STOPOVER DURATION AND HABITAT USE OF SPRING-MIGRATING DABBLING DUCKS IN THE WABASH RIVER VALLEY, USA

BY

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THESIS

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ABSTRACT

Spring migration is an important and often under-studied period of the waterfowl annual cycle. Stopover sites along migration routes contain habitats and resources required by waterfowl to rest and refuel before continuing north to the breeding grounds. The Wabash River Valley (WRV) in southeastern Illinois provides habitat for over 500,000 dabbling ducks each spring. Despite the heavy use of this region, information regarding stopover duration and habitat use of waterfowl is lacking. Stopover duration, or the length of time an individual spends in a distinct region, is an important metric for waterfowl managers to consider while planning for the needs and required resources of migrating birds. Stopover duration for mallards (*Anas platyrhynchos*) and green-winged teal (*Anas crecca*) was approximately 17 days (95% CI: 12.6–22.9 days). This is shorter than current estimates used by conservation planners and may shift objectives. Additionally, mallards and green-winged teal used emergent and woody wetland habitat at rates highly disproportional to the availability of those habitats on the landscape. Both species tended to avoid sites with greater amounts of agricultural in the surrounding landscape, while sites surrounded by greater amounts of open water, upland forest, and upland grassland were more likely to be used. There was also a considerable amount of use in areas under conservation easements, suggesting the importance of these easements in waterfowl management. All of this information will help land managers and conservation planners direct funding to the most important habitats in the WRV and ensure sufficient resources for waterfowl utilizing the region each spring.

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DEDICATION

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CHAPTER 1: GENERAL INTRODUCTION

Historically, waterfowl conservation efforts in North America have often focused on breeding populations and habitat, which is important for hatching, brood rearing, and eventual recruitment into the population. All increases to the population occur during the breeding season, at which time both adults and offspring are more susceptible to danger than at almost any other time of the year (Johnson et al. 1992). Despite this, the non-breeding season is also an important time period for waterfowl and can impact recruitment and population numbers. Waterfowl can spend up to 6 months on wintering grounds in the southern United States which requires large amounts of habitat and resources (Baldassarre and Bolen 1984). Winter habitat selection has also been found to directly impact the probability of reproduction success during the subsequent breeding season in some species (e.g., Sedinger et al. 2011). Spring migration is one of the least understood phases of the waterfowl annual cycle, but it may play a crucial role in breeding success. Research indicates that spring migration habitat and food availability may impact fitness, including reproductive success (Ankney and MacInnes 1978, Afton and Ankney 1991, Stafford et al. 2014).

The Midwest is primarily used for migration habitat by most species and hosts millions of spring-migrating waterfowl each year. Stopover sites provide foraging opportunities and allow migrating waterfowl to rest and refuel before continuing the migration to the breeding grounds. In general, available wetland habitat during spring migration is degraded and food resources are limited for most waterfowl species (Dahl 2006, Straub et al. 2012). For example, despite wide use of agricultural fields during autumn migration, rapid decomposition of waste grains may negate those resource types as useful for foraging in the spring (Foster et al. 2010).

Nevertheless, stopover habitats serve as vital pit stops during spring migration. Knowledge of these stopover habitats is essential for managers to be able to adequately provide appropriate habitat and resources (LaGrange and Dinsmore 1989).

Previous studies have found that the Wabash River Valley (WRV) of southeastern Illinois and southwestern Indiana hosts around 500,000 waterfowl during spring migration (Hennig et al. 2017). Conservation planning and habitat objectives for this region rely on accurate knowledge of stopover duration and habitat and resource needs of these migrating ducks. Stopover duration is the amount of time individuals remain within a specific region during migration and should reflect a balance, with individuals staying only long enough to refuel and rest (Arzel et al. 2006). Current estimates for spring stopover duration in the Mississippi Flyway are lacking for most species. The Upper Mississippi River and Great Lakes Region Joint Venture (UMRGLRJV) lists total spring migration for mallards (*Anas platyrhynchos*) and green-winged teal (*Anas crecca*) at 45 days; however, work on satellite-tracked mallards suggests this estimate may be high (Soulliere et al. 2007; Krementz et al. 2011).

The first chapter of this thesis examines both the spring stopover duration of two dabbling duck species, mallards and green-winged teal, and how those estimates may affect goals and objectives for the region. The second chapter explores habitat use of those species and whether landscape context may serve as a good predictor of use to focus conservation efforts, funding, and research in the future.

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CHAPTER 2: STOPOVER DURATION OF SPRING MIGRATING DABBLING DUCKS IN THE WABASH RIVER VALLEY, USA

2.1 ABSTRACT

During spring migration, waterfowl use stopover sites to rest and replenish nutrient reserves for the remaining migration and subsequent breeding season. The length of time an individual remains within a geographic region before moving to another distinctive region (i.e., stopover duration) can be used by waterfowl managers to develop wetland conservation objectives to ensure resources on the landscape meet the needs of waterfowl during migration. I estimated stopover duration for mallards (*Anas platyrynchos*) and green-winged teal (*A. crecca*) between January and April of 2016 and 2017 in the Wabash River Valley of Illinois and Indiana. Estimated stopover duration for mallards and teal was 17.0 days (95% CI: 12.6–22.9 days). This estimate projects into substantially shorter spring migration than current estimates used by the Upper Mississippi River and Great Lakes Region Joint Venture to set wetland conservation objectives and could affect conservation planning for waterfowl, potentially up to 50% less for both mallards and green-winged teal.

2.2 INTRODUCTION

While considerable effort has been focused on breeding and wintering ecology of waterfowl, migration is still an understudied period of their life cycle (Stafford et al. 2014). In particular, little information is available describing stopover duration, habitat use, and movement patterns of waterfowl during spring migration despite their potential effects on survival, body condition, and subsequent reproductive success (Ankney and MacInnes 1978, Afton and Ankney 1991). These carry-over effects in individuals are lagged processes in one season that can be attributed to effects of a previous season and have been observed in many different avian species (Norris 2005, Norris and Marra 2007, Sedinger and Alisauskas 2014). For example, Sedinger et al. (2011) found that habitat selection of black brant (*Branta bernicla nigricans*) during winter directly impacted probability of reproduction during the subsequent breeding season. Poor foraging conditions for mallards (*Anas platyrhynchos*) during winter can lead to delayed nesting and reduced recruitment (Dubovsky and Kaminski 1994). Northern pintails (*A. acuta*) wintering in the Playa Lakes Region of Texas have experienced decreased body condition which may have influenced overall population decline (Moon et al. 2007). Other research indicates that poor-quality foraging habitat during spring migration can negatively affect body condition at arrival on the breeding grounds, leading to decreased recruitment (Anteau and Afton 2008). Waterfowl must replenish reserves expended during migration, but also obtain resources for egg production and to sustain long incubation bouts during the subsequent breeding season (Krapu 1981). Anteau and Afton (2004, 2008, 2011) hypothesized that population declines in lesser scaup (*Aythya affinis*) may be related to declines in hen condition caused by a decline in quality of spring stopover habitats (i.e., the Spring Condition Hypothesis).

Beyond the consequences of condition for recruitment, timing of arrival also influences survival and reproductive performance. Individuals that arrive earlier on the breeding grounds, generally have greater survival and productivity than individuals that arrive later. Later migrants who are left with poor or unsuitable habitat and may not be able to successfully reproduce (Kokko 1999). As nest initiation date is delayed, average clutch size for mallards decreases and female mallards are more likely to be recruited from earlier nests

(Dzus and Clark 1998, Devries et al. 2008). Additionally, delayed arrival may compound negative influences of poor condition on nest initiation date, as females in good body condition initiated first nests approximately 15 days before individuals in poor body condition (Devries et al. 2008). In order to maximize their breeding potential, dabbling ducks should generally minimize the time spent at stopover sites and the overall time it takes to migrate (Arzel et al. 2006).

Despite the importance of spring migration as a potentially limiting time period, most research on stopover duration of dabbling ducks has been conducted during autumn migration. Stopover duration during autumn migration varies between 15 days and 68 days for mallards migrating in the Mississippi Flyway, potentially varying with habitat quality and arrival date (Krementz et al. 2012, Hagy et al. 2014). Bellrose and Crompton (1970) used leg-band recovery data to estimate a 28-day stopover duration of mallards in the Mississippi migration corridor. O'Neal et al. (2010) used radar data in concert with weekly aerial survey data and similarly estimated mean stopover duration of 28 days for dabbling ducks in the Illinois River Valley. Relative to autumn, spring migration is assumed to be more condensed due to the importance of timing for breeding (Arzel et al. 2006). The only previously published study that I identified suggested spring migration stopover duration for mid-continent mallards was 12 days for birds migrating between Arkansas and the Prairie Pothole Region (PPR; Krementz et al. 2011). However, additional estimates of stopover duration are needed for spring to determine regional and local carrying capacity needs for waterfowl.

Estimates of stopover duration are important for calculating regional carrying capacities and ultimately setting goals for habitat conservation (Soulliere et al. 2007, Hagy et al. 2014). Estimating stopover duration, especially during spring migration, can help managers better evaluate current resource capacity and objectives for managing migrating waterfowl. Managers need a better understanding of habitat needs for a variety of species during this time period, including relatively common species of dabbling ducks, such as mallards and green-winged teal. These two species of dabbling ducks were chosen as study species to encompass a range of variation within dabbling ducks common in the Midwest. Both are habitat and resource generalists and are often used as focal or surrogate species to represent the needs of other dabbling ducks (Soulliere et al. 2007, Blomquist et al. 2014, Raftovich et al. 2014). Mallards and green-winged teal are among the most numerous and widespread duck species in North America and are both important game species with wide distributions (Baldassarre 2014, Zimpfer et al. 2015). These species are representative of the broad taxa of dabbling ducks and data on their spring migration ecology will provide important data for conservation planners in the Midwest.

Ultimately, my overarching goal was to better understand the ecology of two abundant species of dabbling ducks during spring migration and provide information to conservation planners to improve accuracy of carrying capacity models used to set habitat conservation objectives for waterfowl. My objectives were to estimate and identify factors affecting stopover duration of mallards and green-winged teal during spring migration through the Wabash River Valley of southeastern Illinois and southwestern Indiana. I expected to find stopover periods for both mallards and green-winged teal to be ≤14 days and for body condition of individuals to influence stay, with lighter individuals staying longer than heavier individuals. Additionally, I expected stopover duration to vary by arrival date, with individuals arriving in February staying for longer periods than individuals arriving in April.

2.3 MATERIALS AND METHODS

Study Area

Mallards and green-winged teal (hereafter teal) were captured in the Wabash River Valley (WRV) during late winter and spring of 2016 and 2017. The Wabash River is 764 km in length and begins in Fort Recovery, OH and flows southwest until it joins the Ohio River just south of New Haven, IL (Gammon 1998). I defined the WRV as the approximate 100-year floodplain south of Terre Haute, IN, including nearby sections of the lower Embarras, White, Patoka, and Ohio River floodplains where they connected to the Wabash River (Figure 2.1). The WRV was approximately 199,940 ha and covers portions of eight Illinois counties (Edgar, Clark, Crawford, Lawrence, Wabash, Edwards, White, and Gallatin) and five Indiana counties (Vigo, Sullivan, Knox, Gibson, and Posey),

The WRV was dominated by agriculture with approximately 58% of the land being farmed in row crops, such as corn and soybeans (Hennig 2014). Emergent and woody wetlands comprised approximately 5% of the region, were primarily present near rivers and streams, and provided habitat for waterfowl when the Wabash River was at flood stage. The annual precipitation of Lawrenceville, IL, which was the approximate center of the WRV, was 111.5 cm (National Climatic Dataset Centers 2016). The average spring (January through April) temperature was 5° C, the average annual temperature was 13° C, and there were approximately 182 frost free days per year. Spring flooding of the Wabash River and its main tributaries was extremely flashy and flooded adjacent wetlands and agricultural fields for short periods of time and created large areas of temporary waterfowl habitat. Past research indicates that daily use of the WRV by spring migrating waterfowl can exceed 700,000 total ducks during peak migration in February, with the most common species being mallards, teal, and other dabbling ducks (Hennig et al. 2017).

Field Methods

I captured mallards and teal during January through April of 2016–2017 and outfitted a subset of individuals with radio-transmitters. I caught individuals using rocket nets baited with whole kernel corn at 9 trap sites on both public and private land in Illinois (5 sites) and Indiana (4 sites; Figure 2.1). After each capture event, baiting was discontinued at the capture site for ≥7 days to encourage individuals to naturally disperse from the bait sites.

After capture, I determined species and sex and obtained morphological measurements (head, culmen, tarsus, keel, and wing chord length, all measured in mm, and mass [g]) for use in a body condition index (Devries et al. 2008, Arsnoe et al. 2011). I banded individuals with aluminum leg bands and affixed radio-transmitters to individuals prior to release. I deployed three types of transmitters (164–166 MHz; Advanced Telemetry Systems, Isanti, MN) according to the mass of an individual, including Dwyer backpack style radio transmitters (26-g; Model #A1820), glue-on transmitters (2016: 9-g; Model #A2830), and glue-on/suture transmitters (2017: 5-g; Model #A2710). Due to transmitter mass, only glue-on and glue-suture style transmitters were attached to teal while mallards were outfitted with all three types of transmitters to test for transmitter effects. Glue-on and glue-on/suture transmitters were affixed using super glue to the inter-scapular region of the back, where a small spot of feathers was clipped down to the skin. Additionally, glue-on/suture transmitters were attached using two sutures tied to the transmitter (one anterior and one posterior from the transmitter). Ducks were held in standard poultry crates (with water provided) for a maximum of 8 hours after capture and before release. All individuals were released simultaneously at the site after each capture event to help ensure pair-bonded individuals were not separated. All capture, handling, and transmitter-attachment procedures were approved by the University of Illinois Institutional Animal Care and Use Committee (Protocol no. 08029) and authorized under a Federal Bird Banding Permit (no. 06507).

I began tracking radio-tagged individuals within 24-hours of release (Nilsson et al. 2013). Tracking methods included a combination of ground and aerial telemetry. Ground telemetry was conducted using either handheld Yagi antennas and receiver units or vehicle-mounted Yagi antennas and receivers using standard triangulation techniques (Yetter et al. 2017). Vehicles were outfitted with Yagi directional antennas using removable Thule© (Thule Group, Malmö, Sweden) roof racks and were rotated using a geared handle outside of the cab. I used Advanced Telemetry Systems R2000 and R4000 receivers for vehicle tracking, but I used Communication Specialists, Inc. R1000 (Communication Specialist, Inc., Orange, CA) receivers during hand tracking due to lighter weight and smaller size.

I used aerial telemetry to locate birds that had not been detected for an extended length of time on the ground (generally 5–10 days) and to confirm the bird had left the study area.

Aerial telemetry was conducted in a fixed wing aircraft from an altitude of 760 meters. After a general location of an individual was found from the air, approximate location was relayed to a ground tracking team for confirmation.

Generally, individuals were located at least once daily with time of location usually alternating between diurnal and nocturnal periods. Avoiding dawn and dusk as much as possible, diurnal observations were between 0800 and 1700 while nocturnal observations were between 1900 and 0600. At the beginning of each tracking period (diurnal vs. nocturnal), an individual was chosen at random and the area of its last known location was scanned first before researchers searched throughout the study area. Any birds incidentally encountered during the search for the randomly chosen individual were also recorded. If a transmitter was inactive for 8 hours (due to either a mortality event or a detachment), the mortality switch on the transmitter was activated and the transmitter was located for determination of mortality signal and possibly redeployment.

Data Analyses

I estimated total stopover duration using a combination of several methods (Hagy et al. 2014, Stodola et al. 2014). I calculated overall stopover duration following Stodola et al. (2014) by totaling stopover duration pre-capture-adjusted estimates, naïve estimates, and post-detection-adjusted estimates (Figure 2.2). First, I calculated naïve (observed) stopover duration for both mallards and teal by subtracting the date of capture from the date of last detection.

Secondly, I estimated pre-capture-adjusted estimates (the time from true arrival to last detection) using Program DISTANCE (Otis et al. 1993, Lehnen and Krementz 2005). The pre-capture-adjusted duration estimate calculates the sum of pre-capture and naïve stopover, and by subtracting naïve stopover estimates I calculated the pre-capture correction. Because this analysis was dependent on having complete information from capture to departure (i.e., not using data from individuals that shed transmitters), I pooled data from mallards and teal due to small sample sizes. Estimated strip-width was used as an estimate of pre-capture-adjusted duration by fitting models through the probability density function with 3 keys: 1) uniform key with cosine adjustment, 2) uniform key with simple polynomial adjustment, and 3) half-normal key with cosine adjustment. The half-normal key with a cosine adjustment, when used with potential influencing covariates, was determined to be the best fitting model type using lowest Akaike's Information Criterion scores (adjusted for small sample sizes; AIC_c). I assessed the effects of migration status, transmitter type, species, sex, year, body condition, and capture date on pre-capture-adjusted stopover duration using Multiple-Covariate Distance Sampling. Body condition index scores were calculated for each individual bird following Arsnoe et al. (2011) by conducting an ordinary least-squares regression of adjusted mass and an index of body size (principal component 1 of culmen, skull, and tarsus length; Devries et al. 2008). I evaluated the relative fit of my models using AIC_c as well as chi-square goodness-of-fit testing within Program DISTANCE (Table 2.1). I assumed that the probability of capturing an individual was proportional to residence time, that each duck had an equal probability of being captured at any point during stopover, and that radio-tagged individuals behaved similarly to wild, unmarked individuals.

Individuals were assigned a migration status based on a decision rule using naïve stopover duration. Individuals that never left the study region were deemed residents (*n* = 10); individuals that were captured early in the study period, had a naïve stopover of greater than 30 days, and eventually left the study region were considered wintering (*n* = 6); and individuals that had a naïve stopover of less than 30 days were considered migrants (*n* = 40). Migration status, transmitter, and species were potentially confounded due to the link between transmitter type and species, as well as the distribution of those transmitters across the different migratory groups. After exploring my data, I determined that the covariates transmitter and species explained little variation in pre-capture-adjusted stopover duration compared to migration status and dropped them from subsequent models. I obtained pre-capture correction estimates for both migrants as well as a combined migrant-wintering group, but was unable to estimate a correction solely for the wintering group due to small sample size.

Following naïve stopover and pre-capture correction estimation, I calculated a post-detection (the time from last detection until true departure) correction using Cormack-Jolly-Seber (CJS) models in Program MARK. The post-detection-adjusted stopover duration estimate sums the naïve stopover estimate with the post-detection correction (the amount of time an individual remained in the region but went undetected). Similar to the pre-capture correction, I then calculated the post-detection correction by subtracting the naïve stopover from the post-detection-adjusted estimate. For this analysis, I was able to generate estimates separately for mallards and teal due to larger sample size than in the pre-capture analysis (Tables 2.2, 2.3). I evaluated candidate models for detection probability that incorporated covariates for year, sex, body condition, capture date, and ordinal date. I used the best-ranked structure based on AIC_c in my subsequent models for daily persistence. I then created models for apparent survival (which in this case is to be interpreted as daily probability of persisting in the region) which used a grouping variable for migration status and other covariates including year, sex, body condition, capture date, and ordinal date. Competing models were within 2 AIC_c points of the top model and competing models were subsequently evaluated using coefficient values and confidence intervals to determine appropriate post-detection correction.

Lastly, I used my estimates of total stopover duration and the spring migration chronology of mallards from Krementz et al. (2011) to estimate total use days for both mallards and teal migrating through the upper Midwest for comparison with current estimates from the Upper Mississippi River and Great Lakes Region Joint Venture (UMRGLRJV; Soulliere et al. 2007). Krementz et al. (2011) found that mallards made only one stop on average during spring migration through the Mississippi and Central Flyways. Average stopover duration was 12 days at each site and mallards spent a total of 18 days migrating between Arkansas and the Prairie Pothole Region, including stopover, which leaves 6 days for the remainder of migration (Krementz et al. 2011). I calculated total use days for mallards and teal using the same process as the UMRGLRJV, multiplying expected populations during spring migration by total spring migration days, for comparison with current estimates.

2.4 RESULTS

I captured and radio-marked 38 mallards (2016: $n = 7$; 2017: $n = 31$) and 63 teal (2016: $n = 8$; 2017: $n = 55$). Naïve stopover duration was less for mallards classified as migrant ($n = 12$; $\bar{x} = 9.9$ days; 95% CI: 6.4–13.5, range: 2–21) than those classified as wintering ($n = 6$; $\bar{x} = 44.5$ days, 95% CI: 35.7–53.3, range: 32–58). Across migrant status groups naïve stopover duration was 21.3 days for mallards (95% CI: 12.8–29.9, range: 2–58, $n = 18$). Naïve stopover duration of migrant teal was 9.5 days (95% CI: 7.0–12.0, range 1–23 days, $n = 28$). There were no confirmed mortalities in either year.

Issues with transmitter retention led to variable rates of premature detachment among glue-on (mallard: 5; teal: 20), glue-on/suture (mallard: 1; teal: 14), and Dwyer backpack transmitters (mallard: 4). Two glue-on transmitters that detached prematurely were recovered and redeployed.

Pre-capture-adjusted stopover duration estimates and associated pre-capture corrections varied by migration status, but not transmitter, year, sex, median capture date, or body condition based on top models. Pre-capture adjusted stopover duration estimates calculated stopover duration for migrants pooled across species to be 17.0 days (95% CI: 12.6–22.9 days) which yields a pre-capture correction of 7.1 days (95% CI: 2.7–13 days) for mallards and 7.5 days (95% CI: 3.1–13.4 day) for teal. The combined pre-capture adjusted stopover duration estimate pooled across species including both migrants and wintering individuals was 17.9 days (95% CI: 13.7–23.5 days), meaning a pre-capture correction of 8 days.

Post-detection-adjusted stopover duration and post-detection correction estimates for mallards varied by migration status and date (Table 2.2). Individuals arriving later had shorter estimated stopover duration (Figure 2.3). Using the median capture date for mallards as a reference point (day 45), the post-detection-adjusted duration estimate for migrating mallards was 10.1 days (95% CI: 5.2–20.0 days) and 13.8 days (95% CI: 8.1–23.6 days) for the pooled migrant-wintering estimate. Additional covariates that appeared in the top models (within 2 AIC_c points) included sex ($\beta = 0.24$, 95% CI: -0.83–1.32), year ($\beta = 0.31$, 95% CI: -1.04–1.65), and body condition ($\beta = 0.54$, 95% CI: -10.53–11.60); however, each of these had 95% confidence intervals that included zero and likely had small and variable effects on post-capture-adjusted stopover duration. Transmitter type did not explain much variation, thus reaffirming the lack of transmitter effects found in the pre-capture-adjusted stopover duration estimate.

Post-detection-adjusted stopover duration and post-detection estimates for teal varied slightly by median capture date (Table 2.3). Individuals captured later than the median had longer stopovers ($\beta = 0.09$, 95% CI: 0.02–0.15). Additionally, covariates that appeared in the top models ($\Delta AIC_c < 2$) included sex ($\beta = 0.88$, 95% CI: -0.22–1.99) and body condition ($\beta = -3.97$, 95% CI: -10.16–2.22); however, each of these had 95% confidence intervals that included zero.

Post-detection-adjusted stopover duration estimates for both mallards and teal yielded post-detection corrections for mallards (0.2 days) and teal (-1.3 days) that suggest a lack of need for post-detection correction. Confidence intervals for both post-detection-adjusted estimates contain the naïve stopover duration estimates. This, along with high detection probabilities (0.83 for mallards; 0.83 for teal), suggested naïve estimates were sufficient at estimating stopover duration after capture.

My estimated total time of spring migration, including stopover in the WRV, for mallards and teal was 23 days (using the framework borrowed from Krementz et al. 2011; 6 days of migrating plus a 17 day stopover). Using this figure, current mallard use-day estimates in the upper Midwest (129,691,043 use-days, based on a population of 2.8 million mallards and a 45-day spring migration duration) would be reduced by nearly 50% (66,378,000 use-days). Use days for teal would be reduced from 21,937,500 to 11,212,500, a decline of approximately 49%, based on a population of 487,500.

2.5 DISCUSSION

Mallards and teal spent approximately 17 days in the WRV each spring, confirming that it is a highly used region for these species and likely other dabbling ducks during spring migration (Hennig et al. 2017). Stopover duration of teal and mallards in the WRV was longer than mallards moving from Arkansas to the PPR (Krementz et al. 2011). However, total spring migration time in the Upper Midwest is likely substantially shorter than current estimates used by the UMRGLRJV to set habitat conservation objectives and could substantially affect carrying capacity goals (Soulliere et al. 2007).

Total stopover duration of mallards decreased with date, in that mallards captured later in spring had a shorter stopover than those captured earlier. However, I found no effect of date (or any other covariate) on stopover duration of teal. This difference could be a function of flexibility, either in wintering or migration chronology, for teal. According to Baldassarre (2014), 90% of green-winged teal in the Mississippi Flyway winter in the coastal marshes of Louisiana, compared to much more flexible wintering strategies of mallards who may stop short of traditional wintering grounds and over-winter wherever conditions allow. Mallards also tend to migrate north as soon as possible in the spring, generally in early February, to arrive on the breeding grounds as early as weather conditions allow. Green-winged teal have a much more protracted spring migration, suggesting a more consistent migration each year and less pressure to be the first to arrive on the breeding grounds, which are farther north on average than mallards (Baldassarre 2014). My findings would support this consistency within teal and also highlight the flexibility of mallards to adjust migration behavior based on date and other conditions.

I did not find any effects of sex, year, or body condition on stopover duration in either the pre-capture adjusted estimate or the post-capture-adjusted estimate. Krementz et al. (2011) also found no effects of sex or year on stopover duration, and neither they nor Yamaguchi et al. (2008) tested the effects of body condition on stopover duration. Finding no significant difference in stopover duration between sexes is not surprising for mallards, since most have initiated pair bonds before January (Baldassarre 2014). Additionally, since mallard sex ratios are very close to even (slightly skewed towards more males), one could expect pairs to move together. Although green-winged teal do not form pair bonds as early as mallards, by March around 60% of individuals are paired and sex ratios are similar (Rave and Baldassarre

1989). It's possible that one of the sexes is driving migration and stopover duration, but with paired individuals it's difficult to determine.

Other researchers have noted similar variation in migration stopover in other regions and with other species of dabbling ducks. Yamaguchi et al. (2008) found mallards using 1–3 stopover sites and staying anywhere from 1–4 weeks per site during spring migration in Japan and Eastern Asia. In the same study, they estimated stopover duration of 4.5–27.8 days at each site, and found mallards stopping twice on average during spring migration (Yamaguchi et al. 2008). Krementz et al. (2011) examined spring migration patterns of mallards wintering in the Lower Mississippi Alluvial Valley (LMAV) and found that the majority of migrating mallards made one 12-day stopover during spring migration. Differences between my estimates of total stopover duration and these previous studies could be attributed to a variety of factors. Carry-over effects can influence subsequent portions of the annual cycle, and so it is possible that ducks marked in the WRV departed wintering areas in poor condition and needed to spend more time in the WRV replenishing and building energy reserves. Additionally, differences between my stopover estimates and those provided by Krementz et al. (2011) could be due to differences in wintering range or breeding destinations for migrants. Knowledge of wintering and breeding habitat for birds that use the WRV in spring might help identify the causes of these variations in stopover. Mallards breeding in the Prairie Pothole Region have a significantly further distance to travel from the WRV than individuals potentially breeding in the Great Lakes Region, which may influence spring stopover duration. Likewise, there may be different resource requirements of waterfowl that have migrated to the WRV after wintering in Arkansas compared to those wintering in Louisiana, which could impact duration of stay.

One of the largest issues I encountered while assessing stopover duration was transmitter retention. For teal, which are too small for the more secure Dwyer backpack transmitters, 54% of transmitters were shed prior to departure. For mallards, 26% of transmitters were shed prior to departure (17% of Dwyer backpacks, 40% of glue or glue/suture). Although models did not suggest an effect of transmitter type on stopover duration, further studies should be conducted to directly analyze potential effects of transmitters on stopover duration and habitat use. Fleskes (2003) found that radio-tagging northern pintails in California had no significant effect on movements or winter survival, although they cautioned against using prong and suture style transmitters for studies longer than one month. Retention rate was problematic for glue-on and glue-suture transmitters, and individuals that shed their transmitters had to be excluded from some analyses in my study.

Ultimately, spring migration chronology and stopover duration are important for parameterizing energetic carrying capacity models and in developing habitat conservation objectives. Land managers need to know when waterfowl use resources, the duration of use, and what amount of resources is required to meet the demand. Total spring migration time in the Upper Midwest is likely substantially shorter than current estimates (45 days for both mallards and teal) used by the UMRGLRJV to set habitat conservation objectives (Soulliere et al. 2007). Using a combination of my estimate and Krementz et al. (2011) migration chronologies, duck use-day estimates might be significantly lower than current estimates, by as much as 50%. Souilliere et al. (2007) estimated deficits in moist-soil and semi-permanent marsh habitats based on duck use-days in the UMRGLR. My findings suggest lower deficits in these habitats, however both habitat availability and quality are important considerations that deserve additional attention. In particular, resources in many wetlands may not be accessible if they are not flooded during the specific times when ducks are migrating.

Beyond management goals for the UMRGLRJV, my stopover duration estimates can be used to set local management goals for habitat within the WRV. Hennig et al. (2017) found peak migration to range from >300,000 to >700,000 ducks in 2012 and 2013. While this is a large range, combining this with stopover duration estimates gives managers and agencies a starting place to make goals for the WRV. For example, using Hennig et al. (2017) estimates of total ducks in 2013, I could calculate the need for at least 11.9 million duck use-days in the WRV each spring. That many duck use-days in the spring would be in addition to any duck use-days in the preceding fall and winter, and so waterfowl managers need to plan for food abundance and availability at a very large scale during the growing season through conservation easements and moist-soil management.

Two potential variables that could affect migration chronology and stopover duration in the WRV are the breeding and wintering locations of individuals stopping in the region. While the core breeding range for mallards is in the Prairie Pothole Region (approximately 7 million individuals), there is also a significant breeding population in the Great Lakes Region (approximately 500,000 individuals; U.S. Fish and Wildlife Service 2017). The distance from Lawrenceville, IL to those two regions is drastically different, with the Great

Lakes being much closer. This difference may lead to individuals traveling to the Prairie Pothole Region to either spend more time in the WRV collecting resources for a long flight, or less time due to the considerable distance left to travel. Also, wintering location may impact stopover duration as well. Approximately 45% of Mississippi Flyway mallards spend winter in the Mississippi Alluvial Valley in Arkansas and Louisiana with other concentrations in Tennessee (16.8%), Missouri (16.1%), and Illinois (6.7%; Baldassarre 2014). The origin of individuals coming through the WRV and the winter conditions they experienced likely influence variation in stopover. Teal have a much more concentrated wintering population, with 90% of Mississippi Flyway green-winged teal wintering in Louisiana. Differing from mallards, teal generally breed farther north in the boreal forest and parkland region of Canada, and most individuals likely have greater distance to travel after leaving the WRV (Baldassare 2014). Without knowledge of birds' origins and destinations, speculation about the influence of migration distance on stopover duration is difficult, but a potentially valuable topic for future study.

Habitat quality may also influence stopover duration, as other studies have noted a positive correlation between stopover duration and habitat quality (based on models predicting areas of high food abundance) for waterfowl in Arkansas, Illinois, and Canada (O'Neal et al. 2012, Hagy et al. 2014, Beatty et al. 2015). Additionally, stopovers at mid-migration areas may also be hard-wired into waterfowl based on day length and climate factors. Heitmeyer (2006) found that mallards in the Mississippi Alluvial Valley had the potential for consuming up to 222 grams of dry weight in food each day, which could represent up to 20% of an individual's body weight. This would suggest that in areas of high habitat quality, where food is not limiting, stopover duration could be shorter than current estimates. However, remaining at stopover sites longer may allow waterfowl to stop fewer times and ultimately facilitate a faster migration. Past studies suggest that food abundance in the Upper Midwest is low and subject to a great deal of interannual variability, which has implications for habitat use and bird condition during spring migration (Straub et al. 2012, Hagy et al. 2017). More work is needed to understand the role of habitat quality in affecting stopover duration at individual sites as well as implications for the entire migration period.

2.6 MANAGEMENT IMPLICATIONS

On average, individual dabbling ducks are spending just over two weeks each spring in the Wabash River Valley, which combined with abundance estimates from Hennig et al. (2017) would mean at least 11.9 million duck use-days each spring. Providing enough habitat availability and quality for 11.9 million duck use-days should be a high priority for local land managers in the WRV. Scaling up to the entire UMRGLRJV, my estimates would suggest around 49 million duck use-days (based on a population of approximately 2.1 million) are needed for dabbling ducks. Studies like mine and Krementz et al. (2011) help refine stopover durations and migration chronologies in the region, suggesting current habitat goals and objectives may be sufficient for spring migrating waterfowl at current population levels under current conditions, at least in the WRV.

2.7 TABLES AND FIGURES

Table 2.1. Relative support for models of factors affecting stopover duration using Multiple-Covariate Distance Sampling in Program DISTANCE ranked according to Akaike's Information Criterion and adjusted for small sample size (AIC_c), the number of associated parameters (*K*), the change in AIC_c relative to the top model (ΔAIC_c), and the associated Akaike weight (w_i) of radio-marked mallards and green-winged teal in the Wabash River Valley of southeastern Illinois and southwestern Indiana during springs 2016–2017.

Model	*K*	AIC_c	ΔAIC_c	w_i
Migration Status	2	306.3	0.0	0.87
Transmitter	2	310.1	3.8	0.13
Median Capture Date	2	317.6	11.3	0.0
Intercept-only (NULL)	2	335.0	28.7	0.0
Year	2	337.6	31.3	0.0
Sex	2	338.6	32.3	0.0
Body Condition Index	2	340.6	34.3	0.0

Table 2.2. Relative support for models of factors affecting daily persistence probability (post-capture stopover duration) from Program MARK ranked according to Akaike's Information Criterion adjusted for small sample size (AIC_c), the number of associated parameters (*K*), the change in AIC_c relative to the top model (ΔAIC_c), and the associated Akaike weight (w_i) of radio-marked mallards in the Wabash River Valley southeastern Illinois and southwestern Indiana during springs 2016–2017. All models used the same structure for recapture probability, which included body condition and date.

Model	*K*	AIC_c	ΔAIC_c	w_i
Migration Status + Date	7	1064.6	0.00	0.46
Migration Status + Sex + Date	8	1066.4	1.8	0.18
Migration Status + Year + Date	8	1066.4	1.8	0.18
Migration Status + Body Condition Index + Date	8	1066.6	2.0	0.17
Migration Status + Median Capture Date	7	1078.0	13.4	0.00
Migration Status	6	1080.4	15.8	0.00
Transmitter + Date	6	1081.3	16.7	0.00
Migration Status + Year	7	1081.7	17.1	0.00
Migration Status + Sex	7	1082.1	17.5	0.00
Migration Status + BCI	7	1082.1	17.5	0.00
Median Capture Date	5	1083.4	18.8	0.00
Date	5	1087.0	22.4	0.00
Transmitter	5	1089.1	24.5	0.00
Year	5	1098.5	33.9	0.00
Intercept-only (NULL)	4	1099.8	35.2	0.00
Body Condition Index	5	1100.9	36.3	0.00
Sex	5	1101.3	36.7	0.00

Table 2.3. Relative support for models of factors affecting daily persistence probability (post-capture stopover duration) from Program MARK ranked according to Akaike's Information Criterion adjusted for small sample size (AIC_c), the number of associated parameters (*K*), the change in AIC_c relative to the top model (ΔAIC_c), and the associated Akaike weight (w_i) of radio-marked green-winged teal in the Wabash River Valley southeastern Illinois and southwestern Indiana during springs 2016–2017. All models used the same structure for recapture probability, which included body condition and sex.

Model	*K*	AIC_c	ΔAIC_c	w_i
Sex + Median Capture Date	6	357.8	0.0	0.30
Median Capture Date	5	358.5	0.7	0.21
Body Condition Index + Median Capture Date	6	359.1	1.3	0.16
Sex + Body Condition Index + Median Capture Date	7	359.7	1.9	0.12
Intercept-only (NULL)	4	360.7	2.9	0.07
Sex	5	361.9	4.1	0.04
Body Condition Index	5	362.8	5.0	0.02
Date	5	362.8	5.0	0.02
Sex + Body Condition Index	6	363.5	5.7	0.02
Sex + Date	6	364.0	6.2	0.01
Body Condition Index + Date	6	364.9	7.1	0.01
Sex + Body Condition Index + Date	7	365.6	7.8	0.01

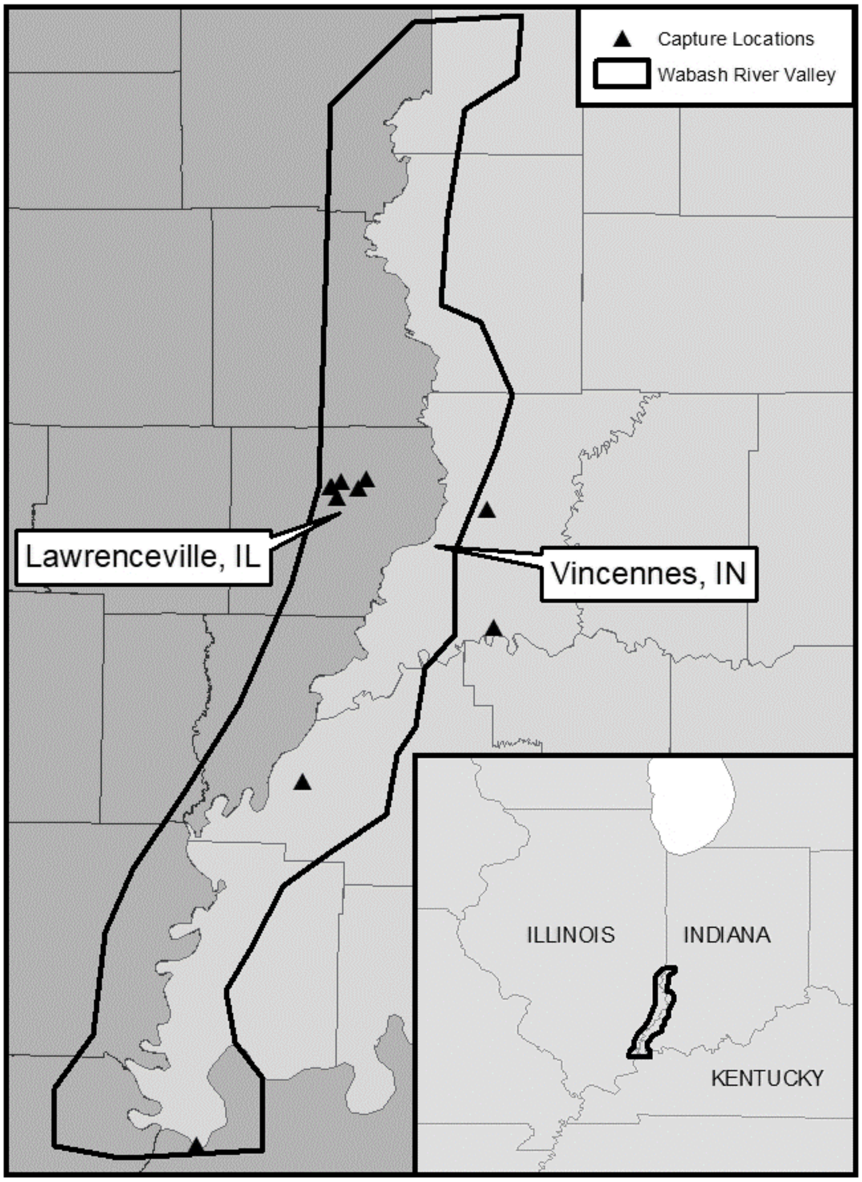

Figure 2.1. The Wabash River Valley study area, delineated by the approximate 100-year floodplain of the Wabash River, capture locations of mallards and green-winged teal (9), and major cities in southeastern Illinois and southwestern Indiana.

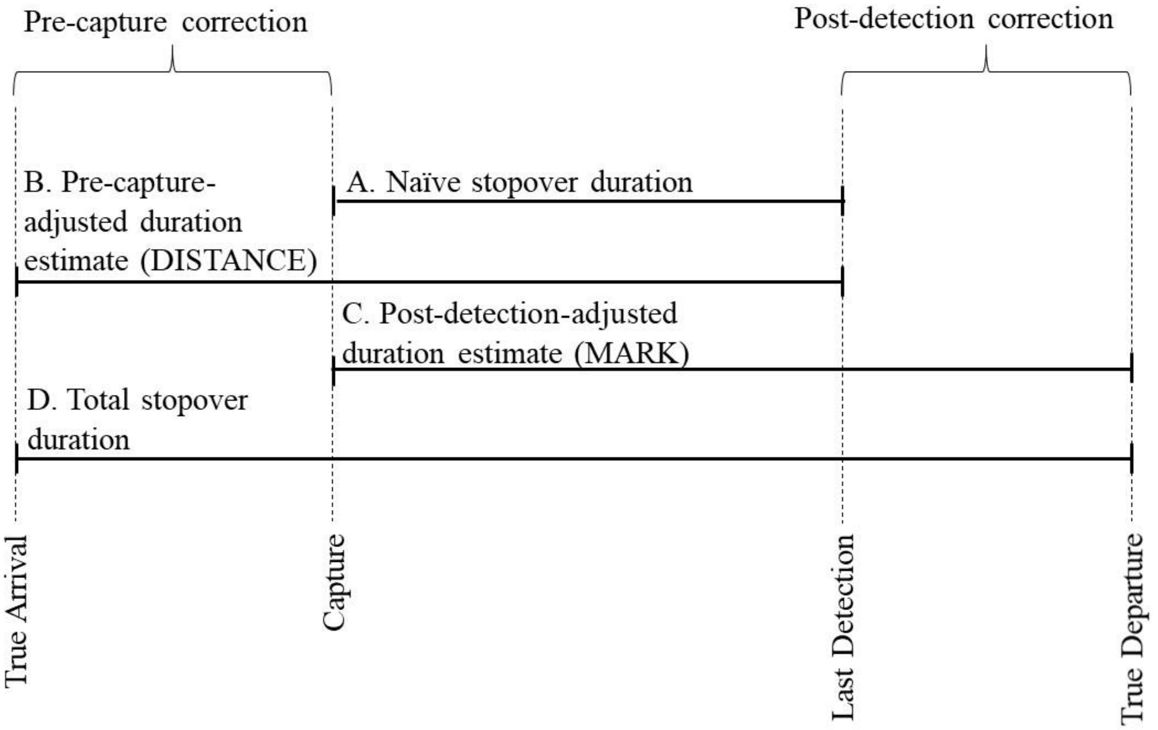

Figure 2.2. Total stopover duration of spring migrating mallards and green-winged teal is calculated by first calculating naïve stopover duration, pre-capture-adjusted stopover duration (Program DISTANCE), and post-capture-adjusted stopover duration (Program MARK). Pre-capture-adjusted stopover duration and post-capture-adjusted stopover duration were then summed and naïve stopover duration was subtracted to produce an estimate for total stopover duration.

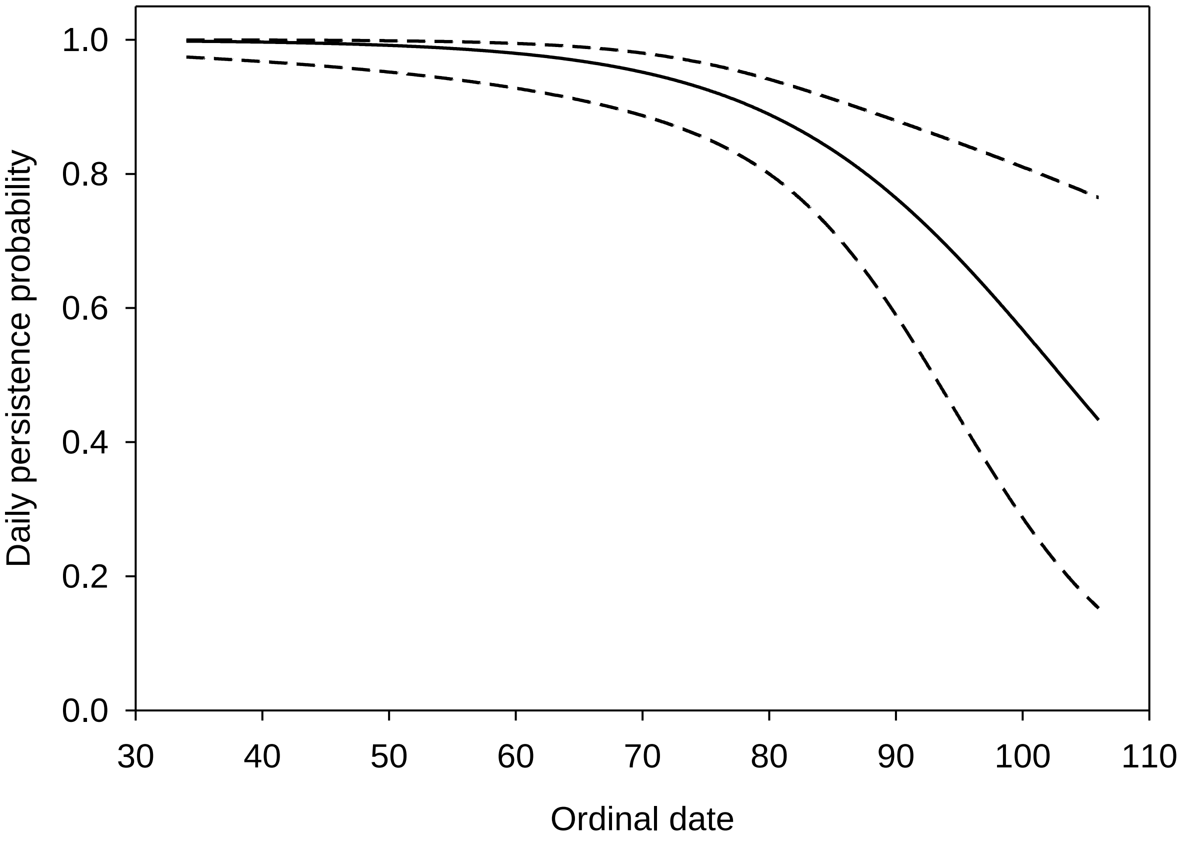

Figure 2.3. Daily persistence probability (the probability that an individual remains in the region from one day to the next) plotted against ordinal date for spring-migrating mallards in the Wabash River Valley of southeastern Illinois and southwestern Indiana in spring 2016 and 2017.

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CHAPTER 3: HABITAT USE OF SPRING MIGRATING DABBLING DUCKS IN THE WABASH RIVER VALLEY, USA

3.1 ABSTRACT

Stopover sites provide crucial habitat for waterfowl to rest and refuel during migration. Knowledge of which habitats are of greatest importance to migrating waterfowl and how the surrounding landscape influences use of those habitats can inform management decisions and conservation plans to adequately meet the resource requirements. Specifically, spring migration habitat is essential for waterfowl preparing for breeding, yet is an understudied period of the life cycle. I placed radio-transmitters on mallards (*Anas platyrhynchos*) and green-winged teal (*Anas crecca*) between January and April of 2016 and 2017 in the Wabash River Valley of Illinois and Indiana to assess habitat use and movement patterns. Both mallards and teal primarily used emergent and woody wetlands. While mallards did not show much difference in resource types used diurnally versus nocturnally, teal did show a propensity to use emergent wetlands at a higher rate during the day and then shift to woody wetlands at night. In general, sites surrounded by greater amounts of open water, upland forest, and upland herbaceous/grassland cover were more likely to be used than areas surrounded by primarily row-crop agriculture. Additionally, private and public lands enrolled in conservation easement programs (such as the Wetland Reserve Program) were frequently used by migrating waterfowl compared to other protected public lands. These findings highlight the importance of a landscape level approach to conservation, specifically focusing on wetlands while minimizing an emphasis on agricultural fields.

3.2 INTRODUCTION

Throughout the non-breeding period of the annual cycle, waterfowl are dependent on a range of resources to meet resource requirements. Wintering mallards in the Mississippi Alluvial Valley tend to use wetlands managed for waterfowl, while spring migrating mallards are dependent on a wide variety of habitats, notably seasonally flooded wetlands (Baldassarre 2014). Wetland loss has exceeded 50% in the continental United States since 1780, with potentially extreme declines in important migration areas of the Midwest, USA (Dahl et al. 1990). For example, Illinois, has lost about 85% of the historic 3.2 million hectares of wetlands statewide (Suloway and Hubbell 1994, Havera 1999). Declining and changing habitat resources for waterfowl, specifically wetlands, has likely affected habitat use and movements through this region.

During migration through the Mississippi Flyway, waterfowl primarily use emergent wetlands, forested wetlands, and agricultural fields (LaGrange and Dinsmore 1989, Heitmeyer 2006, Stafford et al. 2007). While there has been a large amount of previous research on habitat needs during fall migration and winter, relatively little is known about needs during spring migration, despite some evidence suggesting its significant importance (Kross et al. 2008, Stafford et al. 2010). Spring habitat may be critical because of the potential for carry-over effects to the subsequent breeding season. Carry-over effects result from processes or conditions in one season (e.g., wintering) contributing to individual- or population-level outcomes (e.g., recruitment) in a subsequent season (e.g., breeding). Although demonstrating carry-over effects can be challenging, they have been found in many waterbird species (e.g., Norris 2005, Norris and Marra 2007, Sedinger and Alisauskas

2014). For example, poor foraging conditions during winter can lead to delayed nesting, negatively affecting recruitment in mallards (Dubovsky and Kaminski 1994). Individuals arriving in poorer condition may delay or forego nesting resulting in subsequently lower recruitment into the population (Anteau and Afton 2004, 2008). Because of these carry-over effects, knowledge about the availability and quality of spring stopover habitat is crucial.

The Upper Mississippi River Great Lakes Region Joint Venture (UMRGLRJV) has developed habitat restoration, protection, and enhancement objectives based on the energetic requirements of multiple waterfowl species (Soulliere et al. 2007). These habitat objectives can be stepped down to states and bird conservation regions by partners, such as the Illinois Department of Natural Resources, to help prioritize wetland acquisition and management. The UMRGLRJV currently assumes food is a limiting resource during the non-breeding season, which has been supported through recent studies. Current estimates suggest that spring food abundance within wetlands in the Upper Midwest is limited, with 20% of emergent wetlands and >50% of forested and riverine wetlands providing little or no forage value (Brasher et al. 2007, Straub et al. 2012). Even with declines in wetland abundance and foraging habitat quality, migrating waterfowl may also attain nutrients from waste grain in dry or flooded agricultural fields (LaGrange and Dinsmore 1989). However, by spring waste grain from the previous autumn may have decomposed and no longer would be available for migrating ducks (Foster et al. 2010). A better understanding of relative use of different resource types during spring migration is important given that some species of ducks are dependent on resources acquired at these increasingly scarce stopover habitats for later breeding (Krapu 1981, Devries et al. 2008).

Mallards (*Anas platyrhynchos*) and green-winged teal (*Anas crecca*; hereafter teal) are two of the most widespread and abundant dabbling ducks in North America (Zimpfer et al. 2015). Both species are resource generalists and can use a wide array of wetland types during the non-breeding period (Baldassare 2014). During migration through the Mississippi Flyway, mallards use emergent and forested wetlands, as well as agricultural fields (LaGrange and Dinsmore 1989, Heitmeyer 2006, Stafford et al. 2007). Migrating teal tend to use shallow emergent wetlands and mudflats for foraging on macroinvertebrates (Rave and Baldassarre 1989, Baldassarre 2014). As generalists and representatives of dabbling ducks, both of these species are important focal species for conservation planning in the Midwest.

In order to identify which resource types are most important for spring-migrating ducks and to provide land managers with the information needed to most effectively manage and create waterfowl habitats, I 1) determined the primary resource types used by spring-migrating ducks, 2) assessed the influence of surrounding landscape context on habitat use, and 3) determined daily and maximum movement distances within the Wabash River Valley of southeastern Illinois during spring migration. I hypothesized that mallards and teal would use woody wetlands disproportionately more than available given that they provide water, cover, and food. Additionally, I hypothesized that mallards and teal would use flooded agricultural fields extensively to forage on waste grain. I predicted that teal and mallards would use wetland types similarly due to limited food and available wetland area on the landscape, and that landscapes that included wetlands and flooded agriculture would be utilized at a much higher rate. Lastly, I predicted that any movement within the region would be confined to small distances (<10 km) traveled between resource types.

3.3 MATERIALS AND METHODS

Study Area

I studied migrating mallards and teal in the Wabash River Valley (WRV) of southeastern Illinois. Hennig et al. (2017) documented daily use of the WRV in excess of 700,000 ducks during spring migration in February, with mallards and teal among the most abundant species. The Wabash River forms the border between Illinois and Indiana and flows for 764 km from Fort Recovery, Ohio until it joins the Ohio River near New Haven, Illinois (Gammon 1998). For this study, the WRV was defined as the approximate 100-year floodplain from Terra Haute, Indiana to the confluence with the Ohio River, including small sections of tributaries in the Embarras, White, Patoka, and Ohio River floodplains (Hennig et al. 2017; Figure 3.1). The WRV was 199,940 ha and encompassed portions of eight Illinois counties (Edgar, Clark, Crawford, Lawrence, Wabash, Edwards, White, and Gallatin) and five Indiana counties (Vigo, Sullivan, Knox, Gibson, and Posey).

The WRV was composed primarily (58%) of row-crop agriculture, primarily corn and soybeans (Hennig 2014). Emergent (palustrine herbaceous) and woody (palustrine forested and scrub-shrub) wetlands comprised approximately 5% of the WRV and were found most commonly near lakes, rivers, and streams. Frequent and flashy flooding of the Wabash River and its tributaries frequently inundated row-crop fields and riparian woody corridors during late winter and spring and provided temporary habitat for waterfowl. Lawrenceville, IL was located at the approximate center of the WRV and received a mean of 111.5 cm of rainfall annually, with spring temperatures averaging 5° C, annual temperatures averaging 13° C, and approximately 182 frost free days per year (National Climatic Dataset Centers 2016).

Field Methods

I captured and attached radio-transmitters to mallards and teal during spring (January – April) of 2016–2017. I captured individuals using rocket nets baited with whole-kernel corn at 9 separate trap sites in Illinois (5 sites) and Indiana (4 sites) on both private and public land (Fig. 1). Baiting at each site was discontinued for ≥7 days following a capture event to encourage individuals to naturally disperse from the bait sites. I recorded species and sex of and affixed aluminum leg bands to each individual captured. Additionally, I attached a radio transmitter (164–166 MHz; Advanced Telemetry Systems [ATS], Isanti, MN) to a subset of individuals based on random selection of individuals meeting mass and sex requirements (overall goal of 50:50 ratio). I used Dwyer backpacks (mallards only; 26-g; ATS Model A1820), glue-on transmitters (mallards and teal >300 g; 2016: 9-g; ATS Model A2830) and glue-on/suture transmitters (mallards and teal; 2017: 5-g; ATS Model A2710). Glue-on and glue-on/suture transmitters were affixed using super glue to the inter-scapular region of the back, where a small spot of feathers was clipped down to the skin. Additionally, glue-on/suture transmitters were attached using two sutures tied to the transmitter (one anterior and one posterior from the transmitter) following gluing. Ducks were held in standard poultry crates (with water provided) for a maximum of 8 hours following capture transmitter attachment. All individuals from a capture event were released simultaneously at the capture site to ensure pairs were not separated, and all capture, handling, and transmitter-attachment procedures were approved by the University of Illinois Institutional Animal Care and Use Committee (Protocol no. 08029) and authorized under a Federal Bird Banding Permit (no. 06507).

I began tracking all individuals using both ground and aerial telemetry within 24-hours of release (Krementz et al. 2012, Nilsson et al. 2013). I conducted ground telemetry using a combination of handheld Yagi antennas, vehicle-mounted Yagi antennas, and several types of receiver units (hand tracking: R1000, Communication Specialist, Inc., Orange, CA; vehicles: ATS R2000 and R4000) to triangulate individuals using conventional methods (Yetter et al. 2017). I outfitted vehicles with removable Thule© (Thule Group, Malmö, Sweden) roof racks which held Yagi directional antennas turned using an external gear system. I mounted electronic compasses on top of antennas to determine bearings during triangulation. I calibrated electronic compasses to within 0.5° and trained all personnel conducting triangulations until errors were within 3°. I used GPS units to determine and enter the origin of each bearing into a tablet running Location Of A Signal (LOAS; Ecological Software Solutions LLC, Hegymagas, Hungary) software and then used the electronic compass to enter the bearing. Once multiple bearings were entered, I triangulated the position of the transmitter within an error ellipse. As needed, additional bearings were taken to contain the error ellipse to within one resource type (Table 3.1). To classify the resource type associated with each triangulated point, I used aerial imagery as well as visual inspection. Resource type classifications for each point were dry agriculture, wet agriculture, upland grassland, forest, emergent wetlands, woody wetlands, lacustrine, and other (Table 3.1; Cowardin et al. 1979).

When possible, I tracked individuals once diurnally (0800 – 1700) and once nocturnally (1900 – 600) outside of crepuscular periods. When not feasible to locate individuals twice daily, individuals were located once daily alternating between diurnal and nocturnal locations. At the beginning of each tracking shift, a random individual was chosen and the area of its last known location was searched for all active transmitters. Any birds within range were then located and triangulated before opportunistically searching for additional individuals within the area. If a transmitter was inactive for 8 hours (due to either a mortality event or because of a premature detachment), the mortality mode of the transmitter was activated and the pulse rate doubled. I located on foot all transmitters that switched to mortality and assessed fate (e.g., predation, premature detachment, etc.) using professional judgment.

I used aerial telemetry to find individuals that had not been detected from the ground for an extended length of time (usually 5 – 10 days) and to confirm that missing individuals had migrated out of the study area. I conducted aerial telemetry from a fixed-wing aircraft from an altitude of 760 meters. After the general area of an individual was located from the air, approximate coordinates were sent to the ground tracking crew for subsequent triangulation.

Data Analyses

To characterize spatial movements within the WRV, I calculated the distance between consecutive daily locations for each individual and each set of dates available and estimated the associated mean and maximum daily movement distances. To characterize resource selection, I determined the availability of different resource types within the study region using the 2016 Cropland Data Layer (CDL; National Agriculture Statistics Service 2017). I reclassified the CDL into seven resource type components to coincide with my resource-type classifications (Table 3.1). Although the CDL does not have a classification for wet agriculture, I adjusted the estimated availability of each cover type based on resource-specific flooding estimates. I estimated the average extent of flooding in traditionally dry resource types (agriculture, grassland, forest), and reclassified availability of wet agriculture, woody wetlands, and emergent wetlands based on average percentages of flooded row crops, forests, and grasslands, respectively. To estimate average flooding, I conducted weekly ground surveys of randomly selected points throughout the WRV. All points were readily visible from a road, were classified to a specific resource component, and were determined to either be flooded or not. I conducted surveys in both 2016 (n = 182; 40 sites resampled weekly) and 2017 (n = 200 distinct sites) and supplemented these data using previous aerial grid surveys of flooding (Hennig et al. 2017).

Treating each individual bird as a sampling unit, I used Dirichlet Regression to examine effects of species, sex, year, and transmitter type on proportional resource use (Kenward 1992, Aebischer et al. 1993). Because not all resource types were used by each individual, I transformed the proportional resource use values for each individual using the equation:

$y* = \frac{y(N-1)+\frac{1}{C}}{N}$ where *y* is the value to be transformed, N is the number of observed individuals, and C is the number of available resource categories (Smithson and Verkuilen 2006, Maier 2014). Additionally, due to limited data points in certain resource types, I simplified the resource type groups into three groups: emergent wetlands, woody wetlands, and other (which includes all agriculture, herbaceous/grassland, lacustrine, and other). Using DirchletReg (Maier 2015) in Program R (R Core Team 2016), I performed a multivariate regression where response variables (three resource type categories) followed a Dirichlet distribution. DirichletReg calculates means and confidence intervals on the alpha parameters, which are not [0,1] bound, but also shows significant differences in means among groups using p-values. In this analysis, I designated $\alpha = 0.05$ to infer statistical significance.

Additionally, I divided locations into diurnal and nocturnal categories for each individual and averaged individual proportional resource use across all individuals by diel period. Additionally, using the Protected Areas Database from the USGS Gap Analysis Program and the USDA Natural Resources Conservation Service (NRCS) Geospatial Data Gateway, I determined the proportion of locations that occurred on conservation easements (e.g., NRCS Wetland Reserve Program) and other protected local, state, and federal lands.

To examine the effect of surrounding landscape on resource use by mallards and teal, I first generated 19 random points within my study area for each use location to serve as a measure of resource availability. Thus, each use location was paired with 19 random points to create a set of 20 points (Beatty et al. 2014). Random points were restricted to 45 km of each associated use point, which was twice the observed maximum distance between any two used locations for mallards, regardless of time interval between the locations. I defined the landscape surrounding used and random points based on the species-specific average distance moved between consecutive days. I used these distances to create buffers around used and random points, and extracted landscape composition within these buffers. For this analysis, I did not adjust CDL estimates of land cover because my flooding estimates for the larger study region could not be scaled down to individual points. Furthermore, such adjustment would equally affect both used and available points and would therefore not affect conclusions about differences between these point types. I first calculated means and standard errors for each resource types within both used and available points and then compared them using a mixed linear model treating each individual bird along with each set of 20 points as random variables. I assessed differences in landscape compositions between used and available points using a general linear mixed model in R package “nlme” treating each individual and set of points as random effects.

To examine which aspects of landscape composition best differentiated between used and random points, I used generalized mixed linear models with a binomial distribution and logit link function (R package “lme4”). I used the binomial response of used (1) or random (0) as the dependent variable, designated 6 resource types as independent variables (i.e., agriculture, upland grassland, upland forest, emergent wetlands, woody wetlands, and open water), and included individual ducks and sets of points (the grouping of 20 points including both used and random locations) as random effects. Overall, I generated 50 candidate models with different combinations of resource types as predictors. Prior to conducting analyses, I examined multicollinearity between variables and did not include highly correlated variables ($|r| > 0.5$) in the same model. I evaluated support for these candidate models using Akaike's Information Criterion adjusted for small sample size ($\mathrm{AIC_c}$) and assessed top models ($\Delta\mathrm{AIC_c} \leq 2$); Burnham and Anderson 2003).

3.4 RESULTS

General Capture

I captured 38 mallards (2016: $n = 7$; 2017: $n = 31$) and 63 teal (2016: $n = 8$; 2017: $n = 55$) from January–April of 2016–2017 and deployed 101 transmitters. I had 100% survival of all birds during tracking which negated the need for survival analysis, but issues with transmitter retention led to variable rates of premature detachment among glue-on (mallard: 5; teal: 20), glue-on/suture (mallard: 1; teal: 14), and Dwyer backpack transmitters (mallard: 4). Only two transmitters that detached prematurely were recovered and redeployed. I obtained 474 confirmed locations of mallard ($n = 308$) and teal ($n = 166$ teal) across 2016 ($n = 94$) and 2017 ($n = 380$).

Daily Movements

The average distance between locations on consecutive days was more than double for mallards ($\bar{x} = 1.7$ km, SE = 0.2 km, $n = 134$ locations) than for teal ($\bar{x} = 0.8$ km, SE = 0.08 km, $n = 64$ locations). Similarly, the maximum movement distance was greater for mallards (21.7 km) than teal (5.5 km). There were only slight differences in average distances between years for mallards (2016: $n = 46$, $\bar{x} = 1.9$ km, SE = 0.4 km; 2017: $n = 88$, $\bar{x} = 1.6$

km, SE = 0.2 km) and teal (2016: $n = 8$, $\bar{x} = 1.1$ km, SE = 0.3 km; 2017: $n = 56$, $\bar{x} = 0.7$ km, SE = 0.08 km). Additionally, only slight differences were found in average distances between the sexes in mallards (Male: $n = 90$, $\bar{x} = 1.9$ km, SE = 0.2 km; Female: $n = 44$, $\bar{x} = 1.4$ km, SE = 0.3 km) and in teal (Male: $n = 49$, $\bar{x} = 0.8$ km, SE = 0.1 km; Female: $n = 15$, $\bar{x} = 0.5$ km, SE = 0.07 km).

Resource Use

Proportional use of emergent wetlands was greater than availability (1.3%) for mallards (36.1%), teal (62.1%), and both species combined (45.2%; Table 3.2). Additionally, woody wetlands were used disproportionally to availability (4.0%) by mallards (49.7%), teal (31.9%), and combined (43.5%). Overall, 88.7% of all use locations were in either emergent or woody wetlands, despite those resource types comprising only 5.3% of the region. Use of dry row-crops was minimal, and use of flooded row-crops was much less than expected. Resource type use was not affected by species, sex, year, or transmitter type (Table 3.3).

Diurnal resource use for mallards was split between emergent wetlands (36.8%, 95% CI: 25.4–44.0%) and woody wetlands (47.4%, 95% CI: 35.1–47.3%) with much smaller proportions of open water, wet agriculture, dry agriculture, and grassland (Table 3.4). Similarly, nocturnal resource use was very similar for emergent (47.4%, 95% CI: 30.7–58.5%) and woody wetlands for (47.8%, 95% CI: 31.6–56.7%). Diurnal resource use for teal comprised 62.7% (95% CI: 50.7–74.7%) of locations in emergent wetlands and 28.3% (95% CI: 17.6–38.9) of locations in woody wetlands. Nocturnal resource use for teal was also split between emergent (42.2%, 95% CI: 25.9–58.6%) and woody wetlands (54.3%, 95% CI: 37.8–70.8%). In total, 32% of all use points were located within conservation easements, with 14% of mallard points and 67% of all teal points within conservation easements. Comparatively, 0% of mallard use points and 1% of teal use points were found to be on publicly owned and protected land.

Landscape Composition and Selection

Composition of resource types in the landscape was associated with both mallard and teal resource use, but differences in mean composition among resource availability and use was most pronounced in teal (Table 3.5). Across species, points surrounded by less agriculture, more upland grasslands, and more wetlands tended to be used more than expected by chance. However teal also selected areas surrounded by more upland forest and open water than randomly available, and the differences in landscape composition between used and random points were generally much greater for teal than for mallards. For example, teal used landscapes with half as much agriculture, 3 times the wetland area, and 9 times the open water as landscapes that were randomly available (Table 3.5).

For mallards, top models indicated positive relationships between probability of use and cover of wetlands ($\beta = 10.19$; 95% CI: 4.25–16.13) and upland grassland ($\beta = 2.57$; 95% CI: 1.24–3.90) in the surrounding landscape. Negative relationships existed between use and cover of open water ($\beta = -0.84$; 95% CI: -3.55–1.87) and upland forest ($\beta = -0.07$; 95% CI: -0.83–0.69; Table 3.6), but confidence intervals overlapped zero indicating only a weak effect. For teal, the top model indicated positive relationships between probability of use and cover of upland grassland (β = 2.83; 95% CI: 0.81–4.84), upland forest (β = 3.78; 95% CI: 2.84–4.72), and open water in the surrounding landscape (β = 15.29; 95% CI: 13.51–17.07; Table 3.7). Additionally, the model indicated a negative relationship with cover of wetlands (β = -6.221; 95% CI: -13.43–0.98), but the confidence interval included zero indicating only a weak effect.

3.5 DISCUSSION

Mallards and teal primarily used emergent and woody wetlands disproportionately to their availability on the landscape. Although both species used flooded row-crop fields in greater proportion than available, overall use was low relative to emergent and woody wetlands. Moreover, few locations were recorded in dry row-crop fields, despite the dominance of this cover type in the study area, indicating avoidance. Underuse of row-crop fields by dabbling ducks during spring migration indicates that these areas probably should not be considered as an important foraging resource in carrying capacity models of conservation planners. These results contrast those of LaGrange and Dinsmore (1989) during spring migration in Iowa, where a majority of mallard use was focused in flooded agricultural fields. These results from Iowa are almost 30 years old and changing agricultural practices may indicate changing availability of waste grain on the landscape during spring migration (LaGrange and Dinsmore 1989). Foster et al. (2010) noted a rapid decomposition of waste grain after autumn harvest in Tennessee, which would possibly indicate that virtually no waste grain is available at mid-latitude stopover sites during late winter and spring migrations. Also, a shift in nutrient requirements from waste grains to invertebrates during spring migration for ducks preparing for the breeding season is a potential cause for this lack of use of agriculture in my research (Arzel et al. 2006). Krapu (1972) found that hen northern pintails (*Anas acuta*) leading up to the breeding season had diets consisting of over 50% animal matter and that invertebrate consumption increased going into the breeding season. Although no information exists to characterize waste grain or invertebrate density in harvested crop fields in mid-latitude stopover sties in spring, Hagy et al. (2011) noted extremely low invertebrate densities in agricultural crops in Mississippi during winter. Mallards and teal in the WRV may be also be emphasizing high protein diets and are less dependent on grain which would mean an overall lack of importance for agriculture as foraging habitat, though further diet analysis of dabbling ducks in the WRV should be conducted.

On average, dabbling ducks are spending 17 days within the region and are moving minimally once arriving. Yetter et al. (2017) found average daily movements of autumn migrating mallards in the Illinois River Valley to be 2.8 km, which was over a kilometer more than in my study. This difference could be due to different habitat distributions in the Illinois River Valley or to different resource types utilized in autumn versus spring migration. Mallards in that study were more heavily using open water and agricultural habitats, whereas in my study there was more of an emphasis on wetland resources. Additionally, the trend for dabbling ducks to make short movements during spring in the WRV highlights the importance for land managers to take larger landscapes into consideration when planning future restoration or conservation activities. It makes more sense to congregate wetlands and resources into larger complexes as opposed to small, singular, and distant wetlands. Additionally, I was unable to calculate home range sizes due to the limited sample of locations found for each individual. Transmitter retention issues hampered the ability to collect location samples large enough for home range analysis, as 26% of mallard transmitters and 54% of teal transmitters were shed prematurely.

Interestingly, teal in my study dramatically shifted resource use during diurnal and nocturnal periods. Diurnally, most teal use points were in emergent wetlands with some use of woody wetlands. Nocturnally, use of emergent wetlands declined approximately 20% while woody wetland use increased by 26%. Teal have been known to spend up to 68% of their diurnal time foraging, especially while in moist-soil wetlands and mudflats, so perhaps in my study they foraged in emergent wetlands and retreating to the cover of woody wetlands to roost (Johnson and Rohwer 2000, Osborn et al. 2017). On the other hand, mallard use of woody wetlands remained essentially constant both diurnally and nocturnally. Davis et al. (2009) found similar high proportional use of woody wetlands both diurnally and nocturnally among mallard hens wintering in Arkansas and Louisiana. Mallard use of emergent wetland increased by roughly 11% at night, which is most likely attributable to birds that had dispersed to feed and loaf during the day returning to a roost wetland at night. Also, due to the frequent flooding in the region there was usually a gradient between emergent and woody wetlands, which could lead to teal nocturnally foraging intermittently between these resource types.

The discrepancy between dabbling duck use on conservation easements and other public land highlights the importance of private land habitat protection programs, such as the NRCS Wetland Reserve Program (WRP) and the Floodplain Easement Program. Conservation easements comprised approximately 7% of the WRV, yet they accounted for almost a third of all observed dabbling duck use locations in my study. Considering the variability of flooding in the WRV, conservation easements within the region may provide some stability and consistency for migrating waterfowl each spring. Beatty et al. (2014) found similar trends among mallards captured in Saskatchewan and Arkansas that consistently selected areas with WRP and protected sanctuaries. Within the Wabash Valley Region there are 14,857 ha of conservation easements (which include some public lands) as well as 8,359 ha of public land (local, state, and federal) that are not enrolled in conservation easements. While there is minimal land in the area owned by the Illinois Department of Natural Resources and the U.S. Fish and Wildlife Service, agencies should continue to fund and enforce active management of wetlands and conservation easements in the region as these lands are providing needed habitat for spring migrating waterfowl.

My results also suggest that the landscape context influenced resource use. Both mallards and teal selected areas with lower row-crop cover and greater grassland and wetland cover in the surrounding landscape. The pattern of avoiding areas surrounded by row-crops seemed particularly strong for teal, as did an increased selection of areas surrounded by forest and open water. Teal have been known to select areas of dense emergent vegetation during the spring (Murkin et al. 1997). This would explain the strong positive pattern for trees, natural vegetation, and wetlands, and the aversion for row-crop agriculture.

Webb et al. (2010) found a positive relationship between dabbling duck use and wetland area, suggesting wetland complexes drew more waterfowl than isolated wetlands as they provided a variety of forage and cover. Similarly, I found that mallard use increased with greater cover of wetlands and upland grassland in the surrounding while teal use could be predicted by more upland forest and grassland as well as open water. Beatty et al. (2014) found that mallards increased selection for woody wetlands during spring migration compared to autumn migration and my observations seem to support this conclusion. This is congruent with wintering habitat selection of mallards, which spend considerable time in bottomland forests and agricultural fields (Kaminski et al. 1993, Davis and Afton 2010, Baldassarre 2014). Green-winged teal breed in the boreal forest (Moisan 1967) and winter in wetland complexes containing both fresh and brackish waters (Baldassarre 2014). Additionally, wintering teal were less associated with agriculture than mallards (Rave and Baldassarre 1989). In general, dabbling ducks in the WRV during spring selected areas with less agriculture and more natural vegetation, either for more foraging opportunities, more cover, or both.

3.6 MANAGEMENT IMPLICATIONS

With close to 90% of use points for mallards and teal occurring in either emergent or forested wetlands and with these resource types comprising less than 5% of the landscape, managers should focus on conservation and management of existing wetlands as well as restoration of additional natural wetland types. Due to the proclivity of waterfowl to use these areas, conservation easements may be a good model for wetland restoration and protection in the region. While natural flooding provides a fair amount of available habitat at times, an increased number of conservation easements would help provide habitat stability due to the unpredictability of flooding in the region. Existing easements need to be continually managed with appropriate water manipulation and vegetation removal/installation. Also, managers should take into account surrounding landscape when assessing management and restoration, prioritizing areas that already have a complex of natural cover such as wetlands, grasslands, and forests.

3.7 TABLES AND FIGURES

Table 3.1. Resource classifications used to describe mallard and American green-winged teal locations within the Wabash River Valley in spring of 2016 and 2017. Resource classifications for wetlands based on the Cowardin et al. (1979) classification system.

Resource Type	Description
Dry Agriculture	Row-crop agricultural fields without surface water (smaller than 0.2 ha of contiguous water)
Wet Agriculture	Row-crop agricultural fields with standing sheetwater (greater than 0.2 ha of contiguous water)
Upland Grassland	Upland areas with herbaceous vegetation such as road margins and fallow fields.
Forested	Areas dominated by woody vegetation, timber, high shrubs, etc. without water
Emergent Wetland	Palustrine emergent wetlands (moist-soil or other non-agricultural herbaceous vegetation) with a coverage of >30% or open water of a size <8 ha
Woody Wetland	Palustrine forested and scrub-shrub wetland areas
Open Water	Area of open water, such as a lake, pond, or river channel larger than 8 ha with <30% emergent vegetation
Other	Any resource type that does not fit into any other classification (e.g., developed area, barren ground, etc.)

Table 3.2. Proportional resource availability (based on a corrected[1] 2016 Cropland Data Layer from the National Agricultural Statistics Service and the USDA of the Wabash River Region) compared to proportional resource use by mallards (MALL), American green-winged teal (GWTE), and combination both species in the Wabash River Valley during spring of 2016 and 2017.

Resource Type	Available	MALL Use	GWTE Use	Combined Use
Emergent wetland	0.004	0.361	0.621	0.452
Woody wetland	0.040	0.497	0.319	0.435
Wet Agriculture	0.016	0.087	0.036	0.069
Open Water	0.024	0.026	0.018	0.023
Grassland	0.055	0.019	0.000	0.013
Dry Agriculture	0.642	0.010	0.006	0.008
Forest	0.131	0.000	0.000	0.000
Other	0.088	0.000	0.000	0.000

Table 3.3. Coefficients (β) of covariates tested for potential differences in proportional resource use using Dirichlet Regression for mallards (MALL) and green-winged teal (GWTE) in the Wabash River Valley during spring of 2016 and 2017.

Species	β	Lower 95% CI	Upper 95% CI
Emergent Wetlands	0.11	-0.64	0.86
Woody Wetlands	-0.28	-1.05	0.50
Other	-0.11	-0.79	0.58
Sex			
Emergent Wetlands	0.18	-0.37	0.73
Woody Wetlands	0.19	-0.35	0.73
Other	0.03	-0.46	0.52
Year			
Emergent Wetlands	-0.55	-1.37	0.27
Woody Wetlands	-0.79	-1.66	0.08
Other	-0.60	-1.36	0.17
Transmitter			
Emergent Wetlands	0.45	-0.3	1.21
Woody Wetlands	0.41	-0.36	1.17
Other	-0.58	-1.31	0.16

Table 3.4. Average proportion of resource use separated for diurnal and nocturnal periods for mallards and green-winged teal in the Wabash River Valley of southeastern Illinois and southwestern Indiana in springs of 2016 and 2017. Missing values indicate the resource type was not used during that period.

Mallard	Diurnal	Lower 95% CI	Upper 95% CI	Nocturnal	Lower 95% CI	Upper 95% CI
Emergent Wetland	0.368	0.254	0.483	0.474	0.307	0.641
Woody Wetland	0.474	0.351	0.597	0.478	0.316	0.640
Open Water	0.068	-0.013	0.148	–	–	–
Wet Agriculture	0.066	0.027	0.106	0.036	-0.009	0.081
Dry Agriculture	0.016	-0.006	0.037	–	–	–
Upland Grassland	0.009	-0.003	0.020	0.012	-0.005	0.029
Green-winged Teal						
Emergent Wetland	0.627	0.507	0.747	0.422	0.259	0.586
Woody Wetland	0.283	0.176	0.389	0.543	0.378	0.708
Open Water	0.047	-0.017	0.110	0.034	-0.033	0.102
Wet Agriculture	0.036	-0.008	0.080	–	–	–
Dry Agriculture	0.008	-0.007	0.023	–	–	–
Upland Grassland	–	–	–	–	–	–

Table 3.5. Proportion of different land-cover classes in the landscape surrounding used and random (available) points for mallards (*n* = 308) and green-winged teal (*n* = 166) in the Wabash River Valley of southeastern Illinois and southwestern Indiana in springs of 2016 and 2017. Differences were assessed with a general linear mixed model.

Mallard	Used	SE	Available	SE	*F*	*P*
Row-crop Agriculture	0.579	0.003	0.610	0.003	6.08	0.013
Upland Grassland	0.094	0.004	0.078	0.001	14.75	<0.001
Upland Forest	0.212	0.009	0.203	0.002	1.17	0.281
Wetlands	0.008	0.001	0.005	<0.001	12.00	<0.001
Open Water	0.026	0.003	0.023	0.001	1.49	0.222
Other	0.080	0.001	0.082	0.004	0.078	0.781
Green-winged Teal						
Row-crop Agriculture	0.346	0.019	0.640	0.004	234.64	<0.001
Upland Grassland	0.101	0.006	0.067	0.001	30.67	<0.001
Upland Forest	0.316	0.014	0.188	0.003	84.76	<0.001
Wetlands	0.014	0.002	0.005	<0.001	38.65	<0.001
Open Water	0.172	0.005	0.019	0.001	1057.52	<0.001
Other	0.049	0.008	0.081	0.002	17.16	<0.001

Table 3.6. Relative support for candidate models examining the influence of landscape context on resource use of mallards in the Wabash River Valley of southeastern Illinois and southwestern Indiana during spring 2016 and 2017.

Model	n	*k*	AIC_c	ΔAIC_c	w_i
Wetlands + Upland Grassland	6160	4	2433.7	0.0	0.49
Wetlands + Upland Grassland + Open Water	6160	5	2435.3	1.6	0.22
Wetlands + Upland Grassland + Upland Forest	6160	5	2435.7	2.0	0.18
Wetlands + Upland Grassland + Open Water + Upland Forest	6160	6	2437.3	3.6	0.08
Upland Grassland	6160	3	2441.1	7.4	0.01
Upland Grassland + Open Water	6160	4	2442.4	8.7	0.01
Upland Grassland + Upland Forest	6160	4	2443.0	9.3	0.00
Wetlands + Row-crop Agriculture	6160	4	2443.6	9.9	0.00
Wetlands	6160	3	2444.2	10.5	0.00
Upland Grassland + Open Water + Upland Forest	6160	5	2444.3	10.6	0.00
Wetlands + Open Water + Row-crop Agriculture	6160	5	2445.0	11.3	0.00
Wetlands + Upland Forest	6160	4	2445.9	12.2	0.00
Row-crop Agriculture	6160	3	2447.9	14.2	0.00
Intercept-only	6160	2	2451.7	18.0	0.00
Open Water	6160	3	2452.4	18.7	0.00
Upland Forest	6160	3	2452.6	18.9	0.00

Table 3.7. Relative support for candidate models examining the influence of landscape context on resource use of green-winged teal in the Wabash River Valley of southeastern Illinois and southwestern Indiana during spring 2016 and 2017.

Model	n	*k*	AIC_c	ΔAIC_c	w_i
Upland Grassland + Upland Forest + Wetlands + Open Water	3320	6	882.7	0	0.58
Upland Grassland + Upland Forest + Open Water	3320	5	883.8	1.1	0.33
Upland Forest + Wetlands + Open Water	3320	5	887.4	4.7	0.06
Upland Forest + Open Water	3320	4	888.3	5.6	0.03
Row-crop Agriculture + Wetlands + Open Water	3320	5	915.9	33.2	0.00
Row-crop Agriculture + Open Water	3320	4	917.3	34.6	0.00
Upland Grassland + Open Water	3320	4	936.0	53.3	0.00
Upland Grassland + Wetlands + Open Water	3320	5	937.3	54.6	0.00
Open Water	3320	3	942.2	59.5	0.00
Wetlands + Open Water	3320	4	943.5	60.8	0.00
Row-crop Agriculture	3320	3	1128.1	245.4	0.00
Row-crop Agriculture + Wetlands	3320	4	1129.4	246.7	0.00
Upland Forest	3320	3	1258.6	375.9	0.00
Upland Grassland	3320	3	1302.7	420.0	0.00
Wetlands	3320	3	1303.8	421.1	0.00
Intercept-only	3320	2	1324.1	441.4	0.00

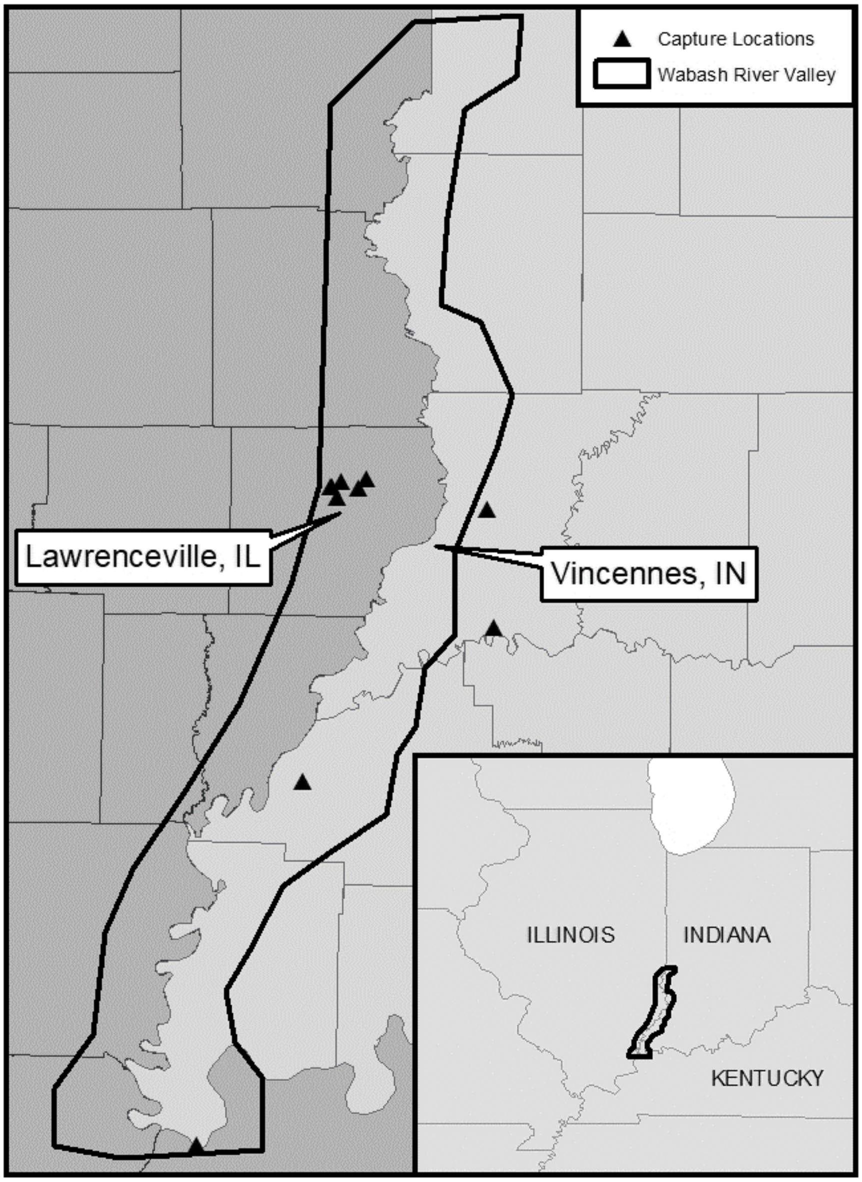

Figure 3.1. Wabash River Valley study region, based on 100-year floodplain of the Wabash River, where I studied spring-migrating ducks. Included are capture locations (9) on private and public land.

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CHAPTER 4: GENERAL CONCLUSION

Each year, millions of waterfowl travel thousands of miles between breeding and wintering grounds in the Mississippi Flyway. During migration, waterfowl use stopover sites to rest and refuel. In spring, these stopover sites are crucial for individuals to obtain the resources required as they prepare for the breeding season. To adequately provide these resources, managers need specific information to characterize resource needs, including population size, stopover duration, and resource selection.

In Chapter 2, I characterized mallard and green-winged teal stopover duration in the Wabash River Valley. I assessed total stopover duration, using a variety of methods, and found that both mallards and teal were spending approximately 17 days in the region during spring migration. Stopover duration is important for managers and conservation planning organizations, such as the Upper Mississippi River Great Lakes Region Joint Venture and the Illinois Department of Natural Resources, in order to calculate expected duck use-days, determine foraging habitat objectives, and estimate resource deficit in the region. My calculations yielded a 50% reduction in foraging habitat requirements for the Joint Venture, although this does not take into consideration actual habitat available on the landscape or the quality of that habitat.

In Chapter 3, I found that the majority of dabbling duck use during spring migration in the Wabash River Valley was in emergent and woody wetlands, including 88% of all locations across species and diel periods, despite only 5% availability on the landscape. Notably, ducks underutilized or avoided dry and flooded agricultural areas even though it was the dominant cover type in the region. Additionally, I assessed all use locations for mallards and teal to determine differences in resource composition surrounding use points and found that landscapes used by mallards was associated with lower compositions of agriculture and higher compositions of upland grasslands and wetlands. Teal also selected areas with lower compositions of agriculture, but they selected landscapes with higher compositions of upland grasslands, upland forests, wetlands, and open water. It was evident that both mallards and teal used areas with more natural vegetation and water on the landscape and not as much agriculture. Also, it was clear that conservation easements within the WRV were highly used by migrating dabbling ducks, illustrating the importance of those programs for habitat conservation on private and public lands.

As waterfowl research continues in the Wabash River Valley, an emphasis on resource availability and quality is essential for meeting the needs of migrating ducks. Conservation efforts in the region should continue focusing on preserving and restoring wetlands, although landscape compositions of resources should be taken into consideration. By using these duration estimates along with the resource selection data, managers can focus conservation efforts and funding on areas that can maximize impact for spring-migrating dabbling ducks.