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Seasonal Resource Selection, Site-Specific Brood Predictors, And Nest Characteristics Of Greater Prairie-Chicken Hens In Northwestern Minnesota

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SEASONAL RESOURCE SELECTION, SITE-SPECIFIC BROOD PREDICTORS, AND NEST CHARACTERISTICS OF GREATER PRAIRIE-CHICKEN HENS IN NORTHWESTERN MINNESOTA

By

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This thesis, submitted by Nathaniel G. Emery in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

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Date

PERMISSION

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ABSTRACT

Greater prairie-chickens, *Tympanuchus cupido pinnatus*, are in decline across the majority of their already receding range due to changing land use patterns and habitat fragmentation. The Agassiz Beach Ridge region of northwestern Minnesota harbors one of the only sustained to increasing populations of prairie-chickens in the country due to the conversion of marginal agricultural lands to grasslands and through conservation entities securing tracts of land allowing for habitat stability and dispersal.

Nesting and brood-rearing habitats are the most limiting factors for population sustainability. Hens were marked with radio transmitters on booming grounds and at nest sites discovered by nest-dragging. Their reproductive ecology is described using three methods; habitat use and selection by brood-rearing hens, local invertebrate and vegetative predictors of brood use, and nest site characterization and success.

By combining remotely-sensed imagery with estimated locations gathered by triangulation I was able to evaluate habitat use and selection of brood-rearing hens in 2008 and 2009. There are signals, though not statistically significant, indicating differential habitat uses between successful and failed brood hens. Treed habitats were used more often than random by successful hens and completely ignored by unsuccessful brood hens Successful brood hens used soybeans in a random manner while unsuccessful brood hens selected soybean fields suggesting a landscape with greater amounts of grassland habitats would be more beneficial than one dominated by row crop agriculture.

For a site-specific view of brood hen use locations, hens were flushed 14 days after the nest hatched and again every 10 days until the brood reached independence in 2008 and 2009. At each flush location invertebrates, vegetation cover, vegetation density and litter depth were measured. Logistic regression analyses showed five parameters that could predict brood presence: greater percent coverage of introduced grasses, greater percent coverage of native forbs, more invertebrates less than 10 mm in length, fewer Orthopterans less than 10 mm in length, and fewer individuals from "Other" invertebrate orders. Site characteristics were recorded at the time of discovery for 150 prairie-chicken nests during the 2007-2009 nesting seasons. Apparent nest success decreased from 47.73% in 2007 to 35% in 2008 to 28.26% in 2009. Nests were evaluated based on three immediate vegetation types; native, smooth brome, and other introduced species. Litter depth and percent overhead coverage were not significantly different among vegetation types. Mean Visual Obstruction Readings were greater at hatched nests than failed nests for all three habitat types. Nests dominated by native vegetation were almost significantly less screened than nests found in smooth brome and other introduced vegetation. Clutch sizes of nests dominated by smooth brome were significantly larger than the other vegetation types

These findings suggest that landscapes with grasslands comprised of introduced grasses and native forbs that produce an abundance of invertebrates less than 10 mm are most likely to improve prairie chicken brood rearing success. To increase nesting success habitats should provide horizontal and vertical cover similar to that of an idle smooth brome planting that provides residual cover during nest initiation and grows quickly to conceal the hen during incubation. Greater vertical concealment appears to increase the likelihood of a nest hatching.

CHAPTER I

INTRODUCTION

GREATER PRAIRIE-CHICKEN ECOLOGY

The tallgrass prairie is highly sought for agricultural development due to the relative lack of topography and highly fertile soils. The intensity of agricultural conversion and anthropogenic development since European settlement has reduced this once vast ecosystem to less than one percent of its original extent (Savage 2004) making it one of the most endangered ecosystems in North America (Noss et al. 1995, Samson and Knopf 1996). Ostlie et al. (1997) report that the long-term survival of 464 Great Plains species is uncertain, primarily due to the loss of prairie habitat.

The greater prairie-chicken (GPC), *Tympanuchus cupido pinnatus*, is an area-sensitive grouse (Hamerstrom et al. 1957, Toepfer 2003) that requires large amounts of grasslands for survival. They are an umbrella species (Poiani et al. 2002), with habitat requirements that encompass habitats necessary for other prairie-obligates. As a resident gamebird, prairie-chickens depend on quality grasslands to satisfy the various stages of their life history within a relatively small area (Hamerstrom and Hamerstrom 1973, Svedarsky et al. 1997). The historic distribution of the prairie chicken was from the prairie provinces of Canada in the north, to Texas in the south, Colorado to the west, and east to Ohio (Schroeder and Robb 1993, Ross et al. 2006). Although present, GPCs in the northern range did not exist in great numbers until after the arrival of modern agriculture (Ross et al. 2006). However, intense row crop production, urban and exurban development, introduction of exotic species, fire suppression, and vegetation succession have combined to extirpate GPC from all but 11 states (Svedarsky et al. 1999, Schroeder et al. 2004).

In lek mating species, aggregated males perform at a communal display site. These charismatic displays occur in open habitats such as recently burned areas (Patten et al. 2007), cropland (Merrill et al. 1999), or in low vegetation such as that found on ridge tops of glacial deposits (Emery unpublished data), and windblown wetland vegetation (Emery unpublished data). The number of cocks occupying a booming ground is often an indicator of the quality of the surrounding habitat (Westemeier 1971). Most hens tend to nest in habitats within a 1 mile (1.6 km) radius after copulation at one of the leks (Schroeder 1993). Telemetry locations of non-booming ground observations were found within 1.2 miles (1.9 km) from a booming ground 90% (n=35,000) of the time (Toepfer 1988). Nesting habitat is often established grasslands with vertical concealment (Robel et al. 1970) of 2.0 dm and <25% litter accumulation (McKee et al. 1998). These grasslands must also be in relatively close proximity to brood rearing cover (Svedarsky and Van Amburg 1996) which may sometimes be shared with nesting cover but is often different. Brood rearing cover must provide overhead concealment from aerial predators, ease of movement at ground level for locomotion and terrestrial predator escape, heavier cover for escape and thermoregulation, open places for dusting and loafing, and abundant invertebrates (Svedarsky et al. 2003). Finally, local habitats must provide heavy residual cover for nighttime roosting and winter protection (Newell et al. 1988). Since females are considered the dispersing gender, the abundance and magnitude of leks is an indicator of the ability of the localized area to satisfy all facets of GPC ecology. Of these requirements, nesting and brood rearing habitats are the most critical factor inhibiting GPC populations (Hamerstrom et al. 1957, Kirsch 1974, Wisdom and Mills 1997, Svedarsky et al. 1999).

The Toepfer model (Toepfer et al. 1990) suggests that GPCs need 4,000 acres (1,619 ha) of suitable grassland to sustain a minimal viable population. That number was based on northern populations which are faring about the best of all state populations as Minnesota and Colorado have increasing populations while Nebraska remains stable (Vodehnal and Haufler 2007). The acquisition or maintenance of that many grassland hectares prohibits the restoration or expansion of populations in many states due to land use and private land ownership issues. Most reductions and extirpations can be attributed to agricultural conversion (Hamerstrom et al. 1957). Therefore, targeting acquisition or management towards priority grasslands most at risk of conversion will make limited conservation dollars go the furthest (Stephens et al. 2008).

GPCs are valued for three primary reasons; 1) their economic importance via ecotourism interest in their reproductive displays, 2) their presence is an indicator of a complete ecosystem due to their diverse, year round habitat requirements, and 3) their value as a highly sought after game species. In Minnesota, the GPC is listed as a Species of Special Concern (Coffin and Pfannmuller 1988). A small remnant population exists in the central part of the state (Svedarsky et al. 1999) but the bulk of GPC exist in the Agassiz Beach Ridges region (Erickson and Farmes 1960, Svedarsky et al. 1997, Merrill et al. 1999). Virtually complete agricultural conversion of the Red River Valley to the west has inhibited dispersion between the Polk County, Minnesota population and a small translocated population in Grand Forks County, ND. Forest succession has been advancing from the east limiting the Minnesota population to a narrow (3-30 km) north-south corridor of suitable habitat along the beach ridges of glacial Lake Agassiz. Highly droughty and rocky ridge tops paired with heavy seepage zones between ridges makes this area difficult for cultivation. The addition of over a hundred thousand acres of Conservation Reserve Program land to the existing grassland network of governmental agency (> 16,000 hectares) and non-governmental conservation (>12,000 hectares) holdings has made Minnesota one of only two increasing GPC populations in the nation (Vodehnal and Haufler 2007).

The objectives of this study are to use different spatial scales to describe what habitats successful GPC brood hens are using in one of North America's currently expanding GPC populations. The desire is that these findings be made available to, and recommendations implemented by, wildlife managers throughout the country to curb the rapid decline of a charismatic and flagship grassland grouse.

CHAPTER II

SEASONAL HABITAT USE AND SELECTION OF GREATER PRAIRIE-CHICKEN FEMALES AND BROODS IN NORTHWESTERN MINNESOTA

INTRODUCTION

The tallgrass prairie landscape has been transformed from contiguous tracts of grass to a patchwork of habitat types impacted by agriculture, urbanization, and other land uses (Vodehnal and Haufler 2007). Approximately 1% of the native prairie remains and the decline is evidence of intensive anthropogenic habitat fragmentation and intensifying land use practices (Savage 2004). As an area-sensitive grassland-obligate (Hamerstrom et al. 1957), greater prairie-chickens (GPC), *Tympanuchus cupido pinnatus*, are experiencing a similar steep decline across the majority of their range (Vodehnal and Haufler 2007). As a species with limited mobility, particularly during the brood-rearing period, a single landscape must provide space, food, and cover throughout the year (Hamerstrom and Hamerstrom 1973). In early spring birds use low vegetation or disturbed areas for their communal lek displays (Svedarsky et al. 2003). Females visit leks to copulate and usually nest within 1.6 km (Svedarsky 1979). Nesting habitat typically consists of residual vegetation to construct a nest bowl and aid in concealment from predators during incubation (Svedarsky et al. 2003). Once eggs hatch, hens will often move to a habitat more advantageous for chicks (Svedarsky et al. 2003). This brood-rearing habitat is more open at ground level for dusting and chick movement yet has enough structure to conceal chicks from aerial and terrestrial predators. It must also provide abundant insects for chicks that rely almost solely on invertebrates to fuel development during their first weeks (Savory 1989). Dense cover for roosting and escape is also preferred within close proximity to foraging and loafing sites (Newell et al. 1988, Toepfer 2003). These same landscapes must finally provide a winter food source in the northern range where GPC generally cannot survive solely on native forage and rely on waste grains (Hamerstrom et al. 1941).

Prior to European settlement, GPC in Minnesota primarily occupied the southeastern corner of the state (Partch 1973, Ross et al. 2006). Populations of GPC erupted as they followed the plow (Svedarsky et al. 2003). Thriving in the prairie-agriculture landscape, by 1900, GPCs inhabited most counties in Minnesota where suitable grasslands existed (Svedarsky et al. 1999). The decline of GPC in Minnesota began with extensive habitat conversion through intensified agriculture and plant succession reclaiming many previously forested tracts (Partch 1973). GPC have maintained their presence in the northwestern part of the state along the beach ridge deposits of ancient glacial Lake Agassiz. Rocks and sandy soil have made this landscape challenging for cultivation thus saving much of the original prairie from conversion to other land uses (Merrill et al. 1999). Privately held prairie parcels in concert with acquisition of grasslands by conservation agencies and non-government organizations harbor the greatest opportunity for sustaining GPC populations in the state (Svedarsky et al. 1999).

During the critical brood-rearing period, chicks are most vulnerable to mortality from predation and exposure (Toepfer 2003). If chicks can survive the first 60-days of life, they are much more likely to survive to adulthood (Toepfer 2003). Identification of habitat types that are preferentially selected or avoided could influence land use decisions to benefit GPC in their northern range. The occupation of an area is termed 'use,' whereas the decision of which habitat to use is 'selection' (Johnson 1980). Organisms may select resources differently when evaluated at multiple spatial scales (Mayor et al. 2009). In this study, second- (home range) and third-order (habitat type) selection (Johnson 1980) of brood-rearing hens was evaluated using a Geographic Information System (ArcGIS, Environmental Systems Research Institute, Redwoods, California). Seasonal selection or avoidance of landscape attributes can influence survival and thus maintenance of GPC populations. Investigation of factors that contribute to the stability of this population during the brood-rearing period could help focus efforts for struggling or isolated populations.

METHODS

Study Area

This study was conducted mostly on the Glacial Ridge Complex (Figure 1), which lies among the ancient beach ridges of Glacial Lake Agassiz. The lake receded from northwestern Minnesota in stages leaving narrow bands of beach deposits around 12,000 years ago. The Glacial Ridge Complex, comprised of the Glacial Ridge National Wildlife Refuge (GRNWR) and adjacent grasslands, lies approximately 12 miles southeast of Crookston in Polk County, Minnesota.

GRNWR began as The Nature Conservancy's (TNC) Glacial Ridge Project, the largest tallgrass prairie and wetland restoration project in North America (Gerla et al. 2012). Restoration of this agriculturally-dominated landscape was initiated in 2000 with a goal of over 8,000 acres of restored wetlands and more than 16,000 acres of restored tallgrass prairie. The resulting complex encompasses nearly 35,000 acres and includes TNC property, transferred parcels of GRNWR, adjoining state Wildlife Management Areas and Scientific and Natural Areas, and private grassland parcels. Between the core restoration area and existing conservation parcels is an agricultural mosaic with interspersed Conservation Reserve Program (CRP) units and agricultural crops. To the west of the study area lies the fertile soils of the Red River Valley, comprised almost entirely of intensive agricultural uses, which provides limited suitable habitat for GPCs.

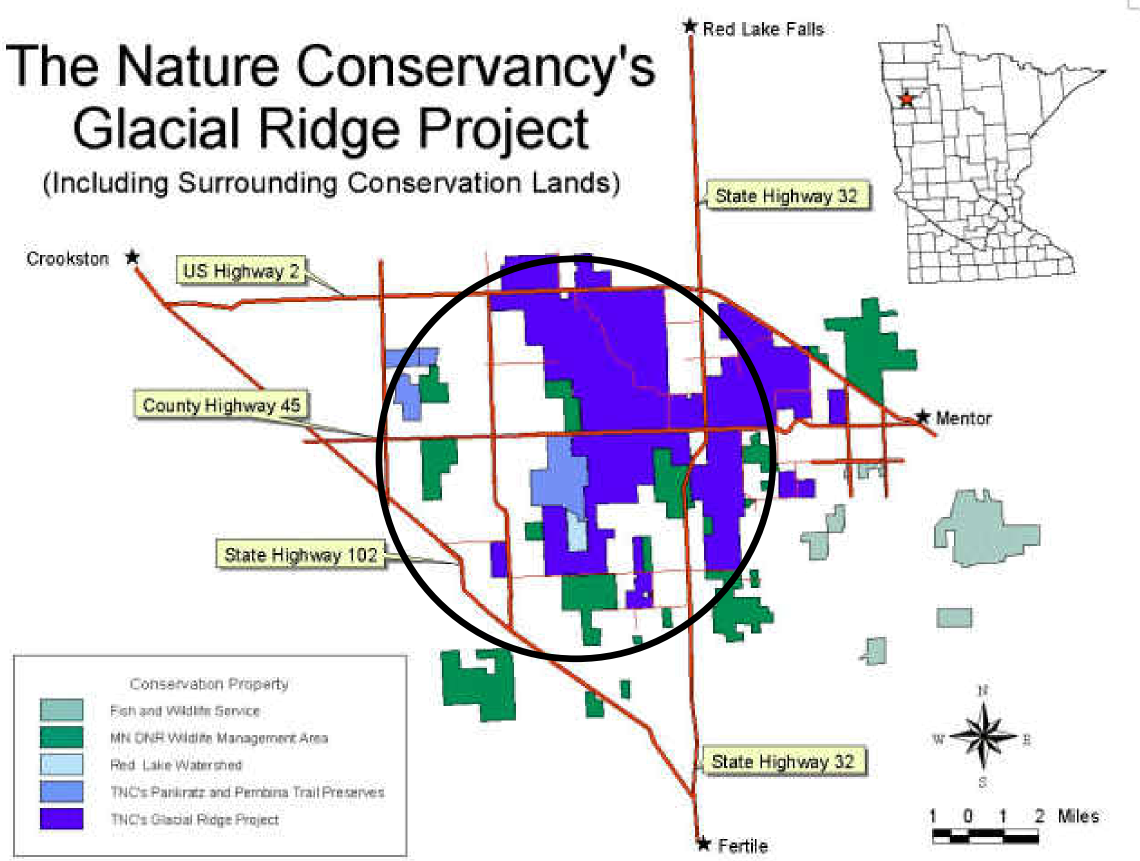

Figure 1. The Nature Conservancy's Glacial Ridge Project (Including Surrounding Conservation Lands). 2004 © TNC. Reprinted with permission from The Nature Conservancy. Adjacent properties were also studied but greater prairie-chickens generally stayed within the area of the black circle.

To the east of the study area is the beginning of the deciduous forest which is also unsuitable for GPCs leaving a ribbon of habitat in a north-south orientation.

Capture

GPC females were captured in April and May of 2008 and 2009 with walk-in traps from eight (five in 2008, three in 2009) booming grounds (Schroeder and Braun 1991). Hens were also captured in long-handled nets (Loos and Rohwer 2002) and with funnel traps (Dietz et al. 1994) on nests discovered by a chain-dragging (Higgins et al. 1977). Lek trapping was primarily on the Glacial Ridge Complex and nest-trapping was primarily conducted on private CRP grasslands within 3 miles of GRNWR. Necklace-style VHF radio transmitters (Model TS25; Telemetry Solutions, Concord, California) were attached (Amstrup 1980). Hens were generally released within 30 minutes after trapping. Each radio weighed between 17 and 19 grams and did not exceed 3% of the hen's body weight. Methods were approved by University of Minnesota Institutional Animal Care and Use Committee (IACUC) proposal #0706A09724 and University of North Dakota IACUC proposal #0801-6.

Apparent Nest Success and Location Estimation

Hens were monitored daily during the pre-nesting and nesting periods using triangulation (Heezen and Tester 1967) via a truck-mounted, null-peak antenna system (Cox et al. 2002). A laptop inside the truck integrated an antenna (Advanced Telemetry Systems, Isanti, Minnesota), digital compass (Azimuth 1000; KVH Industries, Middletown, Rhode Island), and handheld Global Positioning System (Garmin International Inc., Olathe, Kansas) to gather azimuths for triangulation. Location of a Signal software (Ecological Software Solutions, Sacramento, California) uses a maximum-likelihood estimator to calculate real-time location estimates. If the error ellipse was greater than 2000 m^2 after three bearings, an additional azimuth was taken until error fell below 2000 m^2. Hen locations within 40 m of one another for 3 consecutive days were indicative of incubation. Nests not discovered by chain dragging were located with the aid of a hand-held receiver (R4000; Telemetry Solutions, Concord, California) and 3-element yagi antenna. Hens were monitored daily until they were absent from the nest site during the typical incubation hours of 8 a.m. to 4 p.m. (Svedarsky 1983) at which time the nest was revisited and fate of hatch, depredation, or abandonment was assigned to each nest. A nest was considered successful if one or more eggs hatched from the clutch.

Hen locations were estimated 3-4 times per week after nest fate was determined. Telemetry monitoring each day began for a different bird to stagger location estimates to avoid temporal bias. Hens were also located via handheld telemetry 14 days post-hatch and approximately every 10 days after that until 8 weeks post-hatch to determine brood presence or absence (Pitman 2003) adding 5-6 additional locations for each hen.

Habitat Use and Preference

A fixed kernel density estimator (KDE, Seaman and Powell 1996) using Least Squares Cross Validation (Worton 1995, Seaman and Powell 1996) in the Home Range Tools extension for ArcGIS (Rodgers et al. 2005) was used to investigate each brood hen's seasonal range area (hectares) and availability of habitat types within seasonal ranges at the 95% contour level. KDEs are the most preferred method of seasonal range estimation (Kernohan et al. 2001). They may overestimate utilization distribution area (Downs and Horner 2008) but will fully encompass true use. Swihart and Slade (1997) found that KDEs were not as sensitive to autocorrelation bias as the more historically used minimum convex polygon. To investigate the critical brooding period, only locations from hatch to independence (approx 60 days) were included when evaluating habitat use and selection.

ArcMap 9.2 with the Hawth's Tools Extension was used to clip each individual seasonal range from the Cropland Data Layers (CDLs, USDA 2008, USDA 2009) habitat type maps developed through interpretation of remotely-sensed satellite imagery. The CDLs have a 56-meter resolution so habitat types near linear edges such as roads or habitat transitions were either over or underrepresented using this method. The CDLs were used to identify the dominant habitat type within a patch but individual habitat type polygons were digitized using aerial photos with one meter resolution from the National Agriculture Imagery Program (Farm Service Agency 2008, Farm Service Agency 2009). Residential properties and abandoned farmsteads were often combined with the Tree habitat type because of the mature tree component that dominated these sites. Open water was excluded from analysis as it was unavailable for GPC use. Road right-of-ways were combined with the other grassland habitats. Six habitat types were retained for analysis (Table 1).

Habitat types selected by successful brood hens at a rate greater than random show a preference; those selected at a rate lesser than random show avoidance.

Statistical Analysis

A one-tailed t-test was used to compare whether seasonal range size of successful brood hens was smaller than seasonal range size of unsuccessful brood hens using the 95% KDE contour. Due to brood-rearing duties, seasonal ranges in Polk County have been found to be smaller for hens with chicks (Svedarsky 1979). A resource selection function (RSF, Manley et al. 2002:78) was used to test for habitat preference by comparing the ratio of individual hen use locations in each habitat type with the ratio of

Table 1. Six habitat type classifications available to brood-rearing greater prairie-chicken hens derived by remotely-sensed imagery from the United States Department of Agriculture's Cropland Data Layers for Polk County, Minnesota in 2008 and 2009.

Habitat Type	Description
Corn	Monotypic corn croplands
Grassland	Open landscapes dominated by grasses and forbs
Shrub	Shrubland habitats including snowberry (*Symphoricarpos spp.*) and willow (*Salix spp*.)
Small Grain	Monotypic small grain croplands, primarily wheat
Soybean	Monotypic soybean croplands
Tree	Deciduous trees including aspen (*Populus tremuloides*), green ash (*Fraxinus pennsylvanica*), and eastern cottonwood (*Populus deltoides*)

availability for each habitat type within each hen's seasonal range. In this RSF, the location estimates of individually marked hens are considered the habitat use locations and the collection of use locations for each hen during the brood-rearing period were used to create individual seasonal ranges that became the area of available habitats. This design allows the proportions of habitat types to differ between individuals because each RSF is normalized to 1 to simulate equal availability of each habitat type to each hen (Manly et al. 2002). Individual RSFs were then compared between successful brood hens and unsuccessful brood hens. When calculating an RSF value, establishing the sampling unit as each individual bird rather than all GPC use locations removes concern about autocorrelation (Aebischer et al. 1993) and prevents group effects from masking possible significant results.

RESULTS

Eighty-two hens were captured during this study using walk-in traps on leks (n= 33) and on nests discovered by chain drag (n= 49). One hundred six nests were discovered during our hen checks and nest dragging of which 34 hatched an overall apparent nesting success of 32.1% in 2008 and 2009. Brood flush checks beginning at 14 days post-hatch identified 14 of 21 nests had active broods in 2008 and 8 of 13 hatched nests had active broods in 2009. Of those broods, only five broods successfully fledged a total of fifteen chicks in 2008 and two broods fledged a total of three chicks in 2009.

Three hens were censored in 2008 and one in 2009 due to mortality or not enough locations for analysis. Seasonal ranges of successful brood hens were not statistically smaller than those of hens with failed broods in 2008 (Figure 2, two-sample t-test,

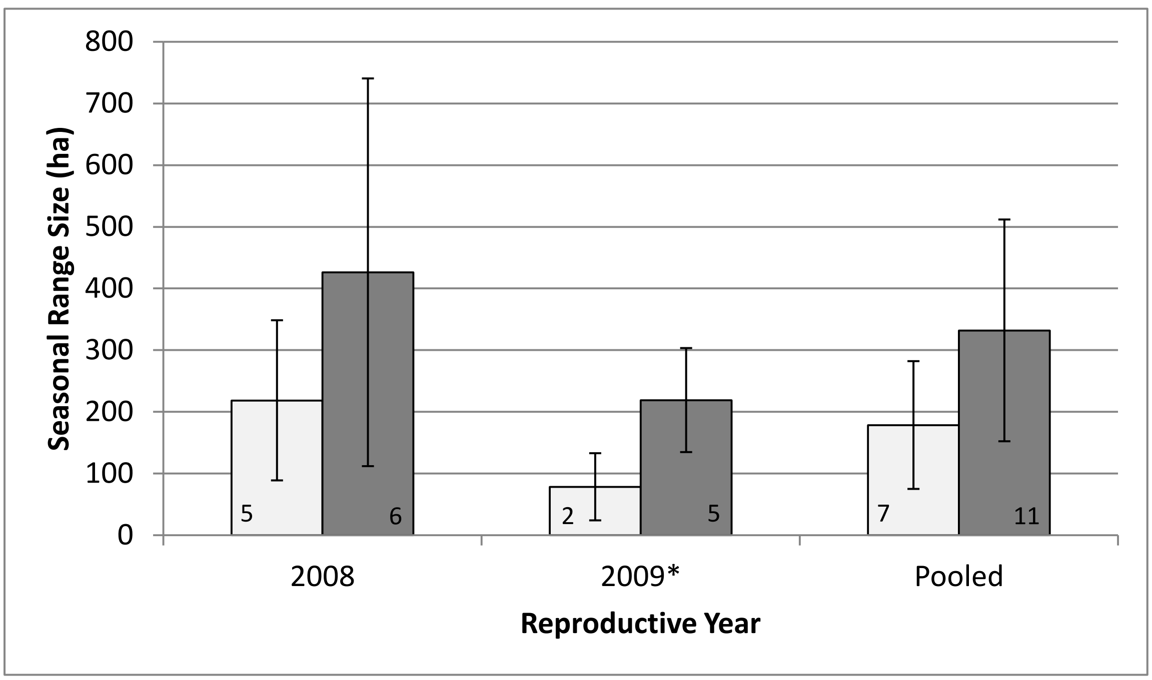

Figure 2. Comparison of mean seasonal range area of greater prairie-chicken hens that successfully reared broods to independence (white) and hens that lost their entire brood (gray). The (*) indicates that the means were significant using a one-tailed t-test with an alpha of 0.05. Error bars indicate 95% confidence interval. The number of hens in each group is listed in the lower corner of each bin.

than those of hens with failed broods in 2009 (Figure 2, two-sample t-test, t=2.7458, df=4.737, P=0.0215). During the entire study, home ranges of successful broods were not smaller than those of failed broods (Figure 2, two-sample t-test, t=1.4496, df=14.988, P=0.0839).

Due to non-normal distribution of the RSF data, Mann-Whitney tests were used to compare habitat RSF values for successful versus non-successful brood hens. A family-wise alpha value of 0.1 was used due to the small sample size and to allow for greater detection of a statistical signal. A comparison between successful and unsuccessful hens was made for each habitat type and the p value for each type was calculated. The Holm's sequential Bonferroni correction (Holm 1979) was used for multiple comparisons to determine adjusted p-values (Table 2). The test p-values were then arranged from smallest to largest and matched to the adjusted p-values, also in increasing order. If the test p-value was below the adjusted p-value, the habitat use was significant and each habitat type was evaluated until the test p-value exceeded the adjusted p-value.

Table 2. Mann-Whitney statistic, p-value, and Bonferroni-corrected p-value used to compare Resource Selection Function coefficients of habitat preference by successful versus unsuccessful greater prairie-chicken brood hens in Polk County, Minnesota in 2008 and 2009. Symbols beside the habitat type indicate preference of successful brood hens (+) or failed brood hens (-) of that habitat at an alpha of 0.05.

Habitat Type	W	*p*	Bonferroni Corrected *p*
Tree (+)	55	0.026	0.016
Soybean (-)	16	0.046	0.020
Grassland	24	0.211	0.025
Small Grain	50	0.305	0.033
Shrub	41	0.740	0.05
Corn	36	0.780	0.10

Hens were initially separated by which year they were marked to test for a year effect but the conservative nature of the Bonferroni test did not have enough power to identify any selection or avoidance of habitat types. When 2008 and 2009 hens were pooled, there was still no significant results although there does seem to be a signal suggesting trees were selected by brood hens and soybean fields were avoided (Table 2). Again, the conservative nature of the Bonferroni test and the family-wise alpha were unable to detect a significant difference but individually, both tree and soybean habitats had a p-value of less than 0.05.

When RSF values were normalized to one so all habitats were evaluated as being equally available, hens with failed broods did not use nor select wooded habitats (RSF mean = 0.00), whereas, successful brood hens selected tree habitat types (RSF mean = 0.266, random use = 0.167). All six use locations in tree habitat were in small clumps of tall deciduous trees with open grassland cover at ground level. Brood hen 150.450 was found with another hen and brood, discovered opportunistically, in an abandoned farmstead with green ash and eastern cottonwood trees and was surrounded by soybeans. The grass below the canopy of the trees was high-mowed with noticeably abundant grasshoppers. Brood hen 150.490 was near a clump of mature eastern cottonwood with grassland undergrowth and surrounded by soybeans which were stunted due to excessive ponding earlier in the spring. Successful brood hen 148.680 was located via telemetry on the very edge of an aspen clone surrounded by a mowed landscape restored from croplands to grasslands by TNC the year previous. 148.680's tree location may be an actual use location or it could have been an estimating error because the trees and the restoration both fell within the location estimate's error ellipse.

Soybean fields were used often by hens with failed broods (RSF mean = 0.425) and was significant before the Bonferroni correction (p=0.046). Hens that successfully raised broods used soybeans at a rate slightly less than random (soybean RSF mean =

0.160, random = 0.167). Successful brood hens averaged 8.14 locations per brood in soybeans which accounted for 26.64% of all hen locations. Unsuccessful brood hens averaged 13.45 locations per brood in soybeans which accounted for 43.40% of all hen locations. Number of locations per brood was very close with successful hens averaging 30.57 locations and unsuccessful hens averaging 31 locations.

DISCUSSION

Hens are more apt to increase movements after losing a brood because they are no longer limited in their movement by the requirements or abilities of the chicks (Svedarsky 1979, Newell 1987). Conversely, Syrowitz (2013) found brood hens had larger home ranges than failed brood hens and attributed the need to search for quality brood habitats for the increased brood hen movements. Ryan et al. (1998) found greater daily brood movement and larger home ranges for hens with broods in a prairie mosaic landscape versus a contiguous prairie landscape. Although the bulk of the study area was comprised of a contiguous prairie, capture efforts were focused on CRP nesting fields in the prairie mosaic around the Glacial Ridge Complex in an effort to capture the most hens. This may explain why 2008 and pooled seasonal ranges were not significantly different although the means were smaller than seasonal ranges of failed brood hens.

The idea of selecting tree cover is counterintuitive for a grassland species. Shrubs have been identified as an important component of the landscape for GPC as roosting and escape cover (Rice and Carter 1982, Svedarsky et al. 1997, Vodehnal 1999). However, tall, overstory woody habitats have not been positively associated with GPC before. Two of the three brood hens that were found in tree habitats actually spent 20 of 29 and 17 of 26 locations respectively in stunted soybean fields surrounding the tree clumps. The use of the tree habitat was probably not due to the canopy element but rather for the edge habitat it provided that likely harbored invertebrates. The third successful hen only had one location in tree habitat and that aspen clone actually had an active red-tailed hawk (*Buteo jamaicensis*) nest. Treed habitats are generally considered “hostile” due to the presence of raptor perches (Winter et al. 2001). Raptors will generally use these tree clumps for nesting or for perching to watch for small mammalian or bird prey. The landscape surrounding two of the used tree habitats was almost exclusively annual production agriculture and would not have harbored the same abundance of prey as a grassland or transition habitat. . This may be the first study to ever show a positive preference of GPCs to trees. Willow and aspen were used by GPC broods on this study area in the 1970s; potentially due to the shade they provide (Svedarsky 1979). Trees are otherwise universally considered a detriment within the GPC range (McKee et al. 1998, Niemuth 2000, Svedarsky et al. 2003, Winter et al. 2006).

Brood hens in a prairie mosaic in Missouri were most often found in croplands versus existing grassland tracts (Ryan et al. 1998). In most of the acquired GPC range, croplands also play a critical role, but only as a winter food source (Hamerstrom and Hamerstrom 1973). The avoidance of croplands is consistent with past studies in the northern GPC range (Svedarsky 1979, Newell 1987, Toepfer and Eng 1988, Keenlance 1998). Sixty-seven percent of brood locations in a 2009 Minnesota study were in grasslands, indicating the avoidance of cropland habitats (Syrowitz 2013). Matthews et al. (2011) also found that brood hens avoided croplands in a grassland-agricultural landscape in southeast Nebraska. Soybean fields where broods were successful had flood damage or other vegetative failure resulting in large pockets of open ground and a diversity of plant height. Soybeans occupied by hens without a brood were often tall and thick and birds flushed from tracks made by equipment spraying insecticides. Burger et al. (1993) found that the mean abundance of invertebrates in soybean fields were four times lower than all CRP mixes they sampled.

CONCLUSION

The Glacial Ridge Complex seems to have abundant available habitat for adult GPCs. Management of existing grasslands for local heterogeneity to satisfy the various life stages of the GPC is recommended. Despite successful hens showing a preference for trees, they are not a recommended landscape attribute for GPC habitats. The selection of tree habitats likely had to do with the transitional cover of the understory, not the vertical nature of the tree itself. Having a diverse landscape with multiple land uses within close proximity should provide for the nesting and brood-rearing requirements of GPC without introducing the negative features of trees. With the conversion of millions of acres from CRP to croplands, providing an agricultural component to landscapes in the GPC northern range is not a priority. As an umbrella species (Poiani et al. 2002), management of landscapes to promote GPC populations will have a cascade effect and benefit many other prairie-obligates.

CHAPTER III

SITE-SPECIFIC FORAGE AND VEGETATIVE CHARACTERISTICS AS PREDICTORS OF GREATER PRAIRIE-CHICKEN BROOD PRESENCE IN NORTHWESTERN MINNESOTA

INTRODUCTION

The tallgrass prairie region has been continually fragmented since early settlement, with approximately 1% of the native prairie remaining (Savage 2004). Consequently, the area-sensitive (Samson1980), grassland-obligate, greater prairie-chicken (*Tympanuchus cupido pinnatus*; hereafter GPC) has experienced similar sharp declines throughout their entire range (Svedarsky et al. 2000). GPCs expanded their range into Minnesota from the southeast on the heels of European settlement (Partch 1973, Ross et al. 2006). In 1900, they thrived in the prairie agriculture landscape, and inhabited most counties in Minnesota (Svedarsky et al. 1999). As agriculture intensified and as plant succession favored woody species, GPC declined and are currently listed as a Species of Special Concern by the Minnesota Department of Natural Resources (Coffin and Pfannmuller 1988). They now primarily occupy the northwest part of Minnesota on the remnant beach ridges left behind when Lake Agassiz drained. Due to glacial deposition and hydrology, these beach ridges are more difficult to convert to agriculture, affording land uses that are more advantageous to GPC.

Habitat, principally for nesting and brood rearing, is thought to be the limiting factor inhibiting current GPC populations (Svedarsky et al. 1999). Svedarsky (1979) found low brood survival to recruitment on The Nature Conservancy's Pembina Trail Preserve which is a subset of the study area. During the next three decades the landscape has been converted to larger tracts of fewer land uses partially due to the draining and filling of ditches (Svedarsky pers. comm.). Newell (1987) also found high mortality of broods at the Sheyenne National Grasslands in North Dakota. Recent studies report low apparent brood survival with only 7.7% and 5.3 % of hatched nests in a Nebraska study fledging young in 2006 and 2007, respectively (Matthews 2007). Of 51 chicks marked with patagial tags, only two were observed the following year in Kansas (Nooker 2007). Much of the mortality within the first 14 days was assumed to be due to their lack of thermoregulation (Rands and Paulhayward 1987) and susceptibility to predators (Toepfer 2003). Without survival and recruitment of chicks, the already imperiled GPC populations will continue to decline and ranges will shrink until they suffer a fate similar to the two other subspecies of *Tympanuchus cupido*; the extinct heath hen and the federally endangered Attwater's prairie-chicken. Geographic and genetic isolation can compound the dangers of reduced populations and bottlenecks will occur, risking extirpation similar to the situations in Illinois (Westemeier et al. 1998) and Wisconsin (Johnson and Dunn 2006).

With brood habitat hypothesized as the most limiting factor in the life history of GPCs, it is important to investigate the local vegetation and invertebrate conditions at locations of hens that are successful in comparison to those that are unsuccessful in raising chicks to fledging. Invertebrates are the primary component of gallinaceous chick diets (Hill 1985, Dahlgren 1990, Park et al. 2001, Jamison et al. 2002, Pratt et al. 2003) so quantifying the abundance and diversity of invertebrate communities at use locations of successful versus failed brood hen locations may predict whether invertebrates are driving the production of juvenile prairie-chickens. Past diet studies concentrated on stomach contents (Yeatter 1943, Kobriger 1965) or chick droppings (Jones 1963, Rumble et al. 1988, Park et al. 2001) which tend to underestimate or completely miss invertebrates that are easily digested and contain fewer structures made of chitin. In this study, hens that successfully hatched at least one egg were followed during the entire 60-day brood period regardless of whether they still had chicks or not. This comparison of used habitats of ultimately successful brood hens versus hens with failed broods has not been described previously. This chapter uses periodic sampling of GPC hen locations to develop a statistical model that would help managers predict whether a successful brood might use a local habitat based on invertebrate and vegetative descriptions.

METHODS

Study Area

The Glacial Ridge Project (Figure 1) lies along the ancient beach ridges of Glacial Lake Agassiz, approximately 12 miles southeast of Crookston in Polk County, Minnesota. The Nature Conservancy's (TNC) Glacial Ridge Project is the largest tallgrass prairie and wetland restoration project in North America (Gerla et al. 2012). Restoration of this agriculturally-dominated landscape was initiated in 2000 with TNC's purchase of over 24,000 acres. Restoration began immediately with the cooperation and funding of several agencies including the U.S. Fish and Wildlife Service (USFWS) and the Natural Resource Conservation Service (NRCS) through administration of the Wetland Reserve Program. The resulting Glacial Ridge Complex encompasses nearly 35,000 acres and includes TNC property, transferred parcels of Glacial Ridge NWR, adjoining state Wildlife Management Areas, Scientific and Natural Areas, and private grassland parcels. Between the core restoration area and these existing conservation parcels is an agriculture matrix with interspersed, small (less than 320 acres) Conservation Reserve Program (CRP) units. To the west of the study area lies the fertile soils of the Red River Valley, comprised of intensive agriculture use, which provides little suitable habitat for prairie chickens (Merrill et al. 1999). To the east of the study area is the beginning of the deciduous forest which is also unsuitable for prairie chickens leaving a ribbon of habitat in a north-south orientation (Merrill et al. 1999). This area holds the largest populations of GPC in Minnesota (Svedarsky et al. 1997).

Capture

Greater prairie-chicken females were captured in 2008 and 2009 with walk-in traps (Schroeder and Braun 1991) from eight booming grounds, five in 2008 and three in 2009, from 1 April through 31 May. Hens were also captured by long-handled net (Loos and Rohwer 2002) and by funnel traps (Dietz et al. 1994) on nests discovered by chain-dragging (Higgins et al. 1977). Necklace-style radio transmitters (Model TS25; Telemetry Solutions, Concord, California) were attached (Amstrup 1980) and hens were immediately released. Each radio weighed between 17 and 19 grams. Methods were approved by University of Minnesota Institutional Animal Care and Use Committee (IACUC) proposal #0706A09724 and University of North Dakota IACUC proposal #0801-6.

Apparent Nest Success

Hens were monitored daily using triangulation (Heezen and Tester 1967) via a truck-mounted, null-peak antenna system (Advanced Telemetry Systems, Isanti, Minnesota). If estimated locations were within 40 m for 3 consecutive days hens were presumed to be incubating. Nests not discovered by chain dragging were located by a hand-held receiver and 3-element yagi antenna. Hens were monitored remotely until they were absent from the nest site during typical incubation hours at which time the nest was revisited and fate of hatch, depredation, or abandonment was assigned to each nest. A nest was considered successful if one or more eggs hatched from the clutch.

Brood Flush Checks

Hens that successfully hatched ≥1 egg were flushed at 14 days post-hatch and approximately every 10 days thereafter until chicks were 8 weeks old (Pitman 2003). Invertebrate and vegetation attributes of use locations were recorded at the time of the flush. The time of day hens were flushed was staggered so that temporal bias was avoided (e.g. if a hen was flushed in the morning at 14 days, she was flushed midday or afternoon 10 days later). Flush checks only occurred during dry conditions to reduce moisture-related impacts on invertebrate sampling and chick exposure.

Two, 15-meter, perpendicular transects were sampled for invertebrates using the sweep-net technique with the site of the hen, if alone, or mean brood flush site as the center point of the sampling transects (Figure 3). Invertebrate sampling was conducted first to avoid disturbing the area while sampling vegetation. The sweep net was a standard 30-centimeter insect net. The dominant field collection techniques for insect sampling include sweep-netting (Jamison et al. 2002, Hagen et al. 2005, Randel et al. 2006), pitfall traps (Jamison et al. 2002), and suction sampling (Randel et al. 2006). A portable technique capable of sampling invertebrates present at the flush event prohibited the use of pitfall and sticky traps although these techniques would have been more effective at capturing ground-dwelling invertebrates. Sweep-net sampling was faster, less expensive, and more effective than vacuum sampling at capturing occurrence and dry biomass of invertebrate forage in Texas grasslands (Randel et al. 2006). Invertebrates were transferred from the net to a resealable plastic bag and frozen until they could be processed.

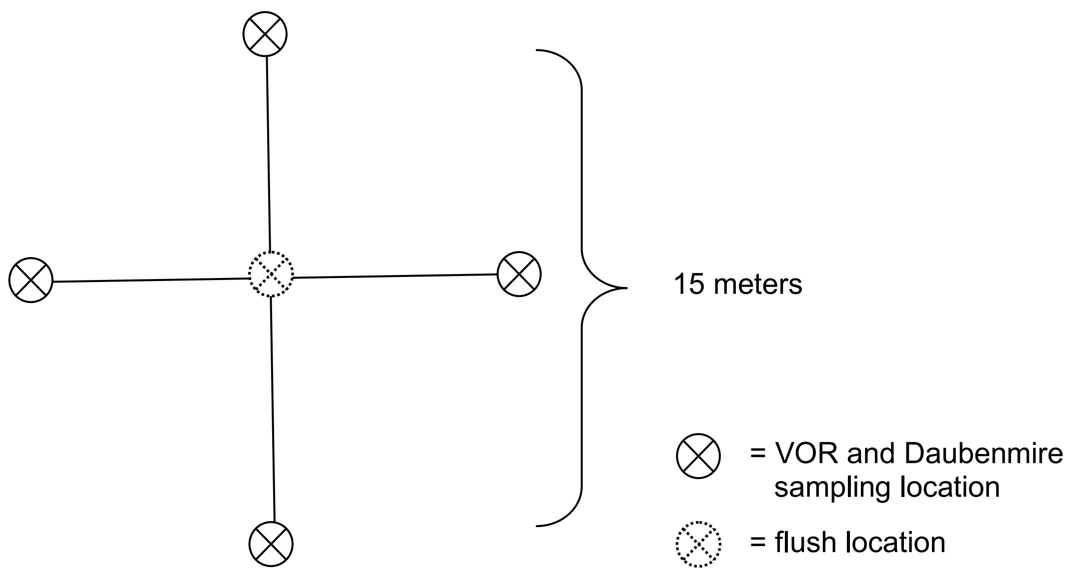

Figure 3. Invertebrate and vegetative sampling locations at greater prairie-chicken brood hen flush locations in Polk County, Minnesota in 2008 and 2009.

Invertebrates were sorted into 7 categories based on taxonomic order: Coleopterans, Heteropterans (including Homoptera and Hemiptera), Hymenopterans, Lepidopterans, Lepidopterous larvae, Orthopterans, and Other (primarily Diptera). Invertebrates were then sorted into 2 size classes; less than 10 millimeters (mm) and greater than 10 mm. It was assumed that chicks of any age could catch and consume invertebrates less than 10mm, whereas anything bigger may be more likely to escape or be otherwise non-consumable. Sorted invertebrates were stored frozen until they could be dried for 72 hours at 60° Celsius in a convection oven. Biomass was weighed to the nearest 0.001 gram for each sorted and dried sample using an electronic balance.

Lepidopterans and Lepidopterous larvae were removed from analysis because they were rarely found in the samples and added unnecessary parameters to the models.

Vegetative data recorded during flush checks included ocular estimates of ground cover to the nearest 5% area within a 0.5m x 0.2m frame (Daubenmire 1959), visual obstruction readings (VOR, Robel et al. 1970), and litter depth. Ground cover categories included: introduced grasses, native grasses, introduced forbs, native forbs, bare ground, and residual vegetation. These measurements were taken at the flush site and at the end of two, 15 meter transects centered on the flush site and oriented in the cardinal directions (Figure 3).

Statistical Analysis

One vegetative and three invertebrate *a priori* logistic regression models were constructed to identify variables best able to predict brood presence. The vegetative model consisted of VOR, litter depth, and proportion of area represented by native grass, introduced grass, native forbs, introduced forbs, residual, and bare ground. All five VOR and litter depth scores for each sampling location were compiled and averaged to get a composite score for the entire site. The first invertebrate model evaluated count and biomass by size only. The second evaluated invertebrate count and biomass by Order. The final invertebrate model evaluated count and biomass by interaction between size and Order.

Model selection was based on parsimony using an information theoretic approach (Burnham and Anderson 2002). The number of parameters estimated was incorporated by the use of Akaike's Information Criterion (Akaike 1985) adjusted for small sample size (AIC_c). Colinearity between all variables in each model was tested. When the correlation test value was greater than 0.80, the individual AIC_c value for each single term logistic regression was calculated and the variable with the lower score was retained in the analysis and the other removed from the model. Stepwise reduction was used to remove the variable contributing the most weight to the model until the most parsimonious model was discovered. Significant terms from each model were combined into a final, pooled model. Colinearity between the remaining variables was tested as above and stepwise reduction was again used to extract the most influential predictors of brood presence. The *popbio* Package in R was used to create graphics with a fitted logistic curve and histograms of the significant final dependent variables (de la Cruz 2005).

RESULTS

Eighty-two hens were captured during this study using walk-in traps (n= 33) and on nests found while chain-dragging (n= 49). Body weights ranged from 760-1140 g, keeping the weight of the collar between 1.5-2.5% of each individual's body weight.

One hundred six nests were discovered during our hen checks and nest dragging of which 34 hatched an overall apparent nesting success of 32.1% in 2008 and 2009. . Of the 34 possible brood hens, 25 were flushed from 1-6 times depending on mortality, loss of radio signal, or land access. Eighty-six individual flushes are included in this analysis. One flush event was censored from the invertebrate models due to the loss of the resealable plastic bag.

Percent coverage of native grass was removed from the analysis because it was ill-fitted for a logistic regression model. No colinearity was found in the vegetative model and proportional coverage of introduced grasses and native forbs are significant in the model (Table 3).

Table 3. Significant vegetative parameters predicting greater prairie-chicken chick presence at 82 brood hen use locations in Polk County, Minnesota in 2008 and 2009.

Parameter	Estimate	SE	z	p
Intercept	-1.4102			
Introduced Grasses	1.9821	0.744	2.665	0.008
Native Forbs	4.2821	2.17	1.968	0.049

Mass of invertebrates less than 10 mm was removed from the size model due to its correlation with the count of invertebrates less than 10 mm. The count of invertebrates less than 10 mm is log-transformed to fit a normal distribution. Total log-transformed count of invertebrates less than 10 mm is the only significant term in the most parsimonious size model (Table 4).

Table 4. Significant invertebrate count and mass by size parameters predicting greater prairie-chicken chick presence at 81 brood hen use locations in Polk County, Minnesota in 2008 and 2009.

Parameter	Estimate	SE	z	p
Intercept	-2.8213			
Count <10mm (log transformed)	0.6011	0.2142	2.806	0.005

Mass and count of Total Orthopterans, Total Heteropterans, and Coleopterans pairs are each correlated so Orthopteran count, Heteropteran mass, and Coleopteran mass were removed from the Order model. Count of all Heteropterans, total count of Others, and mass of Others are significant terms in the invertebrate Order model (Table 5).

Table 5. Significant invertebrate count and mass by Order parameters predicting greater prairie-chicken chick presence at 81 brood hen use locations in Polk County, Minnesota in 2008 and 2009.

Parameter	Estimate	SE	z	p
Intercept	-0.9486			
Count of all Heteropterans	0.0103	0.0046	2.239	0.025
Count of all “Others”	-0.0384	0.0192	-2.003	0.045
Mass of all “Others”	0.0288	0.0149	1.943	0.052

Mass of Orthopterans less than 10 mm, mass of Orthopterans greater than 10 mm, mass of Heteropterans less than 10 mm, count of Heteropterans greater than 10 mm, and mass of Coleopterans less than 10 mm are removed from the size and Order interaction model due to colinearity. Significant terms in the most parsimonious size by Order interaction model are count of Orthopterans less than and greater than 10 mm, count of Heteropterans less than 10 mm, count of Others less than 10 mm, and mass of Others less than 10 mm (Table 6).

All significant terms from the vegetative model and three invertebrate models are pooled into a final model. Count of Heteropterans less than 10 mm is removed due to its correlation with count of all Heteropterans. Significant terms in the most parsimonious model include percent cover of introduced grasses, percent cover of native forbs, less than 10 mm count, total count of Others, and count of Orthopterans less than 10 mm (Table 7). A fitted logistic regression curve was created for each individual significant term in the pooled model (Figures 4-8).

Table 6. Significant invertebrate count and mass by size and Order interaction parameters predicting greater prairie-chicken chick presence at 81 brood hen use locations in Polk County, Minnesota in 2008 and 2009.

Parameter	Estimate	SE	z	p
Intercept	-0.8512			
Count of Orthopterans <10 mm	0.1407	0.0850	1.656	0.098
Count of Orthopterans >10 mm	-0.2339	0.1409	-1.660	0.097
Count of Heteropterans <10 mm	0.0099	0.0044	2.240	0.025
Count of Coleopterans <10 mm	0.0351	0.0197	1.782	0.075
Count of "Others" <10 mm	-0.0620	0.0263	-2.355	0.019
Mass of "Others" <10 mm	0.0451	0.0206	2.192	0.028

Table 7. Final pooled model of significant vegetative and invertebrate parameters predicting greater prairie-chicken chick presence at 81 brood hen use locations in Polk County, Minnesota in 2008 and 2009.

Parameter	Estimate	SE	z	p
Intercept	-3.2210			
Introduced Grasses	1.2963	0.8632	1.502	0.133
Native Forbs	4.1120	2.3778	1.729	0.084
Count <10mm (log transformed)	0.6905	0.2855	2.419	0.016
Count of all "Others"	-0.0178	0.0108	-1.652	0.099
Count of Orthopterans <10 mm	-0.0837	0.0473	-1.766	0.077

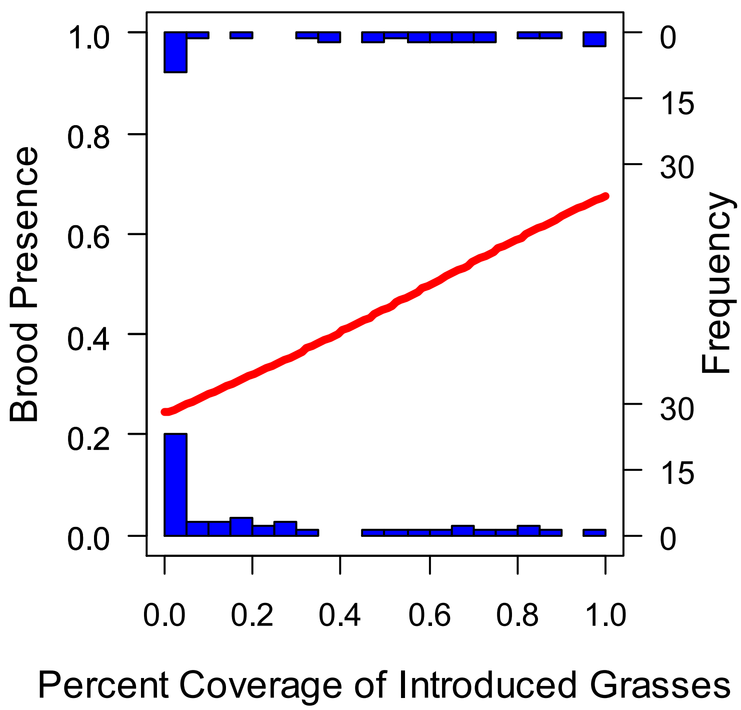

Figure 4. Fitted logistic regression curve showing the probability a site being used by a greater prairie-chicken brood hen given the percent coverage of introduced grasses in Polk County, Minnesota in 2008 and 2009. Histograms at the top of the figure represent the observed data at successful brood hen flush sites, histograms at the bottom represent the observed data at unsuccessful brood hen flush sites.

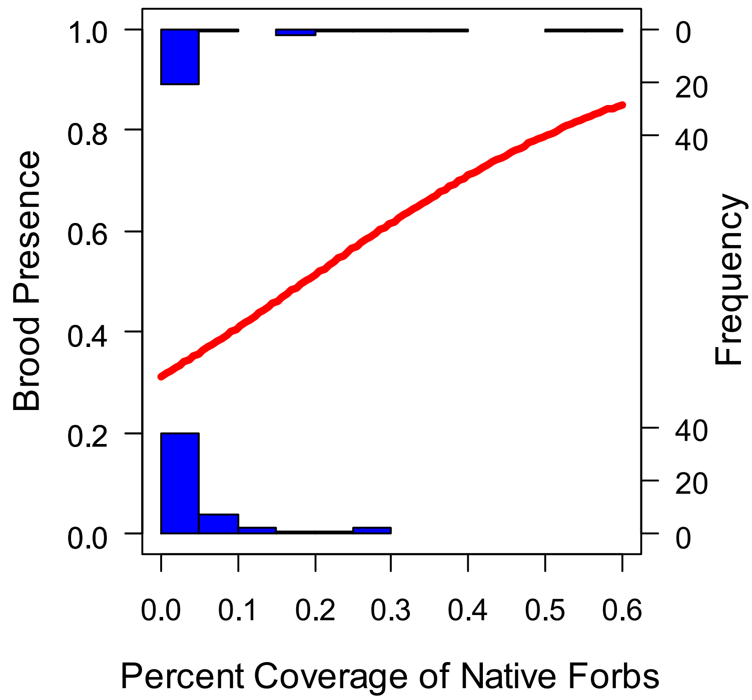

Figure 5. Fitted logistic regression curve showing the probability a site being used by a greater prairie-chicken brood hen given the percent coverage of native forbs in Polk County, Minnesota in 2008 and 2009. Histograms at the top of the figure represent the observed data at successful brood hen flush sites, histograms at the bottom represent the observed data at unsuccessful brood hen flush sites.

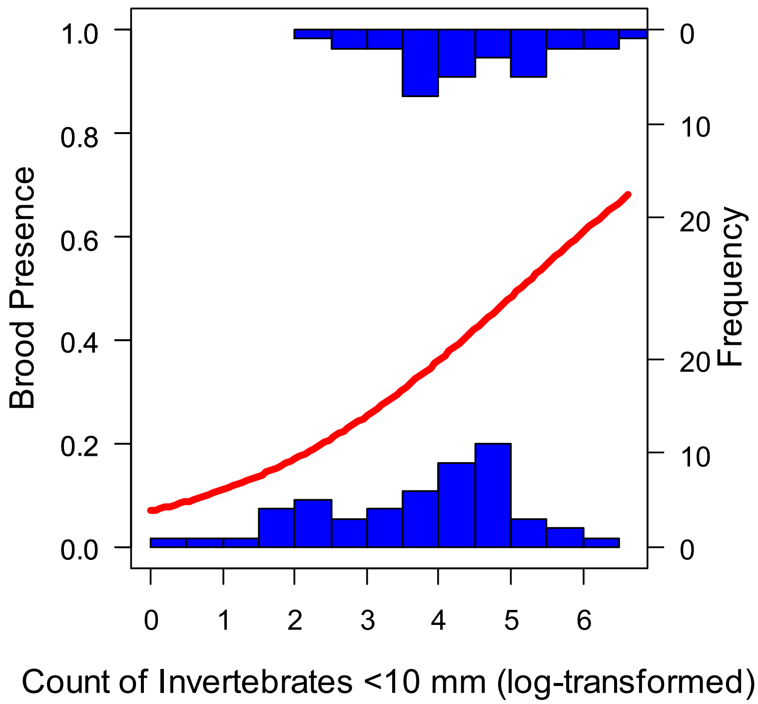

Figure 6. Fitted logistic regression curve showing the probability a site being used by a greater prairie-chicken brood hen given the log-transformed count of invertebrates < 10 mm in Polk County, Minnesota in 2008 and 2009. Histograms at the top of the figure represent the observed data at successful brood hen flush sites, histograms at the bottom represent the observed data at unsuccessful brood hen flush sites.

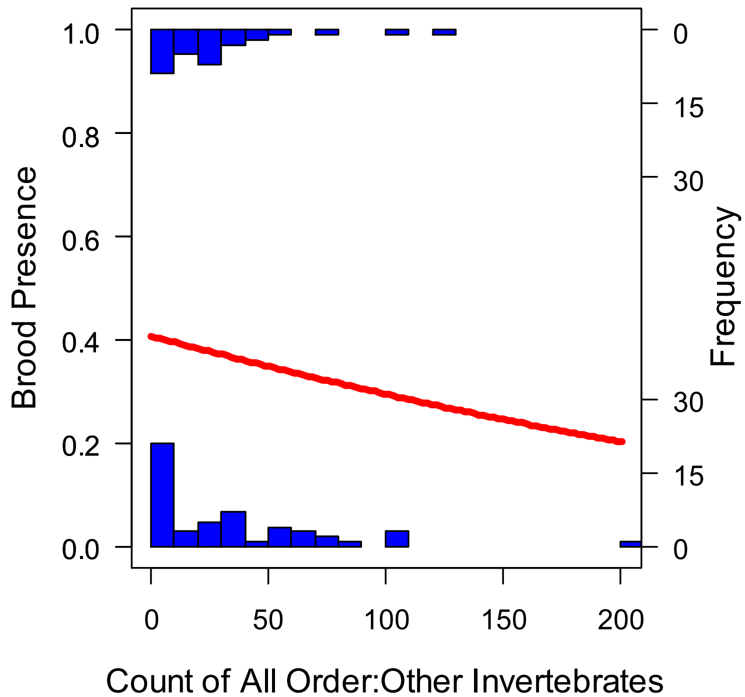

Figure 7. Fitted logistic regression curve showing the probability a site being used by a greater prairie-chicken brood hen given the count of all invertebrates from the invertebrate taxonomic group “Other” in Polk County, Minnesota in 2008 and 2009. Histograms at the top of the figure represent the observed data at successful brood hen flush sites, histograms at the bottom represent the observed data at unsuccessful brood hen flush sites.

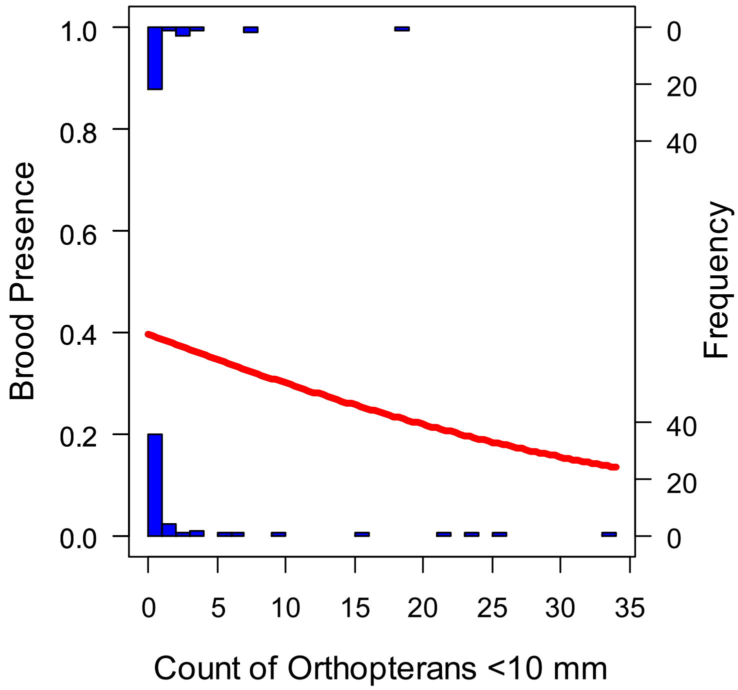

Figure 8. Fitted logistic regression curve showing the probability a site being used by a greater prairie-chicken brood hen given the coiunt of invertebrates < 10 mm from the Orthopteran taxonomic group in Polk County, Minnesota in 2008 and 2009. Histograms at the top of the figure represent the observed data at successful brood hen flush sites, histograms at the bottom represent the observed data at unsuccessful brood hen flush sites.

DISCUSSION

Some hens were not flushed on regular 10-day intervals due to lack of access on multiple private properties. Hagen et al. (2005) and Norton et al. (2010) sampled brood locations within 2 days of actual presence at location. To minimize future disturbance and to make sure we captured the true snapshot of invertebrate and vegetative conditions we sampled at time of flush. Time at the flush location was usually less than 10 minutes but the duration of the disturbance may have negatively impacted brood survival due to exposure.

Percent cover of introduced grass and native forbs are positive predictors of brood presence. The count of small invertebrates trended slightly upward with the increase in introduced grass coverage at brood hen flush locations. GPC have responded positively to cool season stands of CRP (Rodgers and Hoffman 2005, Toepfer 2003). Due to hen capture efforts, most nests were discovered within monotypic stands of smooth brome so that immediately inflated the occurrence of broods in introduced grass. The nest location automatically leads to brood presence within the same patch of habitat. These stands also often occurred as parcels surrounded by row crop agriculture consisting of primarily soybeans and wheat which are often avoided by brood hens (Newell et al. 1988, Matthews et al. 2011). Adults could easily take advantage of the vegetative components and increased coverage of the soybean habitats but the chicks rely heavily on the invertebrate component of the habitat. Soybeans did not support the same invertebrate mass or count (Burger et al. 1993) due to their annual nature, probable insecticide treatments, and monotypic characteristics. GPC hens in large contiguous prairie tracts selected grass-dominated habitats in South Dakota but avoided the smooth brome component (Norton 2010). In northwestern Minnesota, Syrowitz (2013) found the successful brood hens used mixed grass/forb habitats more than failed brood hens. Invertebrate biomass was greatest in undisturbed CRP fields which were primarily idle smooth brome stands (Syrowitz 2013). Invertebrate count was greater in undisturbed CRP and native prairie than disturbed habitats although not significant (Syrowitz 2013). Toepfer (1988) found that 95% of GPC brood locations in Wisconsin were found in grass or mixed grass/forb habitats. Goldenrod (*Solidago spp*), a native species, accounted for most of the forb component (Toepfer 1988). Increasing the forb component in grasslands may decrease GPC dependency on crops (Svedarsky et al. 2003). Rodgers and Hoffman (2005) reported that CRP plantings are most beneficial to prairie grouse species when they are diverse in vegetative height and growth form. The introduction of forbs is a great way to increase the habitat quality of a CRP planting (Rodgers and Hoffman 2005). Flanders-Wanner et al. (2004) showed that heat stress and abundance and timing of precipitation had negative impacts on sharp-tailed grouse broods, *Tympanuchus phasianellus*, in Nebraska. A better vegetative canopy could provide shade to combat high heat days and also reduce the impacts of heavy rainfall (Flanders-Wanner et al. 2004). Jamison et al. (2002) found that invertebrate biomass was more highly associated with forbs than shrubs, grasses, and bare ground in lesser prairie-chicken, *Tympanuchus pallidicinctus*, brood habitats in Kansas.

Many studies of various grouse species have shown that brood success increases with increases in invertebrate count (Hill 1985, Rands 1986, Park et al. 2001). The Attwater's prairie-chicken, *Tympanuchus cupido attwateri*, recovery from federally endangered status seems to be hindered by a lack of invertebrates (Griffin et al. 1997). Pratt et al. (2003) sampled invertebrates in GPC habitat in Minnesota and in Attwater's habitat in Texas and found that although the biomass did not change, Texas had <30% of the numbers of invertebrates further highlighting the need to have small invertebrates available for chicks. Results of invertebrate mass showed that much more chick-friendly (<10 mm) forage was available at locations of successful brood hen locations versus those that had lost their brood and are just caring for themselves further supporting the important role of invertebrates to GPC diet (Table 7).

Invertebrates in the group “Other” were primarily flies and spiders and were a negative predictor of GPC brood use. There are no obvious associations of these invertebrates to any vegetation types or other invertebrate interactions. However, immediately south of the study area, Diptera and Hemiptera were more abundant at failed GPC brood hen locations and permanent sampling transects than at successful brood hen locations during 2009 (Syrowitz 2013).

GPC fecal samples showed a preference for Coleopterans and Orthopterans in Illinois and Oklahoma (Yeatter 1943, Jones 1963). However, this study found that more grasshoppers less than 10 mm would decrease the likelihood of a brood using the site. Syrowitz (2013) again had similar results, finding that beetles and grasshoppers comprised less than 5% of the total invertebrate count in all invertebrate samples. These data suggest that GPC chicks may opportunistically feed on whichever small invertebrates are readily available. This same opportunistic foraging theory appears in two adult GPC populations in Nebraska whose distinctly different diets are driven by available land cover in each study area (Sparks and Sparks 2009).

CONCLUSION

Idle smooth brome stands appear to be quality GPC brood habitat. This is an advantage in the northern states were CRP enrollment is often dominated by smooth brome monocultures which are also preferred for nesting. Increasing the native forb component of these same grassland systems would increase the vegetative heterogeneity which results in increased invertebrate heterogeneity (Engle et al. 2008). The forbs may provide additional invertebrates as well as better structure for chick mobility at ground level for predator evasion and perhaps shade.

Successful brood hens appear to choose locations with abundant invertebrates less than 10 mm for chick forage. GPC seem to be opportunistic with their invertebrate foraging since a commonly reported taxonomic order (grasshoppers) is hardly represented by sweep net sampling in this study area. Perhaps grasshoppers simply were not present in large numbers or in the habitats that GPC brood hens chose during this study since sweep net sampling is not reported to miss this Order.

CHAPTER IV

SITE CHARACTERISTICS AND APPARENT SUCCESS OF GREATER PRAIRIE-CHICKEN NESTS IN NORTHWESTERN MINNESOTA

INTRODUCTION

The tallgrass prairie region has been continually fragmented since early settlement, with approximately 1% of the native prairie remaining (Savage 2004). Consequently, the area-sensitive (Samson 1980), grassland-obligate, greater prairie-chicken (*Tympanuchus cupido pinnatus*; hereafter prairie-chicken) has experienced sharp declines throughout their range (Svedarsky et al. 2000). The prairie-chicken expanded its range into Minnesota from the southeast on the heels of European settlement (Partch 1973, Ross et al. 2006). In 1900, they thrived in the mixed prairie-agriculture landscape, and inhabited most counties in Minnesota (Svedarsky et al. 1999). As agriculture intensified and plant succession favored woody species, prairie-chickens declined and are currently listed as a Species of Special Concern by the Minnesota Department of Natural Resources (Coffin and Pfannmuller 1988). They now primarily occupy the northwest part of Minnesota on the remnant beach ridges left behind when Lake Agassiz drained (Svedarsky et al. 1999). Due to glacial deposition and hydrology, these beach ridges are more difficult to convert to agriculture, affording land uses that are more advantageous to prairie-chickens.

Nesting and brood rearing habitats are considered the limiting factors for prairie-chicken populations (Kirsch 1974, Svedarsky et al. 1999). Prairie-chicken nest sites typically contain residual vegetation from the previous year that is used to line a shallow nest bowl on the ground and provide cover for the incubating hen (Baicich and Harrison 1997). Eggs are laid at a rate of about 1 per day until a full clutch of 10-12 eggs is reached (Baicich and Harrison 1997). Incubation lasts 23-26 days at which time the precocial chicks are tended by the female and brooded closely during the first week of life (Baicich and Harrison 1997). This chapter reports habitat characteristics of prairie-chicken nests discovered in northwestern Minnesota. The prevalence of smooth brome (*Bromus inermis*) in CRP plantings, its monotypic nature, and targeted nest searching lead to the question of whether nest sites dominated by smooth brome are differentially successful than nest sites dominated by either other introduced or native vegetation. Other introduced vegetation was typically also cool season grasses like Kentucky bluegrass (*Poa pratensis*), orchardgrass (*Dactylis glomerata*), and timothy (*Phleum pratense*). Native vegetation was typically big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), or goldenrod (*Solidago spp.*). Minnesota holds one of only a few stable prairie-chicken populations in the world (Vodenhal and Haufler 2007) and as such, may provide a model of land use and habitat management for managers of other prairie-chicken populations.

METHODS

Study Area

The Glacial Ridge Project lies along the ancient beach ridges of Glacial Lake Agassiz, approximately 19 kilometers southeast of Crookston in Polk County, Minnesota. The Nature Conservancy's (TNC) Glacial Ridge Project is the largest tallgrass prairie and wetland restoration project in North America (Gerla et al. 2012). Restoration of this agriculturally-dominated landscape was initiated in 2000 with a goal of over 8,000 acres (3237 ha) of restored wetlands and more than 16,000 acres (6475 ha) of restored tallgrass prairie. The resulting Glacial Ridge Complex encompasses nearly 35,000 acres (14164 ha) and includes TNC property, transferred parcels of Glacial Ridge NWR, adjoining state Wildlife Management Areas, Scientific and Natural Areas, and private grassland parcels. Between the core restoration area and these existing conservation parcels is an agriculture matrix with interspersed, small (less than 130 ha) Conservation Reserve Program (CRP) units.

Nest Discovery and Apparent Nest Success

Hens captured on booming grounds were equipped with radio-transmitters (Amstrup 1980) and monitored daily using triangulation (Heezen and Tester 1967) via a truck-mounted, null-peak antenna system (Advanced Telemetry Systems, Isanti, Minnesota). If estimated locations were within 40 m for 3 consecutive days hens were presumed to be incubating and nests were located by flushing hens with aid from a hand-held receiver and 3-element yagi antenna. Nests were also found by chain-dragging (Higgins et al. 1977) prairie habitats and through opportunistic observation. Due to other study objectives, greater effort was used in nest-dragging which was more productive in finding hens to mark and also allowed for a longer capture season. The majority of grasslands where nest-dragging was conducted were CRP fields that were dominated by introduced cool season grasses.

Marked hens were monitored remotely until they were absent from the nest site during typical incubation hours (Svedarsky 1983) at which time the nest was revisited and fate of hatch, depredation, or abandonment was assigned to each nest. A nest was considered successful if one or more eggs hatched from the clutch. Methods were approved by University of Minnesota Institutional Animal Care and Use Committee (IACUC) proposal #0706A09724 and University of North Dakota IACUC proposal #0801-6.

Nest Site Characteristics

Nest site characteristics were taken at the time of discovery except in the case of the 2 opportunistic discoveries. Measurements taken at each nest include: number of eggs, litter depth, visual obstruction reading (VOR, Robel et al. 1970), percent overhead cover, and dominant site vegetation. Eggs were floated to estimate age of clutch (Westerkov 1950). If there were fewer eggs than a typical clutch or the eggs showed no incubation, number of eggs was updated during any subsequent visit (e.g. capture attempt for radio-marking or when checked for evidence of fate after the hen left the nest site). Litter was measured as the highest point of residual horizontal vegetation. The percentage overhead coverage is considered an important metric for concealment from predators and to shade from the sun and inclement weather (Svedarsky et al. 2003). Dominant nest site vegetation was determined by whichever classification occupied >50% of a 0.5m x 0.2m frame (Daubenmire 1959) placed over the nest bowl. If two vegetation types occupied 50% of the nest site, the dominant type in the local area was assigned.

RESULTS

Fifty five of 150 prairie-chicken nests during this study hatched at least one egg for an overall apparent nesting success of 36.67%. Annual apparent nest success decreased each year of the study (Table 8). Apparent nest success was highest for smooth brome nest sites followed by other introduced vegetation and finally by nest sites dominated by native vegetation (Table 9).

Table 8. Apparent nest success in relation to dominant patch vegetation surrounding 150 greater prairie-chicken nests discovered in Polk County, Minnesota during 2007- 2009.

Year	Habitat	Hatch	Fail	Apparent Nest Success (%)
2007	Introduced	17	16	51.52
	Native	4	7	36.36
	Total	21	23	47.73
2008	Introduced	19	34	35.85
	Native	2	5	28.57
	Total	21	39	35.00
2009	Introduced	11	31	26.19
	Native	2	2	50.00
	Total	13	33	28.26
Entire Study	Introduced	47	81	36.72
	Native	8	14	36.36
	Total	55	95	36.67

Table 9. Comparison of dominant nest site vegetation with smooth brome separated from other introduced vegetation using apparent nest success of 150 greater prairie-chicken nests discovered in Polk County, Minnesota during 2007- 2009.

	Hatch	Fail	Apparent Nest Success
Smooth Brome	33	48	40.74%
Other Introduced	15	28	34.88%
Native	7	19	26.92%
Total	55	95	36.67%

An Analysis of Variance (ANOVA) was used to test for differences in mean nest site characteristics for dominant nest site vegetation. VOR values approached a normal distribution with a log2 transformation. Plant structure was thickest, resulting in the highest VOR values, at nest sites dominated by smooth brome and other introduced vegetation (Table 10). Nest sites dominated by native plants provided nearly significantly less structural screening (1-way ANOVA, $F_2 = 2.789$, $p = 0.065$). For each dominant vegetation type, mean VORs were greater at hatched nests than at failed nests (Table 11).

Table 10. Mean nest site characteristics segregated by immediate nest site vegetation at greater prairie-chicken nests in Polk County, Minnesota from 2007- 2009.

	Dominant Vegetation Type at Nest Site		
	Smooth Brome	Other Introduced	Native
Characteristic	mean ± SE (n)	mean ± SE (n)	mean ± SE (n)
VOR (dm)	2.30 ± 0.10 (78)	2.29 ± 0.16 (40)	1.84 ± 0.19 (26)
Litter (cm)	3.56 ± 0.26 (78)	2.95 ± 0.33 (41)	3.46 ± 0.77 (26)
% Overhead	56.84 ± 4.16 (76)	45.90 ± 5.34 (39)	41.73 ± 6.79 (26)

Litter depth needed a square root transformation to resemble a normal distribution. Litter depths at smooth brome and native-dominated nest sites were similar but not significantly taller than depths at nest sites dominated by other introduced vegetation (1-way ANOVA, $F_2 = 1.108$, $p = 0.333$). Mean litter depths were greater at failed nests for smooth brome and other introduced vegetation but hatched native nest sites saw an almost 2 cm greater litter depth than failed attempts (Table 11).

Clutch size did not have a normal distribution so a Kruskal-Wallis test was used. Clutch size was significantly different among dominant nest site vegetation (Kruskal-Wallis chi-squared = 16.926, p = 0.0002). Smooth brome nests had a median of 14 eggs which is three and two more than clutches found in introduced and native vegetation, respectively (Figure 9).

Percent overhead coverage did not have a normal distribution so a Kruskal-Wallis test was used. Percent overhead cover was greatest at nest sites that were dominated by smooth brome (Table 10) although not significantly different than nest sites dominated by other introduced and native vegetation (Kruskal-Wallis chi-squared = 4.592, p = 0.101).

Table 11. Mean nest site characteristics and clutch size segregated by immediate nest site vegetation and apparent nest success of 150 greater prairie-chicken nests in Polk County, Minnesota from 2007- 2009.

	Smooth Brome		Other Introduced		Native	
Characteristic	Failed	Hatched	Failed	Hatched	Failed	Hatched
VOR (dm)	2.23 ± 0.13	2.40 ± 0.18	2.18 ± 0.18	2.53 ± 0.33	1.74 ± 0.21	2.13 ± 0.44
Litter (cm)	3.87 ± 0.35	3.10 ± 0.39	3.26 ± 0.38	2.36 ± 0.59	2.95 ± 0.66	4.86 ± 2.24
Clutch Size	12.38 ± 0.52	13.61 ± 0.37	9.79 ± 0.77	11.80 ± 0.67	10.32 ± 0.81	12.43 ± 0.78
% Overhead	53.80 ± 5.29	61.50 ± 6.77	43.80 ± 6.97	49.64 ± 8.36	42.37 ± 8.20	40.00 ± 12.86

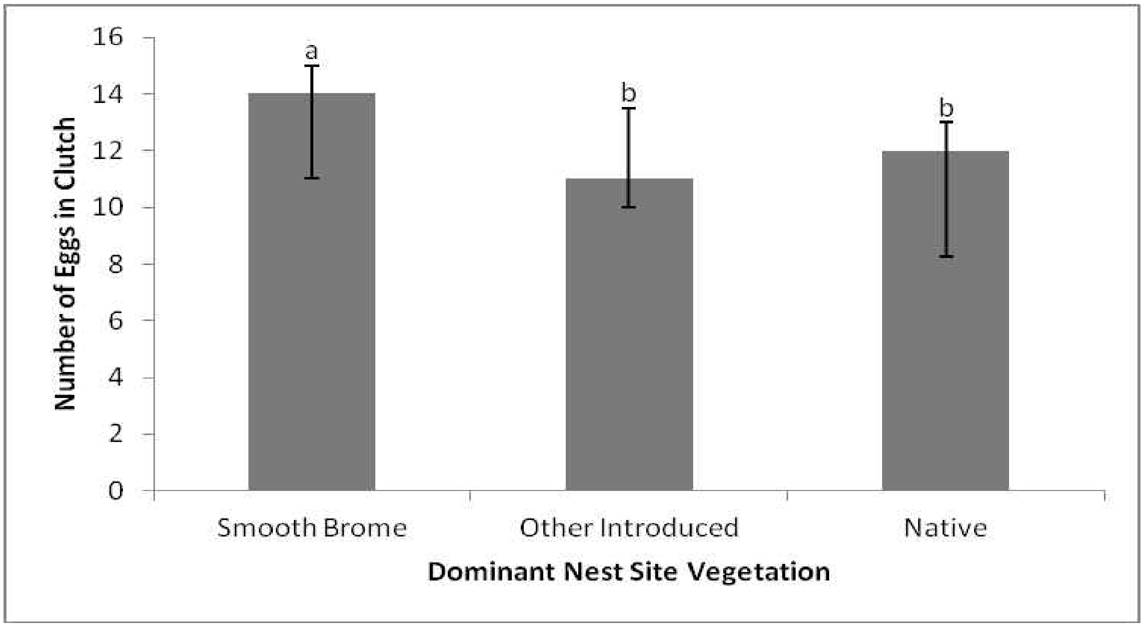

Figure 9. Median clutch size by dominant nest site vegetation at 150 greater prairie-chicken nests discovered in Polk County, Minnesota during 2007- 2009. Error bars indicate the interquartile range of the original data. Letters indicate groups that were different based on a post hoc Bonferroni-corrected Mann-Whitney test.

DISCUSSION

Apparent nest success during this study (Table 8) falls within the range of previous prairie-chicken work by McKee et al. (1998) in Missouri (35%), Ryan et al. (1998) in Missouri (30.0%), Norton (2005) in South Dakota (80.2%), Nooker (2007) in Kansas (20.6%), Matthews (2009) in Nebraska (40%), Anderson (2012) in Nebraska (22.4%), Sandercock et al. (2013) in Kansas (30.3%), and Syrowitz (2013) in Minnesota (50.4%). Nest success in my study area was lower than 55.56% in the 1970s (Svedarsky 1979) and the 2009 apparent nest success of 28.26% is much less than the 2009 apparent nest success of 50.4% (Syrowitz 2013) in multiple counties immediately south of the Glacial Ridge Complex.

The dynamic prairie landscape looks much different from the moment of nest site selection to hatch approximately 37 days later. The vegetation measurements reported are subject to the date of discovery. Conditions during laying or early incubation are most reflective of the actual conditions the hen evaluated when selecting her nest site (Yeatter 1943). The high number of smooth brome dominated nesting sites was a function of targeting CRP fields for nest-dragging efforts due to previous knowledge of nesting preferences locally (Svedarsky 1988) and in other northern parts of the prairie-chicken range (Svedarsky et al. 2003, Toepfer 2003, Matthews 2009). Twenty-five to 30% of landscapes managed for prairie-chickens should include grasslands with residual cover that provides a VOR of 2.0 dm or greater (Svedarsky and Van Amburg 1996). A 2.0 dm VOR would afford a hen virtually full lateral visual protection but also allow the hen to stand up at the nest site and still be able to see potential dangers approaching. Other work has reported mean VORs at prairie-chicken nests of 2.7 dm (Svedarsky 1979), 2-3 dm (Prose 1985), 2.0-4.0 dm throughout the season (Westemeier et al. 1995), and 2.5 dm (Sandercock et al. 2013). Walk (2004) suggests that values of <0.5 dm and >5 dm are unsuitable for prairie-chicken nest success. Sandercock et al. (2013) found that random sites had lower VORs than failed nest sites which had lower VORs than successful nests in Kansas. VOR values on the Glacial Ridge Complex during this study match other published numbers with a study mean of 2.21 dm. Native sites averaged 1.84 dm but they also had an 8% worse nest success.

Nests in smooth brome had some of the highest litter depths indicating abundant residual vegetation and materials for nest bowl construction. McKee et al. (1998) found that nest success was negatively impacted by litter cover over 25%. Svedarsky (1979) also found negative effects on nesting success with increasing litter depth. Litter depths did not differ significantly by hatch/fail or across dominant vegetation types in this study.

A notable increase could be seen in mean litter depth at hatched nests in native vegetation but that mean is being driven by only two observations above 5 cm; 11 cm and 15 cm, respectively. Mean litter depths at hatched versus failed nests seems to indicate some microhabitat differences that could be explored in the future. Successful nests in the two introduced vegetation groups had shorter litter depths than failed nests in the same habitat.

Failed clutch sizes were smaller than hatched clutch sizes for every habitat type. I chose to keep every single nest in the analysis so abandoned, destroyed, and second clutches less likely to succeed are all included. Overall study clutch mean of 11.84 eggs per nest is almost equivalent to the 11.79 eggs per nest observed on the Glacial Ridge Complex from 1975-1977 (Svedarsky 1979). These study means are greater than 10.6 eggs per clutch for first attempts in Nebraska (Anderson 2012) and 10.9 eggs per clutch for first attempts in Kansas (Nooker 2007). McNew et al. (2011) found larger clutch sizes in Kansas with 12.4 and 10.5 eggs per clutch for first and second attempts, respectively.

When Svedarsky (1979) studied a subset of this study area, many of the nest failures were attributed to red foxes, *Vulpes vulpes*. The canid dynamic has shifted from red fox dominated in the 1970s to a landscape now primarily occupied by coyote, *Canis latrans* (Emery unpublished data). Nest success of ducks in similar landscapes was shown to increase with the prevalence of coyotes versus foxes (Sovada et al. 1995). However, in this study apparent nest success was actually lower than in the same general area in the 1970s (Svedarsky 1979). The heavy use of chain-dragging for nest discovery may have created patches with easy predator travel in the tire tracks left behind.

Although nest predators were not identified during this study, striped skunks (*Mephitis mephitis*) were abundant in all years and the mammalian guild at Glacial Ridge consists of canids, raccoons (*Procyon lotor*), ground squirrels, and a variety of mustelids. On multiple occasions, we returned to a nest site to attempt capture and would observe a skunk running the tracks left from our all terrain nest-dragging vehicles which is similar to predator use of vehicle tracks summarized by Svedarsky et al. (2003).

The majority of nests were discovered in non-native grasslands. This is not necessarily indicative of preference because search efforts focused on introduced CRP fields. Nesting hens that were captured on booming grounds lead us multiple times into habitats where we would have never attempted to nest drag including areas that were too wet for drag vehicles or with nearby heavy shrub cover. Nests located in smooth brome vegetation had the highest apparent nest success. These sites had the highest mean values for all reported metrics as well. Residual cover from previous growing seasons provided greater VOR readings and litter depths and the early season growth provided greater percent overhead cover. Prairie-chicken hens seem to be keying on early season conditions that will be most advantageous for concealment and escape cover during the 5 week nesting and incubation period. These results indicate that grasslands managed for prairie-chicken nesting should concentrate on providing residual cover and early season vegetative growth similar to those attributes provided by smooth brome.

CHAPTER V

CONCLUSION

GPC require a diverse landscape to satisfy their various life history requirements within a relatively small area. This study was conducted at the northern edge of their range and was focused on the Glacial Ridge Project which harbors a significant GPC population because of existing grasslands and the introduction of many hectares of prairie tracts created by conservation organizations and the federal CRP program.

Nesting and brood-rearing habitats are considered the most limiting factors to GPC population maintenance and expansion. Hens equipped with radio transmitters were studied during their reproductive efforts in 2008 and 2009 to investigate factors influencing brood success at multiple spatial scales. An additional year of nest data is available from a pilot study in 2007. This research was designed to investigate nest site characteristics, forage and vegetative features at brood hen flush locations, and habitat use and selection during the 60 day brood-rearing period. Wildlife managers can extrapolate these results to create a landscape with similar habitat features for the benefit of other prairie-chicken populations which are in decline across their rapidly receding range.

Apparent nest success decreased each year of the study from a high of 47.73% in 2007 to a low of 28.26% in 2009 for an overall study nest success rate of 36.67%. Dominant vegetation at the immediate nest site was grouped into smooth brome, other introduced species, and native species to investigate potential vegetation effects on apparent nest success. Apparent nest success was highest at sites dominated by smooth brome, other introduced, and native vegetation, in descending order. Clutch size was the only parameter that was statistically different between the vegetation types with smooth brome nests containing 2 or more eggs than nests found within the other vegetation types. Although not significant, Visual Obstruction Readings were higher at smooth brome and other introduced sites than at nests found in native vegetation. When comparing VOR values between successful and failed nests within each vegetation type, the successful nests had a greater VOR in all three vegetation classes suggesting that hens select microhabitats with the greatest vertical cover within the habitat patch.

Though significant only in 2008, hens that successfully raised chicks to independence always averaged smaller seasonal ranges than hens with failed broods suggesting that brood hens limited their foraging efforts when they found quality brood conditions resulting in less exposure to predators and decreased effort committed to movement. Within these seasonal ranges, successful brood hens selected habitat types dominated by deciduous trees and used soybean fields randomly in relation to availability while failed brood hens were highly selective for soybeans. The selection of trees by prairie-chickens has never been reported before and should be received with caution. The tree habitats were used by only three of 18 brood hens and five of the six tree locations were used by hens that were in soybean-dominated landscapes and were likely selecting the grassy transition element of the habitat, not the vertical orientation and canopy of the trees. Establishing trees within the prairie-chicken range is not recommended based on these results. A diverse patchwork of nesting and brood-rearing habitats within close proximity will reduce brood movements and provide abundant foraging and escape cover.

The preference of treed habitat by successful hens and highly disproportionate use of soybeans by hens that lost their brood indicated that certain features within those habitat types are preventing them from moving into the agricultural parcels that were abundant in the study area. All hens that successfully hatched at least one egg were included in this analysis and site-specific vegetative and forage conditions were compared between hens who raised chicks to independence and those that lost their entire brood. The probability of brood use was predicted for vertical and horizontal vegetative factors and invertebrate biomass. Percent coverage of introduced grasses, percent coverage of native forbs, and abundance of invertebrates smaller than 10 mm were all positive predictors of brood presence. Smooth brome was the most common introduced grass on the private lands surrounding the Glacial Ridge Project where most of the nest-dragging and subsequent hen capture efforts occurred. These smooth brome CRP plantings had been idle for years and provided cover from residual materials that resistant to snow flattening and also live vegetation that started growing early in the season. Percent native forb cover provides a canopy component used for shading from the sun and also protection against negative weather events which can cause catastrophic losses due to exposure and a lack of thermoregulation in young chicks. Hens with failed broods are able to satisfy their forage requirements almost anywhere, whereas hens with chicks focused on areas with a greater number of invertebrates less than 10 mm. Count of all invertebrates from other orders and count of Orthopterans less than 10 mm were both negatively associated with brood presence. Flies and arachnids were the primary invertebrates in the Other group and a nearby study in 2009 also found higher fly counts at failed brood hen locations than at sites with broods. There are no apparent associations between these invertebrates groups and any of the vegetative or other invertebrate parameters. The negative relationship with count of small Orthopterans was not anticipated based on their prevalence in almost all prairie grouse brood forage literature. It may be a result of low grasshopper availability during the study so they were not available to be sampled often enough to establish a positive relationship. This hypothesis is supported by a similar brood forage study on prairie-chickens in Minnesota in 2009 that found that beetles and grasshoppers that typically dominate the brood forage literature only comprised 5% of the sampled invertebrate biomass.

A landscape consisting of a patchwork of smaller parcels of diverse land uses should provide hens with brood-rearing habitats in close proximity to preferred nesting sites. Those nesting parcels should mimic the qualities that smooth brome provides as hens seem to be using sites based on residual cover during initiation and taking advantage of the new early season growth afforded by cool-season species during incubation. Idle parcels have greater horizontal litter and residual vertical cover desired by nesting hens. Grasslands managed for GPC should include maintenance in the form of periodic disturbance that encourages a mix of introduced grasses and native forbs. Timing of burning, grazing, or mowing should take into account the requirements of GPC during each season before implementation. Habitats should be able to produce abundant invertebrates less than 10 mm which are favored by broods and contribute to the production of this umbrella species. Soybeans and other agricultural habitats were used randomly in relation to their availability by brood hens but habitats preferred by broods like those with mixed introduced grasses and native forbs should be the primary focus on the landscape.

APPENDICES

Appendix A

Seasonal Range Areas

Table 12. Seasonal range areas (ha) of brood-rearing hens that were successful in raising chicks to fledging in Polk County, Minnesota in 2008 and 2009.

Year	Frequency	Area (ha)
2008	150.430	393.1
2008	150.450	67.95
2008	148.680	297.71
2008	148.730	273.76
2008	148.750	80.24
2008 Mean		218.49
2009	150.300	50.56
2009	150.490	106.09
2009 Mean		78.33
Study Mean		178.44

Table 13. Seasonal range areas (ha) of brood-rearing hens that were not successful in raising chicks to fledging in Polk County, Minnesota in 2008 and 2009.

Year	Frequency	Area (ha)
2008	150.060	496.03
2008	150.070	239.09
2008	150.170	175.78
2008	148.700	169.76
2008	148.820	1308.32
2008	148.860	313.68
2008 Mean		426.03
2009	150.210	117.84
2009	150.230	290.46
2009	150.340	345.27
2009	150.390	148.18
2009	148.890	192.70
2009 Mean		218.89
Study Mean		331.87

Appendix B

Nest Site Characteristics

Table 14. Nest site characteristics observed at 150 greater prairie-chicken nests in Polk County, Minnesota during 2007-2009.

Year	Nest #	VOR	Litter	Clutch	Overhead	Nest_veg	Patch_veg	Fate
2007	5	2.88	1	15	90	2	1	1
2007	10	2.38	2	17	95	2	1	1
2007	13		1	16	100	2	1	0
2007	14	2.25	0	16	40	2	1	0
2007	15	2.63	1	15	90	2	1	0
2007	16	3	1	16	100	2	1	1
2007	17	3	3	15	90	2	1	1
2007	21	2.63	2	16	95	2	1	1
2007	24	1.13	1	15	10	0	0	1
2007	25	1.38	4	13	70	0	0	1
2007	26	1.75	2	14		1	1	0
2007	39	2.63	2	13	65	1	1	0
2007	40	1.63	2	15	95	1	1	0
2007	42	2.13	8	9	30	1	1	1
2007	44	2.75	3	11	0	2	1	1
2007	46	3.38	2	15	70	2	1	1
2007	47	2	3	6	20	1	1	1
2007	51	2.88	3	16	20	1	1	1
2007	53	3.88	2	9	85	2	1	1
2007	57	3.38	1	13	90	2	1	1
2007	60	2.63	1	12	60	2	1	0
2007	62	3.17	1	13	10	2	1	0
2007	64	3.25	3	17	45	2	1	0
2007	66	4.38	0	13	85	2	1	0
2007	74	2.88	2	16	10	2	1	0
2007	79	2.13	4	15	10	2	1	0
2007	80	3.75	3	14	30	2	1	0
2007	81	3.75	4	13	10	2	1	0
2007	83	4.75	1	17	100	2	1	0
2007	88			14		2	1	1
2007	92	4.75	3	14	80	2	1	1
2007	93	3.88	3	10	90	2	1	0
2007	95	2.63	3	12	90	2	1	1
2007	96	2.88	5	9	100	0	0	1
2007	97	1.13	0	12	15	1	1	0
2007	98	2.38	2	13	40	1	1	0

Table 14. Cont.

Year	Nest #	VOR	Litter	Clutch	Overhead	Nest_veg	Patch_veg	Fate
2007	99	2.63	1	6		1	1	1
2007	100	2.63	0	7	0	0	0	1
2007	101	2.75	0	10	95	1	1	0
2007	102	2.5	0	10	80	1	1	1
2007	103	2.75	15	14	90	0	0	0
2007	104	2.88	0	9	100	0	0	1
2007	105	2	2	7	15	1	1	0
2007	106	1.75	0	9	10	2	1	1
2008	1.5			11	50	1	1	0
2008	2	0.625	2	9	10	0	0	1
2008	3	1.75		9	30	2	1	0
2008	6	0.625	0	14	0	2	1	1
2008	7	0.875	7	7	95	0	0	1
2008	8	1	6	9	80	0	0	1
2008	10	1.125	5	16	50	0	0	1
2008	11	1	3	5	50	0	0	1
2008	19	1.125	5	16	10	2	1	1
2008	22	1.125	5	14	100	2	1	1
2008	26	1.125	8	6	60	2	1	1
2008	31	1	3	15	10	2	1	1
2008	32	1.25	8	15	70	2	1	0
2008	33	1.5	4	15	30	2	1	1
2008	37	1.875	5	5	30	2	1	1
2008	39	1.625	6	12	100	2	1	0
2008	40	1.875	3	12	40	2	1	1
2008	43	1.875	6	13	100	2	1	1
2008	44	2	4	15	70	2	1	0
2008	46	2.25	7	7	50	2	1	1
2008	47	1.625	6	13	20	2	1	0
2008	48	0.875	4	15	90	2	1	1
2008	49	1.625	9	14	90	2	1	1
2008	50	1.75	9	16	90	2	1	1
2008	59	2.125	2	13	15	2	1	0
2008	61	2.625	7	12	15	2	1	0
2008	62	2.5	3	14	50	2	1	1
2008	65	2	4	13	50	2	1	1
2008	68	1.875	8	11	20	2	1	1
2008	71	2.375	2	11	0	1	1	0
2008	72	2.625	5	17	70	2	1	1
2008	73	2.125	4	9	75	1	1	1
2008	74	1.25	10	13	40	0	0	1

Table 14. Cont.

Year	Nest #	VOR	Litter	Clutch	Overhead	Nest_veg	Patch_veg	Fate
2008	74.5	1.5	9	10	80	2	1	1
2008	75	0.625	11	13	5	0	0	0
2008	76	1.625	3	12	10	1	1	1
2008	78	1	4	14	10	1	1	1
2008	80	1.625	4	10	10	1	1	1
2008	81	1.375	3	14	80	2	1	0
2008	82	2.25	2	12	20	1	1	1
2008	84	1.625	3	11	10	2	1	1
2008	85	2.625	1	11	100	2	1	0
2008	94	5.875	3	14	50	1	1	0
2008	97	1.5	5	13	50	0	0	0
2008	111	2.375	1	17	100	1	1	1
2008	112	1.875	9	15	80	1	1	0
2008	122	1.125	0	14	50	0	0	0
2008	124	1.875	1	13	5	0	0	0
2008	132	3.25	4	14	60	2	1	1
2008	139	2.75	4	17	60	2	1	1
2008	144		2	14	90	2	1	0
2008	145		4	10	80	1	1	0
2008	146	2.75	5	10	70	1	1	1
2008	147		4	10		1	1	1
2008	149	2.625	0	6	10	0	0	1
2008	151	4.75	6	11	80	1	1	1
2008	152	3.75	3	9	50	2	1	1
2008	153	2	0	7	60	0	0	1
2008	154	3.75	1	11	50	1	1	0
2008	155	2.625	1	7	50	1	1	0
2009	1	3	2	12	30	1	1	1
2009	2	1.375	1	14	10	0	1	1
2009	3	2.625	2	7	0	0	1	1
2009	4	2.75	5	11	25	1	1	1
2009	5	2.25	2	15	30	1	1	1
2009	6	1.5	2	16	0	2	1	1
2009	9	3.875	6	16	50	0	1	1
2009	11	0		14		1	1	1
2009	16	1.625	5	5	0	2	1	1
2009	19	1.625	7	3	30	1	1	1
2009	20	1.5	2	14	40	2	1	1
2009	23	1.5	2	14	85	2	1	0
2009	26	2.5	3	16		2	1	0
2009	27	2.375	2	15	100	2	1	0

Table 14. Cont.

Year	Nest #	VOR	Litter	Clutch	Overhead	Nest_veg	Patch_veg	Fate
2009	31	1.625	3	14	100	2	1	0
2009	40	1.875	2	13	90	2	1	1
2009	52	2.25	5	2	100	2	1	0
2009	54	2.625	9	1	40	2	1	1
2009	55	2.375	5	11	0	2	1	1
2009	57	0		14		2	1	0
2009	67	1.75	3	17	95	2	1	1
2009	71	2.75	3	14	95	2	1	1
2009	73	0.875	2	15	0	2	1	0
2009	81	1	4	6	40	1	1	1
2009	83	1	2	13	10	1	1	1
2009	87	2.5	5	11	10	2	1	1
2009	93	3.125	3	8	100	2	1	0
2009	105	0.75	1	12	60	0	1	1
2009	111	2	4	11	5	1	1	1
2009	113	2.125	3	14	10	1	1	0
2009	114	1	3	13	0	0	0	1
2009	126	1.875	8	12		2	1	0
2009	128	1.75	3	9		2	1	1
2009	130	2.75	4	8	20	2	1	1
2009	133	1.625	4	11	0	2	1	1
2009	134	2	5	13	90	2	1	0
2009	140	2.75	5	6	100	1	1	1
2009	152	2.875	2	2	90	1	1	1
2009	158	1.875	2	4	10	1	0	1
2009	176	3.375	1	2	10	1	1	1
2009	177	2	0	9	10	0	1	1
2009	181	3.25	1	10	40	2	1	1
2009	188	0.875	0	12	95	1	1	1
2009	192	2.75	4	11	95	1	1	1
2009	200	3.75	0	8	70	0	0	0
2009	201	3.25	2	12	10	0	0	0

Nest_veg: 0= Native, 1= other Introduced, 2= Smooth brome
Patch_veg: 0= Native, 1= Introduced
Fate: 0= hatched, 1= failed

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