A STUDY OF THE RELATIONSHIP BETWEEN PLAINS SHARP-TAILED GROUSE NEST SITE SELECTION AND SURVIVAL AND ECOLOGICAL SITE DESCRIPTIONS IN THE NORTHERN PLAINS

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

MASTER OF SCIENCE

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ABSTRACT

Nest site selection and nesting success of plains sharp-tailed grouse were examined on the Grand River National Grassland in South Dakota during the nesting season from 2009-2012. We used conditional logistic regression to assess vegetation production, ecological site description, and landscape position on nest site selection. Two competing models regarding nest site selection: top model consisted of non-native forbs and native cool-season grasses, second best model included all grass and forb. Nine ESDs were used for nesting; loamy and clayey ecological sites most frequently used and produced the highest standing crop. Most frequent observed nest site State were Annual/Pioneer Perennial and Introduced and Invaded Grass. Top model for nest daily survival rates included litter, second-best model included ESD; second-best model showed negative effect for nests initiated in thin claypan, limy backslope, and sandy ecological sites. Based on daily survival estimate and 23-day incubation period, nests were 59% successful.

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DEDICATION

This document is dedicated to my parents, Roy and Lori Klostermeier.

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Species Description

The plains sharp-tailed grouse (*Tympanuchus phasianellus jamesi*; STG) is one of four species of North American grouse (Connelly 1998) with six subspecies that inhabit a broad range of mostly grass and shrub dominated plant communities (Marks 1987). The species was originally described in 1758 by Linnaeus as *Tetrao phasianellus* (Connelly 1998). Historically, STG ranged from Alaska south through western Canada, east to Hudson Bay and west to California and Nevada, originally occupying 21 states and eight provinces and territories (Johnsgard 2002, Marks 2007). Populations have been extirpated from Oregon, California, Nevada, New Mexico, Oklahoma, Kansas, Iowa, and Illinois. Populations nationwide likely peaked around the early 1900's settlement era, since then declining gradually. The North American Breeding Bird Survey recently published trend data showing STG populations with a survey-wide increase of 0.37% from 1966-2015 (Sauer et al. 2017). The plains subspecies populations still occupy much of their historical range; however, range-wide, population pockets are declining, especially in the shortgrass prairie region (Sauer et al. 2017). Many populations may be declining due to habitat loss and degradation (Flake et al. 2010). Northern populations appear to be secure, likely due to the isolated locations in which they inhabit (Marks 2007). Today, STG range from north-central Alaska, northern Manitoba to western Quebec, south to eastern Washington, Idaho, northeastern Utah, Wyoming, and Colorado; in the Great Plains from eastern Colorado and Wyoming across Nebraska, the Dakotas, northern Minnesota, Wisconsin, and Michigan (Johnsgard 1983).

Of the seven historical subspecies, the subspecies (*T.p. hueyi*) is now extinct; this subspecies was classified based on nine specimens of the high-plains grasslands in northeast New Mexico (Connelly 1998, Johnsgard 2002). The other six subspecies are found throughout central and western North America; these include: Alaska STG (*T.p. caurus*), ranging from north-central Alaska east to Yukon Territory and in northern regions of British Columbia, Alberta, and Saskatchewan; Northwestern STG (*T.p. kennicotti*), Northwest Territories; Northern STG (*T.p. phasianellus*), found throughout northern Manitoba, Ontario, and west-central Quebec; Prairie STG (*T.p. campestris*), ranging from east-central Saskatchewan, southern Manitoba, and western Ontario, south across Michigan, Minnesota, and Wisconsin; Columbian STG (*T.p. columbianus*), throughout the Columbia Plateau and Great Basin, also central and southern British Columbia, south to Utah and Colorado; and Plains STG (*T.p. jamesi)*, range throughout the Great Plains east of the Rockies, central and southern Alberta, Saskatchewan, Manitoba, south to Colorado and Nebraska (Marks 2007).

The plains STG subspecies appears to have experienced the least population decline; however, it has been extirpated from northwestern Oklahoma and western Kansas, and its range in eastern Colorado has been reduced considerably (Prose 1987). Intensive agriculture conversion and overgrazing have decreased the STG range in most Great Plains states, although in the Great Lakes states, clear-cut logging have removed coniferous and deciduous forests, in turn expanding the range of the species (Evans 1968). Sharp-tailed grouse populations have decreased approximately 10-50% from their former range in North Dakota and Wyoming, and from 50-90% in Montana, Nebraska, Saskatchewan, and South Dakota. Habitat degradation from intensive grazing practices and conversion of grasslands to other uses (i.e. agriculture) have been major contributors (Johnsgard 1983).

The plains STG is a medium-sized grouse that is slightly smaller than the greater prairie chicken and has an overall body length at approximately 41-47cm; typical body mass ranges from 596-1,031 g, depending upon the season and sex of the bird, as males are typically heavier than females (Connelly 1998, Marks 2007, Flake et al. 2010). Sharp-tailed grouse have a round body with short, sandy-brown legs, short crest on head, and elongated central tail feathers which are cross-barred in females and longitudinal color patterned in males (Henderson et al. 1967, Johnsgard 1973, Connelly 1998, Flake et al. 2010). Sharp-tailed grouse are cryptically colored with head, neck, back, and wings being heavily barred with dark brown, black, gray, and buff coloring (Johnsgard 1973, Connelly 1998, Flake et al. 2010). Both sexes have a crescent-shaped, yellow-orange comb over their eyes, which is more distinct in males during courtship. Males also display violet colored air sacs on the sides of their necks which inflate during courtship (Johnsgard 1973, Connelly 1998, Flake et al. 2010). The upper-wing coverts are linearly patterned with white spotting; breast and upper belly feathers are pale with dark brown V-shaped markings (Connelly 1998, Marks 2007, Flake et al. 2010). Sharp-tailed grouse are characterized by their wedge-shaped tail which is less than 15 cm long and show a great deal of white or light gray when the bird is in flight (Evans 1968; Flake et al. 2010). Other than some minor differences, male and female STG are nearly indistinguishable.

Habitat Requirements

Sharp-tailed grouse habitat include a variety of open, moderately treeless habitats including brushy openings in boreal forests, seral stages of mixed conifer and deciduous forests, grasslands, shortgrass prairie, meadow steppe, mountain shrub, shrub steppe, sagebrush steppe, oak savannah, and riparian habitats (Aldrich 1963, Marks 1987, Johnsgard 2002, Flake et al. 2010). Sharp-tailed grouse choose habitats based on the landscape's general openness, density, and vegetative composition and height. Quality habitats contain a well-balanced mix of grasses, forbs, and shrubs; selection of specific habitat characteristics and vegetative communities vary by geographic region and subspecies (Johnsgard 1973, Kohn 1976, Swenson 1985, Flake et al. 2010).

Transitional areas between habitat types are often used when an area contains high diversity of vegetative species and structure (Marks 1987). Common grass species associated with habitats include bluestems (*Andropogon* spp.), bluegrasses (*Poa* spp.), bromes (*Bromus* spp.), wheatgrasses (*Agropyron* spp.), and needlegrasses (*Heterostipa* spp.). Forb species include clover (*Trifolium* spp), common yarrow (*Achillea millefolium*), dandelion (*Taraxacum officinale*), and goatsbeard (*Tragopogon dubius*). Common shrub species include rose (*Rosa* spp.), cherry (*Prunus* spp.), serviceberry (*Amalanchier* spp.), snowberry (*Symphoricarpos* spp.), and sagebrush (*Artemisia* spp.) (Marks 1987).

Winter Requirements

Habitat requirements in winter are more specific than other times of the year, often relying upon riparian areas, shrubby rangelands, mountain shrub communities, deciduous hardwood shrub draws, and open deciduous and coniferous woods (Connelly 1998, Marks

2007, Flake et al. 2010). During mild winters, grain fields and Conservation Reserve Program (CRP) fields are also used (Connelly 1998, Flake et al. 2010). Although plant species vary within regions, winter habitats are commonly characterized by vegetative species which provide feeding, roosting, and escape cover. Winter habitats which provide adequate cover must also provide abundant food sources (Marks 2007, Flake et al. 2010). While not considered migratory, STG will move short distances (<32 km) to habitats which meet their needs for survival (Marks 2007, Flake et al. 2010). Wintering sites are often at higher elevations, with small trees and taller shrubs, and less snow cover than random locations. Habitat usage in winter varies as a function of snow depth; as snow depth increases, habitat selection shifts from cropland and prairie to shelterbelts and woody vegetation (Swenson 1985, Flake et al. 2010). Sharp-tailed grouse will often burrow under deep snow after eating to roost, allowing them to conserve heat and avoid detection by predators (Hammerstrom and Hammerstrom 1951, Gratson 1988, Marks 2007, Flake et al. 2010).

Lekking Requirements

Habitats used for communal display and breeding sites, called leks, have been defined as an open gathering site where males compete and carry out display and courtship behaviors to attract females (Bergerud 1988, Flake et al. 2010). Lekking habitats are typically found on elevated and disturbed sites where vegetation height and density are low. Leks typically occur on knolls, ridges, hilltops, benches, or other flat areas providing an elevated broad view of the surrounding landscape (Marks 2007, Flake et al. 2010). Sharp-tailed grouse use various locations as lekking sites including rangeland, cropland, plowed areas, muskegs, prairie dog towns, and airport runways. These locations and characteristics typically allow for displays and competition between territorial males, distance their courtship sounds carry, increased visibility, and minimize predation (Marks 2007, Flake et al. 2010). Vegetative species may fluctuate depending on location within the STG range, but for the most part, lek locations are by-and-large constant from year-to-year; however, some locations can alter due to climate, land use, or other human disturbance changes (Marks 2007, Flake et al. 2010).

Males gather on leks beginning early to mid-March to establish territories and remain through May (Sisson 1969, Bergerud 1988, Marks 2007, Flake et al. 2010). Courtship displays (dancing) are performed by males, establishing territorial boundaries and attracting females to the dancing grounds for mating. Dancing occurs on the lek beginning from 30-60 minutes before sunrise, to 2-3 hours after sunrise (Marks 2007, Flake et al. 2010). Displaying males participate in animated dancing displays followed by phases of motionless freezing and often aggressive fighting and face-offs to establish dominance. During these face-offs, males are bent forward (bowing), with head and wings parallel to the ground, tail upright, and air sacs inflated. Displaying males will rush forward or circle one another while rapidly stamping their feet, clicking their central tail feathers, and vocalizing hoots, clucks, cackles, and gobbles (Johnsgard 2001, Marks 2007, Flake et al. 2010). These dances last approximately 30-60 seconds and are most intense when females are present. Males appear to dance in synchrony, starting and stopping on cue; what triggers this dancing sequence is not fully understood, but a theory is that the starting and stopping action is for predator detection purposes, as most predators would be difficult to detect during the display actions (Johnsgard 2001).

Bird numbers on leks (both male and female) range from 2-35 males; an established hierarchy exists, with older more dominant males displaying at the center and younger more subordinate males making up the periphery. Mating is highly variable with the majority of mating performed by dominant, centrally located males (Marks 2007, Flake et al. 2010). Lekking is not an advantage to the competing males; rather, it is advantageous for the females as to be selective in mate characteristics (Flake et al. 2010). Males are promiscuous with a strong relationship between a male's individual dominance and its probable breeding success. The displays and vocalizations performed are concerned with establishing this dominance. Successful matings are achieved by males whom are more likely to maintain centrally located lek territories, have larger sperm volumes, as well as more motile sperm than unsuccessful males (Flake et al. 2010). Males whom display at higher rates typically have higher breeding success than others (Johnsgard 2001). Males will return to lek sites in autumn to re-establish territories and dominance hierarchy relationships (Marks 2007, Flake et al. 2010).

Nesting Requirements

Females spend late spring and summer months nesting and brood rearing. Following a successful copulation, the female leaves the lek and finds a suitable place to make her nest (Johnsgard 2001, Flake et al. 2010). She probably will not revisit the dancing grounds unless in the event of a re-nesting attempt caused by predation or abandonment of her initial nesting attempt. It is thought that nest site is selected before mating, however, at this time, there is no data present to support this theory (Gratson 1988). A single copulation serves to fertilize her entire clutch of ten to twelve eggs (Johnsgard 2001, Flake et al. 2010). The first eggs are typically laid one to three days after copulation; one egg laid daily until total clutch is produced. The female begins incubating the clutch after the last egg has been laid. This period will last from 23-24 days, during this time the female is on the nest all day except for short periods in the morning and evening to feed (Johnsgard 1983, Flake et al. 2010). Nest site initiation distance from lek of copulation has been found an average of 0.4-1.8 km (Connelly 1998, Flake et al. 2010). Male STG have no role in nest site selection or brood rearing after copulation. Nests are shallow, bowl-shaped depressions on the ground; typically made from moss, grasses, sedges, ferns, herbaceous plants, litter, and leaves of shrubs and trees. Sharp-tailed grouse often line the inside of their nests with grasses, sedges, and breast feathers (Connelly 1998, Flake et al. 2010). Habitat selection for nesting STG is driven by predator avoidance; optimal sites provide both vertical and lateral cover concealing females and nests from both avian and mammalian predators (Goddard et al. 2009). Available quality habitat is the predominant component characterizing habitat use, nest success, and consequent population trends (Goddard et al. 2009, Flake et al. 2010).

Nest sites are typically chosen in thick, dense vegetation consisting of grasses and forbs near or within shrubs, with tall, dense residual cover; moreover, sites which provide a variety of structural diversity (Johnsgard 2001, Flake et al. 2010). Optimal nesting sites typically contain vegetative cover that is denser than the surrounding area (Marks 2007, Goddard et al. 2009). Flat land features and north-northeast facing slopes have been found to be chosen more frequently, as these features tend to contain higher amounts of moisture and vegetation. In Idaho, nests are frequently found under sagebrush (*Artemisia* spp.) as well as balsamroot (*Balsamorhiza* spp.) species, and in Minnesota, nests are often found beneath willows and bunch grasses. Yellow sweetclover (*Melilotus officianalis*) is a very effective forb in creating nesting cover needed for protection from predation and shade while nesting (Marks 2007, Flake et al. 2010). Nests are often situated in ungrazed or lightly grazed sites on native prairie, within or at the borders of shrubs or small trees. In other cases, nests can be found in agricultural fields if native vegetation is sparse or otherwise not available (Marks 2007, Flake et al. 2010).

A study conducted by Goddard et al. (2009) in northeastern British Columbia found that during first nesting attempts females primarily selected habitats consisting of greater vegetative vertical cover, grass cover, residual cover, and overall vegetative height. Re-nesting females were also found to select sites with greater vegetative vertical cover, shrub and grass cover, and overall taller vegetation compared with random locations. The study found that nesting sites with increased levels of shrub vertical cover enhanced aerial concealment; taller grass cover increases lateral concealment, and heightened residual vegetative cover aids in concealment of nests until new vegetation grows. An increased selection of these habitat attributes by nesting STG is important, as these vegetative attributes have shown to result in decreased nest predation (Goddard et al. 2009).

Brood Rearing Requirements

Brood rearing habitat selection is principally predator avoidance driven, however, limited by the need for adequate food supply for the precocial chicks. Sharp-tailed grouse chicks rely on insects as their primary food source until approximately five weeks of age when their diets switch to primarily forb species (Goddard et al. 2009, Flake et al. 2010). As such, females generally choose areas with abundant insects and dense forb cover, as these have been observed to provide abundant food sources, predator avoidance, and thermoregulation (Goddard et al. 2009, Flake et al. 2010). Important habitats for brood rearing include areas with abundant and diverse vegetation of grasses, forbs, and shrubs (Connelly 1998). Young STG are able to fly short distances by 10 days of age, becoming increasingly independent. At six to eight weeks old, chicks are almost fully independent and broods begin to disperse from the hen's home range (Johnsgard 1983).

Goddard et al. (2009) found that during the early brood rearing stage (1-15 days), females showed patterns of use within different land use types. The study found use preference for agricultural habitats, hayfields, and cereal crops dominated by grasses and forbs (Goddard et al. 2009). This study found habitats rich in forbs, diversity of shrub species, and interspersion of cover types are important for brood rearing (Goddard et al. 2009). The authors also found that during the late brood rearing stage (15-49 days), STG used edge habitats more than they were available. Edge habitats provide ideal forage and escape cover from the taller, less diverse crops in agricultural fields, in addition to the shelter belts which often border agricultural fields (Goddard et al. 2009).

Food Habits

An animal's selection in food is often ruled by the availability of a forage item and its preference for a given forage item (Jones 1966). Sharp-tailed grouse are a crepuscular species, meaning they feed most intensely in the early morning and late evening hours during the spring, summer, and fall months. In spring and summer when the birds are most active due to breeding and nesting, their diets consist of forbs, grasses, insects, fruits, and flowers. In winter months, the birds feed all throughout the day to maintain energy requirements. In the fall and winter months main food sources are buds, seeds, grains, acorns, herbaceous matter, and fruits. Sharp-tailed grouse often store food in their crop for later digestion and consume small stones to aid in grinding of food. Chokecherry (*Prunus virginiana*) seeds substitute these stones in the winter when gravel is often hard to obtain due to snow and ice (Connelly 1998). Young grouse feed primarily on insects (e.g. grasshoppers, spiders, ants, and weevils) during the first few weeks of life. Later plant buds, leaves, and berries get incorporated into their diet (Johnsgard 1983).

Hillman and Jackson (1973) found that diets of STG during fall and winter months in South Dakota consisted of cultivated crops (55-64%), western snowberry (*Symphoricarpos* occidentalis; 7-19%), and Russian olive (*Elaegnus* angustifolia; 5-15%). In spring and summer months, diets consisted of common dandelion (*Taraxacum* officinale; 4-72%), prairie rose (*Rosa* arkansana; 2-15%), and insects (4-36%). Swanson (1940) conducted a study in Minnesota analyzing prairie STG (*T.p. campestris*) droppings from 550 collections and found the important species making up the highest percentage of their diets were *Polygonum convolvulus*, *Symphoricarpos* spp., *Rosa* spp., *Arctostaphylos uva-ursi*, *Physalis* spp., and *Orthoptera* spp. Jones (1966) found in 169 droppings and 14 food crops taken from Columbian STG (*T.p. columbianus*) that the more important spring, summer, and fall foods were *Poa secunda*, *Bromus tectorum*, *Taraxacum officinale*, *Ranunculus glaberrimus*, and insect species such as *Hemiptera*, *Orthoptera*, *Coleoptera*, and the larvae of other various insect orders.

Harris (1967) conducted a study of foods found in the food crops of 263 STG shot by hunters in 13 northern Minnesota counties in late September and early October. Results of this study revealed 87.8% of the total volume of food was represented by no more than six items: oats, wheat, flax seeds, and other seed species accounted for 53.7% of the total food; clover leaves accounted for another 13.3%; grasshoppers constituted 14.7%; the only plant item not associated with agricultural operations was seeds of *Vaccinium sp.,* accounting for 6.1% of the total volume. This study highlights the value of agricultural food crops to the diet of the STG; some populations of STG successfully inhabit range where few or no grains are to be had, although these food items are regularly eaten if available (Harris 1967).

Management Considerations

Sharp-tailed grouse are a popular game-bird throughout much of its range; it is managed as a game species in 18 states and provinces. Total annual bird harvest varies from year-to-year, and among states and provinces because of weather, population status, bag limits, seasons, and access to hunting areas. Little evidence throughout the species range demonstrates that harvest has an overall negative effect on populations. Harvest impacts may fluctuate more between local or regional populations than the overall species range (Connelly 1998). It is apparent that the effects of habitat degradation and fragmentation across the species range are having an overall negative impact on the species. Sharp-tailed grouse population trends are monitored and assessed using lek counts, brood surveys, harvest surveys, summer flush counts, and wing collections (Marks 2007, Flake et al. 2010). Lek densities provide an index to populations and indirectly reflect changes in habitat quality. Lek monitoring also provides useful information to land managers for evaluations of current and proposed land uses (Connelly 1998, Flake et al. 2010). Information on sex ratios and lek stability is used to adequately and accurately monitor STG populations throughout their range (Marks 2007, Flake et al. 2010).

Sharp-tailed grouse populations generally respond well to habitat management practices that promote high quality nesting habitat, food sources for adults and chicks, winter habitats, and habitats in early- to mid-seral stages (Marks 2007, Flake et al. 2010). In the

Dakotas, grasslands managed for the development of quality grouse habitat by grazing and/or mowing have shown to be of significant value (Barker et al. 1990, Kirby and Grosz 1995). Fire is a useful management tool, as it helps maintain an ideal sub-climax condition (Connelly 1998). Fire can be a threat to STG populations in some areas, but for the most part, fire is ideal and necessary for maintaining healthy grasslands. The impacts of fire hinge on vegetation type, timing, frequency, and size (Marks 2007).

Vegetation manipulation is a useful management strategy used for STG habitats. Techniques vary depending on the vegetation present. In grassland habitats, manipulations such as haying and mowing should be limited or at proper timing as it tends to reduce nesting and brood rearing habitat. In habitats dominated by deciduous shrubs or trees, vegetative manipulation can be beneficial by creating a more open grass-shrub landscape (Marks 2007). If vegetative manipulations are required, managers should try to limit these alterations for the months after the breeding and nesting season (Marks 2007).

Another useful management strategy for STG habitat is the use of grazing systems with livestock. Preferred grazing methods include rotational grazing and deferred grazing (Barker et al. 1990, Grosz and Kirby 1986). Rest-rotation is most effective when residual grass and herbaceous material is left in place each fall for nesting cover and brood-rearing the following spring (Barker et al. 1990, Kirby and Grosz 1995, Marks 2007). Livestock should be fenced out of riparian areas containing trees and shrubs, as these areas provide quality winter habitats. Overgrazing by livestock should be avoided, as this leads to the decline of cover by reducing the amounts of grasses and forbs necessary for nesting and brood rearing (Marks 2007). Continuous overgrazing has shown to be damaging as it can alter the vegetative composition of the grassland resulting in less diverse grasses, forbs, and shrubs that will not sustain STG populations. Overgrazing can be avoided by implementing sound management strategies; properly managed grazing can lead to a diversity of vegetative composition, cover, and structure which benefits STG (Kirby and Grosz 1995, Sedivec et al. 1995, Marks 2007).

Population Status

The population of STG has shown to be in decline over the past 150 years; though population estimates fluctuate greatly from year-to-year. The species are short-lived with high reproductive capacity, as such, these declines are associated with numerous factors including the loss, degradation, and fragmentation of native habitats across the species range resulting in an overall negative impact on the species (Marks 2007, Flake et al. 2010). Other limiting factors include direct and indirect mortality from severe weather, collisions with structures or other anthropogenic effects, depredation from avian and mammalian predators, limited food resources, infectious disease, loss of open landscapes, and the amount and quality of available habitats (Connelly et al. 1998, Flake et al. 2010). The North American Breeding Bird Survey recently published trend data showing STG populations with a survey-wide increase of 0.37% from 1966-2015 (Sauer et al. 2017). The plains subspecies populations still occupy much of their historical range; however, range-wide, population pockets are declining, especially in the shortgrass prairie region (Sauer et al. 2017). Many populations may be declining due to habitat loss and degradation (Flake et al. 2010). Northern populations appear to be stable, likely due to the remote locations in which they inhabit (Marks 2007). Sharp-tailed grouse depend on high-quality habitats distributed across extensive landscapes, as such, they depend upon both publicly and privately-owned lands in both the United States and Canada. Habitat quality largely is determined by activities including grazing, mining, logging, and recreation (Vodehnal et al. 2007). Predation may be the single greatest source of mortality, as STG are highly vulnerable due to their ground nesting habits, large clutch sizes, and lekking behavior; as these are the time periods when predation appears to be highest. Mammalian predators include coyote (*Canis latrans*), striped skunk (*Mephitis mephitis*), ground squirrels (*Sciuridae* spp.), American badger (*Taxidea taxus*), American mink (*Neovison vison*), red fox (*Vulpes vulpes*), long-tailed weasel (*Mustela frenata*), and humans; avian predators include American crow (*Corvus brachyrhynchos*), common raven (*Corvus corax*), red-tailed hawk (*Buteo jamaicensis*), northern goshawk (*Falco peregrinus*), peregrine falcon (*Falco peregrinus*), gyrfalcon (*Falco rusticolus*), great horned owl (*Bubo virginianus*), long-eared owl (*Asio otus*), short-eared owl (*Asio flammeus*), northern harrier (*Circus hudsonius*), prairie falcon (*Falco mexicanus*), and golden eagle (*Aquila chrysaetos*), and bald eagle (*Haliaeetus leucocephalus*; Marks 2007, Flake et al. 2010, Burr et al. 2017).

South Dakota's historical STG range has declined moderately, mainly in the far eastern portions where farming practices have either reduced or eliminated habitat (Johnsgard 2002, Flake et al. 2010). Sharp-tailed grouse still occupy a majority of their historic range in South Dakota and is closely tied to availability of extensive mid- and short-grass prairies (Johnsgard 2002, Flake et al. 2010). There is an annual hunting season, with an average state-wide harvest of approximately 42,000 birds (SDGFP 2019). Breeding bird surveys show that populations are highly variable as the species are short-lived with high reproductive potential, as such, fluctuating numbers from year-to-year can be expected (Flake et al. 2010). The North American Breeding Bird Survey published trend data showing STG populations in South Dakota increased

2.43% from 1966-2015 (Sauer et al. 2017). Survey results from 1966-1992 suggest that the South Dakota population is increasing in the western and northwestern parts of its range but declining in the south (Johnsgard 2002). A study conducted by Robel et al. (1972) during the winters of 1963-1968 at two sites in southern South Dakota found that winter population estimates of STG varied between 0.7 and 1.8 birds·km² in the southwest area and between 0.9 and 1.8 birds·km² in the southeast. The estimated number of STG in the southwest area decreased from 3,789 in the winter of 1964-1965 to 1,517 in the winter of 1967-1968. The estimated population of STG in the southeastern area varied from a high of 1,380 during the winter of 1963-1964 to a low of 638 in the winter of 1967-1968.

In North Dakota, there have been minimal reductions in the STG overall range, with reductions primarily along the heavily cultivated Red River Valley; statewide population has steadily declined since the late 1800's. The North American Breeding Bird Survey recently published trend data showing STG populations in North Dakota increased 0.99% from 1966-2015 (Sauer et al. 2017). Breeding bird surveys from 1966-1992 suggest that the North Dakota population is increasing over most of the state but is declining in the southwest and along the western edges of the Red River Valley (Johnsgard 2002). Data from 22 STG census areas during spring 2006 indicate a statewide increase of 9.4% in males·km². Changes varied from a decrease of 8.6% in one district to an increase of 70.8% in another. In 2005, 152 STG broods were counted with an average of 5.5 young per brood compared to 164 broods with an average of 5.0 young per brood in 2004. Brood routes showed decreases in birds and broods per kilometer from 2004-2005, while data from late summer roadside counts and grouse brood routes showed increases in percent of young from 2004-2005 (NDGF 2006). The relationship between prairie grouse and land use was studied on 46,240 acres in east-central North Dakota during the period 1964-1971; male STG were found to have declined from 166 in 1964 to 57 in 1971 in the study area. These declines were related to the loss of vegetative species diversity and subsequent successional changes (Kirsch et al. 1973).

By the 1980's, Minnesota had experienced a STG range reduction of approximately 60% with the majority of the birds residing in the northern third of the state (Johnsgard 2002). Estimated annual hunter harvests have been in a long-term decline since the 1950's. State estimates in 2000 indicated that the population was about 70% below numbers from the 1980's, the east-central and northwestern portions of the state experiencing a majority of this decline. The North American Breeding Bird Survey recently published trend data showing STG populations in Minnesota have increased 4.48% from 1966-2015 (Sauer et al. 2017). Breeding bird surveys from 1966-1992 suggest that the population is increasing in the east but declining in the west, this trend also continued from 1996-2000 (Johnsgard 2002). The Minnesota Department of Natural Resources has had an intensive brush management program in place in the eastern portion of the state, which is likely contributing to the increasing counts in that region of the state (Johnsgard 2002).

Nebraska has managed to retain much of its STG range, due almost entirely to the 20,000 km^2 Sandhills region where tall- and mixed-grasses and shrubs provide ideal food and cover habitats. Sharp-tailed grouse escaped to the Sandhills as farming and ranching practices removed their preferred habitats in the eastern and southern portions of the state. Their current range corresponds closely to the sandiest parts of the state. Breeding bird surveys from 1966-1992 suggest that the population is increasing in the northwestern and southwestern parts of the state but declining elsewhere (Johnsgard 2002). The North American Breeding Bird Survey recently published trend data showing STG populations in Nebraska have decreased -0.56% from 1966-2015 (Sauer et al. 2017).

Ecological Site

An ecological site divides the landscape into fundamental units for study, evaluation, and management (Bestelmeyer and Brown 2003). These units help managers to recognize and communicate the important differences in vegetation, soil, and ecological processes taking place. These differences can influence the success or failure of management actions or affect the ecosystem services provided and can be used to adjust management practices and analysis of monitoring and assessment data. Ecological sites provide managers with a tool for evaluating and determining overall land potential and help adjust management according to differences in the landscape. Ecological sites provide a basis for bringing together many ecological concepts (Moseley et al. 2010). Ecological sites are delineated using a hierarchical subdivision of land areas according to climate, landforms, and soils. The Major Land Resource Units (MLRA) and Land Resource Units (LRU) used within the USDA-NRCS are the broadest levels within this hierarchy. The MLRA's are regional divisions of the United States based on obvious differences in climate, physiography, plant distribution, and land uses. The LRU's are subdivisions of MLRA's that distinguish areas of different regional climate and/or geomorphology (Bestelmeyer and Brown 2003).

An ecological site, as defined by the Natural Resource Conservation Service (NRCS), is a distinctive kind of land with specific soil and physical characteristics that differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation, and in its ability to respond similarly to management actions and natural disturbances (USDA-NRCS 1997). There’s a direct relationship between alternating soil types and subsequent variation of plant species associated with soil type(s) across the landscape; classifying this relationship into ecological sites aides in understanding the landscape (USDA-NRCS 1997, Boltz and Peacock 2002). Ecological site classification uses environmental factors responsible for development such as climate, soil, geomorphology, hydrology, natural disturbances (fire, drought, grazing), and vegetation to describe the ecological potential of land areas (USDA-NRCS 1997, Boltz and Peacock 2002). An ecological site is recognized and described based on these characteristics and may feature several plant communities that occur over time and/or in response to management actions. Land management decisions require knowledge of these individual sites and their interrelationships to one another on the landscape (USDA-NRCS 1997, Boltz and Peacock 2002). An ecological site describes the potential vegetative communities that could occur on a site, with states and phases, natural and human caused processes which produce shifts from one phase to another, and transitions between states (Karl and Herrick 2010). An ecological site has a characteristic plant community, in both species of plants grown and the amount of annual vegetative biomass produced. Vegetative production can fluctuate greatly by ecological site within or between areas due to differences in soil, water, and topographic relationships. Main ecological site factors which determine type and amount of vegetative species produced consist of surface soil depth, texture, moisture, salinity, fertility, slope, aspect, and annual precipitation (Bestelmeyer et al. 2009).

Ecological sites are based on soil map unit components of the National Cooperative Soil Survey. Soil mapping segments the landscape into individual soil map units, which include soils with different soil horizons or topographic positions (USDA-NRCS 1997, Duniway et al. 2010). It is often not practical to delineate each soil that occurs across a landscape due to the soils being too complicated to tell apart using surface features such as topography and vegetation; therefore, soil map units regularly contain more than one soil. Ecological sites group elements that support plant communities with similar characteristics and react similarly to management and disturbance (USDA-NRCS 1997, Duniway et al. 2010). Differences in ecological sites and states are caused by differences in soil properties and processes; soil properties are the result of the interaction of the five soil forming factors: parent material, climate, topography, biota, and time (USDA-NRCS 1997, Duniway et al. 2010). Soil properties responsible for distinguishing specific ecological sites are those that direct the natural potential of the site to favor distinctive plant species or species groups that compose the characteristic plant communities and differences in the amount of species or species groups in the characteristic plant community. These soil properties are influenced by landscape position, aspect, soil texture, mineralogy, and depth; the most distinguishing factor for rangeland ecological sites being soil water availability (USDA-NRCS 1997, Duniway et al. 2010).

Ecological Site Descriptions

Ecological site descriptions (ESDs) represent a resource to aid land managers and private landowners in better understanding the varying landscapes and how they function in an ecological framework (Gilgert and Zack 2010). Ecological site descriptions are reports that describe and integrate data to illustrate the properties of ecological sites, climatic conditions, vegetation, surface soil properties, and associated hydrologic features of reference conditions that represent either pre-European settlement vegetation and historical range of variation or proper functioning condition and potential natural vegetation, state-and-transition model (STM) graphics and text, description of ecosystem services provided by the ecological site, as well as other interpretations for use and management (Boltz and Peacock 2002, Sedivec and Printz 2012). In other words, the ESD is the document containing information about each individual ecological site that exists across the landscape or region in a particular area of interest (MLRA, LRU).

Land use and management information contained in ESDs include: plant community dynamics, vegetation production, vegetative growth curves, associated wildlife communities, and interpretations for land use and management (Boltz and Peacock 2002). An ESD provides a descriptive breakdown of interactions between soils, vegetation, and land management; foundation to assess and monitor ecological site conditions; framework to assess management opportunities and results; identification of knowledge gaps; opportunity to communicate resource information between agencies, organizations, and disciplines; framework for transferring experience and knowledge between professionals, and local knowledge (Boltz and Peacock 2002).

Ecological site descriptions combine and link information sources and inventory data to plant communities, soil classification, landforms, historical vegetation information, as well as management considerations based on local knowledge (professionals and landowners, ranchers/farmers) and scientific data (USDA-NRCS 1997). Responses of vegetation and soils to management on each individual ecological site are outlined through the STM. The STM is a conceptual diagram describing patterns and causes of transitions between plant communities based on management practices, natural disturbances, and other anthropogenic effects (USDA-

NRCS 1997). Ecological site descriptions, STM, and Geographic Information Systems (GIS) spatial data layers provide a framework for rangeland monitoring and assessment (Karl and Herrick 2010, Sedivec and Printz 2012).

Further efforts have been taken to expand ESDs to include woodlands and forests (Townsend 2010), riparian systems (Stringham and Repp 2010), as well as other multiple ecosystem services provided, such as, wetlands and wildlife habitat (Gilgert and Zack 2010). In addition, remote sensing imagery, such as Landsat-7 coupled with enhanced thematic mapper plus (ETM+) sensors have been used and further proposed to expand and increase these efforts (Maynard et al. 2007).

State-and-Transition Models

State-and-transition models (STMs) are a central component of ESDs and are widely used for ecosystem assessment within rangelands (Briske et al. 2008). As stated prior, STMs are a conceptual diagram representing patterns and causes of transitions between plant communities based on management practices, natural disturbances, and other anthropogenic effects (USDA-NRCS 1997). State-and-transition models are an assembly of alternative stable states which represent the anticipated ecosystems that ecological sites could support. Each state contains community phases representing system dynamics driven independently or in combination with natural and/or anthropogenic activities and disturbances (Bestelmeyer et al. 2003, 2009; Briske et al. 2008). The STM provides information which describes and depicts the mechanisms, indicators, causes, and thresholds of functional change and transitions between plant communities and soils based on management practices, natural disturbances, and other anthropogenic effects, along with pathways for management and restoration (USDA-NRCS

1997). State-and-transition models are simple box-and-arrow diagrams of observed or theoretical successional phases and stable plant community states (boxes), and transition and disturbance pathways between phases and states that can occur on the same spatial areas over time (arrows) and are linked by their dynamic relationships (Bestelmeyer et al. 2003, 2009; Briske et al. 2008, Holmes and Miller 2010).

State-and-transition models have been widely used for management and evaluation of rangelands and are used to help predict potential vegetation changes and identify factors that drive these changes, thus providing useful information describing potential changes in wildlife habitat across landscapes or home ranges (Hemstrom et al. 2002, Holmes and Miller 2010, Shaver 2010). As such, this framework can aid managers in evaluating potential changes in wildlife populations, diversity, and sustainability across vegetative community phases and help to evaluate the consequences of transitions to alternative states. The knowledge of ESDs and the current state and community phase provides information on the mechanisms that shift ecological sites to less desirable states or community phases as well as the likelihood of successful restoration (Holmes and Miller 2010). State-and-transition models can aid in documenting successful pathways for restoration as well as kinds of disturbances leading to deterioration of critical ecosystem properties (Holmes and Miller 2010).

Ecological Thresholds

Ecological thresholds are applied within the state-and-transition model framework as they differentiate among the various stable states that theoretically make up individual ecological sites (Briske et al. 2006). Thresholds have been defined as, “boundaries in space and time between any and all states, such that one or more of the primary ecological processes has been irreversibly changed and must be actively restored before return to the previous state is possible" (Briske et al. 2006). Threshold recognition and prediction helps managers prevent the occurrence of undesirable states, therefore, promoting the occurrence of desirable states. A threshold is best described as the restrictions to the current states resilience once a threshold has been crossed, and one state has changed to another, returning to the former state or a more desired state is difficult without restoration or management alteration (Westoby et al. 1989, Laycock 1991, Bestelmeyer 2006, Briske et al. 2008, Holmes and Miller 2010). This new state results in an entirely new group of vegetative community phases which are very different in plant composition, structure, and function and therefore provide different kinds of habitat for wildlife species (Holmes and Miller 2010).

Ecological thresholds were formed from the multiple stable states concept to help describe boundaries between alternative stable states that have the potential to occur on individual sites (Briske et al. 2006). This concept was the first to emphasize the significance of the idea that ecosystems may move from one stable state to another (Briske et al. 2006). The amount of disturbance or modification required to transform a system from one alternative stable state to another is termed ecological resilience (Briske et al. 2008). Ecosystems can be described as two or more alternative stable states with the occurrence of state transitions based upon shifts between distinctive structures and processes. Thresholds represent environmental factors which alter ecosystem structures and functions beyond the limits of ecological resilience resulting in alternative stable states (Briske et al. 2008).

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CHAPTER 2: COMPARING ECOLOGICAL SITE DESCRIPTIONS TO SELECTED HABITAT CHARACTERISTICS OF PLAINS SHARP-TAILED GROUSE ON THE GRAND RIVER NATIONAL GRASSLAND IN NORTHWEST SOUTH DAKOTA

Introduction

The plains sharp-tailed Grouse (*Tympanuchus phasianellus jamesi*; STG) are a native, gallinaceous bird found throughout much of the Northern Great Plains and western United States (Marks 2007, Vodehnal et al. 2007, Flake et al. 2010). Sharp-tailed grouse are of interest for their aesthetic and recreational values, as well as being an indicator species for overall grassland health and quality (USFS 2002, Vodehnal et al. 2007, Dyke et al. 2010). Sharp-tailed grouse have declined gradually from historic levels across their range (Marks 2007, Vodehnal et al. 2007, Boyd et al. 2011, Dyke et al. 2015). Though a variety of factors have contributed to this decline, essential causes are the conversion, degradation, and fragmentation of extensive prairies within remaining grasslands across the species range (Connelly et al. 1998, Marks 2007, Vodehnal et al. 2007, Beck 2009, Flake et al. 2010, Boyd et al. 2011, Dyke et al. 2015). North American grasslands have been identified as one of the most endangered ecosystems; with conversion, degradation, and fragmentation of native grasslands resulting in many grassland-dependent species being threatened, endangered, or species of concern and showing consistent population declines (Samson et al. 2004, Vodehnal et al. 2007, Boyd et al. 2011, Dyke et al. 2015, Sauer et al. 2017).

Sharp-tailed grouse are area-sensitive and thrive where landscape characteristics such as the amount, quality, type, and patchwork of land uses are such that encourage the presence and abundance of populations (Marks, 2007, Vodehnal et al. 2007, Flake et al. 2010, Boyd et al.

2011). In South Dakota, general distribution and abundance are associated with extensive, unfragmented grasslands or prairie-shrubland ecotypes (Connelly et al. 1998, Flake et al. 2010). Habitat selection and use of vegetative cover by STG is generally dependent upon land use and management, vegetative species diversity, and the availability of quality habitat (Johnsgard 1973, Kohn 1976, Vodehnal et al. 2007). Sharp-tailed grouse are an important indicator species utilized by land managers for overall assessment of management and conservation practices of grasslands (USFS 2002, Dyke et al. 2010). By managing grasslands for STG, many other grassland-dependent species may be adequately provided for (Vodehnal et al. 2007). In general, indicator species possess characteristics that its status and population trend provide insight into the overall health and functionality of the ecosystem to which it belongs (USFS 2002, Dyke et al. 2010). The United States Forest Service (USFS) uses management indicator species to help determine how their management actions influence the overall ecosystem; STG have served as an indicator species for numerous USFS managed grasslands throughout the Great Plains and are now considered a focal species and continue to play an important management role (USFS 2002, Dyke et al. 2010).

The United States Department of Agriculture-Natural Resource Conservation Service (USDA-NRCS) has developed a land classification, monitoring, and management system based on ecological sites. An ecological site is defined as, “a distinctive kind of land with specific physical characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation” (USDA-NRCS 2006). In other words, ecological sites are distinctive landforms with specific soil properties, geology, topography, hydrology, and climate characteristics that differ from each other in their response to management actions and natural disturbances (USDA 1997, Pellant et al. 2005, Williams et al. 2011). The relationship and understanding between landscape variations, alternating soil types and properties, and vegetation communities across the landscape is best described by ecological sites (USDA 1997, Boltz and Peacock 2002). Ecological sites are set up as a localized system within a broader-scale hierarchy of Major Land Resource Areas (MLRAs) and Land Resource Units (LRUs) and are delineated using a hierarchical subdivision of MLRAs and LRUs in relation to climate, landform topography, and soils (USDA, NRCS 2006); MLRA's are regional divisions of the United States based on obvious differences in climate, physiography, plant distribution, and land uses; LRU's are subdivisions of MLRA's that distinguish areas of different regional climate and/or geomorphology (Bestelmeyer and Brown 2010).

Ecological site descriptions (ESDs) are a valuable resource to aid land managers and private landowners to better understand the landscape and how ecological functions occur across the landscape (Gilgert and Zack 2010). Ecological site descriptions are reports that use various data to describe and illustrate the complex properties that make up individual ecological sites; their physiographic features, climatic conditions, hydrologic features, associated vegetative communities, and soil features. Ecological site descriptions include "reference" conditions, which present pre-European settlement vegetation, descriptions of proper functioning conditions, model graphics and text, description of ecosystem services provided, as well as other interpretations for use and management (Boltz and Peacock 2002, Sedivec and Printz 2012). Valuable land use and management information contained in ESDs include: plant community dynamics, state-and-transition models (STMs), annual vegetative production estimates, vegetative growth curves, stocking rates for livestock, and interpretations for land use and management of the site (Boltz and Peacock 2002). State-and-transition models have been developed for each ecological site description to illustrate common and potential plant communities that may occur in response to annual/seasonal climatic events and land management/use practices over time (i.e. threshold changes; Bestelmeyer et al. 2003, Williams et al. 2011). Ecological site descriptions, their STMs, coupled with Geographic Information Systems (GIS) spatial data provide a framework for rangeland monitoring and assessment (Karl and Herrick 2010, Sedivec and Printz 2012). For land managers, ESDs provide insight into what changes can be anticipated in response to management and/or disturbances and provide reference material for the analysis of rangeland management and assessment data (Karl and Herrick 2010, Townsend 2010). Additional efforts have been made to expand ESDs to include woodlands and forests (Townsend 2010), riparian systems (Stringham and Repp 2010), and wetlands and wildlife habitat (Gilgert and Zack 2010).

Despite the growing use of ESDs and STMs in rangeland management, little is known regarding their usefulness in wildlife management (Holmes and Miller 2010, Letnic and Dickman 2010, Williams et al. 2011). Furthermore, while information exists within ESDs and STMs that can be used to predict changes in vegetation composition due to land use, management, and disturbances, little is known regarding wildlife response to changes or their use of plant communities found within the various stages of the STM. The inclusion of information about important biological parameters pertaining to indicator species within ESDs and STMs will provide resource managers an additional tool to help determine not only how management will affect vegetation, but also, how it may impact grassland-dependent wildlife species. As part of a nesting study focused on STG, we questioned whether ESD classifications were useful for determining nest site selection and survival and evaluated how grouse were using certain states within STMs of different ESDs as nesting resources.

The goal of our research was to provide information concerning STG nest ecology that would help make more informed management decisions in future grassland management plans. Our objectives were to: 1) evaluate STG nest site selection and survival based on vegetation characteristics and ESD, and 2) determine which ecological sites are being used by grouse and identify State(s) within STM actively used by nesting grouse. We questioned if nesting STG would select nest sites with greater non-native grasses, non-native forbs, and litter biomass relative to what is available on the landscape. Previous research has demonstrated the importance of structure (vegetation density and height) for nesting STG (Goddard et al. 2009). On the Grand River National Grassland (GRNG), structure is typically provided through non-native grasses, non-native forbs, and litter. We also questioned if nesting STG would select more frequently for ESDs that produce greater annual biomass and that this would result in a positive correlation with nest success. Also, we questioned if nesting STG would tend to select for Loamy ecological site and landscape position and these attributes would have a positive correlation on nest site selection. Regarding STM, we questioned how STG would use States within each ESD as nesting resources and if a State(s) would show correlation on nest site selection and success. Lastly, we analyzed if habitat attributes selected for during nesting could result in greater nest survival relative to those variables found to be unimportant during selection.

Study Area

The study was conducted on the GRNG in Corson and Perkins counties, South Dakota (SD), USA. The GRNG is a management unit of the USFS Dakota Prairie Grasslands. The GRNG is located near Hettinger, North Dakota (ND) and Lemmon, SD; approximately 193 km southwest of Bismarck, ND; and 322 km northeast of Rapid City, SD. The GRNG is approximately 63,000 hectares (ha) managed for multiple uses by the USFS, including cattle grazing. Livestock grazing contributes to the local rural economy and aids in upholding economically viable ranching operations, as well as a tool for grassland management.

The GRNG is located within the Missouri Plateau (unglaciated and glaciated), predominantly unglaciated with the eastern and northern edges glaciated. Soils are primarily mollisols and entisols, which have a frigid soil temperature regime with an ustic soil moisture regime and mixed or smectitic mineralogy (USDA, NRCS 2006). Most of the soils are borolls, ranging from shallow to very deep, excessively drained to moderately well drained, and loamy or clayey. Much of the area supports native grasses and shrubs; with the rest of the area used for dryland farming of small grains crops, corn (*Zia mays*) and alfalfa (*Medicago sativa*; USDA, NRCS 2006). The study area was found within MLRA 54 Rolling Soft Shale Plain, covering approximately 76,000 km^2 in North Dakota (64%), South Dakota (33%), and Montana (3%; USDA, NRCS 2006). Loamy ecological sites dominate the MLRA (Figure 1); however, shallow loamy (Figure 2), clayey (Figure 3), and sandy (Figure 4) ecological sites make up a considerable portion of the area.

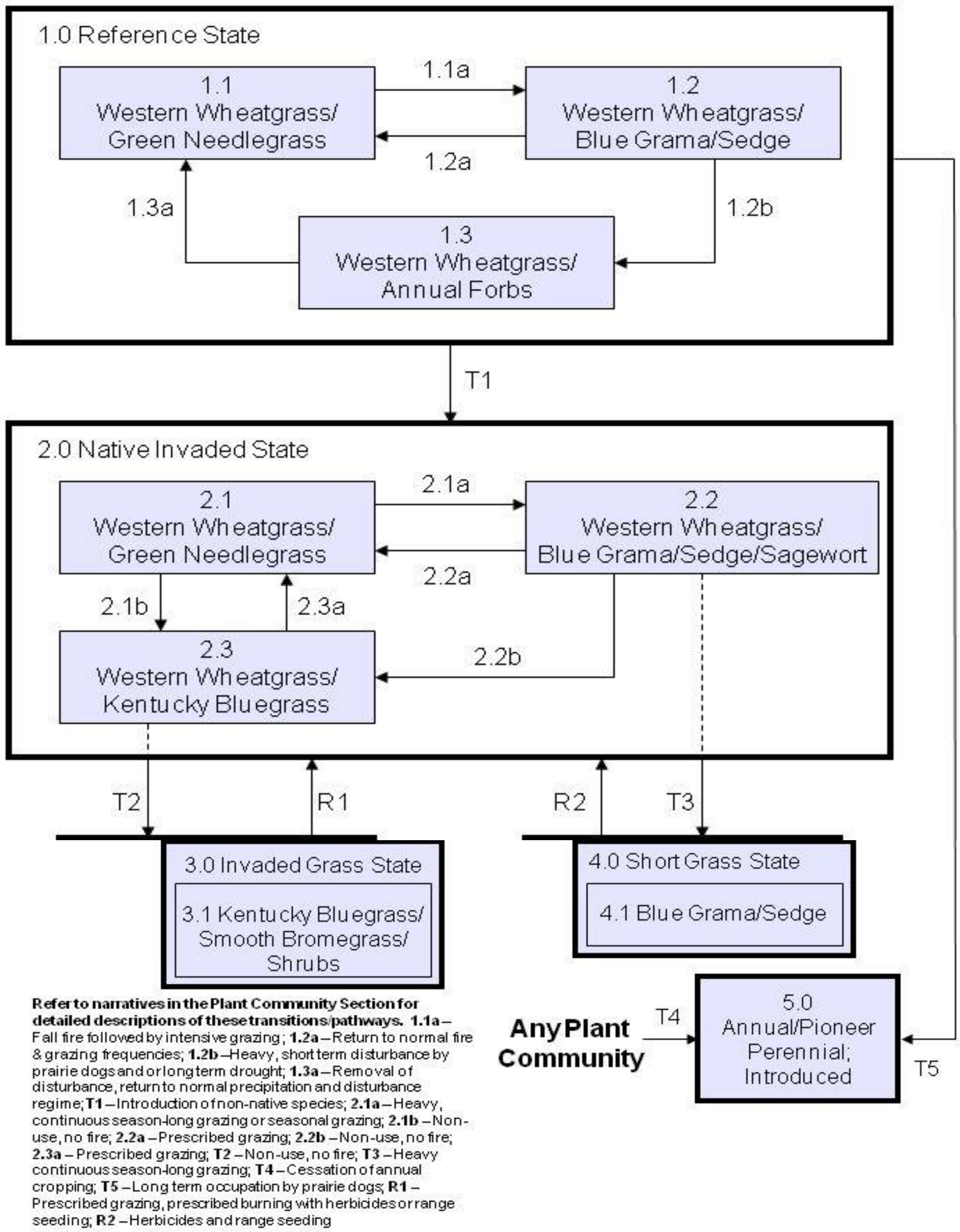

Figure 1. State-and-transition model diagram for loamy ecological site in Major Land Resource Area 54 (USDA-NRCS 2012). Climax Community State 1.0 ‘native’ state of grassland succession, with thresholds “T” and restoration pathways “R” represented in the model for all other states.

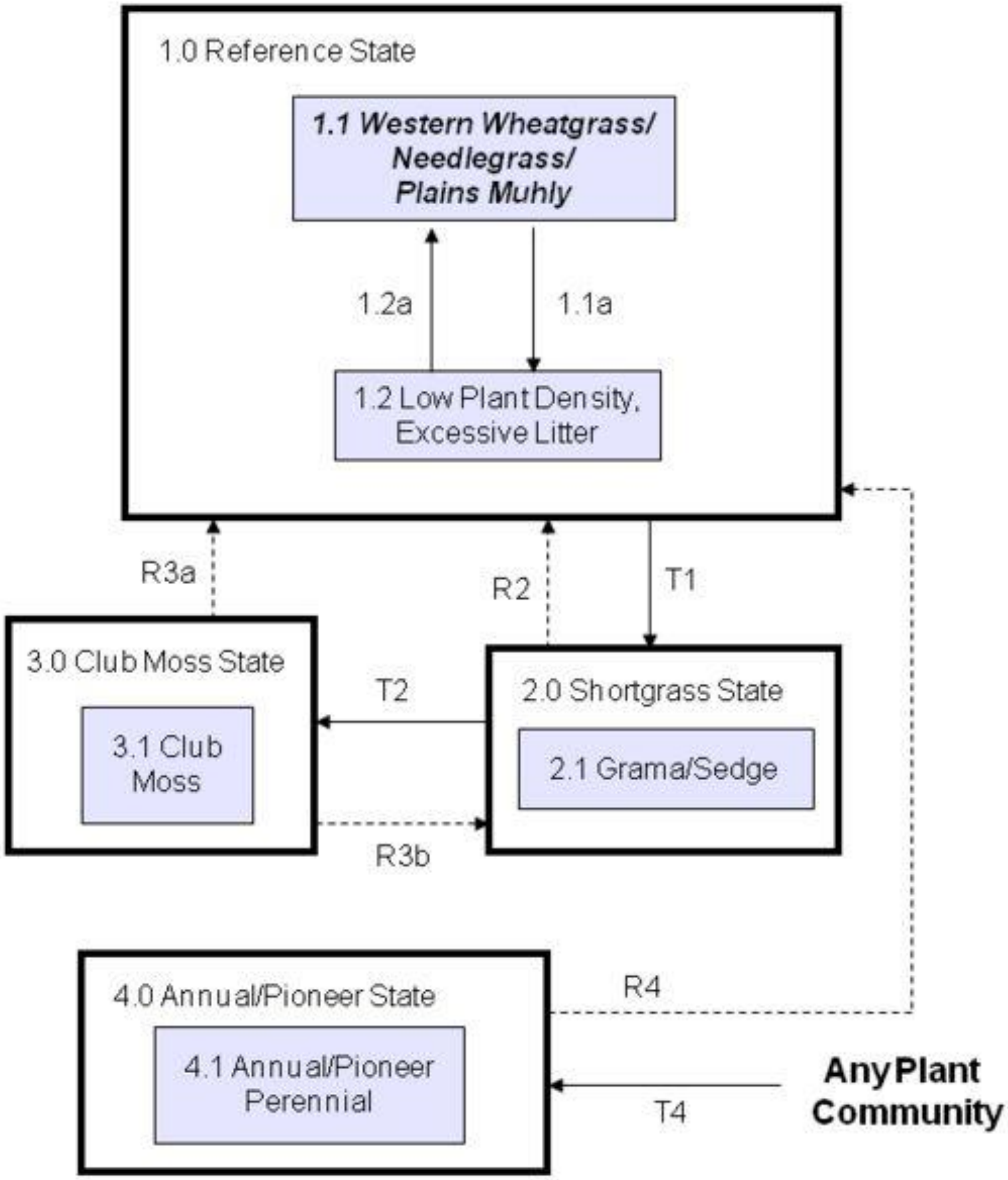

Figure 2. State-and-transition model for shallow loamy ecological site in Major Land Resource Area 54 (USDA-NRCS 2012). Climax Community State 1.0 ‘native’ state of grassland succession, with thresholds “T” and restoration pathways “R” represented in the model for all other states.

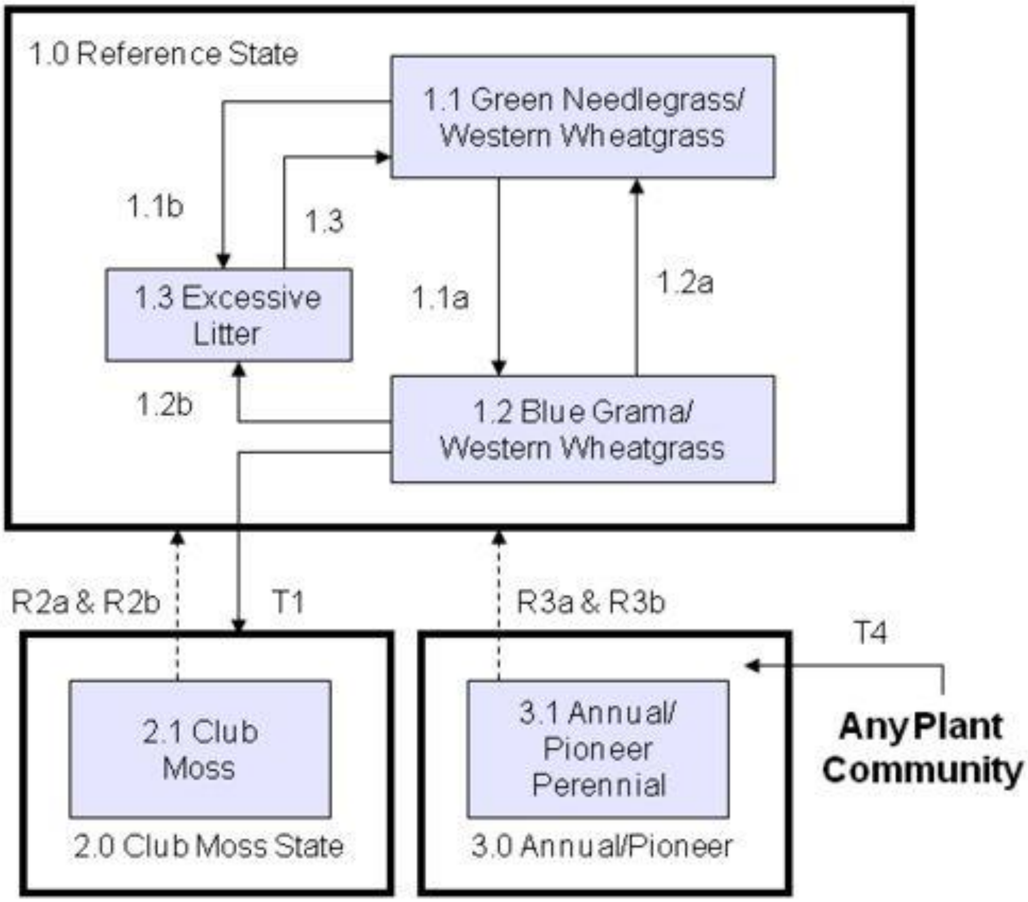

Figure 3. State-and-transition model for clayey ecological site in Major Land Resource Area 54 (USDA-NRCS 2012). Climax Community State 1.0 'native' state of grassland succession, with thresholds "T" and restoration pathways "R" represented in the model for all other states.

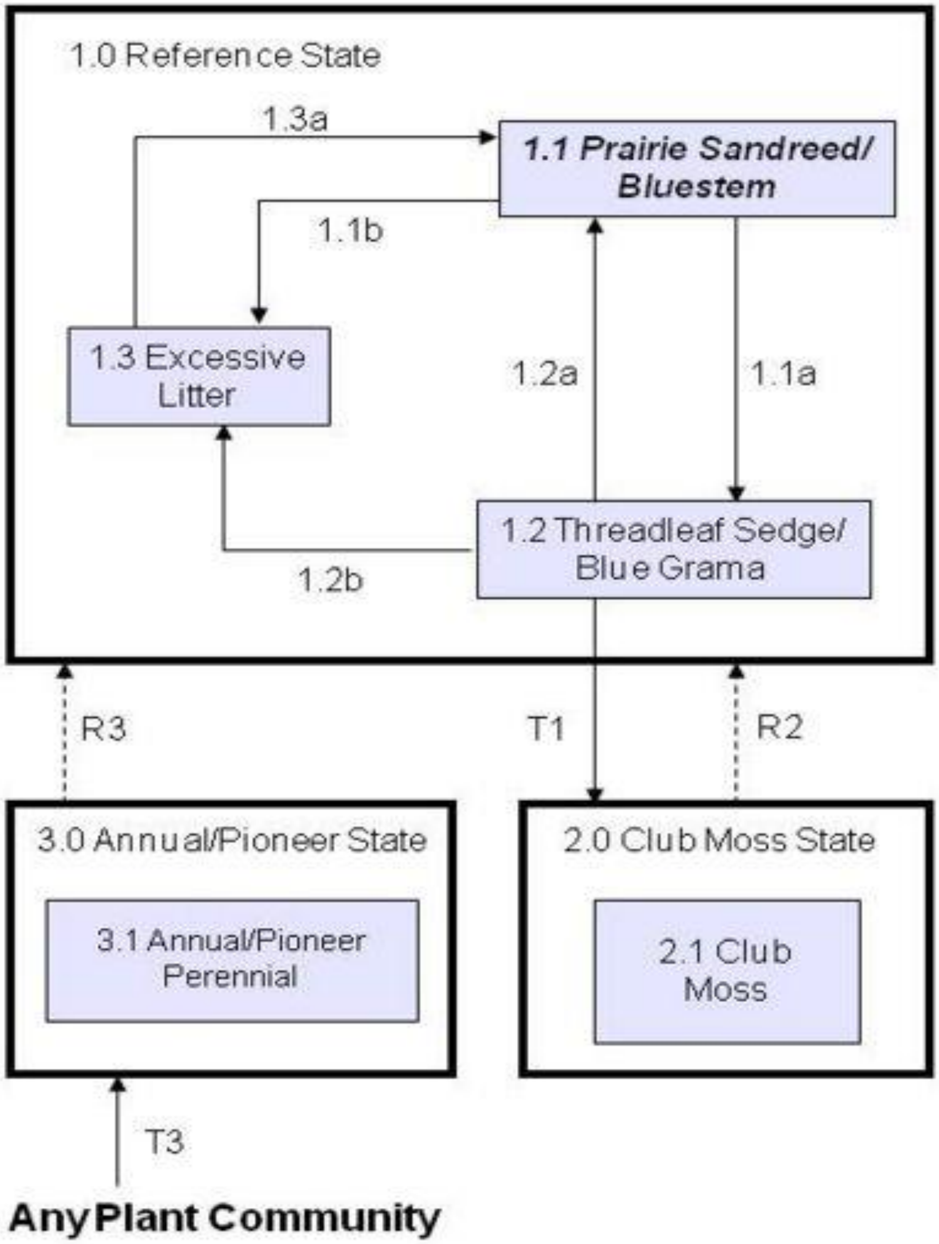

Figure 4. State-and-transition model for sandy ecological site in Major Land Resource Area 54 (USDA-NRCS 2012). Climax Community State 1.0 'native' state of grassland succession, with thresholds "T" and restoration pathways "R" represented in the model for all other states.

The area is considered northern mixed-grass prairie (Hansen 2008) where the vegetative community has been described as a wheatgrass-needlegrass ecotype (Barker and Whitman 1989), with dominant grass species including western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*), needle-and-thread (*Hesperostipa comata*), green needlegrass (*Nassella viridula*), and prairie junegrass (*Koeleria macrantha*). Common forb species include western yarrow (*Achillea millefolium*), purple coneflower (*Echinacea angustifolia*), prairie coneflower (*Ratibida columnifera*), and purple prairie clover (*Dalea purpurea*). The dominant sedge species is thread-leaf sedge (*Carex filifolia*) (Hansen 2008; USDA, NRCS 2011).

The area was intensely farmed during the first half of the twentieth century; a measure of the total affected area is not accurately known (Hansen 2008). The unfavorable effects of tillage on these marginal lands were recognized and most of these tilled lands were abandoned or returned to grass during the Great Depression and Dust Bowl years of the 1930's (Hansen 2008). Crested wheatgrass (*Agropyron cristatum*) was by-and-large the most common grass species used for reseeding efforts, and occupies abandoned fields and much of the GRNG today (Weisner 1980); with more current introductions/invasions of smooth bromegrass (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), yellow sweetclover (*Melilotus officinalis*), common dandelion (*Taraxacum officinale*), and western ragweed (*Ambrosia psilostachya*). Native rangelands on the GRNG are generally restricted to areas with steeper slopes, sandy soils, or other areas deemed un-tillable during the early settlement period (e.g. rocky outcroppings, shallow soils) (USDA, NRCS 2006).

The elevation of the study area ranges from 715 to 890 m. The GRNG, much like the region, has a Köppen climate classification characterized by cold winters and hot summers. The region experiences intermittent severe droughts, and erratic precipitation (355 - 535 mm·year). Annually, the area receives an average of 384 mm of precipitation; typically, in the form of rain; however, average monthly precipitation totals for Corson County and Perkins County, South Dakota from 1981 - 2010, and Hettinger, Adams County, North Dakota from 2009 - 2012 during the nesting season indicate that the GRNG receives its greatest precipitation during the months May - July (Table 1 and Table 2; UNL 2018; USDA-NRCS 2006; NDAWN 2019). Annual precipitation accumulation totals from 2009 - 2012 showed a continuous upward trend in the region during all study years (Table 2; NDAWN 2019). Mean annual air temperature is 3 - 8 C°, with a freeze period lasting for approximately 130 - 165 days. The mean average daily temperature for January is -9 C°, while the mean average daily temperature in July being 22 C° (UNL 2011). Prevailing surface winds are out of the northwest in the winter and south-southwest in the summer (UNL 2011). Year-round surface winds average nearly 18 km·hour (UNL 2011).

Table 1. Monthly growing season average total precipitation (centimeters) Corson and Perkins counties, South Dakota, USA, from 1981-2010. UNL 2018. Available at: https://hprcc.unl.edu/datasets.php?set=CountyData

County	*April*	*May*	*June*	*July*	*August*	*September*
Corson	4.04	6.80	8.23	6.81	4.75	3.73
Perkins	4.23	7.16	7.57	5.94	4.19	3.20

Table 2. Monthly growing season total precipitation (centimeters) Hettinger, Adams County, North Dakota, USA, from 2009-2012. NDAWN 2019. Available at: https://ndawn.ndsu.nodak.edu/weather-data-monthly.html

	2009	*2010*	*2011*	*2012*	*Monthly Normal*
April	2.07	5.16	5.82	7.49	3.80
May	3.52	9.29	11.25	5.59	6.20
June	9.76	7.36	8.12	5.96	8.10
July	5.29	9.29	4.28	10.01	5.80
August	8.44	4.99	5.34	5.66	4.90
September	1.40	8.20	0.87	0.05	3.70

Methods

Data Collection

Female Capture – STG were captured at lekking sites across the GRNG from 2009-2012 utilizing techniques described by Toepfer et al. (1987), and Schroeder and Braun (1991). Funnel traps consisted of chicken wire leads which led into larger cylindrical shaped traps made of galvanized fencing. Each cylindrical trap had one to three entrances. Traps were placed around the lekking arena in various configurations. We weighed, sexed, and banded all captured STG with butt-end aluminum leg bands. Female STG were fitted with 14 g necklace style radio transmitters (Advanced Telemetry Systems (ATS); Isanti, Minnesota).

Locating and Monitoring Nests – We located radio-marked STG two to three times weekly using both homing and triangulation techniques from early breeding, ovipary, and incubation periods. Once a hen was believed to be incubating, we approached the bird on foot to minimize disturbance and reduce the risk of damaging nests. The location of each bird and nest was marked on a Global Positioning System (GPS) unit (Garmin Ltd., Olathe, KS). In the event a nest was present, we flushed the hen to determine clutch size and approximate day of nest initiation. Nest sites were monitored every 5 days until nest fate was determined (Klett et al. 1988). Efforts were taken during future nest checks not to disturb sitting hens. Nests were considered successful if ≥1 egg hatched; identified by the presence of eggshell membranes. The North Dakota State University Institutional Animal Care and Use Committee approved trapping and handling techniques (Approval #0929).

Habitat Measurements – We assessed nest site characteristics following nest completion. We estimated vegetation production and composition by centering a 0.18 m^2 range hoop over the nest bowl and then rolling it over on end, repeating this in all four cardinal directions, and clipping all vegetation within each hoop to ground level, for a total of five clippings per site. We sorted clipped vegetation from each hoop into functional groups including non-native cool season grasses, native cool season grasses, warm season grasses, native forbs, non-native forbs, shrub, *carex* spp., *juncus*/*equisetum* spp., and litter. Vegetation was dried for 48 hours at 55 C°, weighed, and used to calculate the average total $kg \cdot ha^{-1} \cdot functional\ group^{-1}$ for each nest site (BLM 1999). We also collected similar vegetation data at two random points for each nest within the same pasture using identical techniques. This data was further used to help determine appropriate ESD and to assign a current “State” for each nest and available site within the STM for the four most common ESDs within the GRNG (loamy, clayey, shallow loamy, sandy).

Ecological Sites – We determined ESD for nests and random sites using USDA-NRCS protocol where soil type, landform features, elevation, aspect, and vegetation sampling were used for evaluation and determination; soil pits were dug to approximately 61 cm to determine surface and subsurface textures, depth, and other soil characteristics (USDA, NRCS 2014). Vegetation production is variable for each ecological site in a given area due to differences in surface soil depth, soil texture, soil moisture, annual precipitation, local topography, and soil salinity (Printz and Sedivec 2012). Ecological site data for each nest and random location was obtained from the USDA-NRCS Web Soil Survey website (USDA, NRCS 2017) and field verified to ensure an accurate ecological site determination was made. Complete versions of ecological site descriptions are available on the Web at (http://esis.sc.egov.usda.gov/).

State-and-Transition Models – A STM describes alternative states, variability within states, processes that cause plant community shifts, recommendations for maintenance and management of a current state, transitions between states, and recommendations for potential restoration actions (USDA, NRCS 2014). An STM diagram provides a general graphical overview and a visual representation (Figures 1-4) of the potential ecological response(s) of a site to various disturbances and management actions and the various potential transitional pathways that may occur (USDA, NRCS 2014). Current State was determined for each nest and random site using vegetation production totals for each functional group within the four most common ecological sites and associated STM.

Data Analysis

Nest site selection – We used conditional logistic regression for matched case-control data to assess the impact of vegetation production, ESDs, and landscape position on nest site selection of STG. We treated nests sites as cases and random sites as controls (Hosmer and Lemeshow 2000). Thirteen *a priori* models were used to assess nest site selection. We grouped models by biomass and ecological site description. We included the quadratic effect of each covariate at least once within the model set as some birds are known to avoid extremes (Geaumont et al. 2017). Models that included the quadratic responses also included the linear response in the same model. We confirmed covariates within the same model were uncorrelated ($r \geq 0.06$) using a Pearson correlation test prior to analysis.

We used Akaike's Information Criterion corrected for small sample size (AICc) and Akaike weights as evidence of support for each model (Burnham and Anderson 2002). We considered models with difference (Δ) in ΔAIC ≤ 2 of the top model to be supported (Burnham and Anderson 2002). We examined the 95% Confidence Interval (CI) for each coefficient estimate in the top model set to further evaluate the importance of each variable to nest site selection. We considered coefficient estimates that included zero in the 95% CI to be uninformative. Odds ratios were calculated for all variables in the top model set that did not include zero in their 95% CI (Anteau et al. 2012). Conditional regressions were performed in R (R Core Team 2015) using the survival package (Therneau 2015).

State-and-Transition Model - We chose not to statistically compare States within each STM due to infrequent observations in many States. We will present an overlook of the nest site data for all study years and State determination in the Results and Discussion section.

Survival Analysis – Program MARK was used to examine the effect of cover, time, and ESD on STG nest survival. We examined a similar model set as was evaluated during nest site selection. We omitted the landscape position model during survival analyses due to the model not converging and providing felonious results. In addition to the 13 habitat models, we also fitted a constant and year model set for comparison purposes. We fit a constant survival model that included no additional parameters to compare other models to. A total of 15 models investigating the influence of habitat and time on nest survival were examined (Geaumont et al. 2017).

We ranked models using Akaike's Information Criterion corrected for small sample size (AICc) and employed Akaike weights (w_i) as evidence of model support (Akaike 1973, Burnham and Anderson 2002). All models within ΔAICc ≤ 2 of the top model were considered supported (Burnham and Anderson 2002). We examined the 95% Confidence Interval (CI) for each coefficient estimate in the top model set to further evaluate the importance of each variable to nest survival. We considered coefficient estimates that included zero in the 95% CI to be uninformative. Days were standardized within the nesting season with 5 May, the earliest day a nest was located throughout the study, serving as day 1 of the nesting season and 30 July, the last day a nest was monitored, serving as the last day of the nesting season. As a result of the standardized nesting season, 84 daily estimates of survival could be calculated. A logit link function was used during all survival modeling procedures.

Results

Nesting Parameters

We monitored and determined fates for 86 STG nests. The median nest initiation date pooled for all years was 5 May. Nest and available combined mean vegetation production across the GRNG per functional group across all years included: non-native cool season grasses, 625 ± 50.4 kg·ha.; native cool season grasses, 549 ± 35.9 kg·ha.; warm season grasses, 166 ± 14.6 kg·ha.; native forb, 135 ± 11.2 kg·ha.; non-native forb, 96 ± 19.1 kg·ha.; shrub, 86 ± 17.9 kg·ha.; *carex* spp., 87 ± 15.7 kg·ha.; *juncu*s/*equisetum* spp., 0.3 ± 0.37 kg·ha.; and 776 ± 50.4

kg·ha., litter. An average of twelve eggs were laid in a STG nest. The apparent nest success ranged from year to year at 45%, 46%, 71%, and 67% from 2009-2012, respectively. Hens placed their nests an average 1,495 ± 121 m away from their lek of capture (Figure 5).

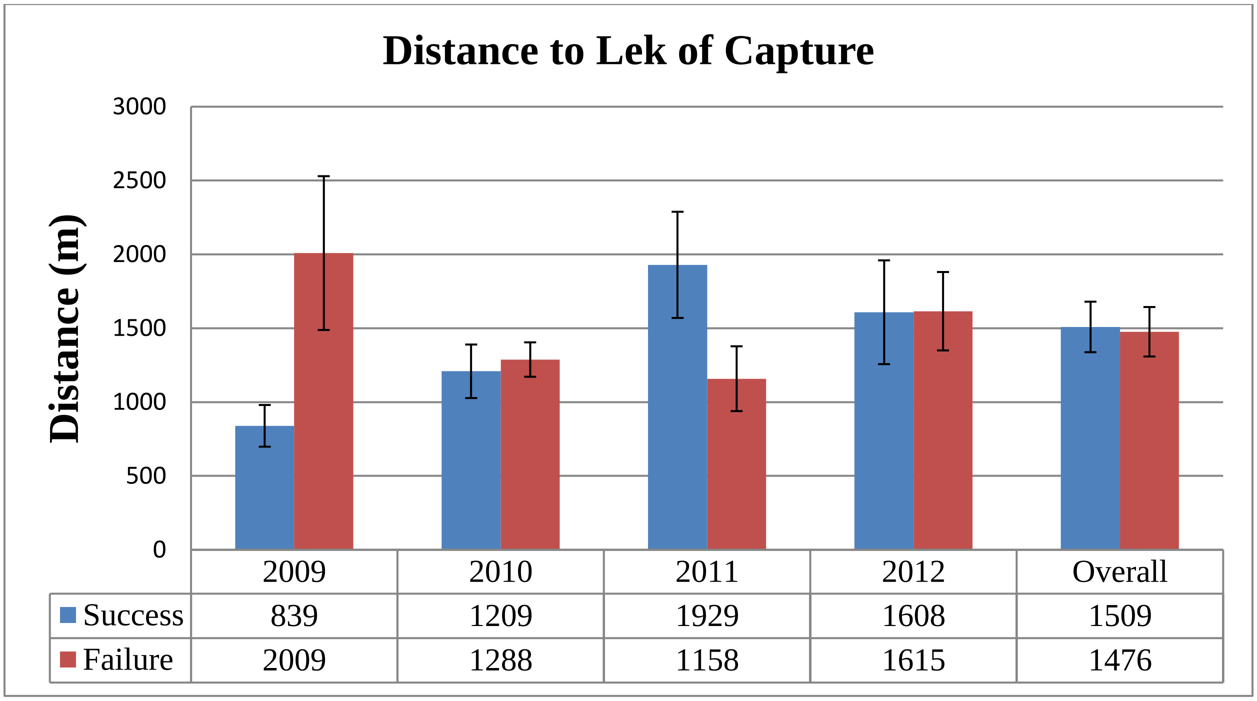

Figure 5. Mean distance and standard error from lek of capture to nest site of successful and failed STG nests (N=86) on the Grand River National Grassland near Lemmon, South Dakota, USA, 2009-2012.

Nest Site Selection – We determined ecological site descriptions for 84 nest and 168 random sites. We identified 13 different ESD and found STG used nine of them for nesting (Figure 6). Loamy ecological site was the most encountered ESD during our study when combining both used and random sites (Figure 7). There were two competing models regarding nest site selection of STG (Table 3). The top model consisted of non-native forbs and native cool-season grasses (AICc = 122.62) and the model including all grass and forb categories was the second best (ΔAICc = 1.08; Table 3). None of the coefficient estimates for variables included in the two top models included zero in their 95% confidence intervals suggesting all played a role in nest site selection (Table 4). All additional models including other variables of interest were not supported (Table 4).

Table 3. Conditional logistic regression models evaluating the influence of specific habitat variables on nest site selection of Plains STG in the Grand River National Grassland near Lemmon, South Dakota, USA, 2009-2012.

Model [a]	*K*	*ΔAICc*	w_i
Non-native Forbs + Native Cool-Season Grasses [b]	2	0.00	0.58
Grasses + Forbs (Separate) [b]	5	1.08	0.34
Grasses + Forbs (Non-native) [b]	4	3.87	0.08
Non-native Forbs (Quadratic) [b]	2	12.22	0.00
Forbs (Separate) [b]	2	16.47	0.00
Litter [b]	1	18.45	0.00
Grasses (Separate) [b]	3	19.46	0.00
Native Grasses (Quadratic) [b]	2	24.89	0.00
Non-native Grasses (Quadratic) [b]	2	37.07	0.00
Total Biomass	1	46.17	0.00
Total Biomass (2)	2	46.42	0.00
Ecological Site Description	12	73.57	0.00
Position	11	73.95	0.00

[a] *K*: indicates number of parameters; *ΔAICc*: difference of each models AICc value from that of the highest-ranked model; w_i: Akaike weights; Grasses: native and non-native cool-season grasses and native warm-season grasses combined; Forbs: native and non-native forbs combined; Litter: residual vegetation; Position: position on the landscape. [b] Functional groups were measured in biomass of overall production in the GRNG.

Table 4. Conditional logistic regression models for coefficient estimate variables of nest site selection and 95% confidence interval from the two top models of nest site selection of STG, Lemmon, SD, USA.

Model	*Expected (coefficient)*	*Expected (-coefficient)*	*Lower 95% CI* [1]	*Upper 95% CI*
Non-native Cool-Season Grasses	0.9999	1.0001	0.9994	1.0005
Native Cool-Season Grasses	0.9983	1.0017	0.9971	0.9994
Warm-Season Grasses	0.9979	1.0021	0.9959	0.9999
Native Forbs	0.9999	1.0001	0.9979	1.0018
Non-Native Forbs	1.0052	0.9948	1.0018	1.0086

[1] CI indicates confidence interval.

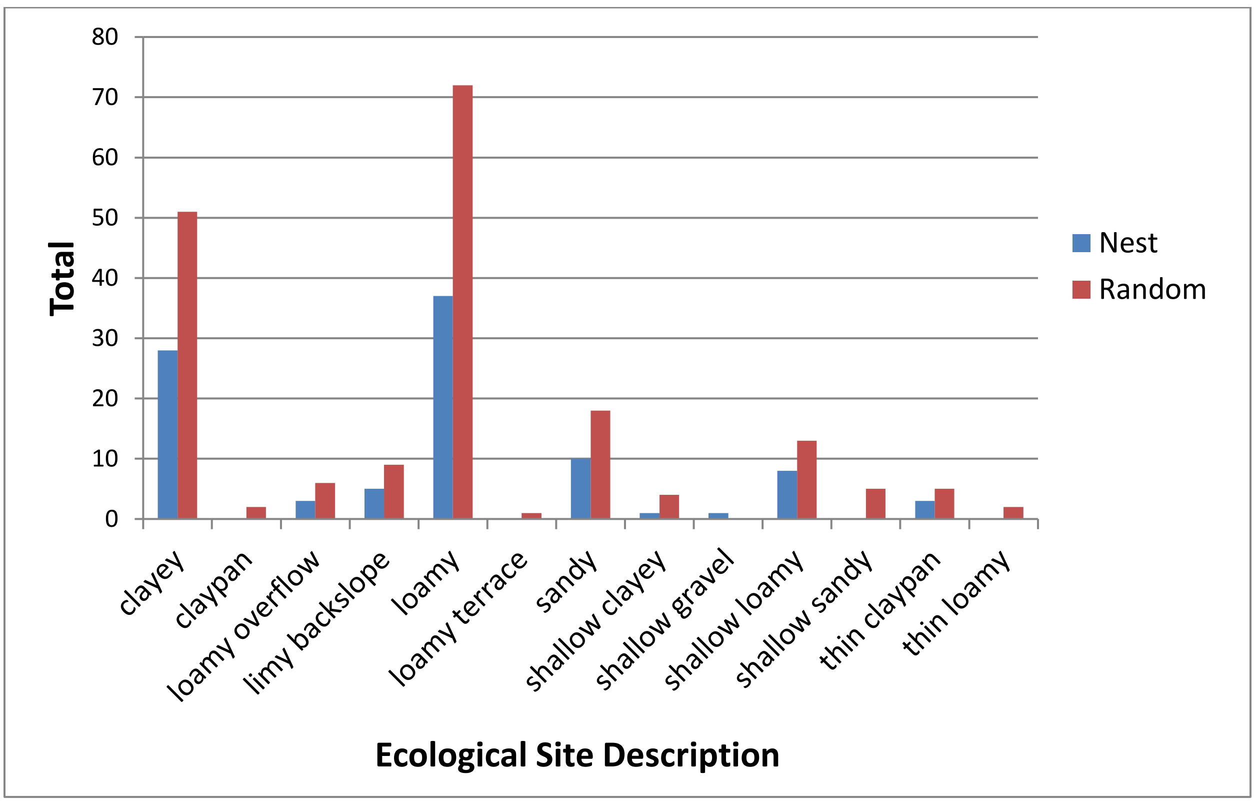

Figure 6. Ecological site descriptions at STG nests and random sites on the Grand River National Grassland near Lemmon, South Dakota, USA, 2009-2012.

State-and-Transition Model – We placed 76 nests and 149 random sites into their associated State within our four most common ESDs. A total of 225 individual State determinations (107 loamy, 73 clayey, 26 sandy, and 19 shallow loamy) were made. For all nest sites within the loamy ESD, only one was within the 1.0 Reference State; 10 nest sites within the 2.0 Native Invaded State; 23 nest sites within the 3.0 Invaded Grass State (30% all nests); two nest sites were within the 4.0 Short Grass State (blue grama/sedge; Table 5; Figure 2). For nests within the shallow loamy ESD only one was within the 1.0 Reference State; two nest sites were within the 2.0 Native Invaded State; no nest or available sites were within the 3.0 Invaded Grass State for this ESD; however, three nest sites were within the 4.0 Short Grass State (blue grama/sedge; Table 5; Figure 3).

Table 5. Nest, random, and percent nest observed per state within the top four ecological site descriptions on the Grand River National Grassland, near Lemmon, SD, USA, 2009-2012.

ESD	State	Nest	Random	Percent Nest Observed
Loamy	**1.1**	0	19	0
	1.2	1	3	1
	1.3	0	3	0
	2.1	2	4	3
	2.2	2	5	3
	2.3	6	14	8
	3.1	23	23	30
	4.1	2	0	3
Shallow Loamy	**1.1**	1	4	1
	1.2	0	8	0
	2.1	2	0	3
	4.1	3	1	4
Clayey	**1.1**	1	10	1
	1.2	3	1	4
	1.3	2	15	3
	3.1	20	21	26
Sandy	**1.1**	0	9	0
	1.3	0	6	0
	3.1	8	3	11

For all nest sites within the clayey ESD, six were within the 1.0 Reference State; no nest sites were within the 2.0 Native Invaded State; 20 nest sites within the 3.0 Invaded Grass State (26% of all nests); no nest sites were within the 4.0 Short Grass State (blue grama/sedge; Table 5; Figure 4). No nest sites within the sandy ESD were within the 1.0 Reference State; no nest sites were within the 2.0 Native Invaded State; eight nest sites within the 3.0 Invaded Grass

State; no nest sites were within the 4.0 Short Grass State (blue grama/sedge; Table 5; Figure 5). The most frequent observed nest site State across the four ESD were Annual/Pioneer Perennial; Introduced and Invaded Grass, 31 total nests and 23 total nests, respectively.

Survival Analysis – We found that daily survival rates of STG nests were most influenced by litter with the second-best model having some support including ESD (Table 6). Despite being included in the top model, the 95% CI for the coefficient estimate for litter included zero (βlitter = 0.0012 ± 0.744, 95% CI = -0.00031 to 0.003), suggesting a lack of influence. Based on the second-best model, the 95% CI for sandy (βsandy = -2.65 ± 1.24, 95% CI = -5.09 to -0.22), thin claypan (βthin claypan = -4.28 ± 1.33, 95% CI = -6.87 to -1.69) and limy backslope (βlimy backslope = -2.67 ± 1.36, 95% CI = -5.31 to -0.001) ESDs did not include zero suggesting a negative influence on the daily nest survival of STG nests located in these ESDs. The 95% CI for all other ESD coefficient estimates included zero. Based on the daily survival estimate associated with the constant survival model (0.977) and a 23-day incubation period, STG nests were 59% successful during our study.

Table 6. Program Mark nest survival models evaluating the impact of specific habitat features on daily nest survival of STG in the Grand River National Grassland near Lemmon, SD, USA, 2009-2012.

Model [1]	*K*	*ΔAICc*	w_i
Litter	2	0.00	0.43
Ecological Site Description	7	2.09	0.15
Constant	1	2.63	0.12
Total Biomass	2	3.93	0.06
Native Warm-Season Grasses	2	4.03	0.06
Total Biomass (2)	3	4.60	0.04
Non-Native Grasses (Quadratic)	3	4.99	0.04
Non-Native Forbs (Quadratic)	3	5.39	0.03
Forbs	3	5.48	0.03
Year	4	6.22	0.02
Non-Native Forbs + Native Cool-Season Grasses	3	6.44	0.02
Grasses	4	7.89	0.01
Native Grasses (Quadratic)	5	9.64	0.00
Grasses + Non-Native Forbs	5	9.85	0.00
Grasses + Forbs	6	10.25	0.00

[1] *K* indicates number of parameters; *ΔAICc*, difference of each models AICc value from that of the highest-ranked model; w_i, Akaike weights; Litter, residual vegetation; Grasses, native and non-native cool-season grasses and native warm-season grasses combined; Forbs, native and non-native forbs combined.

Discussion

Grassland resources provide valuable habitat for many avian species, including STG in the Northern Great Plains. The use of rangelands by grazers, especially livestock, can have varying effects on the grassland resources available to nesting STG from year-to-year. The range profession has seen an increase in use of ESDs and STMs despite little being known regarding their usefulness in aiding wildlife management (Holmes and Miller 2010, Letnic and Dickman 2010, Williams et al. 2011). Our study found that biomass of non-native forbs and native cool-season grasses best characterized differences between nest sites and what was available; a second competing model included the combination of all grasses and forbs categories. Our results suggest that species composition doesn't necessitate the need to resemble the predicted climax community for the site to be considered as a suitable nesting location. Sharp-tailed grouse are likely tolerant to loss of vegetative species diversity and successional changes and are probably seeking vegetative cover for concealment moreover any specific cover type. Loamy and clayey ecological sites were the two most encountered sites during our study, but also produced highest standing crop, which could potentially lead to greater structure for nesting hens. Our observation of STG nest sites with relationship to State within an STM found the most frequent observed nest site State across the four most common ESDs (loamy, shallow loamy, clayey, sandy) were Annual/Pioneer Perennial (e.g. yellow sweetclover, smooth bromegrass, crested wheatgrass, western ragweed); Introduced and Invaded Grass, 31 total nests and 23 total nests, respectively. This observation can likely be attributed to historical and current land uses creating and fostering an environment where early successional stages dominate the landscape and where management practices which further advance grasslands to later successional stages representing a more native or climax community dominated State are lacking. The top model for daily survival rates of STG nests included litter, the second-best model had some support and included ESD; second-best model also showed negative effect on daily nest survival for those nests initiated in thin claypan, limy backslope, and sandy ecological sites. Based on the daily survival estimate associated with the constant survival model (0.977) and a 23-day incubation period, STG nests were 59% successful during our study. Despite being included in the top model, the 95% CI for the coefficient estimate for litter included zero (βlitter = 0.0012 ± 0.744, 95% CI = -0.00031 to 0.003), suggesting a lack of influence. Based on the second-best model, the 95% CI for sandy (β_{sandy} = -2.65 ± 1.24, 95% CI = -5.09 to -0.22), thin claypan ($\beta_{thin\ claypan}$ = -4.28 ± 1.33, 95% CI = -6.87 to -1.69) and limy backslope ($\beta_{limy\ backslope}$ = -2.67 ± 1.36, 95% CI = -5.31 to -0.001) ESDs did not include zero suggesting a negative influence on the daily nest survival of STG nests located in these ESDs. The sandy, thin claypan, and limy backslope ESD nest sites showed attributes of greatest vegetative production being from non-native cool-season grasses and non-native forbs, overall low vegetation production as compared to what the site is capable of, and low shrub and litter production, which may contribute to the negative influence on daily survival.

Our analysis of nest site selection found that biomass of non-native forbs and native cool-season grasses best characterized differences between nest sites and what was available; a second competing model included all grasses and forbs categories in the GRNG across all study years. These findings support our predictions that nesting STG would select nest sites with greater non-native grasses, non-native forbs, and litter biomass relative to what is available on the landscape. Kirby and Grosz (1995) found in southcentral North Dakota, 88% of STG hens preferred to nest in tall, dense cover exceeding four inches and dominated by Kentucky bluegrass and western snowberry. This study highlights the preference of western snowberry dominated plant communities for nest sites, as they compared grazed to non-grazed treatments, finding 75% of all nests located in these plant communities, regardless of treatment. Hillman and Jackson (1973) found nesting STG in central South Dakota constructing nests in grasses and forbs or at the base of a shrub that provided overhead concealment. Our study did not find the importance of western snowberry or other shrub plant communities; however, the prevalence of non-native forbs such as yellow sweet-clover and non-native grasses, along with native cool-season grasses likely provide the needed vertical structure and concealment necessary for STG to have successful nests across the GRNG from year-to-year. Our results also suggest that species composition doesn't necessitate the need to resemble the predicted climax community for the site to be considered as a suitable nesting location. Sharp-tailed grouse are likely tolerant to loss of vegetative species diversity and successional changes and are likely seeking vegetative cover for concealment moreover than any other habitat characteristic (Kirsch et al. 1973).

Selection of a specific habitat characteristic or vegetative community may be more strongly influenced by the overall quality of available habitat to nesting STG (Goddard et al. 2009). We questioned if nesting STG would select more frequently for ESDs that produce greater annual biomass and this would show a positive correlation with nest site selection and success. Our model development of ecological sites found loamy and clayey ecological sites were the two most encountered sites during our study, but also produced highest amounts of standing crop, which could potentially lead to greater structure for nesting hens. Studies in the Northern Great Plains have shown a positive relationship between precipitation and forage production (Smoliak 1986, Sala et al. 1988, Heitschmidt et al. 2005, Patton et al. 2007). Measuring annual standing crop by vegetative clippings and visual obstruction readings (VOR; Robel et al. 1970) are methods commonly used to assess grassland habitat. Woehl (2010) reported mean VOR of 6.0 cm, 5.73 cm, and 5.19 cm on loamy, clayey, and sandy ecological sites, respectively, on the GRNG from 2007 to 2009 with idle to minor grazing. While Klempel (2015) reported mean VOR of 8.3 cm ± 0.77 for loamy, 6.2 cm ± 1.27 for thin loamy, and 8.7 cm ± 0.59 for claypan ecological sites on idle grasslands in the GRNG in 2012.

Roersma (2001) reported poor range condition at nest sites due to climax species comprising less than 25% of the study site and dominated by a western snowberry (*Symphoricarpos occidentalis*)/Kentucky bluegrass/prairie rose (*Rosa arkansana*) community, like what we found in States 2.3 and 3.1. Roersma (2001) concluded that vegetative species composition was not likely to influence STG nest site selection as much as structure and those areas with sufficient residual cover and taller stands of cover throughout the nesting season are selected for their structural components as opposed to actual species present. This study supports our findings, as our results also suggest that species composition doesn't necessitate the need to resemble the predicted climax community (State 1.1, 1.2, 1.3, 2.1, and 2.2) for the site to be considered as a suitable nesting location. We questioned if nesting STG would tend to select for Loamy ecological site and landscape position and if these attributes would have a positive correlation on nest site selection; however, our model development found that this was not supported. Our study does not support the use of ESDs to predict selected habitat characteristic use or base STG management decisions in the GRNG. While ESD speaks to what is capable along the landscape, ESD doesn't account for current and historic land use, management practices, annual or seasonal climatic variations, and how these variables affect available habitat variables such as cover and canopy height, which can immediately affect nest site selection and success of STG from year-to-year. Our findings suggest ESDs could be further defined to be more applicable to STG management by incorporating structural measures known to influence nest site selection and success.

Our observation of STG nest sites with relationship to State within an STM found the most frequent observed nest site State across the four most common ESDs (loamy, shallow loamy, clayey, sandy) were Annual/Pioneer Perennial (e.g. yellow sweetclover, smooth bromegrass, crested wheatgrass, Kentucky bluegrass, western ragweed); Introduced and Invaded Grass, 31 total nests and 23 total nests, respectively (Table 5; Figure 1-4). We questioned how STG would use States within each ESD as nesting resources and if a State(s) would show correlation on nest site selection and success. Our observations showed nest site use and State was overwhelmingly skewed toward sites that are dominated by early successional vegetative stages and low species diversity; typical vegetative species being yellow sweetclover, crested wheatgrass, smooth bromegrass, and Kentucky bluegrass. This observation can likely be attributed to current and historical land uses and reclamation (go-back land) practices employed by the USFS after the dust bowl years creating and fostering an environment where early successional stages dominate the landscape and where conditions which further advance grasslands to later successional stages representing a more native or climax community dominated State are lacking. Differences observed between plant communities and production between sites were likely due to vegetative successional changes and above-average precipitation received over the study years (Table 2). Sharp-tailed grouse are likely tolerant to loss of vegetative species diversity and successional changes and are probably seeking vegetative cover for concealment moreover any specific cover type.

Holmes and Miller (2010) evaluated the use of STMs for predicting changes in habitat use and abundance of grasshopper sparrows (*Ammodramus savannarum*) across five community phases, representing two States in the Columbia Basin, OR. The authors found that changes in grasshopper sparrow abundance significantly differed from one community phase to another within and across States; being most abundant in perennial grasslands and least abundant in depleted community phases. The authors found that STMs help evaluate potential changes in vegetation by comparing pathways and stable successional States for ESDs; the combination of ESDs and STMs allow managers to list current vegetation into community phases and describe potential vegetation communities; STMs list possible pathways for restoration and disturbances which can lead to a decline of ecological site properties and functions; overall, STMs proved to aid in the evaluation of wildlife population changes and viability across community phases and help evaluate the consequences of transitions to alternate states.

State-and-transition models may provide a framework to evaluate potential changes to habitats through management actions or disturbances on vegetation composition and structure and may help predict wildlife species response based on the ecological potential of the site. For example: a majority of nest sites across the GRNG were selected in locations which current State is Annual Pioneer Perennial; Introduced (31 total nests); these conditions were likely created through the discontinuation of tilled agricultural practices and reclamation seeding with non-native vegetative species (e.g. crested wheatgrass). The use of management practices including prescribed grazing and fire, herbicide treatments, and high diversity reclamation seeding could, overtime, allow for the establishment of and transition to a Native Invaded State or other threshold transition to a State with advanced vegetation succession. This State would likely still show signs of disturbance and occurrence or dominance of non-native species, but would resemble a successional stage exhibiting increased amounts of native species, and could be more resilient to climate variations and management actions and could be more suitable to and support greater populations of STG and other grassland dependent species.

Model relationships observed regarding daily survival of STG nests found the top model for included litter, the second-best model had some support and included ESD; second-best model also showed negative effect on daily nest survival for those nests initiated in thin claypan, limy backslope, and sandy ecological sites. Based on the daily survival estimate associated with the constant survival model (0.977) and a 23-day incubation period, STG nests were 59% successful during our study. Despite being included in the top model, the 95% CI for the coefficient estimate for litter included zero ($\beta litter = 0.0012 \pm 0.744$, 95% CI = -0.00031 to 0.003), suggesting a lack of influence. The lack of influence of litter can likely be attributed to our observation of marginal amounts of litter accumulation at nest sites for years 2009 through 2011, with greatest litter accumulation amounts at nest sites observed for year 2012; 21 total nests showed litter accumulation greater than zero across all study years. Litter can be a highly variable habitat component from year-to-year largely due to climatic and management effects. Additionally, our use of a $0.18m^2$ range hoop may have attributed to the lack of litter collected for analysis of standing crop, as this size hoop may have been too small to capture the full amount of standing crop used by the nesting hen for concealment. Our results do not suggest litter to be an important habitat variable on daily nest survival (95% confidence interval of the coefficient estimate included 0); however, litter is likely a contributing factor to nest success due to its aid in concealment and contribution to residual vegetation, as STG begin nesting in advance of the growing season (Eng et al. 1987, Roersma 2001, Prose et al. 2002). Height and density of residual cover during the nesting season are often used as predictors of nesting cover quality for STG (Kohn 1976, Rice and Carter 1982, Messmer 1985, Manske and Barker 1988, Prose et al. 2002). Prose et al. (2002) found STG in the Nebraska Sandhills to select nesting habitat sites in taller (VOR ≥4 cm) residual cover than at random sites.

Goddard et al. (2009) reported nest success of 35% for first nests and 32% for re-nests during their study on habitat features and nest survival in British Columbia, Canada. The authors observed that daily nest survival increased with the amount of woody shrub cover at nest sites during first nest attempts and decreased with greater residual cover at nest sites during re-nest attempts; cover provided from shrubs became less important as the nesting season progressed, and residual vegetation was not a significant predictor of early-season nest survival. Overall, the authors found that STG selected nest sites with greater shrub, grass, residual cover, and taller vegetation. Similarly, Shartell (2018) observed STG nest success in east-central Minnesota of 42% ± 9% and concluded there was no indication hens were selecting for specific nest site characteristics, but that overhead cover and shrub cover were important drivers. Additionally, daily nest survival in our study was comparable to nest success rates of 47 ± 2% reported by Manzer and Hannon (2005) in Alberta, Canada, where the authors found high concealment cover to be the best predictor of nest success. Based on the second-best model, the 95% CI for sandy (βsandy = -2.65 ± 1.24, 95% CI = -5.09 to -0.22), thin claypan (βthin claypan = -4.28 ± 1.33, 95% CI = -6.87 to -1.69) and limy backslope (βlimy backslope = -2.67 ± 1.36, 95% CI = -5.31 to -0.001) ESDs did not include zero suggesting a negative influence on the daily nest survival of STG nests located in these ESDs. The 95% CI for all other ESD coefficient estimates included zero. Nest sites found in the sandy, thin claypan, and limy backslope ESDs contained similar attributes of greatest vegetative production being from non-native cool-season grasses and non-native forbs, overall low vegetation production as compared to what the site is capable of, and low shrub and litter production, which all may contribute to negative influence on daily survival.

Management Implications

Current information included in ESDs and STMs do not address important habitat attributes for STG. If incorporating wildlife specific habitat data into ESDs and STMs is of interest or concern of the USDA-NRCS, they may be able to be improved upon to achieve this goal. The inclusion of lifecycle habitats and important nesting parameters such as structure and biomass of grasses, forbs, and litter pertaining to indicator species like STG within ESDs will help determine not only how management, disturbances, and climatic events will affect vegetation, but also how it may impact grassland-dependent wildlife species. By incorporating habitat and climatic variables into an STM, land managers will have added tools to aid in predicting and monitoring vegetation composition, available habitats and State(s), and consequent wildlife species population response to management practices and other disturbances. Currently, ESDs speak to what is capable along the landscape in terms of percent composition and vegetative production; however, ESDs do not account for current and historic land use, management practices, disturbances, annual or seasonal climatic variations, and how these variables affect available habitat variables such as cover and canopy height, which can immediately affect nest site selection and success of STG from year-to-year. As such, ESD classifications need to be modified to include important STG lifecycle habitat information to be useful for determining nest site selection and survival. To improve the utility of ESDs to wildlife managers the inclusion of vegetative height, canopy cover, and structural measures of visual obstruction (VOR) that are known to influence STG nest site selection and success should be provided. Another consideration to increase the utility of ESDs and STMs to wildlife managers could be to further describe MLRA climatic variables and resultant effects on vegetation production per ecological site and what management considerations should be given depending upon disturbances and management practices in relation to precipitation amounts, current State(s) across the landscape, and desired restoration or threshold changes to a given State(s). Our research highlights the need for ESDs to include strategies for landowners, producers, and wildlife managers that improve ecological diversity and resiliency in times of climatic variability so that grasslands can be affectively managed for both habitat characteristics of grassland dependent species such as STG and livestock production.

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