# A REVIEW OF THE STATE OF SHARP-TAILED GROUSE: WITH MANAGEMENT CONSIDERATIONS IN MINNESOTA AND NORTH DAKOTA

A Paper
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Sciences

By

Matthew Richard Danzl

In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Program:
Natural Resources Management

April 2018

Fargo, North Dakota

# North Dakota State University
Graduate School

**Title**

A REVIEW OF THE STATE OF SHARP-TAILED GROUSE: WITH MANAGEMENT CONSIDERATIONS IN MINNESOTA AND NORTH DAKOTA

**By**

Matthew Richard Danzl

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**

SUPERVISORY COMMITTEE:

Dr. Edward DeKeyser
Chair

Dr. Jack Norland

Dr. Kevin Sedivec

Approved:

April 11th 2018 — Date

Dr. Edward DeKeyser — Department Chair

## ABSTRACT

The sharp-tailed grouse is a member of the family Phasianidae and comprises six subspecies. They are a medium sized bird which are pursued as game in most of its range. Sharp-tailed grouse are found in large areas of North America. They occupy vast grassland areas with various amounts of interspersed brushy components and few trees present. Mating and courtship occur on congregating areas called leks or “dancing grounds”. These areas are a focal element of their local population centers and occupy a portion of their relatively large individual home ranges. Due to their large home ranges, researchers have applied the term “indicator” or “umbrella” species to them because of their importance on the landscape to other species. Portions of their range are decreasing and becoming more fragmented. Principle causes are linked to agriculture development, ecological succession, conifer plantations, and energy development. Populations across their range have declined from historic levels.

## ACKNOWLEDGEMENTS

I would also extend sincere thanks to my advisor, Dr. Edward DeKeyser for accepting me as a graduate student while continually helping me through this journey and seeing it through till the end. Also, for getting me involved with wetland science which has spurred many new professional opportunities. I have Dr. Benjamin Geaumont to thank for getting me started on the topic of sharp-tailed grouse and greatly appreciate the opportunity to conduct field work with the grouse on the Grand River National Grasslands. I would also like to acknowledge the help of Dr. Bryan Neville for his leadership and encouragement while working at Central Grasslands Research Extension Center (CGREC) and attending graduate school. My supervisor at CGREC, Dr. Goujie Wang, also played a key role in offering advice and allowing me to pursue this scholarship while working for him. I appreciate Dr. Jack Norland's teachings, lectures, and influential GIS help. I have Dr. Kevin Sedivec to thank for putting me on my first mule deer which ended up being the first and only deer I've taken with a gun.

This paper would not be possible without the ongoing support of my parents, Dale and Cathy; continually encouraging me to persevere through the difficult times. Thank you for being there for me, I love you. I would also like to extend thanks to Kim and Tim for their frequent encouragement and interest in my progress. Finally, I am also deeply thankful to my wife, Allison, for keeping the ship afloat while this important accomplishment was pursued.

## DEDICATION

I dedicate this paper to my son, Isaac. May you forever be able to enjoy and hunt stable populations of prairie grouse and pass that heritage down to your children and theirs as well.

## TABLE OF CONTENTS

ABSTRACT ..... iii

ACKNOWLEDGEMENTS ..... iv

DEDICATION ..... v

LIST OF TABLES ..... viii

LIST OF FIGURES ..... ix

1. INTRODUCTION ..... 1

2. LIFE HISTORY LITERATURE REVIEW ..... 3

2.1. Species Description ..... 3

2.2. Distribution of Populations ..... 4

2.3. Reproduction ..... 9

2.3.1. Mating System ..... 9

2.3.2. Nesting ..... 11

2.3.3. Brood Rearing and Young ..... 12

2.4. Food Habits ..... 13

2.5. Movement and Migration ..... 15

2.6. Home Ranges ..... 16

2.7. Habitat Selection and Composition ..... 19

2.7.1. Lek ..... 21

2.7.2. Nesting ..... 22

2.7.3. Brood ..... 23

2.7.4. Fall & Winter ..... 24

2.8. Conservation and Population Status ..... 25

3. MANAGEMENT ..... 30

3.1. Minnesota ..... 31

3.2. North Dakota ..... 37

4. CONCLUSIONS ..... 45

LITERATURE CITED ..... 47

## LIST OF TABLES

Table Page

1. Sharp-tailed grouse seasonal and annual home range sizes by male and female in northwest Wisconsin, May 1977 - June 1979. Adapted from Gratson (1988)..... 18

2. Percent of total resident harvest statewide in North Dakota by county (NDGF 2015, 2016)..... 41

## LIST OF FIGURES

Figure Page

1. A male sharp-tailed grouse "dancing" on a lek to attract females. Photo used with permission by Rick Bohn. ..... 4

2. Distribution of sharp-tailed grouse circa 1963. From Aldrich (1963). ..... 6

3. Distribution of sharp-tailed grouse subspecies. Adapted from Aldrich (1963). ..... 6

4. Distribution of sharp-tailed grouse. From Connelly et al. (1998). ..... 7

5. Distribution of prairie grouse. Adapted from Johnson (2008). ..... 8

6. Historic and recent range of sharp-tailed grouse. Adapted from Vodehnal and Haufler (2008). ..... 9

7. Sharp-tailed grouse animal food consumption by age. From Kobriger (1965). ..... 13

8. Optimized summer habitat diagram adapted from Ammann (1957). ..... 20

9. Male sharp-tailed grouse displaying for females (center) in North Dakota. Photo by Rick Bohn, used with permission. ..... 21

10. Sharp-tailed grouse Breeding Bird Survey trend map, 1966 – 2015. Adapted from Sauer et al. (2017). ..... 26

11. Sharp-tailed grouse Breeding Bird Survey relative abundance map, 2011 – 2015. Adapted from Sauer et al. (2017). ..... 27

12. Distribution of verified sharp-tailed grouse occurrences or breeding activity. Breeding Bird Atlas. Adapted from Pfannmuller et al. (2017). ..... 34

13. Minnesota sharp-tailed grouse hunter harvest 1949-1984. Adapted from MDNR 2002. ..... 35

14. Minnesota sharp-tailed grouse abundance on spring lek sites 1980-2017. Adapted from Roy 2017. ..... 36

15. Distribution of sharp-tailed grouse in North Dakota. Adapted from Dyke (2015). ..... 38

16. Sharp-tailed grouse modeled probability distributions based on observed locations. Image adapted from eBird (www.ebird.org) and created [3/8/2018]. ..... 38

17. Resident and non-resident estimated harvest distribution from the 2014 hunting season based primarily on questionnaire results (NDGF 2016). ..... 41

18. Population index based on surveyed male sharp-tailed grouse per square mile at 26 census areas (2,712 $km^2$) across North Dakota. (NDGF 2015, 2016) ..... 42

19. North Dakota sharp-tailed grouse census units (NDGF 2016). ..... 42

20. GAP analysis map of sharp-tailed grouse in North Dakota. Adapted from Strong (2005). The darker shades represent higher probability of occurrence. ..... 43

# 1. INTRODUCTION

Sharp-tailed grouse (STG; *Tympanuchus phasianellus)* are an intriguing and charismatic bird species which range over large portions of the North American grasslands from Alaska south to Kansas. The STG species is composed of six extant subspecies and are discussed further in Chapter 2. They are pursued by upland game hunters in several states including North Dakota and Minnesota. One particular appeal to hunters is the early hunting season. This usually occurs about a month prior to the popular rink-necked pheasant hunting season, arguably the most popular upland game bird in the Northern Plains. Sharp-tailed grouse also attract numerous wildlife viewing enthusiasts to their leks or "dancing grounds" every spring which offers even more recreational opportunities (Connelly et al. 1998). Leks are locations where STG within a given home range gather for mating purposes. Not only are STG a captivating species for many outdoor enthusiasts, but they are an important species for science.

Sharp-tailed grouse are often classified as an indicator of a healthy functioning prairie ecosystem when present in large populations because their requirement of large contiguous tracts of open land habitat (Johnsgard 1983, Vodehnal and Haufler 2008, Hovick et al. 2014). As a consequence, their presence can indicate suitable habitat for other prairie obligate species, which require a structurally diverse grassland habitat (Roersma 2001, SDDGFP 2011). Because of those reasons, land managers adopt strategies to actively make management decisions based on the responses of STG populations. In addition, since STG are game birds, they often receive attention from state agencies to manage for sustainable populations for hunting. For this paper, I will review the life history of STG, then discuss existing state management objectives within Minnesota and North Dakota, attempt to evaluate how effective the states are at achieving their

intended goals, and finally assess the status of STG regarding future research and conservation needs for the species within the region.

# 2. LIFE HISTORY LITERATURE REVIEW

## 2.1. Species Description

Sharp-tailed grouse are in the order Galliformes, which are generally characterized as mostly ground dwelling with strong legs for running and wing shapes designed for short quick bursts of flight (Connelly et al. 1998). This order includes many gamebirds and can be further broken into the subfamily Tetraoninea– the grouse (Gutiérrez et al. 2000). They are a medium sized grouse where their length ranges from 41-47 cm and their mass ranges from 617 g for juvenile females to 1,031 g for males in winter (Connelly et al. 1998). Females in all subspecies are smaller than males.

Sharp-tailed grouse are similar in shape, size, and coloring to the other prairie grouse; the greater prairie-chicken (*Tympanuchus cupido*) and the lesser prairie-chicken (*Tympanuchus pallidicintus*) which have ranges that overlap in portions of North America. Some differences are noted in the color pattern of their feathers; whereby the prairie chickens have much more heavy barring on their underparts versus a V-shaped spotted pattern on the grouse.

Generally, the males and females are similar in appearance; however, they do exhibit sexual dimorphism. Males have a yellow comb above their eyes and a purplish colored air sac on their neck, both of which become more pronounced during courtship display while females lack these characteristics (Evans 1968, Johnsgard 1973; Figure 1). In flight, the tail shows a large amount of white which is about 15 cm long. They can also be sexed by evaluating the rectrices, where the male's color pattern is more longitudinal stripes and females are more transversely barred. The outer primaries can be used to help distinguish young of the year from adults. The young will exhibit a worn look near the tips; whereas the adults show little or no wear. Their crown-feathers are elongated and form a crest when erected (Connelly et al. 1998).

Figure 1. A male sharp-tailed grouse “dancing” on a lek to attract females. Photo used with permission by Rick Bohn.

### 2.2. Distribution of Populations

Sharp-tailed grouse population and range have been on the decline for decades (Connelly et al. 1998, BirdLife International 2016). The most noted reasons for their decline are likely because of habitat loss and fragmentation due to advancing ecological succession, conifer plantations, agricultural development, intensive overgrazing, and more recently energy development (Berg 1997; Giesen and Braun 1993, Hanowski et al. 2000; Roersma 2001, Niemuth 2011, Hovick 2014, Kludt 2016). The decline varies for different subspecies and geographic locations.

The STG population in North America is divided into several subspecies (Figures 2-6). These subspecies include *T. p. phasianellus* (Northern) found in east central Canada, *T. p. kennicotti* (Northwestern) found in the Northwest Territories of Canada, *T. p. caurus* (Alaskan)

found in north central Alaska east to the southern Yukon province and northern British Columbia and Alberta, *T. p. columbianus* (Colombian) found in the Columbian River Basin and the Great Basin, *T. p. campestris* (Prairie) found in the central lowlands and prairies of the upper peninsula of Michigan, Wisconsin, Minnesota, southwestern Ontario, and southeastern Manitoba, *T. p. jamesi* (Plains) (Aldrich 1963, Johnson 2008, Vodehnal and Haufler 2008) found throughout the Great Plains and reported as the largest in body size (Connelly et al. 1998) and a race found in central Canada with no designation. An extinct species *T. p. hueyi,* was found in a very small concentration in northeast New Mexico. This species was considered part of the Plains race, but later determined to be its own separate species (Connelly et al. 1998, Johnsgard 2002).

These subspecies designations were originally based on general geographic locations. However, recent genetic analysis shows mixed gene flows between *T. p. campestris* and *T. p. jamesi* with clear distinction from *T. p. columbianus* (Spaulding et al. 2006, Johnson 2008). The subspecies mainly discussed hereafter are *T. p. jamesi* and *T. p. campestris* found in North Dakota and Minnesota, respectively. The Plains sharp-tailed grouse have been extirpated from Kansas, Oklahoma, and New Mexico and are endangered in Colorado (Prose 1987). Pockets of populations and landscape fragmentation is noticeable when comparing recent to historic ranges (Figures 5 & 6).

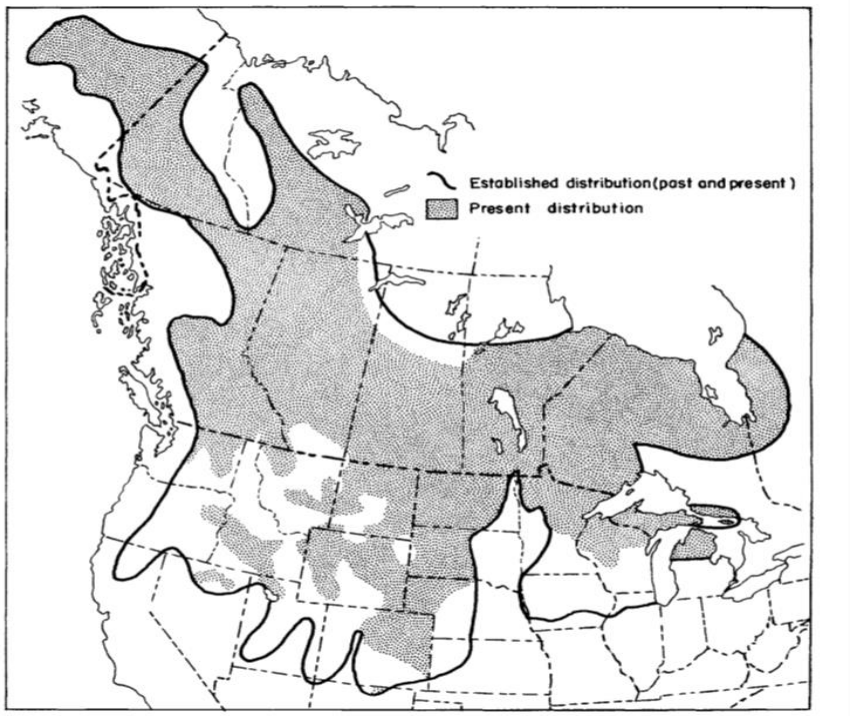


Figure 2. Distribution of sharp-tailed grouse circa 1963. From Aldrich (1963).

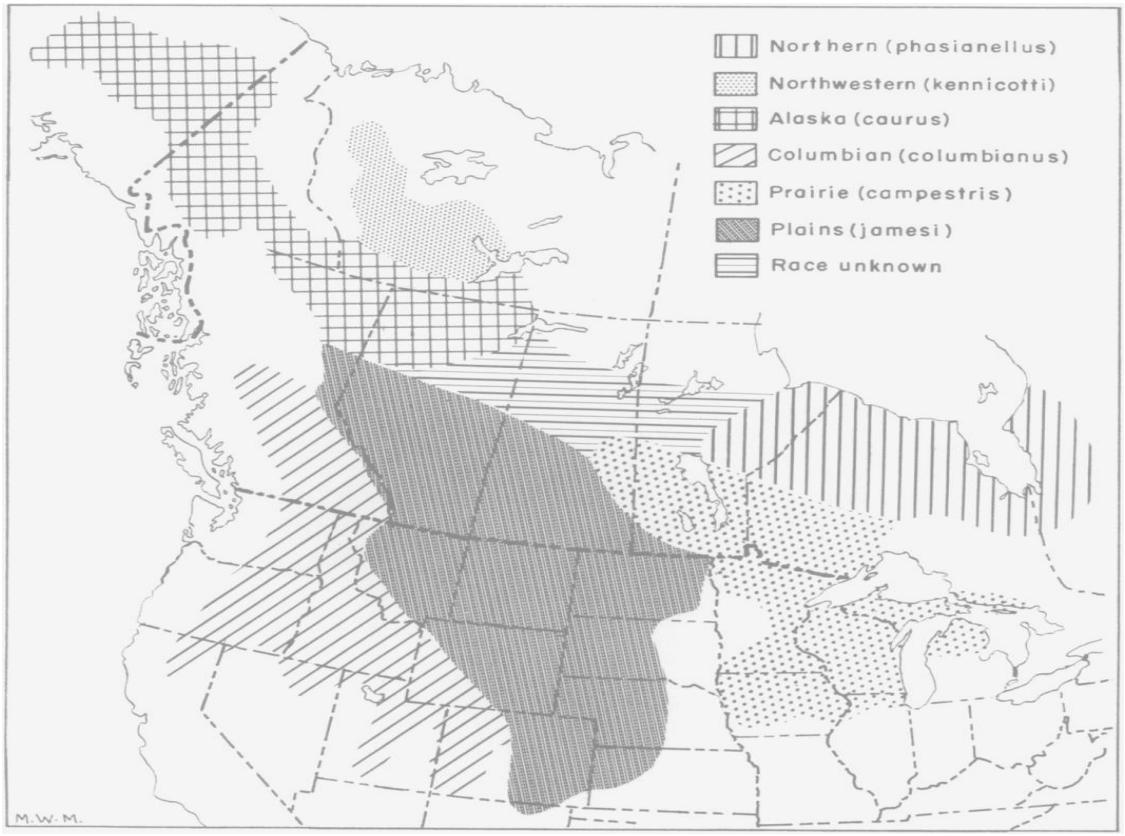


Figure 3. Distribution of sharp-tailed grouse subspecies. Adapted from Aldrich (1963).

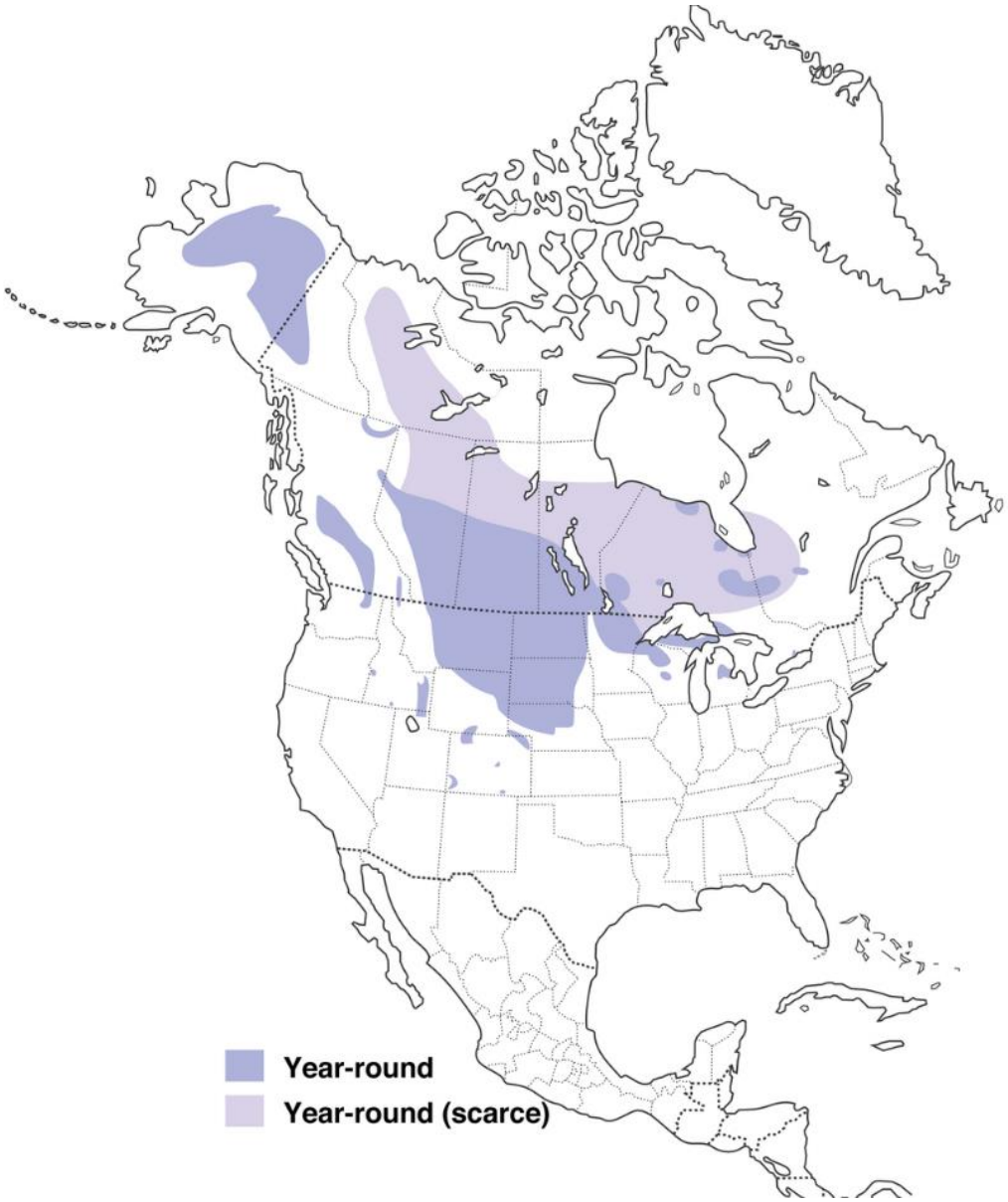


Figure 4. Distribution of sharp-tailed grouse. From Connelly et al. (1998).

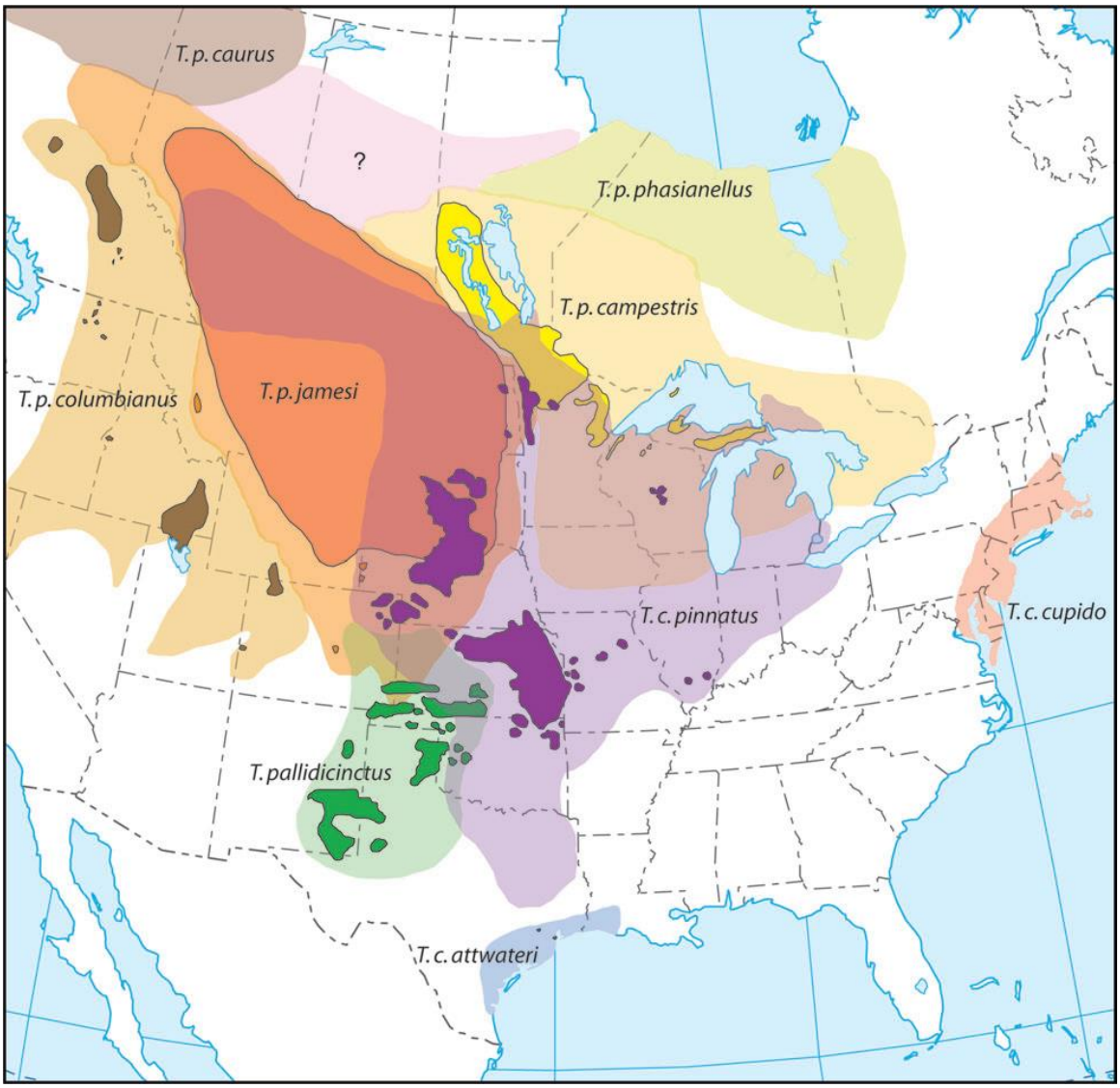


Figure 5. Distribution of prairie grouse. Adapted from Johnson (2008). Shaded areas represent historic and contemporary (outlined in black) distributions of *Tympanuchus* grouse (sharp-tailed grouse, *Tympanuchus phasianellus*; greater prairie chicken, *Tympanuchus cupido*; and lesser prairie chicken, *Tympanuchus pallidicinctus*). The question mark (?) identified in the northern distribution of *T. phasianellus* indicates an area that has not been assigned subspecific status.

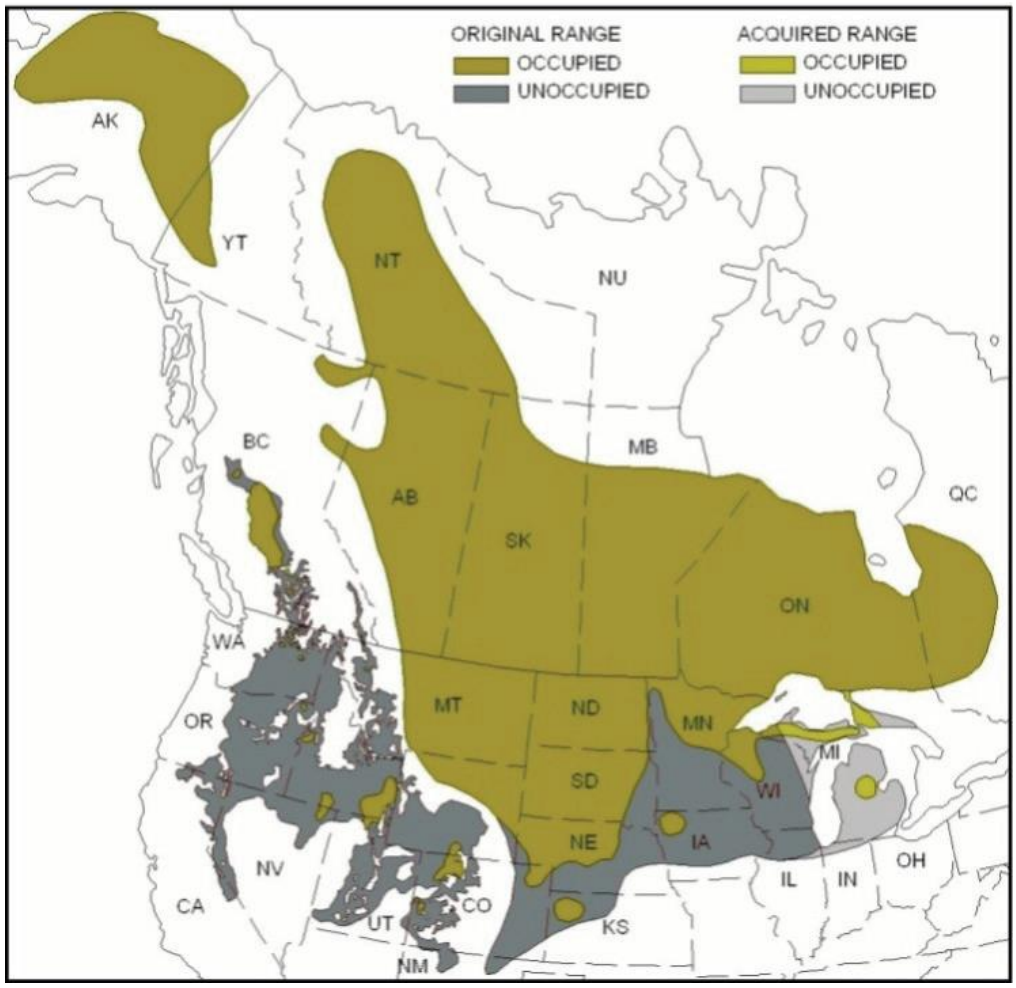


Figure 6. Historic and recent range of sharp-tailed grouse. Adapted from Vodehnal and Haufler (2008).

## 2.3. Reproduction

### 2.3.1. Mating System

Sharp-tailed grouse are believed to be polygamous as is common with lekking species (Connelly et al. 1998). The male STG gather in the springtime for mating on leks, or sometimes referred to as "dancing grounds" because of the dancing-like behavior they display as courtship. The leks are usually located in open areas with sparse vegetation in the immediate vicinity, usually on a hill or small rise, or also peat and muskeg barrens (Aldrich 1963, Berg 1997, Hanowski et al. 2000). Grouse return to the lek site each year unless destroyed or abandoned

(USDA 1999). Habitat and landscape which leks are likely to be found on will be covered later in this text. The males will gather on the leks before the females, with some activity in the fall and winter but generally early spring (March) and begin territorial disputes with sparing and bluffing tactics (USDA 2007). They will continue attending the lek until late May (Houchen 2011). The males congregate in the morning before sunrise and remain for 2-3 hours. The male's lek territories are generally small areas, roughly 1.5 – 3-meter radius, where they display. The mating system is described as clumped polygamy, which means males are clumped close together to defend their territories at the lek (Bergerud 1988a). Because only a few dominant males will do the breeding, lekking is not an advantage to all males. This mating system strategy appears more advantageous to the females to select the reproductive traits she wants from competing males. Once males' territories are established, they will begin dancing and displaying courtship behaviors and vocalizations.

The following is a summarized account from Hart et al. (1950):

> The male sharptail with its head thrust out straight in front, inflated purple air sacs on each side of the neck, wings extended horizontally, and tail fan-like over the back, rushes forward or rotates, stamping its feet in very rapid short steps. The showy white tail is jerked back and forth, and the wings are fluttered slightly. The bird often jumps or makes short flights into the air. The eyebrow is a showy yellow-orange and very large during courtship displays. The "dancing" and "hooting" (a sound similar to that made by a great horned owl) lasts for 30-50 seconds and then the birds "freeze" for a short period, after which the males all repeat the dance in unison.

Their tail feathers rattle and can be described as a "handful of reeds shaken" (Aldrich 1963). The vocalizations can be heard from approximately a one km away (personal observation 2014). Videos of STG are available to view online, which depict their unique and iconic lekking behavior (Galt 2012). When the females are ready to mate, they will walk around the lek while the males are displaying, selecting a male she will mate with. The dominant males will contest territories near the center of lek. Those dominants are the main breeding males. Gratson (1988)

indicates the males will return to their same territorial areas within the lek the next year. No published data on sharp-tailed grouse were found regarding male reproductive competition; however, Hartzler and Jenni (1988) describe a similar lekking grouse species, the sage grouse (*Centrocercus urophasianus*) and found only the most dominant males breed females. Of 16 males that attended a lek, 6 did all the mating and one performed 76% of the mating. However, it is not unreasonable to assume males on the periphery do succeed at occasional sneak copulations. There is little evidence of the underlying reasons how the female actually conducts the mate selection processes. April and May are the peak times for female lek attendance (Connelly et al. 1998). Once mated, the females will leave the lek and immediately begin nesting. She would only return if initial nest failure prompted her to re-nest (Johnsgard 1973).

**2.3.2. Nesting**

Connelly et al. (1998) states there is no data on when the females actually begin selecting the nest site but suggest prior to mating. One possible explanation for the lake of data could be the females are captured and tagged at the lek site, so prior behavior is not well documented. The nests are made of various components of moss, grasses, sedges, ferns, herbaceous plants, and leaves of shrubs and trees, and feathers from the female breast. Since prairie grouse lose upwards of 50% of their nests, the site selection for nesting suggests it is an important factor (Bergerud 1988).

Nesting, incubation and brood rearing are carried out solely by the female (Aldrich 1963). After mating has occurred and adequate nesting cover is found, the female will lay on average, 11 to 13 eggs per clutch (Connelly et al. 1998). The eggs are some variation of olive-buff to pale brown, usually speckled with various browns. Incubation lasts for about 23-24 days

starting after completion of the clutch (Johnsgard 1973). Usually the females won't travel more than 200 meters from the nest during incubation periods (Aldrich 1950).

The females demonstrate infrequent efforts at renesting if first attempts fail (Aldrich 1963). Ammann (1957) reported that approximately 10 percent of broods are produced by renesting (as cited in Aldrich 1963). Further, Johnsgard (1973) contends that little is published on the matter of renesting and those that are published show small percentages of females that do. However, unpublished data from NDSU Hettinger Research Extension Center shows that number to be higher than 10% and a couple of birds attempted a 3rd renesting (B. Geaumont, personal communication 2016). Connelly et al. (1998) also contends renesting is common and fourth nesting attempts have been documented. Additionally, Burgerud (1988) summarizes Christenson (1970) and Schiller (1973) which found an 86% renesting rate of 14 females tracked from radio telemetry in North Dakota and Minnesota, respectively. Rare intraspecific nest parasitism has been documented in Manitoba (Gratson 1989).

### 2.3.3. Brood Rearing and Young

According to Johnsgard (1973), no evidence of any double-brooding in North American grouse has been observed. The young are born precocious with downy feathers and developed legs which give them the ability to leave the nest with the female shortly after hatching. They have a pale yellow body with few dark spots near the eyes and ears with a faint crown line (Aldrich 1963, Johnsgard 1973). The female will lead the young to foraging grounds; however, chicks will feed themselves. The young are able to fly 50 meters by four weeks old and about one forth adult size. Aldrich (1963) noted by eight weeks they are two thirds grown and able to make long flights. Similarly, Johnsgard (1973) stated by eight weeks young are almost fully independent and broods begin to break up and disperse, often long distances. By 12 weeks they

are fully grown and have full flight ability. Annual survival of STG from year one to year two was found to be 12 percent in South Dakota populations (Robel et al. 1972).

### 2.4. Food Habits

Sharp-tailed grouse consume different food based on the bird's age, seasonality, and available food sources in their home range (Prose 1987). Food sources range from animal material (insects) to plant material (grains, fruits, seeds, buds, and leaf vegetation) (Connelly et al. 1998). In Nebraska, it was reported, chicks from three to seven weeks old feed primarily on insects ranging from 91.5 percent of their diets at three weeks to 62.6 percent of their diet at seven weeks of age (Kobriger 1965). By 12 weeks the young are consuming a diet of 91.5% vegetation, which is similar to adults (Kobriger 1965, Figure 7.).

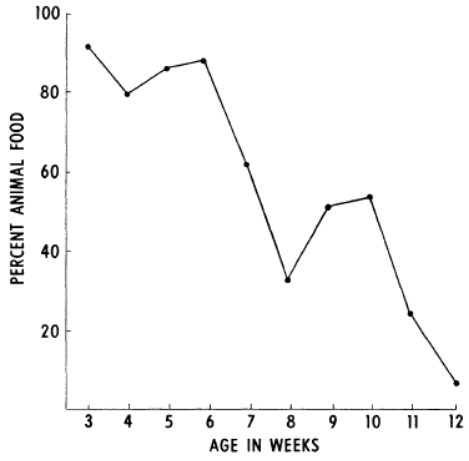


Figure 7. Sharp-tailed grouse animal food consumption by age. From Kobriger (1965).

According to several studies in Nebraska and South Dakota, the most common insect reported in both STG chick and adult diet were short-horned grasshoppers (*Locustidea*) (Kobriger 1965, Hillman and Jackson 1973, Sisson 1976). The average of total volume of summer foods consumed by 46 young STG was 12.3% short-horned grasshoppers and 35% clovers (*Trifolium* spp.), with 29% total insect matter and 66.5% total plant matter (Kobriger 1965). Mitchell and Riegert (1994) report grasshoppers were also the dominant animal matter

consumed by STG in a Montana study, measured by both mass and volume, with the overall percent volume of animal matter in the two-year study varying from 36% to 12%. Specifically, that study occurred in September, so it is reasonable to assume the birds were either adults or immature which tends to support Kobriger's (1965) findings of lower animal food consumption than young STG.

Many studies breakdown food sources based on seasonality – spring/summer and fall/winter. In several studies, the most common summer vegetative food source of STG is clovers, rose (*Rosa* sp.), common dandelion (*Taraxacum officinale*), grasses, grass seed, fruits, smartweed (*Polygonum* spp.), alfalfa (*Medicago sativa*), wheat, and yarrow (*Achillea millefolium*) (Kobriger 1965, Sisson 1976, Connelly et al. 1998, Goddard et al. 2009).

Fall/winter food sources for STG tend to contain more fruits, grains, buds and catkins from shrubs (Mitchell and Riegert 1994, Connelly et al. 1998). Especially with snow cover Johnsgard (1973), noted "catkins, twigs, and buds of trees such as paper birch, aspen, Juneberry, hazel, and bog birch are preferred by STG, as well as the fruit of mountain ash, sumac, common juniper, rose, and black chokecherry." Kobriger (1965) found a substantial drop in clovers and an increase in fruits (mainly wild rose) in fall (October) sampling of STG. In Montana, STG feed primarily on shrub fruits comprising 90-92% of the total vegetation matter found (Mitchell and Riegert 1994). Harris (1967) documented fall foods consumed by STG based on percent volume and noted the majority (55.2%) consisted of grain seeds (oats, wheat, flax, and minor others) in northwestern Minnesota with a landscape describe as brushland, early forest and agriculture. When available, a wide variety of other grains such as buckwheat, field peas, corn, barley, soy beans, millet, and rye have been documented as part of their diet winter (Johnsgard 1973). As seen with the variation in the studies, STG diets are interdependent on their home range and the

corresponding land use and the abundance and availability of food sources (Kobriger 1965, Harris 1967, Mitchell and Riegert 1994).

### 2.5. Movement and Migration

Snow and woody cover are driving factors in STG migration. They are reported to migrate short distances of 34 km to seek woody cover for thermal protection as temperatures get cold (Connelly et al. 1998). Significant changes in the grassland landscape since pre-settlement have occurred. The once vast open prairie has diminished due to expanding settlements and mechanized agricultural land clearing practices. Those practices brought shelterbelts and shrub rows so grouse no longer migrate long distances to find woody cover (Connelly et al. 1998). Males will generally return to breeding grounds sooner than females, arriving approximately March – April while females arrive April – May. Several studies suggest that average breeding season movements lie within 2.0 km from the lek compared to 6.5 km from the lek during winter months (Marks and Marks 1987, Meints 1991, Ulliman 1995, Giesen 1997, Apa 1998, McDonald 1998).

Shorter seasonal movements of STG have also been documented. Gratson (1988) reported spring dispersal of males traveling shorter distances from leks than females at 353 ±80 m and 1024 ± 287 m, respectively. Male STG travel from food and roosting grounds; whereas, the females were measured from nest site to lek. Comparably, Kobridger (1965) reported limited movements of males during spring and summer, generally staying within one km of the lek site. Although variability was described as high, females with broods in June, July, and August moved 285 m, 1,502 m, and 2,094 m away from nest sites, respectively. Similarly, Connelly et al. (1998) reports broods staying with 1.6 km from nest site locations. Hens with broods are

reported to have daily summer movements of 45–276 m (Schiller 1973, Gratson 1983, Gratson 1988, Meints 1991).

### 2.6. Home Ranges

The idea of home range, when referring to STG, can have different meanings depending on what questions one is trying to answer. Home ranges can be described as areas where an *individual* of a species will likely be found throughout its lifecycle. Home ranges can also be classified at the community scale or the population scale by pooling individual home ranges to describe meta-populations. Since individuals exhibit wide variability in habitat preferences (personal observation 2014), for landscape level conservation efforts, it is important to consider population level home ranges. In general, they are usually statistical estimates based on known locations (presence/absence) of a species.

It is important to consider the type of home range studied because home ranges are composed of several geographic locations due to seasonal shifts and habitat needs (Patten et al. 2011). Those needs are dependent on the grouse's life history. Home ranges for STG also vary by sex and age (Gratson 1988). For example, temporal and spatial variation for sharp-tailed grouse's home range consist of spring (primarily) lek habitat, spring/summer nesting habitat, summer brood rearing habitat, and fall/winter habitat; each of these seasonal habitats can vary by sex as well. Similar vegetation can overlap within these seasonal home ranges; however, certain vegetation types become increasingly important with changing seasons.

Since identifying home ranges is a common technique used to analyze habitat selection landscape level trends and needs for conservation and management of wildlife species, numerous methods for estimating home ranges have been developed (Boyce et al 2002, Patten et al. 2011). The construction of Minimum Convex Polygons (MCP) has historically been the most common

method employed during home range studies which are derived from animal point location data by creating a polygon which contains no internal angles >180º, all line segments connecting any pair of points, and has at least four sides (Mohr 1947). The polygon created would contain all of the location points. Several new methods have since become available including the commonly used Kernel Density Estimate (KDE) (Worton 1989, Lichti et al. 2010). Kernel density estimation is a statistical technique for estimating an underlying probability density function from the data input where a kernel (a mathematical representation of the data point) is placed over each observation and the probability density values are created by summing the neighboring values of that point (Horne & Garton 2006). The closer and more the kernels overlap the stronger the relationship and probability of occurrence. This method is frequently termed to represent a Utilization Distribution function which describes the most likely areas the species utilizes (Kernohan et al. 2001). Often studies will utilize both methods for publication in attempts to compare current research with past.

There are a limited number of published studies on STG home ranges, and those which are published, do not always have the same methodology or geographic location. The animal location points are typically gathered from radio collared birds and located via homing. Locations are then documented by a Global Positioning System (GPS). Boisvert et al. (2005) reported female Columbian STG seasonal home ranges for 95% KDE and MCP to be 170 and 108 ha, respectively. Sabb and Marks (1992), and Giesen (1993) both reported MCP home ranges of 187 ha and 110 ha; respectively, for STG. In Wisconsin, Gratson (1988) analyzed home ranges from several different perspectives (e.g. sex, age). He reported an annual range for two males as 593 ± 50 ha using a hybrid method of MCP monthly ranges overlain by each other to create a concave polygon for the year. I conjecture this method is a more accurate description

of their true Utilization Distribution verses standard MCP methodology due to the layering creating a higher "resolution" of points. Annual home ranges for females were not calculated. Home ranges were broken down by season (spring [March, April, May]; summer [June, July, August]; fall [September, October, November]; winter [December, January, February]) for each sex (Table 1.).

Table 1. Sharp-tailed grouse seasonal and annual home range sizes by male and female in northwest Wisconsin, May 1977 - June 1979. Adapted from Gratson (1988).

| | Seasons[a] | | | | |
|---|---|---|---|---|---|
| Sex | Spring | Summer | Fall | Winter | Annual |
| Male | 348 | 82 | 388 | 400 | 593 |
| SE | 11 | 11 | 113 | 66 | 50 |
| N birds | 2 | 8 | 4 | 4 | 2 |
| | | | | | |
| Female | 604 | 156 | 556 | 251 | |
| SE | 111 | 95 | 175 | 84 | |
| N birds | 3 | 2 | 2 | 2 | |

[a] Spring (March, April, May), Summer (June, July, August), Fall (September, October, November).

Sharp-tailed grouse home ranges vary slightly from other prairie grouse (*Tympanuchu*s spp.) according to past studies. Greater prairie chickens were studied by Patten et al. (2011) and Burger et al. (1991), both reported MCP home ranges of 1,371 ha (mean) and 1,577 ha (median), respectively. Patten et al. (2011) also reported a mean annual 95% KDE home range of 2,593 ha. Whereas, Burger et al. (1991) used a 75% harmonic mean to get a seasonal home range of 825 ha. It has been conjectured that larger home ranges of STG represent landscapes that are more fragmented or have less suitable habitat conditions (Sabb and Marks 1992, Patten et al. 2011).

Fragmentation creates less contiguous habitat, causing home ranges to be larger so grouse completing their life history needs, face increasing energetic costs and decreasing survival.

### 2.7. Habitat Selection and Composition

Sharp-tailed grouse select and use different habitats based on seasonality due to different needs in their life cycle. Lekking habitat selection, for instance, begins in the spring, then comes nesting and brood rearing in the summer occupying different habitats, with yet a different habitat selected for in the winter. Those habitats have a common thread of a grassland-brushland requirement but often vary in landscape position and vegetation composition (Connelly et al. 1998). Prairie grouse rely on grass and forb vegetation cover for nesting and brood rearing (Kirby and Grosz 1995). Important plant species associated with STG habitat sources include: little bluestem (*Schizachyrium scoparium*), needle grasses (*Stipa* spp.), rose, clover species, dande1ion, chokecherry (*Prunus virginia*), Russian olive (*Elaeagnus angustifolia*), and western snowberry (*Symphoricarpos occidentalis*) (Prose 1987, Goddard et al. 2009, Houchen 2011). In Minnesota, Berg (1997) characterized important habitat component consisting of various grasses, sedges (*Carex* spp.), willows, (*Salix* spp.), open boreal peatlands (Hanowski et al. 2000), and even large man-made taconite ore tailing basins and overburden dumps.

Additional reports have shown STG also require a woody shrub cover component of 10-40 percent (USDA-NRCS 2007). Habitat requirements will also vary by subspecies with the prairie subspecies adapted to more shrubs and trees and the plains subspecies less tolerant to woody encroachment (Aldrich 1963, Prose 1987). A population of STG will select their home range habitat at the landscape level when it has the right combination of grassland, cropland, and woody vegetation; additionally, selection continues to occur at micro-habitat sites within their home range (Prose 1987, Runia 2009). Ammann (1957) suggests an optimal habitat diagram

with three components (A, B, C) for an area covering 1-square mile, in northern Michigan. (Figure 8).

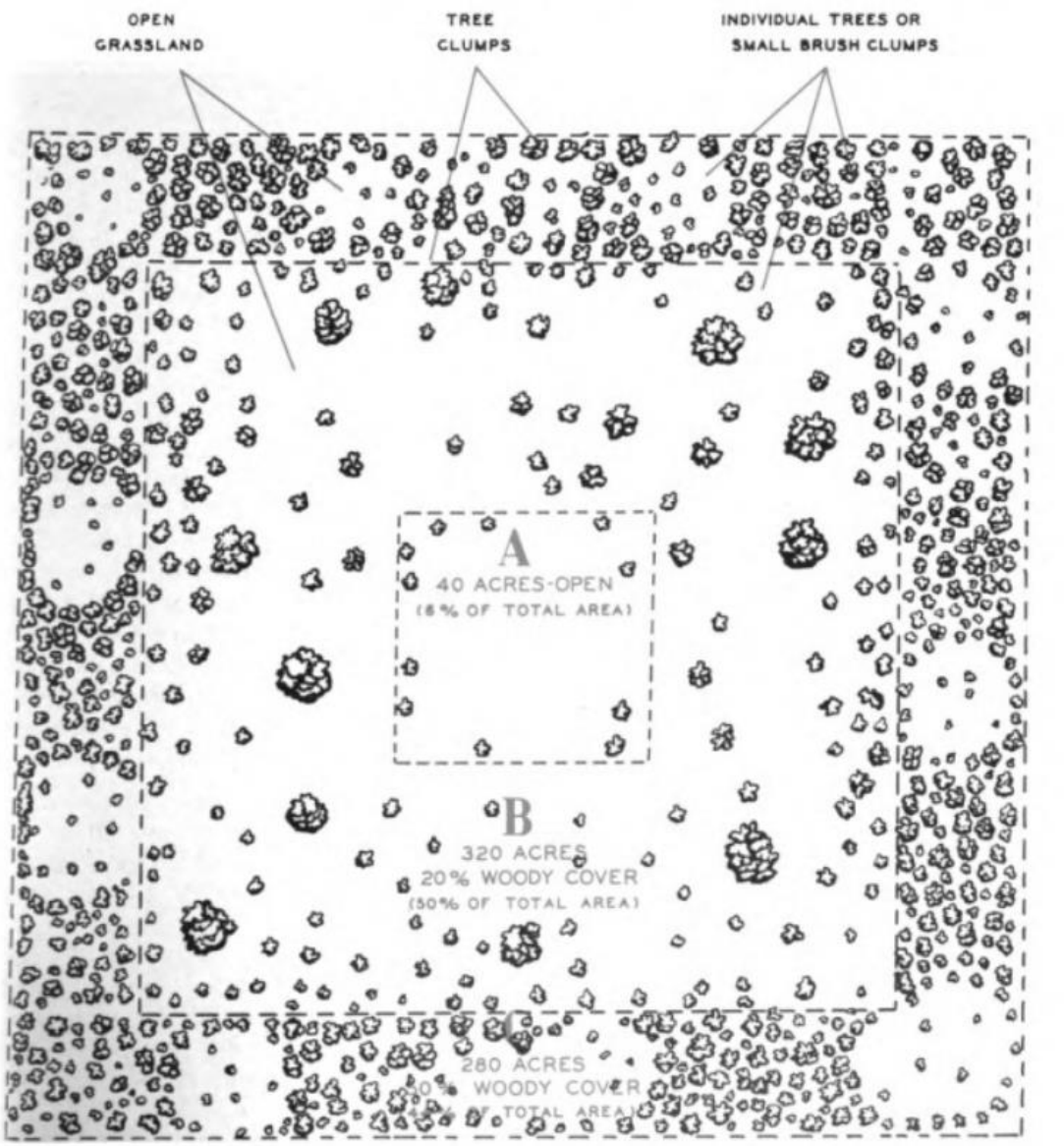


Figure 8. Optimized summer habitat diagram adapted from Ammann (1957).

Along with the landscape and vegetation composition of habitat, STG also depend on the structure and function of the habitat. One of the ways structure is often measured is recording the visual obstruction reading (VOR) on a 1-meter pole (Robel et al. 1970). This method can quantify the average height of grassland in an area which can relate to different grouse needs

such as nesting cover or concealment from predators. However, limitations are apparent when habitat is composed of shrubs and trees.

### 2.7.1. Lek

Landscape composition is a driving factor in lek site selection (Niemuth and Boyce 2004, Hanowski et al. 2000). Aldrich (1963) describes STG preference for lek habitat to be a variety of open cover of rolling knobs and hills with nearby grass, herbs, and shrubs for feeding and roosting. Higher elevation areas are selected to increase visibility from male to male when establishing territories, approaching females within the lek, and from predators (Manske and Barker 1987). Close proximity of concealment cover is also necessary. A variety of grass structure is important including short grasses and interspersed bunchgrasses (Figure 9). Manske and Barker (1987) describe vegetation at lek sites in southeast North Dakota as consisting mainly of blue grama (*Bouteloua gracilis)*, needle and thread (*Hesperostipa comata)*, sun sedge (*Carex heliophila)*, big bluestem (*Andropogon gerardi)*, little bluestem (*Schizachyrium scoparium)*, and switchgrass (*Panicum virgatum)*.

Figure 9. Male sharp-tailed grouse displaying for females (center) in North Dakota. Photo by Rick Bohn, used with permission.

Average spacing between leks was approximately 1,433 m apart in a Wisconsin study (Gratson 1988). Lek locations generally are unchanged from year to year, and males display high fidelity to the same lek each year (Johnsgard 1973, Runia 2009). Berger and Baydack (1992) found that leks were abandoned when forest increased beyond 56% and prairie decreased to below 15% within a 1,000 m radius of the lek. Manzer and Hannon (2005) has reported nest success was four times greater when landscapes were within a 1600 m radius of the leks and have less than 10% crop, and less than 35% cropland and sparse grassland (aggregated). Numerous studies indicate that in order to detect landscape level influences on STG lek presence and nest selection, several spatial scales need to be considered (Hanowski et al. 2000, Niemuth and Boyce 2004, Manzer and Hannon 2008, Runia 2009).

### 2.7.2. Nesting

The nesting component of habitat selection is one of the most important regulating factors relating to STG populations and the most important reproductive decision a female makes (Manske and Barker 1987, Bergerud and Gratson 1988, Runia 2009). The nest site vegetation varies geographically based on the different subspecies' ranges. Several studies suggest the structure of the vegetation at the nest is more important than the individual species, and consists of grass, forb, and shrub components (Hillman and Jackson 1973, Kobriger 1980, Prose 1987, Connelly et al. 1998, Roersma 2001). The important function of the structure is to provide cover. Often nests are found in heavy cover with woody cover accounting up to 75% of the canopy (Aldrich 1963, Connelly et al. 1998). In North Dakota, Burr et al. (2017) found little influence of habitat composition on nesting success at medium spatial scales (450m). Whereas, Manzer and Hannon (2005) found positive correlation of nesting success and habitat with 13 cm concealment

cover (VOR) at a 50m scale and at large spatial scales (1600m) with <10% crops, <35% crops and sparse grassland.

Several studies have reported a range of distances of nest sites in relation to lek site. Aldrich (1963) reported nests usually being found within 0.8 km of lek. Connelly et al. (1998) provided a review of several studies that suggest a range of 0.4-1.8 km from nests to nearest lek. Johnsgard (1973) stated nests are usually found within 1.6 km of the lek. Additionally, Giesen (1997) observed nest sites to be within 2km of lek sites. Manzer and Hannon (2005) stated that ninety-five percent of the hens studied nested within 1,521 m from the nearest lek in a mixed grass prairie landscape. Whereas a study in the pine barrens of Wisconsin noted that the maximum distance of a nest from a lek was 2.2 km (Connolly 2001). Another study indicated STG hens nested an average 1.3 km from the lek site and ranged a maximum of 3.2 km (Kobriger 1980). Further studies divulge the average distance between leks to be 2.6 km (Rippen and Boag 1974, Prose 1987). Sharp-tailed grouse rely on grass and forb vegetation cover for nesting and brood rearing (Kirby and Grosz 1995).

### 2.7.3. Brood

When broods are hatched, they seek habitat with an abundance of insects. Goddard et al. (2009) suggests the broods seek an area with ample forbs along with mixed open patches as to cater to both the hen and chicks' individual needs. Shrubby and woody habitat is favored for broods verses more open areas for nesting hens (Tesky 1994). The maximum threshold that broods used woody cover in a Wisconsin pine barren was with a coverage of 50% shading (Hamerstrom 1963).

Aldrich (1963) noted that STG use cultivated fields during the brooding season; however, he suggested insects and green material were possibly more important than the grains themselves.

### 2.7.4. Fall & Winter

Sharp-tailed grouse begin to congregate in flocks of 10-30 birds in the fall (Aldrich 1963). They tend to forage in cultivated fields when grain is available, while still living in open cover habit of grasses and low scattered brush (Johnsgard 1973). When the cold temperatures occur and snow becomes heavy, they shift towards denser cover for thermal protection.

Wintering habitat requirements usually entail a component of woody vegetation including shrubs, hardwood draws, and deciduous and coniferous woodland particularly when there is little snow cover (Aldrich 1963, Connelly et al. 1998, USDA 2007). White birch and aspen along the edge of open fields were tree species selected in studies conducted in the lake states. In more semi-arid and arid western populations, smaller shrubs, shelterbelts and riparian areas were a major source of these habitats. In North Dakota it was reported the larger flocks transitioned from open prairie habitat to shelterbelts with adjacent tall crops such as corn and sunflowers (Manske and Barker 1987). The importance of these wooded habitats are recognized for visual cover but also for the provided food sources of fruiting shrubs and deciduous tree buds (Johnsgard 1973).

When there is adequate snow, STG will create snow burrows for visual and thermal cover in open stands or dense marsh, and can be increasingly important during severe weather (Grange 1948, USDA 2007). Snow depth is an important driving factor for winter survival, as deaths have been documented when strong winds and low temperatures occurred (Johnsgard 1973). Snow

cover over fall foraging grounds strongly influence habitat selection and can also trigger short migrations of up 34 km (USDA 2007).

### 2.8. Conservation and Population Status

Sharp-tailed grouse require large expanses of grassland/openland to thrive (Vodenhnal and Haufler 2008). Besides agriculture, fragmentation of the prairie landscapes due to oil well pads, new roads, and commercial and residential development will affect grassland bird species (Coppedge 2001, Hovick et al. 2014). The fragmentation of contiguous grassland landscapes may hinder the species in various ways such as reduced fecundity, increased mortality, and added stress (Dunning et al. 1992, Manzer 2008). Habitat-fragmentation involves the size, shape, and distribution of habitat patches as well as the surrounding landscape conditions (Johnson 2000). Runia (2009) has showed that increased landscape fragmentation will negatively affect STG lek presence and found an increase in lek presence in less fragmented landscapes. Loss of grasslands and increasing proportions of cropland at landscape extents has been associated with increasing predator density; a proximate cause of mortality in grassland nesting birds (Manzer and Hannon 2008). Other studies have shown higher nest success in grasslands with a grazing presence verses no grazing; however, the nesting density was lower in the grasslands with more disturbance (Kirby and Grosz 1995; Sedivec et al. 1995). In North Dakota, Kludt (2016) found greater nesting success in a study area with more oil and gas development verses the nearby study area with significantly less development and attributes it to greater predator populations causing nest predation in the location with less development. The establishment of grasslands via the Conservation Reserve Program (CRP) has helped buffer losses; however, reduced acreage in the program will likely lead to population declines (Connelly et a. 1998).

The North American Breeding Bird Survey (BBS) started in 1966 to track the status and trends of North American bird populations, including STG. The survey separates trend data by state, geographic region, country, and also summarizes for the survey wide area. The trend data showed STG populations with a survey wide increase of 0.37% from 1966-2015; however, not statistically different (95% CI -1.50, 1.91, Sauer et al. 2017). The plains subspecies—as a whole, appear to have populations more intact with historical ranges than the eastern, southern and southwestern populations (Figure 10). However, across their range, pockets of their populations are still declining especially in the shortgrass prairie region with the largest downward trend of -2.52% although not statistically (95% CI -11.12, 6.98). Overall abundance of STG appears to be the highest concentrations in eastern Montana (Figure 11, Sauer et al 2017).

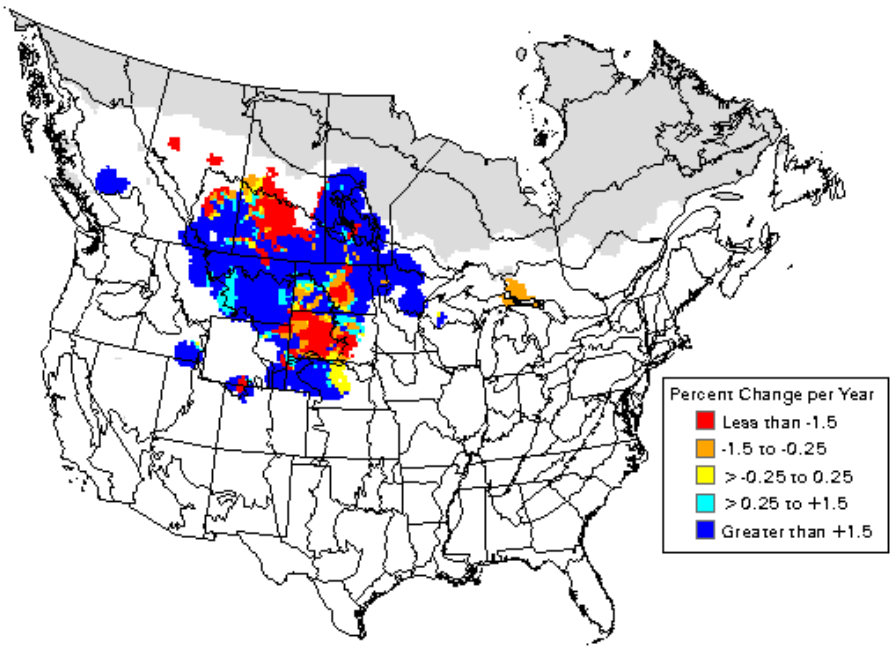


Figure 10. Sharp-tailed grouse Breeding Bird Survey trend map, 1966 – 2015. Adapted from Sauer et al. (2017).

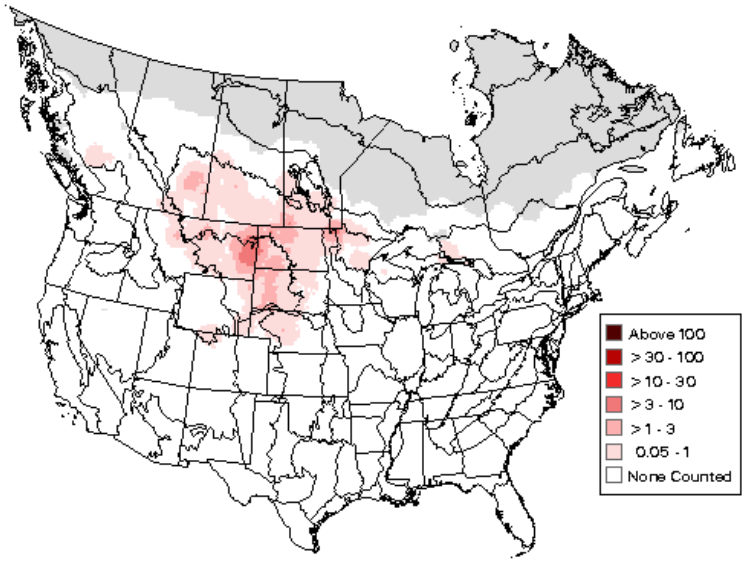


Figure 11. Sharp-tailed grouse Breeding Bird Survey relative abundance map, 2011 – 2015. Adapted from Sauer et al. (2017).

The Colombian STG is the only subspecies to be petitioned for listing under the Endangered Species Act (ESA) and was petitioned twice - in 1995 and 2004. In both instances the United States Fish and Wildlife Service (USFWS) found that based on the information provided in the petitions, listing under the ESA was not warranted (Federal Register Citation pages 71 FR 67318-67325, 65 FR 60391-60396). According to BirdLife International (2016), STG are listed as Least Concern due to large range and decreasing trends are not rapid enough to warrant a more imperil status. The global population is estimated at 600,000 (Partners in Flight 2013).

The Bureau of Land Management (BLM) oversees vast amounts of federal land that are home to STG. The agency classifies the Columbian STG as a sensitive species in Wyoming, Utah, and Idaho. The term sensitive species is used to describe species that occur on BLM land and are “at-risk” for being listed under the ESA.

The number of lek attendance and density of leks across a landscape is used to evaluate population status (Vodenhnal and Haufler 2008). Lek densities varied between studies and

geographic location, but generally were found to be 0.02-0.25 lek/km² as summarized by Vodenhnal and Haufler (2008). It is unknown what the minimum area to sustain a population; however, it was extrapolated to be an area of 5.3 $km^2$ based on Kobriger's (1980) findings of the mean distance from lek to nest site being 1.3 km (Prose 1987). As Prose (1987) further states: "If it is assumed that the breeding ground or lek is the center of activity for a population or individual breeding unit, then the size of the dispersal area around such an activity center should represent a minimum habitat area for that local population." I argue this size should be much larger since this only considers the scale during one part of their life history (nesting). Individuals even from a local population can have short migrations, usually in the fall and winter which can be further than 1.3 km from lek site. In addition, using the distance from lek site to nest site as a radius does not account for dispersal from nest site occurring outward and further from the lek. Species assessment and management have traditionally focused on small spatial scale site evaluations; however, many organisms (especially those with large home ranges and specialist tendencies) would benefit from ecological evaluations occurring at the landscape scale (Dunning et al. 2002). Landscape scale evaluations need to consider two primary factors *landscape physiognomy* and *landscape composition*- the layout and shape of habitat patches and the criteria of landscape qualities such as richness and diversity, respectively. Sharp-tailed grouse's once vast and with a diverse range prior to settlement, have suffered (Figures 2-6) due to fragmentation of the landscape as observed by increasing human development (urbanization, row crops, etc.) (Wright and Wimberly 2013). Continued land use changes are creating novel ecosystems which may reach a transition state that STG can no longer complete their life histories (Hobbs et al. 2009). To complicate things further, the Great Plains and arid west, which typically saw less intense disturbance from intense agriculture, are seeing an increase in negative

anthropogenic structures affecting grouse (Hovick et al. 2014). Although STG may not be as specialized as other Tetraonidae (i.e. Sage grouse), their life history and ecological role (indicator species) still warrants protection of fragmenting grassland and bushland landscapes (Coates et al. 2016). If land management objectives are to increase STG abundance, then it is important to consider not only site-specific habitat conditions but landscape scale influences (Hanowski et al. 2000). Local population trends, policy, and management will be explored more in depth in Chapter 3.

## 3. MANAGEMENT

States manage STG populations differently based on their desired goals. Those goals are based on many factors including but not limited to public input, legislative and agency policies, and scientific research and populations studies. Management can also vary based on subspecies and geographic location due to differences in habitat. Most states still allow hunting of STG. To ensure that hunting pressure doesn't become additive mortality it is suggested that the target harvest should be set at ≤15% of the August populations for management plans (Sandercock 2011).

The National Audubon Society (2018) has created a Conservation Ranching Program to promote grassland conservation partnering with ranching operations that employ bird-friendly management practices. The program identifies STG as a priority bird. Habitat and bird conservation strategies are implemented to try and help priority bird species. By encouraging landowners to adopt the bird-friendly practices, and with third party verification, ranchers can receive a certification. The certification incentivizes the landowner/producer to participate in the program in order to market their product with a certification label as an environmentally friendly product. The verification comes by means of adhering to the program standards which cover four main areas: Habitat Management, Forage and Feeding, Animal Health and Welfare, and Environmental Sustainability. For the program to work, the rancher would adopt a Habitat Management Plan which targets site-specific habitat goals while addressing bird conservation strategies.

North American Grouse Partnership (NAGP) is a national organization dedicated to "promoting the conservation of grouse and the habitats necessary for their survival and reproduction." Their focused areas are Science, Policy, and Management. The organization has

helped to established *THE NORTH AMERICAN GROUSE MANAGEMENT PLAN: a prospectus* (Editors 2004). While this document is listed still as a draft, it was compiled by multiagency grouse experts and highlights many of the challenges and addresses recommendation actions to benefit grouse species. Within the NAGP is a Prairie Grouse Technical Council which hold annual meetings for the advancement of the science of prairie grouse.

### 3.1. Minnesota

Minnesota is fortunate to be home to four different grouse species: ruffed grouse, spruce grouse, greater prairie-chicken, and obviously the STG. The Minnesota Department of Natural Resources' (DNR) Forest Wildlife Populations and Research Group is the state entity that conducts research on sharp-tailed grouse in Minnesota. Several other groups and agencies also contribute to aiding in STG conservation by conducting additional surveys, raising money and awareness, and conducting habitat management. Some of these include: the USFWS, Minnesota Sharp-tailed Grouse Society, Minnesota Breeding Bird Atlas, Pheasants Forever, Ducks Unlimited, and The Nature Conservancy to name a few.

The DNR uses several planning tools to assess and provide guidance to state and local practitioners about natural resources. One such plan, The Prairie Conservation Plan (PCP) (MPPWG 2011), highlights STG and prairie chickens as species that require mid-large size prairie landscapes and prairie corridors connecting such features in a fragmented landscape. As outlined in the PCP, providing prairie corridors can help dispersal of prairie grouse and help stabilize decreasing population and ranges. It recognizes prairie grouse as umbrella species, whereby, offering conservation and protection to prairie grouse that will indirectly benefits other species within their community. Although the subspecies *T. p. campestris* in Minnesota largely inhabits the forest prairie transition of the Tallgrass Aspen Parklands Province and more eastern

brush lands than the prairie corridor, they are found within the prairie core areas and corridors. Additionally, STG and prairie chickens, although infrequently, are known to hybridize where their ranges overlap, and even several male and females of both species occupy the same leks in some areas (Augustine and Trauba, 2015). Their research also alludes to the lack of understanding how the hybridization is affecting the population and whether or not it would be expected to increase with diminishing habitats causing consolidation.

Another planning tool utilized is the Minnesota Wildlife Action Plan (MWAP). Every 10 years the DNR writes the MWAP, focusing on wildlife Species in Greatest Conservation Need. Minnesota defines Species in Greatest Conservation Need (SGCN) as native animals, nongame and game, whose populations are rare, declining, or vulnerable to decline and are below levels desirable to ensure their long-term health and stability. The first time this was applied was in the 2005 MWAP (published 2006) and it identified STG as "Populations well below the range of natural variation in Minnesota. The dominant prairie Galliform was historically the STG." When the plan was updated in 2015 STG were still listed and noted as "rare, vulnerable, declining habitat, aggregate populations." Species with aggregated populations, such as lekking behavior, are especially vulnerable to decline as single large catastrophes or land use changes can substantially reduce their survival.

The DNR is currently managing for STG habitat with several management tools such as prescribed burning, mowing, and a limited amount of grazing where possible on state Wildlife Management Areas (WMAs). Habitat management directed toward STG can be challenging because about 80% of known leks occur on private land (C. Roy, Minnesota Department of Natural Resources, personal communication 2017). The logistics of some management tools/techniques such as prescribed burning can be difficult to apply due to the set of constraints

that exist in order to conduct a burn – like inclement weather and local property/safety concerns associated with prescribed burns. Roy (personal communication 2017) acknowledged the DNR is not currently constructing a state management plan for STG; however, in 1990, long range draft plans were created for sharp-tailed grouse and brushland habitats but were never adopted. A statewide plan would give better direction to local land managers to achieve goals of the state (i.e. increase abundance, increase recreational opportunity, etc.) instead of solely local interests. The need and direction of STG management is also mentioned in the MN DNR Subsection Forest Resource Management Plan (SFRMP) – ASPEN PARKLANDS. This plan provides recommendations for the management of "Openlands" and "Brushland" to benefit sharp-tailed grouse and many other species that use these transitional landscapes. The plan has designated 19 Priority Open Landscape Areas (POLA) for different Land Type Association (LTA) areas based on "appropriate[ness]" for management. These areas are classified as Openland (a habitat consisting of an open complex of vegetation with <1/3 total cover by shrubs and/or trees) or Brushland (a habitat consisting of a semi-open complex of vegetation with >1/3 total cover by shrubs and/or 1/3-2/3 total cover by trees). The plan recognizes that most of the POLA does occur on private land, which can make management more difficult. The DNR is currently gaining traction, with the help of the Minnesota Sharp-tailed grouse Society and other stakeholders, to develop a specific Brushland Conservation Management Plan that would help prioritize habitat for STG.

Without prioritizing for open landscapes, STG may decline due to their juxtaposition of occupying a transition zone that is not quite prairie and not quite forest in the eyes of the DNR programing structure. This is evident by a quick search to reveal a bounty of information on ruffed grouse with specific designations of Ruffed Grouse Management Areas, which include 49

separate areas and cover over 40,000 ha. This is especially troublesome for the east central population which is at greater risk due to more forest encroachment and denser human population, leading to greater development and land fragmentation. The distribution of STG in MN can be generalized by the mapping efforts of the Minnesota Breeding Bird Atlas' Interactive Map (Figure 12, Pfannmuller et al. 2017). There is a distinct Northwest (NW) region and an East Central (EC) region which is also recognized by the DNR's survey efforts (Roy 2017). Each square block indicates whether grouse were just observed or the likelihood of breeding occurrence on a sliding scale from possible to confirmed breeding.

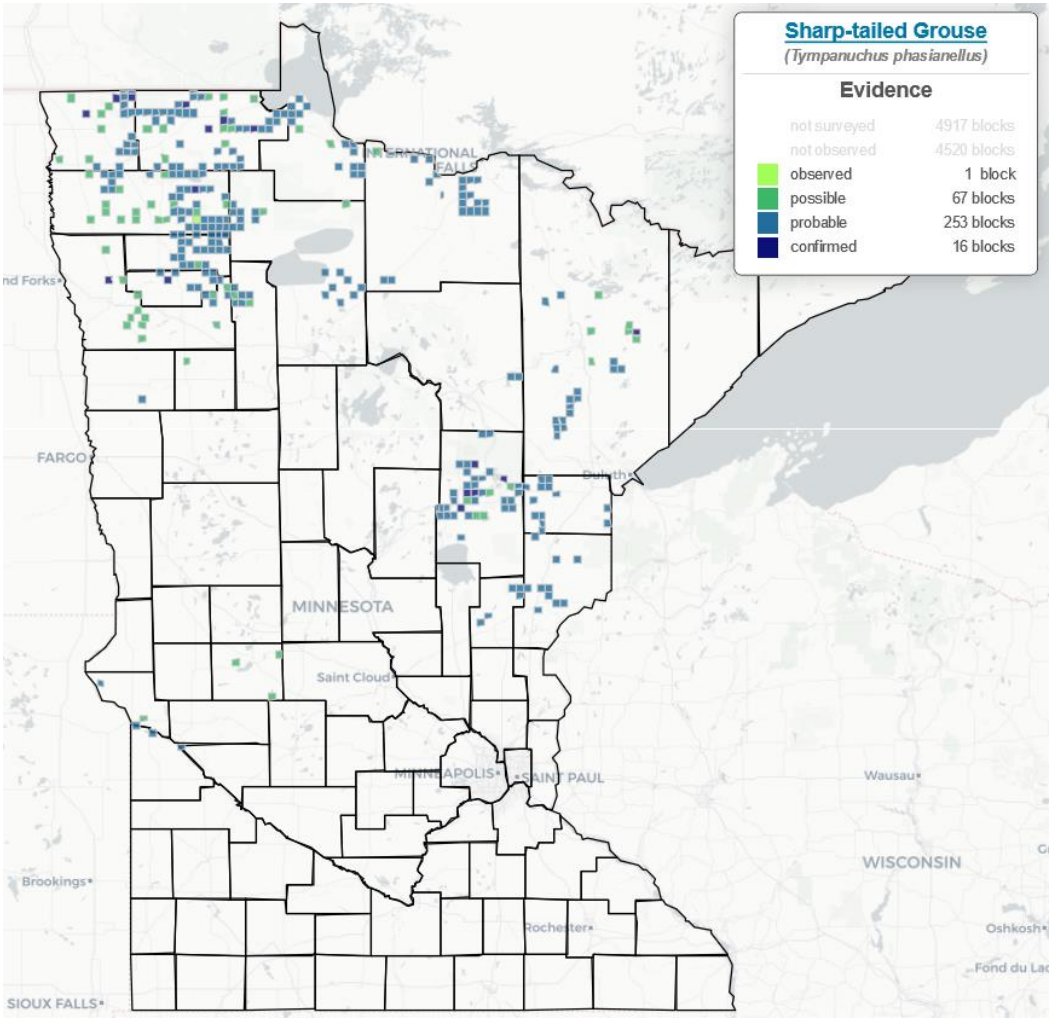


Figure 12. Distribution of verified sharp-tailed grouse occurrences or breeding activity. Breeding Bird Atlas. Adapted from Pfannmuller et al. (2017).

The DNR gathers various information to estimate movement and population status of STG. The major sources include annual lek surveys, hunter harvest numbers, hunter submitted wing samples, and genetic analysis from feathers found at lek sites. According to a 2002 assessment of open landscapes, sharp-tailed grouse populations have been declining for decades which is reflected by a 70% decrease from 1980 to 1999 (MDNR 2002). In addition, long term data show hunter harvest has decreased precipitously from more than 150,000 sharp-tailed grouse in 1949 to approximately 5,000 harvested in 1995 (MDNR 2002, Figure 13).

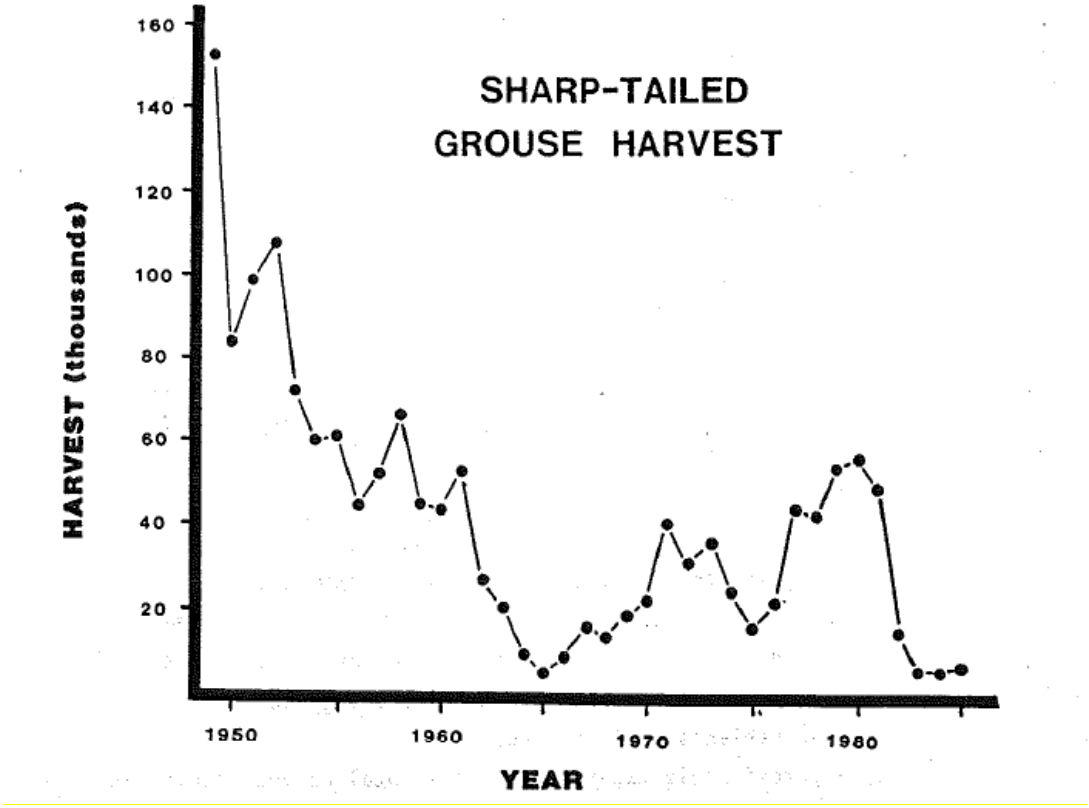


Figure 13. Minnesota sharp-tailed grouse hunter harvest 1949-1984. Adapted from MDNR 2002.

The latest published report on STG spring surveys indicate the 2017 statewide index (Figure 14) falls centrally within the historic range (1980-2017; Roy 2017). The observed grouse/lek index provides an estimate of population levels relative to past years which are

influenced by real population changes as well as other factor (i.e. survey effort). According to Roy (2017), the East Central population is exhibiting multi-year population decline patterns; whereas, the Northwest population remains stable or increasing. In 2017 the DNR made changes to hunting regulations to help protect grouse in the EC region by restricting opening hunting until October 14 (normally September 16) for the that region for the first hunting season length change since 1972 (Berg 1997, MDNR 2017).

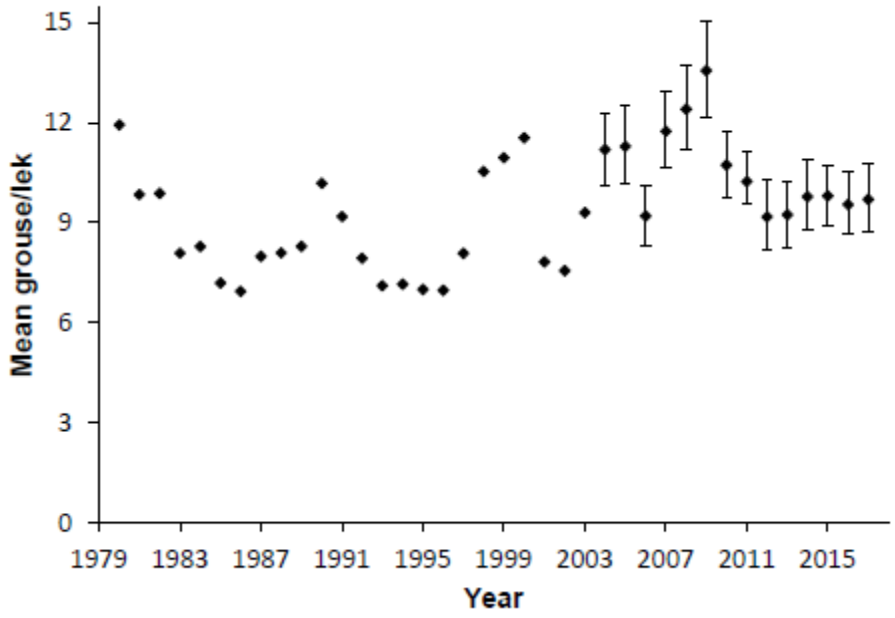


Figure 14. Minnesota sharp-tailed grouse abundance on spring lek sites 1980-2017. Adapted from Roy 2017.

Several research projects are currently underway with implication for STG in Minnesota. They are being conducted by the DNR and various cooperators: Bowling Green State University, University of Minnesota-St. Paul, Southern Illinois University Carbondale, and the United State Environmental Protection Agency (C. Roy, personal communication 2017). Their works are in various stages of completion with titles as follows:

1. **Identifying barriers to movement and effectiveness of corridors for connecting core areas: Landscape genetics of prairie grouse in fragmented landscapes.**
2. **Sharp-tailed Grouse Responses to Fall Prescribed Fire and Mowing.**
3. **Prescribed Burning to Improve Management for Brushland-dependent Species.**
4. **Game and Non-Gamebird Pesticide Exposure.**

### 3.2. North Dakota

North Dakota is also home to four species of North American grouse – the STG, greater prairie chicken, ruffed grouse, and sage grouse. Sharp-tailed grouse in North Dakota are all composed of the *T. p. jamesi* (Plains) subspecies (Figure 5). North Dakota is home to an estimated one third of the North American population of STG (Dyke et al. 2015). North Dakota contains four physiographic ecoregions categorized by the United States Geological Survey as Northwestern Glaciated Plains, Northwestern Great Plains, Northern Glaciated Plains, Lake Agassiz Plain (Bryce et al 1998). Sharp-tailed grouse are believed to be most common in the Missouri plateau region of Northwestern Great Plains (Hagen et al. 2005); however, distribution of STG is statewide (Figure 15, Dyke 2015).

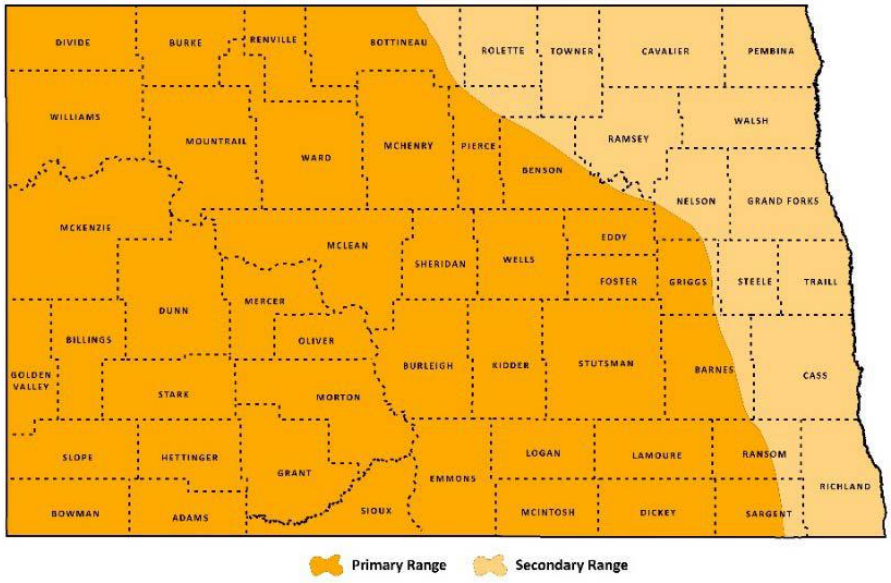


Figure 15. Distribution of sharp-tailed grouse in North Dakota. Adapted from Dyke (2015).

Figure 16 depicts a more specific distribution of sharp-tailed grouse and is derived from Citizen-Science collaborators based on field observations and verified by eBird's rigorous process (Sullivan et al. 2009). This is not based on an exhaustive survey but does document known locations.

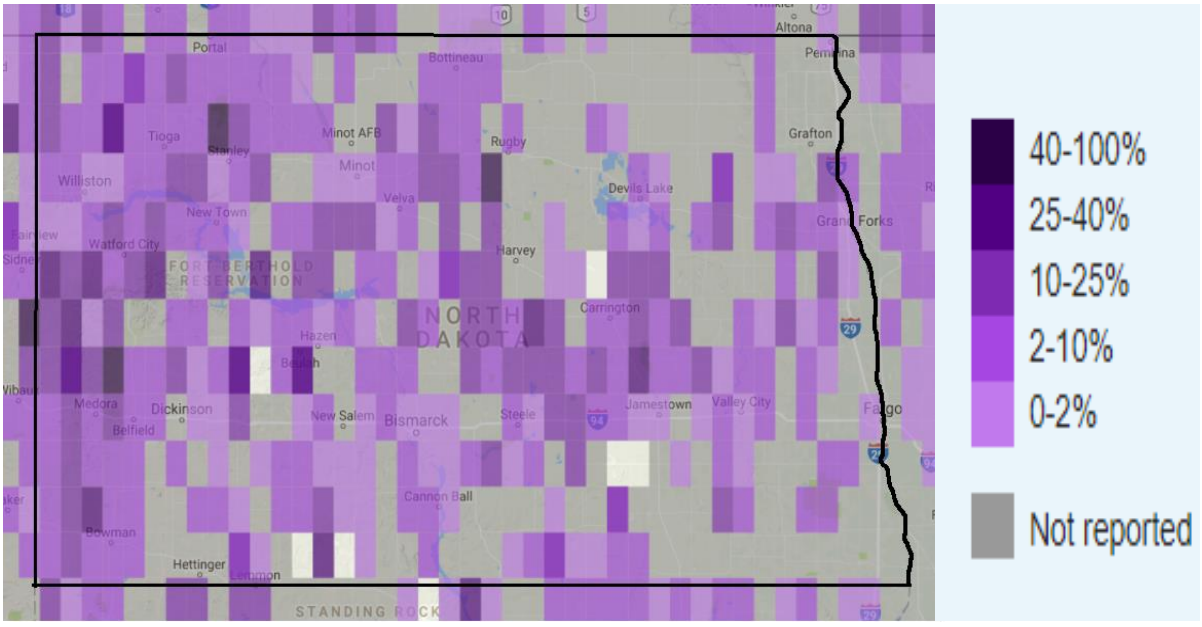


Figure 16. Sharp-tailed grouse modeled probability distributions based on observed locations. Image adapted from eBird (www.ebird.org) and created [3/8/2018].

The North Dakota Game and Fish (NDGF) is the state agency that conducts research and management for STG. The main planning document that is used is for wildlife management and conservation by the NDGF is the North Dakota State Wildlife Action Plan (SWAP), which is published every 10 years and the most current version published in 2015 (Dyke et al. 2015). North Dakota lists STG as a species of conservation priority- level II. The SWAP defines Level II species as those "having a moderate level of conservation priority; or a high level of conservation priority but a substantial level of non-SWG funding is available to them" (Dyke et al. 2015). North Dakota does not currently have a species-specific management plan for STG (J. Kolar, North Dakota Game and Fish, personal communication 2018). Although, STG management and resource recommendations are being integrated into other new statewide plans addressing energy production and CRP acreage losses. In addition, the Public Services Commission (PSC) is advising applicants/developers to work cooperatively with the NDGF to help achieve less impacts to prairie grouse when implementing projects across the state. Furthermore, the US Forest Service (USFS) holds land in North Dakota as a part of the Dakota Prairie Grasslands (DPG) system with STG present in the Little Missouri National Grassland of western North Dakota and in the Sheyenne National Grassland in southeastern, North Dakota. The DPG identifies STG as a Management Indicator Species (MIS). According to the USFS Land and Resource Management Plan for the Dakota Prairie Grasslands Northern Region (2001) key questions are identified to try and address meeting certain legal responsibilities of the DPG: "*What are the population trends for sage and sharp-tailed grouse, and greater prairie chicken, and their associated species? How have management activities affected these trends? Are residual cover levels measured in the fall, providing quality levels of nesting cover the following spring for greater prairie chicken, plains sharp-tailed grouse, and sage grouse?*" based on their.

The USFS lays out specific goals for STG and other MIS: “Provide diverse and quality nesting, brooding, and wintering habitat at levels that, in combination with habitat on adjoining lands, help support stable to increasing sharptailed grouse populations within 10 to 15 years.”

As a game species, STG are generally managed to provide recreational hunting opportunities. The NDGF uses several methodologies to assess the status of grouse in the state. They conduct annual lek surveys, collect and analyze wing samples sent in, and collect hunter harvest information via field checks and mailed surveys. Several metrics are measured such as, brood data, age and sex data, harvest, harvest distribution, and hunter success (NDGF 2016). The total calculated harvest in 2014 was 72,342 STG with an average of 3.45 grouse per hunter based on questionnaire results (Figure 17). This harvest calculation was up about 49% from 2013 harvest of 48,383 grouse (NDGF 2016). Kolar (personal communication 2018) anecdotally estimates the highest harvest number to come from areas near Minot and Stanley, ND. From 2012-2014 Mountrail and McKenzie Counties recorded the highest harvest levels (Table 2.) Data from spring lek counts help provide an index of population trends. Springtime surveys are conducted at 26 areas across 2,712 square kilometers. The NDGF (2016) reported 4,346 males on survey areas in 2015 which marks a 22.4% increase from 2014. Although there are very limited years to compare, the increasing trend of hunter harvest from 2013- 2014 does correspond with an increase in males surveyed per square mile in designated census units compiled by the NDGF (Figures 18 & 19).

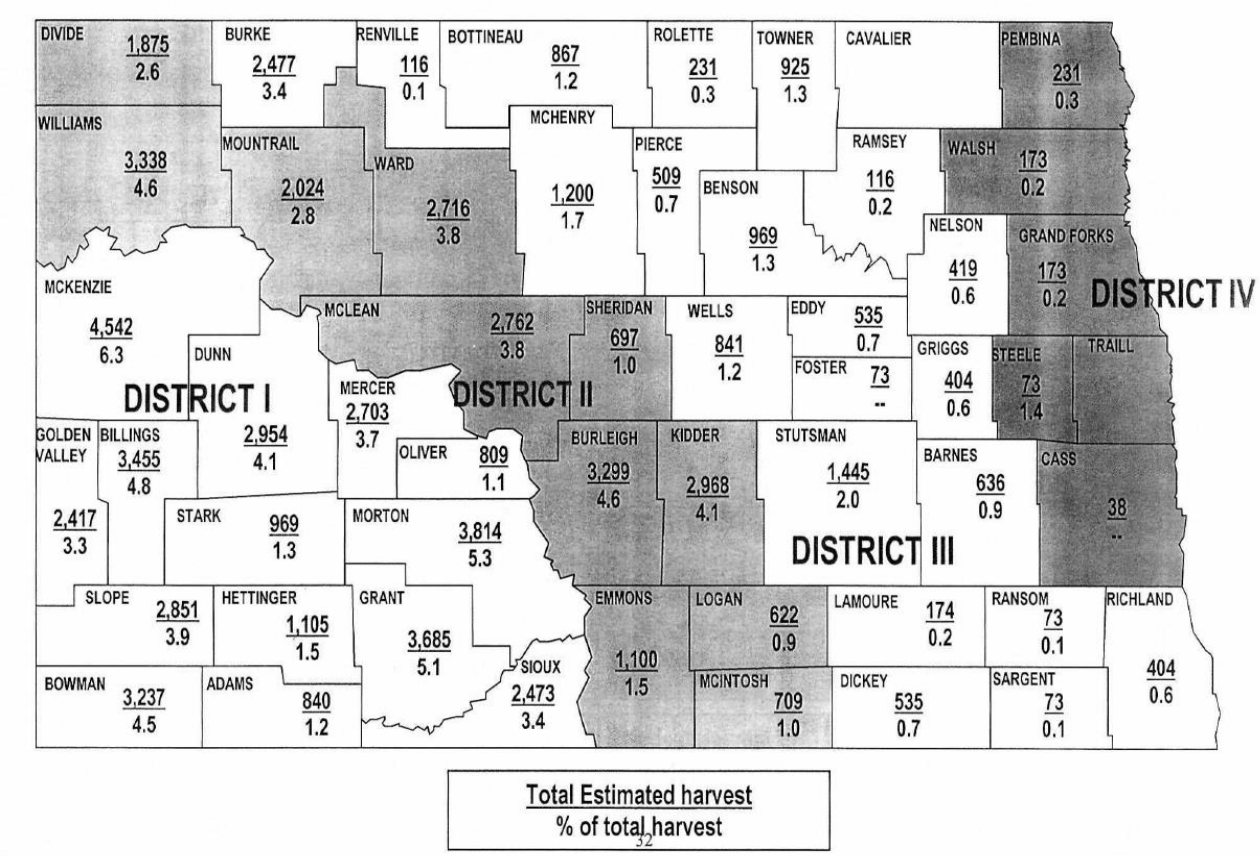


Figure 17. Resident and non-resident estimated harvest distribution from the 2014 hunting season based primarily on questionnaire results (NDGF 2016).

Table 2. Percent of total resident harvest statewide in North Dakota by county (NDGF 2015, 2016).

| Counties with highest harvest* | Year | | |
|---|---|---|---|
| | 2012 | 2013 | 2014 |
| Mountrail | 12.6%, | 10.7%, | |
| McKenzie | | | 6.6% |

*McKenzie was ranked #3 in 2012 and #2 in 2013; Mountrail not in top 6 in 2014

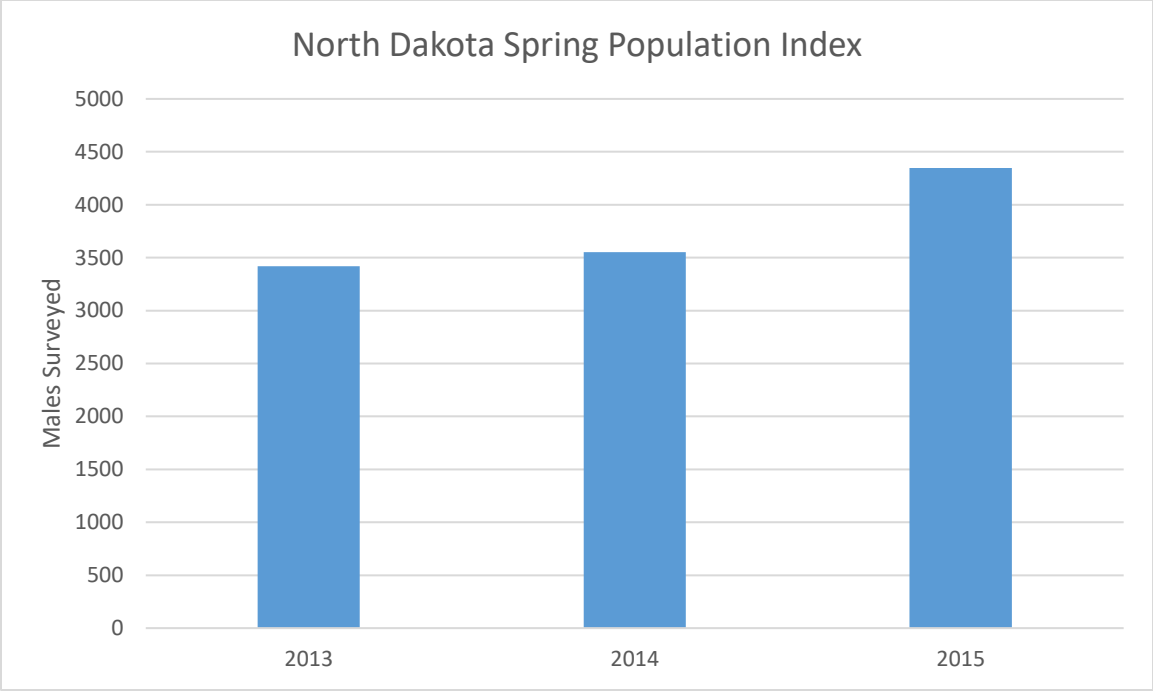


Figure 18. Population index based on surveyed male sharp-tailed grouse per square mile at 26 census areas (2,712 km$^2$) across North Dakota. (NDGF 2015, 2016)

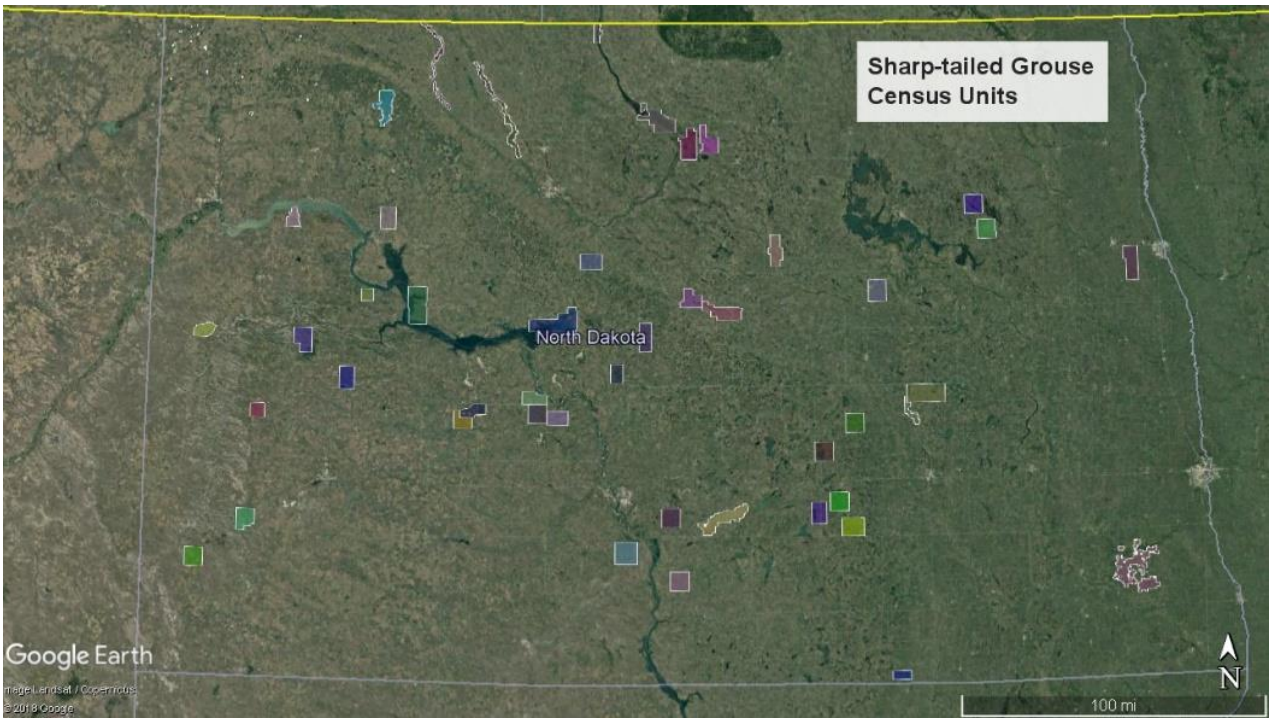


Figure 19. North Dakota sharp-tailed grouse census units (NDGF 2016).

Figure 20 depicts the predicted habitat occurrence and use by STG based on GAP analysis with darker shades being the stronger prediction model for likely habitat and white areas low likelihood of occurrence (Strong et al. 2005). One of the principles of the GAP analysis was also to predict areas that might be suitable for extra management and conservation for protecting land that was suitable habitat but not already public land or protected land. Cropland was considered an area that STG use. Since over 90% of the state is privately owned most areas occupied by STG occurs on private land (Strong et al. 2005).

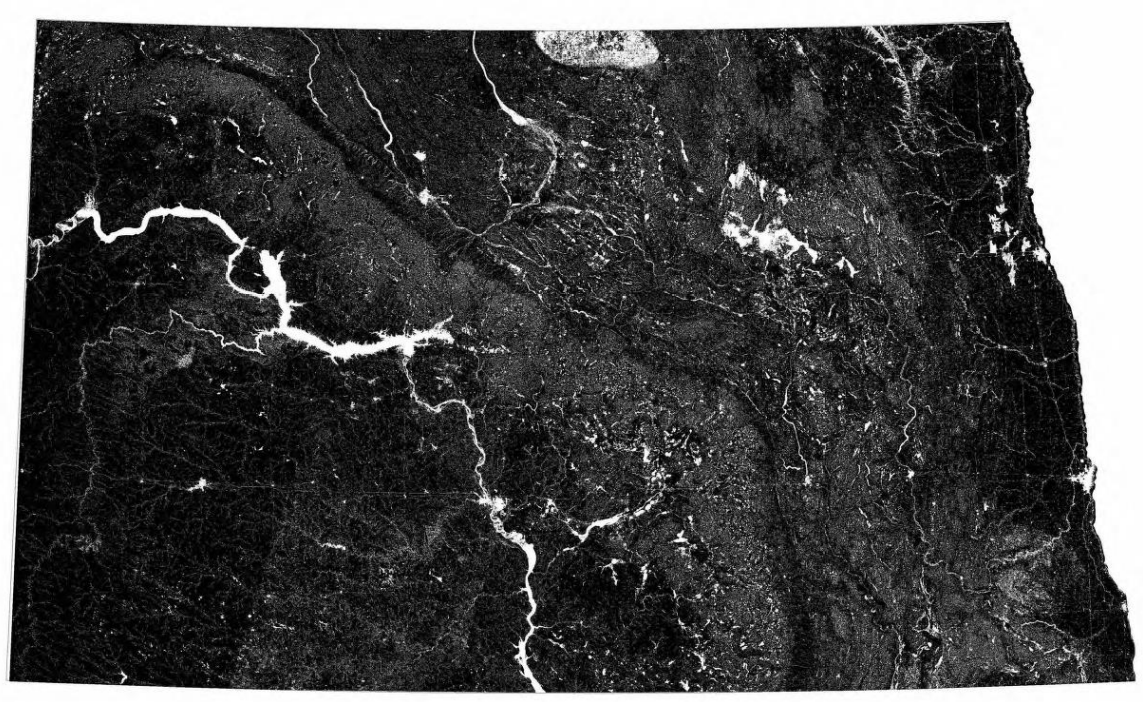

Figure 20. GAP analysis map of sharp-tailed grouse in North Dakota. Adapted from Strong (2005). The darker shades represent higher probability of occurrence.

According to the Breeding Bird Survey (BBS) from 1966-2015 the greatest concentration of STG occurred in northwestern North Dakota, which is also in the heart of Bakken shale formation (Heck et al. 2002; Sauer et al. 2017). The discovery of this formation has caused a recent oil boom in North Dakota due to the advent of hydraulic fracturing or “fracking.” The impacts of oil and gas exploration and extraction in North Dakota and elsewhere are being

investigated and the effects on wildlife and hunting opportunities are realized (Goddard et al. 2009; Dyke 2011, McEnroe and Sapa 2011). Although Kludt (2016), found nesting success to increase in areas with higher oil and gas development, it is unknown if there is a lag effect in which meso-predators will return to the area.

Dyke (2011) has identified research studies to understand the impacts of oil and gas development on the ecology of sharp-tailed grouse. It is unknown at this time of the current status of completion these research projects. The objectives of this study are as follows.

1. **Evaluate the persistence of STG within and outside of energy development areas.**
2. **Quantify movements, reproduction, recruitment, and survival rates within and outside of energy development areas.**
3. **Model STG habitat use to create a predictive, statewide map of available STG habitat. The purpose of the model would provide a tool for proactive planning to avoid, minimize and mitigate the negative effects of development on STG in North Dakota.**

# 4. CONCLUSIONS

Through exploration of STG life histories and published literature, a gap in research has been identified. This species, and land managers, would benefit from more research in the home range, movement, and migration of STG, especially regarding winter time periods which seems less forthcoming in the literature. In addition, further research is warranted to better quantify how changing landscapes are impacting sharp-tailed grouse populations, both local and global.

Sharp-tailed grouse face threats of different magnitude and type depending on their location, but overall main threats can be attributed to habitat loss. The problem of declining habitat quantity and quality regarding STG is well known to the scientific community; however, unless conservation efforts and management plans are imposed more strictly where they exist and created where they don't, habitat will continue to decline from succession and development. Especially undeveloped/uncultivated land under private ownership is prone to habitat degradation by woody encroachment typically due to cost and hardship of maintenance. Since they are a gregarious expansive living species, the majority of their home range and habitat occur on private land. Successful nationwide programs such as the CRP should be encouraged and expanded to work with private landowners whom hold the upper hand in the quantity of habitat owned. The current status of grouse, therefore, lie in the hands of those practicing and promoting conservation across the landscape and will evolve as management plans are enacted to promote a thriving community of sharp-tailed grouse.

Further study to compare the percentage of population that occurs on private land vs public land and evaluate the land cover and management associated with those areas, and how that relates to the overall land ownership within their range is important to examine. These associations can drive management decisions. For example, since 80% of leks are on private land

in Minnesota, does private land occupy 80% of their overall range? The goal would be to evaluate the effectiveness of open landscape management on public lands to see if breeding populations are present/increasing in those areas. One fundamental question would be, if resource managers agree that STG are an umbrella species, is management prioritized to create open landscape habitats within STG historic range for the benefit of multiple species or are their competing interests causing STG to suffer? In addition, there are open landscapes in areas of Minnesota which are within their historic range which don't support grouse or very few (the west central region including Pope, Big Stone, and Lac qui Parle counties). What factors are influencing this?

Why are people drawn to STG and other prairie grouse? Because of their social interactions. Most of a grouse's life is spent hiding in grass or shrubs ducking from predators; however, most of the iconic pictures we easily recognize related with grouse involve their intriguing lekking and courtship behaviors. The congregation of a species can be observed in many different taxa from whales in pods, to a family of beavers, to a convocation of eagles. When animals do this for a specific purpose it seems to resonate strongly with people's innate desire for more social interactions. Going forward wildlife, management, and conservation professionals need to tap deeper into this desire and promote the species in a way to cultivate more public support.

## LITERATURE CITED


Apa, A.D. 1998. Habitat use and movements of sympatric Sage and Columbian Sharp-tailed Grouse in southeastern Idaho. Doctoral dissertation, University of Idaho, Moscow.

Aldrich, J.W. 1963. Geographic orientation of American Tetraonidae. Journal of Wildlife Management 27: 529-545.

Augustine, J.K. and D.R. Trauba. 2015. Potential for behavioral reproductive isolation between greater prairie-chickens and sharp-tailed grouse in west-central Minnesota. Journal of Ethology. 33, pp. 15-24

Ammann, G.A. 1957. The prairie grouse of Michigan. Game Div. Dep. Conservation., Lansing, Mich., Fed. Aid in Wildlife Restoration Project., Mich. 5-R, 37-R, and 70-R, 200 pp.

Berg, W.E. 1997. The sharp-tailed grouse in Minnesota. Minnesota Wildlife Report 10, Department of Natural Resources, Saint Paul, U.S.A.

Bergerud, A.T. 1988a. Mating Systems in Grouse. Pages 439-472 A.T. Bergerud, and M. W. Gratson, editors. Adaptive Strategies and Population Ecology of Northern Grouse. Wildlife Management Institute, Minneapolis, Minnesota, USA

Bergerud, A.T. 1988b. Population ecology of North American grouse. Pages 578-685 A.T. Bergerud, and M. W. Gratson, editors. Adaptive Strategies and Population Ecology of Northern Grouse. Wildlife Management Institute, Minneapolis, Minnesota, USA

Bergerud, A.T. and M. W. Gratson. 1988. "Survival and breeding strategies of grouse." In Adaptive strategies and population ecology of northern grouse., edited by A. T. Bergerud and M. W. Gratson, 473-577. Minneapolis: University of Minnesota Press.

BirdLife International. 2016. *Tympanuchus phasianellus*. The IUCN Red List of Threatened Species 2016: e.T22679511A92816912. <http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22679511A92816912.en.> Downloaded on 26 February 2017.

Boyce, M.S., Vernier, P.R., Nielsen, S.E. & Schmiegelow, F.K. 2002. Evaluating resource selection functions. Ecological Modelling, 157, 281–300.

Bryce, S., J.M. Omernik, D.E. Pater, M. Ulmer, J. Schaar, J. Freeouf, R. Johnson, P. Kuck, and S. H. Azevedo. 1998. Ecoregions of North Dakota and South Dakota. Jamestown, ND: Northern Prairie Wildlife Research Center Online. <http://www.npwrc.usgs.gov/resource/habitat/ndsdeco/index.htm> (Version 30NOV1998).

Burr, P.C., Robinson A.C, Larsen R.T, Newman R.A., Ellis-Felege S.N. 2017. Sharp-Tailed Grouse Nest Survival and Nest Predator Habitat Use in North Dakota's Bakken Oil Field. PLoS ONE 12(1): e0170177. doi:10.1371/journal. pone.0170177

Connelly, J.W., M.W. Gratson and K.P. Reese. 1998. Sharp-tailed grouse (Tympanuchus phasianellus), The Birds of North America (P. G. Rodewald, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America: <https://birdsna-org.ezproxy.lib.ndsu.nodak.edu/Species-Account/bna/species/shtgro>

Connolly, T.T. 2001. Reproductive ecology of sharp-tailed grouse on the pine barrens of northwestern Wisconsin. M. Sc. Thesis, University of Wisconsin-Stevens Point, Wisconsin.

Coppedge, B.R., D.M. Engle, R.E. Masters, and M.S. Gregory. 2001. Avian response to landscape change in fragmented southern Great Plains grasslands. Ecological Applications 11:47–59.

Coates, P.S., Ricca, M.A., Prochazka, B.G., Brooks, M.L., Doherty, K.E., Kroger, and Casazza, M.L. 2016. Wildfire, climate, and invasive grass interactions negatively impact an indicator species by reshaping sagebrush ecosystems. Proceedings of the National Academy of Sciences, 113(45), 12745–12750.

Dunning, J.B., B.J. Danielson, and H.R. Pulliam. 1992. Ecological processes that affect populations in complex landscapes. Oikos 65: 169 D175.

Dyke, S.R, D. Fryda, D. Kleyer, J. Williams, B. Hosek, W. Jensen, S. Johnson, A. Robinson, F. Ryckman, B. Stillings, M. Szymanski, S. Tucker and B. Wiedmann. 2011. Potential impacts of oil and gas development on select North Dakota natural resources; a report to the director. North Dakota Game and Fish Department.

Dyke, S.R., S.K. Johnson, and P.T. Isakson. 2015. North Dakota State Wildlife Action Plan. North Dakota Game and Fish Department, Bismarck, ND.

Editors. 2004. North American grouse management plan. North American Grouse Partnership, Williamsport, MD. < http://www.grousepartners.org/resources/>. Accessed 15 Feb 2018

Evans, K.E. 1968. Characteristics and habitat requirements of the greater prairie chicken and sharp-tailed grouse - a review of the literature. U. S. Forest Service Conservation Research Report 12.

Galt, A. 2012. Sharp-tailed Grouse Lek – Arrowwood National Wildlife Refuge. [Video file]. Retrieved from https://www.youtube.com/watch?v=7nYJxD8dVjw

Giesen K.M, and Braun C.E. 1993. Status and distribution of the Columbian sharp-tailed grouse in Colorado. Prairie Naturalist. 25:237–242.

Giesen, K.M. 1997. Seasonal movements, home ranges, and habitat use by Columbian Sharp-tailed Grouse in Colorado. Colorado Division of Wildlife, Special Report 72.

Gratson, M.W., editor. 1988. Spatial patterns, movements, and cover selection by Sharp-tailed Grouse. Pages 158-192 *in* Adaptive strategies and population ecology of northern grouse. (Bergerud, A. T. and M. W. Gratson, Eds.) University of Minnesota Press, Minneapolis, Minnesota, USA.

Gratson, M.W. 1989a. Intraspecific nest parasitism by sharp-tailed grouse. Wilson Bulletin. no. 101:126-127.

Goddard, A.D., R.D. Dawson, M.P. Gillingham. 2009. Habitat selection by nesting and brood-rearing sharp-tailed grouse. Canadian Journal of Zoology, April 2009, Vol. 87 Issue 4, p326-336

Gutiérrez, R.J., Barrowclough, G.F., Groth, J.G. 2000. "A classification of the grouse (Aves: Tetroninae) based on mitochondrial DNA sequences" (PDF). Wildlife Biology. 6 (4): 205–212.

Hagen, S. K., Patrick T. Isakson, and Steve R. Dyke. 2005. North Dakota Comprehensive Wildlife Conservation Strategy. North Dakota Game and Fish Department. Bismarck, ND. 454 pp. http://www.nd.gov/gnf/conservation/cwcs.html

Hamerstrom, F.N., Jr. 1963. Sharptailed brood habitat in Wisconsin's northern pine barrens. Journal of Wildlife Management. 27(4): 793-802. [15809]

Hanowski, J.M., Christian, D.P. & Niemi, G.J. 2000: Landscape requirements of prairie sharp-tailed grouse *Tympanuchus phasianellus campestris* in Minnesota, USA. - Wildlife. Biology. 6: 257-263.

Harris, S.W. 1967. Fall foods of sharp-tailed grouse in Minnesota. Journal of Wildlife Management 31:585-587.

Hart, M., Lee, O.S., and Low, J.B. 1950. The sharp-tailed grouse in Utah. Utah State Dep. Fish and Game, Fed. Aid Div., Publ. 3, 79 pp.

Hartzler J.E. and D.A. Jenni. 1988. Mate choice by female sage grouse. Pages 240-269 i*n* Adaptive strategies and population ecology of northern grouse. (Bergerud, A. T. and M. W. Gratson, Eds.) University of Minnesota Press, Minneapolis, Minnesota, USA.

Heck, T.J., R.D. LeFever, D.W. Fischer, and J. LeFever. 2002. Overview of the petroleum geology of the North Dakota Williston Basin. Bismarck: North Dakota Geological Survey. https://www.dmr.nd.gov/ndgs/Resources/WBPetroleumnew.asp (accessed January, 2013), Web page modified February 7, 2007.

Hillman, C.N., and W.W. Jackson. 1973. The sharp-tailed grouse in South Dakota. South Dakota Dep. Game, Fish and Parks Tech. Bull. 3. 63 pp.

Hobbs R.J, Higgs E, Harris JA. 2009. Novel ecosystems: Implications for conservation and restoration. Trends in Ecology & Evolution 24(11):599–605

Horne, J.S. and E.O. Garton. 2006. Likelihood cross-validation versus least squares cross-validation for choosing the smoothing parameter in kernel home-range analysis. Journal of Wildlife Management 70:641-648.

Houchen, D.J., 2011. Evaluation of Habitat Selection by Nesting Sharp-Tailed Grouse and Survivorship of Hens, Males, and Nests on the Grand River National Grassland in Northwest South Dakota, USA. M.S. Thesis. North Dakota State University, Fargo. 102 pp.

Hovick, T.J., R.D. Elmore, D.K. Dahlgren, S.D. Fuhlendorf, and D.M. Engle. 2014. Evidence of negative effects of anthropogenic structures on wildlife: a review of grouse survival and behaviour. Journal of Applied Ecology 51:1680–1689.

Johnsgard, P. A. 1973. Sharp-tailed grouse. *in* Grouse and Quails of North America. The University of Nebraska Lincoln press, Lincoln, Nebraska, USA. Accessed 2017 from <http://digitalcommons.unl.edu/bioscigrouse/>

Johnsgard, P.A. 1983. The Grouse of the World. University of Nebraska Press, Lincoln, Nebraska, USA.

Johnsgard, P.A. 2002. Grassland grouse and their conservation. Smithsonian Institution Press, Washington and London.

Johnson, D.H., and L.D. Igl. 1995. Contributions of the Conservation Reserve Program to populations of breeding birds in North Dakota. Wilson Bulletin 107:709-718.

Johnson, D.H., 2000. "Grassland Bird Use of Conservation Reserve Program Fields in the Great Plains". Publications of the US Geological Survey. Paper 29.

Johnson, J.A. 2008. Recent range expansion and divergence among North American prairie grouse. Journal of Heredity, 99, 165–173. DOI: 10.1093/jhered/esn002.

Kernohan, B.J., R.A. Gitzen, and J.J. Millspaugh. 2001. Analysis of animal space use and movements. Pages 125-166 in J. J. Milspaugh and J. M. Marzluff, editors. Radio tracking and animal populations. Academic, New York, New York, USA

Kirby, D. and K. Grosz. 1995. Cattle grazing and sharp-tailed grouse nesting success. Rangelands 17:124-126.

Kludt, R.A. 2016. Nesting Behaviors of Sharp-Tailed Grouse (*Tympanuchus phasianellus*) Using Camera Technology

Kobriger, G.D. 1965. Status, movements, habitats, and foods of prairie grouse on a sandhills refuge. Journal of Wildlife Management. 29(4):788-800.

Kobriger, G.D. 1980. Habitat use by nesting and brooding sharp-tailed grouse in southwestern North Dakota. North Dakota Outdoors 43(1):2-6.

Leopold, A.S. 1953: Intestinal morphology of gallinaceous birds in relation to food habits. Journal of Wildlife Management 17: 197-203.

Lichti, N.I. and R.K. Swihart. 2010. Estimating utilization distributions with kernel versus local convex hull methods. Journal of Wildlife Management 75:413-422

Manske, L.L. and W.T. Barker. 1987. Habitat usage by prairie grouse on the Sheyenne National Grasslands. pp. 8-20. In: A. J. Bjugstad, editor. Prairie Chickens on the Sheyenne National Grasslands. General Technical Report RM-159. Fort Collins, CO: U. S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station.

Manzer, D.L. and S.J. Hannon. 2005. Relating grouse nest success and corvid density to habitat: A multi-scale approach. Journal of Wildlife Management 69:110-123.

Manzer, D.L. and S.J. Hannon. 2008. Survival of sharp-tailed grouse Tympanuchus phasianellus chicks and hens in a fragmented prairie landscape. Wildlife Biology 14:16-25.

Marks, J.S. and V.A. Marks. 1987. Habitat selection by Columbian Sharp-tailed Grouse in west central Idaho. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

Meints, D.R., J.W. Connelly, K.P. Reese, A.R. Sands, and T.P. Hemker. 1992. Habitat suitability index (HSI) procedure for Columbian Sharp-tailed Grouse. University of Idaho Forest, Wildlife, and Range Experimental Station Bulletin 55, Moscow.

Minnesota Department of Natural Resources. Division of Wildlife. 2002. An assessment of open landscapes for management of brushland wildlife habitat in northern and central Minnesota. Minnesota Department of Natural Resources Wildlife Resource Assessment Report 1. Minnesota Department of Natural Resources, St. Paul, Minnesota. 572 pp.

Minnesota Department of Natural Resources. 2006. Tomorrow's Habitat for the Wild and Rare: An Action Plan for Minnesota Wildlife, Comprehensive Wildlife Conservation Strategy. Division of Ecological Services, Minnesota Department of Natural Resources.

Minnesota Department of Natural Resources. 2016. Minnesota's Wildlife Action Plan 2015-2025. Division of Ecological and Water Resources, Minnesota Department of Natural Resources.

Minnesota Department of Natural Resources. 2017. Minnesota Hunting & Trapping Regulations. Minnesota Department of Natural Resources. 500 Lafayette Road St. Paul, MN

Minnesota Prairie Plan Working Group. 2011. Minnesota Prairie Conservation Plan. Minnesota Prairie Plan Working Group, Minneapolis, MN. 55p. <https://www.dnr.state.mn.us/prairieplan/index.html>. Accessed 13 Jan 2018

Mitchell, G.J. and P. W. Riegert. 1994. Sharp-tailed Grouse, Tympanuchus phasianellus, and grasshoppers: food is when you find it. Can. Field-Nat. no. 108:288-291.

McDonald, M.W. 1998. Ecology of Columbian Sharp-tailed Grouse in eastern Washington. Master's thesis, University of Idaho, Moscow

McEnroe, M. and Sapa, A. 2011. Observations and recommendations to reduce fish and wildlife impacts from oil and gas development: a report to the membership of the North Dakota Chapter of the Wildlife Society. Bismarck. 20 pp.

Mohr, C.O. 1947. Table of equivalent populations of North American small mammals. American Midland Naturalist 37:223-249.

National Audubon Society. 2018. Conservation Ranching. <http://www.audubon.org/conservation/ranching>. Accessed 15 Feb 2018.

Niemuth, N.D., and M.S. Boyce. 2004. Influence of landscape composition on sharp-tailed grouse lek location and attendance in Wisconsin pine barrens. Ecoscience 11:209–217.

Niemuth, N.D. 2011. Spatially explicit habitat models for prairie grouse. Pp. 3-20 *in* B. K. Sandercock, K. Martin, and G. Segelbacher (editors). Ecology, conservation, and management of grouse. Studies in Avian Biology (no. 39), University of California Press, Berkeley, CA.

North Dakota Game and Fish Department. 2015. Phase B Upland Game Investigation. "Prairie Grouse Population Data." Wildlife Division. Report No.: C-364.

———. 2016. Phase B Upland Game Investigation. "Prairie Grouse Population Data." Wildlife Division. Report No.: C-373.

Partners in Flight Science Committee 2013. Population Estimates Database, version 2013. Available at http://pif.birdconservancy.org/PopEstimates. Accessed on 11/12/2017.

Pfannmuller, L., G. Niemi, J. Green, B. Sample, N. Walton, E. Zlonis, T. Brown, A. Bracey, G. Host, J. Reed, K. Rewinkel, and N. Will. 2017. The First Minnesota Breeding Bird Atlas (2009-2013).

Patten, M.A., Pruett, C.L. & Wolfe, D.H. 2011. Home range size and movements of greater prairie-chickens. Studies in Avian Biology, 39, 51–62.

Prose, B.L. 2002. Cade, B.S., Hein, D., "Selection of Nesting Habitat by Sharp-tailed Grouse in the Nebraska Sandhills". USGS Staff -Published Research. Paper 89.

Prose, B.L. 1987. Habitat suitability index models: plains sharp-tailed grouse. U.S. Fish Wildlife Service Biological Report 82 (10.142). 31 pp.

Rippin, A.B., and D.A. Boag. 1974. Recruitment to populations of male sharp-tailed grouse. Journal Wildlife Management. 38(4):616-621.

Rippin, A.B. and D. A. Boag. 1974. Spatial organization among sharp-tailed grouse on arenas. Can. J. Zool. 52(5):591-597.

Robel, R.J., J.N. Briggs, A.D. Dayton, and L.C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management. 23:295-297

Robel, R.J., R.F. Henderson, and W. Jackson. 1972. Some sharp-tailed grouse population statistics from South Dakota. The Journal of Wildlife Management 36:87-98.

Roersma, S.J. 2001. Nesting and brood rearing ecology of plains sharp-tailed grouse (*Tympanuchus phasianellus jamesi*) in a mixed-grass/fescue eco-region of Southern Alberta. M.S. Thesis, University of Manitoba, Winnipeg, Manitoba, Canada.

Roy, C. 2017b. 2017 Minnesota Spring Grouse Surveys. Forest Wildlife Populations and Research Group. Minnesota Department of Natural Resources. Grand Rapids, Minnesota.

Runia, T.J. 2009. Influence of the Conservation Reserve Program and landscape composition on the spatial demographics of prairie grouse in northeastern South Dakota. M.S. Thesis. South Dakota State University, Brookings. 96 pp.

Schiller, R.J. 1973. Reproductive ecology of female Sharp-tailed Grouse (Pedioecetes phasianellus) and its relation to early plant succession in northwestern Minnesota. PHD Dissertation, University of Minnesota, St. Paul. 175 pp.

Sandercock, B.K., Nilsen, E.B., Brøseth, H. and Pedersen, H.C. 2011, Is hunting mortality additive or compensatory to natural mortality? Effects of experimental harvest on the survival and cause-specific mortality of willow ptarmigan. Journal of Animal Ecology, 80: 244–258. doi:10.1111/j.1365-2656.2010.01769.x

Sauer, J.R., D.K. Niven, J. E. Hines, D.J. Ziolkowski, Jr, K.L. Pardieck, J.E. Fallon, and W.A. Link. 2017. The North American Breeding Bird Survey, Results and Analysis 1966 - 2015. Version 2.07.2017 USGS Patuxent Wildlife Research Center, Laurel, MD

Sedivec, K.K., W.T. Barker, T.A. Messmer, D.R. Hertel, and K.F. Higgins. 1995. Effects of grazing management on sharp-tailed grouse in North Dakota. Proceedings of the 21st Prairie Grouse Technical Council Medora, North Dakota.

Sisson, L.H. 1976. The sharp-tailed grouse in Nebraska: research study. Nebraska Game and Parks Comm., Lincoln. 88 pp.

South Dakota Department of Game, Fish and Parks. 2011. Prairie Grouse Management Plan for South Dakota, 2011-2015. South Dakota Department of Game, Fish and Parks, Pierre, South Dakota, USA.

Strong, L.L., H.T. Sklebar, and K.E. Kermes. 2005. North Dakota GAP analysis project. Jamestown, ND: Northern Prairie Wildlife Research Center

Sullivan, B.L., C.L. Wood, M.J. Iliff, R.E. Bonney, D. Fink, and S. Kelling. 2009. eBird: a citizen-based bird observation network in the biological sciences. Biological Conservation 142: 2282-2292.

Tesky, J.L. 1994. Tympanuchus phasianellus. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2013, January 9].

Ulliman, M.J. 1995. Winter habitat ecology of Columbian Sharp-tailed Grouse in southeastern Idaho. Master's thesis, University of Idaho, Moscow.

U. S. Department of Agriculture. USFS. 2001. Land and Resource Management Plan for the Dakota Prairie Grasslands Northern Region. Dakota Prairie Grasslands. Bismarck, North Dakota

U.S. Department of Agriculture. 1999. Sharp-tailed grouse (*Tympanuchus phasianellus*) Fish and Wildlife Habitat Management Guide Sheet. Natural Resources Conservation Service (NRCS) – Minnesota.

U.S. Department of Agriculture. 2007. Fish and Wildlife Habitat Management Leaflet Number 40. Sharp-tailed Grouse (*Tympanuchus phasianellus*). Natural Resources Conservation Service (NRCS).

U.S. Department of Agriculture. 2009. Summary Report: 2007 National Resources Inventory, Natural Resources Conservation Service, Washington, DC, and Center for Survey Statistics and Methodology, Iowa State University, Ames, Iowa. 123 pages.

U.S. Department of Agriculture, NRCS. 2018. The PLANTS Database (http://plants.usda.gov, 10 April 2018). National Plant Data Team, Greensboro, NC 27401-4901 USA.

Vodehnal, W.L. and J.B. Haufler, 2008. A grassland conservation plan for prairie grouse. North American Grouse Partnership. Fruita, CO.

Wright C.K. and Wimberly M.C. 2013. Recent land use change in the Western Corn Belt threatens grasslands and wetlands. Proceedings of National Academy of Science USA 110(10):4134–4139

Worton, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70: 164–168.