FACTORS INFLUENCING BREEDING SEASON SURVIVAL OF FEMALE MALLARDS IN THE GREAT LAKES REGION

By

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ABSTRACT

FACTORS INFLUENCING BREEDING SEASON SURVIVAL OF FEMALE MALLARDS IN THE GREAT LAKES REGION

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Mallards (*Anas platyrhynchos*) are one of the most widely studied waterfowl species in North America, yet there are unknown demographic vital rates that are critical to enhancing the management of this waterfowl species. Specifically, information on breeding season survival rates of female mallards in the Great Lakes region is lacking. We estimated breeding season survival for 484 individually radio-marked female mallards across 9 study sites in the Great Lakes region from 2001–2003. We modeled the effects of study site, year, state, female age (after second year [ASY] vs second year [SY]), body condition, and 3 time periods within the breeding season. Additionally, we created utilization distributions (UDs) (i.e., home ranges), estimated core areas for 282 individuals, and quantified land cover types in those core areas to model the effects of those cover types on breeding season survival. Survival ranged from 0.62–0.85 and the mean across all sites was 0.76. Survival was lowest during the peak nesting period, but study site, year, state, age, and body condition had no significant effect on survival. Our top model suggested that breeding season survival decreased as the percent composition of forested cover within the core areas increased ($\beta = -1.740$, 95% CI Lower = –3.282, Upper = –0.197). Breeding season survival estimates were similar to those estimated elsewhere and we failed to detect a strong relationship between most land cover types within core areas and survival, suggesting that female mallard survival in the Great Lakes region may be affected by land cover factors not assessed as a part of this study or at alternative spatial scales.

I would like to dedicate the completion of my thesis to everyone in my life who has helped instill in me the passion that I have for all things wild and to those who taught me to strive to surpass mediocrity and to persist at all costs.

ACKNOWLEDGMENTS

I would like to thank the Upper Mississippi River Great Lakes Region Joint Venture, Ducks Unlimited Inc., and numerous private donors for providing funding for this project. Additionally, I would like to thank my advisor Dr. Scott Winterstein, and my committee members Dr. Gary Roloff, Dr. Dave Luukkonen, and Dr. Charles Nelson for providing support and guidance throughout my progression as a graduate research assistant. I would also like to sincerely thank Dr. John Coluccy of Ducks Unlimited and Ms. Rebecca Humphries who were instrumental in the initiation of my involvement with this project.

I would like to thank the original investigators of the study from 2001–2003 including all of the technicians and researchers. Specifically, I would like to thank John Simpson, one of the original graduate students who willingly provided background information and valuable insight on his experiences regarding the study. I would like to thank Rob Paige with Ducks Unlimited for providing valuable insight as I worked through the spatial analysis component of my project. Additionally, I would like to thank Dr. Robert Montgomery and Kyle Redilla who were an instrumental part in assisting me with the methodology during the latter stages of the project.

I would be remiss if I didn't thank my family for instilling in me the values that helped me achieve this monumental goal. Lastly, but most importantly, I would like to thank my loving wife Jaime, who was the support network and the inspiration that I needed to achieve the goal of acquiring my Master's degree at Michigan State University.

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INTRODUCTION

Factors influencing mallard populations have been the focal point of multiple studies conducted in the Prairie Pothole Region and results from those studies have long been incorporated in the management of mallard populations throughout North America. Research suggests that mid–continent populations of mallards are most sensitive to changes in nest success and female survival during the breeding season (Johnson et al. 1987, Hoekman et al. 2002). However, Coluccy et al. (2008) completed a sensitivity analysis on vital rates affecting mallard productivity in the Great Lakes region using information collected from a 2001–2003 study (see below), and suggested that the variability in mallard population growth was most sensitive to changes in non–breeding survival (36%), duckling survival (32%), and nest success (16%), while other vital rates including breeding season survival accounted for the remaining 16%. Additionally, harvest derivation records suggested that a large proportion (22%–81%) of mallards harvested in the Great Lakes region (i.e., Indiana, Illinois, Ohio, Michigan, and Wisconsin) were produced locally (Zuwerink 2001). Therefore, modeling mallard productivity using estimates of vital rates collected from mid-continent mallard populations in the Prairie Pothole Region may not be entirely appropriate for managers in the Great Lakes region. Although breeding season survival of female mallards accounted for 1% of the variation in Great Lakes mallard populations Coluccy et al. (2008), we acknowledge that other vital rates such as nest success and brood survival are dependent upon females surviving the breeding season. Additionally, understanding the relationship between the effects of land cover types and breeding season survival can provide important information to regional managers looking to increase a suite of vital rates through management actions for mallards in the Great Lakes region.

For this thesis titled "Factors Influencing Breeding Season Survival of Female Mallards in the Great Lakes Region" I analyzed data that were initially collected in 2001–2003, as part of a multi-state study funded by Ducks Unlimited, Inc. (DU). DU was charged with assessing important vital rates and habitat factors influential to mallard productivity within the Great Lakes region in an effort to identify opportunities to potentially increase vital rates through strategic habitat conservation and to address an important information need. The initial data collection, radio-marking of female mallards, and the monitoring of individuals were completed during 2001–2003 prior to my involvement. Originally, three graduate students were tasked with data collection and analyzing mallard vital rates, such as brood survival (Simpson 2005), nest survival (Davis 2008), and a home range analysis (Reichus, unpublished data). Female survival rates during the breeding season and factors affecting those rates were never fully assessed, but were later identified as an important information need by DU and the Upper Mississippi River Great Lakes Region Joint Venture for conservation planning purposes.

I compiled breeding season data and attribute information for each of the individually radio-marked females in the fall of 2012. I created study site maps and utilized nest location data for 9 study sites and visited the study sites to gain perspective on the landscape and land cover types that were utilized by breeding females. Additionally, I toured a study site with one of the original graduate students of the project and discussed study design and monitoring protocols utilized by the researchers. This allowed me to gain valuable insight on specifics of the study design and methods. I amalgamated location estimate data and attribute information including age, body condition, and information specific to breeding efforts for each individually radio-marked female, and formatted this information to ensure accuracy and completeness of the data. The MSU Institutional Animal Care and Use Committee determined that this study was exempt from filing an Animal Use form because it only dealt with the retrieval and analysis of data from paper or electronic records.

My objectives were to 1) estimate breeding season survival rates for female mallards, 2) examine the effects of site, year, and states in addition to female-specific characteristics such as age (SY vs. ASY) and body condition, and 3 periods within the breeding season (i.e., increasing nesting activity, peak nesting activity, and decreasing nesting activity) on survival, and 3) determine effects of land cover types within core areas, distance to land cover types such as wetland, forest, and agriculture from core areas, home range size, and number of core areas on survival.

CHAPTER 1

Effects of Female-Specific Characteristics on Female Mallard Survival during the Breeding Season in the Great Lakes Region

Abstract

Survival of breeding mallards (*Anas platyrhynchos*) has been studied extensively throughout most of the United States and Canada, however, survival estimates for breeding mallards in the Great Lakes region are lacking. We estimated the breeding season survival probability for 484 female mallards radio-marked at 9 different sites throughout Indiana, Michigan, Ohio, and Wisconsin from 2001–2003. We investigated the effects of female- specific characteristics including age, body condition, and 3 periods within the breeding season (e.g., increasing nesting activity, peak nesting activity, and decreasing nesting activity) on survival. Our survival estimates for each of the 9 sites throughout the 18-week breeding season ranged from 0.62 (SE = 0.092) to 0.85 (SE = 0.052) and averaged 0.76 (SE = 0.023). Our best approximating model suggested that weekly survival of female mallards is lowest (0.97 ± SE = 0.004) during peak nesting activity when the greatest proportion of females are actively nesting. Our results suggest that female age and body condition upon arriving on the breeding grounds had no significant effect on survival. Our survival estimates suggest that breeding season survival in the Great Lakes region is similar to that from the Prairie Pothole Region, southern Ontario and elsewhere, suggesting that landscape level variation in land cover types may have little effect on female mallard breeding season survival across North America. Additional research is needed to determine the effects of cover types on female survival, however, management efforts aimed at restoring upland nesting cover and emergent wetlands are likely the greatest ways to increase

important breeding season vital rates influential to population dynamics of Great Lakes region mallards.

Introduction

Mallard (*Anas platyrhynchos*) populations in the Great Lakes region have increased dramatically leading up to the mid-1990's, presumably as a result of eastern expansion associated with widespread landscape alteration (Heusmann 1991), however, current information on mallard population size estimates for Michigan, Minnesota, and Wisconsin from the Waterfowl Breeding Population and Habitat Survey suggests that Great Lakes mallard populations have since declined (Fig 1.1). Previous studies suggested that the Great Lakes mallard population is relatively distinct from other populations and has become increasingly important to regional waterfowl harvests (Anderson and Henny 1972, Munro and Kimball 1982, Zuwerink 2001, Hoekman et al. 2006a, Coluccy et al. 2008). Mallard harvest in the Great Lakes region exceeds that of any other duck species (Raftovich et al. 2011) and harvest in the region are primarily derived from locally produced birds (Munro and Kimball 1982, Zuwerink 2001,).

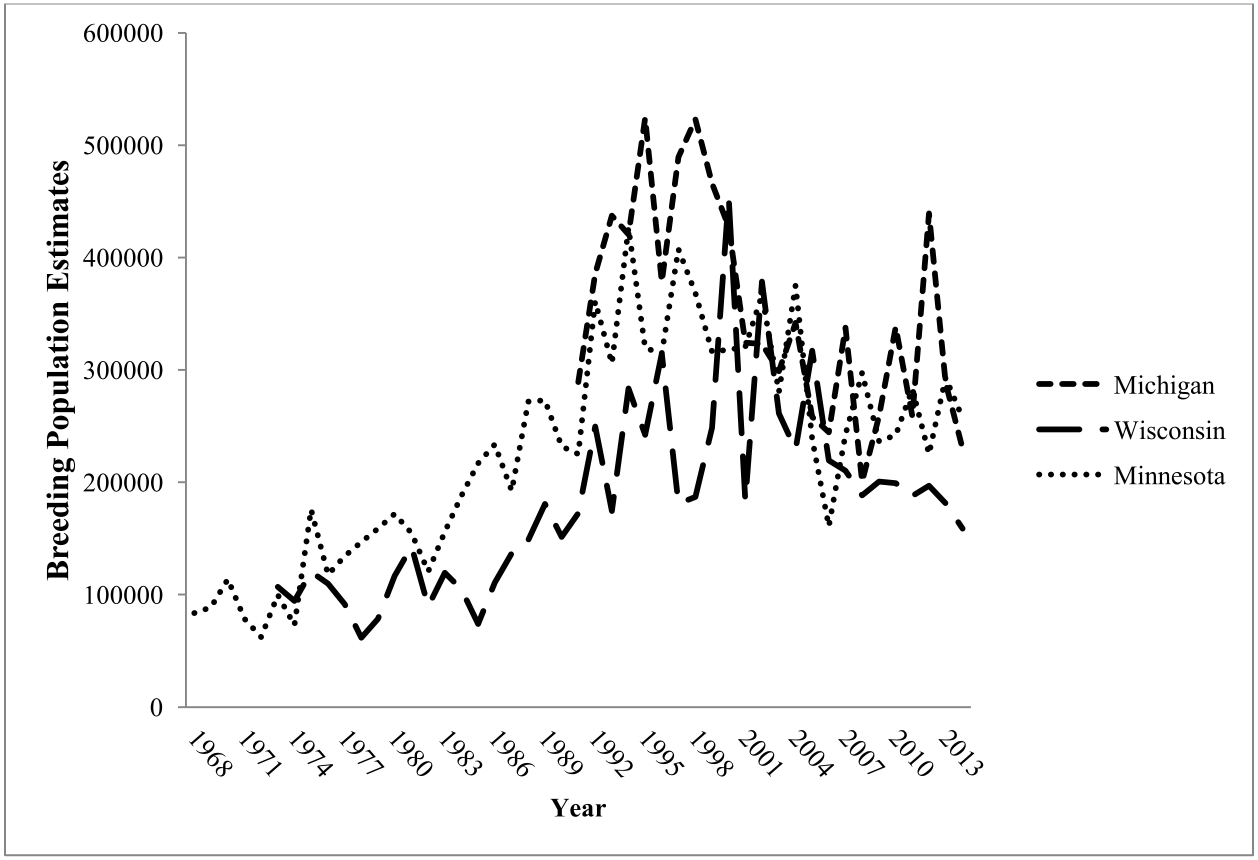

Figure 1.1 Breeding population estimates of mallards in Michigan, Minnesota, and, Wisconsin from 1968–2013 (derived from the Waterfowl Breeding Population and Habitat Survey conducted by the U.S. Fish and Wildlife Service).

Waterfowl incur exhaustive energetic demands throughout the course of the annual cycle, more intensely during the breeding season with the inherent risks that are associated with reproduction (Baldassarre and Bolen 1994). Although the breeding season accounts for a short time period within the annual cycle for waterfowl, a large percentage of the mortality experienced by waterfowl populations occurs during the breeding season (Johnson et al. 1992; 446). Effectively managing waterfowl populations requires that managers understand vital rates that influence population dynamics. Previous studies suggested that mallard population dynamics are largely influenced by processes that occur during the breeding season, including female survival (Hoekman et al. 2002, 2006*a*, Coluccy et al. 2008). Survival of female mallards during the breeding season has been investigated extensively in the Prairie Pothole Region (Cowardin et al. 1985, Dufour and Clark 2002, Devries et al. 2003, Brasher et al. 2006) and elsewhere (Losito et al. 1995, Hoekman et al. 2006*b,* Kaminski et al. 2013). However, information on this important vital rate for mallards in the Great Lakes region is lacking.

Survival of female mallards during the breeding season may be affected by intrinsic or "female-specific" factors in addition to extrinsic factors (e.g., habitat, predators, and weather). Previous studies have tested the effects of age on survival and found that after-second year (ASY) females exert a greater nesting effort than do second year females (SY) (Krapu and Doty 1979, Cowardin el al. 1985, Hoekman et al. 2002) and therefore are believed to be at greater risk of mortality during the breeding season (Reynolds et al. 1995). Additionally, previous studies have indicated that female mallards suffer increased risk of mortality while actively nesting compared to other periods within the breeding season (Johnson and Sargeant 1977, Sargeant et al. 1984, Devries et al. 2003, Brasher et al. 2006, Hoekman et al. 2006a, Arnold et al. 2012).

Female mallard body condition and its effects on survival during hunting and over-wintering periods have been studied extensively (Reinecke et al. 1987, Bergan and Smith 1993, Jeske et al. 1994), however information on the relationship between body condition and survival during the breeding season is lacking. Devries et al (2008) tested the effects of body condition on reproductive measures such as nesting propensity, nest initiation, clutch size, nest survival, and timing of hatch for mallards, but never directly assessed the impact that body condition may have on survival. Although female survival is not completely independent of these reproductive measures, information regarding the effects that body condition may have specific to breeding season survival is lacking. Understanding the effects of body condition as it relates to breeding season survival would provide important information for waterfowl managers throughout the Great Lakes region striving to increase mallard productivity.

Female mallards increase the amount of time spent on nest attendance as individual's progress from nest initiation to clutch completion and incubation (Loos and Rohwer 2004). Devries et al. (2003) and Brasher et al. (2006) found an inverse relationship between the proportion of nesting females and the probability of survival during the breeding season, suggesting that survival was lowest when the greatest numbers of females were actively nesting. Hoekman et al. (2006a.) tested a similar effect on female mallards in Ontario, Canada after noting a mid–season decline in survival; however, an inverse relationship between proportion of nesting females and survival was not found. Assessing survival probabilities of female mallards during periods of increased nesting activity with these data could be beneficial for differentiating between the Great Lakes region mallard population and mallards elsewhere. Additionally, examining the effects of survival during times of increased nesting activities could direct the need for further investigation on the effects of land cover types at a spatial and temporal scale that encompass nest sites and areas of repeated use by females during the breeding season.

From 2012–2014, we analyzed daily location estimates and individual female breeding season attribute data collected from the Great Lakes region in 2001–2003. Our objectives were to: 1) estimate weekly breeding season survival rates for female mallards across 9 sites and 2) evaluate the effects of female-specific characteristics including age and body condition, and evaluate 3 periods within the breeding season (e.g., increasing nesting activity, peak nesting activity, and decreasing nesting activity) on survival.

Study Area

We selected 9 study sites across 4 different states in the Great Lakes region (Fig. 1.2). We selected study sites based on incorporating varying percentages of agriculture and forest land cover types found in the Great Lakes region of the United States (Table 1.1).We utilized National Land Cover Data (NLCD; USGS 2003) with 30–m resolution to quantify percentages of cash crops, dairy pasture, and deciduous forest. We used ERDAS IMAGINE 8.4 GIS software to create an adjusted land cover map of the Great Lakes region by attributing 30 x 30–m grid cells based on the proportion of the aforementioned cover types within a 2 x 2 km area. We selected areas that had wetland densities high enough to support breeding populations of mallards over other potential sites of similar land cover types with lower wetland densities. We took into consideration logistical concerns during the final selection of the study sites so that housing existed for field staff along with a series of adequate road networks to maximize access within the study area.

Figure 1.2 Locations of the 9 study sites within the Great Lakes region where we collected data for research on female mallard survival during the breeding season, 2001–2003. (OH01 = Port Clinton, OH; MI01 =Riverdale, MI; WI01 = Ripon, WI; OH02 = Stueben County, IN; MI02 = Battle Creek, MI; WI02 = Shiocton, WI; OH03 = Akron, OH; MI03 = Big Rapids, MI; WI03 = New Richmond, WI).

Table 1.1 Primary land cover types for the Great Lakes region and associated proportion (%) within those categories created for the initial selection of study sites in the Great Lakes region, 2001–2003. Study Site corresponds to the state (i.e., MI = Michigan, OH = Ohio, WI = Wisconsin, IN = Indiana) and year (2001–2003).

Land Use Category	Proportion of Region	Study Site
Low Forest-High Agriculture	28.4%	MI01,OH01, WI01, WI02
Intermediate Forest- High Agriculture	14.7%	IN02, WI03
Intermediate Forest- Intermediate Agriculture	12.0%	MI02, OH03
High Forest- Intermediate Agriculture	8.3%	MI03
High Forest- Low Agriculture	7.0%	
Intermediate Forest Low Agriculture	6.0%	
Low Forest- Intermediate Agriculture	2.0%	
Low Forest- Low Agriculture	urban	
High Forest- High Agriculture	n/a	

In 2001, study sites were located near Port Clinton, Ohio (41º30'N, 84º59'W); Riverdale, Michigan (43º23'N, 84º50'W); and Ripon, Wisconsin (43º50'N, 88º50'W). In 2002, study sites were located by Stueben County, Indiana (41º38'N, 84º59'W); Battle Creek, Michigan (42º27'N, 85º13'W); and Shiocton, Wisconsin (44º26'N, 88º34'W). In 2003, study sites were located by Akron, Ohio (41º04'N, 81º13'W); Big Rapids, Michigan (43º37'N, 85º13'W); and New Richmond, Wisconsin (45º11'N, 92º 23'W).

Methods

Trapping and Radio-marking

We trapped and radio-marked approximately 60 female mallards prior to nesting using conventional decoy traps at each study site, during late March and early April (Sharp and Lokemoen 1987). We selected decoy trap site locations by scouting and selecting wetland basins sufficient in size to hold breeding mallard pairs and selected wetland basins that pairs were actively using. In certain cases, we trapped several paired hens on the same wetland basin throughout the spring. Land ownership often limited the ability to randomly distribute our trap site locations across the study sites. We banded females with standard United States Geological Survey leg bands and implanted 22–g abdominal Very High Frequency (VHF) transmitters (Advanced Telemetry Systems, Isanti, MN) using surgical procedures outlined by Korschgen et al. (1984). We held radio-marked females for one hour following surgery and released individuals at the trap site location. Additionally, we released males that were captured and banded with the females to avoid disrupting pair bonds.

We monitored and estimated locations of radio-marked females 1–6 times daily using truck-mounted null-array systems (Kenward 1987). We monitored females between the hours of 0600 and 1300 when laying females are likely to be found on the nest (Gloutney et al. 1993).

Researchers used hand-held tracking equipment when locations could not be obtained from the vehicle with null-array systems and to confirm nesting attempts by breeding females. We utilized aircraft to locate missing females after extensive ground searching throughout the study area was unsuccessful. We estimated Universal Transverse Mercator (UTM) locations via triangulation using LOCATE software (Pacer, Truro, NS, Canada).

We measured the body mass (nearest 10 g) for each radio-marked female, with a 1.5-kg Pesola hand-held spring scale. Additionally, we recorded a series of structural measurements including skull length (nearest 0.1 mm) from the occipital protuberance to the bill tip, central culmen (nearest 0.1 mm) from the intersection of skin and premaxilla to the bill tip, tarsus length (nearest 0.1 mm) from the proximal to the lateral condyles of the metatarsus, keel length (nearest 0.1 mm) from the tip of the cranial process to the end of the medial caudal process, and wing chord (nearest 1 mm) from the wrist on bent wing to the tip of the longest primary. To aid in accurately classifying age as either second year (SY) or after second year (ASY) based on feather characteristics, we collected the greater secondary coverts from the right wing (Krapu et al. 1979, R. Clark, Canadian Wildlife Service, unpublished data). We used body mass as an index of body condition but body mass can vary in response to structural size (Alisauskas and Ankeny 1987, Ankeny and Afton 1988, Ankney and Alisauskas 1991). Thus, we conducted a principle components analysis using four of the structural measurements to correct body mass for structural size. We failed to record culmen measurements for 31 females and thus we excluded the culmen measurement from the principal component analysis. We calculated a body-condition index as the first principle component (PC_1) of the four structural variables measured on each female using PROC PRINCOMP in SAS (SAS Institute 2004). To determine if body mass was related to body size, we regressed body mass on PC_1. Body mass was related to body size (F = 148.02, P < 0.0001, R^2 = 0.22) as indicated by the following relationship: Body mass = 1,097.10±3.32 + 33.32±2.74 × (PC_1). We used residuals from the regression to derive a size corrected body mass (Y_i) using the following equation (Ankney and Alisauskas 1991):

$$Y_i = Y_{obs} - [a + b(PC_1)] + \bar{Y}_{obs}$$

Where Y_{obs} is unadjusted body mass and $\bar{Y}_{obs}$ is the mean of unadjusted body mass for all females.

We collected location data and information regarding breeding season behavior for individuals up to 24 weeks after radio-marking. Survival across all study sites was constant (1.0) beyond week 16, therefore we truncated the length of the study period from 24 weeks (mid-Mar – end-Aug) to 18 weeks (mid-Mar – mid-Jul) for the survival analyses. Similar studies estimating breeding season survival of female mallards in other regions estimated survival over the course of a 13–week (Devries et al. 2003) and 16–week period (Hoekman et al. 2006a). However, since estimating brood survival was one of the original emphases of the 2001–2003 study (Simpson 2005), we had location estimates and breeding season data on individual females up to 24 weeks. We estimated the 18-week breeding season survival for 484 radio-marked female mallards (n = 53 at MI01, n = 56 at OH01, n = 53 at WI01, n = 52 at MI02, n = 54 at IN02, n = 56 at WI02, n = 56 at MI03, n = 54 at OH03, n = 50 at WI03) at 9 study-areas from 2001–2003.

We initiated survival estimates by site, year, and state when ≥ 10 radio-marked individuals had entered the study following radio-marking. Following a failed nesting attempt, we monitored females that were found grouped with other individuals and not paired with a male for 2 consecutive days to ensure no additional nesting attempts occurred. We classified individuals no longer exhibiting breeding season behavior as molt migrants and concluded the monitoring for those individuals. We right–censored individuals classified as molt migrants and those that had emigrated from the study sites. Thirty–five individuals were believed to have suffered radio failure throughout the course of the study. We determined the cause of mortality upon location of the transmitter and the carcass when remains were found. In many cases the cause of death could not be determined and we classified the source of mortality as unknown.

Statistical Analyses

We utilized Program MARK (White and Burnham 1999) known–fate models (White and Garrott 1990) to determine the maximum likelihood estimates of female survival at weekly intervals throughout the 18–week study period. We coded individuals as having survived the weekly interval in the analysis if they were located during the weekly interval and known to have survived throughout the entire 7-day period. We temporarily censored individuals whose fate was not recorded throughout one or multiple weekly intervals until fate could be determined. We estimated survival by study area, state, and year prior to estimating the entire sample (i.e., all individuals across all sites) to test for random effects that may have influenced the resulting estimates. We used generalized linear models and the logit link function for testing the effects of female-specific characteristics of age and body condition, and the 3 periods within the breeding season. We modeled survival using a binomial distribution of errors and the logit link function due to our response variable of weekly survival being formatted in a binomial fashion (e.g., 0 = alive, 1 = dead) (McCullagh and Nelder 1989). We incorporated an identity design matrix and the sin link function for estimating weekly survival estimates by individual study sites due to numerical precision errors produced when calculating parameter estimates and standard errors using a full model design matrix in conjunction with the logit link function. We maintained a full model design matrix and the logit link function to determine maximum likelihood estimates of female survival when estimating weekly survival across all sites for all individuals and when testing the effects of individual covariates on survival. We developed our candidate list of a–priori models including the effects of female age, body condition, and period within the breeding season (Table 1.2). We compiled the list largely based on information gathered from previous studies (see Devries et al. 2003, Hoekman et al. 2006a, Kaminski et al. 2013) as well as information collected throughout the course of the study. Our a–priori candidate model list included all additive combinations of covariates and a 2–way interaction between the covariates of female age and body condition. We hypothesized that older females (ASY) may be more experienced and arrive on breeding areas in better condition than younger (SY) females, therefore we felt establishing an interaction between the two covariates made biological sense. We used Akaike's Information Criterion adjusted for small sample size (AICc; Hurvich and Tsai 1995) to select among competing models. Finally, we used AICc weights to assess the relative likelihood of the candidate list of models (Burnham and Anderson 1998).

We classified 3 time periods as (1) weeks 1–6 following initial marking, (2) weeks 7–11 following initial marking, (3) weeks 12–18 following initial marking and representing the conclusion of the study period. The 3 periods corresponded to when the nesting activities of the greatest proportion of females were increasing, at peak, and decreasing (Fig. 1.3). We examined the initiation and termination dates for each individual female that recorded a nesting attempt and compared the proportion of females known to be actively nesting throughout the 18-week breeding season. Multiple extrinsic factors may have influenced the peak of nesting activities across all 9 sites; however, the peak of nesting activity occurred between weeks 7–11 across all sites.

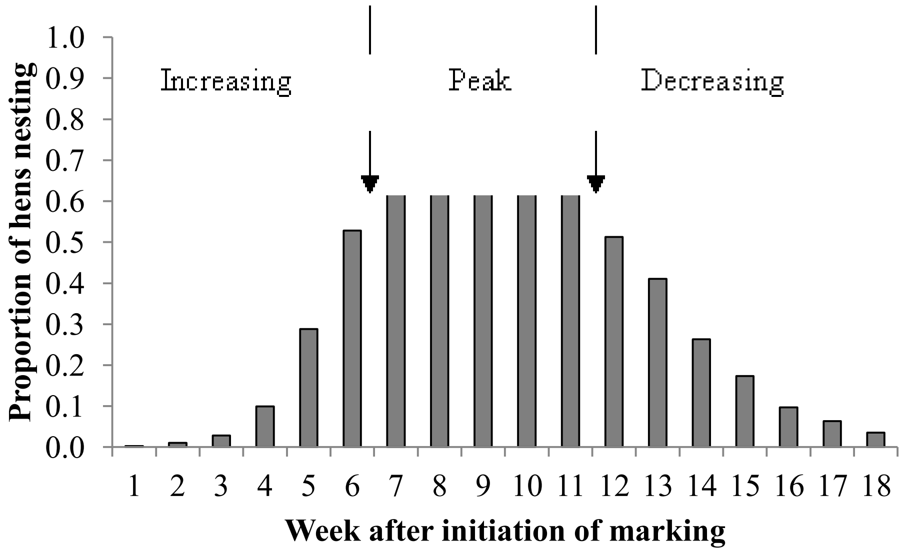

Figure 1.3 Proportion of 481 radio-marked female mallards nesting during the18-week breeding season from 15 March to 18 July grouped by increasing nesting activity, peak nesting activity, and decreasing nesting activity across 9 sites in the Great Lakes region, 2001–2003.

Results

We trapped 536 individual females and fit them with VHF implant radio transmitters (Table 1.2). Two- hundred-thirty individuals were classified as ASY females, 303 as SY, and 3 individuals were of unknown age (Table 1.2).We included individual females with unknown age classifications in the overall survival estimates; however, we removed those individuals from the sample when testing the effects of female-specific characteristics on survival that included age. We categorized 49 individuals that were recorded on site for < 14 days as migrants and removed those individuals from further consideration. Additionally, we removed females from the analysis that died within 7 days of being radio-marked (n = 3). Few individuals (n = 123) were monitored as late as 18–weeks after the onset of monitoring the earliest marked individuals.

Table 1.2 Number of individual female mallards monitored (Transmitters) by study site, age (after second year = ASY, second year = SY, or unknown age = UN), number of individuals with ≥ 1 nesting attempt (Nest), individuals with no recorded nesting attempts (Nonnest), number of marked individuals on study site for < 14 days (Migrants), and number of individual mortalities across all sites for the Great Lakes region, 2001–2003.

Study Site	Transmitters	ASY	SY	UN	Nest	Non-nest	Migrants	Mortalities
MI01	59	25	34	0	47	6	6	11
OH01	57	32	25	0	45	11	1	13
WI01	60	30	29	1	45	10	5	11
IN02	60	32	27	1	47	7	6	7
MI02	60	24	35	1	39	13	8	10
WI02	60	25	35	0	45	12	3	14
MI03	60	19	41	0	45	11	4	9
OH03	60	24	36	0	41	13	6	7
WI03	60	19	41	0	38	12	10	12
Total	536	230	303	3	392	95	49	94

Survival by site ranged from 0.624 (SE = 0.092) at WI03 to 0.847 (SE = 0.054) at IN02, while survival across all sites for all individuals was 0.758 (SE = 0.023). We initiated survival estimates by individual site when ≥ 10 individuals were radio-marked and concluded the breeding season survival estimates upon the week of 12 July to remain consistent with week 18 of the overall study period length (Table 1.3). Ninety-four individuals suffered mortalities throughout the 18-week breeding season. Fifty percent (n = 47) of deaths were the result of mammalian depredation, 15% (n = 14) resulted from avian depredation, 7% (n = 7) were killed by farm equipment (e.g., hay cutting machinery), and 28% (n = 26) were classified as unknown (Table 1.4). One-hundred twenty-three individual females were known to have survived through the week 18 sampling interval of the breeding season. We right censored 267 females in the analysis due to a combination of radio failures (n = 35), and emigration from the study sites.

Table 1.3 Female mallard breeding season survival estimates ($\hat{S}$) and associated standard errors (SE) by study site and year. Survival estimates were initiated when ≥ 10 individuals were radio-marked at each site and concluded mid–July across the Great Lake region, 2001–2003.

Site	Year	Weeks	$\hat{S}$	SE
MI01	2001	16	0.7491	0.0664
OH01	2001	17	0.7294	0.0649
WI01	2001	15	0.8003	0.0565
MI02	2002	17	0.7267	0.0748
IN02	2002	18	0.8471	0.0537
WI02	2002	15	0.726	0.069
MI03	2003	16	0.7884	0.0663
OH03	2003	16	0.7838	0.0785
WI03	2003	15	0.6244	0.0918
Mean		18	0.7573	0.0227

Table 1.4 Mortality sources of radio-marked female mallards during the breeding season by study site in the Great Lakes region, 2001–2003.

Study Area	Mammalian	Avian	Farm Equipment	Unknown	Total
IN02	3	0	0	4	7
MI01	5	2	1	3	11
MI02	8	0	2	0	10
MI03	4	3	1	1	9
OH01	7	1	2	3	13
OH03	2	2	0	3	7
WI01	5	3	0	3	11
WI02	8	2	0	4	14
WI03	5	1	1	5	12
Total	47	14	7	26	94

Differences in survival among female age (β = 0.284, SE = 0.216, 95% CI Lower = -0.140, Upper = 0.708) and body condition (β = 0.002, SE = 0.003, 95% CI Lower =-0.003, Upper = 0.007) were not significant. The principle component analysis for corrected body mass indicated that ASY females had greater mass ($\bar{x}$ = 1104.95 g, SE = 2.808) than did SY females ($\bar{x}$= 1092.39 g, SE = 2.331). We examined the effect of year to year variability (Fig. 1.4) and the effect of state (Fig. 1.5) on female survival throughout the breeding season and found no significant differences. Models that included site received little support (AICc weight < 0.001) and differences among sites were not significant (Table. 1.5).

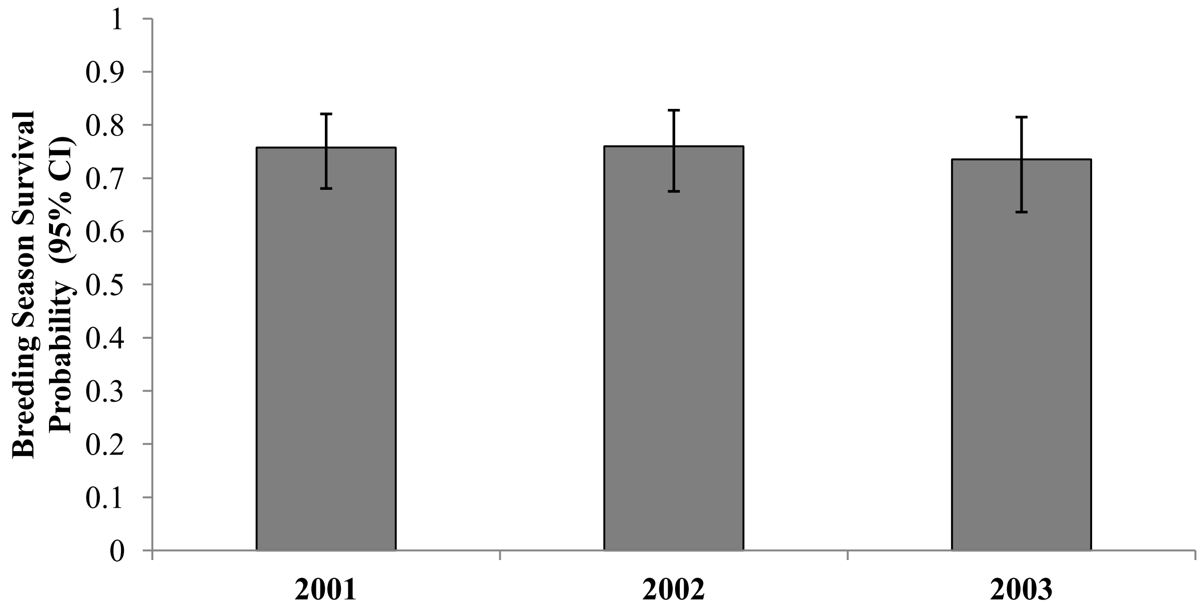

Figure 1.4 Breeding season survival estimates of 484 female mallards by year derived from known-fate models in Program MARK in the Great Lakes region, 2001–2003.

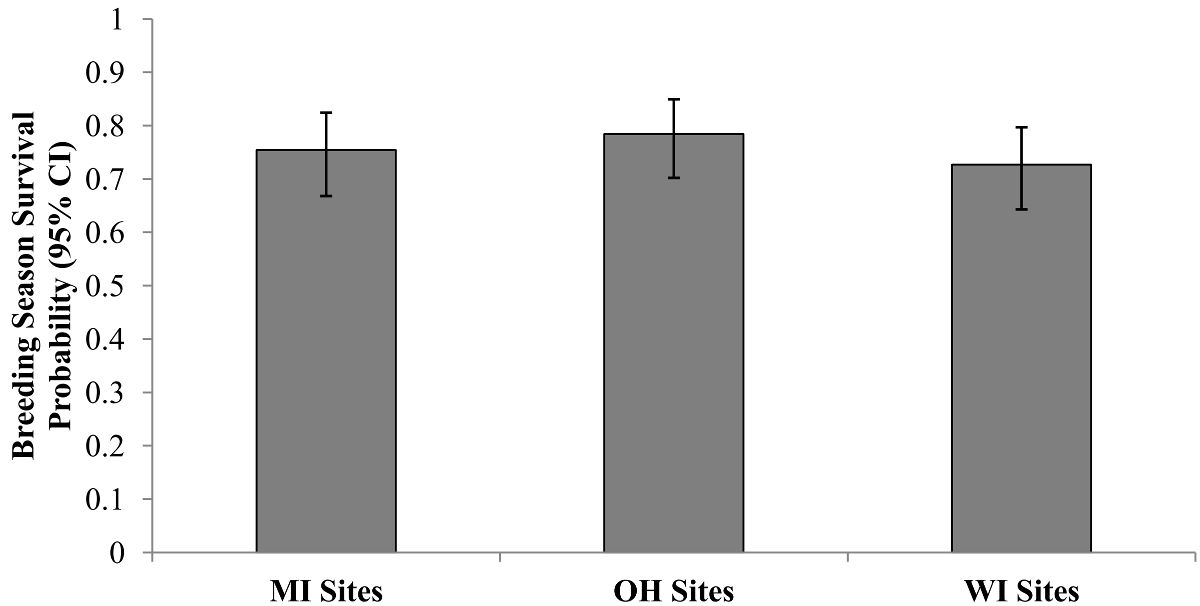

Figure 1.5 Breeding season survival estimates of 484 female mallards by state (e.g., MI = Michigan, OH = Ohio, WI = Wisconsin) derived from known–fate models in Program MARK in the Great Lakes region, 2001–2003. The IN02 study site survival estimate was included within the OH Sites.

Table 1.5 Known-fate candidate model results examining the effects of female-specific characteristics on female mallard survival (n = 484) during the breeding season in the Great Lakes region, 2001–2003. Models are ranked based on Akaike's Information Criterion corrected for sample size (AICc), the difference from the highest ranked model (ΔAICc), and the model weight.

Model[a]	Parameters	AICc	ΔAICc	Model Weight
{S(Nesting Period)}	3	866.4664	0	0.31786
{S(Nesting Period + Age)}	4	866.8938	0.4274	0.2567
{S(Nesting Period + Age* Condition)}	6	867.5294	1.063	0.18682
{S(Nesting Period + Condition)}	4	868.1486	1.6822	0.13707
{S(Nesting Period + Age+ Condition)}	5	868.7819	2.3155	0.09987
{S(Nesting Period + Site)}	11	878.4243	11.9579	0.0008
{S(Nesting Period + Site+ Age)}	12	879.2238	12.7574	0.00054
{S(Nesting Period + Site+ Condition)}	12	880.2316	13.7652	0.00033
{S(.)}	1	902.0776	35.6112	0
{S(Age)}	2	902.3274	35.861	0
{S(Age* Condition)}	4	903.139	36.6726	0
{S(Condition)}	2	903.5702	37.1038	0
{S(Age+ Condition)}	3	904.096	37.6296	0
{S(Site)}	9	912.5018	46.0354	0
{S(Site+ Age)}	10	913.1673	46.7009	0
{S(Site+ Condition)}	10	914.2381	47.7717	0

Our top ranking model provided support for female survival being adversely affected when the greatest proportion of females are at the peak of nesting activity (Table 1.5). The weekly survival estimates for period 1 was 0.997 (SE = 0.001), for period 2 it was 0.971 (SE = 0.004), and for period 3 it was 0.981 (SE = 0.004). Additive affects of female age and body condition included with nesting period were among the top ranking models (ΔAICc $\leq$ 2.3). Breeding incidence among SY females was 0.769 and 0.857 for ASY females.

Discussion

Breeding season survival estimates are available for mallard populations throughout North America; however to our knowledge our study is the first to estimate breeding season survival for female mallards in the Great Lakes region. Our 18-week breeding season survival estimates for female mallards in the Great Lakes region ($\bar{x}$ = 0.75, range = 0.62–0.85) (Table 2) were similar to estimates for female mallards in New Brunswick, Canada ($\bar{x}$ = 0.80, 95% CI 0.60–0.95; Petrie et al. 2000), the Prairie Pothole Region ($\bar{x}$ = 0.76, range 0.63–0.84; Devries et al. 2003), southern Ontario ($\bar{x}$ = 0.75, range 0.65–0.84; Hoekman et al. 2006a), and central New York ($\bar{x}$ = 0.78, range 0.75–0.81; Kaminski et al. 2013). Estimates derived throughout other regions of the mallard breeding range in North America in the aforementioned studies are comparable to ours based on similar study designs, trapping techniques, and radio transmitter types that were used. The use of abdominal implant transmitters likely minimized radio effects on breeding season behavior and ultimately the survival and reproductive efforts of females (Rotella et al. 1993, Paquette et al. 1997). Earlier studies estimating female mallard survival using external transmitters may have resulted in biased survival estimates due to having adverse effects on reproductive efforts of females (Pietz et al. 1993, Paquette et al. 1997).

We found no evidence to suggest that age (ASY vs. SY) had an effect on the survival of female mallards in the Great Lakes region (β = 0.284, SE = 0.216, 95% CI Lower = -0.139 Upper = 0.708). Previous studies have suggested that older females exhibit a greater nesting effort, and therefore may be more susceptible to being killed (Cowardin et al 1985, Reynolds et al. 1995). Additionally, our data suggested that breeding efforts between ASY and SY females were relatively similar, with 203 SY females recording $\geq$ 1 nesting attempt and 186 ASY females recording $\geq$ 1 nesting attempt. However, nearly twice as many SY individuals recorded no nesting attempt (n = 61) when compared to ASY females (n = 31). Our trapping methods were likely biased towards capturing breeding females with established territories and due to the difficulties associated with locating females initiating nests and nesting attempts that may have been missed prior to the onset of marking individuals (McPherson et al. 2003), therefore, it is plausible that we overestimated the number of SY and ASY females that failed to record a nesting attempt. Our results partially support the alternate hypothesis that SY females experience higher annual survival by forgoing breeding efforts altogether or due to higher nonbreeding survival (Dufour and Clark 2002). In their assessments of female mallard survival during the breeding season, Cowardin et al. (1985) and Hoekman et al. (2006a) found no support for large age related differences in survival between ASY and SY females. Conversely, Reynolds et al. (1995) and Devries et al. (2003) found that SY females had slightly higher breeding season survival than did ASY females.

Our results suggest that body condition of female mallards upon arriving to breeding areas had no significant effect on breeding season survival. Previous studies have assessed the importance of body condition to survival during periods of the annual cycle outside of the breeding season (Reinecke et al. 1987, Bergan and Smith 1993, Jeske et al. 1994), but to our knowledge none have assessed the relationship of body condition on the survival of female mallards during the breeding season. Arnold et al. (2012) modeled the effect of body mass on breeding season survival of female mallards and found that survival was negatively correlated to body mass for brood-rearing females trapped on the nest, but not for those that were decoy trapped; however, body mass had no effect on survival during the prenesting, incubation, and postnesting stages of the breeding season. Devries et al. (2008) found that female mallards in better condition had increased nesting propensity, earlier nest initiation dates and larger clutch sizes. We never tested the effects of female body condition on these reproductive measures, however further analysis may be informative for Great Lakes region managers seeking to increase mallard productivity by increasing the quality of habitats available to mallards during spring migration.

Our results indicated a strong relationship between a mid-season decline in survival and increased proportions of nesting females similar to those found by Sargeant et al. (1984) and Devries et al. (2003) who reported that females are at a greater risk of being killed while actively nesting than at any other time during the breeding season. Sixty-four of the 94 mortalities recorded occurred within weeks 7-11 during the peak nesting period. During the study only 34 percent of the females that died (n = 31) were recovered on or near the nest. Additional females were recorded nesting up to the date of mortality and may have been killed while actively nesting, however, the inability to locate the carcass and transmitter immediately after the death of the female or within close proximity of the nest site limited our ability to make that conclusion. Furthermore, we believe that this number may be biased low due to the lack of ability to detect nests during early laying (McPherson et al. 2003). Conversely, increased mortality during the peak of the nesting period could be related to prey-switching behavior of common aerial and terrestrial predators and affected less by the specific breeding activity (Arnold et al. 2012).

Throughout the study 5 females were killed during the brood-rearing season, and 2 individuals were killed while taking a nest break. This would suggest that although a small proportion of individuals were killed not actively attending a nest, certain predators are proficient at capturing and killing females away from nests.

Our results suggested no significant difference in survival across study sites, despite there being great biological variation in survival rates between the WI03 site ($\hat{S} = 0.624$, SE = 0.092) and the IN02 site ($\hat{S} = 0.847$, SE = 0.054). The survival estimate at the WI03 site was greatly influenced by the sample size which was drastically reduced throughout the breeding season following the radio-marking of individuals. Ten radio-marked individuals experienced radio failures, and we classified 10 additional individuals as migrants that were radio-marked and on site <14 days. In addition, we right-censored 31 individuals prior to the conclusion of the 18-week breeding season, thus reducing the number of individuals at risk across all occasions and influencing the survival estimate at the WI03 site. Our inability to detect a significant difference in survival across the additional sites may be due to the similarities in the land cover types utilized by breeding mallards within the sites. Previous studies have suggested that an increase in forested habitat types suitable to avian predators may increase their abundance and therefore increase mortality rates of waterfowl (Sargeant et al. 1993, Losito et al. 1995, and Hoekman et al. 2006a). We selected our study sites to represent the variation of land cover types found within the Great Lakes region by selecting study sites with varying percentages of forest and agriculture cover types at the study area scale, yet we were unable to detect any significant effect on breeding season survival. Mallards use a variety of semi–permanent and permanent wetland basins in the Great Lakes region (Merindino et al. 1995), and these wetland basins attract and support populations of mink (*Neovison vison*); (Arnold and Fritzell 1990), which are proficient at killing female mallards away from the nest (Sargeant et al. 1973, Eberhardt and Sargeant 1977). Mink were identified explicitly as the cause of female mallard death only once, however mink were likely responsible for additional mortalities suffered when females were off the nest. Three females were recorded being killed by farm equipment (i.e., hay cutting machinery) while actively attending a nest. Hoekman et al. (2006a) found that female mortality increased with the onset of haying activities, and in regions of North America where hay cover types dominate the landscape, the effects of haying activities may have far greater impacts on local populations of breeding mallards than found on our study sites.

Management Implications

Breeding season survival estimates for female mallards across the Great Lakes region appear to be relatively consistent with previous estimates throughout mallard breeding ranges in North America. Similarities in breeding season survival probabilities across regions suggest that variations among landscape level cover types may have little effect on this vital rate at large scales and that female mallards appear to be generalists (e.g., adaptable) when selecting habitats to meet their breeding season requirements. Our results indicated that a majority of the mortality suffered by female mallards during the breeding season in the Great Lakes region occurred during the period when the greatest proportion of females are actively nesting and resulted mostly from avian and mammalian predators. Additional research is needed to determine if the effects of land cover types surrounding the nest site and high use areas within individual home ranges influence survival in the Great Lakes region; however, efforts to increase female survival through improving nesting cover may benefit a suite of vital rates affecting mallard productivity and should remain an important emphasis for Great Lakes managers. Few females were killed by farm equipment attending nests in hayland cover; however, efforts to delay haying or altering hay machine equipment to include flushing bars may provide benefits to local mallard populations where high densities of breeding mallards and haying operations are prevalent. We failed to detect any significant effect of body condition on survival. Additionally, we failed to detect a relationship between age and survival thus removing the need to incorporate an age effect on breeding season survival in demographic models for breeding mallards in the Great Lakes region.

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CHAPTER 2

Effects of Cover Types on Female Mallard Survival during the Breeding Season in the Great Lakes Region

Abstract

Understanding the effects of land cover types on important vital rates is critical to understanding the population dynamics of a species and informing conservation planning efforts focused on influencing populations through habitat management. However, information on the effects of land cover types on vital rates is often lacking, particularly for waterfowl species. Here we evaluated female mallard (*Anas platyrhynchos*) survival during the breeding season in relation to variation in land cover types throughout the Great Lakes region. We attached Very High Frequency (VHF) implant transmitters and telemetry-tracked 282 female mallards during the breeding season over a 3-year period at 9 study sites. We estimated home range size via the creation of utilization distributions (UDs) and quantified the core area of these UDs. We utilized known-fate models in Program MARK to test the effects of home range size, land cover type within core areas, and near distances to various land cover types as they relate to breeding season survival. The top-ranking model indicated that the probability of female mallard survival during the breeding season decreased as the proportion of forested land cover increased within the core areas ($\beta = -1.740$, SE= 0.787, 95% CI Lower –3.282 Upper –0.197). No additional upland or wetland land cover types significantly affected breeding season survival suggesting that breeding season survival may be more closely associated with environmental factors that we did not measure (e.g., weather, predator abundance) or are affected by land cover types at larger or smaller scales.

Introduction

Habitat management for waterfowl survival and fecundity is a multi-million dollar industry in the United States. The success of such initiatives hinges on the efficacy of the management techniques for improving waterfowl vital rates during critical periods of the annual cycle, such as the breeding season. Previous studies have suggested that vital rates such as nest success, brood survival and female survival during the breeding season are the most influential to the population dynamics of waterfowl species (Sargeant et al. 1984, Hoekman et al. 2002, 2006a, Coluccy et al. 2008). Thus, quantifying the relationship between waterfowl vital rates and land cover types is integral to effectively manage waterfowl populations (Greenwood et al. 1987, Rotella and Ratti 1992). Such information can guide habitat conservation programs with the objective of increasing waterfowl populations (Cowardin et al. 1995, Ball 1996, Reynolds et al. 1996).

Survival of female mallards during the breeding season is the subject of tremendous scientific attention in the upper Midwest of the United States (Cowardin et al. 1985, Dufour and Clark 2002, Devries et al. 2003, Brasher et al. 2006, Arnold et al. 2012) and elsewhere (Losito et al. 1995, Hoekman et al. 2006b, Kaminski et al. 2013). However, few studies have evaluated the effects of land cover types on female mallard survival (for exceptions see Devries et al. 2003, Mack and Clark 2006, Howerter et al. 2014) and it remains an important information need for the Great Lakes region (Soulliere et al. 2007). Moreover, Great Lakes mallards appear to be relatively distinct from other populations and have become increasingly important to regional waterfowl harvest (Anderson and Henny 1972, Munro and Kimball 1982, Zuwerink 2001,).

Previous studies suggested that female mallards are at greatest risk of mortality during peak nesting periods within the breeding season and while actively nesting (Sargeant et al. 1984, Devries et al. 2003, Brasher et al. 2006, Arnold et al. 2012). Areas within an individual home range that receive the greatest intensities of use are commonly referred to as core areas (Kaufman 1962, Powell et al. 1997). Core areas often encompass nest sites and other ecologically important resources that individuals utilize to meet their seasonal requirements (Burt 1943, Kaufmann 1962, Ford 1983). Therefore, evaluating the effects of land cover types found within core areas and near core areas of female mallards may provide the greatest insight into land cover types that influence survival.

From 2012–2014, we analyzed daily location estimates and individual female breeding season attribute data collected from the Great Lakes region in 2001–2003. Our objectives were to evaluate if female mallard breeding season survival in the Great Lakes region is affected by 1) home range size, 2) number of core areas, 3) proportion of critical land cover types within core areas, and 4) the distance to land cover types such as agriculture, forest, and wetlands.

Study Area

We examined the breeding season land cover requirements of female mallards at 9 different study sites throughout the Great Lakes region (Fig. 2.1). We selected the 9 study sites to represent the range of land cover variation typically found in the Great Lakes (for additional information see Simpson 2005, Davis 2008). The study sites incorporated varying percentages of forest land cover types and agriculture land cover types to represent the variability in cover types typically found within the Great Lakes region of the United States (Table 2.1). We utilized National Land Cover Data (NLCD; USGS 2003) with 30–m resolution to quantify percentages of cash crops, dairy pasture, and deciduous forest. We used ERDAS IMAGINE 8.4 GIS software to attribute 30 x 30–m grid cells of the study sites with the proportion of the aforementioned cover types within a 2 x 2 km area. We narrowed the selection of study sites based on varying combinations of land uses. We selected study sites that had wetland densities high enough to support breeding populations of mallards and selected these sites over other potential sites of similar land cover types with lower wetland densities. We considered logistical concerns during the final selection of the study sites so that housing existed for the field staff along with a series of adequate road networks to maximize access within the study area.

Figure 2.1 Locations of the 9 study sites within the Great Lakes region where we collected data for research on female mallard survival during the breeding season, 2001–2003. (OH01 = Port Clinton, OH; MI01 =Riverdale, MI; WI01 = Ripon, WI; OH02 = Stueben County, IN; MI02 = Battle Creek, MI; WI02 = Shiocton, WI; OH03 = Akron, OH; MI03 = Big Rapids, MI; WI03 = New Richmond, WI).

Table 2.1 Primary land cover types for the Great Lakes region and associated proportion (%) within those categories created for the initial selection of study sites in the Great Lakes region, 2001–2003. Study Site corresponds to the state (i.e., MI = Michigan, OH = Ohio, WI = Wisconsin, IN = Indiana) and year (2001–2003).

Land Use Category	Proportion of Region	Study Site
Low Forest-High Agriculture	28.4%	MI01,OH01, WI01, WI02
Intermediate Forest- High Agriculture	14.7%	IN02, WI03
Intermediate Forest- Intermediate Agriculture	12.0%	MI02, OH03
High Forest- Intermediate Agriculture	8.3%	MI03
High Forest- Low Agriculture	7.0%	
Intermediate Forest Low Agriculture	6.0%	
Low Forest- Intermediate Agriculture	2.0%	
Low Forest- Low Agriculture	urban	
High Forest- High Agriculture	n/a	

Methods

Capture and Monitoring Techniques

We attempted to capture and instrument 60 female mallards at each of the 9 sites with VHF telemetry implant transmitters. We selected decoy trap site locations by scouting wetland basins sufficient in size to hold breeding pairs and occasionally selected wetland basins that pairs were actively using. In certain cases, we trapped several paired hens on the same wetland basin throughout the spring. Additionally, land ownership often limited our ability to randomly distribute trap site locations across the study sites. We trapped females using conventional decoy traps from March to early April (Sharp and Lokemoen 1987). We banded individuals with standard United States Geological Survey leg bands and implanted females with a 22–g abdominal transmitter (Advanced Telemetry Systems, Isanti, MN) using surgical procedures described by Korschegen et al. (1984). We held radio-marked females for one hour following surgical procedures and released at the trap site. We banded and released males that were captured in pairs to avoid disrupting pair bonds.

We tracked radio-marked mallards and estimated locations of individuals 1–6 times daily using truck–mounted null–array systems (Kenward 1987). We attempted to acquire location estimates once daily for all individuals and as many as 6 times daily for individuals who were part of an initial home range study in 2001–2003 (B. Reichus, Oregon State University, unpublished data). We utilized hand–held tracking methods when mallard locations could not be obtained from the vehicle due to location of road networks and to verify nesting attempts of breeding females. We conducted aerial surveys in an effort to locate missing females that may have emigrated from the study site or attempted nesting efforts outside of previously established locations within the study site. In all cases we identified telemetry locations via triangulation using Locate II software (Pacer, Truro, Nova Scotia, Canada).

We monitored all females from the onset of marking (mid–March to early April) to mid–July and two individuals through August. Brood survival was a primary emphasis of the original study; therefore, we monitored females up to 24 weeks to incorporate brood-rearing activities. Previous studies assessing breeding season survival have varied in length, due to temporal and spatial variation associated with the arrival of females on the breeding grounds (see Devries et al. 2003, Hoekman et al. 2006a.). We truncated the length of the study at 18 weeks because it represented a time period when a majority of females emigrated after failed breeding attempts or we ceased monitoring of individuals seen unpaired and flocked and exhibiting non-breeding behavior. This behavior is consistent with the onset of molt migration. Additionally, no mortalities were recorded beyond week 16.

Utilization Distribution Estimation

We estimated utilization distributions (UDs) (i.e., home ranges) and core areas for radio-marked female mallards with ≥ 30 independent locations (Seaman et al. 1999). Due to variation in sampling intensity among our population of mallards (variation between 1 and 6 locations daily), we randomly selected one estimated location per individual per day to avoid bias. We developed UDs in Program R (R Version 2.15.1,www.cran.r–project.org, accessed 29 April 2014) using the 95% isopleth with fixed kernel methods and a plug in matrix bandwidth selection to delineate the extent of these home ranges. (ks package accessed 29 April 2014). The output was an evaluation grid with the intensity of mallard land cover use within the home range represented by the Z-dimension at a 30 m resolution. We converted these grids to raster in ArcMap 10.1

(Environmental System Research Institute, Redlands, CA) expressing the density estimate as percentiles of land cover use. In this case, the 1st percentile corresponded to the area of the home range that was used most intensely by each mallard whereas the 95th percentile corresponded to the area that was used most infrequently. We calculated the size of each 95% UD in hectares to test against the probability of surviving the breeding season.

Core Area Estimation

Core areas within the home range have historically been arbitrarily identified by the 50% isopleth (Laver and Kelly 2008). These arbitrary decision rules will often result in creating core areas if one does not exist, potentially causing problems in studies of habitat and resource selection. Rather core areas should be delineated by separating intensely used areas that relate to the ecology of the animal (Powell at al. 1997, Shivik and Gese 2000, Wilson et al. 2010). To quantitatively delineate the core areas of each mallard home range we employed a Bayesian approach in R (Wilson et al. 2010). This approach utilizes functions within libraries splancs (Rowlingson and Diggle 1993), spatstat (Baddeley and Turner 2005), adehabitat (Calenge 2006), MASS (Venables and Ripley 2002), and MCMC pack (Martin and Quinn 2006) to assess the spatial distribution of location estimates against a Completely Spatially Random (CSR) point pattern (Ripley 1976). We iterated this process 10,000 times in a Monte Carlo simulation for each female to test for departures from a CSR pattern. The resulting model converged at the density percentile that defined the UDs core area.

Land Cover Types

We developed a geographic information system (GIS) to portray the land cover types associated with each study site. We hand digitized the land cover polygons in 2001–2003 from imagery collected as a part of the NLCD (USGS 2003). We ground–truthed the land cover types at each study site within 0.8 km of all female and brood locations. We defined upland cover types as grassland, agriculture, forestland, scrubland, and other. We combined hayland, pastureland, and cropland into a single agriculture land cover layer. We incorporated residential and other developed areas into a single land cover classification named other and we removed these from consideration in our GIS. We incorporated individual wetland basins classified as either emergent, forested, scrub-shrub, or other wetlands according to the methods of Cowardin et al. (1979) and combined them into a single wetland layer.

We created individual GIS shapefile layers in Arc Map containing the land cover types: grassland, wetland, forest, shrubland, and agriculture. We intersected each of the land cover types with each individual core area isopleth, and calculated the area of each land cover type within the core area and estimated the proportion of each cover type. We identified agriculture (range 0.0–1.0) as an important cover type because females mallards have been shown to have reduced survival when nesting in hay fields (Hoekman et al. 2006a) and other commodity types included within the agriculture land cover type may provide less than adequate cover for nesting females, thereby increasing vulnerability to predators (Greenwood et al. 1995, Reynolds et al. 2001, Stephens et al. 2005). We considered forestland (range 0.0–0.9) important because it has been shown to provide adequate roost locations and habitat for aerial predators of upland nesting waterfowl (Losito et al. 1995, Hoekman et al. 2006a). Wetland (range 0.0–1.0) and grassland cover types (range 0.0–1.0) made up a majority of the land cover types utilized by the nesting females in our study (Davis 2008). Increased proportions of grassland cover and wetland cover may impede predator movements thus increasing survival probability (Duebbert 1969). Lastly, we incorporated shrubland cover types (range 0.0–0.8) because increased shrubland cover types within individual home ranges have been shown to increase nest success of mallards (Mack and Clark 2006).

We also considered proximity metrics based on the distance (in meters) from the center of the core area within individual home ranges to the nearest agriculture, forest, and wetland cover types. In cases where mallards had multiple core home ranges we calculated distance from center points of each core area and utilized the mean distance from each land cover type. We also considered the number of core areas per individual (range 1–5) as a covariate to evaluate whether an increase in the number of core areas could be associated with increased nesting effort and therefore potentially influencing survival probability during the breeding season (Reynolds et al. 1995).

Known-fate Models

We developed known-fate models in Program Mark (White and Burnham 1999) to calculate the maximum likelihood estimates of female mallard survival at weekly intervals and throughout the 18–week study period in relation to the land cover types developed in our GIS (White and Garrott 1990). As the response is binary (0 = alive and 1 = dead), we fit models using a binomial distribution of errors and a logit link function (McCullagh and Nelder 1989). Our list of 19 candidate models included only additive combinations of land cover covariates and we had no biological justification to include interactions between any of the additional covariates under assessment. We used an information theoretic approach for model selection [Akaike's Information Criterion adjusting for small sample size (AICc; Hurvich and Tsai 1995)] and ranked models e using AICc weights (AICcω; Burnham and Anderson 1998).

Results

We analyzed the effects of proportion of land cover types within the core areas, near distances of agriculture, forest, and wetland cover types from the center of the core areas, number of core areas, and home range size against breeding season survival of 282 female mallards at 9 different sites across 4 different states from 2001–2003. Thirty-seven individuals died throughout the course of the 18-week study period. We recorded ≥1 nest attempt for 265 individuals over the course of the 18-week period, and recorded no nesting attempts for the remaining 18 individuals.

Our best approximating model indicated that proportion of forest cover type within the core area had the greatest influence on breeding season survival and received more than twice as much support as the next competing model (Table 2.2). The results of our top model ($\beta = -1.740$, 95% CI Lower = –3.282, Upper = –0.197) suggested that survival decreased as the percent composition of forested cover within the core area increased (Fig. 2.2). However, the difference between survival over the 18–week period between the null model (0.824) and our top ranking model (0.829) fell within 2 ΔAICc (Table 2.2). The mean proportion of forested cover within core areas by site ranged from 0.02–0.18, ($\bar{x}$= 0.09, SE = 0.010) (Table 2.3; mean home range size and mean area for each cover type are provided in Table 2.4 and Table 2.5, respectively). The remaining candidate models showed minimal effect on survival (i.e. AICc W <0.10). The effects of home range size and number of core areas per individual female had widely overlapping 95% confidence intervals and were not significant.

Table 2.2 Model results of candidate models testing the effects of the proportion of individual land cover types within the core area, distance from the core area to individual land cover types, number of core areas, and home range size on female mallard (n= 282) survival during the breeding season in the Great Lakes region, 2001–2003.We used known–fate models in Program Mark to evaluate competing model likelihood using Akaike's Information Criterion corrected for sample size (AICc), the difference from the highest ranked model (ΔAICc), and the model weight.

Model[a]	Parameters	AICc	ΔAICc	Model Weight
{S(P_For)}	2	409.81	0	0.28708
{S(.)}	1	411.77	1.96	0.10779
{S(P_Num_Cores)}	2	412.16	2.35	0.0887
{S(P_Wet)}	2	412.86	3.06	0.06231
{S(P_Grass)}	2	413.19	3.38	0.05292
{S(HR)}	2	413.5	3.69	0.04541
{S(D_For)}	2	413.64	3.84	0.04216
{S(D_Wet)}	2	413.72	3.91	0.04057
{S(P_Shrub)}	2	413.76	3.95	0.03989
{S(P_Ag)}	2	413.76	3.95	0.03986
{S(D_Ag)}	2	413.77	3.96	0.03961
{S(D_Ag + P_Wet)}	3	414.71	4.91	0.0247
{S(D_For + P_Wet)}	3	414.77	4.96	0.02407
{S(D_For + P_Grass)}	3	415.09	5.28	0.02045
{S(D_Wet + P_Grass)}	3	415.18	5.37	0.0196
{S(D_Ag + P_Grass)}	3	415.18	5.37	0.01959
{S(D_For + P_Shrub)}	3	415.63	5.82	0.01565
{S(D_Wet + P_Shrub)}	3	415.71	5.91	0.01498
{S(D_Ag + P_Shrub)}	3	415.76	5.95	0.01465

[a] + denotes an additive effect; P_For = proportion forest land cover type; P_Wet = proportion of wetland land cover type; P_Ag = proportion agriculture land cover type; P_Shrub = proportion of shrubland land cover type; P_Grass = proportion of grassland land cover type; D_For = distance to forest land cover type from core area; D_Wet = distance to wetland land cover type from core area; D_Ag = distance to agriculture land cover type from core area; (.) = null model; HR = home range size ha; Num_Cores = Number of core areas per individual female mallard.

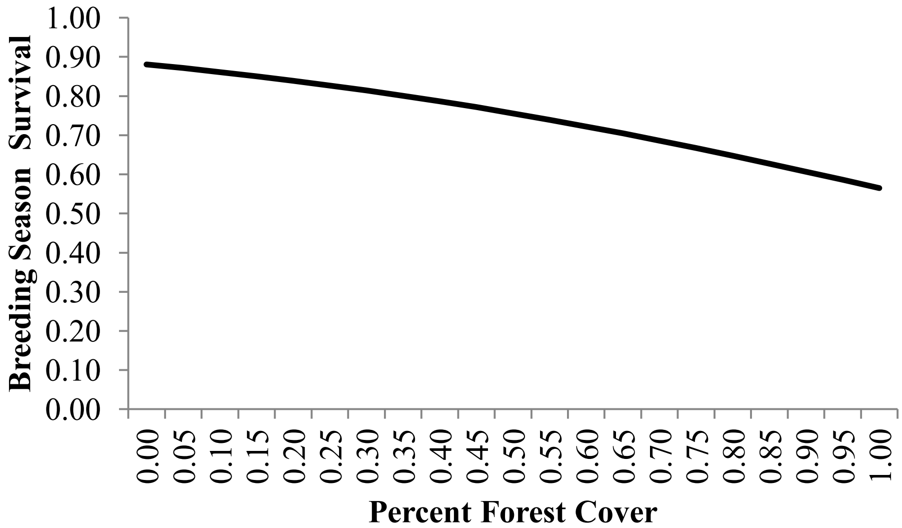

Figure 2.2 Relationship between changes in breeding season survival of female mallards across 18 weeks and percent composition of forested cover within core use areas based on model results derived from Program MARK in the Great Lakes region, 2001–2003.

Table 2.3 Mean proportions of forested cover (P_For), grassland cover (P_Grass), agriculture cover (P_Ag), shrubland cover (P_Shrub), and wetland cover (P_Wet) within individual core areas of female mallards (n = 282) across 9 sites during the breeding season in the Great Lakes region, 2001–2003.

Sites	P_For	P_Grass	P_Ag	P_Shrub	P_Wet
IN02	0.07	0.27	0.39	0.01	0.16
MI01	0.08	0.13	0.50	0.04	0.15
MI02	0.12	0.10	0.20	0.04	0.35
MI03	0.18	0.22	0.14	0.06	0.35
OH01	0.04	0.07	0.50	0.04	0.27
OH03	0.17	0.28	0.21	0.06	0.24
WI01	0.03	0.11	0.20	0.00	0.59
WI02	0.04	0.17	0.22	0.00	0.47
WI03	0.19	0.32	0.13	0.03	0.31
Total (Mean)	0.09	0.18	0.29	0.03	0.32

Table 2.4 Mean home range size (ha) at the 95 percent isopleth (95_Per_HR), mean core area isopleth (Core_Iso), mean number of core areas (Num_Cores), and the core area size (ha) (Core_Area) for each individual female (*n* = 282) across the 9 study sites in the Great Lakes region, 2001–2003.

Sites	95_Per_HR	Core_Iso	Num_Cores	Core_Area
IN02	111.83	0.35	1.34	8.95
MI01	180.27	0.35	1.33	10.61
MI02	62.12	0.35	1.52	4.70
MI03	121.30	0.30	1.45	6.59
OH01	172.06	0.42	1.47	16.20
OH03	165.23	0.40	1.25	15.32
WI01	100.46	0.39	1.16	7.19
WI02	132.31	0.36	1.35	12.44
WI03	166.47	0.38	1.11	10.94
Total (Mean)	132.84	0.37	1.34	10.21

Table 2.5 Mean area (ha) of individual land cover types within individual core areas of female mallards (n = 282) across 9 sites during the breeding season in the Great Lakes region, 2001–2003.

Sites	A_For[a]	A_Grass[b]	A_Ag[c]	A_Shrub[d]	A_Wet[e]
IN02	0.81	2.53	2.57	0.07	1.05
MI01	1.34	1.24	5.90	0.26	0.88
MI02	0.50	0.41	1.12	0.17	1.74
MI03	1.37	0.99	0.96	0.17	3.01
OH01	1.13	1.09	6.83	0.59	5.49
OH03	3.72	2.87	4.28	0.47	3.28
WI01	0.26	0.96	1.72	0.00	3.66
WI02	0.31	2.30	3.11	0.13	5.65
WI03	1.79	1.81	2.84	0.70	3.48
Total (Mean)	1.12	1.58	3.28	0.25	3.10

[a]Area of forested cover types
[b]Area of grassland cover types
[c]Area of agriculture cover type
[d]Area of shrubland cover type
[e]Area of wetland cover type

Discussion

While previous research on mallard vital rates has focused on the effects of habitat level correlates on female mallard survival in the Canadian Prairie Parklands and the Prairie Pothole region, this analysis to our knowledge is the first to assess the effects of land cover types within core areas of a home range on breeding season survival of female mallards in the Great Lakes region. Our top ranking model indicated that increased percent forested cover type within core areas decreased survival probability of female mallards during the breeding season. Additionally, Simpson et al. (2007) found that duckling survival decreased as percent forest increased within 500–m of the brood locations. It is plausible that increased proportions of forest cover types within core areas provide adequate habitat for aerial and terrestrial predators of breeding mallards. However, we suspect that the outcome of this model may have been partially confounded by the proximity of forest cover types to cover types used by breeding mallards because water permanency likely restricted conversion of these areas for agricultural or human development purposes (R. Boyer, personal observation). Additional assessments of this relationship may be necessary.

Mack and Clark (2006) tested the effects of woodlands and shrubland on nest success and female mallard survival in the Prairie Pothole Region, and found that nest success increased in conjunction with increased woodland and shrubland cover, but failed to detect an effect on female survival. Similarly, Davis (2008) suggested that nest success was higher in primarily forested landscapes than on landscapes containing high percentages of agriculture. Probability of survival across the 18–week study period for the top ranking candidate model including proportion of forest cover was slightly higher, however, minimally so when compared to the null model although the effect of forestland on survival was negative. To gain a better understanding of the effect on survival, we investigated the effect of the proportion forest cover within core areas by study site and discovered that it did not have a significant effect on survival across all sites.

Devries et al. (2003) and Howerter et al. (2014) assessed the effects of habitat related variables on the survival of female mallards during the breeding season at the study area scale ($65km^2$), and Mack and Clark (2006) tested female survival at the home range scale and study area scale. Devries et al. (2003) found a relationship between survival of female mallards and increased wetland densities at the study area scale, but failed to detect any relationships between upland habitat treatments and survival. Howerter et al. (2014) provided additional analyses of these data and other data compiled from studies completed in the Canadian Prairie Parklands and the Prairie Pothole Region and found that survival of female mallards increased with the proportion of grassland cover in conjunction with wetland habitats at the study area scale. Mack and Clark (2006) assessed the affects of habitat composition on the survival of female mallards at the home range and study area scales, but failed to detect a relationship. The Canadian Prairie Parklands and the Prairie Pothole Region where the aforementioned studies occurred are comprised of large contiguous blocks of grassland cover types interspersed with high densities of seasonal wetlands (Reynolds 2000). The land cover types found within the Great Lakes region vary significantly in comparison to those assessed in the previous studies.

Our previous analysis of breeding season survival tested the effects of study site, year, and state against survival and found no significant effects. However, we discovered that female survival was lowest during peak nesting activities (Chapter 1). Thus, we refined the scale at which to assess the effects of land cover types on survival to the core area which encompasses the spatial and temporal scale at which females are at greatest risk of mortality (Sargeant et al. 1984, Devries et al. 2003). Arnold et al. (2012) suggested that prey switching behaviors of common upland nesting waterfowl predators may occur concurrent with the peak of the nesting period, which may partially explain our inability to detect a strong relationship between most land cover types and survival. Additionally, our ability to infer the effect of land cover types on survival was limited by the resolution of our spatial data (i.e., 30 m), thus potentially restricting our ability to recognize additional relationships with breeding season survival.

We failed to detect any strong relationships between survival and non-forested upland and wetland cover types. Previous studies suggested that nest survival increases as the abundance of perennial upland grassland increases (Greenwood et al. 1995, Reynolds et al. 1996). Dense nesting cover that has been shown to positively influence nest survival and may influence survival of females during the breeding season. Previous studies have reported mallards nesting in dense stands of emergent vegetation in wetland habitat (Krapu et al. 1979). Wetland cover may offer similar advantages to dense stands of upland nesting cover by increasing physical barriers that reduce the movements and foraging ability of mammalian predators (Duebbert 1969), thus increasing female survival during critical periods of the breeding season. Lastly, agricultural land can pose various threats to nesting waterfowl, especially those lands actively used for haying purposes (Hoekman et al. 2006a). Well known avian and mammalian predators of upland nesting waterfowl commonly use the edges of cover types such as agricultural fields, wetlands, and forests. The distance from the core area to these specific land cover types that support predator communities may affect the survival probabilities of female mallards during the breeding season; however, we were unable to discern any relationship.

Nudds and Ankney (1982) suggested that the home range size of mallards during the breeding season is greatly influenced by resource availability. Individuals with larger home ranges may have been forced into less than adequate nesting habitat when establishing breeding territories (Dzubin 1969, Lindstedt et al.1986, Lokemoen et al. 1990). Additionally, breeding females may need to travel longer distances to meet resource requirements during the breeding season (Mack et al. 2003). Increased home range size could lead to greater time spent traveling between nest site locations and foraging areas (Mack and Clark 2006), leading to increased exposure time to predators therefore increasing the chance of mortality. Our results suggest that home range size occupied during the breeding season had no significant effect on this vital rate; however, the metric results alone from our estimation of breeding season home range size for Great Lakes mallards will be important for regional conservation planning.

Our study design was created to replicate a similar study being conducted by Devries et al. (2003) in the Prairie Pothole Region and the Canadian Prairie Parklands. Similar to Devries et al (2003), our study tried to encompass the greatest amount of geographic and landscape variation across the region to test the effects of various land cover types on the vital rates of mallards in the Great Lake region. Unfortunately, that decision resulted in the lack of temporal replication among study sites. Our inability to detect a strong relationship between land cover types and female survival may have been affected by the inability to replicate the study across multiple years for the same sites (Howerter et al. 2014). Due to constraints related to land ownership, we were unable to randomly select trap site locations throughout the study sites, therefore, trap locations and the nest site locations were often in close proximity to road systems where wetlands or small bodies of water were of greater accessibility for researchers to locate and trap breeding females. The resulting similarities in land cover composition within core areas between individual females may have partially confounded our inabilities to detect any strong effects of most land cover types on breeding season survival.

Management Implications

Female mallard survival during the breeding season is negatively affected by increased proportions of forested cover types within the core areas. Additionally, mallard duckling survival in the Great Lakes region which is one of the most important demographic factors influencing the population dynamics of Great Lakes mallard populations (Coluccy et al. 2008) decreases as the proportion of forested cover increases within a 500 m area of brood locations (Simpson et al. 2007). Waterfowl management interests in the Great Lakes region striving to increase breeding season survival of mallard females and ducklings should focus habitat management efforts in areas with low densities of forested cover types. We failed to detect strong relationships between female mallard breeding season survival and additional upland and wetland land cover types suggesting that female mallard survival in the Great Lakes region may be affected by land cover factors not assessed as a part of this study or at alternative spatial scales. Respectively, breeding season survival of females accounts for approximately 1 percent of the variation in population growth of Great Lakes mallards while nest success and duckling survival account for nearly half of the variation (Coluccy et al. 2008). Thus, efforts to increase duckling survival and nest success through the enhancement and restoration of dense nesting cover and palustrine emergent wetland habitats are likely the best ways to increase mallard productivity throughout the Great Lakes region and should remain the primary focus of regional conservation efforts (Simpson et al. 2007, Coluccy et al. 2008, Davis 2008). These management practices may have limited effects on breeding season survival of females as survival rates appear to be relatively unaffected by varying proportions of critical land cover types within and surrounding core areas.

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