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PRODUCTIVITY AND HABITAT SELECTION OF RING-NECKED PHEASANTS
AND GREATER PRAIRIE-CHICKENS IN NEBRASKA

by

Ty Matthews

A DISSERTATION

Presented to the Faculty of
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In Partial Fulfillment of Requirements

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Major: Natural Resource Sciences

Under the Supervision of Professors Larkin Powell and Andrew Tyre

Lincoln, Nebraska

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NEST AND BROOD SURVIVAL AND HABITAT SELECTION OF RING-NECKED
PHEASANTS AND GREATER PRAIRIE-CHICKENS IN NEBRASKA

Ty Matthews, Ph.D

University of Nebraska, 2009

Advisors: Larkin Powell and Drew Tyre

Ring-Necked Pheasant (*Phasianus colchicus*) and Greater Prairie-chicken (*Tympanuchus cupido pinnatus*) populations have declined in the Midwest since the 1960's. Research has suggested decreased nest and brood survival are the major causes of this decline due to the lack of suitable habitat. Habitat degradation has been attributed to the shift to larger crop fields, lower diversity of crops, and more intensive pesticide and herbicide use. A primary goal of the Conservation Reserve Program (CRP) is to mitigate the loss of wildlife habitat. Early research found that CRP increased the amount of suitable nesting and brood rearing cover for both species but the habitat may start to deteriorate later in the contract. From 2005 to 2006, I studied nest and brood habitat selection and survival of Ring-necked Pheasants in an area where portions of CRP fields had been disced and interseeded in order to rejuvenate the grass stand and to set it back to an early successional stage. I found pheasant hens selected areas in disced and interseeded CRP (DI-CRP) to nest and rear broods over other grassland types. Within fields, I found hens selected areas with high forb content and vegetation density. I also found pheasant nests and broods had a higher survival rate in DI-CRP fields. From 2007 to 2008, I studied nest and brood habitat selection and survival of Greater Prairie-chickens in an area where the population seemed to rebound after the introduction of CRP. I found hens selected

nest sites in CRP fields and these nests had an higher success rate compared to other habitat types. Greater Prairie-chicken broods also selected CRP fields; however, a disproportionate time spent in these fields did not correspond to advantages in brood survival. Higher forb cover corresponded to higher survival of both nests and broods. My research suggests CRP plays an integral part in fulfilling the habitat requirements of these upland game birds. Although beneficial, CRP should be managed to optimize benefit to wildlife.

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CHAPTER 1. Ring-necked pheasant nest and brood-rearing habitat selection in a Nebraska landscape containing managed CRP¹.

¹ To be submitted to Journal of Wildlife Management. Co-authors: J. S. Taylor and L. A. Powell.

Abstract: The Conservation Reserve Program (CRP) has provided critical wildlife habitat for many species since 1985; however, the quality of this habitat for early successional species, such as ring-necked pheasant (*Phasianus colchicus*), may decrease with field age. These late successional fields may lack valuable vegetative and structural diversity needed by pheasants, especially during nesting and brood-rearing stages. Beginning in 2004, all new CRP contracts were required to perform some type of mid-contract management. Included in the acceptable practices were disking and interseeding. During 2005-2006 we evaluated nesting and brood-rearing habitat used by radio-marked hen pheasants in areas where portions of CRP fields had been recently disced and interseeded with legumes. Pheasant hens selected managed portions of CRP fields for both nesting and brood-rearing. Forb cover and vertical cover were important variables associated with nest site placement. Hens with broods also selected vegetation with high forb composition. Disking and legume interseeding appeared to be an effective strategy for improving pheasant use of CRP fields.

INTRODUCTION

The Conservation Reserve Program (CRP) has the potential to transform agricultural landscapes by replacing traditional cropland with large blocks of grasslands thereby enhancing ecological communities within those agricultural systems and providing habitat for early successional and grassland birds (King and Savidge 1995). The quality of these habitats, however, depends on many factors, including management and age (Ryan et al. 1998, Ryan 2000). Fields are initially composed of a diverse mixture of grasses, forbs, legumes, and annual weeds, with an abundance of bare ground. In as little as 6 years, with little or no active management, CRP vegetation often becomes dense, monotypic grassland with a thick accumulation of litter and little bare ground (Millenbah et al. 1996, McCoy et al. 2001). This shift in the composition and structure of the plant community reduces the quality of habitat produced by CRP for many bird species (King and Savidge 1995, Ryan et al. 1998, Rodgers 1999).

For most states in the Great Plains, ring-necked pheasant (*Phasianus colchicus*) populations peaked in the 1950s and 1960s (Dahlgren 1988). Subsequent shifts in agricultural practices have led to a decline in pheasant numbers due to the lack of suitable cover for nesting and brood rearing (Taylor et al. 1978, Dahlgren 1988, Etter et al. 1988). Although CRP was predicted to boost declining numbers of pheasants, the population response was less than anticipated (Church and Taylor 1999; Rodgers 1999). For example, pheasant populations in Nebraska increased during the first 5 to 6 years after the introduction of CRP, but have declined thereafter (Nebraska Game and Parks Commission [NGPC], unpublished data). The quality of CRP grassland habitat for

pheasants may be inversely related to the time since disturbance. To maintain CRP fields in the early successional stages required by pheasants, some type of regular disturbance is needed (King and Savidge 1995, Ryan et al. 1998, Rodgers 1999).

Management of land in CRP prior to 1992 was restricted to emergency haying and mowing (Berner 1988). Since 1992, landowners have been allowed to plan and implement management activities for fields dominated by grasses and lacking forbs. Two types of disturbances were allowed: light discing and prescribed burning. The 2002 Farm Bill included guidelines recognizing the benefit disturbance in these grasslands has for wildlife and gave landowners more opportunities for management. Beginning in 2004, mid-contract management was mandatory on new contracts; options included spraying herbicide, discing and interseeding legumes and other forbs, and prescribed burning (US Department of Agriculture 2003).

Management of CRP fields can improve habitat and food resources for pheasants, especially in monotypic grass stands often found in older CRP fields. Leathers (2003) reported a general increase in the abundance of arthropods, the main food source for pheasant chicks, in disced and interseeded fields compared to those with no management. Similarly, density and diversity of vegetation, as well as bare ground, increased in areas where discing occurred (Greenfield et al. 2002, Greenfield et al. 2003, Leathers 2003). King and Savidge (1995) reported that nesting hens selected dense vegetation and bare ground, which may be created by discing. This structure may also aid chick mobility by creating movement corridors and decreasing encumbrance due to litter.

The purpose of our study was to investigate response of pheasants to habitat management in a landscape affected by mid-contract management. We examined how

pre-nesting movements of hen pheasants were affected by habitat management. We also assessed habitat selection at two spatial scales to assess pheasant response to landscape composition (macro-scale) and vegetation structure and composition (micro-scale).

METHODS

Study Area

We conducted our study in northeast Nebraska during 2005 and 2006. The 83-km² study area was located in the tallgrass prairie ecoregion in Stanton County. The landscape is dominated by cropland including corn, soybean, and alfalfa (Hammond 1982). However, approximately 2,200 ha (5,400 ac) of the study area was composed of cropland that had been enrolled in CRP >10 years prior to the beginning of our study. Fields were initially planted with a mixture of native and nonnative grasses or grass-forb mixtures. Prior to 2002, no management had occurred in the fields since establishment. Preliminary observations revealed fields were generally monocultures of smooth brome (*Bromus inermis*) or switchgrass (*Panicum virgatum*); legume and other forb components were scarce or nonexistent (Taylor 2002).

From 2002 – 2005, portions of 36 CRP fields were disced and interseeded. Each managed portion (range: 16 ha to 240 ha) was disced 2 to 3 times with a tractor-pulled tandem disc designed for sod breakup to a depth of 7.6 to 10.2 cm. All discing depths and seeding rates were performed in accordance with USDA guidelines (Natural Resource Conservation Service [NRCS] 2002). Discing was followed by interseeding with a seed mixture containing alfalfa (*Medicago sativa*), red clover (*Trifolium pratense*), and yellow sweet clover (*Melilotus officinalis*) using a no-till drill. Legumes were seeded at a rate of 6.75 kg/ha (3.38 kg of alfalfa, 1.69 kg of red clover, and 1.69 kg of yellow

sweet clover). All discing and interseeding dates complied with USDA guidelines (NRCS 2002).

No more than $1/3$ ($\bar{x} = 8$ ha [20 acres]) of each field was disced and interseeded each year. Management sites were selected based on topography and landowner preference. Fields that had been mowed in the previous year were disced and interseeded because of the reduction of residual litter and ease of discing. By May 2004, approximately 850 ha (2,100 ac) of the CRP fields were interseeded in the study area. The interseeded area represented 27.8% of the CRP field acres and 10.5% of the study area.

Radio-telemetry

We captured hen pheasants using baited funnel-entrance box traps and night-lighting techniques (Labisky 1959) from January until March of each year at sites with subjectively high winter concentrations of pheasants. Each hen was fitted with a necklace-style radio transmitter weighing <20 g (Model #A3960, Advanced Telemetry Systems, Inc., Isanti, Minnesota, USA) and immediately released. Animal capture and handling protocols were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee (Protocol #05-02-007).

We used vehicles mounted with a null-peak antenna-receiver and an electronic compass (C100, KVH Industries, Inc., Middletown, RI, USA) to estimate the location of each hen by triangulation 5 to 10 times per week from 15 March to 1 August, 2005-2006. Tracking occurred between 0700 and 2000 hr. We rotated the order of location such that each bird was monitored during different times of day. We took ≥ 3 bearings in a 5- to 15- minute period to minimize movement bias. Additional bearings were taken until the

error polygons were $<1,500 \text{ m}^2$ (~22-m radius). UTM coordinates and error polygons were processed in the field using an on-board computer via Location Of A Signal (LOAS) software (Ecological Software Solutions, Urnäsch, Switzerland, Version 4.0).

Nest and Brood Monitoring.

We monitored the activities of hens via telemetry until we could ascertain the hen had begun incubating. The location of each nest was determined 3 to 10 days after initiation of incubation, as determined by sequential hen locations in the same area. While hens were on the nest, we determined the location of the nest within a few meters using a hand held antenna and receiver. We placed flagging 5m to the north and south of the nest to mark the general location of the nest (Giuliano and Daves 2002). We attempted to avoid flushing hens off nests during our initial visit, because flushing may decrease nest success (Evans and Wolfe 1967). When the hen left the nest, we visually located nests and recorded their exact locations using a hand-held GPS unit, and recorded the number of eggs. When telemetry observations indicated incubation had ceased, we checked the nest site for success or failure. Nests were considered failed when all eggs were destroyed or the hen abandoned the nest, and a success if ≥ 1 egg hatched. For successful nests, we recorded the number of hatched eggs.

We located hens with broods for 21 days after hatch. At 10 days post-hatch, we located the roost site of the hen at night and flagged the general area. During the day, after the hen had moved, we looked for signs of pheasant chick presence (e.g., chick droppings, small depressions near roost site). At 21 days post-hatch, we flushed the hen to determine if the brood was still present.

Habitat and Vegetation Sampling.

We evaluated macro-scale, landscape composition to determine nest and brood-site preference among habitats available in the landscape. We created year-specific, vector-based GIS (ArcGIS 9.0, ESRI, Redlands, CA) landcover layer by visually inspecting aerial photographs to classify landcover, and verifying change in crop type through ground-truthing each year. Mid-contract management of CRP fields continued through 2005, and we incorporated these changes into our landcover layers. Our landcover layer included the following landcover classifications: (1) interseeded and (2) non-interseeded warm season CRP fields, (switchgrass, big bluestem [*Andropogon gerardii*], little bluestem [*Schizachyrium scoparium*], indiangrass [*Sorghastrum nutans*], sideoats grama [*Bouteloua curtipendula*]), (3) interseeded and (4) non-interseeded cool season CRP fields (predominantly smooth brome), (5) other grasslands (grazed and hayed pastures, roadsides, ditches), and (6) other landcovers (any landcover not included above).

We recorded micro-habitat data at nest sites and brood locations to assess vegetation characteristics selected within fields. At each nest site, we estimated percent canopy cover for cool season grasses (Cool), warm season grasses (Warm), forbs (Forb), and bare ground (Bare) using a 1-m diameter sampling hoop (modified from Daubenmire 1959). We also assessed the vegetation structure and composition at one random point ≥ 50 m away in the same landcover type. We estimated visual obstruction readings (VOR) to the nearest 0.25 dm at both nest and random sites (Robel et al. 1970). Brood locations were estimated to be within the 18-m radius error polygon of hen location (Riley et al. 1998). For every third location estimate, we recorded percent canopy and

VOR at a random point inside the 18-m radius and one random point at least 50 m from the brood location.

Macrohabitat Selection

Nest habitat

We analyzed nesting habitat selection by using the nest as the sample unit. We used ArcGIS to classify the landcover type for each nest. We defined available habitat as habitat within a circular area centered on the nest. We set the radius of the area equal to the distance a hen can move in either 1 or 2 days: 400-m radius (1-day movement) and 800-m (2-day movement). We grouped the above general landcover classes into (1) interseeded CRP, (2) CRP, (3) other grassland, and (4) other.

We assessed nest habitat selection using two methods, discrete choice modeling and compositional analysis. First, we used discrete choice modeling using categorical variables (Cooper and Millsbaugh 1999, Alldredge and Griswald 2006). Second, we used compositional analysis, which relies on the log-ratio of the proportion of habitat used to the proportion of habitat available (Aebischer et al. 1993). For discrete choice we chose 5 random locations within the 400-m and 800-m buffers of each nest to produce a sample of alternative choices. Random locations were generated using Hawth's Analysis Tools for ArcGIS (Beyer 2004). We estimated selection parameters using conditional logistic regression (clogit, R, 2006).

For compositional analysis, we considered landcover classes to be preferred if the 95% confidence intervals of the log-ratio did not include 0 (equal use and availability). We could not use a typical MANOVA (Aebischer et al. 1993), because our landcover use

for each individual consisted of one location, the nest site. Thus, we calculated the variance of the log ratio (LR) by using the delta method (Powell 2007):

$$\text{var}(LR) = \text{var}(H_U) \cdot \left(\frac{1}{(H_U)} \right)^2 + \text{var}(H_A) \cdot \left(\frac{1}{(H_A)} \right)^2$$

where H_U is the proportion of nests in a particular landcover class and H_A is the proportion of that landcover class available to the hen (Seber 1982, Williams et al. 2002).

Brood habitat

Brood-habitat analysis was conducted in similar fashion to nest preference analysis. We used two methods, discrete choice modeling with categorical variables (Cooper and Millspaugh 1999, Alldredge and Griswald 2006) and compositional analysis (Aebischer et al. 1993) in SAS (Proc GLM, SAS Institute, 2000) to estimate habitat preference for brooding hens. We used the same landcover categories as in the nest selection analysis. We only used locations from hens with broods still present at 21 days after hatching in this analysis. We used 350-m and 700-m radius buffers around each brood location to estimate available habitat, which are 1 and 2 times the average daily movement we measured for brooding hens. In our discrete choice modeling we used five random locations inside the available-habitat buffer for each brood location to provide a sample of alternative brood habitats. For compositional analysis we used the pooled area from all buffers surrounding each daily location as available brood habitat. We did not consider year as a potential predictor variable in our model because habitat use did not vary between years (Table 1).

Microhabitat Selection

We analyzed the microhabitat selection of nesting hens and brood-rearing hens by comparing the microhabitat features of nest sites and brood locations with the features of

randomly available vegetation. We built *a priori* models to describe our predictions, grouping like covariates together to reduce the number of competing models (Grass: warm season grass and cool season grass, Structure: vertical obstruction reading and bare ground). We used discrete choice modeling to quantify the influence of variables on nest and brood habitat selection (Cooper and Millspaugh 1999). We used Akaike's Information Criteria corrected for small sample size calculate Akaike ranks (ΔAIC) and weights (ω_i) for the competing models. We set the number of individuals as the sample size and not individual vegetation sample to avoid possible replication problems. We used model averaging of all models to estimate parameter coefficients and standard errors if the best model had $\omega_i < 0.95$ (Burnham and Anderson 2002).

RESULTS

The landscape of our study area was dominated by agriculture (35.7%) and CRP fields (37.2%). Other landscape features include pastures and other grasslands (19.9%) wetlands (0.5%) woodlands (4.7%) and farmsteads and roads (2.0%).

We caught 54 and 56 hens in 2005 and 2006, respectively, throughout the breeding season. We found 34 nests in 2005 and 39 nests in 2006. Of these nests, 67 (91.0 %) were in CRP fields (Table 1). In the CRP fields, 41 (58.6%) nests were found in fields dominated by warm season grasses, mainly switchgrass. The remaining nests were found in brome-dominated fields. In 2005, 16 of 34 (47%) nests successfully hatched; 11 broods consisted of ≥ 1 chick 21 days post-hatch. Two brooding hens died before day 10. Eleven of 39 (28%) nests were successful in 2006; 6 broods were active after 21 days.

The average daily movement of hens from 3 weeks prior to nesting until incubation was 172 m (SE = 79) while spending an average of 43% (SE = 31%), 22 %

(SE = 27%), 22% (SE = 21%), and 12% (SE = 20%) of the time in CRP, interseeded CRP, crop, and other grassland respectively. Movement during pre-nesting was inversely related to time spent in interseeded landcovers ($F = 9.86$, $P < 0.01$) and positively related to time spent in crops ($F = 13.97$, $P < 0.01$, Figure 1).

Discrete-choice analysis of all nesting hens showed a preference of interseeded CRP over CRP at both 400-m ($\hat{\beta} = 0.95$ SE = 0.31) and 800-m scales ($\hat{\beta} = 1.09$ SE = 0.35, Table 2). Although there were few nests in non-CRP grasslands, nesting use of other grasslands was not avoided when compared to unmanaged CRP fields at the 400-m scale ($\hat{\beta} = -0.25$ SE = 0.55), but was at the 800-m scale ($\hat{\beta} = -1.21$ SE = 0.56). Hens avoided landcovers classified as ‘other’ at both scales when compared to CRP fields. Ranks of preferences from the compositional analysis were: interseeded CRP > CRP > other grassland > other, at both scales. Nesting hens exhibited significant preference ($P < 0.05$) for interseeded CRP over what was available at the 800-m scale and 400-m scale. Nesting hens also avoided landcovers classified as ‘other’ at both scales (Table 2).

We created 8 biological *a priori* models using discrete choice to determine micro-habitat characteristics of nest sites used by pheasant hens (Table 3). Based on AIC_C scores, 2 vegetation models were better at describing nest sites than any of the other models (Table 3). When model parameters were nested and no model showed strong evidence as a top model, we used model averaging to estimate parameter coefficients and standard errors. Nesting hens exhibited a preference for higher proportion of area covered by interseeded forbs and legumes and an increase in visual obstruction readings (Table 4).

We sampled landcover at 469 locations used by the 17 broods. Sites used by broods were located in interseeded CRP (36%), CRP fields (28%), other grassland (18%), and other landcovers (17%). Patch use by broods differed from random points at both the 400-m and 800-m scales according to discrete-choice models (Table 5). We found interseeded CRP areas were selected more than unmanaged CRP by hens with broods at both 400-m ($\hat{\beta} = 0.57$ SE = 0.15) and 800-m ($\hat{\beta} = 1.00$ SE = 0.142) scales (Table 5). Hens with broods showed an avoidance of landcovers classified as ‘other’ compared to CRP (400-m: $\hat{\beta} = -0.72$ SE = 0.17, 800-m: $\hat{\beta} = -0.78$ SE = 0.16). Ranks of landcover preferences from compositional analysis were: interseeded CRP > CRP > other grassland > other at both 400-m and 800-m scales (Table 5). Hens showed a preference for interseeded CRP over ‘other’ landcover (400-m: mean difference = 2.94, SE = 0.89, 800-m: mean difference = 3.43, SE = 0.95). No other landcover classifications were found to effect selection of brood sites ($P < 0.05$, Table 5)

The vegetative structure and composition at brood sites differed from random points in the same field (Table 6). Although discrete-choice models for brood microhabitat selection exhibited model uncertainty, the top model was selected as the best model because of the model’s relative parsimony compared to the second best model (Richards 2008). Brood-rearing hen pheasants selected areas inside a field with high amounts of interseeded forb and legumes (Table 7). Brooding hens also selected sites within patches that had greater visual obstruction over what was randomly available to them (Table 7).

DISCUSSION

Our study supports the notion that CRP can be managed to serve as valuable habitat for nesting pheasants within the context of agricultural landscape. More than 90% of hens' nests were located in CRP fields (Table 1). The higher selection for a grass-legume complex was also noted by Warner et al. (1987) in managed road sides in Illinois. Our data also support the concept that CRP fields left idle for > 10 years generally lose suitability as nesting habitat (Millenbah et al. 1996, Rodgers 1999). Baxter and Wolfe (1973) and Gates and Hale (1975) also showed that monotypic grasslands with little structural variation provided poor nesting cover. Within CRP fields, hens preferred disced and interseeded areas over unmanaged CRP for nesting (Table 2). This trend held true for both extents, although higher preference for managed CRP was greater at 800-m buffer (197% increase) than at 400-m buffer (159% increase). This could be explained by size and relative isolation of interseeded habitats. Many of the nests (46.6%) were in interseeded CRP and this landcover constituted a small percentage of the total area (10.5%). As we changed the scale of habitat considered to be available, the proportion of interseeded habitat often decreased, which had the effect of strengthening the evidence for selection of interseeded CRP.

Nest-site selection was strongly associated with vegetation composition and vegetation density (Table 3). The amount of interseeded legumes and the dense cover provided by this vegetation was the driving factor in determining the selection of nest sites in areas containing managed CRP fields. At the nest-site, hens selected sites with dense vegetation and a high forb component (Tables 3,4). Both of these micro-habitat features were found in managed CRP fields (Negus 2005). Similarly, all vegetative covariates in the models for nesting were positive indicating that hens preferred dense,

tall cover. These characteristics were best provided by grass fields interseeded with alfalfa and sweet clover due to their dense vegetative structure and rapid growth rate compared to grasses.

The positive selection by brooding hens for managed CRP supports the idea that pheasants in this life stage select habitats with high vegetative diversity (Riley et al. 1998), which can be obtained by discing and interseeding monoculture CRP fields. By improving these old CRP fields, brooding-hen use was increased by 77% and 172% compared to unmanaged CRP in the 400m and 800m buffer areas respectively. The requirements of forbs for cover and insect production during brood rearing have been well documented (Hammer 1973, Hill 1985). Sites used by brooding hens had higher forb content than randomly selected habitats with no other covariate having much effect (Tables 5,6).

Recently, biologists have debated the use of compositional analysis for analyzing habitat preference (Thomas and Taylor 2006, Bingham et al. 2007). Our results, using both discrete choice and compositional analysis to compare brood-site preference, did not differ in habitat preference rankings but did in the statistical significance placed on these relationships (Table 3). This may be a result of lower degrees of freedom in the compositional analysis. In compositional analysis, we pooled all used points for each brood into a percentage of time each separate brooding hen was found in each habitat. These percentages were used with the pooled available habitats for each hen. Discrete choice uses each location, along with its paired random points, as separate entries. This substantially increased the number of data points and thus decreased the variance. For this reason, discrete choice seems to be a more efficient way to analyze similar data.

MANAGEMENT IMPLICATIONS

By performing mid-contract management, land managers can set back successional progression of CRP grasslands and reintroduce forbs that have been lost through time, improving declining habitat. In addition to actively selecting disced and interseeded CRP fields, nest success and brood survival were also higher in these habitats (Chapter 2). However, the benefits in terms of production may be short-lived without continued management. Negus (2005) found that 3 years post-treatment, fields were dominated by tall, smooth brome with sparse patches of alfalfa and red clover. Benefits of mid-contract management, including higher nest and brood survival (Chapter 2), may be one or two more years on sites dominated by native warm season grasses. An annual rotation of disturbances, including discing and interseeding, could be used to create a mosaic of cover types to meet the pheasant's diverse habitat needs.

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Table 1-1. Used and available (within 400-m and 800-m radius from nests) nest-site cover types of ring-necked pheasants in landscapes containing managed CRP in Stanton County, Nebraska during 2005 and 2006.

Cover Type	Average available nesting habitat (%)		Nest attempt					
			Initial nest		Renest		Combined	
	400-m	800-m	n	%	n	%	n	%
2005								
CRP	45.96	37.27	11	45.83	4	40.00	15	44.12
Interseeded CRP	24.92	16.06	12	50.00	4	40.00	16	47.06
Other grassland	10.00	13.34	1	4.17	2	20.00	3	8.82
Other	19.12	33.03	0	0.00	0	0.00	0	0.00
2006								
CRP	39.40	31.11	13	46.43	5	45.45	18	46.15
Interseeded CRP	25.24	16.38	12	42.86	6	54.54	18	46.15
Other grassland	10.68	12.52	2	7.14	0	0.00	2	5.13
Other	24.68	40.00	1	3.57	0	0.00	1	2.56

Table 1-2. Macrohabitat discrete-choice coefficient of selection and log-ratio analysis of nesting habitat preference of pheasant hens in Stanton County, Nebraska, 2005-2006.

Variables	Discrete Choice			Log-ratio	
	Parameter estimate	Standard error	<i>P</i>	Log-ratio	Standard error
800-m scale					
CRP	-			0.31	0.21
Interseeded CRP	1.09	0.35	<0.01	1.02	0.29
Other Grassland	-1.21	0.56	0.03	-0.66	0.53
Other	-3.63	1.04	<0.01	-3.29	1.01
400-m scale					
CRP	-			0.06	0.19
Interseeded CRP	0.95	0.31	<0.01	0.62	0.24
Other Grassland	-0.25	0.55	0.66	-0.42	0.55
Other	-2.90	1.05	<0.01	-2.77	1.02

Table 1-3. Comparison of competing discrete-choice models for microhabitat selection of nesting ring-necked pheasants in northeast Nebraska 2005-2006. Models are ranked using Akaike's Information Criterion corrected for a small sample size (AIC_c); K is the number of parameters, ΔAIC_c is the difference of each model's AIC_c value from that of the highest ranked model (row one), and ω_{AIC} is the Akaike weight (sum of all weights = 1.00).

Model	K	AIC_c	ΔAIC_c	ω_{AIC}
FORB ¹ +VOR ² +BARE ³ +COOL ⁴ +WARM ⁵	5	56.64	0.00	0.51
FORB+VOR+BARE	3	56.73	0.09	0.49
FORB+COOL+WARM	3	68.78	12.14	0.00
VOR+BARE	2	70.50	13.86	0.00
VOR+BARE+COOL+WARM	4	71.20	14.56	0.00
FORB	1	79.27	22.63	0.00
COOL+WARM	2	96.71	40.07	0.00
CONSTANT	0	99.81	43.17	0.00

¹ FORB: % cover forbs

² VOR: visual obstruction reading

³ Bare: % bare ground

⁴ COOL: % cover cool-season grass

⁵ WARM: % cover warm-season grass

Table 1-4. Model averaged coefficient (β) estimates and 95% confidence intervals for vegetative composition (% forb, % bare ground, % warm season grass, % cool season grass) and visual obstruction reading (VOR) surrounding nest of ring-necked pheasant hens in northeast Nebraska, 2005-2006.

Parameter	β estimate	SE	Confidence Intervals
VOR	1.14	0.37	$0.41 < \beta < 1.87$
FORB	0.11	0.04	$0.02 < \beta < 0.18$
BARE	0.03	0.02	$-0.1 < \beta < 0.08$
WARM	0.02	0.03	$-0.03 < \beta < 0.08$
COOL	0.01	0.01	$-0.02 < \beta < 0.03$

Table 1-5. Macrohabitat logistic regression and compositional analysis of brood rearing habitat preference of pheasant hens in northeast Nebraska, 2005-2006. Both discrete choice and compositional analysis use Conservation Reserve Program (CRP) habitat as a baseline.

Variables	Discrete Choice			Compositional Analysis		
	Parameter estimate	SE	P	Mean difference of LR	SE	P
800-m scale						
CRP	-			-		
Interseeded CRP	1.00	0.14	<0.01	1.20	1.16	0.32
Other Grassland	-0.12	0.17	0.48	-0.44	1.23	0.72
Other	-0.78	0.16	<0.01	-2.23	1.24	0.09
400-m scale						
CRP	-			-		
Interseeded CRP	0.57	0.15	<0.01	1.12	1.08	0.31
Other Grassland	-0.03	0.18	0.89	-0.27	1.17	0.82
Other	-0.72	0.17	<0.01	-1.82	1.13	0.13

Table 1-6. Comparison of competing discrete-choice models for microhabitat selection of ring-necked pheasant brooding hens in northeast Nebraska 2005-2006. Models are ranked using Akaike's Information Criterion corrected for a small sample size (AIC_c); k is the number of parameters, ΔAIC_c is the difference of each model's AIC_c value from that of the highest ranked model (row one), and ω_{AIC} is the Akaike weight (sum of all weights = 1.00).

Model	K	AIC_c	ΔAIC_c	ω_{AIC}
FORB ¹ +VOR ² +BARE ³	3	106.57	0.00	0.51
FORB+VOR+BARE+COOL ⁴ +WARM ⁵	5	107.11	0.54	0.39
FORB	1	110.27	3.70	0.08
FORB+COOL+WARM	3	113.26	6.70	0.02
VOR+BARE+COOL+WARM	4	132.31	25.74	0.00
VOR+BARE	2	137.79	31.22	0.00
COOL+WARM	2	170.40	63.83	0.00
CONSTANT	0	180.22	73.65	0.00

¹ FORB: % cover forbs

² VOR: visual obstruction reading

³ Bare: % bare ground

⁴ COOL: % cover cool-season grass

⁵ WARM: % cover warm-season grass

Table 1-7. Model averaged coefficient (β) estimates and 95% confidence intervals for the relationship of vegetative composition (% forb, % bare ground, % warm season grass, % cool season grass) and vertical obstruction (VOR) surrounding brood locations with ring-necked pheasant brood survival in northeast Nebraska, 2005-2006.

Parameter	β estimate	SE	Confidence Intervals
Forb	0.10	0.03	$0.04 < \beta < 0.16$
Visual obstruction	0.63	0.28	$0.08 < \beta < 1.19$
Bare ground	0.02	0.02	$-0.01 < \beta < 0.05$

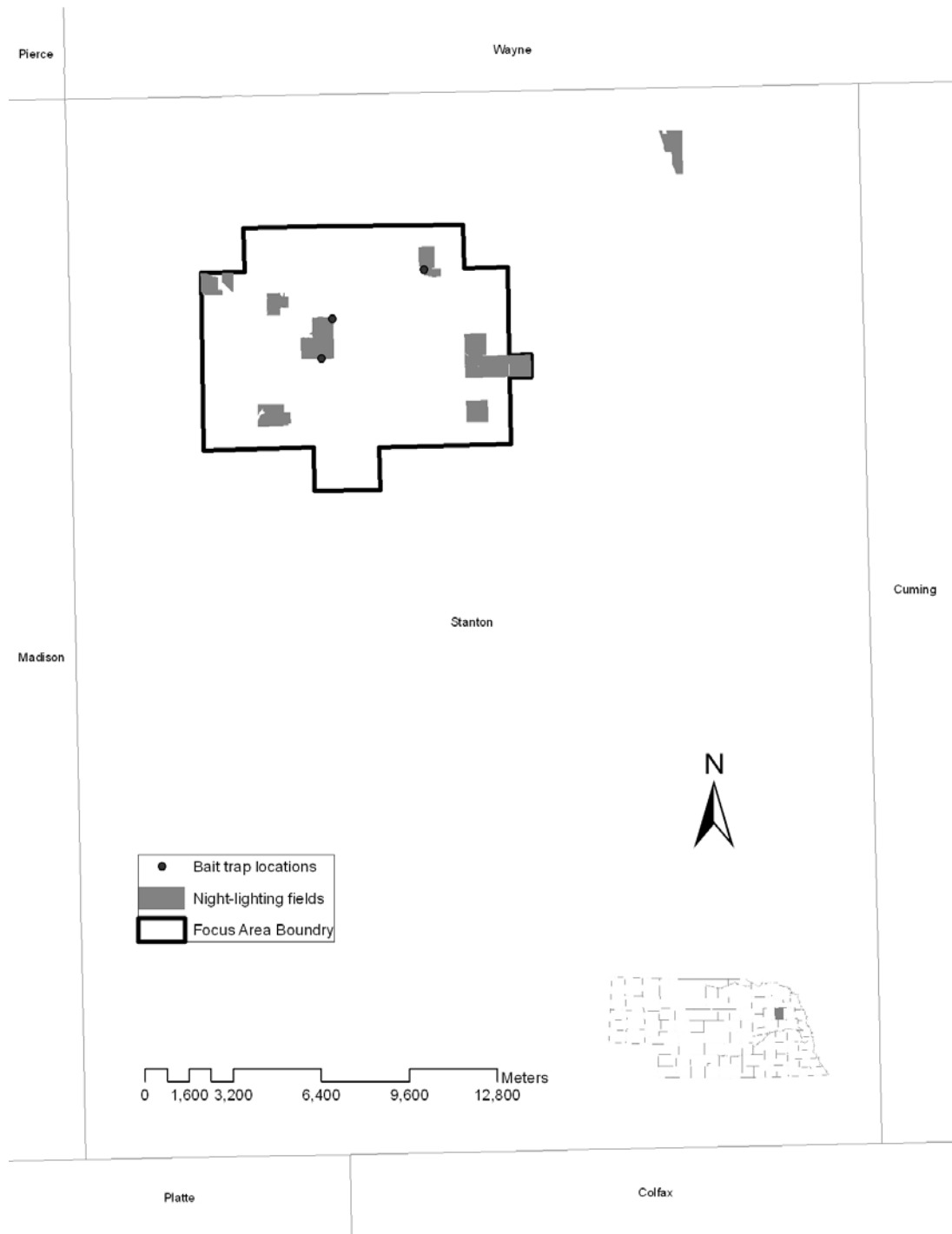


Figure 1-1. Map of study site showing Pheasants Forever/NGPC Focus Area and night-lighting and trapping locations in Stanton County, Nebraska (inset), 2005-2006. Names of surrounding counties are provided near border.

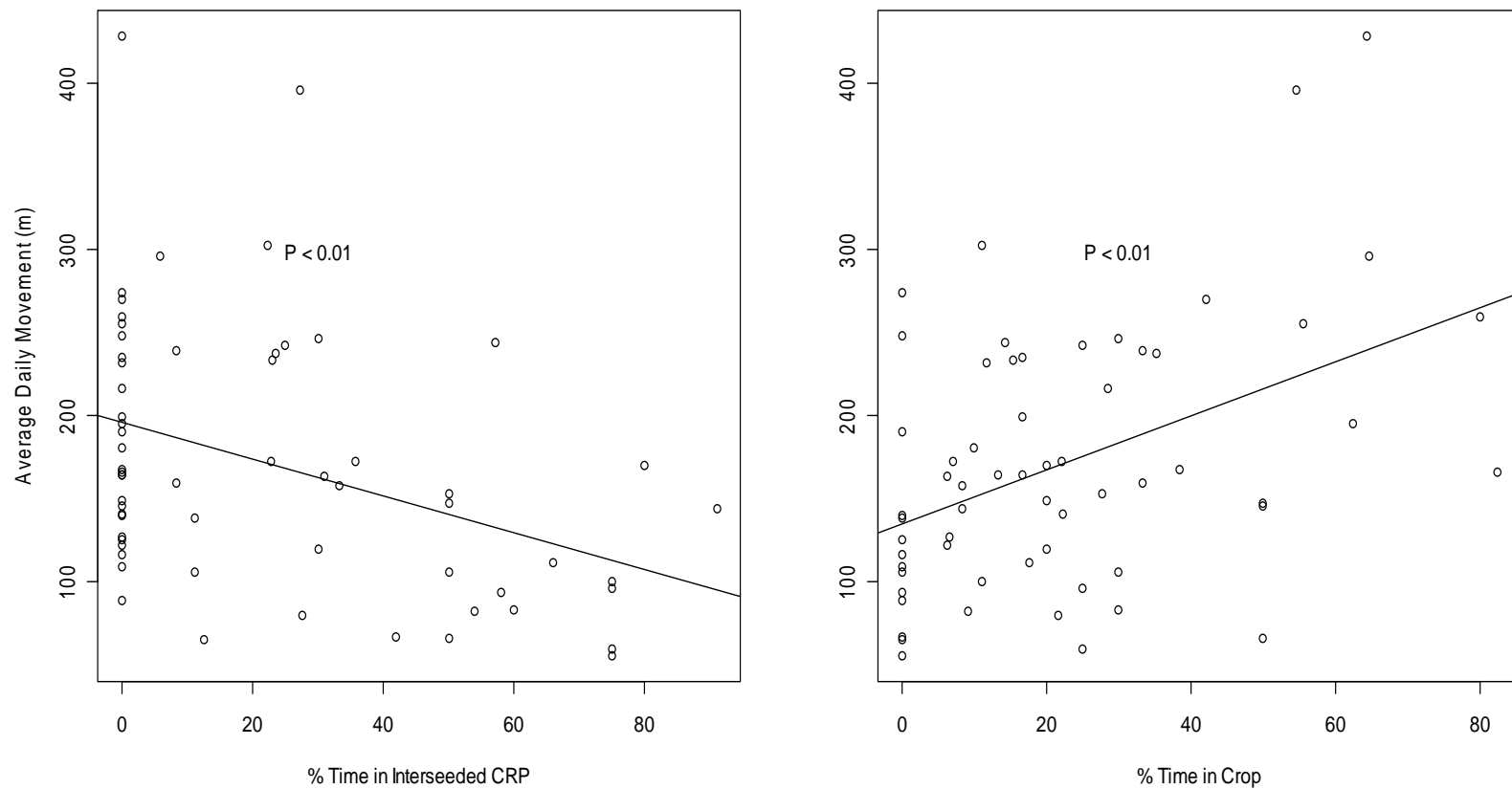


Figure 1-2. Relationship of habitat selected by hen pheasants with average daily movement (m) during the 3 weeks prior to incubation in Stanton County, Nebraska during 2005-2006.

CHAPTER 2. Mid-contract management of CRP provides benefits for ring-necked pheasant nest and brood survival.¹

¹ To be submitted to Journal of Wildlife Management. Co-authors: J. S. Taylor and L. A. Powell.

Abstract: Conservation Reserve Program (CRP) fields may provide good habitat for nesting and brood-rearing ring-necked pheasants (*Phasianus colchicus*) during early stages of succession. The reproductive period is especially critical for pheasant populations, and CRP's benefits to hens and chicks may decrease as fields age due to loss of vegetative diversity, decrease in vegetation density, and accumulation of residual litter. The Nebraska Game and Parks Commission disced and interseeded legumes in mid-contract CRP fields in northeast Nebraska to attempt to reverse this decline in habitat suitability. Our objectives were to assess spatial and temporal variation in nest and brood survival rates of pheasant hens in a landscape affected by mid-contract management. We found daily nest survival varied among habitats; nests in disced and interseeded CRP had a higher daily survival rate (0.984; 95% CI: 0.96, 0.99) than nests in unmanaged grasslands (0.951; 95% CI: 0.94, 0.97). Daily brood survival rates varied by habitat type, brood age, and date of hatch. Brood survival rates increased with time spent in disced and interseeded CRP and as the brood aged. Survival decreased as brood spent more time in cropland and peaked seasonally with broods that hatched on June 15. The positive response of nest and brood survival to discing and interseeding CRP provides further evidence that CRP fields must be managed to optimize wildlife benefits.

INTRODUCTION

Hen survival, as well as nest and brood survival, has been linked to the decline in populations of ring-necked pheasants (*Phasianus colchicus*, hereafter pheasants) throughout the Midwest (Warner et al. 1984, Etter et al. 1988, Schmitz and Clark 1999, Warner et al. 1999). Pheasant mortality increases as hens shift from using protective winter cover to searching for suitable nest sites (Hill and Robertson 1988). Hen survival may be enhanced by having winter cover near abundant, high-quality nesting cover, the latter of which is being lost through current farming practices (Schmitz and Clark 1999). Low nest and brood survival has also been attributed to the loss of quality nesting and brood rearing habitat (Warner et al. 1987, Warner et al. 1999), along with other factors including climate and hatch date (Riley et al. 1998).

A primary goal of the Conservation Reserve Program (CRP) is to mitigate loss of wildlife habitat. Given the billions of dollars (\$1.8 billion in FY06 [USDA 2006]) spent to fund CRP, habitat provisions and guidelines should maximize the use of these federal funds for reaching wildlife population goals. Evidence suggests that CRP is not reaching its potential to provide optimal wildlife habitat, including habitat for ring-necked pheasants, due to the lack of vegetative and structural diversity in CRP fields (Rodgers 1999).

Early research suggested that CRP increased the amount of suitable nesting and brood rearing cover in many of the Great Plains states (Dahlgren 1988). Riley (1995) demonstrated an increase in pheasant numbers in relation to an increase in CRP, but benefits in most states were short lived. CRP was less beneficial to wildlife than

anticipated (Church and Taylor 1999, Rodgers 1999), due to effects of field age on plant succession and lack of active habitat management in fields under CRP contracts (King and Savidge 1995, Ryan et al. 1998, Rodgers 1999). In the early stages of succession, CRP provides dense nesting cover and high diversity vegetation. Early successional vegetation includes forbs which tend to be associated with high invertebrate abundance, the primary food source for pheasant chicks (Hill 1985). Also, bare ground provided by early successional grass stands offers movement corridors used for young pheasants to capture prey and avoid predators (Doxon and Carol 2007). Without active habitat management during the contract period, CRP fields often become dense, monotypic grass stands.

The Nebraska Game and Parks Commission (NGPC) has actively supported discing and interseeding legumes in late successional, monotypic CRP fields since 2002; NGPC's goal was to increase the pheasant abundance by disturbing the later serial stages of CRP grasslands to provide early successional habitats. Negus (2004) and Matthews (Chapter 1) demonstrated that discing and interseeding monotypic CRP fields increase vegetation density, preferred by nesting hens. Similarly, this type of management has been shown to increase forb and legume cover, along with bare ground (Greenfield et al. 2002, Greenfield et al. 2003, Leathers 2003). As vegetation diversity increased post-management, Leathers (2003) found an increase in arthropod abundance. Both nesting and brooding hens preferred disced and interseeded CRP (DI-CRP) to unmanaged CRP fields as a result of an increase in forb and legume content (Chapter 1).

Pheasant productivity can vary within the breeding season and may be affected by weather. Extreme temperatures and precipitation events are thought to negatively affect

nest and brood survival (Riley et al. 1998, Schmitz and Clark 1999). Riley et al. (1998) also found that chicks hatched later in the year had lower body mass and experienced lower survival than those hatched earlier in the breeding season. These factors must also be accounted for when assessing habitat effects in production.

The purpose of our study was to determine the impact discing and interseeding CRP fields have on radio-tagged pheasant productivity in eastern Nebraska. Our objectives were to (1) monitor nests of radio-marked hens to estimate survival rates, (2) monitor broods of radio-marked hens to estimate survival rates, and (3) develop a productivity model to assess landscape effects on pheasant productivity. We assessed variation in nest and brood survival in relation to macro-scale, landscape variables as well as vegetative composition and structure, weather, and temporal variables.

METHODS

Study Area

Our study was conducted in Stanton County, Nebraska during 2005 and 2006. We identified an 83-km² study area located north of Stanton, Nebraska within the tall grass prairie ecoregion (average precipitation, 1893-2003: 671 mm [UNL High Plains Regional Climate Center]). The landscape is now dominated by agricultural development including corn, soybean, and alfalfa production (Hammond 1982). However, approximately 2200 ha (5400 ac) of the cropland in our study site were enrolled in CRP prior to 2005. Most of the CRP fields in this area were well established (> 10 years) at the beginning of our study; no management had occurred in the fields since their enrollment in CRP. Fields were initially planted with a mixture of native or nonnative grass or grass-forb mixtures. Preliminary observations revealed that fields were generally

monocultures of smooth brome (*Bromus inermis*) or switchgrass (*Panicum virgatum*); legume and other forb components were scarce or nonexistent (Taylor 2002).

Habitat Improvements

Field biologists from Nebraska Game and Parks Commission disced and interseeded portions of 36 CRP fields within the study area during 2002–2005. The portions of the target fields were selected for management based on topography and landowner preference. Preference was also given to portions of fields that had been mowed the previous year because mowing reduced residual litter and improved success of discing.

Each portion of the target field was treated with 2–3 passes with a tractor-pulled tandem disc designed for sod breakup to a depth of 8 to 10 cm. A no-till drill was used to interseed a mixture provided of alfalfa (*Medicago sativa*), yellow sweet clover (*Melilotus officinalis*), and/or red clover (*Trifolium pratens*). Legumes were seeded at a rate of 6.75 kg/ha (1.69kg of red clover, 1.69 kg of yellow sweet clover, and 3.38 kg of alfalfa). No more than 1/3 of each target field was disced and interseeded each year. Discing depths, seeding rates, and timing of discing and interseeding complied with United States Department of Agriculture (USDA) guidelines (Natural Resource Conservation Service 2002). By May 2004, approximately 850 ha of CRP had been interseeded in the study area; the interseeded area represented 27.8% of CRP acres and 10.5% of the study area.

Radio-telemetry.

We captured pheasant hens using baited funnel-entrance box traps (Wilbur 1967) and night-lighting techniques (Labisky 1956). We captured hen pheasants in 13 fields within the study area with one field outside the area. We selected trapping and night-

lighting sites based on evidence of high pheasant abundance, but we also attempted to distribute captures throughout the study area. We fitted each hen with a necklace type radio transmitter weighing 18 g (Model #A3960, Advanced Telemetry Systems, Inc., Isanti, Minnesota, USA); marked hens were immediately released. Our animal capture and handling protocols were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee (Protocol #05-02-007).

We used vehicle-mounted, null-peak antenna-receivers with an electronic compass (Gilsdorf et al. 2008) to estimate the location of each hen with triangulation 5–10 times/week from 1 February to 1 August of each year. We located hens between 0700 and 2000 hours, but randomly ordered fields containing hens to locate each bird at different times of day. We took at least three bearings to estimate each location within a 5- to 15-minute period to minimize movement bias. Additional bearings were taken until the error polygon produced was less than 1500 m² (approx 22-m radius). All Universal Transverse Mercator (UTM) coordinates and error polygons were processed in the field by an on-board computer using Location Of A Signal (LOAS) software (Ecological Software Solutions, Urnäsch, Switzerland, Version 4.0). We located missing hens by systematic ground searches and aerial telemetry.

Nest and Brood Monitoring.

The location of each nest was determined 2–5 days after incubation initiation, as determined by sequential hen locations in the same area. While the hen was on the nest, we determined the general location (precision <5 m) of the nest using a hand held antenna-receiver. We placed flagging 5m to the north and south of the nest to mark the general location of the nest (Giuliano and Daves 2002). We attempted to minimize

flushing hens from nests during our initial visit, as disturbance has the potential to decrease nest success (Evans and Wolfe 1967). We obtained the exact location of the nest using a hand-held Global Positioning System unit and recorded the number of eggs in the nest while the hen was away from the nest. We continued to monitor the fate of the nest with telemetry observations of the radio-marked hen. For successful nests, we recorded the number of hatched eggs as determined by the presence of detached shell membranes. Nests were considered successful if ≥ 1 egg hatched. We used daily telemetry observations to locate hens with brood for 21 days after hatch. At days 10 and 21, post-hatch, we flushed hens with broods from nocturnal roost sites to determine if each hen still had a brood. A brood was considered successful if ≥ 1 chick survived.

Habitat and Vegetation Sampling

We determined macro-scale, landscape composition by creating year-specific, vector-based Geographic Information System (GIS: ArcGIS 9.0, ESRI, Redlands, CA) landcover layer. We used aerial photographs and ground-truthing to determine landcover classes for 2005, and we modified the layer for 2006 using ground-truthed observations to determine changes in crop rotation and other adjustments. NGPC continued to initiate discing and interseeding of CRP fields in our study area through 2005, and we incorporated these changes in our landcover layer. Our landcover layer included the following classifications: (1) warm-season CRP (switchgrass, big bluestem [*Andropogon gerardi*], little bluestem [*Schizachyrium scoparium*], Indiangrass [*Sorghastrum nutans*], sideoats grama [*Bouteloua curtipendula*]), (2) warm-season DI-CRP, (3) cool-season CRP (predominantly smooth brome), (4) cool-season DI-CRP, (5) other grasslands

(grazed and hayed pastures, roadsides, ditches, terraces), and (6) other landcover types (any landcover not included above).

We used coordinates of nest and brood locations to assign landcover classifications. We recorded micro-habitat information at each nest site and at every third recorded brood location including overlapping percent canopy cover of grasses (GRASS), forbs (FORB), woody vegetation (WOOD), and bare ground (BARE) to the nearest 5% using a 1-m diameter sampling ring (adapted from Daubenmire 1959). We also estimated vegetative density by using visual obstruction readings (VOR) to the nearest 0.25 dm at the nest site (Robel et al. 1970). We assessed vegetation composition and density at one paired random point for both nest and brood locations ≥ 50 m away in the same field.

Survival analysis

Nest survival

We expected nest survival to vary according to landcover classification, vegetation composition/structure, and weather, as well as temporally. We combined individual covariates to construct a set of 16 *a priori* models. We used a null model with no covariates as the simplest model (constant survival through time and space) for comparison. We compared the null model to models composed of all biological reasonable combinations of the following groups of covariates: 1) landcover type (DI-CRP, CRP, and other grasslands) 2) vegetation composition and structure (% cover; GRASS, FORB, VOR) 3) a quadratic function ($DAY + DAY^2$) of date in breeding season during the nest monitoring interval (DAY: deviation from the median initiation of incubation [May 27]) and 4) weather (average daily temperature [TEMP], average daily

precipitation [PRECIP] during the nest monitoring interval). We did not distinguish between unmanaged CRP and other non-CRP grasslands, as their structure appeared similar. We used unmanaged CRP as our baseline categorical landcover type variable in the model structure. We estimated date of nest initiation for calculating Julian day of initiation by using location data and hen movement patterns. We right-censored nests that we believed were abandoned because of our monitoring.

We used the logistic-exposure method to estimate daily survival of pheasant nests and evaluate time and site-specific factors that may affect survival (Shaffer 2004). The logistic-exposure method allows exposure time, or time between visits, to vary. Logistic-exposure also allows for time-dependant variables to stay constant within monitoring intervals but vary between intervals (Shaffer 2004). We used this method for nest survival because we generally monitored nests five or six times per week. We constructed our models using the Shaffer (2004) structure and an adaptation of the logistic regression model in R (R Development Core Team 2006, Post van der Burg 2005).

Brood survival

We had similar expectations for causes of variation in brood survival. Thus, we compared the null model (i.e., constant survival) to models composed of biological reasonable combinations of the following groups of covariates: 1) landcover (proportion of locations during each monitoring interval in each landcover type: DI-CRP, CRP, other grassland, cropland) 2) time (a quadratic function [DAY+ DAY²] of days past the season's first hatch), and 3) weather (average daily temperature [TEMP], average daily

precipitation [PRECIP] during the monitoring interval). We used unmanaged CRP as the baseline categorical variable in the landcover model structure.

We also used the logistic-exposure method to estimate daily pheasant brood survival, because our observations of brood survival were limited to 2 flushing occasions, at 10 and 21 days after hatch. We encountered numerical difficulties with convergence using the standard iterated weighted least squared method because some categories had no observations of death; all broods survived during the 10- to 21-day period.

Consequently, we estimated survival in a Bayesian-Markov Chain Monte Carlo (MCMC) framework using WinBUGS (Version 1.4.2) and R2WinBUGS package (R package version 2.1-8) in R. For each MCMC run, we used 3 replicate chains of 100,000 iterations, each initialized by sampling a starting value for each parameter from a normal distribution with a mean of 0 and a standard deviation of 0.2. We discarded (ie. burn-in) the first 50,000 samples in order to minimize bias associated with the initial parameters. We thinned the chains of simulation by keeping every 150th simulation to account for any possible autocorrelation between parameters.

We performed model selection using an information-theoretic approach to evaluate *a priori* models for both nest and brood survival. We ranked each model from most to least support given the data using Akaike's Information Criterion corrected for small sample size (AIC_C ; Burnham and Anderson 2002). We used effective sample size ($n = \text{total number of days samples survived} + \text{number of intervals that ended in failure}$) for the calculation of AIC_C (Rotella et al. 2004). We computed Akaike weights (ω_{AIC}) for each model, where ω_{AIC} represents the probability that a model is the best approximating model of those considered given the data (Burnham and Anderson 2002).

To select the best model from the nest and brood model sets, we first selected the top models that had a combined model weight of $\geq 90\%$ (Burnham and Anderson 2002). We selected the highest-ranked model from that set, if the highest-ranked model was the most parsimonious of the set (Richards 2008). When the highest-ranked model was not the most parsimonious, we used conditional model averaging over the 90% confidence set to predict the covariates and associated standard errors (Burnham and Anderson 2002).

We estimated daily nest and brood survival rates as a function of the explanatory variables using either the model averaged predictions or the top predictive model. To describe effects of continuous factors on nest and brood survival, we varied the continuous variable of interest within the observed range while holding all other variables at their mean. We calculated probability of nest (23-day incubation) and brood (21-day period) success as the product of the daily survival for each day in their respective period (Shaffer and Thompson 2007). We estimated 95% confidence intervals using the delta method (Powell 2007). We used weather data from Norfolk Karl Stefan Airport weather station in Norfolk, NE, approximately 16 km west from the center of the study area for both nest and brood survival weather data.

Productivity Model

We used program R to modify Powell et al.'s (1999) stochastic, dynamic, individual-based productivity model to simulate dynamics of pheasants. We used nest and brood survival rates obtained from our concurrent analysis. We used an adult daily survival rate of 0.996 (se = 0.0002; T. Matthews, unpublished data). The results of this study (ie. nest and brood survival, nest size, probability of second and third nest attempt)

were used in the simulation. All vegetation, weather and temporal variables were held at their means to produce the daily nest survival rate and brood survival rate used in each scenario. We simulated three scenarios to assess potential impacts of landscape changes on pheasant productivity: 1) no DI-CRP on landscape (no hens nested or reared broods in DI-CRP), 2) landscape with moderate amounts of DI-CRP (50% of hens nested and reared broods in DI-CRP), and 3) landscape with abundant DI-CRP (100% of hens nested and reared broods in DI-CRP). Each scenario was simulated as a landscape with 2000 hens; we performed 200 simulations of each scenario. For each brood, the model ran for 21 days after hatching. The model outputs were the mean and SD of the number of chicks produced per hen during a breeding season (Powell et al. 1999).

RESULTS

We captured and monitored 110 hens (2005: 54, 2006: 56). We located and monitored 73 nests (2005: 34, 2006: 39) in the 4 landcover classes (DI-CRP: 34, CRP: 33, other grasslands: 5, other: 1). The median incubation start date for first nest attempts pooled over both years was 11 May, and 10 June for second attempts. The median hatch date was 16 June with an average of 11.3 (SE = 3.4) eggs/nest. The probability of a hen attempting a second nest was 0.39, and the probability of third nest attempt was 0.02. Broods surviving to day 21 had an average of 4.8 (SE = 2.1) chicks per brood. Sixteen of 34 (47%) nests successfully hatched in 2005; 11 broods had at least one chick 21 days post-hatch. Two hens died before their broods reached day 10, and the broods were presumed dead. Eleven of 39 (28%) nests were successful in 2006 with 6 broods surviving past 21 days. Ten of 27 hens with broods had the majority of their locations in DI-CRP, more than any other landcover type (CRP: 7, other grassland: 5, row crop: 5).

Nest survival.— No single model was selected through initial model comparisons, so we model-averaged covariate estimates across nine models that cumulatively accounted for $\geq 90\%$ of the ω AIC (Table 1). Landcover had the strongest effect on nest survival and was a covariate present in 8 of the top 9 models (Table 1). The covariate for unmanaged grassland classification differed significantly from zero (baseline DI-CRP; Table 2). Nests found in unmanaged grasslands had a lower rate of daily survival (0.951, 95% CI: 0.941 – 0.972) compared to those in DI-CRP (0.984, 95% CI: 0.957 – 0.994; Table 2). The probability of 23-day nest success (using mean values for day and precipitation) was 0.696 (95% CI: 0.631 – 0.762) for DI-CRP and 0.314 (95% CI: 0.240 – 0.389) for unmanaged grasslands. Vegetation structure and composition was also included in the top model and was present in 4 of the top 5 models, although the model averaged confidence intervals for each parameter included zero (Table 2).

Brood survival.— We found a high correlation between hatch date and temperature ($r=0.77$). Thus, temperature was subsequently removed from our models when hatch date was included. Variation in brood survival was best explained by two models, which both included landcover and hatch date components. The second best model also included weather variables (Table 3). These models accounted for $\geq 90\%$ of the ω AIC; therefore we used the top, most parsimonious model, which indicated that brood survival was a function of landcover and hatch date (Table 3). Brood survival increased as the brood spent a greater proportion of its time in DI-CRP and less time in unmanaged CRP (Table 4, Fig. 1a). Brood survival decreased as time in crop fields increased (Table 4, Fig. 1b). Daily survival of broods declined as the hatch date deviated from June 15 (Table 4, Fig. 2). The probability (using mean value for day and the mean

landcover use information across broods) of a brood surviving to day 21 was 0.710 (95% CI: 0.610 – 0.856). If the landcover use information for all broods was modified by replacing DI-CRP with unmanaged CRP, survival would be reduced to 0.36 (95% CL: 0.100 – 0.701).

Productivity.— Our first scenario, no DI-CRP on the landscape, achieved a mean of 1826 (SE = 92.9) chicks surviving through August 15 from 2000 hens. The second scenario, with 50% of hens nesting and raising broods in DI-CRP, resulted in productivity of 4632 (SE = 151.6) chicks. Last, when 100% of hens nested and raised broods in DI-CRP, productivity increased to 5398 (SE = 155.0) chicks.

DISCUSSION

Our data suggest that nesting hens could double their probability of nest success (69% vs. 31%) by selecting nest sites in DI-CRP areas. Also, productivity, a function of nest success and brood success, was dramatically higher when the simulated landscape contained large amounts of DI-CRP. Our nest success rate in unmanaged grasslands (31%) was similar to rates from Illinois reported by Warner et al. (1987) but below Clark et al.'s (2008) benchmark of 42% nest success, which they suggested is needed to maintain a stable population under average conditions. Certainly, sub-optimal nest success in unmanaged, low diversity grasslands could be partially responsible for the recent decline in pheasant numbers throughout most of the Great Plains states, even after the introduction of CRP (Rodgers 1999). Higher nest success may not always correspond to higher rates of productivity (Powell et al. 1999), but Hill and Robertson (1988) reported that with simulated data a 50% increase over an average nest success rate had a significant effect on autumn pheasant numbers. Our data suggest an increase of

greater than 100%, which should have profound population effects. We suggest that programs that apply mid-contract management to significant portions of a landscape could benefit local pheasant populations through increased nest survival, even if brood survival is unaffected by management of CRP.

Why do hens in DI-CRP have higher nest success? We suggest two possible mechanisms: 1) vegetation structure effects on predators, and 2) higher insect availability as food for hens. Our data do not directly support the first hypothesis, as we did not find that vegetation structure (VOR) at the nest bowl caused variation in nest survival (Tables 1, 2). We did find that DI-CRP fields had greater vegetation density and structural heterogeneity around the nest bowl at the patch scale than monotypic grasslands found in unmanaged CRP and pasture fields (Chapter 1). Also, structural heterogeneity in the habitat patch surrounding the nest can be more important for nest success than the vegetation at the nest (Schranck 1972, Bowman and Harris 1980, Mankin and Warner 1992). Providing large patches with structural heterogeneity around ground nests can decrease the foraging efficiency of nest predators (Bowman and Harris 1980). An increase in heterogeneity at the patch level can increase the search time of nest predators and subsequently decrease the number of clutches found. An increase in the vegetative density in a field may also act as a physical barrier and deter nest predators (Schranck 1972, Duebbert 1969, Schmitz and Clark 1999). Although we did not find a measurable increase in nest survival related to vegetation structure or composition at the nest site, our habitat selection analyses show that pheasants selected nest sites with higher percent forb cover and visual obstruction reading than random sites in the same field, regardless of landcover type (Chapter 1).

Second, Martin et al. (2000) and Rastogi et al. (2006) found that increased food availability resulted in shorter foraging bouts for nesting female songbirds, which resulted in lower rates of nest predation. Food availability in desired insect orders was higher on DI-CRP on our study site (Lucas Negus, NGPC, unpublished data). We did not measure hen foraging behavior, but we did find that hens moved less throughout the landscape when they were in DI-CRP (Chapter 1). Thus, if nesting hens fed primarily in insects, we could logically expect higher insect abundance in DI-CRP to cause the lower rates of nest mortality we observed.

Brood age, hatch date, percent time spent in DI-CRP fields, and percent time spent in crop fields were important predictors of brood survival (Table 3). An increase in daily brood survival as the brood ages has been well documented (Hill 1985, Riley et al. 1998). An increase in daily brood survival that begins at about 10 days of age may be attributed to an increase in the chicks' ability to thermoregulate (Gdowska et al. 1993) and their increased ability to avoid predators through short flights (Cramp and Simmons 1980).

We may be the first to show lower survival early in the season due to a non-linear trend in brood survival during the breeding season for ring-necked pheasants (Fig. 2). Grant et al. (2005) suggested that temporal effects may have been missed in previous studies because of the prevalence of linear modeling approaches. We believe the change in brood survival during the breeding season is related to other measured and unmeasured variables including temperature and insect abundance. Pheasant broods hatching early in the breeding season may experience lower-than-optimal environmental temperatures, retarding cold resistance and increase mortality (Ryser and Morrison 1954). Hill (1985)

found that pheasant chicks reduce the amount of time feeding in cold, wet conditions, and those conditions led to malnutrition, poor growth and ultimately mortality. Broods hatching later in the season may be exposed to higher environmental temperatures, inducing heat stress and water loss, and higher temperatures have been attributed to low production in other galliforms (Flanders-Wanner et al. 2005). Broods hatching early or late in the breeding season may also experience lower insect abundance due to the colder or warmer environmental temperatures (Riley et al. 1998). The decline in brood survival late in the breeding season of pheasants reaffirms the need of pheasant hens to have a successful first nest (Riley et al. 1998). This is reaffirmed in our study where pheasants seemed to nest at the optimum time to achieve the peak survival of broods (Appendix Figure 0-2). This may require land managers to carefully plan the timing of habitat management, such as controlled burning, grazing, discing and haying. Our data suggest that mid-season nests should be considered especially valuable to seasonal pheasant productivity.

Brood survival increased on our study area as hens and broods spent more time in DI-CRP fields, and this trend was especially dramatic for broods that were ≤ 10 days old (Fig. 1a). Although vegetation composition and structure were not included in our survival analysis, we associate the increased brood survival in DI-CRP fields with the influx of legumes and annual forbs and increase in bare ground associated with these types of fields (Chapter 1). Unmanaged CRP fields and pasture may provide adequate overhead cover for pheasant chicks but the vegetation may lack sufficient insect abundance. Abundance of important insect orders (*Coleoptera*, *Hemiptera*, *Hymenoptera*, and *Lepidoptera*) was 2.6 times higher in DI-CRP fields than in

unmanaged CRP fields (Lucas Negus, unpublished data). Hill (1985) found variation in insect abundance to explain 75% of the variation in brood survival. Forbs and other legumes produced in these habitats may also have forage value for brooding hens, including seeds and blossoms, reducing the need to forage in open cropland and the associated risks to predation. Croplands in Nebraska provide little, if any, insect prey for pheasant chicks due to pesticide use; in addition, field edges may create travel lanes for predators, decreasing survival. As hens with broods spend more time in crop fields, chicks may grow more slowly gaining flight and thermoregulation abilities at slower rates.

Unmanaged CRP grasslands also exhibit high vegetation stem density and high amounts of litter accumulation, both of which can decrease chick mobility (Doxon 2005). A decrease in mobility can hinder chicks in prey capture and predator avoidance. Discing CRP fields decreases litter and perennial grass densities and increases bare ground, which creates travel corridors needed for chick movement. Doxon and Carroll (2007) hypothesized that the amount of bare ground, rather than insect abundance, may be most the most critical factor for brood survival.

MANAGEMENT IMPLICATIONS

Our data suggest that the USDA's requirement of mid-contract management of new CRP contracts should benefit pheasant populations in the Midwest. We suggest that mid-contract management would be most effective when discing and interseeding are applied to a large portion of the landscape, as in our study area. A landscape-level approach to pheasant habitat management enhances nest and brood survival by creating a heterogeneous landscape, at both the macro- and micro-habitat level, which can have the

greatest effect on pheasant populations (Clark et al. 2008). Such efforts are labor intensive, but our study suggests that agencies will be rewarded for time spent working with landowners to disturb late successional CRP grasslands. Moreover, this type of management increases habitat quality for other declining species including northern bobwhite quail (*Colinus virginianus*), grasshopper sparrows (*Ammodramus savannarum*), bobolinks (*Dolichonyx oryzivorus*) and other grassland birds (Greenfield et al. 2002, Negus 2005).

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Table 2-1. Comparison of competing logistic-exposure models for ring-necked pheasant daily nest survival in northeast Nebraska, 2005-2006. Models are ranked by AIC_C , Akaike's Information Criterion, adjusted for small sample size; k is the number of parameters, ΔAIC is the difference of each model's AIC_C value from that of the highest ranked model (row one), and ωAIC is the Akaike weight (sum of all weights = 1.00). Sixteen models were considered, and the top nine models represent the 90% confidence set according to their ωAIC .

Model	k	AIC_C	ΔAIC	ωAIC
Landcover ^a + Vegetation ^b	5	247.55	0.00	0.26
Landcover + Vegetation + Day ^c	7	248.95	1.39	0.13
Landcover	2	249.23	1.68	0.12
Landcover + Vegetation + Day + Weather ^d	9	249.44	1.89	0.10
Landcover + Vegetation + Weather	7	249.89	2.34	0.08
Landcover + Day	4	249.99	2.44	0.08
Landcover + Day + Weather	6	251.07	3.52	0.05
Vegetation	4	251.35	3.80	0.04
Landcover + Weather	4	251.43	3.88	0.04
Constant	1	251.43	3.88	0.04
Vegetation + Weather	6	252.86	5.31	0.02
Weather	3	253.30	5.74	0.01
Day	3	253.67	6.11	0.01
Vegetation + Day	6	254.10	6.55	0.01
Vegetation + Day + Weather	8	255.01	7.45	0.01
Day + Weather	5	255.38	7.83	0.01

^aLandcover model: disced and interseeded CRP + unmanaged grassland

^bVegetation model: % grass + % forb + vertical obstruction reading

^cDay model: day + day²

^dWeather model: daily precipitation + daily temperature

Table 2-2. Model averaged coefficient (β) estimates and 95% confidence intervals (CI) for habitat, vegetation structure and composition, day of nest incubation (Day), daily temperature, and daily precipitation effects on survival of nests of ring-necked pheasant hens in northeast Nebraska, 2005-2006. Coefficients were derived from the 90% confidence set.

Parameter	β estimate	95 % CI
Intercept	3.31	$2.06 < \beta < 4.56$
Landcover ^a		
Unmanaged grassland	1.18	$0.004 < \beta < 2.35$
Grass cover	-1.00	$-2.51 < \beta < 0.51$
Forb cover	-0.61	$-2.51 < \beta < 1.29$
Visual obstruction	0.03	$-0.21 < \beta < 0.27$
Day	0.01	$-0.01 < \beta < 0.03$
Day ²	0.00	$-0.002 < \beta < 0.0008$
Temperature	-0.010	$-0.05 < \beta < 0.03$
Precipitation	0.17	$-0.75 < \beta < 1.09$

^aUnmanaged CRP used as baseline in model ($\beta = 0.0$).

Table 2-3. Comparison of competing logistic-exposure models for ring-necked pheasant daily brood in northeast Nebraska, 2005-2006. Models are ranked by AIC_C , Akaike's Information Criterion, adjusted for small sample size; k is the number of parameters, ΔAIC is the difference of each model's AIC_C value from that of the highest ranked model (row one), and ωAIC is the Akaike weight (sum of all weights = 1.00). Eight models were considered; the top two models represent the 90% confidence set according to their ωAIC .

Models	k	AIC_C	ΔAIC	ωAIC
Landcover ^a + Day ^b	7	33.11	0.00	0.88
Landcover + Day + Weather ^c	9	37.44	4.33	0.10
Day	4	42.07	8.96	0.01
Landcover	4	44.07	10.96	0.00
Day + Weather	6	44.39	11.27	0.00
Landcover + weather	6	48.90	15.78	0.00
Constant	1	53.34	20.23	0.00
Weather	3	58.20	25.09	0.00

^aLandcover model: disced and interseeded CRP + unmanaged CRP + other grassland + crop

^bDay model: brood age + hatch date + hatch date²

^cWeather model: daily precipitation + daily temperature

Table 2-4. Posterior coefficient (β) estimates and 95% Bayesian credibility intervals for landcover, brood age and Julian hatch date (Day) for the top model from Table 3 on survival of broods of ring-necked pheasant hens in northeast Nebraska, 2005-2006.

Parameter	β estimate	95% BCI
Intercept	3.63	$1.87 < \beta < 5.39$
Landcover ^a		
Disced and interseeded CRP	3.76	$0.79 < \beta < 6.72$
Other grassland	1.15	$-1.93 < \beta < 4.23$
Crop	-2.72	$-5.43 < \beta < -0.01$
Brood Age ^b		
11 - 21 days	3.39	$0.88 < \beta < 5.9$
Day	0.005	$-0.05 < \beta < 0.06$
Day ²	-0.005	$-0.009 < \beta < -0.0005$

^a Percent time spent in each landcover type, unmanaged CRP used as baseline in model ($\beta = 0.0$).

^b Brood age from 1-10 days used as baseline in model ($\beta = 0.0$).

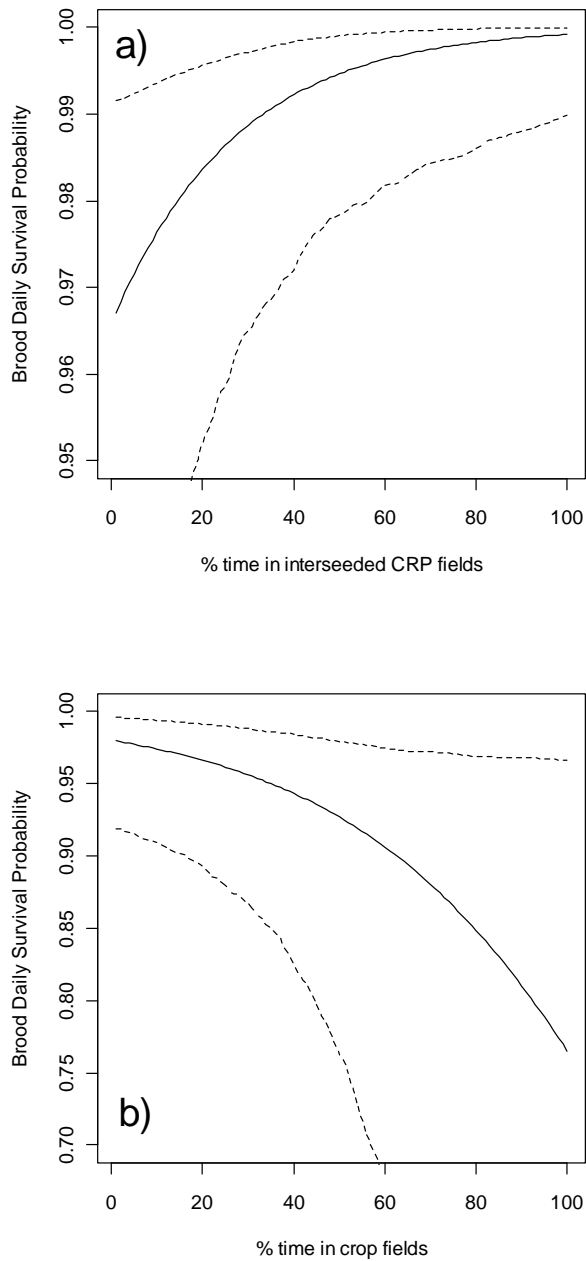


Figure 2-1. Daily survival (95% credibility interval: dotted line) of ring-necked pheasant broods in northeast Nebraska, 2005-2006, as a function of a) time spent in disced and interseeded CRP fields and b) as a function of time spent in crop fields with all other variables held constant and brood age set at 1-10 days.

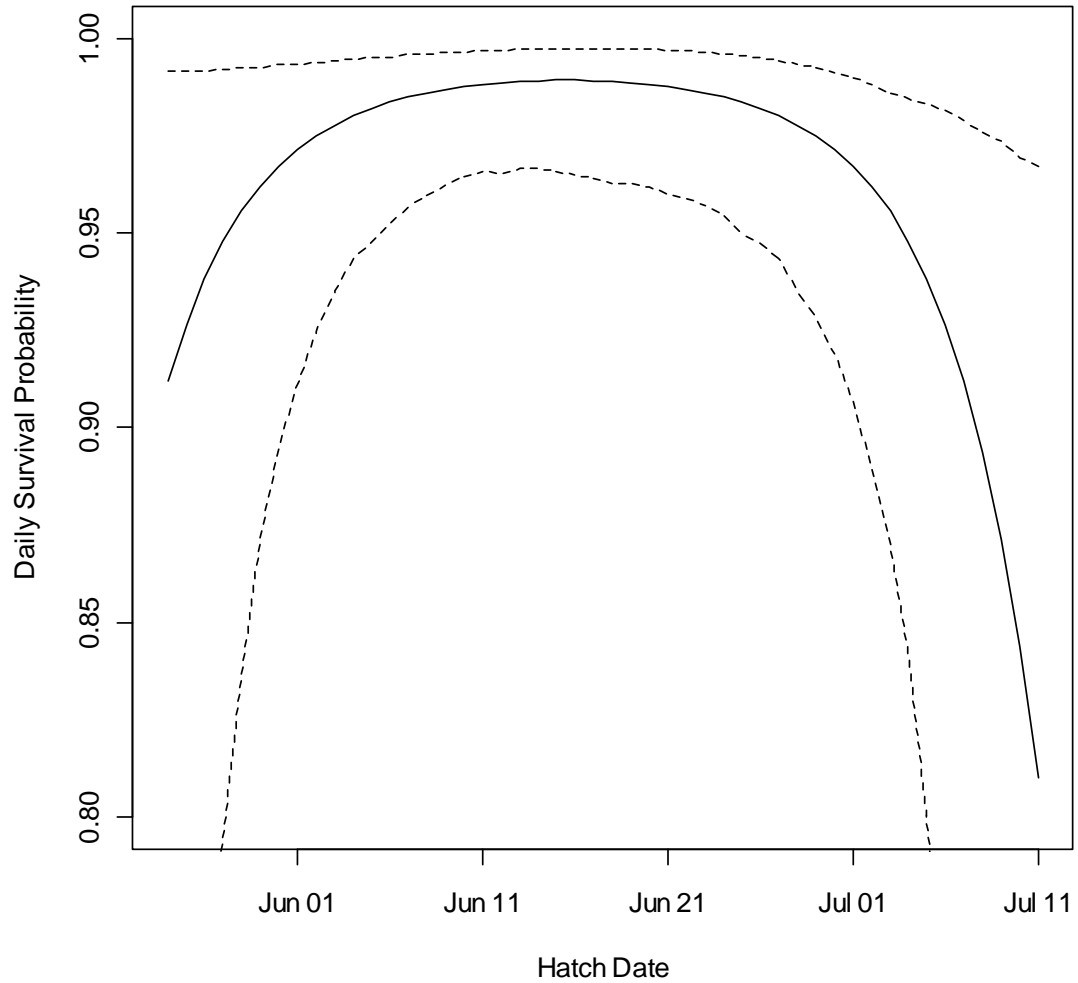


Figure 2-2. The non-linear effect of day in the breeding season on daily survival probability (95% CI: dotted line) of ring-necked pheasant broods in northeast Nebraska, 2005-2006.

CHAPTER 3. Greater Prairie-chicken nest success and habitat and selection in southeastern Nebraska.¹

¹ To be submitted to Journal of Wildlife Management. Co-authors: A. J. Tyre, J. J. Lusk, J. S. Taylor and L. A. Powell.

Abstract Greater prairie-chickens (*Tympanuchus cupido pinnatus*) are reported to nest in grasslands created through the Conservation Reserve Program (CRP). However, it is unknown if nests in CRP grasslands have similar survival rates as those in other grasslands, especially in landscapes with high amounts (>15%) of land enrolled in CRP, such as southeastern Nebraska. Similarly, it is unknown if high diversity seedings or mid-contract management improves habitat for Greater prairie-chickens in low diversity, established CRP grasslands. Therefore, our objectives were to characterize Greater prairie-chicken nest site selection and nest survival rates at both the macro-habitat and micro-habitat level. We monitored 90 nests during 2006-2007, 36 (40%) of which were successful. We compared nest sites' macro- and micro habitat characteristics with random points using discrete choice analyses, and we used logistic exposure analyses to assess the effect of habitat and other variables on nest survival. Prairie-chickens selected cool-season and warm-season CRP fields for nesting at rates 5.70 (95% CI: 2.60, 12.48) and 5.05 (95% CI: 2.17, 11.72), respectively, times higher than they selected rangeland. Prairie-chicken hens' selection of nest sites was affected by micro-habitat features: grass cover, forbs, and standing litter. Hens also selected sites with high topography. Nest survival was influenced by macro-habitat, micro-habitat, and temporal variables; nest survival was higher at sites in CRP fields with dense grass and moderate forb and litter cover. Prairie-chicken populations in southeastern Nebraska have increased because of the reproductive benefits of landscape modification under CRP; populations should benefit from continued management to provide high quality, diverse grasslands.

INTRODUCTION

Greater prairie-chicken (*Tympanuchus cuipdo pinnatus*; hereafter prairie-chicken) numbers in southeastern Nebraska prior to 1990 were extremely low due to conversion of grasslands to agricultural fields (Johnsgard 1983, Schroeder and Robb 1993). Prairie-chickens were never completely extirpated from this region, and the population began to increase noticeably following the restoration of grasslands as part of the United States Department of Agriculture's Conservation Reserve Program (CRP) (Taylor 2000). Although prairie-chickens in southeast Nebraska appear to have benefited from grasslands established through CRP, the mechanisms behind the increase in population size are not well understood. Our goal was to determine the mechanisms responsible for growth in populations of prairie-chickens, with specific focus on the role of CRP grasslands as nesting habitat.

Suitable nesting habitat has been cited as a major limiting factor in sustaining prairie-chicken populations (Bergerud 1988), and nest success may be affected by macrohabitat factors, such as landcover and fragmentation, and microhabitat factors, such as vegetation composition and structure (Hamerstrom et al. 1957, Buhnerkempe et al. 1984, McKee et al. 1998). Svedarsky (1979) found that prairie-chicken selected nest sites in grasslands similar to the CRP fields, typically dominated by smooth brome (*Bromus inermis*), found in southeastern Nebraska. These grasslands provide large expanses of undisturbed grasslands with dense cover up to 30 cm (Svedarsky et al. 2003). Although brome-dominated CRP fields provide suitable vegetation height and densities, it is unknown if the vegetation composition is optimal for nesting due to the increased

litter accumulation and lack of vegetative diversity found in undisturbed CRP fields (Buhnerkempe et al. 1984, Millenbah et al. 1996, McCoy et al. 2001). Native CRP and other undisturbed grasslands may be too tall and dense for nesting (Westemeier 1973, Svedarsky et al. 2003), and grazed pastures and rangelands may be too short and lack sufficient residual litter (Buhnerkempe et al. 1984, Walk 2004).

Nest success is an important factor determining annual recruitment and population stability of prairie-chickens (Horkel et al. 1978, Burger et al. 1988) and may be influenced by nesting habitat (McKee et al. 1998). Wisdom and Mills (1997) reported that nest success, along with brood survival, accounted for the largest amount of variability in population growth. Variability in nest success has been attributed to vegetation composition at the nest site including residual litter, forbs and grass cover (McKee et al. 1998), as well as landcover type (Svedarsky et al. 2003), and distance to woodland (McKee et al. 1998). Fields et al. (2004) also found lesser prairie-chicken (*Tympanuchus pallidicinctus*) nests were negatively affected by precipitation and nest age.

We assessed selection of nesting habitat by radio-tagged Prairie-chickens in a landscape containing grasslands. We evaluated habitat selection at 2 spatial scales to determine the effects of macro-scale, landscape composition, and micro-scale, vegetation structure and composition. Additionally, we examined whether these variables, plus temporal and weather related variables, could be used to predict nest success.

METHODS

Study Area

We studied prairie-chickens in Johnson, Gage, and Pawnee counties in southeastern Nebraska. Our study site was characterized by rolling uplands produced from accumulation of glacial till and loess. Soil types in these counties are generally comprised of Wymore-Pawnee soil association (USDA 1986). The regional climate is midcontinental with an average annual precipitation of 80.4 cm with the majority of that falling between the months of May–August. Average monthly temperature maximum and minimum were 32 and -12 C occurring in July and January, respectively (1893–2007, UNL High Plains Regional Climate Center). Potential predators of prairie-chicken nests in our study area include coyote (*Canis latrans*), striped skunk (*Mephitis mephitis*), red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), opossum (*Didelphis virginiana*), domestic dogs and cats, and various species of snakes and other small mammals.

The landscape in the study area was dominated by agricultural development including corn, soybean, and alfalfa production. In addition, a large proportion of the landscape was maintained as pasture and rangeland (USDA 1986). In 2007, 16,327 ha (40,345 ac; c.17%) of Johnson County and 17,212 ha (42,533 ac; c.15%) of Pawnee County had been enrolled in CRP (Farm Service Agency, USDA).

Trapping and monitoring

We used walk-in traps to capture female prairie-chickens from 2007-2008 (Schroeder and Braun 1991). We trapped hens on 13 leks (2007: 7, 2008: 10), and leks ranged in size from 15 to 70 males. Once captured, we fitted each female with a necklace style radio transmitter (Model #A3960, Advanced Telemetry Systems, Inc., Isanti, Minnesota, USA), and we released each hen immediately at the capture location. Our animal capture

and handling protocols were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee (Protocol #05-02-007).

We estimated the location of each hen 5-10 times per week from time of capture to 1 August using a vehicle mounted with a null-peak antenna-receiver with an electronic compass (Gilsdorf et al. 2008). We randomly chose the order of fields in which we tracked hens to locate each bird at different times of day. We took at least 3 bearings within 10 minutes for each location in order to minimize movement bias. Additional bearings were taken until we received an error polygon of less than 1000 m² (approx 18-m radius). All UTM coordinates and associated error polygons were calculated in the field via an onboard computer and software (Location of a Signal [LOAS], Ecological Software Solutions, Urnäsch, Switzerland, Version 4.0). We located missing hens by systematic ground searches and aerial telemetry. When monitoring indicated a hen was nesting (i.e., 2-3 consecutive identical locations), we visually confirmed nest location and recorded the number of eggs in the nest. To minimize disturbance, we continued to remotely monitor nests via telemetry. Once locations indicated the hen had stopped incubating (i.e., 2-3 locations off nest), we visually inspected the nest to determine the fate for the nest and the number of eggs that hatched. Nests were considered successful if ≥ 1 egg hatched.

Nest Habitat Measurement

We evaluated landscape composition by creating a year-specific, vector-based GIS (ArcGIS 9.0, ESRI, Redlands, CA) landcover layer. We used aerial photographs and extensive ground-truthing to classify each land cover into five landcover types: cropland, grassland, woodland, wetland, and anthropogenic. Grassland cover types were further

divided in 4 subtypes: warm-season CRP fields (predominantly switchgrass [*Panicum virgatum*], big bluestem [*Andropogon gerardii*], little bluestem [*Schizachyrium scoparium*], Indian grass [*Sorghastrum nutans*], or sideoats grama [*Bouteloua curtipendula*]), cool-season CRP fields (dominated by smooth brome and orchard grass [*Dactylis glomerata*]), rangeland, and pastureland. Pastureland was designated as any grassland in a field not enrolled in the CRP program that had previously been in crop production. Rangelands were grasslands that had no history of crop production.

At each nest site, we estimated the percentage of canopy cover for grasses (GRASS), forbs (FORB), standing litter (SL), and bare ground (BARE) using a 1-m diameter sampling hoop (modified from Daubenmire 1959), and we recorded visual obstruction readings (VOR) to the nearest 0.25 dm (Robel et al. 1970). We also assessed the vegetation composition and VOR at five random points in the same field and habitat type created using Hawth's Analysis Tools for ArcGIS (Beyer 2004). In addition, we classified each nest site and random point into 3 topographic categories (TOPO; upper, middle, or lower), relative to the elevation in that particular field using a digital elevation model for Johnson county (DEM, UNL School of Natural Resources).

Analysis and Model Selection

We used discrete choice models to assess nesting habitat selection of female prairie-chickens in 2 analyses, macrohabitat and microhabitat; we used the nest as the sample unit (Cooper and Millsbaugh 1999, McDonald et al. 2006). We selected the discrete choice approach for its ability to simultaneously consider continuous and categorical types of covariates. Also, with discrete choice we were able to customize the composition of the choice set for each location in time and space (Cooper and Millsbaugh

1999, McDonald et al. 2006). We used Cox proportional hazards regression method to develop our macro and microhabitat discrete-choice models. We constructed our models using the COXPH function located in the “survival” package of R (R package version 2.31). We calculated selection ratios for each of the estimates (β_i) using the top model where the selection ratio was defined as e^{β_i} . Selection ratios measure the multiplicative change in relative probability of selection when a covariate is changed by one unit and all other covariates are held constant (McDonald et al. 2006).

We created 16 biologically reasonable, *a priori* models including a null model to evaluate the effects macrohabitat covariates have on habitat selection. Our nest macrohabitat models considered the effect landcover type had on habitat selection. We created a set of covariates for landcover based on our classification of habitat in our study area: cool-season CRP, warm-season CRP, pasture, rangeland, and other habitats (largely anthropogenic and water). We set rangeland as our baseline landcover type. We also considered distance to edge, woodland, and crop in our macrohabitat selection because of the increased potential predator communities and avian perch sites in these areas (Svedarsky et al. 2003, Manzer and Hannon 2005). An edge was classified as any transition in vegetation such as fence rows, tree lines, roads, change in major vegetation type, or other types of boundaries delineating habitat types. We generated 20 nest-specific random points within the nest-specific available habitat for comparison with actual nest locations. We defined available habitat as that within a circular area centered on the lek at which the hen was caught, with a radius set at the distance between the nest and the lek.

We analyzed the microhabitat selection of nesting prairie-chicken hens by comparing the microhabitat features of nest sites with the random microhabitat features taken in the same field. We created 8 biologically reasonable *a priori* models, including a null model, using the following covariates: a quadratic model of vegetation composition (% cover; GRASS + GRASS² + FORB + FORB² + SL + SL²), a quadratic model of vegetation structure (VOR + VOR² + BARE + BARE²), and topography (TOPO). We hypothesized that vegetation composition could be a key component in nest habitat selection (Jones 1963, Kobriger 1965), but may become too dense for suitable habitat (Hamerstrom et al. 1957, Svedarsky 1979). McKee et al. (1998) also suggested standing residual litter is important to conceal early nests but an excess (< 25%) is detrimental to nest success. We used quadratic combinations of vegetation structure variables as suggested by Buhnerkempe et al. (1984). Lastly, based on personal observations, we hypothesized hens would select nest sites where topography would allow for highest survival. Combinations of these groups of covariates were considered because of the effect one covariate may have on the selection of another. We compared the characteristics of each actual nest to characteristics of 5 random vegetation samples.

We estimated daily survival of prairie-chicken nests and evaluated time and site-specific factors that could affect survival using the logistic-exposure method (Shaffer 2004) using the “logexp” package (Post van der Burg 2005) in R. The logistic-exposure method allows exposure time, or time between visits, to vary. Logistic exposure also allows for time-dependant variables to stay constant within monitoring intervals but vary between intervals (Shaffer 2004). We used this method for nest survival because we generally monitored nests five or six times per week. We constructed our models using

the Shaffer (2004) structure and an adaptation of the logistic regression model in R (R Development Core Team 2006, Post van der Burg 2005). We constructed a set of 16 *a priori* models of the following groups of covariates: macrohabitat (best model from macrohabitat selection), microhabitat (best model from microhabitat selection), temporal (Julian day of initiation [day] + day² + nest age [age]), and weather (average daily temperature, average daily precipitation). We hypothesized macro- and micro-habitat characteristics selected by hens would increase nest survival. Temporal variables, such as hatch date and nest age (Fields et al. 2006), and weather variables (Flanders-Wanner et al. 2004) have been shown to affect nest survival of other galliforms. We estimated date of nest initiation for calculating Julian day of initiation by using location data and hen movement patterns. We censored any nests that were thought to be abandoned because of our disturbance during monitoring.

We performed model selection using an information-theoretic approach to evaluate *a priori* models for both nest habitat selection and survival. We ranked each model from most to least support given the data using Akaike's Information Criterion corrected for small sample size (AIC_C; Burnham and Anderson 2002). For nest survival, we used effective sample size ($n = \text{total number of days samples survived} + \text{number of intervals that ended in failure}$) for the calculation of AIC_C (Rotella et al. 2004). We computed Akaike weights (ω_{AIC}) for each model, where ω_{AIC} represents the probability a model is the best approximating model of those considered given the data (Burnham and Anderson 2002). For all model sets, we considered the group of all models with a combined model weight of $\geq 90\%$ (Burnham and Anderson 2002). We selected the top model if it was the most parsimonious of all considered models (Richards 2008).

RESULTS

We captured, radio-tagged, and monitored 100 prairie-chicken hens (2007:38, 2008:62). We located and monitored 90 nests (2007:36, 2008:54) in five different landcover types (Table 1). Mean incubation start date pooled over both years was 17 May for first nest attempts and 5 June for second attempts. Mean hatch date was 12 June, with an average of 11 eggs hatching/nest. Prairie-chicken hens nested a mean distance of 1589 m from the lek at which they were caught, with the largest movement of 6223 m. Thirty-six of 90 nests were successful, 48 nests were depredated, 3 nests were abandoned, and 3 nests were destroyed by mowing. We subsequently removed nests that were mowed from our microhabitat analysis due to the altered vegetation state.

Our discrete-choice analysis of macrohabitat covariates indicated landcover type and distance from woodland were strongly associated with prairie-chicken nesting habitat selection ($AIC_c = 430.23$, $\omega_{AIC} = 0.52$) with the second and third best models also including distance to crop and distance to edge, respectively (Table 2). The estimate from the top model indicated that a hen's relative probability of selecting a nesting location in a cool-season CRP field was 5.70 (95% CI: 2.60, 12.48) times higher than rangeland; the probability of selecting a nesting location in warm-season CRP was 5.05 (95% CI: 2.17, 11.72) times higher than rangeland (Table 3). Prairie-chicken hens were 9.52 (95% CI: 2.02, 45.45) times less likely to nest in landcover types classified as 'other habitat' than rangeland. The top model also indicated the relative probability of a prairie-chicken selecting a point in a field, with landcover types held constant, increased 20% with each 100-m increase of distance from woodland.

The top model for predicting microhabitat selection of nesting prairie-chicken included vegetation composition and topography (Table 4). This model had an AIC_C of 155.13 and ω_{AIC} of 0.9 and therefore was the only model in the 90% confidence set. Prairie-chicken hens selected nest sites in the upper topographic strata in fields 5.78 (95% CI: 2.04, 17.42) times more than the lowest topographic strata and 3.64 (95% CI: 1.59, 7.26) times more than the middle topographic strata (Table 4). We also found a non-linear relationship between nest microhabitat selection and percentage of cover at the nest of grasses, standing litter, and forbs, all increasing as percent cover increases, with peaks occurring at 100%, 51%, and 21% cover respectively (Fig. 1).

Variation in daily nest survival (DNS) was best explained by two models, which both indicated survival was a function of macrohabitat, microhabitat, and time specific covariates with the second best model including weather variables (Table 5). The top two models accounted for $\geq 90\%$ of the ω_{AIC} ; as the best model was the most parsimonious, we selected it as the best model. Survival was higher in both cool-season [DNS = 0.968 (95% CI: 0.919, 0.988)] and warm-season [DNS = 0.975 (95% CI: 0.930, 0.991)] CRP fields than rangeland [DNS = 0.865 (95% CI: 0.624, 0.961)]. Nest survival was also affected by vegetation at the nest site, including a non-linear effect of % grass, standing litter, and forb cover (Table 6, Fig. 2). Nest survival reached its minimum at grass cover of 36% and forb cover of 7%. Nest survival decreased as nests aged and was at its maximum when hens started incubating nests on 28 May (Table 6, Fig. 3).

DISCUSSION

Our study suggests both cool- and warm-season CRP grasslands provide better quality nesting habitat for prairie-chickens than other grassland types in southeastern

Nebraska, which emphasizes the potential for federal land policy to positively affect wildlife populations of conservation concern. Seventy-five percent of radio-marked hens in our sample nested in CRP fields, although this type of landcover only represented 28% of the available landcover. Similarly, 31 nests (45.6%) hatched in CRP fields with only 5 (22.7%) surviving in other grassland types. Svedarsky et al. (2003) also reported selection of CRP fields for nesting by prairie-chickens; but, the CRP fields were planted to smooth brome (*Bromus inermis*) or other cool-season grass mixes. To our knowledge, our study is the first to show that prairie-chicken hens prefer undisturbed native warm-season CRP fields over grazed or hayed rangeland and pastures (Table 3). Although novel, we emphasize differences between our warm-season CRP fields and ‘typical’ warm season CRP fields. First, the majority of warm-season CRP fields in our study area were severely encroached by smooth brome. Although warm season fields have the potential to produce vegetation that is too tall and dense for nesting prairie-chickens (Hamerstrom et al. 1957, Westemeier 1973), we observed that warm-season CRP fields on our study site had not developed full density by the time nesting was initiated; this may contrast with nesting conditions in prairie-chicken habitat in more southern locations. In our warm-season CRP fields, dead, standing vegetation from the previous year probably provided critical cover (Svedarsky et al. 2003), whereas we noted that this was lacking in pasture and rangelands.

In addition to responding to the type of landcover, hens selected nest sites further from woodlands than random points (Table 3). This may be in response to the high abundance of mammalian and avian nest predators along wooded corridors (Svedarsky et al. 2003, Manzer and Hannon 2005). Some rangeland and pastureland may have been

unsuitable for nesting due to the advancement of woody cover, mainly eastern red cedar (*Juniperus virginiana*). Trees can provide a perch site for many avian predators that use visual cues to find prey (Manzer and Hannon 2005). Encroachment of woody cover in CRP fields may not have been as severe due to the relatively young age (<20 years) of the grasslands on our study area.

Nest site habitat selection within fields in our study was strongly associated with vegetation composition, rather than structure, which is similar to the results of McKee et al. (1998). The lack of a response to structure, as measured by VOR, conflicts with the results of Hamerstrom et al. (1957), Tester and Marshall (1962), Jones (1963), and Buhnerkempe et al. (1984). On our study area, it appears that grass cover at the nest site provided concealment from avian nest predators; grass cover may also aid in protection from severe weather events, as long as vegetation structure is above a threshold. The importance of vegetation structure to nest site selection in our study may have been limited by the relatively homogenous vegetation height within fields, which was especially apparent in CRP fields. Hens selected a narrow range of forb cover and standing litter cover; hens were twice as likely to select nesting locations that contained 25% forb cover than areas with 10% or 40% cover (Fig. 1). Forbs, mainly alfalfa (*Medicago sativa*) and red clover (*Trifolium pratense*), found in this moderate density provide the needed over head cover. As the basal stem densities of these plants increase, the vegetation may encumber the hen during flushes to avoid predators. The flush response of prairie-chicken hens when encountering a predator may also explain the selection of the top third of a field in elevation for nesting (Table 4). Females may increase their nest success by selecting a nest site with a good view of their surroundings

(Götmark et al. 1995). Areas of high topography, usually hilltops and ridges, may provide a better vantage point to survey the surrounding area and to be able to flush when approached by predators (Westemeier 1973).

During our study, CRP grasslands provided nest success rates (46.9%, Table 5) similar to the 47.9% found in other areas of the Midwest (Peterson and Silvy 1996) and near the minimum of 50% apparent nest success suggested by Westemeier (1973) for a stable population. This suggests that both warm- and cool-season CRP grasslands provide adequate surrogate grasslands for prairie-chicken nesting and are not the cause of the low juvenile:adult ratios observed in harvested birds in and around our study area (J. Lusk, Nebraska Game and Parks Commission, unpublished data). Since the majority (~75%) of the nests were found in CRP fields, we attribute the low production to low brood survival (Chapter 4). Prairie-chicken hens nesting in non-CRP grasslands and agriculture lands experience a significant decrease in nest survival (Table 5), with an apparent nest success of 21.7%. The disparity in nest survival between CRP and non-CRP grasslands is likely due to the increased vegetative cover, both growing and dead, in the undisturbed CRP grasslands. Survival rates may be improved in rangelands and pasturelands if grazing on portions of pastures was delayed until initial nests have hatched. Morrow (1987) suggested it is critical to use grazing strategies which allow portions of the landscape to produce enough residual cover for the subsequent year's nests for Attwater's prairie-chickens (*Tympanuchus cupido attwateri*).

Grass and forb cover were also good predictors of nest success for prairie-chickens (Tables 5,6) with a positive relationship between daily nest survival and percent cover (Fig. 2). McKee et al. (1998) also found forb and grass cover to be important in

determining nest success. However, unlike McKee et al. (1998), we did not find litter cover (the inverse of our bare ground reading) to be important in nest success. Instead, we found standing litter to have a positive effect on survival up to 25%, and a deleterious effect for higher amounts (Fig. 2). Increased grass and forb components around a nest aid in hiding the nest from predators as well as from adverse weather. Standing litter would also serve this purpose, and seem to provide benefit up to a point. The decrease in survival in nests with >25% standing litter may be caused by a decrease in other important vegetative components. McKee et al. (1998) found a negative relation between litter cover and grass cover. Excessive litter can delay new grass growth and decrease cover for nesting (Westemeier 1973). An increased amount of litter has also been linked with an increase in small mammal populations and in turn to an increase in predator activity in the area (Svedarsky 1979).

The temporal effects (i.e., nest initiation date and nest age) had a large influence on nest survival and were included in the top five models in our analysis (Table 5). The decrease in nest survival as nests age has been shown in other prairie grouse and was attributed to an increase in mammalian predation caused by the increased scent left by the hen and gas exchange from eggs (Fields et al. 2006). As a nest ages, cues that lead to nest discovery by a predator, such as parental movements near the nest (Fontaine and Martin 2006), accumulate (Grant et al. 2005).

The quadratic effect of initiation date on nest success was most likely caused by a variety of variables (Fig. 3). Nests initiated too early in the season would not have adequate growth from the current year's vegetation to hide the nests from predators. Decreased nest survival early in the season due to lack of new vegetation growth may be

compounded in pasturelands and rangelands because of the lack of standing litter cover. Undisturbed CRP fields may provide the only suitable alternative for the early nesting birds. Fields et al. (2006) also found lesser prairie-chickens had decreased nest survival as the season progressed and attributed it to a decrease in female condition and increased humidity. The date of maximum nest survival, relative to nest initiation date, occurs one week after the peak in nest initiation on our study site (T. Matthews, unpublished data). The increase in prey opportunities for nest predators may swamp predation efforts and increase survival for the individual (Krebs and Davies 1997), due to the relatively low densities of prairie-chickens.

Our research suggests that efforts to manage populations of prairie-chicken in southeastern Nebraska should focus on establishing new grasslands and improving the health of established grasslands, especially CRP fields. CRP fields, both native warm-season and cool-season plantings, appear to be providing critical nesting habitat in our study area. In addition, our research would support the use of methods which increase non-woody vegetation heterogeneity and density in grasslands, such as controlled burning, interseeding of forbs, reduction of woody encroachment, and prescribed grazing. Our study further suggests that management efforts should be especially focused on grasslands in areas near or on ridgetops to improve nest habitat suitability and nest survival. In sum, we provide considerable evidence for the need for landscape-level management for Prairie-chickens. Our data suggest that farm policy can be used to support a wildlife species of conservation need through the addition of grasslands to landscapes.

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Table 3-1. Comparison of competing discrete-choice models for prairie-chicken macrohabitat nest selection in southeastern Nebraska, 2007–2008. Models are ranked by AIC_C , Akaike’s Information Criterion, adjusted for small sample size; k is the number of parameters, ΔAIC_C is the difference of each model’s AIC_C value from that of the highest ranked model (row one), and ω_{AIC} is the Akaike weight (sum of all weights = 1.00). Sixteen models were considered, and the top 3 models represent the 90% confidence set according to their ω_{AIC} .

Model	K	AIC_C	ΔAIC_C	ω_{AIC}
Habitat + Dist to woodland	5	430.23	0.00	0.52
Habitat + Dist to woodland +Dist to cropland	6	431.99	1.76	0.22
Habitat + Dist to woodland +Dist to edge	6	432.27	2.04	0.19
Habitat + Dist to woodland +Dist to cropland +Dist to edge	7	434.03	3.80	0.08
Habitat	4	445.35	15.12	0.00
Habitat + Dist to edge	5	446.70	16.47	0.00
Habitat + Dist to cropland	5	447.60	17.37	0.00
Habitat + Dist to cropland +Dist to edge	6	448.99	18.76	0.00
Dist to woodland +Dist to cropland	2	524.28	94.05	0.00
Dist to woodland +Dist to cropland +Dist to edge	3	525.53	95.30	0.00
Dist to cropland	1	527.41	97.18	0.00
Dist to woodland +Dist to edge	2	528.63	98.40	0.00
Dist to edge	1	535.93	105.70	0.00
Dist to cropland +Dist to edge	2	537.84	107.61	0.00
Constant	0	541.93	111.70	0.00
Dist to woodland	1	543.84	113.61	0.00

Table 3-2. Selection ratios and associated 95% confidence intervals for covariates in the top model predicting nest macrohabitat selection for prairie-chickens in southeastern Nebraska, 2007–2008. Rangeland was set as the baseline landcover type.

Covariate	Selection Ratio	95% Confidence Interval	
		lower	upper
Landcover			
Cool-season CRP	5.698	2.602	12.476
Warm-season CRP	5.045	2.171	11.724
Pasture	0.534	0.191	1.492
Other	0.105	0.022	0.496
Rangeland	1.000	-	-
Distance to Woodland	1.002	1.001	1.003

Table 3-3. Selection ratios and associated 95% confidence intervals for covariates in the top model predicting nest microhabitat selection for prairie-chickens in southeastern Nebraska, 2007–2008. Upper-level was set as the baseline elevation.

Covariate	Selection Ratio	95% Confidence Interval	
		lower	upper
% Grass	1.187	1.059	1.253
% Grass ²	0.999	0.999	0.999
% Standing litter	1.166	1.088	1.249
% Standing litter ²	0.998	0.996	0.999
% Forb	1.091	1.005	1.185
% Forb ²	0.998	0.996	0.999
Elevation			
Low	0.168	0.057	0.491
Mid	0.294	0.138	0.627

Table 3-4. Comparison of competing logistic-exposure models for greater prairie-chicken daily nest survival in southeastern Nebraska, 2007-2008. Models are ranked by AIC_C , Akaike's Information Criterion, adjusted for small sample size; k is the number of parameters, ΔAIC_C is the difference of each model's AIC_C value from that of the highest ranked model (row one), and ω_{AIC} is the Akaike weight (sum of all weights = 1.00). Sixteen models were considered; the top 2 models represent the 90% confidence set according to their ω_{AIC} .

Models	k	AIC_C	ΔAIC_C	ω_{AIC}
Macrohabitat ^a + Microhabitat ^b + Temporal ^c	17	336.561	0.000	0.724
Macrohabitat + Microhabitat + Weather ^d + Temporal	19	338.962	2.401	0.218
Microhabitat + Temporal	12	343.065	6.504	0.028
Microhabitat + Weather + Temporal	14	345.821	9.260	0.007
Temporal	4	346.279	9.718	0.006
Macrohabitat + Microhabitat	14	346.324	9.763	0.005
Microhabitat	9	347.567	1.006	0.003
Macrohabitat + Microhabitat + Weather	16	347.581	1.020	0.003
Macrohabitat + Temporal	9	348.288	11.728	0.002
Weather + Temporal	6	348.975	12.414	0.001
Microhabitat + Weather	11	349.653	13.092	0.001
Macrohabitat + Weather + Temporal	11	350.324	13.763	0.001
Constant	1	351.961	15.400	0.000
Weather	3	354.316	17.755	0.000
Macrohabitat	6	355.956	19.395	0.000
Macrohabitat + Weather	8	357.368	20.807	0.000

^a Macrohabitat model: Landcover type + distance to woodland

^b Microhabitat model: % grass cover + % forb cover + % standing litter cover + vertical obstruction reading at nest site

^c Temporal model: Julian day of nest initiation (Day) + Day2 + nest age

^d Weather model: daily precipitation + daily temperature

Table 3-5. Coefficient (β) estimates and 95% confidence intervals for covariates in the top models predicting daily nest survival of greater prairie-chicken nests in southeastern Nebraska, 2007-2008.

Covariate	β Estimate	95% Confidence Interval	
		lower	upper
Intercept	-42.9	-70.771	-15.029
Habitat			
Cool-season CRP	1.555	0.353	2.757
Other	-0.198	-2.08	1.685
Pasture	-0.416	-1.619	0.788
Warm-season CRP	1.823	0.371	3.275
Distance to woodland	0.001	0	0.003
% Grass cover	-0.049	-0.126	0.028
% Grass cover ²	0.001	0.001	0.001
% Standing litter cover	0.046	-0.011	0.103
% Standing litter cover ²	-0.001	-0.002	-0.001
% Forb cover	-0.07	-0.212	0.073
% Forb cover ²	0.006	0.001	0.012
Elevation			
Bottom	0.381	-1.373	2.135
Mid	0.788	0.054	1.523
Julian day	0.619	0.229	1.009
Julian day ²	-0.002	-0.003	-0.001
Nest age	-0.073	-0.125	-0.021

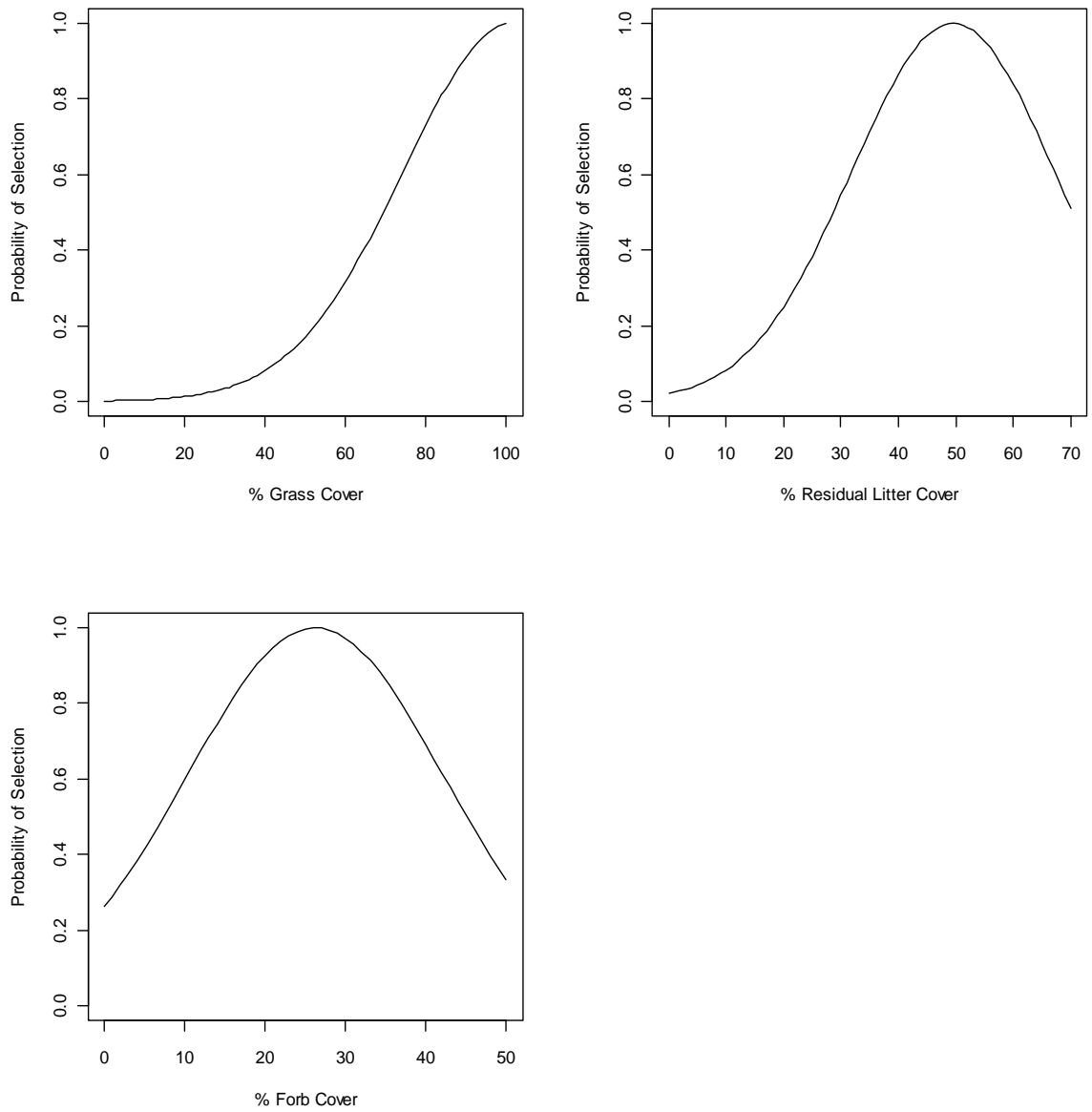


Figure 3-1. Relative probability of selection as a function of covariates in the best microhabitat discrete-choice model by nesting prairie-chicken hens in southeastern Nebraska, 2007–2008. All variables not plotted were held constant at their means to show variation in covariate of interest. Probabilities were scaled to have maximum values of 1.0.

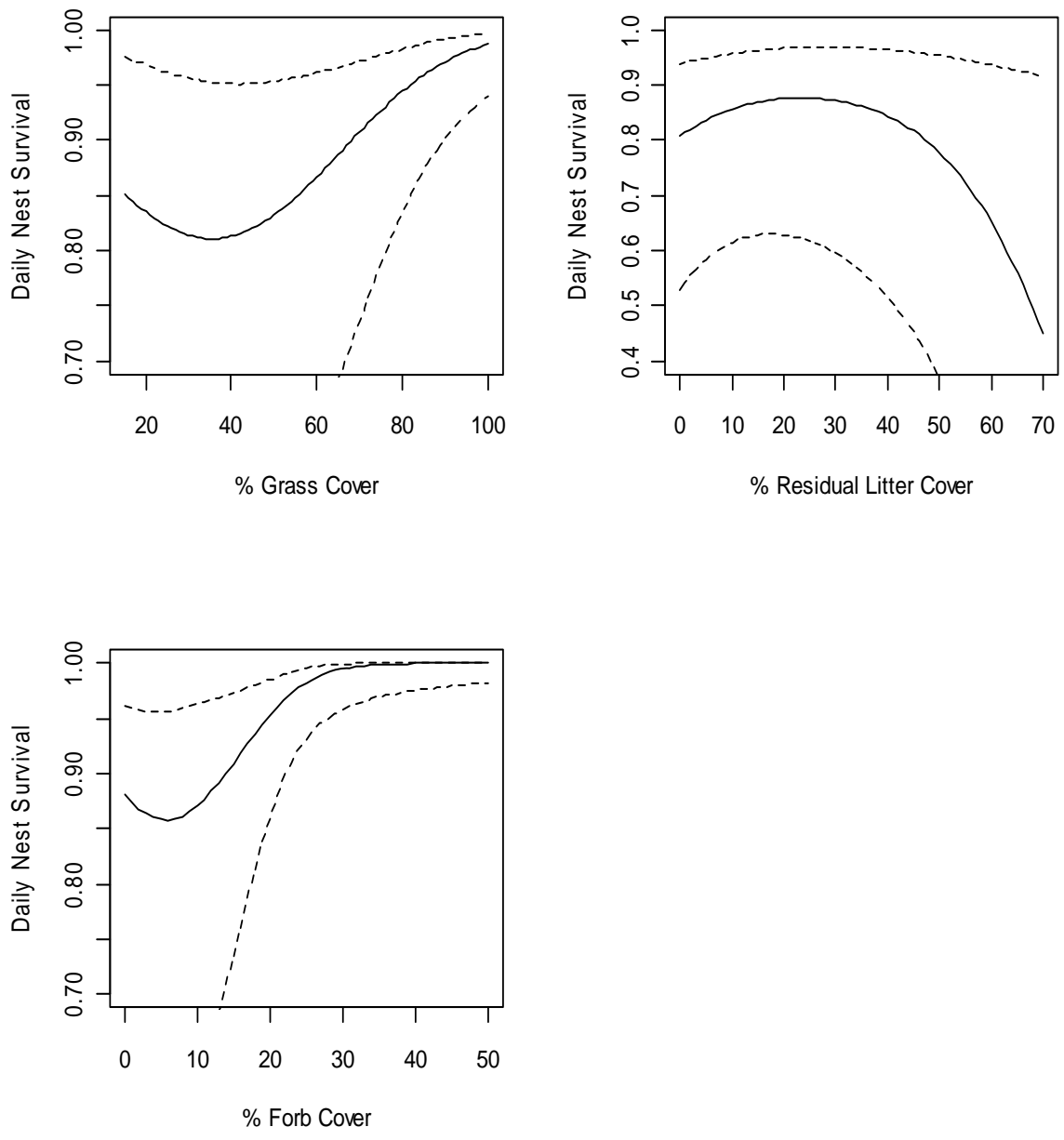


Figure 3-2. Daily nest survival as a function of covariates in the best logistic-exposure model by prairie-chicken hens in southeastern Nebraska, 2007-2008. All covariates not plotted were held constant at their means to show variation in covariate of interest.

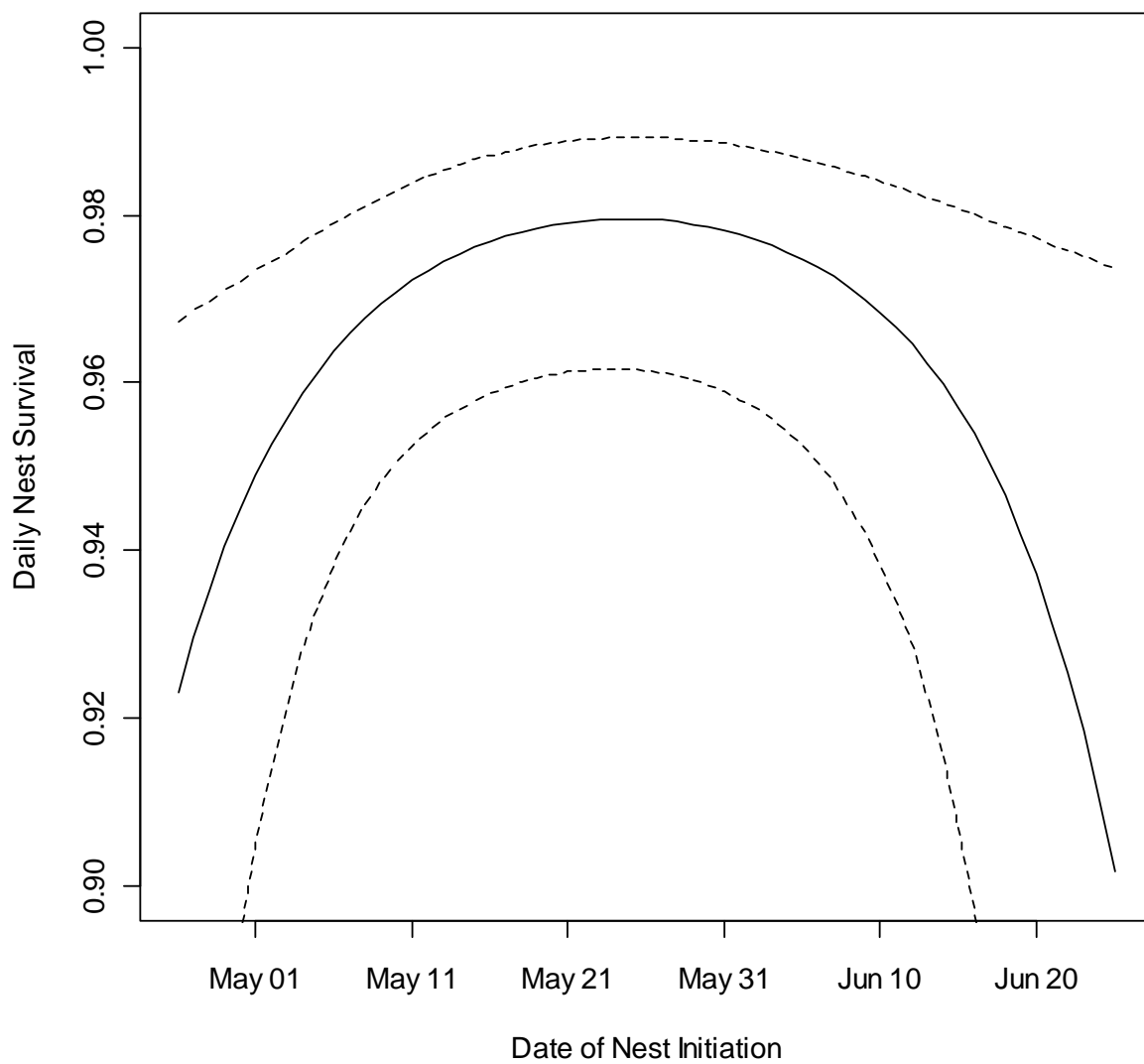


Figure 3-3. Daily nest survival probabilities for greater prairie-chickens in southeastern Nebraska, 2007–2008, as a non-linear function of nest initiation date.

CHAPTER 4. Effects of spatial and temporal variables on Greater Prairie-chicken brood habitat selection and survival.¹

¹ Submitted to Studies in Avian Biology. Co-authors: A. J. Tyre, J. J. Lusk, J. S. Taylor and L. A. Powell.

Abstract. The Greater Prairie-chicken (*Tympanuchus cuipdo pinnatus*) is a species that may benefit from conversion of crop ground to grassland through the Conservation Reserve Program (CRP). CRP grasslands may provide brood rearing habitat, an important component of population persistence. Managers and policy makers lack evidence of CRP's relative contribution to populations of Greater Prairie-chicken. We used radio-telemetry to mark females ($n = 100$) in a landscape in southeast Nebraska, which had >15% of land area enrolled in CRP. We examined macrohabitat and microhabitat selection of brood-rearing females ($n = 36$) using discrete choice models, and examined the variability in brood survival using logistic exposure models. Brood-rearing females selected locations on the landscape inside cool-season CRP grasslands at higher rates than rangeland, but did not select cropland. At the vegetation level, brood-rearing locations had more bare ground and forb cover than random points. However, landcover and vegetation did not affect survival rates of broods; variation in daily survival was best explained by temporal effects such as hatch date and brood age. Our results suggest CRP grasslands provide acceptable brood-rearing habitat, and managers should encourage landowners to create habitat with high forb content and an open understory. Broods in our study had low survival (21-day survival: 0.59 [95% CI: 0.41, 0.77]), which may explain the low juvenile/adult ratio observed in hunter-killed birds in the region. Disturbance of CRP fields to increase bare ground and forb cover may improve their value to Greater Prairie-chicken broods.

INTRODUCTION

Greater Prairie-chicken (*Tympanuchus cuipdo pinnatus*; hereafter prairie-chicken) populations in southeast Nebraska appear to have been benefited by conversion of cropland to grassland through the United States Department of Agriculture's (USDA) Conservation Reserve Program (CRP). Through CRP, landowners receive an annual rental payment to remove highly erodible cropland from production. Prairie-chicken populations in southeast Nebraska comprise the northern-most extension of the Flint Hills population (Vodehnal 1999, Johnsgard 2000). Unlike the Flint Hills in Kansas, southeast Nebraska's landscape was dominated by agricultural row crops. Post-settlement conversion of grasslands to croplands by European settlers caused this prairie-chicken population to decline to low levels (Johnsgard 1983, Schroeder and Robb 1993). However, the population appeared to increase in the 1990's after approximately 15% of the landscape was converted to grassland through CRP (Taylor 2000). Our goal was to understand the mechanisms behind the increase in population size of prairie-chickens.

The Nebraska Game and Parks Commission's (NGPC) long-term management for prairie-chickens in southeast Nebraska is planned with the realization that CRP grasslands could rapidly disappear if the program was removed from the Farm Bill or if profit margins caused landowners to favor crop production over participation in CRP. Svedarksy (1988) and Westemeier et al. (1999) found that prairie-chickens used grasslands similar to the low-diversity, brome-dominated CRP fields found in southeast Nebraska. However, studies of brood success in these habitats are needed to assess the

ability of CRP fields to provide sufficient brood-rearing habitat needed to sustain a population.

Juvenile survival is a key demographic parameter for prairie-chickens and other grouse species (Wisdom and Mills 1997, Sandercock et al. 2005, Hannon and Martin 2006) and quality habitat for nesting and brood rearing is often a limiting factor (Hamerstrom et al. 1957, Bergerud 1988). Brood habitat should provide sufficient bare ground to facilitate chick movement and adequate overhead cover to protect chicks from predators, all close to nesting cover (Vodehnal and Haufler 2007). When left undisturbed for 3–4 years, CRP land can accumulate a substantial amount of vegetative litter and may lack the bare ground needed by prairie-chicken chicks (McCoy et al. 2001). Prairie-chicken chicks also require an abundance of arthropods, the chicks' main food source during the first two weeks (Jones 1963); CRP fields may lack these essential invertebrates due to the low vegetation diversity found in many of these stands. Problems associated with low arthropod abundance may be alleviated when forb and legume species are incorporated into CRP fields or when high diversity grasslands are in close proximity of nesting cover.

Other types of landcover may act as important predictors of brood-rearing habitat for prairie-chickens in southeast Nebraska. Pasturelands (grasslands once used for row-crop production and subsequently seeded with native or non-native grasses), and unplowed rangelands are used for cattle grazing and are thought to be used by brood-rearing females (Horak 1985, Burger et al. 1989). However, it is unclear whether short vegetation typically found in CRP provides adequate concealment from predators or protection from adverse weather to successfully produce broods.

Our goal was to examine prairie-chicken use of habitat for brood-rearing in southeast Nebraska, with specific interest in habitats provided by CRP. Our objectives were to (1) examine brood selection of macro-habitat (landscape composition) and micro-habitat (vegetation structure and local composition), and (2) assess the consequences of habitat use on daily survival of prairie-chicken broods. Demographic information related to brood survival will be used to inform changes in land use policy and to inform management decisions needed to support prairie-chicken populations in southeast Nebraska.

METHODS

Study area

Our study was conducted in Johnson and Pawnee counties in the tallgrass ecoregion of southeast Nebraska. The landscape consisted of rolling uplands produced mainly from glacial till and loess accumulation. Soil types in these counties were characterized by Wymore-Pawnee soil association (USDA 1986). Average annual precipitation was 84 cm with the majority falling between the months of May and August. Average monthly temperature maximum and minimum were 32 °C and -12 °C, occurring in July and January, respectively. Our focus area was dominated by production of corn, soybean, and grazed grassland with millet and sorghum in lesser quantities. In 2007, 163.27 km² (ca.17%) of Johnson County and 172.12 km² (ca.15%) of Pawnee County had been enrolled in CRP (Farm Service Agency, USDA).

Trapping and monitoring

We used walk-in traps to capture female prairie-chickens from 20 March to 19 April in 2007-2008 (Schroeder and Braun 1991). We trapped birds at 13 different leks

during 2007 (7 leks) and 2008 (10 leks). Male attendance ranged from 15 to 70 individuals per lek. Once captured, we fitted each female with a necklace-type radio transmitter (<20 g, Model #A3960, Advanced Telemetry Systems, Inc., Isanti, Minnesota, USA), and released each female immediately at the capture location. Animal capture and handling protocols were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee (Protocol #05-02-007).

We estimated locations of each female 5-10 times per week from time of capture to 1 August using a vehicle mounted with a null-peak dual antenna-receiver with an electronic compass (Gilsdorf et al. 2008). We randomly chose the order of fields in which we tracked the females to avoid temporal biases. We took ≥ 3 bearings within a 10-minute period for each location to minimize error caused by movement. Additional bearings were taken until we received an error polygon of < 0.1 ha (ca. 18-m radius). All UTM coordinates and associated error polygons were calculated in the field via an onboard computer and software (Location of a Signal [LOAS], Ecological Software Solutions, Urnäsch, Switzerland, Version 4.0). We visually confirmed nest locations by approaching females with a hand-held antenna and receiver and flushed females to record the number of eggs in the nest within the first week of incubation. Once daily locations indicated the female had stopped incubating (i.e., 2-3 locations off nest), we visually inspected the nest to determine nest fate and the number of eggs that hatched. We used daily telemetry observations to locate females with broods for 21 days after hatch. We used nocturnal two flush counts on days 10 and 21 post-hatch to determine if a brood was successful (≥ 1 chick at flush). We assigned failed brood fates to females that flushed long distances without returning and we performed systematic ground searches to

confirm total brood failure. We used two subsequent flushes of such females to verify this classification.

Landscape and Vegetation Sampling

We evaluated landscape composition by creating a year-specific, vector-based GIS (ArcGIS 9.0, ESRI, Redlands, CA) landcover layer. We used aerial photographs and extensive ground-truthing through visual inspection to classify each land cover into one of five landcover types: cropland (row crops, alfalfa), grassland, woodland, wetland, and anthropogenic (farmsteads, utility facilities). Grassland cover types were further divided in four subtypes: warm-season CRP fields (predominantly switchgrass [*Panicum virgatum*], big bluestem [*Andropogon gerardii*], little bluestem [*Schizachyrium scoparium*], Indian grass [*Sorghastrum nutans*], or sideoats grama [*Bouteloua curtipendula*]), cool-season CRP fields (predominantly smooth brome [*Bromus inermis*], and orchard grass [*Dactylis glomerata*]), rangeland (unplowed native grasslands), and pastureland (pastures previously plowed).

At every third brood location, we estimated percent canopy cover for cool-season grasses (COOL), warm-season grasses (WARM), forbs (FORB), standing litter (SL) and bare ground (BARE) using a 1-m diameter sampling hoop (modified from Daubenmire 1959) and a visual obstruction reading (VOR) to the nearest 0.25 dm (Robel et al. 1970). BARE was the percent ground that was not covered by residual vegetation below the vegetation canopy. We took the sample from a random location within the 0.1 ha error polygon. We also assessed the vegetation composition and VOR at five random points in the same field and habitat type. All random points were created with Hawth's Analysis Tools for ArcGIS (Beyer 2004), and we used a hand-held GPS receiver to find the point.

Last, we classified each used brood location and random point into three topological categories (TOPO; upper, middle, or lower), relative to the maximum and minimum elevation in that particular field using a digital elevation model (DEM, UNL School of Natural Resources). All sampling was done within two days of locating brood.

Analysis and Model Selection

Discrete choice models calculate the probability of an individual selecting a resource as a function of the attributes of that resource and all other resources within the individual's available habitat (Cooper and Millsbaugh 1999, McDonald et al. 2006). Discrete choice analyses estimate the probability of selection of categorical variables relative to a reference, and we used rangeland as the reference for landcover. We estimated the area of available habitat in two steps. First, we calculated the maximum displacement distance between locations collected on consecutive days for each brood. Second, we calculated available habitat as the circular area around each location with a radius equal to the minimum of these maximum displacement distances. We used Cox proportional hazards regression function (COXPH) located in the "survival" package of R to develop our macro- and microhabitat discrete-choice models (R version 2.31). For each set of models, a correlation matrix was created to avoid any within-scale correlation.

We assessed selection of brood macrohabitat using discrete choice analysis of 16 biologically reasonable *a priori* models including a null model (Cooper and Millsbaugh 1999, McDonald et al. 2006). Our macrohabitat models considered the effect of landcover type on habitat selection. We created a set of covariates for landcover based on our classification of five habitats in our study area: cool-season CRP, warm-season CRP, pasture, rangeland, and other habitats (largely anthropogenic and water). Because

woodlands and edges are known to support larger numbers of mammalian and avian predators and may be avoided by brooding prairie-chicken females (Svedarsky et al. 2003), we also created covariates for linear distance to woodland and edge. We defined an edge as any transition in vegetation such as fence rows, tree lines, roads, change in dominant vegetation type, or other boundaries that delineated habitat types. Finally, we created a covariate for distance to any crop field as crop fields may be an important food source for females (Svedarsky and Van Amburg 1996); brooding females could be attracted to grasslands near crop fields. We generated 20 random locations per brood location within the habitat defined as available to compare against the used locations. We used 20 random locations rather than the five suggested by McFadden (1978) to decrease the variance in covariate coefficients (Baasch 2008). We replaced any random locations that were < 18 m of our brood location estimate, to match the size of our maximum allowable error polygon.

Our microhabitat analysis consisted of eight biologically reasonable *a priori* models using combinations of the following groups of covariates: vegetation composition (% cover; WARM, COOL, FORB, SL), a quadratic model of vegetation structure (VOR + VOR² + bare), and topographic position (TOPO). The seven models with covariates were compared to a null model with no covariates. We hypothesized that vegetation composition is a key component of habitat selection for brooding prairie-chicken females (Jones 1963, Kobriger 1965). We considered a non-linear effect of vegetation structure (VOR) because brooding females generally select areas less dense than nest sites (Jones 1963). Last, we hypothesized that prairie-chicken females may prefer locations where topography allows better detection of potential predators or faster escape flights during

predation attempts. We compared the microhabitat at brood locations with the random points taken within the field containing the nest.

We estimated daily brood survival and assessed the contribution of individual covariates in a set of eight biologically reasonable *a priori* models in a logistic-exposure structure (Shaffer 2004) using R and “logexp” package (Post van der Burg 2005). Our monitoring intervals were usually 10-11 days in length, as we flushed broods at day 10 and day 21, post-hatch. We flushed at 10 days post hatch to assess survival before any chicks had fledged. At day 21, all chicks should have fledged. Our models considered landcover (% of observations during interval spent in: cool-season CRP, warm-season CRP, rangeland, pastureland, cropland), temporal (Julian day of hatch [day] +brood age [categorical: 1–10 days or 11–21 days]), and weather (average daily temperature during monitoring interval [temp], average daily precipitation [precip]). We compared models with covariates to a null model. Flanders-Wanner et al. (2004) found that high temperature and precipitation events negatively impacted Sharp-tailed Grouse (*Tympanuchus phasianellus*) production. Temporal covariates, such as hatch date and brood age, have been found to affect brood survival in other galliform species (Riley et al. 1998, Fields et al. 2006, Hannon and Martin 2006). We used age as a categorical variable (1–10 or 11–21 days old) because we flushed broods in discrete time intervals to avoid influencing survival rates. We used female location and movement patterns to estimate date of hatch. Ten-day and 11-day period survival estimates were calculated as daily survival rates for first 10 days post-hatch ($\hat{S}_{10} = D\hat{S}R_{1-10}^{10}$ and $\hat{S}_{11} = D\hat{S}R_{11-21}^{10}$); 21-day period survival estimates were calculated as $\hat{S}_{21} = \hat{S}_{10}\hat{S}_{11}$. Variances for \hat{S}_{10} , \hat{S}_{11} , and \hat{S}_{21} were approximated using the delta method (Powell 2007).

We performed model selection using an information-theoretic approach to evaluate *a priori* models for brood habitat selection and survival. We ranked each model from most to least support given the data using Akaike's Information Criterion corrected for small sample size (AIC_C ; Burnham and Anderson 2002). For brood survival, we used effective sample size ($n = \text{total number of days the broods survived} + \text{number of intervals that ended in failure}$) for the calculation of AIC_C (Rotella et al. 2004). We computed Akaike weights (ω_i) for each model, where ω_i represents the probability a model being the best approximating model of those considered given the data (Burnham and Anderson 2002). For each analysis, we considered a confidence set of all models with a combined model weight of $\geq 90\%$ (Burnham and Anderson 2002). We selected the top model if it was the most parsimonious of the confidence set. When the highest-ranked model was not the most parsimonious, we used conditional model averaging over the 90% confidence set to estimate the covariates and associated standard errors (Burnham and Anderson 2002:152-153). We limited model-averaged predictions from continuous data to the range of data we observed.

RESULTS

We captured, radio-tagged, and monitored 100 prairie-chicken females (2007:38, 2008:62). We monitored 36 females with broods from successful nests (2007:11; 2008:25). Eighteen broods (50%) survived to 10 days post-hatch (2007: two; 2008: 16). A total of 17 of 18 (95%) broods that were active at 10 days-post hatched survived to day 21.

We obtained 455 locations of brooding females, which were distributed among cool-season CRP (29%), rangeland (27%), pastureland (20%), warm-season CRP (11%),

cropland (7%), and other (6%) landcover classes. Each of our females traveled > 500 m at least once during a 24-hr time period while with young. Thus, we established 500-m radii around each brood location as available habitat for subsequent analyses. Within-scale correlations for each model set were reasonable (< 0.40).

The top macrohabitat-level selection model included effects of landcover type and distance to crop field (Tables 1 and 2). The relative probability of a brooding female selecting a location for her brood in a cool-season CRP field was 1.39 (95% CI: 1.03, 1.88) times higher than rangeland (Table 2). A female's probability of selecting a location in a crop field for brooding is 2.64 (95% CI: 1.87, 3.73) times lower than the chance of selecting rangeland (Table 2). Each increase in distance of 100 m from cropland resulted in a 10% decrease in the relative probability of selection, holding all other variables constant (Table 2, Fig. 1).

The top microhabitat-level selection model included all effects (global model) and had a ω_i of 1.0 ($AIC_c = 71.66$). Prairie-chicken females with a brood selected areas with mid-level topography 11.3 (95% CI: 1.6, 79.8) and 21.7 (95% CI: 3.0, 153) times more than bottom- or high-level topography, respectively (Table 3). Relative probability of selection increased as percent cover of forbs increased, with mean use of 33.6% ($SE=25.4$, range: 0–85%). Selection also increased with an increase in bare ground, with a mean use of 24.8% ($SE=29.9$, range: 0–100%). Probability of selection peaked at approximately 2.25 dm for VOR and decreased as VOR deviated from this point (Fig. 2). Average VOR at use points was 2.4 dm ($SE=0.8$, range: 1–5 dm).

Brood survival was a function of brood age and Julian day of hatch (Table 4). Daily brood survival decreased as nests hatched later in the breeding season and

increased as broods aged. No habitat or landscape characteristics we studied accounted for variation in daily brood survival. The mean daily survival probability of a brood in the 1–10 day old age class was 0.95 (95% CI: 0.95, 0.96), and 0.99 (95% CI: 0.96, 1.00) in the 11–21 day class. The mean probability of a brood surviving to day 21 was 0.59 (95% CI: 0.41, 0.77). The average number of chicks per brood (surviving to day 21) in 2007 was 4.50 (SE=0.71) and 3.13 (SE=2.50) in 2008.

DISCUSSION

Brooding prairie-chicken females in southeast Nebraska selected cool-season CRP fields over other landcovers. Cool-season CRP fields provide large expanses of undisturbed grassland, but our finding is contrary to previous studies, which found brooding females selected disturbed areas such as cultivated pastures, recently burned grasslands, and native prairie hay fields (Jones 1963, Svedarsky 1979, Burger et al. 1989, Westemeier et al. 1995). Rangelands and pastures represented disturbed habitats in our study area, and the lower selection ratio for disturbed grassland may be related to the structure of these grasslands. Large quantities of rangeland and pastureland in our study area may not have been suitable for brood-rearing due to excessive grazing by cattle. Both landcover types were generally grazed year after year and provided little vegetative concealment. In contrast, grazed pastures in the Nebraska Sandhills, which is in the north central part of the state, serve as the main brood-rearing habitat for prairie-chickens (Vodehnal 1999). These grasslands are generally stocked at lower rates and often are grazed in rotational systems, giving brooding females better overhead concealment from predators and adverse weather. We observed that the pastures and rangelands that were used by broods were either lightly grazed or idle, which contrasted with the majority of

available pastures and rangelands on the landscape. Brooding females also selected areas near crop fields in all landcover types, although crop fields themselves were avoided. Grassland-cropland edges may provide favorable complexes of bare ground and structurally-appropriate vegetation consistent with our observations of microhabitat preferences (see below). Females may also forage in these agricultural fields, even though there may be little food for their young. Rumble et al. (1988) found that a large portion of the diets of prairie-chickens in the Sheyenne National Grasslands consisted of agricultural crops, mainly corn and alfalfa. We would expect crops to be even more important to prairie-chicken diets in southeastern Nebraska, because the landscape is dominated by crop fields, which increases availability and use (Horak 1985). Managers should note that an increase of forb and legume components, such as alfalfa and sweet clover, in grasslands may decrease dependence of crop fields by brood rearing females (Svedarsky et al. 2003).

Within selected fields, prairie-chicken females with broods selected vegetation that was high in forb content and bare ground (Fig. 2). Our results are consistent with previous research (Norton 2005, Westemeier et al. 1995), and seem reasonable considering that primary brood behavior during the day consists of foraging for insects and mid-day loafing. Greater forb cover provides a higher abundance of insects, which are the primary food source of prairie-chicken chicks during the critical first two weeks post-hatch (Jones 1963, Schroeder and Braun 1992, Svedarsky et al. 2003). Bare ground and forb cover cannot be simultaneously maximized (Fig. 2), but our data suggest that habitat with a high proportion of forbs and bare ground will be preferred over brooding habitat without these features. Brooding females in our study also selected sites with

intermediate topography, probably related to the vegetation densities and composition associated with each topographic strata. Newell et al. (1988) reported broods in the Sheyenne National Grasslands in South Dakota used lowlands and midlands more than uplands due to the sparse vegetation in upland habitats. The converse may also be true in our study with the majority of the vegetation in the lowlands being too tall and dense. Our results provide support for this assertion since broods selected sites with mid-range visual obstruction readings (1.75 to 3 dm; Fig. 2).

We observed high brood mortality, especially in 2007 (18% 21-day success; 2008: 60% 21-day success), and few chicks per brood at 21 days. Mortality resulted in a 21-day chick survival of only 14.4% for both years combined which is below 37% chick survival 24 days post-hatch found by Newell et al. (1988) and 65% chick survival 21 day post-hatch found by Norton (2005). Thus, it appears that brood survival is responsible for the low juvenile:adult ratios in hunter wing surveys (J. Lusk, NPGC, unpublished data). Since hunting resumed in 1999 in southeast Nebraska, the average juvenile:adult ratio has been 0.91, compared to 1.77 for Nebraska's Sandhills region over this 8 year period (J. Lusk, personal communication).

Prairie-chicken females with broods selected cool-season CRP fields. However, our survival analyses suggest that either land cover as we measured it is not an important factor in brood survival, or that all the habitats used by broods we observed were equally poor. Instead, age of brood and hatch date were the only predictors of survival (Table 4, Fig. 3). One would expect selection patterns to optimize brood survival, but our data show no evidence of a survival advantage to cool-season CRP fields despite their preferential use. It is possible that the high rate of mortality, especially in 2007,

swamped any effects of habitat on survival. It is also possible that prairie-chickens on our study site are responding to an ecological miscue (Misenhalter and Rotenberry 2000, Schlaepfer et al. 2002), associated with invasive brome in cool-season CRP. Regardless, given the population growth observed on our study area since inception of the CRP program, CRP grasslands may benefit nest and/or adult survival to a degree that makes its effect on chick survival relatively unimportant to population persistence.

The relationship of brood survival with age has been well documented by Newell et al. (1988) and Norton (2005). Older chicks have greater ability to make short flights, as well as better development of thermoregulation, which decreases the need of regular brooding by the female (Svedarsky and Van Amburg 1996). Daily brood survival decreased the later in the breeding season that hatching occurred (Fig. 3). This may be a result of declining female condition as the season progressed (Thogmartin and Johnson 1999). Svedarsky et al. (2003) suggested that prairie-chickens are similar to waterfowl in that chicks have an increased survival rate when hatched by females with large fat reserves. Fields et al. (2006) also found declining brood survival in Lesser Prairie-chickens (*Tympanuchus pallidicinctus*) with increasing hatch date and attributed it to confounding weather variables and insect production. Broods hatching later in the breeding season in our study may have experienced lower insect availability, due to higher temperatures and lower precipitation. Higher temperature may also directly affect brood survival by inducing heat stress and water loss (Fields et al. 2006), especially when chicks are unable to thermoregulate on their own. Temperature may indirectly affect brood survival by reducing foraging time. Alhborn (1980) found Lesser Prairie-chickens seek shade and reduce foraging activity during periods of high temperatures. Riley et al.

(1998) found 48% of Ring-necked Pheasant (*Phasianus colchicus*) chicks died from exposure on days when it rained >0.6 cm. We averaged daily temperatures and precipitation during each brood's monitoring period, which tended to suppress extreme highs and lows that may cause mortality. Our monitoring intervals were set at 10 and 21 days to avoid observer bias on survival and habitat use; future studies may wish to weigh these potential biases with the need to investigate effects of short-term weather variability.

The low brood survival observed during our study was due to high levels of predation (Schole et al. in review), which may be attributed to lack and distribution of quality habitat (Schroeder and Baydack 2001). Schole et al. (in review) found 87% of radio-marked prairie-chicken chicks died due to predation in southeast Nebraska during our 2008 field season. The landscape in this area was dissected with tree lines, roads, and power lines, with generally small (<80 ac) tracts of grasslands interspersed through agricultural fields. Habitat fragmentation has been linked to an increase in predation by increasing travel time in poor habitat and increasing diversity and density of predators (Schroeder and Baydack 2001). Similarly, Ryan et al. (1998) demonstrated prairie-chicken broods have smaller home ranges and higher survival in large contiguous grasslands than in a prairie-mosaic landscape.

Grasslands in our study area may have vegetative characteristics which also induce high levels of predation. CRP fields in that area are generally monocultures of brome or switchgrass with few patches of diverse vegetation and high litter accumulation from >10 years of undisturbed growth. Brooding females in CRP fields would have to make longer movements more often in search of suitable habitat, making them and their chicks more

vulnerable to predation. The accumulation of litter has also been linked to an increase in small mammals, and has been suggested to attract mammalian predators (Westemeier 1988). Doxon (2005) found that an accumulation of litter impedes movement of gamebird chicks, and this may affect chicks' ability to escape predators. Undisturbed landcover like CRP fields in this area may need to be managed by rotational grazing, burning, or mowing to maintain proper height, density and species composition (Svedarsky et al. 2003). Additionally, pastures and rangelands are commonly intensively grazed with no years of deferred grazing, which results in large expanses of areas with little to no overhead canopy cover, giving no protection from predators. Pastureland and rangeland in our area were also commonly invaded by woody vegetation, providing perches for avian predators. Frederickson (1996) stated that range conditions needed for satisfactory brood survival may be restricted by intense grazing. For optimal benefit to prairie-chickens, grazed grasslands may need to adopt lower stocking rates or rotational grazing similar to the Sandhills region of north central Nebraska.

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Table 4-1. Comparison of competing discrete-choice models for macrohabitat selection of Greater Prairie-chicken brooding hens in southeast Nebraska 2007-2008. Models are ranked by AIC_c , Akaike's Information Criterion adjusted for small sample size; k is the number of parameters, ΔAIC_c is the difference of each model's AIC_c value from that of the highest ranked model (row one), and ω_{AIC} is the Akaike weight (sum of all weights = 1.00). Models are described in detail in the text; landcover includes 5 covariates (cool-season CRP, warm-season CRP, pasture, rangeland, and other habitats).

Models	K	AIC_c	ΔAIC_c	ω_{AIC}
Landcover + Distance to cropland	6	2725.07	0.00	0.67
Landcover + Distance to woodland + Distance to cropland	7	2726.91	1.84	0.27
Landcover + Distance to cropland + Distance to edge	7	2730.50	5.43	0.04
Landcover + Distance to woodland + Distance to cropland + Distance to edge	8	2733.66	8.59	0.01
Landcover	4	2736.46	11.39	0.00
Landcover + Distance to woodland	5	2738.38	13.31	0.00
Landcover + Distance to edge	5	2740.36	15.29	0.00
Landcover + Distance to woodland + Distance to edge	6	2742.94	17.86	0.00

Distance to woodland	1	2770.36	45.29	0.00
Null	0	2770.52	45.44	0.00
Distance to woodland + Distance to edge	2	2771.95	46.88	0.00
Distance to edge	1	2772.11	47.04	0.00
Distance to cropland + Distance to edge	2	2773.76	48.69	0.00
Distance to cropland	2	2774.16	49.08	0.00
Distance to woodland + Distance to cropland	3	2774.45	49.38	0.00
Distance to woodland + Distance to cropland + Distance to edge	4	2776.81	51.74	0.00

Table 4-2. Selection ratios and associated 95% confidence intervals for covariates in the top model predicting brood macrohabitat selection for Prairie-Chickens in southeast Nebraska, 2007–2008. Rangeland was set as the baseline landcover type.

Covariate	Selection Ratio	95% Confidence Interval	
		lower	upper
Landcover			
Cool-season CRP	1.392	1.028	1.884
Warm-season CRP	1.205	0.826	1.757
Pasture	1.027	0.746	1.415
Other	0.379	0.268	0.535
Rangeland	1.000	-	-
Distance to Cropland	0.999	0.998	0.999

Table 4-3. Selection ratios and associated 95% confidence intervals for variables in the top model predicting brood microhabitat selection for Prairie-Chickens in southeast Nebraska, 2007–2008. Upper-level topography was set as the baseline topographic level.

Covariate	Selection Ratio	95% Confidence Interval	
		lower	upper
% Cool-season grass	1.056	0.996	1.120
% Warm-season grass	1.096	0.894	1.343
% Forb	1.156	1.067	1.252
% Standing litter	0.949	0.874	1.037
% Bare ground	1.074	1.018	1.136
VOR	349.615	8.315	14700.000
VOR2	0.297	0.15	0.592
Topography:			
Bottom	0.521	0.063	4.341
Middle	11.285	1.597	79.832

Table 4-4. Comparison of competing logistic-exposure models for daily brood survival of Greater Prairie-chickens in southeast Nebraska 2005-2006. Models are ranked by AIC_c , Akaike's Information Criterion adjusted for small sample size; k is the number of parameters, ΔAIC_c is the difference of each model's AIC_c value from that of the highest ranked model (row one), and ω_{AIC} is the Akaike weight (sum of all weights = 1.00). Models are described in detail in the text.

Models	k	AIC_c	ΔAIC	ω_{AIC}
Day	3	49.87	0.00	0.55
Day + Climate	5	51.75	1.88	0.21
Habitat + Day + Climate	9	51.76	1.89	0.21
Habitat + Day	7	55.75	5.88	0.03
Climate	3	66.31	16.44	0.00
Constant	1	66.77	16.90	0.00
Habitat + Climate	7	72.64	22.77	0.00
Habitat	5	72.71	22.84	0.00

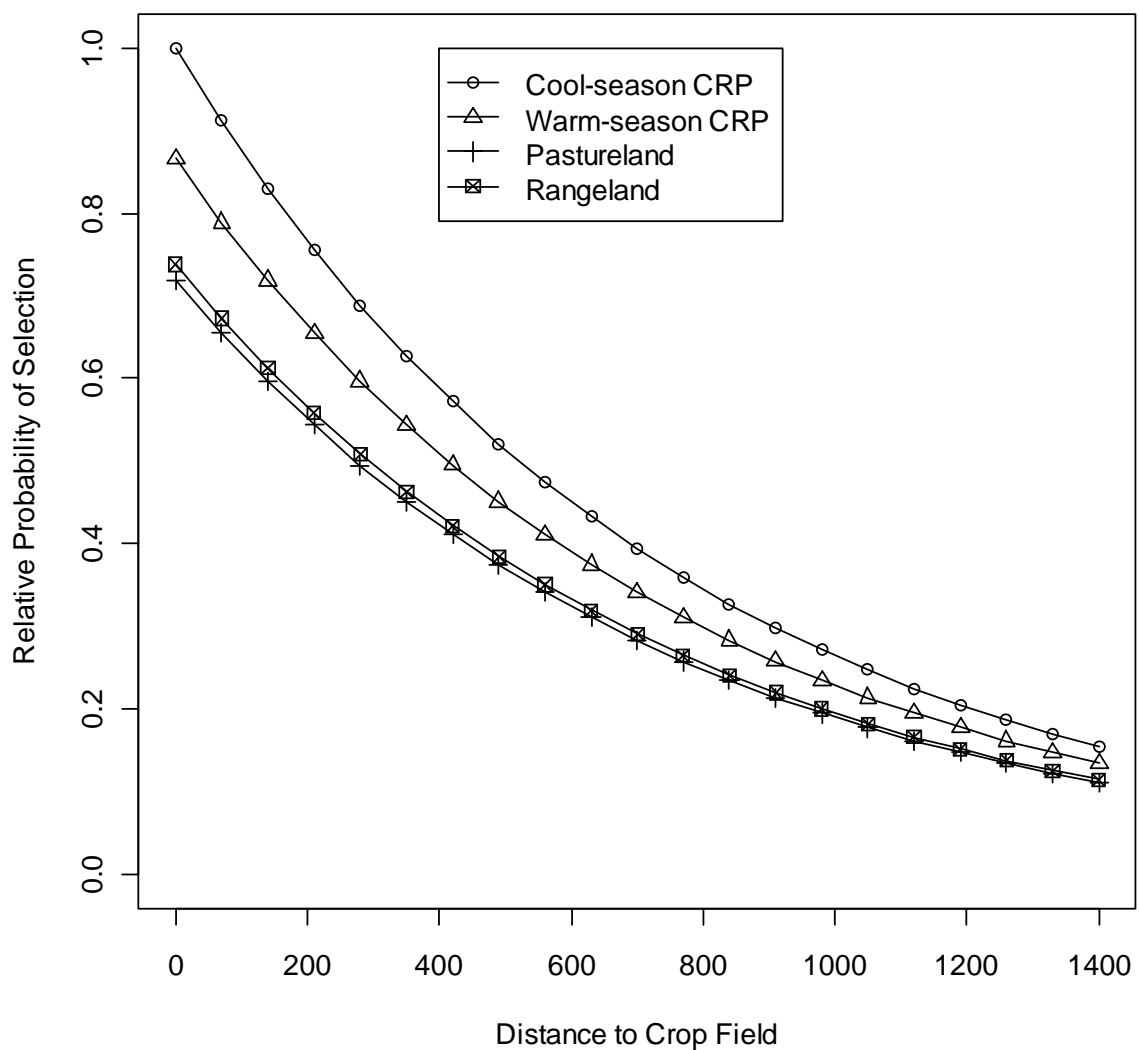


Figure 4-1. Relative probability of selection as a function of distance to cropland and landcover type in the best macrohabitat discrete choice model (Table 1) by Greater Prairie-chicken hens with broods in southeast Nebraska, 2007–2008 . Probabilities were scaled to have a maximum value of 1.0.

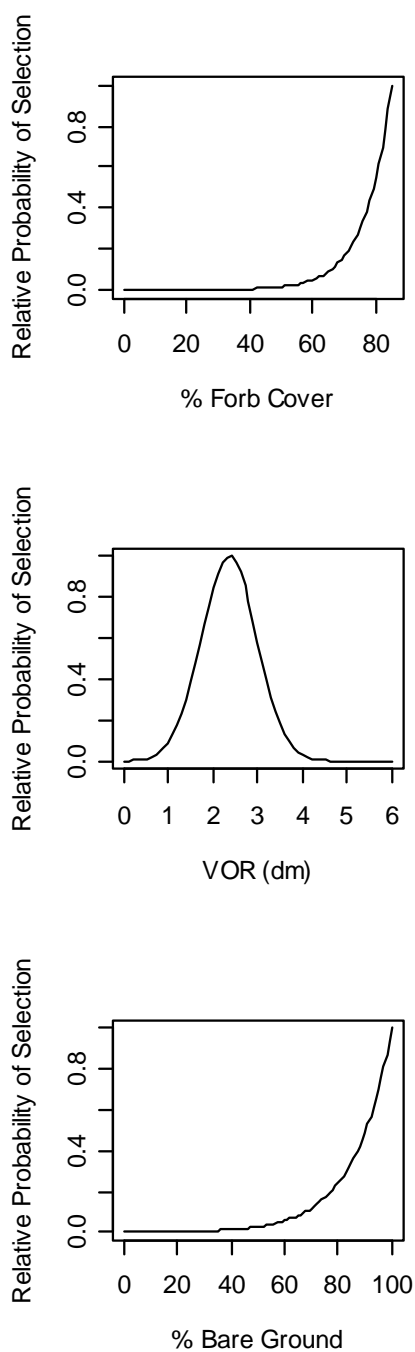


Figure 4-2. Relative probability of selection by Greater Prairie-chicken hens with broods as a function of covariates in the best microhabitat discrete choice model. All variables not plotted were held constant at their means. Probabilities were scaled to have a maximum value of 1.0.

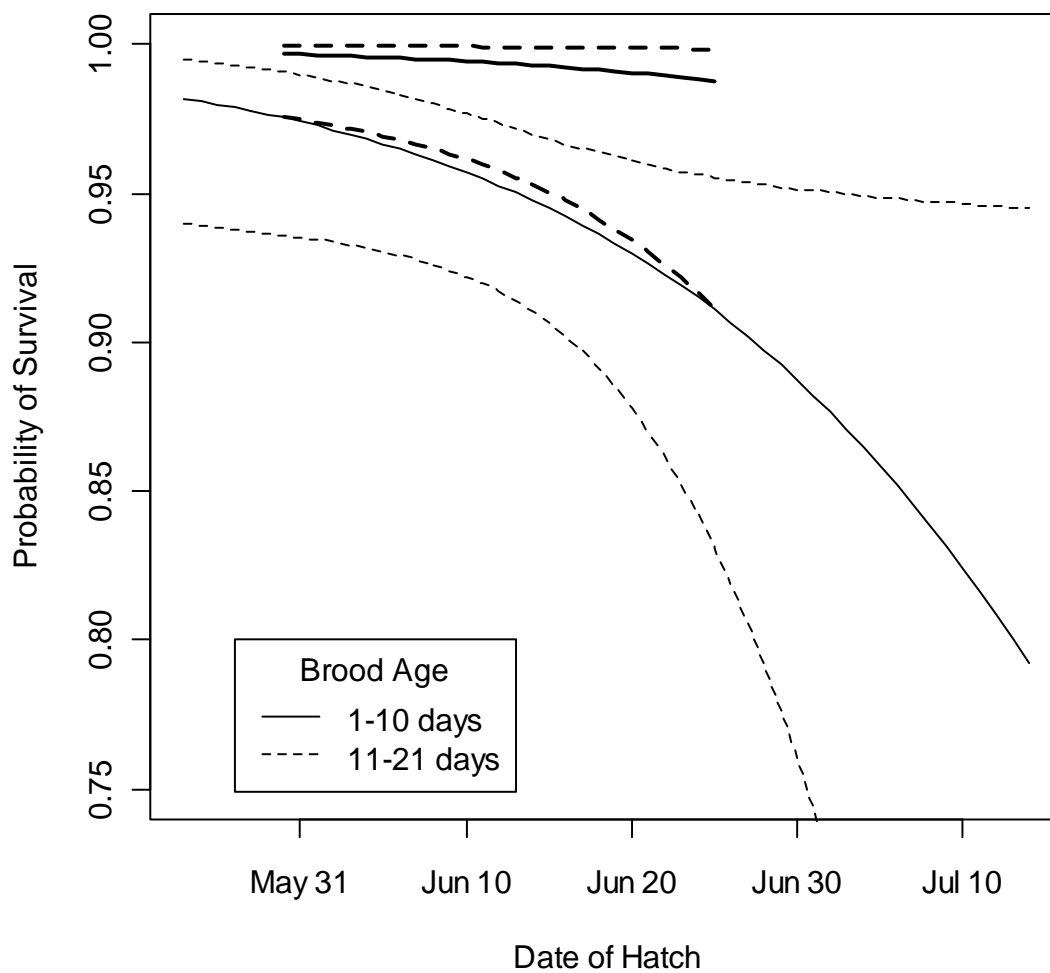


Figure 4-3. The linear effect of hatch date and brood age on daily survival of Greater Prairie-chicken broods in southeast Nebraska, 2007–2008. Estimates are based on the best logistic-exposure model from Table 2 with all other variables held at their mean. Dashed lines are the associated 95% confidence intervals.

APPENDIX 1. Auxiliary presentation of life history and habitat data for ring-necked pheasants and greater prairie-chickens in Nebraska.

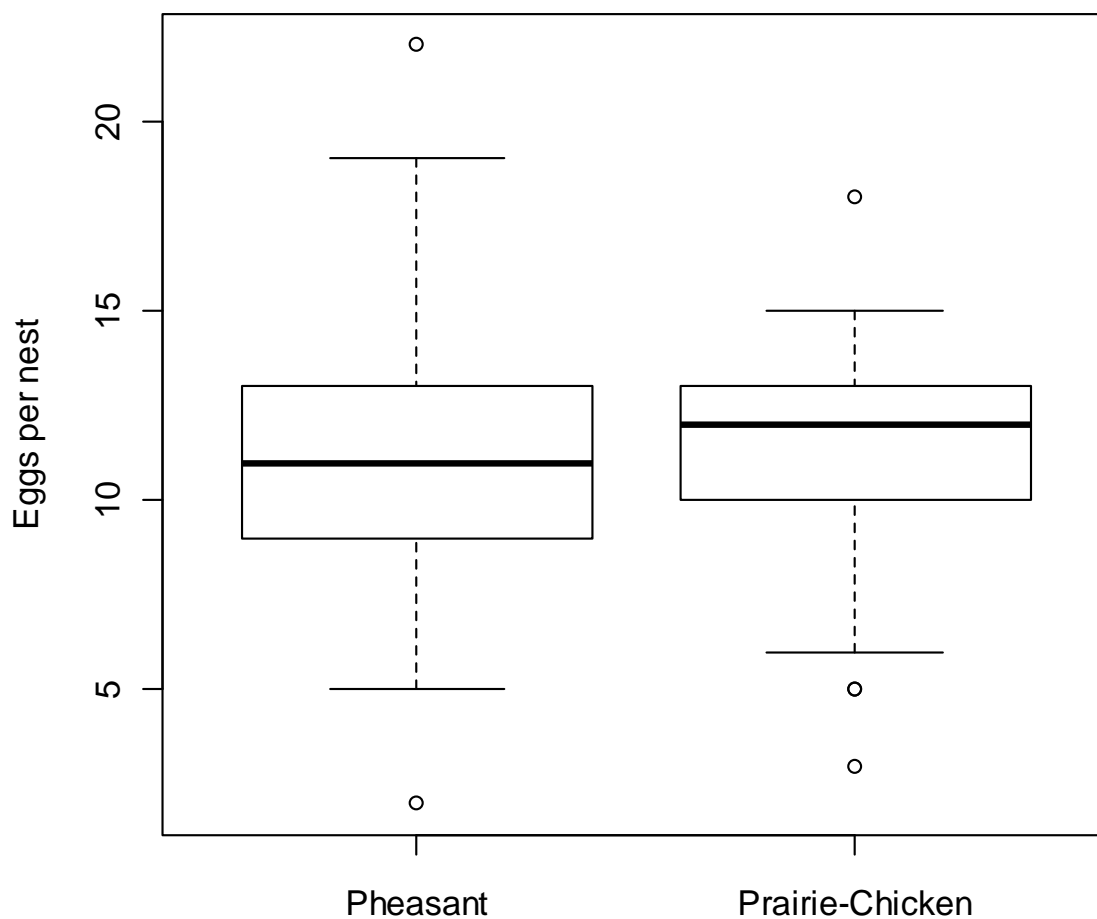


Figure 0-1. Median eggs per nests of ring-necked pheasants in northeastern Nebraska, 2005-2006 (11 eggs/nest), and greater prairie-chickens in southeastern Nebraska, 2007-2008 (12 eggs/nest). Boxes encompass central 50% of observations and length of whiskers = $1.5 \times$ interquartile of the box.

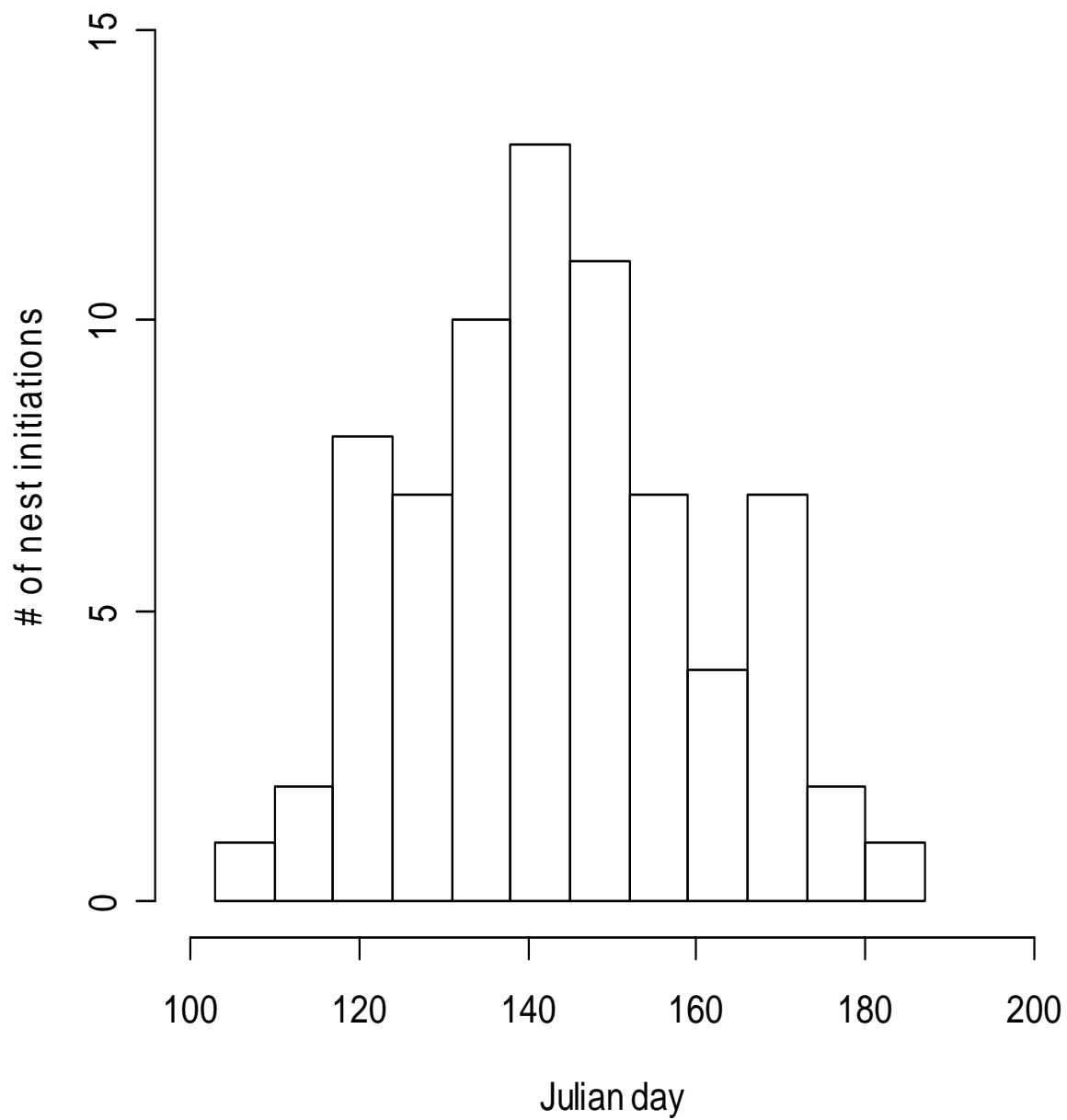


Figure 0-2. Julian day of onset of nest initiation of ring-necked pheasants in northeast Nebraska, 2005-2006. Day 100=April 4.

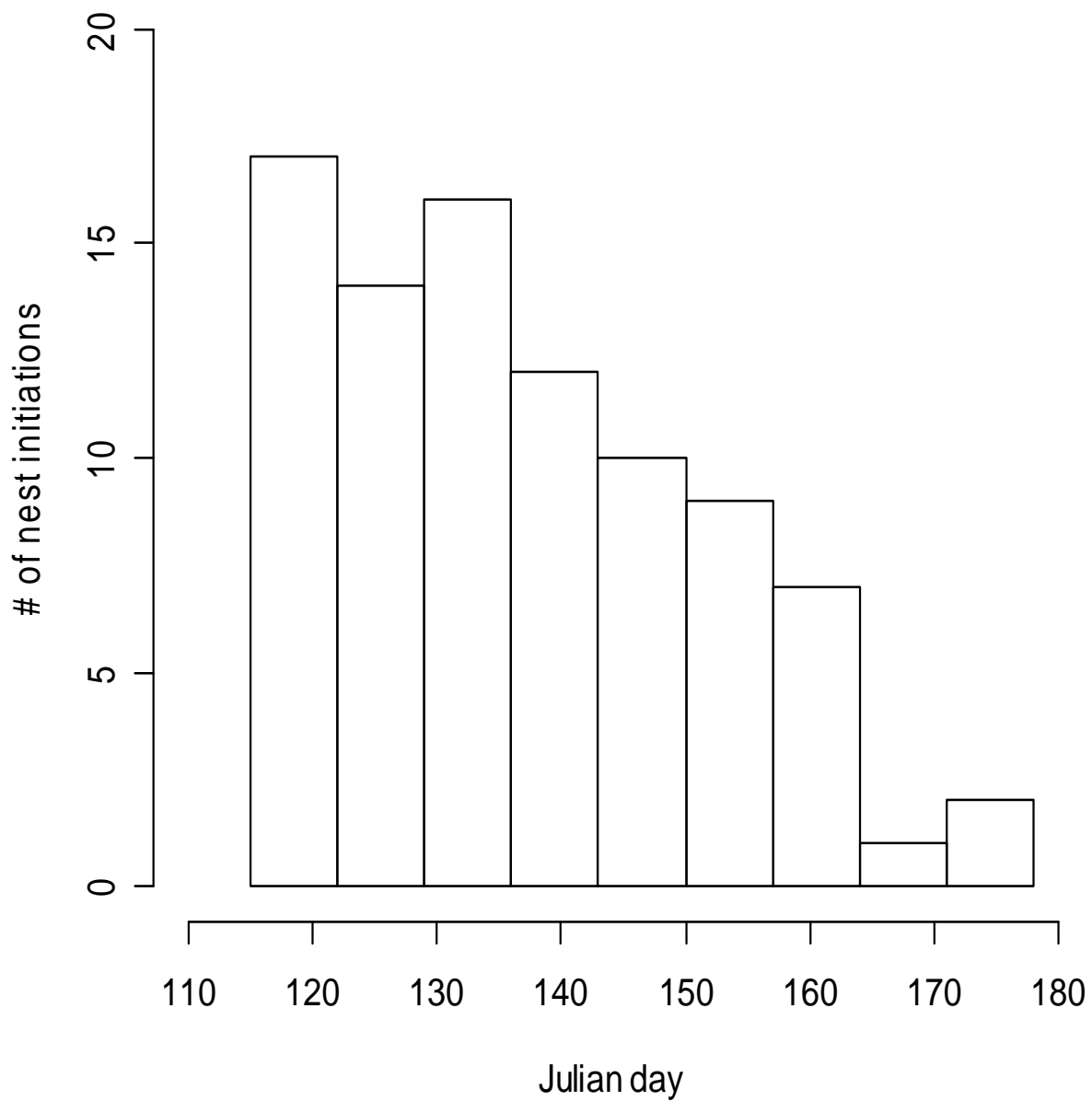


Figure 0-3. Julian day of nest initiation of greater prairie-chickens in southeast Nebraska, 2007-2008. Day 110 = April 14.

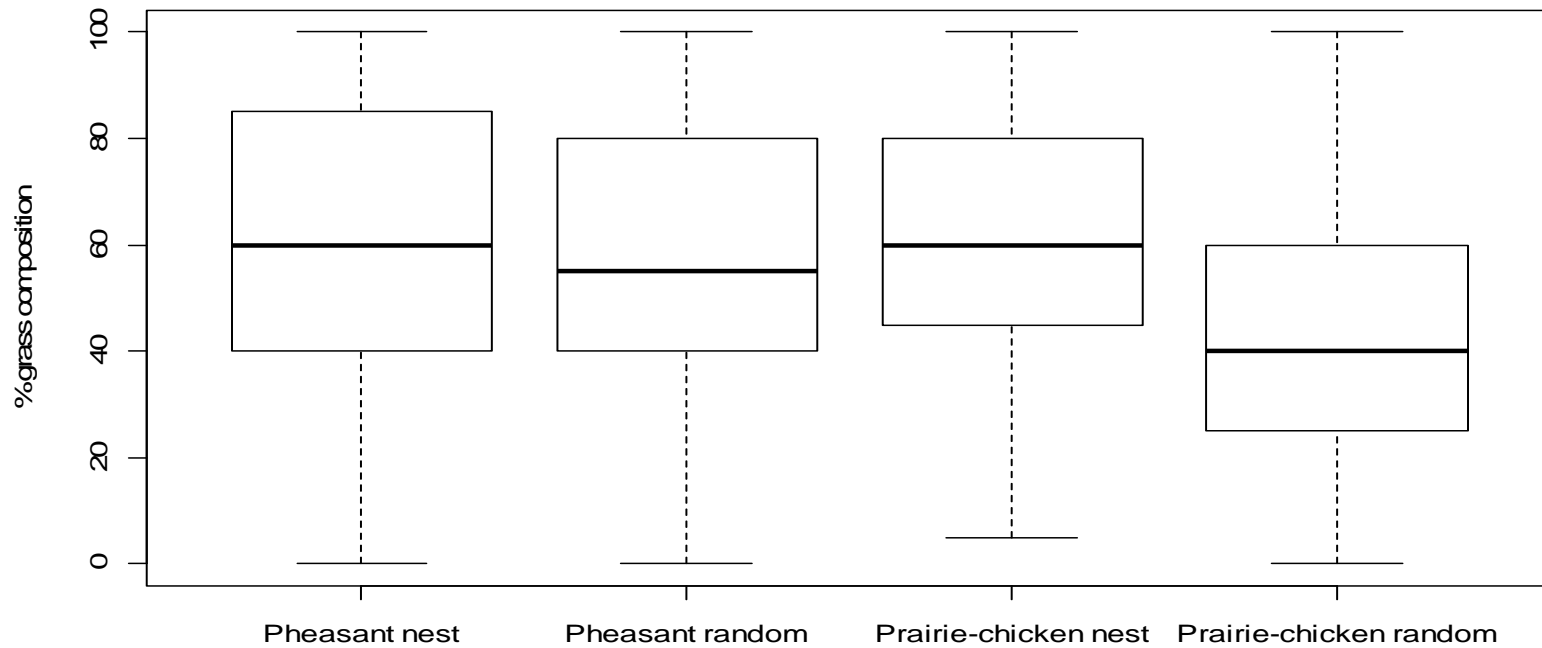


Figure 0-4. Median (solid line) percent cover of grass at nests and associated random points of ring-necked pheasants in northeastern Nebraska, 2005-2006, and greater prairie-chickens in southeastern Nebraska, 2007-2008. Boxes encompass central 50% of observations and length of whiskers = $1.5 \times$ interquartile of the box. Median values are 60, 55, 60, and 40 for pheasant nests, pheasant random points, prairie-chicken nests, prairie-chicken random points, respectively.

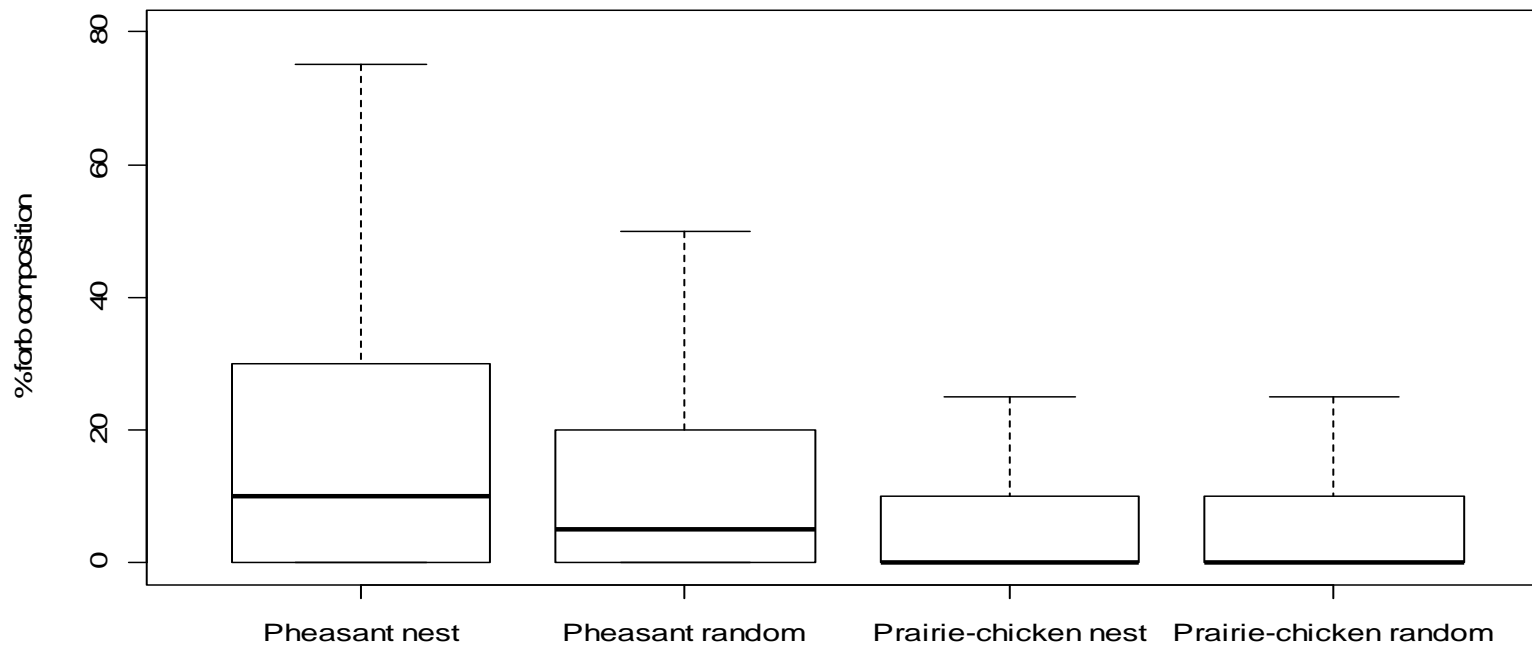


Figure 0-5. Median (solid line) percent cover of forbs at nests and associated random points of ring-necked pheasants in northeastern Nebraska, 2005-2006, and greater prairie-chickens in southeastern Nebraska, 2007-2008. Boxes encompass central 50% of observations and length of whiskers = $1.5 \times$ interquartile of the box. Median values are 10, 5, 0, and 0 for pheasant nests, pheasant random points, prairie-chicken nests, prairie-chicken random points, respectively.



Figure 0-6. Median (solid line) percent cover of bare ground at nests and associated random points of ring-necked pheasants in northeastern Nebraska, 2005-2006, and greater prairie-chickens in southeastern Nebraska, 2007-2008. Boxes encompass central 50% of observations and length of whiskers = 1.5 * interquartile of the box. Median values are 0, 0, 0, and 0 for pheasant nests, pheasant random points, prairie-chicken nests, prairie-chicken random points, respectively.

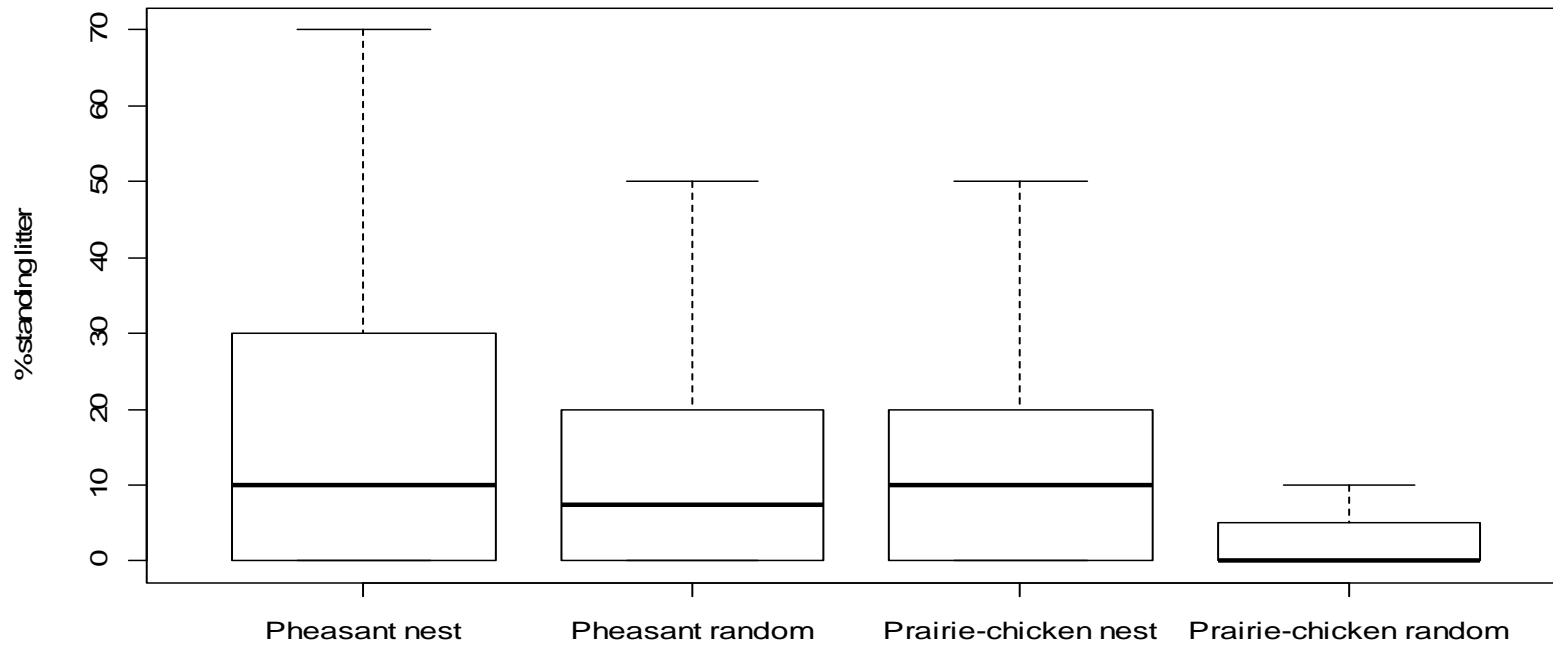


Figure 0-7. Median (solid line) percent cover of standing litter at nests and associated random points of ring-necked pheasants in northeastern Nebraska, 2005-2006, and greater prairie-chickens in southeastern Nebraska, 2007-2008. Boxes encompass central 50% of observations and length of whiskers = 1.5 * interquartile of the box. Median values are 10, 7.5, 10, and 0 for pheasant nests, pheasant random points, prairie-chicken nests, prairie-chicken random points, respectively.

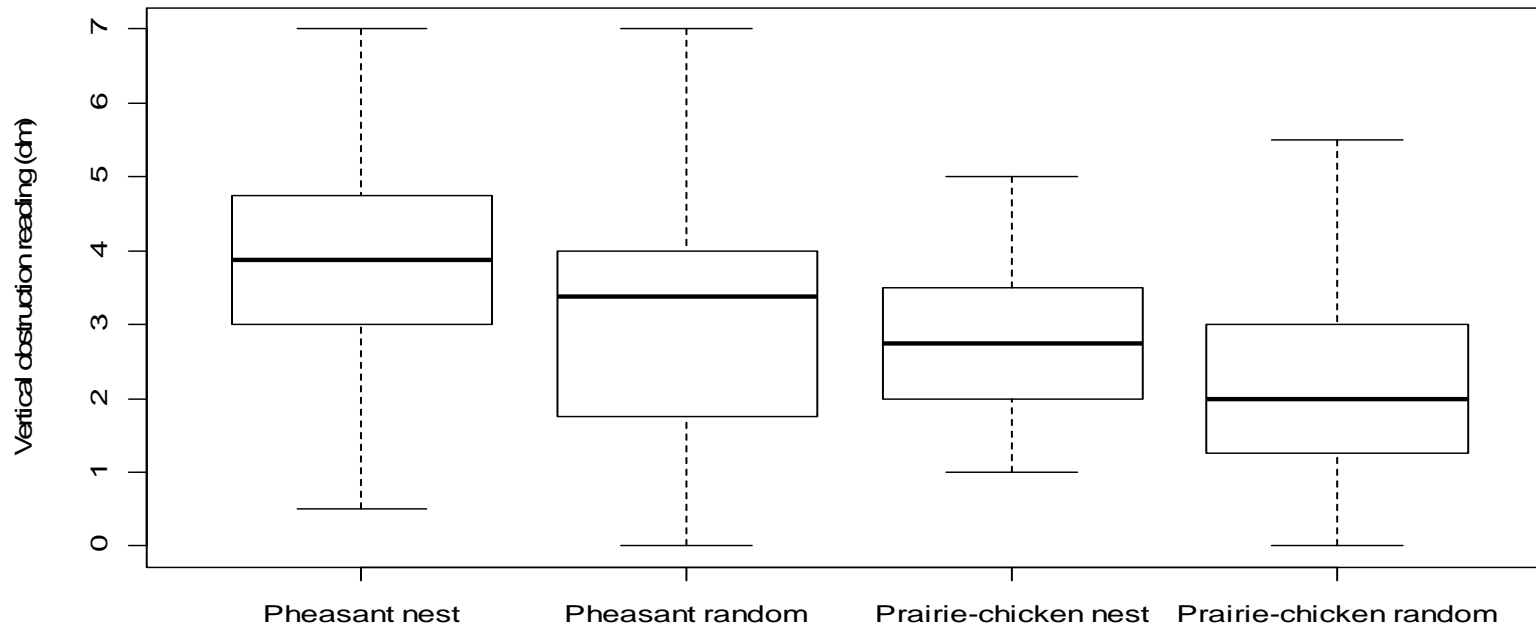


Figure 0-8. Median visual obstruction reading (dm) at nests and associated random points of ring-necked pheasants in northeastern Nebraska, 2005-2006, and greater prairie-chickens in southeastern Nebraska, 2007-2008. Boxes encompass central 50% of observations and length of whiskers = 1.5 * interquartile of the box. Median values are 3.9, 3.4, 2.8, and 2.0 for pheasant nests, pheasant random points, prairie-chicken nests, prairie-chicken random points, respectively.