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EVALUATION OF METHODS USED TO IMPROVE GRASSLANDS AS RING-
NECKED PHEASANT (*Phasianus colchicus*) BROOD HABITAT

BY

MANDY R. ORTH

A dissertation submitted in partial fulfillment of the requirements for the

Doctor of Philosophy

Major in Wildlife and Fisheries Sciences

South Dakota State University

2018

EVALUATION OF METHODS USED TO IMPROVE GRASSLANDS AS RING-
NECKED PHEASANT (*Phasianus colchicus*) BROOD HABITAT

MANDY R. ORTH

This dissertation is approved as a creditable and independent investigation by a candidate for the Doctor of Philosophy in Wildlife and Fisheries Sciences degree and is acceptable for meeting the dissertation requirements for this degree. Acceptance of this dissertation does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Kent C. Jensen, Ph.D.
Dissertation Advisor

Date

Michele R. Dudash, Ph.D.
Head, Department of Natural
Resource Management

Date

Dean, Graduate School

Date

"Hope" is the thing with feathers -
That perches in the soul -
And sings the tune without the words -
And never stops - at all -

And sweetest - in the Gale - is heard -
And sore must be the storm -
That could abash the little Bird
That kept so many warm -

I've heard it in the chillest land -
And on the strangest Sea -
Yet - never - in Extremity,
It asked a crumb - of me.

~ Emily Dickinson¹

¹ Dickinson, E. 1851. "'Hope' is the thing with feathers." Available:
<https://www.poetryfoundation.org/poems/42889/hope-is-the-thing-with-feathers-314>

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ABSTRACT

EVALUATION OF METHODS USED TO IMPROVE GRASSLANDS AS RING-NECKED PHEASANT (*Phasianus colchicus*) BROOD HABITAT

MANDY R. ORTH

2018

Management practices designed for upland game species often focus on nest survival and hen winter survival due to the importance of these life history stages on population vital rates. However, chick survival is an important component of gallinaceous bird population dynamics, but it is poorly understood and often tends to be overlooked. Ideal brood habitat not only provides open understory for easy movement and canopy cover for protection, but also provides an abundance of arthropod foods for chicks. It has been hypothesized that restricted movement of chicks through thick vegetation in unmanaged grasslands results in lower brood survival rates. Research on the effectiveness of grassland management techniques used to improve brood rearing habitat specific to the northern Great Plains is lacking. This project investigated the efficacy of various methods of CRP mid-contract management, including haying, burning, herbicide application, interseeding, and grazing to improve brood rearing habitat for upland game birds as well as the longevity of the benefits provided by those methods. This research focused on assessing arthropod abundance through pitfall trap and sweep net collections, chick mass change and movement rates through the use of human-imprinted ring-necked pheasant (*Phasianus colchicus* Linnaeus) chicks, and vegetation composition and structure through Robel pole, Daubenmire, and litter depth measurements. Analysis of data using Kruskal-Wallis and Akaike's Information Criterion corrected for small sample size (AIC_c)

indicated that treatments incorporating interseeding, herbicide application, or both provided the best results for managing brood habitat. These sites produced the greatest chick mass gain and fastest movement times, and were characterized by reduced litter cover and depth, and increased bare ground and forb cover, which are all beneficial for chick movement and survival.

CHAPTER 1: EVALUATION OF METHODS USED TO IMPROVE GRASSLANDS
AS RING-NECKED PHEASANT (*Phasianus colchicus*) BROOD HABITAT: AN
INTRODUCTION

Ring-necked pheasants (*Phasianus colchicus* Linnaeus; hereafter pheasants) were introduced in South Dakota in the early 1900s (Trautman 1982, South Dakota Department of Game, Fish and Parks 2016). Since that time, South Dakota pheasant populations have fluctuated from more than 10 million pheasants in the mid-1930s to mid-1940s, and the early 1960s, to 2 million or less in the late 1960s and 1970s (Trautman 1982, South Dakota Department of Game, Fish and Parks 2016). Population levels between 2003 and 2010 rivaled the highs of the 1960s, but a declining trend is evident in recent years (Figure 1). These population fluctuations are largely due to large scale habitat conversion, changes in agricultural crops and farming practices, Conservation Reserve Program (CRP) implementation, and weather factors.

During the 1930s much farmland was idled due to drought conditions and the Great Depression, and during the 1940s considerable farmland acres were idled during World War II. The effect of this was the unintentional creation of vast acreages of habitat for pheasants and other grassland birds. The Soil Bank program of the 1960s provided suitable habitat (Erickson and Wiebe 1973, Trautman 1982), and recently the CRP (1985-present) has done the same. Favorable weather conditions have also helped boost population levels in recent years (South Dakota Department of Game, Fish and Parks 2016). Suitable habitat interspersed across large landscapes greatly increases pheasant populations, so it is not surprising that declines in the population have been recorded in

years when grassland habitat was converted to agricultural crops. Pheasants preferentially select grasslands for nesting and roosting, but will utilize any suitable standing cover, such as hay fields, pastures, alfalfa, small grains, and road-side ditches (Hanson 1971, Hanson and Progulske 1973, Warner 1979, Trautman 1982, Clark and Schmitz 1999), as long as it provides the structure needed for protection and concealment.

Winter weather has also been shown to have an impact on pheasant populations. Studies indicate that increased pheasant mortality during severe winter weather is usually due to increased predation, rather than the weather itself (Perkins et al. 1997, Gabbert et al. 1999). Landscapes lacking woody cover, cattail (*Typha* spp.) wetlands, idled grass, and suitable food can further increase winter pheasant losses (Perkins et al. 1997, Gabbert et al. 1999, 2001). Winter losses can be large (35-66%) (Perkins et al. 1997), with losses in South Dakota ranging from 5% in 1947-48 to 97% in 1996-97 (Gabbert et al. 1999). Not surprisingly, pheasant populations declined following severe winters (South Dakota Department of Game, Fish and Parks 2016).

Because of the importance of nest survival and hen winter survival, many studies have investigated how local and landscape-level habitat conditions affect these vital rates, and many management practices for increasing pheasant populations have focused around these factors. While chick survival is an important component of gallinaceous bird population dynamics, it is poorly understood and often tends to be overlooked (Riley et al. 1998). Population modeling in Iowa indicated that pheasant populations are more sensitive to chick survival than nesting success (Clark et al. 2008), which is consistent with similar modeling results for other gallinaceous birds (Wisdom et al. 2000, Svedarsky et al. 2003).

Ideal brood habitat provides open understory that allows chicks to move easily through the habitat and canopy cover to protect them from avian and other predators (United States Department of Agriculture 2014, Doxon and Carroll 2007, Flake et al. 2012, Runia 2013). Areas often used by pheasants include alfalfa fields, and grass fields and other areas with forbs, because these habitats provide high quantities of available arthropods for chicks (Hanson and Progulsk 1973, Trautman 1982, Hill 1985, Matthews 2009). Arthropods are the key component of galliform chick diets during the first few weeks of life because they provide high amounts of protein that is necessary for rapid growth and development (Southwood and Cross 1969, Hurst 1972, Trautman 1982, Healy 1985, Harper and Guynn 1998, Moreby et al. 2006). Studies have shown that for adequate growth, chick's diets need to consist of at least 24-28% protein (Nestler et al. 1942, Hurst 1972, Woodard et al. 1977). Compared to plants, arthropods contain more than four times the protein as well as essential amino acids not found in plant proteins. Additionally, protein from arthropods is more easily assimilated compared to plant protein (Stiven 1961, Doxon and Carroll 2007). Because of this, animal matter can comprise up to 90% of a chick's diet during the first week of life (Dalke 1935, Loughrey and Stinson 1955, Korschgen 1964).

Since arthropod biomass varies with the composition and structure of vegetation (Jamison et al. 2002), arthropod selection by galliform chicks can vary depending on weather conditions, location, and habitat. Despite this variation, chicks tend to select certain arthropods over others when available (Table 1) (Hurst 1972, Trautman 1982, Healy 1985, Hill 1985, Whitmore et al. 1986, United States Department of Agriculture 1999, Doxon and Carroll 2007; 2010, Matthews et al. 2012a). Arthropods selected vary

in size from small, such as leafhoppers, to large, such as grasshopper nymphs, as long as they can be eaten whole (Hurst 1972, Whitmore et al. 1986).

Variation in vegetation composition and structure and weather influences the type of arthropods present and where they are located in the vegetation. Sweep nets, pitfall traps and vacuums have been commonly used to sample arthropods in experiments involving grassland birds. Each method has advantages and disadvantages. Sweep nets tend to be lighter and easier to use than vacuum samplers, however, they tend to be biased toward arthropods located near the tips of vegetation as well as heavier, more active arthropods since the sweeping motion creates air pressure that can displace smaller and lighter arthropods (Hurst 1972, Doxon et al. 2011). Because of this, they can underestimate arthropods near the ground as well as those that can grasp vegetation more firmly (Harper and Guynn 1998). While sweep nets are lighter and easier to use, vacuum samplers are more efficient and collected arthropods are in better condition (Callahan et al. 1966, Doxon et al. 2011). Also, vacuum samplers are more efficient in collecting arthropods near the ground as well as smaller, lighter insects (Hurst 1972, Smith and Burger 2005, Doxon et al. 2011). However, because most collecting bags are inserted into the end of the collection hose, suction can quickly decrease as the bag fills with litter (Dogramaci et al. 2011). While pitfall traps are effective at collecting arthropods commonly found on the ground, they may underestimate arthropods found more commonly on plants (Standen 2000, Smith and Burger 2005). Studies have shown that pitfall traps collect mainly Coleoptera (beetles) and Araneae (spiders), sweep nets collect mostly Diptera (flies), Orthoptera (grasshoppers) and Lepidoptera (butterfly and moth)

larvae, and vacuum samples consist mainly of Hemiptera (true bugs) (Standen 2000, Doxon et al. 2011).

The collection method used depends on what is being studied. Vacuums sample closer to the ground and in low vegetation where more ground birds forage (Hurst 1972), whereas sweep nets sample higher in the vegetation strata (Smith and Burger 2005). Additionally, vacuums tend to collect arthropods in the size classes and types (slower moving) typically selected by foraging chicks (Hurst 1972, Palmer et al. 2001, Smith and Burger 2005, Doxon and Carroll 2010). While each of these methods has advantages and disadvantages, they provide a more accurate estimate of the arthropod community composition when combined (Randel et al. 2006).

Many studies assume that abundance indices calculated by using standard arthropod sampling techniques closely relate to the actual arthropod availability to chicks (Jamison et al. 2002). However, use of human-imprinted chicks suggests that these techniques may not accurately reflect true arthropod availability or selection preferences by gamebirds (Palmer et al. 2001, Smith and Burger 2005). Unlike arthropod sampling techniques, imprinted chicks are more likely to choose arthropods in the physical space available to wild chicks, select arthropods that are physically and nutritionally suitable for wild chicks, and interact with environmental factors of a habitat patch, such as vegetation structure, similar to wild chicks (Hurst 1972, Kimmel and Healy 1987, Palmer et al. 2001, Doxon and Carroll 2010). Researchers studying northern bobwhite (*Colinus virginianus* Linnaeus) foraging rates and insect selection and avoidance found similar results between wild and pen-reared chicks (Palmer 1995, Smith and Burger 2005), supporting the use of human-imprinted chicks for these types of studies. Additionally,

Kimmel and Healy (1987) found that while hens selected the foraging area, they had no other impact on the diets of gray partridge (*Perdix perdix* Linnaeus) chicks.

The importance of brood habitat has been shown in several ways. Pheasant broods that have access to an abundance of arthropods tend to have smaller home ranges which leads to fewer movements and higher survival than broods that do not (Warner et al. 1984, Hill 1985, Ryan et al. 1998, Matthews 2009). Additionally, chicks with access to an abundance of arthropods fledge sooner, which also results in lower predation rates (Nestler et al. 1942, Woodard et al. 1977, Potts 1997).

Loss of suitable nesting and brood habitat can lead to declines in populations due to decreased recruitment into their populations. With agriculture becoming more intensive and prevalent on the landscape, and native grassland habitat declining and becoming more fragmented, many grassland bird populations have declined (Warner et al. 1984, Delisle and Savidge 1997, Riley et al. 1998, Warner et al. 1999). The association of declining pheasant populations with the increase in corn and soybean production in Illinois has long been recognized (Warner 1979, Warner et al. 1984). In recent decades, agricultural practices have also included an increase in herbicide use with the advent and adoption of genetically-modified crops by the farming community. These changes have led to a decrease in cover quality and arthropod density, which can lead to decreased brood survival (Hill 1985, Rands 1985, Chiverton 1999, Warner et al. 1999). Additionally, advances in farming equipment and the economics of farming have led to changes not only in the way crops are planted, but also by what varieties of crops are being planted. No-till farming and high commodity prices for corn and soybeans has diminished the use of wheat and other small grains in favor of planting corn or other row

crops directly into existing wheat stubble (Rodgers 2002). This effectively eliminates one source of cover that pheasants use. Between 1974 and 1997 in Minnesota, small grains, pasture and hay were lost at a rate of 6% per year (Giudice and Haroldson 2002).

The CRP has helped convert cropland back into permanent cover, thus increasing the amount of suitable habitat. In South Dakota, increases in nesting and brood rearing habitat provided by land enrollment programs such as Soil Bank, Cropland Adjustment Program and CRP have led to increases in the pheasant population and helped maintain it at high levels (Trautman 1982, South Dakota Department of Game, Fish and Parks 2016). Researchers in Iowa found a positive association between CRP land enrollment and pheasant numbers (Riley 1995). Haroldson et al. (2006) found that for each 10% increase of grass in the landscape (up to 32%), pheasants increased by an average of 12.4 birds per survey route in the spring and 32.9 birds per route in the summer in Minnesota. In Nebraska, King and Savidge (1995) found pheasants were more abundant in areas with a higher percentage of CRP. White (2012) found that the presence of pheasant broods in eastern South Dakota was greatly influenced by the amount and configuration of CRP grasslands on the landscape and the probability of the presence of pheasant broods increased by 1.01 for every 1 ha increase in CRP.

Not all states, however, have seen these same effects from the CRP. Pheasant populations in Kansas have not responded positively, despite millions of acres of CRP grasslands being added to the landscape. It is thought that both low arthropod abundance and restricted movement of chicks by thick vegetation in unmanaged CRP may be resulting in reduced survival (Rodgers 1999, Warner et al. 1999). Initially, CRP grasslands are planted with a mixture of grasses, forbs, and legumes, and bare ground is

plentiful (Matthews et al. 2012b). In as little as 6 years, forbs tend to decline in abundance and a monoculture of perennial grasses remain (Burger et al. 1990, Millenbah et al. 1996, McCoy et al. 2001, Matthews et al. 2012b). While the remaining grass may be attractive structure for nesting, good brood rearing habitat that includes forbs increases both structural heterogeneity and invertebrate biomass (Green 1984, Warner et al. 1984, Erikstad 1985, Jamison et al. 2002, Doxon and Carroll 2007, Boyd et al. 2011). Over the course of natural succession, CRP loses its value as brood rearing habitat by having reduced arthropod diversity and abundance, as well as having a vegetation structure with a thick understory that impedes chick movement, resulting in reduced chick survival.

Changes in policy have been made to address the issue of declining habitat quality as the stands of CRP age. Since the 2002 Farm Bill, mid-contract CRP management for newly established fields is required (United States Department of Agriculture 2005). The desired outcome is to increase forb abundance and associated arthropod availability, and to provide vegetation structure with less litter and more bare ground to allow for easier chick movement. Grazing, fire, and disking have all been used to promote forb abundance, reduce litter, and increase grass cover on CRP lands (Best et al. 1998, Boyd et al. 2011). Matthews (2009) found that pheasants selected for and experienced higher nest success and brood survival in Nebraska CRP fields that had been disked and interseeded with legumes. Fields treated this way have been found to contain higher insect abundance (Southwood and Cross 1969, Hill 1985, Whitmore et al. 1986, Burger et al. 1994, Oleske et al. 1997, Leathers 2003). Doxon and Carroll (2007) found that incorporating forbs into CRP resulted in fewer fluctuations of invertebrate biomass and abundance. Other studies have also recognized the improvement in brood rearing habitat

resulting from disking and interseeding CRP grasslands (Burger et al. 1990, Manley et al. 1994, Madison et al. 1995, Rodgers 1999, Greenfield et al. 2002, Greenfield et al. 2003). Burning has also been shown to have concurrent increases in forb cover and arthropod abundance and availability (Hurst 1972, Boyd and Bidwell 2001). Yeiser et al. (2015) found that burning alone led to thick stands of grasses with a decrease in forb abundance over time, while herbicide application led to a reduction in unwanted grass species, and increased levels of forbs and desired grass species. Mowing was shown to help increase vegetative diversity by increasing light availability at ground level and by creating belowground root changes beneficial to forb establishment (Williams et al. 2007). Southwood and Cross (1969) found that mowed grasslands had more numerous, but smaller arthropods. Harper et al. (2015) found that grazing over the duration of the growing season led to an increase in and maintenance of an open vegetative structure at ground level suitable for foraging chicks, yet provided canopy cover suitable for nesting hens.

While the end goal of suitable brood habitat is known, the steps required to get there are not clear. Research on the effectiveness of techniques used to improve grasslands for pheasant brood rearing habitat specific to the northern Great Plains is lacking. Doxon and Carroll (2007; 2010) investigated pheasant chick foraging rates and insect abundance in CRP fields planted under several different CRP practices in Kansas, but only interseeding of alfalfa into warm season stands was studied. In Nebraska, Matthews (2009) researched pheasant nest density and success and brood habitat selection between CRP fields that were disked and interseeded and those that were not. Leathers (2003) also investigated invertebrate abundance between those same treatment

types. While disking and interseeding have been studied extensively and are proven methods to improve grasslands, many landowners are reluctant to disturb the soil in fear of noxious weed outbreaks. Although Leathers (2003) found no difference in noxious weed abundance between disked and control areas, finding alternative management methods that landowners would be less reluctant to use would be beneficial.

DISSERTATION RESEARCH

This study was conducted to investigate CRP management methods as well as the longevity of the benefits provided by those methods. In the mid-2000s South Dakota's pheasant population increased in response to, and remained high because of CRP. Even though cropland has become more prominent on the landscape and CRP stands have aged, it is likely that chick survival has remained adequate due to alternative brood rearing habitat found in hay, native grassland, and weedy areas around wetlands. Since brood habitat is often adjacent to, or very near nesting sites, managing nesting habitat to suit both nesting and brood rearing requirements would help increase chick survival. Additionally, as farming shifts from small grains to predominantly row crops, managing for brood habitat will become increasingly more important.

Currently in South Dakota, haying, prescribed fire, disking, and harrowing are approved mid-contract CRP management techniques (South Dakota State Technical Committee 2016). Haying is the most popular method used, but it is unclear if this method results in improved brood rearing habitat. When designing this study, we included methods already approved for use, such as haying and prescribed fire, as well investigated alternative methods not currently approved for use in South Dakota, such as

interseeding and grazing. Since little research has been conducted on these methods in South Dakota, we wanted to test whether the currently approved methods provide any benefits and whether alternative methods result in better outcomes than currently approved methods. Additionally, we wanted to test methods that could potentially increase landowner participation and acreage enrollment in CRP due to alternative uses of enrolled grasslands, such as allowing grazing. Finally, we tested the longevity of benefits provided by the various management methods.

The objectives of this research were to:

1. Determine and compare relative arthropod abundance among CRP grasslands subjected to several management techniques for three consecutive years post management.
2. Determine and compare relative arthropod availability among grasslands subjected to several management techniques for three consecutive years post management using human-imprinted pheasant chicks.
3. Determine and compare vegetation composition and structure among grasslands subjected to several management techniques for three consecutive years post management.

This dissertation is composed of 4 chapters. Chapter 1 provided an overview of background content that is included in Chapters 2-4. Chapter 2 involves an investigation of the role vegetation structure has on the movement of chicks, which plays a role in determining the suitability of grasslands as brood habitat. Chapter 3 involves an

investigation of the different habitat management techniques as well as the longevity of the benefits provided by those treatments. Finally, Chapter 4 provides a summary and discussion of conclusions, management and policy implications, and future research directions.

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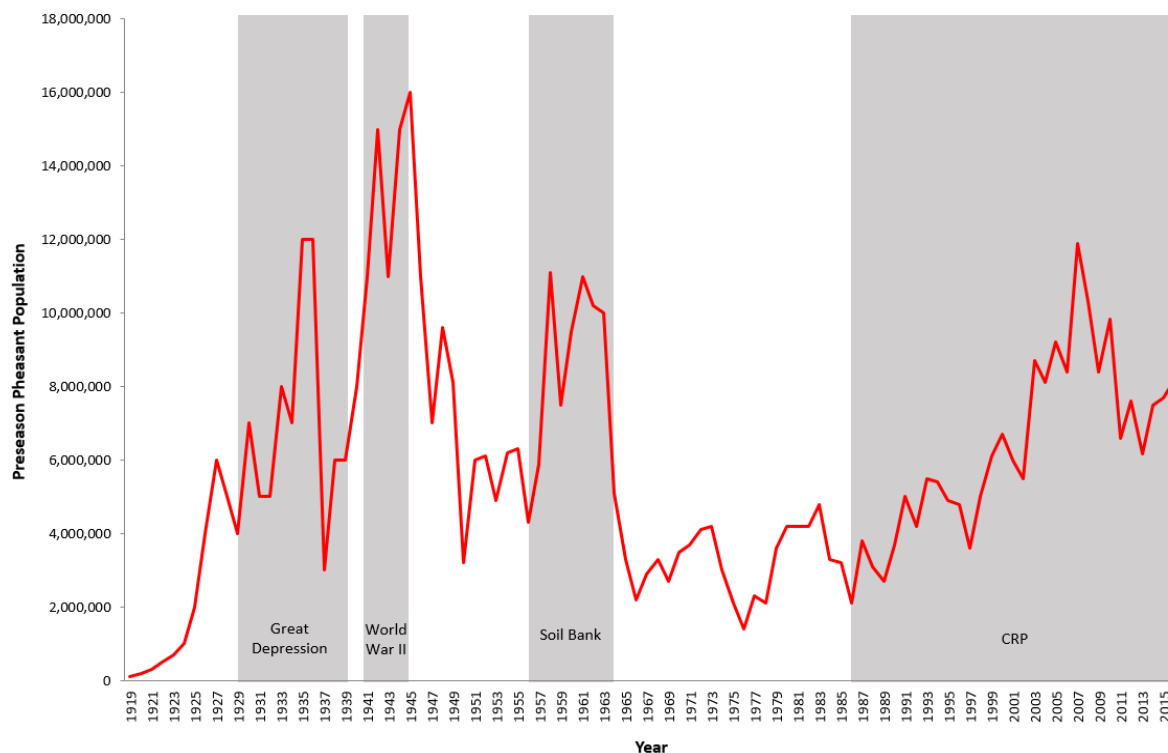


Figure 1. Pheasant population responses to habitat conditions, 1919-2016. Data adapted from preseason pheasant population estimates from South Dakota Game, Fish and Parks (2018).

Table 1. Preferred arthropods of galliform chicks. Summarized from Hurst 1972, Trautman 1982, Healy 1985, Hill 1985, Whitmore et al. 1986, USDA 1999, Doxon and Carroll 2007; 2010, and Matthews et al. 2012a.

Common Name	Order	Family
Beetles	Coleoptera	various
True bugs	Hemiptera	various
Leafhoppers	Hemiptera	Cicadellidae
Planthoppers	Hemiptera	various
Ants	Hymenoptera	Formicidae
Grasshopper nymphs	Orthoptera	various
Cricket nymphs	Orthoptera	Gryllidae
Flies	Diptera	various
Beetle and butterfly larvae	Coleoptera and Lepidoptera	various
Spiders	Araneae	various
Harvestmen	Opiliones	various

CHAPTER 2: EVALUATING THE INFLUENCE OF HABITAT STRUCTURE ON
THE MOVEMENT RATES OF RING-NECKED PHEASANT (*Phasianus colchicus*)
CHICKS²

ABSTRACT

Restricted movement of chicks through thick vegetation in unmanaged Conservation Reserve Program (CRP) lands may result in lower brood survival rates. Our research investigated the efficacy of various methods of CRP mid-contract management to improve brood rearing habitat, as a whole, for upland game birds. The objective of this research was to establish an alternative protocol for conducting chick movement trials that decoupled foraging and movement trials and to determine which grassland management technique best enabled for pheasant chick movement through dense vegetation. Haying, prescribed fire, herbicide application, interseeding, and grazing treatments were applied to six study sites using a randomized complete block design. To assess ease of movement, we measured the time it took human-imprinted pheasant (*Phasianus colchicus* Linnaeus) chicks to cross a 4 meter distance in treatment blocks. Percent canopy cover of grass, forbs, litter, and bare ground were measured within each treatment, along with visual obstruction readings and litter depth measurements. Increased litter depths are associated with slower chick movement rates, while faster chick movement rates were associated with treatments that removed or compacted the litter layer and increased the amount of bare ground. Thus, to facilitate pheasant chick

² *This chapter is being prepared for submission to the Journal of Field Ornithology*

movements, management of upland gamebird habitats should promote vegetation structures with minimal litter, adequate overhead cover, and an open understory.

INTRODUCTION

Chick survival is an important component of gallinaceous bird population dynamics, however it is poorly understood and often tends to be overlooked (Riley et al. 1998). Ideal brood habitat provides open understory that enables easy movement for chicks, adequate overhead cover to shield them from aerial predators, and an abundance of arthropods as a food source (USDA 1999, Doxon and Carroll 2007, Flake et al. 2012).

The U. S. Department of Agriculture's (USDA) Conservation Reserve Program (CRP) has helped convert highly erodible cropland to permanent cover, which has led to an increase in ring-necked pheasant (*Phasianus colchicus* Linnaeus; hereafter pheasant) populations through increased nesting and brood rearing habitat. In South Dakota, the years with the highest pheasant populations correspond to the years with the most habitat available on the landscape (Trautman 1982, South Dakota Department of Game, Fish and Parks 2016). However, due to farm subsidies, high commodity prices spurred by the ethanol industry, and advances in agricultural technology (GAO 2007), approximately 461,342 hectares (ha) of CRP lands have been converted to various cropland uses in South Dakota since 2007 (USDA 2014).

Though CRP has led to pheasant population increases in some states, not all states have seen the same response. It has been suggested that low arthropod abundance and restricted movement of chicks by thick vegetation in unmanaged CRP may be resulting in reduced chick survival (Rodgers 1999, Warner et al. 1999). While CRP grasslands were

initially planted with a mixture of grasses, forbs, and legumes, most of which contained some annual weeds and bare ground (Matthews et al. 2012). Over the course of natural succession, most stands of CRP lose their value as brood rearing habitat by having reduced arthropod diversity and abundance, as well as developing a vegetation structure with a thick understory that impedes chick movement, both of which result in reduced chick survival (Burkhart 2004, Doxon and Carroll 2010).

To address the issue of declining habitat quality as CRP stands age, mid-contract management is now required for newly contracted CRP fields (USDA 2005). The desired outcome is to increase forb abundance and associated arthropod availability, and create a vegetation structure with less litter and more bare ground to enable easier chick movement. Previous studies have investigated the effects of grazing, fire, and disking to promote forb abundance, reduce litter, and increase grass cover on CRP lands (Best et al. 1998, Boyd et al. 2011). Additionally, Matthews (2009) found that pheasants selected for and experienced higher nest success and brood survival in Nebraska CRP fields that had been disked and interseeded with legumes. Greenfield et al. (2002, 2003) found that brood rearing habitat was substantially improved through disking, which led to a decrease in litter and grasses and an increase in forbs, bare ground, and legumes. Mowing has been shown to help increase vegetative diversity by increasing light availability at ground level and by creating belowground root changes that are beneficial to forb establishment (Williams et al. 2007). Harper et al. (2015) found that grazing throughout the duration of the growing season led to an increase in and maintenance of an open vegetative structure at ground level while also providing overhead canopy cover. Yeiser et al. (2015) found that while burning alone led to thick stands of grasses with little bare ground and a

decrease in forb abundance over time, the combination of burning and herbicide application provided the best results by promoting both bare ground and the maintenance of desired forb and grass species (Yeiser 2015).

While studies suggest that CRP mid-contract management methods should improve the mobility of chicks through the understory, very little research has been done to specifically test this relationship. Doxon and Carroll (2010) examined the correlation between chick mobility and the amount of bare ground present using a mobility index and found that more bare ground resulted in easier movement for chicks, however, this assessment was conducted simultaneously with foraging trials where food deprived chicks may be more interested in foraging than specifically moving through the vegetation. The objectives of our study were to (1) establish an alternative protocol for conducting chick movement trials that decoupled foraging and movement trials and (2) determine which grassland management technique best enabled pheasant chick movement through dense vegetation. These results can be used to make recommendations for habitat management practices that enables optimal movement and increases survival rates of pheasant chicks.

METHODS

Study Area

Study sites were located on Game Production Areas (GPAs) managed by the South Dakota Department of Game, Fish and Parks (SDGFP) in eastern South Dakota, and included Casanova GPA, Cottonwood GPA, Gerken GPA, Fordham GPA, Dry Lake #2 North GPA, and Long Lake GPA (Fig. 1).

Management Techniques

Three 4.05 ha (10 acre) cool season and three 4.50 ha (10 acre) warm season Game Production Areas (GPAs) were used as test sites (Table 1). Four of the six sites were divided into four treatment blocks, and two sites, one cool season and one warm season, were divided into six treatment plots to include the grazing treatments. Using a complete randomized design, each management treatment was randomly assigned to one of the 0.81 ha (2 acre) plots in the test site. An unmanaged control plot was located close to treatments. Management treatments are listed in Table 2.

Cool season sites were hayed in fall 2012 prior to the start of the study and were cut to a height of 15-25.5 cm (6-10 inches). Burning of warm season sites occurred in early spring 2013 before fieldwork began by trained SDGFP staff (Table 3).

Cool season plots were interseeded with an alfalfa and clover mixture (Table 4). Warm season plots were interseeded with a mixture of native forbs (Table 5). Seeding was completed in spring 2013 by SDGFP staff using a Great Plains no-till drill.

Herbicides were chosen to suppress existing vegetation to allow interseeded plants a chance to establish and grow and because they are the type most commonly used by landowners. Cool season plots were treated with a combination of 2.24 kg ai ha⁻¹ glyphosate (32 oz ai acre⁻¹) and were applied in spring 2013 by SDGFP staff using a 4.87 m (16 ft) boom mounted on an ATV delivering 120 L ha⁻¹ (12.9 gal acre⁻¹) spray volume via AirMix AM11002 nozzles at 30 PSI. Warm season plots were treated with 2.27 kg ai ha⁻¹ of glyphosate in spring 2013 by SDGFP staff using a 94.63 L (25 gal) ATV tank

sprayer equipped with a 6.7 m (22 ft) boom delivering 121 L ha⁻¹ (13 gal acre⁻¹) spray volume via XR Teejet 8003V8 nozzles at 30 PSI.

Fences were installed to prevent cattle from entering other plots during grazing and were completely closed off after grazing to prevent cattle from re-entering. Fencing was completed by SDGFP staff. Overseeding was done prior to cattle grazing the plots. Plots were grazed in spring 2013 and were part of larger grazing pastures. Cool season grazing plots had a stocking density of 0.72 animal units (AU) acre⁻¹ and were grazed for 15 days. Warm season grazing plots had a stocking density of 0.9 AU acre⁻¹ and were grazed for 31 days.

Human-Imprinted Chicks

Pen-raised one day old pheasant chicks were purchased from a commercial pheasant farm in north-central South Dakota. Imprinting of chicks began immediately after receiving them and was carried out over four days, following previously published methods (Palmer et al. 2001, Smith and Burger 2005, Osborne et al. 2012). The first four days after obtaining the chicks were devoted to imprinting chicks to handlers and exposing them to outdoor habitats. Chicks were housed in pens and had unlimited access to fresh water, food, and heat lamps. Food was provided in the form of commercial chick food as well as access to live arthropods during the imprinting process.

Movement Trials

We used 10 non-fasted, five to 10 day old chicks for the movement trials. All of the chicks used in one trial were of the same age. We conducted trials in June and July of

2013, 2014, and 2015. A 4 meter distance was measured inside the treatment site using a measuring tape. One at a time, a chick was placed at one end of the 4 meter tape. We then walked to the opposite end of the measuring tape being careful not to trample the vegetation, waited for the chick to begin vocalizing a “lost call”, and simultaneously started the timer and began to call to the imprinted chick. When the chick returned to the handler at the end of the 4 meter distance, the timer was stopped and the time recorded (minutes and seconds). A trial was discarded if the chick made a lost call but never moved from the starting point or if a chick did not return after 15 minutes.

Vegetation Sampling

Percent canopy cover of grass, forbs, bare ground, and litter was assessed using a 20 x 50 cm Daubenmire frame (Daubenmire 1959) at five random locations within each treatment. Ground covered by dead vegetation without overhead cover of live plants was classified as litter and ground without dead vegetation or overhead cover of live plants was classified as bare ground. Visual obstruction was recorded using a Robel pole (Robel et al. 1970) at five random locations within each treatment type in each of the four cardinal directions at a height of 1 meter and a distance of 4 meters and recorded to the nearest 0.5 decimeter (Robel et al. 1970). Litter depth was measured with a meter stick to the nearest millimeter at each of the Daubenmire frame locations.

Data Analysis

We used Kruskal-Wallis to compare movement rates of chicks between the different grassland treatments, percent cover, visual obstruction, and litter depth, with an all-pairwise comparisons test to determine statistical significance between samples.

Results of the Kruskal-Wallis test were considered significantly different at a value of $\alpha \leq 0.05$. Regression models were constructed to identify the best predictor for movement rates in cool season and warm season stands. We ranked the models using Akaike's Information Criteria corrected for small sample size (AIC_c), and models were considered competitive if the ΔAIC_c was ≤ 2 units. We also used Akaike weights (w_i) to evaluate the strength of support for each model (Burnham and Anderson 2002). *A priori* regression models for both cool and warm season treatments included percent grass cover, percent forb cover, percent bare ground, percent litter cover, visual obstruction reading, and litter depth as explanatory variables. All statistics were completed using Statistix 9 (Analytical Software, Tallahassee, FL).

RESULTS

Movement Trials

The average chick movement rate across all cool season treatments was 278 seconds (Table 6). While chick movement times (Table 7) on cool season sites were not significantly different ($P = 0.2619$), the fastest movement times were recorded on grazing + overseeding (167.22 sec.) and the slowest movement times were recorded on the haying only (362.81 sec.) and grazing only (376.25 sec.) treatments. The average chick movement rate across all warm season treatments was 252 seconds (Table 6). Average chick movement rates for warm season treatments (Table 8) were significantly different ($P = 0.0000$), with the fastest movement rate recorded on the fire + herbicide (57.86 sec.) treatment and the slowest movement times recorded on the fire + interseeding (303.38 sec.) and control (305.76 sec.) treatments

Vegetation

On cool season sites, percent grass cover (Table 7) was significantly different ($P = 0.0000$) among treatment types and averaged 39.9%. Grazing only (76.5%) and grazing + overseeding (58.5%) had the highest percent grass cover while haying only (26.42%) and haying + interseeding (42.88%) had the lowest. Percent forb cover (Table 7) averaged 11% and was significantly different ($P = 0.0000$), with the highest percent forb cover on haying + herbicide (28.75%) and the lowest on the control (2.18%) and grazing only (0.75%) treatments. Average percent litter cover (Table 7) was 38.7% and was significantly different ($P = 0.0000$). Percent litter cover was highest on the haying only (54.67%) treatment and lowest on the haying + herbicide (26.83%) and grazing only (19.75%) treatments. Percent bare ground on cool season sites (Table 7) was significantly different ($P = 0.0000$) among treatment types and averaged 6.2%. Bare ground was only recorded for the haying + interseeding (14.39%), haying + herbicide (8.5%), and grazing only (3.25%) treatments. The other treatments did not have any measurable bare ground present. Visual obstruction readings (VOR) (Table 7) were significantly different among treatment types ($P = 0.0000$) and averaged 6.6 dm. VOR was highest on haying + interseeding (8.32 dm) and haying only (7.37 dm), while grazing + overseeding (4.45 dm) had the lowest values. Litter depth measurements averaged 24.4 mm (Table 7) and was significantly different among treatment types ($P = 0.0000$). Litter depth was highest on the haying only treatment (47 mm) and lowest on the haying + interseeding treatment (8.99 mm).

On warm season sites (Table 8), percent grass cover averaged 60.7% and was significantly different ($P = 0.0000$) among treatment types. The fire only (77.63%) and

fire + interseeding (77.25%) treatments had the highest percent grass cover while fire + herbicide (10%) had the lowest. Percent forb cover (Table 8) averaged 7.1% and was significantly different ($P = 0.0018$), with the fire + herbicide + interseeding (2.81%) treatment having the highest percent forb cover, while the other treatments had statistically similar lower percent cover. Average percent litter cover (Table 8) was 28.8% and was significantly different ($P = 0.0000$) among treatment types. Percent litter cover was highest on the fire + herbicide (71.25%) and grazing only (57.75%) treatments and lowest on the fire + herbicide + interseeding (13.13%) treatment. Percent bare ground (Table 8) averaged 1.6%, and was significantly different ($P = 0.0000$) among treatment types, with fire + herbicide (15%) having the highest percent bare ground, while the other treatments had statistically similar results near zero. VOR (Table 8) averaged 4.9 dm and was significantly different among treatment types ($P = 0.0000$), with the fire + herbicide + interseeding (7.48 dm) treatment having the highest values and the fire + herbicide (0.3 dm) treatment having the lowest. The average litter depth on warm season sites (Table 8) was 24.3 mm, and was significantly different among treatment types ($P = 0.0000$). Litter depth was highest on the fire only (34.08 mm) and fire + interseeding (28.89 mm) treatments and lowest on the fire + herbicide (7.05 mm) treatment.

Additional Factors Considered

Movement rates of different ages of chicks used in the trials (5 days old, 6 days old, etc.) were compared to determine if age impacted movement rates. Analysis of movement rates for each age group revealed no significant difference ($P = 0.3620$).

We were able to determine chick bond strength based on the order that chicks were loaded into three separate holding pens. Chicks had equal opportunity to enter the holding pens in any order, therefore chicks that entered into the first pen exhibited a stronger bond with the handler than chicks that entered into the third pen. We compared this order to determine if the strength of the bond with the handler impacted movement rates and found no significant difference ($P = 0.3915$) between the three pens.

Average chick movement rates by handler were compared to test for differences among handlers. There was a significant difference between one handler (MO) and the other three handlers ($P = 0.0000$, Fig. 2).

Regression Models

There were three competitive models for explaining chick movement rates (Table 9) on cool season sites. The top model predicted that as the amount of bare ground increased, movement rates became faster ($w_i = 0.426$, $P = 0.0053$). The second model predicted that as both the amount of bare ground and the visual obstruction increased, movement rates were faster ($w_i = 0.232$, $P = 0.0096$). The final model predicted that as the amount of bare ground and grass cover increased, movement rates became faster ($w_i = 0.164$, $P = 0.047$). These three models together carried 82.2% of the weight.

On warm season treatments, there were five competing models in explaining chick movement rates (Table 10), however none of the top models carried much weight. The top model predicted that as litter depth increased, movement rates became slower ($w_i = 0.196$, $P = 0.0053$). The second model predicted that as the amount of forb cover increased, movement rates were slower. ($w_i = 0.153$, $P = 0.0096$). The third model

predicted that as litter depth and percent litter cover decreased, movement rates were slower ($w_i = 0.113$, $P = 0.047$). The fourth model predicted that as the amount of grass cover increased and litter depth decreased, movement rates became slower ($w_i = 0.092$, $P = 0.1496$). The final model predicted that as the amount of grass and forb cover increased, and litter depth decreased, movement rates were faster ($w_i = 0.076$, $P = 0.577$). These top five models together carried 63% of the weight.

Since no single competitive model carried a majority of the weight, and the top model only carried 19.6% of the weight, we were not convinced that these models did a satisfactory job of predicting chick movement rates through warm season sites. Based on these results, we constructed *a posteriori* models, which included environmental variables of time of day, cloud cover, percent humidity, and temperature. When these variables were added (Table 11), the previous top models were replaced with models containing these factors and three new competitive models emerged. The new top model predicted that movement rates were faster later in the day and with increasing cloud cover ($w_i = 0.3445$, $P = 0.0000$). The second model predicted that movement rates were faster later in the day, with increasing cloud cover, and with less litter depth ($w_i = 0.2965$, $P = 0.0001$). The third model predicted that later in the day, increasing cloud cover and increasing temperature led to faster movement rates ($w_i = 0.1332$, $P = 0.0002$). These new top models carried 77% of the weight in explaining movement rates through warm season treatments.

DISCUSSION

When comparing grassland management techniques on cool season sites, chick movement rates among the management techniques were not significantly different, indicating that haying, herbicide application, seeding, grazing, and combinations of those treatments did not produce any differences in ease of movement for chicks in our study area. For warm season treatments, differences emerged in the composition of the understory. Treatments that removed understory vegetation and litter and increased the amount of bare ground, such as fire + herbicide application, showed significantly faster chick movement rates than treatments that either did not alter or changed the vegetative composition of the understory, including fire + interseeding of native forbs and the control.

AIC_c modeling revealed that the best predictor of movement rates on cool season sites was the amount of bare ground and vegetation cover and obstruction. On warm season sites, the best vegetative predictor of movement rates was litter depth and vegetation cover. We also found that environmental variables were more important on warm season sites than cool season, likely because the primary treatment method on warm season sites (fire) removed all standing vegetation and left the chicks more exposed than cool season sites.

We found that both the age of chicks and bond strength did not affect movement rates. Since older chicks are both larger and stronger than younger chicks, we hypothesized that this may reduce the amount of time it took for them to cover the distance and navigate through the vegetation, but found that chick age had no effect.

While older chicks are stronger than younger chicks, they are also more independent and tend to maintain greater distances from the hen when not threatened. We also hypothesized that chicks exhibiting a stronger bond with the handler would move through the vegetation faster due to their desire to return to the safety and security of “mom”, however we found that bond strength did not affect movement rates.

Our analysis revealed that three handlers had statistically similar chick movement rates, while one handler had rates that were significantly less than the others. The three handlers with similar movement rates were seasonal technicians. Because of this, they had fewer total observations than the lead researcher (28, 28, and 53 versus 91) and the methods and techniques were new to them. It is highly likely that experience with the imprinting process and movement trial methodology increases both the confidence of the handler, as well as the ability to locate and track chicks moving through vegetation.

Our first objective was to develop an alternative protocol for conducting chick movement trials that decoupled foraging and movement trials, which we accomplished. Second, we wanted to determine which grassland management technique best enabled pheasant chick movement through dense vegetation. Many studies have reported the importance of bare ground for chick movement (Doxon and Carrol 2010, Greenfield et al. 2002, Greenfield et al. 2003, Harper 2015), and our study supports this as well. Treatments that left standing vegetation (haying) or replaced the vegetation through interseeding resulted in slower movement rates than treatments that removed the vegetation and litter layer (fire + herbicide application). Similar to Yeiser et al. (2015), we found that a combination of burning and herbicide application had better results in providing suitable brood habitat than either treatment alone.

From a grassland management perspective relative to South Dakota CRP fields, we found that treatments that removed vegetation and litter were best for chick movement. While we did not statistically compare cool season treatments with warm season treatments, we documented faster movement rates, more grass cover, less litter cover, and lower visual obstruction readings overall on warm season sites. While our results recommend habitat management techniques that provide good brood habitat, they may not provide optimal habitat for nesting hens or protection from aerial predators due to the lack of overhead cover. The best compromise is a treatment method that provides an open understory for ease of chick movement in finding food and escaping predators and overhead cover for nesting and protection from predators, such as interseeding.

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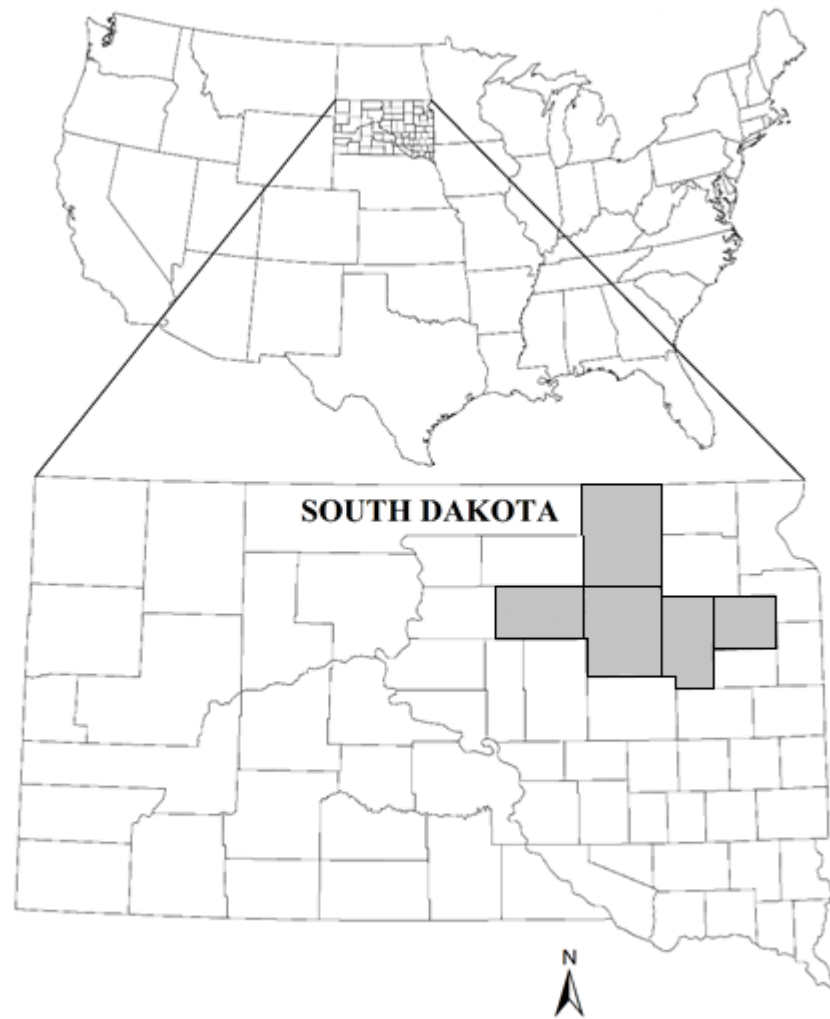


Figure 1. Five county (Clark, Codington, Faulk, Spink, and Brown) area for study of optimal movement of ring-necked pheasant chicks through various vegetation structures in north-central and north-eastern South Dakota, USA, 2013-2015.

Table 1. Game Production Area (GPA) locations and management histories on study site locations in north-central and north-eastern South Dakota, USA, 2013-2015.

Study Site Locations				
	GPA	County	Management History	Center of Site Coordinates
Cool Season	Casanova	Brown	Grass planting mid- to late-90s; hayed on 3-5 year rotation	45°24'15" N, 98°38'30" W
	Gerken	Faulk	Grass planting mid- to late-90s; hayed on 3-5 year rotation	45°00'04" N, 98°56'01" W
	Cottonwood	Spink	Grass planting mid- to late-90s; hayed on 3-5 year rotation	44°46'02" N, 98°41'42" W
Warm Season	Fordham	Clark	Grass planting 2008; Burned 2010	44°46'03" N, 97°55'18" W
	Dry Lake #2 North	Clark	Grass planting 2007	44°41'16" N, 97°39'27" W
	Long Lake	Codington	Grass planting 2007	44°56'50" N, 97°24'48" W

Table 2. Management treatments applied to study sites in north-central and north-eastern South Dakota, USA.

Management Treatments	
Cool Season	Warm Season
Control	Control
Haying only	Prescribed fire only
Haying + interseeding forbs	Prescribed fire + interseeding native forb mix
Haying + herbicide application	Prescribed fire + herbicide application
Haying + herbicide application + interseeding forbs	Prescribed fire + herbicide application + interseeding native forb mix
Grazing	Grazing
Grazing + overseeding	Grazing + overseeding

Table 3. Dates of treatment applications to study sites in north-central and north-eastern South Dakota, USA.

Treatment Applications						
Study Site	Hayed	Prescribed fire	Herbicide application	Interseeded	Cattle On/Off	Overseeding
Cottonwood	After 15 July 2012	-	4 June 2013	11 June 2013	-	-
Casanova	Oct. 2012	-	3 June 2013	10 June 2013	-	-
Gerken	Oct. 2012	-	10 June 2013	11 June 2013	1 June 2013 – 15 June 2013	2 June 2013
Fordham	-	11 June 2013	25 June 2013	18 June 2013	-	-
Dry Lake #2 North	-	11 June 2013	25 June 2013	18 June 2013	-	-
Long Lake	-	17 May 2013	2 June 2013	5 June 2013	25 May 2013 – 25 June 2013	24 May 2013

Table 4. Alfalfa and clover planting mix and seeding rate on cool season study sites in north-central and north-eastern South Dakota, USA.

Common Name	Scientific Name	Percent of mix	Kg ha ⁻¹
Vernal alfalfa	<i>Medicago sativa</i> L.	33.33%	3.36
Alsike clover	<i>Trifolium hybridum</i> L.	16.67%	1.68
Medium red clover	<i>Trifolium pratense</i> L.	16.67%	1.68
White Dutch clover	<i>Trifolium repens</i> L.	16.67%	1.68
Ladino clover	<i>Trifolium repens</i> L.	16.67%	1.68
		100%	10.08

Table 5. Native forb planting mix and seeding rate on warm season study sites in north-central and north-eastern South Dakota, USA.

Common Name	Scientific Name	Full seeding rate	Percent of mix	Seeds needed	Seeds m ⁻²	Kg ha ⁻¹	Grams	Kg	2013 Cost
Black-eyed susan	<i>Rudbeckia hirta</i> L.	0.75	3%	13,068	0.03	19,529.71	4.54	0.005	\$0.17
Blanket flower	<i>Gaillardia aristata</i> Pursh	6.94	7%	30,492	0.07	4,924.64	61.8	0.06	\$4.08
Canada milk vetch	<i>Astragalus canadensis</i> L.	4.09	7%	30,492	0.07	8,356.24	50.75	0.05	\$3.92
Ox-eye sunflower	<i>Heliopsis helianthoides</i> (L.) Sweet	3.33	7%	30,492	0.07	10,263.37	137.21	0.14	\$7.55
Grayhead coneflower	<i>Ratibida pinnata</i> (Vent.) Barnhart	1.74	3%	13,068	0.03	8,417.97	12.47	0.01	\$0.82
Illinois bundleflower	<i>Desmanthus illinoensis</i> (Michx.) MacMill. ex B.L. Rob. & Fernald	18.15	12%	52,272	0.11	3,228.05	279.53	0.28	\$21.57
Maximilian sunflower	<i>Helianthus maximiliani</i> Schrad.	4.36	7 %	30,492	0.07	7,838.76	62.65	0.06	\$4.14
Partridge pea	<i>Chamaecrista fasciculata</i> (Michx.) Greene	3.33	7%	30,492	0.07	10,263.37	320.06	0.32	\$7.76

Table 5 continued. Native forb planting mix and seeding rate on warm season study sites in north-central and north-eastern South Dakota, USA.

Common Name	Scientific Name	Full seeding rate	Percent of mix	Seeds needed	Seeds m ⁻²	Kg ha ⁻¹	Grams	Kg	2013 Cost	
Plains coreopsis	<i>Coreopsis tinctoria</i> Nutt.	0.66	5%	21,780	0.05	36,988.09	56.13	0.05	\$2.35	
Prairie coneflower	<i>Ratibida columnifera</i> (Nutt.) Wooton & Standl.	1.48	5%	21,780	0.05	16,494.69	13.32	0.01	\$1.18	
Purple prairie clover	<i>Dalea purpurea</i> Vent.	9.08	12%	52,272	0.11	6,452.55	78.24	0.08	\$6.03	
Western yarrow	<i>Achillea millefolium</i> L. var. <i>occidentalis</i> DC.	0.39	5%	21,780	0.05	62,595.22	3.4	0.004	\$0.42	
Purple coneflower	<i>Echinacea purpurea</i> (L.) Moench	9.08	12%	52,272	0.11	6,452.55	14.17	0.01	\$0.53	
White prairie clover	<i>Dalea candida</i> Michx. ex Willd.	0.39	8%	34,848	0.07	100,152.37	56.98	0.06	\$6.27	
				100%	435,600	1	301,958	1,151	1	\$66.79

Table 6. Summary of mean chick movement rates (sec.), visual obstruction readings (dm), Daubenmire readings (%), and litter depth (mm) on cool and warm season sites in north-central and north-eastern South Dakota, USA, 2013-2015.

	Cool Season	Warm Season
Chick Movement Rate (sec.)	278	252
Visual Obstruction Reading (dm)	6.6	4.9
Percent Grass	39.9	60.7
Percent Forb	11	7.1
Percent Bare Ground	6.2	1.6
Percent Litter Cover	38.7	28.8
Litter Depth (mm)	24.4	24.3

Table 8. Mean (\pm SE) of chick movement rates (sec.), percent grass, percent forb, percent bare ground, percent litter cover (%), visual obstruction readings (dm), and litter depth (mm) by treatment on warm season sites in north-central and north-eastern South Dakota, USA, 2013-2015. Results of the Kruskal-Wallis tests were considered significantly different at a value of $\alpha \leq 0.05$.

		Chick Movement Rate (sec.)	Percent Grass	Percent Forb	Percent Bare Ground	Percent Litter Cover	Visual Obstruction Reading (dm)	Litter Depth (mm)
Control		305.76 (\pm 35.91)	58.69 (\pm 2.90)	10.06 (\pm 1.97)	1.81 (\pm 0.63)	26.69 (\pm 2.15)	4.97 (\pm 0.14)	27.96 (\pm 3.04)
Fire Only		180.55 (\pm 24.06)	77.63 (\pm 2.73)	3 (\pm 0.95)	0 (\pm 0)	18 (\pm 2.91)	3.65 (\pm 0.13)	34.08 (\pm 3.16)
Fire + Interseeding		303.38 (\pm 24.46)	77.25 (\pm 2.14)	2.81 (\pm 0.69)	0 (\pm 0)	18.94 (\pm 2.17)	5.54 (\pm 0.27)	28.89 (\pm 1.93)
Fire + Herbicide		57.86 (\pm 23.96)	10 (\pm 3.52)	3.75 (\pm 1.47)	15 (\pm 4.48)	71.25 (\pm 5.95)	0.3 (\pm 0.10)	7.05 (\pm 1.24)
Fire + Herbicide + Interseeding		252.50 (\pm 48.83)	62.75 (\pm 5.51)	21.75 (\pm 6.16)	0 (\pm 0)	13.13 (\pm 2.96)	7.48 (\pm 0.27)	13.525 (\pm 1.25)
Grazing Only		131.52 (\pm 32.84)	37.75 (\pm 4.34)	1.13 (\pm 0.94)	0.63 (\pm 0.52)	57.75 (\pm 3.66)	4.88 (\pm 0.40)	17.2 (\pm 2.45)
Treatment Comparison	<i>P</i> value	0.0000	0.0000	0.0018	0.0000	0.0000	0.0000	0.0000

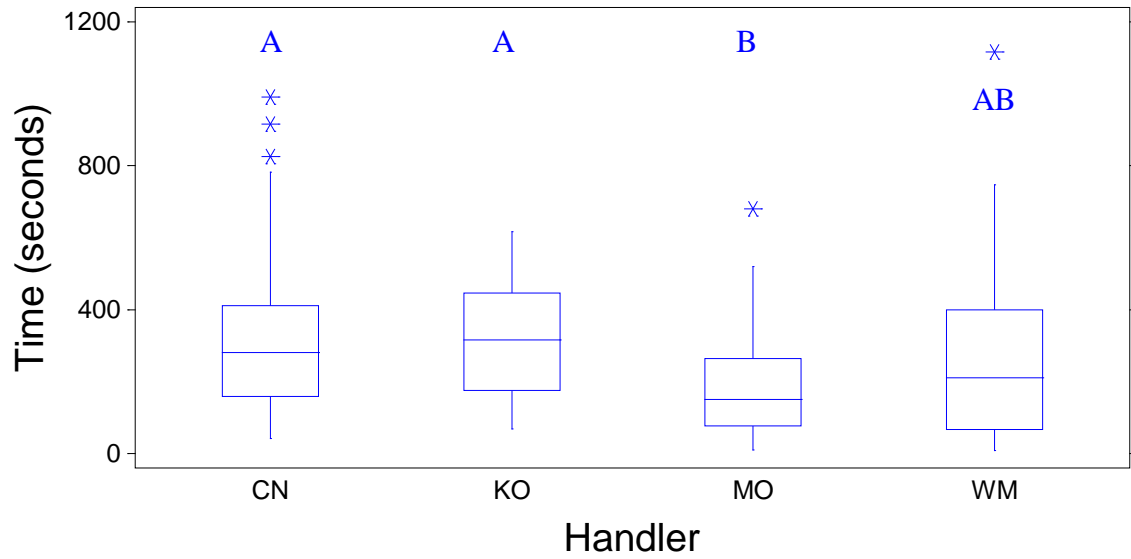


Figure 2. Chick movement rates by handler on study sites in north-central and north-eastern South Dakota, USA. Means accompanied by the same letter are not statistically different ($\alpha = 0.05$). Stars indicate outliers.

Table 9. Ranked regression models predicting chick movement rates for cool season treatments in north-central and north-eastern South Dakota, USA, 2013-2015.

Competitive models = $\Delta AIC_c \leq 2$.

Model	AIC_c^a	ΔAIC_c^b	w_i^c	<i>P</i> value
- Bare Ground	875.78	0.00	0.426	0.0053
- Bare Ground - VOR	877.00	1.22	0.232	0.0096
- Bare Ground - Grass Cover	877.68	1.90	0.164	0.047
- Bare Ground - Grass Cover - VOR	878.62	2.84	0.103	0.1496
- Bare Ground - Grass Cover + Litter				
Depth	879.29	3.51	0.073	0.577
+ Litter Cover + Grass Cover	1031.90	156.12	0.000	0.0145

^a Akaike's information criterion corrected for small sample size, ^b Change in AIC_c relative to minimum AIC_c , ^c Akaike weight (Burnham and Anderson 2002).

Table 10. Ranked *a priori* regression models predicting chick movement rates for warm season treatments in north-central and north-eastern South Dakota, USA, 2013-2015.

Competitive models = $\Delta AIC_c \leq 2$.

Model	AIC _c ^a	ΔAIC_c ^b	w_i ^c	<i>P</i> value
+ Litter Depth	1060.5	0	0.196	0.0096
+ Forb Cover	1061	0.5	0.153	0.047
- Litter Depth - Litter Cover	1061.6	1.1	0.113	0.1496
+ Grass Cover- Litter Depth	1062	1.5	0.092	0.577
- Grass Cover - Forb Cover + Litter Depth	1062.4	1.9	0.076	0.0145
- VOR	1062.7	2.2	0.065	0.0229
+ Bare Ground	1062.8	2.3	0.062	0.0195
+ Grass Cover	1063.1	2.6	0.053	0.0392

^a Akaike's information criterion corrected for small sample size, ^b Change in AIC_c relative to minimum AIC, ^c Akaike weight (Burnham and Anderson 2002).

Table 11. Ranked *a posteriori* regression models for predicting chick movement rates for warm season treatments in north-central and north-eastern South Dakota, USA, 2013-2015. Competitive models = $\Delta AIC_c \leq 2$.

Model	AIC _c ^a	ΔAIC_c ^b	w_i ^c	P value
- Time of Day + Cloud Cover	1044.8	0	0.3445	0.0000
- Time of Day + Cloud Cover - Litter Depth	1045.1	0.3	0.2965	0.0001
- Time of Day + Cloud Cover + Temperature	1046.7	1.9	0.1332	0.0002
- Time of Day + Cloud Cover + Grass Cover - Litter Depth	1047.3	2.5	0.0987	0.0002
- Percent Humidity + Temperature + Cloud Cover - Time of Day	1048.2	3.4	0.0629	0.0003
+ Percent Humidity - Temperature + Cloud Cover	1049.4	4.6	0.0345	0.0005
+ Cloud Cover	1049.9	5.1	0.0269	0.0003
+ Percent Humidity - Temperature	1055.3	10.5	0.0018	0.0053
- Time of Day	1058.7	13.9	0.0003	0.0365
+ Litter Depth	1060.5	15.7	0.0001	0.0096
+ Forb Cover	1061	16.2	0.0001	0.047
- Litter Depth - Litter Cover	1061.6	16.8	7.75E-05	0.1496
+ Grass Cover- Litter Depth	1062	17.2	6.34E-05	0.577
- Grass Cover - Forb Cover + Litter Depth	1062.4	17.6	5.19E-05	0.0145
- VOR	1062.7	17.9	4.47E-05	0.0229
+ Bare Ground	1062.8	18	4.25E-05	0.0195
+ Grass Cover	1063.1	18.3	3.66E-05	0.0392

^a Akaike's information criterion corrected for small sample size, ^b Change in AIC_c relative to minimum AIC, ^c Akaike weight (Burnham and Anderson 2002).

CHAPTER 3: EVALUATION OF METHODS USED TO IMPROVE GRASSLANDS
AS RING-NECKED PHEASANT (*Phasianus colchicus*) HABITAT³

ABSTRACT

Management practices designed for upland game species often focus on nest survival and hen winter survival due to the importance of these life history stages on population vital rates. However, chick survival is an important component of gallinaceous bird population dynamics, but it is poorly understood and often tends to be overlooked. Ideal brood habitat not only provides open understory for easy movement and canopy cover for protection, but also provides an abundance of arthropod foods for chicks. Research on the effectiveness of grassland management techniques used to improve brood rearing habitat specific to the northern Great Plains is lacking. This research investigated the efficacy of various methods of CRP mid-contract management, including haying, burning, herbicide application, interseeding, and grazing, to improve brood rearing habitat for upland game birds as well as the longevity of the benefits provided by those methods. Our research focused on assessing arthropod abundance through pitfall trap and sweep net collections, chick mass change through the use of human-imprinted ring-necked pheasant (*Phasianus colchicus* Linnaeus) chicks, and vegetation composition and structure through Robel pole readings, Daubenmire frame percent cover estimates, and litter depth measurements. Overall, we found that treatments incorporating interseeding, herbicide application, or both provided the best results for managing brood habitat. These plots had the greatest chick mass gain, reduced litter

³ *This chapter is being prepared for submission to Studies in Avian Biology*

cover and depth, and increased bare ground and forb cover, which are all beneficial for chicks.

INTRODUCTION

Historically, many studies have investigated the effects of local and landscape-level habitat conditions on nest success and winter survival, and several studies have suggested that gallinaceous bird populations are more sensitive to chick survival rates than to nesting success rates (Wisdom et al. 2000, Svedarsky et al. 2003, Clark et al. 2008), yet this aspect of gallinaceous bird population dynamics is poorly understood and often overlooked (Riley et al. 1998).

Ideal brood habitat provides an open understory that enables chicks to move easily through the habitat and canopy cover to protect them from avian and other predators (U.S.D.A. 1999, Doxon and Carroll 2007). Areas often used as brood habitat by ring-necked pheasants (*Phasianus colchicus* Linnaeus; hereafter pheasant) include alfalfa fields, grass fields and other areas with forbs, because these habitats provide high quantities of arthropods for chicks (Hanson and Progulske 1973, Trautman 1982, Matthews 2009), which are the key component of galliform chick diets during the first few weeks of life due to the high amounts of protein they provide (Hurst 1972, Trautman 1982, Southwood and Cross 2002). Suitable brood habitat with abundant arthropods leads to smaller home range sizes (Warner et al. 1984, Hill 1985, Matthews 2012) and faster fledging (Nester et al. 1942, Woodard et al. 1977), both of which result in lower predation rates and increased chick survival rates.

As many studies have pointed out, many grassland bird populations have declined due to agriculture becoming more intensive and dominant on the landscape and native habitats are becoming more scarce and fragmented (Delisle and Savidge 1997, Riley et al. 1998, Warner et al. 1999). Changes in agricultural practices, such as the advent and adoption of genetically-modified crops, have led to a decrease in cover quality and arthropod density, which can lead to decreased brood survival (Hill 1985, Rands 1985, Warner et al. 1999). Additionally, advances in farming equipment and the economics of farming have led to changes in the way crops are planted, as well as what types of crops are planted. No-till farming and high commodity prices have reduced the use of small grains in favor of planting row crops such as corn and soybeans (Rodgers 2002), which effectively eliminates one source of cover that pheasants use.

Land retirement programs such as the Conservation Reserve Program (CRP) helped convert cropland to permanent cover, thus increasing the amount of available suitable habitat. In South Dakota, increases in nesting and brood rearing habitat provided by CRP plantings has led to an increase in the pheasant population. The years with the highest pheasant populations correspond to the years with the most suitable habitat available (Trautman 1982, South Dakota Department of Game, Fish and Parks 2016). This trend has been observed in other states as well. Research in Iowa found a positive association between CRP land enrollment and pheasant numbers (Riley 1995). Haroldson et al. (2006) found that for each 10% increase of grass cover in the landscape (up to 32%), pheasants increased by an average of 12.4 birds per survey route in the spring and 32.9 birds per route in the summer in Minnesota. In Nebraska, King and Savidge (1995) found pheasants were more abundant in areas with a higher percentage of CRP. Over the

course of natural succession, however, CRP loses its value as brood rearing habitat due to changes in vegetation structure and composition leading to a thick understory that impedes chick movement, and reduced arthropod diversity and abundance, both of which result in reduced chick survival (Matthews 2009, Eggebo et al. 2003, Tillman and Ronnenberg 2015).

To address this loss in habitat quality, mid-contract management is now required for newly established CRP fields (United States Department of Agriculture 2005). The desired outcome is increased forb abundance and associated arthropod availability, and a vegetation structure with less litter and more bare ground to enable easier chick movement. Grazing, fire, and disking have all been used to promote forb abundance, reduce litter, and increase grass cover on CRP lands (Best et al. 1998, Boyd et al. 2011), however, research on the effectiveness of grassland management techniques to improve brood rearing habitat specific to the northern Great Plains is lacking. Doxon and Carroll (2007, 2010) investigated pheasant chick foraging rates and insect abundance in several different CRP practices in Kansas, but only interseeding of alfalfa into warm season stands was studied. In Nebraska, Matthews (2009) researched pheasant nest density and success and brood habitat selection between CRP fields that were disked and interseeded and those that were not. Leathers (2003) investigated invertebrate abundance between those same treatment types. While disking and interseeding have been studied extensively and are proven methods to improve grasslands, many landowners are reluctant to disturb the soil in fear of noxious weed outbreaks. Although Leathers (2003) found no difference in noxious weed abundance between disked and control areas, finding alternative management methods that landowners would be less reluctant to use would be beneficial.

Currently in South Dakota, haying, prescribed fire, light disking, and harrowing are approved mid-contract management techniques. Haying is the most popular method used, but it is unclear whether this method results in improved brood rearing habitat (South Dakota State Technical Committee 2016). The purpose of our study was to investigate currently approved and unapproved methods of CRP mid-contract management methods, as well as research the longevity of the benefits provided by those methods. Study objectives were to (1) determine and compare relative arthropod abundance among CRP grasslands subject to several management techniques for three consecutive years post management, (2) determine and compare relative arthropod availability using human-imprinted pheasant chicks, and (3) determine and compare vegetation composition and structure.

METHODS AND MATERIALS

Study Area

Our study was conducted on Game Production Areas (GPAs) in north-central and -eastern South Dakota. Three 4.05 ha (10 acre) cool season (Casanova GPA, Cottonwood GPA, Gerken GPA) and three 4.50 ha (10 acre) warm season (Fordham GPA, Dry Lake #2 North GPA, and Long Lake GPA) GPAs were used as test sites (Figure 1, Table 1). These sites were chosen for having similar vegetation composition and management histories as most CRP acres in South Dakota. Each experimental study site was 4.05 hectares (ha; 10 acres) in size. Three sites were classified as cool season stands (Casanova, Cottonwood, and Gerken), and three sites were classified as warm season stands (Fordham, Dry Lake #2 North, Long Lake).

Management Techniques

Four of the six sites were divided into four treatment plots (Casanova, Cottonwood, Fordham, and Dry Lake #2 North), and two sites (Gerken and Long Lake), were divided into six treatment plots to include grazing treatments. Using a complete randomized design, each management treatment was randomly assigned to one of the 0.81 ha (2 acre) plots in the test site. An unmanaged control plot was located close to treatments. Management treatments are listed in Table 2.

Cool season sites were hayed in fall 2012 prior to the start of the study and were cut to a height of 15-25.5 cm (6-10 inches). Warm season sites were burned in early spring 2013 before fieldwork began by trained SDGFP staff (Table 3).

Cool season plots were interseeded with an alfalfa and clover mixture (Table 4). Warm season plots were interseeded with a mixture of native forbs (Table 5). Seeding was completed in spring 2013 by SDGFP staff using a Great Plains no-till drill.

Herbicides were chosen to suppress existing vegetation to allow interseeded plants a chance to establish and grow and because they are the type most commonly used by landowners. Cool season plots were treated with a combination of 2.24 kg ai ha⁻¹ glyphosate (32 oz ai acre⁻¹) and were applied in spring 2013 by SDGFP staff using a 4.87 m (16 ft) boom mounted on an ATV delivering 120 L ha⁻¹ (12.9 gal acre⁻¹) spray volume via AirMix AM11002 nozzles at 30 PSI. Warm season plots were treated with 2.27 kg ai ha⁻¹ of glyphosate in spring 2013 by SDGFP staff using a 94.63 L (25 gal) ATV tank sprayer equipped with a 6.7 m (22 ft) boom delivering 121 L ha⁻¹ (13 gal acre⁻¹) spray volume via XR Teejet 8003V8 nozzles at 30 PSI.

Grazing plots were fenced to prevent cattle from entering other plots during the grazing period and were completely closed off after grazing to prevent cattle from re-entering. Fencing was completed by SDGFP staff. Overseeding was done prior to cattle grazing the plots. Plots were grazed in spring 2013 and were part of larger grazing pastures. Cool season grazing plots had a stocking density of 0.72 animal units (AU) acre⁻¹ and were grazed for 15 days. Warm season grazing plots had a stocking density of 0.9 AU acre⁻¹ and were grazed for 31 days.

Arthropod Sampling

We used two methods of arthropod collection in this study: sweep nets and pitfall traps. Sampling was conducted twice each year, once each in mid-June and mid-July for three consecutive years.

We used a standard 15-inch sweep net to collect samples immediately after chick foraging trials to sample arthropods present for chicks to consume at that time and location. To collect the samples, we established four 10 meter line transects that were oriented outward from the center of each plot in each of the four cardinal directions. Arthropods collected with sweep nets were transferred to a sealable bag, labeled, and stored in a freezer until sorting.

We created our pitfall traps by driving five 2 cm PVC pipes, approximately 20 cm long, into the ground to maintain the holes. We then placed 18 mm test tubes filled with a 50:50 mix of propylene glycol and 80% ethanol into the pipes (P. Johnson personal communication). We used a Geographic Information System (GIS; ArcMap 10.1, Environmental Systems Resource Institute, Redlands, CA) to generate five random

locations per plot. Traps were left open for 7 days, after which the contents were recovered and stored in sealable plastic bags until sorting.

Arthropods were sorted to taxonomic order, suborder, and family. After identification, we dried the arthropods at 60°C (140°F) for 24 hours (Leathers 2003) after which we weighed them (± 0.001 g) to use in dry mass comparisons.

Human-Imprinted Chicks

We purchased pen-raised one day old pheasant chicks from a commercial pheasant farm in north-central South Dakota. Imprinting of chicks began immediately after receiving them and was carried out over four days following previously published methods (Palmer et al. 2001, Smith and Burger 2005, Osborne et al. 2012, M. McInroy personal communication). We devoted the first four days after hatch to imprinting chicks to handlers and exposing them to outdoor habitats. Chicks were housed in indoor pens and had unlimited access to fresh water, food, and heat lamps. Food was provided in the form of commercial chick food as well as access to live arthropods during the imprinting process.

Foraging Trials

We used ten, five to ten day old human-imprinted chicks in each foraging trial to quantify change in body mass for each of the management treatments. Foraging trials were conducted on each of the treatment types at each of the six study sites. Trials were conducted twice, once each during mid-June and mid-July. Foraging trials were conducted when there was little to no dew remaining on the vegetation, no actively

falling precipitation, day time temperature between 18-32°C (65-90°F), and between the hours of 0830 to 1200 and 1630 to 2030 to avoid the hottest time of day. Chicks were food deprived for approximately 9-12 hours prior to each foraging trial (Whitmore et al. 1986, Burke et al. 2008, Doxon and Carroll 2010). Immediately prior to foraging, each chick received an individual identifier, had its cloaca sealed with surgical tissue adhesive and was weighed using a Denver Instruments MXX-123 scale with draft protectors. They were then taken to the center of the treatment plot where they foraged for 30 minutes, were recaptured, euthanized using a CO₂ chamber and weighed post-foraging. Chicks were stored on ice until returning from the field and were then frozen for later examination of crop and gizzard contents (Palmer et al. 2001, Doxon and Carroll 2010).

Vegetation Sampling

Vegetation measurements were collected twice, once each during mid-June and mid-July after foraging trials had concluded for that sampling period. Percent canopy cover of grass, forbs, bare ground, and litter was assessed using a 20 x 50 cm Daubenmire frame (Daubenmire 1959) placed at five random locations within each treatment type. Ground covered by dead vegetation without overhead cover of live plants was classified as litter. Ground without dead vegetation or overhead cover of live plants was classified as bare ground. We recorded visual obstruction readings to the nearest 0.5 decimeter using a Robel pole at five random locations generated by GIS within each treatment type in each of the four cardinal directions at a height of 1 meter and a distance of 4 meters (Robel et al. 1970). Litter depth was measured with a meter stick to the nearest millimeter at each of the Daubenmire frame locations.

Data Analysis

Comparison of dry mass of arthropods on the different treatment types, mass change of chicks in different treatments, visual obstruction, and percent canopy cover were analyzed with Kruskal-Wallis. We used a post hoc all-pairwise comparisons test to determine statistical significance between groups. For an overall comparison of treatments, data from all 3 years was combined for each treatment type to compare treatment effects. To assess the year-to-year trends, each treatment type was analyzed individually. Results of the Kruskal-Wallis tests were considered significantly different at a value of $\alpha \leq 0.05$, and were conducted using Statistix 9 (Analytical Software, Tallahassee, FL).

Diversity metrics were compared using taxon richness, Shannon Index and Simpson's Diversity Index, which were calculated using the Microsoft Excel (2013) diversity add-in. Taxon richness was used to indicate how many taxonomic groups were present. Since richness does not include the abundance of individuals, both the Shannon Index and Simpson's Diversity Index were included since they account for both richness and evenness. Rank abundance curves were used to visually represent both richness and evenness.

RESULTS

Comparison of Treatments

Within cool season sites, significant differences were found among treatments for chick mass change ($P < 0.001$), visual obstruction ($P = 0.005$), percent grass cover ($P <$

0.001), percent forb cover ($P < 0.001$), percent bare ground ($P < 0.001$) percent litter cover ($P < 0.001$), litter depth ($P < 0.001$), and sweep net arthropod dry mass ($P < 0.001$). The only variable with no significant differences among treatment types was pitfall trap arthropod dry mass ($P = 0.30$). Taxon richness ranged from 51 to 87 (Table 6; Figure 2), and was greatest in the haying + herbicide treatment (87 taxa) followed by haying + herbicide + interseeding (77 taxa). Shannon Index values ranged from 2.31 to 3.31, with haying + herbicide having the highest value of 3.31, followed by the haying + herbicide + interseeding with a 3.24 value. Simpson's Diversity Index values ranged from 0.76 to 0.94 (Table 6), with haying + herbicide + interseeding and haying + herbicide having the highest values of 0.94.

Within warm season sites, significant differences among treatments were found for chick mass change ($P < 0.001$), percent grass cover ($P < 0.001$), percent forb cover ($P < 0.001$), percent bare ground ($P < 0.001$), percent litter cover ($P < 0.001$), and litter depth ($P < 0.001$). No significant differences were found for visual obstruction readings ($P = 0.89$), pitfall trap arthropod dry mass ($P = 0.11$), or sweep net arthropod dry mass ($P = 0.28$). Taxon richness ranged from 45 to 80 (Table 7; Figure 3), and was greatest in the fire + interseeding and fire + herbicide treatments (80 taxa each). Shannon Index values ranged from 2.37 to 2.99, and Simpson's Diversity Index values ranged from 0.85 to 0.91 (Table 7). The control plot had the highest Shannon Index of 2.99 and Simpson's Diversity Index values of 0.91, followed by fire + interseeding values of 2.89 and 0.89 and then fire + herbicide of 2.87 and 0.88, respectively.

Trends Over Years

Chicks gained mass in all three years on all treatments with three exceptions: cool season grazing + overseeding and the warm season control plot, both of which resulted in mass loss in 2015 and fire + herbicide + interseeding, which resulted in mass loss in 2014 followed by mass gain in 2015. Not including those treatments just mentioned, three trends were observed in mass change. The cool season control ($P = 0.03$), the cool season grazing + overseeding ($P < 0.001$), and the warm season control ($P = 0.01$) treatments consistently had less chick mass gain over the study, but never resulted in chick mass loss. Haying + interseeding ($P < 0.001$) and haying + herbicide ($P = 0.05$) had a decrease in chick mass values in 2014, followed by an increase in 2015. The haying only ($P = 0.01$) and warm season grazing + overseeding ($P = 0.001$) treatments resulted in an increase in chick mass values in 2014, followed by lesser gains in 2015. No significant differences in chick mass values were detected on the haying + herbicide + interseeding ($P = 0.07$), cool season grazing only ($P = 0.47$), fire + herbicide ($P = 0.90$), fire only ($P = 0.18$), fire + interseeding ($P = 0.25$), and warm season grazing only ($P = 0.36$) treatments.

Most of the treatments resulted in no significant differences in visual obstruction values over the course of our study (haying + interseeding ($P = 0.13$), cool season grazing only ($P = 0.92$), fire + interseeding ($P = 0.37$), fire + herbicide + interseeding ($P = 0.06$), warm season grazing only ($P = 1.00$), warm season control ($P = 0.36$), fire only ($P = 0.39$), and warm season grazing + overseeding ($P = 1.00$)). On the plots that did have significant differences, two trends were observed. The cool season control ($P < 0.001$) and haying only ($P < 0.001$) treatments resulted in a decrease in visual obstruction values over time, and the haying + herbicide ($P = 0.006$), haying + herbicide + interseeding ($P <$

0.001), cool season grazing + overseeding ($P = 0.02$), and fire + herbicide ($P = 0.04$) treatments resulted in an increase in visual obstruction values throughout the study.

Analysis of percent grass cover revealed three trends. The cool season grazing + overseeding ($P < 0.001$), fire only ($P < 0.001$), fire + herbicide ($P < 0.001$), fire + herbicide + interseeding ($P < 0.001$) treatments resulted in an increase in percent grass cover over time. The cool season control ($P < 0.001$), haying only ($P < 0.001$), haying + interseeding ($P < 0.001$), cool season grazing only ($P < 0.001$), fire + interseeding ($P < 0.001$), warm season grazing only ($P < 0.001$), and warm season grazing + overseeding ($P < 0.001$) treatments resulted in an increase in percent grass cover in 2014, followed by a decrease in 2015. Haying + herbicide + interseeding ($P < 0.001$) was the only treatment where percent grass cover decreased in 2014 and then increased in 2015. No significant differences were detected on the haying + herbicide ($P = 0.58$), or warm season control ($P = 0.47$) treatments. None of the treatments resulted in a consistent decrease in grass cover throughout the three years.

Percent forb cover decreased over time on the cool season control ($P < 0.001$), haying only ($P < 0.001$), haying + interseeding ($P = 0.003$), cool season grazing only ($P < 0.001$), and cool season grazing + overseeding ($P = 0.006$) treatments. On the haying + herbicide + interseeding ($P < 0.001$), fire + herbicide ($P < 0.001$), and fire + herbicide + interseeding ($P < 0.001$) treatments, percent forb cover increased in 2014 and then decreased in 2015. On the warm season control ($P < 0.001$), fire + interseeding ($P = 0.01$), and warm season grazing only ($P < 0.001$) treatments, percent forb cover decreased in 2014 and then increased in 2015. Haying + herbicide ($P < 0.001$) was the only treatment where percent forb cover increased throughout the study. No significant

differences were detected on the fire only ($P = 0.39$) and warm season grazing + overseeding ($P = 0.08$) treatments.

Percent bare ground decreased throughout the three years of our study, with many treatments being near zero percent cover in 2015. Many plots showed a consistent decline throughout the years (haying only ($P < 0.001$), haying + interseeding ($P < 0.001$), warm season control ($P < 0.001$), fire only ($P < 0.001$), fire + interseeding ($P < 0.001$), fire + herbicide ($P = 0.0000$), fire + herbicide + interseeding ($P < 0.001$)), while some increased in 2014 and then decreased in 2015 (cool season control ($P < 0.001$), haying + herbicide ($P < 0.001$), haying + herbicide + interseeding ($P < 0.001$), cool season grazing only ($P = 0.01$), cool season grazing + overseeding ($P < 0.001$)). No significant differences in percent bare ground was detected on the warm season grazing only ($P = 0.08$) and warm season grazing + overseeding ($P = 0.14$) treatments.

Percent litter cover decreased throughout our study (haying + herbicide ($P < 0.001$), haying + herbicide + interseeding ($P < 0.001$), cool season grazing only ($P < 0.001$), cool season grazing + overseeding ($P = 0.002$), warm season grazing only ($P < 0.001$), warm season grazing + overseeding ($P < 0.001$)), with the exception of fire + interseeding ($P < 0.001$) which increased over time and the cool season control ($P < 0.001$), haying only ($P < 0.001$), and haying + interseeding ($P < 0.001$) treatments which declined in 2014 and then increased in 2015. No significant differences in percent litter cover was observed on the warm season control ($P = 0.33$), fire only ($P = 0.07$), fire + herbicide ($P = 0.11$), and fire + herbicide + interseeding ($P = 0.10$) treatments.

Overall, litter depth increased throughout our study (haying only ($P < 0.001$), haying + interseeding ($P < 0.001$), cool season grazing only ($P < 0.001$), cool season grazing + overseeding ($P < 0.001$), fire only ($P < 0.001$), fire + interseeding ($P < 0.001$), fire + herbicide ($P < 0.001$), fire + herbicide + interseeding ($P < 0.001$), warm season grazing ($P < 0.001$), warm season grazing + overseeding ($P < 0.001$). The exceptions were haying + herbicide + interseeding ($P < 0.001$), where litter depth decreased over time and the cool season control ($P = 0.08$) and warm season control ($P = 0.06$), which had no statistically significant change.

Pitfall trap arthropod biomass was not statistically different throughout time on the majority of our treatments (cool season control ($P = 0.11$), haying only ($P = 0.06$), haying + herbicide ($P = 0.38$), haying + interseeding ($P = 0.08$), haying + herbicide + interseeding ($P = 0.24$), warm season control ($P = 0.12$), fire + herbicide ($P = 0.24$), fire + herbicide + interseeding ($P = 0.08$), warm season grazing only ($P = 0.44$), warm season grazing + overseeding ($P = 0.94$)). Biomass of arthropods collected with pitfall traps increased over time on the fire + interseeding ($P = 0.01$) treatment, and the cool season grazing only ($P = 0.04$), cool season grazing + overseeding ($P = 0.04$), and fire only ($P < 0.001$) treatments decreased in 2014, followed by an increase in biomass in 2015.

We detected three trends in arthropod biomass collected via sweep nets. Biomass decreased over time on the haying only ($P < 0.001$), cool season grazing only ($P = 0.005$), fire only ($P < 0.001$), fire + interseeding ($P = 0.02$), fire + herbicide + interseeding ($P < 0.001$), and warm season grazing only ($P = 0.02$) treatments. On the cool season control ($P = 0.001$), haying + herbicide + interseeding ($P = 0.02$), and cool season grazing + overseeding ($P < 0.001$) treatments, arthropod biomass collected via

sweep nets increased in 2014, then decreased in 2015. Haying + interseeding ($P = 0.01$) was the only treatment to result in a decrease in biomass in 2014, and then increase in 2015. No significant differences were detected in sweep net arthropod biomass on the haying + herbicide ($P = 0.37$), warm season control ($P = 0.80$), fire + herbicide ($P = 0.91$), and warm season grazing + overseeding ($P = 0.21$) treatments.

Taxon richness increased throughout the study and was highest on all treatments in 2015. The Shannon Index values were highest in 2015 on all treatments except cool season grazing only and warm season grazing + overseeding, which had the highest value in 2013. Simpson's Diversity Index values were highest in 2015 for the majority of our treatments. The exceptions are the cool season grazing only and warm season grazing + overseeding treatments which were highest in 2013, and the cool season control and cool season grazing + overseeding treatments which had the highest Simpson's Diversity Index values in 2014 (Table 8).

DISCUSSION

Comparison of Treatments

Based on the previously mentioned criteria for suitable brood habitat, CRP mid-contract management methods that promote vegetative diversity, such as a reduction in grass cover to allow forb establishment and the resulting increase in arthropod diversity, promote bare ground, and lead to an increase in chick mass are ideal.

Chick mass changes on cool and warm season sites were similar, with the exception of the warm season control which had a decrease in chick mass, indicating that

managed cool and warm season sites both meet the food needs of chicks. The greatest increase in chick mass was seen on the haying + interseeding and haying + herbicide + interseeding treatments on cool season sites and fire + interseeding, fire + herbicide + interseeding, and grazing only on warm season sites.

There was little to no difference in visual obstruction readings among treatment types on both cool and warm season sites, and all treatments had 40 cm or greater vegetation height. This indicates that even though these treatments were designed with brood survival as the focus, they still provided suitable habitat for nesting hens as they require at least 25.5 cm (10 inches) vegetation height for nest concealment (Runia 2013). This is beneficial for chicks because survival rates increase when travel distances to find food decrease (Warner et al. 1984, Hill 1985, Matthews 2012). Treatments that directly impacted grass cover, such as burning and herbicide application led to an increase in forb presence. Also, methods that removed cover and litter led to higher amounts of bare ground and decreased litter depth. Doxon and Carroll (2010) found that more bare ground led to easier movement for chicks and several other studies have reported the importance of bare ground for chick movement (Greenfield et al. 2002, Greenfield et al. 2003, Harper et al. 2015).

In terms of diversity, arthropod communities dominated by a few groups are considered to be less diverse than communities having many different groups with similar abundances. Therefore, as richness and evenness increase, so does diversity. Treatments with a small slope on the rank abundance curves have greater evenness, whereas treatments with a steep slope have lower evenness and are dominated by a few groups. On cool season stands, total arthropod taxon richness was greatest in the haying +

herbicide treatment followed by the haying + herbicide + interseeding. These treatments also had the highest Shannon Index values and highest Simpson's Diversity Index values. On warm season stands, total taxon richness was greatest in the fire + interseeding and fire + herbicide treatments. The control plot had the highest Shannon Index and Simpson's Diversity Index values, followed by fire + interseeding and then fire + herbicide. It is interesting that even though the control plot had the highest diversity index values, it was the only treatment where chicks lost mass while foraging. This suggests that even though the arthropod community was diverse, chicks faced issues that impeded their ability to find and consume food. Ants (Hymenoptera: Formicidae) and spiders (Araneae), which chicks will readily consume (Hurst 1972, Healy 1985, Whitmore et al. 1986, Doxon and Carroll 2010), represented 35% of the arthropods collected on the control plot. This indicates that chicks likely face other problems in unmanaged sites, such as difficulty in locating suitable arthropods or difficulty in moving through the vegetation to capture arthropods due to a thick understory.

Trends Over Years

While the average chick mass change was primarily a gain in mass, the amount of gain decreased throughout the years on cool season treatment plots and grazed plots. Warm season treatment plots showed an upward trend toward the end of the study, indicating that while burning might temporarily decrease the value of the habitat shortly after treatment due to vegetation removal and arthropod abundance changes, it quickly recovers and provides needed food resources for chicks. The largest chick mass gains on both cool and warm season treatment plots occurred in the final year on treatments that included interseeding, herbicide application, and interseeding + herbicide application.

This supports the influence the presence of forbs has on providing abundant food sources for chicks (Eggebo et al. 2003, Taylor et al. 2006). The control plots had a decrease in chick mass gain over time, with the warm season control plot resulting in a net mass loss in 2015, further supporting the idea that the quality of unmanaged sites decreases over time. Our high intensity, short duration grazing treatments on both cool and warm season sites primarily resulted in decreased chick mass gain over time or was not significantly different across years. On our study plots, grazing had minimal to negative effects on chick mass. Harper et al. (2015) found that vegetation structure differs with spring-only grazing versus season-long grazing, with spring-only grazing quickly reverting to characteristics unsuitable for nesting and brood rearing, and season-long grazing maintaining an open structure at ground level as well as canopy cover. Most treatments showed a decrease in chick mass gain during 2014. It is likely that weather conditions played a role in this, as the 2014 temperatures were cooler than average and chicks may have spent more energy to regulate body temperature while foraging than they needed to in 2013 and 2015.

Visual obstruction values were not significantly different between years on most treatments. Three out of the four treatments that resulted in an increase in visual obstruction values included herbicide application. The fact that visual obstruction values were not significantly different among treatments indicates that the vegetation quickly regrows to pre-treatment height and can provide suitable nesting and brood habitat shortly after treatment.

Some of the trends observed in our vegetation results are due to the primary treatment method, particularly burning. Since we removed almost all grass, forb, and

litter cover shortly before sampling the first year, percent cover measurements as well as litter depth were bound to increase throughout the study. After the first or second year of growth, the change in percent grass cover slowed indicating that the vegetation had recovered from the burning treatment. A few treatments set percent grass back short-term, such as haying + herbicide + interseeding, and none of the treatments investigated led to a decrease in percent grass cover throughout the entire study period. McCoy et al. (2001) reported that mowing provided only short-term changes in vegetation structure and found no differences between the years preceding and following mowing. Cool season treatments (haying) resulted in a decrease in percent forbs over time, unless combined with herbicide application or herbicide + interseeding. Applying herbicide suppressed the grass enough for forbs to establish and grow (McCoy et al. 2001, Yeiser et al. 2015). We recorded a large increase in sweet clover abundance during 2014, primarily on the haying + herbicide and haying + herbicide + interseeding treatments. While percent litter cover on most cool season plots and the grazed treatments decreased over the length of the study, percent grass increased which filled in the understory.

Not surprisingly, percent bare ground decreased throughout our study. As grass and forbs fill in, the amount of bare ground decreases, which can lead to restricted chick movements and difficulty in finding and/or capturing food (Matthews 2012, Doxon and Carroll 2010). A few treatments resulted in a temporary increase in bare ground during the first or second year, but by the third year percent bare ground was almost zero.

Overall, litter depth increased throughout our study. The exceptions were the cool season plots that combined haying with herbicide application alone or with interseeding, which led to a decrease in litter depth over time.

Overall arthropod biomass collected with pitfall traps was not affected by our treatments, as indicated by the large number of non-significant results. While the results were not significant, cool season sites primarily had a decreasing trend in arthropod biomass in pitfall traps over time, while arthropod biomass in pitfall traps on warm season sites increased over time (except the control and fire only). Arthropod biomass collected with sweep nets had more significant results than pitfall traps, but showed similar trends on cool season treatment plots, where biomass collected decreased over time. The exception was the haying + herbicide + interseeding treatment. Unlike pitfall traps, arthropod biomass collected via sweep nets on warm season treatment plots decreased over time.

Arthropod taxon richness increased throughout the study and was highest on all treatments in 2015. Shannon Index values were highest in 2015 on all treatments except cool season grazing only and warm season grazing + overseeding, which had the highest values in 2013. Simpson's Diversity Index values were highest in 2015 for the majority of our treatments, with the exception of the cool season grazing only and warm season grazing + overseeding treatments which were highest in 2013, and the cool season control and cool season grazing + overseeding treatments which had the highest Simpson's Diversity Index values in 2014. The grazing treatments had a smaller total sample size than the other treatments since they were only present on 2 sites out of the 6, but like the other treatments, richness was highest in 2015. Diversity indices on grazed plots had more mixed results with some higher values in 2013 or 2014 than in 2015. While the number of arthropod taxon present increased over the course of the study, evenness decreased over time. As Joern and Laws (2012) point out, arthropod responses to

disturbances such as fire and grazing are highly variable among years, sites, timing of disturbance, patch size, and intensity. Because of this, some studies report increases in arthropod diversity and others report decreases. Additionally, when looking at taxonomic level, Panzer (2002) found that at the species level, arthropod response to fire was consistent while at the genera level responses were inconsistent. This highlights the importance of taxonomic identification level in these types of studies.

MANAGEMENT IMPLICATIONS

With the rapid loss of grasslands and declining enrollment of CRP acres, it is important that we manage available habitat to the best of our ability to get the maximum benefit for wildlife. Ideal brood habitat provides open understory that enables chicks to move easily through the habitat, and canopy cover to protect them from avian and other predators (United States Department of Agriculture 1999, Doxon and Carroll 2007). We detected little difference in visual obstruction readings, indicating that all treatments tested meet the criteria of providing canopy cover for concealing chicks and also provide value as nesting habitat in addition to brood habitat. Runia (2013) recommended residual vegetation at least 25.5 cm (10 inches) in height for suitable nesting habitat and Geaumont et al. (2017) found that nests with greater visual obstruction were more successful.

Within warm season stands, we found the greatest increase in chick mass gain during the final year of our study, indicating that it takes approximately 2-3 years for the vegetation and arthropods to recover to a level that provides maximum benefits to broods. While burning immediately reduces vegetation cover and height, this may not have

negative impacts on nesting or brood rearing if it is conducted during early spring, allowing time for vegetation to regrow before the nesting season begins. Also, imperfect, patchy burns will result in some residual vegetation available for hens and chicks.

Treatments that remove litter cover, promote bare ground, and open up the vegetative understory provide better habitat for chicks due to easier movement for escaping predators and finding food. We found that areas treated with herbicide or interseeded with forbs met these requirements (see Chapter 2).

Landowners are often hesitant to disturb the soil due to concerns of increasing noxious weeds. This presents a dilemma for landowners, as Taylor et al. (2006) found a positive association between weeds and desirable arthropods. Additionally, Leathers (2003) found no difference in noxious weed abundance between disked and control areas. We noticed an increase in Canada thistle (*Cirsium arvense*) on some sites and treatments. Canada thistle was also present in the control plots and abundance varied by study site, indicating that Canada thistle presence might be due to the history of the site, small scale soil disturbances, or micro-environmental variations rather than our treatment methods.

Our results indicate that treatments incorporating interseeding and/or herbicide applications modify the understory in ways that provide the most benefits to chicks. We saw slightly better results with herbicide application alone over interseeding alone, and the best results occurred with these methods combined (haying + herbicide + interseeding treatments on cool season stands and fire + herbicide + interseeding treatments on warm season stands), and we encourage state and federal policy to incorporate these as allowed CRP mid-contract management practices. Yeiser et al. (2015) also found that a

combination of treatments had the best results, but were still not perfect. Our results also show this, as some desired habitat variables responded opposite to what would be ideal, but overall these treatments provided the best results in our study.

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Author contributions: K.J. and T.R. conceived the idea; M.O. collected and analyzed the data; and M.O wrote the paper with input from K.J.

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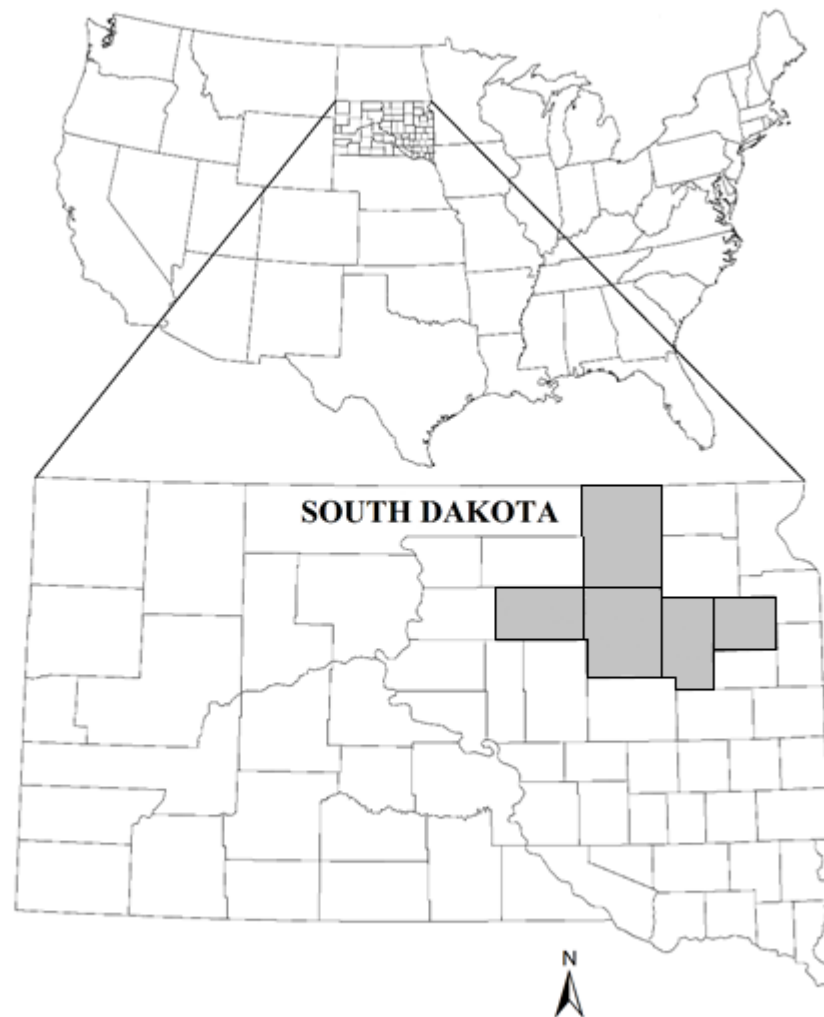


Figure 1. Five county (Clark, Codington, Faulk, Spink, and Brown) study area for evaluating methods used to improve grasslands as pheasant brood habitat in north-central and -eastern South Dakota, USA, 2013-2015.

Table 1. Game Production Area (GPA) locations and management histories on study site locations in north-central and north-eastern South Dakota, USA, 2013-2015.

Study Site Locations				
	GPA	County	Management History	Center of Site Coordinates
Cool Season	Casanova	Brown	Grass planting mid- to late-90s; hayed on 3-5 year rotation	45°24'15" N, 98°38'30" W
	Gerken	Faulk	Grass planting mid- to late-90s; hayed on 3-5 year rotation	45°00'04" N, 98°56'01" W
	Cottonwood	Spink	Grass planting mid- to late-90s; hayed on 3-5 year rotation	44°46'02" N, 98°41'42" W
Warm Season	Fordham	Clark	Grass planting 2008; Burned 2010	44°46'03" N, 97°55'18" W
	Dry Lake #2 North	Clark	Grass planting 2007	44°41'16" N, 97°39'27" W
	Long Lake	Codington	Grass planting 2007	44°56'50" N, 97°24'48" W

Table 2. Seven management treatments applied to study sites in north-central and north-eastern South Dakota, USA.

Management treatments	
Cool Season	Warm Season
Control	Control
Haying only	Prescribed fire only
Haying + interseeding forbs	Prescribed fire + interseeding native forb mix
Haying + herbicide application	Prescribed fire + herbicide application
Haying + herbicide application + interseeding forbs	Prescribed fire + herbicide application + interseeding native forb mix
Grazing	Grazing

Grazing + overseeding

Grazing + overseeding

Table 3. Dates of treatment applications to study sites in north-central and north-eastern South Dakota, USA.

Treatment Applications						
Study Site	Hayed	Prescribed fire	Herbicide application	Interseeded	Cattle On/Off	Overseeding
Cottonwood	After July 15, 2012	-	June 4, 2013	June 11, 2013	-	-
Casanova	Oct. 2012	-	June 3, 2013	June 10, 2013	-	-
Gerken	Oct. 2012	-	June 10, 2013	June 11, 2013	June 1, 2013 – June 15, 2013	June 2, 2013
Fordham	-	June 11, 2013	June 25, 2013	June 18, 2013	-	-
Dry Lake #2 North	-	June 11, 2013	June 25, 2013	June 18, 2013	-	-
Long Lake	-	May 17, 2013	June 2, 2013	June 5, 2013	May 25, 2013 – June 25, 2013	May 24, 2013

Table 4. Alfalfa and clover planting mix and seeding rate on cool season study sites in north-central and north-eastern South Dakota, USA.

Common Name	Scientific Name	Percent of mix	Kg ha ⁻¹
Vernal alfalfa	<i>Medicago sativa</i> L.	33.33%	3.36
Alsike clover	<i>Trifolium hybridum</i> L.	16.67%	1.68
Medium red clover	<i>Trifolium pratense</i> L.	16.67%	1.68
White Dutch clover	<i>Trifolium repens</i> L.	16.67%	1.68
Ladino clover	<i>Trifolium repens</i> L.	16.67%	1.68
		100%	10.08

Table 5. Native forb planting mix and seeding rate on warm season study sites in north-central and north-eastern South Dakota, USA.

Common Name	Scientific Name	Full seeding rate	Percent of mix	Seeds needed	Seeds/Sq Ft	Pounds per acre	Oz.	Lbs.	2013 Cost
Black-eyed susan	<i>Rudbeckia hirta</i> L.	0.75	3.00%	13,068	0.3	17,424.00	0.16	0.01	\$0.17
Blanket flower	<i>Gaillardia aristata</i> Pursh	6.94	7.00%	30,492	0.7	4,393.66	2.18	0.14	\$4.08
Canada milk vetch	<i>Astragalus canadensis</i> L.	4.09	7.00%	30,492	0.7	7,455.26	1.79	0.11	\$3.92
Ox-eye sunflower	<i>Heliopsis helianthoides</i> (L.) Sweet	3.33	7.00%	30,492	0.7	9,156.76	4.84	0.3	\$7.55
Grayhead coneflower	<i>Ratibida pinnata</i> (Vent.) Barnhart	1.74	3.00%	13,068	0.3	7,510.34	0.44	0.03	\$0.82
Illinois bundleflower	<i>Desmanthus illinoensis</i> (Michx.) MacMill. ex B.L. Rob. & Fernald	18.15	12.00%	52,272	1.2	2,880.00	9.86	0.62	\$21.57
Maximilian sunflower	<i>Helianthus maximiliani</i> Schrad.	4.36	7.00%	30,492	0.7	6,993.58	2.21	0.14	\$4.14
Partridge pea	<i>Chamaecrista fasciculata</i> (Michx.) Greene	3.33	7.00%	30,492	0.7	9,156.76	11.29	0.71	\$7.76
Plains coreopsis	<i>Coreopsis tinctoria</i> Nutt.	0.66	5.00%	21,780	0.5	33,000.00	1.98	0.12	\$2.35

Table 5 continued. Native forb planting mix and seeding rate on warm season study sites in north-central and north-eastern South Dakota, USA.

Common Name	Scientific Name	Full seeding rate	Percent of mix	Seeds needed	Seeds/Sq Ft	Pounds per acre	Oz.	Lbs.	2013 Cost
Prairie coneflower	<i>Ratibida columnifera</i> (Nutt.) Wooton & Standl.	1.48	5.00%	21,780	0.5	14,716.22	0.47	0.03	\$1.18
Purple prairie clover	<i>Dalea purpurea</i> Vent.	9.08	12.00%	52,272	1.2	5,756.83	2.76	0.17	\$6.03
Western yarrow	<i>Achillea millefolium</i> L. var. <i>occidentalis</i> DC.	0.39	5.00%	21,780	0.5	55,846.15	0.12	0.01	\$0.42
Purple coneflower	<i>Echinacea purpurea</i> (L.) Moench	9.08	12.00%	52,272	1.2	5,756.83	0.5	0.03	\$0.53
White prairie clover	<i>Dalea candida</i> Michx. ex Willd.	0.39	8.00%	34,848	0.8	89,353.85	2.01	0.13	\$6.27
			100.00%	435,600	10	269,400.23	40.6	2.54	\$66.80

Table 6. Mean (\pm SE) of chick mass change (g), visual obstruction reading (dm), percent grass, percent forb, percent bare ground, percent litter cover (%), litter depth (mm), arthropod dry mass (g), taxon richness, Shannon Index, and Simpson's Diversity Index by treatment on cool season stands 2013-2015.

	Chick Mass Change Per Minute (g)	Visual Obstruction Reading (dm)	Percent Grass	Percent Forb	Percent Bare Ground	Percent Litter Cover	Litter Depth (mm)	Arthropod Dry Mass (g) - Pitfall Traps	Arthropod Dry Mass (g) - Sweep Nets	Taxon Richness	Shannon Index	Simpson's Diversity Index
Control	0.004 (0.001)	6.19 (0.35)	53.89 (7.52)	7.08 (1.35)	2.96 (2.51)	32.64 (6.88)	43.84 (3.21)	0.04 (0.01)	0.011 (0.002)	73	3.03	0.92
Haying Only	0.005 (0.001)	6.72 (0.47)	56.57 (12.34)	8.63 (1.15)	4.29 (2.29)	28.82 (10.19)	28.99 (10.43)	0.04 (0.01)	0.005 (0.0007)	68	3.07	0.92
Haying + Interseeding	0.008 (0.002)	6.48 (0.43)	50.73 (6.15)	6.83 (0.94)	6.26 (3.14)	33.84 (3.69)	25.23 (11.27)	0.04 (0.01)	0.009 (0.002)	69	3.01	0.92
Haying + Herbicide	0.005 (0.001)	5.11 (0.48)	28.05 (1.57)	23.55 (7.85)	4.43 (1.77)	39.90 (11.12)	12.90 (2.63)	0.04 (0.01)	0.009 (0.001)	87	3.31	0.94
Haying + Herbicide + Interseeding	0.006 (0.001)	4.79 (0.43)	27.21 (2.88)	30.72 (12.71)	4.44 (2.97)	35.63 (12.23)	11.02 (1.54)	0.03 (0.01)	0.017 (0.004)	77	3.24	0.94
Grazing Only	0.004 (0.001)	5.17 (0.29)	40.16 (14.34)	10.77 (4.48)	1.23 (0.91)	42.53 (11.52)	28.34 (5.66)	0.05 (0.02)	0.010 (0.002)	51	2.31	0.76
Grazing + Overseeding	0.003 (0.001)	4.43 (0.41)	48.96 (7.08)	7.78 (3.67)	1.96 (1.16)	36.33 (5.65)	23.57 (6.14)	0.03 (0.01)	0.008 (0.001)	52	3.05	0.92

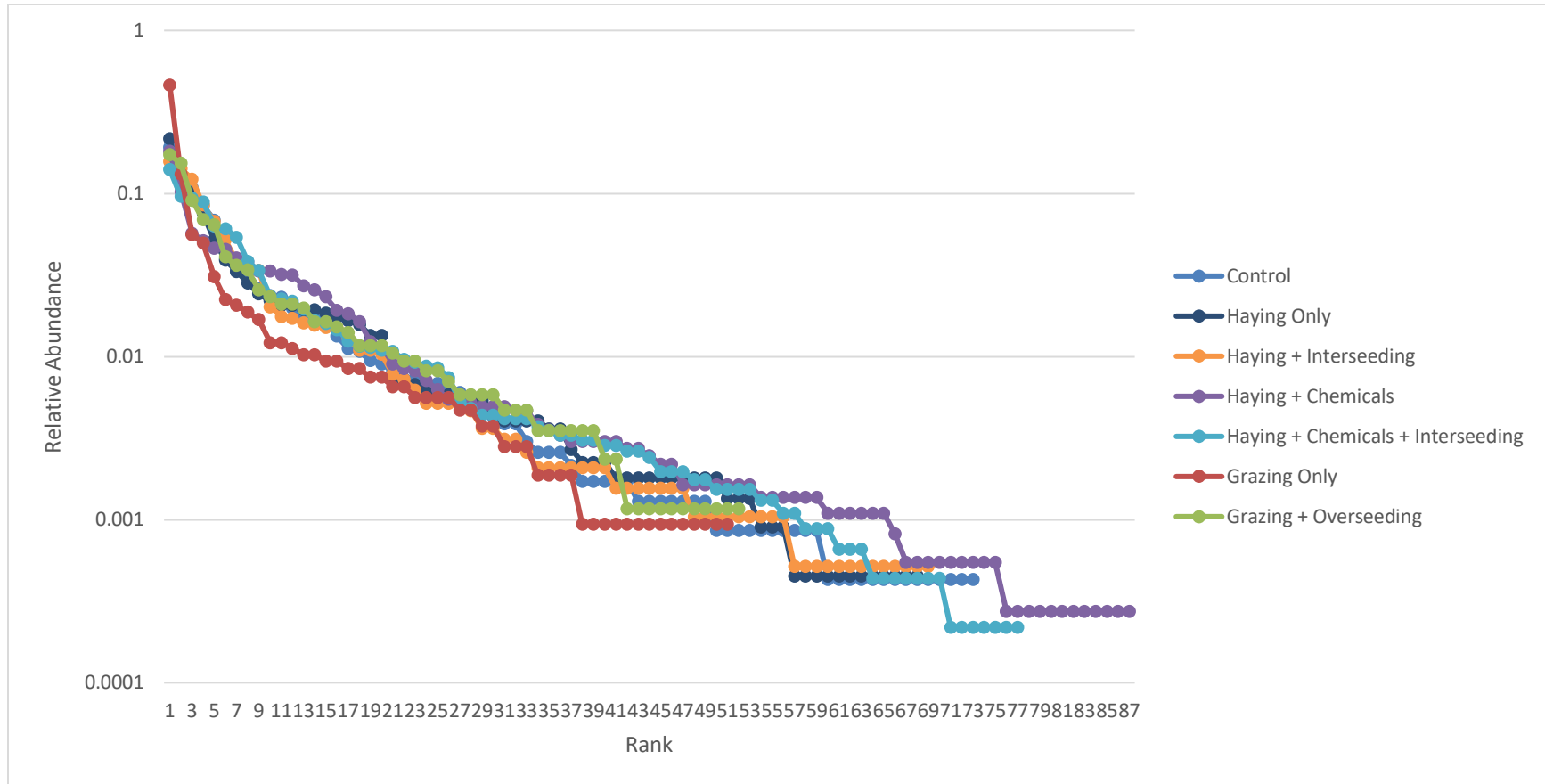


Figure 2. Rank abundance curves for cool season treatments in north-central and north-eastern South Dakota, USA, 2013-2015.

Treatments with a small slope on the rank abundance curves have greater evenness, whereas treatments with a steep slope have lower evenness and are dominated by a few groups.

Table 7. Mean (\pm SE) of chick mass change (g), visual obstruction reading (dm), percent grass, percent forb, percent bare ground, percent litter cover (%), litter depth (mm), arthropod dry mass (g), taxon richness, Shannon Index, and Simpson's Diversity Index by treatment on warm season stands 2013-2015.

	Chick Mass Change Per Minute (g)	Visual Obstruction Reading (dm)	Percent Grass	Percent Forb	Percent Bare Ground	Percent Litter Cover	Litter Depth (mm)	Arthropod Dry Mass (g) - Pitfall Traps	Arthropod Dry Mass (g) - Sweep Nets	Taxon Richness	Shannon Index	Simpson's Diversity Index
Control	-0.0006 (0.005)	4.67 (0.23)	56.66 (1.61)	5.39 (1.27)	1.64 (0.37)	32.71 (1.02)	30.11 (3.066)	0.11 (0.04)	0.008 (0.0009)	74	2.99	0.91
Fire Only	0.004 (0.001)	4.36 (0.38)	53.00 (5.46)	5.76 (1.94)	8.22 (7.57)	30.22 (1.86)	23.64 (9.78)	0.12 (0.07)	0.009 (0.002)	66	2.65	0.86
Fire + Interseeding	0.007 (0.002)	4.80 (0.54)	53.39 (11.51)	6.06 (1.42)	12.70 (11.69)	25.26 (3.77)	25.42 (11.87)	0.14 (0.06)	0.005 (0.003)	80	2.89	0.89
Fire + Herbicide	0.005 (0.001)	4.32 (0.62)	40.53 (12.19)	8.38 (2.77)	17.85 (11.97)	30.89 (2.58)	15.58 (4.01)	0.14 (0.07)	0.007 (0.001)	80	2.87	0.88
Fire + Herbicide + Interseeding	0.006 (0.001)	5.11 (0.75)	40.61 (9.65)	12.82 (4.38)	17.40 (14.85)	27.62 (1.29)	14.84 (5.27)	0.13 (0.08)	0.006 (0.0009)	75	2.79	0.86
Grazing Only	0.008 (0.002)	5.30 (0.87)	52.17 (7.77)	2.71 (2.04)	0.42 (0.21)	43.54 (7.16)	33.75 (8.32)	0.15 (0.10)	0.009 (0.002)	49	2.54	0.86
Grazing + Overseeding	0.005 (0.002)	5.08 (0.44)	56.89 (10.43)	3.00 (0.98)	0.74 (0.39)	41.11 (0.08)	30.71 (8.64)	0.10 (0.06)	0.009 (0.003)	45	2.37	0.85

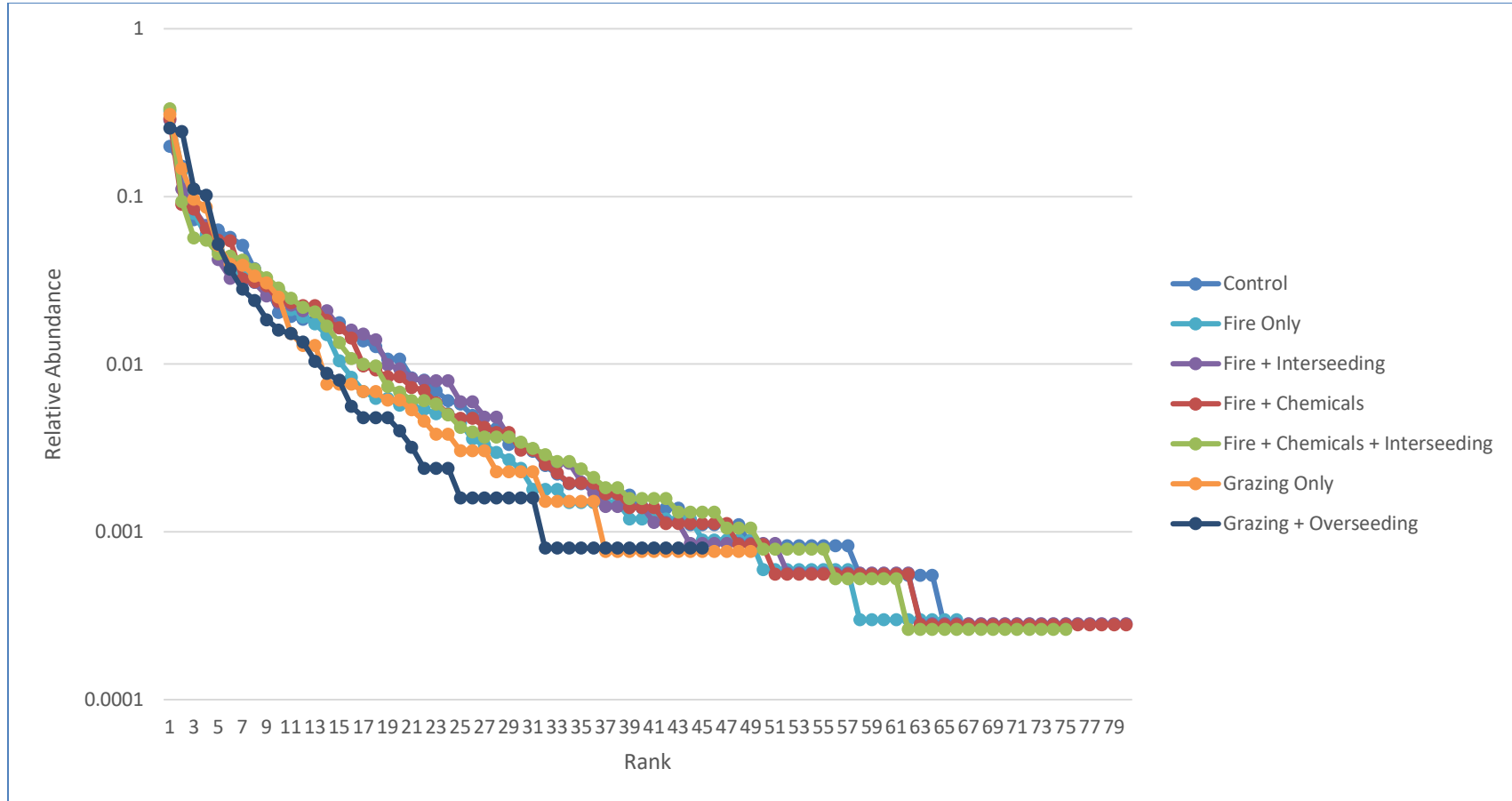


Figure 3. Rank abundance curves for warm season treatments in north-central and north-eastern South Dakota, USA, 2013-2015.

Treatments with a small slope on the rank abundance curves have greater evenness, whereas treatments with a steep slope have lower evenness and are dominated by a few groups.

Table 8. Diversity metrics by year for cool and warm season treatments in north-central and north-eastern South Dakota, USA, 2013-2015.

Treatment	Total Taxon Richness			Shannon Index			Simpson's Diversity Index		
	2013	2014	2015	2013	2014	2015	2013	2014	2015
Cool Season Control	37	41	56	2.63	2.91	2.92	0.88	0.92	0.91
Haying Only	30	42	58	1.97	2.56	3.04	0.68	0.85	0.92
Haying + Interseeding	37	39	48	2.28	2.89	2.99	0.83	0.92	0.93
Haying + Herbicide	33	57	68	2.40	2.96	3.37	0.86	0.89	0.95
Haying + Herbicide + Interseeding	36	48	66	2.54	2.88	3.17	0.88	0.91	0.93
Cool Season Grazing Only	24	26	33	2.36	2.14	1.91	0.85	0.76	0.66
Cool Season Grazing + Overseeding	23	29	37	2.32	2.76	2.86	0.86	0.91	0.91
Warm Season Control	41	43	59	2.76	2.40	3.02	0.91	0.85	0.92
Fire Only	24	41	56	1.71	2.13	2.69	0.64	0.79	0.87
Fire + Interseeding	42	39	61	2.30	2.73	2.94	0.82	0.89	0.90
Fire + Herbicide	31	37	69	2.45	2.18	2.93	0.84	0.79	0.91
Fire + Herbicide + Interseeding	32	37	64	2.01	2.36	2.89	0.74	0.78	0.91
Warm Season Grazing Only	18	21	39	1.69	2.21	2.51	0.65	0.83	0.88
Warm Season Grazing + Overseeding	17	19	34	2.30	1.44	2.12	0.88	0.58	0.77

CHAPTER 4: EVALUATION OF METHODS USED TO IMPROVE GRASSLANDS
AS RING-NECKED PHEASANT BROOD HABITAT: CONCLUSIONS AND
IMPLICATIONS

CONCLUSIONS

The overarching goal of our research was to investigate the efficacy of various methods of CRP mid-contract management, including haying, burning, herbicide application, interseeding, and grazing, to improve brood rearing habitat for ring-necked pheasants as well as evaluate the longevity of the benefits provided by those methods. We found that management treatments on cool season sites resulted in overall chick mass gains throughout the study, but the amount of gain was smaller each year. On warm season sites, chick mass gain was initially impacted by our treatments, primarily due to fire removing the vegetation, but resulted in the greatest increases in chick mass gain in the final year of study. CRP stands composed of warm season grasses led to easier chick movement than stands of cool season grasses.

We did not see significant differences in visual obstruction among treatments or between years on most treatments. Even though these treatments were tested with brood survival as the focus, results indicate they still provide suitable habitat for nesting hens shortly after treatment implementation. This is beneficial for chicks because good brood habitat with abundant arthropods leads to smaller home range sizes (Warner et al. 1984, Hill 1985, Matthews 2012) and faster fledging (Nester et al. 1942, Woodard et al. 1977), both of which result in lower predation rates and increased survival.

Treatments incorporating interseeding and/or herbicide application modified the understory in ways that provided the most benefits to chicks. Thinning of vegetation at ground level and removal of litter led to faster chick movements, as well as desired changes in vegetation for improved chick foraging. These changes include increases in bare ground and forb cover, and short-term decreases in litter cover and litter depth. We saw slightly better results with herbicide application alone over interseeding alone, and the best results occurred with these methods combined (haying + herbicide + interseeding treatments on cool season stands and fire + herbicide + interseeding treatments on warm season stands).

IMPLICATIONS FOR POLICY AND MANAGEMENT

It is increasingly becoming more and more important to manage our remaining habitat in a way that provides the most benefits. Currently, approved CRP mid-contract management methods in South Dakota include light disking, harrowing, prescribed fire, haying, and the honey bee initiative (South Dakota State Technical Committee 2016). Interseeding of forbs and/or legumes, chemical vegetation control or grazing are not accepted as CRP mid-contract management options, however we saw the best outcomes using two of these methods. Based on this, we strongly urge USDA to adopt these as accepted practices. Additionally, haying is the most popular method used for mid-contract management, but research has shown that it provides only few short-term benefits (McCoy et al. 2001, Gruchy and Harper 2014) and agencies could try to persuade more landowners to use other methods.

Landowners are often hesitant to disturb the soil due to concerns of increasing noxious weeds. This presents a dilemma for landowners, as Taylor et al. (2006) found a positive association between the presence of weeds and desirable arthropods. Contrary to these concerns, Leathers (2003) found no difference in noxious weed abundance between disked and control areas. On our sites we noticed an increase in Canada thistle (*Cirsium arvense*) on some sites and treatments. Canada thistle was also present in the control sites and abundance varied by study site, indicating that Canada thistle presence might be due to the history of the site rather than our treatment methods.

Our results revealed that treatments incorporating interseeding and/or herbicide application modify the understory in ways that provide the most benefits to chicks. Slightly better results occurred following herbicide application alone over interseeding alone, and the best results occurred with these methods combined (haying + herbicide + interseeding treatments on cool season stands and fire + herbicide + interseeding treatments on warm season stands). Currently, Minnesota, Iowa, North Dakota, and Nebraska support interseeding of forbs and/or legumes as a management option. Additionally, Nebraska, North Dakota, and Iowa support herbicide application. Nebraska is currently the only neighboring state to contract grazing as a mid-contract management option (Nebraska Pheasants Forever 2015, North Dakota State Technical Council 2016, USDA 2017a, USDA 2017b). Based on our results, we encourage state and federal agencies to amend policies to incorporate all of our treatments as CRP mid-contract management practices.

Until the importance of grasslands and the services and resources they provide is recognized and appreciated, it is highly unlikely the rate of conversion will slow or stop.

Only when these lands are valued will conservation be a priority over the short-term profitability of agricultural production. An analysis by Wright and Wimberly (2013) found that cropland has expanded beyond the total acres of expiring CRP contracts, suggesting that grassland acres beyond those protected by the CRP are also being converted to crops.

Increased funding for the CRP and other land programs, such as the Conservation Reserve Enhancement Program (CREP), would enable states and landowners to protect more acres of vulnerable grasslands. Nationally, acres are often turned down due to enrollment funding caps being reached or due to applications not meeting the Environmental Benefits Index ranking requirement. In the 2014 Farm Bill, the enrollment cap was reduced from 15 million ha (37 million acres) to 9.7 million ha (24 million acres) (USDA 2014) which resulted in the denial of thousands of applications. During the 49th CRP signup, which ran from December 1, 2015 to February 26, 2016, South Dakota submitted 727 applications; only 2 of which were deemed acceptable. In those offers, 17,139 ha (42,350 acres) of land in South Dakota were offered for protection but only 40.9 ha (101 acres) were accepted (USDA 2017c). Demand is greater than the approved acreage caps denying the opportunity to protect more acres and increase enrollment. One example of a program meeting the needs of both conservation and people in South Dakota is the James River Watershed CREP (JRW CREP). Similar to the CRP, the JRW CREP provides an option for landowners to remove land from agricultural production for 10-15 years in exchange for an annual payment. This program has the added benefit of being open to free public access for recreational hunting and fishing without needing landowner permission (USDA 2009). By coupling the JRW CREP with South Dakota's

Walk-in Area Program, landowners receive an additional 40% over the financial incentive for other CRP in the state (USDA 2011). A study of the JRW CREP by Pfrimmer (2017) found that the public access requirement was favored by 43% of enrolled landowners, while only 23% disliked the requirement.

Currently, states within the Prairie Pothole Region (IA, MN, SD, ND, and MT) have the “Sodsaver” provision of the Food, Conservation, and Energy Act of 2008, which was renewed and revamped in the 2014 Farm Bill. The 2008 version precluded any crop insurance coverage for the first 5 years of agricultural production on land converted from native grass (i.e. no previous cropping history) and the provision had to be requested by the governor. The 2014 version reduced the crop insurance premium subsidy rate by 50 percentage points during the first four years of production. This, along with other changes, increased the cost of insuring newly converted cropland and reduced the effective coverage of crop insurance, which disincentivized grassland conversion (Miao et al. 2016).

Increased sanctions, such as those of the Wetland Conservation (“Swampbuster”) provision, could provide a stronger disincentive to grasslands conversion. If implemented, landowners who convert grasslands could lose farm program payments throughout the farm, not just on converted acres. Additionally, they could lose direct payments, loans, CRP payments, and other program benefits (Claassen et al. 2011).

FUTURE RESEARCH

While this research provided insight into which CRP mid-contract management methods provided the most benefits as brood habitat, it could be strengthened through

several future research avenues. This research investigated multiple treatment options on a small scale (0.81 ha (2 acres)), however implementing these treatments on larger scales is important to see whether greater numbers of pheasants actually use the habitat for nesting and brood rearing. Documenting metrics such as nest initiation, nest success, brood survival, brood foraging, and distances traveled would provide additional information about the suitability of the habitat. Additionally, this study was conducted with human-imprinted pheasant chicks. While research suggests that human-imprinted chicks are comparable to wild chicks (Hurst 1972, Kimmel and Healy 1987, Palmer et al. 2001, Doxon and Carroll 2010), it may be worth monitoring wild chicks in these treatments.

Investigating treatment effects over longer periods of time would also be beneficial. Our study was limited to 3 years, when most CRP contracts are 10 years with management occurring at year 5. As a result, there are two years that we were not able to document, and it is possible that there were longer term effects possible which we were not able to measure. McCoy et al. (2001) found that younger fields (age 1-3) had an annual weed and legume component with abundant bare ground, while mature fields (age 4-9) were dominated by perennial grasses and a substantial accumulation of litter. Millenbah et al. (1996) found similar results, except they classified young stands as 1-2 years of age and older stands as 3-6 years of age. A longer term study would have enabled us to evaluate these differences in our study area.

Another avenue of research is to compare arthropod availability and selection. As part of this research, we collected the diet contents of the chicks used in foraging trials. By comparing the arthropods eaten to those collected through pitfall traps and sweep

nets, we can gain an understanding as to whether chicks will consume any arthropods that are present, as long as they are size appropriate, or whether chicks are choosing to eat specific types of arthropods regardless of their abundance. This information could be used to refine management recommendations to reflect management options that increase the presence of specific types or size classes of arthropods.

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