TRAPPING RATES, SURVIVAL, AND HABITAT SELECTION FOR WOOD DUCKS IN CENTRAL WISCONSIN

By

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CHAPTER ONE: PROCEDURES, CAPTURE RATES, AND FACTORS INFLUENCING TRAPPING WOOD DUCKS WITH DECOY TRAPS

ABSTRACT

Wood ducks are one the most common and studied waterfowl species in the Mississippi and Atlantic flyways. However, most research on breeding female populations comes from those nesting in artificial nest boxes. While this capture method might be relatively easy and efficient, it inherently eliminates, or at the very least, reduces the chances of studying wood ducks that nest in natural tree cavities. This seems problematic given most wood ducks do not nest in artificial boxes (Bellrose 1990) and natural cavity availability in the Upper Midwest is increasing annually (Denton et al. 2012). Therefore, my goal was to evaluate trapping wood ducks using decoy traps as an alternative method. I purchased, provided care for, and used 47 domesticated 'decoy' wood ducks in 2017 and 2018 at the Mead Wildlife Management Area (WMA) in central Wisconsin to catch wild pre-breeding female wood ducks. I also evaluated capture rates for baited traps and provided use rates for > 100 artificial next boxes that are managed by the Mead WMA staff. I captured females (n=27) in decoy traps in 2017 and 2018. Females were trapped at a rate of 0.08 birds/trap day in decoy traps both years, but I failed to catch any wood ducks in baited traps. I found that smaller decoys captured more wild females. Use rates of artificial nest boxes by wood ducks was 0.09 and 0.07 in 2017 and 2018, respectively, and were historically low. Domestic wood duck husbandry and health testing logistics can be a time and financial limitation. Decoy trapping was the most successful method for capturing pre-nesting wood ducks and the population of birds I captured from them represents a promising alternative to studying solely box-nesting populations.

INTRODUCTION

Researchers and managers study population dynamics of wildlife species because effective conservation relies on reliable information pertaining to drivers of population change, especially for a harvested species such as the wood duck (*Aix sponsa*). While studying and analyzing band return data can produce annual survival (Koons et al. 2017) and population estimates (Sedinger and Herzog 2012) at large geographic scales (i.e. flyway), these studies cannot isolate factors at localized areas or elucidate within-year drivers of population change. Estimating within season vital rates such as nest success, nest propensity, or within year (i.e. breeding season) survival and others has significant implications for harvest and habitat management strategies and priorities (Hoekman et al. 2002, Coluccy et al. 2008). Furthermore, recent analytical advancements have demonstrated the value of Integrated Population Models (IPMs; Arnold et al. 2017) to better understand drivers of wildlife populations. These IPMs often require reliable parameters that are only estimated with intense and long-duration field study. Studies estimating within-year vital rates, which can ultimately inform IPMs, often require physical capture of wildlife and frequent monitoring for populations of interest. Population models can provide wildlife managers with a species status so priority or focal populations can be identified and managed appropriately (Robinson et al. 2016).

There have been many studies aimed at estimating wood duck breeding season female, brood, and duckling survival (Robb and Bookhout 1990, Davis et al. 2001, Dyson et al. 2018). In most instances, researchers capture wood ducks directly from artificial nest boxes and then place radio transmitters on females to obtain daily survival and location signals (Davis et al. 2001, Dyson et al. 2018). While this method of capture might be relatively easy and efficient, it inherently eliminates, or at the very least, reduces the chances of studying birds that select natural cavities for nest sites. This seems especially problematic if the goal is to provide robust (i.e. reduced bias) parameter estimates that represent a biological breeding population. Taken further, Bellrose (1990) asserted, at a population level, most wood ducks at the flyway level do not nest in artificial boxes and Denton et al. (2012) predicted natural cavity availability in the Upper Midwest is not limiting wood duck population growth. Therefore, very little is known about the relationship between information collected from wood ducks from artificial nest boxes and those that use natural tree cavities. In fact, while there has been a multitude of mark-recapture and radio telemetry studies of female ducks during the nesting and brood-rearing periods of the breeding season, few collected data on adult females prior to nest initiation (but see Robb and Bookhout 1990, David 1986). Clearly, there is an information need for additional efforts to evaluate characteristics of capturing birds pre-breeding.

While there are many techniques available to capture ducks (Evrard and Bacon 1998), using decoy traps have rarely been used to capture wood ducks, yet they might pose a particular advantage if the goal is to study ducks during the breeding season, especially in areas where there is geographic overlap between breeding and migration habitats (Ryan et al. 1998). Decoy traps have been successful for capturing dabbling and diving ducks during the breeding and post-breeding season (Anderson et al. 1980, Sharp and Lokemoen 1987, Ringelman 1990). Decoy traps rely on a behavioral response whereby territorial individuals approach a conspecific with the intent of ejecting it from a territory (Ringelman 1990, Garretson 1998). This territorial response is acute during the pre-breeding and breeding season and near nest locations, thus most birds captured in decoy traps are likely to be nesting nearby or attempting to nest soon. Waterfowl also may be attracted to a decoy trap as a mate-seeking response, resulting in non-target capture of males (i.e. individuals approach to seek a potential mate; Ringelman 1990, Brasher et al. 2014) or as an extra-pair copulation opportunity (i.e. paired individuals approach following female incubation; McKinney 1985). The capture efficiency of baited traps (e.g., swim-in, floating), on the other hand, might be related to the timing of life history events and therefore is more effective when ducks are desiring the type of bait in the trap. For instance, ducks, especially females, are often selecting food like invertebrates, rather than carbohydrates, like corn, during the pre-breeding season (Baldassarre 2014), thus it might be more difficult to capture females on bait during this time. However, catching birds on bait can yield large numbers but many may be migrating through the area, relying on carbohydrates to fuel their migration (Baldassarre 2014). I decided to target capture primarily with decoy traps and compare capture rates with baited traps.

Decoy trapping has successfully been used on breeding waterfowl in Wisconsin (WI) specifically, mallards (*Anas platyrhynchos*) and blue-winged teal (*Spatula discors*; Gatti unpublished reports). While this study demonstrated effectiveness of capturing each target species, wood ducks, were not targeted. I am aware of only one study that captured wood ducks using decoy traps (David 1986) and another one that tried unsuccessfully (Evrard and Bacon 1998). If successful at capturing females, I contend decoy trapping can serve as a promising alternative to only studying birds nesting in artificial nest boxes.

Therefore, I evaluated the effectiveness and describe the procedures to capture wood ducks using decoy traps during the breeding season.

My goal was to evaluate capture methods to provide increased sample precision for studying female wood ducks during the breeding season. My objective was to capture locally nesting wood ducks prior to nest initiation in decoy traps. I hypothesized that decoy trapping would be more successful (i.e. greater capture rates) than bait trapping at capturing local nesting females.

STUDY AREA

The study took place within Wisconsin Department of Natural Resources' Mead Wildlife Management Area (hereafter Mead WMA) located 35 km northwest of Stevens Point, Wisconsin, USA (Figure 1). The area spans areas of Portage, Wood, and Marathon counties. Mead is a 13,000-hectare floodplain, drained by the Little Eau Pleine River, and bordered to the north by the Big Eau Pleine River. Dikes impound several management units designed to hold water for waterfowl where structures control water levels and promote growth of moist-soil plants. Cover types included 27% flowage (impounded wetland), 25% aspen (*Populus* spp.), 13% brush (willow and alder, *Salix* and *Alnu*s spp.), 13% grass-sedge marsh and upland grass, 16% hardwoods (primarily maple-oak basswood, *Acer-Quercus-Tilia* spp.), 3% agriculture, and 3% conifer (Patrice Eyers, personal communication). Forested wetlands are subject to seasonal flooding especially in late winter and spring. The average temperature in March through August 2017 was -1.9°C, 7.7°C, 11.6°C, 18.1°C, 20.3°C, and 17.6°C, respectively. The average temperature in March through August 2018 was -1.9°C, 0.1°C, 12.8°C, 19.2°C, 21.1°C, and 20.2°C, respectively. Precipitation in March through August 2017 was 57.4 mm, 136.1 mm, 119.4 mm, 169.7 mm, 82.6 mm, and 90.7 mm, respectively. Precipitation in March through August 2018 was 28.4 mm, 72.1 mm, 78.7 mm, 133.9 mm, 62.7 mm, and 112.5 mm respectively. On 6 April 2018, Marathon county received 660.4 mm of snow, the most since 6 March 1959 (561.3 mm; NOAA 2019).

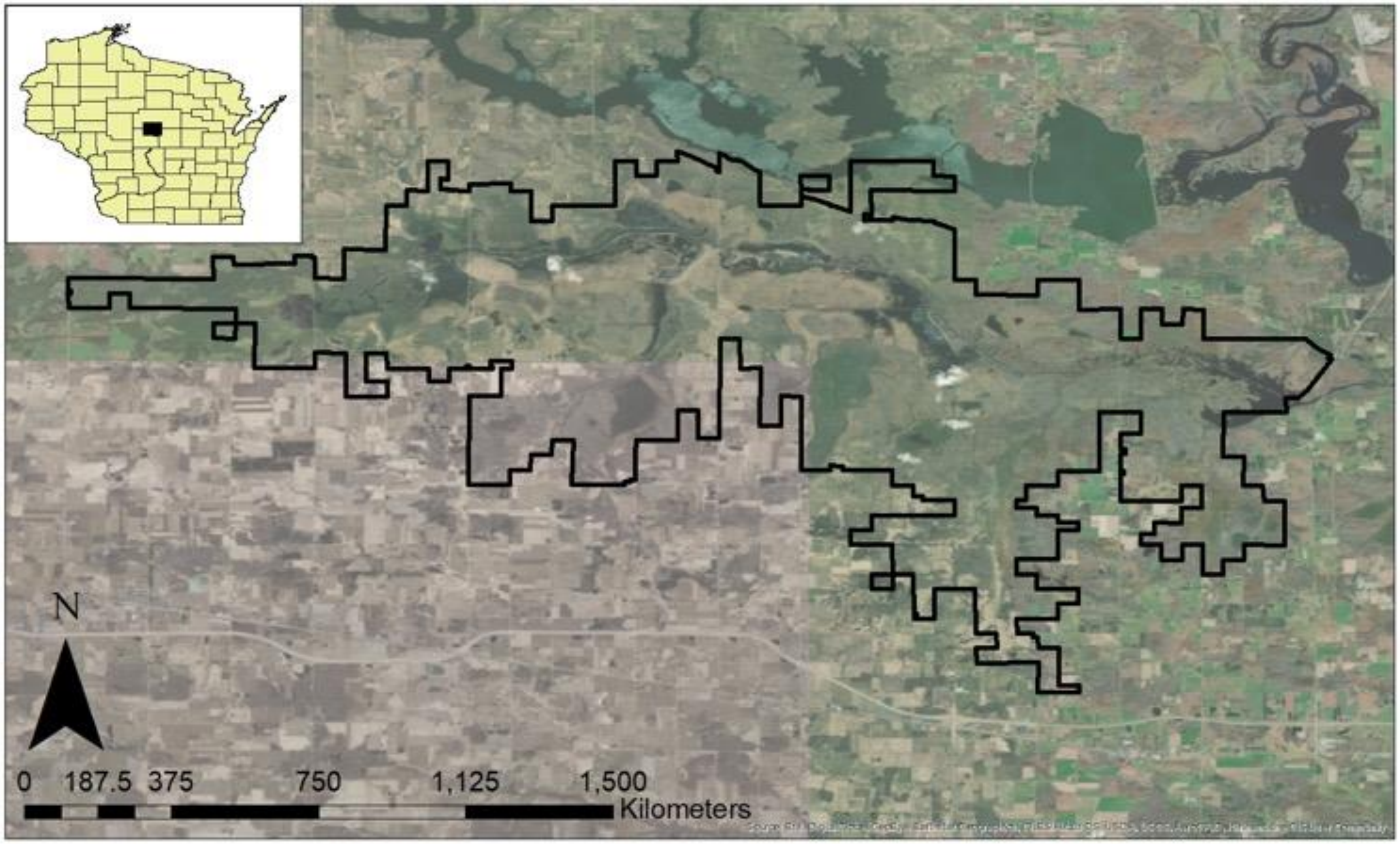

Figure 1. Boundary (black outline) of Mead WMA, WI, USA where female wood ducks were captured and tracked during 2017–2018.

METHODS

Field Methods

Care and Husbandry.—Decoy traps rely on a live ‘decoy’ to attract wild birds. I purchased domesticated female wood ducks (*n* = 12 in 2017, 35 in 2018) from Willow Creek game farm, Rosholt, WI, to serve as decoys. Prior to transfer to my care, all birds had their primary feathers clipped on one wing to prevent flight. Before use in the field, all birds were sampled for bacteria (acid fast stain test), Salmonella, avian influenza and mycoplasma by an attending veterinarian using a cloaca and esophageal swab. All samples were shipped to and tested at the Wildlife Diagnostics Lab in Madison, WI. All females were kept in Institute for Animal Care and Use Committee (IACUC) approved facilities (permit # 2017.03.01) and were provided with whole kernel corn mixed with poultry pellet feed and water ad libitum. Their pen was cleaned, and their straw bedding was refreshed weekly. Water was replenished and replaced twice daily. Decoy ducks weighed between 358-578 g ($\bar{x}$ =483.0, SD=36.4) in 2017 and 326-570 g ($\bar{x}$ =461.8, SD= 39.5) in 2018 and were similar in weight to wild birds (Baldassarre 2014). All birds were marked with colored zip ties and were assigned a letter (e.g., ‘Yellow A’) for individual identification within groups. I separated the flock into three groups for identification and rotation of birds from pens to traps. For example, birds in Group ‘A’ would spend 48 or 72 hours in traps, in 2018 and 2017, respectively, and then be returned to their pen for at least 96 hours to rest and recuperate. The size of their holding pen was 1.5 m^2 in 2017 (0.125 m^2/bird) and 16.8 m^2 in 2018 (0.500 m^2/bird). In 2017, the holding pen was elevated above ground with 1 cm^2 mesh as flooring bases whereas in 2018 the holding pen was not elevated but on a concrete slab. The location of the pens differed between years. In 2017, pens were kept on Mr. Larry Koy's property 40 km from the trap locations. In 2018, ducks were kept in a pen on Dr. Scott Hygnstrom's property 17 km from the trap locations. I transported birds from pens to trap locations in plastic poultry crates (0.95 m L x 0.56 m W x 0.27 m H) and I took care to set birds in decoy traps as soon as possible to reduce sun and heat exposure. Birds were given 150 g of food daily in a plastic cup while in the trap. I measured their weight when they left their pen and upon return. If an individual lost more than 10% of their body weight during their time as a decoy, they were quarantined and were allowed to rest until they regained weight. If a bird died, in a holding pen or decoy trap, I reported it to the WI DNR and submitted the carcass for a necropsy. Several additional bacteriology, molecular, and parasitology tests were performed to determine cause of death.

Capture.—My objective was to capture wild female wood ducks to fix transmitters for a mark-recapture study. I scouted the study area for wood duck pairs daily from early March to mid-May. I used binoculars or a spotting scope and identified birds from a distance as to not disturb their behavior. I then selected locations to place decoy traps based on scouting (i.e. lone female or presumed mated pair present) and accessibility of that location by foot or UTV. I moved decoy traps as often as possible especially after a wild female was captured because I often captured females at new sites. I assumed that female capture sites were in close proximity to a nest site and moved traps to areas where other females were spotted. I operated decoy traps from 7 Apr -26 May 2017 (*n*=6 traps and 163 capture days) and from 20 Apr -12 May 2018 (*n*=12 traps and 240 capture days). In 2018, I modified six traps to float (73 capture days) to adapt to unpredictable water depth. This allowed me to trap when water depth changed rapidly and expanded my ability to catch birds. Fixed decoy traps were constrained to a certain depth, and the wire cage trap set into tabs on t-posts. I modified these decoy traps to float on top of the water on three pontoons made of 12.7-cm diameter PVC pipe. The trap was kept in place by placing t-posts or steel poles in the ground though a 7.6-cm diameter PVC pipe fixed to the trap. Capture began as soon as migrants returned, and ice conditions allowed safe access to capture sites, and continued until I stopped catching females (26 May 2017 and 12 May 2018). I checked for females using artificial nest boxes twice per season to increase overall sample size and for comparisons of capture rates with decoy traps. I set floating traps baited with corn (Evrard and Bacon 1998). I operated two traps (118 capture days) in 2017 and three traps (72 capture days) in 2018. Trail cameras were placed near baited traps to monitor species use. Baited traps were placed in areas where large (i.e. > 10) groups of wood ducks were spotted during scouting sessions.

Statistical Methods

I used a generalized linear model to predict the probability of a decoy duck capturing a wild female. The response variable, captured or not, was binomial and I tested the following five independent variables: decoy weight before entering the trap (g), cumulative captures, UTM location (X and Y coordinate), and Julian date. I built a saturated model (i.e., one with all the additive independent variables) and assumed all variables with $P \leq 0.05$ were significant.

Capture days were summed for each trap type (e.g., decoy, box, bait) by year (2017 and 2018). Capture rates were defined by number of individual males or females that were captured divided by total decoy capture days. Capture rates were calculated as

$$CR_F = \sum_{i=1}^{3} \frac{\#\, females\ captured}{\#\, capture\ days}$$

Where, CR_F = female capture (or use for artificial nest boxes) rate and i=trap type (i.e. decoy, box, bait), and

$$CR_M = \sum_{i=1}^{2} \frac{\#\, males\ captured}{\#\, capture\ days}$$

Where, CR_M = male capture rate and i=trap type (i.e. decoy, bait).

Sex ratios were defined by number of males to females captured in decoy traps. Sex ratio was calculated as

$$Sex\ Ratio = \frac{CR_M}{CR_F}$$

RESULTS

I captured females (*n*=27) in decoy traps, prior to nest initiation, and nest box traps (*n*=16), post-nest initiation, for a 2-year field observation mark-recapture study. Females were trapped at a rate of 0.08 birds/ trap day in decoy traps at the same rate both years. Sex ratios were male-skewed (0.42-0.57 males/ trap day; Table 1) in both years (Figure 2, Figure 3). I observed a use rate of 0.09 in 2017 and 0.07 in 2018 per nest box checked (*n*=100) and captured no birds from floating traps (Table 2). I captured no other waterfowl species during the 2 years but did catch 2 barred owls in 2018 (Figure 5).

I used 12 and 35 decoy females in 2017 and 2018, respectively. Four decoy birds died in 2017 (33% of total) and 13 died in 2018 (37% of total; Table 3). The only significant variable ($P < 0.01$) explaining probability of capturing a wild wood ducks was weight of the decoy duck and the relationship was inversely related ($\beta = -0.014$; Figure 4).

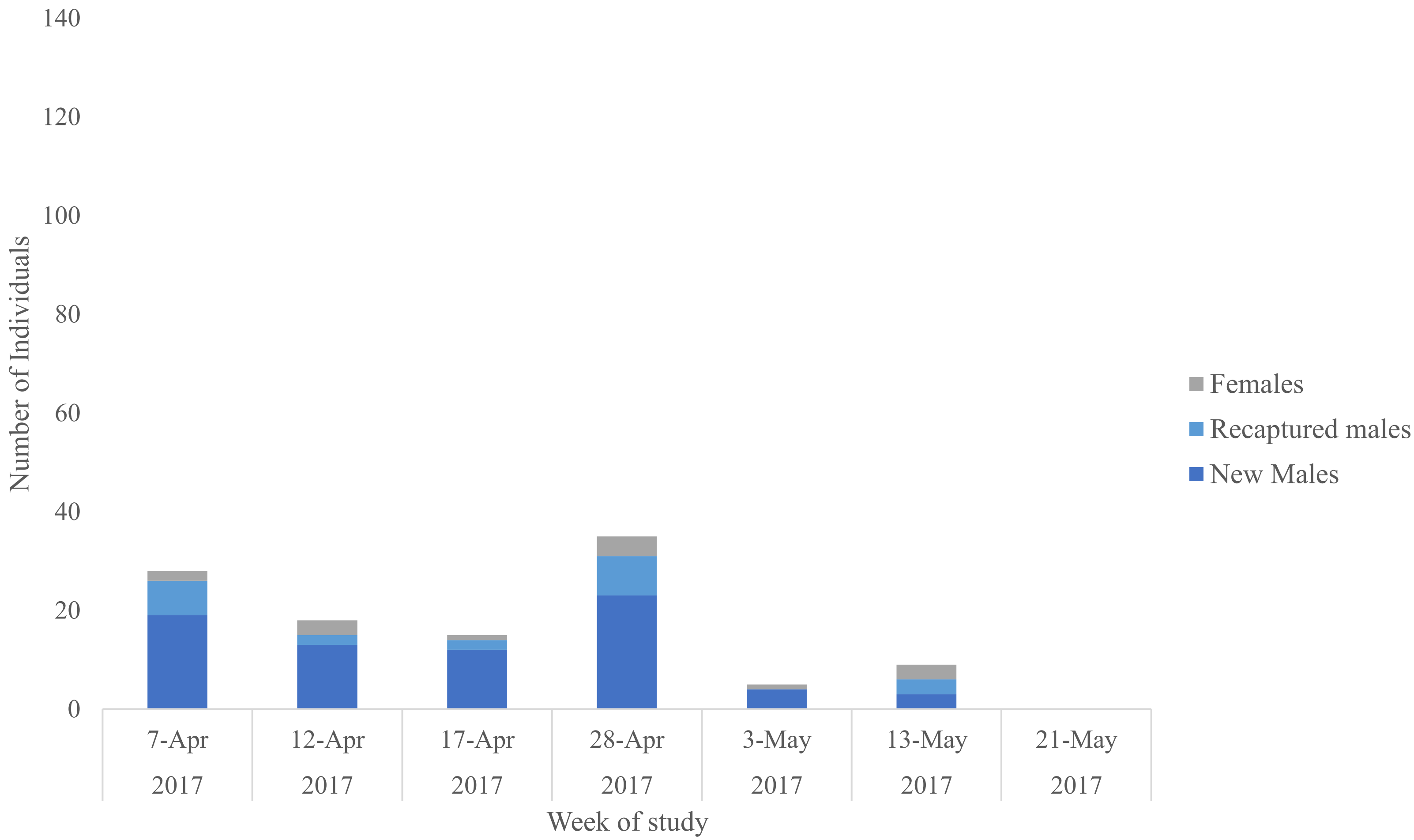

Figure 2. Number of female (grey), new male (dark blue), and recaptured male (light blue) wood ducks captured by decoy traps by week of study at Mead WMA, WI, in 2017.

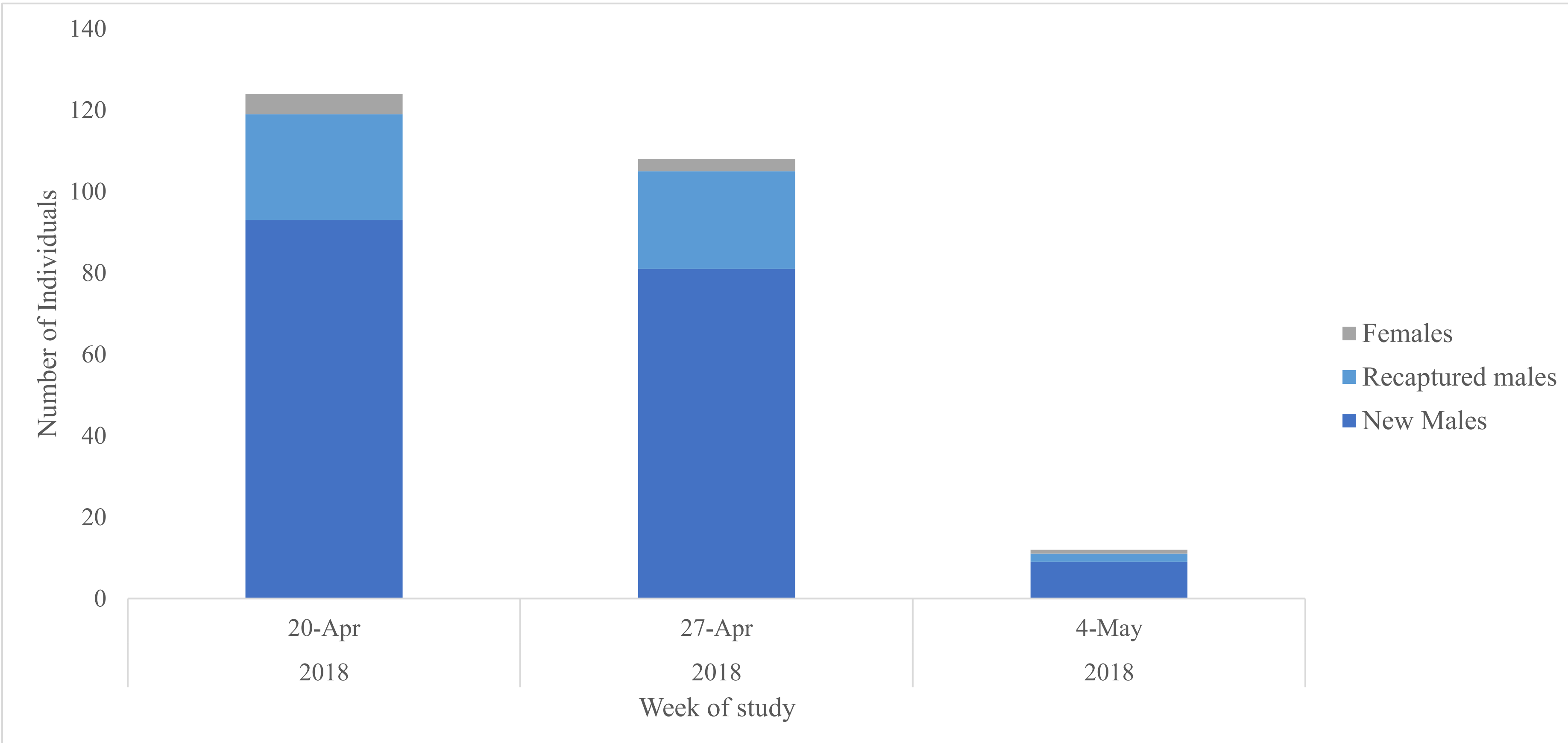

Figure 3. Number of female (grey), new male (dark blue), and recaptured male (light blue) wood ducks captured by decoy traps by week of study at Mead WMA, WI, in 2018.

Table 1. Dates and the number of decoy traps operated, capture rates, and sex ratios for wood ducks at Mead WMA, WI, USA, in 2017 and 2018.

		Decoy traps		Females		Males		
Year	Dates	*n* traps	capture days	*n*	capture rate	*n*	capture rate	Sex ratio (M:F)
2017	7 Apr-26 May	6	118	9	0.08	50	0.42	5.6 : 1
2018	20 Apr-12 May	12	240	18	0.08	149	0.62	8.3 : 1

Table 2. Capture rates and number operated for artificial nest boxes and baited traps for wood duck capture at Mead WMA, WI, USA in 2017 and 2018.

	Baited Traps			Artificial Nest Boxes	
Year	No. Traps	Capture Days	Capture Rate	No. Boxes	Use Rate
2017	2	60	0.00	100	0.09
2018	3	45	0.00	95	0.07

Table 3. Characteristics of decoy wood ducks including number used, mean weight, weight loss for the duration of the study, days of rest between trap rotations, days in trap, and cumulative mortalities in 2017 and 2018 at Mead WMA, WI, USA.

	2017	**2018**
Individuals	12	35
Mean weight (g) (95% CI)	483.0 (464.4, 503.6)	461.8 (449.2, 474.4)
Mean weight loss (g) (95% CI)	-2.1 (-6.9, 2.6)	-8.1 (-12.2, -4.0)
Mean rest days	8.7 (6.5, 10.9)	4.8 (4.2, 5.3)
Days in trap rotation	3	2
Mortalities	4	13

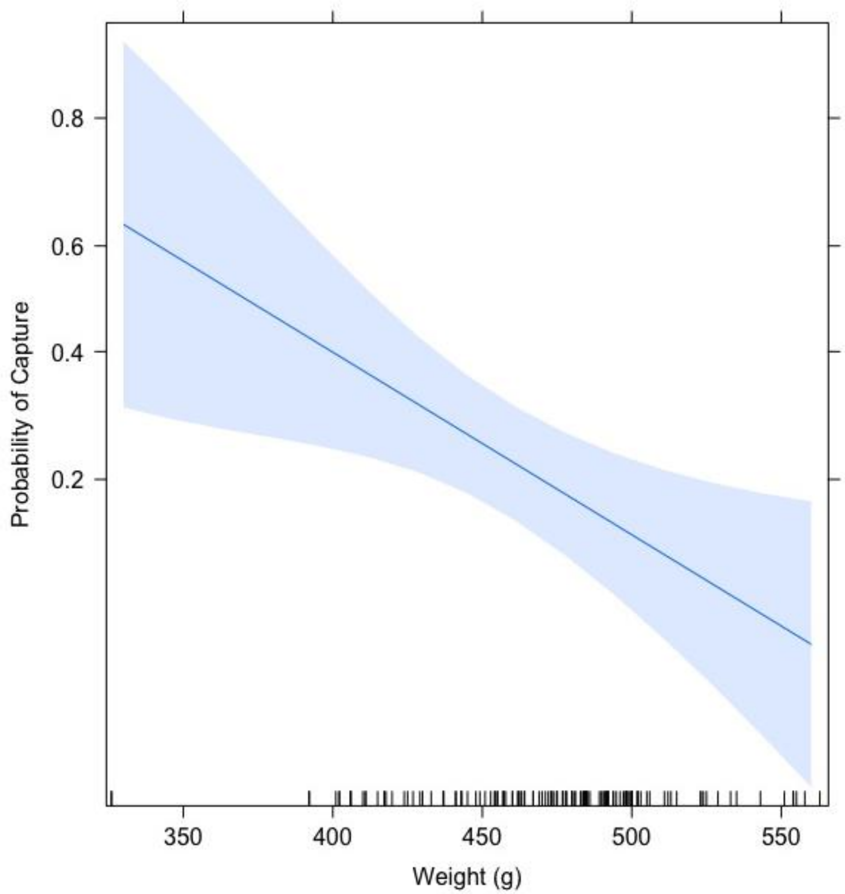

Figure 4. Relationship between probability of capturing a wild female wood duck and decoy weight (g) at Mead WMA in 2017 and 2018. Shaded blue represents 95% confidence region.

Figure 5. Barred owls (*Strix varia*) captured on a trail camera inspecting a decoy trap that contains a domestic female wood duck decoy in a forested wetland at Mead WMA, WI, USA, summer 2018.

DISCUSSION

I found strong support for my hypothesis of decoy trapping being more successful than bait trapping at capturing local nesting wood ducks. Although I tested effectiveness of baited traps in both study years, I never caught a single bird (wood duck or otherwise) with this method; thus, most of my ensuing effort was directed at decoy trapping. Few studies report effective capture rates, but Evrard and Bacon (1998) evaluated the effectiveness of capturing blue-winged teal, mallards, and wood ducks in Wisconsin using four trap designs (e.g., bait, bait with decoy, floating bait, and decoy). They failed to capture any blue-winged teal or wood ducks in decoy traps. However, Gatti (unpublished) reported capture rates (females/day) of 0.09 for blue-winged teal and 0.15 for mallards. My estimated capture rate of 0.08 females/day, is on par with capture rates for blue-winged teal in WI and is the first of its kind estimate for wood ducks, as far as I am aware. I believe my capture rates were enhanced because I scouted and moved traps frequently, something that should be considered for future researchers. Using my estimated capture rates, if future researchers desired to capture 30 wild wood ducks in a season, they would need to operate 12 decoy traps continuously for about 1 month. I demonstrated that catching female wood ducks using decoy traps is a feasible and reliable method.

While the female wood duck capture rate for decoy traps may be relatively low compared to some methods (Evrard and Bacon 1998), I believe there are critical reasons researchers should continue to consider this capture technique, relative to capturing birds exclusively from artificial nest boxes. First, forest age and average tree size are increasing annually throughout most of the wood ducks North American range resulting in greater quantities of natural cavities on the landscape (Denton et al. 2012, Malanchuk 2017). As such, the proportion of wood duck populations nesting in artificial nest boxes is decreasing over time, a phenomenon occurring at Mead WMA where box use rates by wood ducks is historically low. Decoy trapping captures birds prior to nest site selection and avoids relying too heavily on studying a cohort of birds that nest exclusively in artificial nest boxes. In fact, in my study, I wasn't able to demonstrate any of my decoy-trapped wood ducks selecting artificial nest boxes as nest sites. Second, it allows researchers to estimate nesting propensity with reduced bias, a variable that has rarely been evaluated for wood ducks. Gates et al. (1995) captured wood ducks using bait traps in Southern Illinois prior to nest site selection and estimated annual nesting propensity between 43-65% while, Hepp et al. (1989) captured wood ducks from an artificial nest box population in South Carolina and estimate breeding propensity was > 90% for adults and 82% for first-year females. It remains unclear if the discrepancy in these two studies is related to spatial-temporal variation or related more to methodology used to capture ducks. Regardless, I contend that capturing females prior to nest initiation with a method like decoy trapping, is crucial so researchers can understand and estimate breeding propensity and factors that influence it. Third, decoy trapping allows researchers access to pre-nesting birds to evaluate less-studied, yet critical, components of their annual cycle, like nest site selection, pre-nesting adult survival, movement and habitat selection. Lastly, catching pre-nesting wood ducks through decoy trapping allows researchers to empirically demonstrate the net-effect of recruitment of juveniles into a population that came from natural tree cavities versus artificial nest boxes. Studying only artificial nest box populations ignores the trade-offs individuals and populations might make if they chose a natural cavity. To date, most efforts that evaluate recruitment ignore the impact of natural cavities and report the gross effect of artificial nest boxes (Davis et al. 2015). To conclude, the vast majority of what is known about wood duck ecology comes from studies that exclusively used artificial nest boxes to capture ducks. I believe researchers should begin to evaluate if traits, population parameters, and characteristics from these birds are consistent with birds that use natural tree cavities. Decoy trapping wood ducks prior to nest initiation is one reliable method that would allow such evaluations to take place.

Of the variables I evaluated, decoy weight was the only factor in predicting probability of capturing a wild female wood duck and this variable had a negative influence. This finding suggests that smaller decoys capture more wild ducks while the opposite holds true, that larger decoys captured fewer wild ducks. This finding may be a result of territorial dominance. Wild ducks might eject smaller ducks from their territory more easily. Conversely, a limitation of decoy traps, if the goal is to only capture females, is that male capture rates are high and potentially inhibit the ability to capture available females in the area. The decoy traps had 3 separate compartments, and if males are consistently trapped and in multiple compartments, this impairs the ability of the trap to capture nearby females by reducing the number of compartments available. I consistently recaptured many males which further reduced capture rates for females.

Unlike my study, some researchers have effectively captured female wood ducks in traps baited with food prior to-nest initiation. Although I was unable to evaluate this because my baited traps failed to catch any birds, baited traps might be more likely to catch migrating waterfowl, especially in areas where migration and breeding ranges overlap. My decoy traps captured ducks that exhibited nesting behavior and were territorial to a site evidenced by the fact I had few birds (*n*=4) leave my study site immediately upon release. Catching more migrating birds than locally nesting birds presents limitations when researchers track birds with radio transmitter as migrators might emigrate from the study area. Bait traps likely are more effective in areas that have many resident wood ducks (e.g., southern Illinois) or towards the end of migration to ensure that most, or all, captured and radio-tagged individuals stay in the study area (Ryan et al. 1998). I caution future researchers, if they plan to use radio telemetry, against the use of baited traps as their primary capture technique, at least at study areas similar to mine. I contend decoy traps provide the best method for capturing locally-nesting females and obtaining a representative sample of the pre-breeding population.

This research effort was conducted for two breeding seasons, and I experienced different challenges in each. In 2017, my VHF harness neck collars were failing and in 2018 I contended with extreme weather events and substantial decoy mortality. To mitigate one of these challenges, I altered the collar attachment after I recovered six dropped collars and lost contact with an additional three. The original collar design resulted in high rates of dropped and failed transmitters. I hypothesized that the ducks were able to remove or loosen the metal crimping on the collar and decided to switch to a Herculite bib design (Montgomery 1985, Ryan et al. 1998). None of the Herculite bibs were lost. In addition to difficulties with collars, central Wisconsin experienced two late season snow events and record long cold spells in 2018, preventing capture at the peak of nesting. In fact, the start date of 20 April 2018 was at least 1 month after I intended to begin trapping wild ducks. This shortened trapping window in 2018 undoubtedly reduced the total amount of birds I could have captured. A late winter also may have limited food, open water, and cover availability for nesting wood ducks, resulting in poorer body conditions of females. There were also additional challenges with the feasibility of using decoy birds. First, there is an additional cost to purchase, provide food, and care. Decoy mortality was also relatively high (36-37% in 2017 and 2018). There were concerns with disease in the decoy flock, however, pathology results showed no major health concerns. It is possible that decoy birds experience greater rates of stress rotating between pens and traps, but there is additional research needed to determine best practices for caring for a decoy flock of wood ducks. The collar issue and unforeseen and unavoidable weather highlight the challenges of conducting fieldwork in central WI on breeding wood ducks. They also highlight the need to continue these types of studies to enhance the dataset and the knowledge of factors influencing breeding success.

MANAGEMENT IMPLICATIONS

Managers and researchers interested in capturing and tracking locally nesting wild wood ducks, and following them through the breeding season, should consider using decoy traps, especially if they are tracking birds using VHF transmitters. Researchers who aim to capture many females in a breeding season should plan on having an ample amount of traps set. Using my estimated capture rates, if researchers desired to capture 30 wild wood ducks in a season, they would need to operate 12 decoy traps continuously for about 1 month. Assuming the decoy mortality I observed (36%) is consistent and birds were allowed 96 hours to rest, this would require 48 decoy birds to care for. Future researchers should also consider only using the smallest decoys because these birds captured the most wild wood ducks. Care should be taken when planning logistics and husbandry of decoy wood ducks, as this was the primary limiting factor for the field component. As the decoy birds perished, it became increasingly more challenging to design a trapping rotation. Bib-style transmitters are retained better on birds than the manufactured collar design. Decoy trapping was the most successful method for capturing pre-nesting wood ducks and the population of birds I captured from them represents a promising alternative to studying solely box-nesting populations. However, domestic wood duck husbandry and testing logistics can be a time and financial limitation. Researchers should prepare for stress-related mortality in the decoy flock related to the non-domesticated nature of wood ducks.

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CHAPTER TWO: FEMALE WOOD DUCK BREEDING SEASON SURVIVAL AND HABITAT SELECTION IN CENTRAL WISCONSIN

ABSTRACT

Although breeding ecology of wood ducks is well-studied, most research have involved captured birds from artificial nest boxes where females and their offspring might be protected from natural predation. In addition to breeding parameters, most habitat selection studies on wood duck have focused on individuals with confirmed nests. I captured female wood duck priors to nest initiation and from artificial nest boxes, attached VHF transmitters to individuals, and tracked their location throughout the breeding season at Mead Wildlife management area in central Wisconsin during 2017 and 2018. My sample of female wood ducks represented box-nesting (n=16), cavity-nesting (n=8), non-nesting (n=5) ducks, and those that I could not determine nests (n=14). I pooled data across years and estimated breeding season female survival at 0.343(95% CI=0.192-0.613), and this did not vary by mass, trap type, nest attempt, or nest type. This survival estimate was the lowest published breeding season survival estimate I could find, indicating that Mead WMA might be a sink for wood duck populations. Further study is warranted to determine if female survival is consistently low at Mead WMA or if these estimates were a function of random environmental stochasticity. Breeding propensity was 0.44 for females captured pre-nesting but could be as high as 0.72 if unknown status wood ducks indeed initiated a nest. Although I followed 16 females from artificial nest boxes over 2 years, they demonstrated limited recruitment (n=1 successful brood to 30 days), calling into question the value of artificial nest boxes, at least at Mead WMA. Not surprisingly, my sample of wood ducks selected for forested and scrub shrub wetlands, but surprisingly, they also selected for 5 additional

habitats, including habitats with less structural cover, suggesting managers should maintain diverse wetland complexes. Additional research on wood ducks during the breeding season is needed, especially on cavity- and non-nesting individuals.

INTRODUCTION

Although waterfowl are among the most well-studied taxon of wildlife, scientists and managers still need information that informs changes on vital rates through the annual cycle (e.g., breeding survival, nest propensity, nest success, and habitat selection Williams and Nichols 2002, Saether et al. 1996, Bro et al. 2000, Coluccy et al. 2008). Managers also need information on heterogeneity of vital rates relative to differences in habitat quality, as they attempt to link habitat with survival outcomes (Hoekman et al. 2004, Arnold et al. 2017). Researchers can estimate these rates and influential covariates in field-based mark-recapture studies.

Wood ducks have unique habitat requirements in relation to most other ducks in that they require cavities for nesting and typically raise their broods in nearby forested, emergent, and scrub-shrub freshwater wetlands (Bellrose and Holm 1994). Most prior research on wood ducks has come from artificial nest boxes with a strong geographical focus in in the Mississippi Flyway. Artificial nest box programs became a popular habitat management tool for wood ducks in the late 1930's however, due to the maturation and reforestation of the upper Midwest, most wood ducks nest in natural cavities now (Soulliere 1985, Bellrose and Holm 1994). Because few studies have focused on natural cavity nesting ducks there have been very few comparisons between life history traits that's differ between individuals that nest in artificial versus natural tree cavities.

Potentially, current understanding of some population vital rates are not representative of the majority of wood ducks populations (i.e., those that nest in natural cavities).

The United States Fish and Wildlife Service (USFWS) and some state agencies, like Wisconsin, Michigan, and Minnesota (USFWS 2018), estimate population size for many species of waterfowl in the Waterfowl Breeding Population and Habitat Survey (WBPHS). Populations of wood ducks (*Aix sponsa*) are not estimated in the WBPHS because of uncertain detectability in their primary habitat (e.g., forested wetlands; Bellrose and Holm 1994). Instead, population estimated rely, in part, on trends from state-level aerial surveys, and Breeding Bird Survey roadside counts, but they are unreliable estimators of wood duck abundance (Zimmerman et al. 2017). Furthermore, information is limited on how or which vital rates and habitats influence breeding season success for wood ducks, although this level of information exists for many other North American waterfowl (Hoekman et al. 2002, Coluccy et al. 2008, Osnas et al. 2016). To build a reliable population model for wood ducks, which heretofore does not exist, various life history parameter estimates (e.g., breeding season survival, nest success, brood survival) must be provided for the breeding season, including how these may differ among cover types used by female wood ducks and their broods.

Adult female wood duck breeding survival has been studied extensively (Robb and Bookhout 1990, Davis et al. 2001, Dyson 2015) whereas annual survival can be estimated with band recoveries (Dugger et al. 1999). Both survival estimates can inform population estimates for setting harvest and habitat management regulations and policies (Arnold et al. 2017) To this point, most breeding season research has been conducted on females captured from artificial nest boxes. This proposes a potential bias in reporting vital rates, especially those that may be essential to estimating population change and abundance. Similar to the Great Lakes mallard model (Coluccy et al. 2008), vital rates can inform an annual population model for wood ducks for future research and management decisions. Survival estimates during the breeding season can enhance those from banding data and provide a more comprehensive understanding of their annual ecology.

Female survival during the breeding season has been primarily reported for box-nesting wood ducks. An unbiased and representative estimate of female survival is critical because this variable has been linked to population level changes (Coluccy et al. 2008). Only two studies have estimated survival of adult female wood ducks during the breeding season by capturing individuals using baited traps in the upper Midwest (Robb and Bookhout 1990, Anderson 2010). Furthermore, most studies estimating survival have occurred in latitudes further south than this study site. Davis et al. (2007) contends survival is greater for most waterfowl that nest at southern latitudes compared with more northern latitudes. However, few studies have examined survival at this latitude and none ever in WI. In addition, it is still unclear how survival rates may differ between box-nesting and cavity-nesting females or how variables such as nest attempts and nest success influence survival.

Wood ducks typically select dense (e.g., emergent wetlands) and woody (e.g., forest and scrub-shrub) vegetation (Dyson et al. 2018). Management efforts have focused on increasing population abundance by improving vital rates via creation, habitat manipulation, or harvest regulation (Nichols et al. 1995). They prefer forested and forest wetland cover types for nesting, cover, and roosting so it is no surprise that studies have shown that wood ducks select for these types of habitats while avoiding grasslands and agriculture (Granfors and Flake 1999, Dyson et al. 2018). Recently, the Upper Mississippi and Great Lakes Joint Venture identified wood duck brood rearing habitat as an area of future research focus as not much in known about differences in quality. My study of female habitat selection can begin to evaluate the use and selection of habitats used by females with broods.

To address these knowledge gaps, I designed a study with the goal of estimating and understanding which factors influence female wood duck breeding survival and habitat selection. To achieve this goal, I needed to capture adult female wood ducks prior to nest initiation. My first objective was to quantify female breeding season survival and examine which, if any, nesting covariates (i.e. nest attempt, nest type, nest success) influences survival. I hypothesized that population parameters (e.g., adult female survival, nest success, breeding incidence) would be influenced by relevant nesting covariates. I also hypothesized that survival will be lower than previously published studies because female survival is lower in natural cavities, where most of the females nested (Bellrose and Holm 1994). My second objective was to examine the pattern of habitat use by female wood ducks. I hypothesized that females would select forested and forested wetland cover types. Estimates of survival and habitat selection can inform wood duck population models to assist in testing planning assumptions for harvest and habitat management (Coluccy et al. 2008, Soulliere et al. 2017).

STUDY AREA

The study took place within Wisconsin Department of Natural Resources' Mead Wildlife Management Area (hereafter Mead WMA) located 35 km northwest of Stevens Point, Wisconsin, USA (Figure 1). The area spans areas of Portage, Wood, and Marathon counties. Mead is a 13,000-hectare floodplain, drained by the Little Eau Pleine River, and bordered to the north by the Big Eau Pleine River. Dikes impound several management units designed to hold water for waterfowl where structures control water levels and promote growth of moist-soil plants. Cover types included 27% flowage (impounded wetland), 25% aspen (*Populus* spp.), 13% brush (willow and alder, *Salix* and *Alnu*s spp.), 13% grass-sedge marsh and upland grass, 16% hardwoods (primarily maple-oak basswood, *Acer-Quercus-Tilia* spp.), 3% agriculture, and 3% conifer (Patrice Eyers, personal communication). Forested wetlands are subject to seasonal flooding especially in late winter and spring. The average temperature in March through August 2017 was -1.9°C, 7.7°C, 11.6°C, 18.1°C, 20.3°C, and 17.6°C, respectively. The average temperature in March through August 2018 was -1.9°C, 0.1°C, 12.8°C, 19.2°C, 21.1°C, and 20.2°C, respectively. Precipitation in March through August 2017 was 57.4 mm, 136.1 mm, 119.4 mm, 169.7 mm, 82.6 mm, and 90.7 mm, respectively. Precipitation in March through August 2018 was 28.4 mm, 72.1 mm, 78.7 mm, 133.9 mm, 62.7 mm, and 112.5 mm respectively. On 6 April 2018, Marathon county received 660.4 mm of snow, the most since 6 March 1959 (561.3 mm; NOAA 2019).

I focused decoy trapping efforts at three flowages at Mead WMA. I chose trap locations based on known pair sightings acquired from scouting. Most traps were set in forested wetlands, emergent wetlands, and scrub-shrub wetlands near the Little Eau Pleine River floodplain (Appendix A).

METHODS

Field Sampling

I captured wood ducks prior to nest initiation using decoy traps (*n* = 27) and artificial nest boxes (*n* = 16). I operated decoy traps from 7 Apr -26 May 2017 (*n*=6 traps and 163 capture days) and from 20 Apr -12 May 2018 (*n*=12 traps and 240 capture days). In 2018, I modified 6 traps to float (73 capture days) to adapt to unpredictable water depth in the field. To capture female wood ducks from artificial nest boxes I searched all available boxes at Mead. If I found a hen using an artificial nest box, I captured her by first placing an object over the nest entrance/exit hole and then securing her through a side door (Dyson et al. 2018).

All captured males and females received a USFWS size 6 aluminum leg band and males were released after banding. I fit all females with a very-high frequency (VHF) transmitter with a mortality sensor [7g, 23 mm x11 mm, 221 days of battery life; model A3930, Advanced Telemetry Systems (ATS), Isanti, MN, USA]. I assembled factory-designed collars from ATS in 2017. Following collar failure, I switched to a different collar design but retained the physical transmitter. In the lab prior to capturing birds, I adhered each transmitter to a Herculite (Herculite, Emigsville, Pennsylvania, USA) collared fabric bib with epoxy designed to slip over the birds head (Montgomery 1985, Ryan et al. 1998; Figure 1).

All radio-tagged female wood ducks were monitored daily to estimate their location and fate. I located females each day using traditional hand tracking methods during the breeding season (Silvy 2012). I monitored daily survival and location from 7 Apr - 3 Aug 2017 and 22 Apr - 5 Aug 2018. I alternated daily tracking schedules by time-period, early or late, and spatially, east to west and west to east, to reduce temporal and spatial autocorrelation. I measured 2 or 3 bearings, dependent on if I lost the signal or if she moved, from different locations for each female (Mech 1983). I verified azimuth intersections in the field using orthographic photos (Dyson et al. 2018). I assumed females that were at the approximate same location for at least 3 consecutive days were demonstrating nesting behavior. I used triangulation and homing to track females to nest sites in natural cavities in 2018 and brood rearing locations in 2017 and 2018 (Mech 1983). I recorded nest site location (UTM), nest type (box or cavity), and an estimate of incubation stage, for all suspected and confirmed nests. Individuals were tracked until at least 15 days post-hatch, emigration from the study area, loss of signal, or a mortality event. I climbed trees and inspected cavities to confirm wood duck nests in natural cavities. I placed trail cameras facing natural cavity entrances to confirm mortality, abandonment, or hatch.

For birds that I confirmed established a nest, I candled eggs to determine incubation stage during 3 sampling periods (4 May-13 May 2017, 6 Jun-31 Jun 2017, and 14 May-22 May 2018; Weller 1956). Once hatch dates were estimated, I captured these females at approximately 16 days incubation and fit each with a transmitter and leg band. I avoided returning to nests prior to 16 days incubation to reduce likelihood of nest abandonment (Granfors 1996, Dyson 2015).

Procedures for handling and capture of domestic and wild caught wood ducks were approved and permitted by the University of Wisconsin-Stevens Point Institute of Animal Care and Use Committee (permit # 2017.03.01) and the Wisconsin Department of Natural Resources.

Figure 1. A wild female wood duck fit with a Herculite-bib transmitter at Mead WMA, WI, USA in summer 2018.

Data Analyses

Survival.—I estimated adult female survival during the breeding seasons (n = 105 days) of 2017 and 2018. I modeled survival using a Kaplan-Meier framework to allow for staggered entry of individuals (Kaplan and Meier 1958, Pollock et al. 1989). I assumed that right censoring (unknown fates) of females following signal loss, caused by transmitter failure or emigration from the study area, was independent of their fate (Davis et al. 2001). I assumed that survival was not significantly influenced by capture, handling, radio-marking, or marking date. I assumed that all working radio transmitters were located.

I modeled the probability of a female surviving as a function of several biotic factors using a known-fate survival analysis framework in Program R (ver. 3.5.1; Table 3). I fit cox-proportional hazard regression models to investigate the influence of mass (490-680g), trap type (box trap or decoy trap), nest attempted (yes or no), and nest type (artificial box or natural cavity) on the probability of survival (Cox 1972). I examined the hazard ratios for each covariate and considered ratios that did not overlap zero as having a significant effect on survival.

Habitat Selection.— I modeled habitat selection for female wood ducks during the breeding and post-breeding season in 2018 (10 Apr-8 Aug). I excluded locations that represented females at nest sites (n = 252, 42.5% of all locations) because these areas represent nest site selection and I was interested in modelling habitat selection. I excluded observed female locations with broods (n = 33), as an effort to separate adult female habitat selection and brood habitat selection. Therefore, my inferences are best suited for post-hatch female ducks (n = 341 female locations, $\bar{x}$ = 26.5 locations/ female); both successful and unsuccessful nesting ducks. I included triangulated bearings of all females in the habitat selection analysis. I calculated locations and error polygons using Locate III (Nams 2005).

I plotted all used locations and added Wiscland2 level 2 land cover classification as a baselayer in ArcMap 10.5.1 (ESRI Products; Wisconsin Department of Natural Resources 2018). I defined availability by generating a buffer around all used points informed by the 95th percentile of the maximum step length, defined as the maximum distance a wood duck travelled between consecutive known locations ($\bar{x}$=879.7 m, 95% CI=531.9, 1227.5 m). I used 1,227.6 m to define potentially available cover types because this distance represented the maximum distance a female wood duck traveled between consecutive fixes in the data set (Dyson et al. 2018). I generated two random points for every known location within the available area buffer. I pooled used locations across years and individual wood ducks and evaluated available locations with pooled locations (Johnson 1980). I calculated the proportion of used and available habitat for each land cover classification and pooled rare (i.e. those with < 20 points) land cover types together (Table 1). I calculated a z score normalized value for habitat area.

I calculated a resource selection function probability in a used versus available design to evaluate habitat selection by female wood ducks (Boyce et al. 2002, Johnson et al. 2006). I built a Bayesian generalized linear model using the bayesglm function (Gelman et al. 2009) in the arm package (Gelman and Su 2018) for program R (version 3.5.1, R Core Team, Vienna, Austria), specifying the binomial family to model the error distribution. I used logistic regression (i.e., 1 = used location, 0 = random location) and built a saturated model with all linear additive combinations of cover types. I included floating aquatic herbaceous vegetation, emergent wetland, forested wetland, open water, scrub-shrub, agriculture, developed, and forest cover types. The bayesglm function used the Estimation Maximization (EM) algorithm (rather than maximum likelihood) to fit the data, and we specified the default cauchy distribution as a vague prior (Gelman et al. 2009). I examined differences in selection ratios among cover types by comparing beta coefficients and 95% confidence intervals. A positive or negative number where 95% confidence interval for the beta coefficient does not overlap zero indicates wood ducks were selecting or avoiding for these land cover types, respectively. The further the beta coefficient was from zero, the stronger the presumed selection occurs.

RESULTS

Capture

I captured a total of 43 female wood ducks in decoy and nest box traps. In 2017, I captured 9 females in decoy traps prior to nest initiation and 9 after nest initiation, from nest boxes (*see* Chapter 1). In 2018, I captured 18 females prior to nest initiation in decoy traps and 7 females from nest boxes. I tracked females from 6 Apr-28 Jul 2017 and from 21 Apr - 5 Aug 2018. Encounter rates (birds/day/trap) differed by year and sex (Table 1). In 2017, I lost track of 9 pre-nesting females because of faulty collars. Of the 9 females captured in nest boxes in 2017, 2 were predated (22.3%), 5 had successful nests (71.4% nest success), and 1 successfully raised a brood (11.1%) to 30 days. In 2018, of 18 pre-nesting females, I confirmed 8 nested in natural cavities (44.4%). The remaining females (n=5) did not nest (27.8%) or had unknown nesting status (n=5, 27.8%). The remaining birds in the sample (n=7) were captured in artificial nest boxes where they were nesting. Of the 8 females that nested in natural cavities, 6 females were predated (75% mortality) and 1 produced a successful nest (50% nest success) and raised a brood (50%) to 15 days (Table 2). This brood was not observed after 15 days, but it could be assumed as alive if ducklings can survive without their mother after 15 days post-hatch holds (Davis et al. 2001). Of the 7 females captured in artificial nest boxes in 2018, all survived (0% mortality) 5 had successful nests (71.4%), and 0 successfully reared a brood to 15 days.

Female Survival

The probability of a female wood duck (*n*=35) surviving the study period (*n* = 105 days) was 0.343 (95% CI = 0.192- 0.613, *n*=13 mortalities; Table 3, Figure 2). I censored 8 females from survival analysis because of transmitter failure (n=3), capture myopathy (*n*=1), or emigration from the study area (*n*=4). In addition to individuals censored from the analysis, I lost 6 females early in the study period due to transmitter failure. I suspected 2 avian predations because 1 carcass was found in the nest of a bald eagle (*Haliaeetus leucocephalus*) and the other had scattered feathers surrounding the carcass suspended in a tree. I suspected the remaining 11 predations were mammalian as these carcasses were all missing and 5 were found within 100 m of the nest site.

All cox hazard ratios overlapped zero. Therefore, I assumed none of the covariates I tested exerted significant influence of females surviving the breeding season. I calculated additional apparent low and high survival estimates, treating censored birds as dead or alive, respectively (Robb and Bookhout 1990). The female survival probability was 0.503 (95% CI=0.321-0.790) when signal or transmitter loss was discounted and 0.034(95% CI= 0.008-0.142) when it was assumed to be mortality.

Table 1. Encounter rates (individuals/trap day) for male and female wood ducks captured in decoy traps at Mead WMA, WI, USA, in 2017 and 2018.

Year	**Female encounter rate**	**Male encounter rate**
2017[a]	0.08	0.42
2018[b]	0.08	0.62

[a] Encounter rates are based on captured females (*n*=9) and males (*n*=50) in 136 capture days in 2017.

[b] Encounter rates are based on captured females (*n*=18) and males (*n*=139) in 240 capture days in 2018.

Table 2. Number of females captured, censored, and in the study, number of mortality events between nesting and non-nesting females, number of attempted nests and successful nests between nest types for wood ducks, and number of successful broods from a radio telemetry study at Mead WMA, WI, USA for 2017 and 2018.

Parameter	**2017**	**2018**
Females captured	18	25
Censored before study	4	4
Females in study	14	21
Dropped collar	5	0
Mortality events		
Nesting [a]	2	9
Non-nesting	0	2
Attempted nests		
Nest Box	9	7
Cavity [b]	0[c]	8
Successful nests		
Nest Box	5	3
Cavity [b]	0[b]	1
Successful broods		
to 15-days	1	1
to 30-days	1	0
Survived study period	7	10

[a] Nesting females chose natural cavities (n=6) and artificial nest boxes (n=3).

[b] Confirmed (n=2) and suspected (n=6) cavities were pooled.

[c] All individuals captured prior to nest initiation dropped collars. All females left in the study were captured in nest boxes.

Table 3. Probability of survival (S; Kaplan-Meier) for female wood ducks (*n*=35) at Mead WMA, WI, USA 2017─2018.

Day of event	No. at risk	No. deaths	No. censored	Newly Added	(S)	SE	Lower 95% CI	Upper 95% CI
9	7	1	0	0	0.857	0.132	0.633	1
22	13	2	0	5	0.725	0.141	0.495	1
32	16	1	3	1	0.680	0.139	0.455	1
43	21	1	4	1	0.648	0.136	0.429	0.978
45	20	1	1	0	0.615	0.133	0.402	0.941
47	19	1	0	0	0.583	0.130	0.376	0.903
49	18	1	2	0	0.550	0.127	0.350	0.865
51	16	1	1	0	0.516	0.124	0.323	0.825
52	14	1	0	0	0.479	0.120	0.293	0.783
77	11	2	3	0	0.392	0.113	0.223	0.690
85	8	1	1	0	0.343	0.109	0.184	0.639

[a] Day of event refers to the day in the study period when a mortality event occurred.

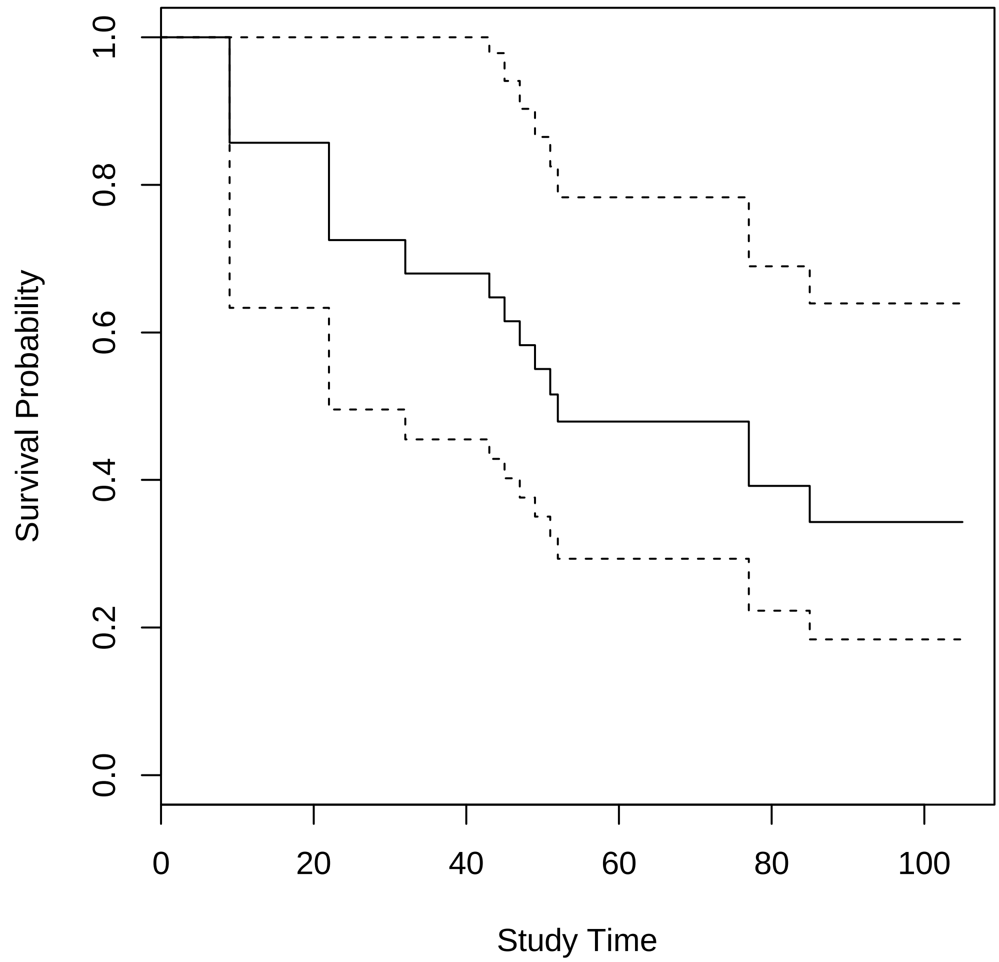

Figure 2. Kaplan-Meier survival estimate for female wood ducks (*n*=35) from the marking day to the end of the study period (*n*=105 days). Changes in slope indicate a mortality and dashed lines are 95% confidence intervals.

Habitat Selection

Habitat selection analysis was based on 341 locations of female wood ducks ($\bar{x}$=17 locations, range=1-70, 95% CI=11-23; Figure 3). The mean error polygon was 8.51 $\pm$ 1.39 hectares. Therefore, I defined used locations as the location with an 82.3m radius. Next, using a 1227.6 m buffer to define availability, I plotted 682 randomly generated locations to calculate selection ratios (Figure 4).

I obtained selection coefficients from a logistic regression for floating aquatic herbaceous vegetation, emergent wetland, forested wetland, open water, scrub-shrub, agriculture, developed, and forest (Figure 5). Female wood ducks selected forested wetland (β=1.334, 95%CI=0.495-2.182), followed by scrub-shrub (β=1.134, 95%CI=0.606-1.663), emergent wetland (β=1.091, 95%CI=0.295-1.887), open water (β=0.726, 95%CI=0.245-1.206), and floating aquatic vegetation (β=0.597, 95%CI=0.269-0.924). Forest (β=0.702, 95%CI=-0.003-1.407), agriculture (β=0.223, 95%CI=-0.550-0.996), and developed areas (β=-0.067, 95%CI=-0.462-0.328) were used in proportion to what was available on the landscape.

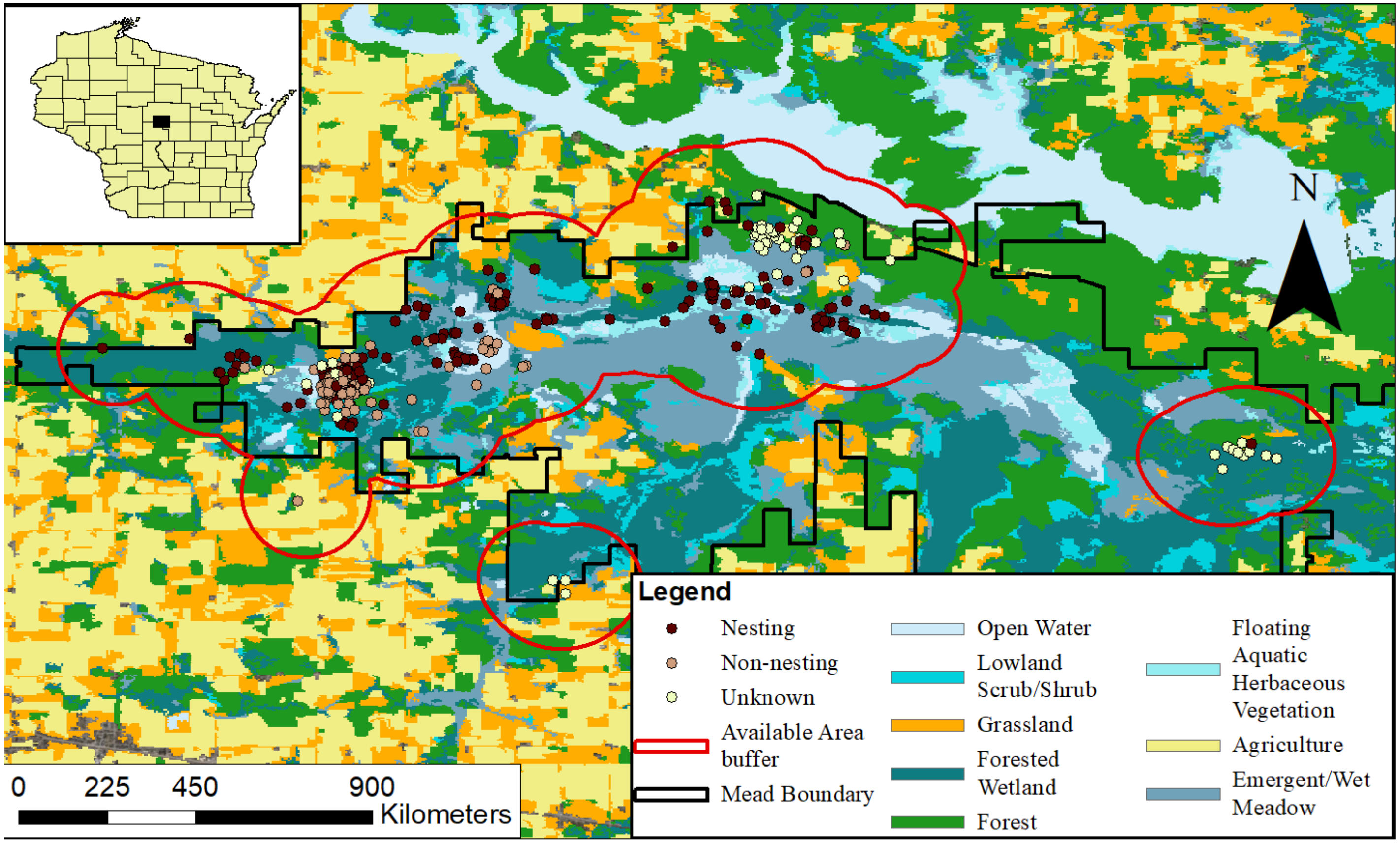

Figure 3. Map of Mead WMA, WI, USA with land cover types and known daily locations for females classified as nesting (*n*=18, 56.3%, burgundy dot), non-nesting (*n*=6, 18.8%, pink dot), or had an unknown nest status (*n*=8, 25%, yellow dot) for female wood ducks (*n*=32) in 2017 and 2018.

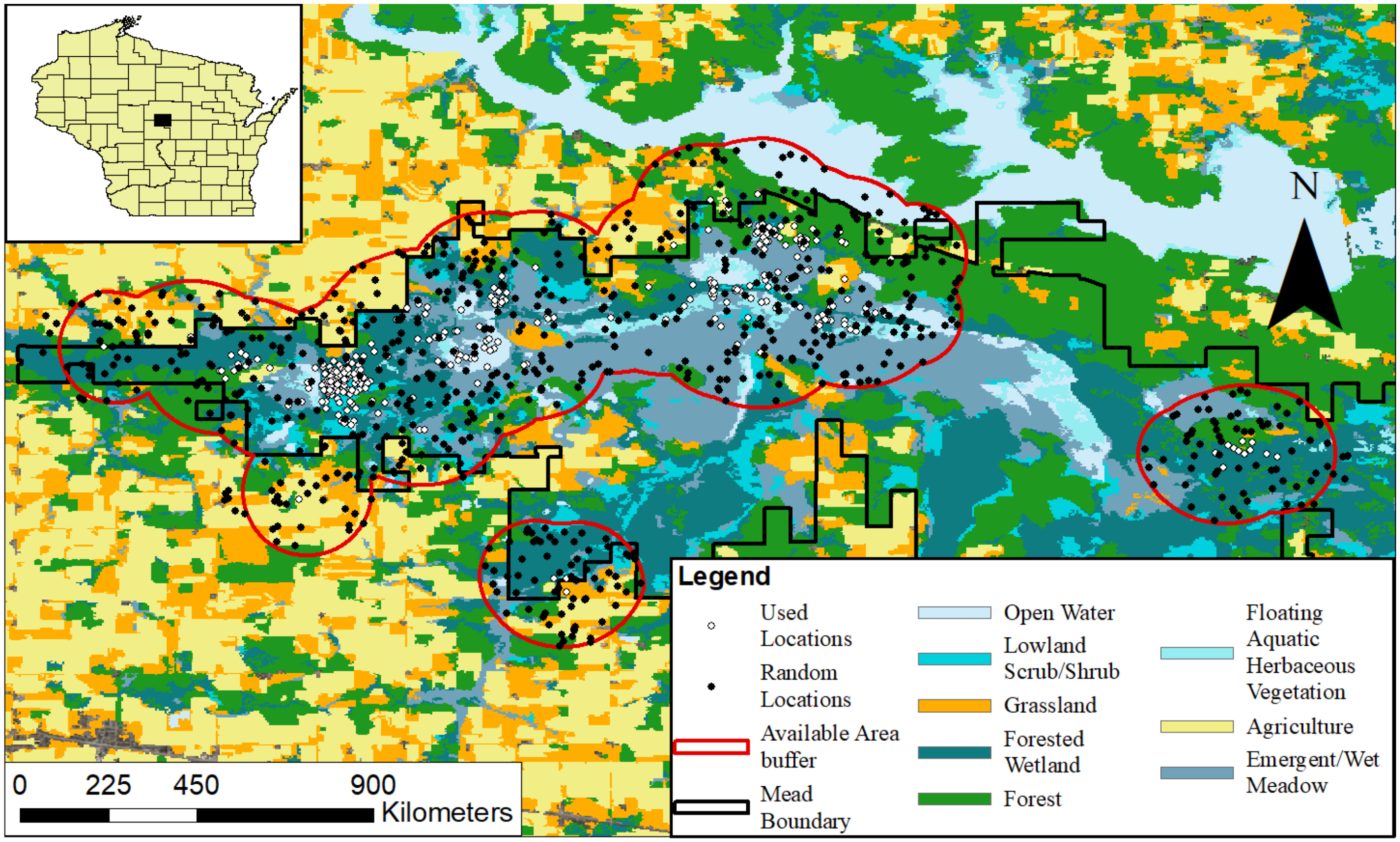

Figure 4. Map of Mead WMA, WI, USA with land cover types and known daily locations (*n*=341, white dots with black outlines) for female wood ducks (*n*=32) and extent of assumed available habitat (red outline) with random locations (*n*=682, black dots) in 2017 and 2018.

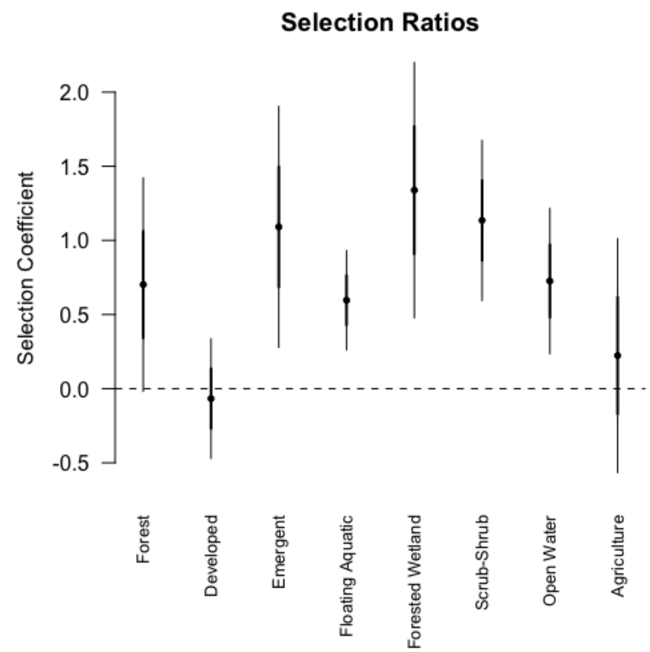

Figure 5. Habitat selection ratios from a Bayesian general linear model. Estimates greater than 0 represent a selection for the associated cover type, while an estimate less than 0 represents avoidance.

DISCUSSION

Capture

This study set foundations and procedural examples for future studies of breeding wood ducks in Wisconsin and the Great Lakes Region. Estimates of female breeding season survival, female and male capture rates from decoy traps, nest propensity, and female habitat selection are all parameters or coefficients that, to my knowledge, are the first of their kind from a study in the state of Wisconsin. In addition, because I captured most female wood ducks prior to nest initiation, these estimates of vital rates, especially survival, are likely more representative to the population of wood ducks at the MWA compared to the cohort that nests in artificial nest boxes. While this study represents only two breeding seasons from one management area in Wisconsin, I was able to provide detailed methodology and some baseline vital rates that can be enhanced and investigated by future research.

The skewed male to female capture ratio in decoy traps (5:1) presumably was due to unpaired males seeking a mate (Ringelman 1990). Although female capture rate was low, non-target catch-rate was high (e.g., males), and emigration occurred, decoy trapping was a reliable method for targeting adult female wood ducks while they were searching for nest sites (Ringelman 1990). Few wood ducks use artificial nest boxes (< 20% use rate over 15 years) at Mead WMA, but wood duck broods are plentiful, suggesting that female wood ducks are using natural cavities in the area to nest (Souillere 1985, Patrice Eyers personal communication). Furthermore, I found only 1 instance of a wood duck brood surviving past 15 days from artificial nest boxes over the 2 years of this study, even though 37.2% (n=16) of the birds I studied were captured from boxes, highlighting the value of natural cavities as the primary source of wood duck recruitment at Mead WMA.

Survival

I captured female wood ducks prior to nest initiation to estimate breeding season survival and habitat selection. Survival of female wood ducks (S=0.343, 95% CI=0.184-0.639) at Mead WMA in 2017 and 2018 was considerably lower than most previous studies, with the exception of Robb and Bookhout (1990) and Anderson (2010), which were the only 2 studies that attempted to estimate survival from females captured prior to nest initiation. If survival, in fact, is lower than previously understood, critical population and habitat management implications may arise, especially for areas like Mead WMA that are perceived as high-quality wood duck breeding habitat (Straub et al. 2019 *in prep*). I tested if female condition (i.e. weight), where they were trapped (i.e. UTM location), if they attempted a nest, and the type of nest (box or cavity) influenced survival probability through the breeding season. I was not able to identify any influential variables. However, the power in these tests was low due to sample size constraints. Future survival models should continue to examine the survival rate and try to identify factors that influence it. I pooled survival data across years because of the low sample size, especially towards the end of the study, and because I did not see a difference in survival probability between years.

My breeding season survival estimate is considerably lower than other published studies (Table 3) and I propose two primary reasons for this. First, Mead is intensively managed area for a diversity of wildlife, including many known species of wood duck predators such as raccoons (*Procyon lotor*), minks (*Neovison vison*), otters (*Lontra* *canadensis*), fishers (*Martes pennanti*), red-tailed hawks (*Buteo jamaicensis*), and bald eagles (*Haliaeetus leucocephalus*). Although I did not estimate predator abundance, I did document barred owls (*Strix varia*) stalking birds (see Chapter 1), a likely fisher predation of hen in an artificial nest box, and likely raccoon predations in natural cavities. Somewhat paradoxically, large intensively managed areas such as Mead might be sinks for cavity nesting wood ducks and other ducks because of their large predator populations. Future studies could evaluate if smaller habitat patches or private lands yield similar results. Another potential reason for lower relative survival might be an artifact of this method of capture. Most other published survival estimates during the breeding season (Table 4) come from female wood ducks captured in artificial nest boxes, some with predator guards (Hepp et al. 1987). Studies such as these practically eliminate predation events for a 40- to 50-day period which includes nest initiation through incubation (Hepp and Kennamer 2011). This period represents greater than half of the entire time I spent monitoring and estimating survival (105 days). I contend this method is less biased and hence a more reliable estimate of the true population than those from studies of box-nesting wood ducks. Not surprisingly, studies in which researchers captured birds similar to those presented above report breeding season survival estimates that are also similar (Robb and Bookhout 1990, Anderson 2010).

The sample of wood ducks I studied experienced predation during the early, middle, and late portions of the breeding season. I observed a clustering of mortality events (n = 6) from day 43 to day 52 of the study. These mortality events may represent increased predation during the incubation period (5 May- 6 Jun), when females are most susceptible to predation (Bellrose and Holm 1994). Robb and Bookhout (1990) found that survival was lowest during incubation (29 Mar-19 May), compared with brood-rearing (20 May-30 Jun) and post-breeding (1 Jul-7 Aug) seasons. Wood ducks are likely more susceptible to predation during incubation. Duck nests are believed to be subject to greater mortality during incubation than during non-nesting or laying periods (Johnson and Sargeant 1977, Cowardin et al. 1985, Kirby and Cowardin 1986). This time period may also reflect early brood-rearing females, which, in wood ducks, may be a period of greater mortality risk (Hartke et al. 2006). Future research warrants further investigation of differences in survival rates among stages of the breeding season.

At least three factors should be considered for why survival estimates were lower than other studies. First, the original collar design failed to adhere to birds so I switched to a Herculite bib. It is possible these bibs influenced survival and movement of the sampled birds but this is unlikely because Herculite bibs have proven effective and with no reported negative effects for other studies (Ryan et al. 1998). Second, there may be a capture effect, whereby I captured inferior birds relative to the breeding population at Mead WMA. If capture rates of inferior birds in decoy traps are greater than other methods, then these birds may already be more likely to die and may negatively bias the estimate. On the contrary, I believe that this method should have the least amount of bias, especially relative to methods that trap females in artificial nest boxes with predator guards. Third, Mead WMA experienced a record late snow fall (see study area) and cold temperatures prevailed well into April during 2018. A recent study by Janke et al. (2018) highlighted the importance and impact of environmental stochasticity during migration and demonstrated severe weather events had negative consequences on blue-winged teal (*Spatula discors*) and lesser scaup (*Aythya affinis*). My sample of wood ducks could have had lower than normal survival because of the cross-seasonal effects of a delayed spring. To the extent that these 3 factors hold true, this survival estimate potentially indicates Mead could be a sink, where recruitment is less than survival, at least for the years I studied there. However, Soulliere (1985) reported the opposite, contending that Mead was a source population for wood ducks and that many locally-hatched birds remain in the area late in the fall season. I propose that it is critical to have more spatial and temporally replication to precisely estimate survival and the influence of vital rates and understand the role of large managed WMAs like Mead in the state of WI.

Another potential factor influencing the breeding season survival estimate is sample size. This survival modelling approach appropriately censors birds if they left the study area or are otherwise unaccounted for. While this approach ensures statistical assumptions are met, it becomes problematic when few birds are in the study population. For instance, after day 77 there were < 10 birds in the study population and each corresponding death had a large per capita decrease in the survival parameter estimate. Because of this, I performed 2 separate post-hoc perturbation exercises and I re-analyzed survival following Robb and Bookhout (1990). The first exercise treated all censored birds as death events and the second treated them as if they survived. If all the censored birds died when they were censored the revised survival estimate would be 0.034, whereas, if they all survived at the time of censoring then the estimate would be 0.503. Even in the most generous instance where I treat censored birds as those they survived, survival of female wood ducks was still about 50% (as high as 79% with 95% CI), an estimate substantially below what others have found. Regardless, future work that enhances sample size should alleviate this concern.

Future studies should focus on expanding this research spatially and temporally to report unbiased and representative estimates of breeding season vital rates for wood ducks in Wisconsin. Similar studies have been conducted in southern Illinois, but there is scant information on female wood duck demographics in the Upper Midwest (Gates et al. 1995). Brood survival has never been estimated for wood ducks that do not use artificial nest boxes. I planned to model brood survival but was limited to only tracking seven broods over two years. Brood survival may also be critical in modeling populations. Additional years of female tracking could provide a more concise data set for estimating female survival during the breeding season and provide the data set to examine what covariates are influential to a female surviving this time period. The addition of other study areas may present geographical differences in population rates (i.e. survival) and habitat preferences. Ultimately, there is a need for a larger and more robust dataset to make inferences of the female wood duck population that is important to managers statewide, regionally, or nationally (Soulliere et al. 2017).

Table 4. Female breeding season survival (s) rate comparison from Mead WMA compared with previously published estimates (1990-2019). Location and type of capture technique provide context for differences.

Source	Location	Capture type	s
Davis et al. 2001	Mississippi	Nest box	0.973
Hartke and Hepp 2004	Alabama, Georgia	Nest box	0.965
Davis et al. 2007	Mississippi, Alabama	Nest box	0.900
Dyson 2015	Ontario	Nest box	0.897
Anderson 2010	Illinois	Bait Trap	0.800
Dugger et al. 1999	Missouri	Nest box	0.630
Robb and Bookhout 1990	Indiana	Bait trap	0.420[a]
Rush 2019 (this study)	Wisconsin	Decoy trap	0.343

[a] Low survival estimate assumes all censored birds survived.

Habitat Selection

Patterns of habitat selection can be vital to researchers and managers and it is critical to habitat management to understand how wood ducks are selecting habitats available on the landscape as it can inform conservation decisions (Soulliere et al. 2017). Female wood ducks at Mead WMA selected cover types like forested wetland, scrub-shrub, and emergent wetland similar to what other studies have found (Table 5; McGilvrey 1969, Hepp and Hair 1977, Dugger and Frederickson 1992, Dyson et al. 2018). But unlike other studies, the wood ducks at Mead WMA selected for open water and floating aquatic vegetation habitats. This result is intriguing because it is commonly assumed that wood ducks avoid open habitats that lack structural cover (McGilvrey 1968, Baldassarre 2014) and display high use and selection for forested wetlands (Gates et al. 1995, Dyson 2018). However, my sample of wood ducks contained many failed (n=5) and non-breeders (n=10). Apparently, habitat selection for females without broods may be different than suitable habitat for females with broods, presumably because they do not have their ducklings to conceal. Females without broods seem to require less dense cover, as observations of selection patterns between nesting and non-nesting wood ducks reveal, and this may explain why open and floating aquatic vegetated habitats appeared to be selected for (Figure 1).

Wood ducks at Mead WMA selected for a diversity of habitats including forested wetlands, scrub-shrub, emergent wetlands, open water, and floating aquatic herbaceous vegetation. This finding reinforces the importance of maintaining and managing a variety of wetland types so wood ducks can meet their diverse needs. Habitat complexity and diversity has been positively correlated with duck abundance (Pearse et al. 2012), but it is noteworthy that even a species like wood duck, which is dogmatically assumed to prefer wooded or scrub-shrub wetlands, apparently prefers a diverse set of habitats. Unfortunately, I was restricted to assess habitat selection of just female wood ducks, and not their broods because brood rearing habitat selection remains a largely unexplored area and one that has been identified as a potential limiting factor for wood ducks (Soulliere et al. 2017).

Alternative reasons may explain why habitat selection for the females in this study is somewhat different than previously reported. Similar to the survival limitations, habitat selection also may be different simply due to sample size. I may not have enough individuals to precisely estimate how these wood ducks are using the habitat. However, enough individual observations were included that I do not believe that sample size is limiting for habitat selection. Also, the wood ducks may show different patterns in habitat selection because the sample is made up of more females without broods (77%) than other studies. I propose that if this is true, then habitat selection for brood-rearing females only should be compare to those selection ratios in other studies. These females were more likely to be found in larger groups and in more open habitats than nesting or brood-rearing females. Finally, Mead may be a unique example of habitat selection given the status of wood duck breeding habitat, including ample forested wetlands, scrub-shrub, and emergent wetlands.

There are numerous areas where future researchers could focus. First, I believe that this study would inherently increase sample size and location precision by introducing GPS transmitters in lieu of radio transmitters. This would allow for more frequent transmissions and increased location precision. This would also provide data for estimating movement patterns of wood ducks and their broods. Second, there should be an expansion of study sites. Mead WMA is ideal because of its proximity to the University of Wisconsin-Stevens Point campus, publicly owned, and for ease of accessibility. However, it is not necessarily representative of the entire state. It is important to sample from unique populations that may use the landscape different (i.e. agriculture-dominated areas, Mississippi River basin).

Table 5. Types of selected habitat from Mead WMA compared with previously published habitat selection for wood ducks and other ducks (2004-2018). Location provides context for differences.

Source	Location	Species	Selected habitat (s)
Dyson et al. 2018	Ontario, Canada	Wood Duck	Monoculture, emergent, forested, scrub-shrub wetlands
Hartke and Hepp 2004	Georgia, USA	Wood Duck	Managed impoundments, lake-influenced wetlands
Granfors and Flake 1999	South Dakota, USA	Wood Duck	Forested wetlands
Rush 2019 (this study)	Wisconsin, USA	Wood Duck	Forested, scrub-shrub, and emergent wetlands; open water, floating aquatic herbaceous vegetation

MANAGEMENT IMPLICATIONS

This research in central Wisconsin has raised questions about our current understanding of the population dynamics of breeding female wood ducks and their interaction with the environment. Mark-recapture studies of females should continue to evaluate the precise impact of these covariates on survival. Bib-style transmitters are retained better than the manufactured collar design, and provide data important for modeling female survival, habitat selection, breeding incidence, and other pertinent breeding season vital rates. Researchers might want to experiment with satellite or GSM transmitters, in lieu of VHF, especially if interested in modelling habitat selection or movement. Females should be captured prior to nest initiation (e.g., with use of a decoy trap) to determine the influence of nest propensity and nest success for individuals that use cavities. This research indicates that females captured prior to nest initiation may have lower survival rates and different patterns in habitat selection that other previous studies. Also, it is important that managers don't discount the value of open water habitats, which traditionally are not thought of as quality dabbling duck habitat. Most importantly, this research has highlighted potential shortcomings of current female wood duck vital rate estimates and proves for a greater need for research that includes all female wood ducks, not only those that attempted to nest in a nest box. I experienced limited recruitment from nest boxes (n=1, 6.25% raised a successful brood to 30 days), meaning that Mead boxes may be a potential sink for wood ducks.

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APPENDIX A

Trap Locations

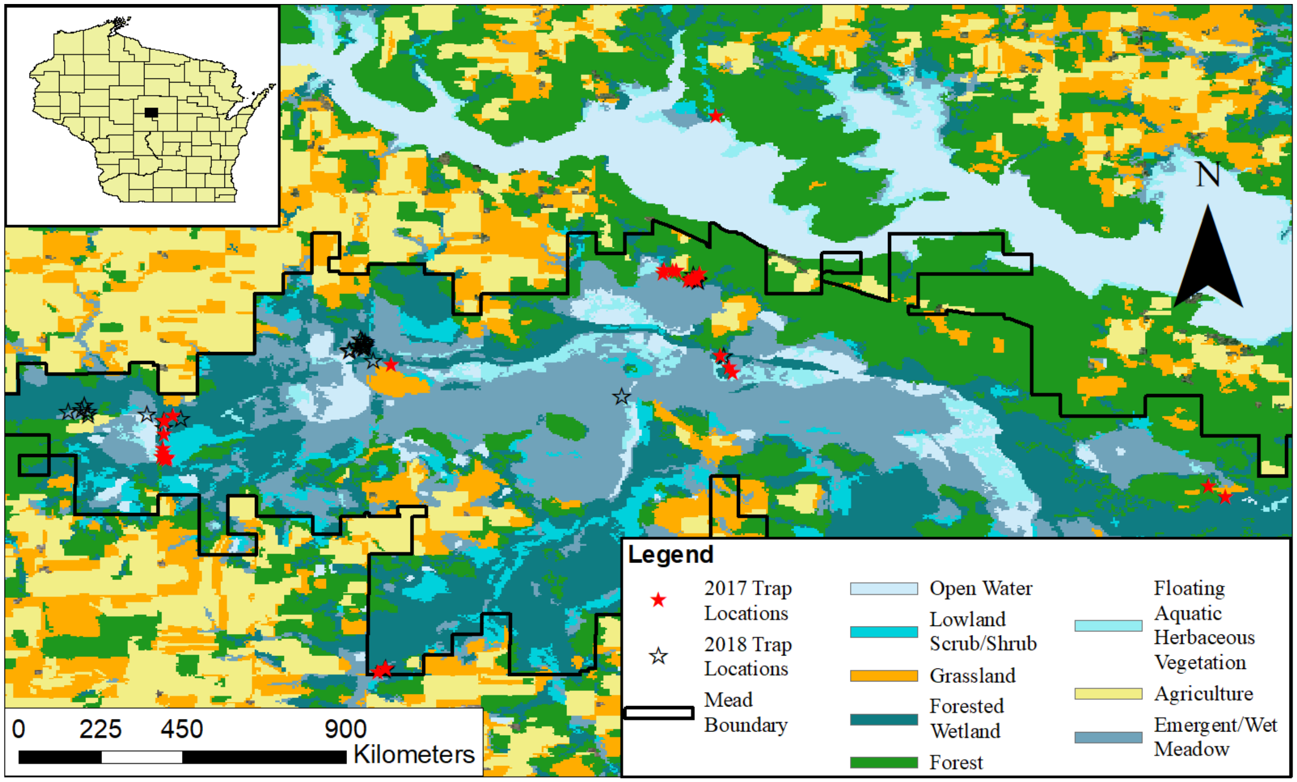

Figure 1. Map of Mead WMA, WI, USA with decoy trap locations (denoted with stars) and land cover types in 2017 (red star) and 2018 (black outlined star).