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Wetland Management Strategies that Maximize Marsh Bird Use in the Midwest

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Executive Summary

In North America, many waterbird species have experienced population declines primarily due to wetland loss and degradation. For example, wetland drainage and conversion to alternate land uses has led to wetland losses exceeding 90% in the Midwest. Further, suitable resources for migrating and breeding marsh birds such as emergent vegetation are present on less than 15% of remaining wetlands in Illinois. With great loss and degradation, there is increased pressure on extant wetlands to support marsh bird and other wetland-dependent avian populations. Wetland conservation, enhancement, and management has become a principle means of restoring waterfowl populations under the North American Waterfowl Management Plan throughout their annual range. Management activities aimed at improving forage and emergent cover for non-breeding waterfowl are assumed to benefit a variety of wetland dependent birds including marsh birds, a secretive guild containing many threatened species and species of conservation concern. However, the timing and intensity of management practices, such as those conducted under traditional moist-soil management, may affect conditions for migrating and breeding marsh birds. Thus, understanding management actions that increase marsh bird occupancy and abundance could increase the quantity and quality of waterbird habitat in the Midwest, USA.

The North American Standardized Marsh Bird Survey Protocol (NASMBSP) has become a unified framework for coordinated marsh bird monitoring and has received widespread application because it accounts for detectability in occupancy estimation. However, long-term data collections, such as the Illinois Natural History Survey's critical trends assessment program (CTAP), provide an opportunity to evaluate trends in marsh bird occupancy using an alternative monitoring protocol at random wetlands across Illinois. Relative to the NASMBSP, the CTAP

methods are less rigorous, but, provided the methods produce small but quantifiable differences, CTAP may provide important information on long-term patterns.

We sought to investigate marsh bird occupancy and abundance across a wide range of representative wetlands types, hydrologic regimes, management practices, and former disturbance regimes in Illinois. We hypothesized that characteristics of wetlands that were actively and passively managed for waterfowl would be positively correlated with marsh bird occupancy and abundance in Illinois during the migration and breeding seasons. Our specific objectives were to: 1) compare marsh bird use of wetland impoundments managed for waterfowl across a continuum of management intensities and strategies to predict how impoundment management actions can increase use by both groups; 2) compare marsh bird use of restored and natural wetlands; and 3) determine characteristics of wetlands and the surrounding landscape that influence marsh bird use of restored wetlands. Our results are important to understanding spatiotemporal, hydrological, and vegetative conditions suitable for multi-species management of wetlands. Moreover, our research provided information regarding the effectiveness of conservation actions, particularly wetland restoration in meeting conservation priorities for migrating birds.

Methods

We assessed marsh bird occupancy and abundance at select and random wetlands across Illinois to better understand how natural wetland characteristics, management for waterfowl, and surrounding landscapes influence marsh bird occupancy and abundance. Specifically, we employed the NASMBSP during late spring and early summer 2015–2017 at focal sites (i.e., randomly selected sites known to be actively or passively managed for waterfowl), reference sites (i.e., emergent, pond, or lake polygons randomly selected from the National Wetland

Inventory [NWI]), and CTAP sites (i.e., randomly selected wetlands concurrently surveyed by the CTAP). Detailed information regarding target species, site selection, survey design, and statistical analyses are available in Bradshaw (2018), which is included in this document, following the executive summary.

Results

During 2015–2017, we conducted 1,033 call-back surveys at 380 points including 150 points within reference NWI sites, 183 points within focal sites, and 47 points within CTAP sites. We recorded 3,680 marsh bird detections including 9 of 10 target species with American coot (*Fulica americana*; 61.3%) and sora (*Porzana carolina*; 26.7%) most often detected. The odds of detecting marsh birds declined approximately 6% (95% CI = 4 – 7) each day from the beginning of the survey period within each region, but detection of individual species varied considerably among the 3 survey periods. Wetland complexity and cover type were the most important predictors of marsh bird occupancy with the odds of occupancy at focal sites (i.e., sites managed for waterfowl) being 1.8 (95% CI = 0.7 – 4.6) times greater and CTAP sites 0.7 (95% CI = 0.3 – 0.9) times lower than NWI reference sites, respectively. The odds of wetland occupancy by marsh birds was 28.7 (95% CI = 3.1 – 271.0) times greater at sites with the greatest level of complexity compared to monotypic sites with the lowest level of complexity.

We further analyzed occupancy rates after classifying marsh bird species by vegetation association (i.e., emergent or open-water) allowing us to examine occupancy rates in relation to factors that may be impacted by waterfowl management. We found that emergent-class marsh birds (e.g., bitterns and rails) had greater occupancy rates early in the survey season, and in wetlands with increased habitat complexity, inundated surface area, and dense persistent emergent vegetation. Specifically, the odds of occupancy decreased 49% (95% CI = −14 – 77) from survey round 1 to 2 and 73% (95% CI = 33 – 89) from survey round 1 to 3. Moreover, the odds of occupancy increased 2% (95% CI = 0 – 3) for every 1% increase in surface water area and 3% (95% CI = 0 – 5) for every 1% increase in the cover of persistent emergent vegetation. Open-water marsh birds (e.g., coots and grebes) were positively related to habitat complexity, and this guild varied among site types and waterfowl management intensities. Occupancy was greatest at intermediate levels of waterfowl management intensity (e.g., semi-permanent marsh, passively managed moist soil). For instance, the odds of open-water marsh birds occupying a wetland were 3 (95% CI = 1 – 12) times greater in wetlands with a level 4 management intensity than sites at level 1 management intensity. Furthermore, the greatest (level 7) management intensity resulted in a 44% (95% CI = 0 – 92) decrease in the odds of occupancy compared to sites at level 1 management intensity.

The best supported model predicting abundance of emergent-class marsh birds included surface water inundation, coverage of dense emergent vegetation, waterfowl management intensity, and wetland complexity. Abundance of emergent-class marsh birds increased 1.6% (95% CI = 1.3 – 2.0) for every 1% increase in inundation and 0.8% (95% CI = 0.6 – 1.1) for every 1% increase in persistent emergent vegetation coverage. Sites with waterfowl management intensity at intermediate levels (i.e., level 3-4 on a 7-point scale) had 1.7 (95% CI = 1.1– 2.4) more emergent-class birds than sites unmanaged (level 1) for waterfowl.

For open-water marsh birds, the best supported model explaining abundance included surface water inundation, persistent emergent vegetation coverage, and open-water coverage. Specifically, the abundance of open-water marsh birds increased 0.23 (95% CI = 0.19 – 0.26) with every 1% increase in inundation, 0.07 (95% CI = 0.05 – 0.09) for each 1% increase in persistent emergent vegetation, and 0.18 (0.16 – 0.21) for each 1% increase in the proportion of open water.

We surveyed 34 wetland sites using the NASMBSP that were also surveyed independently by the CTAP. Across the 3 site-visits under the NASMBSP, we recorded 19 marsh bird detections, while only 10 were detected during CTAP surveys. In 19 of 34 (56%) paired surveys, no marsh birds were detected by either survey protocol. However, in 11 paired surveys, more marsh birds were detected during the NASMBSP surveys, and in 4 paired surveys more marsh birds were detected during the CTAP surveys. Thus, marsh bird occupancy rates varied between survey methods. Results were similar regarding species richness where 11 sites had greater species richness during NASMBSP surveys and 4 had greater richness during CTAP protocol. However, because of high variability and an overall low number of detections at CTAP sites relative to focal and NWI reference sites, there was insufficient evidence that marsh bird detections ($t_{33} = 1.25$, $P = 0.22$) or species richness ($t_{33} = 1.60$, $P = 0.12$) differed among sampling protocols. Generally, CTAP sites were relatively unsuitable for marsh birds and probably should not be used to index trends in marsh bird abundance in Illinois.

Discussion

We found evidence that broad wetland site classification (i.e., focal, random, CTAP) and varying wetland management practices for waterfowl impacted marsh bird occupancy and abundance rates in Illinois. Intermediate levels of waterfowl management positively influenced marsh bird occupancy, yet, not all marsh bird guilds responded to all aspects of management similarly. Across all marsh bird species, wetland sites selected for their active or passive waterfowl management (i.e., focal) had greater occupancy rates than NWI reference sites across Illinois. While intensively managed moist-soil wetlands typically provide more food resources for waterfowl than those passively managed, maximizing co-occurrence of waterfowl and marsh birds appeared best accomplished through less intensive management strategies with less frequent (i.e., 3-yr rotation) drawdowns and maintenance of dense emergent vegetation communities (e.g., cattails) that are inundated by surface water during the growing season. As an example, the Emiquon Preserve (The Nature Conservancy) and the Dixon Waterfowl Refuge at Hennepin and Hopper Lakes (The Wetlands Initiative) along the Illinois River hosted hundreds of thousands of waterfowl and other waterbird use days during migration annually. These sites are managed as semi-permanent emergent marshes and provide a high level of vegetation complexity including substantial areas of dense persistent emergent vegetation that were used extensively by marsh birds.

One wetland characteristic manageable through hydrologic stability is wetland complexity, which was a strong and positive indicator of occupancy for all marsh birds and for emergent marsh bird abundance. Wetland complexity can stem from elevation differences and stable hydrology that together form areas transitioning from permanent deep water to seasonal inundation and encourage growth of disparate communities of facultative and obligate wetland plants. Wetland complexity increases the abundance and diversity of invertebrates, which suggests marsh birds may also be selecting areas with increased food resources. Moreover, marsh birds are a diverse group of species that use varying habitat structure through seasonal or even diel periods to complete socio-physiological needs. Thus, a complex of vegetative communities within a wetland may provide suitable resources for marsh bird breeding including suitable nest site locations near feeding and brood rearing locations.

Hydrology is believed to be the single most important factor in determining wetland suitability for marsh birds. We found that the proportion of a survey location that was inundated during late spring and early summer was a major contributor to occupancy and abundance of marsh birds. Some marsh birds will feed or even nest in upland locations; however, inundation increases accessibility of aquatic forage and decreases mammalian nest predation for breeding individuals. Thus, managers should limit hydrological variation during migratory and breeding periods (i.e., April – July) to encourage marsh bird use of emergent wetlands. Management practices that de-water emergent habitat during or immediately prior to these periods are of primary concern, but in some cases, rising water levels during the breeding season may cause marsh birds to abandon nests from flooding.

Numerous variables chosen to evaluate research objectives were noticeably absent from best supported models of marsh bird occupancy and abundance. Best supported and competing models solely contained factors classified as intrinsic wetland conditions (i.e., complexity, inundation, etc.) and extrinsic landscape scale variables were uncompetitive. Notably, the Ohio Rapid Assessment Method (ORAM), which scored wetland integrity on a few intrinsic conditions but also several anthropogenic stressors including surrounding land use and habitat alteration and development, was not a competitive predictor of marsh bird occupancy or abundance. Other researchers in the Midwest have found the ORAM to accurately signify wetland integrity, but like our study, evidence that landscape characteristics impact waterbird richness and abundance has been mixed. Surrounding landscape conditions themselves may be less important than wetland conditions that directly impact vegetative structure and hydroperiod which provide the foundation for foraging and nesting marsh birds.

Marsh bird occupancy and abundance was unaffected by the protected status of wetlands (i.e., restored or natural). The numerous restoration programs on the landscape in Illinois have many goals and restoration techniques and ultimately the landowner/manager is responsible for managing hydrology. Previous research has found that within restored wetlands those managed as semi-permanent marsh had greatest use by waterbirds in Illinois. Like other studies, resulting hydrological and vegetative conditions appeared to be more important considerations of wetland suitability for marsh birds and these conditions may not be accurately represented by their status as restored or natural. It is noteworthy that two prominent sites along the Illinois River Valley (i.e., Emiquon Preserve and Dixon Waterfowl Refuge) were restored wetlands managed as semi-permanent marsh and exemplified quality marsh bird habitat.

The CTAP protocol included a single wetland visit which resulted in lower but non-significant raw occupancy and species richness rates at surveyed wetlands. Repeated wetland visits under the NASMBSP were intended to allow unbiased estimation of detection rates among a closed population of breeding marsh birds. However, mounting evidence suggests that the NASMBSP survey design is insufficient for meeting key occupancy modeling assumptions because surveys capture migrating marsh birds in mid-latitude states, which violate the closed population assumption. Approximately 61% of Virginia rails (*Rallus limicola*) and sora (*Porzana carolina*) captured and marked in impoundments of western Lake Erie in Ohio apparently migrated within the NASMBSP survey window. We measured a decline (~6% per day) in marsh bird detections over the survey season and presume that many individuals emigrated from our study area during our surveys in Illinois. Future surveys following the NASMBSP should increase sampling effort within bi-weekly periods to calculate detection probability while closure assumptions can be assured.

Marsh bird occupancy rates determined using the NASMBSP were lower at CTAP wetlands than reference NWI wetlands in our study. Both CTAP and reference wetlands were representative of random wetlands in Illinois although they were selected by different methodologies. Surveyed CTAP wetlands were smaller in size than reference wetlands which may have negatively impacted occupancy rates as previous studies have shown greater marsh bird abundance with increasing wetland area. Although the standardize methods of CTAP allow an opportunity to investigate long-term trends in marsh bird occupancy, we caution the general use of occupancy rates obtained through CTAP as they likely underestimate occupancy.

Wetland management is often necessary to provide habitat for migratory waterbirds given the degraded quality of many Illinois wetlands. Without hydrological fluctuations, whether natural or anthropogenic, semi-permanent wetlands would naturally achieve a stable open water ecosystem. Because plant and animal abundance and species richness are greatest at earlier to intermediate stages of the natural wetland cycle, hydrological and mechanical manipulation to maintain early to mid-successional vegetation is beneficial in creating habitat for marsh birds in Illinois. However, it is imperative wetland management is timed such that inundated emergent vegetation remains through the marsh bird migration and breeding seasons. Desired habitat complexity can be achieved by rotating hydrological regimes to promote a diversity of vegetation structure including dense persistent, non-persistent, and aquatic macrophytes.

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MARSH BIRD USE OF WETLANDS MANAGED FOR WATERFOWL IN ILLINOIS

A THESIS

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THE SCHOOL OF GRADUATE STUDIES OF

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IN PARTIAL FULLFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE

MASTER OF SCIENCE

BY

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ABSTRACT

It is widely assumed that wetland management practices for waterfowl benefit a variety of wetland-dependent birds, but few studies have documented factors influencing wetland use by these species. In particular, marsh birds are an understudied guild of migratory birds of conservation concern dependent on emergent wetlands that may benefit from wetland management for waterfowl. I assessed marsh bird occupancy and abundance in wetlands across Illinois to better understand how local wetland characteristics, surrounding landscape context, and management practices for waterfowl influenced marsh bird occupancy and abundance. During late spring and early summer 2015–2017, I conducted 1,033 call-back surveys at 53 focal sites (i.e., passive or active management for waterfowl) and 107 reference sites selected from National Wetland Inventory (NWI; *n* = 73) and Illinois Natural History Survey's Critical Trends Assessment Program (CTAP; *n* = 34) databases, which included 183 focal, 150 NWI, and 47 CTAP individual survey points. I recorded 3,680 total detections, of which American coot (*Fulica americana*) comprised the greatest proportion (61.3%), followed by sora (*Porzana carolina*, 26.7%), pied-billed grebe (*Podilymbus podiceps,* 5.5%), common gallinule (*Gallinula galeata,* 2.5%), Virginia rail (*Rallus limicola,* 1.5%), least bittern (*Ixobrychus exilis,* 1.4%), American bittern (*Botaurus lentiginosus,* 0.9%), king rail (*Rallus elegans,* 0.2%), and yellow rail (*Coturnicops noveboracensis,* 0.1%). Detection probability for both occupancy and abundance was negatively related to ordinal date. Wetland complexity, surface water inundation, and dense, persistent emergent vegetation were positively related to marsh bird occupancy and abundance, but landscape context, intensive management practices for waterfowl, and other factors were generally poor or

inconsistent predictors of marsh bird guilds. Suitable habitat for marsh birds appears to be very limited across most of Illinois, and wetland management practices (e.g., semi-permanent emergent marsh) that retain surface water during the growing season, encourage perennial emergent plants (e.g., *Typha* sp.), and increase wetland complexity could be used to provide habitat suitable for waterfowl and marsh birds.

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CHAPTER 1. COVER AND MANAGEMENT INFLUENCE WETLAND OCCUPANCY BY MARSH BIRDS IN ILLINOIS

ABSTRACT

Few studies have documented factors influencing wetland use by marsh birds, especially in the Midwest were losses of emergent wetlands has been extreme. Marsh birds depend on emergent wetlands in the Midwest during migration and subsequent breeding periods, and habitat loss and degradation is the primary suspected cause for population declines among many of these species. I assessed marsh bird occupancy of wetlands across Illinois to better understand how natural wetland characteristics, wetland management practices, and surrounding landscape characteristics influence marsh bird occupancy. During late spring and early summer 2015–2017, I conducted call-back surveys three times annually at focal sites (i.e., passive or active management for waterfowl) and reference sites selected from National Wetland Inventory (NWI) and Illinois Natural History Survey's Critical Trends Assessment Program (CTAP) databases. Across species and groups, detection probability decreased with ordinal date. Detection declined 7.1% ± 2.1 each week during the marsh bird survey period. Marsh bird occupancy was greatest during my first survey period ($\Psi = 0.71 \pm 0.11$), followed by my second ($\Psi = 0.55 \pm 0.14$) and third survey periods ($\Psi = 0.39 \pm 0.14$). Focal ($\Psi = 0.74 \pm 0.09$) sites had greater occupancy than reference ($\Psi = 0.62 \pm 0.08$) or CTAP reference sites ($\Psi = 0.32 \pm 0.11$). Furthermore, marsh bird occupancy was greater at higher levels of wetland complexity ($\Psi = 0.99 \pm 0.02$), at an intermediate level of waterfowl management intensity ($\Psi = 0.39 \pm 0.178$), at higher proportions of surface water

inundation (max $\Psi = 0.74 \pm 0.089$), and with greater proportions of persistent emergent vegetation cover (max $\Psi = 0.81 \pm 0.148$). My results suggest that wetland management practices encouraging persistent emergent vegetation and surface water inundation during the growing season positively influence marsh bird occupancy. Intense wetland management practices (e.g., active moist-soil management) for waterfowl that include early drawdowns, seasonal vegetation manipulation to maximize annual plant coverage or allow planting of food plots, and control of perennial, emergent plant species likely do not benefit marsh birds. However, wetland management practices (e.g., semi-permanent emergent marsh) that retain surface water during the growing season, encourage perennial emergent plants (e.g., *Typha* sp.), and increase wetland complexity could be used to provide habitat suitable for waterfowl and marsh birds.

INTRODUCTION

Marsh birds are a guild of wetland-dependent migratory birds associated with emergent vegetation communities (i.e., persistent and non-persistent emergent vegetation). In North America, most marsh bird species have experienced population declines (Muller and Storer 1999, Conway 2011) primarily due to wetland loss and degradation (Gibbs et al. 1992, Meanley 1992, Darrah and Krementz 2010). For example, greater than 50% of wetlands were drained and converted to alternate land uses across the United States by the 1970s, with the losses exceeding 90% in the Midwest (Tiner 1984; Harms and Dinsmore 2011, 2013). In Illinois, suitable habitat resources for migrating and breeding marsh birds comprised of emergent vegetation is present on less than 15% of remaining wetlands (Blake-Bradshaw 2018). With great loss and degradation of wetlands, there is increasing pressure on extant wetlands to support marsh bird and other avian populations (Eddleman et al. 1988, Conway et al. 1994, Rehm and Baldassarre 2007). Furthermore, increased management of existing wetlands may be needed to sustain or increase marsh bird populations if widespread wetland creation and restoration gains are not practical (Darrah and Krementz 2010, Lemke et al. 2017). In response to population declines, several species of marsh birds have been listed as species of conservation concern at the state and regional levels (Lor and Malecki 2002, Conway and Gibbs 2005). For example, least bittern (*Ixobrychus exilis*) is considered threatened, and black rail (*Laterallus jamaicensis*), king rail (*Rallus elegans*), and common gallinule (*Gallinula galeata*) are considered endangered in the state of Illinois (IESPB 2015).

Marsh birds are valuable indicators of wetland condition due to their sensitivity to particular vegetation communities and documented vulnerability to accumulation of environmental contaminants in wetland substrates which impact their aquatic invertebrate forage (Conway 2011). Due to their secretive nature and use of densely vegetated wetlands which are difficult to survey, the population status, distribution, and life history requirements of many species of marsh birds are largely undocumented (Glisson et al. 2017, Tozer et al. 2018). Additionally, few studies (Darrah and Krementz 2010, Bolenbaugh et al. 2011, Valente et al. 2011) have documented habitat associations of marsh birds in the Midwest, which may be useful to inform conservation planning and prioritize wetland restoration (Wilson et al. 2018).

Many factors affect marsh bird abundance and diversity in wetlands, including wetland size and isolation (Brown and Dinsmore 1986, 1988; Gibbs et al. 1991; Craig and Beal 1992; Grover and Baldassarre 1995; Craig 2008), wetland connectivity (Brown and Dinsmore 1986, 1988; Craig and Beal 1992), and surrounding anthropogenic land

use (Smith and Chow-Fraser 2010). Although several studies have documented local- scale effects such as water-vegetation interspersion (Lor and Malecki 2006, Rehm and Baldassarre 2007) and vegetation density and height (Sayre and Rundle 1984, Lor and Malecki 2006, Darrah and Krementz 2010) on marsh bird site use, intrinsic vegetation characteristics may be less important than wetland surroundings (DeLuca et al. 2004) and size (Brown and Dinsmore 1986). Understanding species-habitat relationships for species of conservation concern is critical because their recovery and persistence often depend on habitat protection and restoration (Darrah and Krementz 2010, Guisan et al.
2013).

Recent research showed that of the >630,000 ha of wetlands in Illinois, only 9% is comprised of non-persistent emergent vegetation and 5% is comprised of dense persistent emergent vegetation (Blake-Bradshaw 2018). However, the National Wetland Inventory database does not recognize numerous managed wetlands, especially within the Mississippi and Illinois River floodplains of Illinois, indicating that this estimate may be conservative if managed wetlands provide suitable habitat for marsh birds. In managed wetlands, hydrology is often manipulated to promote early-succession vegetation that provides food and habitat for waterfowl during fall migration in conjunction with hunting seasons (Havera 1999, DeStevens and Gramling 2012). Although these intensively managed wetlands produce emergent vegetation that may persist through the year, management practices such as dewatering and soil disturbance may occur in spring and early summer which coincides with marsh bird migration and breeding periods in the Midwest. Although multiple studies suggest active management practices, including those associated with waterfowl management, may influence on marsh bird occupancy

(Darrah and Krementz 2010, Bolenbaugh et al. 2011), it is unknown how the intensity and timing of management practices may affect conditions for marsh birds.

I estimated occupancy by marsh birds across a wide range of wetland vegetation communities, hydrologic regimes, and management practices in Illinois during late spring and early summer 2015–2017. My objectives were to assess wetland occupancy by marsh birds relative to 1) local scale, intrinsic wetland characteristics influenceable by management actions in a short timeframe; 2) landscape scale, extrinsic characteristics influenceable by conservation planning activities over a long timeframe; 3) management practices for other migratory birds, such as waterfowl, influenceable by management actions in a short timeframe; and 4) and stressors related to human activities within and surrounding wetlands potentially influenceable in a short and long timeframe. I predicted that marsh bird occupancy would increase with coverage of emergent vegetation, and marsh bird use would be greater in wetlands managed for waterfowl compared to unmanaged wetlands. My research addressed several priorities in the Midwest bird monitoring framework outlined by Koch et al. (2010), including furthering understanding of the ecology and conservation priorities for migrating birds, evaluating effectiveness of conservation actions such as wetland restoration, and increasing access to bird data relative to landscape characteristics for use in conservation planning.

METHODS

Study area

I monitored marsh birds using call-back surveys on both public and private land across Illinois during 2015–2017. During April, May, and June, average minimum temperatures in Illinois were 4.9, 11.0 and 16.2 (° C), average maximum temperatures were 17.7, 23.5 and 28.4 (° C), average temperatures were 11.3, 17.2, and 22.3 (° C), and average rainfall was 9.2, 10.6, and 11.0 cm (NCEI GIS Agile Team 2017). Illinois has lost approximately 90% of its wetlands (Dahl 2006) primarily to drainage and conversion for agricultural production. Agriculture comprises >76% of land use in Illinois, with corn and soybeans making up approximately 60%. Statewide, wetlands compose <4% of the landscape, with <1% in non-forested wetland cover (Luman et al. 2004)

Illinois lies within the heart of the Mississippi Flyway with breeding grounds of many migratory waterbirds primarily to the north and wintering grounds to the south. Illinois contains 14 natural divisions delimited by factors including topography, soils, bedrock, glacial history, and the distribution of plants and animals (Fig. 1). Illinois is also divided among three separate bird conservation regions (BCRs 22, 23, 24; Sauer et al. 2003). The Mississippi and Illinois River floodplains contain areas that have some of the greatest wetland density in Illinois (Blake-Bradshaw 2018). However, large portions of these floodplains have been isolated from the river system by levees and are managed for agriculture or to provide food for migrating waterfowl, primarily dabbling ducks (*Anas* spp.). In leveed portions of these floodplains, hydrology is managed so that little to no surface water is present during the growing season to encourage annual, moist-soil plants or allow planting of crops (e.g., corn, millet) which are flooded again during fall migration (Lemke et al. 2017). To a lesser extent, some areas are managed as more natural emergent marshes year-round to encourage production of emergent and submersed aquatic vegetation (e.g., cattail [*Typha* spp.], bulrush [*Scirpus* spp.], coontail [*Ceratophylum demersum*]).

Managed wetlands are typically impounded on one or more sides by levees and have water control structures allowing hydrological manipulation consistent with management goals, such as moist-soil management. In particular, moist-soil management is the purposeful drawdown of water to expose soil during the growing season and promote early-succession, annual plants desirable for waterfowl (Gray et al. 2013). Water drawdowns typically occur in late spring or early to mid-summer to provide a suitable window for vegetation to mature and produce seed, and vegetation is reflooded in autumn to make seed available to migrating and wintering waterfowl (Fredrickson and Taylor 1982). These conditions may maximize food production for waterfowl (Bowyer et al. 2005), but drawdowns during migration and breeding seasons of marsh birds and exclusion of perennial species may not provide conditions suitable for marsh birds. Although many wetland conservation and restoration initiatives encourage multi-species design and management, waterfowl are often the primary focal group and little research is available to indicate how waterfowl management practices affect other migratory bird species (Eddlemen et al. 1988, Fournier 2017).

Site selection

I surveyed marsh birds in wetlands managed primarily for migrating waterfowl (i.e., focal) for comparison with randomly-selected reference wetlands statewide.

Reference wetlands included emergent polygons from the National Wetland Inventory (NWI) and wetlands included within the Illinois Natural History Survey's Critical Trends Assessment Program (CTAP). Wetlands less than 0.5 ha in size were not sampled as suggested in the North American Standardized Marsh Bird Survey Protocol (NASMBSP; Conway 2011), and also to enable optimal chances of marsh bird detection due to past research suggesting decreased marsh bird use of small wetlands (Brown and Dinsmore 1986).

I assembled a comprehensive sampling frame of potential focal wetlands managed for waterfowl within Illinois using previous studies (e.g., Bowyer et al. 2005, Stafford et al. 2011) and correspondence with Illinois Department of Natural Resources site managers and biologists, private landowners, and Illinois Natural History Survey staff. I defined waterfowl management to include manipulation of vegetation, hydrology, and soils (i.e., disking, planting, drawdowns; Kaminski et al. 2006) with the intent of increasing food production or habitat suitability for waterfowl (Fredrickson and Taylor 1982). I randomly selected 20 wetlands from the population of focal sites for sampling each year. If sites were unsuitable for marsh birds or were not managed for waterfowl during my first visit, I replaced those sites with another randomly-selected site from the sample population. Additionally, I non-randomly selected and sampled eight focal sites in all years of my study due to their location and accessibility, intermediate intensity management regimes, and history of restoration (e.g., The Nature Conservancy's Emiquon Preserve, Aitchison Waterfowl Refuge of Marshall State Fish and Wildlife Area).

For reference wetlands, I stratified Illinois by natural division and selected sites proportionately by wetland density within natural divisions. I consolidated NWI polygons into 6 classes (Freshwater Pond, Lake, Freshwater Emergent [herbaceous only], Freshwater Scrub-Shrub/Forested, Riverine, and Other) and used total wetland area to determine the number of sample plots in each natural division using Neyman allocation (Neyman 1934). I used the Reversed Randomized Quadrant-Recursive Raster tool in

ArcMap to assign plot locations within wetland area inside each natural division, which created a spatially-balanced sample population (Theobald et al. 2007, Tozer et al. 2018). I reviewed ESRI base map aerial imagery to assess the presence of suitable emergent vegetation at all reference sites for marsh birds and created a sample population of potentially suitable sites each year (e.g., presence of emergent aquatic vegetation; Rehm and Baldassarre 2007). I randomly selected 20 sites from the resulting sample population for marsh bird surveys each year. If sites were unsuitable for marsh birds during my first visit (i.e., lacking inundation or emergent vegetation; Bolenbaugh et al. 2011, Blake- Bradshaw 2018), I replaced those sites with another randomly-selected site from the sample population.

Similar to NWI sites, I used aerial imagery to assess habitat suitability for marsh birds from 60 CTAP sites each year, and subsequently created a sample population from which I randomly selected 20 to survey each year (Rehm and Baldassarre 2007). The CTAP monitors the biological condition of forests, wetlands, streams, and grasslands in Illinois using a sampling frame based on random selection of townships weighted by area for inclusion (Molano-Flores 2002). The CTAP annually selects a representative location within each aforementioned biological community (e.g., wetland) within 60 randomly- selected townships statewide. CTAP sites are resampled on a 5-year schedule. Because CTAP and NWI sites were based on different randomized procedures and spatial data, we assume they cumulatively were representative of the range of wetland conditions present in Illinois. If sites were deemed as likely unsuitable after reviewing aerial photographs of the site or site descriptions from previous CTAP visits or they were unsuitable for marsh birds during my first visit, I replaced those sites with another randomly-selected site from the sample population (Fig. 2). For both CTAP and NWI sample populations, I assumed that sites deemed unsuitable because they did not contain emergent vegetation were unoccupied by marsh birds.

Marsh bird surveys

Prior to marsh bird surveys, I established fixed sample points (n = 1–5) at each selected site with the number of points allocated to each wetland proportional to overall size. All sample points were located in areas that were efficiently accessible, within or adjacent to emergent aquatic vegetation, and spaced ≥ 400 m apart to reduce the chances of double counting individuals (Johnson et al. 2009, Conway 2011). I restricted the maximum number of survey points to 5 per site to allow observers to survey multiple wetlands in a single sampling period. I marked sample points with GPS coordinates and flagging tape to ensure consistency among survey periods.

Once survey routes were established, I surveyed all points among sites following the NASMBSP (Conway 2011), which incorporates a repeated call-back survey design. Call-back surveys can increase vocalization probability of secretive marsh birds, although secretive marsh birds may still be detected during passive surveys (Conway and Gibbs 2011, Glisson et al. 2017). Surveys encompassed the 100-m-radius circle from the marked point. I surveyed each point three times at bi-weekly intervals during 2015–2017 to create an encounter history necessary to estimate probability of site occupancy and detection (MacKenzie et al. 2002). I conducted all surveys between one half hour before sunrise and approximately 2 hours after sunrise (e.g., Bolenbaugh et al. 2011) and avoided heavy rains or high wind conditions to maximize detections (Conway 2011).

Following the NASMBSP, I used a 5-min passive survey and subsequent 1-min alternating series of 30 seconds of calls and 30 seconds of silence of least bittern, yellow rail (*Coturnicops noveboracensis*), black rail, king rail, Virginia rail (*Rallus limicola*), sora (*Porzana carolina*), common gallinule, American bittern (*Botaurus lentiginosus*), American coot (*Fulica americana*), and pied-billed grebe (*Podilymbus podiceps*; Conway 2011). The order of calls was fixed and began with the least intrusive species and ended with the most intrusive species following the NASMBSP (Ribic et al. 1999, Conway 2011). I broadcasted calls using electronic game callers (Western Rivers Pursuit, Maestro Game Calls, LLC., Dallas, Texas, USA; Primos Turbo Dogg, Primos Hunting, Flora, Mississippi, USA). During call-broadcast surveys, I pointed game callers toward emergent vegetation and repeated subsequent surveys at each point using the same cardinal direction. Calls were broadcasted at a volume of 80–90 dB with the observer positioned 1 meter from the game caller (Conway 2011). Because Illinois encompasses two survey zones according to the NASMBSP (Fig. 3; Conway 2011), surveys began
two-weeks later in the northern half of the state (i.e., southern zone start date = 15 April, northern zone start date = 1 May).

During marsh bird surveys, I identified individuals to species by sight or sound. To account for variation in detection probability, I also recorded variables such as wind speed using the Beaufort scale (values 0–5), temperature (° C), cloud cover representing severity of weather (values 0–7), background noise intensity (values 0–4), and the name of the observer(s) as factors (Conway 2011). Prior to conducting surveys, I trained participants on field protocols, bird identification, and estimating distances to calling birds through in-person training sessions, detailed guidebooks, and audiovisual media (Nadau and Conway 2012, Glisson et al. 2017, Tozer et al. 2018).

Wetland Conditions

Following all call-back surveys within a site, I evaluated wetland conditions at each sample point and across the entire site (Table 1). At the site level, I assessed the intensity of waterfowl management activities (1 [no waterfowl management; e.g., lack of evidence of managed drawdowns or vegetation manipulation] – 8 [very intense waterfowl management; e.g., annual soil disturbance, disking and planting food plots, etc.] ; Fig. 4), wetland complexity/interspersion (1 [homogeneous] – 6 [high heterogeneity]; Fig. 5), wetland connectivity (1 [isolated from other wetland] – 8 [adjacent and connected to other wetlands]), and anthropogenic disturbance (Ohio Rapid Assessment Method; ORAM). The ORAM procedure includes potential stressors and indicators of wetland condition, including metrics indicative of wetland quality for marsh birds under a wide variety of modified conditions specific to the Midwest region (e.g., management of hydrology, presence of water control structures, drawdown timing, urban development and adjacent agricultural land use, etc; Blake-Bradshaw 2018). At each sample point, I assessed percent cover by vegetation type, including dense persistent emergent (hereafter, persistent emergent), non-persistent emergent, scrub-shrub, forested, non-rooted floating aquatic vegetation, open water, and aquatic bed (i.e., floating- and submersed aquatic vegetation). At this scale, I also recorded average water depth across the surveyed area within four depth ranges dependent on known water bird feeding guilds (1: dry; 2: very shallow, <10 cm; 3: shallow, <45 cm; 4: deep, > 45 cm) and percent surface water inundation (Conway 2009, Harms and Dinsmore 2013).

Data analysis

I estimated occupancy and detection probability of marsh birds across sites using the *occu* function in the unmarked package for program R, version 3.1 (Fiske et al. 2011; R Core Team 2014). An important assumption regarding detection probability from repeated surveys is that the population is closed: that is, no immigration or emigration of individuals among sampling periods (Mackenzie et al. 2002). Violating this assumption can lead to under estimating detection probability and over estimating occupancy. For example, inclusion of migrating individuals would violate the assumption of a closed population and bias estimates of detection probability low. Due to anecdotal observations from the field and variation in raw detections that were inversely related to sampling period chronology, I judged that my data was unlikely to meet the assumption of closure. Past research suggests that marsh bird migration continues through the monitoring season outlined in the NASMBSP (Fournier 2017). Accordingly, calculating occupancy for more mobile organisms may require shorter periods between repeat visits or the use of spatial replication across multiple surveys within the same area of study (Kendall and White 2009). Thus, I estimated detection probability among sample points within each site and survey period instead of across survey periods. Under this design, I assumed that a species present at a single point within a site was present at all points within that site, and non-detection was a false negative, not true absence. Due to similarities in vegetation and wetland characteristics among survey points within each site and distribution of sample sites in relation to mostly unsuitable habitat surrounding sites, I believe this approach was reasonable and that the probability of meeting this assumption was substantially greater than population closure across the 6-week survey period (Kendall and White 2009). I estimated 95% confidence intervals (CI) for detection probability and expressed standard error (±) of categorical factor levels.

To examine occupancy rates of marsh birds with similar habitat requirements, I grouped species based on taxonomical similarity, patterns of habitat use, and relevance to management (Bolenbaugh et al. 2011). Marsh bird groups included 'all', 'emergent' (i.e., least bittern, American bittern, black rail, king rail, sora, Virginia rail, and yellow rail), and 'open water' (i.e., American coot, common gallinule, and pied-billed grebe; Bolenbaugh et al. 2011). Small sample sizes for most individual species precluded species-specific estimation of occupancy. I used a two-step modeling process by which covariates for detection (p) were modeled first while keeping occupancy (Ψ) constant at the null. I then used the top model for detection in all subsequent models for occupancy (Kroll et al. 2010, Harms and Dinsmore 2013). I assessed correlation among the site-specific covariates by constructing a correlation matrix prior to analysis and removed one of each of the correlated variables ($|r| > 0.5$; Harms and Dinsmore 2013). I modeled occupancy as a function of all remaining independent variables individually and then built additive modeling using biologically plausible combinations of variables that received the most support (Harms and Dinsmore 2013). I compared candidate models using Akaike's Information Criterion (AIC) and considered models ≤ 2 ΔAIC to be competitive (Burnham and Anderson 2002). All predicted probabilities of occupancy were reported with corresponding standards. I then used odds ratios to illustrate effect sizes of variables included in all competitive models (Hosmer and Lemeshow 2000, Freund and Wilson 2003, Jacques et al. 2011).

RESULTS

I recorded 3,680 marsh bird detections during 2015–2017. American coot were most commonly detected (61.3%), followed by sora (26.7%), pied-billed grebe (5.5%), common gallinule (2.5%), Virginia rail (1.5%), least bittern (1.4%), American bittern (0.9%), king rail (0.2%), and yellow rail (0.1%). I detected no black rail during my surveys. Within the emergent group sora represented most of the detections (87.1%), followed by Virginia rail (4.9%), least bittern (4.4%), American bittern (2.9%), king rail (0.5%), and yellow rail (0.2%). Within the open water group American coot represented most of the detections (88.5%), followed by pied-billed grebe (7.9%), and common gallinule (3.6%). For all three marsh bird groups, detection probability declined with ordinal date (Table 2). The odds of detection declined 6% (95% CI = 4 – 7) for the all group, 5% (95% CI = 3 – 7) for emergent group, and 3% (95% CI = 1 – 5) for the open- water group each day (Fig. 6; Table 2).

The highest-ranked model predicting occupancy of the all marsh bird group included wetland complexity and wetland type (Table 3). The odds of wetland occupancy were 28.7 (95% CI = 3.1 – 271.0) times greater at sites with the greatest level of complexity compared to sites at the lowest level of complexity (Fig. 7). The odds of occupancy at a focal site were 1.80 (95% CI = 0.7 – 4.6) times greater than NWI sites (Fig. 8). The odds of occupancy were 71% (95% CI = 31 – 88) less at CTAP sites than NWI sites.

The highest-ranked model predicting occupancy of the emergent group included wetland complexity, survey period, surface water inundation, and persistent emergent vegetation (Table 3). The odds of occupancy were 98 (95% CI = 8 – 123) times greater at the highest level of complexity than the lowest (Fig. 9). The odds of occupancy were 49% (95% CI = -14 – 77) less in survey round 2 than survey round 1 and 73% (95% CI = 33 – 89) less in survey round 3 than survey round 1 (Fig. 10). The odds of occupancy increased 2% (95% CI = 0 – 3; Fig. 11) for every 1% increase in surface water inundation and 3% (95% CI = 0 – 5; Fig. 12) for every 1% increase in the percent cover of persistent emergent vegetation. The highest-ranked model predicting occupancy of the open water group included wetland complexity, site type, and waterfowl management intensity (Table 3). The odds of occupancy was 28 (95% CI = 2 – 37) times greater in the highest level of complexity than at the lowest level of complexity (Fig. 13). The odds of occupancy was 5 (95% CI = 2 – 12) times greater at focal sites compared to NWI sites (Fig. 14). The odds of occupancy was 30% (95% CI = 2 – 77) lower at CTAP sites than NWI sites (Fig. 14).

Occupancy was greatest at intermediate levels of waterfowl management intensity. For instance, the odds of open water-associated marsh bird occupying a wetland was 3 (95% CI = 1 – 12) times greater in wetlands with a level 4 management intensity than sites at level 1 management intensity. Furthermore, a level 7 management intensity resulted in a 44% (95% CI = 0 – 92) decrease in the odds of occupancy compared to sites at level 1 management intensity (Fig. 15).

DISCUSSION

Focal wetlands managed for waterfowl had substantially greater probability of occupancy by marsh birds than reference wetlands. Focal wetlands (4.58 ± 1.91) were ranked at substantially higher management intensity levels than NWI (1.83 ± 1.61) or CTAP wetlands (1.28 ± 0.04). However, intensively managed wetlands for waterfowl were typically less suitable for marsh birds than intermediate levels of wetland management. Management activities that featured late drawdowns or maintained surface water throughout the growing season, encouraged persistent emergent vegetation, and resulted in greater wetland complexity had the greatest potential to provide suitable habitat for both marsh birds and waterfowl (i.e., levels 3–4; Chapter 2).

Dense, persistent emergent vegetation flooded at shallow depths provides cover, nesting infrastructure, and foraging conditions for marsh birds (Darrah and Krementz 2010); however, these habitat resources were rare in reference wetlands that we evaluated (Blake-Bradshaw 2018), but they occurred in at least portions of many sites managed for waterfowl. For example, Emiquon Preserve and the Dixon Waterfowl Refuge at Hennepin and Hopper Lakes along the Illinois River host hundreds of thousands of waterfowl and other waterbirds during migration, but these sites are managed as emergent marshes and provided substantial areas of dense emergent vegetation and were used extensively by marsh birds during my study (Bajer et al. 2009, Hagy et al. 2017, Lemke et al. 2017). While intensively managed moist-soil wetlands can provide more food for waterfowl than those passively managed (Bowyer et al. 2005), maximizing co- occurrence of waterfowl and marsh birds is likely best accomplished using less intensive management strategies with less frequent drawdowns and maintenance of dense emergent vegetation communities (McClain et al. 2018).

Multiple species of marsh birds require diverse habitat resources for nesting and foraging, and more complex wetlands have the potential to provide a greater diversity of these resources to meet the needs of multiple species (Darrah and Krementz 2010, Chapter 2). Several studies have demonstrated that a mixture of wetland cover types, particularly shallow open water interspersed with vegetation, yield the greatest abundance and density of invertebrates (Kaminski and Prince 1981, Reid 1989), thus potentially providing the greatest food resources for marsh birds. Vegetation to water interspersion increases wetland complexity and encourages the use by marsh birds (Weller and Spatcher 1965, Rehm and Baldassarre 2007), waterfowl (Kaminski and Prince 1981), and other species (Hine et al. 2017).

It is often assumed that wetlands managed for waterfowl provide habitat for other wetland-dependent species. Tozer et al. (2018) suggested that managed wetlands have greater marsh bird occupancy rates compared to adjacent unmanaged wetlands, and Fournier (2017) found marsh birds were positively associated with moist-soil vegetation in impoundments managed for waterfowl. In the Midwest, a common goal in managed wetlands is to dewater during the summer to promote annual moist-soil vegetation that produce abundant seeds for waterfowl (Fredrickson and Taylor 1982). Dewatering wetlands prior to the breeding period of most marsh birds also enables managers to plant agricultural crops to produce food for waterfowl in the fall. In many intensively managed wetlands for waterfowl, managers typically remove water shortly after the spring migration of waterfowl (e.g., April–May) and before the primary breeding period for marsh birds (i.e., June–July). Moreover, dense stands of persistent, emergent vegetation are often discouraged through variable hydrologic regimes, chemical control, or physical manipulations to encourage annual plants which produce more food for waterfowl. Thus, intensive management for waterfowl that includes early drawdowns or exclusion of perennial emergent vegetation also reduces marsh bird use (Harms and Dinsmore 2013). In contrast, some managers practice less intensive management strategies due to fiscal or logistical constraints (e.g., lack of water-level manipulation capability) which allows portions of wetlands to be colonized by perennial species or maintain standing watering during the growing season. In my study and others, occupancy by marsh birds was greater in sites with less intensive management practices (Connor and Gabor 2006, Tozer et al. 2018). Management practices that retain water to increase inundation during the marsh bird migrating and breeding season may promote the growth of persistent emergent vegetation, and thus site occupancy by marsh birds (Tozer et al. 2018, Harms and Dinsmore 2013). Many wetland characteristics considered strong predictors of marsh bird use in other studies were not important predictors of marsh bird occupancy in this study (Fournier 2017, Harms and Dinsmore 2013). For example, anthropogenic disturbances were cited in many studies to negatively impact marsh bird occupancy, but our modified ORAM score incorporating agricultural development, potential for pollution, and recreational activities was not associated with occupancy. Stapanian et al. (2004) found that wetland dependent birds including marsh bird abundance and diversity was related to ORAM score. Harms and Dinsmore (2013) found an increase in marsh bird occupancy relative to the cover of reed canary grass (*Phalaris arundinazea*), suggesting that not all invasive plants negatively impact marsh birds. Furthermore, while Fournier (2017) and Wilson et al. (2018) found that wetland use by autumn and spring migrating sora was positively related to non-persistent emergent vegetation, non-persistent emergent vegetation was not a predictor of marsh bird occupancy in this study and was often not flooded during marsh bird surveys.

Flood events likely impact wetland conditions and subsequent marsh bird use. Anecdotally, I observed a large impact from floods on wetlands surveyed in our study. Large flood events of the Illinois and Mississippi rivers have historically occurred following seasonal precipitation cycles. However, due to human interference by largely separating the floodplain and historical hydrology using levees and the installation of locks and dams, flooding of the river systems has become more frequent and less predictable, and floods of greater magnitude are occurring (Lemke et al. 2017). These flood events during the growing season destroy emergent vegetation or raise water levels to the point where all suitable cover is submersed and inaccessible to marsh birds.

Previous studies have noted that the probability of detecting marsh birds varied by time of day, survey date, and weather (Rehm and Baldassarre 2007, Conway and Gibbs 2011). Non-detection of marsh birds may result from true absence or non-detection despite presences due to the bird not calling or being visible during the survey period or the observer failing to hear or see the bird despite a response (Denes et al. 2015). In order to account for all scenarios, an unbiased estimate of detection probability requires survey replication while the population is closed (Mackenzie et al. 2002). In the current NASMBSP, replication is recommended biweekly across a 6-week period. Conway (2011) recommended that initial surveys be conducted after migration and before the initiation of breeding; however, such timing could lead to under sampling those species with the earliest peak-detection periods being missed (Tozer et al. 2018). I noted varying detection probability across days within and among biweekly survey periods, suggesting that detection probability varied through time. Variation in detection could be caused by decreased vocalizations as the breeding season progresses (Tozer et al. 2018), but information about vocal behavior during migration is limited. However, Kaufmann (1989) observed that marsh birds gave similar vocalizations during migration and breeding periods. Additionally, the NASMBSP survey timing was established in order to encompass all marsh bird species' breeding seasons which could explain why detection decreased over time due to varying migration and breeding chronology among marsh birds of interest.

The majority of our detections were sora and American coot, and most occurred in the first and second survey period. Several species (e.g., pied-billed grebe, common gallinule) migrate later in the survey season, but I had fewer overall detections due to lower abundances or other factors (Chapter 2). This temporal relationship with detection probability has been documented in other studies (Rehm and Baldassarre 2007) and my use of multi-species groups with differing migration chronologies and abundances (Fournier 2017) probably exacerbated the effect of date in my study. Consequently, the timing of surveys outlined in the NASMBSP may not be effective at meeting the assumptions required to calculate detection probability of breeding marsh birds using temporal replication over a 6-week timeframe in the Midwest and may need to be adjusted to adequately detect marsh birds of different guilds migrating at different times. Anecdotally, survey frequency would have needed to be one week or less in our study to better ensure the assumption of closure for most species, especially during the early survey period when many detections likely came from migrating individuals. Reducing the time between surveys could decrease the probability of marsh birds moving in or out of the survey area and could potentially increase the number of detections which would improve habitat models and allow species-specific estimation of occupancy rates.

Additionally, using automated recording devises to supplement site visits could be useful to increase detections and survey replications.

MANAGEMENT IMPLICATIONS

Wetland managers should increase coverage of dense, persistent emergent vegetation by maintaining surface water during the growing season for several years in succession to increase marsh bird use of managed wetlands in the Midwest. Managing wetlands to benefit marsh birds and other wetland-dependent species, such as waterfowl, will require maintenance of wetlands in the intermediate stages of marsh succession using multi-year hydrology strategies to stimulate a variety of cover types and food sources to meet the differing needs of each species which can be done by managing for high wetland complexity (Weller and Spatcher 1965). Creating or managing for emergent marshes with semi-permanent water regimes can benefit waterfowl and promote occupancy and use by marsh birds.

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Table 1. List of factors and the corresponding units used as possible predictors of marsh bird detection and abundance in Illinois during late spring and early summer 2015–2017.

Model Group	Factors	Units/Scale
Detection	Time Relative to Sunrise	Minutes
	Temperature	Degrees Celsius
	Sky Cover	0–8
	Wind	0–5
	Background Noise	0–4
	Observer (s)	Observer
	Adjusted Date	1–48
	Ordinal Date	108–167 (April 18 – June 16)
	Year	2015–2017
Abundance	Waterfowl Management Intensity	1–8
	Wetland Complexity	1–6
	Connectivity to Rivers or Streams	0–7
	Management Category	Unmanaged, Passive, Active
	Survey Period	1, 2, 3
	Survey Region	North or South
	Wildlife Management Intensity	0–7
	Site Type[a]	CTAP, NWI, Focal
	Water Depth	0–4
	Surface Water Inundation	% of Survey Point
	Aquatic Bed	% of Survey Point
	Dense Persistent Emergent Vegetation	% of Survey Point
	Non-persistent Emergent Vegetation	% of Survey Point
	Shrub-Scrub	% of Survey Point
	Forested	% of Survey Point
	Open Water	% of Survey Point
	Natural Division	ArcGIS Layer
	ORAM Factors	ORAM Scores

[a]Critical Trends Assessment Program (CTAP), National Wetland Inventory (NWI), Managed for waterfowl (Focal)

Table 2. Model rankings for variables predicting detection probability by species groupings of marsh birds based on Akaike's Information Criterion (AIC), difference in AIC relative to the top model (ΔAIC), relative model weight (w_i), and number of parameters (K) from surveys conducted at focal wetlands managed for waterfowl and reference wetlands throughout Illinois during late spring and early summer 2015–2017.

Group	**Model**[a]	**AIC**	**ΔAIC**	w_i	K
All Marsh Birds	ordinal date	1276.99	0.00	1.00	3
	adjusted date	1286.37	9.38	0.00	3
	temperature	1324.58	47.59	0.00	3
	sky cover	1330.07	53.08	0.00	8
Emergent[b]	adjusted date	1197.54	0.00	0.80	3
	ordinal date	1200.32	2.78	0.20	3
	temperature	1249.32	51.78	0.00	3
	year	1252.63	55.09	0.00	3
Open[c]	adjusted date	1007.04	0.00	0.84	3
	ordinal date	1008.4	1.36	0.13	3
	time	1020.43	13.39	0.02	3
	null	1020.65	13.61	0.00	2

[a] For all models, the occupancy parameter was held constant at the null.
[b] Emergent = *Botaurus lentiginosus*, *Ixobrychuc exilis*, *Porzana carolina*, *Rallus elegans*, *Rallus limicola*, and *Coturnicops novemoracensis.*
[c] Open = *Fulica americana*, *Gallinula galeata*, and *Podilymbus podiceps.*

Table 3. Model rankings for variables predicting occupancy probability by species groupings of marsh birds based on Akaike's Information Criterion (AIC), difference in AIC relative to the top model (ΔAIC), relative model weight (w_i), and number of parameters (*K*) from surveys conducted at focal wetlands managed for waterfowl and reference wetlands throughout Illinois during late spring and early summer 2015–2017.

Group	**Model[a,b]**	**AIC**	**ΔAIC**	w_i	***K***
All Marsh Birds	CMP + TYP	1268.74	0.00	0.97	10
	CMP	1277.13	8.39	1.5e-2	8
	PIN	1277.39	23.78	1.3e-2	5
	TYP	1299.21	30.47	6.7e-6	10
	NULL	1331.08	62.48	2.6e-14	3
Emergent[c]	CMP + PIN + PDP + PRD	1174.11	0.00	0.80	12
	CMP + PDP + PRD	1177.68	3.57	0.13	11
	CMP + PIN + PRD	1179.27	5.16	6.1e-2	11
	CMP + PRD	1197.39	23.28	7.8e-6	10
	NULL	1265.60	91.49	1.1e-20	3
Open[d]	CMP + TYP + WTR	949.08	0.00	0.90	17
	CMP + TYP	954.22	5.14	6.9e-2	10
	CMP + WTR	956.07	6.99	2.8e-2	15
	TYP + WTR	967.22	18.14	1.0e-4	12
	NULL	1020.65	71.56	2.6e-16	3

[a] All occupancy models presented contained the variable ordinal date in detection probability

[b] CMP = wetland complexity, TYP = Site Type, WTR = waterfowl management intensity, PIN = Percent Inundation, PDP = Percent cover dense persistent emergent vegetation, PRD = Survey Period, and NULL = intercept only.

[c] Emergent = *Botaurus lentiginosus*, *Ixobrychuc exilis*, *Porzana carolina*, *Rallus elegans*, *Rallus limicola*, and *Coturnicops novemoracensis.*

[d] Open = *Fulica americana*, *Gallinula galeata*, and *Podilymbus podiceps.*

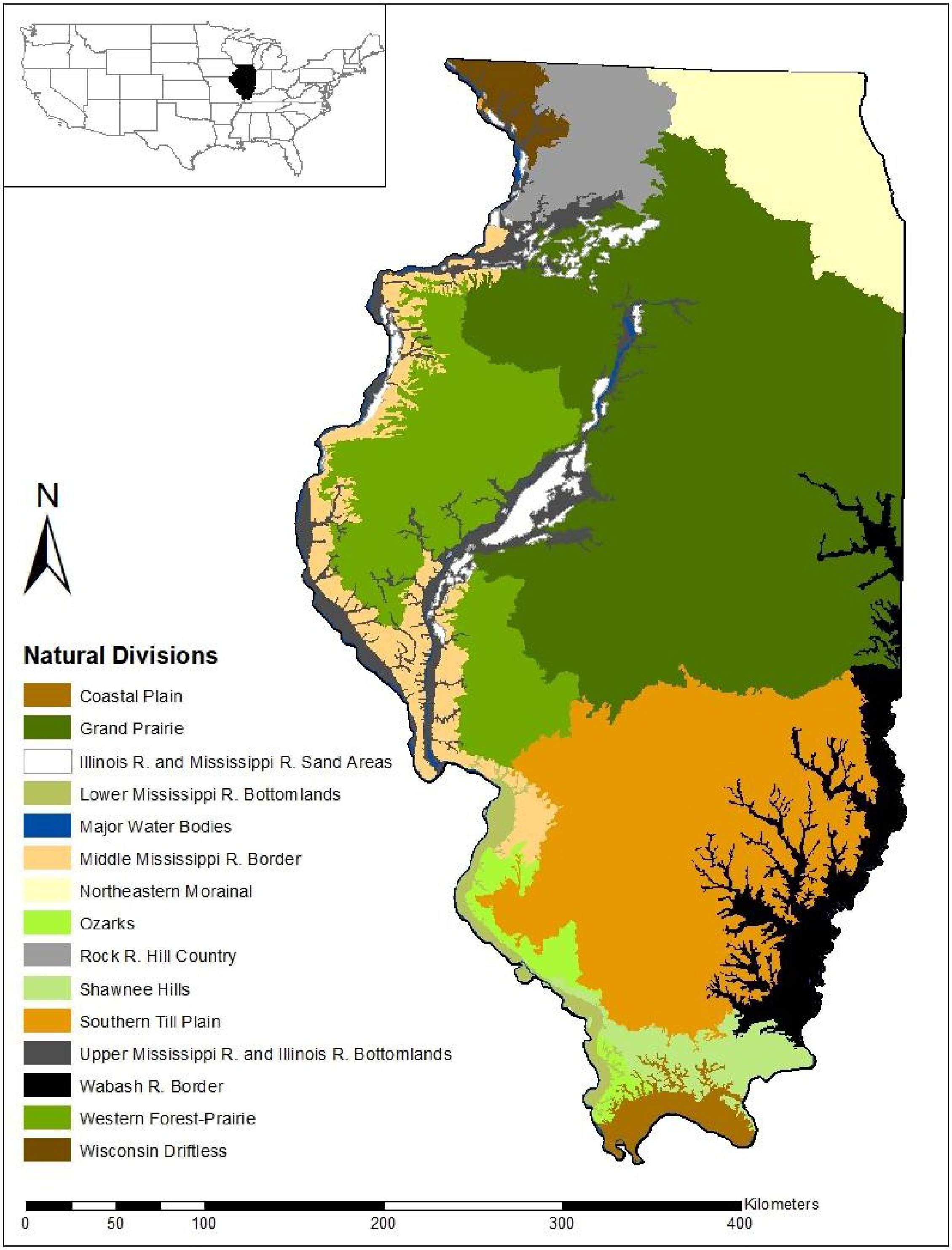

Figure 1. Illinois natural divisions (Schwegman 1973) used to establish survey effort dependent on wetland density in each natural division.

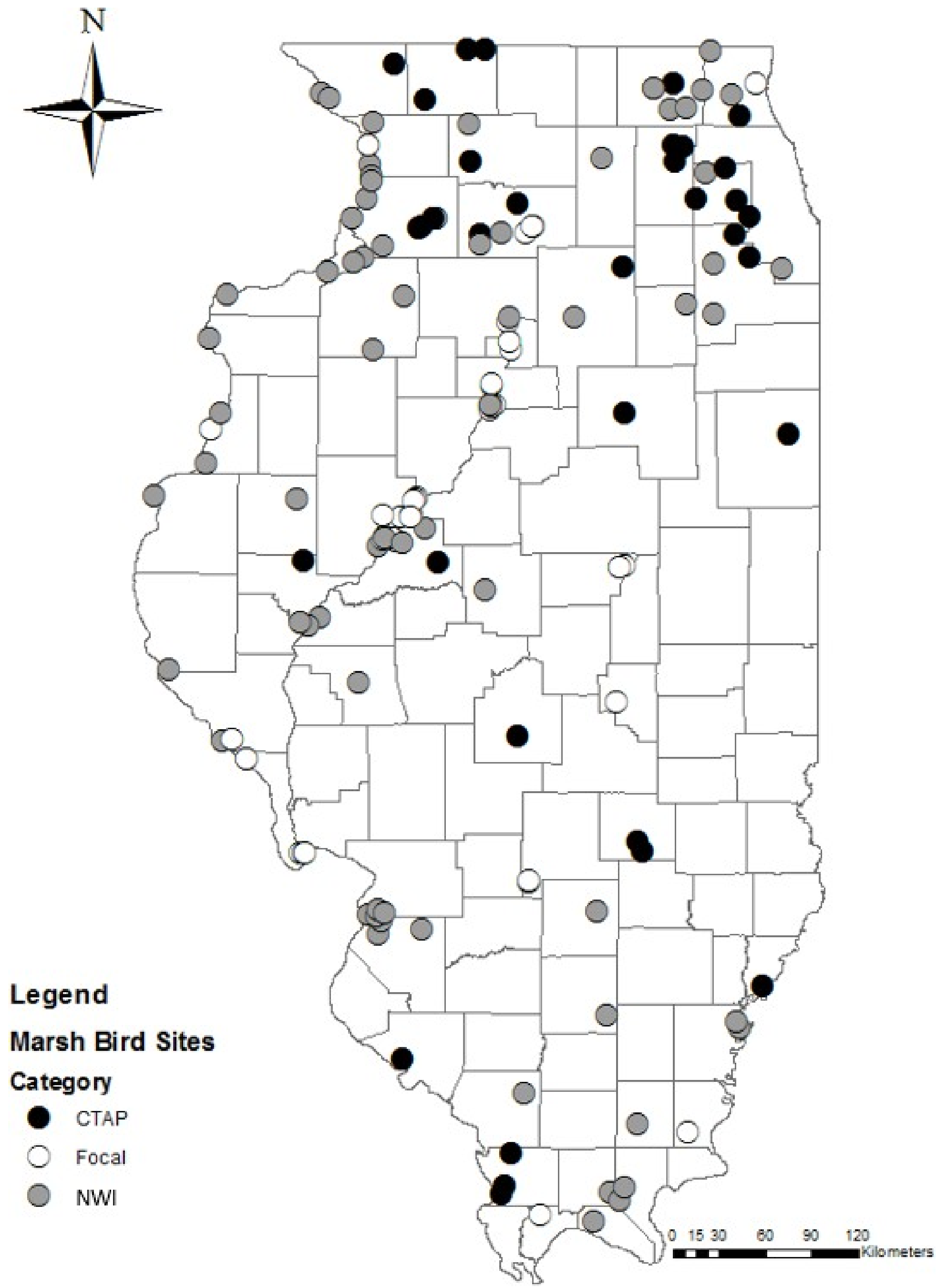

Figure 2. Illinois counties with wetlands (n = 160 sites) surveyed for marsh birds during breeding seasons of 2015–2017. Sites consisted of National Wetland Inventory (NWI; grey), focal (white), and Critical Trends Assessment Program (CTAP [black]) wetlands.

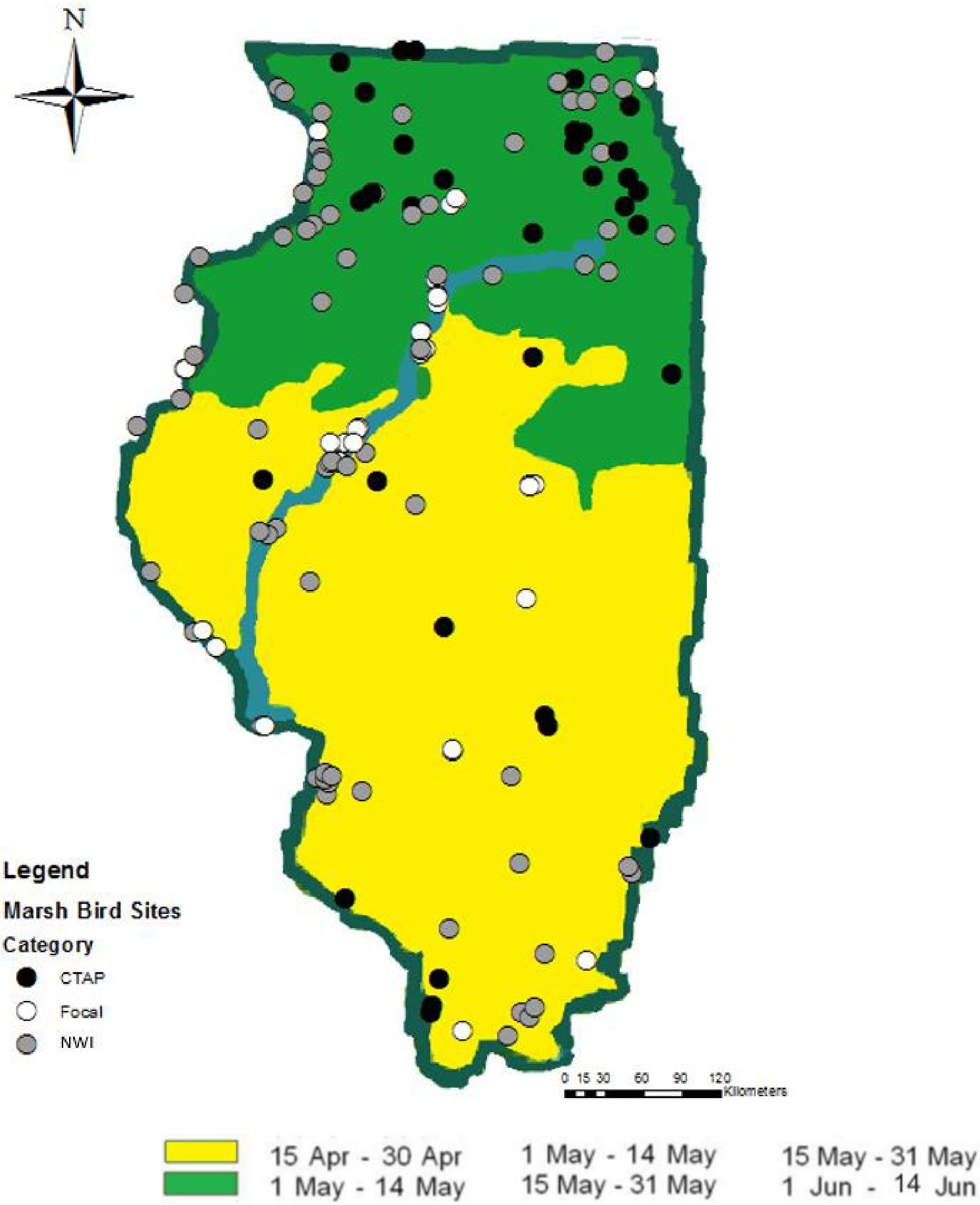

Figure 3. Marsh bird survey dates for two disparate regions of Illinois categorized by average maximum temperatures in May from the PRISM Climate Group at Oregon State University (Conway 2011). Sites consisting of National Wetland Inventory (NWI; grey), focal (white), and Critical Trends Assessment Program (CTAP [black]) wetlands.

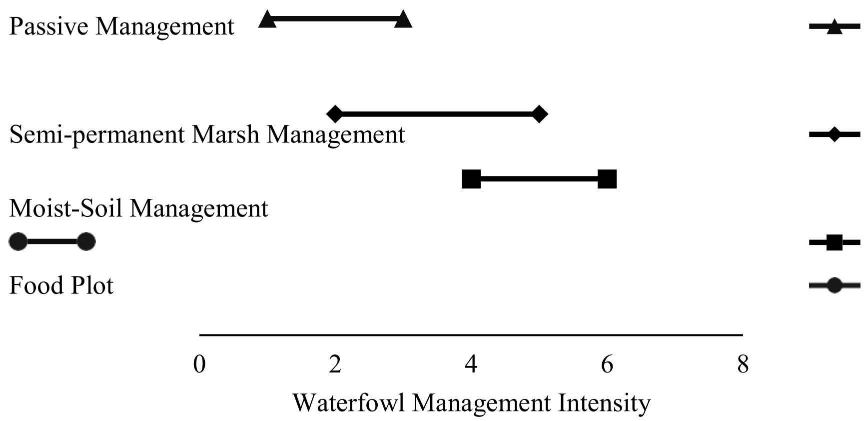

Figure 4. General guidelines used in this study to assist in determining waterfowl management intensity based on observed management strategies with least intensive (passive management) practices near 1 and intensive practices (food plots) at 8.

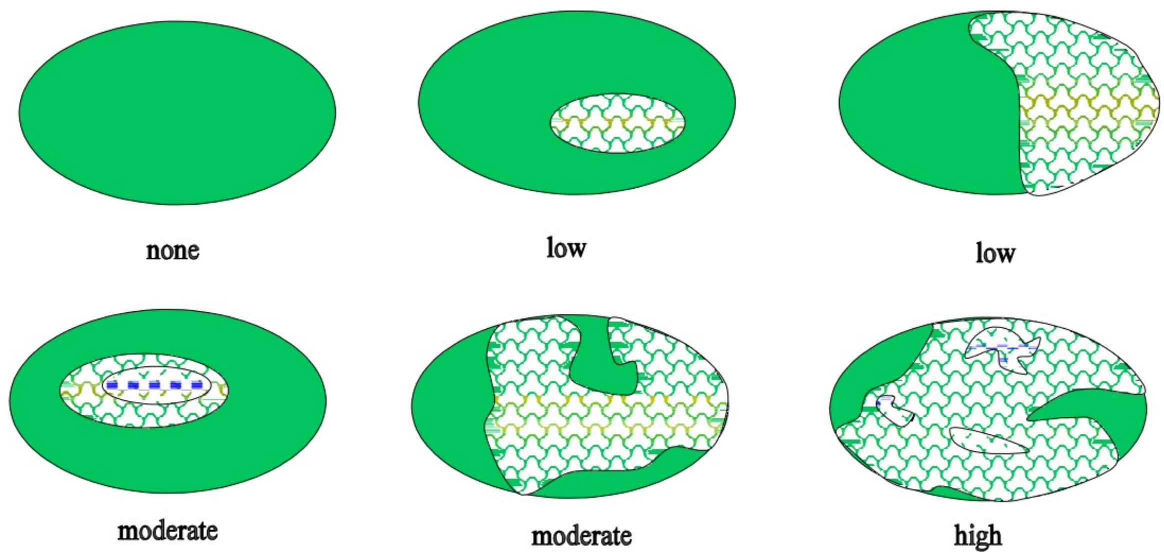

Figure 5. Hypothetical wetlands for estimating degree of complexity. None (1) wetland has no complexity consisting of one monotypic habitat, low (2) wetland has a low degree of complexity consisting of a small area of an additional habitat type, moderately low (3) wetland has a moderately low degree of complexity consisting of a larger area of an additional habitat type, moderate (4) wetland has a moderate degree of complexity consisting of multiple small additional habitat types, moderately high (5) wetland has a moderately high degree of complexity consisting of a large area of an additional habitat type and high edge density, and high (6) wetland has a high degree of complexity consisting of high edge density and more than one additional habitat type (Mack 2001).

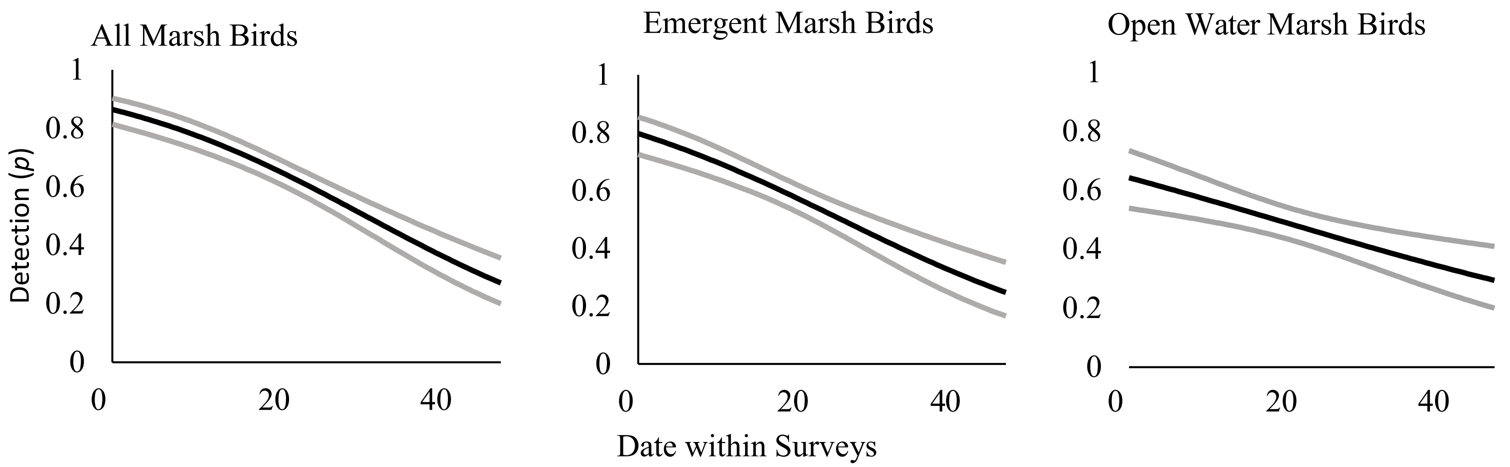

Figure 6. Model estimated marsh bird detection probability (black line) for all three marsh bird groups (± 95 % confidence limits [grey lines]) by adjusted date. Surveys were conducted from day 0 (April 15 or May 1, depending on latitude stratification) to day 48 across Illinois during late spring and early summer 2015–2017.

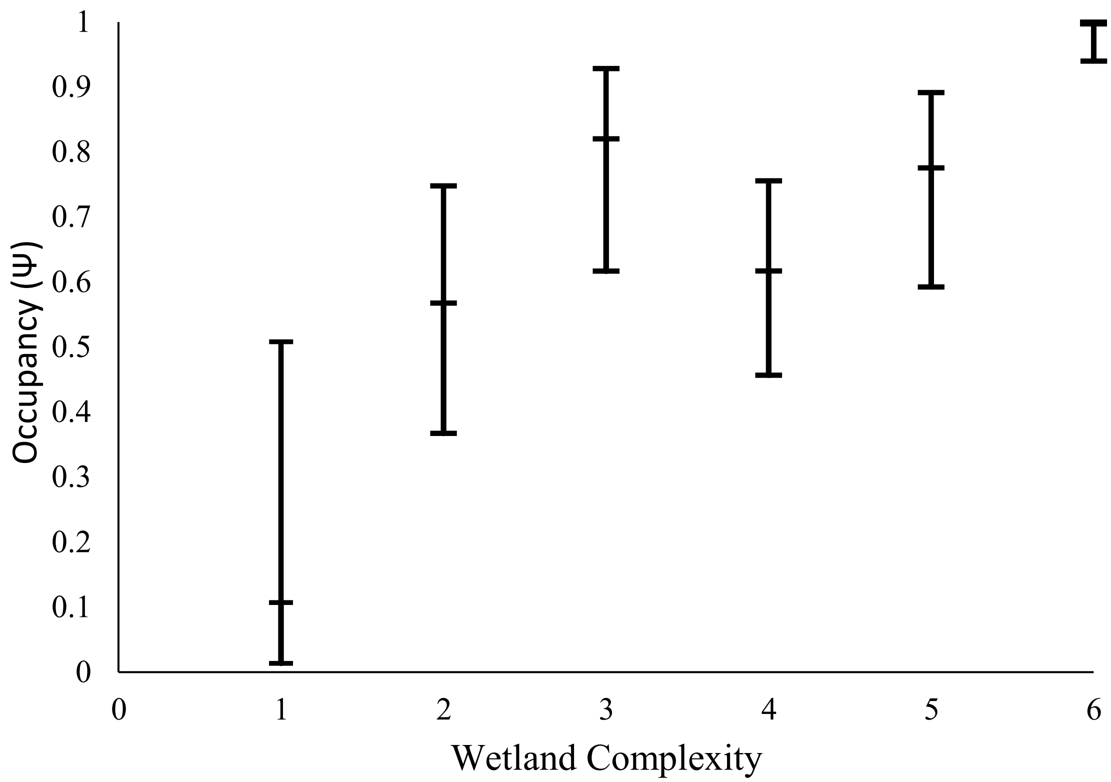

Figure 7. Predicted probability (95% confidence limits) of site occupancy for the all marsh birds group across wetland complexity levels in Illinois during late spring and early summer 2015–2017. Site type (National Wetland Inventory) was held constant.

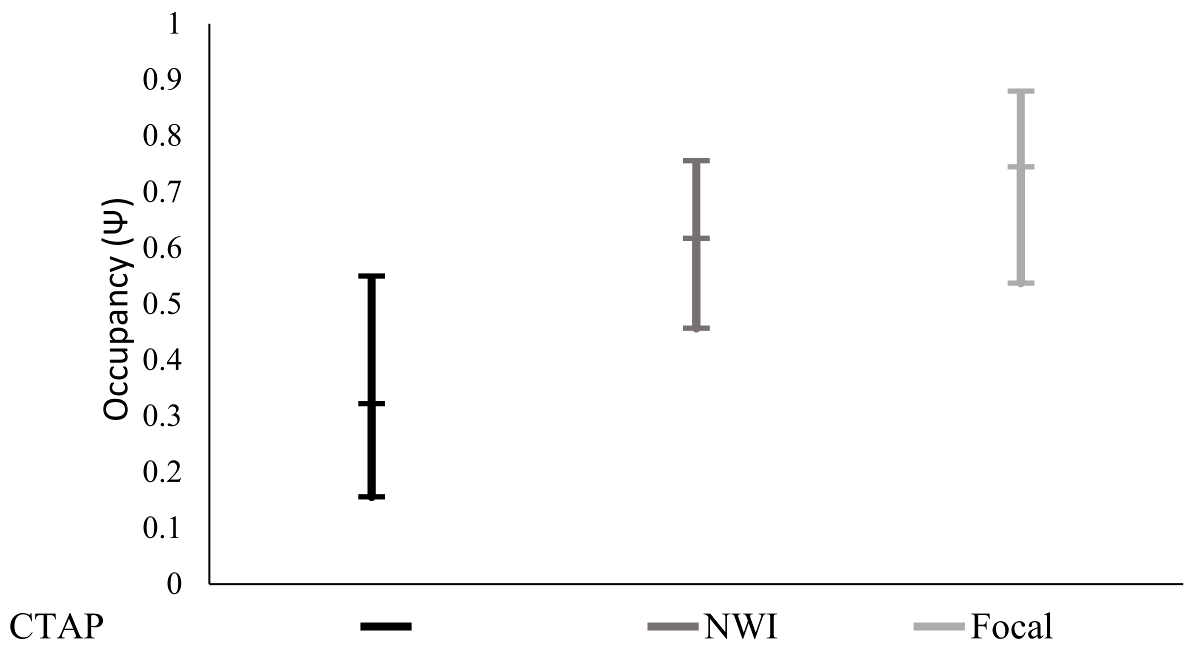

Figure 8. Predicted probability (95% confidence limits) of site occupancy for the all marsh birds group across wetlands managed for waterfowl (focal), Critical Trends Assessment Program (CTAP), and National Wetland Inventory (NWI) site types in Illinois during late spring and early summer 2015–2017. Wetland complexity (level 4) was held constant.

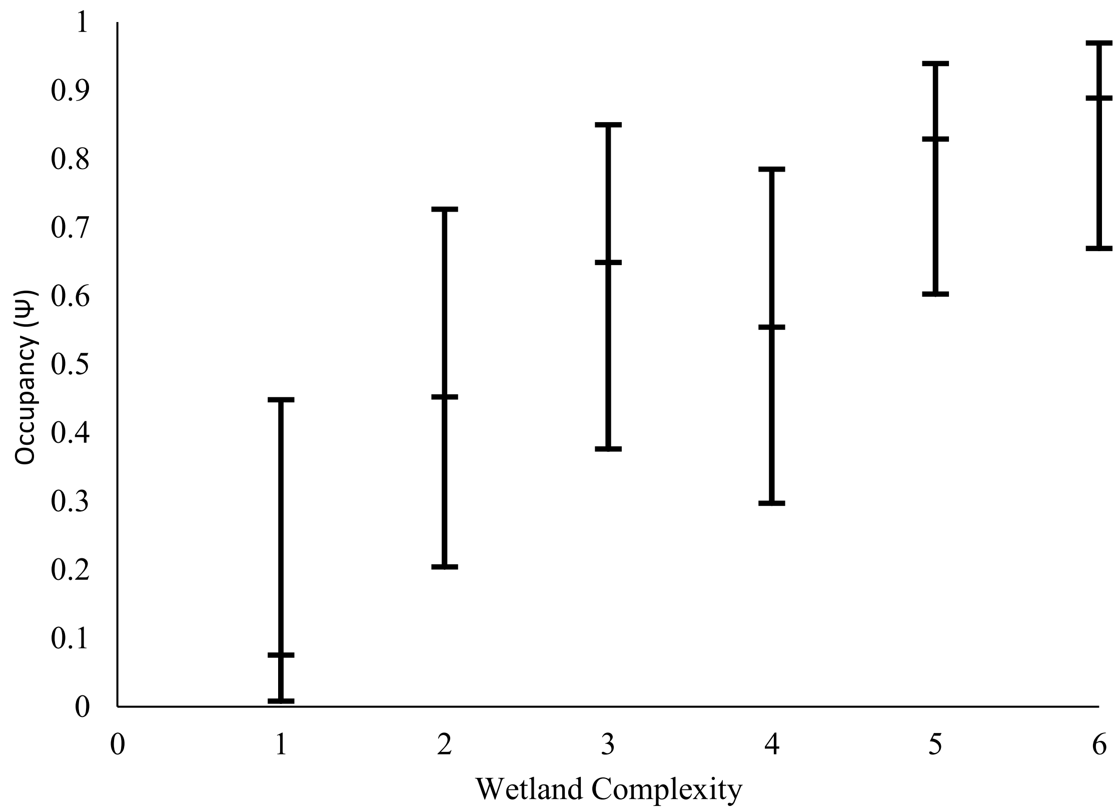

Figure 9. Predicted probability (95% confidence limits) of site occupancy for the emergent marsh bird group (*Botaurus lentiginosus*, *Ixobrychuc exilis*, *Porzana carolina*, *Rallus elegans*, *Rallus limicola*, and *Coturnicops novemoracensis*) across wetland complexity levels in Illinois during late spring and early summer 2015–2017. Wetland survey period (round 2), percent surface water inundation (50%), and percent cover of persistent emergent vegetation (50%) were held constant.

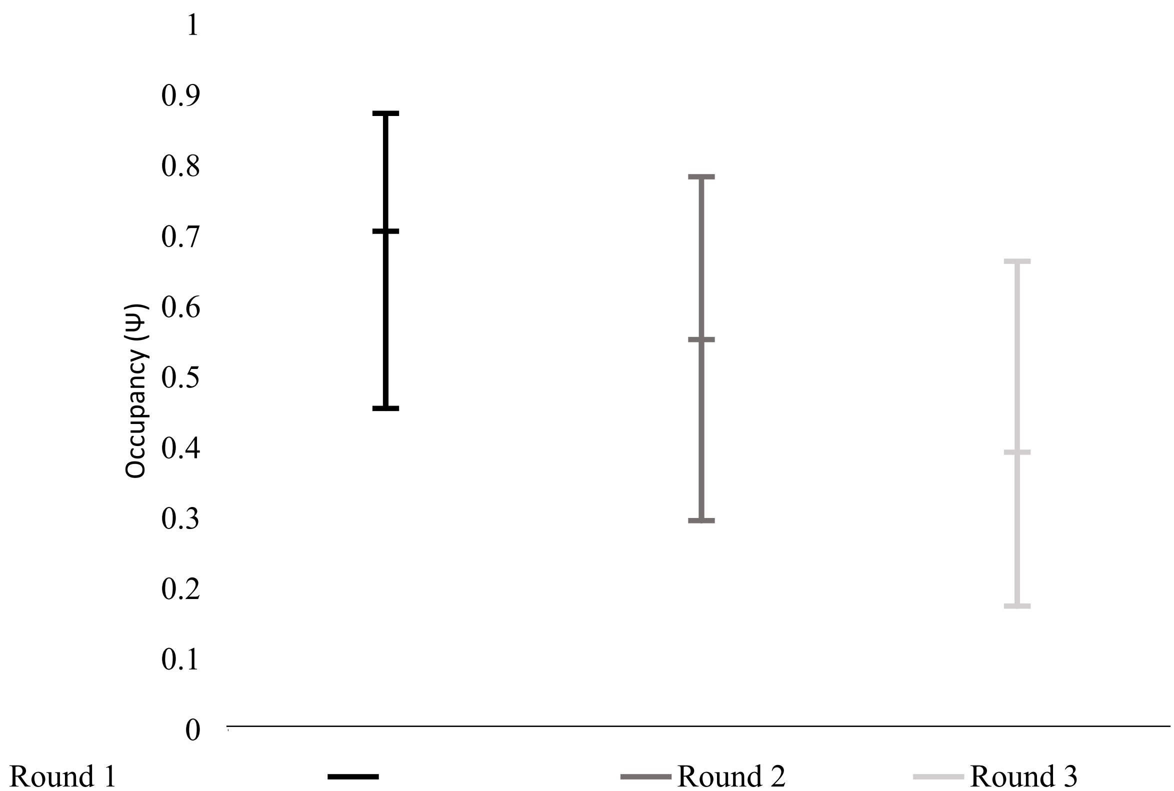

Figure 10. Predicted probability (95% confidence limits) of site occupancy for the emergent marsh bird group (*Botaurus lentiginosus*, *Ixobrychuc exilis*, *Porzana carolina*, *Rallus elegans*, *Rallus limicola*, and *Coturnicops novemoracensis*) among survey rounds in Illinois during late spring and early summer 2015–2017. Wetland complexity (level 4), percent wetland inundation (50%), and percent cover of persistent emergent vegetation (50%) were held constant.

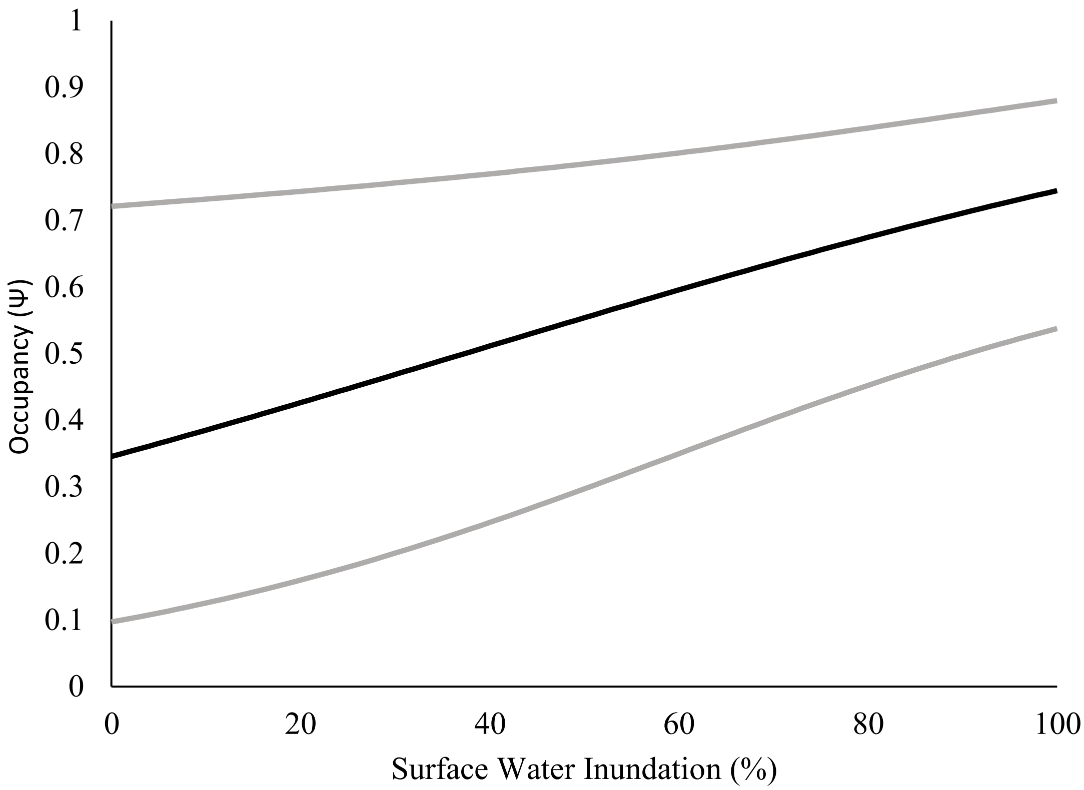

Figure 11. Predicted probability (95% confidence limits) of site occupancy for the emergent marsh bird group (*Botaurus lentiginosus*, *Ixobrychuc exilis*, *Porzana carolina*, *Rallus elegans*, *Rallus limicola*, and *Coturnicops novemoracensis*) across percent surface water inundation in Illinois during late spring and early summer 2015–2017. Wetland survey period (round 2), wetland complexity (level 4), and percent cover of persistent emergent vegetation (50%) were held constant.

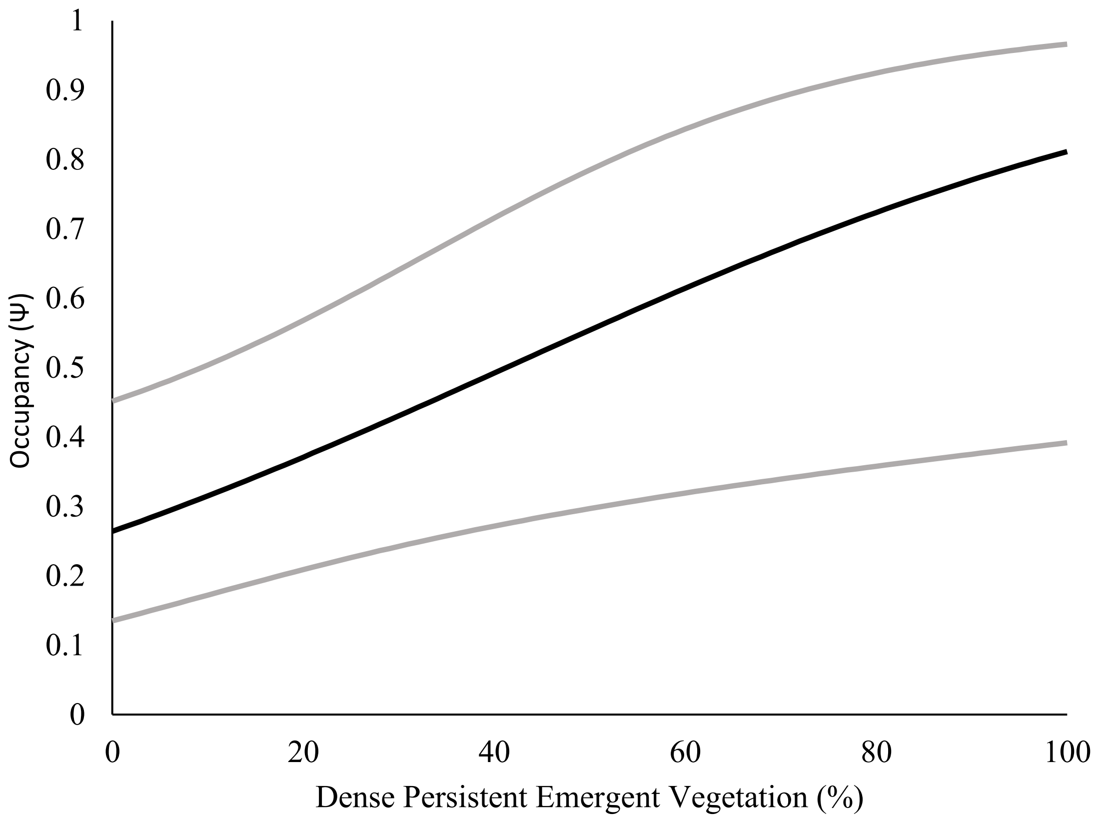

Figure 12. Predicted probability (95% confidence limits) of site occupancy for the emergent-associated marsh bird group (*Botaurus lentiginosus*, *Ixobrychuc exilis*, *Porzana carolina*, *Rallus elegans*, *Rallus limicola*, and *Coturnicops novemoracensis*) across wetland percent cover dense persistent emergent percentages in Illinois, 2015–2017.

Wetland complexity (level 4), wetland survey period (round 2), and surface water inundation (50%) were held constant.

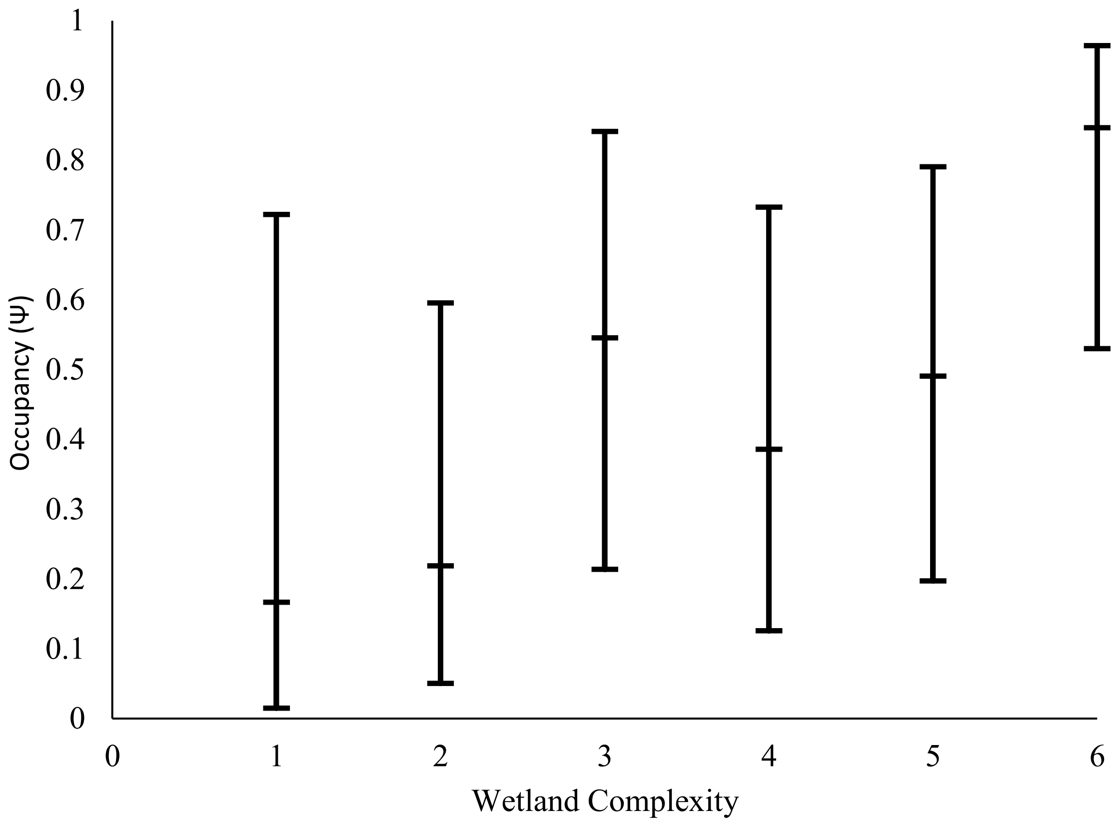

Figure 13. Predicted probability of occupancy for the open water marsh bird group (*Fulica americana*, *Gallinula galeata*, and *Podilymbus podiceps*) across wetland complexity levels in Illinois during late spring and early summer 2015–2017. Site type (National Wetland Inventory) and waterfowl management intensity (level 3) were held constant.

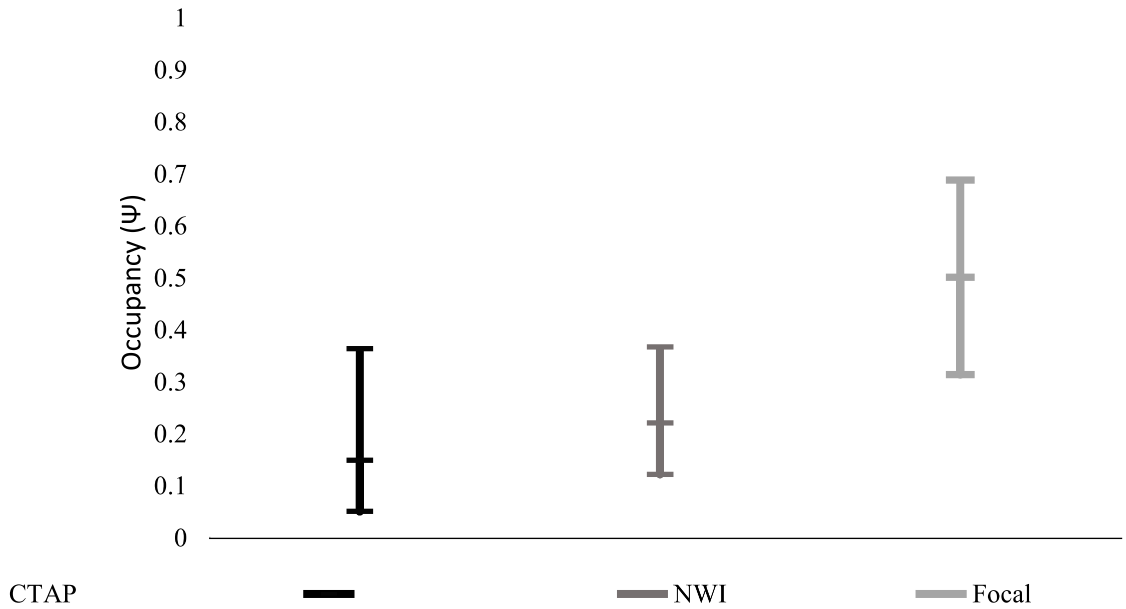

Figure 14. Predicted probability (95% confidence limits) of occupancy for the open water marsh bird group (*Fulica americana*, *Gallinula galeata*, and *Podilymbus podiceps*) across wetlands managed for waterfowl (focal), Critical Trends Assessment Program (CTAP), and National Wetland Inventory (NWI) site types in Illinois during late spring and early summer 2015–2017. Wetland complexity (level 4) and waterfowl management intensity (level 3) were held constant.

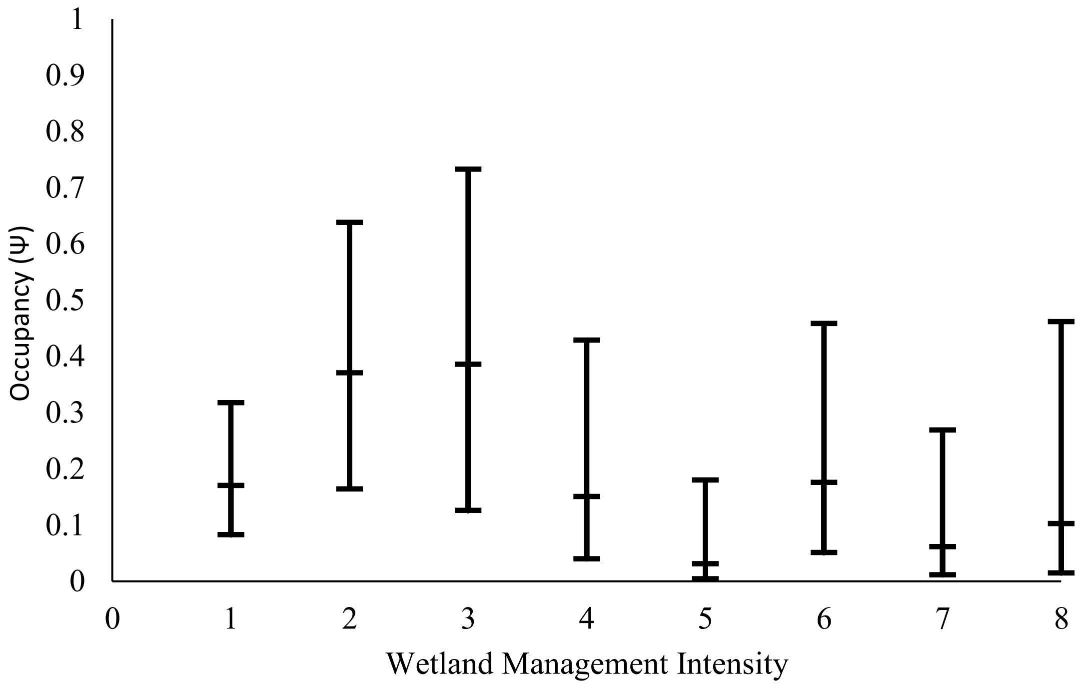

Figure 15. Predicted probability (95% confidence limits) of occupancy for the open water-associated marsh bird group (*Fulica americana*, *Gallinula galeata*, and *Podilymbus podiceps*) across wetland management intensities in Illinois during late spring and early summer 2015–2017. Wetland complexity (level 4) and wetland type (National Wetland Inventory) were held constant.

CHAPTER 2. FACTORS AFFECTING MARSH BIRD ABUNDANCE IN WETLANDS MANAGED FOR WATERFOWL IN ILLINOIS

ABSTRACT

It is widely assumed that waterfowl management activities benefit a variety of wetland dependent birds, but few studies have empirically evaluated those benefits or tradeoffs among multi-species management strategies. In particular, marsh birds are an understudied guild of migratory birds of conservation concern that can be valuable indicators of wetland health and may benefit from wetland management for waterfowl. I assessed marsh bird abundance in wetlands across Illinois to better understand how natural wetland characteristics, impoundment management for waterfowl, and surrounding landscape characteristics influence marsh bird abundance. During late spring and early summer 2015–2017, I repeatedly surveyed marsh birds at wetlands managed for waterfowl (i.e., focal) and reference sites (i.e., National Wetland Inventory [NWI] and Critical Trends Assessment Program [CTAP]) each year. I used distance sampling techniques to estimate marsh bird abundance corrected for imperfect detection and to evaluate competing hypothesis regarding the importance of particular wetland characteristics and management throughout Illinois. Detection probability decreased with ordinal date; the odds of marsh bird detection declined 10.7% ± 0.2 each week during the survey period. Marsh bird abundance varied positively with surface water inundation and cover of open water, but not with waterfowl management intensity or landscape effects.

Wetlands managed at intermediate levels on intensity, such as semi-permanent emergent marsh, can provide suitable habitat for waterfowl and marsh birds. Conservation planners and wetland managers seeking to increase marsh bird abundance while

maintaining suitable habitat for waterfowl and other waterbirds should restore or promote semi-permanently-flooded emergent marshes with abundant dense, persistent emergent vegetation that is shallowly flooded during the growing season.

INTRODUCTION

Marsh birds are a guild of wetland-dependent migratory birds associated with emergent vegetation communities (i.e., persistent and non-persistent emergent vegetation; Cowardin et al. 1979). Most species of marsh birds have experienced population declines in North America (Muller and Storer 1999, Conway 2011) which is thought primarily to be related to wetland loss and degradation (Gibbs et al. 1992, Meanley 1992, Darrah and Krementz 2010). For example, greater than 50% of wetlands were drained and converted to alternate land uses across the United States by the 1970s, with the greatest losses occurring in the Midwest (Tiner 1984; Harms and Dinsmore 2011, 2013). In response to wetland losses and marsh bird population declines, several species are listed as species of conservation concern at the state and regional levels (Lor and Malecki 2002, Conway and Gibbs 2005). With continued wetland losses, there is increasing pressure on extant wetlands to support marsh bird populations (Eddleman et al. 1988, Conway et al. 1994, Rehm and Baldassarre 2007). Furthermore, increased management of existing wetlands may be needed to sustain or increase marsh bird populations (Darrah and Krementz 2010).

Marsh birds are valuable indicators of wetland condition due to their sensitivity to particular vegetation communities and documented vulnerability to accumulation of environmental contaminants in wetland substrates which impact their aquatic invertebrate forage (Conway 2011). Due to their secretive natures and use of densely vegetated wetlands which are difficult to survey, many marsh bird species' population status, distribution, and life history requirements are undocumented (Glisson et al. 2017, Tozer et al. 2018). Additionally, few studies (Darrah and Krementz 2010, Bolenbaugh et al. 2011, Valente et al. 2011) have documented habitat associations of marsh birds in the Midwest, a historically important breeding area with great rates of wetland loss and degradation (Bolenbaugh et al. 2011, Wilson et al. 2018).

Several studies have documented effects of local-scale characteristics such as water-vegetation interspersion (Lor and Malecki 2006, Rehm and Baldassarre 2007) and vegetation density and height (Harms and Dinsmore 2011) on marsh bird site abundance. Moreover, landscape context and wetland surroundings (DeLuca et al. 2004) and size (Brown and Dinsmore 1986) may influence marsh bird abundance as they have for occupancy. However, previously reported habitat associations are highly variable in the Midwest, perhaps because habitat is limited (Harms and Dinsmore 2012). Understanding species-habitat relationships for species of conservation concern is critical because their recovery and persistence often depend on habitat protection and restoration (Darrah and Krementz 2010, Bolenbaugh et al. 2011, Guisan et al. 2013, Harms and Dinsmore 2013).

In Illinois, particularly within the Mississippi and Illinois River floodplains, many wetlands are managed using strategies to provide food and vegetation communities for waterfowl primarily during their fall migration (Havera 1999, DeStevens and Gramling 2012). Multiple studies suggest wetland management practices, including those associated with waterfowl management, may influence marsh bird abundance (Darrah and Krementz 2010, Bolenbaugh et al. 2011). For instance, Tozer et al. (2018) suggested that managed wetlands have greater marsh bird abundance than adjacent unmanaged wetlands. The Upper Mississippi River and Great Lakes Region (UMRGLR) Joint Venture and other conservation partners in the Midwest assume that landscape and site attributes (e.g., wetland management practices) important to waterfowl, especially dabbling ducks, also provide value to marsh birds; however, this assumption needs to be formally tested to guide wetland restoration and management for multi-species guilds in the Midwest (Soulliere et al. 2007).

Wetland management practices include the manipulation of ecosystem processes or attributes to create suitable habitat and/or desired conditions for target wildlife taxa (Gray et al. 2013). Wetland managers often impound low-lying areas using small levees and water control structures to increase the quantity and controllability of surface water during the growing season to encourage hydrophytic vegetation (e.g., *Echinocloa* spp., *Leptochloa* spp., *Polygonum* spp., *Scirpus* spp., *Typha* spp.). Hydrology is a primary driver of wetland vegetation communities (Gray et al. 2013, Lemke et al. 2017), and this characteristic influences wetland use by waterfowl and other wetland-dependent species, such as marsh birds. Studies have shown that some wetland management practices for waterfowl (e.g., moist-soil management) can provide suitable habitat for migrating and breeding marsh birds (Fournier 2017), but the degree to which a variety of waterfowl management practices influences marsh bird abundance across a large geographical area and diverse suite of wetland management practices is unknown.

Many techniques used to manage wildlife in upland areas are used in wetlands for waterfowl management, such as disking, herbicide application, and planting food plots using conventional agricultural practices. For example, encouraging annual, non- persistent emergent vegetation communities using practices that help maintain dominance of early-succession species is commonly known as moist-soil management (Fredrickson and Taylor 1982). Moist-soil management practices include periodic mowing, disking, herbicide applications, or other disturbances that encourage the growth of moist-soil plants. Managing for these non-persistent emergent vegetation communities is desirable because they produce a large amount of seed consumed by migrating waterfowl (Bowyer et al. 2005, Gray et al. 2013). However, moist-soil management and other waterfowl- management practices often discourage perennial species that provide greater structure and are associated with longer hydroperiods during the growing season.

In contrast to more intensive wetland management practices for waterfowl like planting food plots and moist-soil management, semi-permanent emergent marshes comprised of dense, persistent emergent vegetation (e.g., *Typha* sp.) interspersed with open water and other natural wetland communities can provide high-quality habitat for waterfowl and other waterbirds (Hagy et al. 2017, Hine et al. 2017, McClain et al. 2018). Whereas, moist-soil and other intensive wetland management practices employ annual and sometimes early (April–May) drawdowns to encourage non-persistent vegetation, longer hydroperiods which maintain surface water for multiple growing seasons in succession encourage more obligate plant species that cater to a different suite of

wetland-dependent birds than season wetlands (Gray et al. 2013). Burning, application of herbicides, and hydrology manipulations are the primary management practices used to create hemi-marsh conditions in semi-permanent emergent marshes (Gray et al. 2013, Hine et al. 2017). Hemi-marsh has been found to encourage waterfowl use by providing areas to feed and rest while being surrounded by cover (Weller and Spatcher 1965). The management of dispersed stands of persistent emergent vegetation also has been documented to provide cover and could benefit nesting marsh birds.

To better understand how wetland management practices for waterfowl affect marsh bird use of wetlands in the Midwest, USA, I estimated marsh bird abundance across a wide range of wetland vegetation conditions, hydrologic regimes, and waterfowl management practices in Illinois during late spring and early summer 2015–2017. My objectives were to 1) determine intrinsic characteristics of wetlands that influence marsh bird abundance, 2) compare marsh bird abundance in wetlands managed for waterfowl to reference wetlands, and 3) determine if marsh bird abundance differed by management intensity for waterfowl. My goal was to elucidate wetland management regimes currently used for waterfowl that were associated with greatest abundances of marsh birds in order to recommend strategies that benefit multiple taxa. I hypothesized that wetlands intensively managed for waterfowl (e.g., moist-soil) would have greater marsh bird abundance than reference wetlands comprised of a wide spectrum of conditions and management contexts (Fournier 2017). Additionally, I hypothesized that wetlands with high levels of vegetation to water interspersion would influence positively associated with marsh bird abundance consistent with previous tests of the hemi-marsh concept (Kaminski and Prince 1981).

METHODS

Study area

I monitored marsh birds using call-back surveys on both public and private land across Illinois during 2015–2017. During April, May, and June, average minimum temperatures in Illinois were 4.9, 11.0 and 16.2 (° C), average maximum temperatures were 17.7, 23.5 and 28.4 (° C), average temperatures were 11.3, 17.2, and 22.3 (° C), and average rainfall was 9.2, 10.6, and 11.0 cm (NCEI GIS Agile Team 2017). Illinois has lost approximately 90% of its wetlands (Dahl 2006) primarily to drainage and conversion to agricultural production. Agriculture comprises >76% of land use in Illinois, with corn and soybeans making up approximately 60%. Statewide, wetlands compose <4% of the landscape, with <1% in non-forested wetland cover (Luman et al. 2004)

Illinois lies within the heart of the Mississippi Flyway with breeding grounds of many migratory waterbirds primarily to the north and wintering grounds to the south. Illinois contains 14 natural divisions delimited by factors including topography, soils, bedrock, glacial history, and the distribution of plants and animals (Fig. 1). Illinois is also divided among three separate bird conservation regions (BCRs 22, 23, 24; Sauer et al. 2003). The Mississippi and Illinois River floodplains contain areas that have some of the greatest wetland density in Illinois (Blake-Bradshaw 2018). However, large portions of these floodplains have been isolated from the river system by levees and are managed for agriculture or to provide food for migrating waterfowl, primarily dabbling ducks (Anatini). In leveed portions of these floodplains, hydrology is managed so that little to no surface water is present during the growing season to encourage annual, moist-soil plants or allow planting of crops (e.g., corn, millet) which are flooded again during fall migration (Lemke et al. 2017). To a lesser extent, some areas are managed as more natural emergent marshes year-round to encourage production of emergent and submersed aquatic vegetation (e.g., cattail [*Typha* spp.], bulrush [*Scirpus* spp.], coontail [*Ceratophylum demersum*]). Managed wetlands are typically impounded on one or more sides by levees and have water control structures allowing hydrological manipulation consistent with management goals, such as moist-soil management. In particular, moist- soil management is the purposeful drawdown of water to expose seed bank and soil to promote germination of native early-succession, annual plants desirable for waterfowl (Gray et al. 2013). Often, water is drawn down in spring or early summer to promote vegetation growth, and vegetation is reflooded in the autumn to make seed available to migrating and wintering waterfowl (Fredrickson and Taylor 1982). These conditions may maximize food production for waterfowl (Bowyer et al. 2005), but drawdowns before migration and breeding seasons of marsh birds and exclusion of perennial species may not provide conditions suitable for marsh birds. Although many wetland conservation and restoration initiatives encourage multi-species design and management, waterfowl are often the primary focal group and little research is available to indicate how waterfowl management practices affect other migratory bird species (Eddleman et al. 1988, Fournier 2017).

Site selection

I surveyed marsh birds in wetlands managed primarily for migrating waterfowl (i.e., focal) and randomly-selected reference wetlands statewide. Reference wetlands included emergent polygons from the National Wetland Inventory (NWI) and wetlands included within the Illinois Natural History Survey's Critical Trends Assessment Program (CTAP). Wetlands less than 0.5 ha in size were not sampled as suggested in the North American Standardized Marsh Bird Survey Protocol (NASMBSP; Conway 2011), but also to enable optimal chances of marsh bird detection due to past research suggesting decreased marsh bird use of small wetlands (Brown and Dinsmore 1986).

I assembled a comprehensive sampling frame of potential focal wetlands managed for waterfowl within Illinois using previous studies (e.g., Bowyer et al. 2005, Stafford et al. 2011) and correspondence with Illinois Department of Natural Resources site managers and biologists, private landowners, and Illinois Natural History Survey staff. I defined waterfowl management to include manipulation of vegetation, hydrology, and soils (i.e., disking, planting, drawdowns; Kaminski et al. 2006) with the intent of increasing food production or habitat suitability for waterfowl (Fredrickson and Taylor 1982). I randomly selected 20 wetlands from the population of focal sites for sampling each year. If sites were unsuitable for marsh birds or were not managed for waterfowl during my first visit, I replaced those sites with another randomly-selected site from the sample population. Additionally, I non-randomly selected and sampled eight focal sites in all years of my study due to their location and accessibility, intermediate intensity management regimes, and history of restoration (e.g., The Nature Conservancy's Emiquon Preserve, Aitchison Waterfowl Refuge of Marshall State Fish and Wildlife Area).

For NWI wetlands, I stratified Illinois by natural division and selected sites proportionately by wetland density within natural divisions. I consolidated NWI polygons into 6 classes (Freshwater Pond, Lake, Freshwater Emergent [herbaceous only], Freshwater Scrub-Shrub/Forested, Riverine, and Other) and used total wetland area to determine the number of sample plots in each natural division using Neyman allocation (Neyman 1934). I used the Reversed Randomized Quadrant-Recursive Raster tool in ArcMap to assign plot locations within wetland area inside each natural division, which created a spatially-balanced sample population (Theobald et al. 2007, Tozer et al. 2018).

I reviewed ESRI base map aerial imagery to assess the presence of suitable emergent vegetation at all reference sites for marsh birds and created a sample population of potentially suitable sites each year (e.g., presence of emergent aquatic vegetation; Rehm and Baldassarre 2007). I randomly selected 20 sites from the resulting sample population for marsh bird surveys each year. If sites were unsuitable for marsh birds during my first visit (i.e., lacking inundation or emergent vegetation; Bolenbaugh et al. 2011, Blake- Bradshaw 2018), I replaced those sites with another randomly-selected site from the sample population.
Similar to NWI sites, I used aerial imagery to assess habitat suitability for marsh birds from 60 CTAP sites each year, and subsequently created a sample population of potentially suitable sites (Rehm and Baldassarre 2007). The CTAP monitors the biological condition of forests, wetlands, streams, and grasslands in Illinois using a sampling frame based on random selection of townships weighted by area for inclusion (Molano-Flores 2002). The CTAP annually selects a representative location within each aforementioned biological community (e.g., wetland) within 60 random townships. Sites are resampled on a 5-year schedule. I randomly selected 20 CTAP sites to survey for marsh bird occupancy each year. Because CTAP and NWI sample populations were based on different randomized procedures and spatial data, we assume they cumulatively represented a wide range of wetland conditions present in Illinois. If sites were deemed as likely unsuitable after reviewing aerial photographs of the site or site descriptions from previous CTAP visits or they were unsuitable for marsh birds during my first visit, I replaced those sites with another randomly-selected site from the sample population (Fig. 2). For CTAP and NWI sample populations, I assumed that sites deemed unsuitable

because they did not contain emergent vegetation were unoccupied by marsh birds (Blake-Bradshaw 2018).

Marsh bird surveys

Prior to marsh bird surveys, I established fixed sample points (*n* = 1–5) at each selected site with the number of points allocated to each wetland proportional to overall size. All sample points were located in areas that were efficiently accessible, within or adjacent to emergent aquatic vegetation, and spaced ≥ 400 m apart to reduce the chances of double counting individuals (Johnson et al. 2009, Conway 2011). I restricted the maximum number of survey points to 5 per site to allow observers to survey multiple wetlands in a single sampling period. I marked sample points with GPS coordinates and flagging tape to ensure consistency among survey periods.

Once survey routes were established, I surveyed all points among sites following the NASMBSP (Conway 2011), which incorporates a repeated call-back survey design. Call-back surveys can increase vocalization probability of secretive marsh birds, although secretive marsh birds may still be detected during passive surveys (Conway and Gibbs 2011, Glisson et al. 2017). Surveys encompassed the 100-m-radius circle from the marked point. I surveyed each point three times at bi-weekly intervals during 2015–2017 to create the encounter histories necessary to estimate probability of site occupancy and detection (MacKenzie et al. 2002). I conducted all surveys between one half hour before sunrise and 2 hr after sunrise (Bolenbaugh et al. 2011) and avoided heavy rains or high wind conditions to maximize detections (Conway 2011).

Following the NASMBSP, I used a 5-min passive survey and subsequent 1-min alternating series of 30 seconds of calls and 30 seconds of silence of least bittern

(*Ixobrychus exilis*), yellow rail (*Coturnicops noveboracensis*), black rail (*Laterallus jamaicensis*), king rail (*Rallus elegans*), Virginia rail (*Rallus limicola*), sora (*Porzana carolina*), common gallinule (*Gallinula galeata*), American bittern (*Botaurus lentiginosus*), American coot (*Fulica americana*), and pied-billed grebe (*Podilymbus podiceps*; Conway 2011). The order of calls was fixed and began with the least intrusive species and ended with the most intrusive species following the NASMBSP (Ribic et al. 1999, Conway 2011). I broadcasted calls using electronic game callers (Western Rivers Pursuit, Maestro Game Calls, LLC., Dallas, Texas, USA; Primos Turbo Dogg, Primos Hunting, Flora, Mississippi, USA). During call-broadcast surveys, I pointed game callers toward emergent vegetation and repeated subsequent surveys at each point using the same cardinal direction. Calls were broadcasted at a volume of 80–90 dB with the observer positioned 1 meter from the game caller (Conway 2011). Because Illinois encompasses two survey zones according to the NASMBSP (Fig. 3; Conway 2011), surveys began two weeks later in the northern half of the state (i.e., southern zone start date = 15 April, northern zone start date = 1 May).

During marsh bird surveys, I identified individuals to species by sight or sound. To account for variation in detection probability, I also recorded variables such as wind speed using the Beaufort scale (values 0–5), temperature (° C), cloud cover representing severity of weather (values 0–7), background noise intensity (values 0–4), and the name of the observer(s) as factors (Conway 2011). Prior to conducting surveys, I trained observers on field protocols, bird identification, and estimating distances to calling birds through in-person training sessions, detailed guidebooks, and audiovisual media (Nadau and Conway 2012, Glisson et al. 2017, Tozer et al. 2018).

Wetland conditions

Following all call-back surveys within a site, I evaluated wetland conditions at each sample point and across the site (Table 1). At the site level, I assessed the intensity of waterfowl management activities (1 [no waterfowl management; e.g., no evidence of active water manipulation or vegetation management] – 8 [very intense waterfowl management; e.g., annual soil disturbance, disking and planting food plots, etc.]; Fig. 4), wetland complexity/interspersion (1 [homogeneous] – 6 [high heterogeneity]; Fig. 5), wetland connectivity (1 [isolated from other wetland] – 8 [adjacent and connected to other wetlands]), and anthropogenic disturbance using the Ohio Rapid Assessment Method (ORAM). The ORAM procedure includes potential stressors and indicators of wetland condition, including metrics indicative of wetland quality for marsh birds under a wide variety of modified conditions specific to the Midwest region (e.g., management of hydrology, presence of water control structures, drawdown timing, urban development, adjacent agricultural land use; Blake-Bradshaw 2018). At each sample point, I assessed percent cover by vegetation type, including dense persistent emergent, non-persistent emergent, scrub-shrub, forested, non-rooted floating aquatic vegetation, open water, and aquatic bed (i.e., floating-leaved and submersed aquatic vegetation). At this scale, I also visually assessed average water depth within four depth ranges dependent on known water bird feeding guilds (1= dry, 2: very shallow <10 cm, 3: shallow <45 cm, 4: deep > 45 cm) and percent surface water inundation across the surveyed area (Conway 2009, Harms and Dinsmore 2013).

Data analysis

To increase sample size for analyses, I estimated abundance of marsh birds with similar habitat requirements by grouping species based on taxonomical similarity, patterns of habitat use, and relevance to management (Bolenbaugh et al. 2011). Marsh bird groups included 'emergent' (i.e., least bittern, American bittern, black rail, king rail, sora, Virginia rail, and yellow rail) and 'open water' (i.e., American coot, common gallinule, and pied-billed grebe; Bolenbaugh et al. 2011). I estimated abundance and detection probability of marsh birds across sites by conducting distance sampling analysis using the *distsamp* function in the unmarked package for program R, version 3.1 (Fiske et al. 2011, R Core Team 2014). An important assumption regarding detection probability through distance analysis is that detection probability decreases as distance from the observer increases (Conway 2011). In order to reduce variation in distance measurements, I assigned raw distances into bins (0 m–50 m, 51 m–75 m, 76 m–100 m).

I used a two-step modeling process by which covariates for detection (p) were modeled first while holding abundance constant at the null. I then used the top model for detection in all subsequent models for abundance (Kroll et al. 2010, Harms and Dinsmore 2013). I assessed correlation among the site-specific covariates by constructing a correlation matrix prior to analysis and removed correlated variables ($|r| > 0.5$; Harms and Dinsmore 2013). I modeled habitat variables individually and then combinations of variables that received the most support to determine the best-supported combination (Harms and Dinsmore 2013). I compared candidate models using Akaike's Information Criterion (AIC; Burnham and Anderson 2002). AIC tables and effect sizes were generated using the *modSel* function in package unmarked (Fiske et al. 2011; R Core Team 2014). I considered models ≤2 ΔAIC to be competitive (Burnham and Anderson

2002). I estimated 95% confidence intervals (CI) for detection probability and expressed standard error (±) of categorical factor levels.

RESULTS

During 2015–2017, I conducted 1,033 call-back surveys at 380 points consisting of 150 points within NWI sites, 183 points within focal sites, and 47 points within CTAP sites. Overall, I recorded 3,680 detections across nine marsh bird species, and most (71.3%) detections were recorded at distances between 0 m and 50 m. American coot were most commonly detected (61.3%) species, followed by sora (26.7%), pied-billed grebe (5.5%), common gallinule (2.5%), Virginia rail (1.5%), least bittern (1.4%), American bittern (0.9%), king rail (0.2%), and yellow rail (0.1%). Within the emergent group sora represented most of the detections (87.1%), followed by Virginia rail (4.9%), least bittern (4.4%), American bittern (2.9%), king rail (0.5%), and yellow rail (0.2%).

Within the open water group American coot represented most of the detections (88.5%), followed by pied-billed grebe (7.9%), and common gallinule (3.6%). I detected no black rail during my surveys (Table 2).

The best supported model for detection probability included ordinal date. Ordinal date was negatively associated with detection probability for both emergent (Table 3) and open water groups (Table 4). For instance, detection declined 6.9% (95% CI = 3.6 – 10.2) for the emergent and 6.2% (95% CI = 3.3–12.2) for the open water group for every week delay in marsh bird survey (Fig. 6, 7).

The best supported model predicting abundance of the emergent group included surface water inundation, dense emergent vegetation, waterfowl management intensity, and wetland complexity (Table 5). Abundance increased by 0.20 (95% CI = 0.09 – 0.31) for each 1% increase in surface water inundation (Fig. 8) and abundance increased by 0.14 (95% CI = 0.04 – 0.26) for each 1% increase in persistent emergent vegetation (Fig 9). Abundance was greatest at intermediate levels (levels 3–4) of waterfowl management intensity, but the effect size was small (Fig. 10). Abundance was greatest at the highest and intermediate levels of wetland complexity (Fig. 11), but no clear pattern existed across all levels of complexity.

The best supported model predicting the abundance of the open water group included surface water inundation, persistent emergent vegetation, and open water (Table 6). Abundance increased 0.20 (95% CI = 0.14–0.26) for every 1% increase in surface water inundation (Fig. 12), 0.20 (95% CI = 0.12–0.25) for every 1% increase in dense emergent vegetation (Fig. 13), and 1 (0.13–0.28) for every 1% increase in open water (Fig. 14).

DISCUSSION

I found no evidence that marsh bird abundance increased relative to waterfowl management practices that encourage annual, non-persistent emergent vegetation communities. Wetland characteristics such as wetland complexity, surface water inundation, and cover of persistent emergent vegetation were better predictors of marsh bird abundance in my study than management intensity or landscape effects. In the Midwest where suitable habitat is extremely limited (Blake-Bradshaw 2018), intensively managed wetlands for waterfowl probably do not benefit most species of marsh birds.

In contrast with intensively-managed wetlands for waterfowl implementing early and annual drawdowns, perennial, emergent vegetation flooded during the growing season provides marsh birds with dense cover for nesting and foraging (Darrah and

Krementz 2010). Multiple species require a diverse supply of resources for nesting and foraging, and more complex aggregations of wetlands have the potential to provide a diverse supply of resources (Darrah and Krementz 2010). Several studies have demonstrated that a mixture of wetland cover types, particularly open water interspersed with vegetation, yield the greatest abundance and density of invertebrates and potentially provide the greatest food resources for marsh birds (Kaminski and Prince 1981, Reid 1989).

Although there was not strong evidence that sites managed for waterfowl (i.e., focal) were substantially influential on marsh bird abundance as they were for occupancy (Chapter 1), intermediate levels of wetland management intensity for waterfowl seemed to have the greatest potential to increase marsh bird abundance. Throughout the Midwest, moist-soil management is a common strategy to generate abundant energy-rich seeds to be consumed by waterfowl during migration. A previous study found that encouraging non-persistent emergent vegetation including moist-soil plants such as smartweeds (*Polygonum* spp.), barnyardgrass (*Echinochloa* spp.), sedges (*Cyperus* spp.), and rushes (*Juncus* spp.) resulted in greater marsh bird abundance compared to areas without those moist-soil plants (Fournier 2017, Wilson et al. 2018). Moist-soil plants and dense, persistent emergent vegetation most often occurred in intermediate management strategies my study (Fig. 4). Both management strategies often co-occurred with observations of levees with embedded water control structures which seemed to be good indicators of waterfowl management activities in general. Anecdotally, marsh bird use was greatest in moist-soil wetlands with lower levels of management intensity (e.g., disking or major disturbances at 2–4 year intervals and mid- to late-summer drawdowns) and semi-permanent marshes with greater levels of intensity (e.g., drawdowns 4-6 year intervals, control of invasive species such as *Phragmites australis*).

For example, I noticed that several sites managed as emergent marshes consistently had more detections than other sites, such as the Nature Conservancy's Emiquon Nature Preserve and The Wetland Initiative's Dixon Waterfowl Refuge at Hennepin and Hopper Lakes. Both of these sites were larger than most other sites and maintained suitable water levels during the growing season to encourage dense, persistent emergent vegetation, such as *Typha* spp. The sites were classified at intermediate levels of waterfowl management intensity in this study. Compared to other sites such as Illinois Department of Natural Resources' Carlyle Lake impoundments that were more intensively managed (i.e., food plots and annual moist-soil plants) using spring drawdowns. The presence of levees at most intermediately-managed sites facilitated water retention during the growing season and protected against flooding in floodplains which can be persistently high during the growing season leading to unsuitable growing conditions for vegetation (Hine et al. 2017, McClain et al. 2018). In other studies, semi- permanent marshes have been found to support diverse populations of flora and fauna, including waterfowl (Hine et al. 2017, Hagy et al. 2017). Large-scale restoration of semi-permanent marshes has the potential to support marsh-bird populations in the Midwest and in otherwise degraded landscapes.

More intensive management strategies, such as planting agricultural grains (e.g., corn, grain sorghum) to produce food for migrating waterfowl, requires an early drawdown to enable managers to till the soil for planting and an adequate window for plants to mature prior to flooding in the fall. Thus, wetland managers planting food plots typically remove water shortly after the waterfowl spring migration, and this drawdown timing coincides with spring migration of most marsh bird species (April–May; Fredrickson and Taylor 1982). Thus, intensive management for waterfowl that includes early, annual drawdowns or exclusion of perennial emergent vegetation also reduces marsh bird use (Harms and Dinsmore 2013). Conversely, wetlands that were more passively managed and occurred at the low end of the intensity ranking scale often contained monocultures of non-native invasive species (e.g., reed canarygrass [*Phalaris arundinacea*]) or vegetation that is unsuitable for marsh birds (e.g., woody species [e.g., *Cephalanthus occidentalis*., *Salix* spp., *Fraxinus* spp.]) and also had low abundances.

Previous studies have noted that the probability of detecting marsh birds varied by time of day, survey date, levels of background noise and weather (Rehm and Baldassarre 2007, Conway and Gibbs 2011). My results indicated varying detection probability across ordinal date, suggesting that marsh birds became more difficult to detect, or their calling behavior changed through the survey period. Decreased detections could be caused by decreased vocalizations as the breeding season progresses (Rehm and Baldassarre 2007, Tozer et al. 2018), but information about vocal behavior during migration is limited. However, Kaufmann (1989) observed that marsh birds gave similar vocalizations during migration and breeding periods suggesting that vocalization should have been similar through our survey periods which ended prior to breeding for most species. Alternatively, species composition and their willingness to call or the detectability of species-specific calls may also contribute the changes in detection rate over the duration of surveys. Other factors predicted to influence detection, such as the time of the survey or weather conditions, were less important than ordinal date in this study.

MANAGEMENT IMPLICATIONS

Land managers targeting multiple species of migratory wetland-dependent birds need to supply a variety of habitat resources to meet the differing needs of each species by managing for high wetland complexity, when possible. Marsh birds, in general, require extensive stands of dense, emergent vegetation, interspersed with open water.

This interspersion increases cover and food resources that encourage use by a diverse suite of marsh bird species. Management strategies, such as moderate-intensity moist- soil or semi-permanent marsh management, could provide the habitat resources beneficial to marsh birds and waterfowl. Wetland managers should ensure that some wetlands are inundated during late spring and early summer for migrating and breeding marsh birds and use intense practices, such as producing agricultural grains, sparingly if multi-species management is a priority.

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Table 1. List of factors and the corresponding units used to run distance abundance model in Illinois, 2015–2017.

Model Group	Factors	Units/Scale
Detection	Time Relative to Sunrise	Minutes
	Temperature	Degrees Celsius
	Sky	0–8
	Wind	0–5
	Background Noise	0–4
	Observer (s)	Observer
	Ordinal Date	108–168 (April 18 – June 16)
	Year	2015-2017
Abundance	Waterfowl Management Intensity	1–8
	Wetland Complexity	1–6
	Connectivity to Rivers or Streams	0–7
	Management Category	Unmanaged, Passive, Active
	Survey Period	1, 2, 3
	Survey Region	North or South
	Wildlife Management Intensity	0–7
	Site Type[a]	CTAP, NWI, Focal
	Water Depth	0–4
	Surface Water Inundation	% of Survey Point
	Aquatic Bed	% of Survey Point
	Dense Persistent Emergent Vegetation	% of Survey Point
	Non-persistent Emergent Vegetation	% of Survey Point
	Shrub-Scrub	% of Survey Point
	Forested	% of Survey Point
	Open Water	% of Survey Point
	Natural Division	ArcGIS Layer
	Within Strict Protected Area	ArcGIS Layer
	Developed Surrounding Land Use	ArcGIS Layer
	Agriculture Surrounding Land Use	ArcGIS Layer
	ORAM Factors	ORAM Scores

[a]Critical Trends Assessment Program (CTAP), National Wetland Inventory (NWI), Managed for waterfowl (Focal)

Table 2. Raw number of marsh bird detections across focal sites managed for waterfowl and reference sites (Critical Trends Assessment Program [CTAP] and National Wetland Inventory [NWI]) in Illinois during late spring and early summer 2015–2017.

	CTAP			NWI			Focal			Total		
Species	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**
Black rail, *Laterallus jamaicensis*	0	0	0	0	0	0	0	0	0	0	0	0
Least bittern, *Ixobrychus exilis*	0	0	0	7	0	9	12	4	18	19	4	27
Yellow rail, *Coturnicops noveboracensis*	0	0	0	0	0	0	1	1	0	1	1	0
Sora, *Porzana carolina*	3	13	7	137	61	128	176	196	264	316	270	397
Virginia rail, *Rallus limicola*	3	0	0	10	10	7	5	8	12	18	18	19
King rail, *Rallus elegans*	0	0	0	0	0	0	3	0	3	3	0	3
American bittern, *Botaurus lentiginosus*	0	0	0	22	2	3	1	3	2	23	5	5
Common gallinule, *Gallinula galeata*	0	0	0	1	0	1	23	28	39	24	28	40
American coot, *Fulica americana*	3	0	0	136	22	6	640	864	585	779	886	592
Pied-billed grebe, *Podilymbus podiceps*	4	1	0	13	2	5	93	34	50	110	37	55
Total	13	14	7	326	97	159	954	1,138	973	1,293	1,249	1,138

Table 3. Model rankings for variables predicting detection probability of the emergent group of marsh birds based on Akaike's Information Criterion (AIC), difference in AIC relative to the top model (ΔAIC), relative model weight (w_i), and number of parameters (K) from surveys conducted at focal wetlands managed for waterfowl and reference wetlands throughout Illinois during late spring and early summer 2015–2017.

Model[a]	**AIC**	**ΔAIC**	w_i	**K**
ordinal date	4895.6	0.0	1.0	3
temperature	5142.6	246.9	0	3
background noise	5218.5	322.9	0	6
survey region	5221.5	325.8	0	3
sky cover	5229.3	333.6	0	8
wind	5239.1	343.4	0	7
year	5241.1	345.5	0	4
null (intercept only)	5273.2	377.6	0	2

[a] For all models, the abundance parameter was held constant at the null.

Table 4. Model rankings for variables predicting detection probability of the open water group of marsh birds based on Akaike's Information Criterion (AIC), difference in AIC relative to the top model (ΔAIC), relative model weight (w_i), and number of parameters (K) from surveys conducted at focal wetlands managed for waterfowl and reference wetlands throughout Illinois during late spring and early summer 2015–2017.

Model	**AIC**	**ΔAIC**	w_i	**K**
ordinal date	10535.0	0.0	1.0	3
sky cover	11132.0	597.0	0.0	3
survey region	11175.3	640.3	0.0	6
wind	11175.7	640.7	0.0	3
year	11194.3	659.3	0.0	8
background noise	11201.0	666.0	0.0	7
null (intercept only)	11276.5	741.5	0.0	4
temperature	12823.9	2288.9	0.0	2

Table 5. Model rankings for variables predicting abundance of the emergent group of marsh birds based on Akaike's Information Criterion (AIC), difference in AIC relative to the top model (ΔAIC), relative model weight (w_i), and number of parameters (*K*) from surveys conducted at focal wetlands managed for waterfowl and reference wetlands throughout Illinois during late spring and early summer 2015–2017.

Model[a,b]	**AIC**	**ΔAIC**	w_i	**K**
PIN + PDP + FWL + CPX	4268.1	0.00	1.0	17
PIN + FWL + CPX	4326.2	58.1	0.0	16
PIN + PDP + FWL	4337.0	68.9	0.0	11
PDP + FWL + CPX	4353.9	85.8	0.0	16
PIN + PDP + CPX	4389.8	121.6	0.0	11
PIN + FWL	4419.5	151.4	0.0	10
PDP + FWL	4420.7	184.3	0.0	10
PIN + CPX	4452.4	227.5	0.0	10
PDP + CPX	4495.6	231.9	0.0	10
PIN + PDP	4500.0	267.3	0.0	5
FWL + CPX	4535.4	321.6	0.0	15
PIN	4589.7	348.1	0.0	4
NULL	5273.2	1005.1	0.0	2

[a] All distance models presented contained the variable ordinal date in detection probability
[b] PIN = Percent Inundation, PDP = Percent cover dense persistent emergent vegetation, FWL = waterfowl management intensity, CPX = wetland complexity, and NULL = intercept only.

Table 6. Model rankings for variables predicting abundance of the open water group of marsh birds based on Akaike's Information Criterion (AIC), difference in AIC relative to the top model (ΔAIC), relative model weight (w_i), and number of parameters (K) from surveys conducted at focal wetlands managed for waterfowl and reference wetlands throughout Illinois during late spring and early summer 2015–2017.

Model[a,b]	**AIC**	**ΔAIC**	w_i	**K**
PIN + PDP + OPE	9478.1	0.0	0.7	17
PIN + PDP + OPE + DEE	9479.9	1.8	0.3	16
PIN + OPE + DEE	9535.2	57.1	0.0	11
PIN + OPE	9537.0	58.8	0.0	16
PDP + OPE + DEE	9705.8	227.7	0.0	11
PDP + OPE	9722.7	244.6	0.0	10
PIN + PDP + DEE	9740.1	262.0	0.0	10
PIN + DEE	9741.4	263.3	0.0	10
PIN	9759.6	281.5	0.0	10
PIN + PDP	9769.5	291.4	0.0	5
OPE + DEE	10069.3	591.2	0.0	15
OPE	10096.1	618.0	0.0	4
NULL	11276.48	1798.37	0.0	2

[a] All occupancy models presented contained the variable ordinal date in detection probability
[b] PIN = percent inundation, PDP = percent cover dense persistent emergent vegetation, OPE = percent cover open water, DEE = percent cover deep water (>45cm), and NULL = intercept only.

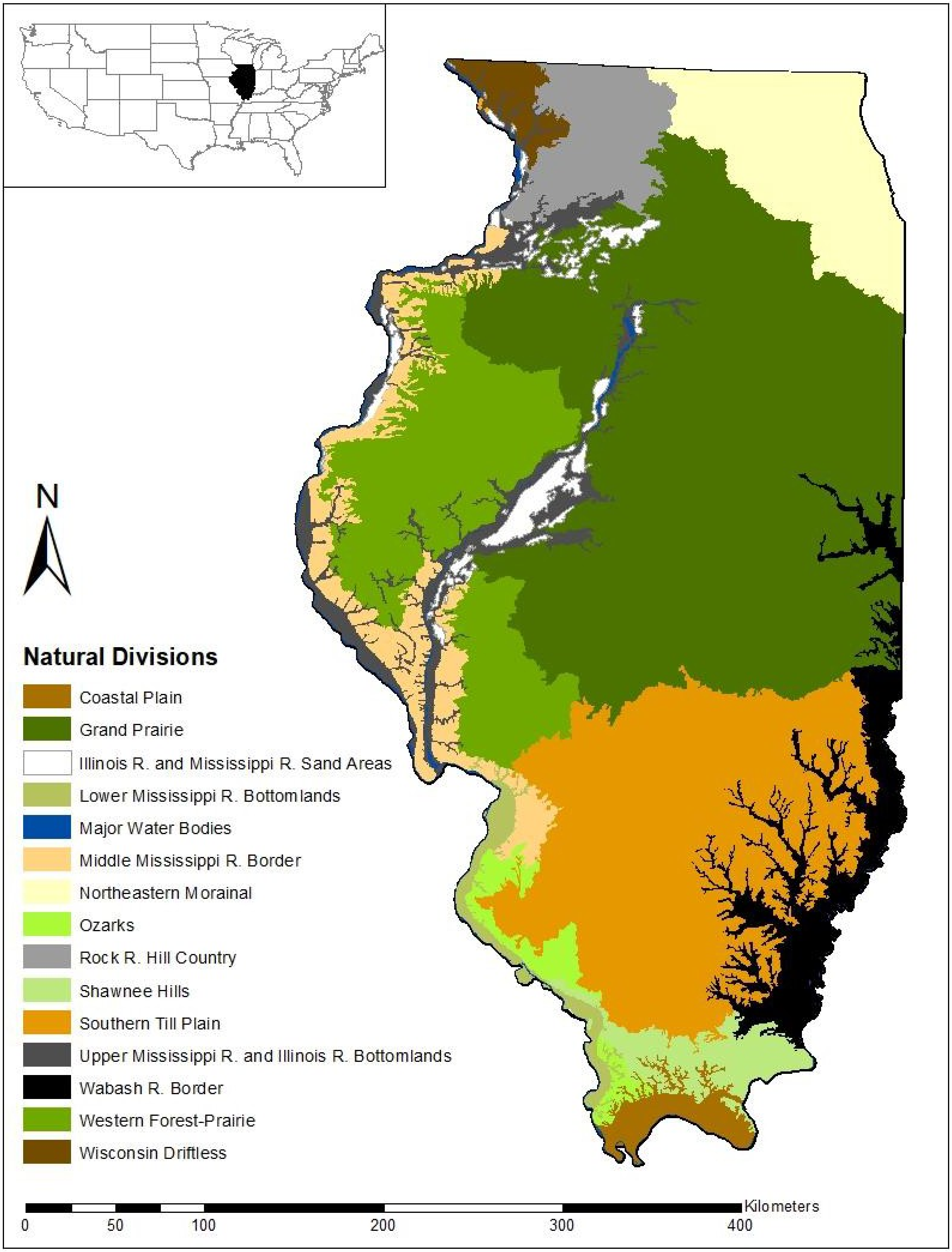

Figure 1. State of Illinois natural divisions (Schwegman 1973) used to establish survey effort dependent on wetland density in each natural division.

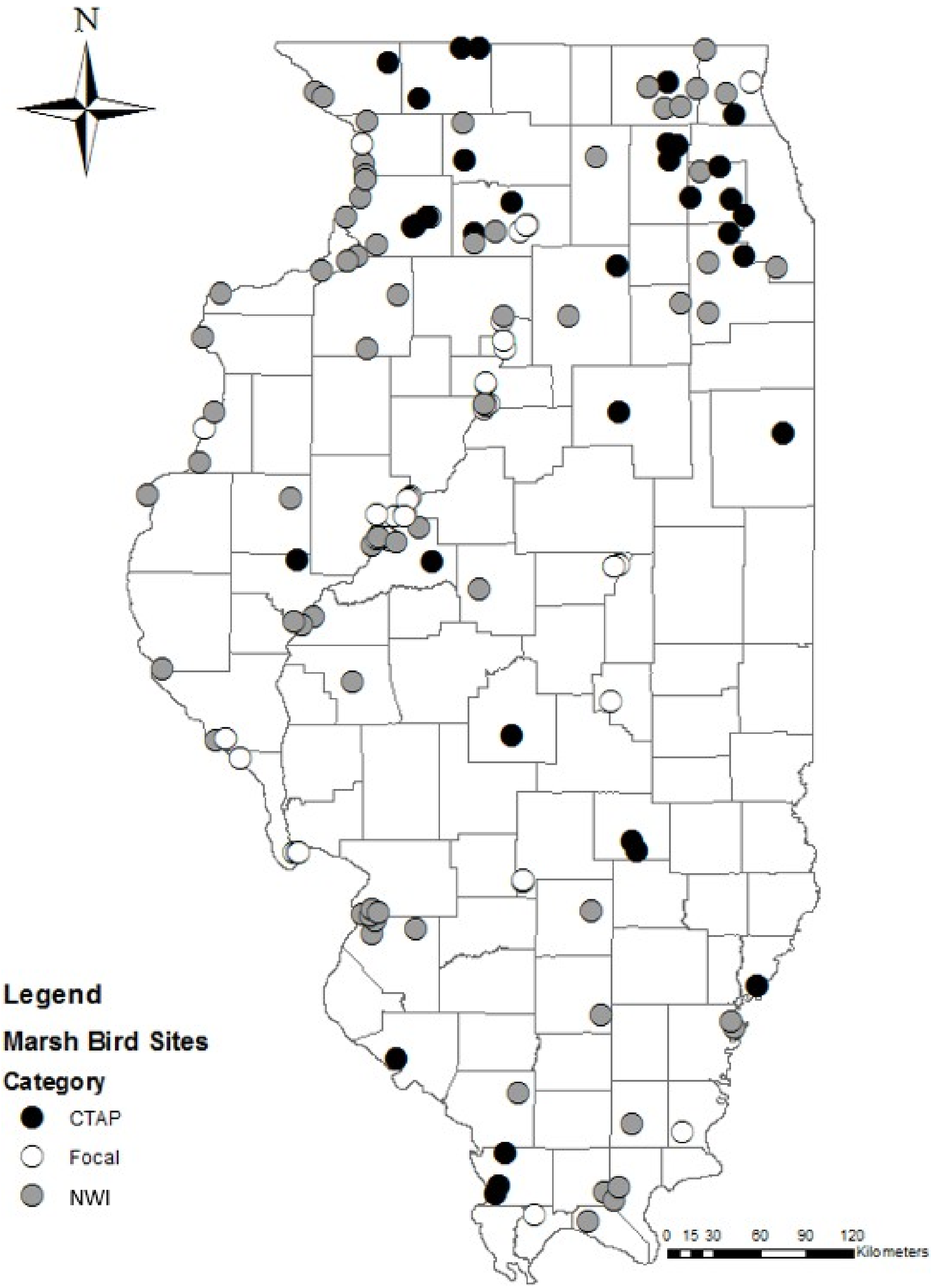

Figure 2. State of Illinois counties with wetlands (n = 160 sites) surveyed for marsh birds during breeding seasons of 2015 – 2017. Each site consisted of 1 – 5 points surveyed 3 times during a 6-week period. Sites consisted of National Wetland Inventory (NWI; grey), focal (white), and Critical Trends Assessment Program (CTAP [black]) wetlands.

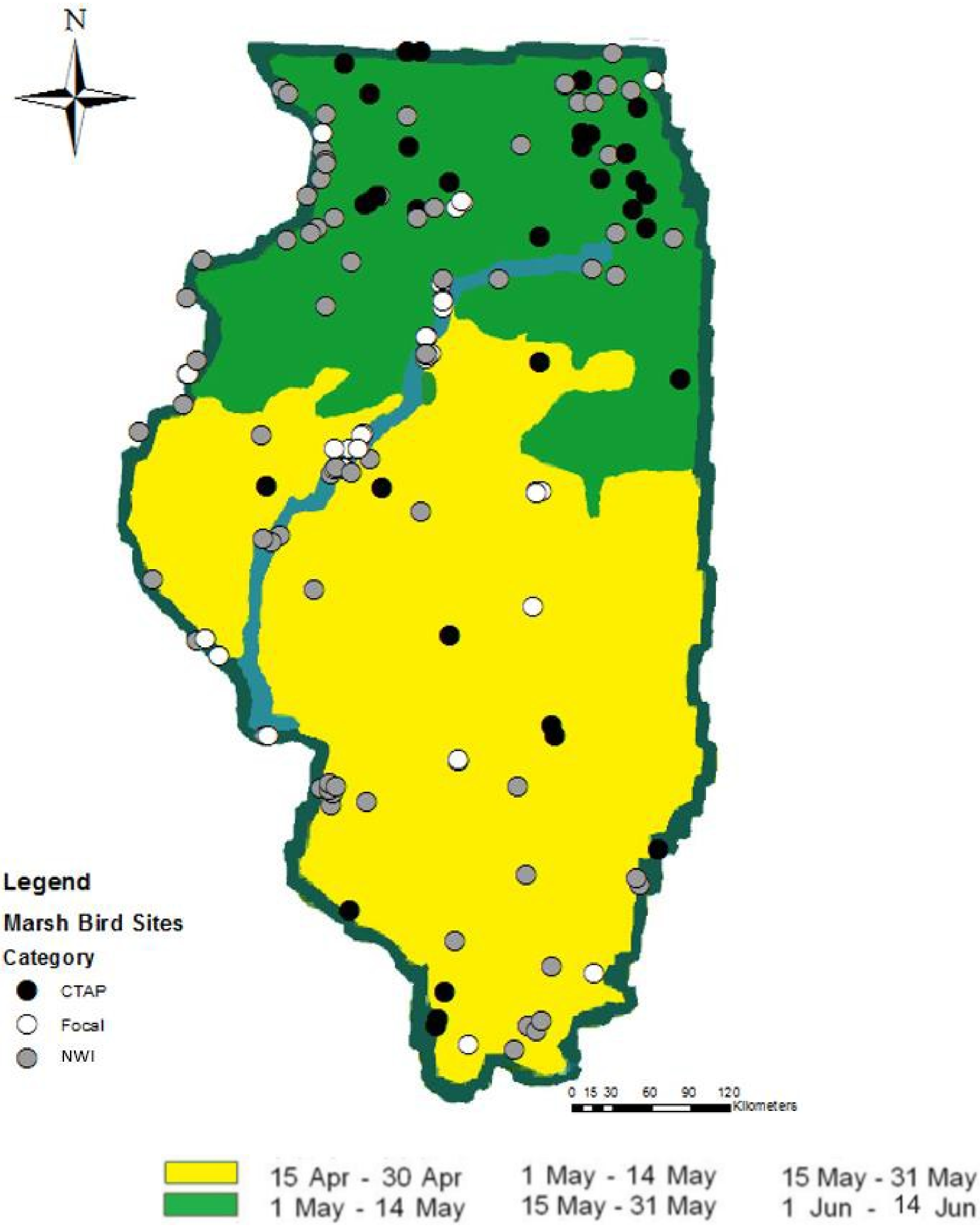

Figure 3. Marsh bird survey dates for two disparate regions of Illinois categorized by average maximum temperatures in May from the PRISM Climate Group at Oregon State University (Conway 2011). Sites consisted of National Wetland Inventory (NWI; grey), focal (white), and Critical Trends Assessment Program (CTAP [black]) wetlands.

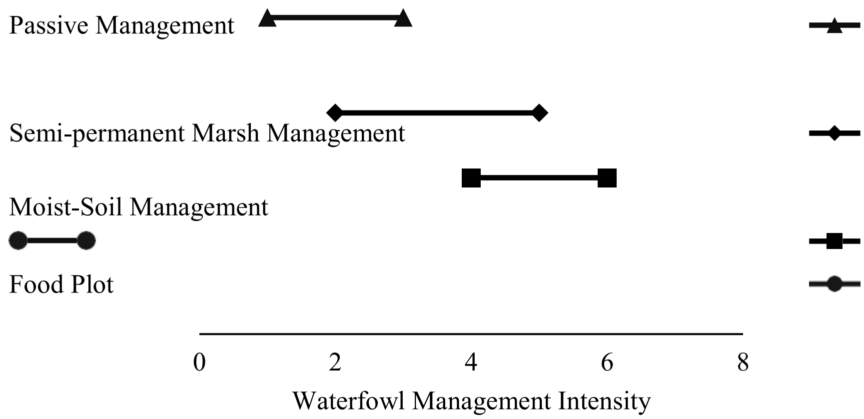

Figure 4. General guidelines used in this study to assist in determining waterfowl management intensity based on observed management strategies with least intensive (passive management) practices near 1 and intensive practices (food plots) at 8.

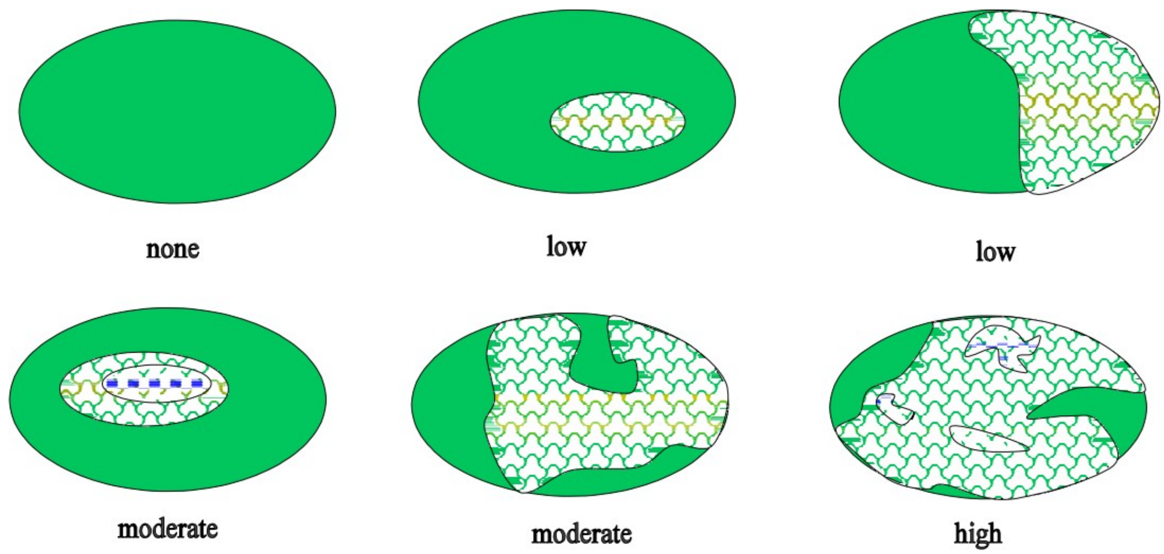

Figure 5. Hypothetical wetlands for estimating degree of complexity. None (1) wetland has no complexity consisting of one monotypic habitat, low (2) wetland has a low degree of complexity consisting of a small area of an additional habitat type, moderately low (3) wetland has a moderately low degree of complexity consisting of a larger area of an additional habitat type, moderate (4) wetland has a moderate degree of complexity consisting of multiple small additional habitat types, moderately high (5) wetland has a moderately high degree of complexity consisting of a large area of an additional habitat type and high edge density, and high (6) wetland has a high degree of complexity consisting of high edge density and more than one additional habitat type (Mack 2001).

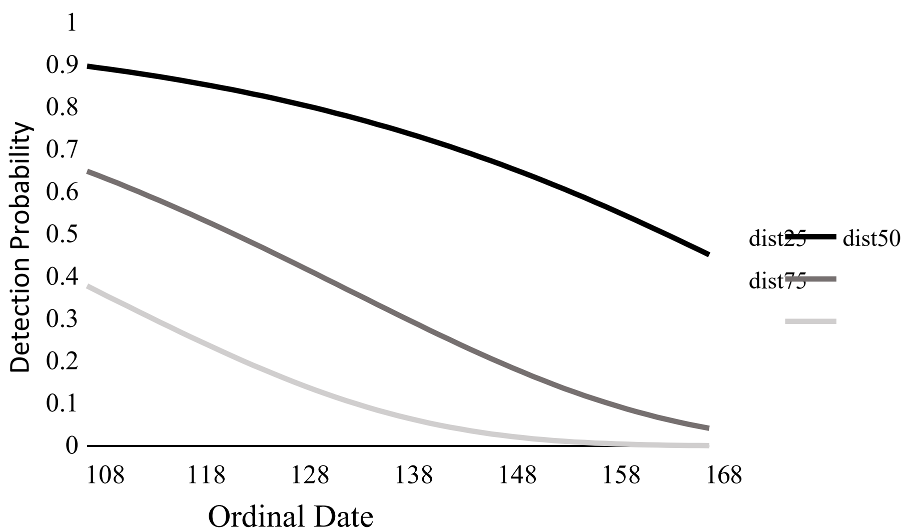

Figure 6. Model estimated detection probability at 25 meters (black line), 50 meters (dark grey line), and 75 meters for the emergent marsh bird group (*Botaurus lentiginosus*, *Ixobrychuc exilis*, *Porzana Carolina*, *Rallus elegans*, *Rallus limicola*, *Coturnicops novemoracensis*) from ordinal day 108 (April 15 or May 1, depending on latitude stratification) to ordinal day 168 during 2015–2017 in Illinois.

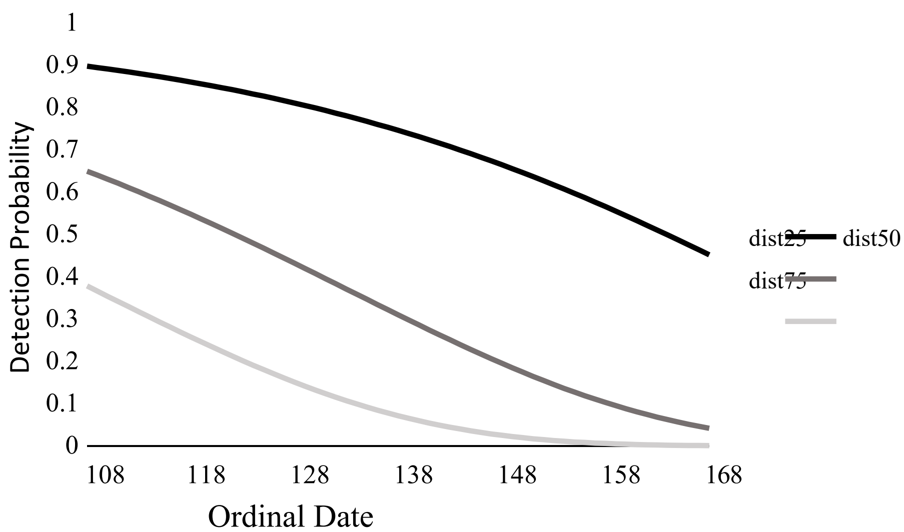

Figure 7. Model estimated detection probability at 25 meters (black line), detection probability at 50 meters (dark grey line), detection probability at 75 meters for open water marsh birds (*Fulica americana*, *Gallinula galeata*, and *Podilymbus podiceps*) from ordinal day 108 (April 15 or May 1, depending on latitude stratification) to ordinal day 168 during 2015–2017 in Illinois.

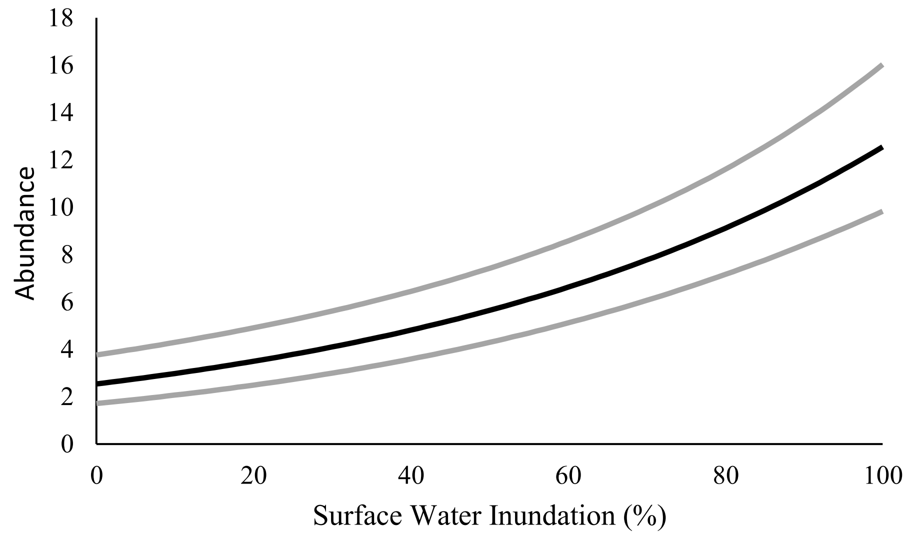

Figure 8. Predicted emergent marsh bird (*Botaurus lentiginosus*, *Ixobrychuc exilis*, *Porzana carolina*, *Rallus elegans*, *Rallus limicola*, and *Coturnicops novemoracensis*) abundance (birds per survey location with 95% confidence limits) across surface water inundation percentages in Illinois during late spring and early summer 2015–2017. Percent persistent emergent vegetation (50%), wetland complexity (level 3), and waterfowl management intensity (level 4) were held constant.

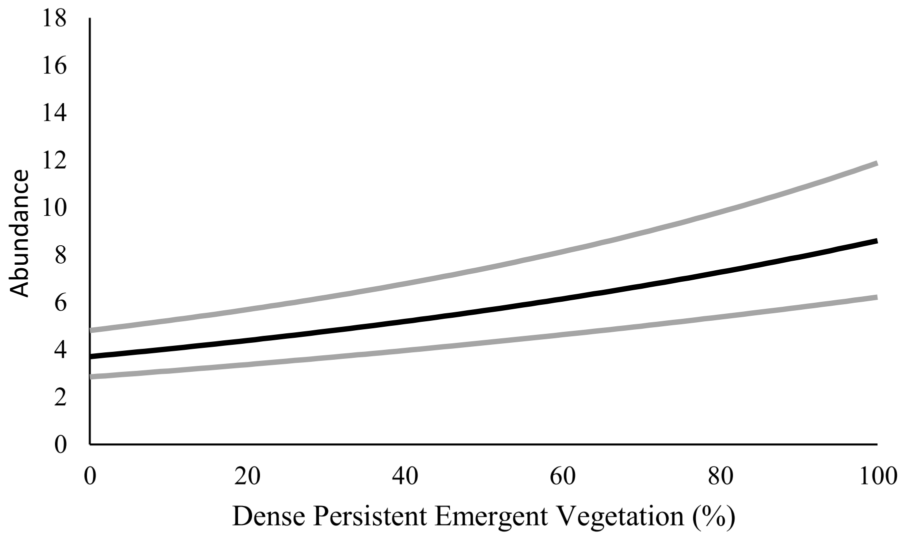

Figure 9. Predicted emergent marsh bird (*Botaurus lentiginosus*, *Ixobrychuc exilis*, *Porzana carolina*, *Rallus elegans*, *Rallus limicola*, and *Coturnicops novemoracensis*) abundance (birds per survey location with 95% confidence limits) across percent dense persistent emergent vegetation coverages in Illinois during late spring and early summer 2015–2017. Percent surface water inundation (50%), wetland complexity (level 3), and waterfowl management intensity (level 4) were held constant.

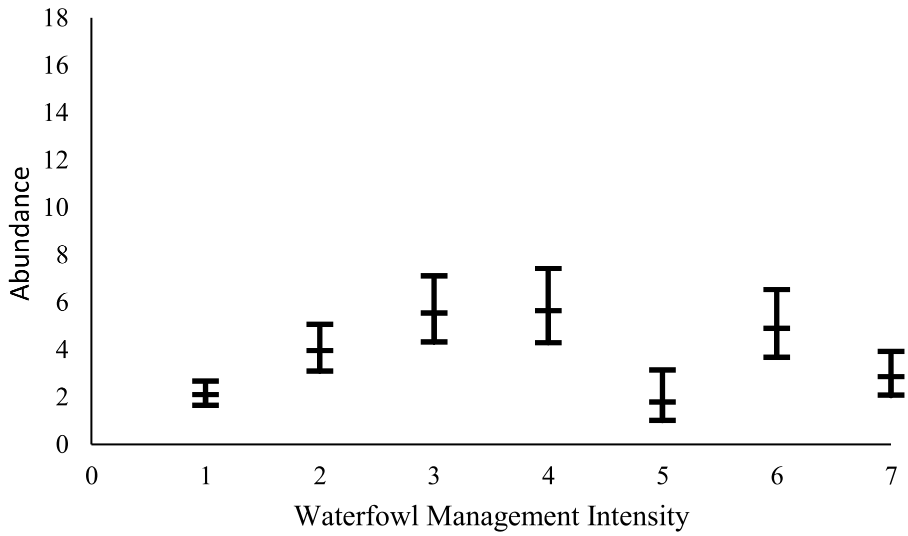

Figure 10. Predicted emergent marsh bird (*Botaurus lentiginosus*, *Ixobrychuc exilis*, *Porzana carolina*, *Rallus elegans*, *Rallus limicola*, and *Coturnicops novemoracensis*) abundance (birds per survey location with 95% confidence limits) across waterfowl management intensities in Illinois during late spring and early summer 2015–2017. Surface water inundation (50%), persistent emergent vegetation (50%), and wetland complexity (level 3) were held constant.

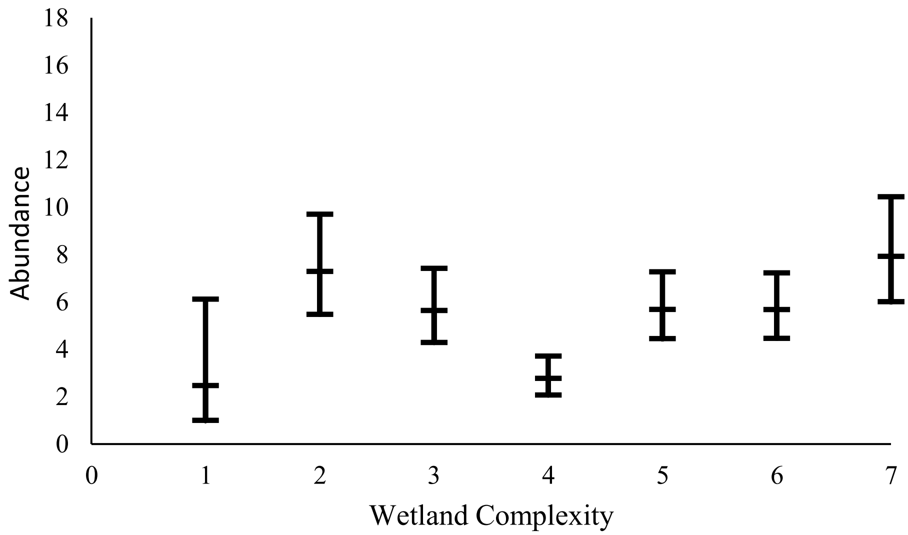

Figure 11. Predicted emergent marsh bird (*Botaurus lentiginosus*, *Ixobrychuc exilis*, *Porzana carolina*, *Rallus elegans*, *Rallus limicola*, and *Coturnicops novemoracensis*) abundance (birds per survey location with 95% confidence limits) across wetland complexity levels in Illinois during late spring and early summer 2015–2017. Surface water inundation (50%), persistent emergent vegetation (50%) and waterfowl management intensity (level 4) were held constant.

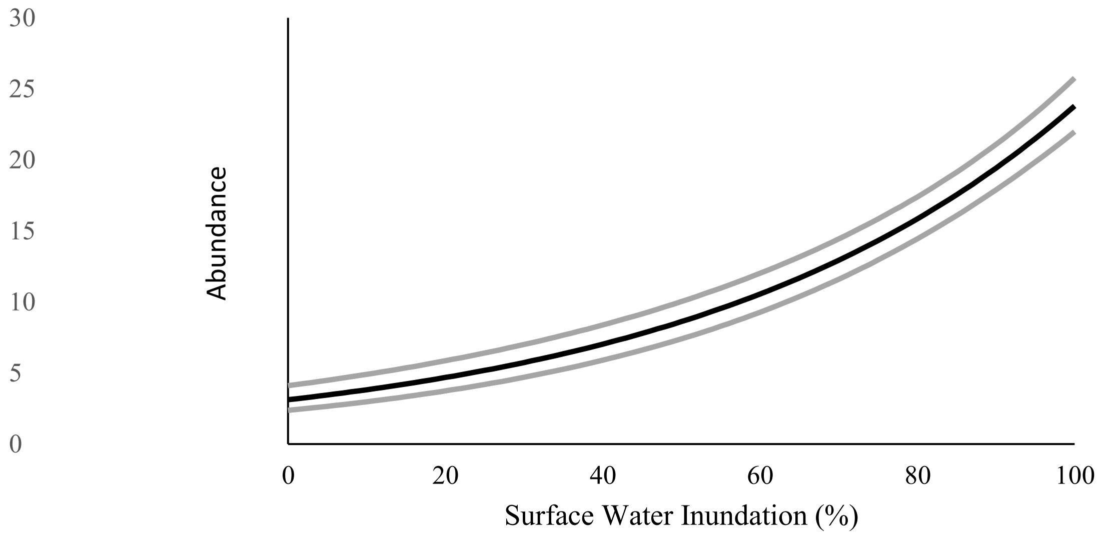

Figure 12. Predicted open water marsh bird (*Fulica americana*, *Gallinula galeata*, and *Podilymbus podiceps*) abundance (birds per survey location with 95% confidence limits) across cover surface water inundation percentages in Illinois during late spring and early summer 2015–2017. Persistent emergent vegetation (50%) and open water (50%) were held constant.

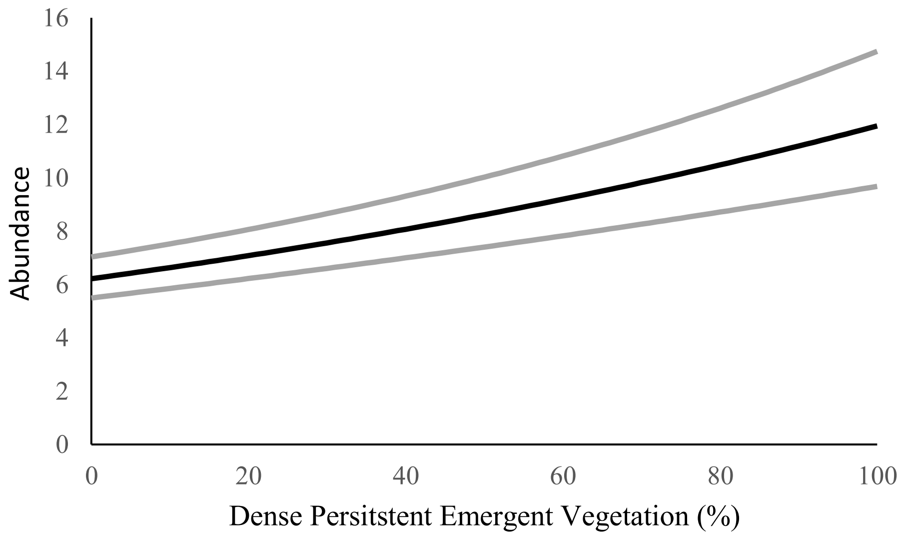

Figure 13. Predicted open water marsh bird (*Fulica americana*, *Gallinula galeata*, and *Podilymbus podiceps*) abundance (birds per survey location with 95% confidence limit) across dense persistent emergent vegetation cover percentages in Illinois during late spring and early summer 2015–2017. Surface water inundation (50%) and percent open water (50%) were held constant.

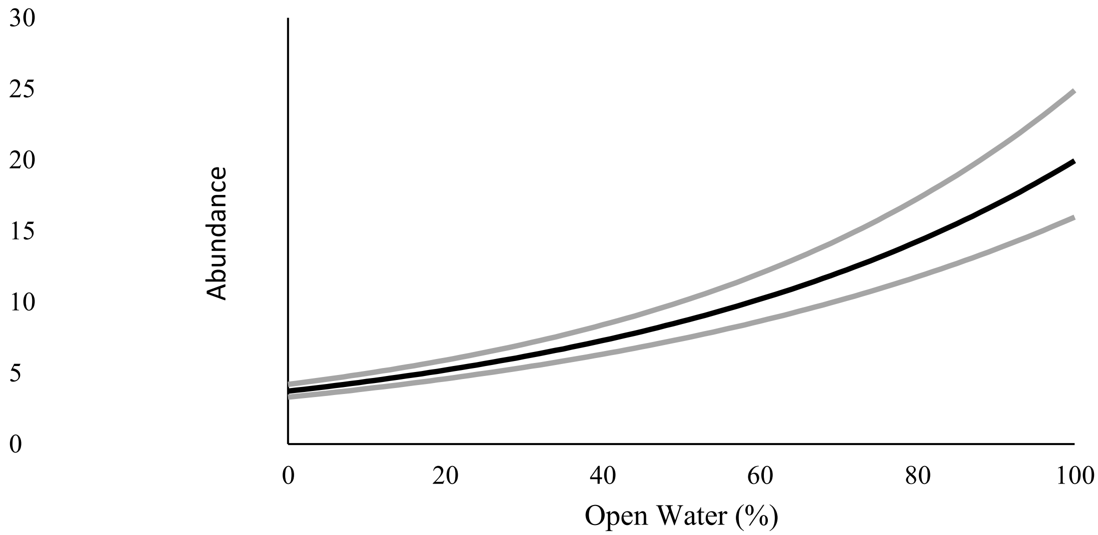

Figure 14. Predicted open water marsh bird (*Fulica americana*, *Gallinula galeata*, and *Podilymbus podiceps*) abundance (birds per survey location with 95% confidence limit) across open water cover percentages in Illinois during late spring and early summer 2015–2017. Surface water inundation (50%) and persistent emergent vegetation (50%) were held constant.

APPENDIX A. COMPARISON OF MARSH BIRD DETECTIONS BETWEEN SAMPLING METHODOLOGIES AT CRITICAL TRENDS ASSESSMENT PROGRAM WETLANDS

I compared the number of detections from marsh bird surveys conducted during this study following the North American Standardized Marsh Bird Survey Protocol (NASMBSP; Conway 2011) and subsequently in the same year by the Critical Trends Assessment Program (CTAP). The CTAP collects data on all birds detected during a single wetland survey using standard, passive point counts and subsequent call-back surveys for marsh birds (Molano-Flores 2002). The CTAP protocol includes only one survey conducted during late May – mid-July whereas the NASMBSP includes 3 surveys during mid-April – early June. Overall, the number of detections were similar among NASMBSP (data collected in this study) and CTAP surveys at CTAP sites (paired t-test, $P = 0.46$). Across sites and surveys, average detections in NASMBSP surveys were 0.3 ± 0.1 in 2015, 0.2 ± 0.1 in 2016, and 0.1 ± 0.1 in 2017. Across sites, average detections for CTAP surveys were 0.6 ± 0.3 in 2015, 0.0 ± 0.0 in 2016, and 0.3 ± 0.2 in 2017.

Although nearly twice as many marsh birds were detected using the NASMBSP protocol, CTAP sites had low numbers of detections in both surveys relative to detections at focal sites managed for waterfowl and those from the National Wetlands Inventory (Chapter 2).

Site	Year	NASMBSP Detections			CTAP Detections
		n	$\bar{x}$	SE	*n*
1	2017	0	0	0	0
2	2017	0	0	0	0
3	2017	1	0.3	0.3	2
4	2017	0	0	0	0
5	2017	0	0	0	2
6	2017	0	0	0	0
7	2017	1	0.3	0.3	0
8	2017	0	0	0	0
9	2017	0	0	0	0
10	2017	0	0	0	0
11	2017	0	0	0	0
12	2017	0	0	0	0
13	2017	2	0.7	0.7	0
14	2016	2	0.7	0.7	0
15	2016	0	0	0	0
16	2016	0	0	0	0
17	2016	2	0.7	0.7	0
18	2015	0	0	0	2
19	2015	4	1.3	1.3	0
20	2015	0	0	0	3
21	2015	1	0.3	0.3	0
22	2015	2	0.7	0.7	1
23	2015	0	0	0	0
24	2015	0	0	0	0
25	2015	1	0.3	0.3	0
26	2015	0	0	0	0
27	2015	0	0	0	0
28	2016	0	0	0	0
29	2016	1	0.3	0.3	0
30	2016	1	0.3	0.3	0
31	2016	1	0.3	0.3	0
32	2016	0	0	0	0
33	2016	0	0	0	0
34	2016	0	0	0	0
	Total	19	0.18	0.05	10

APPENDIX B. COMPARISON OF MARSH BIRD RICHNESS BETWEEN SAMPLING METHODOLOGIES AT CRITICAL TRENDS ASSESSMENT PROGRAM WETLANDS

I compared species richness from marsh bird surveys conducted during this study following the North American Standardized Marsh Bird Survey Protocol (NASMBSP; Conway 2011) and subsequently in the same year by the Critical Trends Assessment Program (CTAP). The CTAP collects data on all birds detected during a single wetland survey using standard, passive point counts and subsequent call-back surveys for marsh birds (Molano-Flores 2002). The CTAP protocol includes only one survey conducted during late May – mid-July whereas the NASMBSP includes 3 surveys during mid-April – early June. Overall, the species richness was similar among NASMBSP (data collected in this study) and CTAP surveys at CTAP sites (paired t-test, $P = 0.55$). Across sites and surveys, average species richness for NASMBSP surveys was 0.2 ± 0.1 in 2015, 0.2 ± 0.1 in 2016, and 0.1 ± 0.0 in 2017. Across sites, species richness for CTAP surveys was 0.2 ± 0.1 in 2015, 0.0 ± 0.0 in 2016, and 0.2 ± 0.2 in 2017. Although species richness using the NASMBSP was approximately twice that of the CTAP protocol, CTAP sites had low numbers of detections in both surveys relative to detections at focal sites managed for waterfowl and those from the National Wetlands Inventory (Chapter 2).

Site	Year	NASMBSP Richness			CTAP Richness
		n	$\bar{x}$	SE	*n*
1	2017	0	0	0	0
2	2017	0	0	0	0
3	2017	1	0.3	0.3	2
4	2017	0	0	0	0
5	2017	0	0	0	1
6	2017	0	0	0	0
7	2017	1	0.3	0.3	0
8	2017	0	0	0	0
9	2017	0	0	0	0
10	2017	0	0	0	0
11	2017	0	0	0	0
12	2017	0	0	0	0
13	2017	1	0.3	0.3	0
14	2016	1	0.3	0.3	0
15	2016	0	0	0	0
16	2016	0	0	0	0
17	2016	1	0.3	0.3	0
18	2015	0	0	0	1
19	2015	3	1	1	0
20	2015	0	0	0	2
21	2015	1	0.3	0.3	0
22	2015	2	0.7	0.7	1
23	2015	0	0	0	0
24	2015	0	0	0	0
25	2015	1	0.3	0.3	0
26	2015	0	0	0	0
27	2015	0	0	0	0
28	2016	0	0	0	0
29	2016	1	0.3	0.3	0
30	2016	1	0.3	0.3	0
31	2016	1	0.3	0.3	0
32	2016	0	0	0	0
33	2016	0	0	0	0
34	2016	0	0	0	0
	Total	15	0.13824	0.03938	7

APPENDIX C. LOCATIONS OF SURVEYED WETLANDS THROUGHOUT ILLINOIS

Latitude and Longitude of sites surveyed for marsh birds during late spring and early summer 2015–2017 in Illinois. Sites included wetlands managed primarily for migrating waterfowl (i.e., focal) and randomly-selected reference wetlands statewide. Reference wetlands included emergent polygons from the National Wetland Inventory (NWI) and sites from the Illinois Natural History Survey's Critical Trends Assessment Program (CTAP). Region was determined using the North American Secretive Marsh Birds Survey Protocol (NASMBSP; Fig. 3; Conway 2011).

Site Number	Year	Category	Region	Longitude	Latitude
1382	2015	CTAP	North	-89.8329078	41.71239348
1402	2015	CTAP	North	-89.85194364	41.70699541
1402	2015	CTAP	North	-89.77166035	41.75011327
191	2015	NWI	North	-90.12475804	41.92109661
1111	2015	NWI	North	-90.125139	41.933221
1213	2015	Focal	North	-90.14648711	42.06819575
1161	2015	NWI	North	-89.49401747	41.63626891
1183	2015	Focal	North	-89.33144697	41.29861612
1203	2015	Focal	North	-89.32316421	41.21503855
1253	2015	Focal	North	-89.31741593	41.1760152
1301	2015	NWI	North	-89.943157	41.410424
181	2015	NWI	North	-89.32167568	41.32169964
21001	2015	NWI	South	-88.83946186	37.25695516
21011	2015	NWI	South	-90.150623	38.660581
21021	2015	NWI	South	-90.0709365	38.63214077
21031	2015	NWI	South	-90.09869841	38.65573437
21041	2015	NWI	South	-90.0944123	38.68779014
21051	2015	NWI	South	-89.8393654	38.59469238
21071	2015	NWI	South	-90.85250555	39.3637713
21081	2015	NWI	South	-87.98300684	38.14771067
21091	2015	NWI	South	-90.20432036	39.70936369
21321	2015	NWI	South	-90.00632671	40.35134837
21343	2015	Focal	South	-89.89898094	40.4523834
21353	2015	Focal	South	-88.70800368	39.62115689
21383	2015	Focal	South	-89.21734897	38.8121772
21403	2015	Focal	South	-90.94195231	39.45324213
21413	2015	Focal	South	-89.87152314	40.52365457
21423	2015	Focal	South	-90.52793995	38.93994097
1121	2015	NWI	North	-88.39294919	42.22233117
1141	2015	NWI	North	-88.13707523	41.33680624
121	2015	NWI	North	-88.29699048	42.22474515
1243	2015	Focal	North	-89.44031344	40.9131159
1312	2015	CTAP	North	-88.36830505	41.9993645
1312	2015	CTAP	North	-88.37147724	42.06699908
1332	2015	CTAP	North	-87.93413215	41.58285735
1362	2015	CTAP	North	-88.00664672	41.82618499
1372	2015	CTAP	North	-88.24342949	41.83355857
141	2015	NWI	North	-88.20377299	42.30677784

Site Number	Year	Category	Region	Longitude	Latitude
1412	2015	CTAP	North	-88.66210886	41.53938174
1422	2015	CTAP	North	-88.31784197	42.06101775
171	2015	NWI	North	-88.30183991	41.37571335
1101	2015	NWI	North	-90.08985822	40.31398399
1223	2015	Focal	North	-89.43363245	40.92686476
1233	2015	Focal	North	-89.40829104	40.93997625
1283	2015	Focal	North	-89.4297148	41.02521392
21393	2015	Focal	South	-88.65388512	40.22803873
22031	2015	NWI	South	-90.05664399	40.34875984
21393	2015	Focal	South	-88.68850677	40.22286353
13013	2016	Focal	North	-89.32735746	41.21210385
23113	2016	Focal	South	-90.06540896	40.34169045
23123	2016	Focal	South	-89.88028069	40.51506559
23133	2016	Focal	South	-89.21210481	38.81569393
23143	2016	Focal	South	-90.93835676	39.45241904
23153	2016	Focal	South	-90.51780708	38.93973761
23163	2016	Focal	South	-89.14523347	37.28800041
23173	2016	Focal	South	-88.68840915	40.22247057
23183	2016	Focal	South	-89.99041187	40.33898345
23193	2016	Focal	South	-89.90132217	40.44554715
23213	2016	Focal	South	-88.2888956	37.66750088
23223	2016	Focal	South	-90.85326297	39.36294218
23233	2016	Focal	South	-90.00692611	40.35138124
13011	2016	NWI	North	-87.74383158	41.53270586
13022	2016	CTAP	North	-89.56679275	42.47792774
13023	2016	Focal	North	-89.4326097	40.93598311
13021	2016	NWI	North	-88.16034815	42.47142531
13033	2016	Focal	North	-91.05822654	40.83321035
13031	2016	NWI	North	-88.48482653	42.31156661
13041	2016	Focal	North	-90.14265601	42.07018024
13042	2016	NWI	North	-90.12541135	41.91061963
13053	2016	Focal	North	-89.43303702	41.02609717
13051	2016	NWI	North	-90.41840014	42.29295227
13063	2016	Focal	North	-89.43104884	40.92807979
13061	2016	NWI	North	-90.06499288	41.63361621
13071	2016	Focal	North	-89.22889829	41.68598622
13071	2016	NWI	North	-91.06646073	41.22963415
13093	2016	Focal	North	-87.888495	42.33222135

Site Number	Year	Category	Region	Longitude	Latitude
13091	2016	NWI	North	-91.00271086	40.90134565
13103	2016	Focal	North	-89.19148004	41.71905869
13101	2016	NWI	North	-90.24506855	41.75144398
13112	2016	CTAP	North	-88.0763995	41.96638224
13111	2016	NWI	North	-88.94457961	41.32354604
13122	2016	CTAP	North	-89.27850378	41.81564728
13121	2016	NWI	North	-90.11822784	41.18193702
13132	2016	CTAP	North	-88.01974164	41.68106514
13131	2016	NWI	North	-90.12069696	42.16438379
13141	2016	NWI	North	-90.37282048	42.26720125
13151	2016	NWI	North	-89.43936324	40.93949191
13161	2016	NWI	North	-90.38185268	41.52078468
23012	2016	CTAP	South	-89.74413306	40.24537807
23011	2016	NWI	South	-89.46667572	40.12047281
23022	2016	CTAP	South	-89.27441406	39.46964635
23021	2016	NWI	South	-90.49515132	39.95996228
23032	2016	CTAP	South	-88.55623378	38.94666389
23031	2016	NWI	South	-90.55939751	40.52083106
23052	2016	NWI	South	-90.54562991	39.97623317
23052	2016	CTAP	South	-87.85035171	38.33616293
23051	2016	NWI	South	-91.30661821	39.76849233
23061	2016	NWI	South	-89.95091681	40.32499339
23072	2016	CTAP	South	-89.31236764	37.57165711
23071	2016	NWI	South	-90.04947586	38.67160249
23081	2016	NWI	South	-88.65560158	37.41207295
23091	2016	NWI	South	-88.57852328	37.70854241
23101	2016	NWI	South	-88.00179932	38.17817151
23112	2016	CTAP	South	-89.35812591	37.42202122
23122	2016	CTAP	South	-89.36861842	37.38401019
301	2017	CTAP	North	-89.46878322	42.47853041
302	2017	CTAP	North	-89.99110588	42.41742969
307	2017	CTAP	North	-89.81459507	42.26534843
392	2017	NWI	North	-88.48529228	42.31097817
304	2017	CTAP	North	-88.37267169	42.33324051
391	2017	NWI	North	-88.0359418	42.2814846
309	2017	CTAP	North	-87.98686274	42.19376028
7031	2017	NWI	North	-89.56132182	42.15599416
353	2017	Focal	North	-90.14541668	42.06996696
310	2017	CTAP	North	-89.5552791	41.99874222
373	2017	NWI	North	-88.78777572	42.00745404

Site Number	Year	Category	Region	Longitude	Latitude
390	2017	NWI	North	-88.18529257	41.95070386
7123	2017	NWI	North	-90.13851891	41.9795463
7186	2017	NWI	North	-90.157691	41.836548
7177	2017	NWI	North	-89.74897468	41.74853597
314	2017	CTAP	North	-89.49188777	41.67960763
7007	2017	NWI	North	-89.375788	41.690099
357	2017	Focal	North	-89.18768596	41.71502039
7036	2017	NWI	North	-90.174769	41.582077
7048	2017	NWI	North	-90.230137	41.558814
313	2017	CTAP	North	-87.93014475	41.75762773
376	2017	NWI	North	-88.14109513	41.55356526
345	2017	Focal	North	-89.32379297	41.2165206
7117	2017	NWI	North	-90.969073	41.421309
318	2017	CTAP	North	-87.70677698	40.80527258
366	2017	Focal	North	-89.43300216	41.02147338
333	2017	Focal	North	-89.43487757	40.935993
317	2017	CTAP	North	-88.66040363	40.89964132
340	2017	Focal	North	-91.0650777	40.83317322
7004	2017	NWI	North	-91.091088	40.678085
7078	2017	NWI	South	-91.38822866	40.53758709
320	2017	CTAP	South	-90.525984	40.252525
338	2017	Focal	South	-88.68733047	40.22319051
7010	2017	NWI	South	-90.42984582	39.99759909
7147	2017	NWI	South	-90.99553004	39.44496056
363	2017	Focal	South	-90.94138033	39.45098905
364	2017	Focal	South	-90.54133424	38.94459128
372	2017	NWI	South	-90.09630231	38.66475339
371	2017	NWI	South	-90.09035369	38.57592824
329	2017	CTAP	South	-89.9529595	38.00719142
370	2017	NWI	South	-89.24395611	37.84790805
368	2017	NWI	South	-88.74010889	37.3883441
369	2017	NWI	South	-88.68413531	37.35746148
375	2017	NWI	South	-88.75545243	38.20288812
374	2017	NWI	South	-88.81504403	38.67350453
336	2017	Focal	South	-89.21587537	38.80993177
324	2017	CTAP	South	-88.58438917	38.99304807
342	2017	Focal	South	-90.0535819	40.35468503
343	2017	Focal	South	-90.006593	40.350037
344	2017	Focal	South	-89.98652472	40.34059829

Site Number	Year	Category	Region	Longitude	Latitude
7003	2017	NWI	South	-89.816287	40.396697
356	2017	Focal	South	-89.955296	40.445451
361	2017	Focal	South	-89.8930285	40.45401161
393	2017	Focal	South	-90.057059	40.45169
335	2017	Focal	South	-89.86195187	40.52649609