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

Nicole M. Davros and Lindsey N. Messinger

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, broods, and individual chicks. In 2016 and 2017, we also collected data on brood-rearing habitat selection within grasslands. Video cameras were used to document nest predation events in 2015 and 2016. We describe preliminary findings within this report; final results are pending. Ultimately, our results will help us better understand the factors that limit reproductive success of pheasants so that natural resource managers can prioritize their grassland management and land acquisition strategies.

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 survival is also a vital component of pheasant population dynamics but it remains 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). Using brood survival estimates is likely 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 nesting, brood habitat suitability, and chick 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) 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., sites dominated by cool-season grasses, warm-season grasses, and high diversity grass-forb mixtures) within 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, brood, chick, 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 [MNDNR Wildlife Management Areas (WMA) 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). Each study site was about 9 mi^2 in size and contained extensive amounts of permanently protected grasslands. 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.

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.

During 2015 and 2016 only, we placed miniature color video cameras (GE 45231 MicroCam Wired Color Camera, Louisville, KY) at a random subset of nests in an attempt to document nest predation events (Cox et al. 2012). We placed cameras during the same hen flushing event in which we floated eggs, and our total time near the nest was ≤20 min. We placed cameras 1-5 m away from the nest bowl at a height of approximately 0.3 m. Cameras had infrared light-emitting diodes (LEDs) to allow recording at night and were connected via a >20 m cable to digital video recorders (DVRs; Model MDVR14H, Super Circuits, Austin, TX) with SD memory cards for video storage and deep-cycle marine batteries for remote power. We stored the DVRs and battery equipment in waterproof containers located >20 m from nests. We later reviewed video footage and archived relevant video clips.

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). 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 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. We monitored hens and their broods via triangulation through the first 4 weeks post-hatching. On day 14 and day 30, we flushed the hen just before sunrise to determine brood survival status and size.

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 d of hatching for successful nests. For nests that failed, we also collected vegetation data at the nest site ≤7 d 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 m^2 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 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 also 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 the vertical density of vegetation 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, we collected vegetation data at 5 brood locations estimated via triangulation and 10 random points outside 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 wk of age and a second home range for age 3-4 wk. For broods not surviving a 2-wk observation period, we generated home ranges and sampled vegetation if at least 1 chick from the brood survived for the first 7 d 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 the same habitat type (i.e., grassland). 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 d 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, litter depth, species richness, VOR, and maximum height of live and dead vegetation using the same methods described above for nest site selection. We separately estimated the cover of the ground layer (i.e., litter and bare ground) using the same 8 cover classes described above. 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.

Data Analyses

To date, we have conducted preliminary analyses on hen and nest survival. We also calculated basic descriptive statistics for nest site selection and brood habitat selection. Preliminary and 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.

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.

Using 2015-2017 data, we conducted a preliminary nest survival analysis using the logistic-exposure method (Shaffer 2004) to estimate daily survival rate (DSR) of nests. We used a constant survival model (PROC GENMOD; SAS v9.3; SAS Institute, Cary, NC) which assumes that survival is constant across time and does not include any nest-specific explanatory variables.

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 ≤0° F.

From 2015-2018, cumulative survival for hens during the breeding season (183-day period pooled across years) across study areas was 0.73 (n = 133; CI: 0.66-0.81; Figure 1). 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 during the 2015-2018 seasons. Using data from 2015-2017 only, we evaluated 99 potential nesting attempts for nest survival analyses. We excluded 12 nests from analysis due to various reasons (e.g., hen abandoned after initial flushing event, nest area flooded prior to researcher's visit, and actual nest bowl was never found). The remaining 87 nests provided 657 observation intervals and 1,244 exposure days for analysis (Shaffer 2004). Overall, we found DSR was 0.9777 ± 0.20 (range: 0.9674-0.9848) which results in a 59.5% overall nest success rate when extrapolated to a 23-day incubation cycle. Our nest success rate is comparable to the rate 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. We used a constant survival model for our initial analyses; however, our future analyses will examine the role of vegetation, spatial (e.g., distance to edge), and temporal (e.g. nest age, date, year) covariates on nest DSRs. In particular, time-specific patterns of nest survival have been documented in several duck and passerine species (Grant et al. 2005, Grant and Shaffer 2012) and such analyses are likely more appropriate for pheasants given their long nesting cycle and extended breeding seasons.

We placed video cameras on approximately 40% of nests in 2015 and 2016. Most hens were tolerant of cameras but a few hens did abandon their nests. However, these hens may have abandoned due to our other research activities (specifically, being flushed to float eggs too early in incubation) rather than the presence of the camera itself. We potentially captured 2 predation events on camera in 2016 but the video qualities were poor due to obstruction from vegetation and windy conditions which greatly reduced our ability to clearly view activity at the nests. One notable observation included a rooster visiting a hen at her nest almost daily during late incubation. Although we could clearly view all nests when cameras were first placed, the rapid growth of vegetation during the nesting cycle later impacted our ability to view nest contents or activities in the immediate area. Windy conditions often compounded our inability to review camera footage by causing vegetation to blow in front of the camera. In the future, we would consider using cameras to document nest predation events but we would alter our camera set-up (e.g., distance to nest, height of camera) to reduce the impact of vegetation and wind on the quality of the footage.

During 2015-2018, we collected vegetation data from 112 nest sites. Using data from 2015-2017 only, we calculated means and standard errors (SE) for 2 groups of comparisons: nest sites versus random points (*n* = 90; Table 1), and successful versus depredated nests (*n* = 52 and *n* = 17, respectively; Table 2). We included all nests regardless of nest fate (e.g., successful, depredated, abandoned, other failure) for the comparison of nest sites versus random points. Percent cover of forbs was similar between nest sites and random points ($\bar{x}$ ± SE = 16.4 ± 2.10% vs. 20.8 ± 2.40%, respectively; Table 1, Figure 2a); however, successful nests had more than twice as much forb cover compared to depredated nests (18.8 ± 3.01% vs. 8.3 ± 2.97%, respectively; Table 2, Figure 2b). The percent cover of standing dead vegetation was greater at nest sites compared to random points nearby (15.0 ± 1.36% vs. 9.9 ± 1.06%, respectively) but hatched nests and depredated nests had similar amounts of standing dead cover (15.1 ± 1.54% and 13.2 ± 4.20%, respectively). Vertical density of the vegetation, as measured by VOR, was similar between nest sites and random points (5.2 ± 0.21 dm vs. 5.3 ± 0.22 dm, respectively; Figure 3a) yet successful nests had greater vertical density compared to depredated nests (5.4 ± 0.26 dm vs. 4.5 ± 0.60 dm, respectively; Figure 3b). Although preliminary, these findings have practical implications for wildlife management activities. For example, previous MNDNR research found that neither burning nor mowing were successful management techniques for increasing forb diversity in warm-season grass-dominated stands (Davros et al. 2014), yet our results show that forb cover is positively associated with pheasant nest success. Therefore, managers should consider other options for increasing forb cover in prairie reconstructions to benefit pheasants. Additionally, we found that hens selected nest sites with more standing dead canopy cover, which is especially important for visual concealment early in the nesting season, and they were more successful when nests had greater vertical density, which is also assumed to provide visual concealment. However, 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). Management actions that create vegetation that provides both visual and olfactory concealment may be key to creating more productive nesting habitat.

We monitored 62 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 loses of first broods

(Dumke and Pils 1979; A. Annis and T.J. Fontaine, personal communication; T. Bogenschutz, personal communication; T. Lyons, personal communication).

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. 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).

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 3, Figure 4). Brood and random locations were composed primarily of litter at the ground level ($\bar{x}$ ± SE = 80.2 ± 3.05% vs. 82.9 ± 2.40%, respectively; Table 3, Figure 4). Grasses were the predominant canopy cover at brood and random locations (55.3 ± 2.89% vs. 52.1 ± 2.32%, respectively) followed by forb cover (15.7 ± 1.57% vs. 17.0 ± 1.34%, respectively). Our future analyses will focus on a hierarchical modeling process to investigate brood-rearing habitat selection during each biweekly period (i.e., weeks 1-2 and weeks 3-4). If sample sizes allow, we will also evaluate differences in habitat selection between successful and unsuccessful broods.

The final results from this study 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 (e.g., grassland reconstruction efforts, forb interseeding) 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.

	Nests 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

[a] Vertical density is the average visual obstruction reading (VOR) as determined by using a Robel pole.

Table 2. 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

[a] Vertical density is the average visual obstruction reading (VOR) as determined by using a Robel pole.

Table 3. 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

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

[b] Vertical density is the average visual obstruction reading (VOR) as determined by using a Robel pole.

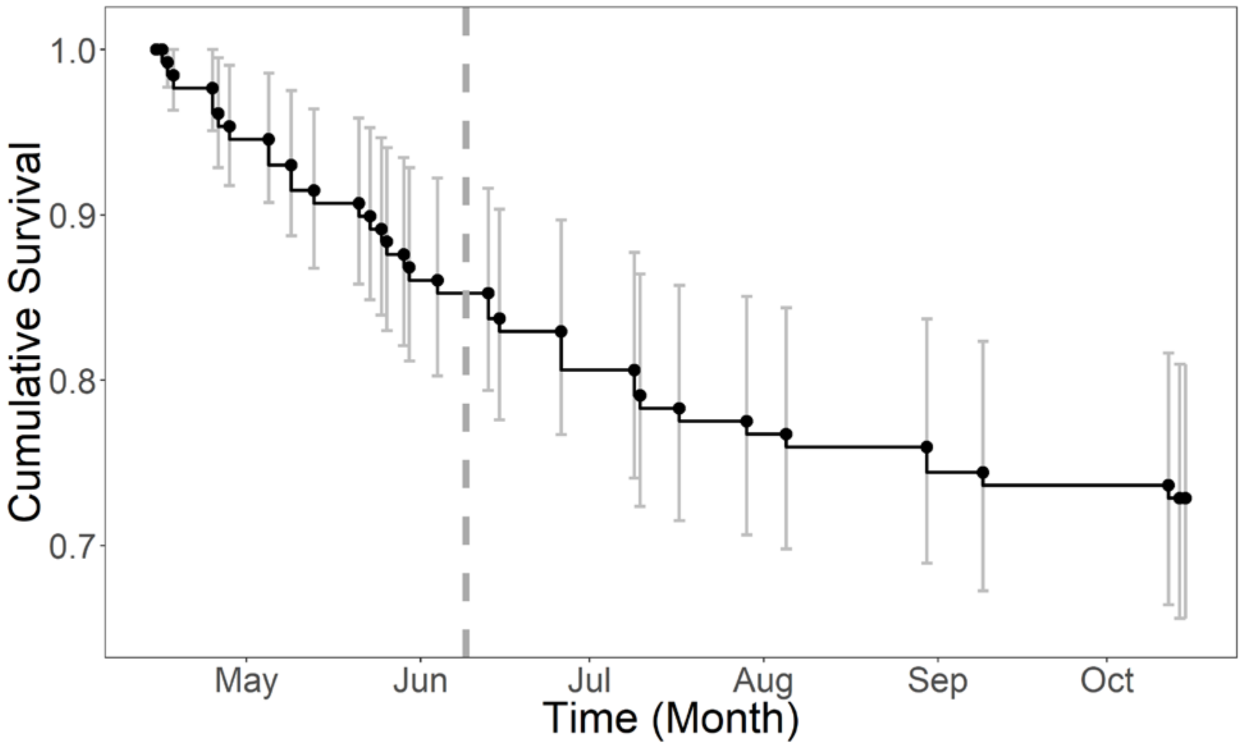

Figure 1. Cumulative survival of radiocollared ring-necked pheasant hens during the 2015-2018 breeding seasons (15 April – 15 October) in southwest Minnesota. Points represent survival estimates at intervals where mortality events took place. Error bars (vertical gray lines extending from each point) represent the upper and lower 95% confidence interval for each survival estimate. The 10-year average (2007-2016) for peak hatch of pheasant nests in Minnesota, as estimated by MNDNR's annual August roadside count surveys, is 12 June and is shown with the vertical gray dashed line.

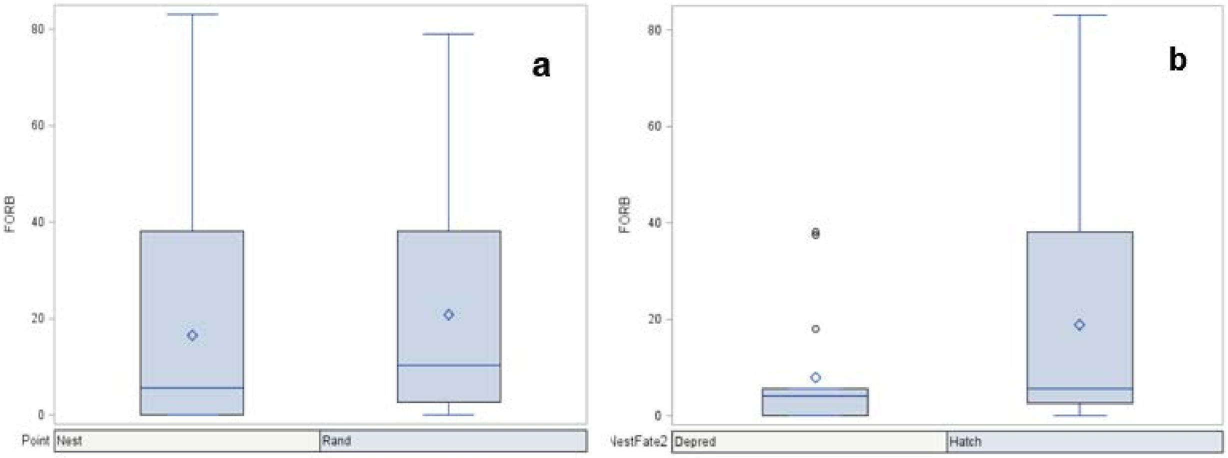

Figure 2. Box plot comparisons of the estimated percent cover of forbs at (a) nest sites versus nearby random points (<15 m away) and (b) depredated versus hatched nests of ring-necked pheasants in southwest Minnesota, 2015-2017.

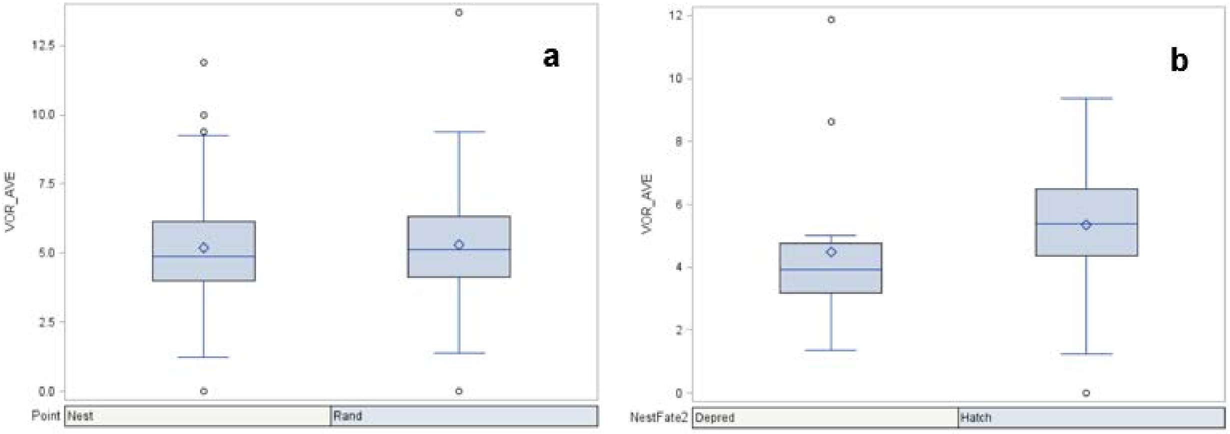

Figure 3. Box plot comparisons of vegetation vertical density, as measured by a visual obstruction reading (VOR) using a Robel pole, at (a) nest sites versus nearby random points (<15 m away) and (b) depredated versus hatched nests of ring-necked pheasants in southwest Minnesota, 2015-2017.

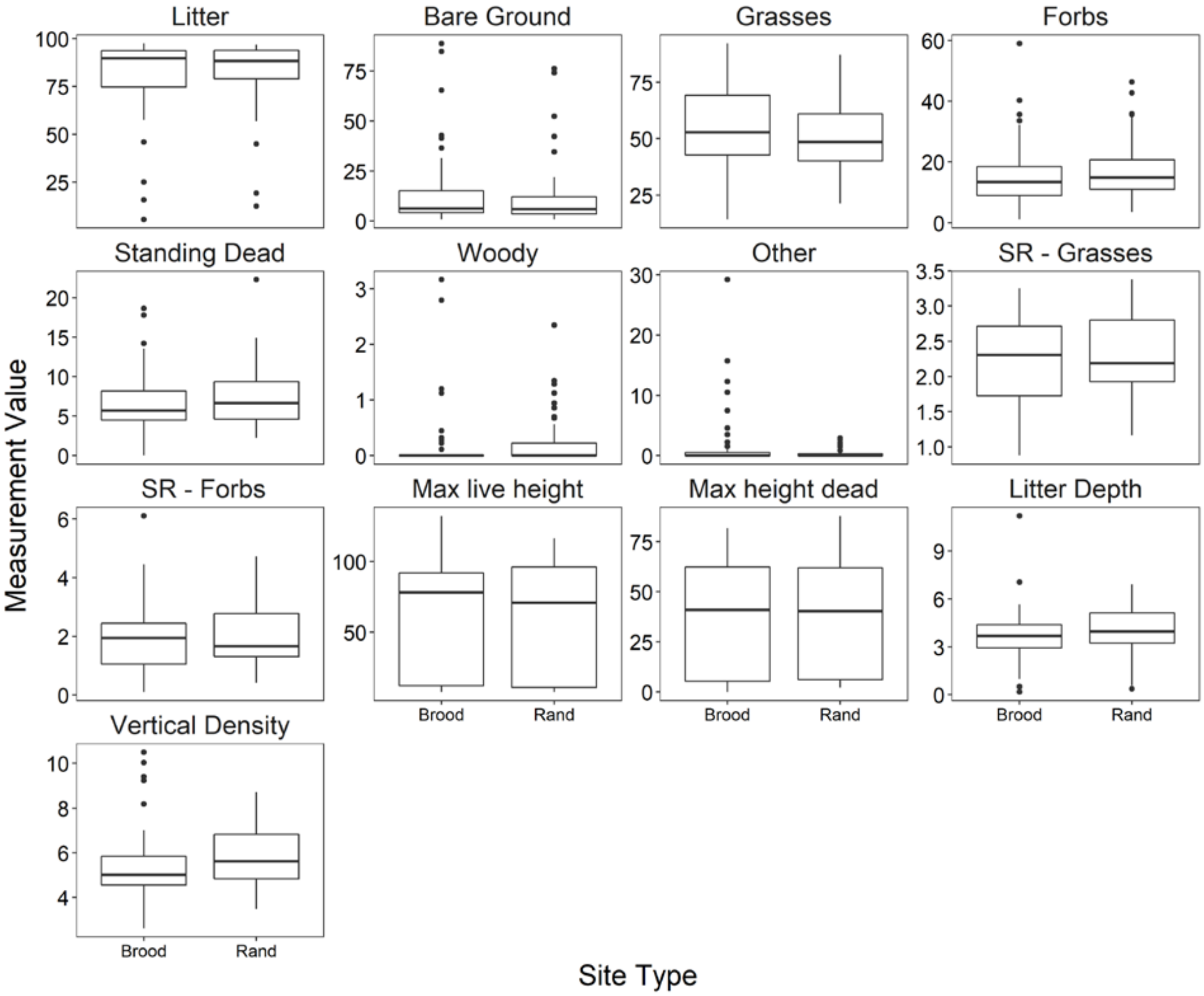

Figure 4. Box plot comparisons of vegetation structure and composition at brood-rearing versus nearby random locations in grasslands in southwest Minnesota, 2016-2017. Random locations were outside of but within 400 m of a brood's biweekly home range [determined by the minimum convex polygon (MCP)]. Vegetation data were collected biweekly up to the first 4 weeks of brood-rearing.