Ring-necked Pheasant Brood Habitat Selection and Movements in an Intensive Agricultural Landscape

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Abstract – Management of row crops can greatly influence wildlife populations in an agriculturally intensive landscape. Many upland gamebird populations, including Phasianus colchicus L. (Ring-necked Pheasant; hereafter pheasant) are experiencing contemporary population declines in such landscapes throughout the Midwest United States. Reduced availability of quality brood habitat may be a factor in these declines. Alternative practices, such as spring cover crops, may increase brood survival and benefit local pheasant populations. Our objectives were to follow radio-tagged females and assess pheasant brood 1) movements among available habitat patches within landscapes including spring cover crops and Conservation Reserve Program (CRP) fields, 2) relative use of available cover types within a landscape, 3) selection of vegetation structure, vegetation composition, and invertebrate community structure by brood-rearing hens in landscapes dominated by row-crop agriculture, and 4) survival rates. Broods were found primarily in grassy areas (native grass, pasture, train track right-of-way, and grass strips) and spring cover crop fields even though cover crops were the least common cover type in all study areas. Brood movements were limited with broods staying near nest locations for 30 days after hatch. Though movements were small, broods were found in multiple cover types, averaging 2.8 out of 6 available cover types. There was no difference between used and random locations for invertebrate metrics including total counts, biomass, and richness; order-specific biomass; and order-specific counts. Visual obstruction and vegetation composition were similar between used and random locations. Across our study sites, we found little support for point-site selection (i.e., within-patch 4th order selection) but significant support for patch-site selection by female pheasants attending broods. Spring cover crops (<5%) and CRP (<15%) comprised a small percentage of the landscape area, but were selected by females attending broods as each contained approximately 25% of brood locations. Apparent survival of pheasant broods was low compared to other studies. Female pheasants selected for spring cover crops and CRP when attending broods, both are alternatives to current row-crop farming practices. As pheasants continue to respond to changes in western Kansas landscapes, homogeneity of cover types found in agricultural landscapes can be detrimental if practices continue to shift from quality pheasant habitat but can be advantageous if practices shift towards favorable management practices.

Introduction

Abundance of many upland gamebird populations across the United States are declining in response to several factors such as invasive plants, declining habitat quality, disease, increasing intensity of row-crop agriculture, and contaminants (Doxon and Carroll 2010, Flake et al. 2012, Rodgers 1999). Within upland gamebirds, *Phasianus colchicus* L. (Ring-necked Pheasant; hereafter pheasant) occupy a unique niche in agriculturally dominated landscapes. Ironically, as a naturalized species, the pheasant is arguably the most recog-

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nized upland gamebird within the United States (Flake et al. 2012, Riley and Schulz 2001). Within the Midwest United States, pheasants are predominately found in cropland-grassland mosaic landscapes but crop rotation, composition of surrounding landscape matrix, and other factors vary greatly within and among states (Flake et al. 2012). Recent declines of pheasants across Midwest United States have managers concerned that current cropping practices and management strategies may be insufficient to maintain sustainable populations of pheasants.

Population trends of upland game birds are particularly sensitive to variation in brood survival partially due to short life spans of adults limiting their opportunities to reproduce (Clark et al. 2008, Flake et al. 2012). Unfortunately, there is little knowledge on pheasant brood survival, movement patterns, resource selection, and diet within the Midwest, with the few previous studies indicating considerable variability across the occupied range (Flake et al. 2012, Hill 1985). Crop rotations across the Midwest vary considerably but in general, pheasants thrive in cropland landscapes with a diverse array of cover types. Providing brood-rearing habitat in close proximity to nesting habitat is important for survival as chicks in broods with larger home ranges have lower survival rates (Hill 1985). Availability of quality brood-rearing habitat (i.e., allowing for easy movement, providing abundant invertebrates, and protection from predators) may be a limiting factor for pheasant chick survival and recruitment, but interactive effects of juxtaposition with nesting and escape cover, landscape-scale resource selection, and movement capacity of chicks remain poorly understood (Doxon and Carroll 2010, Warner 1979).

Many brood management strategies focus on altering active crop fields by planting brood friendly crops (e.g., small grains or some forage crops), altering fallow fields by leaving taller stubble, or planting cover crops (Flake et al. 2012). Specific recommendations for creating or enhancing pheasant brood habitat vary depending on crop type and rotation in row-crop dominated landscapes to maximize benefits for both the producer and local wildlife (Kansas Department of Wildlife Parks and Tourism [KDWPT] 2016, Pheasants Forever 2020). A typical crop rotation practice in western Kansas includes herbicides to maintain fallow fields after *Zea mays* L. (Corn) or *Sorghum bicolor* (L.) Moench (Grain Sorghum) harvest in the fall until *Triticum* sp. L. (Winter Wheat) is planted the following fall (~12–14 months; Roozeboom et al. 2009). Under this management practice, nesting and brood-rearing efforts for pheasants and other birds fall within the period when the field is fallow and available resources are reduced.

Adding spring cover crops, which are planted in March or April and terminated in June or July, to a crop rotation is an alternative management practice that benefits breeding pheasants and other wildlife. By planting spring cover crops, producers benefit from increased organic matter, nitrogen fixation, soil nutrient movement, fewer weeds, and reduced soil compaction and erosion (Ladoni et al. 2016, Villami et al. 2006, Wayman et al. 2014). Managers consider spring cover crops a potential practice for increasing local pheasant recruitment rates, while also providing agricultural benefits, by converting fallow fields to usable habitat during the breeding season (Flake et al. 2012, Godar 2020, KDWPT 2016, Pheasants Forever 2020).

Local pheasant populations may benefit from the additional cover and food resources provided by spring cover crops (Godar 2020, Jeliazkov et al. 2016, KDWPT 2016, Wilcoxen et al. 2018). Many spring cover crop seed mixes contain small grains, which pheasants use as nesting and brood-rearing cover (Flake et al. 2012, Warner 1979, Wilcoxen et al. 2018). Other mixes contain a wide variety of forbs, which attract invertebrates, providing additional food resources for pheasant broods. Producers can select mixes to potentially provide nesting habitat, brood habitat, or both (KDWPT 2016, Wilcoxen et al. 2018). Although planting cover crops is considered beneficial for most wildlife species, wildlife responses to different seed mixes are relatively undocumented (Jeliazkov et al. 2016).

Increasing quality of brood habitat may be key to recruitment of sufficient young for sustainable pheasant populations (Clark et al. 2008, Flake et al. 2012). Newly hatched chicks are dependent on the hen for survival. Following a successful nest, a hen must lead her precocial chicks (with limited mobility) to nearby areas that provide easy movement for the short-legged chicks, abundant insects for foraging, and overhead concealment for protection from adverse weather and predators (Doxon and Carroll 2010, Flake et al. 2012). Often, areas that provide ample nesting sites lack sufficient resources for chicks until they become independent (~30 days after hatch; Flake et al. 2012).

To maximize benefits for managing pheasant broods, managers require information on resource selection and movements by female pheasants attending broods within agricultural landscapes. Planting spring cover crops and management of existing U.S. Department of Agriculture Conservation Reserve Program (CRP) patches are potential strategies for increasing nesting and brood-rearing habitat and enhancing interconnectedness of these habitat patches for pheasants in agricultural landscapes (Godar 2020). The addition of spring cover crops will alter landscapes by providing a potential alternative cover type for broods in addition to soil enhancement for producers. Our objectives were to assess pheasant brood 1) movements post-hatch and among available habitat patches within landscapes including spring cover crops and CRP, 2) relative use of available cover types within a landscape, 3) selection of vegetation structure, vegetation composition, and invertebrate community structure by brood-rearing hens in landscapes dominated by row-crop agriculture, and 4) survival rates. We hypothesized pheasant hens would select spring cover crop fields when raising a brood due to their insect diversity and high percentage of forbs compared to other available cover types (Godar 2020). We predicted pheasant broods would disproportionally use areas with greater insect diversity and percent composition of forbs.

Material and Methods

Study area

Our study area included two ecoregions of Kansas during the 2017–2019 pheasant breeding seasons: High Plains (Graham and Norton counties) and Smoky Hills (Rooks and Russell counties; Fig. 1). Counties were dominated by cropland and interspersed with patches of CRP and native grassland (Godar 2020; National Cooperative Soil Survey 1977, 1982a, 1982b, 1986). Wheat was the primary crop in both ecoregions, with >50% of the cropland planted to wheat. The remaining cropland consisting of Corn, Grain Sorghum, *Glycine max* (L.) Merr. ev. Bragg (Soybeans), and fallow areas (National Cooperative Soil Survey 1977, 1982a, 1982b, 1986).

The High Plains ecoregion consisted of short-grass prairie intermixed with mixed- and western tall-grass prairies (Lauver et al. 1999). The short-grass prairie was dominated by *Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths (Blue Grama) and *B. dactyloides* (Nutt.) Columbus (Buffalograss) with scattered *Aristida purpurea* Nutt. (Purple Threeawn), *Gutierrezia sarothrae* (Pursh) Britt. & Rusby (Broom Snakeweed), *Psoralidium tenuiflorum* (Pursh) Rydb. (Slimflower Scurfpea), and *Ratibida columnifera* (Nutt.) Wooton & Standl. (Upright Prairie Coneflower; Lauver et al. 1999). The western tall-grass prairie in the High Plains was predominantly comprised of *Andropogon gerardii* Vitman (Big Bluestem) and *Sorghastrum nutans* (L.) Nash (Indiangrass) with intermixed *Desmanthus illinoensis*

(Michx.) MacMill. ex B. L. Rob. and Fernald (Illinois Bundleflower), *Glycyrrhiza lepidota* (Nutt.) Pursh (American Licorice), *Panicum virgatum* L. (Switchgrass), *Pascopyrum smithii* (Rydb.) Á.Löve (Western Wheatgrass), *Schoenoplectus pungens* (Vahl) Palla (Common Threesquare), and *Sporobolus cryptandrus* (Torr.) A.Gray (Sand Dropseed; Lauver et al. 1999).

In the Smoky Hills, the Dakota Hills tall-grass prairie was comprised mainly of big Bluestem, Switchgrass, *Schizachyrium scoparium* (Michx.) Nash (Little Bluestem), with *Bouteloua curtipendula* (Michx.) Torr. (Sideoats Grama), *Clematis fremontii* S.Watson (Fremont's Clematis), Indiangrass, *Tradescantia occidentalis* (Britton) Smyth (Prairie Spiderwort), and *Tradescantia tharpii* (Britton) Smyth (Tharp's Spiderwort; Lauver et al. 1999). The mixed-grass prairie in both regions was dominated by Little Bluestem, Sideoats Grama, and *Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths (Blue Grama) with *Ambrosia psilostachya* DC. (Ragweed), Big Bluestem, *Astragalus crassicarpus* var. *crassicarpus* Nutt. (Groundplum Milkvetch), *Bouteloua hirsuta* Lag. (Hairy Grama), Buffalograss, *Calylophus serrulatus* (Nutt.) P.H.Raven (Yellow Sundrops), *Dalea enneandra* Nutt. (Nineanther Prairie Clover), *Liatris punctate* Hook. (Blazing Star), and Indiangrass (Lauver et al. 1999).

We defined the study areas within each county as 2 km around fields where we successfully captured pheasants and 2 km around spring cover crop treatment fields. In 2017, the study area consisted of 9,945 ha in Graham County (Fig. 1). In 2018, we expanded into

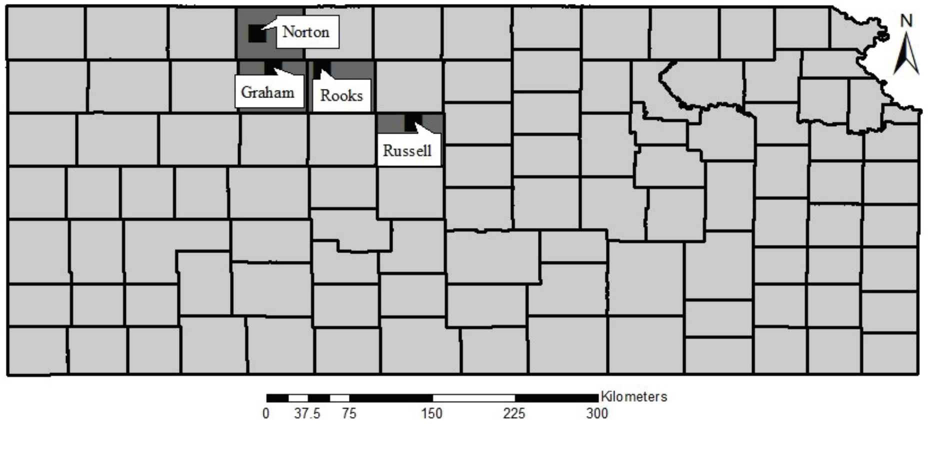

Figure 1. Counties (dark grey) containing Ring-necked Pheasant capture sites and spring cover crops fields (black boxes) in Kansas, 2017-2019; Graham, Norton, Rooks, and Russell.

Russell and Norton counties (19,939 ha; Fig. 1). In 2019, we added 1 study area in Rooks County while continuing research in the first 3 counties (22,958 ha; Fig. 1). The Norton County study sites were located on the Norton Wildlife Area managed by Kansas Department of Wildlife and Parks; all other study sites were on private land. We classified each study area into land cover categories including: cover crop seed mix, growing Corn, growing Grain Sorghum, crop stubble, wheat stubble, CRP, grassland, green wheat, and other. We used National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery to delineate boundaries between land cover categories (hereafter, patch types). We confirmed delineations with site visits. Annual long-term average precipitation and temperature were similar among counties (Table 1). Within study areas, percent crop coverage was similar among counties (Table 1). Graham County had 3% native grass coverage compared to around 30% in the other counties, but did have the second most CRP coverage (Table 1).

Treatment fields

We collaborated with landowners in western Kansas to plant spring cover crop treatment fields (n = 13) in landscapes supporting pheasants during 2017–2019. Fields were in rotation for fall planting of Winter Wheat after a grain crop (Corn or Grain Sorghum). Each study field was ~65 ha, located within 2 km of CRP fields and divided equally into 4 treatment plots (~17 ha), 3 spring cover crop mixes, and a chemical fallow control. How-

Table 1. Summary of climate, weather, and land cover of Ring-necked Pheasant study areas in 4 counties in western Kansas, from 2017–2019. Climate data includes long-term averages of annual precipitation totals (mm) and long-term averages of annual average temperature (°C), from 1981–2010 annual normal data at 3 weather stations (USW00093990-Graham and Rooks, USC00145852-Norton, USW00093997-Russell). Weather data were collected at the same weather stations. Average temperpture was calculated by adding the maximum temperature and minimum temperature and dividing by 2. The study area land cover percentages were estimated from the project's cover type maps of the study areas from 2019. The other cover type includes trees, bodies of water, roads, and manmade objects.

	County			
	Graham	Norton	Rooks	Russell
Average Annual Temperature	11.9	11.0	11.9	12.6
Average Annual Total Precipitation	582.17	656.34	582.17	648.46
2017 Average Temperature	13.2	11.8	13.2	13.7
2018 Average Temperature	12.0	10.3	12.0	13.1
2019 Average Temperature	11.7	10.1	11.7	12.1
2017 Total Precipitation (mm)	590.0	NA	590.0	439.6
2018 Total Precipitation (mm)	921.2	NA	921.2	795.5
2019 Total Precipitation (mm)	744.7	NA	744.7	692.8
Percent Crop	40	37	42	30
Percent Crop Stubble	13	7	3	18
Percent Cover Crop	2	1	1	5
Percent Grass	3	32	33	32
Percent CRP	12	3	15	5
Percent Other	30	20	6	10

ever, plot area varied at times to account for irregular study field area and configuration. We randomly assigned treatments to each plot within the field. Cover crops were planted in mid-March to mid-April, with chemical termination of cover crops in late June or July for compliance with crop insurance requirements. The number of treatments fields per county varied by year with the most treatments occurring in 2019. The area planted to cover crops varied annually due to changing crop rotations and producer interest.

Seed mixes

We selected 3 cover crop seed mixes with a range of seeding rates: GreenSpring (73 kg/ha), Chick Magnet (28 kg/ha), and a Custom Mix (41 kg/ha). GreenSpring was a commonly used mix developed by Star Seed Company (Osbourne, KS, USA) for its agricultural benefits and potential to hay the crop for use as cattle feed. The mix contained cool-season *Pisum sativum* L. (Peas) and *Avena sativa* L. (Oats). Chick Magnet was designed by Star Seed Company for precocial gamebird chicks. The mix contained warm-season, broad-leafed forbs that offer extensive overhead concealment with sparse stems for easy movement by chicks. As a forb-only mix, grasses and volunteer wheat can be controlled with a grass-selective herbicide as necessary. Species included in the mix were *Vigna unguiculata* (L.) Walp. (Cowpeas), cool-season Peas, *Melilotus officinalis* (L.) Pall. (Yellow Sweet Clover), *Brassica* spp. (Hybrid Brassica), *Helianthus* spp. (Sunflower), and *Fagopyrum esculentum* Gilib. (Buckwheat). The final mix was adapted by Star Seed Company and Kansas Department of Wildlife and Parks from a diverse agricultural mix designed by Custer Farms to be adaptive to different climatic conditions and provide a variety of agricultural and wildlife benefits. Species included in the Custom Mix were *Vicia villosa* Roth (Chickling Vetch), *Raphanus raphanistrum* L. (Radish), Oats, cool-season Peas, *Brassica napus* L. (Rapeseed), Sunflowers, *B. rapa* L. (Turnips), and Yellow Sweet Clover. We used chemical fallow treatment as a control in the plot where nothing was planted and broad-spectrum herbicides (e.g., glyphosate) were applied to keep fields free of vegetation. This treatment represented the standard agriculture practice in the absence of planting spring cover crops. Treatment fields totaled 1,192.1 ha across years, with 213.3 ha in chemical fallow, 322.8 ha in Chick Magnet, 334.6 ha in Custom Mix, and 321.4 ha in GreenSpring.

Pheasant capture

We used a combination of night-lighting (Applegate et al. 2002, Flock and Applegate 2002, Gabbert et al. 1999, Gatti et al. 1989) and baited air cannon to capture female pheasants during early February to April 15, 2017 to 2019. Night-lighting was limited to calm nights (winds <16 kmph) with high relative humidity (>60%) to minimize fire risk. No trapping occurred during rain events for the safety of the birds. We fitted captured female pheasants with a 15-g necklace-style very-high-frequency transmitter with an 8-hour mortality switch (Model #A3960, Advanced Telemetry Systems, Inc., Isanti, MN, USA) and a unique numbered aluminum leg band (Draycott et al. 2009). Birds were released at the capture site after approximately 10 minutes of handling. Procedures followed the guidelines for handling wild animals required by the Kansas State University Institutional Animal Care and Use Committee (IACUC #3831) and State of Kansas Scientific, Education, or Exhibition Wildlife Permits (SC-018-2017, SC-024-2018, and SC-015-2019).

Monitoring

Radio-collared females were monitored a minimum of twice a week (usually >4) during nesting, brood rearing, and brood break-up periods from capture through September. Locations were determined using a handheld telemetry system, using a 3-element yagi and handheld radio receiver (Communication Specialists, Inc. Orange, CA, USA), to triangulate the location of each individual. We used Location of a Signal software to estimate error polygons and continued taking bearings until 3 bearings were taken within 20 minutes and estimated an error polygon ≤2,000 m^2 (Ecological Software Solutions 2010). When conditions allowed, nesting hens were monitored daily from a distance to determine nest success and nest hatch day (Matthews et al. 2012a,b). Whenever monitoring indicated that the hen left the nest, the nest was checked to determine if it was still active. If no longer active, researchers determined nest fate. Following a successful hatch, the hen was flushed on the first morning that weather permitted to verify the presence of chicks. Brooding pheasants were triangulated daily and flushed weekly from roosting locations to count surviving chicks for 30 days after hatch.

Habitat surveys

We collected vegetation and insect data at triangulated brood locations within 10 days of a location when conditions and access were possible. A random-paired location within 300 m of the estimated used point and within the same patch was used to assess within patch or point-scale selection (i.e., 4^{th} order selection; Johnson 1980).

We measured the percent cover of bare ground, litter, forbs, warm-season grasses, cool-season grasses, woody species greater and less than 1.5 m tall, crop, and standing crop stubble within a 60-cm Daubenmire frame at the estimated and random location points and 4 m to the north, south, east, and west of each point (Daubenmire 1959). Litter (unrooted, dead vegetation) depth was measured in the northeast corner of each frame using a ruler (cm). Visual obstruction surveys measured the highest dm with 100%, 75%, 50%, 25%, and 0% visual obstruction of the Robel pole from the cardinal directions from 4 m away at 1 m above ground (Robel et al. 1970). We estimated an index to overhead cover by subtracting the light intensity (kLux) at ground level from the light intensity at 1 m above ground to determine the light blocked by vegetation and dividing by the light intensity at 1 m above ground to convert the value to a percentage of light blocked (Extech® EasyView Light Meter, Extech Instruments, Nashua, NH, USA).

We conducted invertebrate sweep surveys at used and random locations during 2017 and 2018. Random distances and bearings were generated in Microsoft Excel (Microsoft Corporation, Santa Rosa, CA, USA) using the random number generator. After the used location surveys were completed, the next combination of distance and bearing was paced out. Transects started at the estimated brood location or random location. We took 100 sweeps heading north and deposited collected invertebrates in a gallon-sized plastic bag. We collected 3 transects per location, taking 5 paces to the east and turning around between the first 2 transects and turning west between the second and third transects (Sullins et al. 2018). Insects were classified by order before being counted, dried to a constant mass, and weighed (g).

Statistical analyses

To assess brood survival rates, we calculated apparent brood survival based on a 30-days post-hatch when chicks transition to independence (Mainwaring 2016). We divided the number of broods surviving to 30 days post-hatch by the number of confirmed successful nests. Few successful nests combined with high mortality early in the brood-rearing state rapidly decreased our sample sizes well below recommended sizes for more intensive survival analyses.

To characterize post-hatch movement patterns of pheasant broods, we measured distances between locations using ArcMap 10.6 to estimate initial distance moved, total distance moved, and daily movements (ESRI 2018, Hanson and Progulske 1973). For initial movements, we measured the distance between the nest and first known brood location, usually within 24 hours, conditions allowing. For total movement, we measured the distance from the nest to the last known brood location, summed linear distances between locations, and estimated the minimum distance from the first location to the last location. Brood locations were monitored daily when conditions allowed and a minimum of three times a week. Due to small sample sizes, based on age, we instead pooled all broods until fledged. Finally, we measured the distance between locations chronologically, maximum distance between locations of a brood, and maximum distance from the mean center of the brood points.

We assigned all known brood locations to a cover type, which were categorized as CRP, grassy areas, crop fields harvested the year of the location, crop stubble (fallow fields), cover crops, or other, to address the objective of relative use of available cover types within a landscape. We combined all crop cover types into a single crop cover type for this analysis. We further determined selection of vegetation structure, vegetation composition, and invertebrate community structure by brood-rearing pheasants at scales of 3rd (cover types within female home range) and 4th (within used patch) order selection. We compared the proportion of cover types within female home ranges to the proportions of cover types of brood locations. The 95% Kernel Density hen home ranges were generated in Program R, version 3.4.1 (R Core Team 2017), using the 'adehabitatHR' package (Calenge 2006). Breeding season home ranges included points from May 15– August 15 with nest locations counted once. We generated selection rankings and ratios using the 'adehabitatHS' package in Program R (3rd order selection; Aebischer et al. 1993, Calenge 2006). Brood sample sizes were small (n = 22), so we pooled data across years.

We compared used to within-patch random locations using 2 techniques to test for 4th order selection (Johnson 1980). First, we used a multivariate analysis of variance (MANOVA) to compare vegetation and invertebrate variables between used and random locations. Second, we used Resource Selection Functions to determine which vegetation and insect variables influenced use by brooding hens (Keating and Cherry 2004, Manly et al. 2002). Triangulated locations were assigned a "1" for used and random locations were assigned a "0" in a logistic regression framework. We used Akaike's information criterion for small sample sizes (AICc) to assess model performance (Anderson et al. 2000, Anderson 2008). We tested vegetation and insect variables in separate model suites. Visual obstruction readings were assessed in one model suite with other vegetation characteristics analyzed in a separate model suite. Competing vegetation models (<2 ΔAICc) within each model suite were combined and then included in a final model suite (Anderson et al. 2000, Anderson 2008). The VOR model suite contained 10 models: 0% VOR, 25% VOR, 50% VOR, 75% VOR, 100% VOR, quadratic 0% VOR, quadratic 25% VOR, quadratic 50% VOR, quadratic 75% VOR, and quadratic 100% VOR. The vegetation composition model suite contained 14 models: average percent grass, average percent forb, average percent vegetation (grass + forb + crop), average overhead cover (light difference), average percent bare ground, average percent ground (bare ground + litter), average percent litter, quadratic average percent grass, quadratic average percent forb, quadratic average percent vegetation (grass + forb + crop), quadratic average over head cover (light difference), quadratic average percent bare ground, quadratic average percent ground (bare ground + litter), and quadratic average percent litter. We limited models to one variable due to inherent correlation between variables within each model suite and inadequate sample size to support testing of more complex models. Insect orders that comprised <5% of the total biomass or count data were pooled for analyses, including Ephemeroptera, Mantodea, Neuroptera, Odonata, Phasmatodea, Psocoptera, Thysanoptera, Trombidiformes, Aranea, and Ixodida. We analyzed Coleopteran counts and biomass, Dipteran counts, Hemipteran counts and biomass, Hymenopteran counts, Lepidopteran biomass, Orthopteran counts and biomass and Psocopteran counts as individual variables. We defined "Richness" as the number of orders present in a sample. Insect models were single variable, linear models (15 models).

Results

We captured 122 female pheasants and recorded 85 confirmed fates of 98 monitored nesting attempts. Of the 22 successful nests, there were 7 successful broods with ≥1 chick with hen at 30 days post-hatch (32%). Apparent brood survival varied annually, with the greatest success rate in 2018 (5 successful broods from 11 hatched nests, 45%; Table 2). The other years of the study each had one successful brood from 6 nests in 2017 (17% apparent survival) and 5 nests in 2019 (20% apparent survival; Table 2). Greater than half of the brood locations were from 2018 (148 out of 244). Five broods were not with the hen the day after hatch for a morning brood flush or any following flushes. Broods were found primarily in grassy areas (native grass, pasture, train track right-of-way, and grass strips) and spring cover crop fields even though cover crops were the least common cover type in all study areas (Fig. 2). In 2018, the year with the greatest apparent survival, spring cover crops and grass were the most used cover types, 32% and 36%, respectively. The most used patch types in 2017 and 2019 were CRP and crop, respectively. Only 5 out of 17 (29%) of the initial locations after hatch were located within CRP despite 53% of nests (n = 85) found in CRP.

Brood movements were limited with broods staying close to the nest for 30 days after hatch (n = 16; Table 3). One brood had only one location and was excluded from the maximum distance between locations and distance from mean center. The distance from the nest to last location was slightly larger (289 m ± 39.7 [SE]) than distance to the first location (164 m ± 31.1). The maximum initial movement was 462 m. The distance between chronological locations ranged from 7 m to 1,212 m with a median distance of 159 m. Brood locations tended to be clustered as the maximum distance from the mean center of brood locations to an individual location averaged 438 m ± 55.0.

Though movements were small, broods were found in multiple cover types, averaging 2.8 out of 6 available cover types for their triangulated locations. Only the brood with one location had one cover type used. No broods used all 6 cover types. Brood locations were

Table 2. Summary of Ring-necked Pheasant females captured and outfitted with radio transmitters, nesting attempts monitored, nests hatched, broods monitored, and successful broods (i.e., at least 1 surviving chick at 30 days post-hatch) in western Kansas, 2017–2019.

	Year		
	2017	2018	2019
Females Captured	40	47	35
Nests Monitored	38	44	16
Nests Hatched	6	11	5
Broods Monitored	5	8	5
Successful Broods	1	5	1

nearly equally distributed among cover crops (23.4%), crops (25.8%), CRP (22.4%), and grass (25.8%; Fig. 2). Crop stubble and other cover types contained 1% of brood locations each. Of the 4 used cover types, crop had the largest presence on the landscape, with 35% coverage in 2018. Cover crops had the smallest presence on the landscape with ≤5%.

Brood use of cover types differed from their availability on the landscape based on female home ranges (3rd order selection). Patch selection by pheasant broods was similar to patch composition of home range of attending female during the breeding season ($\lambda = 0.36$, $P = 0.55$, $n = 16$ females), but there was a difference between brood use of cover types and corresponding availability on the landscape ($P < 0.001$). Ranking of cover types based on brood selection compared to availability in the corresponding home range of attending female during the breeding season, in order of least to most selected, was crop, crop stubble, other, cover crops, CRP, and grass. Crops ($W_i = 0.71$, SE = 0.17), crop stubble ($W_i = 0.92$, SE = 0.38), and other ($W_i = 0.21$, SE = 0.14) cover-type categories were used less than available. Cover crop ($W_i = 1.31$, SE = 0.51), CRP ($W_i = 1.41$, SE = 0.37), and grass ($W_i = 1.20$, SE = 0.34) had selection ratios greater than one, indicating they were used more than available at the female home range scale (3rd order selection). Of locations in cover crops, 58% were in Custom Mix fields, which contained grass and forbs; 25% were in GreenSpring, a grass-only blend; and 17% were in Chick Magnet, a forb-only blend.

There was no difference between used and random locations for invertebrate metrics including total counts, biomass, and richness (Wilks $\lambda = 0.999$, $F_{1,146} = 0.05$, $P = 0.98$);

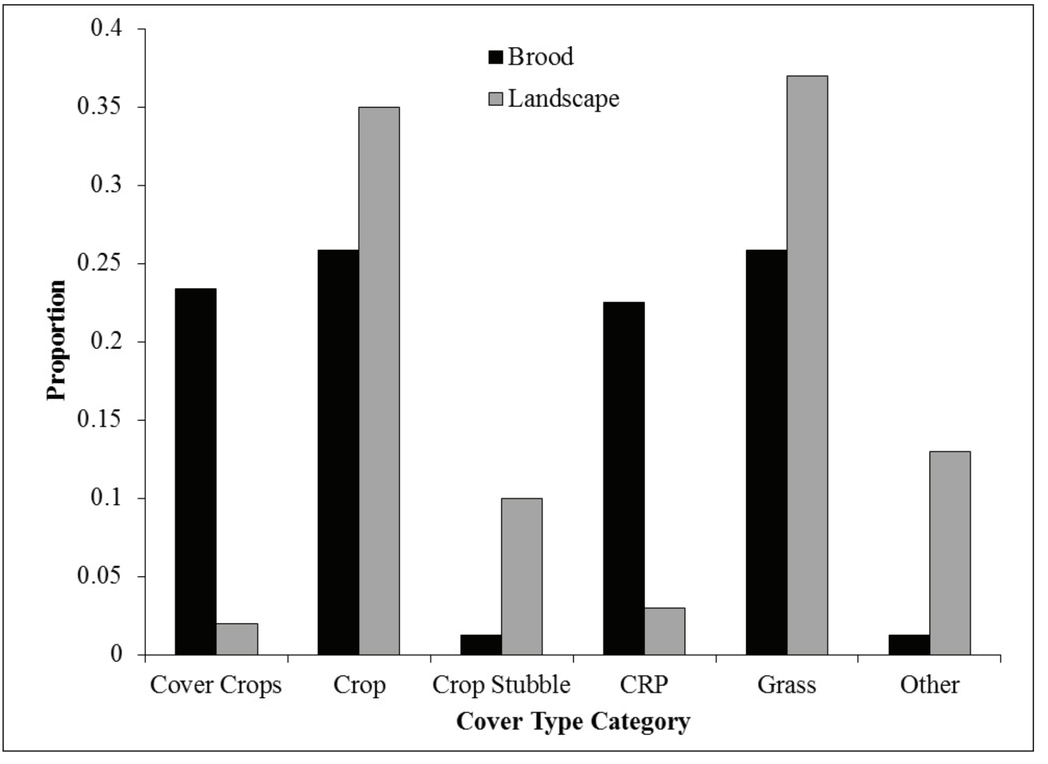

Figure 2. Proportion of cover type categories (other included trees, bodies of water, roads, and man-made objects) of triangulated Ring-necked Pheasant brood locations ($n = 244$) during 2017–2019 in western Kansas, and landscape cover type categories of the study areas in 2018 (148 out of 244 locations).

order-specific biomass (Wilks λ = 0.980, $F_{1,144}$ = 0.58, P = 0.71); and order-specific counts (Wilks λ = 0.984, $F_{1,142}$ = 0.32, P = 0.94). Visual obstruction (Wilks λ = 0.987, $F_{1,418}$ = 1.12, P = 0.35) and vegetation composition (Wilks λ = 0.991, $F_{1,416}$ = 0.60, P = 0.73) were similar between used and random locations.

Results from the resource selection function were similar to MANOVA results. There were no significant relationships indicating selection for any insect or vegetation variable. Insect composition and biomass at brood locations were similar to random locations (n = 150) within occupied patches. All models were competitive (ΔAICc ≤ 2), but none contained a significant relationship indicating selection ($P \geq 0.05$; Table 4). Standard errors associated with averages at used and random locations often overlapped, with differences tending to be within ±1 individual for counts and within ±0.01 g for dry biomass (Table 5). There was more variation in model weight for the vegetation models, leading to 5 competitive models among the 2 model sets (Table 6). However, beta coefficients in the most supported models did not differ from zero ($P \geq 0.05$). The top-ranked models indicate brood locations were associated with more vegetation (β = 0.0037 ± 0.0042, P = 0.37), less litter (β = -0.0051 ± 0.0064, P = 0.43), less bare ground (β = -0.0027 ± 0.0046, P = 0.56), and taller vegetation (β = 0.0017 ± 0.0238, P = 0.94; Table 6). Similar to insect measurements, used and random point averages were remarkably similar, with percent cover composition variables being within a few percentage points of one another and VOR was <1 cm different (Table 7).

Table 3. Average Ring-necked Pheasant brood movement measurements (n = 18) during 2017–2019 in 4 study sites in western Kansas, including average distance moved from the nest location (m), maximum distance between brood locations within a brood (m), and maximum distance from the mean center of all brood locations for the individual brood and an individual location (m).

	Mean	Standard Error	Median	Minimum	Maximum
Distance from Nest to Initial Location (m)	164	31.1	145	35	462
Distance from Nest to Last Location (m)	289	39.7	240	62	664
Sum of Distances Brood Moved (m)	3,045	516.4	3,121	467	7,670
Distance from First to Last Location (m)	243	31.0	213	54	431
Distance Between Locations (m)	218	13.5	159	7	1,212
Maximum Distance Between Locations (m)	692	75.6	672	273	1,348
Maximum Distance from Mean Center (m)	438	55.0	399	148	1,044

Table 4. Ring-necked Pheasant brood resource selection results for insect community collected using insect sweeps at used and random locations during 2017–2019 in western Kansas (n = 364).

Model	AIC_c[a]	ΔAIC_c	w_i	K
Lepidoptera Mass	210.94	0.00	0.10	2
Psocoptera Count	211.14	0.19	0.09	2
Other Count	211.26	0.31	0.08	2
Hemiptera Mass	211.36	0.42	0.08	2
Hymenoptera Count	211.38	0.44	0.08	2
Other Mass	211.90	0.95	0.06	2
Total Count	211.92	0.98	0.06	2
Diptera Count	211.94	0.99	0.06	2
Orthoptera Mass	211.94	1.00	0.06	2
Total Mass	212.00	1.06	0.06	2
Hemiptera Count	212.01	1.06	0.06	2
Coleoptera Count	212.01	1.06	0.06	2
Orthoptera Count	212.02	1.08	0.06	2
Richness	212.02	1.08	0.06	2
Coleoptera Mass	212.03	1.08	0.06	2

[a]AIC*c*- Akaike's Information Criterion for small sample sizes, ΔAIC*c* - difference between AIC_c value relative to the lowest value, w_i -Akaike weights, *K*- number of parameters

Table 5. Average counts (individuals), average dry biomass (g), and richness (number of orders) of 100-m insect sweep transects with standard errors comparing points used by Ring-necked Pheasant broods (n = 75) to random points in the same cover type (n = 75) for insect orders comprising >5% of the total counts or dry biomass during 2017–2019 in western Kansas.

Order	Used ± SE	Random ± SE
Coleoptera Count (Individuals)	21.03 ± 3.38	21.80 ± 5.04
Diptera Count (Individuals)	21.79 ± 2.21	22.79 ± 2.55
Hemiptera Count (Individuals)	30.51 ± 4.70	31.44 ± 4.73
Hymenoptera Count (Individuals)	5.97 ± 0.83	7.91 ± 2.39
Orthoptera Count (Individuals)	10.63 ± 1.78	10.80 ± 1.60
Psocoptera Count (Individuals)	11.48 ± 3.63	7.41 ± 2.43
Total Count (Individuals)	115.19 ± 8.86	119.50 ± 10.38
Coleoptera Mass (g)	0.0391 ± 0.0060	0.0389 ± 0.0066
Hemiptera Mass (g)	0.0712 ±0.0132	0.0590 ± 0.0076
Lepidoptera Mass (g)	0.0336 ± 0.0045	0.0417 ± 0.0065
Orthoptera Mass (g)	0.3291 ± 0.0534	0.3508 ± 0.0551
Total Mass (g)	0.5264 ± 0.0663	0.5398 ± 0.0656
Richness (Number of Orders)	7.00 ± 0.14	6.99 ± 0.14

Discussion

Across our study sites, we found significant support for patch-scale selection within their home ranges by female pheasants attending broods (i.e., among-patch 3rd order selection) but little support for point-site selection (i.e., within-patch 4th order selection). Crop and grass were the dominant cover types at the patch scale (combined >60% across study sites) on the study landscapes, but only about 25% of brood locations occurred in each of these cover types. Spring cover crops (<5%) and CRP (<15%) comprised a small percentage of the cover types at the patch scale, but were strongly selected by females attending broods as each contained approximately 25% of brood locations. Three of 4 of the major used cover types are actively managed and may be altered to influence brood survival and, in turn, pheasant population trends (Clark et al. 2008). Unfortunately, with only 7 successful broods, we lacked sufficient data to determine the effect of patch cover type on brood survival beyond an observation that apparent survival was greatest in the year that use of spring cover crops and grass by broods peaked.

At the home-range scale, cover crop, CRP, and grass cover types were selected more than available, with crop and crop stubble cover types avoided by females with broods. The grass category included native grass, pasture, railroad right-of-way, and grass strips. Similar to our study, Hanson and Progulske (1973) found evidence of cover type selection in South Dakota, where pheasant broods occurred 85% of the time in 4 of 9 cover types: corn (33%), small grain (23%), alfalfa (15%), and residual cover (14%). Their rates of crop

Table 6. Ring-necked Pheasant brood resource selection results for vegetation characteristics of the top models (<2 ΔAIC_c) from 2 model suites for Visual Obstruction Readings (VOR) and overhead composition at used brood locations (n = 212) and random locations (n = 214), during 2017–2019 in western Kansas.

	AIC_c[a]	ΔAIC_c	w_i	K
Average Percent Vegetation	437.12	0.00	0.39	2
Average Percent Litter	438.70	1.58	0.18	2
Average Percent Ground	438.98	1.86	0.15	2
Quadratic Average Vegetation	439.02	1.90	0.15	3
0% VOR	439.32	2.20	0.13	2

[a]AIC*c*- Akaike's Information Criterion for small sample sizes, ΔAIC*c* - difference between AIC_c value relative to the lowest value, w_i -Akaike weights, *K* - number of parameters

Table 7. Average (±SE) point vegetation characteristics comparing points used by Ring-necked Pheasant broods (n = 157) to random points in the same cover type (n = 159) in the top-ranked models (<2 ΔAIC_c; Table 6), during 2017–2019 in western Kansas.

Vegetation Characteristics	Used ± SE	Random ± SE
Average Percent Vegetation (Grass, Forb, Crop)	53.32 ± 2.16	50.56 ± 2.09
Average Percent Litter	29.20 ± 1.381	30.74 ± 1.43
Average Percent Litter and Bare Ground	43.22 ± 2.03	44.79 ± 1.92
Average 0% VOR (dm)	7.83 ± 0.38	7.77 ± 0.37

use were greater than ours, but they estimated 70% of their study area was under cultivation compared to ~30% of our study areas comprised of active crop fields. Brood cover type use in South Dakota shifted as the season progressed and the landscape changed with agricultural activity. For example, broods would move from harvested alfalfa fields to nearby residual cover or corn fields (Hanson and Progulske 1973). Our female pheasants faced similar agricultural disturbances but moved shorter distances. Female pheasants attending broods in South Dakota had larger average major axes, the farthest distance between 2 locations within a home range, of 0.71 mi (~1.14 km; SD = 0.28; Hanson and Progulske 1973), nearly double the average (692 m ± 73) in our study. Larger home ranges decrease pheasant brood survival rates (Hill 1985) but our broods had lower survival regardless of the shorter distances.

Contrary to our hypotheses, point vegetation and insect communities varied little between used and random locations within cover types. Females attending broods did not show significant selection for vegetation characteristics or insect community within used habitat patches. Accounting for the time of the growing season and patch type left little variability in the vegetation measurements (Godar 2020). Limited within-patch vegetation heterogeneity resulted in cover type being the primary source of heterogeneity across the landscape. Rather than remaining within single homogeneous patches, our broods used multiple patch types to secure necessary resources. Within-patch heterogeneity has been shown to affect brood survival. Brood survival in Nebraska increased with time spent in recently disced CRP fields but decreased with time spent in unmanaged CRP fields (Matthews et al. 2012*b*).

Our insect samples, similar to vegetation samples, were homogeneous within patches. Broods locations did not indicate selection for insect orders. Previous studies found patterns in chick diet. Insect remains in fecal samples show chicks forage on Delphacids (Hemipterans), Heteropterans, and Lepidopteran larvae in Illinois (Hill 1985). In western Kansas, hand-raised pheasant chicks selected for Homopterans, Hemipterans, and Coleopterans but the majority of their diet was Hymenopterans and Coleopterans (Doxon and Carroll 2010). In Nebraska, pheasant brood fecal samples frequently contained Coleopterans, Hymenopterans, and Hemipterans (Smith et al. 2015). Hemipterans, though very common in the samples, were a small proportion and selected less than available (Smith et al. 2015). Homogeneity of patch types, especially in simplified systems of cover crops and CRP and relatively small grass patches, limited our ability to detect 4^{th} order selection. Weak patterns in point vegetation and insect communities imply management focusing on landscape composition in landscapes dominated by row crops may provide more benefits to pheasant chicks by allowing access to multiple cover types than focusing on improving a singular cover type.

Spring cover crops were often not present or sufficiently developed on the landscape for nest initiation but still attracted females attending broods. Spring cover crop use increased from nests to broods (2% of nests to 23% of brood locations) while CRP use decreased from nests to broods (53% of nests to 23% of brood locations). Effects of spring cover crops on local pheasant populations will be strongly influenced by the landscape. In our study sites, spring cover crops positively affected pheasants in an agriculturally dominated landscape in a wheat and small grain rotation, interspersed with CRP fields. The positive response to spring cover crops in our study areas was exemplified by strong avoidance to the alternative practice of fallow crop fields by females with broods. Spring cover crops provide additional brood rearing habitat when placed in close proximity to nesting habitat. Furthermore, female pheasants with cover crops in the home ranges had greater survival rates and reproductive output then female pheasants that did not have cover crops in their home range (Godar 2020). The increased reproductive output may be a result of a combination of factors, including female pheasants not having to travel as far with their broods and spring cover crops potentially being a higher quality brood habitat than other options.

As the alternative to spring cover crops, fallow crop fields provide a stark comparison to spring cover crop fields. Fallow crop fields were one of the cover types selected against by female pheasants attending broods. Unlike spring cover crops fields selected by female pheasants attending broods despite their small presence on the landscape, fallow fields were more available and avoided. Fallow crop fields provide the blank canvas of potential cover types. Landowners can use a variety of strategies that may alter the appeal of fallow crop fields to local pheasants with minimal effort, from increasing stubble height to planting cover crops (spring or another modification). With fallow crop fields representing a significant portion of the landscape, small changes in practices may have large effect on local populations of pheasants and other wildlife. The once common practice of weedy wheat stubble (wheat fields with minimal or no post-harvest weed control) is believed to have been the primary driving force behind peak pheasant numbers in Kansas (Rodgers 1999). It is now a rare practice, with producers choosing more intensive crop rotation patterns that leave fields fallow less often. As pheasants continue to respond to changes in western Kansas landscapes, homogeneity of cover types found in agricultural landscapes can be detrimental if practices continue to shift from quality pheasant habitat but can be advantageous if practices shift towards favorable management practices. Female pheasants with broods selected for spring cover crops and CRP. Both land management practices are alternatives to current row-crop farming practices.

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