2012

Association of Ring-Necked Pheasants and Conservation Reserve Program-Grasslands During the Brood-Rearing Season in Eastern South Dakota

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ASSOCIATION OF RING-NECKED PHEASANTS AND CONSERVATION RESERVE PROGRAM-GRASSLANDS DURING THE BROOD-REARING SEASON IN EASTERN SOUTH DAKOTA

BY

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A thesis submitted in partial fulfillment of the requirements for the

Master of Science

Major in Wildlife and Fisheries Science

South Dakota State University

2012

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This thesis is approved as a creditable 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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ACKNOWLEDGEMENTS

I would like to thank my major advisors, Dr. Jonathan A. Jenks and Dr. Daniel E. Hubbard for providing me with the opportunity to further my education and pursue my goals in wildlife research and science. This project evolved quickly after my arrival on campus, and I greatly appreciate the many discussions, expertise, and guidance from both of you to keep this project moving forward and me sane. Special thanks is deserved by Dr. Troy W. Grovenburg for providing many invaluable hours of statistical analysis, ideas, guidance, and support throughout the duration of this study. I would also like to thank Dr. Robert W. Klaver for his GIS and statistical expertise lent to me in no small amount over the course of my study. Without the collaboration, expertise, and guidance of my committee the quality of this study or my education would not have been achieved and for that I am grateful.

I would like to thank my technicians A. Solem, A. Stegemen, and L. Swanson for many tedious hours spent digitizing. This process is time-consuming and tedious, and the quality of data they helped collect was the basis for my project. I would also like to thank T. Runia of South Dakota Game, Fish and Parks for his expertise and review throughout this study. Thanks to J. White, M. Estey, R. Wiliamson, C. Switzer, C. Marsh, T. Kirschenmann, M. Kjellsen, D. Dembkowski, and P. Bergmann for data acquisition, collaboration, and technical assistance. Lastly, but most importantly, I would like to thank D. Drake, T. Symens, and C. Jacobson for being the backbone of our department and providing me answers to any question I may have brought forth, especially use of the fax machine.

I would like to thank my fellow students in the graduate department for providing an atmosphere that made some of the harder days tolerable and for their friendship; South Dakota quickly became home for me. Specific thanks to D. Toy, M. Hanan, N. Docken, M. Greiner, M. Fincel, C. Mosby, C. Mehls, K. Hymrl, J. Krause, N. Baker, I. Sasmal, S. Datta, and C. Warner for your friendship and discussions, and many memorable experiences I was fortunate enough to share with you exploring South Dakota. I would also like to thank Dr. Brian Graeb for many discussions on science, life, and pointing dogs. Thanks to both you and Stephanie for opening the door to training pointing dogs and upland bird hunting. I would also like to thank the many people who have helped form me in my academic and professional career, although there are too many to mention here. Special thanks to the Karrak Lake Research Station, Nunavut, Canada and to all those people who I was fortunate enough to share camp with. Karrak is the foundation of my career and will always be my second home. Specifically, thank you to R. Alisauskas, G. Samelias D. Kellett, K. Drake, J. Traylor, A. Lusignan, J. Denton, K. Swiechowicz, and D. Hogan. I'd also like to thank A. Hampe, M. Vrtiska, J. Dubovsky, T. Hanson, K. Kruse, B. Lake, K. VerCauteren, B. Clark, L. Schulte-Moore, M. Shappell, S. Lawry and all others who have given me opportunities to pursue my dreams in this field, reminding me why I chose this career path to start with.

I have to make a special note to my Deutsch Kurzhaar, Eider. I have never known such complete devotion and energy. With him I came to truly appreciate and love living in South Dakota. He has endured many nights sleeping at my feet while running GIS analyses and writing during this process, and I promise that time will be repaid in full chasing upland birds in the years to come. Lastly, I would like to thank my friends and family, especially my parents Dave and Christy White. Mom and Dad, you have always supported me in my decisions, whether it was heading for the unknown in the Arctic or moving to numerous places throughout the west and Midwest. Without your love, inspiration, and support I never would have been able to achieve what I have, and I am forever grateful to you both.

Funding for this project was provided by Federal Aid in Wildlife Restoration (Project W-75-R, No. 7539), administered through South Dakota Department of Game, Fish and Parks, and by the South Dakota Agriculture Experiment Station.

ABSTRACT

ASSOCIATION OF RING-NECKED PHEASANTS AND CONSERVATION RESERVE PROGRAM-GRASSLANDS DURING THE BROOD-REARING SEASON IN EASTERN SOUTH DAKOTA

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September 2012

Grassland established through the Conservation Reserve Program (CRP) has provided critical habitat for many wildlife species. Recent declines in CRP-grassland acreage attributed to changes in federal enrollment policy, increased biofuels production, and commodity prices may have negative consequences on wildlife populations. Conservation Reserve Program habitats have increased availability of quality nesting and over-winter cover for pheasants (*Phasianus colchicus*) in regions where large-scale conversions of native grasslands to cropland have occurred. The purpose of this study was to quantify the effect of CRP-grasslands on pheasants across a large geographic region. Primary objectives of the study were to determine presence/absence of pheasants and produce a habitat-based model predicting change in pheasant abundance. We used logistic regression and negative binomial regression to evaluate the influence of CRP-grassland availability on pheasant presence and abundance in South Dakota during 2006−2010 using survey data from 84 brood-survey routes. We generated pseudo-absence locations in equal proportion to hen pheasant (*n*

= 5,876) and brood locations (*n* = 4,829) and used a logistic regression to model presence/absence of a hen pheasant and a pheasant brood in eastern South Dakota. We developed 2 sets of models; 1) locations where ≥1 hen pheasant was present and 2) locations where ≥1 hen pheasant with a brood was present at 2 spatial scales; a 500 and 1,000-m buffer around an observation. The top model for hen pheasants and pheasant broods at a 1,000-m scale was [Mean Patch Size + %GRASS + %Hay/Alfalfa + Landscape Shape Index + Patch Density + %CRP-grassland + CRP Mean Patch Size + CRP Patch Density + Spring Precipitation + Row Crop Mean Patch Size + Winter Snowfall + %Wetland + %Wheat + Woody Vegetation Patch Density]. Probability of the presence of a pheasant brood increased by 1.01 (95% CI = 1.003−1.023) for every 1 ha increase in CRP-grassland and probability of the presence of a hen pheasant increased by 1.02 (95% CI = 1.016−1.028) for every 1 ha increase in CRP-grassland. We examined 9,724 (*n* = 23,975 pheasants) spatially explicit pheasant locations using negative binomial regression to predict the response of pheasant abundance to changes in habitat distribution and percentage in eastern South Dakota. Our top model [%CRP + CRP Patch Density + %Row Crop + %Row Crop^2 + %GRASS + GRASS Patch Density + Hay/Alfalfa + Hay/Alfalfa Patch Density + WHEAT] indicated CRP-grasslands, other reproductive habitats associated with pheasant broods, and row crop agriculture influenced pheasants greatest across a large, regional scale. Based on our top model, when all other variables in the model were held constant at their means, pheasant counts increased by 5 (95% CI = 2.99–5.93) birds for every 94.3 ha increase of CRP-grassland. Presence of pheasants was strongly influenced by CRP-grasslands in areas dominated by row crop agriculture. CRP-grassland had a lesser effect predicting pheasant abundance, although the effect may have been diluted by the large variation in land use across eastern South Dakota as well as varying spring precipitation and winter snowfall. This study provided useful insight in the regional influence of the CRP on pheasants in eastern South Dakota. Results will be used to improve pheasant management in South Dakota and assist South Dakota Department Game, Fish and Parks when making decisions concerning Farm Bill dependent habitats and pheasant management. Conservation Reserve Program-grasslands had a positive effect on pheasants in both modeling efforts across eastern South Dakota. However, continued evaluation of the CRP and other land use programs should provide further insight to understanding regional differences in land management on pheasants in eastern South Dakota.

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ABSTRACT

Grassland established through the Conservation Reserve Program (CRP) has provided critical habitat for many wildlife species. Declines in CRP-grassland acreage attributed to changes in federal enrollment policy, increased biofuels production, and commodity prices may have negative consequences on wildlife populations. Conservation Reserve Program habitats have increased availability of quality nesting and over-winter cover for pheasants (*Phasianus colchicus*) in regions where large-scale conversion of native grasslands to cropland have occurred. We used logistic regression to evaluate the influence of CRP-grassland availability on pheasant presence in South Dakota during 2006−2010 using survey data from 84 brood-survey routes. We developed 2 sets of models; 1) locations where ≥1 hen pheasant was present and 2) locations where ≥1 hen pheasant with a brood was present. We generated pseudo-absence locations in equal proportion to hen pheasant (n = 5,876) and brood locations (n = 4,829). The top model for hen pheasants and pheasant broods at a 1000-m scale was [Mean Patch Size + %GRASS + %Hay/Alfalfa + Landscape Shape Index + Patch Density + %CRP-grassland + CRP Mean Patch Size + CRP Patch Density + Spring Precipitation + Row Crop Mean Patch Size + Winter Snowfall + %Wetland + %Wheat + Woody Vegetation Patch Density]. Probability of the presence of a pheasant brood increased by 1.01 (95% CI = 1.003−1.023) for every 1 ha increase in CRP-grassland and probability of the presence of a hen pheasant increased by 1.02 (95% CI = 1.016−1.028) for every 1 ha increase in CRP-grassland. Results from this study will provide valuable information for

conservation and agricultural policy in South Dakota by quantifying production from Farm Bill dependent habitats.

KEY WORDS Conservation Reserve Program, CRP, habitat association, South Dakota, *Phasianus colchicus*, ring-necked pheasants.

INTRODUCTION

Grassland to cropland conversion in the Northern Plains has occurred at an increasing rate in the past decade (Claassen et al. 2011). Recent shifts in regional landscape composition have occurred due to Conservation Reserve Program (CRP) contract expirations (United States Department of Agriculture 2011*a*), increased commodity crop prices (National Agricultural Statistics Service 2011), and federally mandated increases in biofuel production (Fargione et al. 2009). Large-scale grassland conversion and its effects on wildlife, rural economies, and the environment across this region has been well documented (Newton et al. 2005, Nielson et al. 2008, Searchinger et al. 2008, Rashford et al. 2011, Grovenburg et al. 2012*a*, 2012*b*). Conversion of these habitats was associated with losses of grassland-dependent species (Niemuth et al. 2007, Herkert 2009), decreased water quality (Foley et al. 2005), increased soil erosion (Sullivan et al. 2004), and large volume releases of sequestered carbon (Foley et al. 2005), potentially threatening wildlife communities and ecosystems as well as quality of life of rural residents (Weyer et al. 2001).

The CRP is a voluntary land retirement program administered through the Farm Service Agency (FSA) and the United States Department of Agriculture (USDA).

Landowners received an annual fixed rental payment for reverting previously cropped farmland to perennial grass cover or other approved conservation practice for a 10–15 year period (Barbarika et al. 2004). The program originally was enacted to reduce acreage available for agricultural production, to increase the price of commodity crops, and ensure our nation's ability to produce food and fiber. Since that time, other objectives of equal importance include environmental benefits such as reduced soil erosion/water pollution and increased quality habitat for wildlife species (Barbarika et al. 2004). First implemented in 1985 through the Food Security Act, CRP enrollment peaked nationally in 2007 at 14.9 million ha. Between 2007 and 2010, 2.2 million ha of CRP contracts expired and were converted to agricultural crop production (United States Department of Agriculture 2011*a*). Enrollment in South Dakota peaked at 717,876 ha in 1998; 63% (452,262 ha) remained by 2010 (United States Department of Agriculture 2011*a*). Additionally, an estimated 9.8 million ha of grasslands (rangeland and pastureland) existed in South Dakota in 2007; a 5.2% decrease from 1982 (United States Department of Agriculture 2009*b*).

Conservation Reserve Program-grasslands benefit a variety of game and non-game species including waterfowl, grassland nesting birds, and ungulates (Reynolds 2005, Niemuth et al. 2007, Grovenburg et al. 2010). Reynolds (2005) attributed increased production of 2.2 million ducks annually during 1992−2003 to CRP. In North Dakota, nest survival of upland nesting ducks was positively correlated with the amount of grassland habitat at multiple landscape scales (Stephens et al. 2005). In the Prairie Pothole Region (PPR), approximately two million birds from five grassland nesting species would be lost without the presence of CRP habitats (Niemuth et al. 2007). In Minnesota, meadowlark (*Sturnella magna*) indices increased by a mean of 11.7 birds/route in summer for every 10% increase in grassland (Haroldson et al. 2006). Moreover, songbird use of CRP-grassland was 1.4−10.5 times greater than row crop use during the breeding season (Best et al. 1997). In South Dakota, Grovenburg et al. (2010, 2012*b*) documented that CRP-grasslands provided thermal insulation, cover and concealment from predators for white-tailed deer fawns; CRP-grasslands were associated with increased fawn survival.

Ring-necked pheasants (*Phasianus colchicus*; hereafter pheasants) are often associated with mixed agricultural and grassland habitats (Trautman 1982, Patterson and Best 1996). Their presence is linked to ecological characteristics that make them good indicators of changes in agricultural landscapes and successional habitat provided by CRP-grasslands (Nielson et al. 2008). Pheasants use a variety of habitats seasonally (Trautman 1982); during winter, pheasants selected for wetlands (Homan et al. 2000), dense stands of grass vegetation, and shrubs in close proximity to established food sources (Larsen et al. 1994, Gabbert et al. 1999). Dense vegetation such as warm-season grasses, cattail (*Typha* spp.), and reed canary grass (*Phalaris* spp.) were used during extreme winter weather events (Gabbert et al. 1999). Alfalfa (*Medicago sativa*) and dense perennial cool-season grass-legume mixtures and perennial warm-season native grass mixtures were important nesting cover for pheasants (Hanson and Progulske 1973, Hankins 2007). In regions where wheat (*Triticum aestivum*) was abundant, winter wheat was important for brood-rearing (Hammer 1973). In an agricultural landscape, management to ensure brood survival should emphasize perennial grass and legume cover dispersed among crop fields, with grassland cover remaining undisturbed through the primary nesting season (i.e., after 1 August; United States Department of Agriculture 2011*b*). Therefore, a diverse agricultural landscape consisting of a variety of nesting and brood-rearing habitats such as undisturbed grasslands (i.e., CRP) and wheat may directly benefit pheasant populations.

Previous attempts have been made to document the association of pheasants and CRP-grasslands. In South Dakota, Larsen et al. (1994) found increased pheasant counts in food plots in or near CRP fields of switchgrass (*Panicum virgatum*); CRP-grasslands provided adequate winter cover during periods with high snow depths. Areas in southeast Nebraska with 18−21% CRP-grassland coverage versus similarly sized areas with 2−3% CRP-grassland coverage held higher pheasant numbers (King and Savidge 1995). In Iowa, pheasant observations increased by 30% during the first 5 years after the CRP was established (Riley 1995). In the Midwest, pheasants had the greatest potential to benefit from the availability of CRP-grasslands during winter (Best et al. 1998). In northwest Iowa, the addition of ≥15 ha of CRP-grassland patches to an intensively farmed landscape improved nesting conditions, while greatest success was observed in patches ≥ 60 ha (Clark et al. 1999). Eggebo et al. (2003) sampled 42 CRP fields in eastern South Dakota and documented that increased pheasant abundance was associated with field age and cover type, suggesting a mosaic of cool- and warm-season CRP-grassland was most beneficial for pheasants. Additionally, replacement of cropland with CRP-grasslands had a positive effect on pheasant population growth rates in Iowa

(Nusser et al. 2004). In Minnesota, the relative abundance of pheasants increased by 12.4 birds per route in spring and 32.9 birds per route in summer for each 10% increase of grass in the landscape (Haroldson et al. 2006). Most recently, Nielson et al. (2008) assessed Breeding Bird Survey (BBS) data from 9 states during 1987−2005 within the distribution of the pheasant. Across the study area, they concluded there was a 22% (1 pheasant) predicted increase in pheasant counts for an addition of 319 ha of herbaceous CRP.

In South Dakota, pheasants are an economically important game bird, annually providing $220 million in revenue to the state's economy (Janssen et al. 2008). Therefore, accurate estimates of the response of pheasants to changes in land use are necessary for management of this important game species. Limited information exists on the effects of large acreage decreases of CRP-grassland on pheasants in South Dakota; therefore, we modeled hen pheasant and pheasant brood presence as a function of habitat types in eastern South Dakota 2006−2010, a period when large numbers of CRP contracts expired and grassland was converted to crop production (United States Department of Agriculture 2011*a*). We hypothesized that (1) CRP-grasslands would significantly influence the presence of pheasants on the landscape (Patterson and Best 1996, Nusser et al. 2004, Nielson et al. 2008), and that (2) the presence of pheasants would be a function of patch metrics of landscape habitats (Bender et al. 1998, Clark et al. 1999). Our primary objective was to (1) develop a set of habitat-based models using roadside brood-survey data and spatially explicit CRP data that would predict a) presence of hen pheasants and b) presence of pheasant broods, and (2) compare model output with predictions from a model estimating the relationship between pheasant abundance and CRP lands (Nielson et al. 2008).

STUDY AREA

We studied pheasants along 84 brood-survey routes conducted annually 25 July – 15 August, 2006−2010 by South Dakota Department Game, Fish and Parks (SDGFP) in 44 counties in eastern South Dakota (Fig.1.1), total area for all routes = 824,587 ha. The study area was located within 7 physiographic regions of eastern South Dakota; Missouri Coteau, James River Lowland, Minnesota-Red River Lowland, Prairie Coteau, Southeastern Loess Hills, Missouri River Floodplain, and Lake Dakota Plain (Johnson et al. 1995) and contained 11 pheasant management clusters designated by SDGFP (Fig. 1.1). Pheasant management clusters were designated by SDGFP around city centers across the state and were used to summarize annual pheasant population and trend data. Mean spring precipitation (1 April – 31 May) ranged from 7.1 cm–36.1 cm in 2006, 30.6–76.3 cm 2007, 16.3–46.9 cm in 2008, 14.7–29.2 cm in 2009, and 28.4−43.9 cm in 2010 across management clusters. Mean cumulative snowfall (1 November – 31 March) ranged from 73.4−271.5 cm in 2006, 153.4−259.6 cm in 2007, 91.7−252.7 cm in 2008, 175.3−377.7 cm in 2009, and 211.1−323.3 cm in 2010 across management clusters (South Dakota Office of Climatology 2011).

Agriculture (e.g., row crops and small grains) was the predominant land use in the 44 county study area (Smith et al. 2002, South Dakota Agricultural Statistics Service 2011). Cultivated land, pasture-grassland, woody vegetation, and wetland comprised 54.3%, 29.7%, 0.9%, and 4.5%, respectively, of the total land use within the 84 brood-survey routes in eastern South Dakota at the onset of the study in 2006 (United States Department of Agriculture 2010). During the course of our study, CRP enrollment peaked in eastern South Dakota at 454,588 ha in 2007, of which 17.9% was converted to agricultural production by spring 2008 (United States Department of Agriculture 2011*a*). Conservation Reserve Program contracts continued to expire throughout the duration of the study, although CRP loss was mitigated at varying levels and locations through continuous CRP and Conservation Reserve Enhancement Program (CREP) enrollments (United States Department of Agriculture 2011*a*). Woody vegetation (forested cover) was comprised mainly of tree row and shelterbelt plantings (Smith et al. 2002, Grovenburg et al. 2010). The study area lies within the glaciated Prairie Pothole Region of eastern South Dakota (Smith et al. 2002), where approximately 35% of prairie potholes have been drained and converted to cropland (Dahl 1990). Additionally, the study area contained 11,195 ha of State Game Production Area lands and Federal Waterfowl Production Area lands (T. Runia, SDGFP, unpublished data). The majority (83%) of SDGFP's pheasant brood-surveys were located in eastern South Dakota (Switzer 2009) providing an ideal location to study pheasant ecology and land use changes (Trautman 1982).

Tall grass or true prairie remains in portions of eastern South Dakota, giving way to the northern mixed grass prairie in the west (Johnson and Larsen 1999, Higgins et al. 2000). Dominant vegetation in tall grass prairie includes big bluestem (*Andropogon gerardii*), little bluestem (*A. scoparius*) switchgrass, prairie cordgrass (*Spartina pectinata*), and Indian grass (*Sorghastrum nutans*; Johnson and Larson 1999). Species indicative of the northern mixed-grass prairie include western wheatgrass (*Elymus smithii*), big bluestem, porcupine grass (*Stipa spartea*), and little bluestem (Johnson and Larson 1999). Common wetland vegetation included prairie cordgrass, reed canarygrass (*Phalaris arundinacea*), common reed (*Phragmites australis*), cattails, rushes (*Juncus* spp.), and sedges (*Carex* spp.; Johnson and Larson 1999). Cultivated crops included corn (*Zea mays*), soybeans (*Glycine max*), wheat, and alfalfa (South Dakota Agriculture Statistics Service 2011).

Conservation Reserve Program vegetation consisted primarily of CP1 (introduced grasses and legumes), CP2 (native grasses and legumes), and CP10 (existing grasses and legumes; Jones-Farrand et al. 2007, Grovenburg et al. 2012*a*). The CP1 plantings were composed primarily of intermediate wheatgrass (*E. hispidus*), smooth brome (*Bromus inermis*), alfalfa, and sweet clover (*Melilotus* spp.) whereas CP2 plantings consisted of Indian grass, switchgrass, big bluestem, and little bluestem (Best et al. 1997, Higgins 2000, Grovenburg et al. 2012*a*). Haying and grazing of CRP acreage was authorized under certain conditions to improve quality and cover or to provide emergency relief to livestock producers (United States Department of Agriculture 2011*b*).

METHODS

Pheasant Data

We acquired pheasant data for 84 brood-survey routes conducted from 2006–2010 by SDGFP in eastern South Dakota. The South Dakota brood route survey was typical of state-level wildlife surveys used in states with abundant populations of pheasants to obtain information on population trends (Nusser et al. 2004, Switzer 2009). Brood-survey routes were conducted 25 July – 15 August, 2006−2010 annually by SDGFP employees and were located throughout South Dakota along rural gravel roads (Switzer 2009). Routes were approximately 48 km in length and observation periods were standardized (i.e., route start point, observation frame, weather conditions) to reduce error associated between observers and year. SDGFP employees collected pheasant observations along routes from sunrise to no later than 2 hours after sunrise only when standardized weather conditions were optimal for observing pheasants: vegetation was saturated from moderate to heavy dew or rain, cloud cover was limited, and wind velocities were ≤12.9 kph (Switzer 2009). Observers drove routes east to west and recorded number of roosters, hens, broods, and brood size (if possible) at 0.16 km increments using the vehicle odometer. In 2010, 67 of 84 routes collected pheasant observations at paired Cartesian coordinates using CyberTracker version 3.217 (CyberTracker Conservation®, Noordhoek, Cape Town, South Africa) on mobile GPS units. Data dictionaries were created manually to collect data previously recorded using historical data sheets at pheasant observations. Because surveys were conducted in areas known to contain large numbers of pheasants (Switzer 2009), counts for these routes were viewed as indicators of population trends rather than true estimates of pheasant populations (Nusser et al. 2004).

We gave spatial reference to survey route observations using ArcGIS 9.3 (ESRI, Inc., Redlands, California, USA). We digitized survey routes using historical aerial imagery and descriptions of individual routes. We converted routes to points every 0.16 km using the convert features function in XTOOLS PRO (Data East Software, LLC, Novosibirsk, Russia). We exported point files into Microsoft Excel 2010 (Microsoft, Inc., Redmond, Washington, USA) and paired 0.16 km Cartesian coordinates with 0.16 km observations from field data sheets. If an observation was located >0.998 km outside of the spatially referenced transect (2 × pheasant mean home range size; Riley et al. 1998), we censored it from analyses.

Geographic Data

We used standard photo interpretation techniques to digitize and enumerate patches of land cover at a resolution of 5000-m, in accordance with National Wetlands Inventory (NWI) protocol (M. Kjellsen, National Wetlands Inventory, South Dakota State University, personal comm.), using aerial imagery (2006, 2008, and 2010) obtained from the USDA Farm Service Agency (FSA) Aerial Photo Field Office, Salt Lake City, Utah, USA. Aerial imagery was unique among years (e.g., cloud cover, exposure, vegetation height); therefore, we created classification guides (i.e., known land use patches of aerial imagery) using aerial photographs with known classification of land use patches and spatially explicit CRP shape files obtained from the FSA, and the Cropland Data Layer (CDL) 2006–2010 (United States Department of Agriculture 2010). Additionally, spatial coverage of state owned Game Production Areas and federally owned Waterfowl Production Areas acquired from SDGFP were used as guides to classify planted cover habitats as well as CRP lands. We did not censor routes that were adjacent to commercial hunting outfitters that place pen-reared pheasants for commercial hunting purposes because pen-reared pheasants suffer high over-winter mortality and were not likely to contribute to the breeding population of pheasants (Leif 2004, Lusk et al. 2009).

We trained photo interpreters using classification guides to enhance their visual understanding of the landscape, delineate patch boundaries, and classify land cover types (Brown and Schulte 2011). We classified patches into 5 land-cover categories based on their functional differences and our ability to reliably interpret their features from aerial imagery. The land cover classes included disturbed grassland, planted cover, developed, hay/alfalfa, and woody vegetation (Table 1.1). Patches digitized by photo interpreters were error checked on regular intervals by the first author to ensure accuracy and consistency among observers. Because aerial imagery was not available for 2007 and 2009, we used the 2006 coverage for 2007 and the 2008 coverage for 2009. We assumed coverages represented habitat on the ground at that time; CRP acreage decreased by 6.1% and 5.4% between 2006−2007 and 2008−2009, respectively (United States Department of Agriculture 2011*a*).

We obtained spatially explicit Common Land Unit (CLU) and CRP contract information from the FSA from 2006 to 2010. County level CRP contract information was updated and stored by county FSA offices, and archived in the FSA Aerial Photo Field Office, Salt Lake City, Utah. We compared overall acreages from the CRP contract information to acreages reported by FSA during 2006 to 2010. Reported acreages differed substantially in 2007 and 2009; thus, we deemed these data unusable for analyses. Through the use of expiration dates for CRP contract duration and aerial imagery, we used the CRP layer as a guide to validate the digitized classification of CRP habitat types for 2008 and 2010 because acreage output corresponded with FSA reported land units. We quantified and classified CRP habitats in 2006 using the 2002 habitat coverage produced by United States Fish and Wildlife Service (USFWS; M. Esty, Habitat and Population Evaluation Team [HAPET], Bismarck, North Dakota, unpublished data) for the Prairie Pothole Region of the eastern Dakotas. We confirmed classification of CRP habitat patches by overlaying the HAPET coverage onto National Agriculture Imagery Program mosaic (NAIP) aerial imagery 2006 (USDA Farm Service Agency Aerial Photo Field Office, Salt Lake City, Utah, USA). If we identified a habitat patch as grassland with no sign of disturbance (i.e., haying or cutting pattern, cattle trails, presence of cattle) in 2006 using aerial imagery and it corresponded with HAPET's classification as CRP, the patch was classified as CRP. We compared the overall change in CRP enrollment from 2002−2006 to validate the use of the 2002 HAPET coverage as a guide for classifying 2006 CRP-grassland habitats. Conservation Reserve Program enrollment decreased by 6% across eastern South Dakota 2002−2006 (United States Department of Agriculture 2011*a*); thus, we used the 2002 HAPET coverage as a guide to classify CRP-grasslands in 2006. We were unable to use contract age or type for our analyses as those data were not available in the data set obtained from the USFWS.

We used South Dakota CDL 2006−2010 to document land use within buffered areas of survey routes. The CDL contained an accurate spatial coverage of annual crop-specific agricultural practices. Non-agricultural land use coverage within the CDL was dependent on the National Land Cover Data (NCLD; Homer et al. 2007) 2001 (Table 1.2). We converted the digitized land use coverage (i.e., vector data) to a raster dataset using the Convert Features to Raster tool in Spatial Analyst in ArcGIS at a 30-m resolution. We reclassified the digitized grassland coverage and executed a merge onto the cropland data, reclassifying habitat and cropland data classifications using Spatial Analyst in ArcGIS at 30-m resolution (Tables 1.1, 1.2). We used Focal Statistics and Extract Features to Point tools within Spatial Analyst to extract the proportion of each habitat feature around pheasant observations within 500 and 1000-m buffers (1 and 2 times pheasant home range size of 76 ha during brood rearing season; Riley et al. 1998).

To assess quality of the available wetland habitat coverage, we acquired NWI data from the National Wetlands Inventory. We used ArcGIS and the Convert Features to Raster tool in Spatial Analyst to convert NWI data from vector to raster data. We grouped Class II and III wetland types (temporary and seasonal) and Class IV wetlands (semi-permanent) (Stewart and Kantrud 1971) to simplify wetland types for analyses. We modeled wetland coverage from NWI and the CDL independently due to high correlation ($r > |0.50|$) between coverages. During years when winters are classified as severe (i.e., cumulative snowfall > 76.2 cm; T. Bogenschutz, Iowa Department of Natural Resources [IDNR], personal commun.), wetlands can provide important winter habitat for pheasants (Gabbert et al. 1999, Homan et al. 2000); therefore, we included wetlands as a variable in our modeling efforts. Data obtained from NLCD 2001 and CDL 2006-2010 was grouped into a cumulative wetland category (i.e., wetland, herbaceous, and woody wetlands). This wetland coverage included wetlands defined within the palustrine system that contained trees, shrubs, and herbaceous vegetation and wetlands without woody or herbaceous emergents, usually less than 2 m deep at low water and less than 8 ha in size (larger if they supported persistent woody or herbaceous vegetation; Johnson and Higgins 1997). Wetlands are dynamic and important to pheasant ecology (Gabbert et al. 1999, Homan et al. 2000), but due to logistics and limited availability of accurate yearly wetland data, we were unable to produce a dynamic wetland coverage representing temporal change in wetland habitats.

We used a standard shape (i.e., circle) and size to investigate habitat characteristics along transects (Kie et al. 2002, Bowyer and Kie 2006). Therefore, we delineated circular areas at 2 spatial scales (500 and 1000-m buffers around a location; 78.5 ha and 314.2 ha, respectively) around spatially referenced pheasant locations (Clark et al. 1999, Nielson et al. 2008). We measured habitat variables at both spatial scales using FRAGSTATS (version 3); metrics were grouped into 3 categories at patch class and landscape level scales: area, density, and edge (McGarigal et al. 2002). Because metrics within each FRAGSTATS category often are closely related (Hargis et al. 1998), we selected a single metric within each category (Kie et al. 2002), therefore, we present data at each spatial scale for each of the 3 habitat metrics for each land use category using patch density (PD; number of patches/100 ha of the habitat category), mean patch size (AM; mean area in ha of land-cover patches of habitat category), and landscape shape index (LSI; total length of edge or perimeter involving the corresponding habitat divided by the minimum length of habitat edge or perimeter possible for a maximally aggregated habitat; McGarial et al. 2002). We chose patch metrics *a priori* based on previous biological literature important to pheasant ecology in this region (Clark et al. 1999, Haroldson et al. 2006, Nielson et al. 2008).

Weather Data

We obtained weather data from the South Dakota Office of Climatology (South Dakota State University, Brookings, South Dakota, USA) for 1 November – 31 May for each year of the study. We summarized daily mean precipitation and snowfall from weather stations in closest proximity to the center point of established survey routes throughout the extent of the study area using Near Tool in Analysis Tools, ArcGIS 9.3. Cumulative precipitation during peak nesting season can affect nesting and breeding success of pheasants (Martinson and Grondahl 1966, Haroldson et al. 2006) and snowfall accumulation in years prior can negatively affect breeding ecology as mortality increases significantly through poor body condition and increased predator mortality (Edwards et al. 1964, Gabbert et al. 1999, Homan et al. 2000). Therefore, we included mean cumulative precipitation (1 April – 31 May) and cumulative snowfall (1 November – 31 March) as potential variables in our analyses.

Statistical Analysis

We used logistic regression to test for relationships for 2 model sets between the dependent variable 1) locations where ≥1 hen pheasant was present and 2) locations where ≥1 hen pheasant with a brood (i.e., pheasant brood) was present and independent variables (habitat proportions, habitat patch metrics, and weather data) at each spatial scale. Male pheasants normally complete their postnuptial molt earlier in summer than hens (i.e., July) and rarely assume incubation or brood-rearing responsibilities (Trautman 1982); therefore, we modeled only hen pheasant and pheasant brood locations. Prior to modeling, we tested for collinearity between predictor variables with Pearson's correlation matrix (PROC CORR; SAS Institute 2001) and removed 1 variable from each correlated pair ($r > |0.50|$), which resulted in 51 predictor variables at each scale for modeling. We preferentially removed habitat predictor variables correlated with ≥1 other variable based on biological importance from previous literature on pheasant ecology during the brood rearing season. We used multivariate analysis of variance (MANOVA) to determine differences in uncorrelated predictor variables at pheasant locations among clusters. We used nested analysis of variance (ANOVA; PROC GLIMMIX) to determine differences in uncorrelated predictor variables at random and pheasant locations among clusters. We used ArcGIS to generate random locations representing pseudo-absence data points: we used proportionally equal numbers of random points to pheasant locations from 2006 to 2010. We used SAS version 9.2 for statistical analyses (SAS 2008).

We posited 20 models of how hen pheasant and pheasant brood presence might be influenced by CRP-grasslands, disturbed grassland, cropland, woody vegetation, wetland/water, patch metrics, and weather in eastern South Dakota based on biological importance to pheasant ecology (definitions of variables are presented in Table 1.3). We used Akaike's Information Criterion (AIC) to select the most parsimonious model and considered models differing by ≤ 2 ΔAIC from the selected model as potential alternatives (Burnham and Anderson 2002). We used Akaike weights (w_i) as an indication of support for each model. We determined predictive capabilities of models with receiver operating characteristic (ROC) values. We considered ROC values between 0.7 and 0.8 as acceptable discrimination and values between 0.8 and 1.0 as excellent discrimination (Hosmer and Lemeshow 2000). Prior to modeling, we withheld approximately 20% of pheasant locations proportionally by year to validate models and used the SCORE statement in SAS to calculate predicted values for each observation using the top-ranked model (SAS Institute 2008).

RESULTS

Hen pheasants

We examined 5,876 hen pheasant locations (i.e., locations where ≥1 hen pheasant was present; 990 in 2006, 1,184 in 2007, 1,532 in 2008, 818 in 2009, and 1,352 in 2010) and 5,876 random (pseudo-absence) locations in equal proportion to pheasant locations along 84 brood-survey routes throughout the study area.

At the 1,000-m scale, mean habitat variables at hen locations differed ($F_{520, 71594}$ = 36.44, $P < 0.001$) among clusters (Table 1.4). Mean patch size, mean percent grassland, mean percent hay/alfalfa, landscape shape index, mean percent CRP, CRP mean patch size, CRP patch density, patch density, spring precipitation, row crop mean patch size, winter snowfall, mean percent wetland, mean percent wheat, and woody vegetation patch density differed ($F_{10, 7332} \geq 22.58$, $P < 0.001$) among clusters.

Independent variables used for modeling differed at hen and random locations (Table 1.5). Mean percent CRP, grass, mean percent hay/alfalfa, mean percent wheat, CRP mean patch size, CRP patch density, and landscape shape index was greater ($F_{1, 11740}$ ≥ 6.49, $P \leq 0.011$) at hen locations among clusters; whereas, mean patch size, row crop mean patch size, and woody vegetation patch density was greater ($F_{1, 11740} \geq 15.97$, $P <$ 0.001) at random locations among clusters. Mean percent wetland, spring precipitation, winter snowfall, and patch density was similar ($F_{1, 11740} \geq 0.11$, $P \geq 0.416$) at hen and random locations among clusters.

At the 500-m scale, mean habitat variables at hen locations differed ($F_{520, 71594} = 23.71$, $P < 0.001$) among clusters (Table 1.4). Mean patch size, mean percent grass, landscape shape index, mean percent CRP, CRP mean patch size, CRP patch density, patch density, spring precipitation, mean percent row crop, winter snowfall, mean percent wetland, mean percent wheat, and mean percent woody vegetation differed ($F_{10, 7332} \geq 13.69$, $P < 0.001$) among clusters.

Independent variables differed at hen pheasant and random locations (Table 1.5). Mean percent CRP and wheat, CRP mean patch size, CRP patch density, landscape shape index, and patch density was greater ($F_{1, 11740} \geq 16.78$, $P < 0.001$) at hen locations among clusters; whereas mean patch size, mean percent grassland, mean percent row crop, and mean percent woody vegetation was greater ($F_{1, 11740} \geq 32.38$, $P < 0.001$) at random locations among clusters. Spring precipitation, winter snowfall, and mean percent wetland was similar ($F_{1, 11740} \geq 0.32$, $P \geq 0.475$) among hen pheasant and random locations.

We considered [AM_{1000}|Cluster + %$GRASS_{1000}$|Cluster + %HA_{1000}|Cluster + LSI_{1000}|Cluster + PD_{1000}|Cluster + %CRP_{1000}|Cluster + $CRPAM_{1000}$|Cluster + $CRPPD_{1000}$|Cluster + PRCP|Cluster + $RCAM_{1000}$|Cluster + SNFA|Cluster + %$WETL_{1000}$|Cluster + %$WHEAT_{1000}$|Cluster + $WVPD_{1000}$|Cluster] at the 1,000-m scale as the only competing model ($w_i = 1.00$; Table 1.6) for predicting presence of hen pheasants. This model was 154.47 ΔAIC units from remaining models and weight of evidence supporting this model was 10,000 times ≥ remaining models. Main effects were not significant for the environmental variables (Table 1.7) percent grass, CRP patch density, percent hay/alfalfa, spring precipitation, winter snowfall, and percent wheat ($P >$ 0.05) independent of cluster interactions, although they were significant ($P > 0.05$) in ≥ 5 cluster interactions. Parameter estimates (Table 1.7) indicated significant variable effects for percent CRP ($F_{1, 11740} = 200.65$, $P < 0.001$), CRP mean patch size ($F_{1, 11740} = 113.9$, $P < 0.001$), mean patch size ($F_{1, 11740} = 204.69$, $P < 0.001$), landscape shape index ($F_{1, 11740} = 242.19$, $P < 0.001$), row crop mean patch size ($F_{1, 11740} = 15.97$, $P < 0.001$), and woody vegetation patch density ($F_{1, 11740} = 22.53$, $P < 0.001$); percent CRP, CRP mean patch size, landscape shape index, and row crop mean patch size positively influenced the presence of a hen pheasant, while mean patch size at the landscape level and woody vegetation patch density negatively influenced presence of hens. Odds-ratio point estimates (Odds ratio = 1.02, 95% CI = 1.009−1.029) indicated that percent CRP-grassland had a positive association with presence of hens; probability of the presence of a hen pheasant increased by 1.02 for every 1 ha increase in CRP-grassland and by 1.02 (Odds ratio = 1.02, 95% CI = 1.016−1.028) for every 1 ha increase in CRP-grassland mean patch size when all other variables means in the model were held constant. Predictive capability of the model was acceptable (ROC = 0.778). We withheld 1,467 hen locations (247 in 2006, 294 in 2007, 382 in 2008, 205 in 2009, and 338 in 2010) prior to modeling for validation. Predicted probability of p_1 and p_0 of the top-ranked model was 0.5911 (SE = 0.0059) and 0.4049 (SE = 0.0059), respectively, indicating low to moderate fit of the model to the observed data. The final model (Table 1.7) indicated a positive relationship between the presence of a hen pheasant and CRP-grassland at the 1,000-m scale.

Brood locations

We examined 4,829 pheasant broods (i.e., locations where ≥1 hen pheasant + 1 brood was present; 685 in 2006, 1,071 in 2007, 1,248 in 2008, 667 in 2009, and 1,158 in 2010) along 84 SDGFP brood-survey routes. Additionally, we analyzed 5,829 random (pseudo-absence) locations in equal proportion to pheasant locations along 84 brood-survey routes throughout the study area.

At the 1,000-m scale, mean habitat, weather, and patch metric variables at brood locations differed ($F_{520, 58738} = 31.54$, $P < 0.001$) among clusters (Table 1.8). Mean patch size, mean percent grassland, mean percent hay/alfalfa, landscape shape index, mean percent CRP, CRP mean patch size, CRP patch density, patch density, spring precipitation, row crop mean patch size, winter snowfall, mean percent wetland, mean percent wheat, and woody vegetation patch density differed ($F_{10, 6024} \geq 18.83$, $P < 0.001$) among clusters.

Independent variables differed between brood locations and random locations among clusters (Table 1.9). Mean percent CRP, mean percent grass, mean percent hay/alfalfa, mean percent wheat, CRP mean patch size, CRP patch density, and landscape shape index was greater ($F_{1,10\ 604} \geq 4.83$, $P \leq 0.0279$) at brood locations; whereas, mean patch size, row crop mean patch size, and woody vegetation patch density was greater ($F_{1,10\ 604} \geq 13.57$, $P \leq 0.002$) at random locations. Mean percent wetland, spring precipitation, winter snowfall, and patch density was similar ($F_{1,9646} \geq 0.28$, $P \geq 0.102$) at brood and random locations among clusters.

At the 500-m scale, mean habitat, weather, and patch metric variables at pheasant locations differed ($F_{520, 58738} = 20.52$, $P < 0.001$) among clusters (Table 1.8). Landscape mean patch size, mean percent grassland, landscape shape index, mean percent CRP, CRP mean patch size, CRP patch density, landscape patch density, spring precipitation, mean percent row crop, winter snowfall, mean percent wetland, mean percent wheat, and mean percent woody vegetation differed ($F_{10, 6024} \geq 11.21$, $P < 0.001$) among clusters

Independent variables differed at brood and random locations among clusters (Table 1.9). Mean percent CRP, mean percent wheat, CRP mean patch size, CRP patch density, landscape shape index, and patch density was greater ($F_{1,9646} \geq 6.49$, $P \leq 0.008$) at brood locations; whereas, mean percent grassland, mean percent row crop, mean percent woody vegetation, and landscape mean patch size was greater ($F_{1,9646} \geq 16.92$, $P \leq 0.001$) at random locations. Mean percent wetland, spring precipitation, and winter snowfall was similar ($F_{1,9646} \leq 2.67$, $P \geq 0.102$) at brood and random locations.

We considered model [AM_{1000}|Cluster + $\%GRASS_{1000}$|Cluster + $\%HA_{1000}$|Cluster + LSI_{1000}|Cluster + PD_{1000}|Cluster + $\%CRP_{1000}$|Cluster + $CRPAM_{1000}$|Cluster + $CRPPD_{1000}$|Cluster + PRCP|Cluster + $RCAM_{1000}$|Cluster + SNFA|Cluster + $\%WETL_{1000}$|Cluster + $\%WHEAT_{1000}$|Cluster + $WVPD_{1000}$|Cluster] at the 1,000-m scale as the only competing model ($w_i = 1.00$; Table 1.10) for predicting presence of a pheasant brood. This model was 152 ΔAIC units from remaining models and weight of evidence supporting this model was 10,000 times ≥ remaining models. Main effects were not significant for the environmental variables (Table 1.11) percent grass, percent hay/alfalfa, percent wetland, percent wheat, spring precipitation and winter snowfall ($P > 0.05$) when independent of cluster interactions, although they were significant in ≥1 cluster interactions. Parameter estimates (Table 1.11) indicated significant variable effects that percent CRP ($F_{1, 9646} = 144.41$, $P < 0.001$), CRP mean patch size ($F_{1, 9646} = 97.44$, $P < 0.001$), CRP patch density ($F_{1, 9646} = 66.39$, $P < 0.001$), mean patch size ($F_{1, 9646} = 132.08$, $P < 0.001$) and landscape shape index ($F_{1, 9646} = 309.58$, $P < 0.001$), row crop mean patch size ($F_{1, 9646} = 13.57$, $P = 0.002$), and woody vegetation patch density ($F_{1, 9646} = 29.73$, $P < 0.001$) were significant; percent CRP-grassland, CRP-grassland mean patch size, CRP-grassland patch density, patch density, and row crop mean patch size positively influenced presence of pheasant broods while woody vegetation patch density, mean patch size, and landscape shape index negatively influenced presence of pheasant broods. Odds-ratio point estimates (Odds ratio = 1.01, 95% CI = 1.003−1.023) indicated that percent CRP-grassland had a positive effect on the probability of a pheasant brood being present; probability of a pheasant brood being present increased by 1.01 for every 1 ha increase in CRP-grassland, by 1.19 (Odds ratio = 1.19, 95% CI = 1.069−1.316) for every 1-unit increase in patch density of CRP, and by 1.02 (Odds ratio = 1.02, 95% CI = 1.012−1.028) for every 1-ha increase in mean patch size of CRP when means of all other variables in the model were held constant. Predictive capability of the model was acceptable (ROC = 0.778). We removed 1,206 pheasant locations (171 in 2006, 267 in 2007, 312 in 2008, 166 in 2009, and 290 in 2010) prior to modeling for validation. Predicted probability of p_1 and p_0 of the top-ranked model using logistic regression was 0.6375 (SE = 0.0064) and 0.3625 (SE = 0.0064), respectively, which indicated reasonable fit of the model to the observed data.

DISCUSSION

We modeled hen pheasant and pheasant brood locations separately at 2 spatial scales to determine the effects of CRP-grassland, agricultural lands, habitat variables, weather, and patch dynamics on presence of pheasants across the landscape in eastern South Dakota during the brood-rearing season. Due to the nature of road sides surveys, it is possible observations of hens without broods were negatively biased (i.e., brood was present but not observed). Because of methodology used to collect brood-survey data, pheasant brood locations are a sub-sample of hen locations, that meaning hen locations may or may not contain brood locations. Our findings suggest modeling only locations where pheasant broods (i.e., hen pheasants with a brood) were present at the 1,000-m scale (ROC = 0.778, p_1 = 0.6375, p_0 = 0.3625) was a better approach for evaluating pheasant presence than modeling locations where either hen pheasants and/or hen pheasants with a brood were present using roadside survey data. The top-ranked model was the same for hen pheasant and pheasant brood models at the 1,000-m scale. Effects of the independent variables mirrored each other closely in our models (i.e., hen pheasant locations only and hen pheasants with broods), except for percent hay/alfalfa; therefore, we focus our interpretation on the top logistic model for pheasant broods.

Presence of pheasant broods was influenced by the overall availability of habitat types and configuration of specific habitat patches within a 2-home-range radius (314.2 ha) of a pheasant observation as well as cumulative spring precipitation and cumulative winter snowfall. It is important to note that when percent CRP-grassland was modeled as a single independent variable for both modeling efforts, the model was inferior; CRP-grassland in conjunction with other habitat classes, the configuration of these habitats, and weather positively affected presence of pheasants during the brood-rearing season. Specifically, the overall percentage of CRP-grassland, increase in patch size of CRP-grassland, increase in patch density of CRP-grassland, decrease in patch size and landscape shape index, increase in row crop patch size, and decrease in patch density of woody vegetation positively affected the presence of pheasant broods across the South Dakota landscape.

Our findings that pheasant observations were positively associated with CRP-grasslands were consistent with widely held a priori expectations of managers, biologists, and previous literature (Riley 1995, Clark et al. 1999, Haroldson et al. 2006, Nielson et al. 2008). The positive association of pheasant broods and CRP-grasslands in our study was consistent with previous research that reflected the importance of CRP-grasslands to pheasant abundance. In South Dakota, Erickson and Wiebe (1973) estimated an increase of 3−10 million pheasants after nearly 720,000 ha of cropland was converted to grass and legume habitats. In Iowa, pheasant numbers increased by 30% during the first 5 years of the CRP compared to a similar period before the program began (Riley 1995). Across a 9-state region, Nielson et al. (2008) estimated a 22% (1 pheasant) increase in pheasant counts for every 319 ha of CRP-herbaceous cover. Our modeling efforts were consistent with Nielson et al. (2008) in that presence of pheasants was positively associated with CRP-grasslands, and we observed a similar magnitude of effect between pheasant presence and CRP-grasslands. Because of inherent bias with roadside survey data, we did not develop a theoretical response of pheasant abundance in relationship to CRP-grassland within our top model. Further analyses of trend data at a route level in response to landscape-level land use changes is a more appropriate approach to develop an estimate of the response of pheasant abundance to changes in CRP-grassland and other habitat variables. Our purpose herein was to determine the probability of the presence of pheasants using a dynamic habitat coverage.

Parameter estimates for percent CRP-grassland and CRP patch metrics independent of clusters were significant for predicting the presence of pheasant broods in our top model although were inconsistent between cluster interactions (i.e., regional differences in CRP-grasslands and pheasant brood presence). Agricultural practices transitioned from a predominantly wheat and rangeland dominated landscape along the Missouri River in the western portion of our study area to a row crop dominated landscape in the east. Recent pheasant indices were historically larger in the western and central portion of our study area than the east (Runia 2011). Availability of quality, alternative habitats such as wheat production and grazing/range lands coupled with less severe winters and springs in this region may allow for increased production and survival of pheasants. For example, mean percent CRP-grassland was similar between the Aberdeen and Huron clusters; 7.36% (23.1 ha) in Aberdeen and 7.85% (24.7) in Huron, although was not significant in the Huron cluster but was in the Aberdeen cluster. Interestingly, mean percent grassland was significant in the Huron cluster but not Aberdeen; mean percent grassland was greater in Huron (27.4%) at brood locations compared to Aberdeen (23.9%), a difference of 10.9 ha. This suggests that CRP-grasslands may have greater importance affecting the presence of pheasant broods in landscapes where the presence of rangeland and pasture habitat was limiting. Although we were unable to assess the quality of native grassland habitats (e.g., residual stem height, species richness, percent bare cover), we can assume highly degraded grassland habitats provide little cover for nesting and concealment purposes of pheasants, although may support invertebrate production for brood-rearing purposes. Eggebo et al. (2003) stated that vegetation composition and age of CRP-grasslands affected abundance of pheasants. Haroldson et al. (2006) suggested increases in pheasant abundance likely reached a plateau and became negative above 32% grass in a landscape. Because pheasants prefer landscapes of 50-75% cultivated lands intermixed with grassland habitats (Trautman 1982, Riley 1995, Haroldson et al. 2006), it is important to identify the quality and quantity of landscape composition in specific regions when implementing CRP-grassland habitats for the purpose of increasing pheasant production.

Multiple, large-sized patches (i.e., ≥15 ha, optimal ≥60 ha) of CRP-grasslands are beneficial to nesting (Clark et al. 1999) and brood-rearing (Riley et al. 1998) success of pheasants by providing adequate habitat that is relatively secure from predation. The landscape pattern of multiple, larger CRP-grassland patches interspersed among agricultural lands might allow for increased survival through decreased effects of predation (Riley 1995, Clark et al. 1999) and decreased over-winter mortality in areas with adequate winter cover (i.e., warm-season native grass species, wetlands, food plots). During our study, mean patch size of CRP-grasslands was greater at brood locations (9.3

ha, SE = 0.24) than at random locations (6.1 ha, SE = 0.18). Patch density of CRP-grasslands also was greater at brood locations (0.71 patches/100 ha, SE = 0.01) than at random locations (0.63 patches/100 ha, SE = 0.01). Increases in patch size of CRP-grassland habitats as well as patch density positively influenced presence of pheasant broods. Our findings suggest management for pheasant production should focus on larger, multiple patches of CRP-grasslands.

During years when winters are classified as severe (i.e., cumulative snowfall > 76.2 cm; T. Bogenschutz, Iowa Department of Natural Resources [IDNR], personal commun.), wetlands can provide important winter habitat for pheasants (Gabbert et al. 1999, Homan et al. 2000). In eastern South Dakota, these wetlands represent temporary, seasonal, and semi-permanent wetland types (Stewart and Kantrud 1971), which comprised 18.3%, 26%, and 34%, respectively, of total wetland coverage (Johnson and Higgins 1997). Therefore, during saturated conditions, a large proportion of our wetland coverage was likely unavailable to pheasants because these areas were inundated. As a consequence, our results indicated that estimates of effects of percent wetlands exhibited a negative association with the presence of pheasant broods. We do not suggest our findings reflect the true association of pheasants and wetland habitats but rather that this relationship be further examined with a temporally unique wetland coverage (capturing effects of wet/dry cycles) and classification of basins at a finer scale.

Shelterbelts and tree plantings (i.e., woody vegetation) are often used by wildlife managers to provide winter cover for pheasants in agricultural landscapes interspersed with grassland habitat. During our study, effects of woody vegetation patch density were negatively associated with the presence of broods. In this region of South Dakota and much of the Midwest and Northern Great Plains, pheasants use woody vegetation such as tree plantings and shelterbelts for winter cover when there is substantial snowfall accumulation and duration (Gabbert et al. 1999). During the brood-rearing season, hen pheasants with broods use undisturbed grasslands consisting predominately of cool-season native grass species, legume mixes, and adjacent agriculture fields (i.e., wheat and hay/alfalfa; Snyder 1991, Riley et al. 1998). Therefore, it is logical that presence of a pheasant brood was negatively associated with the density of woody vegetation during the time period of our study, although presence of these habitats in the landscape can be beneficial to pheasants because they provide important winter habitat especially in areas where quality winter cover is absent (Lyon 1967, Sather-Blair 1980, Gabbert et al. 1999, Homan et al. 2000).

Pheasants are often associated with mixed agricultural and grassland habitats (Trautman 1982, Patterson and Best 1996) making them good indicators of change in agricultural landscapes and successional habitat provided by CRP-grasslands (Nielson et al. 2008). Multiple studies have suggested a landscape composition of 50−70% agriculture intermixed with 30%−50% grassland is an ideal habitat matrix for optimal pheasant production (Trautman 1982, Riley 1995, Haroldson et al. 2006). In our study, parameter estimates suggested row crop mean patch size was positively associated with the presence of pheasant broods independent of clusters, although among cluster interactions, it was only significant in the Mitchell cluster, suggesting row crop agriculture affected pheasant presence differently by region. Row crop mean patch size was greater at random locations (33.49 ha) than at brood locations (26.64 ha) and percent cropland, although not included in our top model, was greater at random locations (38.4%, 120.7 ha) than at brood locations (32%, 100.5 ha). During our study, brood locations were associated with smaller patches of row crop and less row crop agriculture. Because pheasants are associated with mixed agricultural and grassland habitats, row crop agriculture would increase the presence of pheasants (i.e., broods) up to a certain threshold; however, our analytical approach was not appropriate for determining the threshold for this relationship. Our study supported previous research (Trautman 1982, Riley 1995, Haroldsen et al. 2006) in that presence of pheasant broods was positively associated with agriculture (i.e., row crops) when associated with quality habitats such as CRP-grasslands, winter cover (i.e., wetlands and woody vegetation), and small grain agriculture (i.e., spring and winter wheat). It is important to note that when we constructed a model where all agricultural practices excluding hay/alfalfa were grouped into one agriculture category the model was inferior in comparison to our top model where specific agricultural practices were grouped into unique categories (Table 1.10).

Alternate habitats such as wheat and hay/alfalfa may provide adequate nesting and brood-rearing cover for pheasants in regions void of quality undisturbed grassland (Hammer 1973, Snyder 1984). Percent wheat (i.e., spring and winter wheat combined) was only significant in the Mitchell and Mobridge clusters and was not significant independent of cluster interactions. In the top model, percent hay/alfalfa was only significant in the Huron, Pierre, and Watertown clusters. While model fit was increased by the addition of these habitats, we cannot conclude that wheat and hay/alfalfa directly influenced the presence of broods across eastern South Dakota. This relationship may be better understood at a smaller regional scale, where areas may be void of quality nesting and brood-rearing cover (i.e., dominated row crop agriculture landscape). Previous literature indicates that cultivation, tillage, haying regime, and stem height influences suitability of these habitats for nesting and brood-rearing by pheasants (Snyder 1981, Snyder 1984, Rodgers 2002).

Weather can have a significant effect on upland game bird populations during years of substantial snowfall accumulation and duration, and during spring nesting seasons in years when precipitation is severe (Peterson and Silvy 1994, Perkins et al. 1997, Gabbert et al. 1999). In Iowa, pheasant populations have not increased when cumulative spring precipitation (1 April – 31 May) exceeded 20.3 cm and winter snowfall (31 November – 31 March) exceeded 76.2 cm (T. Bogenschutz, IDNR, personal commun.). Spring precipitation was not significant independent of cluster interactions; however, it was significant in the Brookings, Mobridge, Pierre, Sioux Falls, and Sisseton cluster interactions. Spring precipitation positively affected brood presence in all the aforementioned clusters except Sisseton, which is likely because spring precipitation benefits pheasant production up to a certain threshold (i.e., 20.3 cm; T. Bogenschutz, IDNR, personal commun.). Winter snowfall had no significant effect on brood presence independent of cluster interactions, although it did positively affect presence in the Mobridge cluster interaction. We hypothesized that winter snowfall would have a negative effect on brood presence, although our modeling approach may not be appropriate to determine this relationship. Because pheasant populations, like other upland game bird species, are highly variable and have high reproductive potential in favorable nesting seasons (i.e., ability to re-nest, large clutch size; Wittenberger 1978, Trautman 1982), local populations may be limited by extended duration (i.e., multiple years) of harsh winters and cold, wet springs in areas of quality nesting and foraging habitat.

Composition of landscapes (i.e., 1,000-m buffer of transect routes) differed greatly among management clusters between years (Table 1.12); therefore, it is likely that across eastern South Dakota, presence of CRP-grasslands has different effects on pheasant presence. Our results indicate that CRP-grassland was important to pheasant presence (i.e., presence of hens with broods on the landscape), but this was only evident when other environmental variables were present. The configuration of all habitats within a landscape also affects presence on a landscape. For example, Nielson et al. (2008) documented a negative association between pheasant counts and increased mean patch size of all land-use habitats (i.e., agriculture, grassland, wetland land use patches) and an increased value of index of interspersion and juxtaposition along breeding bird survey (BBS) routes. Our results confirmed this relationship as pheasant observations were negatively associated with larger mean patch size and an increased landscape shape index of all land-use habitats (i.e., an index describing the amount of edge in a landscape). Our top model indicated that, in general, landscapes containing multiple patches of mixed grassland and multiple agriculture habitats positively influenced the presence of pheasants on the landscape (i.e., hens, broods, hens with broods) versus models that consisted solely of either agricultural components or nesting and brood-rearing cover (i.e., CRP-grassland and grass).

Declines in enrolled hectares of the CRP can be attributed to several factors (United States Department of Agriculture 2011*a*, Fargione et al. 2009, Grovenburg et al. 2010). The Food, Conservation, and Energy Act of 2008 reduced national enrollment of CRP to 5.2 million ha for fiscal years 2011 and 2012. In South Dakota, the United States Department of Agriculture projects the expiration of 226,723 ha of CRP-contracts (i.e., general CRP-signup and continuous CRP-signup) through 2017. Increased demand for biofuel production has mandated production of 136 billion L of biofuels by 2022, 740% more than that produced in 2006 (Fargione et al. 2009), which will likely continue conversion of CRP-grasslands to crop production (Secchi and Babcock 2007, Searchinger et al. 2008). In addition to increased demand for commodity crops, corn and soybean prices increased during 2006−2010 from $2.28−$6.01/bushel and $5.65−$12.50/bushel, respectively (National Agriculture Statistics Service 2012). Continued increased trend in commodity crop prices is a disincentive for landowners to enroll marginal land in CRP practices compared because current commodity crop prices substantially exceed the monetary value of CRP-enrolled lands (Janssen et al. 2008). Continued loss of CRP in South Dakota will reduce already limited available cover to pheasants in agriculturally dominated landscapes, reducing their reproductive potential to recover from extended duration of severe winters and springs.

MANAGEMENT IMPLICATIONS

We evaluated pheasant locations over a period (2006−2010) when there were large decreases in CRP-enrollment acreages across eastern South Dakota. Our study indicated that the presence of pheasant broods across eastern South Dakota was influenced greatest by the amount and configuration of CRP-grasslands. We suggest managers should evaluate local and regional landscape composition when discussing pheasant management. Based on our findings, we suggest implementing CRP-grasslands in large blocks as well as incorporating diverse rotations of agriculture practices such as wheat, hay/alfalfa, and row crop in addition to the presence of quality winter habitats. Conservation Reserve Program grasslands alone did not successfully predict the presence of pheasants on the landscape; the presence of multiple perennial based and agriculture habitats best explained the presence of pheasants in eastern South Dakota. Knowing the effect size of CRP-grasslands in addition to other habitat types on the presence of pheasants will aid wildlife managers and policy makers when making decisions concerning Farm Bill habitats. Continued loss of CRP-grasslands in this region and across the northern Great Plains could lead to continued decreases in pheasant populations, therefore it is important to understand the potential effect of loss of these habitats during a period when large numbers of CRP-contracts expired. Pheasant populations continue to flourish in regions of eastern South Dakota; however, as incentives for row crop agriculture continue, habitat provided by the CRP will become more important to sustain pheasant populations.

ACKNOWLEDGMENTS

Funding for this project was provided by Federal Aid in Wildlife Restoration (Project W-75-R, No. 7539), administered through South Dakota Department of Game, Fish and Parks, and by the South Dakota Agricultural Experiment Station**.** We appreciate the support provided by the Department of Natural Resource Management (formerly the Department of Wildlife and Fisheries Sciences) at South Dakota State University. We thank J. White, D. Todey, M. Estey, R. Williamson, C. Marsh, T. Kirschenmann, M. Kjellsen, and P. Bergmann for data acquisition, collaboration, and technical assistance. We also thank A. Solem, A. Stegemen, and L. Swanson for many tedious hours spent digitizing habitat patches. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the United States Government.

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Table 1.1. Land use definitions of habitat patches discernible from historic aerial imagery.

Land Use	Definition	Code
Hay/Alfalfa	Grass, alfalfa, clover, or a grass-legume mix harvested as a crop as evidence by color, texture, and uniform plant cover, usually harvested twice annually (presence of mechanical haying pattern evident).	HA
Disturbed Grassland	Mixed native herbaceous plant cover heterogeneous in color and texture, often showing evidence of grazing (e.g., trails along fence lines or to gates, water, our buildings); trees and shrubs may or may not have been present at low densities (<25% cover).	GRASS
Undisturbed Grassland	Mix of cool-season grass and forb species and warm-season native species planted on previously cropped land (e.g., CRP lands, state and federal management areas); generally undisturbed but may be hayed or grazed intermittently.	CRP
Woody Vegetation	Woody plant cover (≥25%) heterogeneous in color and texture (e.g., shelterbelts, tree plantings, and limited forested areas not associated with home sites).	WV
Developed1	Rural areas with concentrated evidence of human habitation (i.e., the presence of buildings, including a house/shed, and/or barn, driveway(s), forested grove, and pasture.	D1

Table 1.2. Cropland Data Layer (CDL) 2006−2010 classifications and assigned categories for analysis.

Land Use Category	CDL 2006−2009 (grid code) Classifications	Code
Row Crop	(1)-Corn, (4)-Sorghum, (5)-Soybeans, (6)-Sunflowers, (12)-Sweetcorn	RC
Small Grain	(29)-Millet, (28)-Oats, (21)-Barley, (27)-Rye, (31)-Canola	SG
Wheat	(23)-Spring Wheat, (24)-Winter Wheat, (21)-Durum Wheat	WHEAT
Other Ag	(61)-Fallow/Idle Cropland	OA
Wetlands	(87)-Wetlands (190)-Woody Wetlands[a], (195)-Herbaceous Wetlands[a]	WETL
Open Water	(111)-Open Water[a]	OW
Semi-permanent Wetland	Class IV Semi-permanent Wetlands[b] (Stewart and Kantrud 1971)	SEMI
Temporary Wetland	Class II and III Temporary and Seasonal Wetlands[b] (Stewart and Kantrud 1971)	TEMP
Developed2	(121)-Developed/Open Space[a], (122)-Developed/Low Intensity[a], (123)-Developed/Medium Intensity[a], (124)-Developed/High Intensity[a]	D2

[a] Denotes data from National Land Cover Dataset (NLCD) 2001 (Homer et al. 2007);

[b] Denotes dta from national Wetlands Inventory Dataset

Table 1.3. Final variables and definitions used to estimate the presence of hen pheasants with broods and hen pheasants along 84 brood-survey routes in eastern South Dakota, USA, 25 July – 15 August, 2006–2010.

Variable	Definitions [a, b]
AM1000	Mean patch size (ha) at 1000-m
AM500	Mean patch size (ha) at 500-m
D1100	Percent farmsteads at 1000-m
D1500	Percent farmsteads at 500-m
D21000	Percent roads at 1000-m
D2500	Percent roads at 500-m
GRASS1000	Percent disturbed grassland at 1000-m (rangeland and pastureland)
GRASS500	Percent disturbed grassland at 500-m (rangeland and pastureland)
GRAINS1000	Percent grains (all small grain agriculture grouped) at 1000-m
GRAINS500	Percent grains (all small grain agriculture grouped) at 500-m
HA1000	Percent hay/alfalfa at 1000-m
LSI1000	Landscape shape index at 1000-m
LSI500	Landscape shape index at 500-m
[c]CRP1000	Percent [c]CRP-grassland and state/federal grassland at 1000-m

Table 1.3. continued.

Variable	Definitions [a,b]
[c]CRP1000AM	Mean patch size (ha) of [c]CRP-grassland and state/federal grassland at 1000-m
[c]CRP1000PD	Patch density (# patches/100 ha) of [c]CRP-grassland and state/federal grassland at 1000-m
[c]CRP500	Percent [c]CRP-grassland and state/federal grassland at 500-m
[c]CRP500AM	Mean patch size (ha) of [c]CRP-grassland and state/federal grassland at 500-m
[c]CRP500PD	Patch density (# patches/100 ha) of [c]CRP-grassland and state/federal grassland at 500-m
PD1000	Patch density (# patches/100 ha) at 1000-m
PD500	Patch density (# patches/100ha) at 500-m
PRCP	Spring cumulative precipitation (1 April −31 May)
RC1000	Percent row crop at 1000-m
RC1000AM	Mean patch size (ha) of row crop at 1000-m
RC500	Percent row crop at 500-m
SEMIPERM1000	Percent semipermanent wetlands ([d]NWI) at 1000-m
SEMIPERM500	Percent semipermanent wetlands ([d]NWI) at 500-m

Table 1.3. continued.

Variable	Definitions [a,b]
SNFA	Winter cumulative snowfall (1 November − 31 March)
SOD1000	Percent sod (CRP + grass) at 1000-m
SOD500	Percent sod (CRP + grass) at 500-m
TEMP500	Percent temporary wetlands ([d]NWI) at 500-m
WETL1000	Percent wetland ([e]NLCD 2001) at 1000-m
WETL500	Percent wetland ([e]NLCD 2001) at 500-m
WHEAT1000	Percent wheat (spring + winter) at 1000-m
WHEAT500	Percent wheat (spring + winter) at 500-m
WV1000	Percent woody vegetation at 1000-m
WV500	Percent woody vegetation at 500-m
WV1000PD	Patch density (# patches/100 ha) of woody vegetation at 1000-m

[a] Variables measured at 1000-m buffer (area = 314.2 ha) of a pheasant location;

[b] Variables measured at 500-m buffer (area = 157.1 ha) of a pheasant location;

[c] Conservation Reserve Program;

[d] National Wetlands Inventory:

[e] National Land Cover Dataset 2001 (Homer et al. 2007)

Table 1.4. Final variables (including mean, SE, and range) used to predict presence of a hen pheasant in 11 management clusters along 84 brood-survey routes in eastern South Dakota, USA, 2006−2010.

	Aberdeen		Brookings		Chamberlain	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
AM1000	5.28 (0.10)	1.40−44.70	4.77 (0.13)	0.00−31.26	5.74 (0.09)	1.47−34.78
AM500	4.59 (0.12)	1.04−78.30	4.04 (0.13)	1.45−39.06	4.60 (0.08)	0.97−25.95
CRP1000	8.21 (0.32)	0.00−58.58	13.96 (0.58)	0.00−65.32	2.49 (0.17)	0.00−36.33
CRP1000AM	9.07 (0.39)	0.00−97.56	15.30 (1.07)	0.00−184.50	4.16 (0.29)	0.00−62.19
CRP1000PD	0.84 (0.03)	0.00−9.91	1.28 (0.05)	0.00−7.03	0.23 (0.02)	0.00−5.18
CRP500	7.91 (0.36)	0.00−71.62	13.97 (0.75)	0.00−81.70	1.93 (0.18)	0.00−50.88
CRP500AM	4.08 (0.20)	0.00−50.31	7.46 (0.47)	0.00−67.23	1.21 (0.11)	0.00−26.64
CRP500PD	1.33 (0.06)	0.00−12.80	1.90 (0.09)	0.00−10.24	0.36 (0.03)	0.00−12.77
D1100	0.86 (0.04)	0.00−14.47	1.84 (0.07)	0.00−11.43	1.71 (0.05)	0.00−15.27
D1500	0.97 (0.06)	0.00−37.82	2.37 (0.14)	0.00−19.48	2.10 (0.11)	0.00−31.28

Table 1.4. continued.

	Aberdeen		Brookings		Chamberlain	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
D21000	4.76 (0.07)	0.32−23.15	4.77 (0.10)	0.00−17.73	4.10 (0.06)	0.03−15.10
D2500	8.28 (0.11)	0.00−36.21	7.83 (0.16)	0.00−24.06	7.17 (0.09)	0.11−17.19
GRASS1000	23.83 (0.55)	0.00−94.97	13.79 (0.52)	0.00−65.69	34.02 (0.60)	0.00−88.92
GRASS500	17.23 (0.52)	0.00−91.33	11.58 (0.56)	0.00−76.66	24.35 (0.65)	0.00−87.43
GRAINS1000	8.04 (0.30)	0.00−62.28	1.55 (0.16)	0.00−31.83	10.75 (0.37)	0.00−72.54
GRAINS500	7.84 (0.36)	0.00−75.40	1.46 (0.22)	0.00−58.90	9.95 (0.42)	0.00−83.42
HA1000	3.26 (0.15)	0.00−41.34	3.80 (0.22)	0.00−30.71	10.89 (0.30)	0.00−52.48
LSI1000	7.42 (0.20)	1.64−50.68	11.48 (0.46)	0.00−38.72	5.66 (0.15)	1.82−46.98
LSI500	3.28 (0.02)	1.14−7.01	3.22 (0.03)	1.58−4.81	3.09 (0.02)	1.69−6.39
PD1000	21.22 (0.35)	2.24−71.58	17.77 (0.53)	0.00−61.43	20.04 (0.31)	2.15−68.25
PD500	29.57 (0.40)	1.28−95.90	31.02 (0.54)	2.56−69.20	27.13 (0.37)	3.85−103.45

Table 1.4. continued.

	Aberdeen		Brookings		Chamberlain	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
PRCP	13.33 (0.30)	0.00−44.15	13.43 (0.21)	5.74−23.70	14.45 (0.19)	1.27−26.19
RC1000	32.17 (0.63)	0.00−90.36	43.67 (0.86)	0.00−87.72	21.94 (0.45)	0.00−75.00
RC1000AM	25.97 (1.12)	0.00−289.44	34.33 (1.50)	0.00−272.07	17.34 (0.62)	0.00−193.95
RC500	28.49 (0.65)	0.00−86.98	38.43 (0.95)	0.00−87.43	19.35 (0.53)	0.00−87.20
SEMIPERM1000	1.10 (0.10)	0.00−49.13	3.19 (0.23)	0.00−36.93	1.41 (0.10)	0.00−26.67
SEMIPERM500	0.72 (0.09)	0.00−49.39	2.14 (0.22)	0.00−34.15	1.31 (0.14)	0.00−56.84
SNFA	79.61 (0.96)	0.00−161.29	85.34 (1.25)	19.81−179.32	89.17 (0.62)	38.10−138.43
SOD1000	32.04 (0.60)	0.00−94.97	27.75 (0.71)	0.06−74.34	36.51 (0.61)	0.00−88.92
SOD500	25.14 (0.61)	0.00−91.33	25.54 (0.83)	0.00−85.37	26.28 (0.67)	0.00−87.43
TEMP500	5.82 (0.17)	0.00−76.89	3.09 (0.17)	0.00−45.03	4.87 (0.16)	0.00−24.41
WETL1000	3.10 (0.16)	0.00−52.88	5.11 (0.24)	0.00−28.88	1.12 (0.08)	0.00−50.42

Table 1.4. continued.

	Aberdeen		Brookings		Chamberlain	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
WETL500	2.73 (0.16)	0.00−53.86	4.52 (0.27)	0.00−37.59	0.88 (0.08)	0.00−29.79
WHEAT1000	7.95 (0.30)	0.00−62.17	1.35 (0.15)	0.00−31.66	10.13 (0.36)	0.00−72.54
WHEAT500	7.76 (0.35)	0.00−75.40	1.31 (0.21)	0.00−58.90	9.34 (0.42)	0.00−83.42
WV1000	0.72 (0.03)	0.00−6.59	1.13 (0.04)	0.00−5.84	0.82 (0.03)	0.00−6.59
WV1000PD	0.85 (0.02)	0.00−5.45	1.60 (0.06)	0.00−11.22	0.96 (0.02)	0.00−4.80
WV500	0.74 (0.04)	0.00−13.98	1.14 (0.07)	0.00−8.48	0.85 (0.04)	0.00−12.83

Table 1.4. continued.

	Huron		Mitchell		Mobridge	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
AM1000	5.09 (0.07)	1.50−26.04	5.67 (0.09)	1.87−28.44	4.97 (0.10)	1.59−44.64
AM500	4.36 (0.07)	1.20−39.02	4.41 (0.07)	1.09−15.64	4.17 (0.09)	1.20−26.07
CRP1000	7.25 (0.32)	0.00−60.59	7.48 (0.34)	0.00−51.74	7.26 (0.41)	0.00−51.68
CRP1000AM	11.65 (0.64)	0.00−140.04	12.59 (0.63)	0.00−142.83	11.41 (0.70)	0.00−114.39
CRP1000PD	0.57 (0.02)	0.00−6.41	0.61 (0.03)	0.00−7.35	0.48 (0.03)	0.00−7.35
CRP500	7.54 (0.40)	0.00−77.01	7.32 (0.44)	0.00−70.13	6.97 (0.49)	0.00−59.36
CRP500AM	4.43 (0.24)	0.00−49.68	4.70 (0.30)	0.00−56.07	4.61 (0.33)	0.00−35.73
CRP500PD	0.93 (0.04)	0.00−10.25	1.00 (0.06)	0.00−15.29	0.79 (0.05)	0.00−7.68
D1100	1.19 (0.05)	0.00−18.22	1.63 (0.06)	0.00−13.12	0.86 (0.05)	0.00−7.82
D1500	1.55 (0.10)	0.00−32.77	1.94 (0.11)	0.00−21.89	1.02 (0.10)	0.00−17.99
D21000	3.67 (0.06)	0.06−15.99	4.59 (0.07)	0.29−14.87	3.80 (0.09)	0.26−20.83

Table 1.4. continued.

	Huron		Mitchell		Mobridge	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
D2500	7.19 (0.09)	0.00−23.03	7.75 (0.12)	0.11−22.69	7.18 (0.15)	1.03−33.35
GRASS1000	27.68 (0.53)	0.00−91.96	27.80 (0.56)	0.17−85.94	21.64 (0.69)	0.00−94.19
GRASS500	17.02 (0.53)	0.00−89.84	19.72 (0.64)	0.00−86.29	14.37 (0.71)	0.00−85.49
GRAINS1000	8.94 (0.34)	0.00−63.14	6.28 (0.29)	0.00−45.18	20.04 (0.64)	0.00−83.28
GRAINS500	8.73 (0.39)	0.00−79.98	5.79 (0.35)	0.00−61.08	19.26 (0.78)	0.00−88.01
HA1000	6.38 (0.22)	0.00−61.88	10.02 (0.31)	0.00−49.50	4.32 (0.29)	0.00−56.81
LSI1000	6.14 (0.16)	1.43−32.93	6.60 (0.19)	1.95−33.55	4.56 (0.11)	1.68−37.43
LSI500	3.15 (0.02)	1.43−5.77	3.06 (0.02)	1.72−5.21	3.16 (0.02)	1.68−5.28
PD1000	21.93 (0.34)	2.40−66.72	18.59 (0.33)	2.36−53.40	23.01 (0.36)	2.24−62.95
PD500	28.60 (0.37)	2.56−83.01	26.93 (0.36)	6.39−91.95	28.37 (0.46)	3.84−83.11
PRCP	14.16 (0.23)	0.00−41.68	13.48 (0.18)	4.62−26.19	10.15 (0.15)	3.40−16.38

Table 1.4. continued.

Variable[a, b]	Huron		Mitchell		Mobridge	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
RC1000	30.35 (0.57)	0.00−89.58	29.71 (0.62)	0.00−85.66	25.19 (0.70)	0.00−77.66
RC1000AM	26.22 (1.07)	0.00−285.84	23.25 (0.84)	0.00−249.66	20.80 (0.89)	0.00−171.18
RC500	26.60 (0.62)	0.00−86.98	26.23 (0.67)	0.00−87.09	21.65 (0.80)	0.00−83.31
SEMIPERM1000	1.41 (0.07)	0.00−24.09	2.31 (0.09)	0.00−13.64	0.50 (0.05)	0.00−20.23
SEMIPERM500	1.09 (0.08)	0.00−27.16	1.62 (0.11)	0.00−25.44	0.35 (0.03)	0.00−12.49
SNFA	85.03 (0.92)	0.00−149.35	88.14 (0.72)	38.10−130.05	80.97 (1.63)	16.00−171.45
SOD1000	34.94 (0.60)	0.00−91.96	35.29 (0.69)	0.17−93.99	28.90 (0.80)	0.00−94.19
SOD500	24.56 (0.62)	0.00−89.84	27.04 (0.76)	0.00−88.46	21.35 (0.84)	0.00−85.49
TEMP500	7.91 (0.21)	0.00−70.93	5.35 (0.15)	0.00−32.31	3.41 (0.31)	0.00−51.68
WETL1000	2.12 (0.10)	0.00−31.91	1.74 (0.08)	0.00−16.01	0.89 (0.14)	0.00−34.78
WETL500	1.71 (0.11)	0.00−35.29	1.48 (0.09)	0.00−22.12	0.70 (0.17)	0.00−69.90

Table 1.4. continued.

Variable[a, b]	Huron		Mitchell		Mobridge	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
WHEAT1000	8.82 (0.34)	0.00−63.14	6.10 (0.28)	0.00−45.12	19.75 (0.65)	0.00−83.19
WHEAT500	8.65 (0.39)	0.00−79.98	5.64 (0.35)	0.00−61.08	18.99 (0.78)	0.00−88.01
WV1000	0.94 (0.03)	0.00−11.00	0.78 (0.02)	0.00−4.13	0.55 (0.03)	0.00−4.76
WV1000PD	1.02 (0.03)	0.00−6.72	1.05 (0.03)	0.00−6.39	0.71 (0.03)	0.00−5.13
WV500	0.97 (0.05)	0.00−15.36	0.84 (0.04)	0.00−8.94	0.55 (0.04)	0.00−7.68

Table 1.4. continued.

Variable[a, b]	Pierre Mean (SE)	Pierre Range	Sioux Falls Mean (SE)	Sioux Falls Range	Sisseton Mean (SE)	Sisseton Range
AM1000	5.97 (0.16)	1.68−26.04	5.21 (0.17)	1.96−39.11	3.09 (0.13)	1.29−8.68
AM500	4.77 (0.13)	1.15−26.04	4.76 (0.23)	1.35−39.11	2.67 (0.13)	1.01−8.68
CRP1000	2.84 (0.32)	0.00−32.43	6.62 (0.44)	0.00−43.60	9.25 (1.08)	0.00−40.31
CRP1000AM	5.36 (0.62)	0.00−90.09	5.58 (0.52)	0.00−54.45	8.80 (1.29)	0.00−73.62
CRP1000PD	0.19 (0.02)	0.00−1.60	1.19 (0.07)	0.00−7.35	1.50 (0.12)	0.00−5.11
CRP500	2.92 (0.42)	0.00−49.96	6.45 (0.57)	0.00−62.57	9.33 (1.54)	0.00−67.15
CRP500AM	1.75 (0.26)	0.00−36.36	2.75 (0.31)	0.00−51.30	3.90 (0.62)	0.00−27.90
CRP500PD	0.37 (0.05)	0.00−6.41	1.70 (0.12)	0.00−8.96	2.13 (0.27)	0.00−14.03
D1100	1.17 (0.09)	0.00−12.61	2.31 (0.09)	0.00−9.22	1.19 (0.13)	0.00−8.28
D1500	1.64 (0.18)	0.00−19.71	2.63 (0.17)	0.00−16.27	1.50 (0.25)	0.00−11.80
D21000	3.97 (0.11)	0.83−23.00	4.68 (0.13)	0.32−16.99	4.85 (0.22)	0.95−10.49

Table 1.4. continued.

Variable[a, b]	Pierre		Sioux Falls		Sisseton	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
D2500	7.26 (0.16)	2.41−33.69	7.47 (0.20)	0.00−27.04	7.74 (0.31)	1.95−14.78
GRASS1000	19.70 (1.16)	0.00−91.76	11.05 (0.50)	0.00−49.42	8.61 (0.70)	0.00−30.45
GRASS500	13.51 (0.94)	0.00−85.26	9.71 (0.64)	0.00−72.77	6.51 (0.81)	0.00−39.99
GRAINS1000	27.82 (1.04)	0.00−89.52	0.64 (0.11)	0.00−14.07	5.98 (0.78)	0.00−46.84
GRAINS500	23.81 (1.12)	0.00−87.78	0.61 (0.16)	0.00−23.38	5.67 (0.97)	0.00−48.47
HA1000	2.90 (0.27)	0.00−36.87	3.21 (0.25)	0.00−41.60	2.42 (0.39)	0.00−24.84
LSI1000	5.12 (0.22)	1.75−42.87	8.09 (0.49)	1.71−43.87	8.79 (0.90)	2.10−42.22
LSI500	3.01 (0.03)	1.75−5.69	3.10 (0.04)	1.36−4.97	3.85 (0.09)	2.10−6.07
PD1000	19.39 (0.47)	2.99−59.52	19.74 (0.58)	2.56−51.09	34.53 (1.77)	4.68−77.47
PD500	26.70 (0.64)	3.84−87.05	28.97 (0.72)	2.56−74.07	45.31 (1.99)	11.52−98.57
PRCP	11.94 (0.26)	1.96−22.89	14.32 (0.21)	7.72−21.08	10.79 (0.44)	4.72−21.39

Table 1.4. continued.

	Pierre		Sioux Falls		Sisseton	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
RC1000	27.93 (1.01)	0.00−91.30	56.83 (0.91)	4.30−91.87	42.02 (1.82)	0.00−85.54
RC1000AM	27.67 (1.85)	0.00−291.51	57.98 (3.43)	2.37−293.58	26.63 (3.63)	0.00−265.68
RC500	25.55 (1.15)	0.00−85.03	51.63 (1.11)	0.00−89.95	38.09 (2.21)	0.00−81.47
SEMIPERM1000	0.52 (0.05)	0.00−11.80	3.26 (0.37)	0.00−45.92	4.38 (0.41)	0.00−15.44
SEMIPERM500	0.41 (0.06)	0.00−10.66	2.26 (0.33)	0.00−52.94	3.14 (0.46)	0.00−22.35
SNFA	78.27 (1.81)	1.78−135.89	79.82 (1.04)	22.86−125.22	99.09 (3.57)	51.31−179.32
SOD1000	22.55 (1.16)	0.00−91.76	17.67 (0.65)	0.06−57.50	17.85 (1.40)	0.00−63.11
SOD500	16.43 (1.01)	0.00−85.26	16.16 (0.79)	0.00−72.77	15.85 (1.67)	0.00−67.15
TEMP500	2.16 (0.16)	0.00−18.33	3.67 (0.21)	0.00−19.60	4.46 (0.36)	0.00−14.67
WETL1000	0.26 (0.04)	0.00−7.33	3.21 (0.20)	0.00−17.53	8.39 (0.71)	0.03−37.90
WETL500	0.30 (0.09)	0.00−22.00	2.79 (0.25)	0.00−41.71	7.31 (0.79)	0.11−37.47

Table 1.4. continued.

	Pierre		Sioux Falls		Sisseton	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
WHEAT1000	27.14 (1.03)	0.00−88.46	0.61 (0.11)	0.00−12.92	5.88 (0.77)	0.00−46.84
WHEAT500	23.23 (1.11)	0.00−87.78	0.59 (0.16)	0.00−23.38	5.57 (0.95)	0.00−48.47
WV1000	0.58 (0.04)	0.00−4.64	0.68 (0.04)	0.00−4.15	1.01 (0.09)	0.00−4.01
WV1000PD	0.72 (0.05)	0.00−5.77	1.11 (0.05)	0.00−4.48	1.56 (0.11)	0.00−4.80
WV500	0.61 (0.06)	0.00−7.33	0.73 (0.07)	0.00−12.83	1.14 (0.13)	0.00−4.47

Table 1.4. continued.

Variable[a, b]	Watertown Mean (SE)	Watertown Range	Yankton Mean (SE)	Yankton Range
AM1000	4.16 (0.06)	1.22−14.18	5.32 (0.27)	1.70−17.38
AM500	3.55 (0.07)	0.98−26.07	5.10 (0.38)	1.59−26.16
CRP1000	11.19 (0.45)	0.00−53.97	3.35 (0.44)	0.00−25.98
CRP1000AM	10.81 (0.53)	0.00−127.44	4.59 (0.66)	0.00−46.17
CRP1000PD	1.22 (0.04)	0.00−8.66	0.76 (0.10)	0.00−4.48
CRP500	10.42 (0.53)	0.00−69.90	2.85 (0.63)	0.00−41.25
CRP500AM	4.79 (0.28)	0.00−57.15	1.61 (0.36)	0.00−21.87
CRP500PD	1.86 (0.09)	0.00−12.82	1.15 (0.24)	0.00−15.34
D1100	1.58 (0.06)	0.00−21.20	2.22 (0.14)	0.26−7.42
D1500	1.96 (0.11)	0.00−25.67	2.14 (0.28)	0.00−12.72
D21000	4.64 (0.08)	0.11−19.37	4.98 (0.23)	0.60−10.66

Table 1.4. continued.

	Watertown		Yankton	
Variable	Mean (SE)	Range	Mean (SE)	Range
D2500	8.04 (0.14)	0.46−46.07	8.62 (0.34)	2.29−20.28
GRASS1000	17.41 (0.57)	0.00−85.37	12.66 (1.09)	0.00−59.44
GRASS500	14.56 (0.59)	0.00−83.65	8.69 (1.12)	0.00−59.93
GRAINS1000	7.55 (0.31)	0.00−44.98	1.57 (0.39)	0.00−23.55
GRAINS500	6.97 (0.39)	0.00−73.22	1.39 (0.49)	0.00−30.94
HA1000	4.61 (0.22)	0.00−32.03	6.56 (0.66)	0.00−30.74
LSI1000	10.30 (0.36)	1.90−44.57	6.07 (0.61)	1.82−32.97
LSI500	3.40 (0.03)	1.50−6.74	3.03 (0.06)	1.67−4.60
PD1000	22.17 (0.53)	2.34−82.00	21.37 (1.07)	3.08−58.68
PD500	33.83 (0.52)	3.84−102.29	27.22 (1.26)	3.82−62.80
PRCP	14.84 (0.26)	5.13−29.64	14.51 (0.37)	9.42−21.41

Table 1.4. continued.

Variable[a, b]	Watertown Mean (SE)	Watertown Range	Yankton Mean (SE)	Yankton Range
RC1000	34.31 (0.72)	0.00−81.85	57.48 (1.89)	11.75−89.09
RC1000AM	26.08 (1.13)	0.00−261.27	58.19 (6.37)	3.49−285.39
RC500	30.29 (0.78)	0.00−84.45	52.39 (2.18)	2.06−88.46
SEMIPERM1000	3.58 (0.16)	0.00−24.01	0.78 (0.22)	0.00−14.55
SEMIPERM500	2.73 (0.18)	0.00−30.25	0.52 (0.21)	0.00−15.93
SNFA	63.25 (1.29)	5.08−179.32	97.67 (2.16)	68.07−133.60
SOD1000	28.60 (0.68)	0.03−85.37	16.01 (1.23)	0.00−59.44
SOD500	24.99 (0.72)	0.00−84.80	11.53 (1.27)	0.00−59.93
TEMP500	3.58 (0.14)	0.00−32.89	3.00 (0.40)	0.00−22.46
WETL1000	5.60 (0.18)	0.00−24.35	1.18 (0.18)	0.00−10.28
WETL500	4.73 (0.19)	0.00−31.28	1.07 (0.21)	0.00−11.92

Table 1.4. continued.

Variable[a, b]	Watertown Mean (SE)	Watertown Range	Yankton Mean (SE)	Yankton Range
WHEAT1000	7.38 (0.30)	0.00−43.95	1.40 (0.38)	0.00−23.55
WHEAT500	6.81 (0.39)	0.00−73.22	1.07 (0.45)	0.00−30.94
WV1000	1.17 (0.04)	0.00−7.62	1.22 (0.18)	0.00−14.35
WV1000PD	1.54 (0.04)	0.00−8.32	1.50 (0.13)	0.00−5.44
WV500	1.28 (0.06)	0.00−13.52	0.93 (0.20)	0.00−16.50

[a] Variable definitions in Table 1.3;

[b] Aberdeen cluster, *n* = 1,267. Brookings cluster; *n* = 517, Chamberlain cluster; *n* = 1,140. Huron cluster; *n* = 1,221. Mitchell cluster; *n* = 887. Mobridge cluster; *n* = 598. Pierre cluster; *n* = 410. Sioux Falls cluster; *n* = 343. Sisseton cluster; *n* = 98. Watertown cluster; *n* = 756. Yankton cluster; *n* = 106.

Table 1.5. Final variables (including mean, SE, and range) used to predict presence of a hen pheasant along 84 brood-survey routes in eastern South Dakota, USA, 2006−2010 at hen pheasant and random locations.

	Random		Observed	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range
AM1000	5.88 (0.05)	1.13−77.96	5.14 (0.04)	0.00−44.64
AM500	4.59 (0.04)	0.00−39.15	4.29 (0.04)	0.98−78.30
CRP1000	4.90 (0.11)	0.00−66.75	7.29 (0.14)	0.00−65.32
CRP1000AM	6.33 (0.17)	0.00−193.95	9.58 (0.22)	0.00−184.50
CRP1000PD	0.63 (0.01)	0.00−18.86	0.69 (0.01)	0.00−9.91
CRP500	4.37 (0.14)	0.00−80.56	7.01 (0.17)	0.00−81.70
CRP500AM	2.36 (0.08)	0.00−66.42	3.89 (0.10)	0.00−67.23
CRP500PD	0.88 (0.02)	0.00−22.99	1.08 (0.02)	0.00−14.10
D1100	1.59 (0.02)	0.00−23.09	1.40 (0.02)	0.00−21.20
D1500	1.96 (0.04)	0.00−40.57	1.75 (0.04)	0.00−37.82
D21000	4.58 (0.04)	0.00−39.19	4.31 (0.03)	0.03−23.00
D2500	7.78 (0.05)	0.00−49.85	7.61 (0.05)	0.00−46.07
G1000	22.17 (0.27)	0.00−95.08	23.85 (0.25)	0.00−94.97
G500	19.39 (0.28)	0.00−87.55	17.06 (0.25)	0.00−91.33
GRAINS1000	7.24 (0.16)	0.00−91.67	9.54 (0.17)	0.00−89.52

Table 1.5. continued.

	Random		Observed	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range
GRAINS500	6.55 (0.17)	0.00−86.17	8.94 (0.19)	0.00−88.01
HA1000	5.67 (0.10)	0.00−58.41	6.07 (0.10)	0.00−56.81
LSI1000	4.79 (0.02)	1.78−11.88	7.06 (0.09)	0.00−50.68
LSI500	3.14 (0.01)	0.00−7.01	3.18 (0.01)	1.14−6.74
PD1000	21.31 (0.13)	1.28−88.86	20.93 (0.15)	0.00−82.00
PD500	28.78 (0.18)	0.00−128.70	29.31 (0.17)	1.28−102.29
PRCP	13.47 (0.09)	0.00−44.15	13.47 (0.10)	0.00−44.15
RC1000	38.44 (0.32)	0.00−93.13	31.88 (0.27)	0.00−91.87
RC1000AM	33.62 (0.58)	0.00−297.45	26.77 (0.48)	0.00−293.58
RC500	34.82 (0.33)	0.00−87.66	28.22 (0.29)	0.00−89.95
SEMIPERM1000	1.59 (0.05)	0.00−50.59	1.79 (0.05)	0.00−49.13
SEMIPERM500	1.28 (0.05)	0.00−78.38	1.34 (0.05)	0.00−56.84
SNFA	83.24 (0.42)	0.00−179.32	82.05 (0.41)	0.00−179.32
SOD1000	27.07 (0.28)	0.00−95.08	31.14 (0.27)	0.00−94.97
SOD500	23.75 (0.30)	0.00−87.55	24.07 (0.28)	0.00−91.33
TEMP500	4.57 (0.09)	0.00−78.61	4.85 (0.07)	0.00−70.93

Table 1.5. continued.

	Random		Observed	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range
WETL1000	2.57 (0.07)	0.00−73.42	2.52 (0.06)	0.00−52.88
WETL500	2.26 (0.07)	0.00−75.86	2.10 (0.06)	0.00−69.90
WHEAT1000	7.02 (0.15)	0.00−91.67	9.29 (0.17)	0.00−88.46
WHEAT500	6.35 (0.17)	0.00−86.17	8.72 (0.19)	0.00−88.01
WV1000	0.98 (0.02)	0.00−17.19	0.85 (0.01)	0.00−14.35
WV1000PD	1.22 (0.02)	0.00−11.50	1.06 (0.01)	0.00−11.22
WV500	1.18 (0.04)	0.00−81.25	0.88 (0.02)	0.00−16.50

[a] Variable definitions found in Table 1.3;

[b] Random locations; *n* = 5,876. Brood locations; *n* = 5,876.

Table 1.6. Logistic regression models predicting the presence of a hen pheasant along 84 brood-survey routes in eastern South Dakota, USA, 2006–2010 at a 1,000-m scale.

Model[a]	*K*[b]	-2LL	AIC[c]	ΔAIC[d]	*w*[e]	ROC[f]
CRP + CRPAM + CRPPD + GRASS + RCAM + WHEAT + HA + WVPD + WETL + PRCP + SNFA + AM + LSI + PD	165	13148.856	13478.856	0.000	1.00	0.778
CRP + GRASS + WV + WETL + WHEAT + HA + PRCP + SNFA + AM + LSI	120	13391.321	13633.321	154.465	0.00	0.765
CRP + GRASS + WV + WETL + RC + WHEAT + HA + PRCP + SNFA + AM + LSI	132	13380.081	13644.081	165.225	0.00	0.766
CRP + GRASS + WV + WETL + RC + WHEAT + HA + AM + LSI + PD	121	13531.588	13773.588	294.732	0.00	0.758
GRASS + WHEAT + CRP + WETL + LSI + AM	77	13720.787	13874.787	395.931	0.00	0.748
CRP + GRASS + WV + WETL + AM + LSI + PD	88	13745.982	13921.982	443.126	0.00	0.748
WHEAT + CRP + WETL + LSI + AM	66	13853.180	13985.180	506.324	0.00	0.741

Table 1.6. continued.

Model[a]	K^b	-2LL	AIC[c]	ΔAIC[d]	w^e	ROC[f]
CRP + GRASS + WETL + LSI + AM	66	13894.650	14026.650	547.794	0.00	0.740
RC + RCAM + WHEAT + HA + PRCP + SNFA + AM + LSI + PD	110	13911.228	14131.228	652.372	0.00	0.739
CRP + CRPAM + CRPPD + SNFA + AM + LSI	77	14053.867	14207.867	729.011	0.00	0.736
CRP + GRASS + WV + WETL + RC + WHEAT + HA + PRCP + SNFA	110	14390.515	14610.515	1131.659	0.00	0.717
CRP + GRASS + WV + WETL + RC + WHEAT + HA	88	14537.193	14713.193	1234.337	0.00	0.709
SOD + HA + WETL + GRAINS + PRCP + SNFA	77	14667.599	14821.599	1342.743	0.00	0.698
CRP + GRASS + WV + WETL + PRCP + SNFA	77	14618.725	14772.725	1293.869	0.00	0.703
CRP + GRASS + WV + WETL	55	14775.015	14885.015	1406.159	0.00	0.693

Table 1.6. continued.

Model[a]	K^b	-2LL	AIC[c]	ΔAIC[d]	w^e	ROC[f]
SOD + HA + SEMIPERM + GRAINS + PRCP + SNFA	77	14849.097	15003.097	1524.241	0.00	0.689
CRP + CRPAM + CRPPD + SNFA	55	14929.884	15039.884	1561.028	0.00	0.689
CRP	22	15199.040	15243.040	1764.184	0.00	0.661
D1 + D2 + PRCP + SNFA	55	15186.788	15296.788	1817.932	0.00	0.660
PRCP + SNFA	33	15366.328	15432.328	1953.472	0.00	0.641

[a] Description of variables found in Table 1.3; [b] Number of parameters; [c] Akaike's Information Criterion (Burnham and Anderson 2002); [d] Difference in AIC relative to minimum AIC; [e] Akaike weight (Burnham and Anderson 2002); [f] ROC = area under the receiver operating characteristic curve. Values between 0.7 and 0.8 were considered acceptable discrimination (Hosmer and Lemeshow 2000); [g] All variables were interacted with 11 SDGFP pheasant management clusters.

Table 1.7. Parameter estimates (β), standard errors, and significance tests from the top-ranked logistic regression model predicting the presence of a hen pheasant in eastern South Dakota, USA, 2006–2010 at a 1,000-m scale.

Parameter[a, b]	β	SE	Wald chi-quare	*P*
Intercept	-0.998	0.302	10.890	0.001
AM1000	-0.094	0.031	8.868	0.003
AM1000|Aberdeen	0.021	0.039	0.300	0.584
AM1000|Brookings	-0.068	0.079	0.734	0.392
AM1000|Chamberlain	0.030	0.043	0.470	0.493
AM1000|Huron	-0.056	0.044	1.584	0.208
AM1000|Mitchell	0.001	0.056	0.001	0.982
AM1000|Mobridge	0.088	0.050	3.145	0.076
AM1000|Pierre	-0.063	0.053	1.394	0.238
AM1000|Sioux Falls	0.102	0.054	3.500	0.061
AM1000|Sisseton	-0.040	0.274	0.021	0.885
AM1000|Watertown	-0.021	0.072	0.087	0.768
CRP1000	0.019	0.005	15.357	<.0001
CRP1000|Aberdeen	0.027	0.007	13.188	0.0003
CRP1000|Brookings	0.055	0.012	19.811	<.0001

Table 1.7. continued.

Parameter[a, b]	β	SE	Wald chi-square	*P*
CRP1000|Chamberlain	-0.024	0.025	0.944	0.331
CRP1000|Huron	-0.002	0.008	0.092	0.762
CRP1000|Mitchell	-0.035	0.013	7.547	0.006
CRP1000|Mobridge	0.054	0.011	24.194	<.0001
CRP1000|Pierre	-0.059	0.014	18.792	<.0001
CRP1000|Sioux Falls	-0.024	0.015	2.836	0.092
CRP1000|Sisseton	-0.028	0.020	1.970	0.161
CRP1000|Watertown	-0.0004	0.007	0.003	0.959
CRP1000AM	0.022	0.003	47.319	<.0001
CRP1000AM|Aberdeen	-0.030	0.005	38.760	<.0001
CRP1000AM|Brookings	-0.007	0.008	0.693	0.405
CRP1000AM|Chamberlain	0.002	0.012	0.039	0.844
CRP1000AM|Huron	-0.012	0.005	6.761	0.009
CRP1000AM|Mitchell	0.012	0.007	2.654	0.103
CRP1000AM|Mobridge	-0.031	0.005	33.994	<.0001
CRP1000AM|Pierre	0.009	0.009	1.023	0.312
CRP1000AM|Sioux Falls	0.042	0.014	8.894	0.003

Table 1.7. continued.

Parameter[a, b]	β	SE	Wald chi-square	*P*
CRP1000AM|Sisseton	0.036	0.017	4.562	0.033
CRP1000AM|Watertown	-0.010	0.006	3.079	0.079
CRP1000PD	0.087	0.046	3.521	0.061
CRP1000PD|Aberdeen	-0.141	0.062	5.217	0.022
CRP1000PD|Brookings	-0.151	0.106	2.017	0.156
CRP1000PD|Chamberlain	-0.279	0.184	2.311	0.129
CRP1000PD|Huron	0.019	0.085	0.050	0.823
CRP1000PD|Mitchell	0.359	0.127	7.935	0.005
CRP1000PD|Mobridge	-0.027	0.129	0.042	0.837
CRP1000PD|Pierre	0.122	0.272	0.201	0.654
CRP1000PD|Sioux Falls	0.112	0.107	1.094	0.296
CRP1000PD|Sisseton	-0.017	0.190	0.008	0.927
CRP1000PD|Watertown	0.126	0.072	3.037	0.081
GRASS1000	-0.005	0.003	1.942	0.163
GRASS1000|Aberdeen	0.010	0.004	6.185	0.013
GRASS1000|Brookings	0.004	0.008	0.220	0.639
GRASS1000|Chamberlain	0.015	0.006	6.421	0.011

Table 1.7. continued.

Parameter[a, b]	β	SE	Wald chi-square	*P*
GRASS1000|Huron	0.012	0.004	8.355	0.004
GRASS1000|Mitchell	0.033	0.006	35.757	<.0001
GRASS1000|Mobridge	0.010	0.005	3.764	0.052
GRASS1000|Pierre	0.007	0.005	2.049	0.152
GRASS1000|Sioux Falls	-0.032	0.008	14.676	0.0001
GRASS1000|Sisseton	-0.078	0.028	7.539	0.006
GRASS1000|Watertown	0.019	0.005	14.534	0.0001
HA1000	-0.011	0.007	2.928	0.087
HA1000|Aberdeen	-0.005	0.010	0.205	0.651
HA1000|Brookings	0.020	0.015	1.770	0.183
HA1000|Chamberlain	0.010	0.010	1.056	0.304
HA1000|Huron	0.020	0.009	5.000	0.025
HA1000|Mitchell	0.026	0.009	7.849	0.005
HA1000|Mobridge	-0.006	0.011	0.293	0.588
HA1000|Pierre	0.022	0.016	2.013	0.156
HA1000|Sioux Falls	-0.011	0.018	0.399	0.528
HA1000|Sisseton	-0.130	0.055	5.701	0.017

Table 1.7. continued.

Parameter[a, b]	β	SE	Wald chi-square	*P*
HA1000|Watertown	0.029	0.012	5.620	0.018
LSI1000	0.117	0.013	82.068	<.0001
LSI1000|Aberdeen	0.043	0.021	4.142	0.042
LSI1000|Brookings	0.137	0.035	15.576	<.0001
LSI1000|Chamberlain	-0.009	0.028	0.095	0.758
LSI1000|Huron	0.014	0.022	0.406	0.524
LSI1000|Mitchell	0.087	0.031	7.775	0.005
LSI1000|Mobridge	-0.438	0.077	32.289	<.0001
LSI1000|Pierre	-0.015	0.036	0.169	0.681
LSI1000|Sioux Falls	0.108	0.039	7.836	0.005
LSI1000|Sisseton	0.016	0.053	0.087	0.768
LSI1000|Watertown	0.031	0.022	1.989	0.159
PD1000	0.015	0.005	9.298	0.002
PD1000|Aberdeen	-0.012	0.008	2.038	0.153
PD1000|Brookings	-0.025	0.015	2.668	0.102
PD1000|Chamberlain	0.028	0.013	4.481	0.034
PD1000|Huron	-0.004	0.009	0.236	0.627

Table 1.7. continued.

Parameter[a, b]	β	SE	Wald chi-square	*P*
PD1000|Mitchell	0.017	0.016	1.139	0.286
PD1000|Mobridge	0.064	0.016	16.873	<.0001
PD1000|Pierre	-0.029	0.016	3.097	0.079
PD1000|Sioux Falls	-0.001	0.015	0.008	0.929
PD1000|Sisseton	-0.008	0.023	0.132	0.716
PD1000|Watertown	-0.032	0.010	10.614	0.001
PRCP	-0.005	0.009	0.296	0.586
PRCP|Aberdeen	0.011	0.010	1.372	0.242
PRCP|Brookings	0.114	0.020	34.307	<.0001
PRCP|Chamberlain	-0.0004	0.013	0.001	0.978
PRCP|Huron	0.005	0.010	0.273	0.602
PRCP|Mitchell	-0.007	0.014	0.272	0.602
PRCP|Mobridge	0.055	0.021	6.895	0.009
PRCP|Pierre	0.073	0.018	16.277	<.0001
PRCP|Sioux Falls	0.066	0.023	8.602	0.003
PRCP|Sisseton	-0.377	0.070	28.818	<.0001
PRCP|Watertown	0.048	0.012	16.153	<.0001

Table 1.7. continued.

Parameter[a, b]	β	SE	Wald chi-square	*P*
RC1000AM	0.006	0.001	32.201	<.0001
RC1000AM|Aberdeen	-0.002	0.002	1.061	0.303
RC1000AM|Brookings	- 0.0003	0.003	0.014	0.908
RC1000AM|Chamberlain	0.005	0.004	1.194	0.275
RC1000AM|Huron	0.0003	0.002	0.031	0.860
RC1000AM|Mitchell	-0.007	0.002	8.478	0.004
RC1000AM|Mobridge	0.003	0.003	0.598	0.439
RC1000AM|Pierre	-0.001	0.002	0.283	0.595
RC1000AM|Sioux Falls	-0.004	0.002	5.764	0.016
RC1000AM|Sisseton	0.010	0.007	2.131	0.144
RC1000AM|Watertown	-0.005	0.002	5.626	0.018
SNFA	-0.002	0.001	2.718	0.099
SNFA|Aberdeen	0.003	0.002	2.404	0.121
SNFA|Brookings	0.001	0.003	0.204	0.652
SNFA|Chamberlain	0.009	0.003	7.431	0.006
SNFA|Huron	-0.003	0.002	2.389	0.122
SNFA|Mitchell	0.008	0.003	5.097	0.024

Table 1.7. continued.

Parameter[a, b]	β	SE	Wald chi-square	*P*
SNFA|Mobridge	0.007	0.002	10.150	0.001
SNFA|Pierre	-0.004	0.003	1.734	0.188
SNFA|Sioux Falls	-0.002	0.004	0.376	0.540
SNFA|Sisseton	-0.011	0.008	2.063	0.151
SNFA|Watertown	-0.006	0.002	6.947	0.008
WETL1000	-0.054	0.014	14.785	0.0001
WETL1000|Aberdeen	0.001	0.017	0.008	0.931
WETL1000|Brookings	-0.018	0.030	0.351	0.553
WETL1000|Chamberlain	0.021	0.024	0.745	0.388
WETL1000|Huron	-0.028	0.021	1.733	0.188
WETL1000|Mitchell	-0.142	0.031	20.273	<.0001
WETL1000|Mobridge	0.078	0.033	5.544	0.019
WETL1000|Pierre	-0.240	0.091	6.928	0.009
WETL1000|Sioux Falls	-0.108	0.037	8.507	0.004
WETL1000|Sisseton	0.394	0.051	58.950	<.0001
WETL1000|Watertown	0.070	0.020	12.626	0.0004
WHEAT1000	-0.004	0.006	0.455	0.5

Table 1.7. continued.

Parameter[a, b]	β	SE	Wald chi-square	*P*
WHEAT1000|Aberdeen	0.018	0.008	5.825	0.016
WHEAT1000|Brookings	-0.015	0.023	0.432	0.511
WHEAT1000|Chamberlain	0.018	0.009	3.775	0.052
WHEAT1000|Huron	0.018	0.007	6.045	0.014
WHEAT1000|Mitchell	0.015	0.010	2.433	0.119
WHEAT1000|Mobridge	0.066	0.009	57.316	<.0001
WHEAT1000|Pierre	0.020	0.007	7.419	0.007
WHEAT1000|Sioux Falls	-0.075	0.036	4.403	0.036
WHEAT1000|Sisseton	0.016	0.023	0.456	0.499
WHEAT1000|Watertown	0.006	0.010	0.399	0.528
WV1000PD	-0.152	0.030	25.952	<.0001
WV1000PD|Aberdeen	0.091	0.061	2.183	0.140
WV1000PD|Brookings	-0.037	0.072	0.264	0.608
WV1000PD|Chamberlain	-0.243	0.079	9.565	0.002
WV1000PD|Huron	-0.134	0.054	6.066	0.014
WV1000PD|Mitchell	-0.324	0.079	16.788	<.0001
WV1000PD|Mobridge	0.290	0.093	9.773	0.002

Table 1.7. continued.

Parameter[a, b]	β	SE	Wald chi-square	*P*
WV1000PD|Pierre	0.154	0.090	2.969	0.085
WV1000PD|Sioux Falls	0.138	0.100	1.912	0.167
WV1000PD|Sisseton	0.037	0.175	0.046	0.831
WV1000PD|Watertown	0.120	0.061	3.824	0.051
Aberdeen	0.101	0.455	0.049	0.825
Brookings	-1.690	0.871	3.765	0.052
Chamberlain	0.214	0.713	0.090	0.764
Huron	1.068	0.490	4.755	0.029
Mitchell	-0.564	0.759	0.552	0.457
Mobridge	-1.530	0.712	4.624	0.032
Pierre	0.864	0.697	1.537	0.215
Sioux Falls	-1.065	0.767	1.926	0.165
Sisseton	3.709	2.081	3.177	0.075
Watertown	-0.183	0.662	0.076	0.782

[a] Description of variables found in Table 1.3;

[b] | = designates interaction between variables and pheasant management cluster.

Table 1.8. Final variables (including mean, SE, and range) used to predict presence of pheasant broods in 11 management clusters along 84 brood-survey routes in eastern South Dakota, USA, 2006−2010.

	Aberdeen		Brookings		Chamberlain	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
AM1000	5.31 (0.10)	1.40−44.70	4.81 (0.15)	0.00−31.26	5.65 (0.10)	1.63−28.45
AM500	4.59 (0.13)	1.04−78.30	4.05 (0.15)	1.45−39.06	4.52 (0.08)	1.03−19.58
CRP1000	7.85 (0.34)	0.00−58.58	14.40 (0.64)	0.00−65.32	2.25 (0.18)	0.00−36.33
CRP1000AM	8.60 (0.41)	0.00−97.56	15.24 (1.17)	0.00−184.50	3.83 (0.31)	0.00−62.19
CRP1000PD	0.83 (0.03)	0.00−9.91	1.33 (0.05)	0.00−7.03	0.21 (0.02)	0.00−4.16
CRP500	7.43 (0.38)	0.00−63.37	14.18 (0.81)	0.00−81.70	1.64 (0.18)	0.00−50.88
CRP500AM	3.71 (0.21)	0.00−50.31	7.62 (0.53)	0.00−67.23	1.04 (0.12)	0.00−26.64
CRP500PD	1.32 (0.06)	0.00−12.80	1.95 (0.10)	0.00−10.24	0.31 (0.03)	0.00−12.77
D1100	0.83 (0.04)	0.00−14.47	1.86 (0.07)	0.00−10.66	1.67 (0.06)	0.00−15.27

Table 1.8. continued.

Variable[a, b]	Aberdeen		Brookings		Chamberlain	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
D1500	0.97 (0.07)	0.00−37.82	2.41 (0.15)	0.00−19.48	2.01 (0.12)	0.00−22.57
D21000	4.81 (0.08)	0.32−23.15	4.84 (0.12)	0.00−17.73	3.90 (0.06)	0.03−15.10
D2500	8.25 (0.13)	0.00−40.68	7.78 (0.18)	0.00−24.06	6.97 (0.10)	0.11−15.81
GRAINS1000	8.48 (0.33)	0.00−62.28	1.60 (0.18)	0.00−31.83	9.84 (0.38)	0.00−66.21
GRAINS500	8.31 (0.39)	0.00−75.40	1.50 (0.24)	0.00−58.90	9.07 (0.43)	0.00−65.43
GRASS1000	23.91 (0.60)	0.00−94.97	13.43 (0.55)	0.00−65.69	35.23 (0.65)	0.00−88.92
GRASS500	16.98 (0.56)	0.00−91.33	11.29 (0.60)	0.00−76.66	24.72 (0.73)	0.00−87.43
HA1000	3.27 (0.16)	0.00−40.65	3.63 (0.23)	0.00−25.55	11.08 (0.33)	0.00−52.48
LSI1000	7.43 (0.21)	1.64−47.34	11.95 (0.50)	0.00−38.39	4.52 (0.08)	1.82−27.51
LSI500	3.27 (0.02)	1.14−7.01	3.21 (0.03)	1.58−4.81	3.09 (0.02)	1.69−5.89
PD1000	21.18 (0.38)	2.24−71.58	17.32 (0.58)	0.00−55.17	21.19 (0.32)	2.19−61.44

Table 1.8. continued.

	Aberdeen		Brookings		Chamberlain	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
PD500	29.64 (0.43)	1.28−95.90	31.04 (0.58)	2.56−69.20	27.11 (0.40)	5.11−96.84
PRCP	14.03 (0.34)	0.00−44.15	13.26 (0.23)	5.74−23.70	15.03 (0.22)	4.62−26.19
RC1000	32.44 (0.69)	0.00−89.95	43.65 (0.93)	0.00−86.92	21.78 (0.48)	0.00−75.00
RC1000AM	26.29 (1.24)	0.00−287.64	34.65 (1.66)	0.00−272.07	16.38 (0.59)	0.00−178.65
RC500	28.79 (0.71)	0.00−86.98	38.46 (1.03)	0.00−84.11	19.49 (0.58)	0.00−84.00
SEMIPERM100	1.01 (0.09)	0.00−49.13	2.91 (0.23)	0.00−33.09	1.38 (0.12)	0.00−26.67
SEMIPERM500	0.67 (0.08)	0.00−49.39	1.96 (0.23)	0.00−34.15	1.26 (0.16)	0.00−56.84
SNFA	80.16 (0.99)	0.00−161.29	84.69 (1.39)	19.81−179.32	85.26 (0.59)	38.10−123.19
SOD1000	31.76 (0.65)	0.00−94.97	27.83 (0.74)	0.20−74.34	37.48 (0.66)	0.00−88.92
SOD500	24.42 (0.65)	0.00−91.33	25.47 (0.88)	0.00−85.37	26.35 (0.74)	0.00−87.43
TEMP500	5.68 (0.16)	0.00−37.82	3.19 (0.19)	0.00−45.03	4.68 (0.17)	0.00−24.41

Table 1.8. continued.

	Aberdeen		Brookings		Chamberlain	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
WETL1000	2.93 (0.15)	0.00−42.17	5.31 (0.26)	0.00−28.88	1.07 (0.09)	0.00−50.42
WETL500	2.60 (0.16)	0.00−53.40	4.65 (0.29)	0.00−37.59	0.74 (0.08)	0.00−29.79
WHEAT1000	8.39 (0.33)	0.00−62.17	1.41 (0.17)	0.00−31.66	9.36 (0.38)	0.00−66.21
WHEAT500	8.22 (0.39)	0.00−75.40	1.37 (0.23)	0.00−58.90	8.57 (0.42)	0.00−65.20
WV1000	0.71 (0.03)	0.00−6.59	1.11 (0.05)	0.00−5.84	0.87 (0.03)	0.00−6.88
WV1000PD	0.83 (0.03)	0.00−5.45	1.57 (0.06)	0.00−11.22	1.00 (0.03)	0.00−5.11
WV500	0.72 (0.04)	0.00−13.98	1.14 (0.07)	0.00−8.14	0.93 (0.05)	0.00−12.83

Table 1.8. continued.

Variable[a, b]	Huron		Mitchell		Mobridge	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
AM1000	5.13 (0.09)	1.50−26.04	5.71 (0.11)	1.87−28.44	4.89 (0.12)	1.59−44.64
AM500	4.44 (0.09)	1.26−39.02	4.42 (0.08)	1.09−15.62	4.09 (0.09)	1.20−25.98
CRP1000	7.36 (0.37)	0.00−59.22	7.93 (0.39)	0.00−51.74	7.34 (0.44)	0.00−49.39
CRP1000AM	11.72 (0.72)	0.00−140.04	13.19 (0.74)	0.00−142.83	11.64 (0.77)	0.00−114.39
CRP1000PD	0.56 (0.03)	0.00−5.77	0.65 (0.03)	0.00−7.35	0.48 (0.04)	0.00−7.35
CRP500	7.61 (0.45)	0.00−77.01	7.98 (0.52)	0.00−70.13	7.27 (0.53)	0.00−54.32
CRP500AM	4.46 (0.28)	0.00−46.35	5.07 (0.35)	0.00−51.21	4.89 (0.38)	0.00−35.73
CRP500PD	0.94 (0.05)	0.00−10.25	1.07 (0.07)	0.00−15.29	0.77 (0.05)	0.00−7.68
D1100	1.17 (0.06)	0.00−17.96	1.61 (0.06)	0.00−13.12	0.89 (0.06)	0.00−7.82
D1500	1.50 (0.10)	0.00−32.77	1.91 (0.12)	0.00−21.89	1.02 (0.11)	0.00−17.99
D21000	3.54 (0.06)	0.06−15.99	4.54 (0.08)	0.32−12.83	3.66 (0.10)	0.26−20.83

Table 1.8. continued.

Variable[a, b]	Huron		Mitchell		Mobridge	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
D2500	7.18 (0.10)	0.11−18.22	7.61 (0.13)	0.92−22.69	7.08 (0.16)	1.03−33.35
GRAINS1000	8.92 (0.39)	0.00−63.14	6.07 (0.31)	0.00−45.18	19.73 (0.69)	0.00−83.28
GRAINS500	8.77 (0.44)	0.00−75.52	5.56 (0.38)	0.00−61.08	19.09 (0.86)	0.00−88.01
GRASS1000	27.40 (0.62)	0.00−91.96	28.65 (0.64)	0.37−85.94	21.61 (0.73)	0.00−94.19
GRASS500	16.74 (0.61)	0.00−89.84	20.13 (0.73)	0.00−86.29	14.31 (0.75)	0.00−85.49
HA1000	6.39 (0.25)	0.00−61.88	9.92 (0.35)	0.00−49.50	4.34 (0.31)	0.00−56.81
LSI1000	5.40 (0.15)	1.43−32.38	5.86 (0.18)	1.95−33.55	4.33 (0.06)	1.68−9.30
LSI500	3.14 (0.02)	1.43−5.77	3.06 (0.02)	1.72−5.21	3.16 (0.03)	1.68−5.28
PD1000	22.50 (0.37)	2.40−66.72	19.40 (0.37)	2.36−53.40	23.61 (0.39)	2.24−62.95
PD500	28.29 (0.42)	2.56−79.46	27.00 (0.42)	6.40−91.95	28.68 (0.50)	3.85−83.11
PRCP	14.81 (0.27)	0.00−41.68	13.94 (0.22)	4.62−26.19	10.50 (0.16)	5.26−16.38

Table 1.8. continued.

Variable[a, b]	Huron		Mitchell		Mobridge	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
RC1000	30.77 (0.66)	0.00−89.30	28.91 (0.70)	0.00−85.66	25.62 (0.78)	0.00−77.66
RC1000AM	27.58 (1.31)	0.00−284.85	21.90 (0.90)	0.00−249.66	20.95 (0.98)	0.00−171.18
RC500	27.09 (0.71)	0.00−86.98	25.53 (0.76)	0.00−84.80	21.80 (0.88)	0.00−83.31
SEMIPERM100	1.36 (0.08)	0.00−15.56	2.37 (0.10)	0.00−13.55	0.52 (0.06)	0.00−20.23
SEMIPERM500	1.04 (0.08)	0.00−21.89	1.61 (0.12)	0.00−25.44	0.36 (0.04)	0.00−12.49
SNFA	82.87 (1.05)	0.00−149.35	87.49 (0.74)	38.10−123.19	83.92 (1.68)	16.00−171.45
SOD1000	34.76 (0.70)	0.00−91.96	36.58 (0.79)	0.37−93.99	28.95 (0.84)	0.00−94.19
SOD500	24.35 (0.71)	0.00−89.84	28.11 (0.87)	0.00−88.46	21.59 (0.90)	0.00−85.49
TEMP500	7.74 (0.24)	0.00−70.93	5.56 (0.18)	0.00−32.31	3.50 (0.34)	0.00−51.68
WETL1000	1.91 (0.11)	0.00−31.91	1.78 (0.09)	0.00−16.01	0.90 (0.15)	0.00−34.78
WETL500	1.52 (0.12)	0.00−35.29	1.49 (0.11)	0.00−22.12	0.71 (0.20)	0.00−69.90

Table 1.8. continued.

	Huron		Mitchell		Mobridge	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
WHEAT1000	8.81 (0.39)	0.00−63.14	5.88 (0.31)	0.00−45.12	19.44 (0.69)	0.00−83.19
WHEAT500	8.69 (0.44)	0.00−75.52	5.40 (0.38)	0.00−61.08	18.84 (0.86)	0.00−88.01
WV1000	0.93 (0.03)	0.00−11.00	0.77 (0.03)	0.00−3.84	0.54 (0.03)	0.00−4.76
WV1000PD	0.98 (0.03)	0.00−6.72	1.04 (0.03)	0.00−4.16	0.69 (0.03)	0.00−5.13
WV500	0.96 (0.05)	0.00−15.01	0.83 (0.05)	0.00−8.94	0.51 (0.04)	0.00−7.56

Table 1.8. continued.

Variable[a, b]	Pierre		Sioux Falls		Sisseton	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
AM1000	5.99 (0.17)	1.68−26.04	4.93 (0.15)	2.06−22.34	3.11 (0.13)	1.31−8.68
AM500	4.83 (0.16)	1.15−26.04	4.40 (0.21)	1.35−39.11	2.72 (0.14)	1.01−8.68
CRP1000	2.81 (0.35)	0.00−32.43	7.16 (0.49)	0.00−38.88	8.44 (1.10)	0.00−40.31
CRP1000AM	5.60 (0.72)	0.00−90.09	6.10 (0.59)	0.00−54.45	8.14 (1.33)	0.00−73.62
CRP1000PD	0.18 (0.02)	0.00−1.60	1.24 (0.07)	0.00−7.35	1.47 (0.13)	0.00−5.11
CRP500	2.83 (0.46)	0.00−49.96	6.77 (0.63)	0.00−62.57	8.40 (1.59)	0.00−67.15
CRP500AM	1.76 (0.30)	0.00−36.36	2.90 (0.35)	0.00−51.30	3.60 (0.65)	0.00−27.90
CRP500PD	0.35 (0.05)	0.00−6.41	1.75 (0.13)	0.00−8.96	1.97 (0.28)	0.00−14.03
D1100	1.17 (0.10)	0.00−12.61	2.41 (0.10)	0.00−9.22	1.15 (0.14)	0.00−8.28
D1500	1.60 (0.20)	0.00−19.71	2.82 (0.20)	0.00−16.27	1.46 (0.26)	0.00−11.80
D21000	3.86 (0.13)	0.83−23.00	4.70 (0.14)	0.34−16.99	4.84 (0.23)	0.95−10.49

Table 1.8. continued.

	Pierre		Sioux Falls		Sisseton	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
D2500	7.13 (0.18)	2.41−33.69	7.42 (0.22)	0.11−27.04	7.63 (0.32)	1.95−14.67
GRAINS1000	27.90 (1.17)	0.00−89.52	0.70 (0.13)	0.00−14.07	6.26 (0.85)	0.00−46.84
GRAINS500	23.77 (1.24)	0.00−87.78	0.66 (0.18)	0.00−20.51	5.93 (1.04)	0.00−48.47
GRASS1000	19.18 (1.30)	0.00−91.76	11.43 (0.57)	0.00−45.15	8.56 (0.76)	0.00−30.45
GRASS500	13.08 (1.02)	0.00−85.26	9.31 (0.67)	0.00−72.77	6.55 (0.88)	0.00−39.99
HA1000	2.82 (0.30)	0.00−36.87	2.88 (0.22)	0.00−25.30	2.27 (0.40)	0.00−24.84
LSI1000	4.00 (0.07)	1.75−7.72	8.31 (0.55)	1.83−43.87	9.01 (0.99)	2.10−42.22
LSI500	3.01 (0.04)	1.75−5.69	3.14 (0.04)	1.61−4.90	3.79 (0.09)	2.10−6.07
PD1000	20.46 (0.48)	3.84−59.52	20.21 (0.64)	2.84−48.53	33.18 (1.72)	4.68−76.12
PD500	26.77 (0.74)	3.84−87.05	29.94 (0.77)	2.56−74.07	44.17 (1.99)	11.52−98.57
PRCP	12.76 (0.25)	5.38−22.89	14.59 (0.22)	7.72−21.08	10.95 (0.47)	4.72−21.39

Table 1.8. continued.

Variable[a, b]	Pierre		Sioux Falls		Sisseton	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
RC1000	28.62 (1.13)	0.00−91.30	56.04 (0.95)	18.91−91.87	42.78 (1.89)	0.00−85.54
RC1000AM	28.92 (2.16)	0.00−291.51	53.54 (3.49)	6.95−293.58	27.86 (3.94)	0.00−265.68
RC500	26.46 (1.28)	0.00−84.91	51.80 (1.17)	2.52−87.09	39.28 (2.37)	0.00−81.47
SEMIPERM100	0.55 (0.06)	0.00−11.80	3.09 (0.39)	0.00−45.92	4.38 (0.45)	0.00−15.44
SEMIPERM500	0.44 (0.07)	0.00−10.66	1.80 (0.31)	0.00−42.97	3.17 (0.50)	0.00−22.35
SNFA	77.61 (2.04)	1.78−135.89	81.06 (1.15)	22.86−125.22	98.68 (3.74)	51.31−179.32
SOD1000	21.99 (1.30)	0.00−91.76	18.58 (0.73)	0.20−57.50	17.00 (1.46)	0.00−63.11
SOD500	15.92 (1.12)	0.00−85.26	16.09 (0.87)	0.00−72.77	14.95 (1.77)	0.00−67.15
TEMP500	2.19 (0.19)	0.00−18.33	3.65 (0.23)	0.00−19.48	4.57 (0.39)	0.00−14.67
WETL1000	0.21 (0.05)	0.00−7.33	3.23 (0.21)	0.00−17.53	8.55 (0.77)	0.03−37.90
WETL500	0.29 (0.11)	0.00−22.00	2.63 (0.23)	0.00−28.30	7.41 (0.86)	0.11−37.47

Table 1.8. continued.

	Pierre		Sioux Falls		Sisseton	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
WHEAT1000	27.16 (1.16)	0.00−88.46	0.68 (0.13)	0.00−12.92	6.16 (0.84)	0.00−46.84
WHEAT500	23.10 (1.24)	0.00−87.78	0.64 (0.18)	0.00−20.51	5.84 (1.02)	0.00−48.47
WV1000	0.58 (0.04)	0.00−4.64	0.67 (0.04)	0.00−3.95	1.04 (0.09)	0.00−4.01
WV1000PD	0.68 (0.05)	0.00−5.77	1.09 (0.05)	0.00−4.48	1.57 (0.12)	0.00−4.80
WV500	0.60 (0.06)	0.00−7.33	0.75 (0.07)	0.00−12.83	1.15 (0.14)	0.00−4.47

Table 1.8. continued.

	Watertown		Yankton	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range
AM1000	4.19 (0.06)	1.25−14.18	5.35 (0.30)	1.70−17.38
AM500	3.56 (0.07)	0.98−26.07	5.06 (0.41)	1.59−26.16
CRP1000	11.08 (0.47)	0.00−53.97	3.78 (0.51)	0.00−25.98
CRP1000AM	10.66 (0.54)	0.00−127.44	4.88 (0.73)	0.00−46.17
CRP1000PD	1.18 (0.04)	0.00−7.37	0.82 (0.11)	0.00−4.48
CRP500	10.41 (0.57)	0.00−69.90	3.45 (0.73)	0.00−41.25
CRP500AM	4.77 (0.30)	0.00−57.15	1.87 (0.41)	0.00−21.87
CRP500PD	1.84 (0.09)	0.00−12.77	1.33 (0.27)	0.00−15.34
D1100	1.56 (0.06)	0.00−10.60	2.20 (0.15)	0.26−7.42
D1500	1.86 (0.12)	0.00−25.67	2.14 (0.29)	0.00−12.72
D21000	4.74 (0.09)	0.11−19.37	5.00 (0.24)	0.60−10.66

Table 1.8. continued.

Variable[a, b]	Watertown Mean (SE)	Watertown Range	Yankton Mean (SE)	Yankton Range
D2500	8.11 (0.15)	0.46−46.07	8.51 (0.38)	2.29−20.51
GRAINS1000	7.89 (0.33)	0.00−44.98	1.50 (0.40)	0.00−23.55
GRAINS500	7.38 (0.43)	0.00−73.22	1.21 (0.45)	0.00−27.04
GRASS1000	17.03 (0.58)	0.00−69.61	13.25 (1.16)	0.00−59.44
GRASS500	14.03 (0.61)	0.00−78.15	9.17 (1.22)	0.00−59.93
HA1000	4.71 (0.24)	0.00−30.37	6.47 (0.71)	0.00−30.74
LSI1000	10.54 (0.39)	1.90−44.57	5.98 (0.62)	1.82−32.97
LSI500	3.39 (0.03)	1.50−5.94	3.03 (0.07)	1.67−4.60
PD1000	21.72 (0.55)	2.34−79.69	21.52 (1.14)	3.08−58.68
PD500	33.83 (0.56)	3.84−102.29	27.70 (1.35)	3.82−62.80
PRCP	15.00 (0.28)	5.13−29.64	14.49 (0.40)	9.42−21.41

Table 1.8. continued.

	Watertown		Yankton	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range
RC1000	34.46 (0.77)	0.00−81.85	56.35 (2.05)	11.75−89.09
RC1000AM	26.34 (1.22)	0.00−261.27	57.32 (6.98)	3.49−285.39
RC500	30.47 (0.84)	0.00−84.45	51.45 (2.34)	2.06−88.46
SEMIPERM100	3.45 (0.17)	0.00−24.01	0.92 (0.24)	0.00−14.55
SEMIPERM500	2.73 (0.20)	0.00−30.25	0.62 (0.24)	0.00−15.93
SNFA	63.72 (1.37)	5.08−179.32	98.68 (2.34)	68.07−133.60
SOD1000	28.11 (0.71)	0.03−76.17	17.03 (1.31)	0.00−59.44
SOD500	24.43 (0.77)	0.00−84.80	12.62 (1.39)	0.00−59.93
TEMP500	3.58 (0.15)	0.00−32.89	3.15 (0.46)	0.00−22.46
WETL1000	5.48 (0.18)	0.00−24.35	1.27 (0.20)	0.00−10.28
WETL500	4.76 (0.21)	0.00−31.28	1.09 (0.22)	0.00−11.92

Table 1.8. continued.

	Watertown		Yankton	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range
WHEAT1000	7.72 (0.33)	0.00−43.95	1.30 (0.39)	0.00−23.55
WHEAT500	7.21 (0.43)	0.00−73.22	0.87 (0.38)	0.00−27.04
WV1000	1.19 (0.04)	0.00−7.62	1.25 (0.20)	0.00−14.35
WV1000PD	1.58 (0.05)	0.00−8.32	1.47 (0.14)	0.00−5.44
WV500	1.25 (0.07)	0.00−13.52	0.92 (0.22)	0.00−16.50

[a] Variable definitions in Table 1.3;

[b] Aberdeen cluster, *n* = 1,069. Brookings cluster; *n* = 433, Chamberlain cluster; *n* = 928. Huron cluster; *n* = 943. Mitchell cluster; *n* = 698. Mobridge cluster; *n* = 507. Pierre cluster; *n* = 337. Sioux Falls cluster; *n* = 276. Sisseton cluster; *n* = 89. Watertown cluster; *n* = 660. Yankton cluster; *n* = 95.

Table 1.9. Final variables (including mean, SE, and range) used to predict presence of pheasant brood along 84 brood-survey routes in eastern South Dakota, USA, 2006−2010 at pheasant brood and random locations.

	Random		Observed	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range
AM1000	5.88 (0.05)	1.21−77.96	5.20 (0.04)	0.00−44.70
AM500	4.63 (0.05)	0.00−39.15	4.37 (0.04)	0.98−78.30
CRP1000	4.99 (0.13)	0.00−66.75	7.24 (0.15)	0.00−59.22
CRP1000AM	6.10 (0.18)	0.00−166.32	9.30 (0.24)	0.00−184.50
CRP1000PD	0.63 (0.01)	0.00−10.88	0.71 (0.01)	0.00−9.91
CRP500	4.48 (0.15)	0.00−80.56	7.04 (0.18)	0.00−81.70
CRP500AM	2.28 (0.08)	0.00−66.42	3.85 (0.11)	0.00−67.23
CRP500PD	0.88 (0.02)	0.00−17.90	1.10 (0.03)	0.00−15.34
D1100	1.59 (0.03)	0.00−23.09	1.38 (0.02)	0.00−17.96
D1500	1.95 (0.05)	0.00−40.57	1.63 (0.04)	0.00−32.77
D21000	4.55 (0.04)	0.00−26.79	4.37 (0.03)	0.00−23.15
D2500	7.76 (0.05)	0.00−49.85	7.77 (0.05)	0.00−46.07
GRAINS1000	7.26 (0.17)	0.00−91.67	9.41 (0.18)	0.00−89.52

Table 1.9. continued.

	Random		Observed	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range
GRASS500	19.45 (0.31)	0.00−87.55	16.46 (0.26)	0.00−91.33
HA1000	5.72 (0.11)	0.00−58.41	6.07 (0.11)	0.00−61.88
LSI1000	4.80 (0.02)	1.80−11.58	6.73 (0.10)	0.00−47.34
LSI500	3.15 (0.01)	0.00−7.01	3.18 (0.01)	1.14−7.01
PD1000	21.35 (0.14)	1.28−82.84	21.18 (0.16)	0.00−79.69
PD500	28.75 (0.20)	0.00−128.70	29.05 (0.19)	1.28−102.29
PRCP	13.81 (0.10)	0.00−44.15	14.07 (0.11)	0.00−44.15
RC1000	38.37 (0.35)	0.00−92.48	32.03 (0.30)	0.00−91.59
RC1000AM	33.49 (0.64)	0.00−297.45	26.64 (0.52)	0.00−293.58
RC500	34.69 (0.37)	0.00−87.66	28.48 (0.32)	0.00−88.46
SEMIPERM100	1.57 (0.05)	0.00−50.59	1.72 (0.05)	0.00−49.13
SEMIPERM500	1.28 (0.06)	0.00−78.38	1.27 (0.05)	0.00−56.84
SNFA	83.68 (0.46)	0.00−179.32	81.67 (0.44)	0.00−179.32
SOD1000	27.06 (0.31)	0.00−95.08	30.99 (0.29)	0.00−94.97
SOD500	23.92 (0.33)	0.00−87.55	23.49 (0.30)	0.00−91.33
TEMP500	4.54 (0.09)	0.00−78.61	4.91 (0.08)	0.00−70.93

Table 1.9. continued.

	Random		Observed	
Variable[a, b]	Mean (SE)	Range	Mean (SE)	Range
WETL1000	2.55 (0.07)	0.00−73.42	2.53 (0.06)	0.00−42.17
WETL500	2.22 (0.08)	0.00−75.86	2.15 (0.06)	0.00−53.40
WHEAT1000	7.05 (0.17)	0.00−91.67	9.18 (0.18)	0.00−87.38
WHEAT500	6.36 (0.19)	0.00−86.17	8.67 (0.20)	0.00−86.17
WV1000	0.99 (0.02)	0.00−17.19	0.85 (0.01)	0.00−14.35
WV1000PD	1.22 (0.02)	0.00−10.87	1.05 (0.01)	0.00−11.22
WV500	1.18 (0.05)	0.00−81.25	0.86 (0.02)	0.00−16.50

[a] Variable definitions found in Table 1.3;

[b] Random locations; *n* = 4,829. Brood locations; *n* = 4,829.

Table 1.10. Logistic regression models predicting the presence of a pheasant brood along 84 brood-survey routes in eastern South Dakota, USA, 2006−2010 at a 1,000-m scale.

Model[a]	*K*[b]	-2LL	AIC[c]	ΔAIC[d]	*w*[e]	ROC[f]
CRP + CRPAM + CRPPD + GRASS + RCAM + WHEAT + HA + WVPD + WETL + PRCP + SNFA + AM + LSI + PD	165	10715.103	11045.103	0	1	0.778
CRP + GRASS + WV + WETL + WHEAT + HA + PRCP + SNFA + AM + LSI	121	10955.263	11197.263	152	0	0.767
CRP + GRASS + WV + WETL + RC + WHEAT + HA + PRCP + SNFA + AM + LSI	132	10946.420	11210.420	165	0	0.767
CRP + GRASS + WV + WETL + RC + WHEAT + HA + AM + LSI + PD	121	11048.602	11290.602	245	0	0.759
CRP + GRASS + WV + WETL + AM + LSI + PD	88	11194.865	11370.865	326	0	0.749
GRASS + WHEAT + CRP + WETL + LSI + AM	77	11304.373	11458.373	413	0	0.745
RC + RCAM + WHEAT + HA + PRCP + SNFA + AM + LSI + PD	110	11312.908	11532.908	488	0	0.740
CRP + GRASS + WETL + LSI + AM	66	11413.531	11545.531	500	0	0.738

Table 1.10. continued.

Model[a]	K^b	-2LL	AIC[c]	ΔAIC[d]	w^e	ROC[f]
WHEAT + CRP + WETL + LSI + AM	66	11395.851	11527.851	483	0	0.739
CRP + CRPAM + CRPPD + SNFA + AM + LSI	77	11516.866	11670.866	626	0	0.734
CRP + GRASS + WV + WETL + RC + WHEAT + HA + PRCP + SNFA	110	11894.666	12114.666	1070	0	0.713
CRP + GRASS + WV + WETL + RC + WHEAT + HA	88	12006.681	12182.681	1138	0	0.706
CRP + GRASS + WV + WETL + PRCP + SNFA	77	12067.144	12221.144	1176	0	0.702
SOD + HA + WETL + GRAINS + PRCP + SNFA	77	12114.794	12268.794	1224	0	0.692
CRP + GRASS + WV + WETL	55	12190.830	12300.830	1256	0	0.692
SOD + HA + SEMIPERM + GRAINS + PRCP + SNFA	77	12281.065	12435.065	1390	0	0.681
CRP + CRPAM + CRPPD + SNFA	55	12361.200	12471.200	1426	0	0.680
CRP	22	12568.597	12612.597	1567	0	0.656

Table 1.10. continued.

Model[a]	K^b	-2LL	AIC[c]	ΔAIC[d]	w^e	ROC[f]
D1 + D2 + PRCP + SNFA	55	12524.966	12634.966	1590	0	0.656
PRCP + SNFA	33	12689.165	12755.165	1710	0	0.634

[a] Description of variables found in Table 1.3; [b] Number of parameters; [c] Akaike's Information Criterion (Burnham and Anderson 2002); [d] Difference in AIC relative to minimum AIC; [e] Akaike weight (Burnham and Anderson 2002); [f] ROC = area under the receiver operating characteristic curve. Values between 0.7 and 0.8 were considered acceptable discrimination (Hosmer and Lemeshow 2000); [g] All variables were interacted with 11 SDGFP pheasant management clusters.

Table 1.11. Parameter estimates (*β*), standard errors, and significance tests from the top-ranked logistic regression model predicting the presence of a pheasant brood in eastern South Dakota, USA, 2006−2010 at a 1,000-m scale.

Parameter[a, b]	β	SE	Wald chi-square	*P*
Intercept	0.036	0.346	0.011	0.917
AM1000	-0.128	0.039	10.656	0.001
AM1000|Aberdeen	0.082	0.045	3.309	0.069
AM1000|Brookings	0.154	0.063	5.932	0.015
AM1000|Chamberlain	0.034	0.052	0.434	0.510
AM1000|Huron	-0.003	0.050	0.005	0.944
AM1000|Mitchell	0.072	0.060	1.423	0.233
AM1000|Mobridge	0.008	0.077	0.012	0.912
AM1000|Pierre	0.017	0.055	0.097	0.755
AM1000|Sioux Falls	0.032	0.086	0.143	0.705
AM1000|Sisseton	-0.469	0.354	1.754	0.185
AM1000|Watertown	0.024	0.079	0.089	0.766
CRP1000	0.013	0.005	6.170	0.013
CRP1000|Aberdeen	0.027	0.008	10.928	0.001
CRP1000|Brookings	0.051	0.012	17.032	<.0001

Table 1.11. continued.

Parameter[a, b]	β	SE	Wald chi-square	*P*
CRP1000|Chamberlain	-0.034	0.028	1.510	0.219
CRP1000|Huron	0.013	0.009	2.158	0.142
CRP1000|Mitchell	-0.034	0.014	5.819	0.016
CRP1000|Mobridge	0.044	0.013	11.141	0.001
CRP1000|Pierre	-0.068	0.017	15.584	<.0001
CRP1000|Sioux Falls	-0.014	0.016	0.793	0.373
CRP1000|Sisseton	-0.026	0.021	1.513	0.219
CRP1000|Watertown	0.0004	0.008	0.003	0.956
CRP1000AM	0.020	0.004	28.643	<.0001
CRP1000AM|Aberdeen	-0.030	0.006	29.933	<.0001
CRP1000AM|Brookings	-0.007	0.008	0.799	0.372
CRP1000AM|Chamberlain	0.020	0.015	1.900	0.168
CRP1000AM|Huron	-0.010	0.005	4.009	0.045
CRP1000AM|Mitchell	0.018	0.008	4.887	0.027
CRP1000AM|Mobridge	-0.030	0.007	20.658	<.0001
CRP1000AM|Pierre	-0.001	0.013	0.013	0.911
CRP1000AM|Sioux Falls	0.034	0.016	4.392	0.036

Table 1.11. continued.

Parameter[a, b]	β	SE	Wald chi-square	*P*
CRP1000AM|Sisseton	0.018	0.017	1.151	0.283
CRP1000AM|Watertown	-0.002	0.006	0.136	0.713
CRP1000PD	0.171	0.053	10.375	0.001
CRP1000PD|Aberdeen	-0.132	0.073	3.233	0.072
CRP1000PD|Brookings	-0.163	0.113	2.076	0.150
CRP1000PD|Chamberlain	-0.291	0.193	2.277	0.131
CRP1000PD|Huron	-0.092	0.097	0.891	0.345
CRP1000PD|Mitchell	0.324	0.144	5.066	0.024
CRP1000PD|Mobridge	0.042	0.185	0.051	0.822
CRP1000PD|Pierre	0.641	0.325	3.891	0.049
CRP1000PD|Sioux Falls	0.121	0.117	1.062	0.303
CRP1000PD|Sisseton	-0.344	0.217	2.516	0.113
CRP1000PD|Watertown	-0.048	0.081	0.351	0.554
GRASS1000	-0.002	0.003	0.394	0.530
GRASS1000|Aberdeen	0.007	0.004	3.306	0.069
GRASS1000|Brookings	0.003	0.008	0.170	0.680
GRASS1000|Chamberlain	0.008	0.006	1.462	0.227

Table 1.11. continued.

Parameter[a, b]	β	SE	Wald chi-square	*P*
GRASS1000|Huron	0.011	0.004	6.647	0.010
GRASS1000|Mitchell	0.028	0.006	24.216	<.0001
GRASS1000|Mobridge	-0.001	0.006	0.024	0.877
GRASS1000|Pierre	0.0002	0.005	0.001	0.977
GRASS1000|Sioux Falls	-0.027	0.009	9.300	0.002
GRASS1000|Sisseton	-0.043	0.023	3.329	0.068
GRASS1000|Watertown	0.015	0.005	8.084	0.005
HA1000	-0.008	0.006	1.467	0.226
HA1000|Aberdeen	-0.005	0.011	0.190	0.663
HA1000|Brookings	0.018	0.016	1.223	0.269
HA1000|Chamberlain	-0.0003	0.010	0.001	0.979
HA1000|Huron	0.019	0.009	4.414	0.036
HA1000|Mitchell	0.018	0.009	3.501	0.061
HA1000|Mobridge	-0.015	0.013	1.308	0.253
HA1000|Pierre	0.048	0.018	7.139	0.008
HA1000|Sioux Falls	-0.040	0.022	3.361	0.067
HA1000|Sisseton	-0.087	0.049	3.195	0.074

Table 1.11. continued.

Parameter[a, b]	β	SE	Wald chi-square	*P*
HA1000|Watertown	0.030	0.013	5.880	0.015
LSI1000	-0.184	0.025	53.747	<.0001
LSI1000|Aberdeen	0.357	0.031	130.052	<.0001
LSI1000|Brookings	0.462	0.043	114.165	<.0001
LSI1000|Chamberlain	0.184	0.041	20.423	<.0001
LSI1000|Huron	0.285	0.033	76.955	<.0001
LSI1000|Mitchell	0.360	0.040	79.464	<.0001
LSI1000|Mobridge	-1.430	0.138	107.136	<.0001
LSI1000|Pierre	-1.476	0.183	65.170	<.0001
LSI1000|Sioux Falls	0.376	0.050	57.777	<.0001
LSI1000|Sisseton	0.249	0.058	18.320	<.0001
LSI1000|Watertown	0.324	0.032	101.908	<.0001
PD1000	0.036	0.006	34.288	<.0001
PD1000|Aberdeen	-0.031	0.009	11.382	0.001
PD1000|Brookings	-0.024	0.016	2.269	0.132
PD1000|Chamberlain	-0.0002	0.015	0.000	0.992
PD1000|Huron	-0.028	0.010	7.802	0.005

Table 1.11. continued.

Parameter[a, b]	β	SE	Wald chi-square	*P*
PD1000|Mitchell	0.0003	0.017	0.000	0.988
PD1000|Mobridge	0.145	0.026	31.515	<.0001
PD1000|Pierre	0.132	0.028	22.978	<.0001
PD1000|Sioux Falls	-0.052	0.021	6.408	0.011
PD1000|Sisseton	-0.063	0.028	5.210	0.023
PD1000|Watertown	-0.057	0.012	24.699	<.0001
PRCP	0.011	0.009	1.420	0.234
PRCP|Aberdeen	0.002	0.010	0.032	0.859
PRCP|Brookings	0.084	0.020	17.507	<.0001
PRCP|Chamberlain	-0.005	0.014	0.143	0.706
PRCP|Huron	-0.006	0.011	0.270	0.603
PRCP|Mitchell	-0.004	0.015	0.088	0.767
PRCP|Mobridge	0.141	0.027	26.416	<.0001
PRCP|Pierre	0.113	0.023	24.755	<.0001
PRCP|Sioux Falls	0.066	0.026	6.530	0.011
PRCP|Sisseton	-0.383	0.073	27.572	<.0001
PRCP|Watertown	0.021	0.013	2.605	0.107

Table 1.11. continued.

Parameter[a, b]	β	SE	Wald chi-square	*P*
RC1000AM	0.004	0.001	8.764	0.003
RC1000AM|Aberdeen	-0.0002	0.002	0.007	0.935
RC1000AM|Brookings	-0.002	0.003	0.303	0.582
RC1000AM|Chamberlain	0.006	0.005	1.415	0.234
RC1000AM|Huron	0.002	0.002	0.487	0.485
RC1000AM|Mitchell	-0.005	0.003	4.000	0.046
RC1000AM|Mobridge	0.003	0.004	0.415	0.519
RC1000AM|Pierre	-0.001	0.003	0.208	0.648
RC1000AM|Sioux Falls	-0.004	0.002	2.587	0.108
RC1000AM|Sisseton	0.001	0.012	0.004	0.947
RC1000AM|Watertown	-0.002	0.002	0.669	0.414
SNFA	-0.002	0.001	3.337	0.068
SNFA|Aberdeen	0.004	0.002	3.591	0.058
SNFA|Brookings	0.001	0.003	0.117	0.733
SNFA|Chamberlain	-0.001	0.004	0.136	0.712
SNFA|Huron	-0.003	0.002	2.375	0.123
SNFA|Mitchell	0.004	0.004	0.893	0.345

Table 1.11. continued.

Parameter[a, b]	β	SE	Wald chi-square	*P*
SNFA|Mobridge	0.012	0.003	23.352	<.0001
SNFA|Pierre	0.002	0.003	0.218	0.641
SNFA|Sioux Falls	0.001	0.004	0.069	0.793
SNFA|Sisseton	-0.011	0.007	2.627	0.105
SNFA|Watertown	-0.002	0.002	0.767	0.381
WETL1000	-0.028	0.015	3.652	0.056
WETL1000|Aberdeen	-0.030	0.018	2.746	0.098
WETL1000|Brookings	-0.019	0.030	0.387	0.534
WETL1000|Chamberlain	-0.037	0.029	1.629	0.202
WETL1000|Huron	-0.058	0.023	6.129	0.013
WETL1000|Mitchell	-0.132	0.031	17.710	<.0001
WETL1000|Mobridge	0.121	0.044	7.560	0.006
WETL1000|Pierre	-0.106	0.094	1.275	0.259
WETL1000|Sioux Falls	-0.122	0.042	8.582	0.003
WETL1000|Sisseton	0.366	0.055	44.225	<.0001
WETL1000|Watertown	0.064	0.021	8.954	0.003
WHEAT1000	0.002	0.006	0.168	0.682

Table 1.11. continued.

Parameter[a, b]	β	SE	Wald chi-square	*P*
WHEAT1000|Aberdeen	0.014	0.007	3.280	0.070
WHEAT1000|Brookings	0.006	0.022	0.078	0.780
WHEAT1000|Chamberlain	0.007	0.010	0.519	0.471
WHEAT1000|Huron	0.014	0.007	3.352	0.067
WHEAT1000|Mitchell	0.021	0.010	4.450	0.035
WHEAT1000|Mobridge	0.042	0.010	17.724	<.0001
WHEAT1000|Pierre	0.011	0.008	1.926	0.165
WHEAT1000|Sioux Falls	-0.060	0.036	2.798	0.094
WHEAT1000|Sisseton	0.0002	0.021	0.000	0.994
WHEAT1000|Watertown	0.017	0.010	3.139	0.076
WV1000PD	-0.145	0.032	20.302	<.0001
WV1000PD|Aberdeen	0.022	0.066	0.112	0.739
WV1000PD|Brookings	0.012	0.072	0.027	0.870
WV1000PD|Chamberlain	-0.141	0.086	2.697	0.101
WV1000PD|Huron	-0.190	0.061	9.652	0.002
WV1000PD|Mitchell	-0.320	0.085	14.016	0.0002
WV1000PD|Mobridge	0.133	0.117	1.290	0.256

Table 1.11. continued.

Parameter[a, b]	β	SE	Wald chi-square	*P*
WV1000PD|Pierre	0.320	0.109	8.634	0.003
WV1000PD|Sioux Falls	-0.049	0.118	0.171	0.680
WV1000PD|Sisseton	0.250	0.169	2.189	0.139
WV1000PD|Watertown	0.096	0.067	2.054	0.152
Aberdeen	-1.223	0.493	6.160	0.013
Brookings	-4.108	0.848	23.498	<.0001
Chamberlain	0.936	0.850	1.214	0.271
Huron	0.067	0.531	0.016	0.900
Mitchell	-1.753	0.795	4.864	0.027
Mobridge	0.943	1.043	0.818	0.366
Pierre	2.328	0.801	8.450	0.004
Sioux Falls	-1.191	1.063	1.257	0.262
Sisseton	6.208	2.422	6.572	0.010
Watertown	-1.202	0.730	2.710	0.100

[a] Description of variables found in Table 1.3;

[b] | = designates interaction between variables and pheasant management cluster.

Table 1.12. Land cover availability (%) of major land use categories for pheasants within 1,000-m buffer of brood-survey routes in east-river South Dakota, USA, study area, summer 2006−2010.

Cluster	Row Crop	Small Grain	Wheat	Grass	CRP[a]	Woody Vegetation	Hay/ Alfalfa	Wetlands
				2006				
Aberdeen	35.3	0.2	8.2	25.2	6.0	0.7	3.5	7.2
Brookings	43.1	0.1	2.5	13.6	10.8	1.1	3.4	8.1
Chamberlain	22.7	0.6	9.1	37.5	2.8	0.8	11.1	1.5
Huron	34.0	0.1	6.3	29.4	5.3	1.0	7.5	3.7
Mitchell	50.9	0.2	5.9	16.6	3.0	0.9	7.3	2.0
Mobridge	24.3	0.4	13.5	27.4	5.8	0.5	2.9	1.7
Pierre	21.9	1.0	23.3	30.5	1.5	0.5	4.6	1.1
Sioux Falls	63.7	0.1	0.2	11.0	3.7	0.7	2.8	3.9
Sisseton	43.5	0.1	7.2	9.8	7.4	1.2	1.8	13.2
Watertown	33.7	0.2	8.1	18.0	9.9	1.2	4.7	7.4
Yankton	54.4	0.1	1.5	14.2	2.4	1.7	9.4	2.9

Table 1.12. continued.

Cluster	Row Crop	Small Grain	Wheat	Grass	CRP[a]	Woody Vegetation	Hay/ Alfalfa	Wetlands
				2007				
Aberdeen	38.1	0.2	7.5	27.5	6.5	0.8	3.8	3.1
Brookings	47.8	0.2	2.0	15.1	10.6	1.3	3.5	4.0
Chamberlain	18.4	0.4	12.0	37.7	2.8	0.9	11.2	1.1
Huron	34.7	0.2	6.9	30.1	5.0	1.1	7.6	2.3
Mitchell	48.8	0.1	7.6	16.7	2.8	1.0	7.4	1.4
Mobridge	20.8	0.4	14.4	29.3	6.8	0.6	3.1	0.3
Pierre	22.6	1.6	22.4	31.4	1.6	0.6	4.7	0.1
Sioux Falls	63.0	0.1	0.5	12.0	4.0	0.8	2.9	2.0
Sisseton	45.6	0	7.1	10.2	7.4	1.4	2.0	10.0
Watertown	37.8	0.2	6.0	18.8	9.5	1.4	4.9	4.8
Yankton	52.2	0.2	2.1	14.6	2.2	1.7	9.7	2.1

Table 1.12. continued.

Cluster	Row Crop	Small Grain	Wheat	Grass	CRP[a]	Woody Vegetation	Hay/ Alfalfa	Wetlands
				2008				
Aberdeen	36.9	0	9.6	27.0	5.5	0.8	4.2	2.0
Brookings	48.6	0.1	2.5	15.0	9.8	1.3	3.3	3.0
Chamberlain	20.0	0.1	11.0	36.4	2.7	0.9	10.6	0.7
Huron	36.9	0.1	5.6	29.1	4.8	1.1	7.0	1.7
Mitchell	50.2	0	6.1	15.8	2.9	1.0	7.5	1.3
Mobridge	21.9	0.2	16.5	26.1	6.4	0.6	5.5	0.3
Pierre	22.3	1.3	23.1	29.7	1.5	0.6	4.1	0.1
Sioux Falls	63.2	0	0.6	11.8	4.0	0.8	3.9	1.3
Sisseton	47.5	0	7.8	9.0	6.1	1.4	2.6	6.8
Watertown	37.6	0	8.1	17.8	9.3	1.3	5.1	3.4
Yankton	53.1	0	2.3	15	2.4	1.8	8.4	1.1

Table 1.12. continued.

Cluster	Row Crop	Small Grain	Wheat	Grass	CRP[a]	Woody Vegetation	Hay/ Alfalfa	Wetlands
				2009				
Aberdeen	32.6	0.1	5.6	26.1	5.4	0.8	4.1	3.3
Brookings	47.3	0.2	2.5	14.8	9.6	1.3	3.3	3.5
Chamberlain	25.1	0.6	7.3	36.7	2.7	0.9	10.7	0.8
Huron	36.5	0.1	4.6	29.1	4.8	1.1	7.0	1.7
Mitchell	49.7	0.1	5.9	15.9	2.9	1.0	7.5	1.2
Mobridge	24.2	0.3	15.8	25.7	6.2	0.6	5.5	0.3
Pierre	25.0	1.2	21.4	29.8	1.5	0.6	4.1	0.1
Sioux Falls	62.1	0	0.4	11.8	3.9	0.8	3.9	1.5
Sisseton	47.0	0.1	5.7	9.2	6.1	1.3	2.7	8.0
Watertown	37.7	0.1	5.8	17.6	9.2	1.3	5.0	4.3
Yankton	52.8	0.2	1.6	15.0	2.5	1.8	8.5	0.9

Table 1.12. continued.

Cluster	Row Crop	Small Grain	Wheat	Grass	CRP[a]	Woody Vegetation	Hay/ Alfalfa	Wetlands
				2010				
Aberdeen	25.2	0.1	5.7	25.1	4.6	0.9	4.5	3.4
Brookings	54.0	0.3	1.5	14.4	8.0	1.4	3.9	3.1
Chamberlain	29.7	0.3	4.7	36.0	3.1	1.0	9.7	0.9
Huron	37.5	0.1	3.8	28.6	4.6	1.1	6.2	2.3
Mitchell	56.9	0.1	2.9	15.4	3.3	1.0	6.7	1.7
Mobridge	28.8	0.4	14.9	24.2	5.7	0.6	5.8	0.3
Pierre	25.2	0.7	23.6	28.7	1.3	0.6	4.0	0.1
Sioux Falls	67.3	0.1	0.2	11.8	3.7	0.8	3.3	1.2
Sisseton	52.4	0	5.8	9.6	5.9	1.4	2.2	6.6
Watertown	40.4	0.2	6.2	17.9	8.4	1.4	4.4	3.7
Yankton	59.6	0.1	1.4	14.9	2.6	1.8	7.1	0.8

[a] Conservation Reserve Program perennial habitat base.

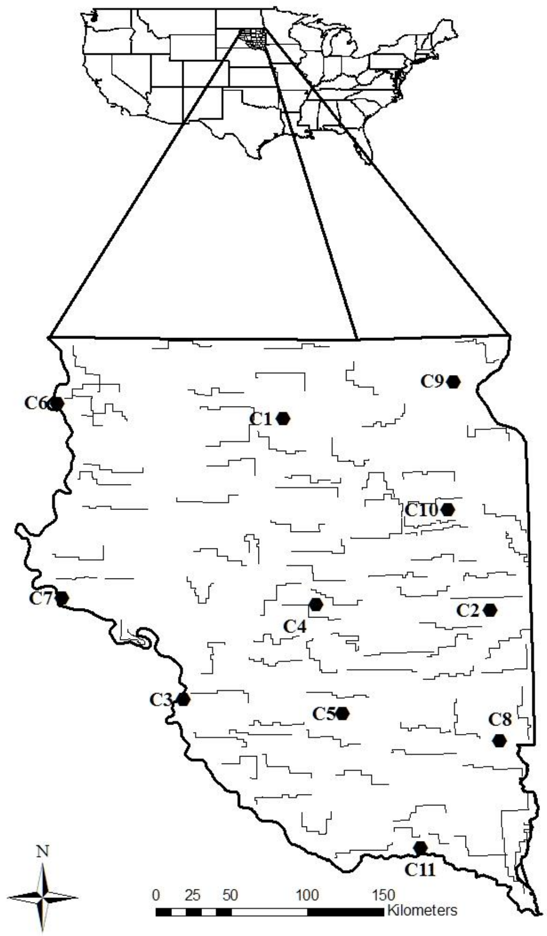

Figure 1.1. Ring-necked pheasant (*Phasianus colchicus*) brood-survey routes (84) and South Dakota Game, Fish and Parks pheasant management clusters (11) in east-river South Dakota, USA where we studied the effects of habitat on presence of hen pheasants and broods during the brood-rearing season 2006−2010. C1 =Aberdeen, C2 =Brookings, C3 =Chamberlain, C4 =Huron, C5 =Mitchell, C6 =Mobridge, C7 =Pierre, C8 =Sioux Falls, C9 =Sisseton, C10 =Watertown, and C11 =Yankton.

CHAPTER 2

USE OF ROADSIDE SURVEYS TO DETERMINE THE ASSOCATION OF RING-NECKED PHEASANTS AND CONSERVATION RESERVE PROGRAM GRASSLANDS

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ABSTRACT

Grassland established through the Conservation Reserve Program (CRP) has provided critical habitat for many wildlife species. Declines in CRP-grassland acreage attributed to changes in federal enrollment policy, increased biofuels production, and commodity prices may have negative consequences on wildlife populations. Recent pheasants per mile (PPM; i.e., 1.6 km) trends in South Dakota decreased significantly (41%) in comparison to the 10-year mean. We used historical roadside survey data and negative binomial regression to evaluate the association between ring-necked pheasant (*Phasianus colchicus*) abundance and CRP-grasslands along 84 brood-survey routes (2006−2010). We developed models *a priori* using total pheasant count as our response variable and used habitat variables developed in a GIS within a 1,000-m buffer around pheasant locations as our independent variables. Our top model [%CRP + CRP Patch Density + %Row Crop + %Row Crop^2 + %GRASS + GRASS Patch Density + %Hay/Alfalfa + Hay/Alfalfa Patch Density + %WHEAT] (w_i = 1.0, Pearson/df = 1.121) suggested CRP-grasslands, other habitats associated with pheasant broods, and row crop agriculture influenced pheasants greatest across a large, regional scale. Based on our top model, when all other variables means were held constant, pheasant counts increased by 5 (95% CI = 2.99 – 5.93) birds for every 94.3 ha increase of CRP-grassland. Results from this study demonstrate that the use of established wildlife surveys provide valuable information for conservation and agricultural policy in South Dakota by quantifying pheasant production from Farm Bill dependent habitats.

KEY WORDS Conservation Reserve Program, CRP, habitat association, South Dakota, *Phasianus colchicus*, ring-necked pheasants.

INTRODUCTION

Grassland to cropland conversion in the Northern Plains has occurred at an increasing rate in the past decade (Claassen et al. 2011). Recent shifts in regional landscape composition have occurred due to Conservation Reserve Program (CRP) contract expirations (United States Department of Agriculture 2011*a*), increased commodity crop prices (National Agricultural Statistics Service 2011), and federally mandated increases in biofuel production (Fargione et al. 2009). Large-scale grassland conversion and its effects on wildlife, rural economies, and the environment across this region has been well documented (Newton et al. 2005, Nielson et al. 2008, Searchinger et al. 2008, Rashford et al. 2011, Grovenburg et al. 2012*a*, 2012*b*). Conversion of these habitats was associated with losses of grassland-dependent species (Niemuth et al. 2007, Herkert 2009), decreased water quality (Foley et al. 2005), increased soil erosion (Sullivan et al. 2004), and large volume releases of sequestered carbon (Foley et al. 2005), potentially threatening wildlife communities and ecosystems as well as quality of life of rural residents (Weyer et al. 2001).

The CRP is a voluntary land retirement program administered by the Farm Service Agency (FSA) of the United States Department of Agriculture (USDA). Landowners receive an annual fixed rental payment for reverting previously farmed agricultural land to perennial grass cover or other approved conservation cover for a 10–15 year period (Barbarika et al. 2004). The program originally was enacted to reduce acreage available for agricultural production, increase the price of commodity crops, and ensure our nation's ability to produce food and fiber. Since that time, other objectives of equal importance include environmental benefits such as reduced soil erosion/water pollution and increased quality habitat for wildlife species (Barbarika et al. 2004). First implemented in 1985 through the Food Security Act, CRP enrollment peaked nationally in 2007 at 14.9 million ha. Between 2007 and 2010, 2.2 million ha of CRP contracts expired and were converted back to agricultural crop production (United States Department of Agriculture 2011*a*). Enrollment in South Dakota peaked at 717,876 ha in 1998; 63% remained by 2010 (United States Department of Agriculture 2011*a*). By 2007, an estimated 9.8 million ha of grasslands (rangeland and pastureland) existed in South Dakota; a 5.2% decrease from 1982 (United States Department of Agriculture 2009*b*).

Ring-necked pheasants (*Phasianus colchicus*; hereafter pheasants) are associated with mixed agricultural and grassland habitats such as CRP (Trautman 1982, Patterson and Best 1996) and presence is linked to ecological characteristics that make them a good indicator of change in agricultural landscapes and successional habitat provided by CRP-grasslands (Nielson et al. 2008). Pheasants use a variety of habitats seasonally (Trautman 1982); during winter, pheasants selected for wetlands (Homan et al. 2000), dense stands of grass vegetation, and shrubs in close proximity to established food sources (Larsen et al. 1994, Gabbert et al. 1999). Dense vegetation such as warm-season grasses, cattail (*Typha* spp.), and reed canary grass (*Phalaris* sp.) were used during extreme winter weather events (Gabbert et al. 1999). Alfalfa (*Medigo sativa*) and dense perennial cool-season grass-legume mixtures and perennial warm-season native grass mixtures were important components of nesting cover for pheasants (Hanson and Progulske 1973, Hankins 2007). In regions where wheat (*Triticum aestivum*) was abundant, winter wheat was important for brood-rearing purposes (Hammer 1973); although Rodgers (1999, 2002) suggested that use of herbicide and low wheat stubble heights negatively affected pheasant populations. Wheat habitat also may be important nesting habitat for pheasants, even when CRP-grasslands are available (B. Pauli, SDSU, unpublished data). In an agricultural landscape, management to ensure brood survival should emphasize perennial grass and legume cover dispersed among crop fields, with grassland cover remaining undisturbed through the primary nesting season (i.e., 1 August; USDA 2011*b*). Therefore, a diverse agricultural landscape consisting of a variety of nesting and brood-rearing habitats such as undisturbed grasslands (i.e., CRP) and wheat may directly benefit pheasant populations.

Previous attempts have been made to document the association between pheasants and CRP-grasslands using pheasant count data from roadside surveys and the Breeding Bird Survey (BBS). Areas in southeast Nebraska with 18−21% CRP-grassland coverage versus similarly sized areas with 2−3% CRP-grassland coverage supported higher pheasant numbers (King and Savidge 1995). In Iowa, pheasant observations increased by 30% during the first 5 years after the CRP was established in comparison to a similar period without the CRP (Riley 1995). Eggebo et al. (2003) sampled 42 CRP fields in eastern South Dakota and documented that increased pheasant abundance was associated with field age and cover type, suggesting a mosaic of cool- and warm-season CRP-grassland was most beneficial for pheasants. Additionally, replacement of cropland with CRP-grasslands had a positive effect on pheasant population growth rates in Iowa (Nusser et al. 2004). In south-central Minnesota, pheasant survey counts increased by an average of 12.4 birds per route in spring and by 32.9 birds per route in summer for each 10% increase of grass in the landscape (Haroldson et al. 2006). Most recently, Nielson et al. (2008) assessed Breeding Bird Survey (BBS) data from 9 states during 1987−2005 within the distribution of the pheasant. Across the study area, they concluded there was a 22% (1 pheasant) predicted increase in pheasant counts for an addition of 319 ha of herbaceous CRP.

Total pheasant counts in eastern South Dakota decreased by 9% from 2006 – 2010 (Runia 2011), a period when 110,846 ha of CRP expired (United States Department of Agriculture 2011*a*). In eastern South Dakota, the 10-year average pheasant per mile (PPM; 1.6 km) index decreased significantly in 10 of the 11 management clusters within eastern South Dakota (Runia 2011). Statewide PPM index trends (2011) decreased by 46% (6.54 PPM to 3.55 PPM) compared to the 2010 index. In comparison to the 10-year mean, the 2011 index was 41% lower (2011 = 3.55, 10-year mean = 6.04, $P < 0.001$). Statewide, 89% of routes surveyed indicated a decrease from 2010 and the 10-year average; 12 routes showed an increase (Runia 2011).

In South Dakota, pheasants are an economically important game bird, annually providing $220 million in revenue to the state's economy (Janssen et al. 2008). Therefore, accurate estimates of the response of pheasants to changes in land use are necessary for management of this important game species. Limited information exists on the effects of large acreage decreases of CRP-grassland on pheasants in South Dakota; therefore, we modeled total pheasant count as a function of habitat types in eastern South Dakota 2006−2010, a period when large numbers of CRP contracts expired, grassland was converted to crop production (United States Department of Agriculture 2011*a*), and spatially explicit CRP-grassland habitat data was available. We hypothesized that pheasant abundance would be strongly correlated with availability of CRP-grasslands. Our primary objective was to develop a set of habitat-based models using roadside brood-survey data and spatially explicit CRP data that would predict a) the association of pheasants and land use habitats, and b) predict the response of pheasant counts to changes in CRP-grasslands.

STUDY AREA

We studied pheasants along 84 brood-survey routes conducted annually 25 July – 15 August, 2006−2010 by South Dakota Department of Game, Fish and Parks (SDGFP) in 44 counties in eastern South Dakota (Fig.1.1), total area for all routes = 824,587 ha. The study area was located within 7 physiographic regions of eastern South Dakota; Missouri Coteau, James River Lowland, Minnesota-Red River Lowland, Prairie Coteau, Southeastern Loess Hills, Missouri River Floodplain, and Lake Dakota Plain (Johnson et al. 1995). Mean spring precipitation (1 April – 31 May) ranged from 7.1 cm–36.1 cm in 2006, 30.6–76.3 cm 2007, 16.3–46.9 cm in 2008, 14.7–29.2 cm in 2009, and 28.4−43.9 cm in 2010 across SDGFP management clusters (pheasant management clusters were designated by SDGFP around city centers across the state and used to summarize annual pheasant population and trend data for management purposes). Mean cumulative snowfall (1 November – 31 March) ranged from 73.4−271.5 cm in 2006, 153.4−259.6 cm in 2007, 91.7−252.7 cm in 2008, 175.3−377.7 cm in 2009, and 211.1−323.3 cm in 2010 across SDGFP management clusters (South Dakota Office of Climatology 2011).

Agriculture (i.e., row crops and small grains) was the predominant land use in the 44 county study area (Smith et al. 2002, South Dakota Agricultural Statistics Service 2011). Cultivated land, pasture-grassland, woody vegetation, and wetland comprised 54.3%, 29.7%, 0.9%, and 4.5%, respectively, of total land use within the 84 brood-survey routes at the onset of data collection in 2006 (United States Department of Agriculture 2010). During our study, CRP enrollment peaked in eastern South Dakota at 454,588 ha in 2007, of which 17.9% was converted to agricultural production by spring 2008 (United States Department of Agriculture 2011*a*). Conservation Reserve Program contracts continued to expire throughout the duration of the study, although CRP loss was mitigated at varying levels and locations through continuous CRP and Conservation Reserve Enhancement Program (CREP) enrollments (United States Department of Agriculture 2011*a*). Woody vegetation (forested cover) was comprised mainly of tree row and shelterbelt plantings (Smith et al. 2002, Grovenburg et al. 2010). The study area lies within the glaciated Prairie Pothole Region of eastern South Dakota (Smith et al. 2002), where approximately 35% of prairie potholes have been drained and converted to cropland (Dahl 1990). Additionally, the study area contained 11,195 ha of State Game Production Area lands and Federal Waterfowl Production Area lands, which were primarily comprised of perennial upland vegetation (T. Runia, SDFGP, unpublished data). The majority (83%) of SDGF&P's pheasant brood surveys were located in eastern

South Dakota (Switzer 2009) providing an ideal location to study pheasant ecology and land-use changes (Trautman 1982).

Tall grass or true prairie remains in portions of eastern South Dakota, giving way to the northern mixed-grass prairie in the west (Johnson and Larsen 1999, Higgins et al. 2000). Dominant vegetation in tall-grass prairie includes big bluestem (*Andropogon gerardii*), little bluestem (*A. scoparius*) switchgrass (*Panicum virgatum*), prairie cordgrass (*Spartina pectinata*), and Indian grass (*Sorghastrum nutans*; Johnson and Larson 1999). Species indicative of the northern mixed-grass prairie include western wheatgrass (*Elymus smithii*), big bluestem, porcupine grass (*Stipa spartea*), and little bluestem (Johnson and Larson 1999). Common wetland vegetation included prairie cordgrass, reed canarygrass (*Phalaris arundinacea*), common reed (*Phragmites australis*), cattails (*Typha* sp.), rushes (*Juncus* spp.), and sedges (*Carex* spp.; Johnson and Larson 1999). Dominant cultivated crops included corn (*Zea mays*), soybeans (*Glycine max*), wheat, and alfalfa (South Dakota Agriculture Statistics Service 2011).

Conservation Reserve Program vegetation consisted primarily of CP1 (introduced grasses and legumes), CP2 (native grasses and legumes), and CP10 (existing grasses and legumes; Jones-Farrand et al. 2007, Grovenburg et al. 2012*a*). The CP1 plantings were composed primarily of intermediate wheatgrass (*E. hispidus*), smooth brome (*Bromus inermis*), alfalfa, and sweet clover (*Melilotus* spp.) whereas CP2 plantings consisted of Indian grass, switchgrass, big bluestem, and little bluestem (Best et al. 1997, Higgins 2000, Grovenburg et al. 2012*a*). Haying and grazing of CRP acreage was authorized under certain conditions to improve quality and cover or to provide emergency relief to livestock producers (United States Department of Agriculture 2011*b*).

METHODS

Pheasant Data

We acquired pheasant data for 84 brood-survey routes conducted from 2006–2010 by SDGFP in eastern South Dakota. The South Dakota brood route survey was typical of state-level wildlife surveys used in states with abundant populations of pheasants to obtain information on population trends (Nusser et al. 2004, Switzer 2009). Brood routes were conducted 25 July – 15 August annually by SDGFP employees and were located throughout South Dakota along rural gravel roads (Switzer 2009). Routes were approximately 48 km in length and observation periods were standardized (i.e., route start point, observation frame, weather conditions) to reduce error associated among observers and year. SDGFP employees collected pheasant observations along routes from sunrise to no later than 2 hours after sunrise only when standardized weather conditions were optimal for observing pheasants: vegetation was saturated from moderate to heavy dew or rain, cloud cover was limited, and wind velocities were ≤12.9 kph (Switzer 2009). Observers drove routes east to west and recorded number of roosters, hens, broods, and brood size (if possible) at 0.16 km increments using the vehicle odometer. In 2010, 67 of 84 routes collected pheasant observations at paired Cartesian coordinates using CyberTracker version 3.217 (CyberTracker Conservation®, Noordhoek, Cape Town, South Africa) on mobile GPS units. Data dictionaries were created manually to collect data previously recorded using historical data sheets at pheasant observations. Because surveys were conducted in areas known to contain large numbers of pheasants (Switzer 2009), counts for these routes were viewed as indicators of population trend rather than true estimates of pheasant populations (Nusser et al. 2004).

We gave spatial reference to survey route observations using ArcGIS 9.3 (ESRI, Inc., Redlands, CA, USA). We digitized survey routes using historical aerial imagery and descriptions of individual routes. We converted routes to points every 0.16 km using the convert features function in XTOOLS PRO (Data East Software, LLC, Novosibirsk, Russia). We exported point files into Microsoft Excel 2010 (Microsoft, Inc., Redmond, Washington, USA) and paired 0.16 km Cartesian coordinates with 0.16 km observations from field data sheets. If an observation was located >0.998 km outside of the spatially referenced transect (2 × pheasant mean home range size; Riley et al. 1998), we censored it from analyses.

Geographic Data

We used standard photo interpretation techniques to digitize and enumerate patches of land cover at a resolution of 5000 m, current with National Wetlands Inventory (NWI) protocol (M. Kjellsen, National Wetlands Inventory, South Dakota State University, personal comm.), using aerial imagery (2006, 2008, and 2010) obtained from the USDA Farm Service Agency (FSA) Aerial Photo Field Office, Salt Lake City, Utah, USA. Aerial imagery was unique among years (e.g., cloud cover, exposure, vegetation height); therefore, we created classification guides (i.e., known land use patches of aerial imagery) using aerial photographs with known classification of land use patches and spatially explicit CRP shape files obtained from the FSA and the Cropland Data Layer (CDL) 2006–2010 (United States Department of Agriculture 2010).

Additionally, spatial coverages of state owned Game Production Areas and federally owned Waterfowl Production Areas acquired from SDGFP were used as guides to classify planted cover habitats as well as CRP lands. We did not censor routes that were adjacent to commercial hunting outfitters that release pen-reared pheasants for commercial hunting purposes because pen-reared pheasants suffer high over-winter mortality and were not likely to contribute to the breeding population of pheasants (Leif 2004, Lusk et al. 2009).

We trained photo interpreters using classification guides to enhance their visual understanding of the landscape, delineate patch boundaries, and classify land cover types (Brown and Schulte 2011). We classified patches into 5 land-cover categories based on their functional differences and our ability to reliably interpret their features from aerial imagery. The land-cover classes included disturbed grassland, planted cover, developed, hay/alfalfa, and woody vegetation (Table 2.1). Patches digitized by photo interpreters were error checked at regular intervals by the first author to ensure accuracy and consistency among observers. Because aerial imagery was not available for 2007 and 2009, we used the 2006 coverage for 2007 and the 2008 coverage for 2009. We assumed coverages represented habitat on the ground at that time; CRP acreage decreased by 6.1% and 5.4% between 2006−2007 and 2008−2009, respectively (United States Department of Agriculture 2011*a*).

We obtained spatially explicit Common Land Unit (CLU) and CRP contract information from the FSA from 2006 to 2010. County level CRP contract information was updated, stored by county FSA offices, and archived in the Aerial Photo Field Office, Salt Lake City, Utah, USA. We compared overall acreages from the CRP contract information to acreages reported by FSA during 2006 to 2010. Reported acreages differed substantially in 2007 and 2009; thus, we deemed these data unusable for analyses. Through the use of expiration dates for CRP contract duration and aerial imagery, we used the CRP layer as a guide to validate the digitized classification of CRP habitat types for 2008 and 2010 because acreage output corresponded with FSA reported land units. We quantified and classified CRP habitats in 2006 using a 2002 habitat coverage produced by United States Fish and Wildlife Service (USFWS; M. Esty, Habitat and Population Evaluation Team [HAPET], Bismarck, North Dakota, unpublished data) for the Prairie Pothole Region of the eastern Dakotas. We confirmed classification of CRP habitat patches by overlaying the HAPET coverage onto National Agriculture Imagery Program mosaic (NAIP) aerial imagery 2006 (USDA Farm Service Agency Aerial Photo Field Office, Salt Lake City, Utah, USA). If we identified a habitat patch as grassland with no sign of disturbance (i.e., haying or cutting pattern, cattle trails, presence of cattle) in 2006 using aerial imagery and it corresponded with HAPET's classification as CRP, the patch was classified as CRP. We compared the overall change in CRP enrollment from 2002−2006 to validate the use of the 2002 HAPET coverage as a guide for classifying 2006 CRP-grassland habitats. Conservation Reserve Program enrollment decreased by 6% across eastern South Dakota 2002−2006 (United States Department of

Agriculture 2011*a*); thus, we used the 2002 HAPET coverage as a guide to classify CRP-grasslands in 2006. We were unable to use contract age or type for our analysis as those data were not available in the data set obtained from the USFWS.

We used the CDL 2006−2010 for South Dakota to document land use within buffered areas of survey routes. The CDL contained an accurate spatial coverage of annual crop-specific agricultural practices. Non-agricultural land use coverage within the CDL was dependent on the National Land Cover Data (NCLD; Homer et al. 2007) 2001 (Table 2.2). We converted the digitized land use coverage (i.e., vector data) to a raster dataset using the Convert Features to Raster tool in Spatial Analyst in ArcGIS at a 30-m resolution. We reclassified the digitized grassland coverage and executed a merge onto the cropland data, reclassifying habitat and cropland data classifications using Spatial Analyst in ArcGIS at a 30-m resolution (Tables 2.1, 2.2). We used Focal Statistics and Extract Features to Point tools within Spatial Analyst to extract the proportion of each habitat feature around pheasant observations within 1,000-m buffers (2 times pheasant home range size of 76 ha during brood rearing season; Riley et al. 1998).

To assess quality of the available wetland habitat coverage, we acquired NWI data from the National Wetlands Inventory. We used ArcGIS and the Convert Features to Raster tool in Spatial Analyst to convert NWI data from vector to raster data. We grouped Class II and III wetland types (temporary and seasonal) and Class IV wetlands (semi-permanent) (Stewart and Kantrud 1971) to simplify wetland types for analyses. We modeled wetland coverage from NWI and the CDL independently due to high correlation ($r > |0.50|$) between coverages. Wetlands are dynamic and important to pheasant ecology (Gabbert et al. 1999, Homan et al. 2000), but due to logistics and limited availability of accurate yearly wetland data, we were unable to produce a dynamic wetland coverage representing temporal change in wetland habitats.

We used a standard shape (i.e., circle) and a set size to investigate habitat characteristics along transects (Kie et al. 2002, Bowyer and Kie 2006). Therefore, we delineated circular areas at 314.2 ha (1,000-m) around spatially referenced pheasant locations (Chapter 1, Riley et al. 1998, Nielson et al. 2008). We measured habitat variables at a 1,000-m scale using FRAGSTATS (version 3); metrics were grouped into 3 categories at patch class and landscape level scales: area, density, and edge (McGarigal et al. 2002). Because metrics within each FRAGSTATS category often are closely related (Hargis et al. 1998), we selected a single metric within each category (Kie et al. 2002). To test for potentially confounding relationships, we evaluated collinearity among predictor variables using Pearson's correlation coefficient ($r > |0.50|$); therefore, we present data for each of the 3 habitat metrics for each land use category using patch density (PD; number of patches/100 ha of the habitat category), mean patch size (AM; mean area in ha of land-cover patches of habitat category), and landscape shape index (LSI; total length of edge or perimeter involving the corresponding habitat divided by the minimum length of habitat edge or perimeter possible for a maximally aggregated habitat; McGarial et al. 2002). We chose patch metrics *a priori* based on previous biological literature important to pheasant ecology in this region (Clark et al. 1999, Haroldson et al. 2006, Nielson et al. 2008).

Statistical Analysis

We used negative binomial regression to test for relationships between the dependent variable (total pheasant count = roosters, hens, and broods) and independent variables (habitat proportions, habitat patch metrics, and weather data). Pheasant count data fit the negative binomial distribution more accurately than Poisson or normal distribution; therefore, we used negative binomial regression (White and Bennetts 1996). We modeled the total pheasant count at the transect scale. We used the mean value of each independent variable for all pheasant locations along each unique survey transect. Modeling effort conducted previously (Chapter 1) showed better model fit and predictive probability (ROC = 0.778, p_1 = 0.6375, p_0 = 0.3625) for models at the 1,000-m scale than for those at a 500-m scale; thus, we only modeled at the 1,000-m spatial scale. Prior to modeling, we tested for collinearity between predictor variables with Pearson's correlation matrix (PROC CORR; SAS Institute 2001) and removed 1 variable from each correlated pair ($r > |0.50|$), which resulted in 51 predictor variables for modeling. We preferentially removed variables correlated with ≥1 other variable based on biological importance from previous literature on pheasant ecology during the brood rearing season. We used SAS version 9.2 for statistical analyses (SAS 2008).

We posited 17 models of how pheasant abundance might be influenced by CRP-grasslands, disturbed grassland, row crops, small grains, woody vegetation, wetland/water, and patch metrics in eastern South Dakota based on biological importance to pheasant ecology (Definitions of variables are presented in Table 2.3). We used Akaike's Information Criterion (AIC) to select the most parsimonious model and considered models differing by ≤ 2 ΔAIC from the selected model as potential alternatives (Burnham and Anderson 2002). We used Akaike weights (w_i) as an indication of support for each model.

RESULTS

Land use

Conservation Reserve Program-grassland decreased by 5,547 ha and row crop (i.e., corn and soybean production) increased by 24,220 ha in eastern South Dakota within 84 brood-survey routes during 2006−2010 (Table 2.4). During this period grass, hay/alfalfa, and wheat also decreased by 4,559 ha (2.45%), 1,761 ha (3.8%), and 13,297 ha (22.2%), respectively (Table 2.4).

Mean area of CRP-grasslands, wheat, and row crop within a 1,000-m buffer of all pheasant locations decreased by 4.6 ha, 0.1 ha, and 13.2 ha, respectively, while mean area of grass, and hay/alfalfa increased from 2006−2010 (Table 2.5). Mean percent of habitat variables used to predict pheasant abundance found in Table 2.6.

Pheasant abundance

We examined 9,724 pheasant locations; 1,557 in 2006, 1,856 in 2007, 2,560 in 2008, 1,380 in 2009, and 2,371 in 2010 along 84 brood-survey routes throughout the study area. Total pheasant count was 23,975 pheasants (3,842 in 2006, 4,411 in 2007, 6,841 in 2008, 3,472 in 2009, and 5,409 in 2010). We considered [CRP + CRP_{PD} + RC + RC^2 + GRASS + $GRASS_{PD}$ + HA + HA_{PD} + WHEAT] as the only competing model (w_i = 1.00; Table 2.7) for predicting the response of pheasant abundance to changes in habitat distribution and percentage along transects. This model was 35.4 ΔAIC units from remaining models and weight of evidence supporting this model was 10,000 times ≥ remaining models. Model fit was acceptable (Pearson's Chi-Square, df = 1.121).

Effects were not significant for the land use variables percent CRP-grassland, percent grass, percent hay/alfalfa, and hay/alfalfa patch density ($P > 0.05$). Parameter estimates (Table 2.8) indicated significant variable effects for CRP patch density ($P = 0.015$), percent row crop ($P < 0.001$), percent row crop squared ($P < 0.001$), GRASS patch density ($P = 0.037$), and percent wheat ($P = 0.007$); percent row crop and percent wheat positively influenced pheasant abundance while CRP patch density, GRASS patch density, and row crop squared negatively influenced pheasant abundance. Although percent CRP was not significant, it was included in the top-ranked AIC model; therefore, we predicted pheasant count as a function of increase in percent CRP. Based on the top-ranked model, when all other variables were held constant at their mean values, predicted change of pheasant counts increased by 5 pheasants (95% CI = 2.99–5.93) when CRP-grassland was increased by 94.3 ha (30%).

DISCUSSION

We modeled total pheasant count using negative binomial regression as a function of CRP-grassland, agricultural lands, habitat variables, and patch dynamics across eastern South Dakota. We developed a set of *a priori* models based on landscape variables important to pheasant ecology and evaluated them at a 1,000-m spatial scale in accordance with results from Chapter 1. Based on our top model, a 30% (94.3 ha) increase in CRP-grassland would result in an additional 5 pheasants on the landscape. While the positive relationship between pheasant abundance and CRP-grasslands found mirrored results from previous literature (King and Savidge 1995, Riley 1995, Haroldson et al. 2006, Nielson et al. 2008), the magnitude of pheasant abundance in response to change in CRP-grasslands and other habitat variables in the top model was smaller than originally hypothesized.

We quantified the change in habitat configuration and use over time around spatially explicit pheasant observations across eastern South Dakota, and modeled changes of habitat at a local level (i.e., 1,000-m buffer around a pheasant location) across a large geographic region (i.e., all 84 survey routes) to estimate the effect of CRP-grasslands on pheasant abundance. The relatively small effect size of CRP-grasslands on pheasant abundance may be an artifact of concurrent changes in land use (i.e., loss of other reproductive habitats such as wheat, native grasslands, and hay/alfalfa; Guidice and Haroldson 2007) and variation in geographic region such as change in soils, topography, and climate. For example, pheasant abundance and nest success were generally higher in CRP-grasslands than in croplands (King and Savidge 1995, Best et al. 1997, Clark et al. 1999), but in our study the proportion of CRP-grassland varied across the agricultural landscape (0.0–97.5 ha at pheasant locations, 1.4–176.8 ha at the route level) in eastern South Dakota from 2006−2010. Therefore, changes in land use and practices in the remaining portion of the landscape may have a much larger effect on pheasant populations across a regional scale than the CRP. Despite the loss of 5,547 ha of CRP-grasslands from 2006−2010 within a 1,000-m buffer of brood-survey routes, mean CRP-grassland only decreased by 4.6 ha at a pheasant location, while the PPM index suggested large population decreases (46%) statewide when comparing the 10-year average to the

2011 PPM index (Runia 2011). Other reproductive habitats such as grass, hay/alfalfa, and wheat decreased within a 1,000-m buffer of all routes. Conversely, row crop increased region-wide over the course of the study yet decreased at pheasant locations. Other studies have examined range-wide effects of the CRP and agricultural lands on pheasant abundance. Nusser et al. (2004) failed to find a strong, range-wide increase in Iowa, which was similar to results in Minnesota (Guidice and Haroldson 2007). Also, more recently, Nielson et al. (2008) reported a weak, negative population trend in a study evaluating CRP-habitats and pheasant locations from BBS data across a 9-state region during 1987−2005 in which they documented a predicted increase of 1 pheasant for an addition of 319 ha of CRP-grassland. Our estimates predicted a stronger relationship between pheasant abundance and CRP-grasslands of 5 pheasants for an addition of 94 ha of CRP-grassland. As Guidice and Haroldson (2007) stated, lack of a range-wide increase should not be interpreted as evidence that the CRP did not have a positive effect on local pheasant populations. Chapter 1 used pheasant locations in eastern South Dakota to build a logistic regression model to determine presence/absence of hen pheasant and pheasant broods. Pheasant presence was positively affected by the presence of CRP-grasslands on the landscape, although response varied by region, suggesting CRP-grassland affected pheasant presence and abundance differently as land use practices shifted across the landscape.

Conservation Reserve Program patch density and grassland patch density negatively influenced the abundance of pheasants during our study. Previous literature indicated that large-sized patches (i.e., ≥15 ha, optimal ≥60 ha) of CRP habitats were beneficial to nest success (Clark et al. 1999) by providing adequate habitat that is relatively secure from predation. As patch density increases in a landscape, habitat becomes more fragmented and isolated; therefore, it is logical that pheasant abundance was negatively associated with patch density of nesting habitats such as CRP-grassland and other grasslands (e.g., rangeland). Local habitat conditions are important to pheasant dynamics as well as landscape composition and configuration, which both effect survival and recruitment (Perkins et al. 1997, Clark et al. 1999, Schmitz and Clark 1999). Therefore, using radio-marked birds may be a better means to quantify the importance of CRP-grasslands and other reproductive habitats.

Pheasants are often associated with mixed agricultural and grassland habitats (Trautman 1982, Patterson and Best 1996) making them good indicators of change in agricultural landscapes and successional habitat provided by CRP-grasslands (Nielson et al. 2008). Multiple studies have suggested a landscape composition of 50%−70% agriculture intermixed with 30%−50% grassland is an ideal habitat matrix for optimal pheasant production (Trautman 1982, Riley 1995, Haroldson et al. 2006). Our study documented a lower percentage of row crops at pheasant locations than these previous estimates, although this may be simply a difference in characterization of the landscape (i.e., row crop versus all agricultural practices). The positive association between pheasant counts and percent row crop mirrors previous research suggesting agriculture intermixed with grassland habitats is beneficial. While percent row crop positively influenced pheasant abundance, percent row crop squared was negative. This was understandable as row crop squared likely reached a threshold at which it negatively affected pheasant abundance.

Alternate habitats such as wheat and hay/alfalfa may provide adequate nesting and brood-rearing cover for pheasants in regions void of quality undisturbed grassland (Hammer 1973, Snyder 1984) such as intact grasslands and CRP-grasslands. Percent wheat (i.e., spring and winter wheat combined) was statistically significant in the top model, and positively influenced pheasant abundance. Percent hay/alfalfa was not significant in the top model, although it did increase model fit and positively influenced pheasant abundance. Loss of hay/alfalfa was minimal, and the lack of temporal variation may provide insight as to why it was not significant in the model. Chapter 1 documented that both wheat and hay/alfalfa production were important to the presence of pheasants on the landscape in specific management regions of South Dakota, providing inference that the influence of these habitats on pheasant populations varies by region and agricultural practice. The relationship between alternative reproductive habitats such as wheat and hay/alfalfa production and pheasant abundance was likely sensitive to cultivation, tillage, haying regime, and stem height influences (Snyder 1981, 1984, Rodgers 2002), and may be better evaluated at a smaller scale (i.e., separate study areas where wheat and hay/alfalfa production is dominant and/or minimal).

Large-scale wildlife monitoring programs such as the South Dakota August roadside survey were designed to quantify changes in a population index for management purposes (Nusser et al. 2004, Guidice and Haroldson 2007). Unfortunately, existing wildlife monitoring programs are not necessarily designed to address changes in land use and other environmental variables over time. In our study, SDGFP brood-surveys were dispersed across the landscape evenly (84 routes in 44 counties), although routes were selected non-randomly and only sampled pheasants along established, long-term pheasant routes; therefore, routes may not represent non-sampled areas. Also, data were collected along survey routes 1–5 times per year, with the highest count reported in our analyses. Because the number of pheasants observed on a given route can be highly variable (Kozicky 1952, Rice 2003), the magnitude of pheasant response and land use changes may not be reflected by traditional roadside survey counts. Nevertheless, due to timeliness of large-scale changes in land use, these data provide valuable information to address current associations with land use.

We contend the use of roadside brood-survey data be used with caution when assessing the relationship between population abundance and change in habitat and configuration and percentage across a large spatial scale. Landscape spatial patterns and wildlife populations are complex and can occur at multiple spatial and temporal scales (Johnson and Igl 2001, Bakker et al. 2002); therefore, dectability may be an issue with roadside surveys. Effective modeling of changes in abundance from a "snap-shot" in time across a regional scale may not represent the true relationship certain habitats such as CRP-grasslands have on wildlife populations. Likewise, due to ever changing policies and Farm Bill programs over large geographic regions, it is difficult to obtain data sets that accurately reflect changes in landscape composition and use at a local scale. For example, Chapter 1 found that the presence of pheasants was positively associated with CRP-grassland but varied across the region when habitat variables were interacted with management units. Although beneficial in quantifying the relationship across a geographic region, these types of analyses are often hard to interpret and use for practical management applications. Variation in climate, accurate spatial data sets, and observer bias may contribute to the complexity of modeling large-scale land use changes and wildlife populations (Brennan and Kuvlesky 2005, Winter et al. 2006).

Similar to recent efforts (e.g., Nusser et al. 2004, Haroldson et al. 2006, Nielson et al. 2008), we attempted to link change in land use across a large, regional scale and pheasant abundance. Haroldson et al. (2006) reported an increase of 12.4 pheasants per route in spring and 32.9 pheasants per route in summer with an increase of 10% grassland habitat to the landscape. Our results mirrored this response, although at a lesser magnitude. Because land use varies greatly from the Missouri River (i.e., predominantly wheat and cattle grazing agriculture) to the eastern border (i.e., predominantly row crop agriculture; Chapter 1, Smith et al. 2002), the importance of CRP-grassland to pheasant abundance likely differs across eastern South Dakota. Study areas evaluated by Haroldson et al. (2006) were dominated by row crop agriculture, likely increasing the importance of CRP-grasslands to pheasant abundance; whereas our modeling effort attempted to quantify the relationship between pheasants and CRP across a large geographic region characterized by multiple land use practices. Similarly, spring precipitation was greatest in 2007 (i.e., ≥70 cm, although varied greatly across eastern South Dakota) and winter snowfall was greatest in 2009 and 2010 (i.e., ≥320 cm, although varied greatly across eastern South Dakota; Chapter 1), likely influencing pheasant populations. While our findings support other research that indicated the CRP and pheasant abundance was positively associated, our effect size of the response may have been diluted by other concurrent land use changes and annual weather events.

During periods characterized by changes in Farm Bill policy that effect land use over a large geographic region, it will be important in the future to identify methodology that will accurately address species specific-habitat issues as they arise. We suggest designing future studies using repeated, multiple transects (Haroldson et al. 2006) and radio-telemetry (Leif 1995, Clark et al. 1999) in geographically unique locations to evaluate the relationship between pheasants and Farm Bill dependent habitats such as CRP.

MANAGEMENT IMPLICATIONS

Our results suggest that higher numbers of pheasants are associated with increased establishment of CRP-grasslands in fewer patches (i.e., single, larger patches) in a given landscape. We encourage continued support for the CRP, prioritizing conservation efforts and funding in landscapes dominated by row crop agriculture (>70%) to increase pheasant abundance and support other wildlife species such as nesting song-birds, waterfowl, and white-tailed deer. In regions such as eastern South Dakota, pheasant population persistence is not directly tied to one habitat such as CRP as it is in regions such as Iowa and Minnesota where row crop agriculture dominates the landscape. Continued loss of CRP-grasslands, specifically in landscapes closer in proximity to the eastern border of South Dakota, could lead to continued decreases in pheasant populations; therefore, it is important to understand the relationship between pheasants and the CRP during a period when large amounts of CRP-contracts expired. As Farm

Bill policy changes, continuing efforts to document this relationship in areas where the CRP may influence pheasant populations will be important for wildlife managers and policymakers alike.

ACKNOWLEDGMENTS

Funding for this project was provided by Federal Aid in Wildlife Restoration (Project W-75-R, No. 7539), administered through South Dakota Department of Game, Fish and Parks, and by the South Dakota Agricultural Experiment Station. We appreciate the support provided by the Department of Natural Resource Management (formerly the Department of Wildlife and Fisheries Sciences) at South Dakota State University. We thank J. White, D. Todey, M. Estey, R. Williamson, C. Marsh, T. Kirschenmann, M. Kjellsen, and P. Bergmann for data acquisition, collaboration, and technical assistance. We also thank A. Solem, A. Stegemen, and L. Swanson for many tedious hours spent digitizing habitat patches. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the United States Government.

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Table 2.1. Land use definitions of habitat patches discernible from historic aerial imagery.

Land Use	Definition	Code
Hay/Alfalfa	Grass, alfalfa, clover, or a grass-legume mix harvested as a crop as evidence by color, texture, and uniform plant cover, usually harvested twice annually (presence of mechanical haying pattern evident).	HA
Disturbed Grassland	Mixed native herbaceous plant cover heterogeneous in color and texture, often showing evidence of grazing (e.g., trails along fence lines or to gates, water, our buildings); trees and shrubs may or may not have been present at low densities (<25% cover).	GRASS
Undisturbed Grassland	Mix of cool-season grass and forb species and warm-season native species planted on previously cropped land (e.g. Conservation Reserve Program lands, state and federal management areas); generally undisturbed but may be hayed or grazed intermittently.	CRP

Table 2.2. Cropland Data Layer (CDL) 2006−2010 classifications and assigned categories used for analysis.

Land Use Category	CDL 2006−2009 (grid code) Classifications	Code
Row Crop	(1)-Corn, (4)-Sorghum, (5)-Soybeans, (6)-Sunflowers, (12)-Sweetcorn	RC
Wheat	(23)-Spring Wheat, (24)-Winter Wheat, (21)-Durum Wheat	WHEAT
Wetlands	(87)-Wetlands (190)-Woody Wetlands[a], (195)-Herbaceous Wetlands[a]	Wetl

Table 2.3. Final variables and definitions used to estimate pheasant abundance in eastern South Dakota, USA, 25 July – 15 August, 2006−2010.

Variable	Definitions [a, b, c]
Pheasant Count	Sum of rooster, hen, and brood counts at the route level
AM	Mean patch size (ha) of all habitats at landscape level
[b]CRP	Percent CRP-grassland and state/federal grassland
[b]CRP^2	Percent CRP-grassland and state/federal grassland squared
[b]CRP^2*RC	Percent CRP-grassland and state/federal grassland squared interacted with percent row crop
[b]CRP_{PD}	Patch density (# patches/100 ha) of [c]CRP-grassland and state/federal grassland at 1000-m
GRASS	Percent disturbed grassland (rangeland and pastureland)
$GRASS_{PD}$	Patch density of grass
HA	Percent hay/alfalfa
HA_{PD}	Patch density of hay/alfalfa
LSI	Landscape shape index
PD	Patch density (#patches/100ha) of all habitats at landscape
RC	Percent row crop
RC^2	Percent row crop squared

Table 2.3. continued.

Variable	Definitions [a, b]
RC_{PD}	Patch density of row crop
Wetl	Percent wetland
WHEAT	Percent wheat (spring + winter)

[a] All variables measured at 1000-m buffer (area = 314.2 ha) of a pheasant observation

[b] Conservation Reserve Program

[c] All variables were averaged by brood-survey route 2006–2010.

Table 2.4. Change in habitat categories (ha) within 1,000-m buffer of 84 brood-survey routes used in eastern South Dakota, 2006−2010.

Land Use [a]	2006–2007	2007–2008	2008–2009	2009–2010	2006–2010
CRP	286	-2,649	-356	-2,829	-5,547
Grass	8,305	-7,324	-1,105	-4,435	-4,559
Hay/Alfalfa	1,391	512	-27	-3,637	-1,761
Row Crop	2,756	6,118	-2,763	18,109	24,220
Wheat	1,897	2,609	-13,056	-4,748	-13,297
Woody Vegetation	753	88	9	220	1,071

[a] Definition of variables in Table 2.3.

Table 2.5. Mean change in habitat categories (ha) within a 1,000-m buffer of a pheasant location[b] used to estimate pheasant abundance in eastern South Dakota, 2006−2010.

Row Labels [a]	2006-2007	2007-2008	2008-2009	2009-2010	2006-2010
CRP	-0.3	-4.8	1.9	-1.5	-4.6
Grass	9.5	6.0	0.7	-1.5	14.7
Hay/Alfalfa	2.7	2.5	-1.9	1.3	4.6
Row Crop	-5.8	-5.7	1.7	-3.4	-13.2
Wheat	0.2	2.7	-9.2	6.1	-0.1

[a] Definition of variables in Table 2.3.

[b] n = 9,724 pheasant locations

Table 2.6. Final variables (including mean, SE, and range) used to predict pheasant abundance in eastern South Dakota, USA, 2006−2010 at a 1000-m scale (*n* =313).

Variable[a]	Mean	SE
Pheasant Count	76.597	3.421
AM	5.192	0.100
CRP	6.880	0.307
CRP^2	76.779	7.068
CRP^2*RC	2439.800	204.800
CRP_{PD}	0.794	0.032
GRASS	20.972	0.661
$GRASS_{PD}$	2.134	0.051
HA	5.358	0.209
HA_{PD}	0.531	0.019
LSI	7.084	0.370
PD	21.227	0.552
RC	37.659	0.946
RC^2	1697.1	79.3
RC_{PD}	2.003	0.075

Table 2.6. continued.

Variable[a,]	Mean	SE
Wetl	2.848	0.190
Wheat	7.095	0.431

[a] Variable definitions in Table 2.3.

Table 2.7. Negative binomial linear regression models used to predict pheasant abundance in eastern South Dakota, USA, 2006−2010 at a 1,000-m scale.

Model[a]	*K*[b]	AIC[c]	ΔAIC[d]	*w*[e]	Pearson /df
CRP + CRP_{PD} + RC + RC^2 + GRASS + $GRASS_{PD}$ + HA + HA_{PD} + Wheat	10	3086.12	0.00	1.00	1.121
CRP + CRP_{PD} + RC + G + GPD + HA + HA_{PD} + Wheat + CRP^2 + CRP^2*RC	11	3121.53	35.41	0.00	1.102
CRP + CRP_{PD} + RC + GRASS + $GRASS_{PD}$ + HA + HA_{PD} + Wheat	9	3138.77	52.65	0.00	1.058
CRP + RC + GRASS + HA + Wheat + CRP*RC	7	3142.33	56.20	0.00	1.058
CRP + RC + RC^2	4	3144.86	58.74	0.00	1.145
CRP + RC + RC^2+ RC^2*CRP	5	3144.93	58.81	0.00	1.143
CRP + RC + GRASS + HA + Wheat + CRP^2 + CRP^2*RC	8	3146.05	59.93	0.00	1.081
CRP + GRASS + HA + Wheat + Wetl	6	3158.87	72.75	0.00	1.072
CRP + RC + GRASS + HA + Wheat	6	3159.16	73.04	0.00	1.056
CRP + GRASS + HA + Wheat	5	3159.58	73.45	0.00	1.055
CRP + GRASS + RC + Wheat	5	3161.29	75.17	0.00	1.068
CRP + RC + Wheat + HA	5	3163.03	76.91	0.00	1.060

Table 2.7. continued.

Model[a]	K^b	AIC[c]	ΔAIC[d]	w^e	Pearson/df
CRP + CRP_{PD} + RC + RC_{PD}	5	3178.18	92.05	0.00	1.100
CRP + GRASS + RC	4	3194.38	108.25	0.00	1.112
CRPPD + $GRASS_{PD}$ + HAPD	4	3235.58	149.46	0.00	0.960
PD + LSI + AM	4	3294.39	208.27	0.00	1.063
CRP	2	3297.83	211.71	0.00	1.110

[a] Description of variables found in Table 2.3; [b] Number of parameters; [c] Akaike's Information Criterion (Burnham and Anderson 2002); [d] Difference in AIC relative to minimum AIC; [e] Akaike weight (Burnham and Anderson 2002); [f] Pearson/df = goodness of fit

Table 2.8. Parameter estimates (*β*), standard errors, and significance tests from the top-ranked negative binomial regression model used to predict pheasant abundance in eastern South Dakota, USA, 2006−2010 at a 1,000-m scale.

Parameter[a]	β	SE	Wald chi-square	*P*
Intercept	3.6005	0.4463	65.08	<.0001
CRP	0.0117	0.0095	1.52	0.2179
CRP_{PD}	-0.2270	0.0931	5.94	0.0148
RC	0.0574	0.0098	34.56	<.0001
RC^2	-0.0009	0.0001	63.05	<.0001
GRASS	0.0090	0.0061	2.22	0.1363
$GRASS_{PD}$	-0.0999	0.0480	4.33	0.0374
HA	0.0036	0.0134	0.07	0.7897
HA_{PD}	-0.1096	0.1234	0.79	0.3744
WHEAT	0.0197	0.0074	7.17	0.0074

[a] Description of variables found in Table 2.3.

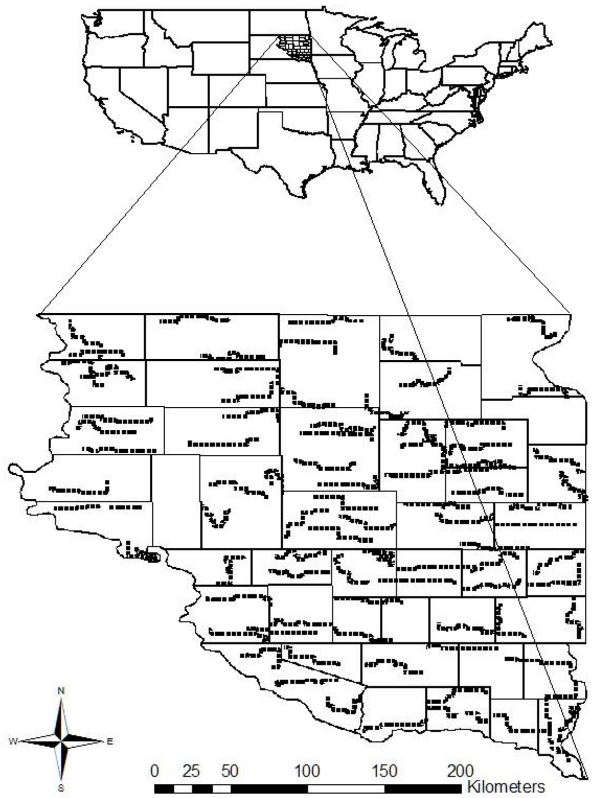

Figure 2.1. Ring-necked pheasant (*Phasianus colchicus*) brood-survey routes (84) conducted annually from 25 July to 15 August 2006 – 2010 in eastern South Dakota, USA where we studied the effects of changes in land use on the abundance of pheasants.