Batáry and Báldi 2004, Báldi and Batáry 2005, Jedlikowski et al. 2015). Additionally, for nesting Least Bitterns and Common Gallinules the deep-water marsh interior may serve as a predator deterrent for mammalian predators (Hoover 2005). Racoons, American Mink, and Fox Snakes were observed in our study and are often associated with terrestrial or stream environments adjacent to wetlands and benefit from using wetland habitat edges for direct travel, successful hunting, or thermoregulation (i.e. snakes) (Weatherhead and Blouin-Demers 2004, Barding and Nelson 2008, Ahlers et al. 2016). However, for edge nesting birds, nest proximity to edge habitats may result in an increased risk of predation as a result of habitat overlap between predator and prey (Batáry and Báldi 2004, Báldi and Batáry 2005). Our findings are consistent with past work on Least Bitterns which found dewatering bridged marsh interior to surrounding dikes via mudflats, thereby connecting edge habitat to marsh interior, and increased nest predation (Post 1998). We did not observe this relationship in Common Gallinules, presumably because Least Bitterns more strongly prefer edges of robust emergent vegetation for foraging, and Common Gallinules, often observed swimming in open water, selected for deeper water areas towards the marsh interior, but there is a need for more information to better understand this relationship (Weller 1961, Moore et al. 2009).

Deeper water during the critical incubation and nestling periods was also found to be important for predicting predation risk by mammals, primarily raccoons, an edge obligate omnivore and a major predator in midwestern wetlands (Picman and Schriml 1994, Barding and Nelson 2008). High water levels may deter mammalian movement, decrease effective searching, and subsequently limit predation risk (Picman et al. 1993, Picman and Schriml 1994, Jobin and Picman 1997, Hoover 2005). Water depth was also important for predicting losses from abandonments and predators we failed to identify because of camera failure or cameras and nests being knocked down during a predation event. We believe this relationship arose because unidentified predators were likely mammals, which were observed knocking over nests when identified on camera, and so could have also knocked over cameras leading to a lack of predator identification. In addition, nesting birds evaluate risks, which likely caused them to abandon nests in low-quality habitat with less water and presumably less access to aquatic food resources or habitat at greater risk of predation by mammals (Weller 1961, Lima 2009). Given the impact of water level management on survival that we found, future work on other wetland nesting birds (e.g., blackbirds, sparrows, wrens) would benefit from examining similar questions to better inform wetland management decisions (Picman et al. 1993, Post 1998).

Fox Snake predation was found to vary between years, which we believe results from the landscape of our study site and habitat use of snakes, not the dewatering regimen as seen in mammals, unknown predators, and abandonments. Snakes are ectotherms and as mentioned above they seek thermally hospitable and predator-safe habitats, such as wetland edge habitat (Blouin-Demers and Weatherhead 2001, Lee 2006). Outside of the vegetated wetland edge and on exposed mudflat a snake risks overheating and depredation (Weatherhead and Blouin-Demers 2004). In 2020, higher starting water levels created pre-dewatering marsh habitat with an inundated and vegetated edge, ideal for both nesting marsh birds and snakes. However, in 2021, starting water levels were too low to inundate the edge vegetation and create conditions amenable to nesting marsh birds, so the nearest nests were located nearer the marsh interior which was only accessible by passing through exposed mudflat and water. Bird predation was not found to be supported by any of our habitat variables and we believe this could be due to the high degree of variability between our avian predators and because we only observed egg breaking, not consumption, with bird predation events.

In 2021, when habitat conditions were largely unchanging between nests due to the late season low intensity dewatering, we observed a stronger relationship between nest survival and factors affecting nest visibility and activity. More visible nests had poorer survival, and studies of open-nesting birds in the tropics, desert, and grasslands, suggest when habitat conditions have facilitated access to or visibility of a nest, activity at or around a nest can act as a visual or olfactory cue to alert predators (Skutch 1949, Martin et al. 2000, Colombelli-Négrel and Kleindorfer 2005). The day of year also impacted nest survival to varying degrees, likely due to nesting periods overlapping or failing to overlap with climatic conditions, food availability, or predator activity (Siikamäki 1998, Sperry et al. 2008, Cain III et al. 2010).

In conclusion, our results support retaining water in emergent wetlands during peak nesting dates to deter mammalian predators and improve overall nest survival of secretive marsh birds, as has been demonstrated with past studies of wetland nesting birds (Picman et al. 1993, Post 1998, Hoover 2005). Our study demonstrates the value of identifying habitat components associated with predator communities to better manage nest loss. We believe management goals, such as moist-soil seed production, invasive species control, and emergent wetland habitat creation, can still be met and vulnerable nesting birds can receive adequate protection by managing water-levels outside of active breeding periods (May-June). This will ensure reproductive needs of secretive marsh birds are met, as demonstrated in 2021 when less volume of water was removed outside of peak breeding periods (Jobin et al. 2009, Bradshaw et al. 2020). Primary concerns for shifting dewatering until after peak breeding activity are potential negative impacts on moist soil seed production (with a shorter growing and seed development season) and robust emergent vegetation growth for waterfowl and other wetland dependent species. Studies have found early dewatering in May runs the risk of increasing encroachment of emergent invasive and woody species (Fleming et al. 2012). Alternatively, late summer dewatering in late July or August, after native and invasive submerged aquatic vegetation have matured, covers exposed mudflat with plants and reduces heat and light penetration to soil, which can inhibit moist soil plant growth and the length of time precipitation can collect in a dewatered wetland to inundate moist-soil seeds for waterfowl consumption (Fleming et al. 2012, Hine et al. 2017). However, research suggests slow mid-season dewatering in late June or early July can still produce substantial desirable moist-soil plants (i.e. rice cutgrass, pigweed, smartweed) and generate robust emergent vegetation growth (Bellrose 1941, Fredrickson and Taylor 1982, Merendino et al. 1990, Bowyer et al. 2005).

Acknowledgments

Funding was provided by a State Wildlife Grant (T-122-R) from the Illinois Department of Natural Resources and the United States Fish and Wildlife Service, as well as through the Illinois Ornithological Society (DuPage Birding Club, Chicago Audubon Society) and American Ornithological Society. We thank K. D. Blodgett and S. McClure of The Nature Conservancy for access to Emiquon Preserve, and L. Hinz and R. Smith of the Illinois Department of Natural Resources for their assistance. We thank N. Hargett, C. Stephens, N. Pietrunti, C. Beach, J. Stutzman, C. Cremer, A. Yetter, C. Kross, M. Lowers, and A. Gilbert for assistance with fieldwork and equipment management.

TABLES AND FIGURES

Table 2.1. Parameter estimates for the effects of nest cameras and visit frequency, on nest fate in 2020 and 2021.

Marsh Bird Species	Disturbance	Coefficient (β)	85% Confidence Interval
Least Bittern	Camera	0.1781	-0.0784 to 0.4346
	Visit Frequency	-0.6574	-1.5979 to 0.2831
Common Gallinule	Camera	-0.8053	-1.4703 to -0.1403
	Visit Frequency	-0.4479	-1.3603 to 0.4645
Black-crowned Night-Heron	Camera	15.7708	-3855.6740 to 3887.2156

Table 2.2. Predators identified at nests of marsh birds at Emiquon Preserve, Illinois, USA 2020-2021. Nests of marsh birds observed included Least Bittern (LEBI), Common Gallinule (COGA), and Black-crowned Night-Heron (BCNH).

Predator Class	Predator Identity	Number of Events
Mammal	Raccoon	5 (3 COGA, 2 LEBI)
	American Mink	3 (3 LEBI)
	Unidentified	2 (2 LEBI)
Snake	Fox Snake	5 (3 COGA, 2 LEBI)
Avian	Black-crowned Night Heron	1 (1 BCNH)
	Common Gallinule	1 (1 COGA)
	Marsh Wren	2 (2 LEBI)
	Brown-headed Cowbird	1 (1 COGA)
Other	Unknown[a]	10 (4 COGA, 6 LEBI)
	Abandoned[b]	9 (6 COGA, 3 LEBI)
Total		39

[a] Predators were unidentified on cameras due to cameras or nests coming down or camera battery failure.

[b] Abandoned nests were included only if an incubator was confirmed, and a nest was abandoned if not attended for 24 hours.

Table 2.3. Model selection results for logistic exposure models explaining Least Bittern nest survival in 2020 and 2021 as a function of spatial and temporal variables.

Spatial Models 2020 and 2021

Model	*k*	AIC_c	ΔAIC_c	w_i
Water Depth + Distance to Shore + Year	4	241.39	0.00	0.84
Water Depth + Distance to Shore	3	245.15	3.77	0.13
Water Depth	2	247.86	6.47	0.03
Year	2	256.75	15.36	0.00
Distance to Shore	2	263.64	22.25	0.00
Constant Survival	1	268.45	27.07	0.00
Avg. Emergent Vegetation Height	2	269.52	28.13	0.00
Nest Height	2	270.41	29.02	0.00
Nest Height × Avg. Emergent Vegetation Height	4	272.37	30.98	0.00

Temporal Models and Competitive Spatial Models 2020 and 2021

Model	*k*	AIC_c	ΔAIC_c	w_i
Water Depth + Distance to Shore + Year	4	241.39	0.00	1.00
Constant Survival	1	268.45	27.07	0.00
Clutch Size	2	269.84	28.45	0.00
Nest Stage	2	270.19	28.80	0.00
Day of Year	2	270.44	29.05	0.00

Table 2.4. Model selection results for logistic exposure models explaining Common Gallinule nest survival in 2020 and 2021 as a function of spatial and temporal variables.

Spatial Models 2020 and 2021

Model	k	AIC_c	$\Delta\ AIC_c$	w_i
Water Depth + Year	3	194.93	0.00	0.80
Water Depth	2	199.68	4.75	0.07
Nest Height × Avg. Emergent Vegetation Height	4	200.22	5.29	0.06
Water Depth + Distance to Shore	3	201.17	6.24	0.04
Year	2	203.12	8.19	0.01
Nest Height	2	203.47	8.54	0.01
Avg. Emergent Vegetation Height	2	203.75	8.82	0.01
Constant Survival	1	210.47	15.54	0.00
Distance to Shore	2	212.49	17.56	0.00

Temporal Models and Competitive Spatial Models 2020 and 2021

Model	k	AIC_c	$\Delta\ AIC_c$	w_i
Water Depth + Year	3	194.93	0.00	0.95
Day of Year	2	200.99	6.06	0.05
Constant Survival	1	210.47	15.54	0.00
Nest Stage	2	210.60	15.67	0.00
Clutch Size	2	211.84	16.91	0.00

Table 2.5. Least Bittern and Common Gallinule daily survival rate and incubation survival rate in 2020 and 2021 with 85% confidence intervals.

Species	2020		2021	
	DSR[a]	**Survival to Hatch[b]**	**DSR**	**Survival to Hatch**
Least Bittern	0.9704 (0.9463-0.0.9721)	0.6000 (0.3913-0.6181)	0.9897 (0.9818-0.9942)	0.8386 (7318-0.9058)
Common Gallinule	0.9376 (0.9050-0.9600)	0.2584 (0.1229-0.4243)	0.9825 (0.9721-0.9891)	0.6902 (0.5520-0.7944)

[a] Daily survival rate

[b] Daily survival rate exponentiated to average Least Bittern (17 days) and Common Gallinule (21 days) incubation length.

Table 2.6. Model selection results for logistic exposure models explaining Black-crowned Night-Heron nest survival in 2020 and 2021 as a function of spatial and temporal variables.

Spatial Models 2020 and 2021

Model	k	AIC_c	ΔAIC_c	w_i
Water Depth + Distance to Shore	3	23.24	0.00	0.40
Distance to Shore	2	25.31	2.07	0.14
Water Depth	2	25.76	2.52	0.11
Constant Survival	1	25.80	2.56	0.11
Avg. Emergent Vegetation Height	2	26.00	2.76	0.10
Nest Height × Avg. Emergent Vegetation Height	4	26.09	2.85	0.09
Nest Height	2	27.58	4.33	0.05

Temporal Models and Competitive Spatial Models 2020 and 2021

Model	k	AIC_c	ΔAIC_c	w_i
Water Depth + Distance to Shore	3	23.24	0.00	0.41
Day of Year	2	23.87	0.63	0.30
Nest Stage	2	25.28	2.04	0.14
Constant Survival	2	25.80	2.56	0.11
Clutch Size	2	27.92	4.67	0.04

Table 2.7. Model selection results for logistic exposure models explaining Least Bittern nest survival in 2021 as a function of spatial and temporal variables.

Spatial Models 2021

Model	k	AIC_c	ΔAIC_c	w_i
Visibility	3	66.76	0.00	0.28
Habitat Openness + Visibility	2	67.76	1.00	0.17
Water Depth + Visibility	3	68.07	1.31	0.14
Constant Survival	1	68.86	2.11	0.10
Water Depth	2	69.08	2.32	0.09
Avg. Emergent Vegetation Height	2	70.07	3.31	0.05
Habitat Openness	2	70.20	3.44	0.05
Nest Height	2	70.21	3.45	0.05
Stem Density	2	70.62	3.86	0.04
Water Depth + Distance to Shore	3	70.78	4.03	0.04

Temporal Models and Top Ranked Spatial Model 2021

Model	k	AIC_c	ΔAIC_c	w_i
Day of Year	2	65.65	0.00	0.40
Visibility	2	66.76	1.10	0.23
Nest Stage	2	66.95	1.30	0.21
Clutch Size	2	68.83	3.18	0.08
Constant Survival	1	68.86	3.21	0.08

Table 2.8. Model selection results for logistic exposure models explaining Common Gallinule nest survival in 2021 as a function of spatial and temporal variables.

Spatial Models 2021

Model	k	AIC_c	ΔAIC_c	$AIC_c\ w_i$
Avg. Emergent Vegetation Height	2	108.69	0.00	0.28
Water Depth + Distance to Shore	3	109.45	0.76	0.19
Nest Height	2	109.51	0.82	0.18
Water Depth	2	110.00	1.31	0.14
Constant Survival	1	111.88	3.19	0.06
Water Depth + Visibility	3	112.00	3.31	0.05
Habitat Openness	2	112.72	4.03	0.04
Stem Density	2	113.68	4.99	0.02
Visibility	2	113.91	5.22	0.02
Habitat Openness + Visibility	3	114.76	6.07	0.01

Temporal Models and Top Ranked Spatial Model 2021

Model	k	AIC_c	ΔAIC_c	w_i
Avg. Emergent Vegetation Height	2	108.69	0.00	0.53
Day of Year	2	110.06	1.37	0.27
Constant Survival	1	111.88	3.19	0.11
Nest Stage	2	113.20	4.51	0.05
Clutch Size	2	113.91	5.22	0.04

Table 2.9. Model selection results for multinomial regressions explaining predator-specific patterns of nest failure in 2020 and 2021 as a function of spatial and temporal variables.

Spatial Models 2020 and 2021

Model	*k*	AIC_c	ΔAIC_c	w_i
Water Depth + Year	12	417.86	0.00	0.72
Water Depth	8	420.33	2.47	0.21
Year	8	422.74	4.88	0.06
Constant Survival	4	428.59	10.73	0.00
Avg. Emergent Vegetation Height	8	429.27	11.41	0.00
Nest Height	8	433.68	15.83	0.00
Distance to Shore	8	435.18	17.32	0.00
Nest Height × Avg. Emergent Vegetation Height	16	442.77	24.91	0.00

Temporal Models and Competitive Spatial Models 2020 and 2021

Model	*k*	AIC_c	ΔAIC_c	w_i
Water Depth + Year	12	417.86	0.00	0.71
Water Depth	8	420.33	2.47	0.21
Year	8	422.74	4.88	0.06
Day of Year	8	425.90	8.04	0.01
Clutch Size	8	427.40	9.54	0.00
Constant Survival	4	428.59	10.73	0.00
Nest Stage	8	431.86	14.00	0.00

Table 2.10. Parameter estimates for competitive predator-specific multinomial models of nest failure in 2020 and 2021.

Variable	Predator Class	Coefficient (β)	85% Confidence Interval
Water Depth	**Mammal**	**-0.0501**	**-0.0808 to -0.0195**
	Snake	0.0291	-0.0051 to 0.0634
	Bird	-0.0021	-0.0376 to 0.0334
	Other	**-0.0271**	**-0.0456 to -0.0087**
Year	**Mammal**	**-2.1729**	**-3.6938 to -0.6520**
	Snake	**-20.5543**	**-**
	Bird	-0.3812	-1.6992 to 0.9369
	Other	-0.0811	-0.7496 to 0.5875

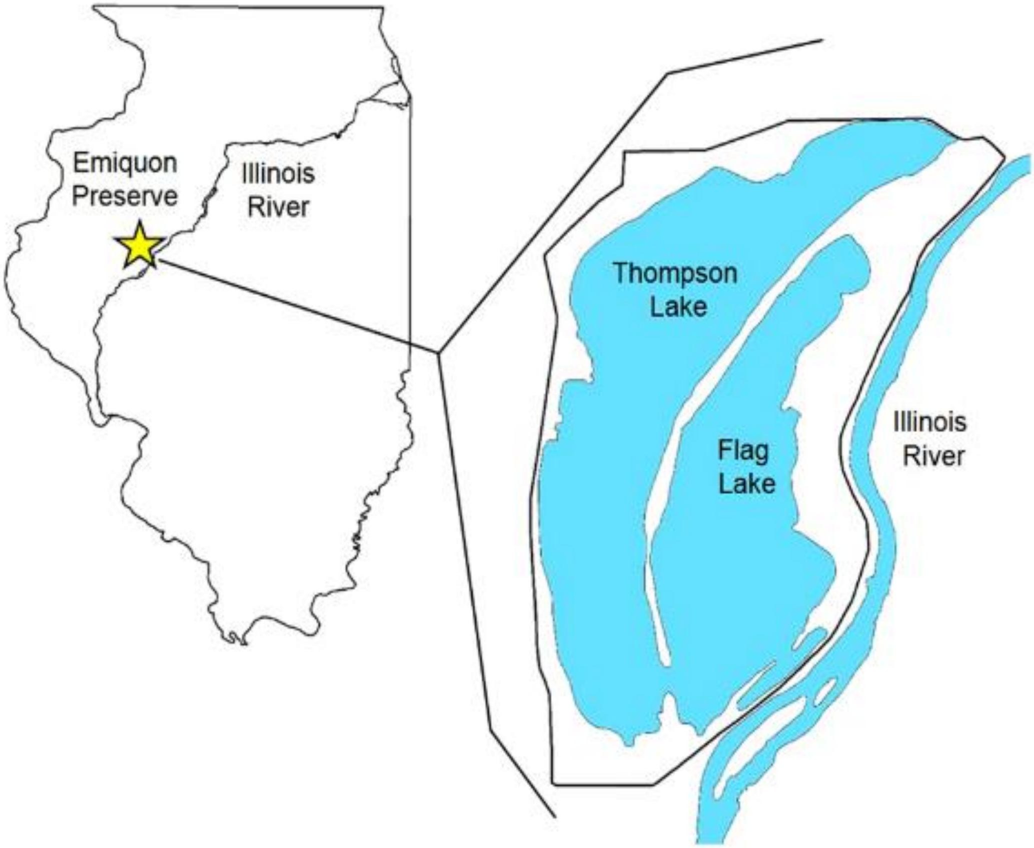


Figure 2.1. Emiquon Preserve is located west of the LaGrange Reach (river miles 121-126) of the Illinois River in Fulton County, Illinois, USA. Emiquon Preserve consists of Thompson Lake, Flag Lake, and surrounding vegetation (Hine et al. 2017).

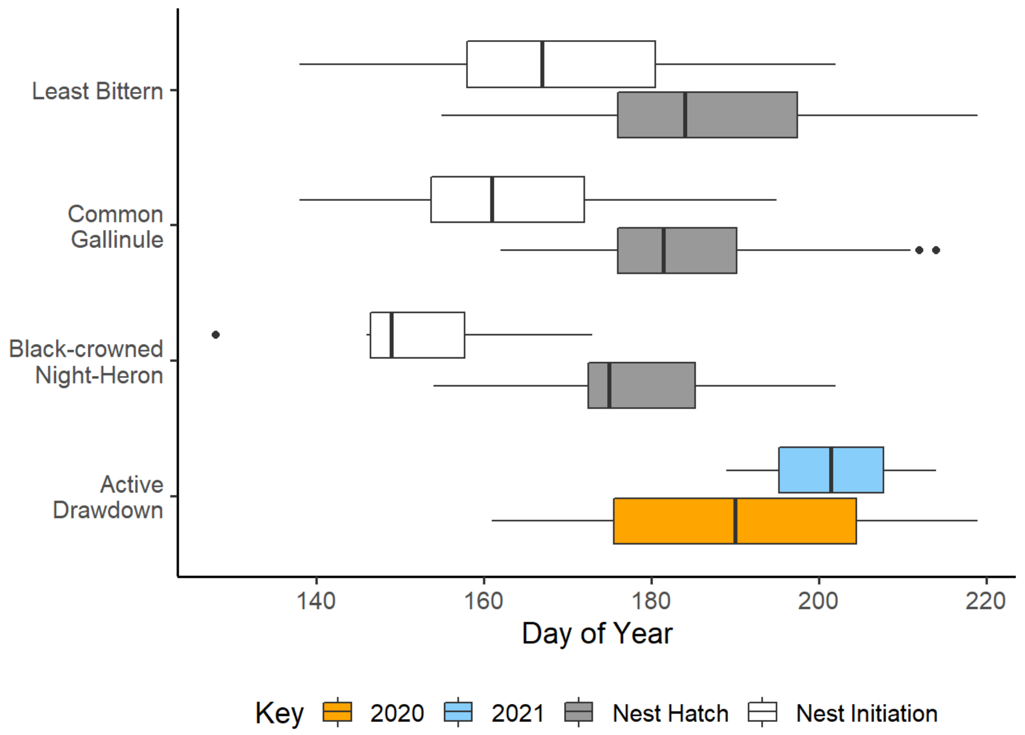


Figure 2.2. Peak nesting dates per species based on 2020 and 2021 nest initiation dates and predicted hatch dates compared to 2020 and 2021 dewatering dates. Day 140 corresponds to May 19.

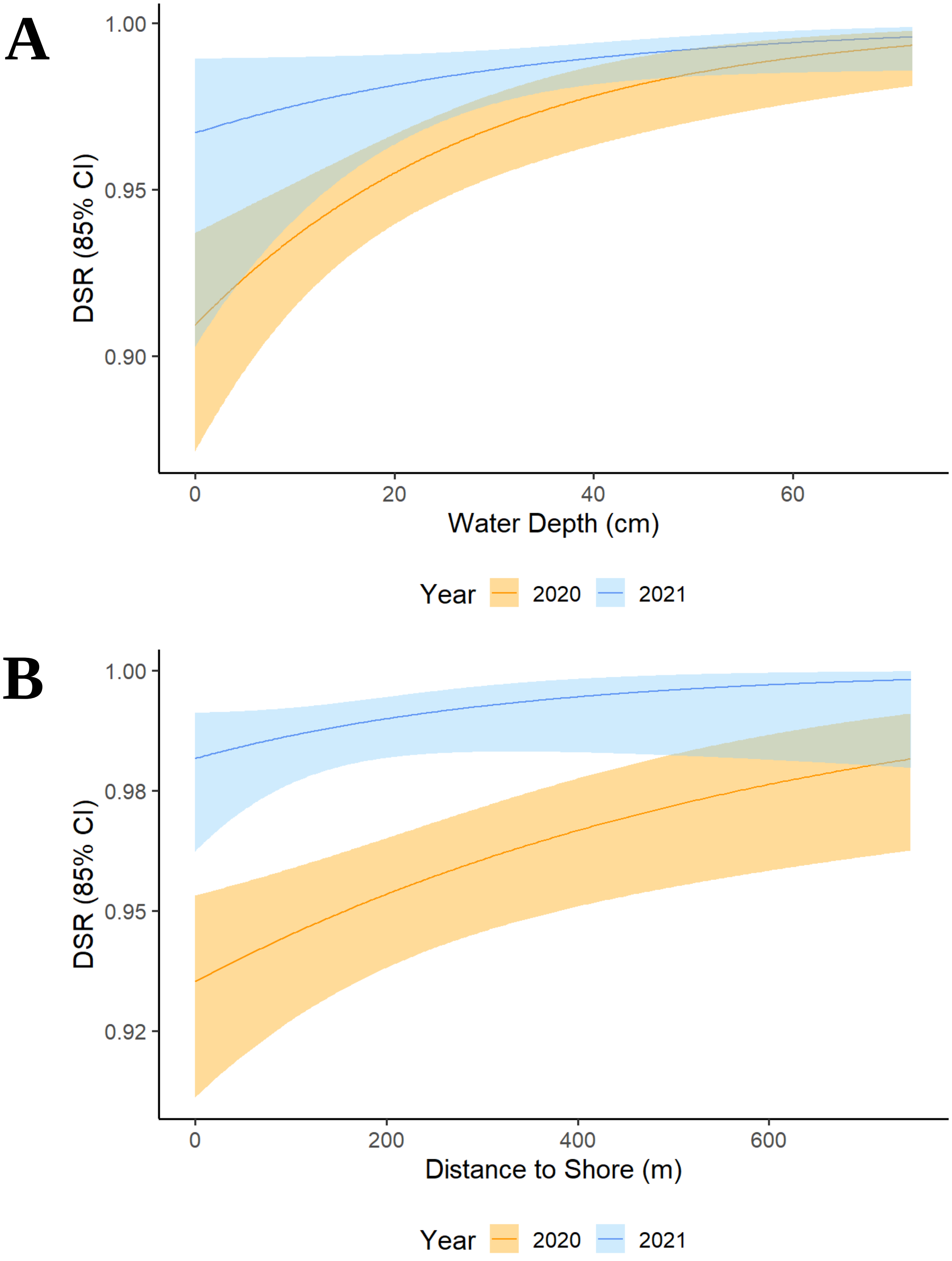


Figure 2.3. Daily survival rate (DSR) of Least Bittern nests in 2020 and 2021 at Emiquon Preserve, Illinois, USA, as a function of water depth (cm) and year (**A**) and distance to shore (m) and year (**B**).

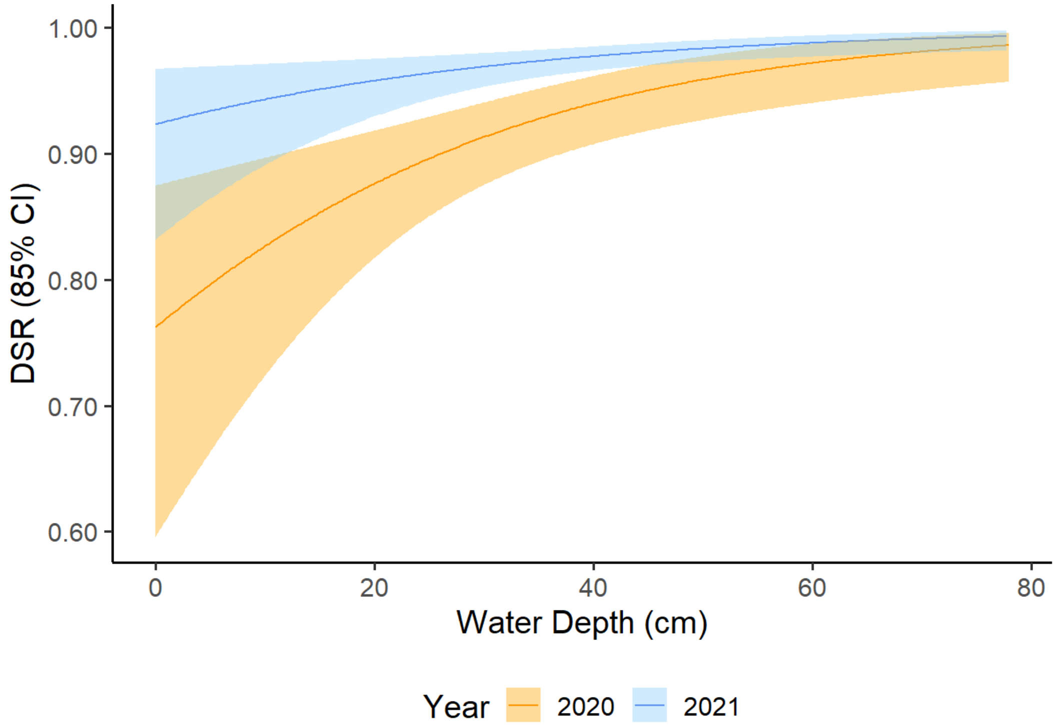


Figure 2.4. Daily survival rate (DSR) of Common Gallinule nests in 2020 and 2021 at Emiquon Preserve, Illinois, USA, as a function of water depth (cm) and year.

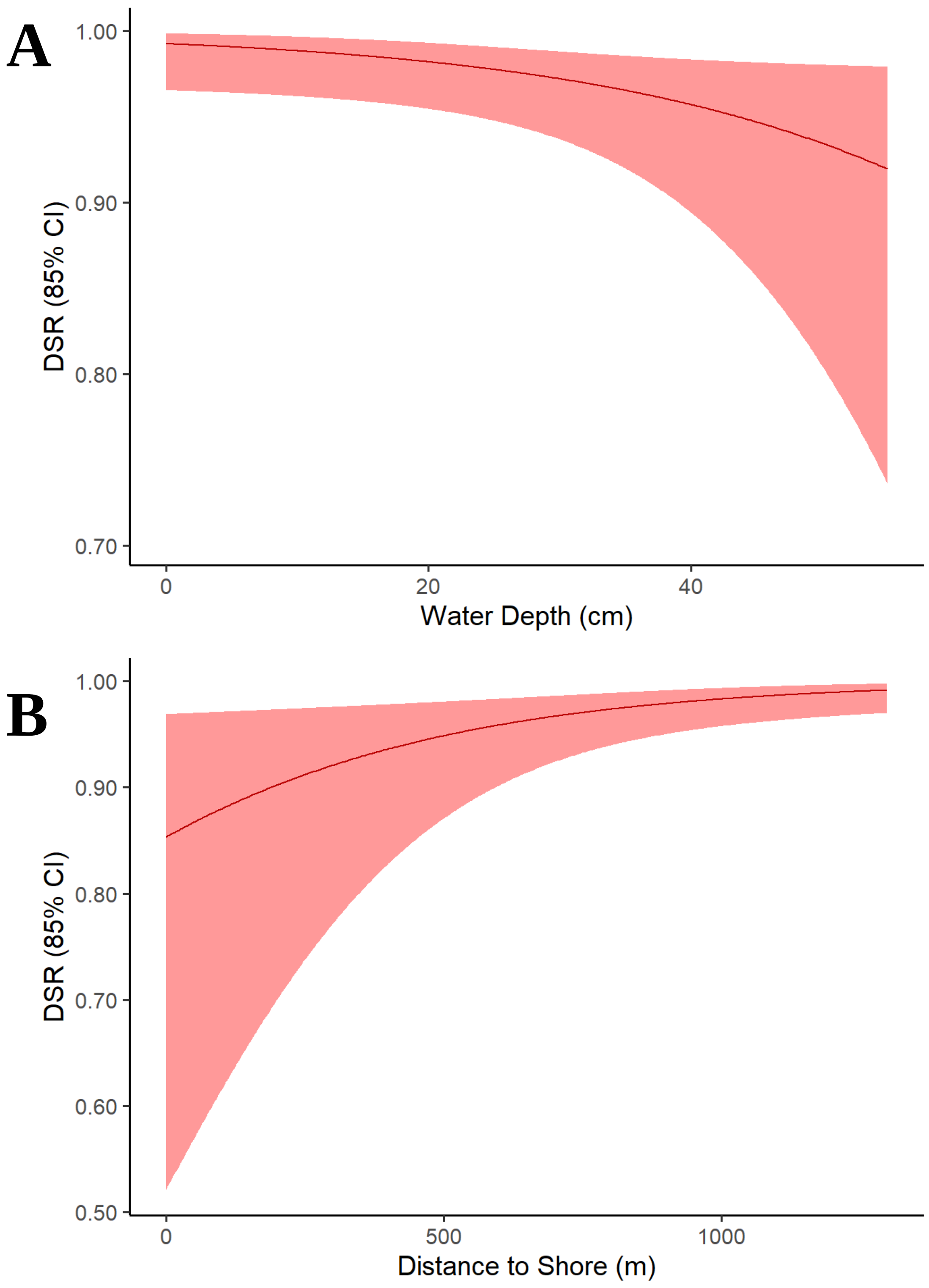
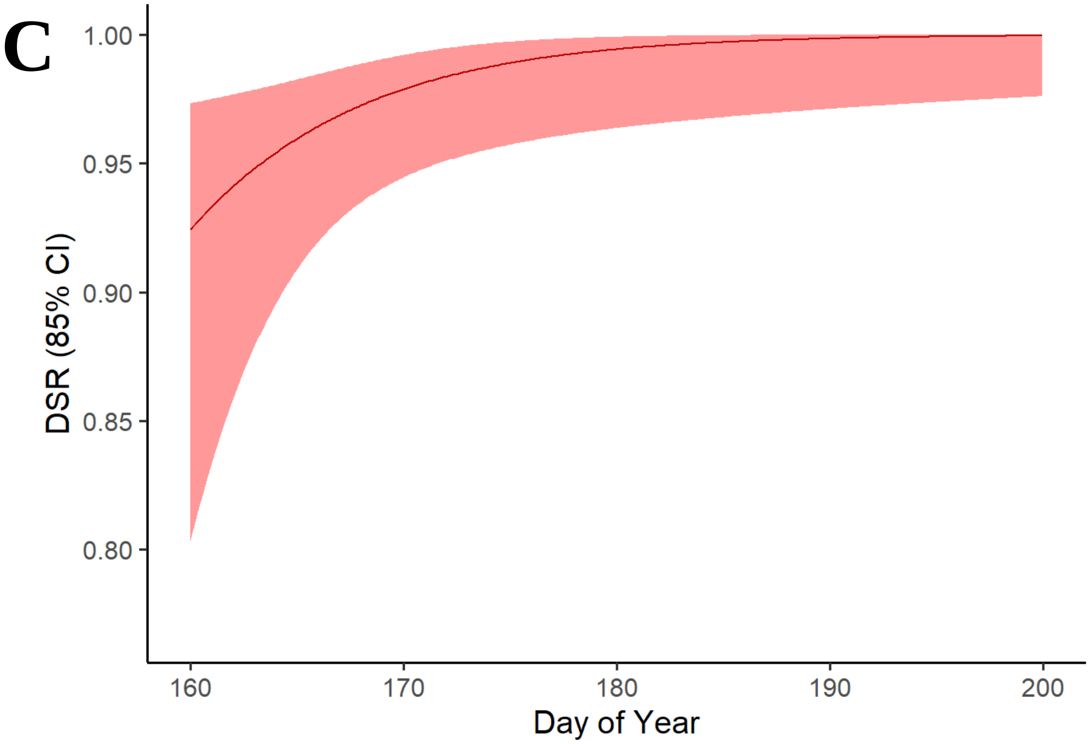


Figure 2.5. Daily survival rate (DSR) of Black-crowned Night-Heron nests in 2020 and 2021 at Emiquon Preserve, Illinois, USA, as a function of water depth (cm) (**A**), distance to shore (m) (**B**), and day of year (**C**).

Figure 2.5 (cont.)



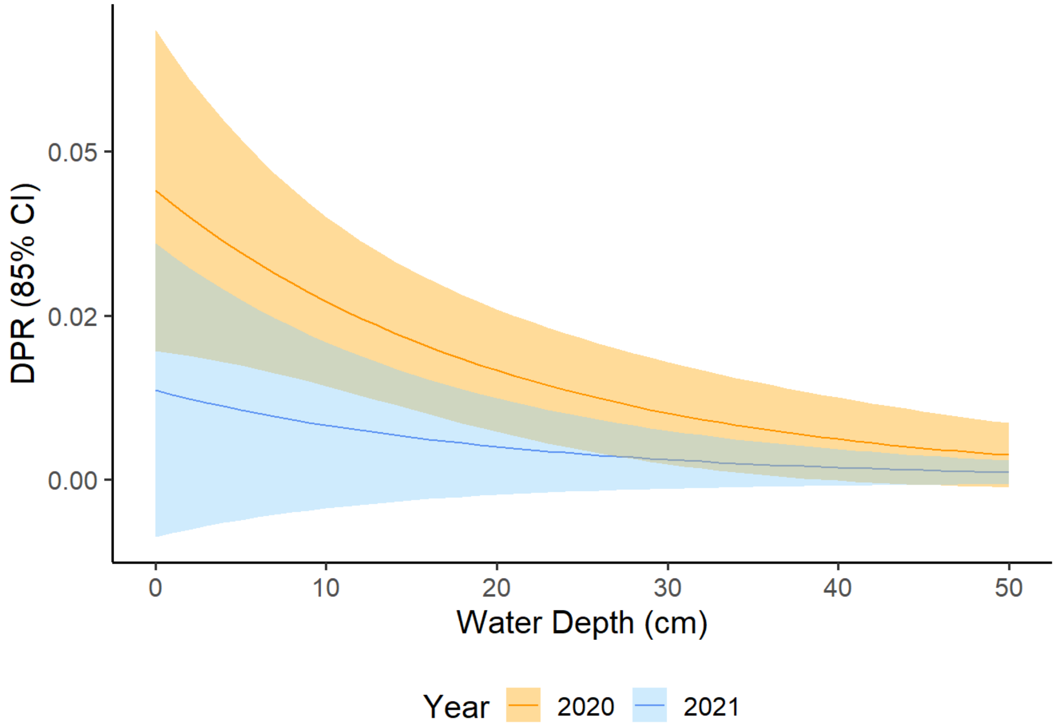


Figure 2.6. Daily predation rate (DPR) of all marsh bird nests with cameras (n=80) in 2020 and 2021 at Emiquon Preserve, Illinois, USA, as a function of mammalian predation risk and water depth (cm) and year.

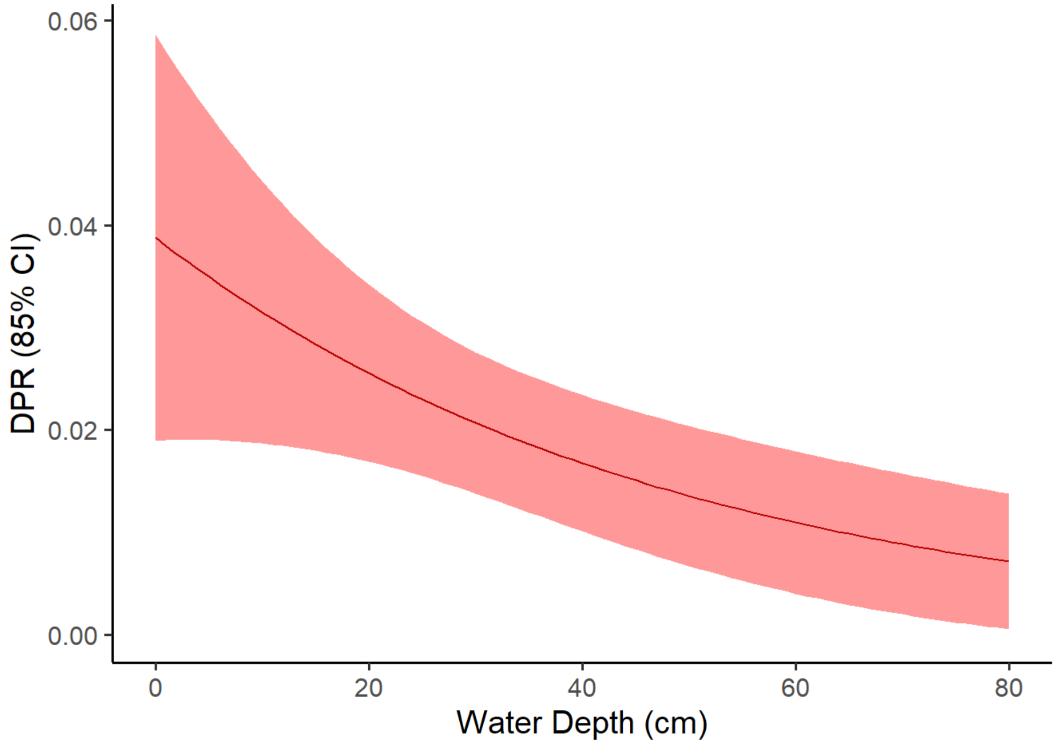


Figure 2.7. Daily predation rate (DPR) of all marsh bird nests with cameras (n=80) in 2020 and 2021 at Emiquon Preserve, Illinois, USA, as a function of other losses (unknown predators, abandonments) and water depth (cm).

LITERATURE CITED

Ahlers, A. A., E. J. Heske, and R. L. Schooley (2016). Prey distribution, potential landscape supplementation, and urbanization affect occupancy dynamics of American Mink in streams. Landscape Ecology 31:1601-1613.

Báldi, A., and P. Batáry (2005). Nest predation in European reedbeds: Different losses in edges but similar losses in interiors. Folia Zoologica 54:285-292.

Barding, E. E., and T. A. Nelson (2008). Raccoons use habitat edges in northern Illinois. American Midland Naturalist 159:394-402.

Batáry, P., and A. Báldi (2004). Evidence of an edge effect on avian nest success. Conservation Biology 18:389-400.

Bellrose, F. C. (1941). Duck Food Plants of the Illinois River Valley. Illinois Natural History Survey Bulletin 21:237-280.

Benson, T. J., J. D. Brown, and J. C. Bednarz (2010). Identifying predators clarifies predictors of nest success in a temperate passerine. Journal of Animal Ecology 79:225-234.

Bent, A. C. (1963). Life Histories of North American Marsh Birds. Dover Publications, Inc., NY, USA.

Blouin-Demers, G., and P. J. Weatherhead (2001). Habitat use by Black Rat Snakes (*Elaphe obsoleta obsoleta*) in fragmented forests. Ecology 82:2882-2896.

Bowyer, M. W., J. D. Stafford, A. P. Yetter, C. S. Hine, M. M. Horath, and S. P. Havera (2005). Moist-soil plant seed production for waterfowl at Chautauqua National Wildlife Refuge, Illinois. American Midland Naturalist 154:331-341.

Bradshaw, T. M., A. G. Blake-Bradshaw, A. M. V. Fournier, J. D. Lancaster, J. O'Connell, M. W. Jacques, M. W. Eichholz, and H. M. Hagy (2020). Marsh bird occupancy of wetlands managed for waterfowl in the midwestern USA. PLoS ONE 15: 1-19.

Burnham, K. P., and D. R. Anderson. (2002). Model Selection and Multimodel Inference: A Practical Information-theoretic Approach. Springer-Verlag, NY, USA.

Cain III, J. W., K. S. Smallwood, M. L. Morrison, and H. L. Loffland (2010). Influence of mammal activity on nesting success of passerines. Journal of Wildlife Management 70:522-531.

Chiavacci, S. J., T. J. Benson, and M. P. Ward (2018). Linking landscape composition to predator-specific nest predation requires examining multiple landscape scales. Journal of Applied Ecology 55:2082-2092.

Chen, H., and M. Lemke (2009). Emiquon floodplain restoration - partnership, implementation, research, and challenges. Restoration News Midwest 1:2–5.

Chen, H., S. Popovich, A. McEuen, A., and B. Briddel (2017). Carbon and nitrogen storage of a restored wetland at Illinois' Emiquon Preserve: Potential for carbon sequestration. Hydrobiologia, 804:139-150.

Colombelli-Négrel, D., and S. Kleindorfer (2005). Nest height, nest concealment, and predator type predict nest predation in Superb Fairy-wrens (*Malurus cyaneus*). Ecological Society of Japan 24:921-928.

Cox, W. A., M. S. Pruett, T. J. Benson, S. J. Chiavacci, and F. R. Thompson III (2012). Development of camera technology for monitoring nests. Studies in Avian Biology 43:185-210.

Dahl, T. E. (1990). Wetland losses in the United States 1780’s to 1980’s. U.S. Department of the Interior, Fish and Wildlife Service, Washington. D.C.

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.

DeGregorio, B. A., P. J. Weatherhead, M. P. Ward, and J. H. Sperry (2016). Do seasonal patterns of Rat Snake (*Pantherophis obsoletus*) and Black Racer (*Coluber constrictor*) activity predict avian nest predation? Ecology and Evolution 6:2034-2043.

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

Fairbairn, S. E., and J. J. Dinsmore (2001). Factors associated with occurrence and density of wetland birds in the Prairie Pothole region of Iowa. Journal of the Iowa Academy of Science 108:8-14.

Fleming, K. S., R. M. Kaminski, T. E. Tietjen, M. L. Schummer, G. N. Ervin, and K. D. Nelms (2012). Vegetative forage quality and moist-soil management on wetlands reserve programs land in Mississippi. Wetlands 32:919-929.

Fournier, A. M. V., D. C. Mengel, E. Gbur, A. Raedeke, and D. G. Krementz (2019). Evaluating tradeoffs in the response of Sora (*Porzana carolina*) and waterfowl to the timing of early autumn wetland inundation. Waterbirds 42:168-178.

Fournier, A. M. V., J. D. Lancaster, A. P. Yetter, C. S. Hine, T. Beckerman, J. Figge, A. Gioe, M. Greider-Wagner, D. Jen, C. Johnson, M. R. Larreur, et al. (2021). Nest success and nest site selection of wetland birds in a restored wetland system. Avian Conservation and Ecology 16. https://doi.org/10.5751/ACE-01782-160106

Frederick, P. C., and M. W. Collopy (1989). The role of predation in determining reproductive success of colonially nesting wading birds in the Florida Everglades. Condor 91:860-867.

Fredrickson, L. H. (1971). Common Gallinule breeding biology and development. Auk 88:914-919.

Fredrickson, L. H., and T. S. Taylor (1982). Management of seasonally flooded impoundments for wildlife. U.S. Department of the Interior, Fish and Wildlife Service: Resource Publication 148.

Guhin, V., and G. Hayes (2015). Habitat Restoration and Water Quality Management: Key Projects and Practices for Streams, Riparian Areas and Wetlands in California. Elkhorn Slough National Estuarine Research Reserve, Elkhorn Slough Coastal Training Program Elkhorn, CA, USA.

Hanson, H. C. (1954). Criteria of age of incubated Mallard, Wood Duck, and bob-white quail eggs. Auk 71:267-272.

Hanson, H. C., and C. W. Kossack (1957). Methods and criteria for aging incubated eggs and nestlings of the Mourning Dove. Wilson Bulletin 69:91-101.

Harms, T. M., and S. J. Dinsmore (2013). Habitat associations of secretive marsh birds in Iowa. Wetlands 33:561-571.

Havera, S. P. S. B. Suloway, and J. E. Hoffman (1997). Wetlands in the midwest with special reference to Illinois. (M. W. Schwartz, Editor). Conservation in Highly Fragmented Landscapes. Springer, Boston, MA.

Herranz, J., M. Yanes, and F. Suárez (2002). Does photo-monitoring affect nest predation? Journal of Field Ornithology 73:97-101.

Hine, C. S., H. M. Hagy, M. M. Horath, A. P. Yetter, R. V. Smith, and J. D. Stafford (2017). Response of aquatic vegetation communities and other wetland cover types to floodplain restoration at Emiquon Preserve. Hydrobiologia 804:59-71.

Hoefler, J. (1980). Status and distribution of Black-crowned Night-Herons in Wisconsin. Proceedings of the Colonial Waterbird Group 3:75-84.

Holland, C. C., J. Honea, S. E. Gwin, and M. E. Kentula (1995). Wetland degradation and loss in the rapidly urbanizing area of Portland, Oregon. Wetlands 15:336-345.

Holway, D. A. (1991). Nest-site selection and the importance of nest concealment in the Black-throated Blue Warbler. Condor 93:575-581.

Hoover, J. P. (2005). Water depth influences nest predation for a wetland-dependent bird in fragmented bottomland forests. Biological Conservation 127:37-45.

Illinois Endangered Species Protection Board (IESPB) 2020. Checklist of Illinois endangered and threatened animals and plants. https://www2.illinois.gov/dnr/ESPB/Pages/default.aspx

Jedlikowski, J., M. Brzeziński, and P. Chibowski (2015). Habitat variables affecting nest predation rates at small ponds: A case study of the Little Crake *Porzana parva* and Water Rail *Rallus aquaticus*. Bird Study 62:190-201.

Jobin, B., and J. Picman (1997). Factors affecting predation on artificial nests in marshes. Journal of Wildlife Management 61:792-800.

Jobin, B., B., L. Robillard, and C. Latendresse (2009). Response of a Least Bittern (*Ixobrychus exilis*) population to interannual water level fluctuations. Waterbirds 32:73-80.

Lane, J. J., and K. C. Jensen (1999). Moist soil impoundments for wetland wildlife. U.S. Army Corps of Engineers Technical Report EL-99-11.

Lee, Y. M. (2006). Monitoring of Eastern Fox Snakes (*Pantherophis gloydi*) in response to habitat restoration at Sterling State Park in southeast Michigan. Michigan Department of Natural Resources Report No. 2006-17.

Lemke, M. J., J. W. Walk, A. M. Lemke, R. E. Sparks, and K. D. Blodgett. (2017). Introduction: The ecology of a river floodplain and the Emiquon Preserve. Hydrobiologia 804:1-17.

Lemke, M. J., H. M. Hagy, A. F. Casper, and H. Chen, (2018). Floodplain wetland restoration along the Illinois river. In Ecological Restoration in the Midwest. (C. Lenhart, and P. C. Smiley, Editors). University of Iowa Press, IA, USA.

Lima, S. L. (2009). Predators and the breeding bird: Behavioral and reproductive flexibility under the risk of predation. Biological Reviews 84:485-513.

Lyons, T. P., J. R. Miller, D. M. Debinski, and D. M. Engle (2015). Predator identity influences the effect of habitat management on nest predation. Ecological Applications 25:1596-1605.

Ma, Z., Y. Cai, and J. Chen (2010). Managing wetland habitats for waterbirds: An international perspective. Wetlands 30:15-27.

Martin, T. E., J. Scott, and C. Menge (2000). Nest predation increases with parental activity: Separating nest site and parental activity effects. Proceedings of the Royal Society of London B 267:2287-2293.

Merendino, M. T., L. M. Smith, H. R. Murkin, and R. L. Pederson (1990). The response of prairie wetland vegetation to seasonality of drawdown. Wildlife Society Bulletin 18:245-251.

Moore, S., J. R. Nawrot, and J. P. Severson (2009). Wetland-scale habitat determinants influencing Least Bittern use of created wetlands. Waterbirds 32:16-24.

Newman, D. S., R. E. Warner, and P. C. Mankin (2003) Creating Habitats and Homes for Illinois Wildlife. Illinois Department of Natural Resources, IL, USA.

Noble, G. K., M. Wurm, and A. Schmidt (1938). Social behavior of the Black-crowned Night-Heron. Auk 55:7-40.

Olmos, F. (2002). Nest location, clutch size, and nest success in the Scarlet Ibis *Eudocimus ruber*. Ibis 145:E12-E18.

Picman, J., M. L. Milks, and M. Leptich (1993). Patterns of predation on passerine nests in marshes: Effects of water depth and distance from edge. Auk 110:89-94.

Picman, J., and L. M. Schriml (1994). A camera study of temporal patterns of nest predation in different habitats. Wilson Bulletin 106:456-465.

Pierce, A. R., and S. L. King (2013). Valley plugs, land use, and phytogeomorphic response. (J. F. Shroder, Editor). Treatise on Geomorphology, Volume 12.

Post, W. (1998). Reproduction of Least Bitterns in a managed wetland. Colonial Waterbirds 21:268-273.

Quesnelle, P. E., L. Fahrig, L., and K. E. Lindsay (2013). Effects of habitat loss, habitat configuration and matrix composition on declining wetland species. Biological Conservation 160:200–208.

R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/.

Ricklefs, R. E. (1969). An analysis of nesting mortality in birds. Smithsonian Contributions to Zoology 9:1-48.

Rosenberg, K. V., A. M. Dokter, P. J. Blancher, J. R. Sauer, A. C. Smith, P. A. Smith, J. C. Stanton, A. Panjabi, L. Helft, M. Parr, and P. P. Marra (2019). Decline of the North

American avifauna. Science 366:120–124.

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

Shaffer, T. L. (2004). A unified approach to analyzing nest success. Auk 121:526-540.

Siikamäki, P. (1998). Limitation of reproductive success by food availability and breeding time in Pied Flycatchers. Ecology 79:1789-1796.

Skutch, A. F. (1949). Do tropical birds rear as many young as they can nourish? Ibis 91:430-455.

Soulliere, G. J., M. A. Al-Saffar, R. L. Pierce, M. J. Monfils, L. R. Wires, B. W. Loges, B. T. Shirkey, N. S. Miller, R. D. Schultheis, F. A. Nelson, A. M. Sidie- Slettedahl, et al. (2018). Upper Mississippi River and Great Lakes Region Joint Venture waterbird habitat conservation strategy – 2018 Revision. U.S. Fish and Wildlife Service.

Sperry, J. H., R. G. Peak, D. A. Cimprich, and P. J. Weatherhead (2008). Snake activity affects seasonal variation in nest predation risk for birds. Journal of Avian Biology 39:379-383.

Uzun, A. (2009). Do the height and location of Black-crowned Night-Heron (*Nycticorax nycticorax*) nests affect egg production and breeding success? Waterbirds 32:357-359.

Vanausdall, R. A., and S. J. Dinsmore (2019). Habitat associations of migratory waterbirds using restored shallow lakes in Iowa. Waterbirds 42:135-153.

vanMiddlesworth, T. D., N. N. Michaels, and A. F. Casper (2015). The Nature Conservancy’s Emiquon Preserve: Fish and Aquatic Vegetation Monitoring 6-Year (2007-2012) Report. Illinois Natural History Survey Technical Report 2014 (01).

vanRees-Siewert, K. L., and J. J. Dinsmore (1996). Influence of wetland age on bird use of restored wetlands in Iowa. Wetlands 16:577-582.

Weatherhead, P. J., and G. Blouin-Demers (2004). Understanding avian nest predation: Why ornithologists should study snakes. Journal of Avian Biology 35:185-190.

Weller, M. W. (1961). Breeding biology of the Least Bittern. Wilson Bulletin 73:11-35.

Weller, M. W., and C.S. Spatcher (1965). Role of habitat in the distribution and abundance of marsh birds. Iowa State University of Science and Technology Special Report No. 43.

Wilson, E. D., W. E. Jensen, and R. Schultheis (2018). Habitat use by secretive marsh birds during spring and fall migration in moist-soil wetlands in Kansas. Wilson Journal of Ornithology 130:385-396.

Young, A. D. (1988). A portable candler for birds’ eggs. Journal of Field Ornithology 59:266-268.

Zedler, J. B. and S. Kercher (2005). Wetland resources: Status, trends, ecosystem services, and restorability. Annual Review of Environment and Resources 30:39–74.

CHAPTER 3: POST-FLEDGING SURVIVAL AND HABITAT USE OF JUVENILE LEAST BITTERNS (IXOBRYCHUS *EXILIS*)

ABSTRACT

The post-fledging period, defined as the period after a young bird leaves their nest, is a crucial stage for young birds and is often when they face the highest risk of mortality. Current management for breeding birds has been primarily informed by the nesting and adult stages while the post-fledging period is often understudied, despite birds spending an equal or greater amount of time in the post-fledging period than they do in the nest. In 2020 and 2021 we studied post-fledging habitat use and survival of 50 Least Bitterns (*Ixobrychus exilis*), a cryptic marsh bird of conservation concern. We found fledglings selected denser and taller marsh vegetation than available and relied on persistent emergent vegetation which likely provides greater predator protection, thermal refuge, and foraging opportunities. We also found fledgling habitat use was age-dependent and related to flight ability, with younger, pre-flight fledglings selecting denser habitats and older juveniles with flight ability selecting more open habitat. We also found that unlike most post-fledging studies, Least Bittern fledglings exhibited very low mortality, with 86% surviving until 30 days post-hatch, often leaving Emiquon Preserve around this time. Mortality resulted from predation and exposure, and the greatest mortality risk was in the three days following fledging and in 2020, a year characterized by high water levels in the spring and early season, high volume drawdowns for management. Our results suggest that both densely vegetated and more open marsh habitat are important for fledgling Least Bitterns.

Keywords Least Bittern, *Ixobrychus exilis*, fledgling survival, fledgling habitat use.

Lay Summary

- The post-fledging period, the time between when a young bird leaves the nest and gains independence, is understudied yet critically important for conservation and management.
- We studied post-fledging habitat use and survival of Least Bitterns, a marsh bird species of conservation concern that has experienced substantial habitat loss and is likely affected by wetland management strategies that alter vegetation conditions and the presence of water.
- We found post-fledging Least Bitterns selected habitats over water with dense and tall vegetation, such as cattail, and as they got older, they selected more open habitats that were presumably better for foraging. We also found mortality was greatest in the 3 days after fledging but decreased soon after.
- Our study suggests management for Least Bitterns should create an interspersion of densely vegetated and open areas within inundated marshes during the post-fledging period.

INTRODUCTION

Habitat use during the breeding season tends to focus exclusively on the nesting period, ignoring the months before and after nesting, and these results are used to inform management of habitat for the entire breeding season. The post-fledging period, the time between when a bird leaves the nest and reaches independence, remains relatively understudied and most studies of altricial or semi-altricial species are restricted to songbirds despite it being a critical and challenging life history stage across all bird species (Small et al. 2015, Naef-Daenzer and Grüebler 2016, Jones et al. 2017). Fledglings are non-territorial and cryptic, making traditional re-sighting and recapturing methods ineffective, which has likely contributed to the limited studies of this life stage, but the increased use of radio-telemetry has helped to mitigate these challenges (Bogner and Baldassarre 2002, White and Faaborg 2008, Raybuck et al. 2020). These studies have demonstrated that habitat needs during the post-fledging period often differ from what adult birds require, as seen in studies of forest birds (Anders et al. 1998, Burke et al. 2017, Raybuck et al. 2020), waterbirds (Morton et al. 1989), and grassland birds (Small et al. 2015). Furthermore, the post-fledging period is dynamic, and as fledglings learn new skills and gain independence, age-specific patterns of habitat use can arise and further complicate management decisions (White and Faaborg 2008, Jones et al. 2017). These patterns may be a result of greater mobility from flight allowing older fledglings to prioritize resource acquisition over strict predator protection and select riskier habitats less conducive to predator avoidance (Small et al. 2015, Raybuck et al. 2020).

The post-fledging period is also of critical importance because survival is often lower in this stage than others because of fledglings' inexperience foraging, navigating, and avoiding predators (Anders et al. 1997, Cox et al. 2014). Post-fledging survival is important for population persistence and can be a limiting stage for some species (Anders et al. 1997, Parker et al. 2003). Survival may vary with juvenile age, as increased mobility and flight ability likely allows greater predator evasion (Anders et al. 1997, Raybuck et al. 2020), and vegetation structure and presence of water may also influence survival during the post-fledging period (Anders et al. 1998, Bogner and Baldassarre 2002, Jones and Bock 2005, Jones et al. 2017). For management and conservation actions to be effective, decisions should be informed by all life stages, including the post-fledging period, but we lack information on this period for most species (Norris and Marra 2007, Cox et al. 2014).

The Least Bittern (*Ixobrychus exilis*) is an inconspicuous wetland-obligate bird and, like many marsh birds, has experienced widespread population declines, primarily driven by habitat loss and degradation (Eddleman et al. 1988, Ward et al. 2010). In the upper Midwest the Least Bittern has experienced a 4.9% annual decline, though estimates are not very accurate because secretive wetland nesting species tend to be under sampled in classic roadside surveying efforts (Kleen et al. 2004, Lawler and O'Connor 2004, Gray et al. 2013). In the United States, 53% of colonial-era wetland area was drained by the 1980s for agricultural expansion and urbanization, and the Midwest was particularly impacted by this drainage effort (Dahl 1990). In more recent decades wetlands are being restored and managed to support a wide suite of wetland dependent species. One management strategy used in emergent wetlands is periodically conducting drawdowns to mimic historic flood regimes, recharge groundwater, control the spread of invasive species (i.e. *Phalaris arundinacea*, Lavergne and Molofsky 2006), and restore habitat structure and complexity for a variety of wetland plants and animals (e.g., moist-soil plants, waterfowl, shorebirds, marsh birds) (Lane and Jensen 1999, U.S. EPA 2008, Guhin and Hayes 2015). Water-level management creates a mosaic of habitats, including emergent hemi-marsh (i.e. 50:50 water:vegetation) and non-persistent emergent, open water, and mudflat, benefitting diverse plant and animal communities, including many species of marsh birds (Rundle and Fredrickson 1981, Wilson 2016, Tozer et al. 2018, Fournier et al. 2019). In Least Bitterns, adult occupancy has been found to be greatest in hemi-marsh conditions, described as areas of high degrees of vegetation interspersion, and inundation of 0-57 cm, and adult habitat use is generally used to inform habitat management for the species (Bogner and Baldassarre 2002, Rehm and Baldassarre 2007, Bolenbaugh et al. 2011, Bradshaw et al. 2020).

In an effort to inform management for Least Bitterns, we set out to determine habitat use and causes of mortality in Least Bittern fledglings. More specifically, we studied habitat preferences and survival in Least Bittern fledglings as a function of age, habitat conditions, and temporal factors. We expected to see age-specific patterns of habitat use and survival and high mortality due to predation, starvation, or exposure in the post-fledging period.

METHODS

Study Site

Our study was conducted in 2020 and 2021 at Emiquon Preserve, a 2,723 ha floodplain wetland in Fulton County, Illinois managed by The Nature Conservancy (Chen et al. 2017). In 1924, following levee construction, what is now Emiquon Preserve was disconnected from the Illinois River, drained, and used for agriculture for 80 years (Havera et al. 2003, Lemke et al. 2017). In 2000, The Nature Conservancy purchased the land to restore the floodplain wetland and its ecosystem services through active water management. Today, Emiquon Preserve provides habitat for hundreds of thousands of waterfowl and other waterbirds during migration and provides breeding habitat for marsh birds, including Least Bitterns, within its complex shoreline (Fournier et al. 2021).

Capturing and Marking Fledglings

From May through July 2020 and 2021, we located Least Bittern nests by systematically surveying dense emergent vegetation and hemi-marsh (Chapter 2). We visited nests every 3-5 days until nestlings reached fledging age and at these visits, we measured nestling mass (day 12-18 post-hatch; Bogner and Baldassarre 2002). We monitored the growth of 342 fledgling Least Bitterns aged 0-17 days after hatching at 50 nests in 2020 and 2021. We observed a linear growth curve within this limited 17-day period with an estimated 4.3 g gained per day (day 0 = 6.1g). Based on their growth patterns, we attached radio tags the same day juveniles fledged (i.e. 15 days post-hatch) when they weighed between 56 and 85 g (average 68 g) from near a subset of nests (1-2 per brood) and banded them with a USGS aluminum band and a unique combination of plastic color bands on their tarsometatarsus. We also outfitted fledglings with a 1.7 or 3.0 g VHF radio-tag with a 64- to 185-day life expectancy, respectively (Lotek, Newmarket, Ontario, Canada). We superglued a transmitter between each fledgling's scapulars with the antenna pointing towards the tail following methods from Raim (1978). We weighed juveniles before attaching radio-tags to ensure radio-tag weight was below 5% of fledgling body weight (Raim 1978).

Radio Telemetry

We located fledglings one time every 1-3 days between 05:30 and 16:00 (CDT), when they were expected to be active. We located fledglings by homing with a receiver (Advanced Telemetry Systems, Isanti, Minnesota, USA) and a 3-element Yagi antenna from June 17-August 21 in 2020 and July 4-August 8 in 2021. We did not track fledglings in adverse weather (i.e. high winds, heavy rain, lightning). Before fledglings attained flight (day 15-29 post-hatch; Bogner and Baldassarre 2002), fledglings would generally remain motionless in a bill-up stance or move quickly through vegetation by grasping stems with their feet, allowing us to determine exact fledgling locations. After fledglings attained flight (≥29 days post-hatch; Bogner and Baldassarre 2002), the juveniles would often take flight when we approached, and color bands were visible in flight. We determined fledgling location based on these visual encounters or when the signal strength indicated the bird was present but had moved before we visually located the individual. All locations were recorded on a handheld GPS (Garmin, Olathe, Kansas, USA). From our 2020 data, when birds were tracked daily, we calculated the minimum daily distance moved by calculating the Euclidean distance between a fledgling's GPS location and the previous day's location. We stopped tracking fledglings if radio-tags fell off, fledglings died, fledglings had left our site, or it was August 21, 2020 or August 8, 2021, when all tagged birds were > 26 days old, an age after which tags were frequently dropped or birds left the site.

Habitat Measurements

We documented habitat characteristics at fledgling locations and at paired random points in 2021. Habitat measurements were taken the same day a fledgling was re-sighted at both the fledgling location and the paired random point. The random point was selected using a random cardinal direction and distance from the fledgling location. Distance from the fledgling location was age-specific based on movement data from 2020. Paired points for 15-20 days post-hatch were between 0 and 25 m, 26-100 m for 21-28 days post-hatch, and 101-250 m for ≥29 days post-hatch (Figure 3.1). If the random point was not in usable habitat for Least Bitterns (i.e. deep open water without perching material), we re-selected a distance and direction.

We recorded water depth, height of emergent vegetation (average height of shortest and tallest vegetation from root to tip within 1-meter of the located fledgling), and percent cover of water and emergent vegetation within 2.5 m at each fledgling location and paired random point. We also classified each point into one of three dominant vegetation types: persistent emergent (*Typha spp*. and *Scirpus spp*.), non-persistent emergent (moist-soil plants), or other (mudflat, floating leaved, woody), as well as one of three categories for habitat openness: open-marsh (open water or aquatic bed interspersed with 0%-30% cover by emergent vegetation), hemi-marsh (open water or aquatic bed interspersed with 40%-60% cover by emergent vegetation), or dense-marsh (open water or aquatic bed interspersed with 70%-100% cover by emergent or vegetation). If a fledgling could not be located and we assumed the bird was in motion or out of range, habitat measurements were not taken.

Fledgling Fate

Fledglings were assigned one of three fates during each tracking event: (1) survived = seen alive or tag predictably moving, (2) died = found dead or limbs were found with key identifiers (i.e. leg bands, radio-tag), or (3) unknown = radio-tag was found not attached to the bird and fate was unknown, or the VHF signal was out of range. If a bird with an unknown fate was subsequently found alive, we retroactively classified the chick's fate as survived for the previous unknown interval.

Statistical Analyses

We examined daily mass of nestlings and fledglings up to 3-days post-fledging using a linear regression with the *lm* function in R after confirming assumptions were met (R Core Team 2013). Next, we examined daily distance traveled by age to inform the selection radius of paired random points for our habitat-use analyses. We log-transformed distance to meet normality assumptions and fit a linear regression using the g*lmer* function and a Gaussian distribution in the lme4 package in R (R Core Team 2013). We included bird ID and nest ID as random effects to account for the non-independence of sampling the same individual multiple times and sampling more than one individual from the same nest, because birds in the same clutch may occupy more similar spaces (Anders et al. 1998).

To examine habitat differences between used and random points we used a generalized linear mixed model with the *glmer* function and a binomial distribution and logit link function in the *lme4* package in R (R Core Team 2013). We included bird ID, nest ID, and paired points as random effects to account for the non-independence of sampling the same individual multiple times, sampling more than one individual from the same nest, and having multiple random locations associated with individuals and nests. Our response variable was whether a point was used (1) or randomly selected (0), and our predictor variables were water depth, emergent vegetation height, and category of habitat openness. We measured the correlation of variables within models to ensure highly correlated variables (|*r*|>0.7) were not used in models together, and we tested all models for overdispersion. We ranked models using an information-theoretic approach corrected for small sample sizes (AIC_c; Burnham and Anderson 2002) and considered models within 8 ΔAIC_c units of the top model to be competitive, due to the additional parameters from the random effects. Models with dominant vegetation had convergence problems and the variable was excluded from these analyses, so we ran separate *glmer* models (binomial distributions and logit link function) in *lme4* for each habitat type and present results as coefficient estimates (β) and 95% confidence intervals (R Core Team 2013). Our response variable for this analysis was whether a point was used (1) or randomly selected (0), and our predictor variables were dominant vegetation which was used as an individual category compared against all others (Y or N) and repeated for each category. We also examined habitat use versus availability for fledglings pre-flight and post-flight in two separate analyses using the same methods above. Flight was attained between 23 and 38 days of age (average 31 days), so we used a cutoff of 31 days to determine flight ability for habitat use.

To examine post-fledging survival as a function of habitat variables, we developed a priori hypotheses and used logistic exposure models (Shaffer 2004). Our response variable was fledgling fate (survived or died) for each interval, and our predictor variables were water depth, year, day of the year, age, and dominant vegetation and habitat openness categories. We assessed correlation among variables within models to ensure highly correlated variables (|*r*|>0.7) were not used in models together and examined models for overdispersion. We again ranked models using AIC_c (Burnham and Anderson 2002) and considered models to be competitive when within

2 ΔAIC_c units of the most parsimonious model, rather than 8 ΔAIC_c units as used above, which was a result of no random effects providing additional parameters.

RESULTS

Fledgling Radiotagging

In 2020, fledging dates ranged from June 15-August 14, and in 2021 fledging dates ranged from June 30-August 12. We attached transmitters to 50 fledglings (2020 = 16, 2021 = 34) and determined their fate and location every 1-4 days (mean= 2.5 days). Tag retention averaged 15.4 days (range: 0-29 days). Fledglings began flight around day 31 post-hatch (± 3.8[SD]; range: 23-37 days) and juvenile movement increased with age, and subsequently flight ability (Figure 3.1).

Fledgling Habitat Use

We measured habitat characteristics at 231 fledgling locations and 231 paired points for 34 Least Bittern fledglings in 2021. The best-supported model included the additive effects of habitat openness and emergent vegetation height (w_i = 1.00) (Table 3.1). Probability of use increased in taller emergent vegetation and there was selection for hemi-marsh (0.55 ± 0.04 (SE)) and dense-marsh (0.56 ± 0.03) over open-marsh (0.14 ± 0.05) habitat (Figure 3.2). In our separate analysis of dominant vegetation type, we also found all fledglings were selecting for persistent emergent vegetation and selecting against floating leaved vegetation (Table 3.2).

We collected data at 162 fledgling locations and 162 paired points were during the pre-flight period, and 69 Least Bittern fledgling locations and 69 paired points were during the post-flight period. The additive effects of habitat openness and emergent vegetation height were strongly supported for both periods (w_i = 1.00 and w_i = 0.1.00, Table 3.1). Pre-flight fledglings showed preference for taller emergent vegetation in all cases and for dense-marsh (0.58 ± 0.04) over hemi-marsh (0.47 ± 0.05) and avoidance of open-marsh habitat (0.03 ± 0.03) (Figure 3.3). Post-flight fledglings showed preference for taller emergent vegetation in all cases as well and selected for hemi-marsh (0.69 ± 0.07) over dense-marsh habitat (0.50 ± 0.07) but used open-marsh habitat more than pre-flight fledglings (0.24 ± 0.08) (Figure 3.4). In our separate analyses of dominant vegetation type, we observed all fledglings and pre-flight fledglings selecting for persistent emergent vegetation and against floating leaved vegetation, however, post-flight fledglings selected for persistent emergent vegetation and showed a weak selection for floating-leaved vegetation (Table 3.2). Additionally, an analysis of habitat openness, a variable in all top ranked models, and dominant vegetation type showed fledglings selected for persistent emergent vegetation (i.e. *Typha spp.*, *Scirpus spp.*) and floating leaved vegetation (i.e. *Nelumbo lutea*) over other vegetation types (Table 3.3). This analysis also presented the stronger preference for floating-leaved vegetation in fledglings who have attained flight compared to their pre-flight counterparts, as can be found in more open habitats (Table 3.3). Finally, water depth was not included in competitive models, but did perform significantly better than the random selection model in pre- and post-flight analyses and suggested post-flight fledglings selected for deeper water habitats (Table 3.2).

Fledgling Survival

We monitored 50 Least Bittern fledglings from 15-40 days post-hatch in 2020 and 2021, and 6 were omitted from analyses because of tag loss during the first interval with no signs of depredation (tags remained within a few meters where fledglings were captured and released). Of the remaining 44, 4 (9.1%) died between 0-11 days post-fledging (3.5 ± 5.1[SE] days) and 40 (90.9%) survived until the radio-tag fell off or the bird had left the site. One mortality was due to predation and three mortalities were likely due to exposure (i.e., had no evidence of predation and the radio-tag was still attached). Post-fledging survival was best explained by additive effects of age and year (w_i = 0.77) (Table 3.4). Daily survival was lowest in 2020 and immediately following fledging (Figure 3.5). Daily survival rates of fledglings in 2020 and 2021 correspond to 2-week survival estimates of 88.1% and 98.6%, respectively. We did not find any habitat variables that were strong predictors of survival (Table 3.4).

DISCUSSION

Following fledging, Least Bitterns selected dense habitats with tall emergent vegetation, not unlike the habitat Least Bittern adults select for nesting (Lor and Malecki 2006). Studies of post-fledging habitat use in grasslands and forest have also found selection for dense vegetated habitat, presumably to decrease predation risk while also providing refuge from adverse weather conditions (Small et al. 2015, Jones et al. 2017). Least Bittern fledglings also selected persistent emergent vegetation and emergent floating leaved vegetation over non-persistent and woody vegetation types, and while in dense herbaceous vegetation they were found beneath the cover of lotus or cattail leaves and rarely exposed. This finding supports the idea that fledglings select habitat with greater cover and fewer canopy gaps for greater predator protection (Small et al. 2015, Raybuck et al. 2020)

Fledgling habitat use also appears to be dependent on age and mobility. We found pre-flight fledglings (15-30 days post-hatch) selected denser habitat than those that could fly (31+ days post-hatch). Pre-flight fledglings are likely less adept at evading predators and benefit from remaining in taller and denser vegetation while they complete development (Anders et al. 1997, Jones and Bock 2005, Jones et al. 2017). Alternatively, flighted fledglings transitioned into more open spaces (i.e. hemi-marsh, open-marsh) as they gained mobility, potentially allowing them to exploit areas with abundant food but less cover (Moore et al. 2009, Darrah and Krementz 2010, Fisher and Davis 2011, Small et al. 2015, Jones et al. 2017).

Post-fledging survival is highly variable across species (23-87% 3 weeks post-fledging), and in some species fledgling survival has a greater impact on population growth than other demographic parameters (Anders et al. 1997, Todd et al. 2003, Fisher and Davis 2011, Cox et al. 2014, Cox et al. 2019). The low-mortality observed in our study contrasts other studies of open-nesting birds, however high fledgling survival has also been seen in wetland birds such as American Black Ducks (97.4%, Longcore et al. 1991), Harlequin Ducks (99.0%, Regehr 2003), and Wood Storks (96.5%, Hylton 2004) in the first 2-weeks post-fledging. Most mortality in our study was due to exposure rather than predations, again contrasting from studies of open-nesting forest and grassland passerines where predation was the leading cause of mortalities (Sullivan 1989, Naef-Daenzer et al. 2001, Yackel Adams et al. 2006, Jones et al. 2017). The low post-fledging mortality and few predation-caused deaths of Least Bitterns could be a direct result of a combination of factors including deeper water deterring terrestrial predators such as raccoons (Chapter 2) and selection of denser habitats (Bogner and Baldassarre 2002, Hoover 2005, Jones and Bock 2005).

As with other post-fledging studies, mortality risk was greatest in the 3 days following fledging (Yackel Adams et al. 2006, Raybuck et al. 2020). Studies have frequently demonstrated a post-fledging bottleneck in altricial and semi-altricial birds with markedly elevated mortality in the first week following fledging that abruptly decreases and asymptotes at high survival (Jones et al. 2016, Naef-Daenzer and Grüebler 2016, Jones et al. 2020). The greatest threats to fledglings at this time are predation, starvation, and exposure due to a lack of experience foraging, avoiding predators, and selecting habitats (Ricklefs 1969, Newton 1998, Naef-Daenzer et al. 2001, Hylton 2004). This relationship suggests threats are greatest in the short period when younger birds lack the ability to fly away when threatened and instead remain still, avoiding detection, and survival rate increases as flight is attained (Sullivan 1989, Anders et al. 1997, Cox and Kesler 2012). During radiotracking, Least Bitterns that were unable to fly usually adopted the bill-up stance typical of bitterns aiding in camouflage. However, mortality due to predation and exposure was likely greatest because of inexperience foraging and movement into new locations (Bates and Ballard 2014).

All but one mortality was observed in 2020, which may be a result of habitat changes caused by a large intensity drawdown at Emiquon Preserve between June and August that removed 1.4 m of water, though overall post-fledging survival was ultimately high. This drawdown removed standing water beneath many marsh bird nests, leading to greater predation, particularly by mammals (Chapter 2). For young fledglings with low mobility, the removal of water could place these birds at risk of death due to exposure, starvation, or predation.

Although we did not find habitat factors that influenced survival, the presence and extent of water at larger scales can be important for creating viable nesting habitat, preventing terrestrial predator access to the marsh interior, and controlling the abundance and availability of prey for young waterbirds, so more work is needed on the complex relationships between water-level management and fledgling survival (Picman et al. 1993, Gawlik 2002, Jedlikowski et al. 2015). Prey availability is another important avenue for future research involving fledging survival, and although it was not measured directly in our study, prey availability can also impact mass and growth of fledglings and has been found to be meaningful in past studies of post-fledging survival (Neaf-Daenzer et al. 2001, Neaf-Daenzer and Gruebler 2016, Cox et al. 2019). In this study we focused on the first 2 weeks of the post-fledging period, as many birds left

Emiquon Preserve between 2 weeks and 1 month post fledging. Given our study looked at a small frame of time within the post fledging period, more research is needed to understand where fledgings are moving after 1 month, what habitat decisions they are making, and how these decisions are impacting their mortality. Additionally, a juvenile bird's first migration and winter can also be hazardous as the bird is not experienced in handling additional stressors including exhaustion, lack of useable habitat, and extreme weather conditions (Kersten and Brenninkmeijer 1995, Wiens et al. 2006, Borkhataria et al. 2012, Geary et al. 2015), so more work is needed to assess survival and habitat use as young birds reach independence and engage in their first fall migration and winter.

While research and management decisions often focus on the nesting period, the post-fledging period can be as or more important given that individuals spend as much or more time in this stage (Anders et al. 1998, Burke et al. 2017, Jones et al. 2017). In a previous study focused solely on nest survival, we found management, such as active dewatering, outside of critical Least Bittern nesting stages can create suitable nesting habitat while limiting predation risk at nests (Chapter 2). In this study, we also suggest wetland management that creates densely vegetated inundated habitats during the post-fledging period may support an increased survival of fledgling Least Bitterns and continue to provide habitat for adult Least Bitterns.

Acknowledgments

Funding and support were provided by State Wildlife Grant (T-122-R) from the Illinois Department of Natural Resources and the United States Fish and Wildlife Service as well as the Champaign County Audubon Society. We thank K. D. Blodgett and S. McClure of The Nature Conservancy for access to Emiquon Preserve, and L. Hinz and R. Smith of the Illinois Department of Natural Resources for facilitating this work. We thank N. Hargett, C. Stephens, N.

Pietrunti, C. Beach, M. Lowers, and A. Yetter for assistance with field surveys and equipment management.

TABLES AND FIGURES

Table 3.1. Model selection results for logistic regressions explaining all, pre-flight (15-30 days post-hatch), and post-flight (31+ days post-hatch) habitat selection by fledgling Least Bittern in 2021.

		All Ages			Pre-Flight (15-30 days post-hatch)			Flight (31+ days post-hatch)		
Model	k	AIC_c	ΔAIC_c	w_i	AIC_c	ΔAIC_c	w_i	AIC_c	ΔAIC_c	w_i
Habitat Openness + Avg. Emergent Vegetation Height	7	579.55	0.00	1.00	384.05	0.00	1.00	174.86	0.00	0.93
Habitat Openness	6	598.88	19.34	0.00	419.56	35.51	0.00	180.84	5.98	0.05
Water Depth + Avg. Emergent Vegetation Height	6	605.48	25.94	0.00	406.76	22.71	0.00	182.44	7.58	0.02
Avg. Emergent Vegetation Height	5	610.13	30.58	0.00	417.49	33.43	0.00	184.95	10.09	0.00
Intercept Only (Random Selection)	4	648.59	69.04	0.00	457.33	73.27	0.00	199.60	24.74	0.00
Water Depth	5	650.43	70.88	0.00	458.49	74.43	0.00	194.65	19.79	0.00

Table 3.2. Coefficient estimates (β) and 95% confidence intervals for variables explaining all, pre-flight (15-30 days post-hatch), and post-flight (31+ days post-hatch) habitat selection by fledgling Least Bitterns in 2021.

	All Ages		Pre-Flight (15-30 days post-hatch)		Flight (31+ days post-hatch)	
Variable	β	95% CI	β	95% CI	β	95% CI
Water Depth (cm)	2.18×10^3	-8.09×10^3 to 12.45×10^3	-5.97×10^3	-18.66×10^3 to 6.72×10^3	3.29 x 10^2	0.77×10^2 to 5.8×10^2
Avg. Emergent Vegetation Height (cm)	101.00	68.00 to 133.00	161.00	106.00 to 216.00	130.00	64.00 to 199.00
Open Marsh[a]	-2.36	-3.14 to -1.58	-3.80	-5.82 to -1.79	-1.64	-2.62 to -0.66
Hemi Marsh[b]	-0.14	-0.55 to 0.28	-0.45	-0.93 to 0.03	0.64	-0.18 to 1.47
Dense Marsh[c]	0.33	0.07 to 0.58	0.37	0.08 to 0.66	0.18	-0.35 to 0.71
Persistent Emergent Vegetation	1.01	0.62 to 1.40	1.51	0.91 to 2.10	1.02	0.25 to 1.79
Floating Leaved Vegetation	-0.51	-0.91 to -0.11	-1.34	-1.94 to -0.73	0.47	-0.20 to 1.15
Other Vegetation[d]	-0.33	-	-0.34	-	-0.34	-

[a] Open marsh habitat is defined as 100:0 to 70:30 open water/mudflat to vegetation ratio.

[b] Hemi-marsh habitat is defined as 60:40 to 40:60 open water/mudflat to vegetation ratio.

[c] Dense marsh habitat is defined as 30:70 to 0:100 open water/mudflat to vegetation ratio.

[d] Other vegetation is defined as non-persistent emergent, woody, or submerged (i.e.mudflat)

Table 3.3. Matrix of dominant vegetation and habitat openness explaining habitat use for post-fledging Least Bitterns in 2021.

All ages						
	Dominant Vegetation					
	Persistent Emergent		Floating-leaved		Other[a]	
Habitat Openness	Used	Random	Used	Random	Used	Random
Open[b]	4	26	4	9	0	26
Hemi[c]	56	40	27	28	0	1
Dense[d]	112	53	28	47	0	1
Pre-flight (15-30 days post-hatch)						
	Persistent Emergent		Floating-leaved		Other	
Habitat Openness	Used	Random	Used	Random	Used	Random
Open	1	23	0	2	0	6
Hemi	45	37	6	18	0	0
Dense	99	46	11	30	0	0
Flight (31+ days post-hatch)						
	Persistent Emergent		Floating-leaved		Other	
Habitat Openness	Used	Random	Used	Random	Used	Random
Open	3	3	4	7	0	20
Hemi	11	3	21	10	0	1
Dense	13	7	17	17	0	1

[a] Other vegetation is defined as non-persistent emergent, woody, or submerged (i.e.mudflat)

[b] Open marsh habitat is defined as 100:0 to 70:30 open water/mudflat to vegetation ratio.

[c] Hemi-marsh habitat is defined as 60:40 to 40:60 open water/mudflat to vegetation ratio.

[d] Dense marsh habitat is defined as 30:70 to 0:100 open water/mudflat to vegetation ratio.

Table 3.4. Model selection results for the logistic exposure regressions explaining Least Bittern post-fledging survival in 2020 and 2021 as a function of spatial and temporal variables.

Model	*k*	AIC_c	ΔAIC_c	w_i
Year + Age	3	39.13	0.00	0.77
Year	2	42.51	3.37	0.14
Age	2	43.91	4.77	0.07
Constant Survival	1	48.62	9.48	0.01
Water Depth	2	49.96	10.83	0.00
Habitat Openness	3	50.04	10.90	0.00
Distance from the Nest	2	50.47	11.34	0.00
Day of the Year	2	50.50	11.37	0.00
Water Depth + Habitat Openness	4	51.12	11.99	0.00
Dominant Vegetation	3	51.38	12.24	0.00

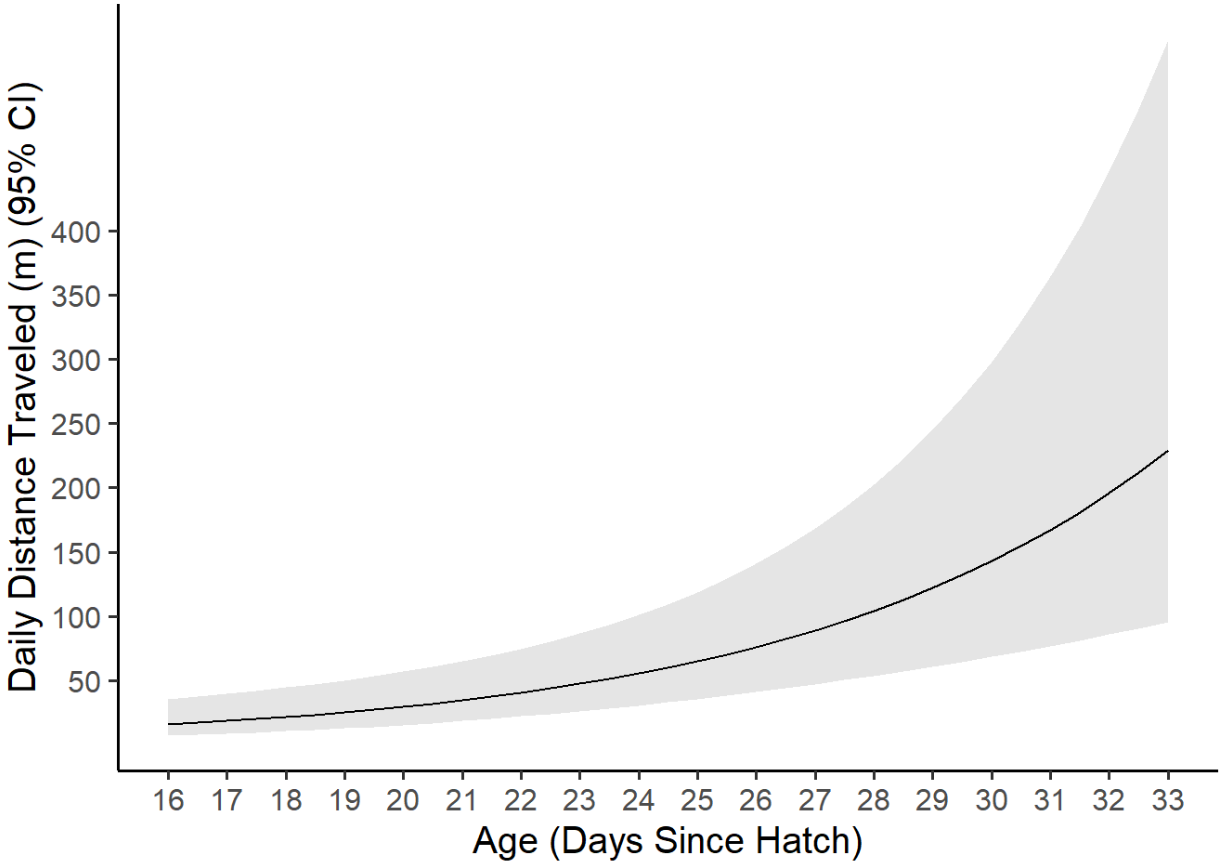


Figure 3.1. Predicted daily movement distance of Least Bittern fledglings (n=6) in 2020 at Emiquon Preserve, Illinois, USA.

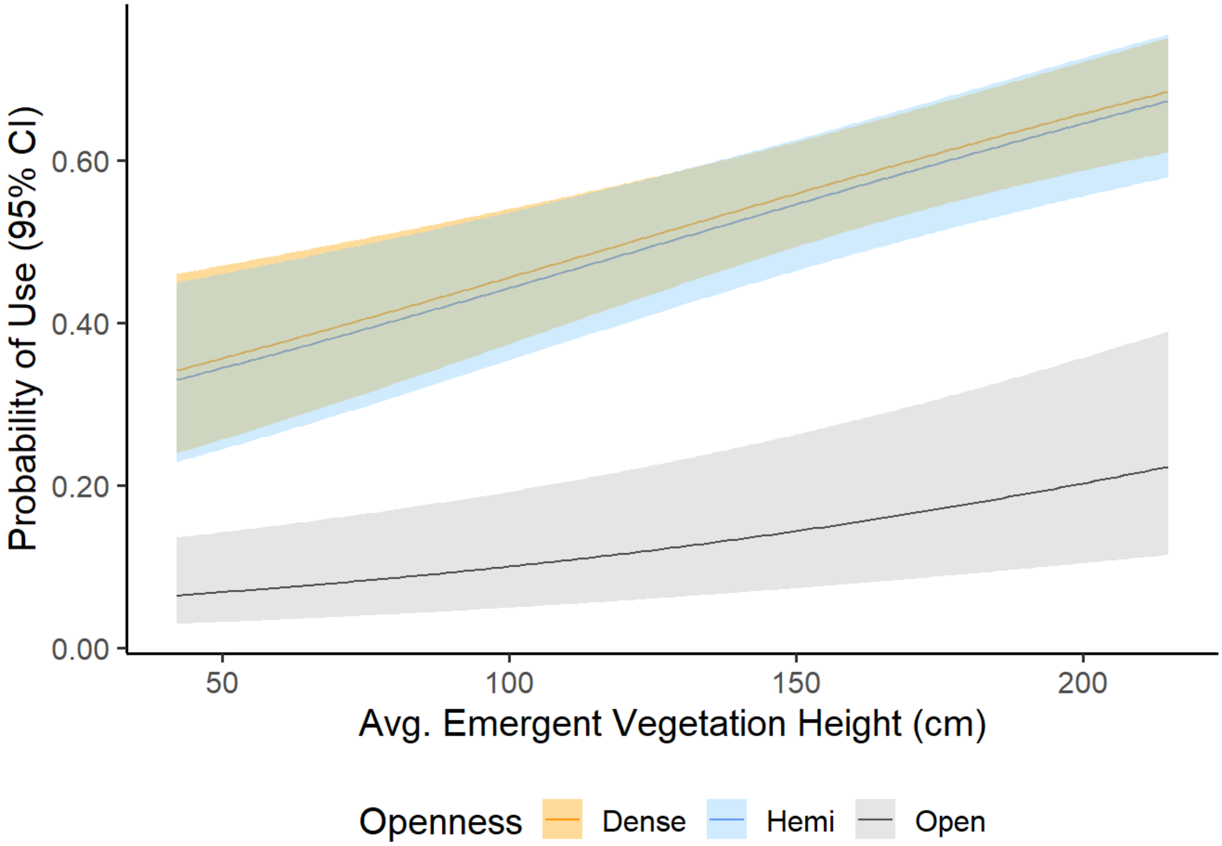


Figure 3.2. Probability of use for post-fledging Least Bitterns in 2021 at Emiquon Preserve, Illinois, USA, as a function of emergent vegetation height (cm) and habitat openness (open marsh, hemi marsh, dense marsh).

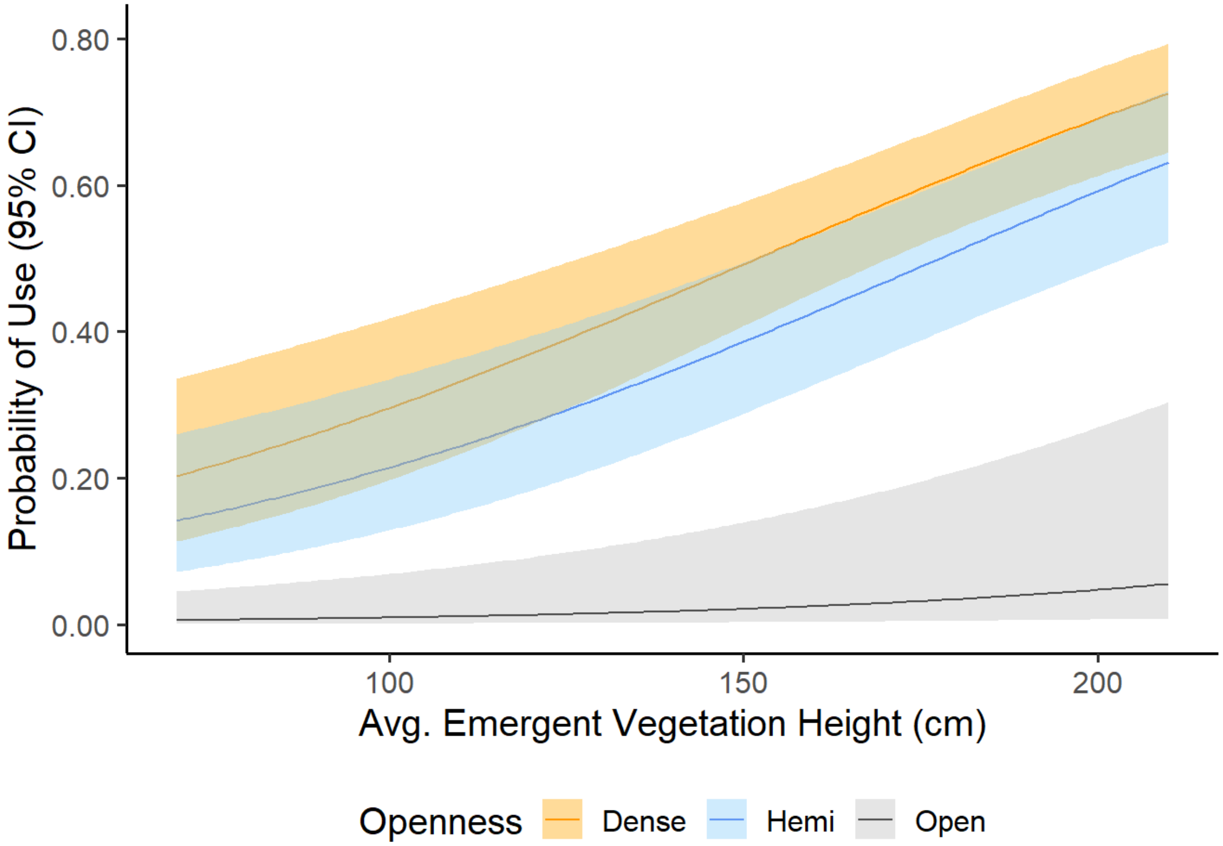


Figure 3.3. Probability of use for pre-flight (15-30 days post hatch) Least Bittern fledglings in 2021 at Emiquon Preserve, Illinois, USA, as a function of emergent vegetation height (cm) and habitat openness (open marsh, hemi marsh, dense marsh).

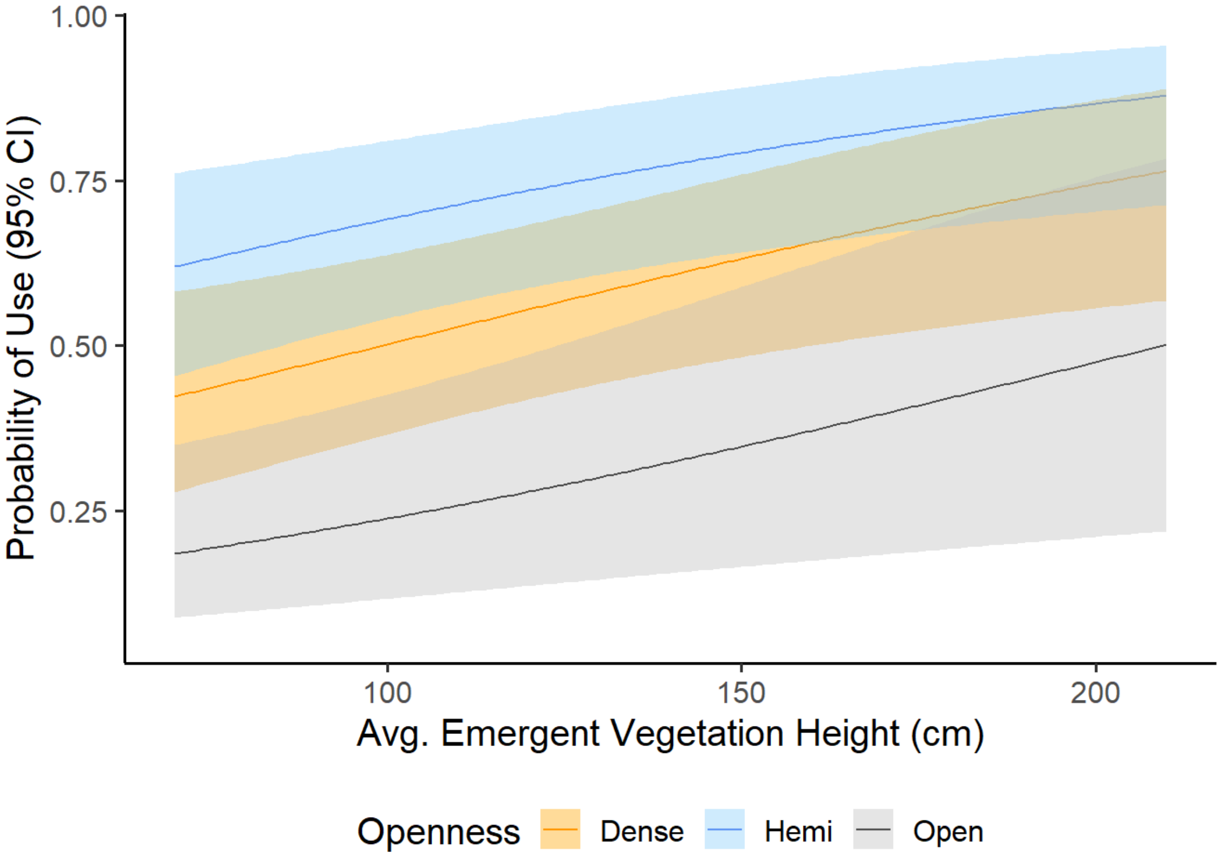


Figure 3.4. Probability of use for post-flight (31+ days post hatch) Least Bittern fledglings in 2021 at Emiquon Preserve, Illinois, USA, as a function of emergent vegetation height (cm) and habitat openness (open marsh, hemi marsh, dense marsh).

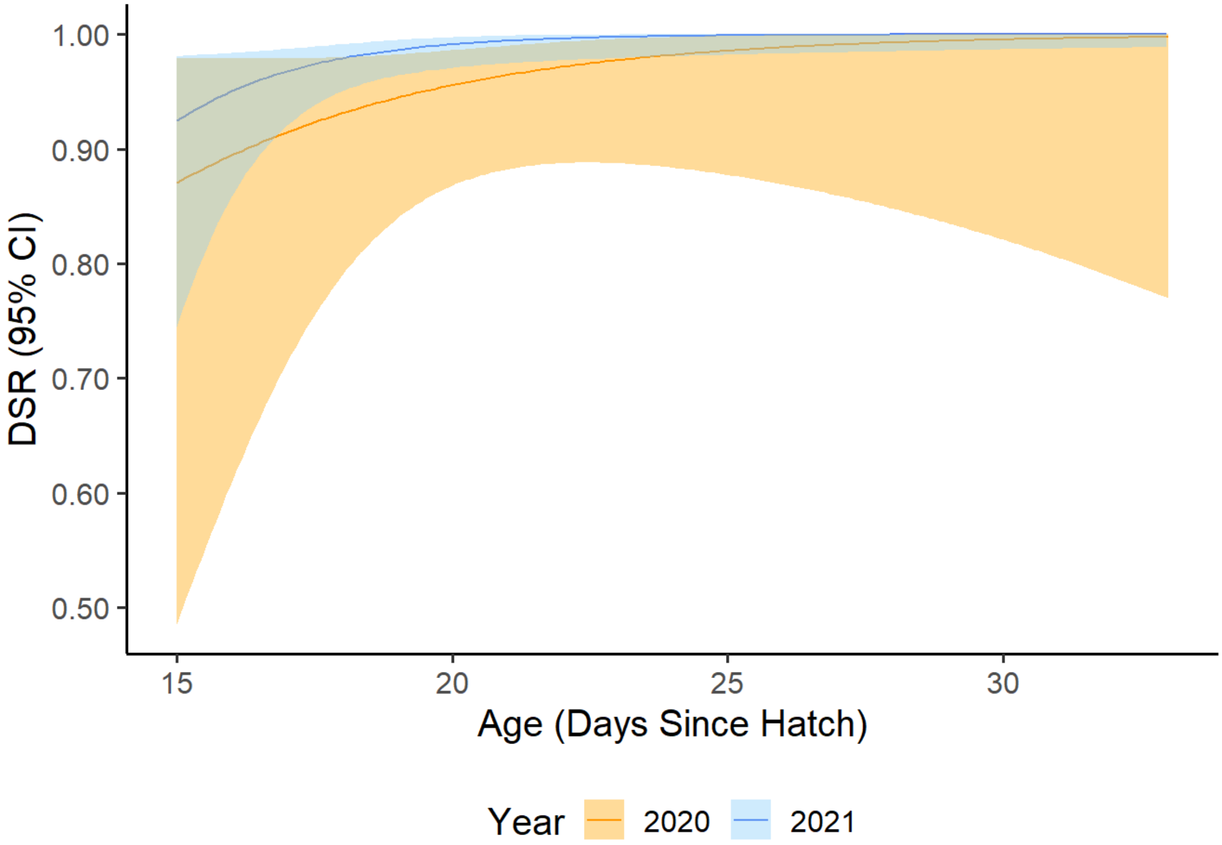


Figure 3.5. Daily survival rate (DSR) of post-fledging Least Bitterns in 2020 and 2021 at Emiquon Preserve, Illinois, USA as a function of age (days since hatch) and year.

LITERATURE CITED

Anders, A. D., D. C. Dearborn, J. Faaborg, and F. R. Thompson III (1997). Juvenile survival in a population of neotropical migrant birds. Conservation Biology 11:698-707.

Anders, A. D., J. Faaborg, and F. R. Thompson III (1998). Postfledging dispersal, habitat use, and home-range size of juvenile Wood Thrushes. Auk 115:349-358.

Bates, E. M., and B. M. Ballard (2014). Factors influencing behavior and success of foraging Reddish Egrets (*Egretta rufescens*). Waterbirds 37:191-202.

Bogner, H. E., and G. A. Baldassarre (2002). Home range, movement, and nesting of Least Bitterns in western New York. Wilson Bulletin 114:297-308.

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.

Borkhataria, R. R., P. C. Frederick, R. A. Keller, and J. A. Collazo (2012). Temporal variation in local wetland hydrology influences postdispersal survival of juvenile Wood Storks (*Mycteria americana*). Auk 129:517-528.

Bradshaw, T. M., A. G. Blake-Bradshaw, A. M. V. Fournier, J. D. Lancaster, J. O’Connell, M. W. Jacques, M. W. Eichholz, and H. M. Hagy (2020). Marsh bird occupancy of wetlands managed for waterfowl in the midwestern USA. PLoS ONE 15: 1-19.

Burke, A. D., F. R. Thompson III, and J. Faaborg (2017). Variation in early-successional habitat use among independent juvenile forest breeding birds. Wilson Journal of Ornithology 129:235-246.

Burnham, K. P., and D. R. Anderson. (2002). Model Selection and Multimodel Inference: A Practical Information-theoretic Approach. Springer-Verlag, NY, USA.

Chen, H., S. Popovich, A. McEuen, A., and B. Briddel (2017). Carbon and nitrogen storage of a restored wetland at Illinois' Emiquon Preserve: Potential for carbon sequestration. Hydrobiologia 804:139-150.

Cox, A. S., and D. C. Kesler (2012). Reevaluating the cost of natal dispersal: Post-fledging survival of Red-bellied Woodpeckers. Condor 114:341-347.

Cox, W. A., A. C. Schwarzer, and B. Tornwall (2019). Postfledging survival of the Worthington's Marsh Wren (*Cistothorus palustris griseus*). Avian Conservation and Ecology 14:19.

Cox, W. A., F. R. Thompson III, A. S. Cox, and J. Faaborg (2014). Post-fledging survival in passerine birds and the value of post-fledging studies to conservation. Journal of Wildlife Management 78:183-193.

Dahl, T. E. (1990). Wetland losses in the United States 1780's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington. D.C.

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.

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

Fisher, R. J., and S. K. Davis (2011). Post-fledging dispersal, habitat use, and survival of Sprague's Pipits: Are planted grasslands a good substitute for native? Biological Conservation 144:263-271.

Fournier, A. M. V., D. C. Mengel, E. Gbur, A. Raedeke, and D. G. Krementz (2019). Evaluating tradeoffs in the response of Sora (*Porzana carolina*) and waterfowl to the timing of early autumn wetland inundation. Waterbirds 42:168-178.

Fournier, A. M. V., J. D. Lancaster, A. P. Yetter, C. S. Hine, T. Beckerman, J. Figge, A. Gioe, M. Greider-Wagner, D. Jen, C. Johnson, M. R. Larreur, et al. (2021). Nest success and nest site selection of wetland birds in a restored wetland system. Avian Conservation and Ecology 16. https://doi.org/10.5751/ACE-01782-160106

Gawlik, D. E. (2002). The effects of prey availability on the numerical response of wading birds. Ecological Monographs 72:329-346.

Geary, B., M. C. Green, and B. M. Ballard (2015). Movements and survival of juvenile Reddish Egrets *Egretta rufescens* on the Gulf of Mexico coast. Endangered Species Research 28:123-133.

Gray, M. J., M. J. Chamberlain, D. A. Buehler, and W. B. Sutton (2013). Wetland wildlife monitoring and assessment. In Wetland Techniques: Volume 2: Organisms (J. T. Anderson and C. A. Davis, Editors). Springer, Netherlands.

Guhin, V., and G. Hayes (2015). Habitat Restoration and Water Quality Management: Key Projects and Practices for Streams, Riparian Areas and Wetlands in California. Elkhorn Slough National Estuarine Research Reserve, Elkhorn Slough Coastal Training Program Elkhorn, CA, USA.

Havera, S. P., K. E. Roat, and L. L. Anderson (2003). The Thompson Lake/Emiquon Story: The biology, drainage, and restoration of an Illinois River bottomland lake. Illinois Natural History Survey Special Publication 25:1-40.

Hoover, J. P. (2005). Water depth influences nest predation for a wetland-dependent bird in fragmented bottomland forests. Biological Conservation 127:37-45.

Hylton, R. A. (2004). Survival, movement patterns, and habitat use of juvenile Wood Storks, *Mycteria americana*. M.S. Thesis, University of Florida, Gainesville, FL, USA.

Jedlikowski, J., M. Brzeziński, and P. Chibowski (2015). Habitat variables affecting nest predation rates at small ponds: A case study of the Little Crake *Porzana parva* and Water Rail *Rallus aquaticus*. Bird Study 62:190-201.

Jones, T. M., J. D. Brawn, I. J. Ausprey, A. C. Vitz, A. D. Rodewald, D. W. Raybuck, T. J. Boves, C. J. Fiss, D. J. McNeil, S. H. Stoleson, J. L. Larkin, et al. (2020). Parental benefits and offspring costs reflect parent-offspring conflict over the age of fledging among songbirds. PNAS 117:30539-30546.

Jones, T. M., J. D. Brawn, and M. P. Ward (2017). Post-fledging habitat use in the Dickcissel. Condor 119:497-504.

Jones, T. M., M. P. Ward, T. J. Benson, and J. D. Brawn (2016). Variation in nestling body condition and wing development predict cause-specific mortality in fledgling Dickcissels. Journal of Avian Biology 48:439-447.

Jones, Z. F., and C. E. Bock (2005). The Botteri's Sparrow and exotic Arizona grasslands: An ecological trap or habitat regained? Condor 107:731-741.

Kersten, M., and A. Brenninkmeijer (1995). Growth, fledgling success and post-fledging survival of juvenile Oystercatchers *Haematopus ostralegus*. Ibis 137:396-404.

Kleen, V. M., L. Cordle, and R. A. Montgomery (2004). Illinois Breeding Bird Atlas. Illinois Natural History Survey Special Publication no. 26.

Lane, J. J., and K. C. Jensen (1999). Moist soil impoundments for wetland wildlife. U.S. Army Corps of Engineers Technical Report EL-99-11.

Lavergne, S., and J. Molofsky (2006). Control strategies for the invasive Reed Canary Grass (*Phalaris arundinacea L.*) in North American wetlands: The need for an integrated management plan. Natural Areas Journal 26:208-214.

Lawler, J. J., and R. J. O'Connor (2004). How well do consistently monitored breeding bird survey routes represent the environments of the conterminous United States? Condor 106:801-814.

Lemke, A. M., J. R. Herkert, J. W. Walk, and K. D. Blodgett (2017). Application of key ecological attributes to assess early restoration of river floodplain habitats: A case study. Hydrobiologia 804:19-33.

Longcore, J. R., D. G. McAuley, and C. Frazer (1991). Survival of postfledging female American Black Ducks. Journal of Wildlife Management 55:573-580.

Lor, S., and R. A. Malecki (2006). Breeding ecology and nesting habitat associations of five marsh bird species in western New York. Waterbirds 29:427–436.

Moore, S., J. R. Nawrot, and J. P. Severson (2009). Wetland-scale habitat determinants influencing Least Bittern use of created wetlands. Waterbirds 32:16-24.

Morton, J. M., R. L. Kirkpatrick, M. R. Vaughan, and D. F. Stauffer (1989). Habitat use and movements of American Black Ducks in winter. Journal of Wildlife Management 53:390-400.

Naef-Daenzer, B., and M. U. Grüebler (2016). Post-fledging survival of altricial birds: Ecological determinants and adaptation. Journal of Field Ornithology 87:227-250.

Naef-Daenzer, B., F. Widmer, and M. Number (2001). Differential post-fledging survival of Great and Coal Tits in relation to their condition and fledging date. Journal of Animal Ecology 70:730-738.

Newton, I. (1998). Population Limitation in Birds. Academic Press, San Diego, CA, USA.

Norris, D. R., and P. P. Marra (2007). Seasonal interactions, habitat quality, and population dynamics in migratory birds. Condor 109:535-547.

Parker, N., E. Cam, D. B. Lank, and F. Cooke (2003). Post-fledging survival of Marbled Murrelets *Brachyramphus marmoratus* estimated with radio-marked juveniles in Desolation Sound, British Columbia. Marine Ornithology 31:207-212.

Picman, J., M. L. Milks, and M. Leptich (1993). Patterns of predation on passerine nests in marshes: Effects of water depth and distance from edge. Auk 110:89-94.

R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/.

Raim, A. (1978). A radio transmitter attachment for small passerine birds. Bird-Banding 49:326-332.

Raybuck, D. W., J. L. Larkin, S. H. Stoleson, and T. J. Boves (2020). Radio-tracking reveals insight into survival and dynamic habitat selection of fledgling Cerulean Warblers. Condor: Ornithological Applications 122:1-15.

Regehr, H. M. (2003). Survival and movement of postfledging juvenile Harlequin Ducks. Wilson Bulletin 115:423-430.

Rehm, E. M., and G. A. Baldassarre (2007). The influence of interspersion on marsh bird abundance in New York. Wilson Journal of Ornithology 119:648-654.

Ricklefs, R. E. (1969). An analysis of nesting mortality in birds. Smithsonian Contributions to Zoology 9:1-48.

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

Shaffer, T. L. (2004). A unified approach to analyzing nest success. Auk 121:526-540.

Small, D. M., P. J. Blank, and B. Lohr (2015). Habitat use and movement patterns by dependent and independent juvenile Grasshopper Sparrows during the post-fledging period. Journal of Field Ornithology 86:17-26.

Sullivan, K. A. (1989). Predation and starvation: Age-specific mortality in juvenile juncos (*Junco phaenotus*). Journal of Animal Ecology 58:275-286.

Todd, L. D., R. G. Poulin, T. I. Wellicome, and R. M. Brigham (2003). Post-fledging survival of Burrowing Owls in Saskatchewan. Journal of Wildlife Management 67:512-519.

Tozer, D. C., O. Steele, and M. Gloutney (2018). Multispecies benefits of wetland conservation for marsh birds, frogs, and species at risk. Journal of Environmental Management 212:160-168.

United States Environmental Protection Agency (U.S. EPA) (2008). Methods for Evaluating Wetland Condition: Wetland Hydrology. Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA-822-R-08-024.

Ward, M. P., B. Semel, and J. R. Herkert (2010). Identifying the ecological causes of long-term declines of wetland-dependent birds in an urbanizing landscape. Biodiversity and Conservation 19:3287-3300.

White, J. D., and J. Faaborg (2008). Post-fledging movement and spatial habitat-use patterns of juvenile Swainson’s Thrushes. Wilson Journal of Ornithology 120:62-73.

Wiens, J. D., B. R. Noon, and R. T. Reynolds (2006). Post-fledging survival of Northern Goshawks: The importance of prey abundance, weather, and dispersal. Ecological Applications 16:406-418.

Wilson, E. D. (2016). Phenological assessment of marsh bird distribution within and among moist-soil managed wetlands in Kansas. M.S. Thesis, Emporia State University, Emporia, KS, USA.

Yackel Adams, A. A., S. K. Skagen, and J. A. Savidge (2006). Modelling post-fledging survival of Lark Buntings in response to ecological and biological factors. Ecology 87:178-188.

CHAPTER 4: SUMMARY

The primary objective of this research was to evaluate the impact of spring and summer dewatering for wetland management on survival and predation risk of marsh bird nests and habitat selection and survival of post-fledging Least Bitterns (*Ixobrychus exilis*). In chapter 2, I monitored the survival of 158 marsh bird nests as a result of changing habitat conditions during dewatering. For a subset of these nests (n=80), I also monitored predation risk as a factor of predator identity. In this first study, I focused my efforts on Least Bittern, Common Gallinule (*Gallinula galeata*), Black-crowned Night-Heron (*Nycticorax nycticorax*), and American Coot (*Fulica americana*) nests at Emiquon Preserve in Fulton County, Illinois in 2020 and 2021. I found nest survival of Least Bitterns and Common Gallinules was related to water depth and timing and volume of dewatering, and survival increased with deeper water below the nest and when dewatering was initiated in July, as opposed to June, and pulled off less water. Additionally, water depth and the volume and timing of dewatering shared the same relationship with predation risk by mammals, and greater risk was observed at nests over shallower water and in the year of the large volume dewatering initiated in June.

In chapter 3, I used radiotelemetry to investigate how Least Bittern fledglings selected habitat on a dewatered marsh and how these decisions affected mortality risk. I radio-tagged and tracked 50 fledglings hatched from nests monitored in chapter 2. The post-fledging period is the time after young birds leave the nest until they reach independence, and while it is understudied and underused to inform management decisions for birds, it is a crucial life stage as this period often faces the highest mortality. I found fledgling habitat use was contingent on age and flight ability. Young fledglings selected taller and denser emergent marsh habitat which offered greater predator protection, while juveniles with flight ability, and presumably the ability to evade predators, selected for more open emergent marsh habitat, likely better for foraging. Additionally, I observed a survival bottleneck a few days post-fledging, but overall survival was high and few mortalities were observed. This observation supports the idea that mobile, camouflaged, and secretive fledglings coming from nests suspended over water are better equipped to avoid predators than sedentary nests and do not need to disperse far to access food resources, and fledglings need water and dense habitat during this low dispersal period to meet their survival needs.

In conclusion, I found (1) deeper water during the critical nesting period was vitally important for marsh bird nest survival and deterring mammal predators and (2) post-fledging Least Bitterns used different habitats as they age, shifting from denser habitats to more open and hemi-marsh habitats. For this reason, I suggest wetland dewatering should be delayed until after the peak period of marsh bird nesting (May-June) at sites where management for conservation-priority marsh birds is a focus. Additionally, I suggest that the post-fledging period of Least Bitterns be accounted for in management decisions, and management actions that create densely vegetated inundated habitats during the post-fledging period may provide habitat and support increased survival for Least Bitterns.

APPENDIX A: CHAPTER 2 NESTING BIRD HABITAT

Table A1. Marsh bird species-specific nest site characteristics at Emiquon Preserve, Illinois, USA, in 2020 and 2021.

	American Coot (n = 1)		Black-crowned Night-Heron (n = 10)		Common Gallinule (n = 64)		Least Bittern (n = 83)	
Variable	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Water depth (cm)	71.00	-	26.40	0-51	44.22	0-76	37.09	0-72
Avg. Emergent Vegetation Height (cm)	217.00	-	190.50	142-210	186.47	98-228	183.17	102.5-245
% Open	30.00	-	3.00	0-30	24.61	0-70	21.02	0-75
% Horizontal Vegetation	70.00	-	97.00	70-100	75.23	30-100	78.98	25-100
% Dense Emergent	50.00	-	96.00	70-100	70.78	30-100	69.04	10-100
% Non-persistent Emergent	0.00	-	0.00	-	0.31	0-10	2.29	0-95
% Woody	0.00	-	0.00	-	0.00	-	0.00	-
% Inundated	100.00	-	84.00	20-100	97.34	0-100	97.53	30-100

APPENDIX B: CHAPTER 3 LEAST BITTERN JUVENILE WEIGHT GAIN

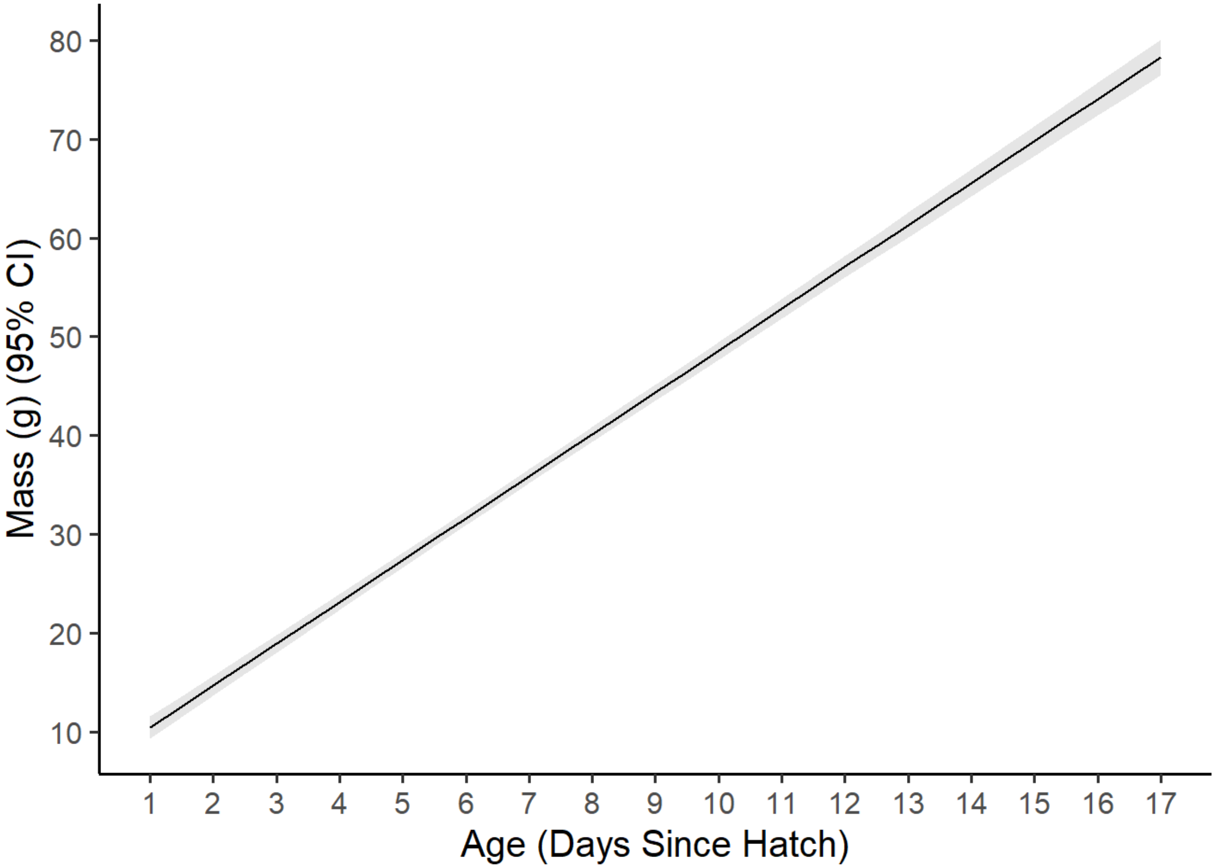


Figure B1. Predicted daily mass (g) of Least Bittern fledglings (n=50 nests) in 2020 and 2021 at Emiquon Preserve, Illinois, USA.