



NESTING AND BROOD-REARING HABITAT SELECTION AND SURVIVAL RATES OF RING-NECKED PHEASANTS IN PRAIRIE RECONSTRUCTIONS IN SOUTHWEST MINNESOTA

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SUMMARY OF FINDINGS

Ring-necked pheasant (*Phasianus colchicus*) responses to the amount of grassland on the landscape have been well documented, but we lack current information on the individual components of reproductive success (e.g., nest success, brood success, chick survival) that are driving pheasant population dynamics in Minnesota. From early spring 2015 through summer 2018, we radiocollared 164 hens on 2 study sites in southwest Minnesota and monitored them during nesting and brood-rearing each year. We collected vegetation data on nest site selection and survival data on hens, nests, individual chicks, and broods. In 2016 and 2017, we also collected data on brood-rearing habitat selection within grasslands. Overall, nest, chick, and brood survival rates were high due to the large amounts of grassland cover in the landscape. Preliminary analyses showed that the best-supported models included study area for nest survival and a constant survival model for chick survival to 21 days. The best-supported model for brood survival to 5 weeks included year and vegetation type (cool season versus forb-rich/warm-season native grass mixes). Brood survival was highest in 2015 and lowest in 2018; broods hatched in sites dominated by forb-rich, warm-season native grass mixes had higher survival than broods in cool-season sites. Based on these preliminary results, we recommend that managers continue to focus on acquiring and restoring habitat in large grassland complexes. They should also prioritize forb-rich seed mixes with native, warm-season grasses over cool-season grass mixes.

INTRODUCTION

Ring-necked pheasant (*Phasianus colchicus*) population dynamics are driven largely by variation in survival rates. Although adverse weather can impact survival rates in some years, predation is the primary cause of mortality for hens and their young (Peterson et al. 1988, Riley et al. 1998). Predator control efforts can help improve reproductive output over short time periods, but such efforts are economically and ecologically inappropriate over the long-term and at the landscape scale (Chesness et al. 1968, Riley and Schulz 2001). Management aimed at increasing pheasant populations has instead focused primarily on providing abundant nesting cover to minimize the effects of predation and maximize reproductive success. As acres enrolled in the Conservation Reserve Program (CRP) and similar cropland retirement programs decline in Minnesota, providing suitable habitat on public lands to sustain populations will become more critical for mediating the effects of predation and weather on pheasant population dynamics. However, the interaction between habitat and predation will no doubt remain. Thus, gaining new insights into the relationship between pheasant habitat selection and subsequent survival rates will be important for improving wildlife management strategies on publicly-owned lands.

Predation during the nesting season is a major factor affecting pheasant population dynamics. Nest predation is the leading cause of nest failure for many grassland-nesting birds, including

pheasants (Chesness et al. 1968, Clark et al. 1999), and can limit productivity. Additionally, hens take only short recesses from incubating which puts them at greater risk to predation during nesting (Giudice and Ratti 2001, Riley and Schulz 2001). Management efforts aimed at increasing patch size and reducing edge effects are assumed to alleviate rates of predation on birds and their nests (e.g., Johnson and Temple 1990, Sample and Mossman 1997, Winter et al. 2000); however, the composition of the landscape surrounding a patch (Clark et al. 1999, Heske et al. 2001) and the vegetation within a patch (Klug et al. 2009, Lyons 2013, Fogarty et al. 2017) also play important roles in determining susceptibility to nest predation.

Advances in video camera technology have allowed better monitoring of bird nests and provided evidence that nest predator communities are more complex than previously thought (Pietz et al. 2012). In particular, the predators associated with nest depredation events can vary with the structure and diversity of nesting cover (e.g., percent cover of litter, forbs, or cool-season grasses; Klug et al. 2009, Lyons 2013). Thus, management actions attempting to mitigate the impact of predators may not necessarily reduce rates of nest predation but rather create a spatial or temporal shift in the nest predator community and susceptibility to nest predation (Benson et al. 2010, Thompson and Ribic 2012). Nest predator communities also vary across regions and habitats and results from studies of other species or in other states may not be entirely applicable to Minnesota's pheasant population (Thompson and Ribic 2012, Benson et al. 2013). Understanding how management at the site level (e.g., vegetation structure, composition, and diversity) impacts the dynamics of nest predation is an important but as of yet unintegrated step in our ability to manage habitat for increased productivity of pheasants and other grassland birds (Jiménez and Conover 2001).

Chick and brood survival are vital components of pheasant population dynamics but they remain poorly understood (Riley et al. 1998, Giudice and Ratti 2001). Assessing the causes of pheasant chick mortality has been difficult because many previous studies have relied on estimates of brood survival (e.g., the proportion of broods in which ≥ 1 chick survived to a certain age) rather than survival of individual chicks within a brood (e.g., Meyers et al. 1988, Matthews et al. 2012; but see Riley et al. 1998, Lyons et al. 2020). Using brood survival estimates can be unreliable because brood mixing can occur (Meyers et al. 1988; N. Davros, personal observations). Further, lack of data on individual chicks (e.g., body condition, cause of death) prevents us from understanding the role of different factors (e.g., exposure, food limitation, predation) that lead to variation in recruitment. Evidence that predation is the leading cause of chick mortality for grassland gamebirds in North America is well-established (e.g., Riley et al. 1998, Schole et al. 2011). Food availability has been implicated as an important factor explaining chick survival for many gamebird species in Europe (Green 1984, Hill 1985, Potts 2012); however, strong evidence that food is a major limiting factor for survival of chicks in North America is still lacking. Moreover, food availability and rates of predation likely interact in relation to vegetation structure and composition and confound conclusions from chick survival and food resource studies (Hill 1985). Finally, death from exposure has been shown to decrease chick survival rates, especially after periods with increased precipitation when chicks are still very young and unable to fully thermoregulate (Riley et al. 1998, Schole et al. 2011). Risk of exposure and starvation may interact to decrease chick survival, but few studies have been able to directly address this question (but see Riley et al. 1998). Therefore, additional data are needed to understand the interplay between these potential limiting factors on brood habitat selection and chick survival in different grasslands within Minnesota's pheasant range.

Minnesota Department of Natural Resources (MNDNR) wildlife managers in the farmland region have indicated a need for more information on pheasant habitat selection and survival in relation to prairie reconstruction and management activities. Indeed, better understanding the factors that limit brood production and chick survival will help natural resource agencies prioritize their

management strategies at both the local (e.g., forb interseeding, reconstruction seed mixes) and landscape (e.g., acquisition priorities) levels in the face of reduced CRP acreages. Additionally, obtaining data on individual components of pheasant population dynamics will aid in future assessment of MNDNR management activities (e.g., Prairie Plan implementation [Minnesota Prairie Plan Working Group 2011], conservation grazing) and agricultural land use practices (e.g., cover crops, pesticide use) on Minnesota's pheasant population.

OBJECTIVES

Our overall objective was to evaluate the relative importance of within-patch diversity (e.g., grassland parcels dominated by cool-season grasses, warm-season grasses, and high diversity grass-forb mixtures) within MNDNR-managed Wildlife Management Area (WMA) project areas on pheasant productivity. Specifically, we:

1. Evaluated pheasant nest site selection and nest, brood, chick, and adult hen (hereafter, hen) survival in relation to grassland vegetation cover and composition.
2. Evaluated pheasant brood-rearing habitat selection in relation to grassland vegetation cover and composition.
3. Evaluated the relative importance of different factors (e.g., vegetation, predation, weather) on nest, chick, brood, and hen survival.

STUDY AREA

We conducted our study in the southwest region of Minnesota, a core region of the state's pheasant range. Topography ranged from flat to gently rolling. This region was intensively farmed, and corn and soybeans combined accounted for approximately 75% of the landscape (U.S. Department of Agriculture 2013a, U.S. Department of Agriculture 2013b). Grasslands, including those on private land (CRP, Reinvest in Minnesota [RIM], Conservation Reserve Enhancement Program [CREP], and Wetlands Reserve Program [WRP]) and public land (WMAs and U.S. Fish & Wildlife Service [USFWS] Waterfowl Production Areas [WPA]) accounted for 6.3% of the landscape in this region (Davros 2016).

For our study sites, we selected 2 WMA project areas representative of the grassland/wetland habitat complexes that are a goal of the Prairie Plan (Minnesota Prairie Plan Working Group 2011) and the Pheasant Summit Action Plan (MNDNR 2015) (Figure 1). Each study site was about 5,760 acres in size and contained extensive amounts of grasslands and wetlands embedded in an agricultural matrix. The Lamberton WMA study site (Redwood County) was a large, nearly contiguous WMA complex with >1,100 acres of permanently protected upland and wetland habitats. The Worthington Wells study site (Nobles County) had >1,500 acres of permanently protected habitat that spanned multiple WMAs, the Okabena-Ocheda Watershed District, and USFWS lands.

METHODS

Data Collection

We conducted our research during the 2015-2018 breeding seasons. Our 2015 pilot season allowed us to refine methods and protocols for the study's expansion during 2016-2018. However, we also had a smaller field crew in 2018 who were time-limited due to a concurrent research project; thus, we were unable to collect some data in 2018 and we note this below, where applicable.

We captured hen pheasants in each study site during 6 time periods: 2 February – 15 April 2015, 7 October – 11 November 2015, 11 January – 29 April 2016, 26 September – 15 November 2016, 18 March – 14 April 2017, and 18 September – 11 October 2017 (hereafter

referred to as spring 2015, fall 2015, spring 2016, fall 2016, spring 2017, and fall 2017, respectively). We used 2 capture techniques: baited walk-in traps and netting via nighttime spotlighting from a 6-wheel utility-task vehicle (UTV). We weighed each hen to the nearest 5.0 g, measured her right tarsus to the nearest 0.5 mm, and placed a uniquely numbered aluminum leg band on her right leg. We then fitted her with a 16.0-g necklace-style very high frequency (VHF) radiotransmitter with integrated mortality switch (Advanced Telemetry Systems (ATS), Isanti, MN) before releasing her at the site of capture.

We began radiotracking hens 3-5 times per week in late April each year to determine the onset of incubation. We assumed incubation had begun when a hen's radio signal was projected from the same location for several consecutive days. We flushed each hen from her nest once between incubation day 5-20 to determine clutch size and floated 3-5 eggs to estimate hatch date (Westerskov 1950, Carroll 1988). We marked the location of nests using a global positioning system (GPS) receiver. We also placed flagging ≤ 5 m from nests to aid relocation efforts. If a hen began making large daily movements prior to being flushed, we assumed nest failure and waited for the hen to resettle and begin incubating again before attempting another flush. We used the homing technique on radiocollars emitting a mortality signal to retrieve the collars and determine a fate. We used the presence and condition of any bodily remains and the condition of the radiocollar (e.g., teeth marks, feathers plucked, body intact but frozen, frayed collar, missing crimp) and nearby evidence (e.g., predator scat, den site) to determine survival status (e.g., mortality vs. unknown) and assign a potential cause of death (e.g., predation, human/machinery, weather), if applicable.

Near the estimated hatch date of known nests, we monitored hen activity 2-3 times daily to pinpoint a hatching event. We assumed hatching was occurring when a hen's signal fluctuated in intensity (Riley et al. 1998). In 2015-2017 only, we captured 1-3 chicks by hand between day 0-2 (day 0 = hatch day) once the hen and her brood had moved away from the nest. We used 2 techniques to capture chicks. The first technique involved flushing the hen from her brood and using a decoy and playback to call chicks to us while we hid in the grass. The second technique involved flushing the hen from her brood just before sunrise during brooding and capturing chicks by hand as they scattered. We never captured more than 50% of the brood at one time. We also never kept the hen away from her remaining brood for >30 minutes to minimize risk of hypothermia for the uncaptured chicks. We discontinued chick capture attempts for a particular brood if we were unsuccessful at capturing any chicks by the end of day 2.

We transported captured chicks in a small cooler or waist belt heated with hand-warmers to a nearby field truck for processing. We weighed each chick to the nearest 0.1 g and we measured tarsus length to the nearest 0.5 mm before suturing a 0.65-g backpack-style VHF radiotransmitter without mortality switch (ATS, Isanti, MN) to the chick's back (Burkepile et al. 2002, Dahlgren et al. 2010). Handling time lasted <5 min per chick and we returned all captured chicks to the hen within 30-60 min of capture. We followed the methods of Riley et al (1998) to return chicks to the hen.

We monitored hens and their broods via triangulation through 5 weeks post-hatching. We triangulated hens and their broods 2-3 times daily ≥ 3 times per week. Each bearing-coordinate pair was taken ≥ 100 m from target hens and their broods to reduce disturbance. We used specialized computer software (LOAS, Ecological Software Solutions LLC) to generate estimated locations from bearing-coordinate pairings. To estimate brood survival status and size, we used the homing technique to flush hens just before sunrise to detect and count chicks; however, our effort varied among years. During 2015, we flushed broods 2-3 times per week through 5 weeks. During 2016 and 2017, we flushed broods twice between days 10-14 and twice between days 28-32.

To estimate individual chick survival, we listened for the signal of each radiomarked chick every 1-3 days in conjunction with monitoring the hen. We relied primarily on fluctuation in the chick's signal to determine survival status as backpack transmitters were too small to accommodate a mortality sensor. If the signal indicated that the chick was not moving, we used the homing technique to locate the transmitter and we searched the area for a carcass and any evidence for a cause of death.

We collected vegetation data at the nest site within 7 days of hatching for successful nests. For nests that failed, we also collected vegetation data at the nest site ≤ 7 days after the estimated hatch date. At each nest site, we visually estimated percent cover (Daubenmire 1959) of the upper canopy (i.e., grasses, forbs, standing dead vegetation, woody vegetation) using a 0.5 m² sampling quadrat. We estimated percent cover using 8 classes: 0%, 1-10%, 11-25%, 26-50%, 51-75%, 76-90%, 91-99%, and 100%. We separately estimated percent cover of the ground layer (i.e., litter, bare ground, rocks/other) using the same 8 classes. We estimated litter depth to the nearest cm and we counted the number of grass and forb species to determine species richness within the quadrat. We recorded visual obstruction readings from 4 m away at a height of 1 m (VOR; Robel et al. 1970) in each of the 4 cardinal directions to determine vertical vegetation density to the nearest 0.5 dm around the nest. Finally, we recorded the maximum height of live and standing dead vegetation within 0.5 m of the Robel pole. We repeated these sampling efforts at 2 random locations within 15 m of the nest site.

To evaluate brood habitat selection within grasslands during 2016-2017 only, we collected vegetation data at 5 brood locations estimated via triangulation and 10 random points outside of but within 400 m of each brood's biweekly home range. We generated biweekly home ranges twice for each brood: one home range for the first 2 weeks of age and a second home range for age 3-4 weeks. For broods not surviving a 2-week observation period, we generated home ranges and sampled vegetation if at least 1 chick from the brood survived for the first 7 days of the observation period. We used a Geographic Information System (GIS; ArcMap 10.2, ESRI, Redlands, CA) to estimate each biweekly home range using the minimum convex polygon tool. We also used GIS to generate the random points for sampling within 400 m of the biweekly home range. We restricted the selection of random points so that they were within grassland cover because our primary objective was to evaluate brood selection within this cover type. Any estimated brood locations or generated random points falling in habitat types other than grassland (e.g., row crop, wetlands, woodlots) were not sampled. We considered road right-of-ways in the grasslands category and included them in sampling efforts. We collected vegetation data within 7 days of the end of each biweekly interval. At each estimated brood point, we sampled 1 center point and 3 equidistant points (10 m north, 10 m southwest, and 10 m southeast) to capture the spatial variation associated with a brood location (i.e., hens and their broods were mobile and thus distributed around a point). We estimated percent upper canopy cover, ground layer cover, litter depth, species richness, VOR, and maximum height of live and dead vegetation using the same methods described above for nest site selection. We repeated this sampling scheme at each of the 10 random points associated with each brood's biweekly home range. If more than 50% of our brood triangulations were in habitat types other than grassland, we did not sample vegetation for that home range and associated random points. If a hen with a similar-aged brood had a home range that overlapped with another hen, we only sampled 5 additional random points associated with that second brood's home range.

We also qualitatively assessed vegetation within each WMA parcel (i.e., field-scale vegetation classification) and assigned it to one of the following categories based on predominant plant species present: cool-season grasses, warm-season native grasses, and forb-rich/warm-season native grass mixture (Figure 1).

Data Analyses

To date, we have conducted preliminary analyses on hen, nest, brood, and chick survival. We also calculated basic descriptive statistics ($\bar{x} \pm SE$) for nest sites and brood locations. Final data analyses were ongoing at the time of this report; thus, not all analyses have been included here and not all research objectives are addressed below. Final analyses will be incorporated into manuscripts submitted for peer-reviewed publication.

We conducted a preliminary survival analysis to evaluate hen survival during the nesting and brood-rearing phases (15 April – 15 October; hereafter, breeding season) only. We estimated cumulative survival using a Kaplan-Meier analysis approach in R v3.3.2 (R Core Team, 2016). The Kaplan-Meier approach assumes a known fate for each individual. As such, some individuals were censored at various intervals during the analysis period because they were reported missing and not relocated or their fate was otherwise unknown (e.g., slipped or failed radiocollar). We also excluded individuals with mortality or censor events occurring outside of the analysis period from this particular analysis.

We used the logistic exposure method (Shaffer 2004) to estimate daily survival rates of nests by specifying a custom link function within R (version 3.6). We used the AICcmodavg package (Mazerolle 2019) to calculate AIC_c scores, rank models, and calculate model weights and model-averaged estimates of daily survival.

We first examined univariate models that included terms related to annual and seasonal variation in daily survival rates. We considered models that included terms for different survival among years and models that included effects of month, week of the nesting season, or linear and quadratic terms for week of the nesting season. As no temporal covariates ranked better than the null (intercept-only model, constant survival), we next examined support for models with nest-site vegetation measurements only. We compared models that contained terms for visual obstruction reading (VOR), the coefficient of variation of VOR (a measure of heterogeneity in vegetation density; Bowman 1980), the additive effects of ground cover (bare ground, litter cover, litter depth), the additive effects of canopy cover (forbs, standing dead, and grass), and the total number of forb and grass species found at the nest site.

Only the model containing the effect of study area ranked higher than the null model. Because all other models that ranked lower had similar likelihoods, we inferred that these models included uninformative parameters and excluded them from the model-averaging procedure (Arnold 2010). Thus, we recalculated model weights and generated model-averaged estimates of daily survival rate from the study area and null model only. We extrapolated a 35-d survival probability (10-12 days laying, 23-25 days incubation) from daily survival rate estimates and generated 85% confidence intervals using the delta method (Powell 2007).

We used a robust-design occupancy model within program MARK (version 9.0; White and Burnham 1990) to estimate weekly survival of broods (≥ 1 chick alive) from flush encounters while also accounting for imperfect detection.

We parameterized the model to estimate extinction (brood mortality), colonization, and detection, treating Psi (the probability a brood is alive) as a latent parameter. We fixed colonization to 0 to prevent zombie pheasants and only included covariates on the detection process (p) and extinction (mortality). We fixed Psi during the first time period to 1 to ensure that all broods started out alive. We only considered two different models for detection probability, a constant detection probability among primary periods and one where we allowed detection to vary among each week post-hatch. We identified the best detection model by holding mortality constant and finding the minimum AIC_c.

After identifying the best model for detection, we compared different models for brood mortality probability. Models included the effect of year, different mortality probabilities among weeks, differing mortality during the first and second week post-hatch but similar mortality among weeks 3-5, precipitation during the first 10 days post-hatch, and study area. We also examined support for field-scale vegetation composition, as well as the additive effects of year and field-scale vegetation composition, the additive effect of precipitation and field-scale vegetation, and the interaction between week-specific mortality and field-scale vegetation composition. The additive effects of year and field-scale vegetation composition were the top-ranked model and we based our inference on only this model.

We again used the logistic exposure method to estimate daily survival of radio-marked chicks and the AICcmodavg package (Mazerolle 2019) to calculate AIC_c scores, rank models, and calculate model weights and model-averaged estimates of daily survival. We constructed models by first examining support for a random effect term to account for non-independent survival of marked chicks from the same brood. We then proceeded to examine support for fixed effects as single covariates. We first tested for temporal covariates, including terms for chick age (days post-hatch), year, and hatch date. We then tested whether chick mass at capture and vegetation cover type at the field-scale affected survival. The top-ranked model included the random effect of brood and vegetation at the field-scale and we computed 21-day survival estimates from the top-ranked model only.

RESULTS AND DISCUSSION

We radiocollared 164 hen pheasants during the 6 trapping periods across our 2 study sites from spring 2015 through fall 2017. We used baited walk-in traps during spring 2015 and spring 2016 only as they were not a productive capture technique. In 2016, we set cameras at the traps and found that pheasants were not motivated to use the bait when winter conditions were mild. Only 3 hens were captured using the walk-in traps (2% of total hen captures) during those 2 seasons whereas 161 hens (98%) were captured by spotlighting across all trapping seasons. We ended spotlighting capture efforts at the onset of the nesting season which limited our ability to increase sample sizes. In the future, we would consider using baited walk-in traps in late winter if weather conditions were severe enough to warrant this method. Winter conditions are considered severe for pheasants when snow is ≥ 6 inches deep and temperatures reach $\leq 0^\circ$ F.

From 2015-2018, cumulative survival for hens during the breeding season (183-day period pooled across years) across study areas was 0.73 (95% CI: 0.66-0.81; $n=133$; Figure 2). During the 4 breeding seasons, 59% of marked individuals ($n=79$) suffered a known mortality event. Of these mortality events, 86% were attributed to predation events, 5% to human causes (specifically, vehicle collision and agricultural equipment), and $<1\%$ to research-related marking. Although the Kaplan-Meier survival method provides a quick estimate of hen survival, the strict assumptions of this model are likely inappropriate given our dataset. Because nearly 32% of individuals were censored during this analysis due to unknown fates (in particular, slipped radiocollars), our subsequent survival analyses may use methods that include expert knowledge to incorporate uncertainty in fate to refine survival estimates (Walsh et al. 2018).

We monitored 132 potential nesting attempts overall but excluded some nests from analyses for various reasons (e.g., hen abandoned after initial flushing event, nest area flooded prior to researcher's visit, actual nest bowl was never found). Fifty-three percent of nests hatched ($n=70$), 42% failed ($n=56$), and 5% had unknown fates ($n=6$).

We found that hens selected nest sites with more standing dead cover but did not select nest sites with more forb cover ($n=107$ nests; Figure 3). The percent cover of standing dead vegetation was greater at nest sites compared to random points nearby ($15.0 \pm 1.36\%$ vs. $9.9 \pm$

1.06%, respectively; Table 1) whereas the percent cover of forbs was slightly lower at nest sites than random points ($16.4 \pm 2.10\%$ vs. $20.8 \pm 2.40\%$, respectively; Table 1, Figure 4a).

We used 101 nests in our preliminary nest survival analyses, which provided 909 observation intervals and 1,625 exposure days for analysis (Shaffer 2004). Our best-supported model of nest survival included study site (Table 2). Nest survival was high overall but was greater at Worthington Wells ($\bar{x} = 0.984$, 85% CI: 0.976-0.990) than Lamberton ($\bar{x} = 0.973$; 85% CI: 0.961-0.981). Extrapolating to a 35-day exposure period (laying and incubation), nest survival probability was 0.585 (85% CI = 0.438-0.719) at Worthington Wells and 0.318 (85% CI = 0.264-0.514) at Lamberton (Figure 5). Our nest success rates are comparable to the rates found by Clark et al. (2008) in their study of a large, contiguous grassland landscape of northern Iowa. Although the relationship between landscape fragmentation and nest success cannot be automatically inferred across study areas or regions (Benson et al. 2013), our results lend further support to the idea that landscapes with large amounts of grassland cover can benefit pheasant nest productivity in the upper Midwest.

Although our models that included canopy cover, composition, and richness metrics were not competitive (Table 2), we note that successful nests had more than twice as much forb cover compared to depredated nests ($18.8 \pm 3.01\%$ vs. $8.3 \pm 2.97\%$, respectively; Table 3, Figure 4b). Our preliminary canopy cover model included all canopy cover metrics (i.e., grasses, forbs, standing dead, woody), and we did not build models that incorporated cover, composition, and/or richness metrics together. Whereas hens may select nest sites for certain characteristics such as standing dead vegetation because it provides important visual concealment from predators early in the growing season, predator search efficiency and success may rely on other vegetative characteristics. Indeed, recent studies suggest that increased structural heterogeneity of the vegetation may better conceal nests from olfactory-based nest predators (Fogarty et al. 2017, Fogarty et al. 2018). Our future analyses may include a forb-only model and models that combine vegetation structure and composition metrics. Exploring these additional models may help inform management approaches that can create more productive nesting habitat.

Given annual differences in weather and the long nesting cycle and extended breeding season length of pheasants, we hypothesized that year and time of season would be important covariates in explaining patterns of nest survival. However, none of our models that included these covariates were competitive. Time-specific patterns of nest survival have been documented in several duck and passerine species (Grant et al. 2005, Grant and Shaffer 2012).

We monitored 59 broods for survival during the 4 years of our study. We documented at least 1 hen who re-nested after losing her brood between 1-2 wk of age. Although rare, other researchers have also documented second brood attempts after early losses of first broods (Dumke and Pils 1979; A. Annis and T.J. Fontaine, personal communication; T. Bogenschutz, personal communication). Using our field-scale classification of vegetation, our best-supported brood survival models included year and vegetation. Broods had lower survival in 2018 (Figure 6). When we averaged across years, broods associated with forb-rich and/or warm-season grass dominated fields had higher survival than broods in cool-season dominated fields (Figure 7). Our results are consistent with other studies that have shown that pheasant hens with broods selected areas with more forb-rich vegetation which, when managed frequently to reduce litter, provides the best option for mobility and food resources for pheasant chicks (Doxon and Carroll 2010, Matthews et al. 2012).

During 2016 and 2017 only, we collected vegetation data related to brood habitat selection for 40 broods. Our preliminary descriptive analyses suggest brood-rearing and nearby random locations were similar in vegetative structure and composition (Table 4). Brood and random

locations were composed primarily of litter at the ground level ($80.2 \pm 3.05\%$ vs. $82.9 \pm 2.40\%$, respectively; Table 4). Grasses were the predominant canopy cover at brood and random locations ($55.3 \pm 2.89\%$ vs. $52.1 \pm 2.32\%$, respectively) followed by forb cover ($15.7 \pm 1.57\%$ vs. $17.0 \pm 1.34\%$, respectively). Our future analyses will incorporate this finer-scale vegetation data to evaluate brood survival.

We captured and radiomarked 84 chicks between day 0-2 during the 2015-2017 breeding seasons. During the 2016 and 2017 field seasons only, we recaptured 7 chicks between day 12-15 and replaced their 0.65 g transmitters with sutured, 1.1-g or 1.3 g backpack-style transmitters ($n=6$; ATS, Isanti, MN) or another 0.65 g transmitter ($n=1$). Recapturing radiomarked chicks at this age was relatively easy and may be a viable option to replace lighter transmitters with heavier ones that have a longer battery life, thereby allowing monitoring of chicks beyond 4 wk of age in future work. We attributed known fates ($n=38$) as follows: 32% died due to predation, 26% died from exposure, 24% of chicks died due to unknown causes, 11% died due to human-induced causes (specifically, agricultural operations, vehicle collisions, and researcher activities), and 8% survived beyond 30 days.

Our best supported model of chick survival included vegetation at the field-scale (Table 2). Unlike brood survival, individual chicks survived at a higher rate on fields comprised of primarily cool-season exotic grasses (21-day survival = 0.880, 85% CI: 0.649-0.967) than fields dominated by warm-season native grasses or forb-rich warm-season grass mixes (21-day survival = 0.551; 85% CI: 0.378-0.714). One explanation for this relationship could be that chicks, especially younger ones, may have lower mobility in native stands of vegetation that have not been recently disturbed by fire, grazing, or mowing to reduce litter cover (e.g., Lyons 2017). Still, the mechanisms that influence individual chick survival may differ from those that affect survival of the brood in aggregate, and may just be another example of the importance of scale in ecology (Levin 1992, Hernández 2020). Similar to our hen survival analyses, our future chick survival analyses may use methods that incorporate expert knowledge about uncertain fates to refine estimates (Walsh et al. 2018).

MANAGEMENT IMPLICATIONS

Based on our preliminary results to date, we recommend that managers continue to prioritize land acquisition and restoration efforts in larger grassland/wetland complexes such as those outlined in the Minnesota Prairie Plan and Pheasant Action Plan. Within grassland parcels, they should focus on reconstructions that use forb-rich seed mixes to benefit brood survival. Final results from this study are pending and will relate survival rates to nesting and brood-rearing habitat selection within prairie reconstructions. Ultimately, the data gathered will help managers better understand factors that may limit pheasant productivity so that they can prioritize their within-field management activities in an era of reduced grassland habitat acres on the landscape.

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Table 1. Descriptive statistics for vegetation surveys at sites used for nesting by ring-necked pheasant hens and nearby random points (≤ 15 m away) as a comparison in southwest Minnesota during the 2015-2017 breeding seasons.

	Nest sites ($n=90$)		Random points ($n=90$)	
	Mean	SE	Mean	SE
% Canopy cover				
Grasses	40.3	2.80	42.9	2.49
Forbs	16.4	2.10	20.8	2.40
Standing dead	15.0	1.36	9.9	1.06
Species richness				
Total	4.0	0.27	4.5	0.28
Grasses	1.8	0.10	1.9	0.09
Forbs	2.2	0.23	2.5	0.23
Maximum height (cm)				
Live vegetation	53.1	4.74	57.2	5.21
Dead vegetation	56.9	6.64	44.8	4.60
Litter depth (cm)	2.9	0.31	4.2	0.29
Vertical density (dm) ^a	5.2	0.21	5.3	0.22

^aVertical density is the average visual obstruction reading (VOR) as determined by using a Robel pole.

Table 2. Number of parameters (K), Akaike's Information Criterion (calculated for small sample sizes; AIC_c) difference from AIC_c of the best-supported model (ΔAIC_c), model likelihood, and model weight for models explaining ring-necked pheasant nest survival and chick survival in Wildlife Management Areas (WMAs) in southwest Minnesota during 2015-2018. Also shown is the model-averaged weight for the top two models for nest survival.

Model	K	AIC_c	ΔAIC_c	Model Likelihood	Model Weight	Model-averaged Weight
Nest survival						
Study area	2	290.47	0.00	1.00	0.53	0.79
Intercept-only	1	293.10	2.63	0.27	0.14	0.21
Chick survival						
Vegetation type ^a	3	152.68	0.00	1.00	0.41	
Brood effect	2	153.83	1.15	0.56	0.23	
Chick age	3	153.93	1.25	0.54	0.22	

^aBased on qualitative assessment of the dominant vegetation type at the field-scale: cool-season exotic grasses, warm-season native grasses, or a forb-rich warm-season grass mix.

Table 3. Descriptive statistics for vegetation surveys at successful versus depredated nest sites of ring-necked pheasants in southwest Minnesota during the 2015-2017 breeding seasons.

	Successful nests (n=52)		Depredated nests (n=17)	
	Mean	SE	Mean	SE
% Canopy cover				
Grasses	41.1	3.42	43.0	8.35
Forbs	18.8	3.01	8.3	2.97
Standing dead	15.1	1.54	13.2	4.20
Species richness				
Total	4.3	0.37	3.8	0.63
Grasses	1.9	0.13	1.8	0.22
Forbs	2.4	0.30	1.9	0.62
Maximum height (cm)				
Live vegetation	53.1	6.56	63.7	7.73
Dead vegetation	55.2	8.42	50.2	12.80
Litter depth (cm)	2.5	0.28	3.0	0.47
Vertical density (dm) ^a	5.4	0.26	4.5	0.60

^aVertical density is the average visual obstruction reading (VOR) as determined by using a Robel pole.

Table 4. Descriptive statistics for vegetation surveys at locations used by ring-necked pheasant broods and nearby paired random locations^a in southwest Minnesota during the 2016 and 2017 breeding seasons. Vegetation data were collected biweekly up to the first 4 weeks of brood rearing and was constrained to grassland habitats [e.g., Wildlife Management Areas (WMA), roadsides, Conservation Reserve Program (CRP) fields] only.

	Brood locations (n=48)		Random locations (n=52)	
	Mean	SE	Mean	SE
% Ground cover				
Litter	80.2	3.05	82.9	2.40
Bare ground	14.6	2.91	12.3	2.27
% Canopy cover				
Grasses	55.3	2.89	52.1	2.32
Forbs	15.7	1.57	17.0	1.34
Standing dead	6.7	0.59	7.4	0.53
Woody	0.2	0.09	0.2	0.07
Other	1.9	0.76	0.3	0.10
Species richness				
Grasses	2.2	0.10	2.3	0.08
Forbs	2.0	0.17	2.0	0.16
Maximum height (cm)				
Live vegetation	61.0	6.04	57.1	5.72
Dead vegetation	36.0	4.06	36.7	3.94
Litter depth (cm)	3.6	0.26	4.1	0.21
Vertical density (dm) ^b	5.5	0.24	5.7	0.19

^aPaired random locations were outside of but within 400 m of a brood's biweekly home range [determined by the minimum convex polygon (MCP)].

^bVertical density is the average visual obstruction reading (VOR) as determined by using a Robel pole.

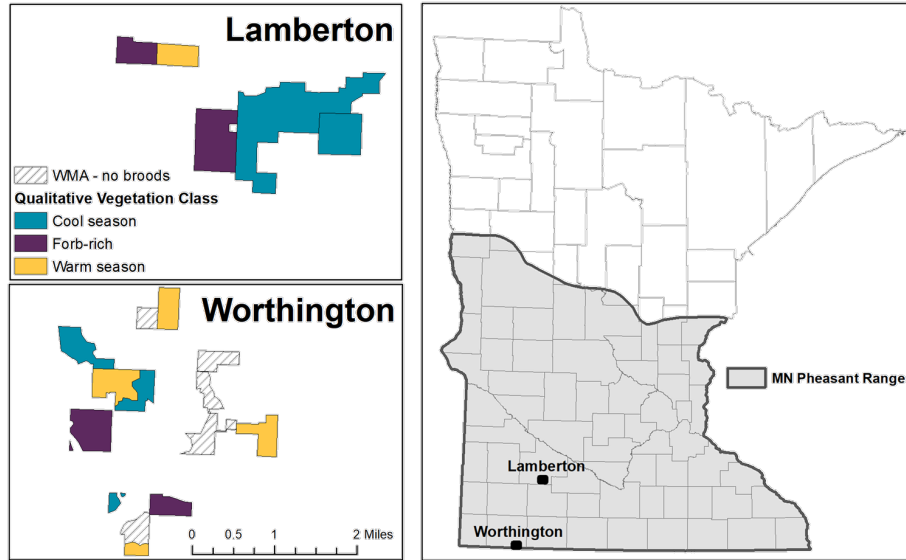


Figure 1. Location of 2 Wildlife Management Area (WMA) grassland/wetland complexes in southwest Minnesota used as study sites to evaluate ring-necked pheasant habitat selection and survival from 2015-2018. Maps on the left show individual WMA parcels that comprise the Lamberton and Worthington Wells complexes; white space depicts the agricultural matrix in which these complexes were embedded. Parcels were categorized as cool-season grasses (blue), forb-rich/warm-season native grass mixes (purple), or warm-season native grasses (yellow) based on qualitative assessment of predominant plant species present in each parcel.

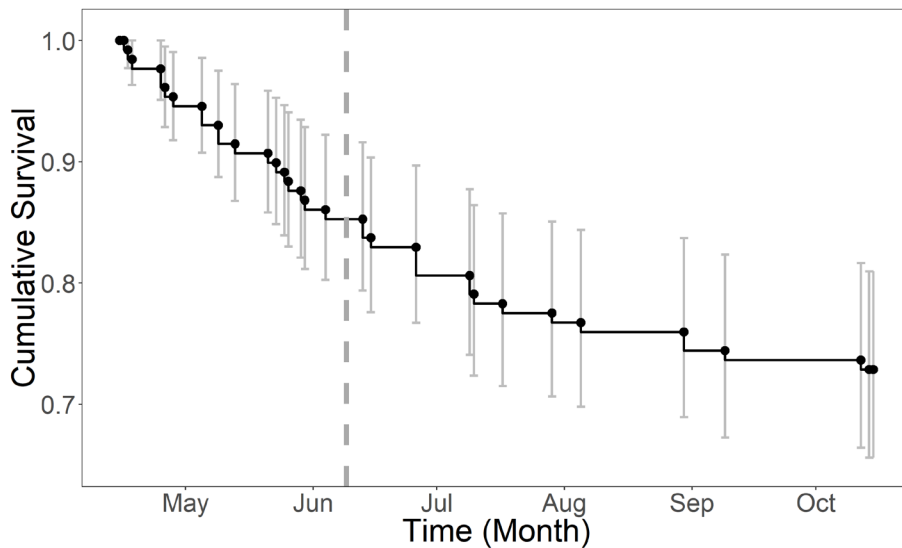


Figure 2. Cumulative survival of radiocollared ring-necked pheasant hens during the 2015-2018 breeding seasons (15 April – 15 October) in southwest Minnesota. Points represent survival estimates at intervals where mortality events took place. Error bars (vertical solid gray lines) represent the upper and lower 95% confidence interval for each survival estimate. The vertical gray dashed line shows the 10-year average (2007-2016) for peak hatch (June 12) of pheasant nests in Minnesota, as estimated by Minnesota Department of Natural Resources' annual August roadside count surveys.

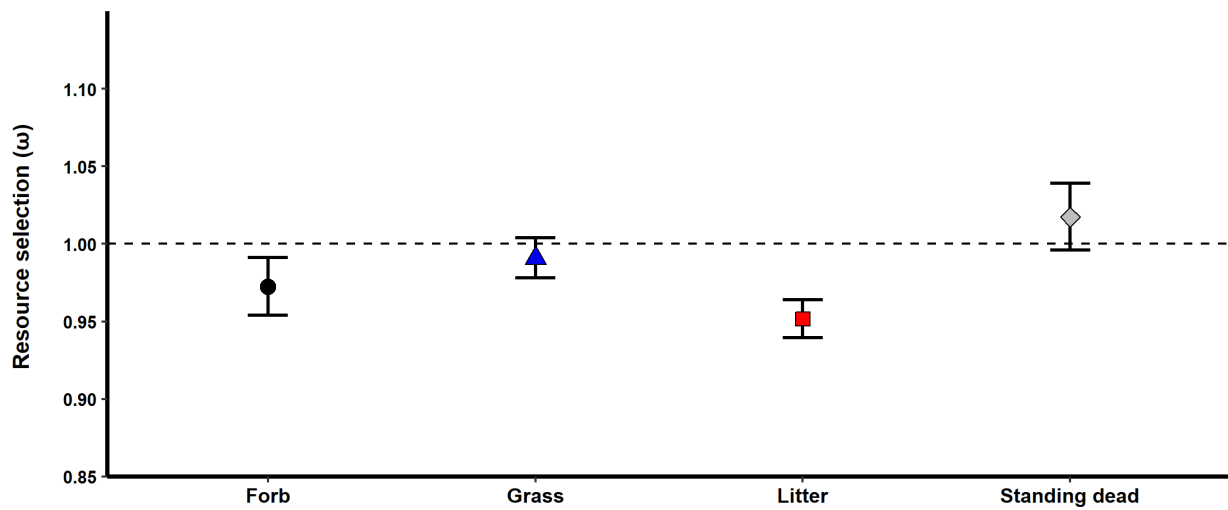


Figure 3. Resource selection of ring-necked pheasant hens for nest site characteristics including percent cover of forbs, grasses, litter, and standing dead vegetation at nests in southwest Minnesota, 2015-2017. Values falling above the dashed line at 1.00 indicate selection for a particular canopy cover metric whereas values below the dashed line indicate selection against that metric.

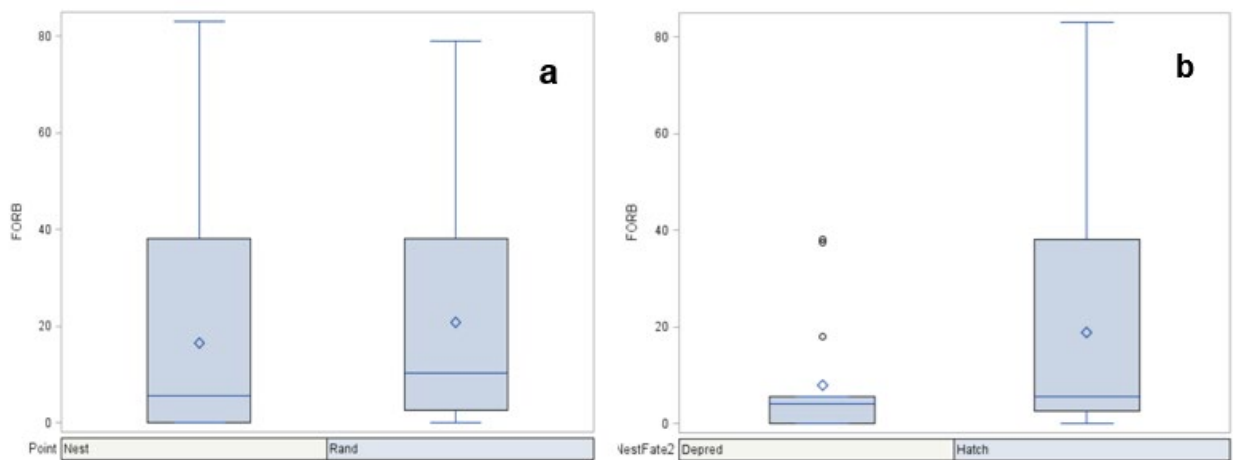


Figure 4. Box plot comparisons of estimated percent cover of forbs at (a) nest sites versus nearby random points (<15 m away) and (b) depredated versus hatched nests of ring-necked pheasants in southwest Minnesota, 2015-2017.

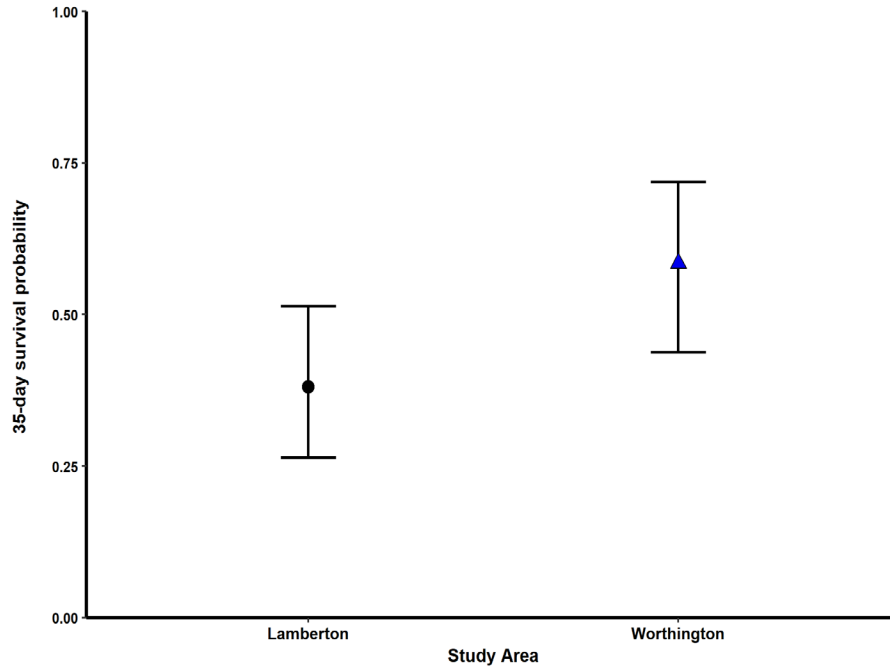


Figure 5. Nest survival probability for a 35-day exposure period (laying and incubation stages) for ring-necked pheasants in the Lamberton (black circle) and Worthington Wells (blue triangle) project areas in southwest Minnesota during 2015-2018 nesting seasons.

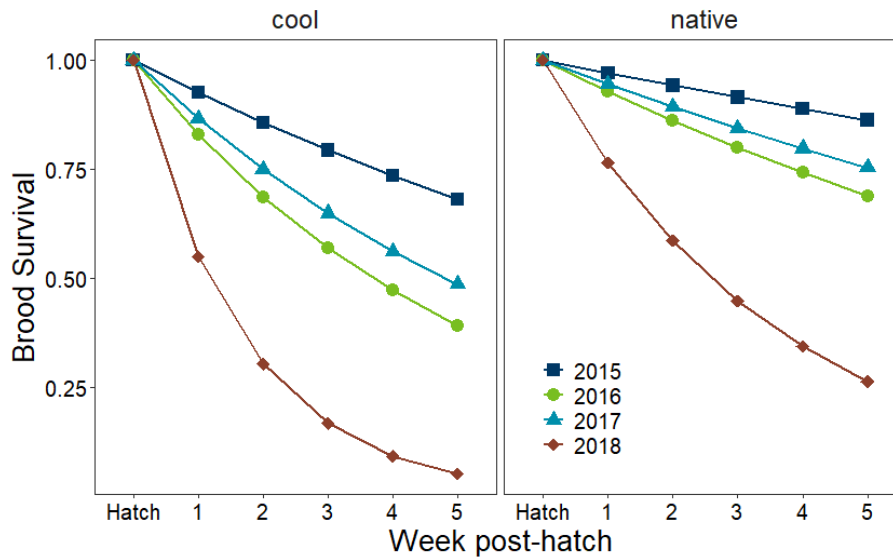


Figure 6. Survival of ring-necked pheasant broods to 5 weeks of age by year (2015-2018) and within-parcel vegetation type in southwest Minnesota. The figure on the left shows brood survival by year in Wildlife Management Area (WMA) parcels dominated by cool-season grasses. The figure on the right shows brood survival by year in WMA parcels dominated by warm-season native grasses or forb-rich mixes.

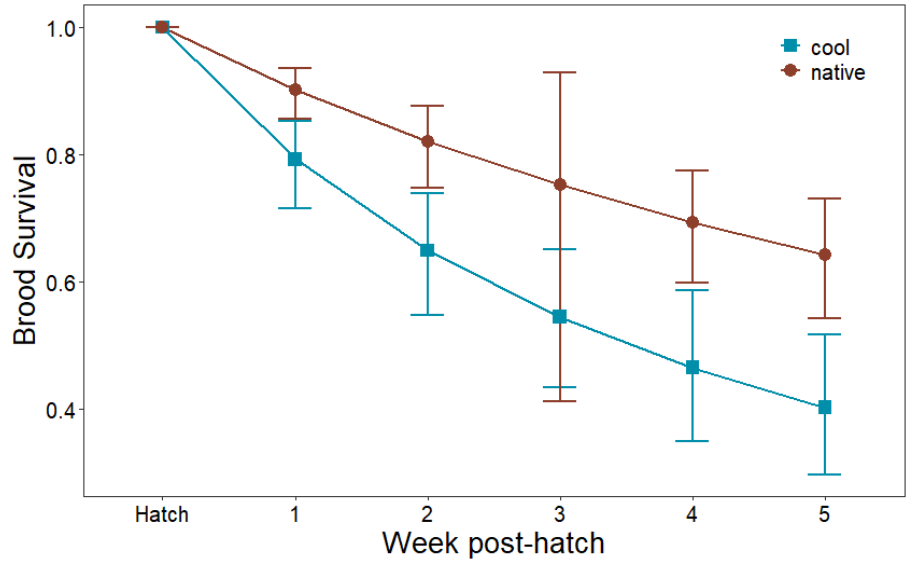


Figure 7. Survival of ring-necked pheasant broods to 5 weeks of age by within-parcel vegetation type (blue squares: Wildlife Management Area [WMA] parcels dominated by cool-season grasses; red circles: WMA parcels dominated by warm-season native grasses or forb-rich mixes); 85% confidence intervals are shown. Broods were monitored during 2015-2018 in southwest Minnesota.