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Wetland Management Strategies that Maximize Marsh Bird Use in the Midwest

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Executive Summary

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. We assessed marsh bird occupancy of wetlands across Illinois to better understand how natural wetland characteristics, management for waterfowl, and surrounding landscape characteristics influence marsh bird occupancy of wetlands.

During late spring and early summer 2015–2017, we conducted call-back surveys to assess marsh bird occupancy of wetlands with respect to wetland characteristics and management throughout Illinois. We surveyed marsh birds three times annually at focal sites (i.e., sites selected for their passive or active management for waterfowl), random sites (i.e., emergent, pond, or lake polygons from the National Wetland Inventory), and Critical Trends Assessment Program (CTAP) sites (i.e., randomly selected wetlands concurrently surveyed by the Illinois Natural History Survey's CTAP).

We recorded 3,680 marsh bird detections including nine of ten 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 33.9% (33.0 – 34.9%) each week from the beginning of the survey period. The odds that a marsh bird occupyied a random or focal wetland site was 2.29 (0.44 – 6.99) and 5.11 (1.10 – 16.78) times greater than a CTAP wetland, respectively. Focal wetlands had 0.8 (-0.54 – 6.10) times greater odds of being occupied than random wetlands. Moreover, marsh bird occupancy generally increased with wetland

complexity. Specifically, sites classified as moderately-low (level 2) and moderately-high (level 5) complex were 9.91 (0.21 – 97.60) and 27.79 (2.05 – 270.56) times more likely to be occupied than monotypic habitats (level 1), respectively. We further analyzed marsh bird data separately by vegetation association allowing us to further examine patterns of occupancy by marsh bird guild. For example, marsh bird species associated with emergent vegetation occupied wetlands with greater habitat complexity, inundation area, and proportion of habitat classified as dense persistent emergent vegetation, whereas, open-water associated marsh birds were positively related to habitat complexity, and varied among site types and waterfowl management intensities.

Under detailed circumstances, waterfowl habitat management positively influenced marsh bird occupancy, yet, not all marsh bird species or guilds responded accordingly. Specifically, open-water associated marsh birds had greater occupancy of focal managed waterfowl sites, whereas, the intensity of waterfowl management and other site characteristics determined the attractiveness of wetlands to marsh birds associated with emergent vegetation. At great levels of waterfowl management intensity, managers control hydrology or mechanically disturb soils or vegetation limiting the growth or persistence of emergent vegetation sought by secretive marsh birds during the spring migration period. Moreover, drainage of wetlands to prepare for spring planting of agricultural grains or to promote early successional vegetation prior to completion of marsh bird migration creates inaccessible habitat and likely drives some of the patterns witnessed. Marsh bird occupancy can be increased on areas managed for waterfowl if practices maintain inundated emergent vegetation through the marsh bird breeding season. Additionally, managers should focus efforts on wetlands in landscapes with limited disturbance, high habitat complexity, large wetland area, and high percent cover of dense persistent emergent vegetation lead to increased marsh bird occupancy rates.

The following information is a preliminary thesis chapter addressing the first and third objectives outlined in the scope of work. Analyses addressing the second objective are ongoing and will be reported in full in the upcoming final performance report (on or before 31 March 2019). All results presented at this time are preliminary and subject to change.

INTRODUCTION

Marsh birds are a guild of wetland dependent birds associated with emergent vegetation communities (i.e., persistent and non-persistent emergent vegetation). Most marsh bird species 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 other land uses across the United States by the 1970s, with the greatest losses occurring in the Midwest and California (Tiner 1984; Harms and Dinsmore 2011, 2013). With such a high loss of wetlands, 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). In response to wetland losses and population declines, several species of marsh birds are 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 health and condition due to their documented vulnerability to accumulation of environmental contaminants in wetland substrates which impact their aquatic invertebrate forage (Conway 2011). Moreover, marsh birds are vulnerable to monotypic stands of invasive plant species (e.g. *Lythrum salicaria*, hybrid *Typha*, *Phalaris arundinacea*, *Phragmites*,; Gibbs et al. 1992; Monfils et al. 2013). Recent research has begun to understand the population status, distribution, and life history requirements of many marsh bird species (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 Great Plains region of the United States, a historically important breeding area with very high rates of wetland loss and degradation (Bolenbaugh et al. 2011).

Many factors affect marsh bird abundance and diversity, such as wetland size and isolation (Brown and Dinsmore 1986; Gibbs et al. 1991; Grover and Baldassarre 1995). Several studies have documented effects of wetland connectivity (Brown and Dinsmore 1986, 1988; Craig and Beal 1992), wetland size (Brown and Dinsmore 1986, 1988; Craig and Beal 1992; Craig 2008), and human land use (Smith and Chow-Fraser 2010) on marsh bird abundance and diversity. Other 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 (Sayre and Rundle 1984; Lor and Malecki 2006; Darrah and Krementz 2010) on marsh bird site use or occupancy. Moreover, intrinsic vegetation characteristics may be less important than wetland surroundings (DeLuca et al. 2004) and size (Brown and Dinsmore 1986) on site marsh bird use. However, wetland characteristics, such as emergent vegetation type and height, can influence occupancy rates of wetland complexes, but associations with intrinsic and extrinsic factors are highly variable in the Midwest, perhaps because habitat is limited (Bolenbaugh et al. 2011). 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).

In Illinois, particularly within the Mississippi and Illinois River flood plains there are managed wetlands using strategies to provide food and habitat for waterfowl primarily during their fall migration (Havera 1999; DeStevens & Gramling 2012). Multiple studies suggest management practices, including those associated with waterfowl management can have an influence on marsh bird occupancy (Darrah and Krementz 2010; Bolenbaugh et al. 2011). Tozer et al. 2018 suggests that managed wetlands have an improved marsh bird occupancy rate compared to adjacent unmanaged wetlands.

I determined marsh bird occupancy across a wide range of wetland classes (e.g., emergent, scrub-shrub, forested, aquatic bed), hydrologic regimes (e.g., temporary, seasonal, semi-permanent), and waterfowl management practices (e.g., active, passive, unmanaged) in Illinois during late spring and early summer 2015–2017. My objectives were to 1) compare marsh bird use of restored and natural wetlands, 2) determine characteristics of wetlands and the surrounding landscape that influence marsh bird use of restored wetlands and 3) compare marsh bird use of wetlands managed for waterfowl across a continuum of management intensities and strategies to predict how these actions which have been documented to increase waterfowl use can increase marsh bird occupancy. Additionally, I surveyed marsh birds using the standard protocols on wetlands concurrently surveyed within the Illinois Critical Trends Assessment Program (CTAP). CTAP is a long-term program established in 1997 that monitors the biological condition of Illinois' forests, grasslands, and wetlands. My goal was to provide insight to CTAP to determine if their wetland bird survey protocol produces similar results to the nationally standardized marsh bird survey protocol used across the Midwest (Conway 2011). Moreover, 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 the months 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 primarily to drainage and conversion to agricultural production, which comprises >75% of Illinois' land use (Havera 1999). Despite human alteration, Illinois continues to support migrating and breeding wetland-associated birds, including marsh birds. Illinois lies within the heart of the Mississippi Flyway with breeding grounds 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). The Mississippi and Illinois River floodplains contain large bottomland areas that have some of the greatest wetland density in Illinois. However, large portions of these wetlands have been isolated from the river system by levees and are impacted by altered hydrology which influences growth of submersed and emergent aquatic vegetation. The presence of levees and water control structures enable the inundation levels of a wetland to be drastically manipulated thus not providing adequate habitat for submersed aquatic vegetation to grow and produce the food and shelter for biota (Moore et al. 2010; Stafford et al. 2011). Moreover, most managed wetlands within these areas are impoundments that are managed for waterfowl, primarily dabbling ducks (*Anas* spp.). In particular, moist-soil management is the manipulation of water, weed banks, and soil to promote germination of desirable wetland plant and waterfowl. Conservation initiatives in Illinois similar to other regions in the United States encourage multi-species design and management, but often waterfowl are the primary focal group (King et al. 2006; DeStevens and Gramling 2012).

Site selection

To fulfil the objectives of my study, I surveyed marsh bird occupancy and assessed wetland conditions at random sites (i.e., emergent polygons from the National Wetland Inventory with emergent vegetation present), focal sites (i.e., those known to manage habitat for waterfowl), and Critical Trends Assessment Program (CTAP) sites. Wetlands less than 0.5 ha in size were not sampled (Conway 2011). For random wetlands, I stratified Illinois by natural division and allocated survey effort proportionately by wetland density within natural divisions. I consolidated National Wetland Inventory (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 then 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; Miller 2016; Tozer et al. 2018). I reviewed ESRI base map aerial imagery to assess the presence of suitable emergent vegetation at all random sites for marsh birds and created a population of potentially suitable sites each year (e.g., presence of emergent aquatic vegetation; Rehm and Baldassarre 2007). I randomly selected 20 random sites from the resulting sampling population for marsh bird surveys each year. If sites were unsuitable for marsh birds during my first visit, I replaced those sites with another randomly-selected site from the sample population.

I assembled a comprehensive list of potential focal wetlands using literature (Stafford et al. 2011) and interviews of IDNR waterfowl program staff, district wildlife biologists, site managers, 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. Frequent soil and/or vegetation disturbance encourage annual plant communities used by waterfowl and other wildlife for food, cover, and resting (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, waterfowl management regimes, and history of restoration (e.g., The Nature Conservancy's Emiquon Preserve, Aichison Waterfowl Refuge of Marshall State Fish and Wildlife Area).

Like random sites, I used aerial imagery and other available information to assess the suitability for marsh birds of sites CTAP had selected (approximately 60 each year) and created a population of potentially suitable sites each year (Rehm and Baldassarre 2007). I randomly selected 20 CTAP sites from the resulting sampling population for marsh bird surveys each year. If sites were unsuitable for marsh birds during my first visit, I replaced those sites with another randomly-selected site from the sample population (Fig. 2).

Marsh bird surveys

Prior to marsh bird surveys, I established 1–5 fixed sample points at each selected site that were readily accessible and within or adjacent to emergent aquatic vegetation (Conway 2011). I marked sample points with GPS coordinates and flagging tape to ensure consistency among survey periods. I ensured points were spaced ≥ 400 m apart within each site to reduce the chances of double sampling individuals. Therefore, the number of points within each site was dependent on wetland size, accessibility, logistical constraints, and area of suitable habitat (Johnson et al. 2009; Conway 2011). However, I restricted the maximum number of survey points to 5/site to allow observers to survey multiple wetlands in a single sampling period.

Once survey routes were established, I surveyed all points among sites following the North American Standardized Marsh Bird Survey Protocol (NASMBSP; Conway 2011), which incorporates a repeated call-back survey design. Call-back surveys are a popular technique that 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 100-m-radius circle from the marked point. I surveyed each point three times, bi-weekly 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 hours after sunrise (e.g., Bolenbaugh et al. 2011). I conducted surveys only during weather conditions that were suitable for audible detection (i.e., avoided heavy rains or high wind conditions; 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 is split into 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).

Within marsh bird surveys, I estimated the distance and direction of each individual marsh bird detected from the survey point by sight or sound and identified individuals to species. 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).

Habitat measurements

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] – 8 [very intense waterfowl management; e.g., disking and planting food plots]), wetland complexity/interspersion (1 [homogeneous] – 6 [high heterogeneity]; Fig. 4), 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, etc). 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- 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 inundated (Conway 2009; Harms and Dinsmore 2013).

Data analysis

I estimated occupancy and detection probability of marsh birds across sites using the *occu* function in package unmarked 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 biased estimates of occupancy or an altered meaning of the resulting data. After exploring my data, I suspected that my data violated the closed population assumption across my three sampling periods due to substantial differences in raw detections that were inversely related to sampling period chronology. Based on this trend and other anecdotal observations in the field, I suspected that the initial sampling period included both migrating and breeding individuals (Kaufmann 1983). Inclusion of individuals during migration would likely violate the assumption of a closed population and bias my estimates of detection probability low. According to Kendall and White (2009), calculating occupancy for a more mobile organism may require shorter periods between repeat visits or the use of spatial replication consisting of conducting multiple surveys within the same area of study. Therefore, I estimated detection probability among sample points within each site and survey period instead of across survey periods. Under this design, my assumption was that a species present at any one point within a site was present at every point within the site. I was comfortable with this assumption due to similarities within vegetation and wetland characteristics among survey points within each site. As my sample sites were often surrounded by unsuitable habitat, I believed that this assumption was reasonable and much more likely than a closed population across the 6-week survey period (Kendall and White 2009).

To examine occupancy rates of marsh birds with similar habitat requirements, I grouped species into groups based on taxonomical similarity, patterns of habitat use, and relevance to management (Bolenbaugh et al. 2010). Marsh bird groups included "all", "emergent-associated" (i.e., least bittern, American bittern, black rail, king rail, sora, Virginia rail, and yellow rail), and "open water-associated" (i.e., American coot, common gallinule, and pied-billed grebe; Bolenbaugh et al. 2010).

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 correlated variables ($|r| > 0.5$; Harms and Dinsmore 2013). I modeled habitat variables individually and then combinations of habitats 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).

RESULTS

Results presented in this report are preliminary and subject to change. I conducted 1,033 call-back surveys at 160 sites, including 73 random, 53 focal, and 34 CTAP wetlands. Within sites, I surveyed 150 random, 183 focal and 47 CTAP points. I recorded 3,680 detections across nine marsh bird species 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 (Table 2).

Marsh bird occupancy

For all three marsh bird groups, ordinal date was negatively associated with detection probability (Table 2). For all marsh birds, detection declined 7.1% (SE=2.1) for every week delay in marsh bird survey (Fig. 5), emergent-associated marsh birds detection declined 7.5% (SE=1.7) for every week delay (Fig. 6), and open-water associated marsh birds detection declined 6.9% (SE=2.0) for every week delay in marsh bird survey (Fig. 7).

The best supported model predicting all marsh bird occupancy included wetland complexity and wetland type (Table 4). In general, occupancy was positively related to wetland complexity with greatest occupancy at the greatest level of complexity (Ψ=0.99 SE=0.02; Fig. 8). Site type (i.e., focal, random, CTAP) was also included in the top model (Fig. 9). Focal sites had the greatest occupancy (Ψ=0.74 SE=0.09), followed by random (Ψ=0.61 SE=0.08) and CTAP (Ψ=0.32 SE=0.11) sites.

In the emergent-associated marsh bird group, wetland complexity, survey period, percent inundated, and percent cover of dense persistent vegetation were included in the top model (Table 4). Occupancy was positively related to large levels of wetland complexity with the highest occupancy at the highest level of complexity (Ψ = 0.88, SE = 0.069; Fig. 11. Occupancy decreased by survey period (Period 1 Ψ = 0.71, SE = 0.111; Period 2 Ψ = 0.55, SE = 0.136; Period 3 Ψ = 0.39, SE = 0.136; Fig. 11). As the percent area inundated increased 5%, occupancy increased 0.05 (max Ψ = 0.74, SE = 0.089, min Ψ = 0.35, SE = 0.183; Fig. 12) and as percent cover of dense emergent vegetation increased 5%, occupancy increased 0.05 (max Ψ = 0.81, SE = 0.148, min Ψ = 0.26, SE = 0.082; Fig. 13).

For the open water-associated marsh birds group, wetland complexity, site type and level of waterfowl management was included in the best supported model. Wetlands with the highest habitat complexity had the highest occupancy (Ψ = 0.84, SE = 0.105; Fig 14). Focal sites had the highest occupancy (Ψ = 0.74, SE = 0.145), followed by random (Ψ = 0.38, SE = 0.178) and CTAP (Ψ = 0.30, SE = 0.201) sites (Fig. 15). Occupancy was greatest at middle levels of waterfowl management intensity (Ψ = 0.39, SE = 0.178), followed by low intensity low (Ψ = 0.17, SE = 0.059) and high intensity (Ψ = 0.10, SE = 0.095; Fig. 16).

DISCUSSION

Habitat characteristics such as high wetland complexity, large wetland area inundated and high cover of persistent emergent vegetation are positively correlated with marsh bird richness and occupancy. This could be attributed to emergent vegetation providing marsh birds with the dense vegetation required for cover, nesting infrastructure and foraging conditions (Darrah and Krementz 2010). Multiple species require a diverse supply of resources for nesting and foraging and complex habitats have the potential to provide a diverse supply of resources (Darrah and Krementz 2010). Several studies have demonstrated that a mixture of different habitat types, particularly shallow pools of 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. Other studies observed that marshes with low complexity, typically with low level of waterfowl management, were generally characterized by large, thick, dry stands of cattail that impede movements of marsh birds and discourage nesting (Manci and Rusch 1988; Gibbs et al. 1991).

In my study, the importance of the site type in the models suggests that there are differences between the three categories of wetlands (i.e., focal, random, CTAP). For the all marsh birds group, my analysis suggests that there is no significant difference between random sites and focal sites, but there is a difference between random and CTAP. Such differences could be from CTAP selecting sites years prior to my study, representing the gradual degradation or loss of emergent wetlands in Illinois. The gradual degradation or loss of emergent wetlands could result in more degraded wetlands or less emergent wetlands in their sample population, compared to the randomly selected sites representing the current status of remaining emergent wetlands during the years of my study. On the other hand, according to my open water-associated marsh bird group analysis, random wetlands were more similar to CTAP sites compared to focal sites. Differences between focal and random could be attributed to differences in management levels demonstrated in the differences between the average level of management for each site type (CTAP = 1.28 SE = 0.04, Random = 1.83 SE = 1.61, Focal = 4.58 SE = 1.91).

My study suggests an intermediate level of wetland management for waterfowl has the greatest potential to increase marsh bird occupancy and richness. In the Midwest, a common goal in managed wetlands is to lower water levels to enable seed producing moist-soil vegetation to grow during the summer. Removing water from the landscape also enables managers to plant agricultural crops to produce food for waterfowl in the fall. Land managers typically remove water shortly after the waterfowl spring migration, which coincides with seasonal migration of marsh birds. Thus, intensive management for waterfowl that includes early drawdowns or exclusion of perennial emergent vegetation also reduces marsh bird use (Harms and Dinsmore 2013). A less intensive management practice in the Midwest is the presence of established levees. Levees function to protect against flood waters, prevent sediment loads from entering the wetland, and in the retention of water while surrounding landscapes are dry. In my study and others, occupancy and richness was higher in sites with less intensive management practices including the presence of levees (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).

Previous studies have noted that probability of detecting marsh birds varied by time of day, survey date, and weather (Conway and Gibbs 2011). Marsh birds can be unavailable for detection for numerous reasons including they truly are absent or present but not detected by observers (Denes et al. 2015). Birds also can be missed because observers fail to detect marsh birds even though they were visible or audible (Denes et al. 2015). To calculate detection probability there needs to be survey replication while the population is closed and unchanging (Mackenzie et al. 2002). In the current NASMDBSP, replication is recommended during two-week survey periods across a 6 week time frame. Conway (2011) recommended that initial surveys be conducted after migration and before the initiation of breeding, however such timing could lead to under sampling of those species with the earliest peak-detection periods being missed (Tozer et al 2018). I noted varying detection probability across day within the survey period and during the three survey periods, suggesting that detection probability varied over time. The variation could be due to the decrease in vocalization as the breeding season progresses or it could be that the populations inhabiting the sites in this study were not closed and most likely the populations were migrating through to other breeding grounds. Further, information about vocal behavior during migration is limited, but Kaufmann (1989) observed that marsh birds gave similar vocalizations during migration and breeding periods. Consequently, the timing of surveys outlined in the NASMBSP is not effective at meeting the assumptions required to calculate detection probability using temporal replication over a 6 week timeframe in the Midwest.

In conclusion, my study found that detection probability varied by date as other studies have found. Occupancy was influenced by wetland complexity, site type, and waterfowl management intensity. Other factors that influenced occupancy were percent area inundated and percent cover of dense persistent emergent vegetation. The highest occupancy levels were associated with focal sites characterized by high levels of wetland complexity and inundation, greater availability? of persistent emergent vegetation, and moderate levels of waterfowl management.

Land managers targetting multiple species need to supply a variety of habitat types to meet the differing needs of each species by managing for high habitat complexity. Marsh birds in general require more extensive stands of tall emergent vegetation, interspersed with small pools of water categorized as hemimarsh. This interspersion increases habitat complexity and encourages the use by a diverse group of birds such as marsh birds (Darrah and Krementz 2010). By practicing moderate levels of waterfowl management, such as the presence of levees which passively sustains constant water levels, could provide the inundation, persistent emergent vegetation, and habitat complexity that this study suggests is positively correlated to marsh bird occupancy and richness.

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Figure 11. Predicted probability of occupancy for the emergent-associated marsh bird group according to the top model manipulating wetland habitat complexity while the remaining top model factors remain constant (Wetland Survey Period = 2, Percent Inundated = 50%, Percent Cover of Persistent Emergent Vegetation = 50%) in Illinois, 2015–2017.

Figure 12. Predicted probability of occupancy for the emergent-associated marsh bird group according to the top model manipulating wetland percent inundated while the remaining top model factors remain constant (Wetland Survey Period = 2, wetland Habitat Complexity = 4, Percent Cover of Persistent Emergent Vegetation = 50%) in Illinois, 2015–2017.

Figure 13. Predicted probability of occupancy for the emergent-associated marsh bird group according to the top model manipulating wetland percent cover dense persistent emergent vegetation while the remaining top model factors remain constant (Wetland Survey Period = 2, wetland Habitat Complexity = 4, Percent inundated = 50%) in Illinois, 2015–2017.

Figure 14. Predicted probability of occupancy for the open water-associated marsh bird group according to the top model manipulating wetland complexity levels while the remaining top model factors remain constant (Type = Random and Waterfowl Management Intensity = 3) in Illinois, 2015–2017.

Figure 15. Predicted probability of occupancy for the open water-associated marsh bird group according to the top model manipulating site type while the remaining top model factors remain constant (wetland Habitat Complexity = 4 and waterfowl Management intensity = 3) in Illinois, 2015–2017.

Figure 16. Predicted probability of occupancy for the open water-associated marsh bird group according to the top model manipulating wetland waterfowl management intensity while the remaining top model factors remain constant (Wetland Habitat Complexity = 4 and Type= Random) in Illinois, 2015–2017.

Table 1. List of factors and the corresponding units and model group used to run occupancy model and linear mixed effect model in Illinois, 2015–2017. (Note detection model group was only used in occupancy model)

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 Initials
	Adjusted Date	1–48
	Year	2015-2017
Category	Intensity of Waterfowl Management Activities	1–8
	Wetland Habitat Complexity	0–6
	Wetland Connectivity to Rivers or Streams	0–7
	Management Category	Unmanaged, Passive, Active
	Period	1, 2, 3
	Survey Region	North or South
	Wildlife Management	0–7
	Site Type	CTAP, Random, Focal
Cover Metrics	Average Water Depth	0–4
	Percent Area Inundation	% of Survey Point
	Percent Area Aquatic Bed	% of Survey Point
	Percent Cover Dense Persistent Emergent Vegetation	% of Survey Point
	Percent Cover Non-persistent Emergent Vegetation	% of Survey Point
	Percent Cover Shrub-Scrub	% of Survey Point
	Percent Cover Forested	% of Survey Point
	Percent Cover Open Water	% of Survey Point
Disturbance	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 Protocol

Table 1. Environmental factor relation detection model results by marsh bird group where Ψ = occupancy, p = detection, and k = number of parameters in Illinois, 2015–2017.

Group	Model	AIC	ΔAIC	K
All Marsh Birds	p (ordinal date) Ψ (.)	1276.99	0.00	3
	p (date) Ψ (.)	1286.37	9.38	3
	p (temperature) Ψ (.)	1324.58	47.59	3
	p (sky cover) Ψ (.)	1330.07	53.08	8
Emergent	p (date) Ψ (.)	1197.54	0.00	3
	p (ordinal date) Ψ (.)	1200.32	2.78	3
	p (temperature) Ψ (.)	1249.32	51.78	3
	p (year) Ψ (.)	1252.63	55.09	3
Open	p (date) Ψ (.)	1007.04	0.00	3
	p (ordinal date) Ψ (.)	1008.4	1.36	3
	p (time) Ψ (.)	1020.43	13.39	3
	p (.) Ψ (.)	1020.65	13.61	2

Table 3. Raw number of marsh bird detections across site types and years in Illinois, 2015–2017.

	CTAP			**Random**			**Focal**			**Total**		
	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 4. Habitat metric occupancy model results by marsh bird group, where Ψ = occupancy, p = detection, k = number of parameters, CMP = Level of complexity, TYP = Type, WTR = Level of waterfowl management, PIN = Percent Inundation, PDP = Percent cover dense persistent emergent vegetation, RND = Round and PRD = Period in Illinois, 2015–2017.

Group	Model	AIC	ΔAIC	K
All Marsh Birds	p(ordinal date) Ψ (CMP+ TYP)	1268.74	0.00	10
	p(ordinal date) Ψ (CMP)	1277.13	8.39	8
	p(ordinal date) Ψ (TYP)	1292.52	23.78	5
	p(ordinal date) Ψ (WTR)	1299.21	30.47	10
Emergent	p(ordinal date) Ψ (CMP + PIN + PDP + PRD)	1174.11	0.00	12
	p(ordinal date) Ψ (CMP + PDP + PRD)	1177.68	3.57	11
	p(ordinal date) Ψ (CMP + PIN + PRD)	1179.27	5.16	11
	p(ordinal date) Ψ (CMP + PRD)	1197.39	23.28	10
Open	p(ordinal date) Ψ (CMP + TYP + WTR)	949.08	0.00	17
	p(ordinal date) Ψ (CMP + TYP)	954.22	5.14	10
	p(ordinal date) Ψ (CMP + WTR)	956.07	6.99	15
	p(ordinal date) Ψ (TYP + WTR)	967.22	18.14	12
Rails	p(ordinal date) Ψ (CMP + PIN + PDP + RND)	1122.81	0.00	12
	p(ordinal date) Ψ (CMP + PIN + RND)	1126.81	4.00	11
	p(ordinal date) Ψ (CMP + PDP + RND)	1127.33	4.52	11
	p(ordinal date) Ψ (CMP + RND)	1145.6	22.79	10

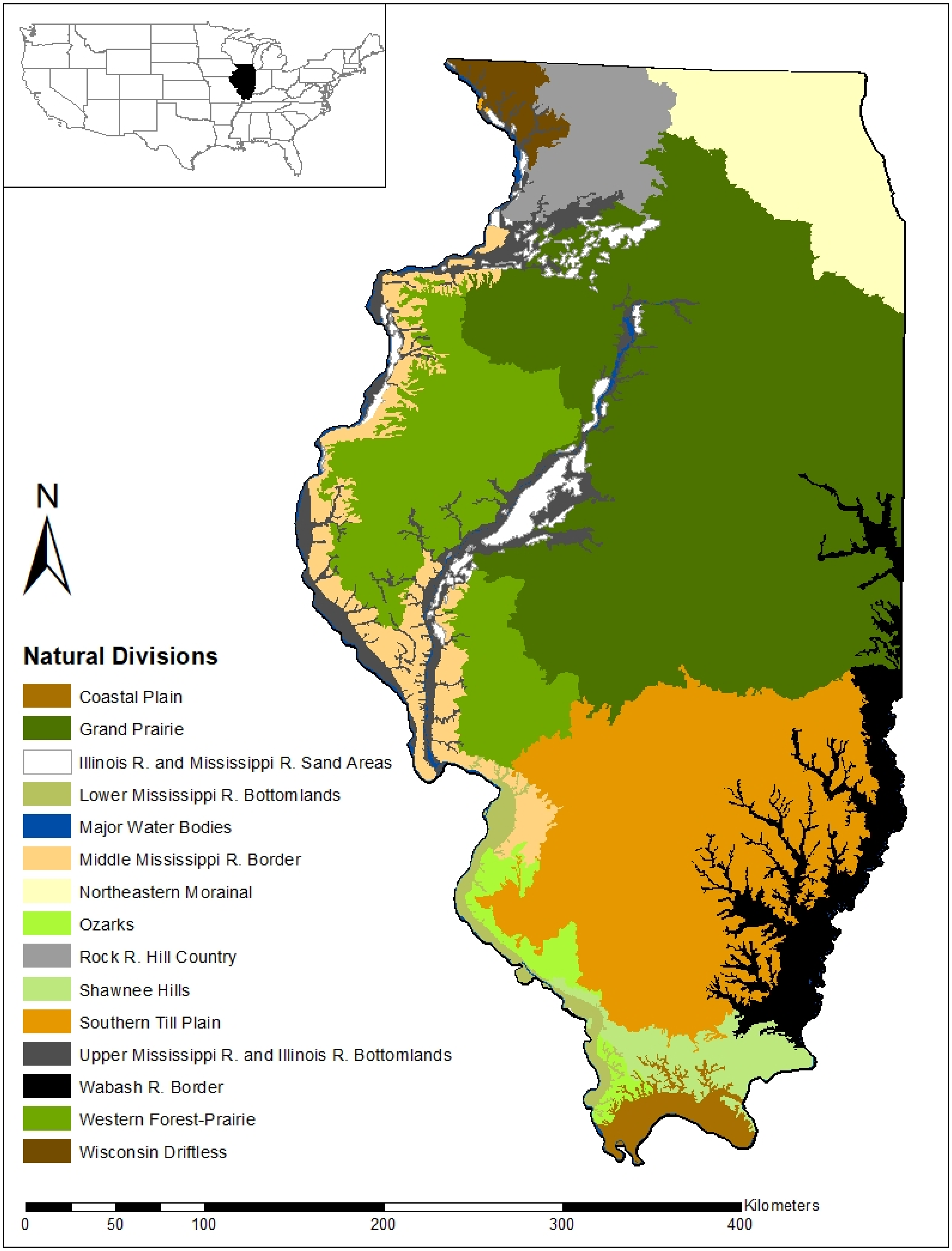

Figure 1. State of Illinois natural divisions (Blake-Bradshaw 2018) used to establish survey effort dependent on wetland density in each natural division.

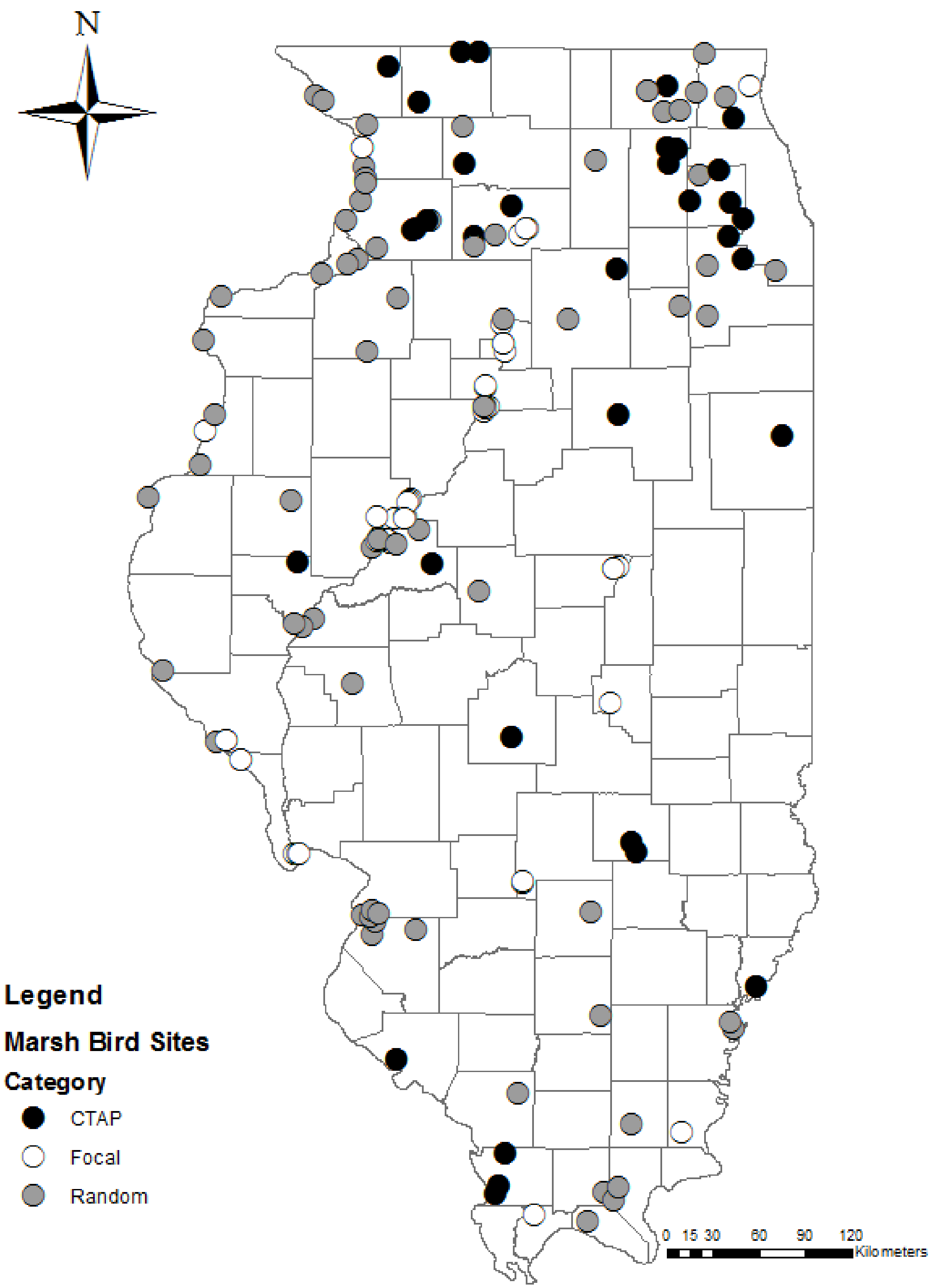

Figure 2. State of Illinois counties with wetlands (n = 160 sites) surveyed for marsh birds during breeding seasons of 2015 – 2017. Each site consisted of 1 – 5 points surveyed 3 times during a 6-week period. Sites consisted of 73 random (grey), 53 focal (white), and 34 CTAP wetlands (black).

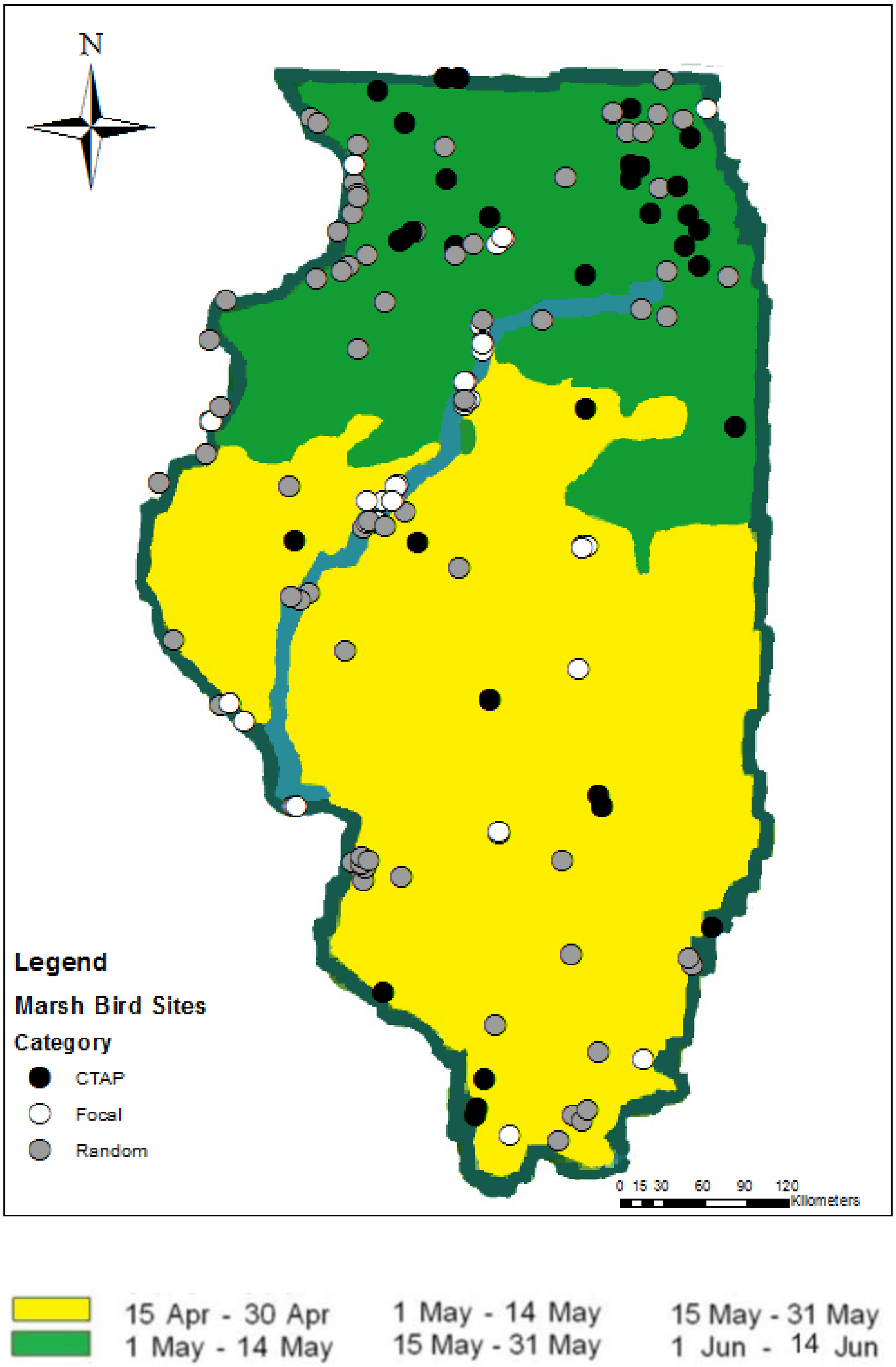

Figure 3. Marsh bird survey dates for two disparate regions of Illinois categorized by average maximum temperatures in May from the PRISM Climate Group at Oregon State University (Conway 2011). Sites consisting of Random (grey), Focal (white), and CTAP (black).

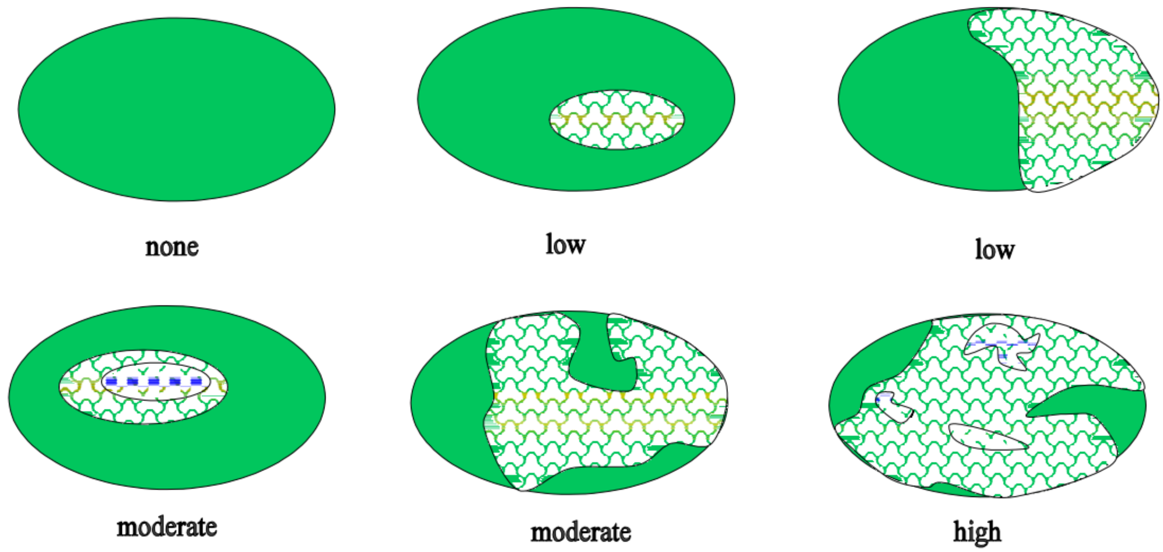

Figure 4. Hypothetical wetlands for estimating degree of complexity/interspersion. None (1) wetland has no complexity consisting of one monotypic habitat, low (2) wetland has a low degree of complexity consisting of a small area of an additional habitat type, moderately low (3) wetland has a moderately 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).

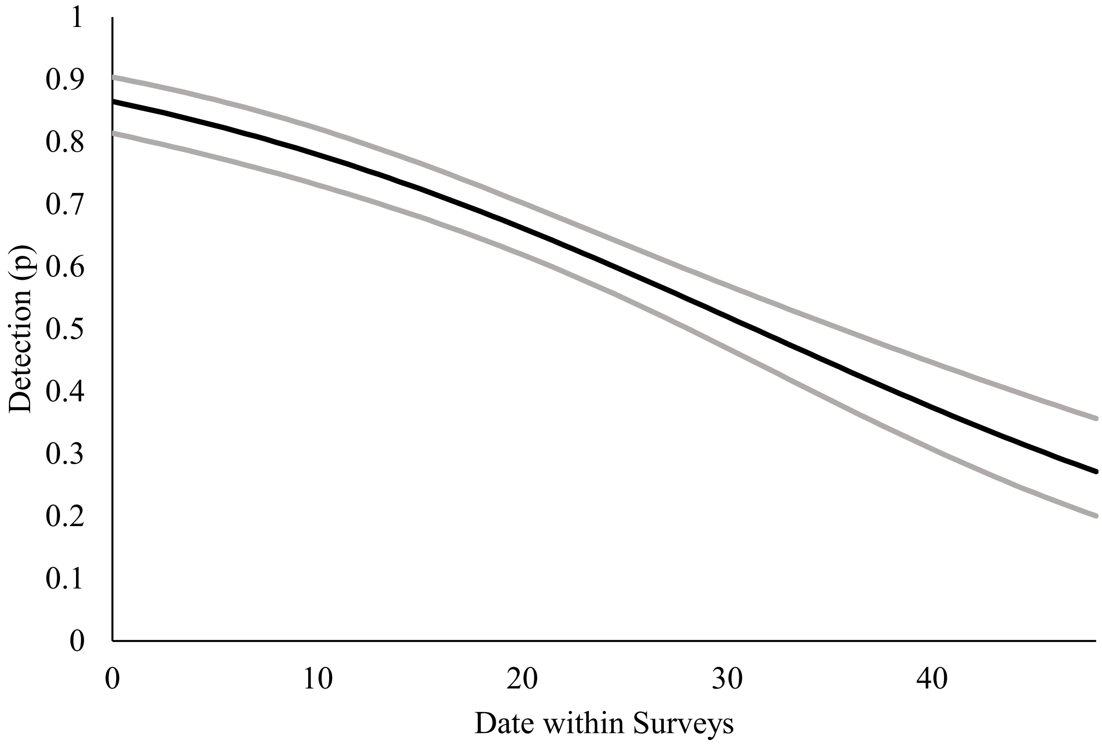

Figure 5. Model estimated marsh bird detection probability (black line) for all marsh birds (± 95 % confidence limits [grey lines]) by survey date. Surveys were conducted from day 0 (April 15 or May 1, depending on latitude stratification) to day 48 across Illinois during late spring, early summer 2015–2017.

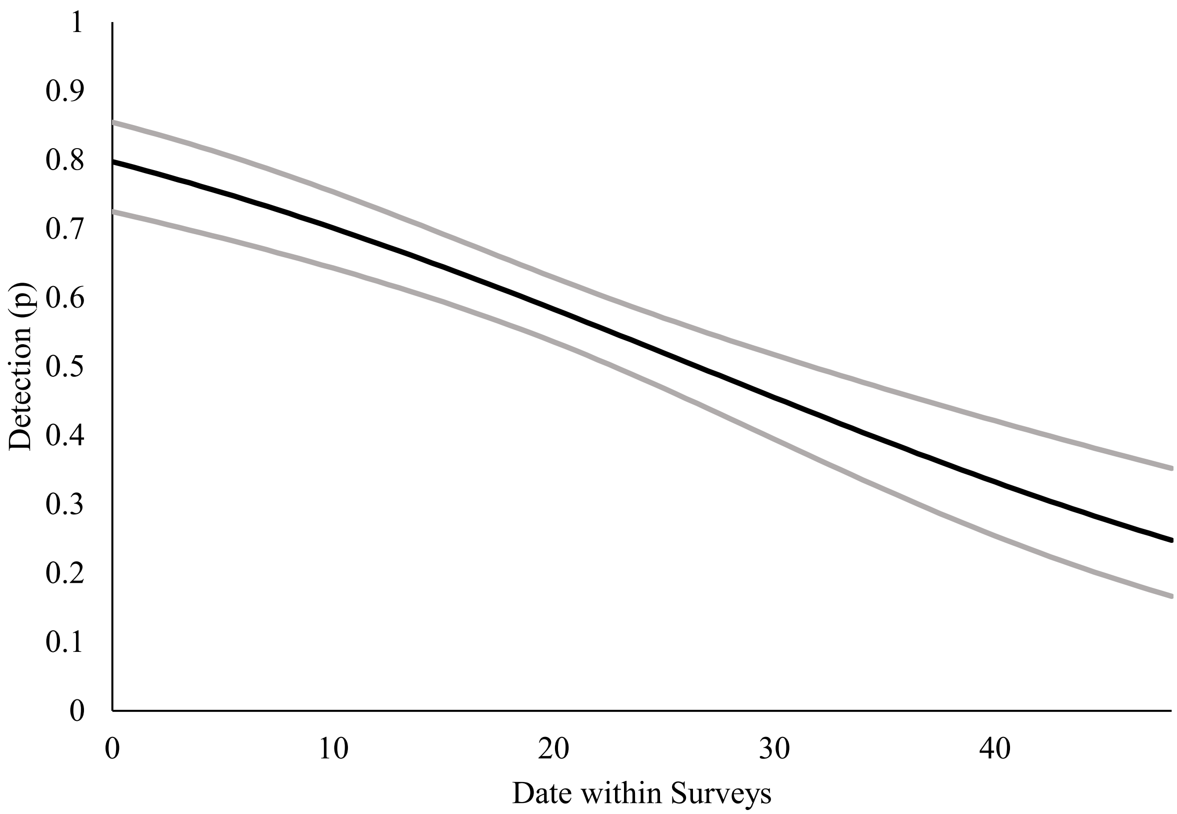

Figure 6. Model estimated marsh bird detection probability (black line) for emergent-associated marsh birds (± 95 % confidence limits [grey lines]) by survey date. Surveys were conducted from day 0 (April 15 or May 1, depending on latitude stratification) to day 48 across Illinois during late spring,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

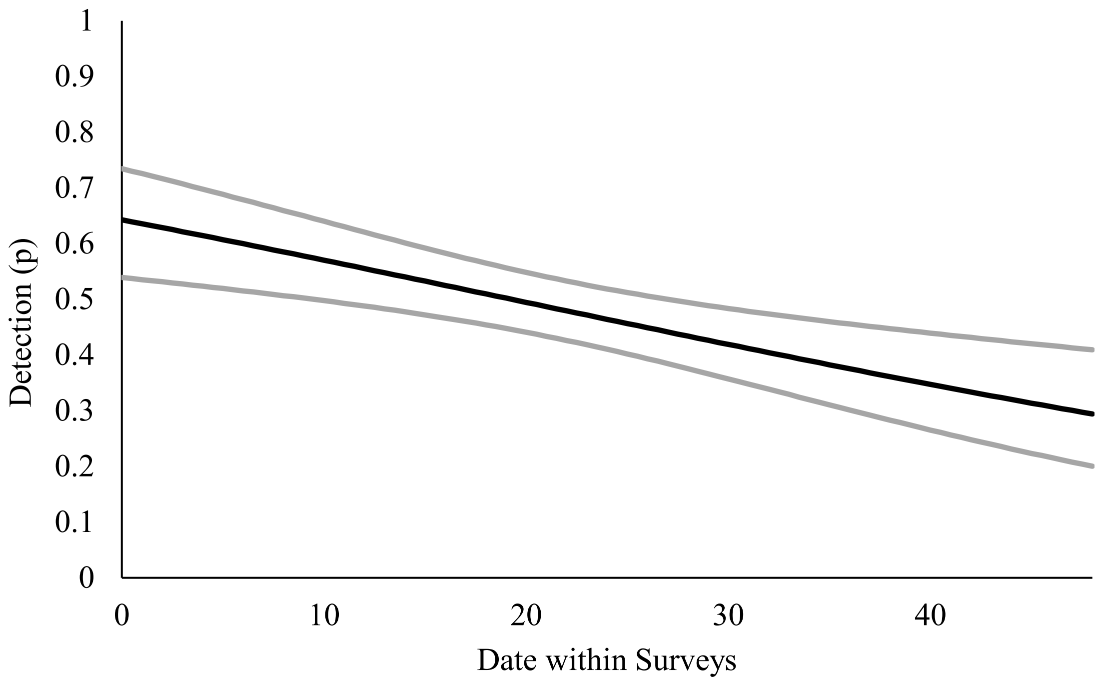

Figure 7. Model estimated marsh bird detection probability (black line) for open water-associated marsh birds (± 95 % confidence limits [grey lines]) by survey date. Surveys were conducted from day 0 (April 15 or May 1, depending on latitude stratification) to day 48 across Illinois during late spring, early summer 2015–2017.

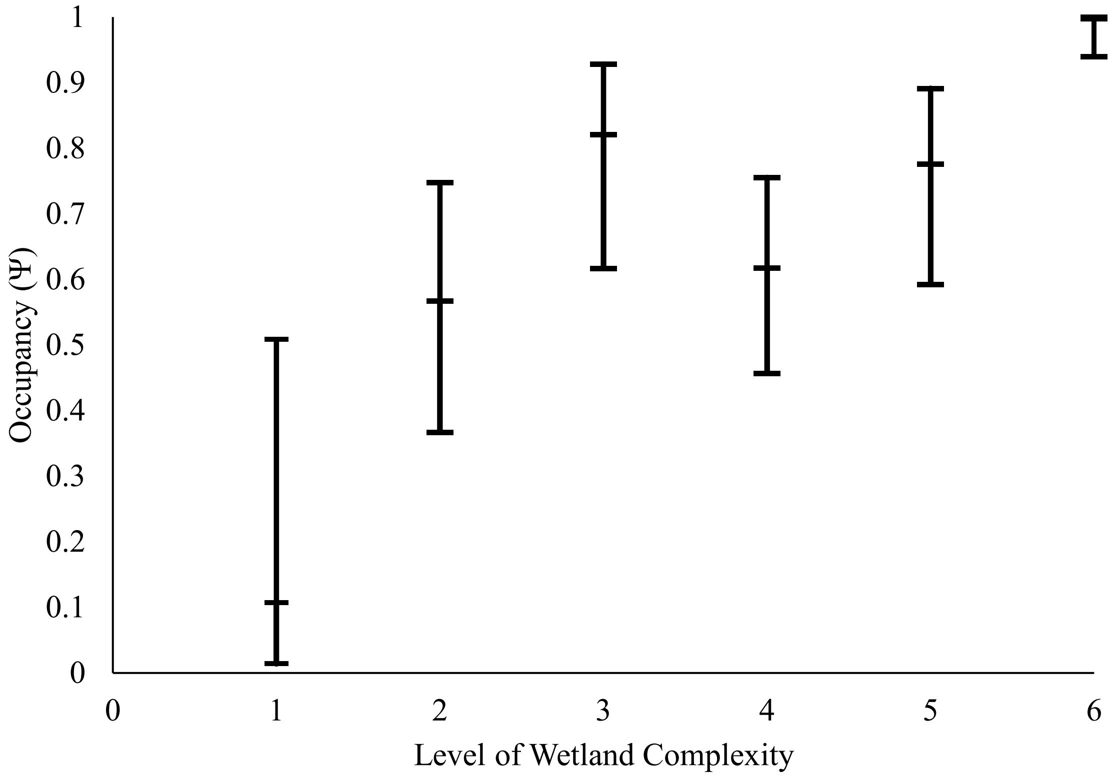

Figure 8. Predicted probability of site occupancy for the all marsh birds group according to the top model manipulating wetland complexity levels while the remaining top model factor remains constant (Type = Random) in Illinois, 2015–2017.

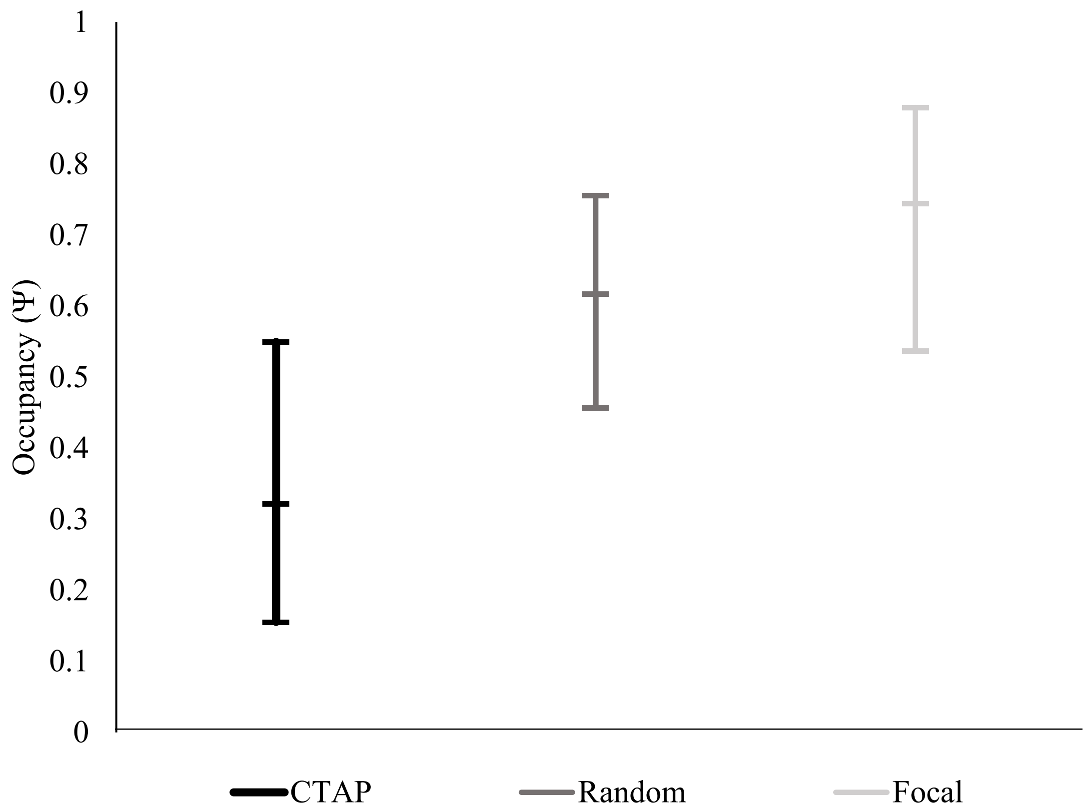

Figure 9. Predicted probability of site occupancy for the all marsh birds group according to the top model manipulating site type while the remaining top model factor remains constant (wetland Habitat Complexity = 4) in Illinois, 2015–2017.

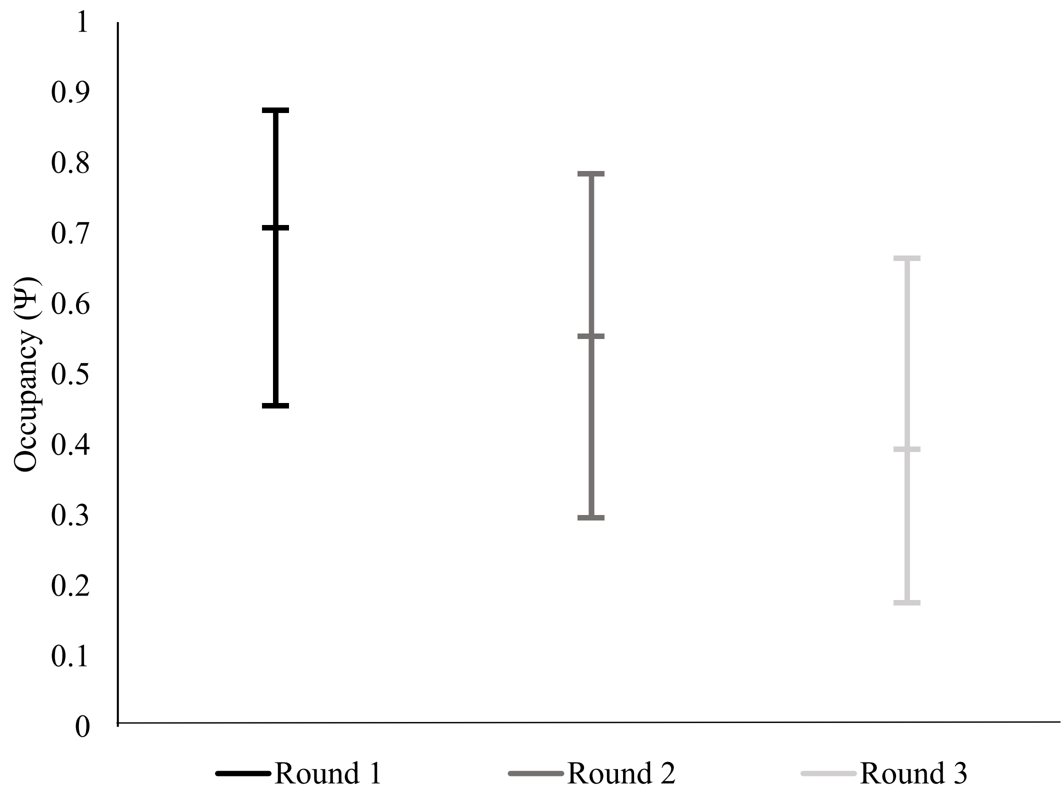

Figure 10. Predicted probability of occupancy for the emergent-associated marsh bird group according to the top model manipulating wetland survey period while the remaining top model factors remain constant (Wetland Habitat Complexity = 4, Percent Inundated = 50%, Percent Cover of Persistent Emergent Vegetation = 50%) in Illinois, 2015–2017.

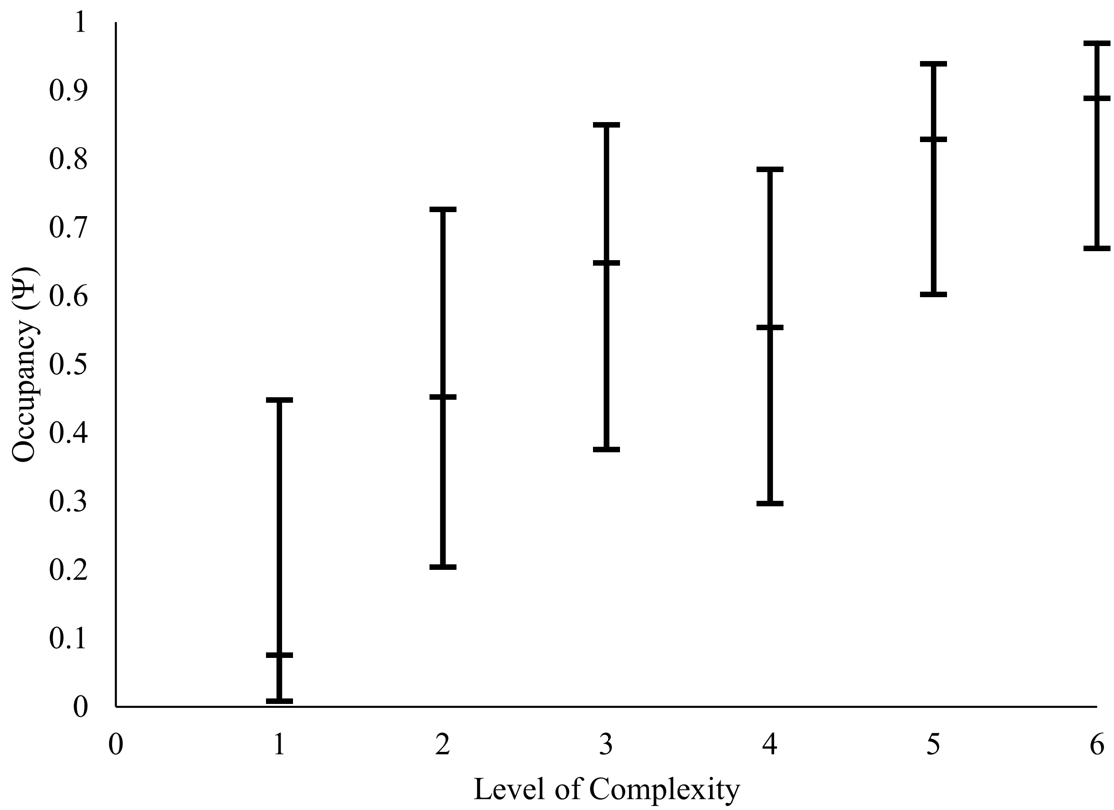

Figure 11. Predicted probability of occupancy for the emergent-associated marsh bird group according to the top model manipulating wetland habitat complexity while the remaining top model factors remain constant (Wetland Survey Period = 2, Percent Inundated = 50%, Percent Cover of Persistent Emergent Vegetation = 50%) in Illinois, 2015–2017.

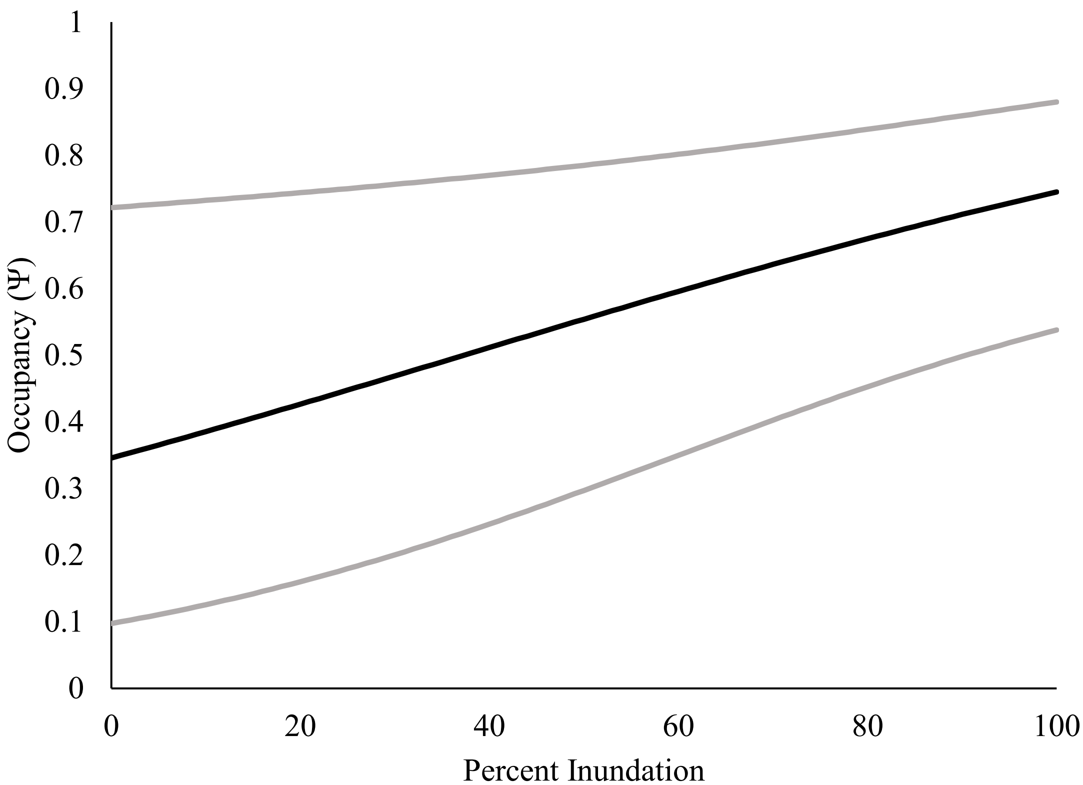

Figure 12. Predicted probability of occupancy for the emergent-associated marsh bird group according to the top model manipulating wetland percent inundated while the remaining top model factors remain constant (Wetland Survey Period = 2, wetland Habitat Complexity = 4, Percent Cover of Persistent Emergent Vegetation = 50%) in Illinois, 2015–2017 .

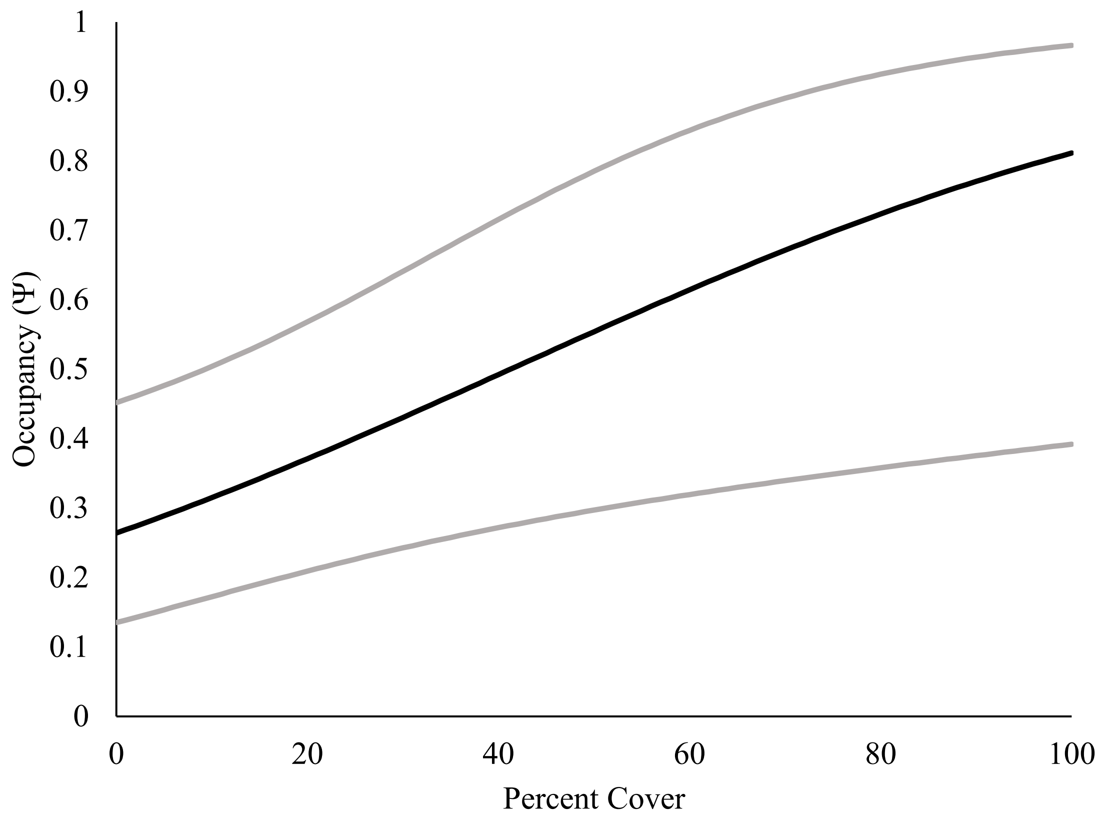

Figure 13. Predicted probability of occupancy for the emergent-associated marsh bird group according to the top model manipulating wetland percent cover dense persistent emergent vegetation while the remaining top model factors remain constant (Wetland Survey Period = 2, wetland Habitat Complexity = 4, Percent inundated = 50%) in Illinois, 2015–2017.

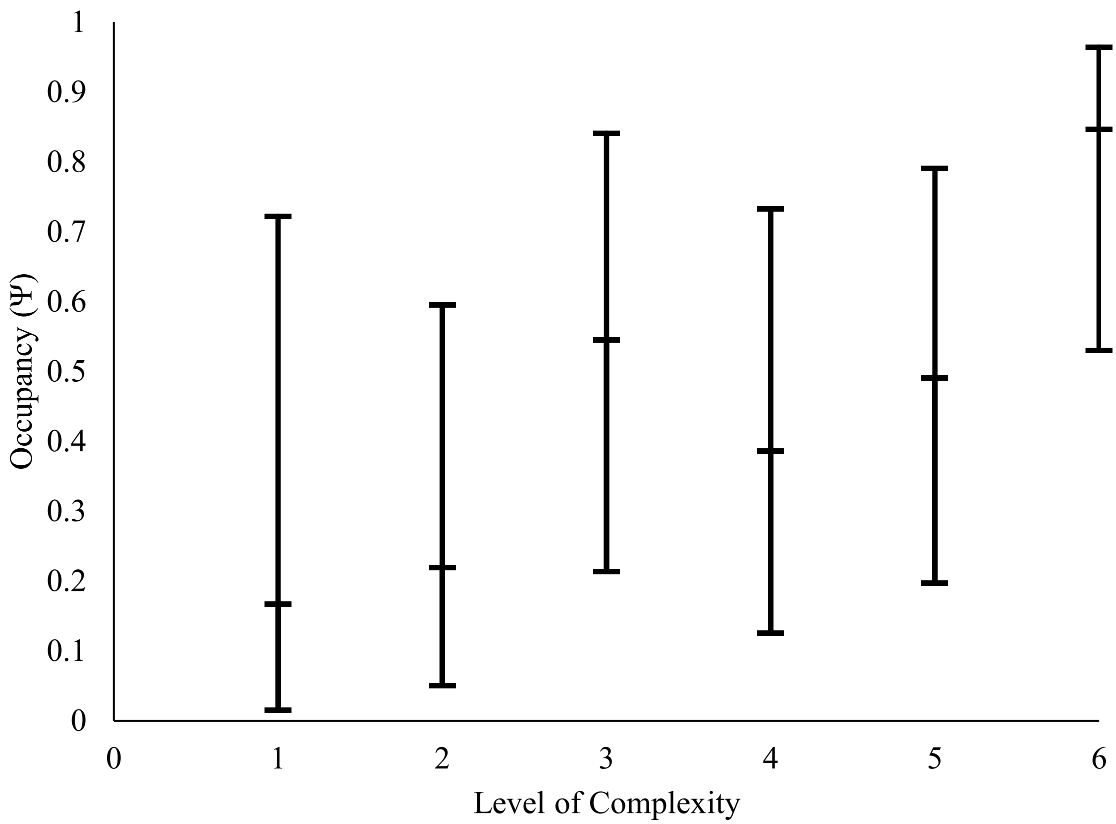

Figure 14. Predicted probability of occupancy for the open water-associated marsh bird group according to the top model manipulating wetland complexity levels while the remaining top model factors remain constant (Type = Random and Waterfowl Management Intensity = 3) in Illinois, 2015–2017.

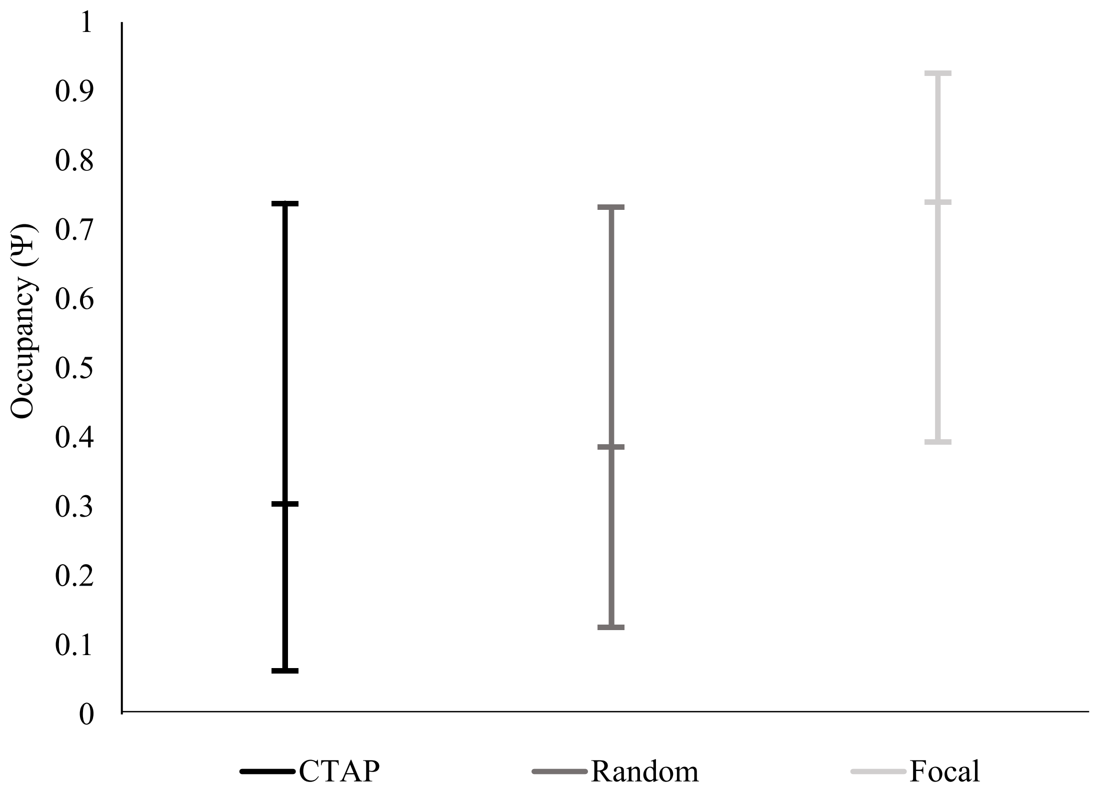

Figure 15. Predicted probability of occupancy for the open water-associated marsh bird group according to the top model manipulating site type while the remaining top model factors remain constant (wetland Habitat Complexity = 4 and waterfowl Management intensity = 3) in Illinois, 2015–2017.

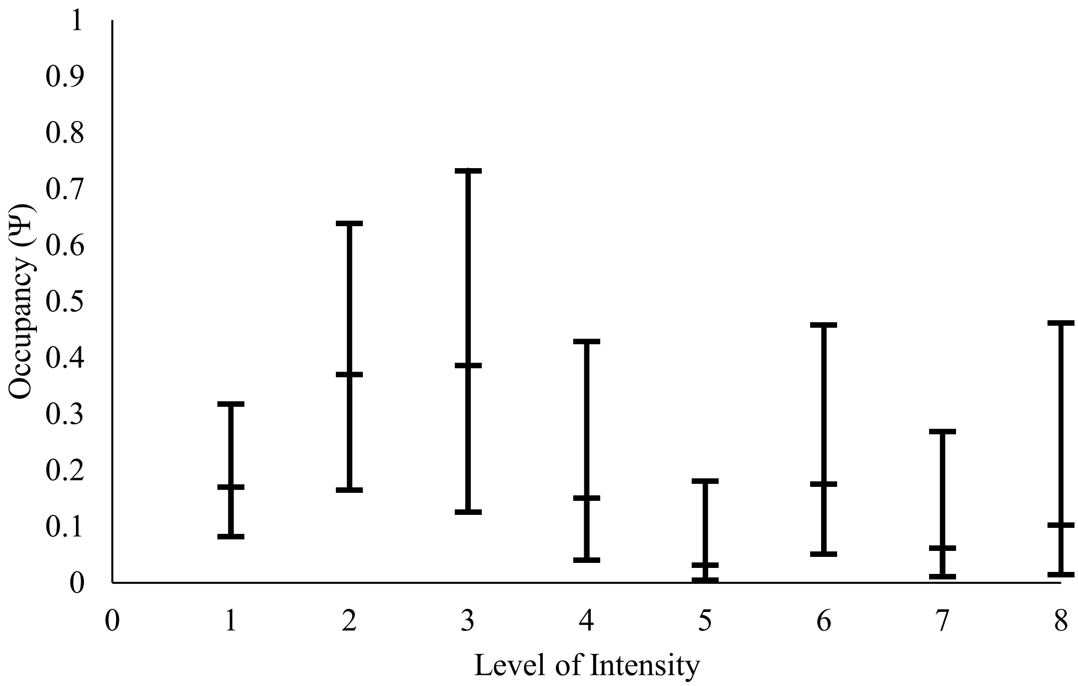

Figure 16. Predicted probability of occupancy for the open water-associated marsh bird group according to the top model manipulating wetland waterfowl management intensity while the remaining top model factors remain constant (Wetland Habitat Complexity = 4 and Type= Random) in Illinois, 2015 – 2017 .