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 in 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 spring 2017, we radiocollared 122 hens on 2 study sites in southwestern Minnesota and monitored them during nesting and brood-rearing each year. We collected data on nest site selection and hen, nest, brood, and chick survival each year. In 2016 and 2017, we also collected data on brood-rearing habitat selection. Video cameras were used to document nest predation events in 2015 and 2016. Preliminary descriptive findings are described within this report as this study is ongoing and final results are pending. Ultimately, the results will be used to 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 population dynamics are driven largely by variation in survival rates, and 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 to increase 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 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) also play important roles in determining susceptibility to nest predation.

Recent 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). 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, unpublished data). 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, better data are needed to understand the interplay between these potential limiting factors on brood habitat selection and chick survival in different grassland habitat types 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 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 or other grassland reconstruction activities) and landscape (e.g., acquisition priorities) levels in this new era 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, forb interseeding] and agricultural land use practices (e.g., pesticide use) on Minnesota's pheasant population.

OBJECTIVES

Our overall objective is to evaluate the relative importance of within-patch diversity [e.g., sites dominated by smooth brome (*Bromus inermis*), warm-season grasses, and high diversity grass-forb mixtures] within Wildlife Management Area (WMA) project areas on pheasant productivity. Specifically, we will:

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

Results from a pilot study during the 2015 breeding season allowed us to refine methods and protocols for the study's expansion in 2016 and 2017, and the 2017 field season was still underway at the time of this report. Therefore, we present only preliminary results here. A more complete evaluation of results is pending further data analyses.

STUDY AREA

Our study is being conducted in the southwest region of Minnesota. Topography ranges from flat to gently rolling. This region is intensively farmed, and corn and soybeans combined account for approximately 75% of the landscape (U.S. Department of Agriculture 2013a, U.S. Department of Agriculture 2013b). Grassland habitats, 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)] account for 6.3% of the landscape in this region (Davros 2016). The southwest region lies within the core of Minnesota's pheasant range, and MNDNR's 2016 August roadside counts indicated 96.0 pheasants per 100 mi driven (Davros 2016).

We selected 2 WMA project areas as study sites. Each study site is about 9 mi^2 in size and contains extensive amounts of permanently protected grassland habitat. The Lamberton WMA study site (Redwood County) is a large, nearly contiguous WMA complex with >1,100 acres of permanently protected upland and wetland habitats. The Worthington Wells study site (Nobles County) has >1,500 acres of permanently protected habitat that spans multiple WMAs, the Okabena-Ocheda Watershed District, and USFWS lands.

METHODS

Data Collection

We captured hen pheasants in each study site during 5 time periods: 2 February – 15 April 2015, 7 October – 11 November 2015, 11 January – 29 April 2016, 26 September – 15 November 2016, and 18 March – 14 April 2017 (hereafter referred to as spring 2015, fall 2015, spring 2016, fall 2016, and spring 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 the right tarsus to the nearest 0.5 mm, banded her with a uniquely numbered aluminum leg band, and fitted her with a 16.0-g necklace-style VHF radiotransmitter with integrated mortality switch [Advanced Telemetry Systems (ATS), Isanti, MN] before release.

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 hens from their nests between incubation day 5-20 to determine clutch size and floated a subset of eggs to estimate hatch dates (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 her nest failed and we waited for her 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. We used the condition of the hen's body and/or 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 alive/dead status and potential cause of death, 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). Cameras were placed at nests at the same time that hens were flushed to float eggs, and our total time at 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 to digital video recorders (Model MDVR14H, Super Circuits, Austin, TX) with SD memory cards and deep-cycle marine batteries housed in waterproof containers >20 m from nests. Video footage was later reviewed in the office and relevant video clips were archived.

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 in. The second technique involved flushing the hen from her brood just before sunrise while she was brooding them 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 brood for >30 minutes to minimize risk of hypothermia for the 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 determined the mass of 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 sensor (ATS, Isanti, MN) to the chick's back (Burkepile et al. 2002, Dahlgren et al. 2010). Handling time lasted <5 min per chick and all chicks were returned 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. We took each bearing from ≥100 m away to reduce disturbance to the hen and her brood. We then used specialized computer software (LOAS, Ecological Software Solutions LLC) to generate estimated locations. We monitored hens and their broods through the first 4 weeks post-hatching. On day 14 and day 30, we flushed the hen just before sunrise to determine brood 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 if it was alive and moving. 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 evidence relating to the 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 canopy cover (Daubenmire 1959) of grasses, forbs, litter, bare ground, woody vegetation, and other (e.g., logs, rocks) using a 0.5 m^2 sampling quadrat. We estimated percent cover on an overlapping basis using 8 classes: 0%, 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 (VOR; Robel et al. 1970) in the 4 cardinal directions to determine the vertical density of vegetation to the nearest 0.5 dm around the nest and 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 points within 15 m of the nest site.

To evaluate brood habitat selection, we collected vegetation data at 5 estimated brood locations (hereafter, brood points) and 10 random points outside of each brood's biweekly home range until each brood was 4 weeks old. First, we mapped each brood's estimated locations in a Geographic Information System (GIS; ArcMap 10.2, ESRI, Redlands, CA) to estimate their biweekly home range. We defined each biweekly home range as the area bounded within all estimated brood points for that 2-week time period. We placed a 100 m buffer around the home range and used a random point generator in ArcMap to select 10 random points outside of the home range for comparison. We restricted the selection of random points so that they were within the same habitat type (e.g., grassland). Roadsides were considered as available grassland habitat and included in sampling efforts. We then collected vegetation data at each brood point and each random point within 7 days of the biweekly interval. At each brood point, we sampled 1 center point and 3 equidistant points 10 m away to capture the spatial variation of a brood location. We estimated percent 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 repeated this sampling scheme at each of the 10 random points associated with each brood's biweekly home range. We restricted the sampling of brood habitat selection to field types other than row crops. If a hen and her brood spent more than 50% of their time in a row crop field during the 2-week period of observation, we did not include them in habitat sampling efforts. If more than one hen with a similar-aged brood was using the same habitat patch during the same time period, we only sampled 5 additional random points within that patch. Finally, we did not collect brood habitat data if a hen lost her entire brood within the first week of each 2-week observation window.

Data Analyses

To date, we have conducted preliminary analyses on hen survival and nest survival. We also calculated basic descriptive statistics for nest site selection. Data proofing for 2016 and data collection for 2017 were still ongoing at the time of this report; thus, not all analyses have included the 2016 and/or 2017 data and not all research objectives are addressed below.

We conducted a preliminary survival analysis to evaluate adult hen survival during the nesting and brood-rearing phases (15 April – 15 October; hereafter, breeding season) only. For hens captured in 2015 and 2016, 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, 10 individuals were censored at various intervals during the analysis period when they were reported missing and not relocated or their fate was otherwise reported as uncertain (e.g., slipped radiocollar, radiocollar malfunction, etc.). Individuals with capture and mortality or censor events occurring outside of the analysis period were excluded from the analysis.

Using the 2015 data only, we conducted a preliminary nest survival analysis using the logistic-exposure method (Shaffer 2004) to estimate daily survival rates (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 captured 122 hens during the 5 trapping periods across both sites from spring 2015 to spring 2017 (Table 1). The baited walk-in traps were not a productive capture technique. We speculate that pheasants were not motivated to use bait due to mild winter conditions with above-average food availability each year. Only 3 hens were captured using the walk-in traps (2.5%) whereas 119 hens (97.5%) were captured by spotlighting. We ended spotlighting capture efforts at the onset of the breeding 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.

In 2015 and 2016, cumulative survival during the breeding season (183 day period pooled across years) for adult hens (*n* = 64) across study areas was 0.79 (CI: 0.69-0.90; Figure 1). During the 2 breeding seasons, 20% of marked individuals (*n* = 12) suffered a known mortality event (Figure 2). Of these mortality events, 75% were attributed to predation events, 17% 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 may be inappropriate given our dataset. Because nearly 14% of individuals were censored during this analysis due to unknown fates (in particular, slipped radiocollars; Figure 2), subsequent survival analyses will work to include expert knowledge to incorporate uncertainty in fate to refine survival estimates (A. Norton, personal communication).

Due to mortalities (*n* = 3) and dropped collars (*n* = 2; unknown causes), we were able to monitor only 15 hens during the 2015 nesting season. One unmarked hen was flushed incidentally during field work and her nest was also monitored. Therefore, we monitored a total of 22 nests from 16 hens. Four nests were abandoned presumably due to research-related activities; therefore, we excluded them from our analysis of nest success. Twelve of 18 nests hatched successfully (67% apparent nest success). The 2015 DSR was 0.9406 ± 0.41 (range: 0.8731-0.9729) which results in an 11.7% overall nest success rate when extrapolated to a 35-day nesting cycle (12 days laying + 23 days incubation). We used a constant survival model due to our low sample sizes; however, future analyses will examine the role of vegetation, spatial (e.g., distance to edge), and temporal (e.g. nest age, ordinal 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.

During 2015 and 2016 only, we placed video cameras on approximately 40% of nests each year. Most hens were tolerant of cameras but a few hens did abandon their nests. However, these hens likely did not abandon due solely to cameras as hens not receiving cameras at their nests were also prone to abandonment, especially if flushed during early incubation. Notable observations included a rooster visiting a hen at her nest almost daily during late incubation (Figure 3) and a chick appearing on video 3 h prior to its hen leading her brood away from another nest. We potentially captured 2 predation events on camera in 2016 but the video qualities were low due to vegetation growth and windy conditions which greatly reduced our ability to clearly view activity at the nests. Although all nests were visible when cameras were first placed, the rapid growth of vegetation during the nesting cycle quickly 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 again 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.

We captured and tagged 81 chicks between day 0-2 during the 2015-2017 breeding seasons. During the 2016 and 2017 field seasons, we recaptured 3 chicks between day 12-15 and replaced their 0.65 g transmitters with sutured 1.1-g backpack-style transmitters (ATS, Isanti, MN). Recapturing radiomarked chicks at this age was relatively easy and seems like a viable option to replace lighter transmitters with heavier ones that have a longer battery life, thereby allowing monitoring of chicks beyond 4 weeks of age in future work. Similar to our hen survival analyses, future chick survival analyses will use additional information from these individuals to refine survival estimates when fates are uncertain.

We collected vegetation data from 19 nest sites in 2015. We calculated means and standard errors (SE) for 2 groups of comparisons: nest sites versus random points (Table 2), and successful versus depredated nests (Table 3). We included all nests regardless of nest fate (e.g., successful, depredated, abandoned, other failure) for the comparison of nest sites versus random points. Hens seemed to use nest sites with slightly less grass cover, lower total species richness, lower grass species richness, and shallower litter depth compared to random points nearby. Hens that successfully hatched a nest in 2015 appeared to use nest sites with less grass and forb cover but more standing dead vegetation cover, reduced species richness of both grasses and forbs, and reduced VOR. Sample sizes for both of these comparisons are low, however, and more data are needed to make formal comparisons.

The last field season of data collection is currently underway. The final results from this study will relate pheasant survival rates to nesting and brood-rearing habitat selection. Ultimately, the information gained will help managers better understand the factors that may limit pheasant productivity so that they can prioritize their management activities in an era of reduced grassland habitat on the landscape.

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Table 1. Ring-necked pheasant hen captures by season[a] and method[b] in southwestern Minnesota, 2015-2017.

	Spring '15		Fall '15[c]		Spring '16		Fall '16[c]		Spring '17[c]		
	BWT	Spot	BWT	Spot	BWT	Spot	BWT	Spot	BWT	Spot	Totals
Study Area											
Lamberton	2	8	.	8	1	12	.	12	.	18	61
Worthington Wells	0	10	.	11	0	15	.	9	.	16	61
Totals	2	18	.	19	1	27	.	21	.	34	122

[a] Season dates include: Spring 2015 = 2 February-15 April; Fall 2015 = 7 October-11 November; Spring 2016 =11 January-29 April; Fall 2016 = 26 September-15 November; Spring 2017 = 18 March-14 April.

[b] Capture methods included: baited walk-in traps (BWT) and netting via nighttime spotlighting from a utility-task vehicle (Spot).

[c] Walk-in traps were not used during fall trapping efforts or during Spring 2017.

Table 2. 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 southwestern Minnesota. Data are shown for 2015 only.

	Nest sites (*n* = 19)		Random points (*n* = 19)	
	Mean	SE	Mean	SE
% Canopy cover[a]				
Grasses	3.4	0.30	3.6	0.18
Forbs	0.9	0.22	1.0	0.20
Standing dead	1.6	0.14	1.5	0.14
Species richness				
Total	3.3	0.62	3.6	0.51
Grasses	1.4	0.14	1.7	0.18
Forbs	1.8	0.59	1.8	0.44
Litter depth (cm)	2.8	0.43	3.3	0.46
VOR (dm)[b]	4.9	0.50	5.1	0.42

[a] Means and SEs for canopy cover measurements were transcribed into cover classes for analysis and have not been back-transcribed. Cover classes include: 0 = 0%, 1 = 0.1-10%, 2 = 11-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-90%, 6 = 91-99%, and 7 = 100%.

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

Table 3. Descriptive statistics for vegetation surveys at successful versus depredated nest sites of ring-necked pheasants in southwestern Minnesota during summer 2015 only.

	Successful Nests (*n* = 9)		Depredated Nests (*n* = 4)	
	Mean	SE	Mean	SE
% Canopy cover[a]				
Grasses	3.4	0.44	3.8	0.85
Forbs	0.9	0.20	1.8	0.48
Standing dead	1.7	0.17	1.0	0.00
Species richness				
Total	3.1	0.56	6.8	1.65
Grasses	1.4	0.18	1.8	0.48
Forbs	1.6	0.53	4.8	1.93
Litter depth (cm)	2.3	0.55	2.3	1.41
VOR (dm)[b]	4.3	0.53	6.2	1.95

[a] Means and SEs for canopy cover measurements were transcribed into cover classes for analysis and have not been back-transcribed. Cover classes include: 0 = 0%, 1 = 0.1-10%, 2 = 11-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-90%, 6 = 91-99%, and 7 = 100%.

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

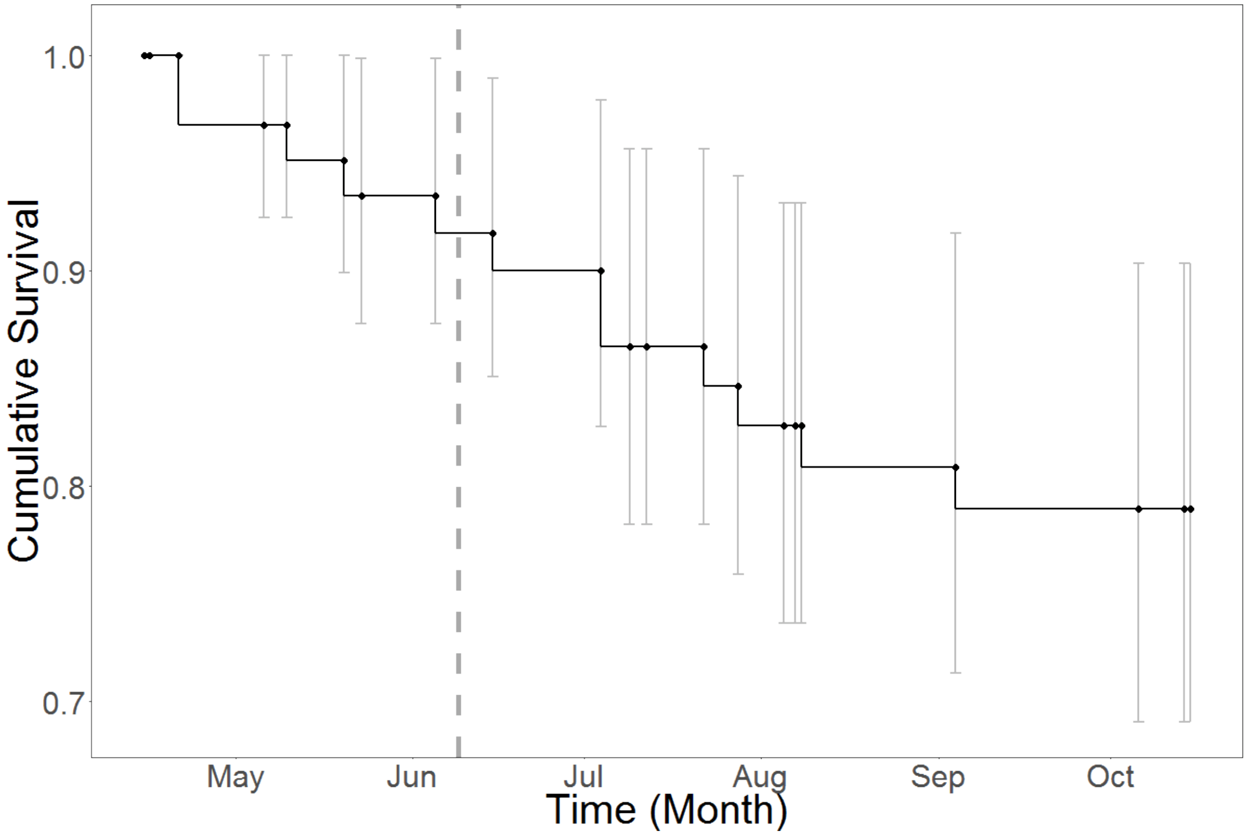

Figure 1. Cumulative survival of radiocollared ring-necked pheasant hens during the 2015 and 2016 breeding seasons (15 April – 15 October) in southwest Minnesota. Points represent survival estimates at intervals where mortality events took place. Error bars (vertical gray lines extending from each point) 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.

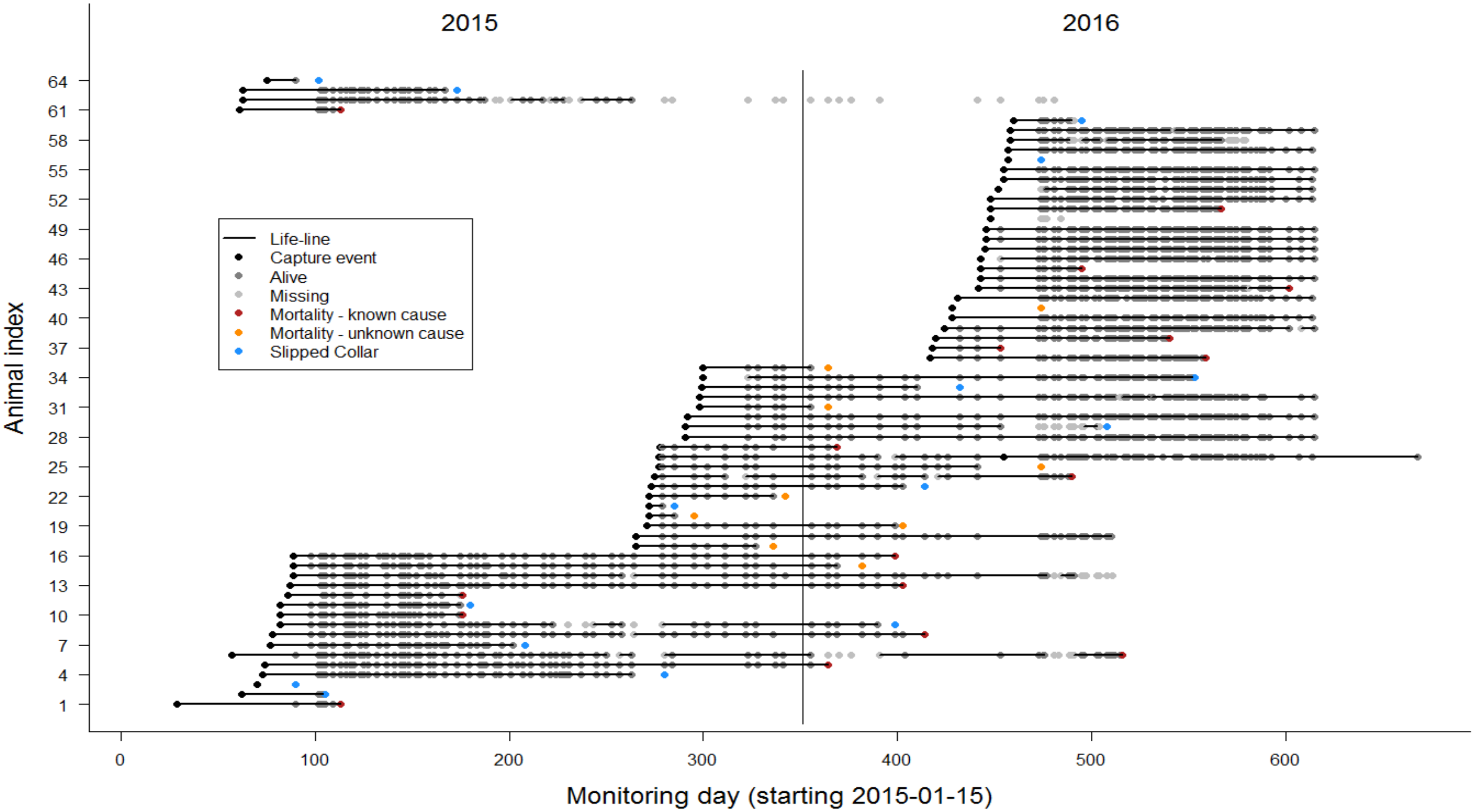

Figure 2. Survival and monitoring history of 64 ring-necked pheasant hens captured and radiocollared from 1 January 2015 – 15 October 2016 in southwest Minnesota. Each row in the figure represents an individual hen. For each individual, the first black point represents the capture date. Subsequent points indicate the monitoring frequency and status of each hen over time. Points for each hen are connected by a black “life-line” if the hen status is alive at both points. Breaks in the line indicate periods were the individual was monitored but not located and the line ends with a mortality event or the end of the monitoring interval specified above. The terminal point for each hen is colored to indicate the cause of mortality [red = known-cause mortality events (e.g., predation, vehicle collisions, mowing/haying operations, etc); orange = unknown-cause mortality events or end of monitoring status; blue = slipped radiocollar; dark gray = alive; light gray = missing].

Figure 3. A ring-necked pheasant rooster visits a hen at her nest during late incubation in southwest Minnesota during May 2015.