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An Evaluation of Duck and Ring-Necked Pheasant Nest Survival and Nest Density in Relation to Patch Size and Landscape Variables in Eastern South Dakota

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AN EVALUATION OF DUCK AND RING-NECKED PHEASANT NEST SURVIVAL AND NEST DENSITY IN RELATION TO PATCH SIZE AND LANDSCAPE VARIABLES IN EASTERN SOUTH DAKOTA

BY

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This thesis is approved as a credible and independent investigation by a candidate for the Master of Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ABSTRACT

AN EVALUATION OF DUCK AND RING-NECKED PHEASANT NEST SURVIVAL AND NEST DENSITY IN RELATION TO PATCH SIZE AND LANDSCAPE VARIABLES IN EASTERN SOUTH DAKOTA

Keith J. Fisk

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Grassland ecosystems in South Dakota have experienced significant transformations over the last 100 years. Landscapes are currently dominated by large agricultural fields interspersed with small, isolated grassland patches. These isolated grassland patches are hypothesized to experience decreased nest survival rates for ring-necked pheasants (*Phasianus colchicus*) and dabbling duck species due to small size and high degrees of fragmentation. Several natural resource agencies currently conserve grasslands throughout eastern South Dakota, but wildlife managers seek more information on how the size and spatial arrangement of grasslands affect targeted conservation strategies. Therefore, the objectives of this study were to: (1) evaluate the relationship of duck and pheasant nest survival and nest density between different grassland patch sizes, (2) evaluate the effects of woody cover (i.e., shelterbelts) on duck and pheasant nest survival and nest density, and (3) evaluate how landscape composition and the spatial arrangement of landscape features affect duck and pheasant nest survival and nest density in eastern South Dakota.

I located duck (n=1,008) and ring-necked pheasant (n=595) nests on 44 patches that ranged in size from 3.64 to 56.66 ha in 12 counties in eastern South Dakota during the nesting seasons of 2008 and 2009. I analyzed nest survival data in Program MARK and developed models that best explain the interactions between nest survival and vegetation variables, patch size, presence of woody cover, and landscape composition. Three out of four duck species exhibited increased nest survival in landscapes with larger proportions of grassland and wetlands. For example, blue-winged teal (*Anas discors*) nest survival rates increased approximately 10% when the wetland area increased from 10% to 30%. Ring-necked pheasant nest survival decreased significantly in areas with larger proportions of farmsteads within 1,600 m. In landscapes with 1% farmstead area, nest survival was approximately 13%, but when the farmstead area was increased to 2% nest survival decreased to 6%. Additionally, ring-necked pheasant nest survival decreased with larger proportions of cropland within the surrounding landscape. Grassland patch size, the presence of woody cover, and the distance to woody cover were weakly supported in nest survival models for duck species. However, the presence of woody cover and the distance to woody cover did not affect ring-necked pheasant nest survival. Patch size, grassland proportions, and wetland proportions within the surrounding landscape increased nest densities of most species. Therefore, wildlife managers need to evaluate current landscape composition when determining locations to

implement habitat conservation strategies that are intended to maximize duck and ring-necked pheasant production.

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INTRODUCTION

Prairie landscapes within the northern Great Plains are one of North America's most endangered ecosystems (Samson and Knopf 1994, Van Dyke et al. 2004). These grassland ecosystems have been severely altered over the last 100 years because of human development. Recent advances in row crop technology and higher commodity prices have caused many landscape changes (Higgins et al. 2002). Commodity crops are highly subsidized by Federal farm programs, creating an economic incentive for landowners to convert grasslands to cropland (U.S. Governmental Accountability Office 2007). Consequently, South Dakota has lost over 85% (2,551,000 hectares) of its historical grasslands (Samson and Knopf 1994) and over 35% of the wetlands have been drained (Dahl 1990). These transformations have severely fragmented the prairie landscape. Many of the remaining grasslands, both privately and publicly owned, are small, isolated patches surrounded by intensively cultivated cropland or further fragmented by the inclusion of planted woodlands (i.e., shelterbelts).

Despite tremendous habitat loss, this area of the Prairie Pothole Region (PPR) continues to be the primary breeding habitat for many waterfowl species (Batt et al. 1989) and ring-necked pheasants (*Phasianus colchicus*, hereafter pheasants). Dabbling duck densities are extremely high in this region due to the numerous small wetlands formed by glacial activity about 10,000 years ago (Higgins et al. 2002). In addition, South Dakota is home to the largest population of pheasants in North America (Trautman 1982). In 2008, this population was estimated at over 9 million birds (Chad Switzer, personal communication, South Dakota Game Fish and Parks, 3/4/2009). This area also attracts large numbers of hunters each year, who in 2006 spent over $185 million on hunting-related expenditures in South Dakota (U.S. Department of Interior 2006). Therefore, grassland protection and restoration activities are top conservation priorities for many natural resource agencies within South Dakota.

As a result of the landscape-level changes (i.e., fragmentation and grassland loss) to the prairie landscape, duck and pheasant nest survival have declined (Reynolds et al. 2001, Clark et al. 1999). Beauchamp et al. (1996) stated that reduced duck nest survival throughout the PPR is a major factor in declining duck populations. Mammalian predator communities have experienced significant change in the prairie landscape as well. Populations of raccoons (*Procyon lotor*) and striped skunks (*Mephitis mephitis*) have increased with fragmentation of the landscape (Cowardin et al. 1983, Sargeant et al. 1993). Consequently, predation has been identified as a principal agent in determining nest survival of upland nesting birds (Warner et al. 1987, Klett et al. 1988, Clark and Bogenschutz 1999). For example, Greenwood (1986) found only a 5% nest survival rate for duck species in North Dakota and 97% of all nest failures in his study were caused by predation. Predators reportedly encounter more nests in fragmented landscapes, which in turn reduces nest survival (Higgins 1977, Phillips et al. 2003). Therefore, patch size may ultimately play a significant role in duck and pheasant nest survival.

The results of several studies attempting to link nest survival to patch size have been inconsistent. For example, some researchers found that duck nest survival was lower in small, isolated patches when compared to large continuous blocks of grasslands (Klett 1988, Greenwood et al. 1995). Sovada et al. (2000) found that patches smaller than 32 ha experienced the lowest nest survival rates when compared to medium (33-130 ha) and large patches (>130 ha). But, Horn et al. (2005) found that duck nest survival was lowest in moderately sized patches (approx. 66 ha) and highest in small (2-24 ha) and large patches (88-192 ha). Furthermore, some studies found that there was no relationship between patch size and duck nest survival (Clark and Nudds 1991, Jimenez et al. 2007). In addition, research pertaining to pheasant nest survival and patch size has also produced conflicting results. Gates and Hale (1975) found that pheasant nest survival was highest in larger patches (approx. 16 ha) when compared to small linear habitats. But, Clark et al. (1999) found that pheasant nest survival was highest in small (approx. 2 ha) patches when compared to large (>15 ha) patches. Additionally, no studies have evaluated the effects of patch size on pheasant nest survival in eastern South Dakota.

Current land-use patterns may also influence duck and pheasant nest survival in this region. Researchers have found that nest survival of duck species was positively related to the amount of grassland within the study area (Reynolds et al. 2001, Stephens et al. 2005). In addition, Phillips et al. (2003) found that duck nest survival was higher in areas with >45% of perennial grassland, than areas that consisted of <20% perennial grassland. Furthermore, Clark et al. (1999) determined that pheasant populations cannot increase in landscapes with large amounts of cropland because of poor nest survival. Conversely, he also found that nest survival can be relatively high in small grassland patches where the total grassland composition is reduced to <10%; although the small number of nests produced in these areas cannot significantly increase the population.

Finally, further fragmentation of prairie landscapes caused by woody cover is also thought to influence duck and pheasant nest survival (Snyder 1984, Gazda et al. 2002). Researchers have found that duck nest survival decreased as the amount of woody cover increased within the study area during one year (Gazda et al. 2002). But, the removal of woody cover did not change duck nest survival between treatment and control areas. However, some researchers have found that pheasant nest survival and nest densities are increased in or near areas with woody cover (Olson 1975, Robertson 1996). Conversely, Snyder (1984) found that pheasant nest predation was greater in an area with extensive woodland plantings. Consequently, a lack of research, or conflicting management strategies have many wildlife managers questioning current acquisition policies and conservation strategies and programs. Therefore, the objectives of this project were to (1) evaluate the relationship of duck and pheasant nest survival and nest density between different grassland patch sizes, (2) evaluate the effects of woodland plantings (i.e., shelterbelts) on duck and pheasant nest survival and nest density, and (3) assess the effects of landscape composition and spatial arrangement of landscape features on duck and pheasant nest survival and nest density in eastern South Dakota.

STUDY AREA

The state of South Dakota is divided approximately in half by the Missouri River, which runs north and south. All of the study sites were located east of the Missouri River in the following counties: Aurora, Beadle, Brookings, Hamlin, Hanson, Hutchinson, Kingsbury, Lake, McCook, Miner, Minnehaha, and Moody (Figure 1). This area is characterized by glaciated topography and is divided into three major physiographic regions: the Prairie Coteau, the James River Lowlands, and the southern Missouri Coteau (Gartner and Hull Sieg 1996).

The Prairie Coteau is a wedge-shaped formation that has gentle rolling topography, while the James River Lowlands are relatively flat (Johnson et al. 1995). The southern Missouri Coteau consists of gentle undulations and is more arid. These three regions contain many temporary and seasonal wetlands that were created during glaciation (Bryce et al. 1998). Land elevations range from 363 to 636 m above sea level while mean annual precipitation ranges from 45 to 55 cm, and mean July temperatures range from 15.6 to 31.7° Celsius across eastern South Dakota (Bryce et al. 1998).

These regions were previously described as tallgrass and mixed-grass prairies; however, current agricultural practices have cultivated the majority of the land for corn (*Zea mays*) and soybean (*Glycine max*) production (Bryce et al. 1998). Less than 1% of the original tallgrass prairie (Higgins 1999) and less than 30% of the original mixed-grass prairie currently exists in South Dakota due to conversion to crop production (Samson et al. 1998). Potential natural graminoid vegetation within these grasslands include, big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), switchgrass (*Panicum virgatum*), Indiangrass (*Sorghastrum nutans*), western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*), green needlegrass (*Stipa viridula*) and porcupine grass (*Hesperostipa spartea*). The landscape in eastern South Dakota is also highly fragmented with a 1-mile x 1-mile network of roads and contains many planted shelterbelts (Trautman 1982).

METHODS

Site Selection

All study sites were located on Game Production Areas (GPAs) or Waterfowl Production Areas (WPAs). These publicly-owned lands are managed by the South Dakota Department of Game, Fish, and Parks (SDGF&P) and the U.S. Fish and Wildlife Service (USFWS), respectively. Both agencies manage these areas for wildlife production. However, SDGF&P manages specifically for pheasants and white-tailed deer, while the USFWS manages for waterfowl production and migratory bird use. Both agencies restore their grasslands with similar mixtures of warm and cool season native grasses. Mixtures include combinations of big bluestem, Indiangrass, little bluestem, switchgrass, sideoats grama (*Bouteloua curtipendula*), western wheatgrass (*Elymus smithii*), slender wheatgrass (*Elymus trachycaulus*), green needlegrass, and small amounts of alfalfa (*Medicago sativa*) and red clover (*Trifolium pratense)*, or leadplant (*Amorpha canescens*) and Maximilian sunflower (*Helianthus maximiliani*). These mixtures create diverse vegetative structure that is preferred by nesting ducks and pheasants (Clark and Bogenschutz 1999, Reynolds et al. 2006). These management areas also contained limited invasions of Smooth bromegrass (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*).

Nest survival and density is thought to be influenced by many factors, including vegetation, patch size, landscape composition, and yearly population fluctuations. Therefore, site selection was completed to encompass a range of patch sizes and landscape composition while keeping vegetation consistent. Sites were selected non-randomly by evaluating aerial photography and physical patch characteristics that would allow me to keep patch vegetation consistent (i.e., patches dominated by warm-season native grasses which were interspersed with cool-season native grasses), while still reflecting differences in patch size, woody cover on a patch edge, and surrounding landscape composition. All sites were located a minimum of 3.2 km from one another to avoid pseudo-replication of landscape metrices.

During the 2008 nesting season, 44 patches were searched for nests (Table 1). During the 2009 nesting season, 41 patches were searched (Table 2). The majority of sites (n=33) were sampled in both years. However, in 2009 I added 10 new sites and 13 sites were discarded. This was done because of habitat management (i.e., burning or grazing) and to distribute the patch sizes more evenly. Sampled patches ranged in size from 3.64 to 56.66 ha and were separated into three categories: small (0-18 ha), medium (19-33ha), and large (34-57 ha) to ensure equal areas of patch sizes were searched and to have the ability to test differences in vegetation structure between patch size categories. These patch sizes are representative of grasslands that are planted for nesting habitat on GPAs and WPAs in eastern South Dakota. In 2008 and 2009, approximately equal areas of different-sized patches were searched throughout the study area, 880.99 ha and 804.10 ha, respectively.

Patch Definition

A patch was determined by using the protocol developed by the Regional Grassland Bird Area Sensitivity Group (2001), Bakker et al. (2002), and Horn et al. (2005). A patch was defined as the contiguous grassland area in the same cover-type and condition. For example, a patch boundary was delineated when disturbed grassland or cropland bordered the survey area. Seasonal, semi-permanent, or permanent wetlands ≥400 m in width were considered patch boundaries. Wetlands < 400 m in width were not considered patch boundaries, but these areas were subtracted from the patch area. Temporary wetlands were not subtracted from the patch area if dry, as these areas provide valuable nesting cover during some years (Gates 1965). In addition, minimum maintenance roads and fences that traversed the patch were not considered boundaries unless a different cover-type existed on the opposite side. However, maintained roads or shelterbelts that bordered the patch area by at least 90% were considered patch boundaries.

Landscape Composition

Landscape composition was quantified with ARC/MAP (2008) Geographic Information Systems (GIS) software by evaluating 2008 aerial photography obtained from the U.S. Department of Agriculture’s Farm Service Agency and ground-truthing. By combining these two methods, my GIS layer depicted the most accurate and current land use patterns. I used a 1,600 m circular buffer for the spatial scale that was created around the center of each patch. Land use was digitized into six landcover categories:

Cropland, Grassland Disturbed, Grassland Undisturbed, Wetland, Woodland, and Farmsteads (Table 3). Roadways and railroads were used to delineate landcover categories and were divided equally among intersecting landcover categories. The Grassland Disturbed category contained grasslands that were annually hayed or grazed. Alfalfa fields were included in this category because ducks and pheasants readily nest in this cover-type (Duebbert and Lokemoen 1976, Clark et al. 1999). The Grassland Undisturbed category consisted of grasslands enrolled in the Conservation Reserve Program (CRP) or similar programs, GPAs, WPAs, and other grasslands not actively managed during the nesting season. In addition, both grasslands categories (i.e., Grassland Disturbed and Grassland Undisturbed) were combined to make up the Grassland Total category. Wetland areas were calculated by using GIS data obtained from the National Wetland Inventory (NWI) office St. Petersburg, Florida, USA, and 2008 aerial photograph analysis. Because wetland areas are not static through time, it was necessary to adjust the NWI wetland areas by the most recent aerial photographs that were available (Bob Klaver, personal communication, U.S. Geological Survey, 4/16/2009). Distance from nest locations to woody cover was measured using ARC/MAP (2008) in meters.

Nest Searches

Nest searches were conducted two times during the nesting season (i.e., May 1 through July 25). I determined two nest searches would allow the greatest number of nests to be located within time and budget constraints. By searching the sampled patches twice, I could effectively detect females that were re-nesting or initiating nests later in the nesting season (Klett et al. 1986, Greenwood et al. 1995). The first nest search began on May 6, while the second search began on June 12 during both years. Grassland patches were searched for duck and pheasant nests using a 30-m chain pulled between two all-terrain vehicles following procedures described by Higgins et al. (1969) and Klett et al. (1986). A third person or spotter walked behind the center of the chain to help identify the location of flushed hens more effectively. Areas within study sites that were not conducive to nest dragging (i.e., wet areas) were searched on foot with techniques described by Basore et al. (1986). To avoid human-caused nest failures, nest searches were not conducted in cold, wet weather.

Marking Nests and Determining Nest Survival

Once a nest was located, it was marked with a small wire flag placed 4 m to the north and recorded with a hand-held Global Positioning System (GPS) unit. Species, date, time, clutch size, incubation stage, and Universal Transverse Mercator (UTM) coordinates were recorded for all nests. Pheasant clutches were aged by floating an egg from the clutch in a container of water (Westerskov 1950). Duck and other species' clutches were aged by candling the eggs (Weller 1956). Nests were re-visited every 7-10 days until their fate (i.e., hatched, destroyed, or abandoned) was determined. Nests were considered successful if ≥1 egg hatched. Successful nests were determined by the presence of detached membranes (Klett et al. 1986). Abandoned nests were identified by cold eggs and the lack of evidence of incubation. Meanwhile, depredated nests were identified by destroyed eggs, displaced nest material, or the disappearance of eggs. Researchers approached the nest from different directions upon each visit to avoid trampling vegetation. Additionally, if the female was present, researchers backed away and visited the nest at a later date. Nest checks were kept short (i.e., less than 3 minutes) to minimize human scent and disturbance. In addition, all nest checks were completed by the same observer during both years.

Vegetation Measurements

Visual obstructions readings (VORs), vegetation composition, litter depth, and effective leaf height were measured within one meter of every nest location at the time of detection to quantify the vegetative structure. A modified Robel pole was used to measure the highest point of complete (100%) visual obstruction (Robel et al. 1970). These measurements were recorded to the nearest 0.25 dm. Measurements were taken in the four cardinal directions four meters from the pole and one meter above the ground. These four readings were combined to provide an average reading for each nest. Vegetation composition was determined by identifying the two dominant plant species at each nest location. Litter depth measurements were taken by pushing a wooden ruler through the litter until it touched the ground and then a reading was taken in centimeters (cm). Effective leaf height was measured as an estimate of the height of the majority of first leaves above the understory and recorded to the nearest 0.25 dm. Effective leaf height was measured because it was determined to be a key indicator of taller vegetation when present, but height-density is low (Higgins et al. 2002). In addition, five random

VORs (i.e., four readings per point at five locations) were taken throughout the patch following the completion of nest searches to provide a representative sample of vegetation composition and structure.

Statistical Analysis

Vegetation Measurements

The vegetation readings for patches sampled during both years were combined and the means were calculated, after determining there was no significant difference between years. Meanwhile, the actual vegetation readings were used for patches only sampled during one year. I used SYSTAT 12.0 (SYSTAT 2002) to perform all statistical analyses. I then used analysis of variance (ANOVA) tests to determine if there were any significant differences between vegetation structure and patch size categories. I considered tests to be significant at the $p < 0.05$ level.

Nest Density

Nest densities were calculated by dividing the total number of nests found per patch by the total area searched (Higgins 1977). Since this estimate is a composite of the nests found over a time span, it over-estimates nest density at any given time (Hill 1984). However, because only a fraction of nests are detected (Sowls 1955, Gloutney et al. 1993) my estimates are a conservative estimate of total nest density over the entire nesting season. Nest densities at sites searched in both years were not significantly different between years ($p \geq 0.05$) for any species, so they were combined and the mean values were calculated, while the actual nest density values for patches searched during only one year were used. This was done to avoid pseudo-replication of patches in my regression analysis. Nests that were eventually abandoned were included in my nest density estimates because these nests were initiated and occupied at the time they were located.

I used SYSTAT 12.0 (SYSTAT 2002) to perform all statistical analyses. I used ANOVA tests to determine any significant differences in nest density among patches that had woody cover on an edge and those patches that did not. I considered tests to be significant at the $p < 0.05$ level. *A priori* models established from the literature were used with complete multiple linear regression to develop competing models to evaluate the influence of local patch and landscape attributes on nest density for each species (see Table 4 for definitions of model variables). I focused *a priori* models on the main effects of interest, which included: patch size, landscape variables, and vegetation variables. The vegetation measurements Leaf height and Robel were correlated. Meanwhile, the landscape composition categories that were correlated were Grassland Undisturbed and Cropland, Grassland Total and Cropland, and Grassland Total and Grassland Disturbed. Therefore, only one of the correlated variables in each group was used in model building at one time. I included competing models for all single vegetation variables and landscape composition variables that were considered to be biologically important to each species being analyzed. I used Akaike's Information Criterion corrected for small sample size (AICc) which is defined as:

$$AICc = -2\log L + 2K\left(\frac{n}{N-K-1}\right)$$

where log L is the natural logarithm of the likelihood function evaluated at the maximum likelihood estimates, K is the number of estimable parameters, and *n* is the sample size, to determine the most appropriate models for each species (Akaike 1969, Burnham and Anderson 2002). I considered the model that produced the smallest AICc value the best approximation for the information in the data set, however, models with ΔAICc <2 were considered equally plausible models of the data (Burnham and Anderson 2002).

Nest Survival

The nest survival model in program MARK (White and Burnham 1999, Dinsmore and Dinsmore 2007) was used to determine nest survival probabilities as specific functions of patch size, year, nest-age, search, woody cover, distance to woody cover, landscape composition, and vegetation structure (Dinsmore et al. 2002) (Table 5). All species that had more than 30 nests located were analyzed individually. Nests for duck species were not combined because each species has somewhat different nesting chronology, microhabitat preferences (Horn et al. 2005), and initial model results indicated a species effect. Abandoned nests were not used in the nest survival analysis because it was impossible to determine if nests were abandoned because of human or natural causes. I used AICc values and model weight (w_i) to determine the most appropriate models (Akaike 1969, Burnham and Anderson 2002). I considered models that produced ΔAICc values <2 to be equally plausible models for the data (Burnham and Anderson 2002). I focused *a priori* models on the main effects of interest, which included: patch size, landscape variables, presence of woody cover, distance from nest to woody cover, vegetation variables, year, nest-age, search, and constant Daily Survival Rate (DSR). I also included models considered biologically significant to each species being analyzed based on a review of the literature and field observations. Next, potential interactions of the best resulting models were added to evaluate whether different combinations of covariates were having a greater effect on nest survival than original models (Horn et al. 2005, Stephens et al. 2005). The relative importance of each covariate was assessed by examining the Beta-values (β). These values indicated how and to what degree each covariate affected nest survival in all plausible models (Dinsmore and Dinsmore 2007).

Incubation time and clutch size vary by species and region (Bellrose 1976, Trautman 1982) and were incorporated into Mayfield (1975) nest survival estimates. Actual nest survival estimates (i.e., the nest survival percentages) were calculated by raising the model's predicted DSR to a power equal to the mean laying plus incubation periods for successful clutches (Mayfield 1975, Klett et al. 1988) (Table 6). The DSR was defined as the probability that the nest would survive to the next day.

RESULTS

Patch Vegetation

There were no significant differences (p >0.05) in VORs, litter depth, and effective leaf height among size categories (i.e., small, medium, and large) of sampled patches (Table 7). This indicated that patch vegetative structure did not vary greatly among patch size categories of the study sites.

Nest Density

During the 2008 and 2009 nesting seasons, a total of 1,645 nests were located within the sampled patches representing 12 species of upland nesting birds (Table 8). Species were only analyzed when ≥ 30 nests were located. After all exclusions, a total of 1,585 nests which included blue-winged teal, mallard, gadwall, northern shoveler, and ring-necked pheasant were used in my analysis.

Blue-winged teal

A total of 432 blue-winged teal nests were located within the sampled patches for 2008 and 2009. The abandonment rate was quite low (2.6%) when pooled for both years. Nest density estimates varied from 0 to 0.9 nests/ha across sampled sites. There was no significant difference in nest density between patches that had woody cover present on an edge, and patches that did not ($F = 0.45$; $df = 1,52$; $P = 0.83$). Total grassland was included in all competing models (Table 9), and was negatively correlated with nest density. The proportion of farmsteads and Robel readings tended to decrease nest density estimates and were included in four of seven and three of seven competing models, respectively. Meanwhile, the proportion of wetlands was positively related to nest density.

Gadwall

A total of 155 gadwall nests were located within the study areas and used in analysis. Gadwall exhibited a 3.3% abandonment rate when pooled for both years. Nest density estimates ranged between 0 and 0.64 nests/ha across sampled sites. There was no significant difference in nest density estimates among patches with woody cover present and those without ($F = 2.42$; $df = 1{,}52$; $P = 0.13$). All three competing models included the proportion of farmsteads, as an individual variable or combined with other variables. The proportion of farmsteads was negatively associated to nest density estimates in all competing models (Table 10). Patch size was positively related to nest density and was included in two of three competing models. Meanwhile, the proportion of wetlands only occurred in the third-ranked model after being combined with patch size and the proportion of farmsteads. The proportion of wetlands had a positive association with nest density.

Mallard

During 2008 and 2009, a total of 345 mallard nests were located and included in analysis. Mallards exhibited an abandonment rate of 5.5% when pooled for both field seasons and nest densities ranged from 0 to 1.34 nests/ha. There was no significant difference between patches with woody cover on an edge and those without ($F = 0.03$; *df*

= 1,52; *P* = 0.87). Patch size was positively related to nest density and was included in all competing models (Table 11). As patch size increased from 20 ha to 40 ha, nest density increased by approximately 0.15 nests/ha (Figure 2). Litter depth, proportion of wetlands, and the proportion of woodlands were included in top-ranked models and increased nest density estimates, when combined individually with patch size. In addition, Robel readings and the proportion of total grassland were both negatively related to nest density when individually combined with patch size.

Northern shoveler

During both field seasons, a total of 58 northern shoveler nests were located and used in analysis. Northern shoveler abandonment rate was 5.2% when pooled for both years. Nest density estimates ranged from 0 to 0.27 nests/ha across sampled sites. Patches that had woody cover on an edge and those that did not, had no significant difference in nest density ($F = 1.72$; $df = 1,52$; $P = 0.20$). The proportion of disturbed grassland within 1,600 m was positively related to nest density and was included in four of seven competing models (Table 12). Meanwhile, Robel readings occurred in two competing models (as a single variable or when combined with other variables) where it was negatively related to nest density. The proportion of total grassland and patch size produced competing models where they were both positively related to nest density. Finally, the proportion of wetlands was positively related to nest density in a single competing model, when combined with the proportion of disturbed grassland.

Ring-necked pheasant

During 2008 and 2009, a total of 595 ring-necked pheasant nests were located and included in my analysis. Pheasants exhibited a 32.8% abandonment rate, and nest density estimates varied from 0 to 1.41 nests/ha across sampled areas. There was no significant difference in nest density estimates between patches with woody cover present along an edge and those without ($F = 0.56$; $df = 1{,}52$; $P = 0.46$). The highest-ranked model contained the proportion of cropland which was negatively related to nest density. However, after evaluating other competing models, proportions of cropland was replaced by proportions of total grassland which was positively related to nest density, in three of four competing models. The proportion of farmsteads was included in all four plausible models, and was negatively related to nest density (Table 13). In addition, Robel readings were positively related to nest density in three of four models. The proportion of wetlands, when combined with other variables occurred in one competing model and was positively related to nest density.

Nest Survival

A total of 1,158 nests with known fates (i.e., hatched or destroyed) were used in nest survival models (Table 14). Nest survival models were developed for species with ≥ 30 nests, which included blue-winged teal, mallard, gadwall, northern shoveler, and ring-necked pheasant. All nests that were destroyed by researchers, abandoned, or flooded were not included in analysis. Although I did not collect data on the abundance of nest predators within the sampled patches, I observed the following species during routine fieldwork: coyote (*Canis latrans*), red fox (*Vulpes vulpes*), striped skunk, raccoon, badger (*Taxidea taxus*), thirteen-lined ground squirrels (*Spermophilus tridecemlineatus)*, and feral cats (*Felis catus*). Coyotes, red foxes, and raccoons were also detected on several study sites during a concurrent study.

Blue-winged teal

A total of 407 blue-winged teal nests were used in my analysis. Hatch dates of successful nests ranged from June 2 to July 27. The constant DSR for 2008 was 0.9611 (95%CI = 0.9539 - 0.9671) and in 2009 it was 0.9577 (95%CI = 0.9484 - 0.9653), with Mayfield (1975) nest survival estimates of 25.9% and 23.0%, respectively. The proportion of wetlands and total grassland within the landscape and search were included in all four competing models (Table 15). In the overall best model, nest survival increased with the proportion of wetlands (β=2.216, SE=0.994) within 1,600 m (Figure 3). In addition, larger proportions of total grassland (β=1.943, SE=0.533) increased nest survival (Figure 4). Meanwhile, there was a slight increase in nest survival for patches with woody cover on an edge (β=0.223, SE=0.146) and a decrease in nest survival for nests found within the second search (β=-0.495, SE=0.154). The third-best model revealed that nest survival was negatively related to larger distances to woody cover; however, this effect was negligible (β=-0.021, SE=0.019). Patch size was included in the fourth-ranked model and was positively related. However, this relationship was weakly supported (β=0.005, SE=0.005). No individual vegetation readings produced any models $\leq$ 2 ΔAICc of the best-ranked model.

Gadwall

A total of 149 gadwall nests were used in my analysis. Gadwall displayed the latest hatch date of all duck species in my study, with hatch dates ranging from June 10 until August 1. Mayfield (1975) nest survival estimates for 2008 and 2009 were 24.6% and 26.7%, respectively. The constant DSR for 2008 was 0.9618 (95%CI = 0.9501 - 0.9709) and for 2009 was 0.9640 (95%CI = 0.9483 - 0.9751). The overall best model contained the proportion of cropland (β=-2.436, SE=0.937) and litter depth (β=-0.135, SE=0.063), where the proportion of cropland within 1,600 m was the dominant mechanism controlling nest survival (Table 16, Figure 5). These two covariates were also included in all other plausible models. However, the third-best model included the proportion of total grassland when combined with litter depth with a positive relationship between the proportion of total grassland (β=1.759, SE=0.722) and nest survival. But, the negative relationship between the proportion of cropland and nest survival seemed to describe the interaction better (i.e., a higher weighted model). Litter depth (β=-0.130, SE=0.063) was negatively related to nest survival.

Patch size was negatively related to nest survival in the second-best model, however, the effect was minimal (β=-0.014, SE=0.011). The fourth-ranked model indicated that nests found during the first search had slightly higher survivorship. Furthermore, nests that were located in patches that had woody cover present on an edge exhibited a slightly lower survival rate than nests in patches without woody cover. Similarly, nests located closer to woody cover had lower survival than those at greater distances; however, these effects were minimal. In the seventh-ranked model, the proportion of farmsteads did positively affect nest survival, although the effect was negligible. Finally, nest age was included with the eighth-ranked model, but had no significant effects on nest survival.

Mallard

I included a total of 326 mallard nests in my analysis. Hatch dates of successful mallard nests ranged from May 17 to July 31. Mallards had the earliest hatch date of all duck species during my research. The nesting seasons of 2008 and 2009 exhibited different nest survival rates for mallards. The constant DSR for 2008 was 0.9447 (95%CI = 0.9346 - 0.9533) and in 2009 it was 0.9305 (95%CI = 0.9132 - 0.9446), with Mayfield (1975) nest survival estimates of 12.2% and 7.0%, respectively. Although nest survival estimates appear quite different between years, the year effect did not result in any competing models.

Constant DSR (β=2.719, SE=0.249) was the most-supported covariate when combined with several other factors within the top ranked models (Table 17). Distance from nests to woody cover was positively correlated with nest survival (β=0.071, SE=0.019), but was weakly supported. There was more support for an effect of search (β=-0.361, SE=0.166); nests found within the first search had higher survival rates. The second-best model indicated that higher leaf height readings (included in six of seven models) negatively affected nest survival (β=-0.010, SE=0.006), but this effect was negligible. The second-best model also indicated that the presence of woody cover (β=-

0.534, SE=0.149) on a patch edge was negatively related to nest survival. In addition, there was support for larger proportions of wetlands to positively impact nest survival in the fifth-ranked model. Furthermore, patch size was included in the fourth-and sixth-ranked models, although there was no support for any affect on nest survival in either case.

Northern Shoveler

A total of 53 Northern shoveler nests were used in analysis. Hatch dates of successful nests ranged from May 30 to July 14. The constant DSR for 2008 was 0.9652 (95%CI = 0.9428 - 0.9790) and in 2009 it was 0.9358 (95%CI = 0.8918 - 0.9626), with Mayfield (1975) nest survival estimates of 29.99% and 10.48%, respectively. The best overall model, contained the proportion of undisturbed grassland (β=4.702, SE=2.763) and leaf height (β=-0.042, SE=0.024). Larger proportions of undisturbed grassland within 1,600 m largely contributed to increased nest survival (Figure 6). Leaf height was negatively related to nest survival in the top model, but weakly supported. However, the second-best model indicated strong evidence for a year effect (Table 18). Nest survival decreased nearly 20% between 2008 and 2009. Larger patch size increased nest survival in the fourth-, eighth-, and tenth-ranked models, but with minimal support ($\beta \leq 0.027$). Finally, the fifth-best model contained only constant DSR, which indicated that no other covariate explained nest survival better.

Two other competing models (fourth- and seventh-ranked) contained the proportion of cropland, which was negatively correlated to nest survival in both models.

When nest age was included with the same covariates as the top-ranked model, there was little support for any effect with nest age. Smaller distances from nests to woody cover had a negative effect on nest survival in the 12th-ranked model, but showed minimal support (β=-0.015, SE=0.061). Meanwhile, woody cover on an edge was combined with other highly ranked covariates, which produced a plausible model, where it was positively related to nest survival, but with little support.

Ring-necked pheasant

A total of 223 ring-necked pheasant nests were used in analysis. Due to the females' unwillingness to flush off of nests, researchers accidently destroyed 22 nests, while six other nests were destroyed due to flooding. These nests were not included in the analysis. Hatch dates varied widely, and ranged from May 21 until August 12. Pheasants experienced Mayfield (1975) nest survival estimates of 13.2% in 2008, while in 2009 it was 4.8%. The constant DSR for 2008 was 0.9403 (95%CI = 0.9302 - 0.9490), while in 2009 it was 0.9119 (95%CI = 0.8936 - 0.9272). While these survival rates were quite different, year effect did not enter any competing models. Only three models produced ΔAICc ≤2 (Table 19). The best overall model, included cropland (β=-1.206, SE=0.446), farmsteads (β=-22.654, SE=7.854), Robel reading (β=-0.081, SE=0.052), and nest age (β=0.023 SE=0.009). Farmsteads played the most significant role in all the top-ranked models, where higher proportions lead to decreased nest survival (Figure 7). In addition, larger proportions of cropland decreased nest survival (Figure 8). Higher Robel readings were negatively related to nest survival, although the relationship was negligible. Nest age was also included in the top-ranked model, however, with such a low β-value (0.023, SE=0.009), there is virtually no support for this covariate.

The second-ranked model also included patch size (β=0.003, SE=0.005) when combined with the covariates within the best overall model, but the effect was insignificant. The third-ranked model contained the same covariates as the best-ranked model, but the proportion of cropland and was replaced by the proportion of undisturbed grassland. The proportion of undisturbed grasslands (β=1.711, SE=0.733) within the landscape played an important role in increasing nest survival; however, support for the proportion of farmsteads (β=-18.409, SE=8.069) was greater.

DISCUSSION

Blue-winged teal

Blue-winged teal nest density was strongly influenced by the proportion of grassland and wetland habitat in the surrounding landscape. As more nesting habitat became available, females spread out which lowered overall nest density. In contrast, fields that had larger proportions of wetlands within the landscape produced higher nest densities. High wetland densities have long been known to attract high densities of breeding ducks (Cowardin et al. 1995). Other researchers have found similar results (Cowardin et al. 1995, Arnold et al. 2005) and Stephens et al. (2005) speculated that areas with greater wetland densities could achieve higher nest densities.

Wildlife managers manage grassland restorations for a diversity of habitats. However, many times these restorations are dominated by tall, dense vegetation. My results indicate that this practice may not be the most suitable for attracting large numbers of nesting teal. Blue-winged teal nest densities were lowest in fields with tall, dense vegetation. In South Dakota, blue-winged teal are known to prefer shorter vegetation (Spencer Vaa, personal communication, South Dakota Game Fish and Parks, 1/13/2010). Therefore, areas that have higher VORs will attract fewer nesting females (i.e., lower nest densities). This relationship can also explain why nest density estimates decreased with larger proportions of total grassland within the landscape. Because the category total grasslands contained a high proportion of disturbed grasslands when compared to undisturbed grasslands, more preferred nesting areas (i.e., grasslands with shorter vegetation) were available. As more total grasslands occurred within the area, there was simply more available nesting habitat, which spread out the females, thereby, lowering nest density.

Meanwhile, the proportions of farmsteads within the landscape also entered several competing models. Larger proportions of farmsteads were correlated with decreased nest density. While this relationship is difficult to explain, perhaps it is a result of human disturbance. As more farmsteads appear within the landscape, perhaps more human disturbance is experienced by nesting females which results in females selecting nesting sites in areas further away from human activity. Human disturbance has been found to negatively affect many avian species (Boyle and Samson 1985, Pease et al. 2005). Blue-winged teal respond to human activities (i.e., recreational walking, vehicle use, and everyday activities) in the same manner, ultimately avoiding areas where these activities regularly occur.

Nest survival of blue-winged teal was significantly correlated with larger proportions of wetlands within the surrounding landscape. As wetland area in the landscape increased from 10% to 30%, nest survival increased nearly 10%. Large numbers of breeding ducks have been known to be attracted to areas with high densities of wetlands (Cowardin et al. 1995). Because my study sites were located within the PPR, I predicted that nest survival would increase with increased amounts of wetlands. However, Stephens et al. (2005) found that the number of wetlands within the landscape was negatively related to nest survival, while Reynolds et al. (2001) found that wetland area did not enter any models when determining nest survival. However, because my nest density models included a positive relationship with wetland area as well, renesting may have played a significant role in overall nest survival. Several researchers stated that renesting potential is largely responsible for increasing nest survival (Bellrose 1976, Klett et al. 1988). The reason behind this process is that higher nest densities “flood” the landscape with nests, which allow a greater number of nests to be successful. Clark and Shutler (1999) stated that areas that experienced higher nest densities could potentially result in higher nest survival estimates. Because blue-winged teal have short incubation periods and are mid- to late-season nesters, high nest densities may have contributed to increased nest survival estimates even though many nests were destroyed by predators.

More grassland on the landscape had a positive effect on nest survival. This trend has been documented by several researchers within the PPR (Reynolds et al. 2001, Horn et al. 2005, Stephens et al. 2005) and supports many agencies’ management strategies of protecting grasslands. One possible explanation for this relationship is that some nest predators are affected by the amount of grassland in certain areas (Sovada et al. 1995). During recent years, red fox have been displaced by coyotes in eastern South Dakota (Sovada et al. 1995). Even though coyotes do depredate duck nests (Sooter 1946), duck nest depredation is much more severe by red fox (Johnson et al. 1989). In addition, coyotes have been known to suppress raccoon populations (Sargeant et al. 1993). Therefore, if the areas that contained higher proportions of total grassland also contained more coyotes, as suggested by Phillips et al. (2003), higher nest survival could exist.

During my research, patch size did not play a significant role in determining nest survival; this indicated that small grassland patches are capable of producing adequate nest survival, if the patches are located within landscapes that contain a higher proportion of grassland. The presence of woody cover on an edge and search were included in probable models; however, there was little support for any effect caused by these covariates. Cowardin et al. (1985) concluded that a nest survival rate of nearly 20% would be needed to maintain teal populations. My nest survival rates ranged from approximately 23% to 26%, which is above that threshold. Consequently, higher nest survival is ultimately driven by area of wetland and grassland (disturbed and undisturbed) within a given landscape. When these two factors are combined with high nest densities and the lack of dominant nest predators (i.e., red fox) blue-winged teal nest survival has the potential to be above average, as my research indicated.

Gadwall

Patch size and the proportion of farmsteads within the landscape exhibited the most influential effects on gadwall nest density. Gadwalls experienced the same pattern as blue-winged teal when evaluating farmstead area; larger proportions of farmsteads were correlated with decreased nest density. As more farmsteads appear within the landscape, perhaps more human disturbance is experienced by nesting females which results in nesting in areas further away from human activity. Many avian species have been found to be disrupted from normal activities because of human disturbance (Boyle and Samson 1985, Pease et al. 2005). Therefore, gadwalls respond to human activities, such as vehicle use, recreational walking, and everyday activities in the same manner, which is to avoid areas where human activity regularly occurs. Thus, areas that contain high proportions of farmsteads and human-occupied dwellings will exhibit lower nest densities.

Gadwall nest density also increased with patch size. Larger patches of preferred nesting cover simply attracted larger numbers of females, which resulted in higher nest densities. Additionally, Arnold et al. (2005) and Horn et al. (2005) found that more duck nests occurred in larger patches. Since certain habitat and landscape characteristics are more attractive to nesting female ducks (Cowardin et al. 1995, Stephens et al. 2005) and because philopatry plays a critical role in determining nest site location (Clark and Shutler 1999), areas with good nesting habitat (i.e., GPAs, WPAs, or CRP) attracted more nesting females. Consequently, when large undisturbed grassland patches readily occur with good wetland conditions, gadwalls will continue to exhibit high nest densities.

Gadwall nest survival decreased significantly with increased proportions of cropland within the surrounding landscape. An increase in cropland area from 20% to 60% resulted in a decrease in nest survival from approximately 40% to only 10%. In addition, research has shown that some nest predators actually select isolated patches of cover rather than areas with large amounts of grassland (Kuehl and Clark 2002). Furthermore, Phillips et al. (2003) found that nest survival rates were lower in areas that contained smaller amounts of grassland in the overall landscape. Consequently, as grassland loss continues in eastern South Dakota gadwalls will experience decreased nest survival.

Litter depth played a limited role in determining nest survival. As litter depths increased, gadwall nest survival tended to decrease, although this effect was weak. Horn et al. (2005) stated that individual species have micro-habitat preferences when selecting nesting sites. Gadwalls tend to seek out stands of dense vegetation for nest sites when compared to other dabbling duck species (Bellrose 1976). In addition, gadwall nest survival has been strongly related to individual vegetative characteristics (Hines and Mitchell 1983, Crabtree et al.1989). During my study, extremely dense vegetation was correlated with high amounts of litter, probably due to the previous years' vegetation build-up. Because litter depth was supported in all plausible models, the relationship between nest survival and litter depth could be a result of this species selecting areas with more litter, even though the chances of raising a successful nest are unlikely.

Finally, nests found in smaller grassland patches and nests that were initiated earlier expressed higher gadwall nest survival rates; however, the relationships were weakly supported. The primary factor driving nest survival for gadwalls was the proportion of cropland within 1,600 m. Grassland protection has been a longtime management strategy for many agencies and is supported by much research (Reynolds et al. 2001, Stephens et al. 2005). Without an adequate amount of grassland (i.e., undisturbed or disturbed) on the landscape and a low proportion of farmsteads, nest density and survival will continue to decrease.

Mallard

Large grassland patches supported higher densities of mallard nests during my research. In fact, patch size was the most important factor when determining nest density. Similarly, other researchers have found that larger patches support more duck nests when compared to small patches (Arnold et al. 2005, Horn et al. 2005). Female mallards are known to be highly philopatric (McLandress et al. 1996) and to prefer specific habitat types and landscape characteristics (Cowardin et al. 1995, Stephens et al. 2005). Consequently, large patches of good nesting cover and wetland conditions (i.e., GPAs, WPAs, and CRP) attracted more nesting females which resulted in higher nest densities. Several other variables resulted in competing models when individually combined with patch size, although there was minimal support for any effect from these variables. Therefore, patch size is the most critical aspect in determining mallard nest densities within eastern South Dakota. However, the proportion of those nests that actually survive ultimately dictates how the population will be affected.

The most influential factor that contributed to nest survival for mallards in my study was the constant DSR. This indicated that no other covariate played a significant role in determining nest survival. However, other covariates were weakly supported and explained some of the variation in mallard nest survival estimates. One factor that contributed to increased nest survival was that nests found within the first search had higher survival rates. Sovada et al. (2000) also found that duck nest survival was slightly higher for nests initiated earlier in the nesting season. In addition, mallards exhibited the earliest hatch dates of any duck species in my study, which resulted in very early nest initiation dates. Consequently, nest predators may not become dependent upon nests as a food source until later in the spring, when more nests are readily available. Weller (1979) also hypothesized that predators do not focus on nests until later in the nesting season when a larger number of nests provide a more reliable food source. Additionally, as nest predators raise young later in the spring, more predators occur on the landscape. Researchers have suggested that factors that influence nest survival may change as the nesting season progresses (Sovada et al. 2000). This type of interaction (i.e., fewer predators searching for nests earlier in the season) could be the reason why my study found higher nest survival within the first search.

The presence of woody cover on a patch edge was included in several plausible models where it was weakly related to decreased nest survival. Others have also found little effect of edge on nest survival in other areas of the PPR (Pasitschniak-Arts et al. 1998). Additionally, the distance to woody cover played a limited role in nest survival during my research. While this trend wasn't strongly supported, it does hint that nests located farther away from woody cover have higher survival rates. In Montana, Gazda et al. (2002) found that depredation rates of artificial nests decreased slightly with increased distances from woody cover. But, most of these nests were depredated by Black-billed magpies (*Pica pica*) which rarely occur in eastern South Dakota and few nests in my study were destroyed by avian predators. While research indicates mammalian nest predators may utilize woody edges as travel corridors (Winter et al. 2000), my research is the first to indicate a correlation between woody cover and survival of real nests (i.e., not artificial nests). Until this relationship can be further researched, I recommend against planting woody cover within or adjacent to duck nesting habitat. In addition to the potential negative effect that woody cover has on nest survival, planting woody cover would decrease the overall grassland proportion which was strongly correlated to increased nest survival of other duck species and pheasants during my research.

The only landscape factor that was included in any plausible mallard nest survival model was the proportion of wetlands. My results indicated that as wetland area increased, nest survival increased as well. Other researchers also found that high densities of wetlands resulted in more nests being productive (Ball et al. 1995). But, Reynolds et al. (2001) found that wetland area did not enter any models when determining nest survival. However, because my nest density models included a positive relationship with the proportion of wetlands, renesting may have played a significant role in overall nest survival. This outcome is similar to the trend that my blue-winged teal results exhibited, which provides more support for increased nest survival in areas with larger proportions of wetlands.

Against my prediction, patch size had only a weak effect on nest survival. While this covariate entered two probable models, the relationship was almost zero in both cases with β-values less than 0.005. Perhaps this occurred because the largest patch that I sampled was 56.66 ha, which wouldn't contain much "core area." Eastern South Dakota is severely fragmented and restored grasslands (i.e., CRP, GPAs, and WPAs) are rarely over 57 ha. Consequently, my research focused on restored grassland patch sizes currently available for nesting ducks in eastern South Dakota. However, if I had sampled larger patches, perhaps patch size would have become more important in determining nest survival. Nevertheless, during my research patch size played a limited role in determining nest survival in fields located in eastern South Dakota. Others have found this relationship to occur in other areas of the PPR (Clark and Nudds 1991, Jimenez et al. 2007). Still, Horn et al. (2005) found that positive correlations do exist between nest survival and patch size (2-192 ha), but my research indicated that landscape composition is the most critical factor. Leaf height was also included in several plausible models; however, there was minimal support for any effect. Effective leaf height is another index of structural suitability of the vegetation cover for upland nesting birds (Higgins et al. 2002). But, VORs and litter depth did not enter any competing models. Therefore, I assume individual vegetation readings played an insignificant role in determining nest survival of mallards.

Finally, Cowardin et al. (1985) recommended that at least a 15% nest survival rate was needed to maintain mallard populations. My mallard nest survival rates ranged from 7% to 12% for 2008 and 2009, respectively. These low nest survival rates indicate that maintenance levels are not adequately being met from the areas I sampled in eastern South Dakota; therefore, populations of mallards may be declining in this area. Furthermore, because constant DSR played the most significant role in all competing models, nest survival is largely determined by spatial and temporal factors associated with nest location. Possible factors include distance to wetland edges and the time-period when nest predators start utilizing nests as a food source. Predator communities are known to directly affect nest survival of duck species (Jimenez et al. 2007). When and where a nest is located in relationship to which predator species occur within the patch ultimately determines if that nest will succeed. I fully support this theory, because none of my competing models revealed any significant trends that directly affected mallard nest survival.

Northern Shoveler

Northern shoveler nest density models included a large number (n=13) of competing models that contained many different variables. This large number of models indicated that numerous variables were responsible for affecting nest density, rather than one specific variable (Burnham and Anderson 2002). However, larger proportions of disturbed grasslands appeared in several competing models. As these proportions increased, so did nest density. In most other duck species that I examined, there was a positive relationship that occurred between the proportions of total grassland and nest density. Proportions of total grassland and disturbed grassland were correlated; however, the proportion of disturbed grasslands described the interaction with northern shoveler nest density better. Several other researchers have found similar relationships between duck nest density and larger proportions of grasslands (Reynolds et al. 2001, Horn et al. 2005, Stephens et al. 2005).

Higher VORs were negatively associated with nest density, while patch size was positively related. Northern shovelers are known to prefer shorter vegetation over tall vegetation for nesting purposes (Bellrose 1976). Arnold et al. (2005) also found that nest densities of dabbling ducks increased with patch size. Perhaps these habitat preferences (i.e., short vegetation and larger patches) directly affected my nest density estimates. However, the relationship between the proportions of total grassland probably influenced nest density more than these other variables. Shovelers have higher nest densities when they exist in areas with larger amounts of grassland (Reynolds et al. 2001). But, factors that affect nest survival could be very different from factors that increase nest density. For example, if areas with high nest densities also experienced a high degree of nest predation, lower survival rates could be expected.

Nest survival of duck species is often affected by the amount of undisturbed grasslands in a specific area (Reynolds et al. 2006). My results indicated that the proportion of undisturbed grasslands within the landscape was the major factor that affected northern shoveler nest survival. As proportions of undisturbed grasslands increased from 10% to 20%, nest survival increased nearly 20%. This relationship was found by other researchers as well (Reynolds et al. 2001). Other probable models included combining undisturbed grasslands with leaf height or patch size. However, neither of these two covariates had any measurable effect on nest survival, indicated by extremely low confidence intervals (i.e., 0.08<). Year effect did produce a competing model for nest survival, which could potentially explain the variations I saw in my nest survival estimates. Jimenez et al. (2007) found that nest survival rates varied greatly between years, making it difficult to actually determine what factors were affecting nest survival.

Finally, 13 competing models (≤ 2 AICc) were produced with different covariates or combinations of covariates. This large number of competing models indicate that any plausible models' covariates could be contributing to the increase or decrease in nest survival (Burnham and Anderson 2002). Furthermore, this could be a result of only having 53 nests, which were scattered over various types of landscapes.

Ring-necked pheasant

Pheasant nest densities were higher in unfragmented landscapes. Positive correlations between grassland area and higher nest density were found in all competing models. Other researchers have found similar relationships to occur between pheasants and the total area of grassland. As more grassland cover is available, higher nest densities occur (Gates and Hall 1975). Additionally, the proportions of farmsteads played an important role when determining nest density. Larger proportions of farmsteads were negatively associated with nest density in all plausible models. While this relationship is difficult to explain, perhaps it is a result of the nest predators that are associated with farmstead area. As more farmsteads appear within the landscape, more nest predators are present because of the human development (Lariviere et al. 1999, Kuehl and Clark 2002). These high predator densities that occur near human dwellings or farmsteads could potentially be the reason why nest density estimates decreased with increased proportions of farmsteads.

Higher nest densities were also associated with higher VORs. Olson (1975) documented that vegetation structure is an important consideration for increasing pheasant nest productivity. Therefore, pheasant nest densities have the potential to be higher in undisturbed grasslands and disturbed grasslands that are managed for higher vegetative structure. Finally, larger proportions of wetlands were positively correlated with nest density. Many of my sampled areas contained food-plots and wetlands, both of which have been shown to increase winter survival (Larsen et al. 1994, Gabbert et al. 1999). Pheasants don't typically disperse very far from wintering areas (Trautman 1982) and most nesting hens remain associated with the wetland complexes that comprised their winter range (Dumke and Pils 1979). During my research, areas with greater proportions of wetlands resulted in higher nest densities because more hens overwintered in the areas with more wetlands (i.e., better winter cover).

My nest density estimates (0 to 1.4 nests/ha) were similar to results presented by Keyser (1986), but lower than Rohlfing (2004) and Hankins (2007). Their estimates were higher due to the intensive nest searching methods (i.e., searching with hockey sticks) they employed. This method allowed them to locate all nests, both active and depredated. However, their nest density estimates are probably biased higher than actual nest densities because they used both active and depredated nests (Hill 1984). The nest dragging methods I utilized only located nests that had hens actively attending them, which is a conservative estimate of actual nest density, because not all active nests are located (Sowls 1955, Gloutney et al. 1993). Additionally, during the two years that I monitored nests, nest abandonment rates were approximately 32%. Nest abandonment usually occurs from dump nesting or predation, but can also occur from research procedures (Solomon 1984). Several others have documented similar rates of abandonment (Olson 1975, Keyser 1986). This large proportion of abandoned nests also decreased the likelihood of higher nest densities contributing to overall higher nest survival, because the abandoned nests were not used in the survival models.

The proportion of farmsteads within 1,600 m greatly affected pheasant nest survival. Larger proportions of farmsteads were strongly correlated with decreased nest survival. For example, as the proportion of farmsteads increased from 1% to 2%, nest survival decreased over 7%. Moreover, all plausible nest survival models included multiple covariates, but the proportion of farmsteads played the most significant role in each model. Researchers have found that several major nest predators (particularly striped skunks) are affected by the density of farmsteads within a given landscape (Lariviere et al. 1999, Kuehl and Clark 2002). In addition, predation has been determined to be the major factor that drives pheasant nest survival (Chesness et al. 1968, Clark and Bogenschutz 1999). The largest proportion of farmsteads within my sampled landscapes consisted of 5.5%. While this value isn't abnormally large when compared to other categories, when scattered throughout the landscape it does reflect the significance that larger proportions of farmsteads can have on nest survival (Figure 9). Additionally, Greenwood (1986) found that his nest survival rates increased by 10% when striped skunks were removed from nearby areas. Therefore, it is likely that the proportion of farmsteads played such a significant role in my results because the density of farmsteads has the ability to impact predator populations. For example, if the juxta-position of farmsteads were closer to the sampled grassland habitats, more skunks could have been present to depredate nests, which would in turn lower nest survival.

The proportion of cropland that occurred within the landscape also played a role in determining nest survival. Nest survival was negatively correlated with cropland area in the landscape, regardless of grassland patch size. This relationship has been found by other researchers (Olson 1975, Trautman 1982). In addition, Clark et al. (1999) found that pheasant nest survival increased as grassland core area increased within the study area in Iowa. There are two possible reasons why my results experienced this relationship. First, most nests are concentrated in remaining grassland patches in landscapes dominated by agriculture (Riley 1995, Clark et al. 1999). And second, the lack of grassland patches within the landscape also concentrates predators into these remaining grassland patches (Kuehl and Clark 2002, Phillips et al. 2003, Reynolds et al. 2006), which in turn reduces nest survival.

Although larger patch sizes have been previously thought to positively affect pheasant nest survival (Gate and Hall 1975), my results indicated that small patches can function as good habitat when these patches are located in landscapes with a large amount of grassland. Furthermore, the most influential factors that affected nest survival were the proportions of farmsteads and cropland within 1,600 m. Therefore, pheasant nests located in landscapes that have large proportions of farmsteads and are highly fragmented by agriculture will experience very low survival rates.

Finally, woody cover has been shown to provide critical shelter for pheasants during severe winters (Gabbert et al. 1999). However, the effect that this type of habitat has on nest survival is unclear. Snyder (1984) found that pheasant nest predation was greater in an area with extensive woodland plantings. Meanwhile, Olson (1975) found higher nest survival rates for nests near woody cover. During my research (n=223 nests), the presence of woody cover on a patch edge or the distance from nests to woody cover did not enter any plausible models. This indicated no support for these covariates to affect nest survival in either direction.

Lastly, Clark et al. (1999) found nest survival estimates of 53% and 39% in landscapes with varied amounts of grassland in Iowa. My nest survival estimates were much lower for 2008 and 2009, 13% and 5%, respectively. However, other researchers in South Dakota have found low nest survival estimates that ranged from 11% to 23% (Trautman 1965, Hankins 2007). South Dakota experienced a significant loss of CRP land (approximately 153,800 ha) between 2007 and 2008 (Switzer 2009). My nest survival estimates were lower than previously found estimates, because of this recent landscape change. Several landscapes that I sampled had CRP loss that occurred the previous year. This could have directly affected my nest survival estimates because nesting hens were concentrated into the remaining grassland patches (Clark et al. 1999) along with nest predators (Kuehl and Clark 2002, Phillips et al. 2003) which in turn, produced lower rates of pheasant nest survival.

SUMMARY AND MANAGEMENT RECOMMENDATIONS

Prairie landscapes in South Dakota have undergone tremendous habitat changes within the last 100 years (Higgins et al. 2002). Wildlife managers are faced with difficult management decisions when trying to maximize duck or pheasant production in landscapes that continue to experience habitat loss and high populations of nest predators. My research was intended to provide managers with more information regarding patch size, woody cover, and landscape composition when implementing management strategies or selecting focus areas for conservation programs that are designed to increase duck and pheasant production in eastern South Dakota.

Wildlife managers rarely have the ability to manage specific wildlife areas for individual species and often manage for a variety of duck species or pheasants concurrently. Often times, what is good management for one group is also good for the other. Therefore, I will address my management recommendations for dabbling ducks (including the four species I analyzed) and pheasants.

Dabbling ducks

Cowardin et al. (1985) recommended that a 15 to 20% nest survival rate was necessary to maintain duck populations. During my study in 2008 and 2009, dabbling ducks experienced overall nest survival rates of 21% and 17%, respectively. These rates are sufficient to maintain duck populations, but population growth cannot occur under some current landscape conditions and predator populations. Most duck species exhibited higher nest survival in landscapes with larger proportions of grassland and wetlands. While this conservation strategy is the focus of many natural resource agencies already, patch size and the presence of woody cover is also often times considered. My results indicated that duck production can be sufficient in both small and large patches, as long as there are adequate proportions of grasslands (i.e., >40%) within the surrounding landscape. While large undisturbed grassland patches do provide ducks with areas of good nesting cover, having larger proportions of grasslands (i.e., disturbed and undisturbed) throughout the landscape seems to be more important. Woody cover did not greatly affect nest survivorship of duck species during my research.

Increased duck production from private and public lands is an objective of the Prairie Pothole Joint Venture (Ringleman et al. 2005). Therefore, I recommend that waterfowl managers focus conservation efforts on landscapes with a matrix of grasslands and a high density of wetlands. The areas of focus must include all types of grasslands such as: pastures, haylands, and undisturbed plantings. Patches of undisturbed cover that are relatively small in size should not be overlooked if other areas of grassland, such as pastures are adjacent to or within 1,600 m. Additionally, areas where grassland loss is at higher risk should be a top priority. Stephens et al. (2008) identified areas where the risk of grassland loss is highest in areas of North Dakota and South Dakota. However, wetland density also plays a critical role in determining nest survival. While the PPR contains high densities of wetlands, wetland loss continues to occur at a dramatic rate. Many types of CRP contracts require the restoration of wetlands. This program has the benefit of conserving both grassland and wetland habitat simultaneously. Similar to my results, Reynolds et al. (2006) found that when CRP occurred in landscapes with large amounts of grassland, very high nest survival resulted. Therefore, I recommend that agencies enhance programs designed to protect grassland and wetland resources at a landscape level.

Subsequently, another challenge that waterfowl managers face when protecting wetland resources, is the potential effect that climate change may have on wetland conditions within eastern South Dakota. Research has indicated a potential shift in favorable wetland conditions eastward, where fewer wetlands and grasslands currently exist, if temperatures increase slightly and decreased precipitation is experienced (Johnson et al. 2005, Johnson et al. 2010). This problem only compounds the difficult decisions that waterfowl managers face when trying to decide where conservation funds should be focused, but this aspect needs to be seriously considered.

Finally, one may ask why nest survival rates varied so much between mallards and blue-winged teal during my research. The differences may have been a result of nest predator species and specific habitat preferences. Some nest predators are known to utilize wetland edges for foraging (Greenwood et al. 1999), which sometimes reduces nest survival for nests located closer to wetland edges (Stephens et al. 2005). Moreover, Duebbert and Lokemoen (1976) found that nest survival rates of mallards and blue-winged teal varied between species as well as distance from wetland edges. They found nest survival rates of approximately 22% (mallard) and 40% (blue-winged teal) for nests located approximately 400 m from wetland edges. My results were similarly affected because all study sites had wetlands embedded within the boundaries. This patch characteristic made it difficult for females to nest large distances from wetlands. Consequently, the proximity of nests to wetland edges resulted in the differences experienced between nest survival rates between the two species.

Lastly, predation greatly influences duck nest survival (Klett et al. 1988, Reynolds et al. 2006). Many different nest predators occur throughout eastern South Dakota. However, each species has different landscape preferences and search patterns. My nest survival estimates may have been linked to specific landscape characteristics and arrangement that favored individual predator species. Therefore, as predator populations fluctuate and change along with the prairie landscape, they will continue to greatly affect duck nest survival. I recommend future investigators inventory and evaluate predator populations in different landscapes in eastern South Dakota. Waterfowl managers know which predator species are present in eastern South Dakota, but do not know what current populations are at or understand how specific landscape features affect these species. Only when predator populations are more thoroughly understood, will waterfowl managers be more successful at increasing nest survival.

Pheasants

Wildlife managers have long been aware of the relationship between pheasant nest survival and grasslands. However, my research was one of few projects that have evaluated patch size and pheasant nest survival. Ultimately, small and large patches are both capable of producing good nest survival if the surrounding landscape has adequate amounts of grassland within 1,600 m. As the amount of grassland increases within a given landscape, nest survival increases. My research supports this management strategy as well. But, nest survival rates were most significantly impacted by the proportion of farmsteads within the landscape during my research. While several nest predators have been known to be positively affected by the density of farmsteads that occur within a specific landscape, few researchers have experienced such significant relationships when evaluating nest survival. I suspect that these results were exacerbated by the unique situation (i.e., tremendous CRP loss) that occurred in eastern South Dakota during my research.

In 2007, the year previous to the beginning of my research, South Dakota had one of the highest pheasant population estimates since the 1940s (Switzer et al. 2009). In addition, South Dakota lost approximately 153,800 ha of CRP land during that same time period. Nest survival rates for pheasants were very low (5-13%) during the course of this research. These low rates were greatly affected by the decrease in CRP lands within landscapes that I sampled and my results support this hypothesis. This large number of hens experienced a significant decrease in nesting cover, which could have concentrated hens and nest predators into the remaining habitat. The high nest densities I experienced indicated that many hens were nesting in the available habitat, and sometimes the only nesting habitat. Additionally, because areas of eastern South Dakota contain high densities of farmsteads (abandoned or occupied) which are known to attract several nest predators, proved to be detrimental. Therefore, striped skunks and other nest predators had little trouble finding nests, which reduced overall nest survival.

Nest survival rates varied greatly between pheasants and ducks during my research. There are two possible explanations: (1) predators use search images to locate nests and (2) scent-trails left by female ducks or pheasants. Although ducks and pheasants nest within the same patches, they have very different nesting characteristics. Duck nests contain a large amount of down and the female covers the eggs when she leaves (i.e., completely concealed). In contrast, pheasant nests contain few feathers and are fully exposed when the female is gone. This difference often allows nest predators to locate pheasant nests more readily by sight. Nams (1997) found that skunks are capable of producing search images when locating food. Because pheasant nests are fully exposed, perhaps predators are more able to detect pheasant nests.

Second, ducks and pheasants approach their nests very differently. Female ducks fly over the nest and land in close proximity. Then they walk a short distance to the nest and get on the eggs. Meanwhile, female pheasants walk to the nest from large distances and then get on the eggs (Trautman 1982). Both groups leave scent-trails, however, the trail is much longer and more likely to be detected by a predator, in the case of pheasants. Olfactory cues, such as scent from adult birds, are thought to be important to mammals depredating duck nests (Clark and Wobeser 1997). Perhaps this long scent-trail actually allowed predators to follow the females' path to the nest location, which could have increased nest predation of pheasants. However, I suggest that future researchers evaluate these hypotheses before sound conclusions can be made.

Other Recommendations

Lastly, nearly all grassland patches that were sampled contained wheel tracks created by vehicles that were spraying noxious weeds at some time. Several times, I observed nests within a few feet of wheel tracks. I also observed egg shell fragments and nest material in or near the wheel tracks. These tracks (i.e., corridors through thick vegetation) could have enabled predators more opportunities to search and detect nests, which lowered nest survival of all avian species. Hankins (2007) also proposed that wheel tracks could potentially allow nest predators easier access to nests. I recommend that wildlife managers evaluate other options such as: biological control, sprayers with longer booms, or aerial spraying when contemplating weed control during the nesting season. I also suggest that future research be conducted to evaluate this hypothesis.

Finally, patch size and the presence of woody cover had little effect on duck or pheasant nest survival during my research. One conservation program that is directly responsible for the protection of small grassland patches is the U.S. Department of Agriculture's Farmable Wetland Program. This program is designed to protect previously farmed wetlands and the surrounding areas, up to approximately 16 ha. I recommend great support for this program, as long as other grassland habitat is available within the surrounding landscape, and a low density of farmsteads exists. If a protected tract is completely surrounded by cropland in an area with large numbers of farmsteads, nest survival will be very low. In addition, woody cover affected nest survival minimally. I recommend that woody cover is planted in areas where pheasants desperately need additional winter cover or there is an extreme lack of woody cover within the landscape. However, because several studies have shown woody cover does negatively affect many grassland bird species (Bakker 2003), I caution wildlife managers in the application of this management technique.

Ultimately, the biggest challenge that wildlife managers currently experience is the lack of funding for conservation programs. Extremely high land prices have severely limited the amount of land that conservation agencies can effectively protect. For example, the USFWS administers an active easement program in eastern South Dakota. However, current conservation dollars are not enough to meet the waiting list of willing landowners. There are over 650 landowners currently waiting for conservation easement offers in eastern South Dakota (Tom Tornow, personal communication, USFWS, 9/22/2009). In addition, CRP funding has been greatly reduced. Therefore, the best conservation strategies for increasing duck and pheasant nest survival in eastern South Dakota is to evaluate focus areas on a landscape-level and protect all grasslands regardless of patch size in areas with high proportions of grasslands and low densities of farmsteads.

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Table 1. Site, county, legal description, type of site, and patch size searched during the 2008 nesting season in eastern South Dakota.

Site	County	Legal Description	Type	Patch Size (ha)
Humphrey	Aurora	SE 1/4 Sec 22, T104N, R66W	Tree	13.35
Maine	Aurora	SW 1/4 Sec 35, T103N, R65W	Grass	18.62
Tieleban	Aurora	SE 1/4 Sec 4, T101N, R63W	Grass	3.64
Bauer	Beadle	SE 1/4 Sec 29, T111N, R59W	Grass	56.66
Borden	Beadle	SW 1/4 Sec 10, T110N, R64W	Grass	10.52
Brecken Slough	Beadle	SW 1/4 Sec 7, T111N, R64W	Grass	19.42
Cain Creek	Beadle	S 1/2 Sec 11, T109N, R62W	Grass	29.95
Ingle	Beadle	SW 1/4 Sec 21, T109N, R60W	Tree	27.52
Cheever	Brookings	SE 1/4 Sec 29, T109N, R51W	Grass	3.64
Dry Lake	Brookings	NE 1/4 Sec 9, T110N, R52W	Grass	42.49
Kenneth Nelson	Brookings	NE 1/4 Sec 25, T109N, R52W	Grass	10.52
Larsen	Brookings	SE 1/4 Sec 31, T110N, R52W	Tree	4.45
Matson	Brookings	NW 1/4 Sec 31, T109N, R52W	Grass	33.59
Wenk	Brookings	SW 1/4 Sec 7, T109N, R52W	Tree	21.45
West Oakwood	Brookings	N 1/2 Sec 2, T111N, R52W	Grass	46.54
Winter Haven	Brookings	NE 1/4 Sec 36, T109N, R51W	Grass	8.09
Welker	Hanson	SE 1/4 Sec 4, T102N, R57W	Grass	21.45
Henke	Hutchinson	SW 1/4 Sec 14, T98N, R60W	Grass	9.71
Knodel	Hutchinson	NW 1/4 Sec 5, T97N, R56W	Tree	13.76
Mayer	Hutchinson	NW 1/4 Sec13, T99N, R58W	Tree	4.45

Table 1. continued

Site	County	Legal Description	Type	Patch Size (ha)
Halligan	Hamlin	SE 1/4 Sec 28, T113N, R55W	Grass	41.28
Brunick	Kingsbury	NE 1/4 Sec 34, T110N, R53W	Grass	21.45
Easland	Kingsbury	NW 1/4 Sec 14, T111N, R55W	Grass	28.33
Hoyer	Kingsbury	SE 1/4 Sec 23, T109N, R55W	Grass	13.76
Jadozi	Kingsbury	NW 1/4 Sec 33, T109N, R55W	Tree	8.9
Kattke	Kingsbury	SE 1/4 Sec 36, T109N, R55W	Tree	7.69
R.S. Anderson	Kingsbury	SE 1/4 Sec 26, T112N, R55W	Tree	12.55
Silver Lake	Kingsbury	NW 1/4 Sec 36, T111N, R56W	Grass	23.88
Warne	Kingsbury	SE 1/4 Sec 7, T110N, R53W	Grass	5.26
Whitewood Slough	Kingsbury	NW 1/4 Sec 25, T110N, R55W	Tree	22.66
Fischer	Lake	SW 1/4 Sec 22, T107N, R54W	Tree	7.69
Floyd-Gaarder	Lake	SE 1/4 Sec 5, T108N, R52W	Tree	6.88
Kattke	Lake	NW 1/4 Sec 8, T108N, R53W	Grass	13.76
Lake Henry	Lake	NW 1/4 Sec 4, T105N, R54W	Tree	10.52
Reynolds Slough	Lake	NE 1/4 Sec 31, T106N, R53W	Tree	35.21
Wentworth	Lake	SW 1/4 Sec 11, T106N, R51W	Grass	23.88
Holm	McCook	SW 1/4 Sec 1, T103N, R56W	Grass	16.99
Janssen	McCook	N 1/2 Sec 9, T102N, R56W	Tree	52.61
Rief	McCook	SW 1/4 Sec 17, T103N, R55W	Grass	22.66
Burke	Miner	NW 1/4 Sec 21, T106N, R57W	Tree	4.86
Chip Allen	Miner	NE 1/4 Sec 29, T105N, R58W	Tree	44.92

Table 1. Continued

Site	County	Legal Description	Type	Patch Size (ha)
Corbin	Miner	SE 1/4 Sec 4, T106N, R57W	Grass	25.89
Hein	Miner	NW 1/4 Sec 22, T106N, R56W	Grass	23.47
Lake Carthage	Miner	NW 1/4 Sec 8, T108N, R57W	Tree	6.07
TOTAL				880.99

Table 2. Site, county, legal description, type of site, and patch size searched during the 2009 nesting season in eastern South Dakota.

Site	County	Legal Description	Type	Patch Size (ha)
Bauer	Beadle	SE 1/4 Sec 29, T111N, R59W	Grass	56.66
Borden	Beadle	SW 1/4 Sec 10, T110N, R64W	Grass	10.52
Brecken Slough	Beadle	SW 1/4 Sec 7, T111N, R64W	Grass	19.42
Cain Creek	Beadle	S 1/2 Sec 11, T109N, R62W	Grass	29.95
Ingle	Beadle	SW 1/4 Sec 21, T109N, R60W	Tree	27.52
Kleinsasser	Beadle	NW 1/4 Sec 15, T112N, R62W	Grass	37.64
Wipf	Beadle	SE 1/4 Sec 1, T112N, R62W	Grass	5.66
Cheever	Brookings	SE 1/4 Sec 29, T109N, R51W	Grass	3.64
Dry Lake	Brookings	NE 1/4 Sec 9, T110N, R52W	Grass	42.49
Kenneth Nelson	Brookings	NE 1/4 Sec 25, T109N, R52W	Grass	10.52
Larsen	Brookings	SE 1/4 Sec 31, T110N, R52W	Tree	4.45
Matson	Brookings	NW 1/4 Sec 31, T109N, R52W	Grass	33.59
Wenk 2	Brookings	SW 1/4 Sec 7, T109N, R52W	Tree	34.4
Winter Haven	Brookings	NE 1/4 Sec 36, T109N, R51W	Grass	8.09
Welker	Hanson	SE 1/4 Sec 4, T102N, R57W	Grass	21.45
Brunick	Kingsbury	NE 1/4 Sec 34, T110N, R53W	Grass	21.45
Easland	Kingsbury	NW 1/4 Sec 14, T111N, R55W	Grass	28.33
Hoyer	Kingsbury	SE 1/4 Sec 23, T109N, R55W	Grass	13.76
Jadozi	Kingsbury	NW 1/4 Sec 33, T109N, R55W	Tree	8.9
Kattke	Kingsbury	SE 1/4 Sec 36, T109N, R55W	Tree	7.69

Table 2. continued

Site	County	Legal Description	Type	Patch Size (ha)
R.S. Anderson	Kingsbury	SE 1/4 Sec 26, T112N, R55W	Tree	12.55
Silver Lake 2	Kingsbury	NW 1/4 Sec 26, T111N, R56W	Tree	19.83
Warne	Kingsbury	SE 1/4 Sec 7, T110N, R53W	Grass	5.26
Whitewood Slough	Kingsbury	NW 1/4 Sec 25, T110N, R55W	Tree	22.66
Fischer	Lake	SW 1/4 Sec 22, T107N, R54W	Tree	7.69
Floyd-Gaarder	Lake	SE 1/4 Sec 5, T108N, R52W	Tree	6.88
Hart	Lake	SW 1/4 Sec 28, T107N, R52W	Grass	11.33
Kattke	Lake	NW 1/4 Sec 8, T108N, R53W	Grass	13.76
Lake Henry	Lake	NW 1/4 Sec 4, T105N, R54W	Tree	10.52
Molskness	Lake	NE 1/4 Sec 36, T107N, R51W	Grass	10.93
Reynolds Slough	Lake	NE 1/4 Sec 31, T106N, R53W	Tree	35.21
Holm	McCook	SW 1/4 Sec 1, T103N, R56W	Grass	16.99
Janssen	McCook	N 1/2 Sec 9, T102N, R56W	Tree	52.61
Burke	Miner	NW 1/4 Sec 21, T106N, R57W	Tree	4.86
Chip Allen	Miner	NE 1/4 Sec 29, T105N, R58W	Tree	44.92
Hein	Miner	NW 1/4 Sec 22, T106N, R56W	Grass	23.47
Lake Carthage	Miner	NW 1/4 Sec 8, T108N, R57W	Tree	6.07
Hartle	Minnehaha	SE 1/4 Sec 29, T102N, R52W	Tree	27.92
Jordan	Minnehaha	SW 1/4 Sec 19, T101N, R51W	Tree	14.16
Dobbs	Moody	SE 1/4 Sec 33, T108N, R50W	Tree	15.38
Long	Moody	NW 1/4 Sec 8, T108N, R50W	Grass	14.97
TOTAL				804.10

Table 3. Definitions of general land use categories used to evaluate landscapes surrounding patch locations in eastern South Dakota, 2008-2009.

Land Use Category	Definition
Cropland	Row crop and small grain (i.e., agricultural fields)
Farmstead	Actual farm locations, rural residents, and towns
Grassland Disturbed	Planted or native grasslands that are annually hayed or grazed (i.e., pastures and hay-fields) including alfalfa fields
Grassland Undisturbed	Planted or native grasslands that not hayed or grazed (i.e., CRP, GPAs, or WPAs)
Wetland	Open water or emergent wetlands
Woodland	Trees, shrubs, or woody vegetation
Grassland Total	All grassland categories (i.e., Grassland Disturbed and Grassland Undisturbed)

Table 4. Independent variables used in analysis of duck and pheasant nest density models in eastern South Dakota, 2008-2009.

Variable	Explanation	Units	Variable Type
Cropland	% of cropland in 1,600 m buffer	Proportion	Continuous
Farmsteads	% of farmstead area in 1,600 m buffer	Proportion	Continuous
GrassD	% of disturbed grassland area in 1,600 m buffer	Proportion	Continuous
GrassTtl	% of total grassland area in 1,600 m buffer	Proportion	Continuous
GrassU	% of undisturbed grassland area in 1,600 m buffer	Proportion	Continuous
LfHt	Effective leaf height at nest	Decimeters	Continuous
Litter	Litter depth at nest	Centimeters	Continuous
PatchSz	Area of patch	Hectares	Continuous
Robel	Visual obstruction at nest	Decimeters	Continuous
Wetland	% of wetland area in 1,600 m buffer	Proportion	Continuous
Woodland	% of woodland area in 1,600 m buffer	Proportion	Continuous

Table 5. Independent variables used in analysis of duck and pheasant nest survival models in eastern South Dakota, 2008-2009.

Variable	Explanation	Units	Variable Type
Age	Age of nest when located	Number (days)	Continuous
Cropland	% of cropland area in 1,600 m buffer	Proportion	Continuous
Distance	Distance from trees on patch edge to nest	Meters	Continuous
DSR	Constant Daily Survival Rate	Number (days)	Constant
Farmsteads	% of farmstead area in 1,600 m buffer	Proportion	Continuous
GrassD	% of disturbed grassland area in 1,600 m buffer	Proportion	Continuous
GrassTtl	% of total grassland area in 1,600 m buffer	Proportion	Continuous
GrassU	% of undisturbed grassland area in 1,600 m buffer	Proportion	Continuous
LfHt	Effective leaf height at nest	Decimeters	Continuous
Litter	Litter depth at nest	Centimeters	Continuous
PatchSz	Area of patch	Hectares	Continuous
Robel	Visual obstruction at nest	Decimeters	Continuous
Search	1st search or 2nd search	0 or 1	Categorical
Trees	No trees present or trees present at ≥1 patch edge	0 or 1	Categorical
Wetland	% of wetland area in 1,600 m buffer	Proportion	Continuous
Woodland	% of woodland area in 1,600 m buffer	Proportion	Continuous
Year	2008 or 2009 nesting season	0 or 1	Categorical

Table 6. Average clutch size and incubation periods used for calculating the value for Mayfield (1975) nest survival estimates, 2008-2009.

Species	Clutch size	Incubation period	Value for Mayfield (1975) estimates
Blue-winged teal (*Anas discors*)	10	24	34
Gadwall (*Anas strepera*)	10	26	36
Mallard (*Anas platyrhynchos*)	9	28	37
Northern shoveler (*Anas clypeata*)	9	25	34
Ring-necked pheasant (*Phasianus colchicus*)	10	23	33

Table 7. Results of ANOVA tests (significant at the $p < 0.05$ level) comparing vegetation measurements between size categories of grassland patches sampled during the 2008 and 2009 nesting season in eastern South Dakota.

Type of Measurement	Degrees of Freedom	F-ratio	P-value
Visual Obstruction Readings	1, 52	0.32	0.73
Effective Leaf Height	1, 52	0.07	0.93
Litter Depth	1, 52	0.29	0.75

Table 8. Common and scientific names and number of nests located during the 2008 and 2009 nesting seasons in eastern South Dakota.

Species	Scientific Name	2008	2009	Total
American bittern	*Botaurus lentiginosus*	2	1	3
American wigeon	*Anas americana*	1	0	1
American woodcock	*Scolopax minor*	0	1	1
Blue-winged teal	*Anas discors*	253	179	432
Gadwall	*Anas strepera*	99	56	155
Mallard	*Anas platyrhynchos*	237	108	345
Mourning dove	*Zenaida macroura*	0	11	11
Northern harrier	*Circus cyaneus*	3	2	5
Northern pintail	*Anas acuta*	14	4	18
Northern shoveler	*Anas clypeata*	34	24	58
Ring-necked pheasant	*Phasianus colchicus*	379	216	595
Upland sandpiper	*Bartramia longicauda*	8	13	21
TOTAL		1,030	615	1,645

Table 9. Best explanatory models for nest density of blue-winged teal (*Anas discors*) in eastern South Dakota, 2008 and 2009. Models were evaluated using Akaike's Information Criteria adjusted for small sample size (AICc). See Table 4 for explanations of variables.

Model Name	AICc	ΔAICc	No. of Parameters
-GrassTtl-Farmsteads-Robel	-7.781	0	3
-GrassTtl-Farmsteads	-7.574	-0.207	2
-GrassTtl	-7.062	-0.719	1
-GrassTtl+Wetland-Farmsteads	-6.899	-0.882	3
-GrassTtl+Wetlands	-6.684	-1.097	2
-GrassTtl+Wetlands-Farmsteads-Robel	-6.313	-1.468	4
-GrassTtl+Wetland-Robel	-5.937	-1.844	3
-GrassU+Wetland-Robel	-5.472	-2.309	3
-GrassTtl+PatchSz-Robel-Farmsteads	-5.39	-2.391	4
GrassTtl+PatchSz	-5.29	-2.491	2
+GrassU	-4.679	-3.102	1
-GrassTtl+Wetland+PatchSz	-4.482	-2.58	3
-GrassU+Wetland-Robel+PatchSz	-4.259	-2.803	4
-Robel	-4.027	-3.035	1
-GrassD	-3.125	-3.937	1
-Robel+Wetland	-3.039	-4.023	2
-Farmsteads	-1.915	-5.147	1
+Wetland-Farmsteads	-1.833	-5.229	2
+Wetland	-1.79	-5.272	1

Table 9. continued.

Model Name	AICc	ΔAICc	No. of Parameters
-LfHt	-1.081	-5.981	1
+PatchSz+Wetland	-0.919	-6.862	2
+Woodland	0.159	-7.058	1
+Litter	0.247	-7.146	1
+PatchSz	0.635	-7.534	1

Table 10. Best explanatory models for nest density of gadwall (*Anas strepera*) in eastern South Dakota, 2008 and 2009. Models were evaluated using Akaike's Information Criteria adjusted for small sample size (AICc). See Table 4 for explanations of variables.

Model Name	AICc	ΔAICc	No. of Parameters
-Farmsteads	-82.864	0	1
+PatchSz-Farmsteads	-82.57	-0.294	2
+PatchSz +Wetland-Farmsteads	-81.99	-0.874	3
+PatchSz+Farmsteads+GrassTtl	-80.845	-2.019	3
+GrassTtl+Wetland	-80.563	-2.301	2
+PatchSz	-80.459	-2.405	1
+PatchSz+Wetland	-80.042	-2.822	2
+Wetland	-79.125	-3.739	1
+PatchSz-GrassU	-78.689	-4.175	2
+PatchSz+Wetland-GrassU	-78.519	-4.345	3
+GrassU	-78.453	-4.411	1
+PatchSz-GrassTtl	-78.371	-4.493	2
+PatchSz-Woodland	-78.268	-4.596	2
+PatchSz+Wetland-Robel	-78.131	-4.733	3
+PatchSz+Litter	-78.125	-4.739	2
+PatchSz+Wetland-GrassTtl	-77.723	-5.141	3
-Robel	-77.58	-5.284	1
-Woodland	-77.503	-5.361	1
+Litter	-77.068	-5.796	1

Table 10. continued.

Model Name	AICc	ΔAICc	No. of Parameters
-GrassTtl	-76.966	-5.898	1
+LfHt	-76.93	-5.934	1

Table 11. Best explanatory models for nest density of mallards (*Anas platyrhynchos*) in eastern South Dakota, 2008 and 2009. Models were evaluated using Akaike's Information Criteria adjusted for small sample size (AICc). See Table 4 for explanations of variables.

Model Name	AICc	ΔAICc	No. of Parameters
+PatchSz	-10.11	0	1
+PatchSz+Litter	-8.863	-1.247	2
+PatchSz+Woodland	-8.631	-1.479	2
+PatchSz-Robel	-8.351	-1.759	2
+PatchSz-GrassTtl	-8.348	-1.762	2
+PatchSz+Wetland	-8.123	-1.987	2
+PatchSz+GrassU	-7.796	-2.314	2
+PatchSz-GrassTtl+Litter	-7.321	-2.789	3
+PatchSz-Litter-Robel	-7.289	-2.821	3
+Wetland	-6.873	-3.237	1
-Litter	-6.617	-3.493	1
+Woodland	-6.409	-3.701	1
-GrassTtl	-6.384	-3.726	1
+PatchSz-GrassTtl+Wetland	-6.17	-3.94	3
+PatchSz-Robel+Wetland	-6.097	-4.013	3
-GrassT+Wetland	-4.657	-5.453	2
+PatchSz+Farmsteads	12.591	-22.701	2
+Farmsteads	13.943	-22.806	1
+GrassU	14.079	-24.189	1

Table 12. Best explanatory models for nest density of Northern shovelers (*Anas clypeata*) in eastern South Dakota, 2008 and 2009. Models were evaluated using Akaike's Information Criteria adjusted for small sample size (AICc). See Table 4 for explanations of variables.

Model Name	**AICc**	**ΔAICc**	No. of Parameters
+GrassD	-159.761	0	1
+GrassD-Robel	-158.82	-0.941	2
+GrassTtl	-158.609	-1.152	1
-Robel	-158.292	-1.469	1
+PatchSz	-158.224	-1.537	1
+GrassD+Wetland	-158.146	-1.615	2
+PatchSz+GrassD	-158.077	-1.684	2
-Woodland	-157.716	-2.045	1
+GrassD-Farmsteads	-157.688	-2.073	2
+Litter	-157.678	-2.083	1
+GrassD+Litter	-157.45	-2.311	2
+GrassD+Woodland	-157.438	-2.323	2
+Wetland	-157.215	-2.546	1
+GrassD+Wetland-Robel	-156.808	-2.953	3
-Farmsteads	-156.681	-3.08	1
+GrassTtl+Wetland	-156.667	-3.094	2
GrassTtl+PatchSz+Wetland	-156.656	-3.105	3
+PatchSz+GrassTtl	-156.638	-3.123	2
+PatchSz-Robel	-156.634	-3.127	2

Table 12. continued.

Model Name	**AICc**	**ΔAICc**	**No. of Parameters**
+PatchSz+GrassD+Wetland	-156.217	-3.544	3
+PatchSz+Wetland	-156.074	-3.687	2
+GrassU	-155.698	-4.063	1

Table 13. Best explanatory models for nest density of ring-necked pheasants (*Phasianus colchicus*) in eastern South Dakota, 2008 and 2009. Models were evaluated using Akaike's Information Criteria adjusted for small sample size (AICc). See Table 4 for explanations of variables.

Model Name	AICc	ΔAICc	No. of Parameters
-Cropland+Robel-Farmsteads	10.341	0	3
+GrassTtl-Farmsteads+Robel+Wetland	12.219	-1.878	4
+GrassTtl-Farmsteads	12.326	-1.985	2
+GrassTtl+Robel-Farmsteads	12.326	-1.985	3
-Cropland	12.597	-2.256	1
+GrassU+Robel	12.805	-2.464	2
+GrassTtl	12.919	-2.578	1
+GrassTtl+Wetland+Robel	12.942	-2.601	3
+Farmsteads	12.961	-2.62	1
+GrassU-Farmsteads	13.031	-2.69	2
+GrassU+Robel+Wetlands-Farmsteads	13.178	-2.837	4
+Robel	13.232	-2.891	1
GrassTtl+Wetland	13.32	-2.979	2
+GrassTtl+Robel	13.417	-3.076	2
+Wetland	13.497	-3.156	1
+GrassU	13.597	-3.256	1
+GrassTtl+Litter	14.558	-4.217	2
+GrassTtl+GrassU+Robel	15.185	-4.844	3
+PatchSz+GrassU+Robel	15.234	-4.893	3

Table 13. continued

Model Name	AICc	ΔAICc	No. of Parameters
+PatchSz+GrassTtl	15.502	-5.161	2
+PatchSz+Wetland	15.684	-5.343	2
GrassTtl+Wetland+PatchSz	15.71	-5.369	3
+GrassU+Litter	15.927	-5.586	2
-Woodland	16.45	-6.109	1
+PatchSz	16.522	-6.181	1
+PatchSz+GrassTtl+GrassU	16.891	-6.55	3
-Litter	17.218	-6.877	1
+PatchSz+GrassTtl-Woodland	17.603	-7.262	3

Table 14. Total number of nests with known fates used in nest survival models during the 2008 and 2009 nesting seasons in eastern South Dakota. Includes only species with ≥ 30 nests.

Species	Total Nests
Blue-winged teal (*Anas discors*)	407
Gadwall (*Anas strepera*)	149
Mallard (*Anas platyrhynchos*)	326
Northern shoveler (*Anas clypeata*)	53
Ring-necked pheasant (*Phasianus colchicus*)	223
TOTAL	1,158

Table 15. Summary of model selection results for nest survival of blue-winged teal (*Anas discors*) in eastern South Dakota, 2008 and 2009. Models were evaluated using Akaike's Information Criteria adjusted for small sample size (AICc). See Table 5 for explanations of covariates.

Model	AICc	ΔAICc	w_i	*K*	Deviance
+Wetland+GrassTtl-Search+Trees	878.884	0	0.195	5	868.871
+Wetland+GrassTtl-Search	879.245	0.361	0.163	4	871.237
+Wetland+GrassTtl-Search-Distance	879.993	1.108	0.112	5	869.980
PatchSz+Wetland+GrassTtl+Search	880.418	1.534	0.090	5	870.405
+Wetland+GrassTtl+Search-Farmsteads	881.002	2.11	0.067	5	870.989
+Wetland+GrassTtl-Search-Litter	881.179	2.294	0.062	5	871.166
+Wetland+GrassTtl-Search-Robel	881.248	2.363	0.059	5	871.235
+GrassTtl+Trees	881.914	3.029	0.040	4	873.905
+Wetland+GrassTtl-Age	882.244	3.359	0.036	4	874.235
+PatchSz+Wetland+GrassTtl-Search-Litter	882.373	3.488	0.034	6	870.355
+PatchSz+Wetland+GrassTtl-Search-Robel	882.412	3.528	0.033	6	870.394
+GrassTtl+Trees+Distance	882.531	3.647	0.031	5	872.51
+GrassTtl-Search	883.008	4.123	0.024	3	877.003
+PatchSz-Search+GrassTtl	883.395	4.510	0.020	4	875.386
+Wetland+GrassTtl	886.070	7.185	0.005	3	880.064
+PatchSz-Age-Search	887.102	8.218	0.003	4	879.094
+GrassTtl+Wetland+Distance	887.301	8.417	0.0029	4	879.293
+Wetland+GrassTtl+Woodland	887.413	8.529	0.002	4	879.405
+PatchSz+Wetland+GrassTtl	887.612	8.728	0.002	4	879.604

Table 15. continued.

Model	AICc	ΔAICc	w_i	*K*	Deviance
+Wetland+GrassTtl+Trees+Distance	887.868	8.984	0.002	5	877.855
+PatchSz-Search	888.127	9.243	0.001	3	882.122
+PatchSz-Search+Wetland	888.608	9.723	0.001	4	880.599
-Search	889.239	10.355	0.001	2	885.237
+GrassTtl	893.069	14.185	0	2	889.067
+PatchSz+GrassTtl	893.882	14.998	0	3	887.877
+PatchSz+Wetland	897.079	18.195	0	3	891.074
+Wetland	897.730	18.846	0	2	893.728
+PatchSz-Age	898.036	19.151	0	3	892.030
-LfHt	898.258	19.374	0	2	894.250
+Wetland+GrassU	898.404	19.520	0	3	892.399
+PatchSz	898.679	19.794	0	2	894.676
+Constant DSR	899.294	20.409	0	1	897.293
-Age	899.389	20.504	0	2	895.386
+GrassU	899.548	20.663	0	2	895.545
+PatchSz+Trees	900.260	21.375	0	3	894.255
-Robel	900.802	21.917	0	2	896.799
Year	900.910	22.025	0	2	896.907
+Woodland	901.018	22.133	0	2	897.015
+Trees	901.028	22.143	0	2	897.025

Table 15. continued.

Model	AICc	ΔAICc	w_i	K	Deviance
-Litter	901.223	22.339	0	2	897.221
-Farmsteads	901.250	22.365	0	2	897.247
Year+Wetland+GrassTtl-Search	938.314	59.429	0	4	930.305

Table 16. Summary of model selection results for nest survival of gadwalls (*Anas strepera*) in eastern South Dakota, 2008 and 2009. Models were evaluated using Akaike's Information Criteria adjusted for small sample size (AICc). See Table 5 for explanations of covariates.

Model	AICc	ΔAICc	w_i	K	Deviance
-Cropland-Litter	321.253	0	0.113	3	315.240
-Cropland-Litter-PatchSz	321.709	0.456	0.090	4	313.687
+GrassTtl-Litter	322.379	1.126	0.064	3	316.366
-Cropland-Litter-PatchSz-Search	322.833	1.579	0.051	5	312.799
-Cropland-Litter-Trees	323.117	1.864	0.044	4	315.095
-Cropland-Litter+Distance	323.130	1.876	0.044	4	315.108
-Cropland-Litter+Farmsteads	323.257	2.003	0.041	4	315.235
-Cropland-Litter-Age	323.258	2.005	0.041	4	315.236
-Cropland-Litter-PatchSz-Trees	323.347	2.093	0.039	5	313.313
-PatchSz+GrassTtl-Litter	323.351	2.097	0.039	4	315.328
+GrassTtl-Litter+Woodland	323.419	2.165	0.038	4	315.397
+GrassTtl-Litter+Wetland	323.540	2.286	0.036	4	315.518
-PatchSz+Wetland+GrassTtl-Litter	323.693	2.439	0.033	5	313.659
+GrassTtl-Litter+LfHt	324.099	2.845	0.027	4	316.077
+GrassTtl-Litter+Robel	324.168	2.914	0.026	4	316.14
+GrassTtl-Trees-Litter	324.174	2.920	0.026	4	316.152
+GrassTtl	324.271	3.017	0.025	2	320.264
-Cropland	324.394	3.140	0.023	2	320.388
-Cropland+Robel	324.772	3.518	0.019	3	318.758

Table 16. continued.

Model	AICc	ΔAICc	w_i	*K*	Deviance
-PatchSz+GrassTtl	325.082	3.828	0.016	3	319.068
-PatchSz+GrassTtl-Litter+Woodland	325.113	3.859	0.016	5	315.080
+GrassTtl-Litter+Wetland-Age	325.551	4.297	0.013	5	315.517
+GrassTtl+Robel	325.672	4.418	0.012	3	319.658
-PatchSz+GrassTtl+Wetland	325.705	4.451	0.012	4	317.682
+GrassTtl+LfHt	325.805	4.552	0.011	3	319.792
+GrassTtl+Wetland	325.816	4.562	0.011	3	319.802
+GrassTtl-Search	326.039	4.785	0.010	3	320.025
+GrassTtl-Trees	326.295	5.041	0.009	3	320.282
-Litter	326.735	5.481	0.007	2	322.729
+Constant DSR	327.254	6.000	0.005	1	325.252
+GrassTtl+Wetland-Search	327.608	6.354	0.004	4	319.586
+GrassTtl+Wetland-Age	327.806	6.553	0.004	4	319.784
+Robel	328.062	6.808	0.003	2	324.055
+LfHt	328.135	6.881	0.003	2	324.128
-Search	328.192	6.938	0.003	2	324.185
-PatchSz-Litter	328.605	7.351	0.002	3	322.592
+Wetland	328.897	7.643	0.002	2	324.890
-PatchSz	329.019	7.765	0.002	2	325.013
-Trees	329.085	7.831	0.002	2	325.078

Table 16. continued.

Model	AICc	ΔAICc	w_i	*K*	Deviance
+Distance	329.109	7.855	0.002	2	325.102
Year	329.192	7.938	0.002	2	325.180
-Woodland	329.231	7.977	0.002	2	325.224
-Farmsteads	329.234	7.980	0.002	2	325.227
-Age	329.243	7.989	0.002	2	325.236
+GrassU	329.258	8.004	0.002	2	325.251
-PatchSz+Wetland-Litter	330.082	8.828	0.001	4	322.060
+GrassU-Litter+Wetland	330.242	8.988	0.001	4	322.219
-PatchSz+Wetland	330.636	9.383	0.001	3	324.623
-PatchSz-Trees	330.738	9.484	0	3	324.725
-PatchSz-Farmsteads	330.775	9.521	0	3	324.762
Year+GrassTtl-Litter	407.891	86.637	0	3	401.878

Table 17. Summary of model selection results for nest survival of mallards (*Anas platyrhynchos*) in eastern South Dakota, 2008 and 2009. Models were evaluated using Akaike's Information Criteria adjusted for small sample size (AICc). See Table 5 for explanations of covariates.

Model	AICc	ΔAICc	w_i	*K*	Deviance
DSR+Distance-LfHt-Search	623.782	0	0.148	4	615.767
DSR-Trees-LfHt-Search	624.423	0.642	0.107	4	616.408
DSR-Trees-Search	624.825	1.043	0.088	3	618.816
DSR+Distance-LfHt-Search+PatchSz	625.234	1.452	0.071	5	615.211
DSR-Trees+Wetland-Search-LfHt	625.530	1.749	0.062	5	615.508
DSR-Trees-LfHt-Search+PatchSz	625.641	1.859	0.058	5	615.618
DSR-Trees+Distance-LfHt-Search	625.647	1.865	0.058	5	615.625
-Trees-LfHt-Search-Farmsteads	625.932	2.150	0.050	5	615.909
-Trees-LfHt+GrassTtl-Search	626.193	2.412	0.044	5	616.171
-Trees-Search+PatchSz	626.230	2.448	0.043	4	618.215
-Trees-LfHt-Search-Age	626.382	2.600	0.040	5	616.359
-Trees+Wetland-Search-LfHt+Distance	626.898	3.116	0.031	6	614.866
-Trees-LfHt	627.040	3.258	0.029	3	621.031
-Trees-LfHt+PatchSz	627.924	4.142	0.019	4	619.909
-Trees-LfHt+Wetland+GrassTtl	628.096	4.314	0.017	5	618.074
-Trees-LfHt+Wetland	628.185	4.403	0.016	4	620.170
-Trees-Litter	628.359	4.577	0.015	3	622.350
-Trees-LfHt+GrassTtl	628.653	4.871	0.013	4	620.638
-Trees-LfHt+Woodland	628.855	5.073	0.012	4	620.840

Table 17. continued.

Model	AICc	ΔAICc	w_i	K	Deviance
-Trees-LfHt+GrassU	628.901	5.119	0.011	4	620.886
+PatchSz-Trees-LfHt+Wetland+GrassTtl	628.993	5.212	0.011	6	616.962
-Trees-LfHt-Age	629.045	5.263	0.011	4	621.030
-Trees-LfHt+PatchSz+GrassTtl	629.594	5.812	0.008	5	619.571
-Trees	630.109	6.327	0.006	2	626.105
-Trees-Robel	630.383	6.601	0.005	3	624.374
+Distance	630.706	6.924	0.005	2	626.702
-Trees+Wetland	630.785	7.003	0.004	3	624.776
-Trees+PatchSz	631.217	7.435	0.004	3	625.207
+GrassTtl+Wetland-Trees	631.228	7.446	0.004	4	623.212
-Trees+Distance	631.894	8.112	0.003	3	625.885
-Trees+GrassTtl	631.998	8.216	0.002	3	625.989
-Trees+Wetland+Distance	632.633	8.851	0.002	4	624.618
+GrassTtl+PatchSz-Trees	633.152	9.370	0.001	4	625.137
+PatchSz-LfHt-Search	634.968	11.186	0.001	4	626.953
-Search	636.077	12.295	0	2	632.072
-Age+Search	638.069	14.287	0	3	632.060
-LfHt	638.958	15.176	0	2	634.953
+GrassTtl+Wetland	639.782	16.000	0	3	633.773
+GrassTtl+Wetland+PatchSz	640.161	16.380	0	4	632.146

Table 17. continued.

Model	AICc	ΔAICc	w_i	K	Deviance
-Robel	640.920	17.138	0	2	636.915
+PatchSz+Wetland	641.237	17.455	0	3	635.228
+Wetland	641.639	17.857	0	2	637.634
Year	643.325	19.543	0	2	639.320
+PatchSz	643.401	19.619	0	2	639.396
+Constant DSR	643.799	20.017	0	1	641.798
-Litter	644.174	20.392	0	2	640.169
-Farmsteads	644.775	20.993	0	2	640.770
+Woodland	644.940	21.158	0	2	640.936
GrassU	645.023	21.241	0	2	641.018
+GrassTtl+PatchSz	645.312	21.530	0	3	639.303
+Age	645.503	21.721	0	2	641.499
+GrassTtl	645.591	21.809	0	2	641.586

Table 18. Summary of model selection results for nest survival of northern shovelers (*Anas clypeata*) in eastern South Dakota, 2008 and 2009. Models were evaluated using Akaike's Information Criteria adjusted for small sample size (AICc). See Table 5 for explanations of covariates.

Model	AICc	ΔAICc	w_i	*K*	Deviance
+GrassU-LfHt	102.455	0	0.090	3	96.409
Year	103.284	0.829	0.060	2	99.261
+GrassU	103.552	1.097	0.052	2	99.529
-LfHt+PatchSz-Cropland	103.834	1.379	0.045	4	95.756
+Constant DSR	103.868	1.413	0.044	1	101.860
-LfHt	103.965	1.510	0.042	2	99.942
-LfHt-Cropland	104.188	1.732	0.038	3	98.141
-LfHt+PatchSz	104.210	1.755	0.037	3	98.163
+GrassTtl-LfHt	104.248	1.792	0.037	3	98.201
+GrassU-LfHt+PatchSz	104.381	1.926	0.034	4	96.303
+GrassU-LfHt+Age	104.410	1.954	0.034	4	96.332
+GrassU-LfHt-Distance	104.429	1.973	0.034	4	96.351
+GrassU-LfHt+Trees	104.429	1.974	0.034	4	96.351
-Cropland	104.856	2.400	0.027	2	100.832
+GrassTtl	105.042	2.587	0.025	2	101.019
+Litter	105.106	2.651	0.024	2	101.083
+PatchSz	105.275	2.820	0.022	2	101.252
+GrassU+PatchSz	105.499	3.043	0.020	3	99.452
-LfHt+PatchSz-Cropland+Search	105.581	3.125	0.019	5	95.463

Table 18. continued.

Model	AICc	ΔAICc	w_i	K	Deviance
-Robel	105.689	3.233	0.018	2	101.665
+Trees	105.691	3.236	0.018	2	101.668
-LfHt+Wetland	105.721	3.265	0.018	3	99.674
+Wetland	105.784	3.329	0.017	2	101.761
+Woodland	105.813	3.357	0.017	2	101.789
+Age	105.831	3.375	0.017	2	101.807
-LfHt+Age	105.838	3.383	0.017	3	99.792
-LfHt+PatchSz-Cropland+Age	105.839	3.384	0.017	5	95.721
-LfHt+PatchSz-Cropland+Wetland	105.844	3.388	0.017	5	95.726
-Search	105.845	3.390	0.017	2	101.822
+GrassD	105.850	3.395	0.017	2	101.827
+Farmsteads	105.883	3.428	0.016	2	101.860
+GrassU-LfHt+Trees-Distance	106.468	4.012	0.012	5	96.350
+PatchSz+GrassTtl	106.528	4.072	0.012	3	100.481
+GrassTtl+Wetland	106.935	4.480	0.010	3	100.888
+PatchSz+Trees	107.063	4.608	0.009	3	101.016
+Litter+GrassD	107.067	4.612	0.009	3	101.020
+PatchSz+Farmsteads	107.158	4.702	0.009	3	101.111
+PatchSz+Wetland	107.211	4.756	0.008	3	101.164
+Trees-Distance	107.570	5.115	0.007	3	101.523

Table 18. continued.

Model	AICc	ΔAICc	w_i	K	Deviance
+PatchSz+GrassTtl+Wetland	108.457	6.001	0.004	4	100.378
Year+GrassU-LfHt	120.037	17.582	0	3	113.990
Year+GrassU	125.915	23.460	0	2	121.892
Year+PatchSz-LfHt	127.100	24.645	0	3	121.053
Year+PatchSz	183.041	80.585	0	2	179.017
Year+Age	209.383	106.928	0	2	205.360
Year-Search	398.045	295.589	0	2	394.021

Table 19. Summary of model selection results for nest survival of ring-necked pheasants (*Phasianus colchicus*) in eastern South Dakota, 2008 and 2009. Models were evaluated using Akaike's Information Criteria adjusted for small sample size (AICc). See Table 5 for explanations of covariates.

Model	AICc	ΔAICc	w_i	*K*	Deviance
-Cropland-Farmsteads-Robel+Age	715.401	0	0.448	5	705.380
-Cropland-Farmsteads-Robel+Age+PatchSz	717.017	1.616	0.200	6	704.987
+GrassU-Farmsteads-Robel+Age	717.416	2.014	0.164	5	707.394
-Cropland-Farmsteads-Robel	720.153	4.751	0.042	4	712.138
-Cropland-Farmsteads	721.669	6.267	0.020	3	715.660
+PatchSz-Cropland-Farmsteads-Robel	721.702	6.301	0.019	5	711.680
-Cropland-Farmsteads-Robel-Trees	721.919	6.518	0.017	5	711.897
+GrassTtl-Farmsteads-Robel	722.187	6.786	0.015	4	714.173
-Cropland-Farmsteads-Trees+Distance	722.338	6.937	0.014	5	712.316
+PatchSz-Cropland-Farmsteads	722.989	7.587	0.010	4	714.974
-Cropland-Farmsteads-Trees	723.555	8.154	0.008	4	715.541
-Cropland-Farmsteads+Wetland	723.605	8.203	0.007	4	715.590
+PatchSz+GrassTtl-Farmsteads-Robel	723.873	8.471	0.006	5	713.851
+PatchSz-Cropland-Farmsteads-Trees+Distance	724.228	8.827	0.005	6	712.197
+PatchSz-Cropland	725.170	9.769	0.003	3	719.162
+PatchSz+GrassTtl-Farmsteads	725.354	9.953	0.003	4	717.340
+Wetland+GrassTtl+PatchSz	725.861	10.460	0.002	4	717.847
-Cropland-Trees+Distance	725.964	10.563	0.002	4	717.950
+PatchSz+GrassU-Farmsteads+Robel	726.210	10.808	0.002	5	716.188

Table 19. continued.

Model	AICc	ΔAICc	w_i	*K*	Deviance
+GrassU	726.534	11.133	0.002	2	722.530
Year	726.671	11.269	0.002	2	722.666
+Wetland+GrassTtl	726.759	11.357	0.002	3	720.750
+PatchSz+GrassTtl-Robel	726.790	11.388	0.002	4	718.775
-Cropland	726.859	11.457	0.001	2	722.854
-Farmsteads	727.977	12.575	0.001	2	723.972
+Age	728.030	12.629	0.001	2	724.026
+PatchSz+GrassTtl	728.170	12.769	0.001	3	722.161
+GrassTtl	729.744	14.343	0	2	725.740
+PatchSz-Robel	730.549	15.148	0	3	724.540
+PatchSz	730.878	15.476	0	2	726.873
+PatchSz+Wetland	731.880	16.479	0	3	725.871
+Distance+PatchSz	732.116	16.715	0	3	726.107
-Woodland	733.167	17.766	0	2	729.163
-Robel	733.187	17.785	0	2	729.182
-LfHt	733.798	18.397	0	2	729.794
Constant DSR	733.983	18.581	0	1	731.981
-Trees	734.851	19.450	0	2	730.847
+Wetland	735.042	19.641	0	2	731.038
-Litter	735.904	20.503	0	2	731.900
-Search	735.976	20.574	0	2	731.971

Figure 1. Counties containing study sites in eastern South Dakota, during the 2008-2009 nesting seasons.

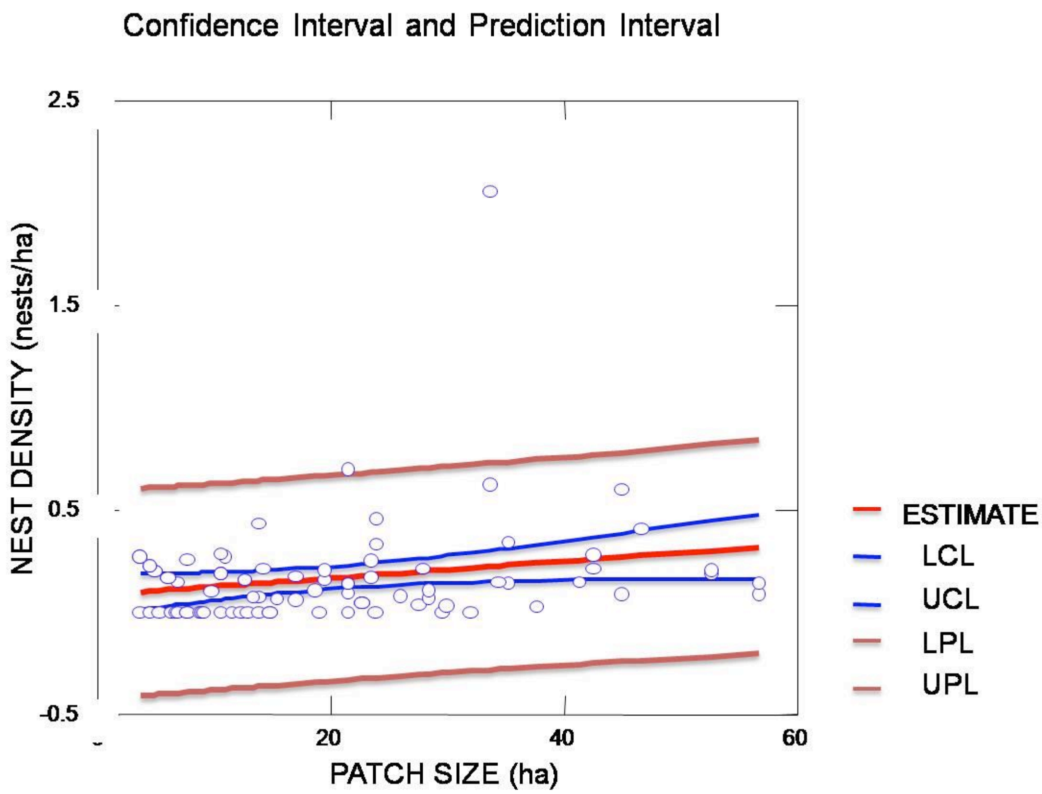

Figure 2. Relationship between nest density of mallards (*Anas platyrhynchos*) and patch size in sampled patches in eastern South Dakota, 2008-2009. Blue lines indicate upper and lower confidence levels and red lines indicate upper and lower predicted levels.

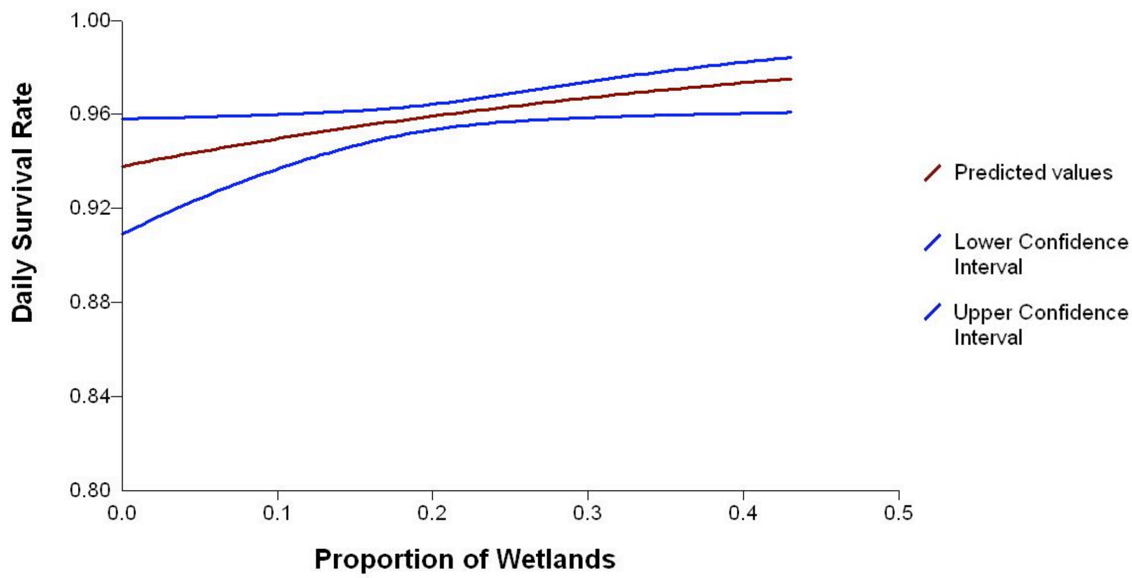

Figure 3. Blue-winged teal (*Anas discors*) (n=407) nest survival in relation to the proportion of wetlands within 1,600 m of sampled patches in eastern South Dakota, 2008-2009. Blue lines indicate 95% confidence intervals.

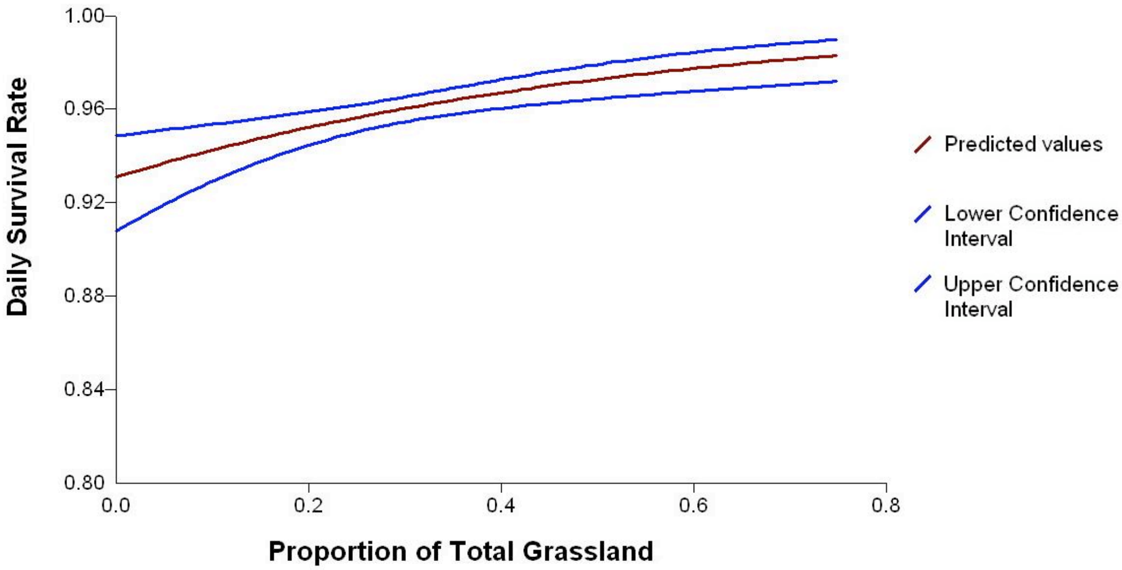

Figure 4. Blue-winged teal (*Anas discors*) (n=407) nest survival in relation to the proportion of total grassland within 1,600 m of sampled patches in eastern South Dakota, 2008-2009. Blue lines indicate 95% confidence intervals.

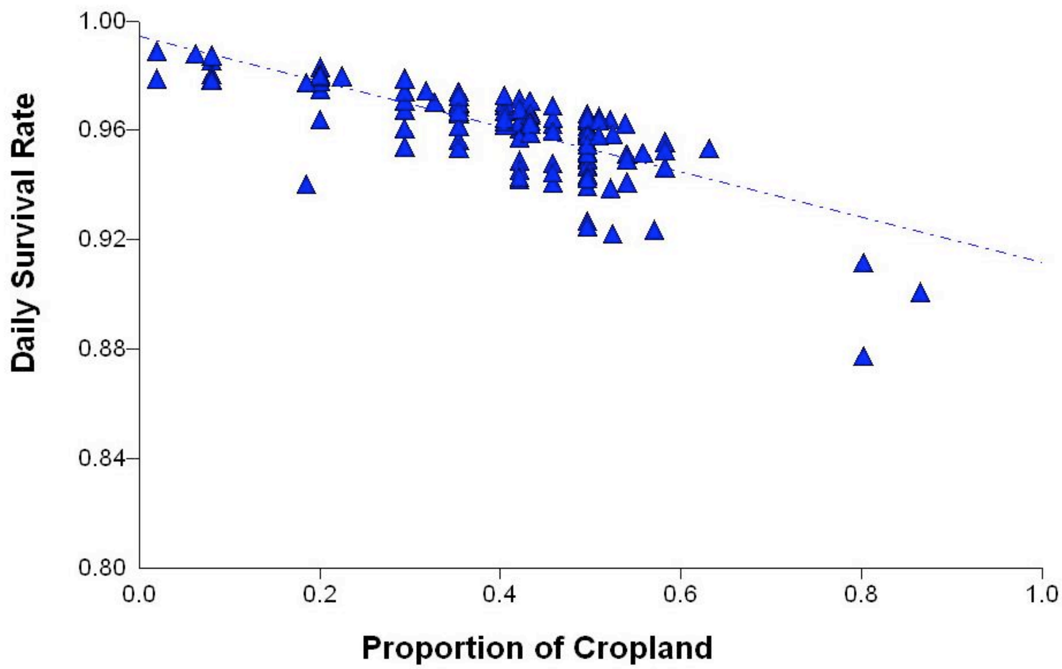

Figure 5. Gadwall (*Anas strepera*) (n=149) nest survival in relation to the proportion of cropland within 1,600 m of sampled patches in eastern South Dakota, 2008-2009. Dashed line indicates best-fit-trend.

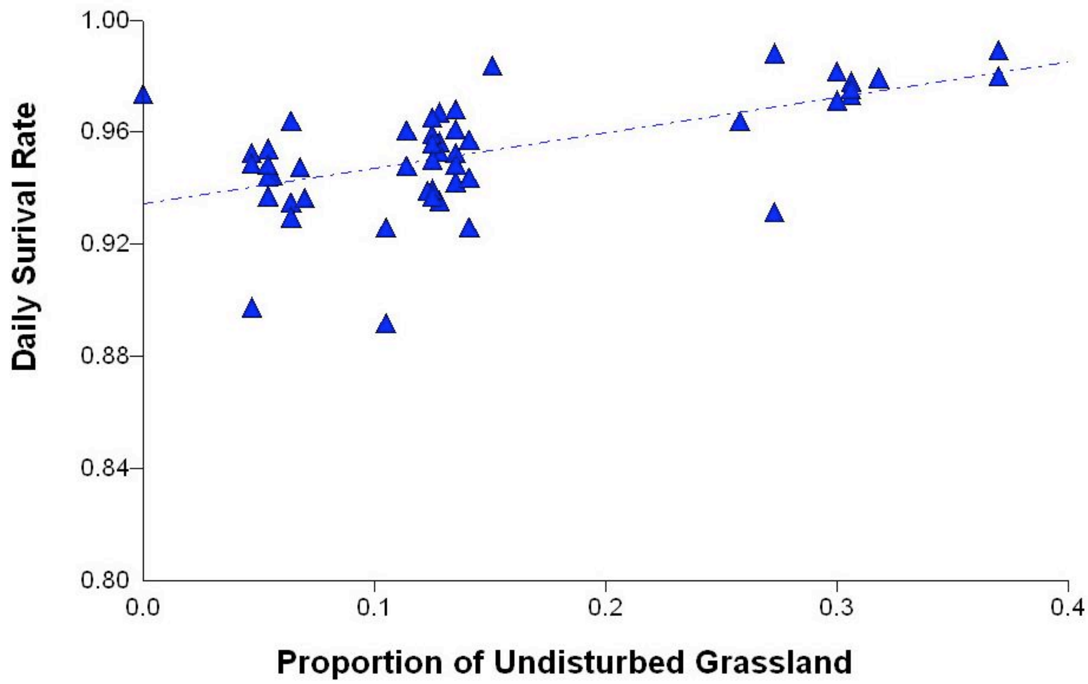

Figure 6. Northern shoveler (*Anas clypeata*) (n=56) nest survival in relation to the proportion of undisturbed grassland within 1,600 m of sampled patches in eastern South Dakota, 2008-2009. Dashed line indicates best-fit-trend.

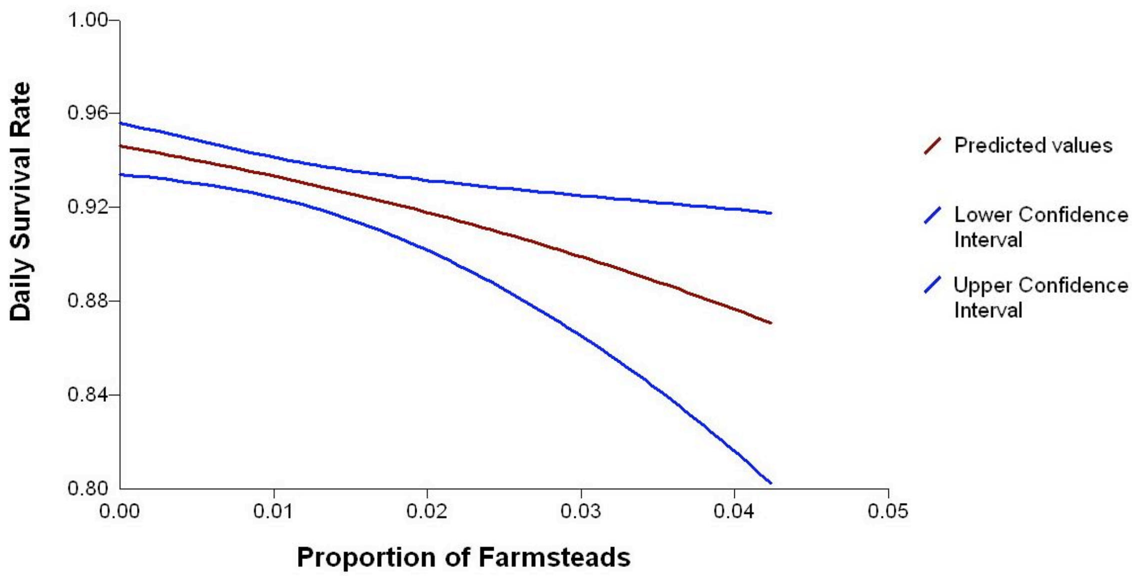

Figure 7. Ring-necked pheasant (*Phasianus colchicus*) (n=223) nest survival in relation to the proportion of farmsteads within 1,600 m of sampled patches in eastern South Dakota, 2008-2009. Blue lines indicate 95% confidence intervals.

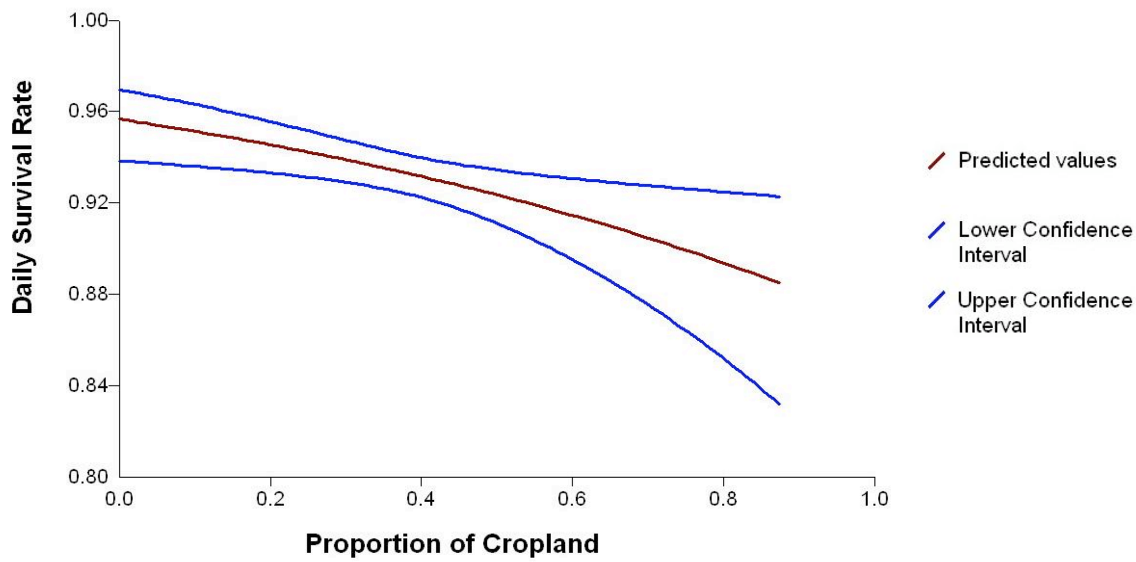

Figure 8. Ring-necked pheasant (*Phasianus colchicus*) (n=223) nest survival in relation to the proportion of cropland within 1,600 m of sampled patches in eastern South Dakota, 2008-2009. Blue lines indicate 95% confidence intervals.

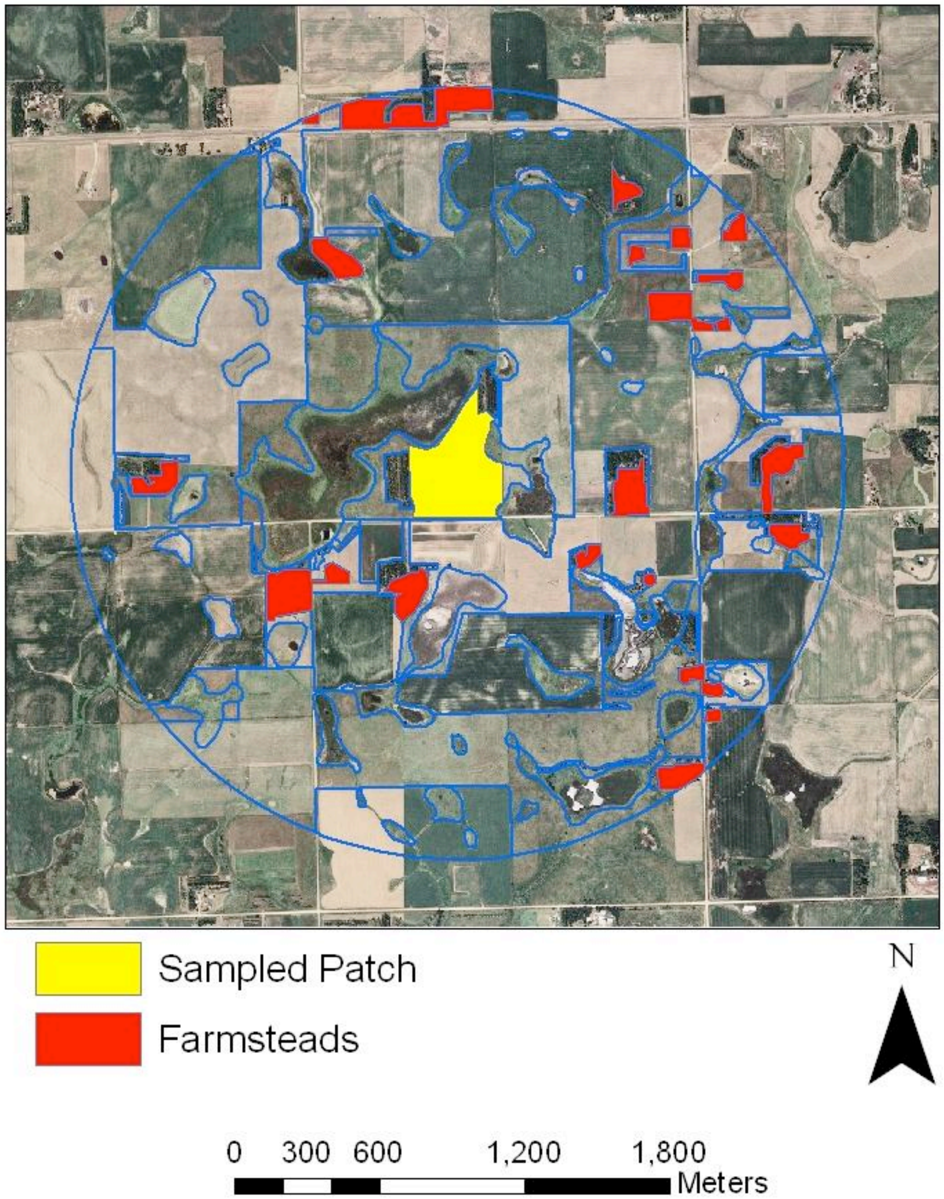

Figure 9. Aerial photo depicting a sampled patch with a large proportion of farmsteads (5.5%) within 1,600 m of a sampled patch of grassland in Minnehaha County, South Dakota, 2009.