EVALUATION OF RING-NECKED PHEASANT BROOD REARING HABITAT AND SURVIVAL ON POST-CONSERVATION RESERVE PROGRAM GRASSLANDS IN SOUTHWEST NORTH DAKOTA

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

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ABSTRACT

From 2008-2011, we analyzed brood habitat selection and survival of Chinese ring-necked pheasant (*Phasianus colchicus*) from hatch until approximately 30 days post-hatch. We monitored 98 broods at two sites in Adams County, ND. These sites were previously enrolled in the Conservation Reserve Program and were being managed under a multiple land use system including hayed, idled and season-long grazed land as well as no-till corn (*Zea* mays) and no-till barley (*Hordeum vulgare*) crop treatments. Measurements pertaining to the insect and vegetation community and structure were recorded at utilized brood locations and available locations within the study sites. Variability in brood survival was best explained by precipitation events, temperature, brood age a linear and quadratic time trend. Comparisons among models were made using Akaike's Information Criterion (AIC_c). Within our study area, no habitat selection was found in the season-long, hay, and idle treatments with respect to the habitat variables we measured.

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INTRODUCTION

The Chinese ring-necked pheasant (*Phasianus colchicus*) is an introduced game bird species in North America (Trautman 1982). In North and South Dakota, this is the most frequently harvested game bird during recent years. Therefore, it draws significant attention due to its economic importance and its historical legacy. An abundance of pheasant has not always occurred in the Dakotas, with large scale fluctuations in North Dakota's population common throughout its colonization (Cluett 1941). In 1953, 1966 and 1969 pheasant populations in South Dakota were low enough to close the pheasant hunting season (Trautman 1982). Economically, declines in pheasant hunting not only hurt the state's revenue through a loss of hunting licenses sold, but also negatively impacts rural landowners that may benefit from fee hunting or another hunting related industry.

Pheasant populations respond to large scale changes in land use such as conservation easements, like the Conservation Reserve Program (CRP) created by the United States Congress and the President. This program is implemented through the United States Department of Agriculture (USDA) (Riley 1995). The mechanisms behind this relationship are most likely the increased nesting and brood rearing habitat provided by idled farmland under such programs (Erickson and Wiebe 1973; King and Savidge 1995; Riley 1995; Ryan et al. 1998; Evard 2000; Eggebo et al. 2003; Nusser et al. 2004). Nesting habitat is generally viewed as one of the biggest factors limiting population size (Robertson 1996), while other studies have found the brood rearing stage as a critical period during the pheasant's life cycle (Warner 1984; Riley et al. 1998).

Conservation efforts similar to the CRP began in 1956 with the Soil Bank Act. Since their establishment, these conservation practices have played an important role for North Dakota's agriculture and wildlife production. As of December 2012, active CRP contracts in North Dakota totaled 967,568 hectares in 32,379 contracts from 16,065 farms, totaling around 5.3% of the state's land base (USDA 2012). These contracts provide a temporary diversion from crop production and promote the planting of perennial grasses, providing valuable wildlife habitat, improving water quality and reducing soil erosion on marginal and highly erodible farmlands. Contracts last for ten years or longer. As contracts expire many landowners will return their land to active crop production, which is likely to have impacts on the natural resources of the area.

Loss of CRP lands may negatively affect pheasant populations in some areas as well as limit incoming revenue through hunting related activities. The purpose of our study is to gain a better understanding of pheasant habitat requirements during the brood rearing stage (mid to Late Summer) under a multitude of land uses reflecting the changes that occur when a CRP contract expires. Understanding this relationship is critical to predicting the impact that loss of CRP lands will have on pheasant populations.

Understanding the micro-habitat and macro-habitat selection by pheasant broods will help us understand the impact that expiring CRP contracts have on pheasant populations. This information is valuable to landowners and wildlife managers in order to protect the tradition of pheasant hunting as well as the monetary value it provides. Furthermore, post-CRP land can be returned to several different types of production, and different options may be more compatible with pheasant production then others. Evaluation of different land uses on the critical life stages of pheasant can allow landowners and wildlife professionals to make conservation minded decisions and protect future wildlife populations, and provide a source of income to the rural communities.

LITERATURE REVIEW

Importance of Hunting in Rural Economics

Chinese ring-necked pheasants (*Phasianus* colchicus), hereafter pheasant, are an economically important natural resource in southwestern North Dakota. Hunters annually stimulate economic activity in these rural communities through direct purchases of hunting equipment and indirect service requirements such as lodging and dining. By maintaining pheasant habitat, landowners create recreational revenue that is supplemental to ongoing agricultural operations or conservation leases. Consequently, loss of pheasants and habitat is equivalent to the loss of money in these communities. A study of the northern bob-white quail (*Colinus virginianus*) in the southeastern United States found population decline of this bird was correlated with hunter attrition, lack of hunter recruitment, and caused economic losses in rural communities and specific industries (Burger et al. 1999). Sustaining stable pheasant numbers and habitat in North Dakota is both environmentally and economically important, for similar reasons.

Profits and revenues derived from hunting are not limited to the purchase of hunting licenses alone. Many of these additional expenses directly benefit rural communities that support pheasant hunting. Approximately 90% of the money spent on pheasant hunting and 80% of non-resident expenditures in South Dakota go towards goods, services, and hunting accommodations (Trautman 1982). These expenses were clarified by Steinback (1999) when he described three levels of economic impacts created by sportsmen. These expenses are directly applicable to pheasant hunters in North Dakota. Direct impacts are created from the sales, income, and employment generated through initial purchases (i.e., fees to landowners for hunting privileges). Indirect impacts are the sales, income, and employment to those industries that support the activity (e.g., sale of hunting equipment, lodging, and gasoline sales). Finally, induced impacts are created when the recipients of this economic impact continue to circulate this income (e.g., commodities bought by employees of supporting industries). The sum of these three areas is the total economic impacts created by sportsmen and illustrates the diversity of economic benefits that come with pheasant hunting in North Dakota. Calculating these expenditures is not always straightforward. However, a study by Grado et al. (2001) in Mississippi showed the diversity of hunting related expenses for waterfowl (Table 1).

Table 1. Distribution of expenditures ($/hunter/activity day) in a six county region during the 1998-1999 waterfowl hunting season in Mississippi (Grado et al. 2001).

	Public sites		Private lodges	
Expenditure	$	%	$	%
Ammunition	3.95	6.5	1.95	1.0
Clothing, boots	1.25	2.1	0.03	0.0
Dog-related	0.08	0.1	4.07	2.0
Entertainment	5.00	8.3	1.70	0.8
Equipment-related	5.70	9.4	0.00	0.0
Game processing	0.50	0.8	0.00	0.0
Guns, knives, etc.	1.64	2.7	0.00	0.0
Hunter accessories	0.58	1.0	0.00	0.0
Hunting and site fees	1.05	1.7	185.75	92.3
Licenses	0.86	1.4	0.01	0.0
Lodging	11.04	18.3	0.00	0.0
Restaurants, groceries	14.86	24.6	3.26	1.6
Shopping	6.28	10.4	0.00	0.0
Transportation	7.61	12.6	4.36	2.2
Total	60.41	100.0	201.14	100.0

$ = U.S. Dollars

A study by Gan and Luzar (1993) on total impacts of waterfowl hunters in Louisiana, showed the average cost of hunting per season for those hunters who leased recreation access was calculated at $1,371.93, which included hunting-related expenses such as lodging, gas, and ammunition. They found that the total cost of hunting per season was not the biggest influence on hunter’s decisions to hunt waterfowl. However, maximum duck bag limit and length of hunting season were ranked as major influences. These results suggest that if the cost of hunting increases, money from hunters will continue to enter rural communities if adequate game remains in the area. Therefore, loss of habitat or decreased pheasant numbers can diminish this incoming revenue.

Loss of habitat has been found as a major factor preventing waterfowl hunters as well as other outdoor enthusiast from pursuing their sports in other states (Adams et al. 1997). The similarities between waterfowl hunting and upland game bird hunting imply that loss of pheasant habitat could be directly equivalent to loss of money in rural North Dakota communities. Furthermore, loss of habitat can lead to site congestion in remaining hunting areas. Site congestion was a major influence on the decision of whether or not to hunt in a study done in Louisiana (Gan and Luzar 1993). Other important factors that influence hunters were travel time to hunting area, type of hunting party and type of hunting areas.

Pheasant hunting not only provides a valuable economic stimulus to rural North Dakota communities but also helps diversify the local economy. Creating multiple sources of income in communities helps stabilize the economy and add resilience and adaptability during recession. These benefits, which often go overlooked, are important factors for the future of any economy and opportunities for diversification should be capitalized. In southwestern North Dakota the addition of recreational hunting revenue to an economy driven mainly by agriculture, helps both supplement and diversify the land owner’s income.

History of Ring-Necked Pheasant

Pheasant introductions in North America and Europe have a complex history. These birds were introduced from Asia and have become an abundant species in several countries outside their natural range. Efforts to establish pheasants were driven by its popularity as a game species, and pheasant hunting in the United States is an economically and culturally significant activity (Trautman 1982). The history of pheasant colonization involves many different subspecies and several groups attempting to introduce the bird. Currently the pheasant subspecies of England is a hybrid known as the “English ring-necked pheasant” and this strain along with Asiatic subspecies made up the early introductions into the United States. These isolated attempts to establish pheasant in North America all ended in failure until a Chinese subspecies was introduced in the Willamette Valley of Oregon. This introduction combined with supplemental introductions of other subspecies led to the current American strain containing a genetic makeup of 15 different subspecies. The American strain that emerged from this complicated series of breeding and introductions is known simply as *Phasianus colchicus,* Chinese ring-necked pheasants, or pheasant.

The earliest recorded attempt to establish pheasants in the United States was by the former Governor of New York, Colonel John Montgomerie in 1733 (Studholme et al. 1956). Montgomerie introduced one dozen Old English Black Necked Pheasants on Nutten Island now known as Governors Island in New York. A second attempt at pheasant introduction in 1790 was carried out in New Jersey by Richard Bach, the son-in-law of Benjamin Franklin. Later, in the early 19th century, both George Washington and Governor Wentworth of New Hampshire introduced pheasant into the northeast but their attempts were also unsuccessful. All of these introductions most likely utilized the Old English Black Necked strains from aviaries or game farms (Weigand and Janson 1976).

The first substantial and successful introduction occurred in 1882 through Judge Owen N. Denny in the Willamette Valley/Peterson Butte area in Oregon (Bent 1963). These birds were shipped from the American Counsel in Shanghai, China and they flourished upon introduction. Slightly later, in 1887, the eastern United States had its first successful introduction through Rutherford Stuyvesant with pheasant taken from England. Successful stocking efforts in South Dakota took place quickly after these introductions. The release of pheasant in North Dakota began only a few years later. However, North Dakota Game and Fish Department personnel suggest South Dakota's stocking efforts had more of an influence on pheasant populations than introductions within North Dakota (ND GF, First Annual Report, 1930, p. 54).

The first recorded effort to release pheasant in South Dakota was documented in 1891 in a Sturgis newspaper (Trautman 1982). The article reported N. L. Witcher was in the process of receiving pheasant from Oregon and planned on releasing them in the West River grouse range. However, it is unclear if these birds were ever received or released. In 1898, Dr. A. Zetlitz of Sioux Falls, South Dakota received several varieties of pheasant from Illinois. Zetlitz released 10 of these birds, which were most likely the English ring-neck variety, near the junction of the Split Rock and Sioux rivers in Minnehaha County, South Dakota. These birds were initially successful and were documented as far away as Yankton County, South Dakota in 1902. Eventually, this population of birds disappeared and another release was carried out by Dr. Zetlitz in 1903 near the Split Rock Township of eastern South Dakota. Trautman (1982) suggested the original release may have been unsuccessful due to poorly managed hunting. In 1908 and 1909, A. E. Cooper and E. L. Ebbert released pheasant in Spink County, South Dakota.

These birds were purchased from a game farm in Pennsylvania but it is unknown what subspecies these birds belonged to. This introduction was also successful. Ten years later Spink County became home to the first South Dakota pheasant hunting season (1919). The South Dakota Department of Game and Fish took over the majority of pheasant introductions in 1911. Pheasant were purchased from aviaries and commercial game farms and released primarily in East River counties in South Dakota.

The earliest stocking effort in North Dakota was documented in 1910 using 75 birds from the St. John Hatchery (Johnson and Knue 1989). Later, pheasant stocking operations were aided substantially by the Bottineau and Grafton State Game Farms in 1915. The biggest effort in North Dakota was made by the North Dakota Game and Fish department in 1932 when 15,460 birds were trapped in Dickey, Sargent, and Richland counties and released in 45 counties throughout the state. These efforts combined with hard work from farmers and sportsmen throughout the state established strong pheasant populations in most of North Dakota.

Table 2 (below) shows the first pheasant hunting seasons in some states and provinces around ND as well as Oregon, a state which played a key role in pheasant introductions throughout North America. Hunting seasons in North Dakota were brief for the first 8 years (1931-1938) and never lasted longer than 10 days (Trautman 1982). By the mid 1940s pheasant were abundant in North and South Dakota despite liberal bag limits and longer hunting seasons. South Dakota pheasant populations reached a peak of over 16 million estimated birds during 1945. Pheasant populations fluctuated widely after 1945 and went into decline until the mid 1950s when another population boom occurred. This period of high density, between 1956-1963, is often cited as a response to the abundant favorable habitat established by idle farmland through the Soil Bank Program (Trautman 1982; Johnson and Knue 1989).

Table 2. Date of first hunting season in selected states and provinces for ring-necked pheasant (Studholme et al. 1956; Trautman 1982; Blair 1987; Johnson and Knue 1989).

State	Year
Montana	1928
Wyoming	1933
Nebraska	1927
South Dakota	1919
Oregon	1892
North Dakota	1931
Minnesota	1924
Saskatchewan	1939
Manitoba	1941

Hunting success fluctuated widely during pheasant colonization. Cluett (1941) estimated that 20 million birds were harvested in South Dakota from 1919 to 1940 with an average kill of 1.5 million per season between 1929 and 1940. In the peak harvest year of 1945 approximately 7.5 million birds were taken in South Dakota (Trautman 1982). However, in 1953, 1966, and 1969 the South Dakota and North Dakota pheasant seasons were closed. The latter two of these closures were most likely associated with a severe winter in 1964 - 1965 and the expiration of Soil Bank Contracts returning idled land to agricultural production (Johnson and Knue 1989). In the 1970s pheasant hunting fell behind both sharp-tailed grouse (*Tympanuchus phasianellus*) and hungarian partridge (*Perdix perdix*) with respect to birds harvested. Current pheasant harvests in North Dakota are fairly stable and average 622,602 total harvested birds per season for 2000–2010 (North Dakota Game and Fish data; Table 3).

Table 3. Number of ring-necked pheasants harvested in North Dakota from 2000-2010.

Year	Resident Harvest	Non-Resident Harvest	Total Harvest
2000	199,514	84,245	283,759
2001	261,487	160,099	421,586
2002	339,669	178,152	517,821
2003	401,321	190,745	592,066
2004	353,234	230,785	584,019
2005	574,673	235,102	809,775
2006	529,356	221,431	750,787
2007	586,098	321,336	907,434
2008	586,645	190,064	776,709
2009	453,758	198,020	651,778
2010	401,920	150,964	552,884

Winter Habitat

Severe winter weather in the Northern Great Plains can alter the availability of adequate winter cover and cause increased mortality of pheasants (Gabbert et al. 1999). This critical period, defined as the overwintering stage, takes place from late autumn to the onset of spring. Overwintering is considered one of the critical stages within the annual life cycle of pheasant along with the reproductive and brood rearing stages (Trautman 1982). Several studies conducted in the Northern Great Plains suggest winter survival may be the limiting factor for pheasant populations in this region (Riley et al. 1994; Evard 1996; Homan et al. 2000). Winter survival in the Northern Great Plains can be described as a breeding population bottleneck where the severity of the winter season determines the proportion of the autumn population that survives to participate in the next breeding season (Trautman 1982). These poor winters result in low autumn to spring hen carryover which results in a low breeding population. Kimball (1948) found that pheasant in South Dakota will generally experience severe winter mortality approximately one out of every six years. These high periods of mortality are functions of extended snow cover that buries food sources and renders certain habitat types ineffective combined with extended periods of low temperatures, strong winds, and increased diurnal movement in search of resources (Frank and Woehler 1969; Perkins et al. 1997). The pheasant of the Northern Great Plains are not alone in this regard. Research from other regions, such as southern Idaho, has also found that winter mortality may be the limiting factor for pheasant populations (Lepitch 1992).

Concentrated storms are an important cause of winter mortality. A blizzard in early March of 1966 killed 86% of pheasant in north-central counties of South Dakota (Trautman and Fredrickson 1967). These events, combined with other poor conditions, such as lower breeding success, have the potential to wipe out populations in two years due to the short life span of these birds. In order to avoid these local crashes in pheasant populations there has been a tremendous amount of research focusing on winter habitat selection and survival of this bird. Adequate cover and food resources during severe weather events allow populations to survive through the winter (Trautman 1982). These studies span most of the pheasant’s range because local patterns of habitat use and movements vary in response to local habitat conditions which makes regional data on pheasant behavior not universally applicable (Gatti et al. 1989). These studies generally look for the disproportional use of some habitat types over others. Furthermore, because winter is often the season where the carrying-capacity for pheasants is the lowest, due to mowing and harvest operation, land use is often a major concern.

Wetlands, sloughs, and marshlands serve as quality winter habitat for roosting and loafing when available during mild winters (Frank and Woehler 1969; Trautman 1982; Penrod Hill 1985; Gatti et al. 1989; Gabbert et al. 1999; Homan et al. 2000). Emergent vegetation within these habitat types has stiff erect characteristics that resists lodging and generally retains leaves throughout the winter. This vegetation provides thermal protection from storms and winds as well as escape cover from predators. This plant community is generally composed of willow (*Salix spp.*) and cattail (*Typha spp.*) species. In South Dakota this community was described by Larsen et al. (1994) as primarily being made up of cattails, river bulrush (*Scirpus fluviatilis*), common reed (*Phragmites communis*), and willow. In southern Idaho, this habitat was associated with irrigation drain water and consisted mostly of common cattail (*Typha latifolia*) and willow which also provides habitat for overwintering pheasant (Lepitch 1992). In North Dakota, pheasant were found to move into the semi-permanent wetland habitats from upland vegetation when snow depths became ≥ 30cm (Homan et al. 2000). Peak use of shrub-sedge wetlands, which are distinctive Wisconsin wetland plant communities dominated by small woody vegetation, occurred in November and December, but were the most widely used habitat from October through April in Wisconsin (Gatti et al. 1989). Recently, there has been a push towards cattail management in North Dakota favoring sparser stands of emergent vegetation with higher ecological function and diversity. These practices eliminate important thermal protection and cover for overwintering pheasant (Homan et al. 2000).

Despite preference for wetland habitats, pheasant showed plasticity in selection of overwintering habitats during severe conditions. When wind-driven snow inundates herbaceous habitats and renders them unavailable for use, woodland and food plot habitats are essential to the winter survival of pheasants (Gabbert et al. 1999). In these conditions, pheasant habitat use will shift towards wooded habitats such as shelterbelts or riparian woodlands (Trautman 1982; Gatti et al. 1989; Gabbert et al. 1999; Homan et al. 2000). Gabbert et al. (1999) investigated this relationship using radio-marked hens and showed a significant relationship between pheasant survival and utilization of shelterbelts during extreme winters. In Wisconsin, pheasant increasingly utilized upland hardwoods when snow cover exceeded 28cm (Gatti et al. 1989). In North Dakota, this value was slightly higher and transitions from cattail communities to woodlands did not occur until ≥ 38cm (Homan et al. 2000).

Shrubs and coniferous species are particularly important for effective woodland winter habitat as they provide visual obstruction in the understory creating thermal and protective cover (Larsen et al. 1994). Bue (1949) found that shelterbelts should be at least 200 feet wide and contain a substantial understory of low branches and one more row of dense shrubs around the outside. In South Dakota the majority of shelterbelts, generally consist of seven to eight rows of woody vegetation and were planted between 1936 and 1965. These shelterbelts lacked upkeep and experienced improper use by livestock through rubbing, overgrazing, and excessive trampling from high densities, causing many of these structures to decline in value (Trautman 1982). Many of these shelterbelts may no longer be able to provide effective severe winter habitat for these birds.

A study done in central Illinois also noted the value of continuous winter cover in the survival of pheasant over the winter (Warner and David 1982). In Utah, wooded habitat for overwintering pheasant is provided by sagebrush communities (Smith and Greenwood 1983). Understory visual obstruction is also important in these communities and grazing was shown to negatively affect pheasant utilization of these communities over non-grazed units (Lepitch 1992). Additionally, shelterbelts also may provide protection from raptor species and shade for wildlife during the summer months, and thereby serve a dual purpose (Trautman 1982).

A winter food source is vital for the survival of overwintering pheasant (Trautman 1982). An eastern South Dakota study showed that female pheasant with access to an adequate corn or corn-sorghum food plot, had higher quality diets and more fat reserves than females without access to food plots (Larsen et al. 1994). Without an annual food plot, pheasant will utilize weed patches, grain stubble, harvested crop fields and other food sources to meet energy requirements. Animal food material in winter is scarce; mostly limited to only grasshopper remains, and this amount generally decreases steadily from December to February (Trautman 1982). Plant material consumed during the overwintering stage is also somewhat scarce and made up largely of grain hulls and waste grains. For this reason, agricultural policies that favor waste grain and mimic more antiquated farming procedures will provide pheasant with more food sources during the overwintering stage. Artificial feeding, in contrast to providing an annual food plot, is generally ineffective and labor intensive for the land manager, landowner or wildlife specialist (Trautman 1982).

In many localities, corn or sorghum wheat (*Sorghum bicolor*) annual food plots are used to support overwintering pheasant (Bogenschultz et al. 1995). Comparisons between these two food sources did not suggest that one diet provided a better food source than another. Diets consisting entirely of these food sources may lack certain nutrients or amino acids but pheasant most likely supplement these diets with surrounding natural foods in order to obtain all their dietary requirements. Annual food plots can be utilized as winter cover habitat in areas lacking natural winter cover (Frank and Woehler 1969). Annual plots of forage sorghums and sorghum-sudan grass hybrids (*S. bicolor x S. sudanese*) provide good winter cover on upland sites lacking woodland or wetland winter habitat. Frank and Woehler (1969) also showed that these annual food/cover plots can be used to provide short term winter cover until other winter habitats are established such as a newly planted shelterbelt. These plots can even be supplemented by adding corn and soybeans into the mixture.

Juxtaposition of winter habitats to annual food sources is important to pheasant winter survival (Larsen et al. 1994; Bogenschultz et al. 1995). Proximity of food sources to winter habitats helps minimize diurnal movements and reduces energy requirements (Warner and David 1982). Proximity is also a dominant factor for winter habitat selection (Grondahl 1953). This relationship was evident in a study conducted by Kirsh (1950) where 88% of the woodland habitats utilized by pheasant were within ¼ mile of a significant food source. As travel time increases pheasant predation also increased (Trautman 1982; Gatti et al. 1989). This relationship was displayed by Gatti et al. (1989) where those females preyed upon had significantly larger home ranges then surviving females. Increases in movement may be a result of buried food sources, loss of adequate habitat and increased energy requirements all of which are correlated with extreme winter conditions. Juvenile birds also have been found to have significantly larger daily movements than adult pheasant (Homan et al. 2000).

Pheasant predation may occur from small mammalian carnivores such as; red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), badger (*Taxidea taxis*), striped skunk (*Mephitis mephitis*), spotted skunk (*Spilogale putorius*), and feral cat (*Felis domesticus*) or avian predation (Trautman 1982). Avian predation is correlated with increased snow depth and cover (Wagner et al. 1965; Dumke and Pils 1973; Penrod and Hill 1985; Homan et al. 2000). Furthermore, frequency of occurrence of pheasants in red fox stomachs increases in years when winter severity is high (Dumke and Pils 1973). Trautman (1982) suggested that the abundance of these predators has probably increased due to changes in land use and habitat alteration. Abandoned farmsteads, establishment of woody species and removal of large predators may be responsible for the high numbers of smaller carnivores.

Starvation is also a frequent cause of death in pheasant overwintering in South Dakota (Trautman 1982). In the severe winter of 1936-1937, 80% percent of the autumn population died of starvation (Beed 1938). However authors noted that this mortality may have been influenced by an earlier severe drought which produced a crop shortage, limiting the food available to overwintering pheasant. Starving pheasant will die when body weight reaches 50-60% of their normal weight (Trautman 1982). These birds become thin and lethargic and unable to fly or walk, they start feeding on extremely low quality food sources such as straw, fragments of cornstalks, manure and even carrion. These birds will generally perish in their roosts. Pheasant may also perish from freezing, asphyxiation from ice buildup on the nostrils, pneumonia, and illegal shooting during the winter months (Green 1938). For example, Warner and David (1978) found that 82% of dead birds had food in their crops and normal reserves of body fat after an intense winter storm suggesting a cause of death other than starvation or predation.

Spring Dispersal and Territory Establishment

Pheasant are seasonally territorial (Leffingwell 1928; Wight 1933; Basket 1947; Taber 1949; Burger 1966). During late winter, pheasant are concentrated in areas offering food and thermal cover (Burger 1966). As the days gradually get warmer, males begin to appear further away from these wintering areas marking the beginning of the dispersal period. The newly inhabited territory is defined as territory cover for males and nesting cover for females. For males, this is where territory displays and crowing will take place (Robertson 1996). These movements coincide with the disintegration of male groups and increased male to male conflict. Females at this stage begin to form harems and select a male to mate with. Some studies have shown this period to be a gradual and leisurely transition from winter to summer range (Burger

1966; Schmitz and Clark 1999). Other studies describe the spring dispersal period to be an explosive phenomenon (Gates and Hale 1974).

The spring dispersal period is one of two periods of local movement for an otherwise sedentary bird with the other movement period being the congregation of winter habitat around October (Hill and Ridley 1987). The majority of the male spring dispersal movement occurs in April and males generally break up from pairs in March (Burger 1966). Dominant males may tend to separate earlier from winter male groups. Taber (1949) found that by the end of February, the most successful and dominant males generally separated from one another. Females disperse from winter habitat at a later date, generally mid-April to early May (Gates and Hale 1974). April is also the period of the highest courtship display activity (Taber 1949). In June, July and August pheasant gradually end their courtship and breeding activity with males relinquishing territories and ceasing to crow (Taber 1949). When males begin to peacefully congregate together at a common feeding station, territorial behavior has ceased (Burger 1966).

Male territory habitat is often overlooked by managers (Clark et al. 1999). However, some research suggests that this habitat may be a limiting factor in some areas of North America (Robertson 1996; Leif 2005). Suitable male territory cover contains shrubs and woody cover that surrounds areas of relatively open habitat. These territories are also in close proximity to existing patches of winter cover and suitable nesting habitat (Taber 1949; Burger 1966; Smith et al. 1999; Leif 2005). Males displayed avoidance for monotypic habitats in a study by Burger (1966) during this time period. However, in areas where only monotypic habitat is available, idled herbaceous cover has been shown to meet both the male and female breeding requirements. Presence of woody cover with high ground-level stem density will enhance this habitat (Leif

2005). Furthermore, Gates and Hale (1974) found that a strong preference was shown for some component of wetland cover in the breeding territories of cocks in Wisconsin.

During this time period, breeding pheasants use woody and idled habitat more frequently in midday hours and open habitats and cropland in the early morning. This pattern increases their chances of being seen by potential mates in the morning and provides concealment from predators and escape cover later in the day (Leif 2005). More dominant males, which are able to defend local territories closer to wintering habitat, have smaller home ranges that contain a larger proportion of woody habitat and less open territory. Males that are forced to disperse to more ephemeral habitats have more enlarged home ranges and a greater proportion of open habitats. This may reflect the lower suitability of these open habitats for territory cover. These open and semi-open areas are used heavily by males as peak-hour crowing sites, display sites and courtship sites (Burger 1966). Areas of habitat with higher proportions of cover were utilized during the remainder of the day which suggests that predator avoidance is also responsible for habitat selection in the spring (Smith et al. 1999). Furthermore, edge density within a hen's spring habitat had an inverse relationship to instantaneous mortality such as mammalian and avian predation (Schmitz and Clark 1999).

Spring dispersal movements vary considerably based on sex and age (Gates and Hale 1974; Hill and Ridley 1987; Smith et al. 1999). Hens are more mobile than cocks, and juveniles are more mobile than established adults during the spring dispersal period. There is also a positive relationship between the density of the winter population and the distance of dispersal in the spring (Gates and Hale 1974). This relationship may function as a population control mechanism as higher populations of pheasants are required to disperse further in the spring into lower quality habitat where reproduction is less successful. Finally, dispersion movements are also related to the severity of the winter (Gates and Hale 1974; Leif 2005). More severe winters cause habitat degradation from snow-pack, wetlands filling with water and matted herbaceous cover that forces pheasant to move further in the spring to find adequate habitat.

Leif (2005) studied pheasant in eastern South Dakota and found that males dispersed further into lower quality upland habitat when they were juveniles and stayed relatively closer to winter habitats as adults. He divided these two groups into localized and ephemeral breeders. Seventy three percent of male pheasants dispersed >500m from winter habitat to their spring breeding location and they moved an average of 3.2 ± 0.3 km. Those males on the more ephemeral territories held larger territories then localized males at 45.4 ± 2.9 ha and 18.4 ± 0.9 ha, respectively (Leif 2005). Larger territory sizes were not related to more females (Ridley and Hill 1987).

Male territories show plasticity and may change due to environmental changes, hen movements, and pressure from adjacent cocks (Taber 1949). Territories changed in a gradual and definite direction as the breeding season progressed and males frequently followed harems outside of their original territory (Burger 1966). Territory size is inversely related to population density, and changes will occur as latecomers attempt to establish territories in already crowded areas or when a male dies and creates a vacancy. Gates and Hale (1974) found that the territories of cocks were overlapping and not confined to a defended area. Instead, cocks formed zones of intolerance. Males that ventured too close to a male of a defending territory, often while following a harem of females, would elicit a territorial response from that male. Kuck et al. (1970) found that South Dakota hens had an average home range of 12.5 ha in the spring and summer. Females have been found to nest outside of the male’s territory that they copulated with. Therefore, females generally have a larger territory then males at this time of year (Ridley and Hill 1987). During this period the female spends around 35% of her time outside the range of the male.

As females disperse from winter cover they form smaller harem groups which will later be accompanied by a male (Ridley and Hill 1987). Harems accumulate gradually and are not only a function of females preferring to live in groups but most likely evolved as a function of mate guarding with females selecting males that fend off harassment of other males. Excessive energy expenditure during the early spring season leads to lower nesting success and females escorted by a territorial male spend more time feeding, less time running and less time being alert. This relationship infers that females are selecting for the quality of the occupying male in the habitat and not simply the quality of the habitat itself.

Once females settle into their breeding ranges they remain monogamous with that male (Ridley and Hill 1987). Harem size is larger than should be expected in some harems which imply that there are unequal breeding opportunities for males in the population (Ridley and Hill 1987; Swenson 1978; Goransson 1980; Ridley and Hill 1987). Females select for established males over new males and will breed with the same male for more than one year even if his territory position has changed (Ridley and Hill 1987). Males selected by females have demonstrated that they are the undisputed dominant within the area. They spend significantly less time feeding and more time alert then other males which enable females to feed and remain free of harassment by other males. Sparring, chasing, bluffing and other aggressive male to male behaviors were found to be density dependent (Taber 1949; Burger 1966; Gates and Hale 1974). As population pressure increases some males can be seen sparring 3-4 times daily (Taber 1949).

Spring dispersal is also correlated with crowing behavior for male pheasant (Taber 1949; Burger 1966). Crowing alerts rival males as well as potential mates of the cock’s location in the landscape. Maximum crowing intensity occurs from 45 minutes before to 30 minutes after sunrise (Burger 1966). Cocks will begin crowing in late February, with most of the cocks crowing by mid-April. Crowing ceases by the end of June. However, cocks that begin crowing later in the season also stop crowing later in the season so that all males generally show a three month crowing season. Variations in the initiation of crowing may be related to testis weight which was shown to have a direct correlation with crowing intensity (Taber 1949). Bouts of mid-day concentrated crowing are often triggered by a passage of hens into areas of higher cock densities. These bouts generally involve 3 - 10 males all crowing for 15 - 40 minutes (Burger 1966).

Several studies documented the occurrence of non-territorial males (Taber 1949; Burger 1966; Gates and Hale 1974; Hill and Ridley 1987; Leif 2005). Males that failed to establish and defend a territory may have done so for several reasons. Non-territorial males may be injured or be in poor condition (Burger 1966). They may be pen-raised birds or birds with a direct lineage to pen-raised birds that are more sedentary and unable to successfully establish a territory (Gates and Hale 1974; Leif 2005). Non-territorial males have never been documented crowing, they retain small wattles until they are in very close contact with hens, which rarely happens, and they do not cluck, fight, or display to hens after mid-April (Taber 1949). Generally, non-territorial males were as localized as territorial cocks during the breeding season and were more concentrated around winter habitat then in upland areas.

Nest Selection

Providing attractive and secure nesting cover increases a hen’s chances of successfully hatching a clutch (Robertson 1996). Many studies have been conducted to determine what defines secure nesting cover throughout the pheasant range in North America. This habitat is generally viewed as one of the biggest factors limiting population size (Robertson 1996). However, it should be noted that winter survival and male territory cover can also play large roles in determining pheasant abundance especially in certain regions. Nesting birds should select parts of the landscape that will enhance reproduction and survival (Clark et al. 1999). This relationship allows researchers to study nesting cover preference based on nest success and the habitat selection during nest initiation.

In most studies large blocks of grassland show the greatest nest success; however, the surrounding landscape is also important (Clark et al. 1999). During the initial one third of the nesting season, from April to mid-May, residual/old plant material from the previous year is the only material available for nesting (Trautman 1982; Nielson et al. 2008). Therefore, mowing, livestock grazing, burning and late summer plowing may not harm the current year's nests but it will take away from early season nesting cover for the following year. Furthermore, hay cutting in late summer will also reduce the value of nesting cover for pheasant the following spring (Hays and Farmer 1990). Potential nesting sites during this early part of the nesting season are mainly comprised of scattered fencerows, roadsides, tree groves, shelterbelts, sloughs, weedy grain stubble, ungrazed or lightly grazed pastures, steep rough or wet patches in hayfields or odd acreages, and those lands set aside as undisturbed land. In mid-May, alfalfa (*Medicago sativa*) quickly provides more nesting cover (Hanson and Progulske 1973).

Different regions vary in their ability to provide nesting cover. In Illinois, forbs like red clover (*Trifolium pratense*), alfalfa, sweet clover (*Melilotus officianalis*), white clover (*Trifolium repens*), and grasses such as timothy grass (*Phleum pratense*) and smooth brome (*Bromus inermis*) are important species providing nesting cover (Hanson 1970). Alfalfa and cool season grasses were also found to be important nesting cover for pheasant in Nebraska (Baxter and

Wolfe 1973). In our study plots, located in Adams County, North Dakota, nest sites were composed primarily of cool season grasses (87%); including smooth brome and intermediate wheatgrass (*Thinopyrum intermedium*), with alfalfa and sweet clover common legumes at 10% of the composition (Geaumont 2009). Seeded warm season pastures for livestock forage such as switchgrass (*Panicum virgatum*), Indian grass (*Sorgastrum nutans*) and big bluestem (*Andropogon gerardii*) provided suitable nesting cover for pheasant in a study conducted in Iowa (George et al. 1979)

A study by King and Savidge (1995) suggested that vegetation structure may be more important to nesting birds than plant species. Hens nesting in Wisconsin found a variety of plant species acceptable for canopy cover so long as the plant's old or new growth provided concealment (Dumke and Pils 1979). Plant height and density were important factors in nest site selection in Illinois (Hanson 1970) and in Montana (Fondell and Ball 2004). Height and density correlated positively with nest density. These vegetation factors may reduce losses from predators and provide cooler micro-environments through shading which favor egg hatching. In Adams County, North Dakota, the average Visual Obstruction Reading (VOR) around nests was 2.08 dm in season-long grazed pastures and 2.0 dm on Idle pastures (Geaumont 2009). The greatest number of nests in these two cover types was initiated in areas of greater than or equal to a VOR of 2.50dm. No nests were initiated in the 0-0.49 dm VOR category (Geaumont 2009; Table 4).

In many regions single-species stands of vegetation are rarely used for nesting (Dumke and Pils 1979). However in drier regions, such as eastern Colorado, winter wheat (*Triticum aestivum*) crops provide the most valuable nesting cover during years of high precipitation (Snyder 1984).

Table 4. Visual obstruction readings at ring-necked pheasant nests on idle and season-long grazed Conservation Reserve Program lands in southwest North Dakota, 2006-2008 (Geaumont 2009).

[a] n=69

[b] n=35

Treatment						
	Season-Long[a]			Idle[b]		
VOR category (dm)	Available nesting habitat (%)	Nests/ha available cover[c]	Nest Attempts (%)	Available nesting habitat (%)	Nests/ha available cover[c]	Nest Attempts (%)
0-0.49	8	0.00	0	2	0.00	0
0.50-0.99	16	0.29	17	12	0.13	3
1.0-1.49	31	0.19	22	23	0.55	22
1.50-1.99	22	0.26	22	19	0.66	25
2.0-2.49	14	0.11	8	24	0.32	16
≥ 2.50	9	0.95	31	20	0.66	34

[c] $=n \cdot ha^{-1} \cdot yr^{-1}$

In 1979 and 1980, nests initiated in winter wheat in eastern Colorado contained an average of 87% of the successful nests. The high success rate of these nests may be due to the grasslands in this area providing poor nesting habitat by having a lower vegetation height and lower density. Similarly, pheasant in the high plains of Texas utilized forage crops and small grains as nesting cover (Whiteside and Guthery 1983). However, pheasant tend to select suitable cover at nest sites irrespective of plot-level conditions, suggesting birds select based on micro-site selection rather than plot level conditions (Fondell and Ball 2004). Small variations within a crop field or pasture may provide suitable nesting cover that is often overlooked by managers and landowners.

In most regions, diverted farmland and grassland pastures are primary nesting habitats (Dumke and Pils 1979, Warner and Etter 1989, Riley et al. 1994, King and Savidge 1995, Schmitz and Clark 1999). Warner and Etter (1989) stated that diverted farmland that is safe nesting cover has been and probably always will be an important component of prime pheasant range in the Midwest. A study conducted in Wisconsin found that retired cropland was favored over hayfields, wetlands, and strip cover because it provided adequate nesting cover for the entire nesting season (Dumke and Pils 1979). However, wetlands and strip cover were used early in the nesting season. In Nebraska, cool season pastures, warm season pastures and native prairie all had greater numbers of nesting females than crop land (King and Savidge 1995). The most successful nests, in a four year Iowa study, were located in idle cover and grassed waterways (Riley et al. 1994). Grassed waterways contained 31% of the nests, although they only represented 3% of the study area. Schmitz and Clark (1999) also found that pheasant in Iowa selected home ranges in the spring with proportionally more grassland than was available across the landscape.

Nests are considered successful if the hen is able to hatch at least one chick. However, estimating nest success is not as straightforward. Nests can be evaluated as simply as the number of nests observed that end up hatching, or they can be evaluated based on their stage of development. By incorporating the stage of development into the analysis, researchers account for the amount of risk/exposure that a nest has already gone through before discovery. Incorporating this factor into the analysis was proposed by Mayfield (1969) and is known as the Mayfield method. Agricultural operations, predation, trampling and nest abandonment are the main causes of nest failure. A four year study conducted in Iowa found 44% of nesting females were successful in their first nesting attempt (Riley et al. 1994). Their analysis did not incorporate the Mayfield method into their estimation. Initial nest success levels for each year varied from 28% to 55% in this study.

In North Dakota, Geaumont (2009) found that nest success levels varied among cover types, including season-long grazing, idled land, hayed pastures, no-till corn, and no-till barley. Annual success rates did not differ between treatments; however, a treatment X year interaction was recognized which did not allow for a discussion of treatments (Geaumont 2009; Table 5).

Pheasant generally lay one egg per day and lay an average clutch size of 10 eggs. These eggs are then incubated for 23-24 days. Therefore, the complete nesting cycle averages 33-34 days, which is generally incompatible with alfalfa harvest for all but the earliest of nests (Trautman 1982). Furthermore, the time spent on nests increased with the amount of eggs laid (Kuck et al. 1970). The length of time that nesting cover remains undestroyed is an important factor determining nest success in active agricultural areas. Seeded warm season pastures such as switchgrass , Indian grass, and big bluestem had significantly higher nest success than alfalfa, orchard grass (*Dactylis glomerata*) and other hay meadows due to early season cutting of the later land uses (Fondell and Ball 2004).

Table 5. Pheasant apparent nest success (%) and standard errors by treatment on Post-Conservation Reserve Program lands in southwest North Dakota (Geaumont 2009).

Year(s)	Treatments				
	Season-Long	Idle	Hay Pasture	No-till Corn	No-till Barley
2006	80 (18)	10 (10)	50 (14)	0	100 (100)
2007	50 (5)	60 (5)	100 (100)	0	0
2008	65 (48)	70 (31)	0	0	0
2006-2008	65 (17)	47 (32)	50 (21)	0	33 (33)

Every region will have slightly different circumstances related to agricultural conflicts and nesting activities. Any hay cutting during the nesting season reduces nesting success and increases female and chick mortality (Warner and Etter 1989). Generally, mowing/haying operations should wait until after July in order to ensure nests have hatched and broods are mobile (Patterson and Best 1996). However, in eastern Colorado, cutting winter wheat crops prior to the incubation stages (April to Early May) increases nest success, otherwise nests will be destroyed during the early spring harvest and re-nesting will occur in wheat fields which could then be destroyed again in July harvests (Snyder 1984).

Poor timing with agricultural activities can significantly reduce pheasant populations. In Iowa, mowing operations in early June destroyed all nests and killed 73% of hens in an alfalfa/orchard grass pasture (George et al. 1979). Initial cultivation of stubble fields destroyed more pheasant nests than were lost to predators in eastern Colorado, thereby representing a significant contribution to nest destruction (Snyder 1984). About 65% of incubating hens were struck by farm equipment in Illinois and only 1 of 7 hens struck during cutting was typically alive at the end of the summer (Warner and Etter 1989). Additionally, emergency hay cutting on CRP fields during the pheasant nesting and brood rearing season significantly reduced production due to nest destruction and direct mortality (Hays and Farmer 1990).

Trends in modern agriculture threaten nest success (Warner et al. 1999). In many areas, the lack of undisturbed cover from increased agriculture production, leads to more nests in vulnerable landscapes (Warner and Etter 1989). These nests experience higher levels of nest destruction from haying or trampling. There has also been a significant trend towards earlier hay harvest in all states except Indiana and Missouri since WWII. Most alfalfa in the Midwest is now cut 4-5 times compared with 2-3 times only a few decades ago. Cultivation procedures and other structures installed on to machinery will decrease nest destruction but are not commonly used (Snyder 1984). Installing flushing bars onto farm equipment is one practice found to increase nesting success (Calverley and Sankowski 1995). Equipment with these structures installed may still destroy the nest but allows the hen to escape. However, these structures can be costly for producers and are rarely used.

Nest trampling by livestock is considered rare but can be a direct result of livestock presence (Fondell and Ball 2004). Ungrazed plots consisted of reduced forb cover, increased litter cover, increased litter depth, and increased VOR of vegetation. Pheasant nest locations in Montana were positively correlated with VOR and therefore negatively correlated with grazing (Fondell and Ball 2004). However, nest selection is correlated with vegetation and grazing is only a factor affecting the plant community. Therefore, grazing should not be looked at as the chief factor determining nest site selection in areas with grazing and nesting activity. Geaumont (2009) found no significant nest success differences among different post CRP treatments, which included season-long grazing and idled land, in a study done in southwestern, North Dakota.

Several studies showed nest predation as the primary cause of nest failure (Chesness et al. 1968; Dumke and Pils 1979; Riley et al. 1994; Clark et al. 1999; Schmitz and Clark 1999; Geaumont 2009). Mammalian predation was generally the dominant form of predation. However, avian predation did play a significant role in several areas including eastern Colorado (Snyder 1985). In Colorado, great horned owls (*Bubo virginianus*), cooper’s hawks (*Accipiter cooperii*) and prairie falcons (*Falco mexicanus*) were identified as the dominant avian predators. In intensely farmed regions crow (*Corvus brachyrhynchos*) can also become a common nest predator (Chesness et al. 1968).

Predation was the primary cause of death to hens in spring in an Iowa study, and accounted for 87.5% of the deaths (Schmitz and Clark 1999). The majority of deaths (66.7%) were due to mammalian predation. Another study in Iowa found that mammalian predation accounted for 61% of nest losses over a four year period (Riley et al. 1994). Mammalian predators accounted for 98% of nest failures in southwestern, North Dakota and striped skunks (*Mephitis mephitis*) were the primary culprit (Geaumont 2009). Patterson and Best (1996) found that the primary mammalian predators of pheasant nests in Iowa were red fox (*Vulpes vulpes*), striped skunk, raccoon (*Procyon lotor*) and farm cats (*Felis catus*). Chesness et al. (1968) found a similar suite of predators in southern MN.

Predation varied depending on several factors; however, predation was highest on poorly concealed nests (Chesness et al. 1968). The highest predation rates were shown to take place on nests established early in the season in residual cover from the previous year. Increased edge habitat has also been shown to increase predation (Clark et al. 1999). On a land with different habitats, predators will concentrate their hunting pressure to areas with heavier cover (Chesness et al. 1968). Therefore, increasing distance from edge and limiting fragmentation are important factors for improving nest success (Clark et al. 1999). Birds showed preference for nesting in areas further away from the edge.

Nest abandonment is another factor limiting nest success. Hens will sometimes abandon a nest based on discovery of the researcher (Gates 1966). Ten of eleven abandonment cases in a four year Iowa study were investigator related (Riley et al. 1994); four of five hens abandoned their nests when they were initially radio-equipped in a study conducted in South Dakota (Kuck et al. 1970). Geaumont (2009) found that 35% of nests were abandoned in southwestern, North

Dakota. However, hens are less likely to abandon their nests as the length of incubation progresses (Warner and Etter 1989).

The percentage of hens that eventually produce a brood is higher than the percentage of nests that are successful (Gates 1966). Therefore, hens will initiate another nest when the previous one has failed; this behavior is called re-nesting. A period of renewed ovarian development, called the re-nesting interval, takes place between nesting events. The re-nesting interval lengthens as the stage of incubation advances when the first nest was terminated. The re-nesting interval for two hens in a South Dakota study was 10 and 11 days (Kuck et al. 1970). However, re-nesting can be close to instantaneous in some situations when eggs are un-incubated (Gates 1966). In Wisconsin, there was an average of 6.4 days between nest loss and onset of laying a second clutch (Dumke and Pils 1979). In this same study, all unsuccessful hens re-nested at least once and many re-nested even after this. One hen was recorded re-nesting four times, hatching a brood on 3 August. Re-nesting efforts produced 40% of the broods in Wisconsin. Of hens losing their first nest, 71% re-nested during a four year study in Iowa. Their second nests had a success rate of 40% (Riley et al. 1994). Another study in Iowa found that 83% of adults re-nested after losing their first nest; whereas, only 58% of juveniles re-nested after losing their first nest. However, juvenile re-nests were more successful than adult’s at 75% to 15% respectively (Riley et al. 1994). Hens are also more likely to re-nest if disrupted early in incubation (Kuck et al. 1970).

Because of agricultural activity, the suite of available nesting habitats for pheasant will change from the initial nest selection period (Gates 1966). Pheasant usually do not re-nest in tracts where their nests were destroyed, therefore re-nesting attempts may occur in an entirely different cover types (Warner and Etter 1989). In Wisconsin, 79% of re-nesting efforts were initiated in cover types different from the original cover (Dumke and Pils 1979). There was an average distance between nests of 396 m, (range 63 m – 2,264 m) between the first and second nesting effort. In South Dakota, two hen pheasant were recorded re-nesting approximately 148 m and 176 m from the first nest (Kuck et al. 1970).

Ranges for hens were 8 ha – 21 ha, and averaged 12.5 ha during the nesting season (Kuck et al. 1970). As incubation progresses hens remain closer to their nests, shrinking their activity centers (Hanson and Progulske 1973). Average home range size was found to be the smallest during the peak hatching period (15 - 30 June) in a South Dakota study (Hanson and Progulske 1973). Following hatching, home range sizes increase in the post-breeding season with a large increase in home range size in August and September. This range size increase could likely be a response to crop harvests and activity centers may shift after these events.

Brood Rearing

The brood rearing stage is another critical period during the pheasant's life cycle. Successful brood rearing is enhanced by access to particular food resources, mostly insects, as well as appropriate cover habitat (Trautman 1982). Cover is dependent on vegetation characteristics such as VOR and litter depth. These plant communities also support the insect populations the broods depend on, therefore these two requirements are inter-related and are the focus of many brood rearing studies (Hill 1985). Upon hatching chicks are capable of locomotion immediately; however, their ability to escape predators is still relatively undeveloped and predation becomes a major threat to brood survival (Trautman 1982). Riley et al. (1998) reported mammalian predation was responsible for greater than 85% of brood mortality in Iowa. Brood rearing habitat must provide for both the dietary requirements of young chick as well as their cover. Marginal habitats have been shown to increase the territory that broods are required to cover to meet their resource needs. As a consequence these movements further expose broods to the risk of predation (Warner 1984).

Adequate brood rearing habitat varies by region and can be affected by the predominant agricultural activities in the area (Warner et al. 1999). In most localities broods show disproportional use for certain habitat types over others available in the landscape (Hammer 1973). One exception to this rule is the Willamette Valley in Oregon where pheasant showed no significant differences in use of cover types over those available within the landscape (Meyers et al. 1998; Table 6). Nevertheless, the survival of Willamette Valley broods was related to the habitat the birds utilized as well as the age of the broods. Grain fields (wheat, oat (*Avena sativa*) and barley) provided the most secure hatching and early brood rearing cover (from 1-7 days). Strip cover (roadsides, fencerows and roadside ditches) was the least productive habitat for hatching success and early brood survival due to predation pressure. However, it was shown to be selected during nest establishment and was used frequently by broods that survived during days 8 - 44. Survival of broods in the Willamette Valley is therefore related to frequency and timing of habitat use by broods.

Alfalfa, proved to be an important cover type throughout the brood rearing season for all months from June to October in South Dakota (Hanson and Progulske 1973). Alfalfa was the top selection for overall preference during all periods of the brood rearing stage when analyzed with a cover use index procedure developed by Robel et al. (1970). Other habitats, such as sown small grain fields, corn fields, and shelterbelts, were used intermittently for nesting and roosting during this same period. Pheasant targeted corn (33%), small grains (oats and rye (*Secale cereal*)) (23%), alfalfa (15%), and residual cover (14%) more than any other land types. Residual cover and small grains were most heavily used in early summer and approximately 90% of the birds

Table 6. Cover type use by pheasant broods comparing survived and perished for three time periods in western Oregon, 1980-1983 (Meyers et al. 1998).

	Cover type used (%)[a]					
	Hatching		Days 1-7		Days 8-44	
Cover Types	Broods that perished in ≤7 days (n=26;26)[b]	Broods surviving ≥8 days (n=67;67)[b]	Broods that perished in ≤7 days (n=26;27)[b]	Broods surviving ≥8 days (n=70;130)[b]	Broods that perished between 8-44 days (n=26;94)[b]	Broods surviving ≥45 days (n=28; 277)[b]
Grain fields	15	55^{**}	15	52^{**}	44	40
Strip vegetation	35	8^{**}	11	4	5	15^{*}
Seed Grasses	27	15	19	18	16	7^{*}
Grassland	16	16	37	15^{*}	30	30
Miscellaneous	8	6	19	11	5	8

[a] Distribution of percentage among the 5 cover types were significantly different between those broods that survived and those that did not for each period. Significant individual comparisons within a time period are shown with * ($P < 0.05$) and ** ($P < 0.01$).
[b] Sample size (number of broods; number of locations).

observed were in these locations during June and the first half of July. In September, only 7% of the locations were in these habitats. Small grains were highly preferred from mid-June to mid-July. Corn was used during all periods of the day after 1 July and was utilized progressively more after mid-July.

In Illinois, an area that is intensely dominated by row crop agriculture, brood activity was significantly higher in oat fields compared to hay fields (Warner 1979). Oat fields provide appealing cover for pheasant in Illinois (Warner 1984). Ease of movement, concealment, and abundance of insects make oat fields a prime foraging cover for pheasants (Warner 1984). Prime feeding areas during this time period are strongly correlated with insect abundance (Basore et al. 1987). During the early brood rearing stage (1-4 weeks) other habitats in Illinois, such as corn and soybeans, are of little value to pheasant chicks because of their low arthropod abundance

(Hill 1976). Nevertheless, pheasant broods will attempt to utilize the habitats available when ideal cover types are absent. Basore et al. (1987) found that pheasant in Iowa will utilize row crops for food in the absence of hayfields for the early brood rearing stage. In certain situations arthropod abundance is not the primary factor determining habitat selection. For example, a British study found that during the first four weeks, 68% of pheasant chick locations were in cereal fields, and only 8% in woodlands, which were significantly less then what was available in this area (Hill 1985). Avoidance of woodland habitat was still present despite a higher level of arthropod abundance. These pheasant also showed preference for rough grass, weedy areas and winter barley (*Hordeum vulgare*).

Several studies have shown that differences in brood survival are associated with the habitats utilized during this time period (Meyers et al. 1988; Riley et al. 1998; Clark and Bogenschutz 1999). For example, broods hatched in grain fields perished significantly less frequently than those hatched in other habitats in the Willamette Valley of Oregon (Meyers et al. 1988). In northern Iowa researchers found a positive association between hens with broods in grassland cover and brood survival (Riley et al. 1998). Lower amounts of grassland cover corresponded to more variability in chick survival. This study also found that highly fragmented landscapes, did not allow for high numbers of chick survival. There is also a lower survival rate associated with late-hatched chicks from re-nesting attempts (Clark and Bogenschutz 1999).

Changes in modern agriculture have also had an effect on brood rearing habitat (Warner 1979; Warner 1984; Basore et al. 1987; Clark and Bogenschutz 1999; Warner et al. 1999). Oat fields, which are high value brood rearing habitat, are threatened with changing farm practices favoring less small grains and more soybeans and corn crops in Illinois (Warner 1984). Without small grain habitat, pheasant broods will make greater use of marginal brood rearing habitat such as corn and soybeans. Warner (1979) concluded that availability of insects and weedy forbs for pheasant chicks in this area had reached critical levels which may detrimentally affect their ability to complete normal life cycles. Under these intense agricultural situations, brood rearing habitat may be equally as limiting as nesting habitat (Warner 1979; Clark and Bogenschutz 1999). Other changes in modern agriculture, such as the late seeding of mono-typic oats in Illinois, have also been found to be of little value to foraging pheasant (Warner et al. 1999). No-tillage fields, while beneficial for soil health and other ecological properties did not show a significantly different availability of arthropods when compared with other tillage practices in a study done in Iowa. However, the value of no-tillage fields to meet other requirements of the brood rearing stage compared to conventional tilling is unclear (Basore et al. 1987).

The effects of herbicide, pesticide and insecticide application have the ability to reduce available food and quality habitat for pheasant broods (Warner 1984). Prior to the advent and usage of herbicides, most crops had an undergrowth of grassy weeds and forbs that provided invertebrates and small seeds for young chicks (Warner et al. 1999). Brood rearing habitat in intensely farmed regions, such as Illinois, has not only decreased in size but has also declined in quality. Researchers have shown improvements in chick survival by eliminating the use of pesticides on small grain field margins, there-by increasing insect forage and providing more food for pheasant broods (Chiverton 1994). Other studies such as Warner et al. (1982) have found similar relationships; insect control for soybean farming has been linked to smaller insect populations in central Illinois and thus less food for pheasant chicks.

Utilization of specific cover types throughout the diurnal cycle has been another major focus of brood rearing research (Hanson and Progulske 1973; Warner 1979; Meyers et al. 1998). Variation in this selection also appears to be regional and Meyer et al. (1988) found that there was no difference in cover types used by broods during morning, mid-day and afternoon time periods in the Willamette Valley of Oregon. In contrast, South Dakota broods were found in corn fields, pastures, and summer fallow pastures during the day but avoided these areas at night (Hanson and Progulske 1973). They utilized small grain fields equally throughout the 24 hour period and shelterbelts were used at their greatest extent in the morning period but the least in the afternoon. Alfalfa was found to be the most extensively used cover type for both day and night throughout the brood rearing season. In Illinois, differences in cover type have been studied based on the diurnal cycle (Warner 1979). Broods focused activity primarily in oat fields during the day as well as the night when this habitat was available, suggesting that oat fields in this area are valuable both as suitable roosting cover and as primary feeding areas. In Nebraska, hayfields were most frequented by pheasant at nighttime (Hammer 1973).

The use of row crops by pheasants has generally been shown to increase during the afternoon hours (Bennet and Hendrickson 1938; Hammer 1973; Hanson and Progulske 1973; Warner 1979). Pheasant broods roosted primarily in hay and small grains, and they were relatively inactive until after sunrise (Warner 1979). Several researchers believe this period of inactivity may correspond with dew accumulation on vegetation (Fisher et al. 1947; Klonglan 1955; Warner 1979). During the early morning period pheasant in Iowa moved to open areas, which was likely a response to the heavy dew in the grass habitat. During the mid-day hours, pheasant moved to heavier cover areas as the dew evaporated (Warner 1979). Pheasant waited until after daylight to leave nesting cover and return to their roost. These daily movement patterns were recorded by Warner (1979) and displayed below (Warner 1979; Table 7).

Table 7. Frequency of locations of pheasant broods by primary cover types for different daily time periods in Illinois (Warner 1979).

		Brood Locations			
Time Period	Observed v. Expected	Corn and Soybeans	Hay and Oats	Edge, strip, and Roadside	Total
Night (2131-0530)	OBS EXP[a]	3 7.3	14 9.6	5 5.1	22 □ x_2^2 = 4.55[b]
Early Morning (0531-0930)	OBS EXP	36 36.6	46 47.8	28 25.7	110 □ x_2^2 = 0.29
Midday (0931-1330)	OBS EXP	44 51.6	70 67.3	41 36.2	155 □ x_2^2 = 1.87
Afternoon (1331-1730)	OBS EXP	45 33.9*	44 44.3	13 23.8□	102 □ x_2^2 = 8.54‡
Evening (1731-2130)	OBS EXP	16 14.6	14 19.1	14 10.3	44 □ x_2^2 = 2.82
Total		144	188	101	433
□ x_4^2		7.43	3.56	7.08	□ x_8^2 = 18.07‡

[a] Expected values (EXP) calculated from the percentage of total locations observed (OBS) in each cover type for all periods combined: 144/433 □ 144 = 7.3.
[b] Representing the chi square notation using two degrees of freedom
* 0.10 > P > 0.05; □ 0.05 > P > 0.025; ‡ 0.025 > P > 0.01.

Considerable variation between home range sizes has also been detected and varies by location. The variation is correlated with the age of the brood, agricultural activities and habitat quality (Kuck et al. 1970; Warner 1979; Hanson and Progulske 1973; Hill 1985; Riley et al. 1998). Immediately upon hatching females and broods stay close to their nest for several hours unless predators, machinery or some other disturbance force them to move (Baskett 1947). During the peak hatching period, the home range of hens and their broods is the smallest it will be for the entire brood rearing season (Hanson and Progulske 1973). In South Dakota, significant increases in home range size were seen after this period (Hanson and Progulske 1973). In South

Dakota, brood ranges increased from the nesting range to 12.9 - 15.7 ha in July through the first two weeks in August (Hanson and Progulske 1973). During the last two weeks of August this range increased to 28.7 ha followed by a range decrease to 22.3 ha for the last two weeks of September.

Another South Dakota study looked at hen home ranges during the brood rearing stage (Kuck et al. 1970). Home ranges were recorded at 8.1 - 21 ha and averaged 12.5 ha. Brood rearing was restricted to 2 – 4 ha around the nest for the first 3 weeks following hatch. Similar patterns were found in northern Iowa (Riley et al. 1998). A four year study conducted by Riley et al. (1998) found that broods generally stayed within 100 m of their nest location for two 2 days after hatch. After this, movements up to 1,000 m were observed. This study was conducted in two counties in Iowa; they found the mean home range area in the two counties to be 76 and 66 ha for the duration of the study (Riley et al. 1998; Table 8).

Comparisons of brood home range size were broken down by Hill (1985) for the first three weeks of the brood rearing stage. In Great Britain home ranges were reported as 4.8 ± 1.0 ha, compared to Illinois broods which occupied 5 -10 ha. In South Dakota, broods home ranges were at 2 - 4 ha (Kuck et al. 1970) and 11 ha (Hanson and Progulske 1973). Movements between successive nocturnal roosts were recorded by Hill (1985) in Great Britain. Roosts had a mean maximum range length (the distance between the two most widely separated locations) of 376 ± 38 m (range 235-493 m), and the mean distance between successive nocturnal roosts was 75 ± 13 m.

Table 8. Home range area (ha) based on minimum convex polygon estimator of pheasant hens with chicks during nesting and brood rearing in Palo Alto and Kossuth counties, Iowa, 1990-94 (Taken from Riley et al. 1998).

Year	Palo Alto county, IA			Kossuth county, IA		
	mean	SE	M_i^a	mean	SE	M_i
1990	56	22	16	63	42	7
1991	21	6	19	15	2	3
1992	111	26	25	52	18	5
1993	84	17	15	179	90	3
1994	102	29	13	57	18	11
1990-94	76	20	88	66	30	29

[a] Number of hens with broods

Variations in brood home range size were found to be correlated with the quality of brood rearing habitat (Warner 1984; Hill 1985; Warner et al. 1999). Illinois pheasant broods in diverse habitats had smaller home ranges than their counterparts in corn-soybean monocultures (Warner 1984; Warner et al. 1999). These increases in range size are likely a function of food supply and the brood's dietary needs (Hill 1985). However, Warner et al. (1999) speculated that this increase could represent the hen's dietary requirements as well because little is known about whether brooding hens forage primarily in response to their own nutritional needs or if they will alter their optimal feeding pattern to accommodate chicks. Dietary analysis by Hill (1985) found that there was overlap in diets between the hens and broods during the brood rearing stage. However, arthropods were still only a minor part of the hen's diet. Increases in home range size do not come without a price, and Hill (1985) confirmed an increase in brood rearing failure with increases in distance between the two furthest locations of nocturnal roost sites. Hill's research (1985) also illuminated the diversity of arthropods present in the diet of pheasant chicks (Hill 1985; Table 9).

Table 9. Composition of arthropod component by dry weight (%) of pheasant chick's diets (seven brood) and selection index (value derived by dividing arthropod samples collected from the home range by the weight value represented in the diet) of pheasant in England (Hill 1985).

Food item	Percent in the diet	Selection Index
Araneidae	2.3	0.2
Aphididae	8.1	1.8
Cicadellidae	4.1	0.3
Delphacidae	10.4	1.3
Heteroptera	17.5	0.7
Sawfly adult	0.1	1.0
Sawfly larvae	18.6	4.0
Lepidoptera larvae	11.6	8.9
Ichneumonidae	0.7	2.3
Braconidae	1.1	0.4
Formicidae	0.7	7.0
Carabidae adult	2.3	2.9
Carabidae larvae	0.4	4.0
Staphylinidae adults	1.0	0.6
Staphylinidae larvae	0.6	6.0
Curculionidae	3.7	1.4
Elateridae	2.2	22.0
Other Coleoptera	1.6	0.6
Tipulidae	6.4	64.0
Other Diptera	5.7	0.5
Chrysomelidae	0.1	0.5
Dermaptera	0.6	6.0

Many of the changes in behavior and home range size throughout the brood rearing season can be clarified by looking at the change in dietary requirements as pheasant chicks mature (Hanson and Progulske 1973; Warner 1979; Warner 1984; Hill 1985). Young chicks eat animal matter almost exclusively (Hill 1976; Whitmore et al. 1986; Basore et al. 1987). Dietary shifts towards a higher proportion of plant matter occur from 2 - 4 weeks at which time pheasant broods primarily target weed seeds and cultivated grains (Warner et al. 1982; Hill 1985). Hill (1985) analyzed fecal matter from broods in Great Britain at this stage and found a significant increase in the biomass of *Poa annua* and *Agrostis* spp. as chicks increased in age. During this dietary shift home range size often increases and broods will show increased use of cropfields until 6 - 7 weeks of age where this effect levels off (Hanson and Progulske 1973; Warner 1979; Hill 1985). This relationship becomes an important factor in determining the quality of brood rearing habitat in an area. In intensely farmed regions, younger broods have a significantly higher mortality rate than their slightly older counterparts (Warner 1984; Meyers et al. 1988). This difference may be due to the changes in dietary requirements that allow broods to utilize new habitats but also their increased mobility and flight ability which allows them to escape predators.

It is important to note that not all researchers have observed this relationship (Ewing et al. 1992). In some areas, cover types may have the ability to provide for both younger and older chicks without requiring an expansion in home range. This relationship is one that requires further research and also requires a landscape level analysis of an area. Agricultural activities have also been cited for the increase in home range size as the aging of broods often coincides with crop harvests (Kozicky 1951; Hammer 1973; Hanson and Progulske 1973; Warner 1979). However, a study by Warner (1979) found that changes in use of cover by broods over the summer appeared to be more a function of age and maturation rather than crop phenology or harvest.

Because brood dietary requirements are a major factor in determining behavior and habitat use of young chicks, there have been many studies targeting the needs and preferences for young pheasant (Scott et al. 1955; Woodward et al. 1977; Warner et al. 1982; Hill 1985; Basore et al. 1987). Mortality has been linked to the amount of protein in the diet for young pheasants with increases in protein leading to higher rates of survival (Scott et al. 1955). Hill (1985) found that arthropod densities in the home range of broods explained 75% of the variables often coincide with chick survival during the brood rearing stage but this relationship may not always be directly caused by death from exposure to inclement weather. Hill (1985) found that when mean temperature in the month of May was combined with variations in insect abundance using a multiple regression analysis, 95% of the variation in chick survival was explained.

Monthly temperatures and rainfall were able to explain variation in arthropod communities. Therefore, inclement weather while still directly causing mortality in some cases also has an indirect effect of limiting the food supply to young broods, causing additional stress. Insect abundance is strongly correlated with brood survival (Hill 1985). However, most arthropod abundances occur towards the end of the summer after the majority of the brood's diets have already shifted towards plant based foods (Basore et al. 1987).

Receiving sufficient protein levels during the first 24 days post-hatch is necessary for adequate growth (Warner 1984). High protein diets favor good early feathering and allow for satisfactory growth (Woodward et al. 1977). However these results decline with age, and the amount of protein needed in the diets of older pheasant chicks to maintain adequate growth becomes increasingly smaller up to 14 weeks. In a laboratory study conducted by Woodward et al. (1977), optimal levels of dietary protein for young chicks were determined to be 24% for the first 8 weeks, 20% for the next 8 weeks and 10 - 12% protein was sufficient after 16 total weeks. Protein in this study was entirely plant based, demonstrating that sources other than arthropod biomass can be important protein resources. Determining the minimal amount of arthropod abundance needed for growing broods therefore depends on both the characteristics of the plant tissue in the habitat as well as the quality and quantity of the protein source provided by the insects.

Another laboratory study demonstrated that the differences in growth between pheasant on a low and high protein diet were most evident during the first three weeks (Warner et al. 1982). Beyond 24 days both low protein diets as well as high protein diets allowed for adequate growth. Despite the need for protein in the diet of young pheasant, restricted protein diet studies found that pheasant fed high protein levels and low protein levels all weighed the same by 20 weeks of age; however the timing of their growth was not equal (Woodward et al. 1977).

A multiple regression analysis in Great Britain found that weather variables and insect abundance explained 95% of the variation in chick survival (Hill 1985). In this analysis four insect groups (carabids, chrysomelids and sawfly and lepidoptera larvae) explained 67% of the variation, demonstrating that some insect groups are more important during the brood rearing stage than others. Using a fecal analysis, Hill (1985) was able to determine that several groups of insects were highly preferred by pheasant broods, while several other groups (Araneidae, Cicadellidae and Braconidae) were not. This study found that pheasant broods were opportunistic feeders and would feed heavily on ants when they were present in large numbers.

Higher biomass consumption was shown to have a positive relationship with chick survival (Hill 1985). However, different insect taxa were found to explain significantly more of the chick survival than other arthropods. This relationship infers that some insect groups provide higher quality food resources than other. Chicks ingesting more sawfly larvae and Heteroptera showed higher survival rates than other broods.

Insects found in pheasant diets were represented in both corn and soybean fields in Iowa (Basore et al. 1987). These habitats have previously been cited as marginal brood rearing habitat despite the presence of the following orders (Isopoda, Araneida, Orthoptera, Homoptera, Coleoptera, Lepidoptera, Diptera, Hymenoptera, Odonata, Nueroptera, Ephemeroptera, Trichoptera and Hemiptera). Problems with this environment may be related to arthropod distribution and density or other requirements of brood rearing pheasant such as roosting and concealment.

Pheasant chick survival and mean brood size are two other indicators of population health that are often documented (Riley et al. 1998; Riley and Riley 1999; Riley and Schulz 2001). In North Dakota, mean brood size declined statewide between 1962 and 1993, and between 1971 and 1993 in the central region of the state (Riley and Riley 1999). In South Dakota the same trend was observed between 1978 and 1996. There has also been a steady decrease documented in brood survival in Illinois from 78% in the 1940s to 54% in the late 1970s (Warner et al. 1999; Riley and Schulz 2001). Survival has been even more extreme for young pheasant in northern Iowa where chick survival at 28 days was estimated to be 11-57% (Riley and Schulz 2001). The significant, long term declines in mean brood size and chick survival for pheasants over much of the Midwest have been attributed to habitat loss, especially grasslands due to their importance as nesting and brood cover. However, extreme single or multi-year weather events during the pheasant nesting and brood rearing season can cause declines (Riley et al. 1999).

Because predation takes such a large toll on pheasant survival, predator control programs have often been implemented (Riley et al. 1999). Riley and Schulz (2001) researched both the feasibility and effectiveness of these programs and determined that they can be effective in increasing pheasant populations if practiced regularly and intensely. However, maintaining these programs is costly and generally economically unfeasible. Investing money in conservation practices that reduce predation pressure and encourage pheasant production may be more effective in increasing pheasant numbers than predator control alone (Riley and Schulz 2001). For example, the cost of removing predators in Idaho was conservatively estimated at 736 labor hours being used in 1995 - 1996 to remove 37 foxes, 57 skunks, and 45 feral cats on two study areas. The cost was calculated to be $75 to $100 per predator. Furthermore benefits to pheasant populations last only as long as predator control programs remain in effect and predator numbers can quickly increase once control is removed.

Timing and mass at hatch have been linked to chick survival (Riley et al. 1998). Chick mortality in Iowa has been shown to increase by 2.3% for each day chicks are hatched after median hatch date (Riley et al. 1998). Mass at hatch was also found to be related to chick mortality. For every gram above the average chick mass at hatch (18.5 ± 0.13g) survival was decreased by 10%. Broods from late hatches or re-nesting attempts show lower clutch sizes, lower chick mass, and subsequently reduced chick survival. This evidence suggests that broods from re-nesting attempts have a higher chance of mortality, which demonstrates the importance of quality nesting habitat that persists through the season.

Exposure is another significant cause of mortality for pheasant chicks and affects younger chicks substantially more than older ones (Ryser and Morrison 1954). Thermal neutrality in 14 day old domestic chickens (*Gallus domesticus*), another gallinaceous species, has been shown to be around 35°C (Barott and Pringle 1946). Temperatures below this can be acclimated to by chicks but the acclimatization requires cold weather stimulus (Scott et al. 1955). Cold snaps before the acclimatization process, such as immediately upon hatching can be detrimental for pheasant broods. Young birds continue to be more susceptible to colder temperatures following the hatching period and a laboratory study found exposure of three day old chicks to 30 min at 20°C was enough to kill 50% of the chicks, at seven days old this same temperature exposure only killed 14%, and while at 11 days, no birds were killed (Ryser and Morrison 1954). Riley et al. (1998) inferred that starvation may also play a role in these deaths since arthropods, which are the primary diet at this stage, are also unable to survive these adverse weather conditions.

Conservation Reserve Program

The Conservation Reserve Program, Title XII of the Federal Food Security Act (i.e., Farm Bill), was created in 1985 under the administration of the United States Department of Agriculture, although similar conservation practices were achieved with an earlier piece of legislation, the Soil Bank Act in 1956. The goals of CRP were to promote planting of perennial grasses and forbs which would improve water quality and prevent soil erosion, two consequences associated with intensive agricultural practices (Geaumont 2006). Under CRP, farmers are able to enter 10-year contracts that defer marginal and highly erodible cropland from agricultural use. Recently CRP contracts have also focused on creating prime wildlife habitat, winter wildlife food resources and pollinator habitat.

There have been other federal farm programs initiated in the past that have also temporarily retired private agricultural land from both crop production and livestock grazing (Berner 1988). The Agricultural Act of 1956, created the Soil Bank Program allowing farmer’s to retire cropland under contract for annual payment. The land retirement portion of this program was repealed in 1965. The Food and Agricultural Act of 1965 continued the long term diversion programs under the Crop Adjustment Program (CAP) of 1965. Both programs contributed significantly to wildlife habitat and were the predecessors to the modern CRP program (Erickson and Wiebe 1973; Berner 1988; Riley 1995). Recent recoveries of pheasant populations have been attributed to the perennial grasslands currently enrolled in the CRP (Schmitz and Clark 1999).

Poor nesting success and loss of native grasslands is a major factor for pheasant decline in the Midwest (Clark et al. 1999; Eggebo et al. 2003). However, the large blocks of perennial grassland set aside from the CRP have shown a positive correlation with pheasant abundance (Erickson and Wiebe 1973; King and Savidge 1995; Riley 1995; Ryan et al. 1998; Evard 2000; Eggebo et al. 2003; Nusser et al. 2004). Several studies have also shown positive trends in nesting density and nesting success associated with CRP land compared to other land uses in the area (Luttschwager and Higgins 1992; Camp and Best 1994; Patterson and Best 1996). Pheasant have also been positively correlated with the landscape level characteristics of an area (King and Savidge 1995; Nielson et al. 2008). In Nebraska, areas with approximately 20% of the land enrolled in CRP contracts contained significantly more pheasant than areas with <5% CRP (King and Savidge 1995).

Utilization studies of CRP lands have also been a major focus of research and pheasant were found to be a frequent user of CRP lands in Kansas, Nebraska, Minnesota, Wisconsin, Illinois and Missouri (Best et al. 1995). Pheasant have been observed in the winter on CRP land in Missouri (McCoy et al. 2001a) as well as Iowa, Michigan and Kansas (Best et al. 1998). They utilize these areas as valuable winter habitat in both North Dakota and Nebraska (Delisle and Savidge 1997; Homan et al. 2000).

CRP contracts are not uniform throughout a region and many decisions on plant establishment have to do with program requirements, landowner preference, location, slope, soil type and the hydrology of an area. In North Dakota the main options for establishment are permanent introduced grasses and legumes known as Conservation Practice 1 (CP1) and permanent native grasses (CP2). Within these categories there are also several different options for seed mixtures. However, common CP1 grass species include crested wheatgrass (*Agropyron cristatum*), smooth brome, timothy (Best et al. 1998; McCoy et al. 2001a; Geaumont 2009). Common CP1 legumes are alfalfa and sweet clover (*Melilotis spp*.). Native warm season grasses that are commonly planted in CP2 pastures are Indiangrass, switchgrass and big bluestem. Recently alternative options for CRP have been initiated including: permanent wildlife habitat (CP4D), which is aimed at providing cover, food and wildlife; wildlife food plots (CP12), which are generally annual crop species aimed at providing a winter food resource to wildlife; rare and declining habitat (CP25), aimed at conserving tall and mixed grass prairie in certain counties in North Dakota; and pollinator habitat (CP42), which establishes plant species that aid pollinators.

Current active CRP contracts in the United States, as of July 2012, consisted of 11.97 million ha in 737,873 contracts from 409,374 farms nationwide (USDA 2012). In North Dakota current CRP contracts were totaled at 967,589 ha, in 32,379 contracts from 16,065 farms, totaling around 5.3% of the state land. Vegetation structure was analyzed in CP1 and CP2 plantings established in 1986-1987 and analyzed in the summer and winter of 1989 (Burger et al. 1990). Winter VORs were significantly higher in CP2 plots ($\bar{x}$ = 7.6 cm) compared to CP1 plots ($\bar{x}$ = 2.9cm), summer VORs were higher with CP2, averaging 43.2cm compared to 21.6cm in the CP1 plots. Litter depth did not differ between CP1 and CP2 plots in winter or in the summer.

Comparisons between CP1 and CP2 pastures as suitable pheasant habitat were carried out by Eggebo et al. (2003) in a study conducted in eastern South Dakota. This study, which was conducted in June, found that more crowing pheasant and brood sightings were recorded in older (10-13 years) cool-season (CP1) CRP plots than any other age or cover type. Newly established CP1 plots (1-3 years) acquired vegetation structure faster than CP2 plots of a similar age and these new cool season fields were structurally indistinguishable from old CP1 and CP2 fields one year after establishment. These data help explain the observation noted by Eggebo et al. (2003) that many landowners have resisted planting warm-season grass mixtures not only because the seed is more expensive and requires specialized equipment for planting but also because the vegetation normally takes 3-5 years to establish.

CP1 fields 10-13 years of age provided the best pheasant habitat for both the nesting and brood rearing season (Eggebo et al. 2003). Furthermore, 2-3 and 10-13 year old CP1 fields provided better nesting and brood rearing habitat than CP2 fields of comparable age. Researchers also noted that intermediate aged fields (4-7 years) which still contain a forb component may provide optimal nesting cover and brood rearing habitat. Furthermore, CP2 fields, may have been undervalued in this study due to the timing of sampling. Researchers noted that an analysis conducted later in the summer would show an increase in CP2 vegetation structure after these plants have completed their growing season. These plants also provide valuable winter cover due to the stiffness of the vegetation associated with warm season species. From this study, researchers recommended extending CRP contracts another 5-10 years to provide the adequate vegetation structure. They also recommended higher flexibility in seed choices including a mosaic of both cool season introduced species and warm season grasses to aid pheasant throughout their life cycle.

The CRP contracts in 2004 were modified to include a stronger commitment to mid-contract management. Practices included disking and interseeding to replenish the forb component of CRP pastures. Without these practices many CRP lands increasingly convert to a monotypic grassland with thick litter accumulation (Millenbah et al. 1996, McCoy et al. 2001b). Matthews et al. (2012a, 2012b) looked at the response of pheasant populations to these management practices compared to traditionally managed CRP field in northeastern Nebraska. Hens showed selection for greater forb cover and vertical density, therefore favoring the interseeded CRP over the traditionally managed pastures. The mechanisms behind this selection may be related to greater invertebrate abundance and, therefore, food resources from the increased forb component, as well as the vegetation structure and its effects on predators (Matthews et al. 2012b). Therefore disking and interseeding legumes could be responsible for increases in nest survival and brood rearing (Matthews et al. 2012a, Matthews et al. 2012b).

Landscape Effects

As technology increases there are an increasing number of state and national databases available to assess landscape level agricultural and environmental trends in natural resources (Nusser et al. 2004). Obstacles to large scale data are being overcome by federally sponsored surveys that monitor the status and trends in land use, natural resources and agricultural practices, including the U.S. Forest Service Inventory and Analysis Program, the USDA Census of Agriculture, and the USDA National Resources Inventory which shows trends for non-federal lands. State based surveys, such as the Illinois Landcover Database, have helped landscape level analyses related to wildlife research. Improvement in software has also aided these assessments and programs like Geographic Information Systems (GIS), Landsat, Remote Sensing and Spatial Pattern Analysis Program for Categorical Maps (FRAGSTATS). Older databases are also being used for landscape level research such as black and white aerial photography (Woodward et al. 2001).

Habitat use is a multi-scale phenomenon and the landscape context should always be evaluated (Best et al. 2001). Constible et al. (2006) stated that landscape characteristics have the ability to influence biotic processes, abiotic processes, and species' interactions to influence the space use in certain species. These characteristics have been broken down into several commonly analyzed macro-habitat variables that are currently the foci of these research studies. Some of these variables include, but are not limited to; habitat patch size, patch shape, isolation or connectivity, proximity to edge features, habitat richness, evenness, interspersion, juxtaposition, mean landscape composition, changes in landscape composition or Landscape Change Index (LCI), current landscape composition, proportion of a certain cover type and proximity to resources such as water. Knowledge of the extent and distribution of potentially suitable landscapes can enhance management efforts as well as determine the presence or absence of a suitable landscape matrix (Roseberry and Sudkamp 1998).

This research has helped clarify many relationships that wildlife have with their habitat, which would have been hard to determine with smaller scale studies. For example, a study done in Iowa utilized large scale units such as Major Land Resource Area (MLRA), eight digit Hydrological Unit Code (HUC), and the county to define polygons throughout the state (Nusser et al. 2004). These polygons were then matched up with count data from the state's annual pheasant population survey to analyze the impacts of CRP on pheasant populations. Landscape level analyses also have the ability to tease out certain data relationships that would be hard to reveal using conventional smaller scale studies. Nielson et al. (2008) looked at a variety of habitat types including CRP across nine states and found that of these habitats, percent herbaceous vegetation in CRP within 1,000 m was positively associated with pheasant populations. There have been several other landscape level studies focused on a variety of species. This research offers valuable insight towards the tools and methods that can be used to enhance our understanding of the pheasant relationship with their landscape. These studies should be a major focus of future research.

MATERIALS AND METHODS

Study Area

This study was conducted at two separate sites near Hettinger, North Dakota, in Adams County located approximately eight to ten km apart. Both sites were located on private land leased to North Dakota State University to conduct research on CRP lands. The two study sites will be hereby known as the Fitch and Clement sites after their landowners. These sites were located in an un-glaciated region of the Northern Great Plains characterized by rolling terrain and scattered buttes. Adams County lies entirely within the Major Land Resource Area (MLRA) 54, known as the Rolling Soft Shale Plains (NRCS 2010). This MLRA is located primarily in North and South Dakota, with a small fraction (3%) located in Montana. This area comprises 75,870 km^2 and is underlain by soft calcareous shales, siltstones, and sandstones which contain the principal sources of groundwater in this region. Farming and ranching operations are the major land uses in this area, producing a combination of cash grains and livestock. Over half of this MLRA still supports native grasses and shrubs that support grazing livestock. Around one-third of the land is used for dry-farmed crops like wheat, barley, oats, rye, flax (*Linum usitatissimum*), corn, alfalfa, and sunflowers (*Helianthus annuus*). Small portions of this region are irrigated.

The climate in this region is continental and semiarid, characterized by warm summers and relatively cold winters (Ulmer and Conta 1987). Annual precipitation in this region is 31.5 cm, with an average air temperature of 6.14°C over the last 21 years (NDAWN 2012). Approximately 80 percent of this precipitation is received from April through September (NDAWN 2012). This area is prone to fluctuating fluvial and drought cycles. The town of Hettinger, which is near both study sites, has an elevation of 813.8 meters above mean sea level.

Parent materials on these study sites are calcareous shale and sandstone (Ulmer and Conta 1987). Three dominant soils and several minor soils exist. At the Clement site, Vebar-Flasher and Vebar-Parshall are the dominant soils and Shambo loam, Harriet loam, and Arnegard are the minor soils, both dominant soils are well drained (Sebesta 2010; USDA-NRCS 2012a). The dominant ecological sites associated with these soil types are sandy for Vebar-Flasher and loamy overflow for Vebar-Parshall. However, other ecological sites that were associated with the Clements site are loamy, shallow loamy, and loamy fine sand. On the Fitch site, Vebar-Parshall and Harriet loam are the dominant soils while Belfield-Savage-Daglum and Daglum-Rhoades are the minor soils (Sebesta 2010; USDA-NRCS 2012b). Harriet loam soils are generally poorly drained. The dominant ecological site associated with Harriet loam soils is saline lowland. Primary conservation concerns in our study region with respect to soil are wind erosion, water erosion, maintenance and control of organic matter, management of soil moisture, and control of saline seeps (USDA-NRCS 2010)

The Clement site was 259 ha and located on sections 19 and 30, T129N, R95W, and 24, T129N, R96W, approximately four km south of Hettinger. The Fitch site was also 259 ha and located on sections 31 and 32, T130N, R96W, approximately eight km west of Hettinger. Both sites have a vegetation composition in regulation with CRP requirements (USDA-SCS 1988, 1989, 1992). The Fitch site was established as CRP cover vegetation in 1989 under a permanent introduced grasses and legumes (CP1) mixture. This site was planted as 60% intermediate wheatgrass (*Elymus hispidus* (P. Opiz) Melderis), 30% alfalfa (*Medicago sativa* L.), and 10% yellow sweet clover. The Clement site was made up of two separate contracts. The first of these was established in 1988 and reflects the same vegetation cover as the aforementioned Fitch site. The second portion of the Clement site, enrolled in 1992, also planted as a CP1 mixture, was established with a seed mixture of 30% intermediate wheatgrass, 30% crested wheatgrass (*Agropyron cristatum* (L.) Gaertn), 30% alfalfa, and 10% yellow sweet clover.

Treatment Application

Research was conducted in compliance with the North Dakota State University Institutional Animal Care and Use Committee (IACUC) throughout this study (Protocol # A0845 and A11034). Our study sites were developed to represent two replicates in order to evaluate the ability of a multiple land use management system to provide both agricultural and wildlife outputs on post-CRP lands in North Dakota. The original study employed a randomized complete block design (RCBD) with four treatments and a control, with the treatments including: 1) 129 ha season-long grazing (SL); 2) 32 ha hay land (HAY), 3) 32 ha no-till corn (NTC), 4) 32 ha no-till Barley (NTB); and 5) a control, consisting of 32 ha of land left idle (IDLE) and represented CRP under continued enrollment.

The SL treatment was grazed from June 1 to January 1 annually with Angus cattle. Stocking rates were adjusted annually to meet 50 percent disappearance of vegetation and varied between 33 and 45 cow-calf pairs for the 129 ha treatment per year. Stocking rates for our grazed treatments varied between 1.6 AUM/ha and 2.4 AUM/ha throughout the four years of the study (Table 10). These densities were determined by the site’s ability to produce forage and maintain wildlife cover, which varied depending on weather factors such as precipitation, and temperature.

Table 10. Stocking rates (AUM/ha) by treatment on the Fitch and Clement sites near Hettinger, ND, in 2008-2011.

Years	Clement Season-long Treatment	Clement Cropland	Fitch Season-long Treatment	Fitch Cropland
2008	2.1	2.1	2.1	2.1
2009	2.3	2.3	1.9	1.9
2010	1.8	2.4	1.6	2.1
2011	1.8	2.4	1.6	2.1

The HAY treatment was harvested annually by the second week in July, with the harvested hay fed to cattle during the spring calving season. Both the NTB and NTC plots were sprayed with glyphosate at a rate of 5.22 l/ha in late-April, 2006, when the crops were established. In early May, barley was planted annually with a no-till seeder in the NTB treatments and later harvested as hay. The NTC was planted with a no-till seeder in early June and left as standing feed for cattle and wildlife forage. Cattle were allowed to graze the NTC and residue from the NTB from January 1 until mid-April.

Nest Searching

In order to tag broods with radio tracking devices, we needed to be present with the chicks during, or quickly after, the hatching period. We located nests in late spring and early summer using two primary methods. Our first method to locate nests utilized the chain drag technique as described by Higgins et al. (1969). This method required a 30 m chain, 0.80 cm in diameter attached behind two all-terrain vehicles and driven 20 m apart at 11 to 15 km/hour across each treatment. When hens were flushed, the area was scanned thoroughly until a nest was found or it was determined that no nest was present. Each treatment was searched in its entirety four to five times annually. The time between searches varied from between 10 to 14 days. Any previously located nests were avoided during future nest searches.

Any nests containing at least one egg were marked by a handheld Global Positioning System (GPS) device and a wire stalked flag placed 5 m north of the nest. The second method (Chessness et al. 1968) used to locate nests required investigators to search on foot through pre-marked 0.405 ha plots. Investigators walked abreast through the plots using PVC poles or sturdy sticks to part the vegetation in front of them while they walked. Each plot was covered in its entirety. Ten percent of the SL treatment and idle control were searched at each site. A small number of our nests were found by following radio-marked hens which were the focus of another ongoing study looking at winter survival.

We determined nest stage and initiation date of the nest by utilizing the egg floating method developed by Westerskov (1950). This method uses the development and enlargement of the air sack inside the egg and its corresponding changes in buoyancy to determine hatching date and stage of development. In this method, an egg is removed from the nest and placed into water. Prior to becoming buoyant the angle at which the egg sits in the bottom of the water will gradually change with development until the egg is positioned vertically in the column. These angles are correlated with embryo development. At eight to eleven days of embryo development the egg floats above the water plane. Upon buoyancy, the area of the egg above water can be measured to predict the days until hatch. Nest searching began the first week of May and continued until early or mid-July.

Marking Broods

Investigators returned to each nest on the date predicted for egg hatching. Newly hatched chicks were captured by hand after the hen had flushed from the nest. Chicks were tagged with two different radio transmitters depending on the year they were captured. We used a 0.56 gram transmitter with a warranty life of 15 days in 2008 and 2009. However, in 2010 and 2011 we switched to a 0.65 gram transmitter with a warranty life of 33 days. This switch was done in order to collect a greater amount of data and analyze broods at a later stage of development. These transmitters did not contain a mortality switch. To attach these transmitters a small area of feathers were shaved from between the chick's wings in the scapular region and attached to this bare region using superglue. A study done looking at a similar, but more invasive radio-marking technique, found the transmitters of similar weights caused no significant weight differences, growth behaviors, survival differences or pecking behaviors in pheasant chicks (Ewing et al. 1994).

Investigators attempted to attach transmitters to at least three chicks in each brood. However, if fewer than three birds were captured or if less than three transmitters were available broods were still tagged with one or two transmitters but excluded from the survival analysis.

Monitoring Broods

Broods were tracked on 1-3 day intervals using a handheld Yagi antenna and R2000 receiver (Advanced Telemetry Systems). Broods were located using the homing technique as described by White and Garrott (1990). Some broods were classified as un-located when searches were terminated due to it being unreasonable the transmitters were still active and investigators determined they were unlikely to find the brood. In some cases, lightning threatened the safety of the researchers using telemetry equipment and searching was ended prematurely. Depending on time, these broods were either found later that same day or became the primary target of the next day's search to ensure that the brood was not lost entirely. In some instances, broods moved onto private land. Some landowners allowed us to track these broods while others did not permit access. In the latter situations, triangulation was used whenever possible to determine the land use cover that the brood was utilizing (White and Garrott 1990). Signals that failed to move and were located on inaccessible private land were determined dead/lost after failure to move for three or more days. Nevertheless, these signals were still located daily to ensure that the brood was not just exceedingly sedentary.

When brood movement between two days was smaller than average, we would flush the hen and brood in order to ensure survival. Each chick would be located individually to ensure the bird was alive and that the radio transmitter was still attached to the chick. This method was also used when one signal from a chick was separated at a reasonable distance from the remainder of the brood. Failures to locate broods later in the season were generally due to loss of battery power in the radio transmitter. These failures could be supported by the number of days the transmitter had been deployed. Other failures to locate chicks were attributed to dispersal of the brood which increased travel distances among chicks and more frequent and farther movements onto adjacent private land.

Successfully located broods were recorded by location using a GPS handheld receiver. We avoided flushing the hen whenever accurate reads could be taken. This was especially true on cold and wet days with younger broods to avoid disturbing young chicks already experiencing thermal stress. Time of day, land use and GPS coordinates were taken at brood location. We made an effort to find broods utilizing all cover types at different times throughout the diurnal cycle to have a wide range of informative data from each year. Time stages were divided into four periods: morning (sunrise to three hours after); midday (five to eight hours after sunrise); evening (four hours before sunset to sunset); and night (one hour after sunset to one hour before sunrise).

Vegetation Sampling

Vegetation characteristics were taken at approximately every fourth known brood location regardless of treatment. Vegetation characteristics were quantified within a week of the brood’s presence to ensure the vegetation community still reflected the same characteristics present upon utilization. To determine available cover within each treatment, a random point within 50 m of the used location was generated and vegetation was quantified at each random point using similar techniques as those used at each brood location. Random points were kept within the same treatment type as its corresponding used location.

Vegetation at both used and available points was quantified along two perpendicular 25 m transects that intersected either the used or random point. Visual Obstruction Readings (VOR) were collected using a Robel pole at 1.5 m in height and marked out at 0.25 dm intervals (Robel et al. 1970). The Robel pole was observed from a distance of 4.0 m and at a height of 1.0 m from the four cardinal directions. The first marking on the Robel pole that was not obstructed was recorded by investigators and the pole was read at each of the four cardinal directions. The mean of these four measurements was calculated to obtain a site average. Litter depth, maximum live and maximum dead standing vegetation measurements were gathered at one meter intervals along each transect. The VOR, litter depth, maximum live and dead standing vegetation from each set of perpendicular transects were averaged across all frames to generate one set of data for each quantified brood or available location.

Canopy cover was estimated using a 1.0 m^2 frame placed at two meter intervals along each transect. Measurements were calculated for the percent of each vegetative species within the frame using ocular estimates. This technique was modified from the Daubenmire method (Daubenmire 1959). The Daubenmire frame is 20 x 50 cm^2, where our frame was 1.0 m^2. Measurements were taken on an undisturbed transect side to avoid a human trampling effect. Along with the percent of each plant species occurring in each frame, the percent litter and bareground within each frame were recorded. Transect data were an average from all frames to generate one set of data for each quantified brood or available location. We also formed functional group categories based on the average frame data for each plot. Functional groups included grass, grass-like, shrubs, and forbs.

Basal cover was estimated using a 10-pin point frame at 1 m intervals along each transect (Owensby 1973; Cook and Stubbendieck 1986). This instrument allows for 10 narrow aluminum pins to drop vertically onto basal cover, allowing investigators to determine the basal cover percentages attributed by litter, bare ground and live species. The 10-pin point data were averaged across all frames to generate one set of data for each quantified brood or available location.

Insect Sampling

Insect collections were performed on the same plots that were used during vegetation sampling within 36 hours of brood discovery to accurately reflect the insect community when the brood was present. We collected insects using a sweep net, 40.5 cm in diameter, designed for sampling insects. This device consisted of a tube of cloth sealed at one end with a circular metal frame connected to keep the cloth open. The frame was attached to the end of a wooden handle. Insects were sampled by starting at one end of each 25 m transect and sweeping insects as the sampler walked along the right side of the tape until the end was reached. The sampler then turned around and swept insects on the opposite side of the tape until reaching their original starting point. Insects collected at each perpendicular 25 m transects were combined to make one sample representative of either a brood location or an available site. All collection was done at walking speed.

The investigator would quickly close the net opening to keep flying insects from escaping at the end of the collection. The contents of the sweep net were transferred into a one gallon re-sealable plastic bag for storage and future analysis. Collections were frozen for ≥ 12 hours to kill insects prior to sorting. After freezing, all plant matter was removed from the collections and insects were sorted by order (Orthoptera, Hemiptera, Coleoptera, Diptera, Hymenoptera, Aranae, Nueroptera, and others). These orders were weighed upon separation giving us a wet weight of each insect order at each used or available location. We also calculated total insect biomass for each used or available location.

Statistical Analyses

To facilitate the evaluation of differences in the insect and plant communities at used and random plots, we performed a non-metric multi-dimensional scaling (NMS) on both the plant species data (frequency) and insect data based on insect orders. The NMS procedure can be used as an ordination technique or it can be used to assess the dimensionality of a data set (McCune and Grace 2001). We used the NMS analyses as a data reduction technique to reduce the dimensionality of our plant species and insect data down to selected axes which best described the data. For the NMS analyses, we grouped all used and available plots regardless of treatment. We used PC-ORD 6, manufactured by MjM Software in Gleneden Beach, Oregon, U.S.A. and the Relative Sorenson distance measure during NMS analyses (Kruskal and Wish 1978; Clarke

1993; McCune and Mefford 2011). Starting coordinates were random and supplied by a random number generator within PC-ORD 6. We set the maximum number of iterations to 500 and the maximum number of axes to six. The NMS analyses were performed using the autopilot tool provided in PC-ORD 6. Axes selection used the following criteria: 1) the highest dimensions with a reduction of 5 or more in the stress of real data, 2) a $P \leq 0.05$ for the Monte Carlo test comparing stress for the real data to a randomized dataset, and 3) final solutions with stress < 20, number of iterations <150, and instability <0.0005. All graphical outputs were varimax rotated. Plant species or insect orders that had an *r*-value of > 0.4 or < 0.4 with the selected axes were considered significant drivers of our ordination axis and provided the ability to describe the patterns of plant and insect community ordination. Both the insect and plant species data were transformed prior to analyses. We used the arc-sine transformation for the plant canopy data. Insect data were transformed using the square root transformation. Budescu and Appelbaum (1981) recommended this transformation when the largest variances are found in the largest samples of the data set and when the largest sample is more than five times the size of the smallest sample in the data set. Our insect data met both these criterion justifying our transformation procedures.

Axis scores for the selected axes of each transect were recorded and used in future logistic regression analyses. This procedure allowed us to detect differences in the assemblage of plant or insect species at each transect which may not be apparent when the data are analyzed by functional forms or total insect biomass alone.

Due to too few brood locations in some treatments within certain years, we were unable to evaluate habitat variables within some treatments. We considered five used locations per treatment per year as sufficient; however, this criterion was not easily met for both the NTB and

NTC treatments. Therefore, we choose to group used and random locations at both study sites in the season-long treatment by year (Table 11). We also selected to group used and random locations at both study sites within the idle and hay treatments by year. Hence, we compared brood habitat use between a grazed (season-long) and ungrazed (idle and hay) treatment.

Table 11. Season-long (SL) and Non Grazed (NG) treatment by year groupings and the number of pheasant brood utilized transects in each group. These groupings contained enough utilized observations to be used in the logistic regression procedure in a study near Hettinger, ND 2008-2011.

Study area, treatment and year	Number of Used Transects	Study area, treatment and year	Number of Used Transects
Fitch SL 2008	40	Clement SL 2008	11
Fitch SL 2009	17	Clement SL 2009	14
Fitch SL 2010	7	Clement SL 2010	10
Fitch SL 2011	19	Clement SL 2011	7
Fitch NG 2008	6	Clement NG 2009	16
Fitch NG 2009	8	Clement NG 2011	10
Fitch NG 2011	5		

Univariate logistic regression was performed to detect differences in the selected axis scores generated during NMS analyses between used and available plots. We used logistic regression to assess differences in VOR, litter depth, maximum and dead vegetation height, and for each functional group between used and available plots within each grazed and non-grazed grouping. We also used logistic regression to assess differences in basal area density which was assessed with our 10-pin intercept frame. For all tests a *P*-value of ≤ 0.05 for the Likelihood Ratio statistic was considered significant. We hypothesized that there would be no difference between used and random sites for all selected resource characteristics (Manly et al. 2002). We chose logistic regression opposed to other forms of regression because of its ability to handle multiple continuous variables (ratio and interval data) as well as discrete, scale and categorical variables which allows us to comprehensively evaluate the influence of the habitat variables on brood locations at the micro-habitat scale (Neter et al. 1996; Hosmer and Lemeshow 2000). The regression procedure was run using the SAS PROC LOGISTIC procedure as implemented in the Enterprise program (SAS Institute 2010).

We excluded four measurements from our logistic regression analysis due to their irregular data properties and their overall lack of presence in our study. These four variables were forb and grass density assessed using the 10-pin point frame, and shrub and grass-like canopy cover plant functional groups. Shrubs and grass-like plants were mostly absent from the transects, although some sedges such as thread-leaf sedge (*Carex filifolia*) and sun sedge (*Carex heliophila*) were found.

Following logistic regression analyses, we used a data fusion procedure known as Fisher's combined probability test to perform a meta-analysis on the independent tests conducted using logistic regression (Mosteller and Fisher 1948). Fisher's combined probability test produces a test statistic X^2 that has a chi-squared distribution with 2k degrees of freedom with k being the number of *P*-values being combined. The null hypothesis of Fisher's combined probability test assumes the null hypothesis for every independent test is true. This method helps assess a global null hypothesis that pheasant were not showing selection or avoidance for any of these habitat variables regardless of treatment groups. A *P*-value ≤ 0.05 was considered significant.

Daily survival rates (DSR) of broods were estimated using the nest survival capability available in program MARK (White and Burnham 1999). Use of this analyses type was justified due to the irregularity with which some broods were found (Dinsmore et al. 2002). We estimated DSR as a function of the additive contributions of two or more explanatory and time-specific individual covariates (White and Burnham 1999). We ranked candidate models based on Akaike's Information Criterion (AICc) corrected for small sample size (AIC_c; Akaike 1973, Burnham and Anderson 2002). AIC_c has been justified for selecting the most parsimonious models through balancing uncertainty and variance in model selection (Sugiura 1978; Hurvich and Tsai 1989). Those models scoring the lowest AIC_c have the shortest Kullback-Leibler distance, and represent the models closest to full truth, which is never completely known. We used ΔAIC, a second order variant to AIC, to rank models from the most to least supported by the data (Rotella et al. 2004). We calculated Akaike weights (w_i) for our models which represented weight of support for each model. We summed the Akaike weights for like models that contained common terms to evaluate the support for each term or covariate (Burnham and Anderson 2002). Models were run using the logit-link function available through program MARK. We standardized all years to a common start date of 6 June which was the earliest hatch date recorded throughout our study. Furthermore, the last day we monitored broods throughout our study was 29 July, resulting in 54 estimates of DSR. We were unable to perform goodness of fit testing for our specific data type because no method currently exists in Program MARK. We proceeded under an assumption of normality during our analysis as well as an assumption of a moderate to low level measure of over-dispersion. No model averaging was performed with our data due to recommendations against this procedure when working with survival data which incorporate linear or quadratic time trends found in Wilson et al. (2007).

Analyses of DSR were performed in two stages based on a priori models attempting to explain the variation on survival rates. During the first stage of analysis, we fit a null model with no covariates and a constant DSR for comparison with models that included covariates. We then evaluated the impact of habitat type, year, and brood age with constant, linear (T) and quadratic (T^2) time trends on DSR of broods. We treated years as separate attribute groups. We evaluated eight models during stage one of DSR analyses. We hypothesized that DSR would vary by year, habitat type, within the brooding season, and by brood age.

During the second stage of DSR analyses, we compared the best model from stage one analyses with models that added other temporal variables to the best model from stage one. Models used in stage two included all possible 1-, 2-, 3-way additive combinations of temporal variables including, maximum daily temperature (C°), minimum daily temperature (C°), daily precipitation (cm), and a one day lag in precipitation. The weather data used for these analyses were from the North Dakota Agricultural Weather Network Station in Hettinger, North Dakota. We hypothesized that survival would increase with higher maximum temperatures and decrease following precipitation events. Mechanisms underlying these relationships may be the inability of chicks to thermo regulate during the early stages of life (Aulie 1976; Horak and Applegate 1999). We evaluated nine models during stage two analyses of DSR.

RESULTS

Habitat Characteristics

We observed 90 broods from 2008 through 2011; 33 in 2008, 21 in 2009, 12 in 2010 and 24 broods in 2011. A total of 786 pheasant brood locations were observed throughout the four year study (Table 12). These locations can be compared to the brood's original tagging locations found in Table 13. Yearly observations consisted of 202, 143, 73, and 368 sightings from 2008 through 2011; respectively. The majority of pheasant locations occurred in the season-long treatment. Habitat data were recorded on 389 transects, with 197 brood locations and 192 random locations comprising the total transects. Number of transects by land use type utilized by the broods is displayed in Table 14.

Table 12. Number of pheasant brood observations by year and treatment near Hettinger, ND, in 2008 - 2011.

Observations					
	2008	2009	2010	2011	Treatment Totals
Season-Long	112	53	25	114	304
Hay	29	31	10	74	144
Idle	24	23	13	31	91
Corn	8	0	0	6	14
Barley	7	20	9	22	58
Private	18	15	16	105	154
Other	4	1	0	16	21
Annual Total	**202**	**143**	**73**	**368**	**786**

Table 13. Original tagging locations by treatment and year of pheasant broods near Hettinger, ND, in 2008 - 2011.

Tagging Locations by Treatment							
	Season-long	Idle	Hay	Corn	Barley	Other	Total
2008	24	6	2	0	0	1	33
2009	11	5	3	0	2	0	21
2010	7	3	2	0	0	0	12
2011	13	4	5	0	0	2	24

Table 14. Number of transects for utilized pheasant broods by year and location, and number of transects by land use type within year and location near Hettinger, ND in 2008 – 2011.

Utilized Transects					
2008 Clement			2008 Fitch		
14 Transects	Hay	3	53 Transects	Hay	1
	Season-long	11		Season-long	40
2009 Clement				Idle	5
32 Transects	Hay	12		Barley	3
	Season-long	14		Corn	3
	Idle	4	2009 Fitch		
	Barley	2	25 Transects	Hay	4
2010 Clement				Season-long	17
12 Transects	Hay	1		Idle	4
	Season-long	10	2010 Fitch		
	Idle	1	13 Transects	Hay	2
2011 Clement				Season-long	7
23 transects	Hay	6		Idle	2
	Season-long	7		Barley	2
	Idle	4	2011 Fitch		
	Barley	6	25 Transects	Hay	2
				Season-long	19
				Idle	3
				Other*	1

* Fallowed Barley field

The earliest recorded hatch of the study occurred on 6 June 2008. The latest recorded first hatch of the season occurred on 11 June 2009. In 2010 and 2011, the first hatch occurred on 9 June and 8 June, respectively, resulting in a very narrow difference in initial hatch dates for all four years. The latest recorded hatch for each year was 14 July, 9 July, 15 July and 20 July in 2008 through 2011, respectively. Hatching dates are described throughout the season for each year in Figure 1.

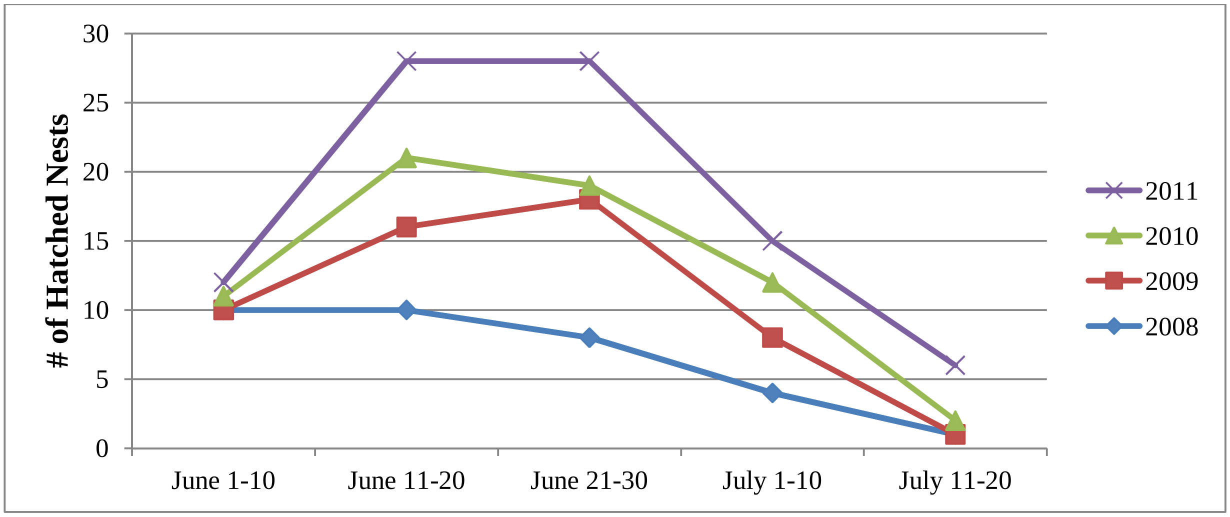

Figure 1. Number of ring-necked pheasant nests hatched within five 10 day periods near Hettinger, ND in 2008 - 2011.

Vegetation

The average ring-necked pheasant brood location had a VOR of 2.0 dm, maximum live vegetation height of 7.23 dm, and average litter depth of 0.29 cm (Table 15). The typical brood location consisted of a canopy cover of 37.6% grass, 29.2% forbs, 12.5% litter cover and 20.1% bare ground (Table 15). Basal cover at these sites, consisted of 21.5% bare ground, 71.3% litter cover, 5.1% grass and 2.1% forbs (Table 15).

Table 15. The overall mean and standard deviation (σ) for each habitat variable used by ring-necked pheasant broods for the Clement and Fitch study sites near Hettinger, ND, from 2008-2011.

Vegetation Variable	Mean for all broods and study sites	Standard Deviation (σ)
VOR	2.0 dm[1]	1.2 dm
Maximum Live Height	7.23 dm	2.0 dm
Litter Depth	0.29 cm[2]	0.37 cm
Canopy Bare Ground	20.1%	16.9%
Canopy Litter Cover	12.5%	10.8%
Canopy Forbs	29.2%	24.1%
Canopy Grass	37.6%	21.0%
Basal Bare Ground	21.5%	23.1%
Basal Litter	71.3%	21.4%
Basal Grass	5.1%	5.0%
Basal Forbs	2.1%	2.3%

[1] (dm) = Decimeter
[2] (cm) = Centimeter

The average random point had a VOR of 1.97 dm, average maximum live vegetation height of 7.12 dm, and average litter depth of 0.30 cm (Table 16). A canopy cover characteristic of these random transects averaged 36.1% grass, 31.1% forbs, 13.5% litter cover and 18.4% bare ground (Table 16). Basal cover characteristics of these random transects were 23.2% bare ground, 69.8% litter cover, 5.1% grass and 1.9% forbs (Table 16). Some of these transect characteristics are broken down further in Appendix A.

Table 16. The overall mean and standard deviation (σ) for each habitat variable of random locations for the Clement and Fitch study sites near Hettinger, ND, from 2008-2011.

Vegetation Variable	Mean for all broods and study sites	Standard Deviation (σ)
VOR	1.97 dm[1]	1.38 dm
Maximum Live Height	7.12 dm	2.02 dm
Litter Depth	0.30 cm[2]	0.46 cm
Canopy Bare Ground	18.4%	17.7%
Canopy Litter Cover	13.5%	10.8%
Canopy Forbs	31.1%	24.3%
Canopy Grass	36.1%	22.9%
Basal Bare Ground	23.2%	22.8%
Basal Litter	69.8%	21.4%
Basal Grass	5.1%	7.5%
Basal Forbs	1.9%	2.2%

[1] (dm) = Decimeter
[2] (cm) = Centimeter

Non-metric Multi-dimensional Scaling

The plant community analysis had a final stress score of 12.31 with 110 iterations and a final instability of <0.001. Axis one explained 32.5% of the structure in the data while axis two explained 31.1% and axis three 24%. A total of 106 individual plant species occurred in our random and used plots. Axis scores generated during NMS analyses are presented in Appendix A-D. These scores were the values used in our logistic regression analysis between grazed and non-grazed treatments, study year and study site.

We found that axis one had a negative relationship with smooth brome (*r*-value = -0.507) and Kentucky bluegrass (*r*-value = -0.676 (Appendix E). Axis one had a positive relationship with intermediate wheatgrass (*r*-value = 0.528) and alfalfa (*r*-value = 0.658). Axis two had a positive relationship with intermediate wheatgrass (*r*-value = 0.73). Finally, axis three had a positive relationship with crested wheatgrass (*r*-value = 0.642) and a negative relationship with smooth brome (*r*-value -0.638).

Logistic Regression Analysis

We found no differences ($P<0.05$) in vegetation axis scores between used and available plots generated using NMS (Appendix G). Of the 221 independent logistic regression tests run on the various vegetation variables, six tests were statistically different according to the likelihood ratio test. Two of these were related to vegetative habitat characteristics, maximum height of live vegetation in the Clement 2009 NG group (P=0.0395) and percent bare ground in the Fitch 2011 season-long grazed group (P=0.0096). No differences were seen with respect to any other vegetative variables between used versus available plots in these groupings. All regression test results are reported in Appendix G.

Fisher’s Combined Probability Test

The meta-analysis using Fisher’s combined probability test with all the *p*-values from the vegetative variable logistic regression analysis supported the overall null hypothesis; there is no evidence that pheasant broods are showing selection for the measured vegetative habitat variables compared to those that are available within our study sites. Results of the meta-analysis test for vegetation are presented in Tables 17 and 18. However, the logistic regression and meta-analysis tests were only applicable to our previously described treatment groupings of season-long grazed and non-grazed treatments. Because of the limited number of samples in certain treatments that necessitated the grouping of treatments over sites, the original design and treatments were not investigated with this analysis.

Table 17. Incremental R^2 values from non-metric multi-dimensional scaling analysis of the vegetation composition data on pheasant brooding habitat near Hettinger, ND, in 2008 - 2011.

Vegetation	
	R^2
Axis	**Increment**
1	0.325
2	0.311
3	0.240

Insects

Utilized brood locations had an average total insect biomass of 3.15 g per transect throughout the duration of the study (Table 19). The most abundant order of insects, in terms of biomass, was Orthoptera with an average 1.83 g at each utilized transect. Neuroptera was the least abundant insect order, although more rare insect orders may have been present but were included in the other category in our analysis. In contrast, random transects had an average total insect biomass of 3.46 g (Table 20). Orthoptera was still the most abundant Order reported, averaging 2.04 g per transect. Similarly, Neuroptera was the least abundant Order with an average 0.01 g per transect. Total insect biomass is broken down further in Appendix I.

Table 18. Results from Fisher's combined probability test ran on independent logistic regression tests between used and available pheasant brood vegetative habitat variables, combining *p*-values by variable for grazed and non-grazed treatments, near Hettinger, ND, from 2008-2011.

Grazed Treatments			Non-Grazed Treatments		
Factors	**Probability Score**	**Number of *p*-values combined**	**Factors**	**Probability Score**	**Number of *p*-values combined**
Bare Ground	0.3002	8	Bare Ground	0.7312	5
VOR	0.5917	8	VOR	0.7950	5
Canopy % Grass	0.5727	8	Canopy % Grass	0.8638	5
Canopy % Forbs	0.8016	8	Canopy % Forbs	0.5805	5
Litter Depth	0.8772	8	Litter Depth	0.4844	5
Basal Bare Ground	0.6506	8	Basal Bare Ground	0.9709	5
Basal Litter	0.9360	8	Basal Litter	0.7571	5
Canopy % Litter Cover	0.8988	8	Canopy % Litter Cover	0.4551	5
Max Live Plant	0.7379	8	Max Live Plant	0.4112	5
Max Dead Plant	0.7173	8	Max Dead Plant	0.3714	5
Vegetation Axis 1	0.8281	8	Vegetation Axis 1	0.8565	5
Vegetation Axis 2	0.7818	8	Vegetation Axis 2	0.5032	5
Vegetation Axis 3	0.8724	8	Vegetation Axis 3	0.5667	5

Table 19. Mean insect biomass in grams (g) by Order from transects utilized by ring-necked pheasant broods near Hettinger, ND, from 2008-2011.

Order	Mean Insect Biomass (g) per Transect
Orthoptera	1.83
Hemiptera	0.54
Coleoptera	0.24
Diptera	0.14
Hymenoptera	0.05
Araneae	0.05
Nueroptera	0.02
Other	0.27
Total Biomass	3.15

Table 20. Mean insect biomass in grams (g) by Order from transects available to ring-necked pheasant broods near Hettinger, ND from 2008-2011.

Order	Mean Insect Biomass (g) per Transect
Orthoptera	2.04
Hemiptera	0.66
Coleoptera	0.22
Diptera	0.19
Hymenoptera	0.07
Araneae	0.06
Nueroptera	0.01
Other	0.23
Total Biomass	3.46

Non-Metric Multi-Dimensional Scaling

The insect analysis using non-metric multi-dimensional scaling showed a final stress of 8.42 for the 3-dimensional solution, with 70 iterations and a final instability of 0.00. Axis one explained 54.8% of the structure in the data while axis two explained 26.7% and axis three

14.2%. The order Orthoptera had a positive relationship with axis one (*r*-value = 0.585) (Appendix I). There were no orders that had an *r*-value deemed interpreted for Axis 2 or 3.

Logistic Regression Analysis

Based on logistic regression analysis, there were three differences between used and available plots with respect to the axis scores generated from NMS of insect biomass. These differences included insect Axis 2 in the Clement 2008 season-long grazed group (P=0.04), insect Axis 2 in the Fitch 2009 season-long grazed group (P=0.0365), and insect Axis 3 in the Fitch non-grazed 2009 group (P=0.038) (Appendix G). Another difference (P=0.0481) was revealed in total insect biomass between used and available plots in the Fitch season-long 2008 grazed group.

Fisher's Combined Probability Test

The Fisher's combined probability test using the *p*-values from various insect variables found no differences (P<0.05) between brood locations and available sites. Results of the meta-analysis test for insects in Tables 21 and 22. Using the *p*-values from all the variables the Fisher's combined probability test found that neither the grazed or non-grazed analyses resulted in any significant differences between used and available (Table 23).

Table 21. Incremental R^2 values from non-metric multi-dimensional scaling analysis of the Insect community data on pheasant brooding habitat near Hettinger, ND, in 2008 - 2011.

Insect Community	
R^2	
Axis	**Increment**
1	0.548
2	0.267
3	0.142

Table 22. Results from Fisher's combined probability test ran on independent logistic regression tests between used and available pheasant brood habitat insect variables, combining *p*-values by variable for grazed and non-grazed treatments, near Hettinger, ND, from 2008-2011.

Grazed Treatments			Non-Grazed Treatments		
Factors	**Probability Score**	**Number of *p*-values combined**	**Factors**	**Probability Score**	**Number of *p*-values combined**
Total Insect Biomass	0.4381	8	Total Insect Biomass	0.3882	5
Insect Axis 1	0.3752	8	Insect Axis 1	0.7189	5
Insect Axis 2	0.3199	8	Insect Axis 2	0.6087	5
Insect Axis 3	0.8746	8	Insect Axis 3	0.1432	5

Table 23. Results from Fisher's combined probability test ran on independent logistic regression tests between used and available pheasant brood habitat variables, combining *p*-values by study site, treatment and year, as well as for all years and all habitat variables for grazed and non-grazed treatments near Hettinger, ND, from 2008-2011.

Combined Factors, Each Treatment/Year			For All Factors Combined with Treatment		
Treatment/ Year	**Combined *p*-value**	**Number of p-values combined**	**Test**	**Probability Score**	**Combined *p*-value**
Clement SL 2008	0.6621	17	All Grazed, All Factors	0.9943	136
Clement SL 2009	0.8609	17	All Non-Grazed, All Factors	0.9448	85
Clement SL 2010	0.8347	17			
Clement SL 2011	0.8557	17			
Fitch SL 2008	0.5697	17			
Fitch SL 2009	0.5799	17			
Fitch SL 2010	0.9904	17			
Fitch SL 2011	0.7338	17			
Clement NG 2009	0.2047	17			
Clement NG 2011	0.9981	17			
Fitch NG 2008	0.7002	17			
Fitch NG 2009	0.3658	17			
Fitch NG 2011	0.9637	17			

Brood Survival Analysis

Sixty-eight broods were used during survival analyses. Based on stage one analysis of daily survival rates (DSR), brood survival was a function of brood age, linear time trend, and a quadratic time trend (Table 24). This model estimated four parameters and had an Akaike's Information Criterion score (AICc) of 250.62. Support for this model was only 0.14 AICc units better than the second best model with three estimated parameters. However, the second best model also included a linear time trend and a quadratic time trend. Summed AIC_c weights were greatest for the linear time trend (0.95; Table 24). The DSR of broods tended to increase throughout the brood rearing season with periodic reductions in success. Also, DSR of broods increased as the brood aged, although the confidence interval for this parameter included zero ($\hat{\beta}_{\text{broodage}} = 0.06$ (95% CL = -0.02, 0.13). There was little support for models that included habitat or year effects. Beta estimates from the top model are included in Table 24.

Stage two analysis of DSR indicated that, in addition to broodage, linear time trend, and quadratic time trend, brood survival was a function of a one day lag in precipitation and maximum daily temperature (Table 24). This model estimated six parameters and had an Akaike's Information Criterion adjusted for small sample size score (AICc) of 244.92. This model was 1.82 AIC_c units better than the second model which included the addition of minimum daily temperature. In general, DSR of broods decreased the day following a rain event and increased with increasing maximum daily temperatures. However, several parameter estimates on a logit scale included zero. Beta estimates for the top model are presented in Table 25.

Table 24. First and second stage models of daily survival rates of ring-necked pheasant broods near Hettinger, ND from 2008-2011. Models are ranked by difference in Akaike's Information Criterion for small sample size (∆AIC*c*), T^1 = Linear Time Trend, T^2 = Quadratic Time Trend.

Models	No. of parameters	AIC*c*	Delta AIC*c*	AIC*c* weights (w_i)
First-stage models				
S*(Broodage + [T^1] + [T^2])	4	250.62	0.00	0.33
S([T^1]+ [T^2])	3	250.76	0.14	0.30
S([T^1])	2	251.83	1.22	0.18
S(Broodage + [T^1])	3	252.35	1.74	0.14
S(Null)	1	255.42	4.80	0.03
S(Broodage)	2	256.01	5.40	0.02
S(Idle + Season-Long + Hay)	3	258.61	8.00	0.01
S(Year)	4	260.43	9.82	0.001
Second-stage models				
S(Broodage + [T^1] + [T^2] + Precipitation Lag + Maximum Temperature (C°))	6	244.92	0.00	0.37
S(Broodage +[T^1] + [T^2] + Precipitation Lag + Maximum Temperature (C°) + Minimum Temperature (C°))	7	246.12	1.21	0.20
S(Broodage +[T^1] + [T^2] + Precipitation Lag)	5	246.64	1.72	0.16
S(Broodage + [T^1] + [T^2] + Maximum Temperature (C°))	5	246.96	2.05	0.13
S(Broodage + [T^1] + [T^2] + Precipitation + Precipitation Lag)	6	248.31	3.39	0.07
S(Broodage + [T^1] + [T^2] + Precipitation Lag + Minimum Temperature (C°))	6	248.66	3.74	0.06
S(Broodage + [T^1] + [T^2] + Precipitation)	5	252.32	7.41	0.01
S(Broodage + [T^1] + [T^2] + Minimum Temperature (C°))	5	252.61	7.70	0.01

*S = Survival probability as a function of the contained variables

Table 25. Parameter estimates for the model with the lowest AIC_c score in Program MARK evaluating daily survival rate for Linear Time Trend (T), Quadratic Time Trend (T^2), One Day Lag in Precipitation (LagPrecip), and Maximum Daily Temperature for pheasant broods near Hettinger, ND from 2008-2011.

			95% Confidence Interval	
Parameter	Beta	Standard Error	Lower	Upper
Broodage	0.05	0.04	-0.03	1.13
T	0.10	0.08	-0.06	0.25
T^2	-0.001	0.001	-0.003	0.001
LagPrecip	-1.11	0.50	-2.09	-0.13
MaxTemp	0.06	0.03	-3.75E-04	0.11

The estimate for a one day lag in precipitation did not include zero and had a combined AIC_c weight of 0.80 (Table 25). We evaluated the effects of brood age, one day lag in precipitation, and time within the brooding season on DSR by plotting curves with select values for each variable in the logistic regression equation. Using precipitation data from 2010, Figures 2 and 3, show the effect of precipitation on brood survival for broods that were one and 20 days of age during early, mid, and late brood rearing season while holding the maximum daily temperature at an average value. We considered days 1-18 as early (6 June-23 June), days 19-36 as mid (24 June-11 July) and 37-54 as late (12 July-29July) within the brood rearing season. Broods occurring during each time period had similar survival patterns as those depicted in Figures 2 and 3 with broods hatching early in the season having lower survival rates than those hatched mid and later in the season. Regardless of time period in which broods occurred the effect of precipitation on brood survival was negative and resulted in decreased survival. Data from 2010 were used to evaluate the effect of maximum daily temperature on brood survival for a brood which was present early, mid, and late during the brooding season for broods at 10 days

(Figure 4). Conversely to the negative effect of precipitation on brood survival, warming temperatures increased the survival probability of broods throughout the season.

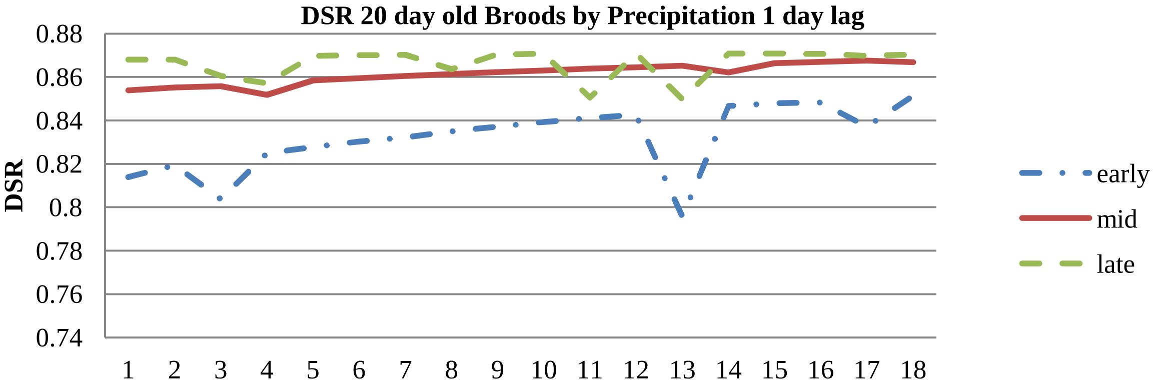

Figure 2. Daily survival rate (DSR) of pheasant broods modeled by precipitation one day lag near Hettinger, ND in 2010, representing broods that were beginning rearing stage at 20 days of age. Days 1-18 on the x-axis represent both the early 1-18 (6 June-23 June), days, the mid; days 19-36 (24 June-11 July), and late days 37-54 (12 July-29 July) depending on line style. Brood age was held constant at 20 days of age.

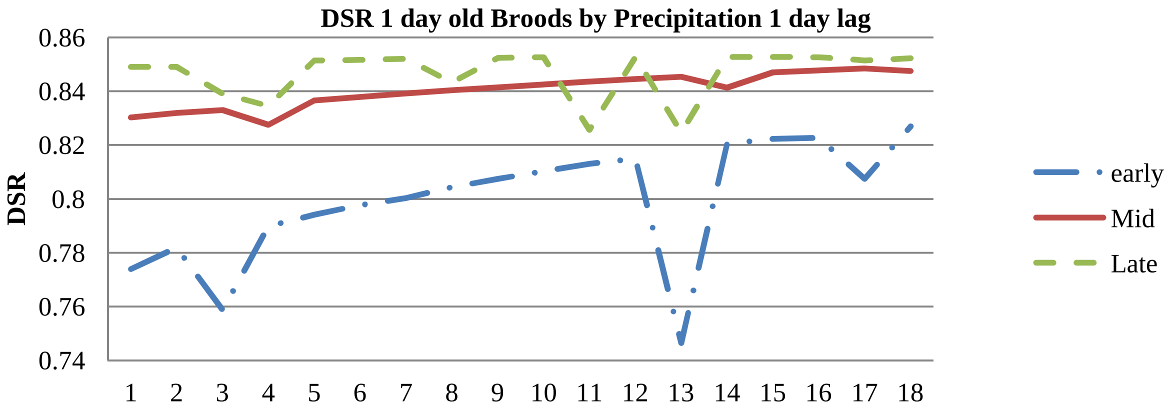

Figure 3. Daily survival rate (DSR) of pheasant broods modeled by precipitation one day lag near Hettinger, ND in 2010. Graphs represent broods that were beginning rearing stage at 1 day of age. Days 1-18 on the x-axis represent both the early 1-18 (6 June-23 June), days, the mid; days 19-36 (24 June-11 July), and late days 37-54 (12 July-29 July) depending on line style. Brood age was held constant at one day of age.

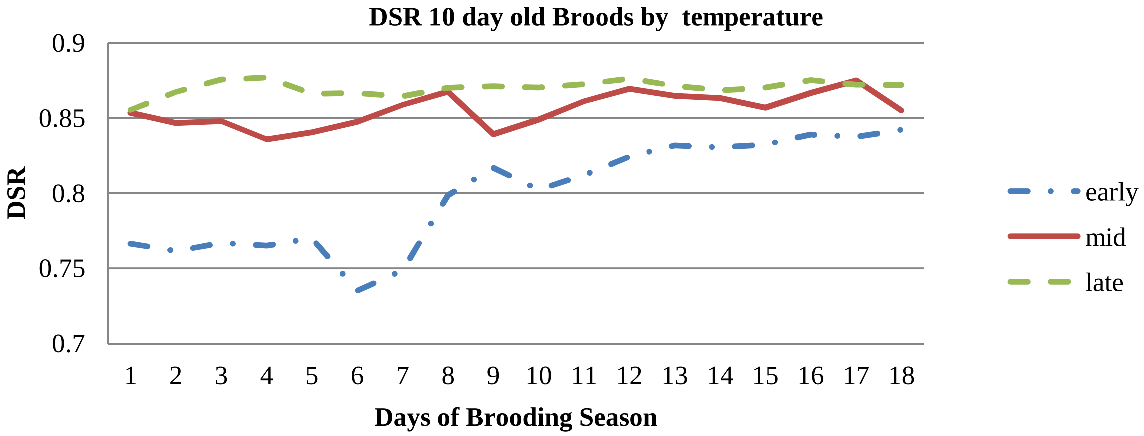

Figure 4. Daily Survival Rate (DSR) of pheasant broods modeled by temperature data beginning at 10 days of age near Hettinger, ND in 2010. Days 1-18 on the x-axis represent both the early 1-18 (6 June-23 June) days, the mid; days 19-36 (24 June-11 July), and late days 37-54 (12 July-29 July) depending on line style. Brood age was held constant at 10 days of age.

DISCUSSION

Habitat Selection

Despite the presence of individual habitat variables that showed selection by pheasant broods, these results were not indicative of an overall pattern of selection as demonstrated by the combined *p*-value test. The combined *p*-value test attempts to reveal the probability of the sequence of independent measures of brood selection which under this study was found to be consistent with a series of chance events. Previous wildlife studies have found that animals will select for specific vegetation characteristics and habitat resources such as thermal cover, food abundance, and predator avoidance (McDonald et al. 2012). Selection for food resources may occur to maximize energy intake, obtain specific nutrients or minimize toxin intake. These selection processes enhance survival or diminish chances of mortality. Several opportunities should exist within our study areas that would logically benefit these broods. For example, higher levels of insect biomass should provide more abundant food sources for pheasant broods. Furthermore, this relationship could have been illuminated by the higher forb components these insects depend on. Nevertheless, higher forb and insect abundance were not selected by broods compared to available habitat.

Higher measures of visual obstruction should also help conceal broods and protect them from predation; therefore, diminishing their chance of mortality. These survival advantages related to concealment cover were found in Hanson (1970) from research on pheasant nest density and vegetation characteristics. Fondell and Ball (2004) noted a similar relationship in their research in Montana with pheasant nesting. Height and density correlated positively with nest density. These vegetation factors may reduce losses from predators. Other vegetation characteristics allowing efficient escape from predators should also enhance brood survival. This relationship, between escaping ability of the prey and the characteristics of the vegetation in the habitat, was illuminated in a study by Rumble and Flake (1983) while looking at waterfowl broods in South Dakota. Several other hypotheses could be formulated in addition to these explanations. However, there are also several explanations for the lack of significant selection and avoidance processes we observed.

Pastures at our study sites were all planted to the standard 1989 CP1 permanent and introduced grass mixtures explained earlier in this manuscript. One possible explanation for the lack of selection or avoidance is that these pastures did not contain enough variability to detect any differences because of this uniform planting. Our study sites were fairly uniform throughout the 259 ha, with only a few exceptions such as a small saline seep at the Fitch season-long treatment and a small area of low productivity in the southwestern portion of the Clements season-long treatment. This lack of variability may have precluded any selection processes occurring within our study areas. However, this habitat apparently meets all the requirements for brood rearing pheasant. Pheasant broods might not be forced to select for specific locations within the study site because all of their needs were met regardless of where they sit on the landscape. The selection between habitats or landscape level selection was not analyzed in this study. This study was restricted to micro-habitat selection within treatments or habitats. There could very well be selection among habitats and landscapes. Such an analysis if undertaken could very well show that habitats with low concealment values and thermal protection like the corn treatment was different from perennial vegetation. Conducting this same study design on an area with more variability, such as native pasture, may either elucidate brood rearing habitat selection or require broods to show selection which is not occurring at our study area. The question remains that even if selection was shown to be occurring in diverse habitats is that selection essential for meeting the requirements of the broods in this area given those requirements were met without selection on these treatments?

Another possible explanation for these results could be explained by the availability of food during the first eight weeks of brood rearing. During these critical weeks, broods are dependent on insects as their primary food source (Hill 1976; Whitmore et al. 1986; Basore et al. 1987). These insects are dependent on forbs (Warner 1984) which were abundant on our study sites. A diminished forb component, which can occur with pasture age, could have the ability to constrain a pheasant brood’s food resource. This study design, repeated on pastures with a less abundant forb component may have revealed selection processes occurring with respect to forb abundance as well as insect biomass depending on these plants.

Additionally, the pheasant’s ability to colonize diverse habitats throughout North America demonstrates their adaptability as a generalist species. This trait may help explain some of our observations. Generalist species have the ability to meet their habitat and survival requirements easier than some other species, particularly those dependent on a specific plant or insect species. In our study area, pheasant broods may have all their brood rearing habitat requirements met, utilizing their advantage as a generalist species and therefore failing to show any selection processes occurring in our study.

No other pheasant brood rearing studies, that we are aware of, found a total lack of selection similar to our research. This may reflect many things including the somewhat conservative grazing intensity that we utilized as well as the uniformity of our study sites. Furthermore, our results may be specific to our region. Nevertheless, our management practices on these study sites show evidence that we created quality brood rearing habitat. This may be related to the surrounding landscape and land use practices.

Brood Survival

Results from the brood survival analysis contained two closely parsimonious models when we evaluated our results using AIC_c scores, which have the ability to balance the fit of the model against the number of parameters estimated. These two models explained the variability in brood survival through daily temperature, precipitation events, brood age, and a linear and quadratic time trend. These analyses rarely provide the mechanisms behind these variables and our study is no exception. However, several of these relationships have been reported in other research studies allowing us to make strong predictions about these underlying mechanisms behind these models (Ryser and Morrison 1954; Aulie 1976; Horak and Applegate 1999).

Brood survival was shown to increase throughout the season, and in our study, common causes of mortality in pheasant broods were exposure, predation, and conflict with haying equipment. As broods gain mobility and flight ability with age, they have a stronger ability to evade predators (Aulie 1976; Horak and Applegate 1999). It is possible that this increase in mobility may also help broods avoid haying equipment. Another mechanism underlying this relationship may come from increased cold resistance and thermoregulatory abilities pheasant chicks gain with body mass and age (Ryser and Morrison 1954). These traits affect a chick’s ability to survive inclement weather and precipitation events. Young chicks frequently perish following rainstorms coupled with cold temperatures, but as broods age their chances of surviving these events becomes greater (Horak and Applegate 1999). Therefore, this relationship not only helps explain the presence of brood age in the model, but also relates to maximum temperature and the precipitation lag variable. The precipitation lag variable has been tested in other avian brood rearing studies and nest survival studies (Moynahan et al. 2007). This variable may be related to the predation of young broods. These are two weather components that showed a direct impact on brood survival.

The effects of the precipitation lag variable may also be explained by the moisture facilitated predation hypothesis (Lehman et al. 2008). The mechanisms underlying this hypothesis state that as precipitation increases, wet birds create more scent from increased bacterial growth on the skin and feathers (Syrotuck 1972). Mammalian predators relying on olfactory cues are then able to locate these birds better, increasing predation. Therefore, the days following precipitation events, when the birds are still wet and the predators are active, could lead to an increase in chick mortality through mammalian predation.

The presence of the linear and quadratic time trends in this model suggest that brood survival increased as the season progressed, but that a decrease, or curvature in survival was present somewhere throughout the season. This relationship may also be related to weather. The presence of early spring storms and cold temperatures during early June may have an impact on brood survival. Curvature of survival could be a function of our haying operation on these study sites, which was responsible for an increase in chick mortality. However, this curvature could also be related to other factors such as increased predation or weather characteristics. Additional research would be needed to uncover the underlying mechanism behind this relationship.

Researchers also found that intense hailstorms early in the year could significantly increase brood mortality. Weather events such as these, as well as differences in predator abundance from year to year, can help explain variation in annual brood survival. Survival can also be attributed to the differences in the quality of nesting habitat as well as the quality of breeding adults each season, both of which are affected by weather and the size of the pheasant population in the immediate area. Population pressure has been shown to force competition for quality nesting habitat and territory cover which can drain pheasant of precious energy reserves during this critical period. Gates and Hale (1974) illuminated this relationship by showing a positive relationship between winter population density and the distance of dispersal in the spring. This loss of energy may carry over to the brood rearing stage and may also force hen’s to re-nest after their first attempt is unsuccessful. Re-nesting attempts have been shown to have higher failure rates and those nests that hatch would also be at a disadvantage (Riley et al. 1994). Additionally, hard winters with excessive snow pack leave much less senesced vegetation for nest concealment, forcing pheasant to move further in the spring to find adequate habitat which continues to support the relationship between population size, weather and brood survival variation (Leif 2005). However, many more factors may influence annual brood survival variation and only a targeted research study could tease out these relationships for each individual year.

Weather Data

Weather differences among years were not drastic enough to cause year to be a significant driver of brood survival. Nevertheless, weather variables were an important aspect of brood survival as predicted by several top models.

Precipitation and temperature varied within each of the four studied brood rearing seasons. July and August were the hottest months in our study region based on average maximum daily temperature and focusing on the months of May through August (Table 26). Rainfall was generally the greatest in June and July with the exception of 2009 where July only received 3.18 cm (NDAWN 2012). Throughout the study, the month with the highest amount of rainfall was June of 2008 with 14.40 cm. Based on the months of May through August, 2010 was the wettest, with 33.83 cm of precipitation falling, 2009 was the driest brood rearing season with 20.3 cm. Our results clearly demonstrate the role weather can play on brood survival and therefore need to be considered as we draw conclusions from this research and managers make management decisions. However, while managers can control such things as grazing pressure and land use, they have little ability to manipulate the weather and therefore need to make management decisions that provide ideal habitat that will aid pheasants during times of precipitation and cold weather events.

Table 26. Weather variables during the pheasant brood rearing season from 2008 – 2011 from the North Dakota Agricultural Weather Network Hettinger station (NDAWN 2012).

Year	Month	Average Maximum Temperature (C°)	Average Minimum Temperature (C°)	Total Rain-fall (cm)
2008	May	19	3	2.67
	June	23	11	14.40
	July	26	13	12.24
	August	27	13	3.63
2009	May	19	4	3.94
	June	23	10	6.35
	July	25	11	3.18
	August	24	11	6.83
2010	May	20	8	5.74
	June	24	12	9.70
	July	27	15	9.80
	August	27	15	8.59
2011	May	18	6	7.98
	June	24	13	6.65
	July	29	16	8.08
	August	27	14	4.50

Regional Pheasant Data

Regional changes in pheasant abundance were characterized by the North Dakota Game and Fish Department's annual brood survey (Table 27). Based on the North Dakota Game and Fish Department's brood count data, the southwest district, which encompasses our study area, had the highest concentration of broods in 2008 (S. Kohn personal communications, January 2012). During this year, there was an average of 23.4 broods observed for every 100 mile or 160.9 km transect. The lowest brood concentrations were seen in 2011. Bird concentration was the greatest in 2008 with 205.7 birds observed per transect and it was the lowest in 2009 with 113.7 birds per transect. These regional values likely influence the pheasant abundance on our study sites and must be taken into consideration when evaluating our results.

Table 27. North Dakota Game and Fish Department pheasant brood summary from the southwest district (district 3) from 2008 – 2011 (S. Kohn personal communications, January 2012).

Totals Observed	2008	2009	2010	2011
Broods per 100 miles	23.4	14.8	18.9	14.0
Birds per 100 miles	205.7	113.7	160.3	118.7

Economic Considerations

North Dakota's pheasant population is an important economic resource, particularly in some rural communities. Their value can be seen through revenue generated from fee hunting, lodging expenses, the sale of hunting supplies, and several other sources (Steinback 1999). CRP contracts are a closely related economic issue which protect and retain this population.

Unfortunately, CRP contracts have undergone a two percent reduction in the percentage of North Dakotan land enrolled in CRP between 2002 and 2012 (USDA 2012). This reduction went from 7.3 percent to 5.3 percent. The trend is expected to continue due to fluctuating agricultural prices. As the value of certain crops rise, CRP contract holders may discover economic opportunities through retiring their CRP contracts rather than renewing them.

Homan et al. (1998) and Geaumont (2009) showed that CRP lands are important pheasant habitat in North Dakota. Conversions of active CRP contracts into row crops may impact the ability of the landscape to support pheasant populations (Luttschwager and Higgins 1992; Camp and Best 1994; Patterson and Best 1996). While our study shows no direct evidence that brood rearing would be threatened in a row crop dominated habitat, it does show that active CRP contracts as well as land uses that retain perennial vegetation likely meet all the habitat requirements for these broods, which supports pheasants compatibility with moderate grazing levels. We would suggest retention of CRP contracts will continue to support pheasant populations and that these contracts also serve as important habitat during the brood rearing stage. Furthermore, economic opportunities that arise from agricultural fluctuations may be short lived, whereas, wildlife habitat and the populations they support; provides a long term renewable resource.

Food Resources

Food availability is another primary concern during the brood rearing stage. Pheasant brood-rearing habitat requires a food resource from arthropods which are aided by forb abundance. A healthy forb community will ensure a good arthropod population. While our research did not detect any selection processes in regard to insect or forb abundance, researchers did note that the pastures retained an abundant forb component contributed to the ability of these pastures to provide adequate brood rearing habitat. Older stands with diminishing forb components can be improved through reseeding, which is a common practice with many CRP contracts. Forb abundance can also be improved through prescribed grazing and burning.

CONCLUSIONS

Our results suggest perennial vegetation retained through active CRP contracts, and those land conversions that retain perennial vegetation, meet habitat requirements for the pheasant brood rearing stage. There are several factors which may limit the applicability of these findings to other situations. Our results may be specific to southwestern North Dakota and northwestern South Dakota. Furthermore, it also may be specific to those stands within this region with an abundant forb component and similar ecological sites and uniformity. Native range situations and other deviations from our study area may show different relationships with pheasant brood rearing habitat selection.

Our research does uphold the importance of CRP and perennial vegetation for pheasant habitat and notes that declines in CRP, especially when that land is converted to cropland, may limit the species' ability to successfully hatch and rear offspring as was alluded to by the lack of brood locations occurring in our cropping treatments. Habitats similar to our study area, both vegetative and with respect to insect abundance can be expected to meet brood rearing requirements. Our management suggestions support the conservation of these habitats as well as some of the more traditional management practices related to harvesting protected nesting cover.

Our survival analysis supports some of the relationships found by other brood rearing research. Survival of young broods is heavily influenced by weather patterns as well as predation and altercations with farm equipment. As broods age, we can expect their likelihood of survival to increase.

Extensions of our research to landscape level selection could aid our knowledge and future decision making. Other more closely related questions, could help researchers discriminate more selection processes. Additional data could also be used to analyze selection processes in cropland habitat and aid research in building more complex models of resource selection within broods.

Furthermore, it would be beneficial to study this question in areas practicing different grazing systems. Our grazed pasture proved to be compatible with the pheasant brood rearing stage, more intensive grazing may have been incompatible. However, the compositional changes that occur after grazing may offer benefits by reinvigorating forb species. Changes in cover, plant species composition and patchiness under different grazing strategies should be included in the future of pheasant research.

MANAGEMENT IMPLICATIONS

There are several important management considerations that our research generates. The most important of these being CRP land, as well as agricultural practices retaining perennial vegetation on post-CRP lands, provides both brood rearing and nesting habitat for pheasant in southwestern North Dakota and northwestern South Dakota. If pheasant conservation is a concern for CRP contract holders, they should be aware that removal of this habitat may affect their land’s ability to provide habitat during these critical life stages. If CRP contracts are to be retired, agricultural uses retaining perennial vegetation, such as grazing and haying on these lands will provide adequate habitat for brood rearing and nesting pheasant. In those lands converted to a haying operation, pheasant conservation can likely be enhanced by haying later in the season, altering traditional cutting patterns, and using structures such as flushing bars. Protecting food availability to brooding pheasant in these habitats depends on maintaining a healthy and abundant forb component. Older pastures with a diminished forb component can likely be enhanced as brood rearing habitat by increasing desirable forb species which in return should provide habitat for arthropods that young pheasant rely on.

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APPENDIX A: MEANS AND STANDARD DEVIATIONS (σ) OF HABITAT VARIABLES AT PHEASANT BROOD LOCATIONS AND RANDOM POINTS FOR THE CLEMENT AND FITCH SEASON-LONG (SL) AND NON-GRAZED (NG) TREATMENTS NEAR HETTINGER, ND, IN 2008 – 2011

(dm) = Decimeter
(cm) = Centimeter

	VOR (dm)		Litter Depth (cm)		% Bare Ground Canopy		% Grass Canopy		
	mean	**σ**	**mean**	**σ**	**mean**	**σ**	**mean**	**σ**	**n**
Clement SL 2008 Utilized	1.54	1.17	0.45	0.35	25.38	13.72	48.50	6.36	11
Clement SL 2008 Available	1.85	1.33	0.59	0.37	25.61	14.96	44.80	8.15	7
Clement SL 2009 Utilized	1.59	1.12	0.21	0.15	10.74	11.73	18.84	17.71	14
Clement SL 2009 Available	0.84	0.57	0.14	0.09	14.05	7.92	18.36	29.46	13
Clement SL 2010 Utilized	2.21	0.90	0.27	0.43	4.92	3.86	49.22	20.91	10
Clement SL 2010 Available	2.34	1.31	0.36	0.64	9.57	7.16	46.99	9.07	13
Clement SL 2011 Utilized	1.98	0.69	0.16	0.14	27.87	10.10	44.70	12.67	7
Clement SL 2011 Available	1.32	1.00	0.15	0.14	30.97	9.88	34.34	11.54	7
Fitch NG 2008 Utilized	1.62	0.62	1.11	0.60	13.81	12.42	36.71	10.12	6
Fitch NG 2008 Available	1.90	1.06	1.53	0.91	10.21	15.21	44.20	11.21	8
Fitch NG 2009 Utilized	1.56	0.98	0.48	0.52	2.03	0.81	8.10	16.73	8
Fitch NG 2009 Available	1.57	0.75	0.44	0.50	7.05	9.66	2.82	2.93	10
Fitch NG 2011 Utilized	2.99	0.73	0.16	0.09	19.45	5.49	43.97	20.64	5
Fitch NG 2011 Available	2.47	1.10	0.21	0.09	17.70	15.88	45.62	19.09	5
Clement NG 2009 Utilized	2.03	0.90	0.43	0.50	6.54	7.08	20.29	12.61	16
Clement NG 2009 Available	1.81	0.72	0.27	0.42	9.20	9.31	24.70	13.07	19

	VOR (dm)		Litter Depth (cm)		% Bare Ground Canopy		% Grass Canopy		
	mean	**σ**	**mean**	**σ**	**mean**	**σ**	**mean**	**σ**	**n**
Clement NG 2011 Utilized	3.30	0.91	0.21	0.09	23.69	11.32	39.19	13.66	10
Clement NG 2011 Available	3.06	0.96	0.18	0.08	25.45	13.59	36.27	10.85	10
Fitch SL 2008 Utilized	1.31	0.39	0.25	0.23	35.59	13.94	47.99	8.20	40
Fitch SL 2008 Available	1.25	0.48	0.31	0.33	34.58	14.08	46.91	5.31	14
Fitch SL 2009 Utilized	0.98	0.43	0.16	0.07	4.18	4.16	4.93	7.77	17
Fitch SL 2009 Available	0.97	0.39	0.17	0.09	10.05	23.41	5.81	15.24	17
Fitch SL 2010 Utilized	1.38	0.42	0.17	0.05	10.20	11.03	56.21	8.98	7
Fitch SL 2010 Available	1.77	1.45	0.26	0.33	7.91	7.13	60.46	10.46	7
Fitch SL 2011 Utilized	3.18	0.85	0.14	0.03	23.24	6.64	45.81	10.17	19
Fitch SL 2011 Available	3.44	0.79	0.15	0.03	17.29	5.05	46.35	13.76	19

APPENDIX B: CLEMENT GRAZED TRANSECT AXIS SCORES FOR INSECT ORDER AND PLANT SPECIES NMS ANALYSIS

* N/R = not recorded

Used v Available	Year	Insect Axis 1	Insect Axis 2	Insect Axis 3	Veg Axis 1	Veg Axis 2	Veg Axis 3
Available	1	0.3453	0.1934	-0.0352	0.7287	0.8241	0.0639
Available	1	-0.6253	0.1939	-0.2172	-0.1131	-0.6409	1.7910
Available	1	-0.8155	0.4928	-0.3794	-1.0807	-0.0938	0.6492
Available	1	-0.8981	0.3728	0.0799	-0.4223	-0.3230	0.9669
Available	1	-1.0749	0.2531	0.0927	0.7650	0.3901	0.0528
Available	1	-0.9208	0.8767	-0.2545	0.7592	0.4781	0.0879
Available	1	-0.6978	0.8795	-0.2553	0.1706	0.4634	0.1199
Used	1	0.4589	-0.2226	0.3090	0.6402	0.4923	-0.0419
Used	1	-0.0993	0.8634	-0.1911	0.7499	0.3944	0.1232
Used	1	-0.0136	-0.1328	-0.1415	0.6656	0.7415	0.0193
Used	1	0.3917	0.1267	-0.4363	-0.3058	0.1981	-0.5268
Used	1	0.2783	0.0559	0.0588	0.6451	0.9038	0.1069
Used	1	-1.0384	0.4462	0.1244	-0.1704	-0.6540	1.7533
Used	1	0.1202	-0.3898	-0.1807	-0.1657	-0.5783	1.6561
Used	1	-0.7235	-0.5038	0.4390	-0.5000	0.1857	0.4877
Used	1	-0.9388	-0.7581	0.3996	0.6529	0.6788	0.1127
Used	1	-0.3836	-0.2981	-0.6812	0.7987	0.6834	0.0532
Used	1	0.2562	-0.1330	-0.1401	0.7383	0.5719	0.0709
Available	2	-0.4533	-0.3663	0.0113	0.7518	-0.9318	-0.2822
Available	2	-0.4673	-0.6171	0.5932	0.4703	-0.7937	-0.4304
Available	2	-0.3268	-0.5029	0.0590	-0.4854	-0.8474	0.1436
Available	2	-0.3834	-0.3150	-0.1143	0.7460	-0.8811	-0.2346
Available	2	0.3466	0.0629	-0.0191	0.5843	-0.8678	-0.2066
Available	2	0.3968	0.0402	0.0679	0.6425	-1.0005	-0.2867
Available	2	0.8198	0.2223	0.0737	-0.4966	-0.4019	1.4062
Available	2	0.6939	0.2074	0.0618	0.6266	-0.8459	-0.2264
Available	2	0.2876	-0.0782	-0.0161	0.6275	-0.9856	-0.2748
Available	2	-0.0560	-0.2722	0.0321	0.7884	-0.9502	-0.2725
Available	2	0.9408	0.1905	0.0847	0.5528	-1.1129	-0.3577
Available	2	0.6430	-0.1653	-0.4236	-0.3878	-0.4031	1.3239
Available	2	1.0788	0.0832	0.0210	0.2764	-0.9837	1.0251
Used	2	-0.7344	-0.7434	0.7368	0.5757	-0.8378	-0.3071
Used	2	-0.6385	-0.6375	0.3539	0.5553	-0.8708	-0.2778
Used	2	-0.5104	-0.5078	0.1500	-0.6391	-0.5869	0.2662
Used	2	0.3069	-0.0540	0.0880	0.1381	-0.7406	-0.5921
Used	2	0.3876	0.1184	0.0793	0.2443	-0.8065	-0.4770

Used v Available	Year	Insect Axis 1	Insect Axis 2	Insect Axis 3	Veg Axis 1	Veg Axis 2	Veg Axis 3
Used	2	0.2228	-0.2285	-0.0728	0.5668	-1.1468	-0.3006
Used	2	0.7134	0.0181	-0.1004	0.0746	-0.4824	-0.0536
Used	2	-0.3905	-0.0095	0.2815	0.3047	-0.7490	0.0353
Used	2	0.2134	-0.1646	-0.0293	-0.7712	-0.4189	0.6873
Used	2	0.6374	-0.0284	-0.0616	0.3682	-0.8275	-0.4188
Used	2	0.0071	-0.2940	0.1373	0.7713	-0.9571	-0.3163
Used	2	0.3673	-0.0448	-0.3953	-0.0072	-0.4878	-0.3391
Used	2	0.4878	0.0871	-0.0579	0.4956	-1.3752	-0.2151
Used	2	0.3707	0.1515	-0.2139	-0.1809	-0.4446	-0.0798
Used	3	N/R*	N/R*	N/R*	0.1554	-0.5098	1.3850
Available	3	0.0851	0.1231	0.2690	0.5961	0.5074	0.0826
Available	3	0.7182	-0.0793	0.1823	-0.8726	-0.4671	1.0260
Available	3	-0.1242	-0.4750	0.7421	0.6889	0.4371	0.0543
Available	3	0.0135	-0.1077	0.0870	0.7096	0.4088	0.0428
Available	3	0.9341	-0.0596	0.0038	-0.9431	-0.4653	0.9473
Available	3	0.7016	-0.0624	0.1363	-0.1831	-0.7818	1.5125
Available	3	0.9655	0.0519	0.0580	0.5288	0.6518	0.2675
Available	3	0.6696	-0.1054	0.2012	0.7075	0.3922	0.0177
Available	3	0.7912	0.0369	0.1441	-0.3736	-0.3500	1.1240
Available	3	0.6235	0.0322	0.1773	0.6871	0.4251	0.0788
Available	3	-0.8866	0.7775	0.4788	0.7707	0.4480	0.0240
Available	3	0.1809	-0.0483	0.1579	0.6851	0.4539	0.0532
Used	3	0.3795	-0.2602	0.3531	-0.4628	-0.5143	1.3607
Used	3	-0.5053	-0.5745	-0.0345	0.4813	0.5176	0.4546
Used	3	0.8062	-0.0310	0.1531	-0.7575	-0.3593	1.1206
Used	3	-0.0127	0.7024	0.2153	0.3190	0.1440	0.4262
Used	3	0.7579	0.3032	0.0965	-1.1142	0.7252	0.6305
Used	3	0.8536	-0.0463	-0.5826	0.5852	0.4094	0.0040
Used	3	0.7013	0.2112	-0.0997	0.7367	0.3608	0.0458
Used	3	0.8667	-0.0177	-0.1585	-0.3890	0.5257	0.5535
Available	4	-0.9790	-0.2752	-1.2724	0.0426	0.3495	0.0689
Available	4	-0.9352	-0.1301	0.4140	0.8055	0.3448	0.1139
Available	4	-0.4185	0.0539	0.0745	0.7633	0.2317	0.2609
Available	4	0.5469	0.0582	-0.0330	0.1751	-0.2484	1.5984
Available	4	-0.3247	-0.2609	0.5079	0.4808	0.4429	0.1630
Available	4	-1.0732	1.1687	0.1694	0.6256	0.2777	-0.0098
Available	4	-0.2451	-0.7546	-0.0751	-0.7935	-0.0128	0.7426
Used	4	-0.6721	0.3991	-1.0088	0.1493	0.6495	0.3188
Used	4	-0.9291	-0.2873	0.4265	0.6588	0.3127	0.0067
Used	4	-0.8498	0.5565	-0.0305	-0.4528	0.2186	0.0500
Used	4	0.5286	0.0302	0.0461	-0.4540	-0.1743	1.2041

Used v Available	Year	Insect Axis 1	Insect Axis 2	Insect Axis 3	Veg Axis 1	Veg Axis 2	Veg Axis 3
Used	4	-0.3232	-0.6502	0.4355	0.6270	0.6112	0.0915
Used	4	-0.8874	1.5989	0.2401	0.5046	0.3164	0.1098
Used	4	-0.7828	-0.3692	0.6574	-0.8591	-0.3021	0.8974

APPENDIX C: CLEMENT NON-GRAZED TRANSECT AXIS SCORES FOR INSECT ORDER AND PLANT SPECIES NMS ANALYSIS

* N/R = not recorded

Used v Available	Year	Insect Axis 1	Insect Axis 2	Insect Axis 3	Veg Axis 1	Veg Axis 2	Veg Axis 3
Available	1	0.2394	-0.1664	0.2107	-0.1256	0.5717	-0.1538
Available	1	-0.7532	0.6646	0.5548	0.3832	0.8379	-0.1328
Available	1	-1.2008	0.0424	0.8685	0.1173	0.5673	-0.1550
Available	1	-1.2814	-0.1030	0.4399	0.6336	0.9952	0.1204
Available	1	-0.3539	0.2961	-0.2732	-1.3147	0.0815	0.3824
Available	1	0.9622	0.0388	0.1062	0.5078	0.8337	0.0068
Available	1	-0.6978	0.8795	-0.2553	-0.8258	0.1812	-0.7631
Available	1	0.0773	-0.1285	0.4166	0.5698	0.8014	-0.0221
Available	1	0.8947	-0.0194	0.1032	-1.3714	-0.1639	0.5947
Available	1	-1.1347	-0.5153	0.3229	-0.8134	0.4595	0.6088
Available	1	-1.0762	0.1510	0.2428	0.2752	0.2291	0.3611
Available	1	-1.0952	-0.6878	0.1023	0.7083	0.8539	0.0952
Available	1	-0.9038	-0.4608	0.5029	-0.1765	0.7897	0.0684
Available	1	-0.7157	-0.7967	0.5716	0.1977	0.7732	-0.2482
Used	1	-0.0411	-0.5120	0.6593	0.1920	0.5259	0.0882
Used	1	-1.1404	-0.0105	0.9571	0.5039	1.1148	0.0025
Used	1	-0.6812	-0.8302	0.8649	0.2849	0.8301	-0.0207
Used	1	0.0470	-0.5173	-0.3812	0.4038	1.0311	0.3211
Used	1	0.0634	0.2635	0.3123	0.4938	1.0232	0.1347
Used	1	-0.7081	0.3586	-0.1470	0.1987	0.8444	-0.3394
Used	1	0.0179	0.2423	-0.3266	-0.2571	1.2182	0.9143
Used	1	0.4491	-0.1280	0.0587	-0.8380	0.2284	-0.6180
Used	1	-0.2693	-0.7764	0.6455	0.0788	0.7938	0.2068
Used	1	-0.3451	-0.6745	0.7952	0.5890	0.6424	-0.0636
Used	1	-0.1925	0.7591	-0.1863	0.0856	0.8189	-0.1793
Used	1	-0.0339	0.3589	-0.0906	0.2749	0.8373	0.2735
Used	1	0.1625	0.1667	-0.1167	-1.0572	0.0308	-0.7204
Used	1	0.2554	0.9526	0.1872	-1.0062	0.3579	0.3298
Used	1	0.1091	-0.5423	0.1214	-1.0719	0.0211	-0.6371
Used	1	-1.1810	0.3624	0.7967	-0.8552	0.9436	1.5188
Used	1	-0.4606	-0.5653	1.1287	0.6278	0.9488	0.2012
Used	1	-1.0197	-0.6630	-0.7663	-0.8095	0.8326	1.4892
Used	1	0.5480	-0.1416	-0.8214	-1.1006	0.6305	0.9551
Used	1	0.3286	0.2847	-0.3730	-0.2305	-0.1388	-0.6709
Used	1	-0.3679	-0.1991	-0.1251	0.5210	0.8073	0.1876
Used	1	-1.1384	-0.6104	-0.5905	0.1252	0.9316	0.0491

Used v Available	Year	Insect Axis 1	Insect Axis 2	Insect Axis 3	Veg Axis 1	Veg Axis 2	Veg Axis 3
Used	1	-1.1404	-0.0104	0.9571	0.1203	0.7961	-0.2267
Used	1	0.1508	-0.3835	0.4916	0.4007	0.8105	-0.0710
Used	1	0.4589	-0.2226	0.3090	0.0149	0.7001	-0.4995
Used	1	0.9574	-0.6379	-0.5857	0.1320	1.0635	0.2824
Used	1	0.2076	0.0605	0.3109	0.3861	0.8351	-0.0293
Used	1	0.0573	0.0469	0.3778	0.4060	0.9413	-0.0962
Used	1	0.2437	0.4131	-0.0638	-0.8132	0.0558	-0.7393
Used	1	-1.1173	0.8325	0.7144	0.5417	0.7503	0.1179
Used	1	-0.3468	-0.8003	0.2188	0.4706	0.7287	0.3447
Used	1	-0.1071	0.6815	0.3495	0.1504	0.7429	0.0777
Used	1	-0.9418	-0.9567	1.1353	0.5782	0.9345	0.1291
Used	1	N/R*	N/R*	N/R*	0.0654	0.7908	-0.0260
Used	1	-0.5624	0.8306	0.4416	-0.9198	0.1405	-0.4916
Used	1	0.9005	0.3347	0.8936	0.3920	0.8951	0.0420
Used	1	0.9582	-0.6457	-0.5761	-1.1795	0.5404	0.0563
Used	1	0.0753	-0.0164	-0.3464	0.3005	0.7914	-0.1504
Used	1	-1.1748	0.7808	-0.3333	0.2446	0.7056	0.2622
Used	1	-0.8550	-0.3250	0.3465	0.2556	0.5897	-0.0246
Available	2	1.1146	0.0877	0.0531	-0.7624	-0.1009	-0.3549
Available	2	1.0555	0.1558	0.0554	0.2997	-1.0660	-0.4294
Available	2	1.0518	0.0750	0.0089	-0.8607	0.1302	-0.8501
Available	2	0.8268	0.2026	-0.0537	-0.5523	-0.0240	-0.8138
Available	2	1.0123	0.0749	-0.0047	-1.3993	1.8633	-0.6303
Available	2	1.0224	0.1492	0.0235	-0.3996	-0.7816	-0.0496
Available	2	0.8501	0.0158	-0.0092	-0.1797	-0.9152	0.0455
Available	2	0.8023	0.0754	0.0112	0.5117	-1.1417	-0.3455
Available	2	0.8341	0.1481	0.0192	-0.0647	-0.8173	-0.3702
Available	2	0.7883	-0.0120	0.0310	0.4347	-0.9886	-0.2288
Available	2	0.8461	-0.0362	-0.1150	0.1842	-0.7532	-0.5323
Available	2	1.0084	0.1806	0.0581	-0.0688	-0.8485	-0.5891
Available	2	0.9440	0.1738	0.0156	-0.8517	0.0221	-1.0931
Available	2	1.0730	0.0736	0.0720	0.3572	-1.3177	-0.3292
Available	2	0.8068	0.0545	0.0835	0.3035	-0.9347	0.0563
Available	2	1.0739	0.0802	0.0457	-1.0551	0.5853	1.1511
Available	2	0.8324	0.0780	0.0758	0.2365	-0.7408	-0.2505
Used	2	0.7631	-0.1048	0.0497	-1.0548	-0.0685	0.2611
Used	2	1.1021	0.0896	0.0765	-0.5276	-0.2014	-0.3325
Used	2	1.1039	0.1489	0.0626	-0.3872	-0.0622	-0.9266
Used	2	1.0846	0.0824	0.0484	-0.4266	-0.0390	-0.9697
Used	2	1.0081	0.0510	0.0161	-1.2283	0.0647	0.2929
Used	2	0.9088	0.0388	-0.0063	0.5804	-1.1200	-0.2559

Used v Available	Year	Insect Axis 1	Insect Axis 2	Insect Axis 3	Veg Axis 1	Veg Axis 2	Veg Axis 3
Used	2	0.6481	-0.0492	0.0076	0.6246	-0.9985	-0.2630
Used	2	0.8368	0.0974	0.0046	0.4180	-0.8834	-0.4361
Used	2	0.6364	0.0694	0.0064	0.3518	-0.8345	-0.3136
Used	2	0.8844	0.0288	0.0768	0.0237	-0.8417	-0.1915
Used	2	0.9121	0.0069	0.0001	0.1508	-0.8483	-0.2891
Used	2	0.8591	0.0034	0.0578	0.2482	-0.9462	-0.1997
Used	2	0.5650	0.0480	0.0040	-1.2957	-0.1966	0.3749
Used	2	0.9102	-0.0144	0.0737	-0.7830	-1.1083	0.1384
Used	2	0.4413	-0.2911	-0.2479	-0.7524	-0.0239	-0.6038
Used	2	1.0780	0.0859	-0.0091	-0.9686	-0.0442	-0.7992
Used	2	1.0255	0.0646	0.0485	-0.8607	-0.0444	-0.5703
Available	3	1.0490	0.2353	-0.0025	-1.3650	-0.1657	0.6797
Available	3	N/R*	N/R*	N/R*	-0.8323	0.0506	-0.6804
Available	3	1.1312	0.1196	-0.0043	-0.4676	0.4618	-1.2580
Available	3	0.1128	0.3648	0.2858	-0.0099	0.7974	-0.1460
Available	3	-0.5348	-0.0780	0.3518	-0.4423	0.1383	-0.6197
Available	3	N/R*	N/R*	N/R*	0.6668	0.9681	0.0761
Available	3	N/R*	N/R*	N/R*	-1.0599	0.0127	-0.1909
Used	3	N/R*	N/R*	N/R*	-0.7228	0.1061	-0.5480
Used	3	1.1933	0.1237	0.0545	-0.0833	0.4951	-0.1667
Used	3	N/R*	N/R*	N/R*	-1.2721	-0.1236	0.2706
Used	3	N/R*	N/R*	N/R*	0.2416	0.4571	0.3285
Used	3	0.4604	0.0504	-0.0110	-0.0576	0.4429	-0.1803
Used	3	0.2479	0.1158	0.2667	-0.4542	0.1683	-0.5159
Used	3	1.1932	0.1237	0.0545	-0.6938	0.3005	0.3073
Available	4	-0.9993	0.0788	0.2720	0.4613	0.5275	0.1279
Available	4	-0.7838	-0.1870	-0.3618	-0.9071	0.1432	-0.9568
Available	4	-1.1989	-0.4960	-0.0084	-0.0738	0.3243	-0.1699
Available	4	0.4381	0.0004	-0.0576	0.1393	0.3569	-0.0360
Available	4	0.9000	0.1829	-0.0335	-0.0124	0.1495	-0.4633
Available	4	0.9071	0.0257	0.0660	0.0748	0.3433	-0.2384
Available	4	1.0628	0.0783	-0.0014	-1.0803	0.0806	-0.1783
Available	4	1.0135	0.0677	0.0702	-1.2445	-0.0765	-0.0473
Available	4	-0.3582	0.1433	-0.1343	0.6500	0.2429	0.0872
Available	4	0.9694	0.0716	-0.0975	0.3396	0.1168	0.0663
Available	4	0.6253	0.0083	0.1864	0.1809	0.2073	-0.2331
Available	4	0.7075	0.0746	-0.0293	0.8405	0.3536	0.0148
Available	4	1.0279	0.0867	-0.0437	0.7910	0.3267	-0.0187
Available	4	1.0812	0.0859	-0.0052	-0.6655	0.4058	-0.4397
Available	4	0.9329	0.0566	0.0160	0.5499	0.2991	-0.0222
Available	4	0.8383	-0.0129	0.1419	0.4733	0.3687	-0.2544

Used v Available	**Year**	**Insect Axis 1**	**Insect Axis 2**	**Insect Axis 3**	**Veg Axis 1**	**Veg Axis 2**	**Veg Axis 3**
Available	4	0.2636	-0.0598	-0.0659	0.4183	0.0861	0.2549
Available	4	0.6187	-0.1360	0.2257	0.8476	0.1883	-0.1339
Available	4	N/R*	N/R*	N/R*	0.6184	0.3953	-0.0979
Used	4	-0.7684	-0.6915	-0.1091	-0.1291	0.4986	0.3811
Used	4	-0.7417	-0.3479	-0.4594	-0.9415	0.1667	-0.5831
Used	4	-1.0513	-0.2636	0.0749	0.5398	0.3926	-0.0548
Used	4	0.1799	0.0141	0.0269	0.1361	0.4165	-0.3187
Used	4	0.7442	0.0189	0.0145	-0.1785	0.3991	-0.0281
Used	4	1.0063	0.1497	0.0089	-0.1782	-0.0988	-0.7154
Used	4	1.0255	0.0632	0.0176	-1.0034	0.1288	-0.6607
Used	4	1.1149	0.0848	0.0576	-1.0737	0.0800	-0.4723
Used	4	-0.0454	-0.0318	-0.0740	0.7739	0.3977	-0.0535
Used	4	0.9420	0.1113	0.0521	0.7147	0.4742	0.0248
Used	4	0.8556	0.0212	0.0686	0.7115	0.2717	0.0027
Used	4	0.8385	0.0058	0.0218	0.0961	0.2356	-0.2418
Used	4	1.1933	0.1237	0.0545	0.2995	0.2984	-0.2561
Used	4	0.8143	0.1200	0.0332	0.3376	0.5170	0.1226
Used	4	0.7913	0.0869	-0.0504	0.7210	0.3288	0.0132
Used	4	1.0149	0.0644	0.0279	0.2089	0.3766	-0.0309
Used	4	0.2517	-0.3284	0.4248	0.7519	0.3976	-0.0653
Used	4	0.8586	0.1843	-0.3267	0.3107	0.3863	-0.3779
Used	4	N/R*	N/R*	N/R*	0.3824	0.2803	-0.3293

APPENDIX D: FITCH GRAZED TRANSECT AXIS SCORES FOR INSECT ORDER AND PLANT SPECIES NMS ANALYSIS

* N/R = not recorded

Used v Available	Year	Insect Axis 1	Insect Axis 2	Insect Axis 3	Veg Axis 1	Veg Axis 2	Veg Axis 3
Available	1	0.2394	-0.1664	0.2107	-0.1256	0.5717	-0.1538
Available	1	-0.7532	0.6646	0.5548	0.3832	0.8379	-0.1328
Available	1	-1.2008	0.0424	0.8685	0.1173	0.5673	-0.1550
Available	1	-1.2814	-0.1030	0.4399	0.6336	0.9952	0.1204
Available	1	-0.3539	0.2961	-0.2732	-1.3147	0.0815	0.3824
Available	1	0.9622	0.0388	0.1062	0.5078	0.8337	0.0068
Available	1	-0.6978	0.8795	-0.2553	-0.8258	0.1812	-0.7631
Available	1	0.0773	-0.1285	0.4166	0.5698	0.8014	-0.0221
Available	1	0.8947	-0.0194	0.1032	-1.3714	-0.1639	0.5947
Available	1	-1.1347	-0.5153	0.3229	-0.8134	0.4595	0.6088
Available	1	-1.0762	0.1510	0.2428	0.2752	0.2291	0.3611
Available	1	-1.0952	-0.6878	0.1023	0.7083	0.8539	0.0952
Available	1	-0.9038	-0.4608	0.5029	-0.1765	0.7897	0.0684
Available	1	-0.7157	-0.7967	0.5716	0.1977	0.7732	-0.2482
Used	1	-0.0411	-0.5120	0.6593	0.1920	0.5259	0.0882
Used	1	-1.1404	-0.0105	0.9571	0.5039	1.1148	0.0025
Used	1	-0.6812	-0.8302	0.8649	0.2849	0.8301	-0.0207
Used	1	0.0470	-0.5173	-0.3812	0.4038	1.0311	0.3211
Used	1	0.0634	0.2635	0.3123	0.4938	1.0232	0.1347
Used	1	-0.7081	0.3586	-0.1470	0.1987	0.8444	-0.3394
Used	1	0.0179	0.2423	-0.3266	-0.2571	1.2182	0.9143
Used	1	0.4491	-0.1280	0.0587	-0.8380	0.2284	-0.6180
Used	1	-0.2693	-0.7764	0.6455	0.0788	0.7938	0.2068
Used	1	-0.3451	-0.6745	0.7952	0.5890	0.6424	-0.0636
Used	1	-0.1925	0.7591	-0.1863	0.0856	0.8189	-0.1793
Used	1	-0.0339	0.3589	-0.0906	0.2749	0.8373	0.2735
Used	1	0.1625	0.1667	-0.1167	-1.0572	0.0308	-0.7204
Used	1	0.2554	0.9526	0.1872	-1.0062	0.3579	0.3298
Used	1	0.1091	-0.5423	0.1214	-1.0719	0.0211	-0.6371
Used	1	-1.1810	0.3624	0.7967	-0.8552	0.9436	1.5188
Used	1	-0.4606	-0.5653	1.1287	0.6278	0.9488	0.2012
Used	1	-1.0197	-0.6630	-0.7663	-0.8095	0.8326	1.4892
Used	1	0.5480	-0.1416	-0.8214	-1.1006	0.6305	0.9551
Used	1	0.3286	0.2847	-0.3730	-0.2305	-0.1388	-0.6709
Used	1	-0.3679	-0.1991	-0.1251	0.5210	0.8073	0.1876
Used	1	-1.1384	-0.6104	-0.5905	0.1252	0.9316	0.0491

Used v Available	Year	Insect Axis 1	Insect Axis 2	Insect Axis 3	Veg Axis 1	Veg Axis 2	Veg Axis 3
Used	1	-1.1404	-0.0104	0.9571	0.1203	0.7961	-0.2267
Used	1	0.1508	-0.3835	0.4916	0.4007	0.8105	-0.0710
Used	1	0.4589	-0.2226	0.3090	0.0149	0.7001	-0.4995
Used	1	0.9574	-0.6379	-0.5857	0.1320	1.0635	0.2824
Used	1	0.2076	0.0605	0.3109	0.3861	0.8351	-0.0293
Used	1	0.0573	0.0469	0.3778	0.4060	0.9413	-0.0962
Used	1	0.2437	0.4131	-0.0638	-0.8132	0.0558	-0.7393
Used	1	-1.1173	0.8325	0.7144	0.5417	0.7503	0.1179
Used	1	-0.3468	-0.8003	0.2188	0.4706	0.7287	0.3447
Used	1	-0.1071	0.6815	0.3495	0.1504	0.7429	0.0777
Used	1	-0.9418	-0.9567	1.1353	0.5782	0.9345	0.1291
Used	1	N/R*	N/R*	N/R*	0.0654	0.7908	-0.0260
Used	1	-0.5624	0.8306	0.4416	-0.9198	0.1405	-0.4916
Used	1	0.9005	0.3347	0.8936	0.3920	0.8951	0.0420
Used	1	0.9582	-0.6457	-0.5761	-1.1795	0.5404	0.0563
Used	1	0.0753	-0.0164	-0.3464	0.3005	0.7914	-0.1504
Used	1	-1.1748	0.7808	-0.3333	0.2446	0.7056	0.2622
Used	1	-0.8550	-0.3250	0.3465	0.2556	0.5897	-0.0246
Available	2	1.1146	0.0877	0.0531	-0.7624	-0.1009	-0.3549
Available	2	1.0555	0.1558	0.0554	0.2997	-1.0660	-0.4294
Available	2	1.0518	0.0750	0.0089	-0.8607	0.1302	-0.8501
Available	2	0.8268	0.2026	-0.0537	-0.5523	-0.0240	-0.8138
Available	2	1.0123	0.0749	-0.0047	-1.3993	1.8633	-0.6303
Available	2	1.0224	0.1492	0.0235	-0.3996	-0.7816	-0.0496
Available	2	0.8501	0.0158	-0.0092	-0.1797	-0.9152	0.0455
Available	2	0.8023	0.0754	0.0112	0.5117	-1.1417	-0.3455
Available	2	0.8341	0.1481	0.0192	-0.0647	-0.8173	-0.3702
Available	2	0.7883	-0.0120	0.0310	0.4347	-0.9886	-0.2288
Available	2	0.8461	-0.0362	-0.1150	0.1842	-0.7532	-0.5323
Available	2	1.0084	0.1806	0.0581	-0.0688	-0.8485	-0.5891
Available	2	0.9440	0.1738	0.0156	-0.8517	0.0221	-1.0931
Available	2	1.0730	0.0736	0.0720	0.3572	-1.3177	-0.3292
Available	2	0.8068	0.0545	0.0835	0.3035	-0.9347	0.0563
Available	2	1.0739	0.0802	0.0457	-1.0551	0.5853	1.1511
Available	2	0.8324	0.0780	0.0758	0.2365	-0.7408	-0.2505
Used	2	0.7631	-0.1048	0.0497	-1.0548	-0.0685	0.2611
Used	2	1.1021	0.0896	0.0765	-0.5276	-0.2014	-0.3325
Used	2	1.1039	0.1489	0.0626	-0.3872	-0.0622	-0.9266
Used	2	1.0846	0.0824	0.0484	-0.4266	-0.0390	-0.9697
Used	2	1.0081	0.0510	0.0161	-1.2283	0.0647	0.2929
Used	2	0.9088	0.0388	-0.0063	0.5804	-1.1200	-0.2559

Used v Available	Year	Insect Axis 1	Insect Axis 2	Insect Axis 3	Veg Axis 1	Veg Axis 2	Veg Axis 3
Used	2	0.6481	-0.0492	0.0076	0.6246	-0.9985	-0.2630
Used	2	0.8368	0.0974	0.0046	0.4180	-0.8834	-0.4361
Used	2	0.6364	0.0694	0.0064	0.3518	-0.8345	-0.3136
Used	2	0.8844	0.0288	0.0768	0.0237	-0.8417	-0.1915
Used	2	0.9121	0.0069	0.0001	0.1508	-0.8483	-0.2891
Used	2	0.8591	0.0034	0.0578	0.2482	-0.9462	-0.1997
Used	2	0.5650	0.0480	0.0040	-1.2957	-0.1966	0.3749
Used	2	0.9102	-0.0144	0.0737	-0.7830	-1.1083	0.1384
Used	2	0.4413	-0.2911	-0.2479	-0.7524	-0.0239	-0.6038
Used	2	1.0780	0.0859	-0.0091	-0.9686	-0.0442	-0.7992
Used	2	1.0255	0.0646	0.0485	-0.8607	-0.0444	-0.5703
Available	3	1.0490	0.2353	-0.0025	-1.3650	-0.1657	0.6797
Available	3	N/R*	N/R*	N/R*	-0.8323	0.0506	-0.6804
Available	3	1.1312	0.1196	-0.0043	-0.4676	0.4618	-1.2580
Available	3	0.1128	0.3648	0.2858	-0.0099	0.7974	-0.1460
Available	3	-0.5348	-0.0780	0.3518	-0.4423	0.1383	-0.6197
Available	3	N/R*	N/R*	N/R*	0.6668	0.9681	0.0761
Available	3	N/R*	N/R*	N/R*	-1.0599	0.0127	-0.1909
Used	3	N/R*	N/R*	N/R*	-0.7228	0.1061	-0.5480
Used	3	1.1933	0.1237	0.0545	-0.0833	0.4951	-0.1667
Used	3	N/R*	N/R*	N/R*	-1.2721	-0.1236	0.2706
Used	3	N/R*	N/R*	N/R*	0.2416	0.4571	0.3285
Used	3	0.4604	0.0504	-0.0110	-0.0576	0.4429	-0.1803
Used	3	0.2479	0.1158	0.2667	-0.4542	0.1683	-0.5159
Used	3	1.1932	0.1237	0.0545	-0.6938	0.3005	0.3073
Available	4	-0.9993	0.0788	0.2720	0.4613	0.5275	0.1279
Available	4	-0.7838	-0.1870	-0.3618	-0.9071	0.1432	-0.9568
Available	4	-1.1989	-0.4960	-0.0084	-0.0738	0.3243	-0.1699
Available	4	0.4381	0.0004	-0.0576	0.1393	0.3569	-0.0360
Available	4	0.9000	0.1829	-0.0335	-0.0124	0.1495	-0.4633
Available	4	0.9071	0.0257	0.0660	0.0748	0.3433	-0.2384
Available	4	1.0628	0.0783	-0.0014	-1.0803	0.0806	-0.1783
Available	4	1.0135	0.0677	0.0702	-1.2445	-0.0765	-0.0473
Available	4	-0.3582	0.1433	-0.1343	0.6500	0.2429	0.0872
Available	4	0.9694	0.0716	-0.0975	0.3396	0.1168	0.0663
Available	4	0.6253	0.0083	0.1864	0.1809	0.2073	-0.2331
Available	4	0.7075	0.0746	-0.0293	0.8405	0.3536	0.0148
Available	4	1.0279	0.0867	-0.0437	0.7910	0.3267	-0.0187
Available	4	1.0812	0.0859	-0.0052	-0.6655	0.4058	-0.4397
Available	4	0.9329	0.0566	0.0160	0.5499	0.2991	-0.0222
Available	4	0.8383	-0.0129	0.1419	0.4733	0.3687	-0.2544

Used v Available	Year	Insect Axis 1	Insect Axis 2	Insect Axis 3	Veg Axis 1	Veg Axis 2	Veg Axis 3
Available	4	0.2636	-0.0598	-0.0659	0.4183	0.0861	0.2549
Available	4	0.6187	-0.136	0.2257	0.8476	0.1883	-0.1339
Available	4	N/R*	N/R*	N/R*	0.6184	0.3953	-0.0979
Used	4	-0.7684	-0.6915	-0.1091	-0.1291	0.4986	0.3811
Used	4	-0.7417	-0.3479	-0.4594	-0.9415	0.1667	-0.5831
Used	4	-1.0513	-0.2636	0.0749	0.5398	0.3926	-0.0548
Used	4	0.1799	0.0141	0.0269	0.1361	0.4165	-0.3187
Used	4	0.7442	0.0189	0.0145	-0.1785	0.3991	-0.0281
Used	4	1.0063	0.1497	0.0089	-0.1782	-0.0988	-0.7154
Used	4	1.0255	0.0632	0.0176	-1.0034	0.1288	-0.6607
Used	4	1.1149	0.0848	0.0576	-1.0737	0.0800	-0.4723
Used	4	-0.0454	-0.0318	-0.0740	0.7739	0.3977	-0.0535
Used	4	0.9420	0.1113	0.0521	0.7147	0.4742	0.0248
Used	4	0.8556	0.0212	0.0686	0.7115	0.2717	0.0027
Used	4	0.8385	0.0058	0.0218	0.0961	0.2356	-0.2418
Used	4	1.1933	0.1237	0.0545	0.2995	0.2984	-0.2561
Used	4	0.8143	0.1200	0.0332	0.3376	0.5170	0.1226
Used	4	0.7913	0.0869	-0.0504	0.7210	0.3288	0.0132
Used	4	1.0149	0.0644	0.0279	0.2089	0.3766	-0.0309
Used	4	0.2517	-0.3284	0.4248	0.7519	0.3976	-0.0653
Used	4	0.8586	0.1843	-0.3267	0.3107	0.3863	-0.3779
Used	4	N/R*	N/R*	N/R*	0.3824	0.2803	-0.3293

APPENDIX E: CORRELATION SCORES OF PLANT SPECIES FROM NON-METRIC MULTI-DIMENSIONAL SCALING ANALYSIS FROM THE CLEMENT AND FITCH STUDY AREAS NEAR HETTINGER, ND, IN 2008-2011

Axis	**1**	**2**	**3**	**Axis**	**1**	**2**	**3**
	r	**r**	**r**		**r**	**r**	**r**
Achillea millefolium	-0.38	0.02	-0.10	*Hordeum jubatum*	-0.17	0.12	0.15
Agropyron cristatum	-0.07	-0.25	0.64	*Hordeum vulgare*	0.02	-0.01	0.05
Ambrosia artemisiifolia	-0.15	0.05	-0.03	*Juncus balticus*	-0.04	-0.11	-0.07
Ambrosia psilostachya	-0.09	0.01	-0.07	*Koeleria macrantha*	-0.05	-0.12	0.19
Anemone patens	-0.04	-0.04	0.13	*Lactuca oblongifolia*	-0.20	-0.10	0.18
Antennaria neglecta	0.08	-0.10	-0.03	*Lactuca serriola*	-0.15	0.01	-0.03
Antennaria parvifolia	0.06	0.09	-0.01	*Lactuca tatarica*	-0.08	-0.05	0.10
Artemisia campestris	-0.14	-0.01	0.01	*Lepidium densiflorum*	0.00	-0.08	0.01
Artemisia dracunculus	-0.01	-0.09	-0.05	*Liatrus punctata*	-0.17	-0.06	0.20
Artemisia frigid	-0.19	-0.06	0.28	*Lomatium foeniculaceum*	-0.10	-0.01	0.01
Artemisia ludoviciana	-0.35	-0.05	0.08	*Lygodesmia juncea*	0.01	-0.13	0.16
Asclepias speciosa	-0.11	0.01	-0.11	*Medicago sativa*	0.66	-0.23	-0.17
Asclepias syriaca	-0.10	-0.01	-0.05	*Melilotus officinalis*	0.19	0.13	0.15
Aster ericoides	-0.10	-0.03	0.04	*Nassella viridula*	-0.16	-0.06	0.10
Aster spp.	-0.11	0.08	0.03	*Opuntia fragilis*	-0.13	-0.04	0.04
Astragulus spp.	-0.12	-0.08	-0.11	*Opuntia polyacantha*	-0.01	-0.06	0.19
Bouteloua dactyloides	0.03	-0.08	-0.05	*Panicum virgatum*	0.06	0.02	0.12
Bouteloua gracilis	-0.09	-0.10	0.22	*Pascopyrum smithii*	-0.29	-0.06	0.15
Brassicaceae spp.	-0.08	-0.04	0.01	*Penstemon glaber*	0.04	0.04	0.04

Axis	**1**	**2**	**3**	**Axis**	**1**	**2**	**3**
	r	**r**	**r**		**r**	**r**	**r**
Bromus inermis	-0.51	0.03	-0.64	*Plantago patagonica*	-0.06	-0.14	0.17
Bromus japonicas	-0.02	0.07	-0.13	*Poa pratensis*	-0.68	-0.11	0.16
Bromus tectorum	0.01	0.02	-0.03	*Potentilla fruticosa*	-0.09	0.00	-0.07
Buchloe dactyloides	-0.07	-0.01	0.04	*Psoralea argophylla*	-0.13	-0.14	0.28
Calamovilfa longifolia	-0.08	-0.12	-0.01	*Psoralea esculenta*	-0.09	-0.01	0.11
Carex Filifolia	-0.07	-0.16	0.36	*Ratibida columnifera*	-0.07	-0.05	0.18
Carex heliophila	-0.10	-0.03	-0.07	*Rosa arkansana*	-0.07	-0.08	-0.09
Carex praegracilis	-0.10	0.07	0.08	*Rumex crispus*	-0.12	0.06	0.07
Chenopodium album	-0.17	-0.04	-0.01	*Rumex occidentalis*	-0.10	0.01	-0.08
Chrysopsis villosa	0.03	0.05	0.07	*Salsola iberica*	0.07	-0.06	0.01
Cirsium arvense	0.03	0.08	0.05	*Salsola tragus*	0.05	-0.04	-0.04
Cirsium flodmanii	-0.13	0.02	-0.03	*Schizachyrium scoparium*	0.05	-0.04	0.07
Cirsium undulatum	-0.14	-0.02	-0.04	*Senecio* spp.	-0.04	-0.05	0.15
Collomia linearis	-0.17	-0.11	0.04	*Solidago missouriensis*	0.01	0.02	-0.07
Convolvulus arvensis	0.14	-0.29	-0.13	*Solidago mollis*	-0.09	-0.07	0.01
Conyza Canadensis	0.07	0.05	0.01	*Solidago rigida*	-0.17	-0.03	0.05
Dalea purpurea	-0.02	-0.07	0.16	*Sonchus arvensis*	-0.13	-0.07	-0.03
Descurainia pinnata	0.04	0.04	0.02	*Son ole*	-0.12	0.03	-0.13
Descurainia Sophia	0.07	-0.09	-0.10	*Spartina pectinata*	-0.15	0.07	-0.05
Distichlis spicata	-0.08	0.01	-0.09	*Sphaeralcea coccinea*	-0.16	-0.13	0.36
Dyssodia papposa	-0.11	-0.01	-0.01	*Sporobolus airoides*	-0.08	0.02	-0.12

Axis	**1**	**2**	**3**	**Axis**	**1**	**2**	**3**
	r	**r**	**r**		**r**	**r**	**r**
Echinacea angustifolia	0.06	0.04	0.01	*Sta ten*	-0.03	0.05	0.06
Elytrigia repens	-0.09	-0.03	-0.07	*Stipa comata*	-0.11	-0.03	0.12
Elymus trachycaulus	-0.21	0.16	0.26	*Sym eri*	-0.04	0.03	-0.09
Erigeron strigosus	0.08	0.06	0.01	*Taraxacum officinale*	-0.07	-0.16	0.07
Erysimum asperum	0.04	0.03	0.05	*Thinopyrum intermedium*	0.53	0.73	0.05
Euphorbia esula	-0.09	0.04	-0.02	*Thlapsi arvense*	-0.13	-0.03	-0.01
Gaura coccinea	-0.13	-0.01	0.08	*Tragopogon dubius*	0.15	-0.05	-0.04
Glycyrrhiza lepidota	-0.25	0.01	-0.08	Unknown 1	0.04	-0.08	-0.04
Grindelia squarrosa	-0.10	0.04	0.03	Unknown 2	-0.08	0.02	0.02
Hedeoma hispida	-0.01	-0.05	-0.03	Unknown 3	-0.09	0.03	0.04
Helianthus annuus	-0.07	-0.03	-0.03	*Vicia americana*	-0.14	-0.05	0.05
Helianthus maximiliani	-0.17	0.01	-0.06	*Zea mays*	-0.04	-0.12	0.11
Hesperostipa comate	-0.08	-0.11	0.26				
Heterotheca villosa	-0.10	-0.05	0.03				

APPENDIX F: FITCH NON-GRAZED TRANSECT AXIS SCORES FOR INSECT ORDER AND PLANT SPECIES NMS ANALYSIS

* N/R = not recorded

Used v Available	Year	Insect Axis 1	Insect Axis 2	Insect Axis 3	Veg Axis 1	Veg Axis 2	Veg Axis 3
Available	1	-0.2845	-0.1164	-0.3879	0.9011	-0.2748	-0.4858
Available	1	-0.3388	-0.0406	-0.5309	-1.0601	0.0595	-0.6471
Available	1	-0.8698	-0.5553	-0.2534	0.5694	-0.4559	0.6230
Available	1	-0.2867	0.8071	-0.4823	-0.0900	0.3583	-0.0658
Available	1	0.5469	-0.2283	-0.4832	-1.2958	-0.2196	0.3121
Available	1	-0.9698	1.8089	0.5364	0.6337	0.2287	-0.2800
Available	1	-0.9047	-0.8586	0.0196	-1.1573	-0.0636	-0.4901
Available	1	-0.6400	-0.5556	0.1189	-1.0249	0.0588	-0.8236
Used	1	-1.2140	0.5611	-0.1817	0.9337	-0.5959	0.7141
Used	1	-0.3539	0.2961	-0.2732	-1.3105	-0.3065	0.4378
Used	1	-1.3547	-0.2365	-0.3364	0.0810	0.3010	-0.4422
Used	1	-0.9699	1.8084	0.5378	-0.8813	0.2524	-0.9434
Used	1	0.3909	-0.8788	0.0765	-0.3890	0.4895	-0.1814
Used	1	-0.6754	-0.1328	0.7949	0.4378	1.0145	0.1333
Available	2	0.2704	-0.2384	0.0108	0.2765	-0.7429	-0.4029
Available	2	0.2515	-0.4452	-0.0745	-0.9060	0.0740	-0.7664
Available	2	0.0959	0.0903	-0.0392	-1.1754	-0.0760	-0.2860
Available	2	-1.0763	-1.1339	0.2651	0.2503	-0.4549	-0.4748
Available	2	0.3341	-0.2856	0.3779	-1.0486	0.0043	-0.6983
Available	2	-0.8414	-0.7632	0.1530	-0.3348	-0.4703	-0.4315
Available	2	-1.0537	-0.3101	0.2931	-0.2886	-0.4844	-0.1182
Available	2	-0.8476	0.2463	0.3597	0.5697	-0.8435	-0.2332
Available	2	0.0773	-0.1974	0.1969	0.6686	-0.8566	-0.0716
Available	2	0.0862	-0.1651	0.2815	0.8049	-0.7196	-0.1973
Used	2	-0.6844	-0.6615	0.4836	-0.2063	-0.7885	-0.0435
Used	2	0.4373	-0.0678	-0.4606	-0.8959	0.1955	-1.1105
Used	2	0.3620	0.1753	-0.1213	-0.3241	-0.5096	-0.6617
Used	2	0.9332	0.0810	-0.0042	-0.9461	-0.4522	-0.8254
Used	2	-0.4318	-0.2210	-0.2703	0.5045	0.0740	-0.0509
Used	2	-0.0385	-0.6461	-0.4124	-1.1180	-0.1024	0.0849
Used	2	-0.1430	-0.3284	-0.5654	-0.2042	-0.3212	-0.8055
Used	2	N/R*	N/R*	N/R*	-0.2395	0.0240	0.0019
Available	3	-0.3535	0.3173	0.2303	0.0387	0.0831	0.0545
Available	3	-0.2864	-0.8422	0.5215	-1.1864	-0.0844	-0.1059
Available	3	-0.0281	-0.5393	0.2278	-0.1587	0.2974	0.3855
Available	3	-0.1825	0.3298	-0.2053	0.1150	0.5454	0.0015

Used v Available	**Year**	**Insect Axis 1**	**Insect Axis 2**	**Insect Axis 3**	**Veg Axis 1**	**Veg Axis 2**	**Veg Axis 3**
Used	3	0.1508	-0.3835	0.4916	0.0607	0.8654	0.1116
Used	3	-0.1326	-0.3505	0.5138	-1.0085	0.3962	-0.1638
Used	3	N/R*	N/R*	N/R*	0.1158	-0.1052	-0.6777
Used	3	N/R*	N/R*	N/R*	0.3381	0.5692	0.2303
Available	4	-0.7202	0.3183	-0.5290	-1.0809	0.0083	-0.4368
Available	4	-1.0702	1.3384	-0.8817	-0.7681	0.1900	-0.0270
Available	4	-0.9558	0.5131	-0.9880	-0.2801	-0.1124	-0.8891
Available	4	-1.0934	-0.2789	-0.6882	0.0823	-0.0838	-0.5364
Available	4	-0.4002	0.7482	-0.6772	-0.7677	-0.0431	0.0903
Used	4	0.0584	-0.3200	-1.0104	-1.2071	-0.2527	0.1363
Used	4	-0.9698	1.8081	0.5388	-0.9070	-0.1268	-0.2651
Used	4	-0.6134	0.1805	-1.0268	-1.2316	-0.3708	0.1521
Used	4	-1.0092	-0.1786	-1.1781	-0.3663	-0.1094	-0.3565
Used	4	-1.1149	-0.1065	-0.8785	0.2379	0.0846	-0.1042

APPENDIX G: UNIVARIATE TESTS, UNIT ODDS RATIOS (UOR) AND 95% CONFIDENCE INTERVALS (95% CI) FROM UNIVARIATE LOGISTIC REGRESSIONS COMPARING UTILIZED BROOD LOCATIONS TO AVAILABLE LOCATIONS IN GRAZED (SL) AND NON-GRAZED (NG) PERENNIAL VEGETATION TREATMENTS (SEASON-LONG GRAZED, HAY PASTURE AND IDLE TREATMENTS) ON TWO STUDY SITES (REFERRED TO AS FITCH AND CLEMENT) FROM 2008-2011 IN SOUTHWESTERN ND, USA

Treatment/Covariate	x^2	*P* value	UOR	95% CI
Fitch NG 2011				
% Bare Ground Cover	0.0662	0.7969	1.016	0.903-1.143
VOR	0.8328	0.3615	2.088	0.430-10.148
Total Insect Biomass	0.0034	0.9532	0.966	0.306-3.052
% Forb Cover	0.0175	0.8948	1.006	0.924-1.095
% Grass Cover	0.0214	0.8837	1.005	0.937-1.078
Litter Depth	1.0904	0.2964	<0.001	<0.001->999.999
Basal Bare Ground Density	0.1764	0.6745	2.851	0.021-379.080
Basal Litter Density	0.1932	0.6602	3.001	0.022-403.226
% Litter Cover	0.0087	0.9257	0.997	0.935-1.063
Maximum Height Live Vegetation	0.8784	0.3486	0.493	0.112-2.165
Maximum Height Dead Vegetation	0.6843	0.4081	1.635	0.510-5.245
Insect Axis 1 Score	0.2617	0.6089	0.389	0.010-14.489
Insect Axis 2 Score	0.3310	0.5651	1.750	0.260-11.766
Insect Axis 3 Score	0.0204	0.8864	0.821	0.055-12.218
Vegetation Axis 1 Score	0.1725	0.6761	1.718	0.136-21.744
Vegetation Axis 2 Score	1.7501	0.1859	>999.999	0.016->999.999
Vegetation Axis 3 Score	1.5398	0.2147	0.044	<0.001-6.150
Fitch NG 2009				
% Bare Ground Cover	1.3478	0.2457	1.157	0.904-1.481
VOR	0.0010	0.9751	1.018	0.322-3.224
Total Insect Biomass	0.7998	0.3711	0.597	0.193-1.850
% Forb Cover	1.0351	0.3090	1.038	0.966-1.117
% Grass Cover	0.6642	0.4151	0.944	0.822-1.084
Litter Depth	0.0249	0.8745	0.856	0.124-5.906
Basal Bare Ground Density	0.0016	0.9685	0.789	<0.001->999.999
Basal Litter Density	2.1006	0.1472	<0.001	<0.001-91.367
% Litter Cover	3.0162	0.0824	0.880	0.762-1.017
Maximum Height Live Vegetation	0.0229	0.8796	0.922	0.324-2.625
Maximum Height Dead Vegetation	0.4188	0.5176	5.303	0.034-829.944
Insect Axis 1 Score	0.3054	0.2532	0.331	0.050-2.204
Insect Axis 2 Score	0.2211	0.6382	0.505	0.029-8.690
Insect Axis 3 Score	4.3070	0.0380	222.293	1.350->999.999
Vegetation Axis 1 Score	1.0142	0.3139	2.210	0.472-10.344

Treatment/Covariate	x^2	*P* value	UOR	95% CI
Vegetation Axis 2 Score	1.7478	0.1861	0.136	0.007-2.619
Vegetation Axis 3 Score	0.1312	0.7172	1.664	0.106-26.199
Fitch NG 2008				
% Bare Ground Cover	0.2517	0.6159	0.980	0.904-1.062
VOR	0.3627	0.5470	1.500	0.401-5.611
Total Insect Biomass	1.5992	0.2060	1.850	0.713-4.802
% Forb Cover	0.0751	0.7840	1.010	0.939-1.087
% Grass Cover	1.5328	0.2157	1.076	0.958-1.207
Litter Depth	0.9826	0.3216	2.105	0.483-9.171
Basal Bare Ground Density	0.2219	0.6376	0.417	0.011-15.833
Basal Litter Density	0.2276	0.6333	2.796	0.041-191.107
% Litter Cover	0.5300	0.4666	0.973	0.903-1.048
Maximum Height Live Vegetation	0.0981	0.7541	1.140	0.503-0.7541
Maximum Height Dead Vegetation	2.6014	0.1068	0.316	0.078-1.282
Insect Axis 1 Score	0.5960	0.4401	2.336	0.271-20.138
Insect Axis 2 Score	0.2031	0.6523	0.745	0.207-2.681
Insect Axis 3 Score	1.5051	0.2199	0.165	0.009-2.930
Vegetation Axis 1 Score	0.0818	0.7749	0.829	0.228-3.007
Vegetation Axis 2 Score	1.0059	0.3159	0.230	0.013-4.068
Vegetation Axis 3 Score	0.4414	0.5064	0.487	0.058-4.075
Clement NG 2011				
% Bare Ground Cover	0.1091	0.7412	1.013	0.940-1.090
VOR	0.3634	0.5466	0.737	0.273-1.987
Total Insect Biomass	0.5251	0.4691	0.864	0.583-1.283
% Forb Cover	0.0002	0.9874	1.001	0.911-1.100
% Grass Cover	0.3030	0.5820	0.979	0.908-1.056
Litter Depth	0.8868	0.3463	0.003	<0.001-625.377
Basal Bare Ground Density	0.0838	0.7722	1.669	0.052-53.412
Basal Litter Density	0.0550	0.8146	0.657	0.020-21.927
% Litter Cover	0.2416	0.6231	1.052	0.858-1.290
Maximum Height Live Vegetation	0.2421	0.6227	0.866	0.489-1.535
Maximum Height Dead Vegetation	0.0260	0.8719	0.949	0.503-1.792
Insect Axis 1 Score	0.0126	0.9106	1.097	0.218-5.514
Insect Axis 2 Score	1.5019	0.2204	0.140	0.006-3.255
Insect Axis 3 Score	0.0398	0.8419	1.161	0.267-5.045
Vegetation Axis 1 Score	0.1606	0.6886	1.720	0.121-24.444
Vegetation Axis 2 Score	0.0000	1.0000	1.000	0.011-87.612
Vegetation Axis 3 Score	0.2463	0.6197	1.657	0.226-12.164
Clement NG 2009				
% Bare Ground Cover	0.8790	0.3485	1.042	0.956-1.135
VOR	0.6510	0.4198	0.702	0.297-1.659
Total Insect Biomass	2.1253	0.1449	1.334	0.905-1.966
% Forb Cover	1.0060	0.3159	0.977	0.933-1.023

Treatment/Covariate	x^2	*P* value	UOR	95% CI
% Grass Cover	1.0288	0.3104	1.028	0.974-1.086
Litter Depth	1.0821	0.2982	0.436	0.092-2.081
Basal Bare Ground Density	0.3173	0.5733	6.523	0.010->999.999
Basal Litter Density	0.1343	0.7140	4.026	0.002->999.999
% Litter Cover	0.9484	0.3301	0.952	0.861-1.051
Maximum Height Live Vegetation	4.2399	0.0395	0.506	0.265-0.968
Maximum Height Dead Vegetation	1.4604	0.2269	2.519	0.563-11.266
Insect Axis 1 Score	0.5169	0.4722	1.929	0.322-11.566
Insect Axis 2 Score	0.9941	0.3187	8.640	0.125-599.112
Insect Axis 3 Score	2.6603	0.1029	22.812	0.532-977.731
Vegetation Axis 1 Score	0.3245	0.5689	0.623	0.122-3.172
Vegetation Axis 2 Score	0.0259	0.8721	1.317	0.046-37.804
Vegetation Axis 3 Score	1.1893	0.2755	3.183	0.397-25.493
Clement SL 2008				
% Bare Ground Cover	0.0013	0.9718	1.001	0.933-1.075
VOR	0.2934	0.5880	1.249	0.559-2.789
Total Insect Biomass	1.0835	0.2979	0.754	0.443-1.284
% Forb Cover	0.6430	0.4226	1.032	0.956-1.115
% Grass Cover	1.1298	0.2878	0.916	0.780-1.077
Litter Depth	0.6781	0.4102	3.245	0.197-53.468
Basal Bare Ground Density	0.3308	0.5652	8.470	0.006->999.999
Basal Litter Density	0.1699	0.6802	0.194	<0.001-470.187
% Litter Cover	0.0298	0.8629	1.015	0.857-1.203
Maximum Height Live Vegetation	0.0711	0.7897	1.073	0.64-1.798
Maximum Height Dead Vegetation	0.0205	0.8861	0.876	0.143-5.367
Insect Axis 1 Score	3.2693	0.0706	0.132	0.015-1.185
Insect Axis 2 Score	4.2187	0.0400	36.73	1.179->999.999
Insect Axis 3 Score	0.4982	0.4803	0.286	0.009-9.220
Vegetation Axis 1 Score	0.6579	0.4173	0.496	0.091-2.704
Vegetation Axis 2 Score	0.5046	0.4775	0.498	0.073-3.406
Vegetation Axis 3 Score	0.3358	0.5623	1.526	0.365-6.380
Fitch SL 2008				
% Bare Ground Cover	0.0563	0.8125	0.995	0.952-1.039
VOR	0.2242	0.6359	0.696	0.155-3.119
Total Insect Biomass	3.9082	0.0481	1.972	1.006-3.865
% Forb Cover	0.6681	0.4137	1.043	0.943-1.154
% Grass Cover	0.2178	0.6407	0.980	0.902-1.065
Litter Depth	0.6706	0.4128	2.584	0.266-25.055
Basal Bare Ground Density	1.6613	0.1974	0.009	<0.001-11.520
Basal Litter Density	0.1723	0.6781	0.426	0.008-23.967
% Litter Cover	0.0383	0.8448	1.006	0.947-1.068
Maximum Height Live Vegetation	3.1732	0.0749	0.591	0.331-1.054
Maximum Height Dead Vegetation	1.1377	0.2861	0.434	0.093-2.013

Treatment/Covariate	**x^2**	***P* value**	**UOR**	**95% CI**
Insect Axis 1 Score	2.0771	0.1495	0.481	0.178-1.301
Insect Axis 2 Score	0.0010	0.9751	1.019	0.312-3.329
Insect Axis 3 Score	0.0010	0.9751	1.019	0.312-3.329
Vegetation Axis 1 Score	0.0870	0.7681	0.862	0.321-2.312
Vegetation Axis 2 Score	1.9088	0.1671	0.284	0.048-1.693
Vegetation Axis 3 Score	0.0012	0.9723	0.977	0.262-3.642
Clement SL 2009				
% Bare Ground Cover	0.0183	0.8923	0.995	0.921-1.074
VOR	2.0364	0.1536	0.513	0.205-1.283
Total Insect Biomass	0.2897	0.5904	1.104	0.77-1.584
% Forb Cover	0.0332	0.8554	0.997	0.964-1.030
% Grass Cover	0.1842	0.6678	0.992	0.956-1.030
Litter Depth	0.0043	0.9475	0.832	0.004-196.709
Basal Bare Ground Density	0.2043	0.6513	2.692	0.037-197.244
Basal Litter Density	0.1880	0.6646	0.427	0.009-19.922
% Litter Cover	0.6546	0.4185	1.049	0.934-1.177
Maximum Height Live Vegetation	0.3057	0.5803	0.891	0.591-1.343
Maximum Height Dead Vegetation	2.0221	0.1550	0.489	0.182-1.311
Insect Axis 1 Score	0.7330	0.3919	1.960	0.42-9.151
Insect Axis 2 Score	0.2328	0.6294	1.996	0.120-33.088
Insect Axis 3 Score	0.1116	0.7383	0.579	0.023-14.284
Vegetation Axis 1 Score	1.0224	0.3120	2.446	0.432-13.852
Vegetation Axis 2 Score	0.7185	0.3966	0.246	0.010-6.290
Vegetation Axis 3 Score	1.6170	0.2035	3.037	0.548-16.822
Fitch SL 2009				
% Bare Ground Cover	0.5023	0.4785	1.040	0.933-1.159
VOR	0.0062	0.9374	0.935	0.176-4.975
Total Insect Biomass	0.0433	0.8333	1.021	0.842-1.238
% Forb Cover	1.0834	0.2979	0.973	0.924-1.024
% Grass Cover	0.0475	0.8275	1.006	0.950-1.067
Litter Depth	0.0668	0.7960	3.264	<0.001->999.999
Basal Bare Ground Density	2.3906	0.1221	>999.999	0.065->999.999
Basal Litter Density	1.2262	0.2681	0.011	<0.001-31.400
% Litter Cover	0.0327	0.8565	0.991	0.9-1.091
Maximum Height Live Vegetation	2.3339	0.1266	1.687	0.862-3.300
Maximum Height Dead Vegetation	1.8338	0.1757	0.463	0.152-1.411
Insect Axis 1 Score	1.4594	0.2270	15.600	0.181->999.999
Insect Axis 2 Score	4.3759	0.0365	>999.999	2.330->999.999
Insect Axis 3 Score	0.0780	0.7800	4.825	<0.001->999.999
Vegetation Axis 1 Score	0.3234	0.5695	1.382	0.453-4.216
Vegetation Axis 2 Score	0.0099	0.9209	1.055	0.365-3.052
Vegetation Axis 3 Score	0.0430	0.8358	0.849	0.182-3.972

Treatment/Covariate	x^2	*P* value	UOR	95% CI
Clement SL 2010				
% Bare Ground Cover	2.8456	0.0916	1.155	0.977-1.367
VOR	0.0830	0.7732	1.117	0.526-2.373
Total Insect Biomass	1.0209	0.3123	1.247	0.812-1.915
% Forb Cover	0.1463	0.7021	1.013	0.947-1.084
% Grass Cover	0.1291	0.7194	0.989	0.934-1.048
Litter Depth	0.1409	0.7074	1.363	0.270-6.879
Basal Bare Ground Density	0.3085	0.5786	0.186	<0.001-70.408
Basal Litter Density	0.0998	0.7520	2.440	0.010-616.730
% Litter Cover	1.3759	0.2408	0.900	0.755-1.073
Maximum Height Live Vegetation	0.0004	0.9843	1.004	0.684-1.474
Maximum Height Dead Vegetation	0.5560	0.4559	0.446	0.053-3.724
Insect Axis 1 Score	0.1568	0.6922	0.690	0.11-4.324
Insect Axis 2 Score	0.0418	0.8380	0.740	0.041-13.251
Insect Axis 3 Score	2.5594	0.1096	260.921	0.286->999.999
Vegetation Axis 1 Score	1.0910	0.2960	2.101	0.522-8.456
Vegetation Axis 2 Score	0.0009	0.9767	0.973	0.153-6.203
Vegetation Axis 3 Score	0.9580	0.3277	0.428	0.078-2.340
Fitch SL 2010				
% Bare Ground Cover	0.2364	0.6268	0.969	0.855-1.099
VOR	0.4655	0.4951	1.564	0.433-5.651
Total Insect Biomass	0.0001	0.9930	1.002	0.709-1.416
% Forb Cover	0.6615	0.4160	0.946	0.828-1.081
% Grass Cover	0.7007	0.4026	1.053	0.933-1.189
Litter Depth	0.4172	0.5183	7.536	0.016->999.999
Basal Bare Ground Density	0.1484	0.7001	0.099	<0.001->999.999
Basal Litter Density	0.1581	0.6910	0.061	<0.001->999.999
% Litter Cover	0.3716	0.5421	1.058	0.882-1.270
Maximum Height Live Vegetation	0.0862	0.7691	0.911	0.491-1.692
Maximum Height Dead Vegetation	0.0001	0.9909	0.996	0.489-2.029
Insect Axis 1 Score	0.5910	0.4421	0.371	0.03-4.646
Insect Axis 2 Score	0.4213	0.5163	64.620	<0.001->999.999
Insect Axis 3 Score	0.4331	0.5105	31.463	0.001->999.999
Vegetation Axis 1 Score	0.0500	0.8231	0.807	0.123-5.305
Vegetation Axis 2 Score	0.1211	0.7279	1.803	0.065-49.882
Vegetation Axis 3 Score	0.7550	0.3849	0.358	0.035-3.632
Clement SL 2011				
% Bare Ground Cover	0.3752	0.5402	1.037	0.924-1.163
VOR	1.7992	0.1798	0.359	0.08-1.605
Total Insect Biomass	1.0093	0.3151	0.831	0.579-1.193
% Forb Cover	2.5857	0.1078	1.169	0.966-1.415
% Grass Cover	2.1281	0.1446	0.925	0.833-1.027
Litter Depth	0.0373	0.8469	0.442	<0.001->999.999

Treatment/Covariate	**x^2**	***P* value**	**UOR**	**95% CI**
Basal Bare Ground Density	0.7162	0.3974	9.041	0.055->999.999
Basal Litter Density	0.7654	0.3817	0.090	<0.001-19.885
% Litter Cover	0.0176	0.8943	1.009	0.882-1.154
Maximum Height Live Vegetation	0.0000	0.9988	1.000	0.558-1.795
Maximum Height Dead Vegetation	0.1083	0.7421	1.137	0.529-2.444
Insect Axis 1 Score	0.0657	0.7977	1.313	0.164-10.542
Insect Axis 2 Score	0.3440	0.5575	0.598	0.107-3.333
Insect Axis 3 Score	0.2378	0.6258	0.601	0.078-4.644
Vegetation Axis 1 Score	0.8079	0.3688	2.488	0.341-18.168
Vegetation Axis 2 Score	0.0531	0.8178	0.649	0.016-25.799
Vegetation Axis 3 Score	0.0200	0.8874	1.168	0.136-10.008
Fitch SL 2011				
% Bare Ground Cover	6.7026	0.0096	0.836	0.730-0.957
VOR	1.4107	0.2349	1.658	0.720-3.822
Total Insect Biomass	0.6026	0.4376	0.952	0.841-1.078
% Forb Cover	0.3646	0.5460	1.019	0.959-1.082
% Grass Cover	0.0160	0.8992	1.004	0.949-1.061
Litter Depth	1.7282	0.1886	>999.999	<0.001->999.999
Basal Bare Ground Density	0.0140	0.9058	0.777	0.012-50.732
Basal Litter Density	0.0103	0.9193	1.241	0.019-80.727
% Litter Cover	1.0411	0.3076	1.041	0.964-1.123
Maximum Height Live Vegetation	0.1262	0.7224	1.119	0.603-2.076
Maximum Height Dead Vegetation	0.0209	0.8851	1.038	0.625-1.725
Insect Axis 1 Score	0.0525	0.8188	0.898	0.357-2.257
Insect Axis 2 Score	0.3535	0.5521	2.942	0.084-103.170
Insect Axis 3 Score	0.0842	0.7717	1.850	0.029-118.034
Vegetation Axis 1 Score	0.0073	0.9321	0.955	0.330-2.763
Vegetation Axis 2 Score	1.6873	0.1940	0.048	<0.001-4.679
Vegetation Axis 3 Score	0.1643	0.6852	1.638	0.151-17.809

APPENDIX H: MEANS AND STANDARD DEVIATIONS (σ) OF UTILIZED AND AVAILABLE INSECT BIOMASS COLLECTIONS FROM THE CLEMENT AND FITCH NON-GRAZED (NG) AND SEASON-LONG GRAZED (SL) TREATMENTS NEAR HETTINGER, ND, IN 2008 – 2011

	Total Insect Biomass (grams)			Total Insect Biomass (grams)	
Clements	mean	σ	Fitch	mean	σ
2008 SL Utilized	3.21	2.65	2008 SL Utilized	0.86	0.77
2008 SL Available	2.10	0.94	2008 SL Available	3.05	3.75
2009 SL Utilized	3.63	1.67	2009 SL Utilized	5.52	4.15
2009 SL Available	4.96	3.14	2009 SL Available	5.77	2.97
2010 SL Utilized	2.86	3.31	2010 SL Utilized	4.98	5.14
2010 SL Available	4.15	2.26	2010 SL Available	5.00	4.05
2011 SL Utilized	5.34	5.73	2011 SL Utilized	6.94	6.59
2011 SL Available	2.86	1.71	2011 SL Available	5.5	4.41
2009 NG Utilized	3.19	1.86	2008 NG Utilized	0.92	0.95
2009 NG Available	4.14	1.87	2008 NG Available	2.83	2.94
2011 NG Utilized	4.08	2.64	2009 NG Utilized	1.96	1.05
2011 NG Available	3.32	2.15	2009 NG Available	1.56	0.81
			2011 NG Utilized	1.33	1.18
			2011 NG Available	1.29	1.23

APPENDIX I: CORRELATION SCORES OF INSECT ORDERS FROM NON-METRIC MULTI-DIMENSIONAL SCALING ANALYSIS FROM THE CLEMENT AND FITCH STUDY AREAS NEAR HETTINGER, ND, IN 2008 – 2011

Axis	1	2	3
	r	r	r
Orthoptera	0.585	0.047	0.031
Hemiptera	-0.223	-0.339	0.281
Coleoptera	-0.343	-0.013	-0.359
Diptera	-0.086	-0.184	-0.256
Hymenoptera	-0.045	-0.186	-0.118
Araneae	-0.097	-0.130	-0.270
Nueroptera	-0.085	-0.166	0.094
Other	-0.191	0.299	0.037