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Restoration Plan for Sharp-tailed Grouse Recovery in Western Montana

Developed for the Montana Department of Fish, Wildlife, and Parks

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Cover photo from Montana Fish Wildlife and Parks

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EXECUTIVE SUMMARY

Sharp-tailed grouse (*Tympanuchus phasianellus*) were once the most important upland game bird in Montana and occurred throughout much of the state, including grassland dominated mountain valleys west of the Continental Divide. However, western populations in Montana declined rapidly during the 19th century as Euro-Americans settled mountain valley habitats. Currently sharp-tailed grouse populations are widespread and stable east of the Divide but effectively extirpated in western Montana. This plan evaluates the potential for population recovery and outlines activities needed to restore a viable population of sharp-tailed grouse in western Montana.

Sharp-tailed grouse are the most widespread species of prairie-grouse (genus *Tympanuchus*), and occupy diverse grassland, steppe, and mixed-shrub ecosystems throughout central and northern North America. As a result, the species is thought to tolerate greater variation in plant community types and composition than other species of prairie-grouse. Plasticity in habitat utilization suggests high potential for successful translocations and reintroductions. Nevertheless, specific habitat requirements vary throughout the year; thus the availability and appropriate juxtaposition of key seasonal habitat components should be considered when selecting potential restoration sites. Within optimum sharp-tailed grouse habitat, large tracts of native grassland are maintained, mixed with areas of shrub cover, wooded draws, and some cropland. Relatively large, intact, and high quality native grassland or mixed-shrub habitats are required for nesting. Suitable nesting cover can be provided by herbaceous vegetation in more productive eastern ecosystems or a mix of shrub (e.g., sagebrush (*Artemisia* spp.)) and residual grass cover in dryer western ecosystems. Habitat edges, along with other areas transitioning from sparse to dense vegetation provide access to food resources in close proximity to escape cover and are often selected for by sharp-tailed grouse broods. Shrubby or woody areas, which provide thermal cover and food, are thought to become increasingly important to sharp-tailed grouse during the late fall and winter.

Habitat quality and quantity directly affect demographic performance of sharp-tailed grouse populations. The species has consistently high reproductive effort and a relatively fast life-history. Population sensitivity analyses indicate that reproductive success is one of the most influential demographic parameters affecting population dynamics. However, the timing and severity of weather events can also greatly influence overwinter survival and recruitment of birds to spring breeding populations. Thus management efforts to improve population performance should focus on nesting and brood-rearing habitats, followed by winter habitats. Within continuous grassland habitats, rangeland and grazing management is likely the most significant driver of habitat conditions and population performance. Management that provides compositionally and structurally diverse native grassland habitats with sufficient residual vegetation will improve reproductive success and survival.

To evaluate whether a viable population of reintroduced sharp-tailed grouse could exist in western Montana, we used life-history information from the published literature to conduct a population viability analysis (PVA). Our results suggest that under demographic rates that may result from existing habitat conditions, a population of sharp-tailed grouse in western Montana was not viable (i.e., did not have a 95% probability of persistence at 50 years post-establishment). However, a simulated management scenario where improvements to nesting and winter habitat increased fecundity and overwinter survival resulted in a viable population.

Assuming habitat improvements occur prior to translocations, a population composed of ≥ 280 individuals, and ideally ≥ 500 will be necessary to ensure population persistence over a 50-year period, which might be achieved through the translocation methods we describe. Environmental stochasticity had significant effects on 50-year population persistence and larger populations were more effective at recovering from random declines associated with annual environmental variability. The minimum amount of suitable habitat required to support a viable population was 4,340–7,750 ha, assuming habitat is sufficient to support an average density of 15.5 grouse per km^2.

All three potential restoration sites meet the minimum dynamic area needed to support a minimum population size of 280 birds. However, results of field-based habitat assessments indicate that the Blackfoot Valley site is the most similar to areas currently occupied by sharp-tailed grouse and should be the focus of initial sharp-tailed grouse habitat and population restoration. Several habitat enhancements that improve nesting and brood-rearing habitat and protect and enhance winter cover should be implemented prior to reintroducing sharp-tailed grouse to the Blackfoot Valley, including conifer removal, appropriate livestock management, and restoration of deciduous shrub habitats. Seasonal movements and space use can be large for sharp-tailed grouse, and cooperation among landowners and managers across large restoration areas will be needed for successful recovery.

Reintroductions of sharp-tailed grouse should follow protocols that minimize translocation-related mortalities, reduce movements away from the initial release sites, facilitate the quick establishments of leks, and assure sufficient genetic variation of founders to prevent genetic bottlenecks and inbreeding. Initial capture and translocation efforts should focus on establishing active leks with displaying males. Fall translocation of males has been shown to improve the probability of lek establishment and the likelihood of settlement by females released the following spring. Given the heavy mating skew of prairie-grouse, sex ratios of released birds should be 2 females to 1 male. The success of prairie-grouse reintroductions increases with the number of translocated birds and at least 100 birds (≥ 33 males; ≥ 66 females). Translocated birds should come from multiple source populations with similar environmental conditions, high fitness, and a similar evolutionary history to historic populations at reintroduction sites to minimize negative impacts to source populations and maximize genetic diversity. Periodic supplementation of additional females may be required if habitat connections with other populations cannot be re-established.

INTRODUCTION

Sharp-tailed grouse once occurred throughout Montana, including grassland dominated mountain valleys west of the Continental Divide (Lord 1866, Thompson 1985). Today, healthy populations of sharp-tailed grouse occupy much of their original grassland habitats east of Continental Divide (Anderson and Farrar, unpublished manuscript), whereas populations west of the Divide may be extirpated (Young and Wood 2012). Declines of sharp-tailed grouse in western Montana were noted as early as 1921 and by 1987 populations had declined to a level requiring management intervention (Saunders and Bailey 1921, Cope 1992, Young and Wood 2012). Several attempts to supplement declining populations of sharp-tailed grouse with translocated grouse from other areas occurred in western Montana during the late 20th century. These translocations slowed times to population extinctions, but were not successful in preserving populations in western Montana (Young and Wood 2012). The last known accounts of sharp-tailed grouse observed in western Montana are two anecdotal reports of ≤ 5 individuals from 2003 (Fitzpatrick 2003).

The causes of the decline of sharp-tailed grouse populations in western Montana and the reasons for the failure of early translocation programs are unknown (Anderson and Farrar, unpublished manuscript). In other areas historically occupied by sharp-tailed grouse, declines have been attributed to habitat loss, fragmentation, and degradation resulting from cultivation, overgrazing by livestock, fire suppression, mineral exploitation, and urban development (Yocom 1952, Leupin 2003). It is likely that these same human influences are responsible for declines in western Montana and may currently limit the potential restoration of populations west of the Divide. Nevertheless, a desire to restore sharp-tailed grouse to western Montana has persisted and several entities have combined efforts to determine the feasibility of a successful reintroduction of sharp-tailed grouse to western Montana. This plan identifies population recovery objectives and outlines activities needed to restore a viable population of sharp-tailed grouse in western Montana.

The goals of this restoration plan are to (1) evaluate whether three potential restoration areas in western Montana identified by the Montana Department of Fish Wildlife and Parks (MTFWP) have the potential to support viable populations of sharp-tailed grouse, and (2) describe actions needed to establish and manage a successful reintroduction of sharp-tailed grouse in western Montana. This recovery plan is organized into four sections. The first section reviews the current status of sharp-tailed grouse both nationally and within the state of Montana. The second section reviews the biology, ecology, and life history of sharp-tailed grouse. The third section examines the potential for recovery of sharp-tailed grouse populations in western Montana. The fourth section introduces recovery objectives and provides detailed management actions needed to implement a successful reintroduction program for sharp-tailed grouse in western Montana.

STATUS

TAXONOMY

Sharp-tailed grouse are classified in the order Galliformes, family Phasianidae, and sub-family Tetraoninae. Linnaeus originally described sharp-tailed grouse as *Tetrao phasianellus* in 1758, but the species was later placed in the monotypic genus *Pedioecetes* by Baird in 1858 (Connelly et al. 1998). *Pedioecetes* was later merged with *Tympanuchus*, due to the similarities between sharp-tailed grouse and prairie-chickens (Hudson et al. 1966, Short 1967). There are seven subspecies of sharp-tailed grouse, two of which are native to Montana; the Columbian sharp-tailed grouse (*T. p. columbianus*) and plains sharp-tailed grouse (*T. p. jamesi*; Connelly et al. 1998). Originally, the two subspecies were thought to be separated by the Continental Divide, with *T. p. columbianus* occurring in western Montana. However, evidence suggests that several historic sharp-tailed grouse subpopulations in western Montana were genetically more similar to plains than Columbian subspecies (Warheit and Dean 2009).

DESCRIPTION

Sharp-tailed grouse are a medium-sized grouse measuring 41–47 cm (16–18.5 in) in length and 569–1,031 grams (1.25–2.25 lbs); mass varies with season and sex (Connelly et al. 1998, Rusch et al. 2000). Both males and females are cryptically colored with heavily barred upperparts and white underparts (Connelly et al. 1998, Stinson and Schroeder 2012). Nostrils and legs are feathered and there are crescent-shaped, yellowish-orange combs over the eyes (Edminster 1954, Connelly et al. 1998). The tail is wedge-shaped, with the two middle tail feathers extending beyond the other tail feathers about 5 cm (Stinson and Schroeder 2012). The crown feathers are elongated and form a crest when erected (Connelly et al. 1998). Male sharp-tailed grouse are identified by linearly-marked central tail feathers (rectrices) and a pinkish to pale-violet air sac (cervical apterium) on each side of the neck, which is typically exposed and inflated during displays. Females are marked by central rectrices that are transversely barred and less longitudinally striped, and lighter crown feathers that are more barred (Henderson et al. 1967, Connelly et al. 1998).

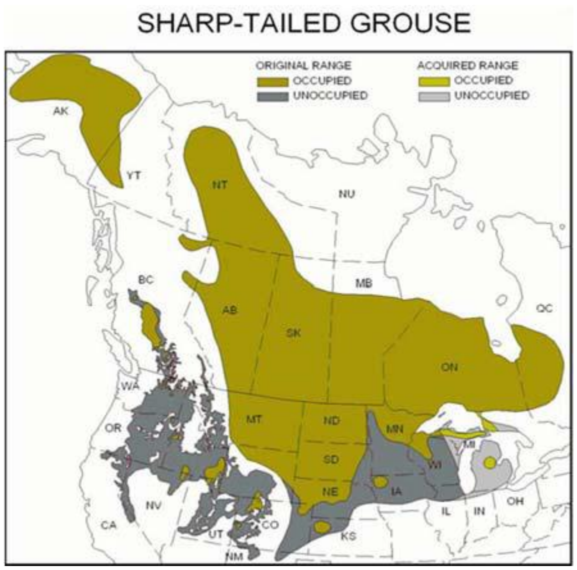


Figure 1: Historical and current ranges of sharp-tailed grouse in North America. (Schroeder et al. 2004)

GEOGRAPHICAL DISTRIBUTION

Sharp-tailed grouse are the most widespread and adaptable of all North American prairie-grouse species (Schroeder et al. 2004), historically ranging across 21 states and 8 Canadian provinces (Figure 1; Aldrich 1963, Johnsgard 1973). However, regional populations of sharp-tailed grouse have declined and the species is now extirpated from Kansas, Illinois, California, Oklahoma, Iowa, Nevada, New Mexico and Oregon (Johnsgard 1973, Miller and Graul 1980). Declines are mainly attributed to habitat loss and fragmentation associated with the conversion of native grasslands to cultivated agricultural and other human development (Connelly et al. 1998, Schroeder et al. 2004). Montana sharp-tailed grouse populations have been considered extirpated west of the Continental Divide since the late 2000s (Figure 2; Young and Wood 2012), whereas populations east of the Divide are considered secure and support seasonal hunting (Montana Field Guide 2016).

CONSERVATION STATUS

National Status

Sharp-tailed grouse are considered secure and do not warrant threatened or species of conservation concern status within the United States or Canada (Council 2011, BirdLife International 2012, Panjabi et al. 2012, NatureServe Accessed 9/24/2016). However, of the six sub species of sharp-tailed grouse, Columbian sharp-tailed grouse are considered of highest preservation concern within the United States (Miller and Graul 1980). Columbian sharp-tailed grouse have been petitioned twice for threatened or endangered species listing, however, both instances resulted in a ‘not warranted for listing’ determination (United States Fish and Wildlife Service 2000; 2006). Columbian sharp-tailed grouse are listed as threatened in the state of Washington (Stinson and Schroeder 2012), a species of concern in British Columbia (Leupin and Chutter 2007) and by the United States Fish and Wildlife Service (USFWS), and as a sensitive species with the Bureau of Land Management (BLM) and United States Forest Service (USFS).

Montana Status

Within Montana, sharp-tailed grouse are classified as an upland game bird species east of the Continental Divide, where populations are considered secure (NatureServe Accessed 9/24/2016). Sharp-tailed grouse west of the Continental Divide are classified as a critically imperiled and believed to be extirpated (Young and Wood 2012). Presently, sharp-tailed grouse hunting occurs east of the Continental Divide, while west of Continental Divide a sharp-tailed grouse hunting season has not occurred since 1948 (A. K. Wood, Montana Fish Wildlife and Parks, personal communication). A state conservation plan for Columbian sharp-tailed grouse was produced in 1991 (Wood 1991).

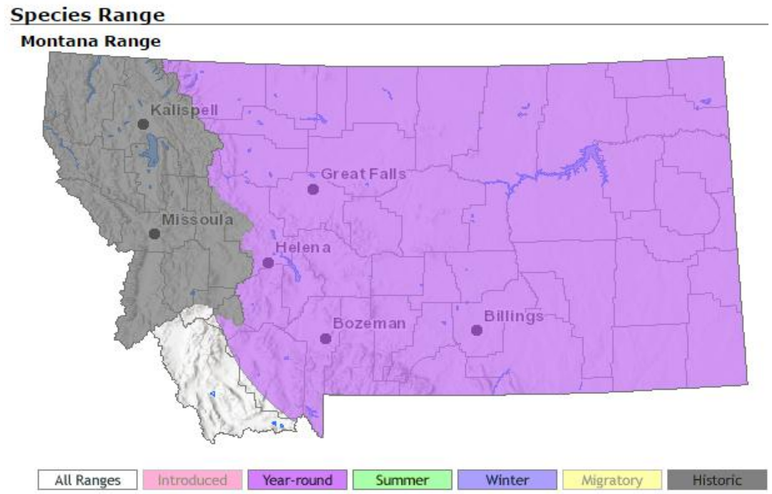


Figure 2: Historical and current range of sharp-tailed grouse in Montana.
(Montana Field Guide 2016)

Umbrella Species

Sharp-tailed grouse have been identified as a potential umbrella species for northern grassland and shrub-grassland ecosystems (Roersma 2001, Spieles 2010). An umbrella species is a species whose conservation provides additional protection service to several co-occurring species (Roberge and Angelstam 2004). Umbrella species allow wildlife and land managers to identify and apply conservation management that benefits co-occurring species through a single species' management. Sharp-tailed grouse management occurs across diverse habitat, which encompasses many co-occurring species that use similar habitats for nesting, brood-rearing, and cover (Roersma 2001, Spieles 2010).

BIOLOGY, ECOLOGY, AND LIFE HISTORY

BEHAVIOR

Territorial Behavior

According to Johnsgard (2016), the social displays of sharp-tailed grouse are defined as those which aid aggressive functions, displays which are concerned with courtship and mating, and displays which are correlated with broadcasting the location of the display grounds or leks. The social displays of sharp-tailed grouse are unusually detailed and complete (Lumdsen 1965 as reviewed in; Johnsgard 2016). Flutter jumps and cackling calls are regarded as gestures that serve to communicate the location of the lek and individual males, although both sexes perform cackling calls (Johnsgard 2016). Cackling calls are often given by approaching females, stimulating males on the lek into dynamic displays of flutter jumping and tail rattling (Johnsgard 2016). Male displays are often aggressive, acting to establish and maintain territories, attract females to dominant males, and establish sexual recognition (Connelly et al. 1998, Johnsgard 2016). Territoriality in females has not been documented, but it is speculated it may occur near nesting areas (Connelly et al. 1998).

Typical use of landscapes by sharp-tailed grouse corresponds to distinct spring-autumn and winter home ranges (Boisvert et al. 2005, Hoffman et al. 2015). Female sharp-tailed grouse generally nest and raise their broods within 2.5 km of leks (Boisvert et al. 2005, Hoffman et al. 2015). The findings of Boisvert et al. (2005) suggest that females select nest sites within or adjacent to suitable nesting and brood-rearing areas. Females can also show attraction to previously used nesting areas; Hoffman et al. (2015) noted that median distance between nest sites in successive years was 0.3 km, however, females do not use the same nest bowls in subsequent attempts. Male sharp-tailed grouse have a high fidelity to their leks, and stay within 2 km of the lek throughout the breeding season and into the fall (Boisvert et al. 2005). Both males and females are typically found farther away from leks during winter (Connelly et al. 2000). The distances travelled between spring-autumn and winter ranges generally averages <10 km, but may exceed 40 km (Connelly et al. 2000). However, sharp-tailed grouse may remain on spring-autumn ranges during mild winters, or alternate moving between these ranges depending on the snow conditions (Connelly et al. 2000).

Mating Behavior

Sharp-tailed grouse are polygynous and have a lek mating system in which male and female courtship and mating is generally limited to the lek site. Occasional mating may occur away from the lek (Sexton 1979). Some juvenile males will establish territories at leks during their first fall, and fall lek attendance can be important for learning the traditional lek sites and forming mating hierarchies prior to the spring breeding season (Johnsgard 2016). Primary male sharp-tailed grouse mating behavior consists of performing a dance on a selected lek site within the bird's spring home range during mornings and evenings from April to mid-May (Connelly et al. 1998, Johnsgard 2016). The dance consists of animated and relaxing phases, and the intricate details of this behavior are described in Connelly et al. (1998) and Johnsgard (2016). Mating success of males at leks is highly skewed, and the dominant male may receive up to 90% of all copulations (Robel et al. 1972). Male mating success on the lek has been attributed to a combination of time spent displaying and the size of the dominant males (Gratson 1993). However, recent molecular analyses

Figure 3: Male sharp-tailed grouse displaying in eastern Montana.
Photo by Megan Milligan.

of other lek mating grouse have found that successful males have greater genetic diversity and higher testosterone than failed breeders (Augustine et al. 2011). Females tend to visit leks 1–10 times within a breeding season and may attend more than one lek (Landel 1989, Connelly et al. 1998). Because other males disrupt copulation attempts, females will often re-mate the same day or within a few days (Gratson et al. 1991, Connelly et al. 1998).

The physical interactions of sharp-tailed grouse have been well documented (Connelly et al. 1998). Male interactions at lek and concentrated foraging areas include aggressive behavior that involve pecking and feather-pulling, wing beating, and jabbing and scratching with the feet while 0–1 m in the air (Connelly et al. 1998). The most intense and frequent interactions among male sharp-tailed grouse occur at the boundaries individual lek territories and during trespass situations when a receptive female is attending (Connelly et al. 1998). Aggressive interactions at leks rarely cause injury, however severe injury and death has been documented (Connelly et al. 1998).

Diet

The spring and summer diet of adults is primarily composed of vegetative material consisting of flowers, grasses and forbs including grass seeds and leaves, as well as insects including Coleoptera, Hymenoptera, and Orthoptera (Giesen and Connelly 1993). Jones (1966) found that green plant material represented the major proportion of the diet of sharp-tailed grouse in spring and summer in eastern Washington. Connelly et al. (1998) states that clover (*Trifolium* spp.), fruits, goldenrod (*Solidago* spp.), hawkweed (*Hieracium canadense*), grasses, grass seed, rose (*Rosa* spp.), dandelion (*Taraxacum officinale*), corn (*Zea mays*), gromwell (*Lithospermum* spp.), smartweed (*Polygonum* spp.), alfalfa (*Medicago sativa*), Oregon grape (*Berberis repens*), goatsbeard (*Tragopogon dubius*), wheat (*Triticum aestivum*), western yarrow (*Achillea millefolium*), mule-ears (*Wyethia amplexicaulis*), sagebrush buttercup (*Ranunculus glaberrimus*) can all be found in spring and summer sharp-tailed grouse diet. Sharp-tailed grouse chicks diet is primarily composed of insects until 2–5 weeks of age (Goddard et al. 2009).

The fall diet is comparable to summer, but may include higher proportions of insects and agricultural crops, where they are available (Giesen and Connelly 1993). Reports show that fruits, grain, acorns, tamarack (*Larix laricina*) leaf buds, water birch (*Betula papyrifera*) buds and catkins, dwarf birch (*B. nana*) buds and catkins, rose hips, quaking aspen (*Populus tremuloides*) buds, sunflower (*Helianthus* spp.), chokecherry (*Prunus virginiana*) buds, goldenrod, sumac (*Rhus* spp.), grasses, snowberry (*Symphoricarpos albus*), Russian olive (*Eleagnus angustifolia*) fruits, black hawthorn (*Crataegus douglasii*), serviceberry (*Amelanchier alnifolia*), silver buffalo berry (*Shepherdia argentea*), willow (*Salix spp.*) buds, mule-ears, maple (*Acer* spp.) buds, dandelion (Oct only), grasshoppers (*Caelifera*), beetles (*Coleoptera*), midges (*Rhopalomyia* spp.), and galls from sagebrush can comprise the diet of sharp-tailed grouse during the fall and winter (Connelly et al. 1998). Thomas (1984) found that winter diet was heavily comprised of leaf buds and catkins for sharp-tailed grouse in Ontario. In western Idaho, the buds of serviceberry and chokecherry were often consumed by sharp-tailed grouse during winter, and were often the most abundant food source (Marks and Marks 1988).

DEMOGRAPHY

Reproduction

Nesting

Female sharp-tailed grouse incubate eggs and raise young without assistance from males. Nests are typically within 1.6 km from a female's breeding lek (Schroeder 1996) but can vary from 0.4–1.8 km (Artmann 1970, Christenson 1970, Schiller 1973, Kohn 1976, Bergerud and Gratson 1988, Meints 1991)

The majority of females will initiate at least one nest per year. Average clutch size is 10–12 eggs, but can be highly variable across populations (Table 1). Clutch sizes are similar for adult and yearling females (Boisvert 2002, Collins 2004). If the initial clutch is lost to predation during laying or early in incubation, females will often renest, and clutch sizes of renests are often smaller than first nest attempts. Between 20–69% of females in Colorado renested after losing their initial clutch (Boisvert 2002, Collins 2004) and up to 73% renested in Washington (McDonald 1998) and in eastern Montana (McNew et al. 2016). The probability of renesting likely declines as the nesting season progresses (McNew et al. 2011).

Figure 4: Successfully hatched sharp-tailed grouse nest in eastern Montana.
Photo by Megan Milligan

The incubation period for sharp-tailed grouse is 21–26 days (Gross 1930, Hillman and Jackson 1973, Boisvert 2002), with variation attributed to environmental conditions. Peak of hatch occurs in late May and early June depending on the geographic area and environmental conditions; median hatch date varied from 30 May in Washington (Schroeder 1996) to 13 June in Idaho (Apa 1998).

Overall nest success, which is the proportion of nests that hatch ≥1 egg, can vary across years and sites for several reasons, including differences in weather, age structure of the population, predator populations, and differences in available nesting cover (McDonald 1998). Nest success in previous studies has varied from 0.32 in Utah (Hart et al. 1950) to 0.72 in Idaho (Meints 1991). In 2016, nest survival of a population of sharp-tailed grouse in eastern Montana was 0.38 (McNew et al. 2016). Nest success can also vary between first nests and renest attempts (Schroeder 1996, Williamson 2009). Nest success is often reported to be higher for adults than for yearling females (Bergerud et al. 1988), although others have observed no difference in nest success between adult and yearling sharp-tailed grouse (Apa 1998, Collins 2004). In nests that are successful, egg viability, or the proportion of eggs that hatch, is typically high with at least 90% of eggs hatching in healthy populations (Meints 1991).

Table 1. Reproductive parameters related to nesting habits of sharp-tailed grouse.
Reported for studies in North America. Multiple numbers represent different years or study areas within the same study.

State/Study	Average clutch size (SE)	Range of clutch size	% Nesting effort	% Renest effort (SE)	Peak hatch	% Eggs hatched (SE)	% Nest success (SE)
British Columbia							
Goddard (2007)	12.2 (0.8)			60 (NA)			
Goddard and Dawson (2009b)							0.49 (0.08)
Colorado							
Giesen (1987)[a]	10.8 (NA)						
Boisvert (2002)[a]	10.2 (NA)		100; 97	20 (NA); 28 (NA)			0.42 (0.07) [b]
Collins (2004)[a]	10.4 (NA)		100; 97	69 (NA); 36 (NA)			0.63 (0.04) [b]
Idaho							
Apa (1998)[a]	10.4 (NA)		100		13 June		0.58 (0.08) [b]
Meints (1991)[a]	11.9 (NA)	10-13	100	66 (NA)		91 (NA)	0.72 (0.09) [b]
Marks and Marks (1987)					early - late June		
Montana							
McNew et al. (2016)	11.4 (0.32)	10-19	100	73.3 (0.05)	15 June	90 (0.03)	0.337 (0.07)
Nebraska							
Sisson (1976)	11.6 (0.57)					92 (NA)	0.50 (0.09)[b]
North Dakota							
Williamson (2009)	13.3 (NA); 10.4 (NA)	7-17					0.49 (0.05)
Utah							
Hart et al. (1950)[a]	10.9 (NA)	3-17			late May - June		0.32 (0.04) [b]
Washington							
Schroeder (1994)[a]	10.4 (NA)			66 (NA)	30 May		0.43 (0.06) [b]
McDonald (1998)[a]	12.2 (NA)	11-14	>88	73 (NA)			
Wisconsin							
Hamerstrom (1939)	12.1 (NA)	9-17				99.3 (NA)	

s cited in Stinson and Schroeder (2012)
[b]SE calculated based on proportion and reported sample size

Brood rearing

Female sharp-tailed grouse only rear one brood per year. Chicks are born precocial and follow the female away from the nest shortly after hatching. Chicks cannot thermoregulate for up to two weeks after hatching (Bergerud and Gratson 1988), making them vulnerable to environmental conditions. Broods remain with the hen and relatively close to the nesting area throughout the summer (Marks and Marks 1987, Gratson 1988, Meints 1991). Daily summer movements range from 45–276 m (Schiller 1973, Gratson 1983;1988, Meints 1991), and in Utah, broods had traveled only 46 m from hatch site by the time they were one month old (Hart et al. 1950). In Washington, broods traveled less than 0.5 km from their nest site during the early summer period (Schroeder 1996).

Brood success and chick survival

Chick survival beyond the first two months of age is a key determinant of population dynamics and may be an even more limiting factor than nest success (McDonald 1998). As in most grouse species, the highest period of chick mortality for sharp-tailed grouse is before they are 2–3 weeks of age, partially due to the fact that chicks cannot yet fly well or thermoregulate (Bergerud et al. 1988). As a result, chicks are vulnerable to three main sources of mortality: predation, starvation, and exposure during cold, wet weather. Chick survival to 35-d of age was 0.34 in British Columbia (Hodgson et al. 2009) and ranged from 13–45% for populations in Colorado (Collins 2004). Brood success, or the percentage of hens that rear ≥1 chick, ranged from a low of 43% in one habitat in Colorado (Collins 2004) to 67% in British Columbia (Table 2; Hodgson et al. 2009). Of broods successful, the number of chicks surviving to 45 days ranged from 2.5 in Washington (McDonald 1998) to 4.4 chicks in Colorado (Boisvert 2002).

Figure 5: Sharp-tailed grouse chick in eastern Montana.
Photo provided by Megan Milligan.

Table 2. Reproductive parameters related to brood success of sharp-tailed grouse. Reported for studies in North America.

State/Study	% Brood success (SE, age in days)	% Chick survival (SE, age in days)	Brood size (n, age in days)
Alberta			
Manzer and Hannon (2008)		47 (0.09, 30)	
British Columbia			
Goddard and Dawson (2009a)	67 (0.09, 035)	34 (0.07, 35)	3.59 (0.71, 30)
Colorado			
Boisvert (2002)[a]	64 (NA, 49); 85 (NA, 49)	49 (NA, 49); 47 (NA, 49)	4.4 (NA, 49)
Collins (2004)[a]	48-92 (NA, 49); 53-56 (NA, 49)	44.8, 13.3 (NA, 49); 19.7, 14.2 (NA, 49)	4.2 (NA, 49); 2.7 (NA, 49)
Idaho			
Meints (1991)[a]	53 (NA, 28)		4.1 (NA, 28)
Montana			
McNew et al. (2016)	51.9 (0.09, 14)	46.9 (0.10, 14)	2.9 (0.79, 14)
North Dakota			
Williamson (2009)	23 (0.09)		
Utah			
Hart et al. (1950)[a]		56 (NA, from 30-60)	
Washington			
Schroeder (1994)[a]		54.2 (NA, 48)	5.2 (NA, 45-75)
McDonald (1998) [a]	50 (NA, 45)	12 (NA, 45)	2.5 (NA, 45)

[a]as cited in Stinson and Schroeder (2012)

Survival and Sources of Mortality

Reported annual survival for sharp-tailed grouse ranges from 0.17–0.43 (Connelly et al. 1998), but was observed to be as high as 0.71 in South Dakota (Robel et al. 1972) and 0.82 during one year in Idaho (Table 3; Ulliman 1995). Significant differences in survival between either adults and yearlings or between sexes have not been found (Boisvert 2002, Collins 2004), but seasonal patterns and causes of mortality may differ between sexes. Increased female mortality can occur during the nesting season, while male mortality increases during the breeding season when birds are attending leks (Collins 2004). However, periods of peak mortality depend on the severity of the winter. In Idaho, survival rates ranged from 0.86 in a mild winter to only 0.29 in a severe winter (Ulliman 1995). Adult mortality is affected by a range of factors, with predation and hunting being the most significant. Maximum lifespan of sharp-tailed grouse is 7.5 years (Connelly et al. 1998). While no estimates for juvenile overwinter mortality for sharp-tailed grouse exist, estimates for similar species include 0.8 for greater sage-grouse (*Centrocercus urophasianus*; Beck et al. 2006) and 0.7 for lesser prairie-chickens (*T. pallidicinctus*; Pitman et al. 2006).

Table 3. Annual adult survival rates of sharp-tailed grouse throughout North America. Multiple numbers represent different years in the same study.

Area/Study	Annual Survival (SE)	Method
Alberta		
Manzer and Hannon (2008)	0.53 (0.05)	Kaplan Meier
Colorado		
Boisvert (2002)[a]	0.20 (NA)	Kaplan Meier, staggered entry
Collins (2004)[a]	0.33 (NA), 0.45 (NA)	Kaplan Meier, staggered entry
Idaho		
Ulliman (1995)[a]	0.86 (NA), 0.29 (NA)	all fates known
Montana		
Cope (1992)[a]	0.48 (NA)	recapture rates
North Dakota		
Williamson (2009)	0.72 (0.07), 0.43 (0.07)	Kaplan Meier, staggered entry
South Dakota		
Robel et al. (1972)[a]	0.70 (NA), 0.72 (NA)	recapture rates
Washington		
Schroeder (1994)[a]	0.40 (NA)	
Schroeder (1996)[a]	0.57 (NA)	Kaplan Meier product limit
McDonald (1998)[a]	0.55 (NA)	Kaplan Meier

[a]as cited in Stinson and Schroeder (2012)

Predation

Figure 6: Depredated sharp-tailed grouse nest in eastern Montana.
Photo by Megan Milligan.

Predation has a major influence on sharp-tailed grouse population dynamics as it can affect nest success, juvenile survival, and survival of adult birds (Schroeder and Baydack 2001). Predation rate is related to habitat quality and distribution, population dynamics, and predator behavior (Schroeder and Baydack 2001). Species that display and breed on leks are often more conspicuous to predators, increasing predation risk (Marks and Marks 1987). In addition, a shortage of quality habitat or widespread habitat degradation can increase both visibility and mortality of juvenile birds and nests (Schroeder and Baydack 2001).

Several studies have found predation to be the primary cause of mortality for sharp-tailed grouse (Boisvert 2002, Collins 2004). Boisvert (2002) assigned 74% of mortalities to predation, with 41% attributed to mammals and 33% to avian predators. Another study in Colorado was able to assign case to 54% of mortalities and 97% of them were attributed to predation, with mammals responsible for 61% and avian predators responsible for 36% (Collins 2004). Primary predators include coyote (*Canis latrans*), mink (*Mustela vison*), red fox (*Vulpes vulpes*), northern goshawk (*Accipiter gentilis*), gyrfalcon (*Falco rusticolus*), peregrine falcon (*F. peregrinus*), rough-legged hawk (*Buteo lagopus*), northern harrier (*Circus cyaneus*), red-tailed hawk (*B. jamaicensis*), long-eared owl (*Asio otus*), and great horned owl (*Bubo virginianus*; Connelly et al. 1998, Schroeder and Baydack 2001). Predators of nests include coyote, striped skunk (*Mephitis mephitis*), ground squirrels (*Spermophilus* spp.), black-billed magpie (*Pica pica*), common raven (*Corvus corax*), and American crow (*C. brachyrynchos*), but determining the species responsible for nest predation can be problematic (Connelly et al. 1998, Schroeder and Baydack 2001).

Hunting

Although there is little empirical evidence with regards to the influences of hunting on sharp-tailed grouse populations, some studies suggest that hunting mortality is at least partially additive to natural mortality (Bergerud et al. 1988). Estimates of harvest rates range from 12–39% (Connelly et al. 1998) with higher harvest rates more likely to be additive (Sandercock et al. 2011, Blomberg 2015). Harvest rates likely vary with grouse population size, timing of hunting, weather, and habitat quality. In addition, sharp-tailed grouse congregate on leks in the fall and in flocks during the winter, which could make them vulnerable to over-harvesting (Marks and Marks 1987).

Disease and parasitism

Infectious disease is not common in sharp-tailed grouse (Connelly et al. 1998), but parasites are widespread with some populations having consistently high parasite loads (Boddicker 1967). While little evidence exists that parasites cause direct mortality among sharp-tailed grouse, they could play a role in populations that are already stressed (Boddicker 1967). Common parasites include ticks (Acarina), chiggers (*Trombidiidae*), lice (Mallophaga), tapeworms (Cestoda), round worms (Nematoda), hippoboscid flies (*Ornithomyiaanchineuria*), and mites (*Ornithonyssus sylviarum*; Boddicker 1967).

Collisions

Collisions with fences and power lines have traditionally been considered an important source of mortality for sage-grouse and other prairie-grouse, such as the lesser prairie-chicken (Wolfe et al. 2007), but recent evidence suggests that collisions have little effect on population dynamics of lesser prairie chickens (Robinson et al. 2016). There is no evidence to suggest that collisions constitute a significant proportion of mortalities for sharp-tailed grouse populations.

Cultivation

While the direct effects of cultivation likely represent a small proportion of sharp-tailed grouse mortality, cultivated lands can facilitate increased mortality through numerical increases or functional responses of predators. Annual female survival was found to be twice as high for a congener of sharp-tailed grouse, greater prairie-chickens, in contiguous grassland habitats when compared to areas heavily fragmented by agriculture (McNew et al. 2012a). Females will occasionally build nests in cultivated fields, which can result in mortality or nest failure due to mowing and plowing activities (Hart et al. 1950). In Utah, 4.7% of females and 1% of juveniles were killed by farm implements, and 82% of nests in stubble fields were destroyed by plowing (Hart et al. 1950).

HOME RANGE

A home range is the area over which an animal regularly travels to gather food, find mates, or care for young (Burt 1943). The size of a home range for sharp-tailed grouse varies with topography, season, food availability, and vegetative cover (Meints 1991, Stinson and Schroeder 2012). However, home range within individual seasons are typically less than 200 ha (Boisvert et al. 2005, Hoffman et al. 2015). Home ranges can be much larger in areas with poor habitat, either due to heavy livestock grazing, poor vegetative cover, or drought (Marks and Marks 1987, Collins 2004, Stinson and Schroeder 2012).

Reported home ranges for sharp-tailed grouse vary from 22.4–1,168 ha (Giesen 1987, Marks and Marks 1987, Hofmann and Dobler 1988, Collins 2004). Boisvert (2002) found summer to fall home ranges varied from 75 ha to 112 ha in size depending on habitat type (Table 4). Summer home ranges were 77 to 4,077 ha for 37 female sharp-tailed grouse occupying northern mixed prairie habitat in eastern Montana (McNew et al. 2016).

Table 4. Observed home range sizes listed by state, study, and site location. Assumes summer to fall study unless otherwise specified.

State/Study/Site/Season	Number of birds observed	Median size of home range (ha)
Colorado		
(Giesen 1987)	20	147
(Collins 2004)		
Shrub-steppe, 2001	18	246
Shrub-steppe, 2002	25	1,168
Mine reclamation, 2001	13	75
Mine reclamation, 2002	14	69
(Boisvert 2002)		
Mine reclamation	34	75
CRP	20	112
Winter	6 females	185
Winter	5 males	337
Idaho		
(Marks and Marks 1987)	15	147
(Ulliman 1995)		
1992 Winter	3 females	44
1992 Winter	6 males	140
1993 Winter	8 females	177
1993 Winter	3 males	313
Montana		
(Cope 1992)	5 females	357
(Cope 1992)	6 males	166
(McNew et al. 2016)	37 females	569
Washington		
(Hofmann and Dobler 1988)	3	22.4

Winter home ranges vary spatially and in time as well. Winter home ranges were much larger than summer through fall home ranges in Colorado (Boisvert 2002). Ulliman (1995) reported winter home range sizes varied from 44–313 ha depending on sex with smaller home ranges than males (Table 4). Home range sizes of native sharp-tailed grouse in the mountain valley habitats of western Montana are generally unknown. Home ranges of transplanted female (n = 5) and male (n = 6) sharp-tailed grouse in the Tobacco Valley calculated with minimum convex polygons were 357 and 166 ha, respectively (Table 5; Cope 1992). The last known accounts of sharp-tailed grouse spotted in western Montana are two anecdotal reports from 2003 that are referenced by Fitzpatrick (2003).

SEASONAL MOVEMENTS

Sharp-tailed grouse typically move relatively short distances between summer and fall home ranges (Robb and Schroeder 2012, Stinson and Schroeder 2012), although Hoffman et al. (2015) reported that sharp-tailed grouse can move over 40 km between their summer-fall and winter ranges. Most movements between summer-fall and winter ranges are less than 10 km (Table 5; Hoffman et al. 2015). Males have been observed to travel 0.2–36.5 km from leks to winter ranges (Ulliman 1995, Schroeder 1996, Collins 2004, Boisvert et al. 2005), whereas females have been reported to move 0.4–48.9-km (Ulliman 1995, Schroeder 1996, Collins 2004, Boisvert et al. 2005).

Table 5. Observed distances moved from lekking sites to wintering areas of sharp-tailed grouse.

State/Study	Number of birds observed	Median distance (km)	Mean distance (km)	Range of distance (ha)
Colorado				
(Collins 2004)				
Males	47	5.4	6.5	0.5-28.6
Females	28	7.5	10.4	0.5-48.9
(Boisvert et al. 2005)				
Males	13	21.5	20.0	4.2-36.5
Females	17	21.4	22.1	3.1-41.5
Idaho				
(Ulliman 1995)				
Males	10	1.4		0.5-3.7
Females	15	3.3		0.8-9.9
Washington				
(Schroeder 1996)				
Males	41	2.2	2.8	0.2-7.1
Females	28	3.8	4.4	0.4-11.4

On average, female sharp-tailed grouse were found to move 1.3 km from their lek of capture to nesting sites (Schroeder 1994, Robb and Schroeder 2012). Hoffman et al. (2015) also reported that females traveled less than 2 km from lek sites to nesting and brood-rearing sites. Collins (2004) found the females monitored in his study only moved an average of 0.8 km from nesting sites to brood-rearing locations. However, some females moved more than 3.5 km to brood-rearing sites, potentially due to drought conditions (Collins 2004).

In mixed grass prairie habitats of South Dakota, Robel et al. (1972) observed that male sharp-tailed grouse moved an average of 13.4 km (1.6–45 km) from site of capture in winter habitat to the location the bird was recovered at during hunting season the following fall. The distance females moved between winter and summer ranges was larger than that of males and ranged from 1.6 to 150 km at one study location and 1.6 to 63 km at another location (Table 6; Robel et al. 1972).

Table 6. Observed distances moved by female sharp-tailed grouse from lekking sites of capture to nesting sites.

State/Study	Number of birds observed	Median distance (km)	Mean distance (km)	Range of distance (ha)
Colorado				
(Collins 2004)	130	1.0	1.5	0.1-21.7
(Boisvert et al. 2005)	58	0.6	1.3	0.1-11.3
Idaho				
(Meints 1991)	16		1.2	
South Dakota				
(Robel et al. 1972)				
Missouri River Area				
Males	42		5.1	1.6-12.9
Females	60		14.8	1.6-62.8
Kadoka Area				
Males	121		8.1	1.6-45.1
Females	112		16.1	1.6-150
Washington				
(Schroeder 1996)	42	0.8	1.6	0.1-7.0

DISPERSAL

Little is known about natal dispersal in sharp-tailed grouse because studies of radio-marked juvenile sharp-tailed grouse are generally lacking (Robb and Schroeder 2012).

POPULATION DYNAMICS

Sharp-tailed grouse have high reproductive potential, with high rates of nesting (typically around 100%), large clutch sizes, and high hatching rates (Table 1). Therefore, reproductive success and mortality have the largest potential to influence population dynamics. Sensitivity analyses of populations of Columbian sharp-tailed grouse and lesser prairie-chickens found that nest and brood survival had the largest impact on population dynamics (Hagen et al. 2009, Gillette 2014). However, the relative importance of adult survival and fecundity varied between populations of greater prairie-chickens, suggesting that human land use patterns can affect the influence of vital rates on population dynamics, as well as the vital rates themselves (McNew et al. 2012a).

Sex ratios

In a lekking species like the sharp-tailed grouse, where a small proportion of males (<19%) obtain the majority of copulations (Robel 1970, Gratson et al. 1991), sex ratios could have an influence on population dynamics. With such a small proportion of males responsible for copulations, reproductive output in sharp-tailed grouse is driven entirely by the population of females. Thus, a reproductive output could be negatively affected by a sex ratio that was skewed towards males. However, there is no evidence that sharp-tailed grouse sex ratios differ from 1:1 either at hatch or in adult populations (Stinson and Schroeder 2012).

Population density

While little to no information is available on sharp-tailed grouse population densities in the winter, breeding densities vary from 0.6–5.5 birds per km^2 (Connelly et al. 1998), with densities varying with habitat quality (Table 7). Environmental conditions can also influence population densities; in Idaho, average breeding densities were much lower after a harsh than a mild winter (0.1-1.9 vs 0.6-1.4 birds per km^2; Ulliman 1995). In addition, habitat fragmentation has been shown to decrease carrying capacity in other species of grouse (Marshall and Edwards-Jones 1998).

Table 7. Reported densities of sharp-tailed grouse populations in the breeding and non-breeding season.

State	Breeding density (per km^2)	Winter density (per km^2)	Habitat quality	Source
Colorado	3.1-4.5		good	Rogers (1969)[a]
Colorado	0.4-1.2		low	Rogers (1969)[a]
Idaho	1		NA	Ulliman (1995)[a]
Nebraska	0.6-7.0		NA	Sisson (1976)[a]
South Dakota	1.6-4.4	0.4-1.2	NA	Hillman and Jackson (1973)
Washington		33.3	NA	
Wisconsin	6.2		average	Hamerstrom (1939)
Wisconsin	25		high	Hamerstrom (1939)
Wisconsin	1.1-1.3		NA	Grange (1948)

[a]as cited in Stinson and Schroeder (2012)

Threats to Small Populations

The persistence of a small population is determined by a combination of environmental, demographic, and genetic factors, and small populations can be particularly susceptible to stochastic events. Small populations are especially susceptible to extreme weather events, fire or disease (Shaffer 1981). Small changes in sex ratios or age distributions can affect reproductive success and recruitment, which has implications for genetic diversity (Gilpin 1986). In addition, demographic and genetic factors can interact so that a population enters a feedback loop accelerating population declines, or an extinction vortex.

Genetic health, including heterogeneity and allelic diversity, is a particularly important consideration for small populations. Lower genetic diversity can facilitate inbreeding depression, which can result in lower fecundity, resistance to disease, and a population that is less capable of adapting to changing environments (Gilpin 1986, Allendorf and Ryman 2002). Inbreeding depression has led to the decline and extinction of several wild grouse populations (Brook et al. 2002) and has been linked to lower fertility in populations of the greater prairie-chicken, a congener of sharp-tailed grouse (Bouzat et al. 1998). Spatial structure and isolation of populations can also have a large influence on genetic health and population persistence. In greater prairie-chickens, isolated populations have been shown to have lower genetic diversity (Bouzat et al. 1998, Johnson et al. 2003). Isolated populations require significantly more individuals to maintain genetic health compared to populations that have even minimal exchange with other populations (Lande and Barrowclough 1987).

Minimum Viable Population

The minimum viable population is the smallest initial population that will result in a population that has an acceptable probability of persistence over a predetermined amount of time (Shaffer 1981). The minimum viable population size is related to the ability of a population to withstand stochastic events, as well as changes in reproductive success and recruitment related to variation in food availability, predation, disease, and habitat change. It is recommended that 95% of the heterozygosity in a population be maintained over a period of 100 years (Allendorf and Ryman 2002). In general, a population of 500 individuals is considered essential to maintain the evolutionary potential of a species (Soulé and Frankel 1981).

To estimate a minimum population size, an effective population size must first be determined. The effective population size (N_e) is the proportion of a population that will breed and pass genetic information on to the next generation. Effective population size can be influenced by fluctuations in true population size, variation in clutch size, and unequal sex ratios (Frankham 1995). In sharp-tailed grouse, effective population size would primarily be influenced by their lek mating system in which a minority of the males are responsible for the majority of breeding. Lek-mating systems reduce N_e because only a small proportion of males actually pass on genetic information. Population fluctuations are also a feature of the dynamics of some grouse populations (Lindström 1994), with sharp-tailed grouse in Wisconsin exhibiting a 10-year population cycle (Evrard et al. 2000). The extremity of these fluctuations could influence N_e by affecting the number of individuals required to endure stochastic events.

The ratio of effective population size to census population (N_e/N) can be used to calculate how many individuals are required in the census population to achieve an effective population size of 500. While no estimates exist for sharp-tailed grouse, other studies have addressed similar species and breeding ratios of 0.16 and 0.19 have been estimated for greater sage-grouse (Schroeder 2000), and Gunnison sage-grouse (*C. minimus*; Stiver et al. 2008), respectively, and suggest that a census population of at least 3,200 sage-grouse would be necessary for an effective population of 500 to maintain genetic health. Another study estimated the minimum viable census populations for greater prairie-chickens as more than 3,000 individuals (Walk 2004), and a population viability analysis for sharp-tailed grouse suggested that populations of fewer than 200 individuals had an unacceptably high risk of extinction (Temple 1992). Immigration and emigration are also needed to prevent genetic isolation and movement of 1–10 individuals per generation is generally sufficient (Mills and Allendorf 1996). However, populations of sharp-tailed grouse separated by >10 km could be genetically isolated (Stinson and Schroeder 2012), which would increase the census population required to maintain genetic health.

The area required to support a population depends on the quantity and quality of the habitat. While little information exists, winter densities of sharp-tailed grouse are generally lower than breeding densities and so nesting and brood-rearing habitat could be more of a limiting factor (Table 7). When considering habitat quality, avoiding sink habitats would be an important consideration. Sink habitats are those where reproduction within that habitat are insufficient to outweigh local mortality, but where populations persist due to immigration from more productive source habitats (Pulliam 1988). Little information exists on sink habitats for plains sharp-tailed grouse, but other studies have found that areas in the Conservation Reserve Program

(CRP) constituted sink habitats for Columbian sharp-tailed grouse (Gillette 2014). Studies of other species of grouse found that areas with high conifer encroachment and those treated with herbicide were avoided by greater sage-grouse (Casazza et al. 2011) and lesser prairie-chickens, respectively (Patten and Kelly 2010). Cultivated land can act as an ecological trap, as well, with females building nests in cultivated fields, which can result in mortality or nest failure due to mowing and plowing (Hart et al. 1950). Potential sink habitats should be considered when determining the minimum area required to support a population.

ECOLOGICAL RELATIONSHIPS

Potential sites for sharp-tailed grouse reintroduction in western Montana coincide with the geographic distributions of dusky grouse (*Dendragapus obscurus*), spruce grouse (*Falcipeenis canadensis*), and ruffed grouse (*Bonasa umbellus*). The sites are also within the ranges for non-native game birds, including the wild turkey (*Meleagris gallopavo)*, Hungarian partridge (*Perdix perdix*), and ring-necked pheasant (*Phasianus colchicus*). Available interspecific competition studies are lacking in sharp-tailed grouse literature.

Dusky grouse may be a potential source of competition for nesting and brood-rearing habitat for sharp-tailed grouse in western Montana. In Montana, dusky grouse nesting habitat is generally located in shrub-steppe and bunchgrass communities within 2 km of a forest edge (Zwickel and Bendell 2004). Dusky grouse broods are reared in grass-forb communities until late summer when they move to deciduous thickets (Mussehl 1960). Montane conifer forests are selected by dusky grouse as winter habitat (Zwickel and Bendell 2004), which does not overlap with the preferred winter habitat of sharp-tailed grouse.

Ruffed grouse use quaking aspen as yearlong habitat and food (Svoboda and Gullion 1972). Sharp-tailed grouse select aspen stands as winter forage and habitat (Hart et al. 1950). Competition for winter habitat with ruffed grouse could be of special concern for a reintroduced sharp-tailed grouse population that has winter cover as a limiting factor.

Wild turkey brood habitat consists of grasses and forbs similar to sharp-tailed grouse brood-rearing habitat (Kamees 2002). In Utah, Hart et al. (1950) observed that sharp-tailed grouse avoided areas previously foraged by domestic turkeys for up to two months. A large flock of wild turkeys may have a similar impact but interspecific competition has not been reported. Nevertheless, reintroduction programs for sharp-tailed grouse should consider whether proposed sites are currently inhabited by wild turkeys.

Ring-necked pheasants have been documented to disrupt leks and harass prairie-chickens at winter feeding stations (Sharp 1957, Vance and Westemeier 1979). While prairie-chickens were frequently flushed by the pheasants, sharp-tailed grouse dominated interactions with the pheasants (Sharp 1957). Hart et al. (1950) documented that sharp-tailed grouse tolerate ring-necked pheasants at lekking grounds without aggression. While sharp-tailed grouse and pheasant spring and summer diets were similar, there was little competition during winter due to differing winter habitat preference (Hart et al. 1950).

Ring-necked pheasants will parasitize the nests of sharp-tailed grouse, which may result reduced nest success (Vance and Westemeier 1979, Geaumon et al. 2010). Vance and Westemeier (1979) reported greater prairie-chickens abandoned eggs with viable embryos, presumably because females left with the parasitic pheasant brood, which hatched before her own eggs. While sharp-tailed grouse have an incubation period similar to that of ring-necked pheasants, 21–24 days and

23–25 respectively, pheasant eggs in sharp-tailed grouse nests frequently hatch before sharp-tailed grouse eggs (Geaumon et al. 2010), and suggests that nest parasitism by ring-necked pheasants could result in reduced fecundity of grouse in areas with abundant pheasant populations.

Ring-necked pheasants and wild turkeys have been introduced in western Montana to varying success. These two non-native game birds may pose a risk of competition and lower nest success rate for sharp-tailed grouse. To increase the likelihood of a viable population of sharp-tailed grouse being established in western Montana, management programs aimed at introducing or increasing populations of ring-necked pheasants or wild turkeys in key areas of sharp-tailed grouse reintroduction should be avoided. Once a self-sustaining sharp-tailed grouse population has been established or additional research suggests these species do not interfere with sharp-tailed grouse, management to enhance pheasants or wild turkeys may be warranted.

HABITAT REQUIREMENTS

The grassland habitat of plains sharp-tailed grouse is described as subclimax brush or shrub-grassland, and occurs throughout the much of Montana, North Dakota, Wyoming, southern Saskatchewan and Alberta, and portions of South Dakota, Nebraska, and Colorado (Aldrich 1963). Of the factors that limit sharp-tailed grouse populations, habitat quality and quantity are among the most important (Hillman and Jackson 1973, Prose 1987). For this reason, the presence of sharp-tailed grouse in an area is often seen as an indicator of quality rangeland (Hillman and Jackson 1973). Specific habitat needs are quite variable throughout the range of sharp-tailed grouse and among subspecies, making the scope of inference for management often difficult to extend beyond a certain geographic area (Goddard and Dawson 2009b). Nevertheless, some general habitat conditions exist for the species.

Prairie-grouse require adequate cover during the breeding season for nesting and rearing broods, and the non-breeding season for hiding from predators and minimizing exposure to wet and cold weather (Jones 1968). During all seasons, sharp-tailed grouse use deciduous shrubs which produce high energy food from berries, buds, and leaves (Evans and Dietz 1974). Within optimum sharp-tailed grouse habitat, large tracts of native grassland are maintained, mixed with areas of shrub cover, wooded draws, and some cropland (Swenson 1985). In addition to providing high energy food resources, deciduous shrubs offer important cover for sharp-tailed grouse in areas with heavy cattle grazing (Nielsen and Yde 1982). In a moderately grazed grassland, shrubs are an important aspect of sharp-tailed grouse habitat (Prose 1987). Habitat for rangeland wildlife species can be both conserved and improved through cattle grazing if properly managed, but it can also be negatively impacted if overgrazed (Hillman and Jackson 1973, Sedivec et al. 1990).

The size, composition, and arrangement of seasonal habitats is critical to maintain viable populations of sharp-tailed grouse (Temple 1992, Hoffman et al. 2015). Sensitivity to isolation becomes more pronounced as habitat patches become smaller, especially if barriers like coniferous forest prevent movement of individuals among semi-isolated subpopulations (Temple 1992). Over cultivation and large-scale development in important sharp-tailed grouse habitat has also been shown to cause population declines (Buss and Dziedzic 1995). The quality of prairie-grouse habitat declines with conifer encroachment, which fragments the landscape and facilitates numerical or function responses in predators (McNew et al. 2012b, Coates et al. in press). Sharp-tailed grouse nests are more vulnerable to predation if they are located close to perch sites for raptors, such as wooded edge habitats or trees on the landscape (Manzer and Hannon 2005). Avoidance of forested areas by sharp-tailed grouse may be due to higher predator abundance in these areas (Goddard and Dawson 2009b). Although no studies have directly associated sparse conifer encroachment with decreased sharp-tailed grouse survival or recruitment, studies have found that greater sage-grouse avoid conifers (Doherty et al. 2008) and experience negative population-level impacts due to conifer encroachment (Baruch-Mordo et al. 2013, Coates et al. in press).

Breeding Season

Lekking

Sharp-tailed grouse leks are located on relatively flat sites free from tall vegetation and are often found at an elevated location, such as hilltops (Evans 1968, Connelly et al. 1998). Lek habitat requirements are much less stringent in terms of cover than nesting or brooding habitat requirements, and most leks have 85–100% visibility (Jones 1968). Lek sites are typically surrounded by quality nesting habitats and female sharp-tailed grouse commonly nest within 1.6 km of a lek (Stinson and Schroeder 2012). Restoration efforts for sharp-tailed grouse must ensure suitable nesting habitat is within 1.6 km of suitable of historic lek sites.

Nesting

High quality grassland with intermixed shrubby cover is ideal for sharp-tailed grouse nesting (Hillman and Jackson 1973, Prose 1987). Native grasses, such as western wheatgrass (*Pascopyrum smithii*), bluebunch wheatgrass (*Pseudoroegneria spicata*), and Idaho fescue (*Festuca idahoensis*), offer sharp-tailed grouse better nesting cover than non-native grasses like crested wheatgrass (*Agropyron cristatum*) and cheatgrass (*Bromus tectorum*; Stinson and Schroeder 2012). Fine scale nest site conditions selected by females varies throughout their range and between subspecies. Specifically, selection for low to mid-height shrubs (< 1 m) increases as the availability of herbaceous nest cover declines. At a highly productive grassland site in southwestern North Dakota, Kohn (1976) found less than 10% of nests located near woody vegetation. However, Kantrud and Higgins (1992) observed that nesting females used both herbaceous and woody cover when initiating nests in North and South Dakota, Montana, and Manitoba. In more arid regions, Columbian sharp-tailed grouse typically place nests near or under both deciduous shrubs and sagebrush (Marks and Marks 1987, Giesen and Connelly 1993). The use of shrubs for nesting also varies temporally throughout the season. Shrubby areas of habitat offer important concealment for sharp-tailed grouse during the first nesting attempt, but relative importance may decline throughout the nesting season as herbaceous cover improves (Goddard and Dawson 2009b). Kohn

Figure 7: Sharp-tailed hen on nest in eastern Montana. Photo by Megan Milligan.

(1976) also found that when herbaceous cover provided poor cover (VOR ≤1), sharp-tailed grouse selected shrub cover for nesting sites. Plasticity in nest site selection behavior relative to type of nesting cover allow for broad geographical distributions.

Regardless of the type of cover, sharp-tailed grouse have been found to select for taller and denser vegetative cover at and around the nest sites (Evans 1968, Kohn 1976, Prose 1987, Manzer and Hannon 2005). The majority of upland game birds nest at sites where height of vegetation, visual obstruction, and percent residual grass and litter were all relatively high (Kantrud and Higgins 1992). Nests located in larger patches (50 m radius) of more densely vegetated areas have been found to be more successful than those located in small patches (2 m radius; Manzer and Hannon 2005). Larger patches around nest sites offer the hen more concealment from predators during periods spent off the nest during laying or foraging (Manzer and Hannon 2005). Sharp-tailed grouse often experience a tradeoff between nest cover and adult survival, which is why many species select for mid-range values of cover (Wiebe and Martin 1998, McNew et al. 2013). Landscapes with dominant cropland (>10%) and sparse or fragmented areas of grassland were large factors in nest success of sharp-tailed grouse, as nests located in areas of cropland and low herbaceous cover had a decreased success and survival rate compared to nests located in more dense vegetative cover (Manzer and Hannon 2005).

Brood-rearing

Quality grassland provides suitable habitat for both nesting and brood rearing (Kohn 1976). Similar to nesting habitat, suitable brood habitat varies broadly across the range of the species. In addition, habitat type used by sharp-tailed grouse varies throughout the day. During the mid-day heat, hens with broods were found in brushy areas and later in the day found in areas dominated by shorter herbaceous vegetation (Kohn 1976). High forb cover is important in areas where female sharp-tailed grouse are raising broods; high forb abundance is positively associated with invertebrates, which are the main food source of young sharp-tailed grouse chicks (Goddard et al. 2009). Also, areas with scattered forb cover and openings in dense herbaceous vegetation are important for increased brood mobility when traveling and foraging (Svedarsky et al. 2003, Norton 2005). Agricultural fields can also be used for summer forage of both grains and associated insects (Evans 1968). Habitat edges, along with other areas of quick gradients from sparse to dense vegetation provide access to food resources in close proximity to escape cover and are often selected for by sharp-tailed grouse broods (Goddard and Dawson 2009b).

Non-breeding Season

Shrubby or woody cover is thought to become increasing important to sharp-tailed grouse during the fall (Northrup 1991). Shrubby draws and riparian areas provide food resources as well as thermal cover (Marshall and Jensen 1937, Swenson 1985). Grassland areas and cropland were the main components of sharp-tailed grouse habitat used throughout the summer and fall in an eastern Montana study, but as fall progressed, sharp-tailed grouse shifted use to areas with more abundant shrubs (Swenson 1985). In addition to shifting, home range sizes also increase during the fall and winter and include more diverse habitat types (Boisvert et al. 2005).

Areas with brush are especially important during the winter because sharp-tailed grouse rely heavily on buds and berries for food and rely on shrubs for cover (Evans 1968). During winter months, sharp-tailed grouse use grassland habitat the least, with wooded draws and adjacent areas of agricultural cropland receiving the majority of use (Swenson 1985, Deeble 1996). Use of brushy and wooded areas increases with increasing snow depth (Swenson 1985, Northrup 1991).

Shrubs that produce quality food resources (see *Diet* above) and provide winter cover are necessary for a viable sharp-tailed grouse population (Prose 1987). Up to 90% of sharp-tailed grouse winter habitat usage can occur in deciduous shrub cover (Nielsen and Yde 1982), with the majority of use occurring in silver buffaloberry, along with a small percent of woods rose (*R. woodsii*), snowberry, and chokecherry. Creeping juniper (*Juniperus horizontalis*) and silver sagebrush (*A. cana*) were rarely used by sharp-tailed grouse at one study area in eastern Montana (Nielsen and Yde 1982). However, Northrup (1991) found juniper (*Juniperus* spp.) to be the major cover and food selected by sharp-tailed grouse in the fall and winter at another Montana study area, suggesting plasticity in winter habitat selection across relatively small spatial extents.

HABITAT MANAGEMENT

Fire

Fire can be an important tool to the restoration of the sharp-tailed grouse under the right circumstances. Fire can promote growth of desired native plants that are fire tolerant and reduce undesired plants such as conifers (Giesen and Connelly 1993). However, prescribed fires applied at the wrong place or time can also be detrimental to many grouse species. While fires can remove undesired species such as conifers, fires may also facilitate the establishment of invasive species like cheatgrass. Both productivity of the prairie and the fire frequency and intensity can be altered by invasive species which may have long term effects on grouse habitat selection (Menalled et al. 2008). The decline of Columbian sharp-tailed grouse in Washington during the 1950's was caused, in part, by burning wheat field stubble which resulted in high nest losses (Buss and Dziedzic 1995). When fires are too intense and leave little cover, sharp-tailed grouse have abandoned lek sites the following year (Hart et al. 1950). All parties and agencies involved with the restoration should come to a consensus on the appropriateness of fire as a management tool.

Herbicide

Herbicides that target or indirectly affect essential plants necessary for sharp-tailed grouse can also have a detrimental impacts on sharp-tailed grouse, especially if applied in large amounts and at certain life-cycles of the plant. If key cover species are killed during the nesting or brooding season, the young can be exposed and become vulnerable to predation (Oedekoven 1985). Herbicides can also kill native plants and promote the growth of more resistant, non-native species that have lower habitat value for sharp-tailed grouse (Hart et al. 1950). Nevertheless, more selective herbicides may be useful in improving nesting or winter habitats, as long as they do not interfere with desired or native prairie species. One example of this is using herbicides to kill cheatgrass and promote deciduous growth (Whitson 2003).

Invasive Species

Encroachment of conifers in sagebrush-steppe is a major consideration when evaluating potential management programs or when selecting potential sharp-tailed grouse restoration sites. Greater sage-grouse avoid otherwise suitable habitats encroached by pinion-juniper (Commons et al. 1999, Casazza et al. 2011). In Oregon, no active sage-grouse leks were found within a kilometer of habitats with more than 4% conifer cover (Baruch-Mordo et al. 2013). The spatial arrangement of conifers is important as well; sage-grouse will continue to use conifer-encroached habitats if conifers were clustered rather than evenly dispersed across the landscape (Baruch-Mordo et al. 2013). Sage-grouse avoidance of conifers is attributed to greater availability of perches for raptors (Baruch-Mordo et al. 2013). In Colorado, Commons et al. (1999) documented that all sage-grouse mortality recorded was due to raptors, and survival improved after the removal of juniper from habitats. Empirical data on the effects of conifer encroachment on sharp-tailed grouse are lacking. However, sage-grouse and sharp-tailed grouse select similar nesting and brood-rearing habitats where their distributions overlap, and sharp-tailed grouse likely evolved in areas free of juniper cover. Recent research in the Great Basin, indicates that even low conifer cover (1–5%) can have negative effects on the survival and productivity of sage-grouse (Coates et al. in press, Severson et al. in press). Conifers can be removed using mechanical or fire treatment to improve sharp-tailed grouse habitat. However, managers should consider treatment methods in relation to the subspecies of big sagebrush (*A. tridentata*) as certain sub-species are slower to recover from fire (Baxter et al. in press). Considerations of ecological site condition and historic fire return interval should be evaluated to reduce the likelihood of increasing invasive grasses and forbs (Miller et al. 2014).

Invasion of rangelands by nonnative annual grasses and noxious weeds decreases habitat quality for prairie-grouse. Exotic annual grass invasions closely associated with historic overgrazing include cheatgrass and medusahead (*Taeniatherum caput-medusae*; D'Antonio and Vitousek 1992), Kentucky bluegrass (*Poa pratensis*), smooth brome (*Bromus inermis*), intermediate wheatgrass (*Thinopyrum intermedium*) and crested wheatgrass; these species were originally seeded to improve livestock forage in arid pastures (D'Antonio and Vitousek 1992). Noxious invasive weeds, like spotted knapweed (*Centaurea stoebe*), reduce the diversity of native species in grasslands (Key and Center 1988). Sod-forming grasses (*e.g.*, smooth brome) reduce the cover and diversity of forbs in the understudy (Bunnell et al. 2004) which reduces nesting and brood-rearing habitat quality for prairie-grouse (Dahlgren 2006). In Colorado, Boisvert (2002) observed that sharp-tailed grouse mortality was 11 times higher for birds on CRP lands comprised of non-native, sod-forming grasses than sharp-tailed grouse that selected native grasslands; nest success in these non-native CRP grasslands was only 14% (Boisvert 2002). In Washington, CRP lands dominated by nonnative bunchgrass (*e.g.*, crested wheatgrass) were selected by females for nesting, but nesting success was only 18%, suggesting non-native grassland habitats may be demographic sinks (McDonald 1998). In Idaho, sharp-tailed grouse occurring on CRP lands dominated by crested wheatgrass, intermediate wheatgrass, and smooth brome had reproductive rates that resulted in declining rates of population change (λ=0.77) compared to those in native shrub-steppe rangelands (λ=1.08; Gillette 2014). Nonnative plants should be controlled using accepted methods depending on invasive species composition, such as burning with pre-emergent herbicide and reseeding.

Livestock Grazing

Some areas within the Blackfoot and Drummond sharp-tailed grouse reintroduction sites are used for livestock grazing, which could potentially affect sharp-tailed grouse recovery. If managed appropriately, livestock grazing and sharp-tailed grouse habitat conservation or improvement are compatible. Little research has focused on the direct effects of livestock grazing on sharp-tailed grouse but several studies have investigated the effects of grazing on vegetation, and how that correlates to prairie-grouse habitat requirements (Kirsch et al. 1973, Marks and Marks 1987). Livestock managers can manipulate the timing, intensity, and duration of grazing in combination with type of livestock, weather, and site information to maintain or improve seasonal sharp-tailed grouse habitat (Giesen and Connelly 1993, Crawford et al. 2004). A spring-deferred grazing system where pastures are grazed in late summer, fall, or winter can maintain cool-season perennial grass and forb production in sagebrush habitats for grouse nesting and brood-rearing (Kirby and Grosz 1995, Crawford et al. 2004, Lupis et al. 2006). Inversely, if greater sagebrush cover is desired, pastures could be grazed heavily (> 60% utilization) late spring or early summer, when cool-season grasses are sensitive to defoliation, to decrease perennial grass vigor and promote greater sagebrush cover, although heavy grazing may also increase invasive grass cover (Crawford et al. 2004). Targeted sheep grazing can reduce invasive weeds and sagebrush, and promote grass and forb production. However, sheep grazing in the spring may also reduce forbs available to grouse (Pedersen et al. 2003, Crawford et al. 2004).

Other grazing systems can also benefit sharp-tailed grouse. Rest-rotation grazing systems allow pastures to be rested for one or two years and accumulate residual cover, which is necessary for grouse nesting and brood-rearing habitat in some areas. Kirby and Grosz (1995) reported higher densities of successful nests (successful nests per 41 ha) of plains sharp-tailed grouse in ungrazed pastures compared to adjacent grazed pastures within a rest-rotation grazing system. One study showed that sharp-tailed grouse moved to ungrazed areas for nesting following livestock use (Brown 1961), but other studies observed that grouse did not move into ungrazed pastures, and instead utilized the cover that was available in grazed pastures (Nielsen and Yde 1982, Crawford et al. 2004). In tallgrass prairie ecosystems, a heterogeneous rangeland management regime (i.e., patch-burn grazing) results in higher nest success as well as higher adult survival for greater prairie chickens (McNew et al. 2015, Winder et al. in press). Patch-burn grazing creates a shifting mosaic of diverse grassland habitats that mimic the historically patchy distribution of grassland habitat types that occurred prior to European settlement (Fuhlendorf et al. 2002). If managed appropriately, rotational and patch-burn grazing systems create habitat heterogeneity, potentially meeting all seasonal habitat requirements for prairie-grouse in a relatively small geographic area. However, patch-burn grazing may not be appropriate for other grassland ecosystems and may need to be modified in a sagebrush-steppe ecosystem where vegetation has different responses to fire and grazing. Generally, historical fire-return intervals were longer in western portions of the sharp-tailed grouse range, but disturbances by herbivores may still have been patchy in space and time, and contemporary grazing by livestock can facilitate habitat improvements for grassland birds if managed appropriately (Derner et al. 2009).

Livestock grazing can also be detrimental to sharp-tailed grouse if managed inappropriately. Grazing has the potential to reduce important food plants and insects available during brood-rearing, remove residual vegetation that is an important element of nesting cover, and degrade winter riparian habitat (Stinson and Schroeder 2012). Several studies have indicated a general avoidance of grazed landscapes by prairie-grouse for breeding, nesting, and brood-rearing, attributed to poorer range condition and a lower diversity of grasses and forbs (Marks and Marks 1987, Saab and Marks 1992, Hoffman 2001, Collins 2004). However, early research did not differentiate grazing into specific grazing systems.

An important negative impact of inappropriate livestock management to sharp-tailed grouse habitat is the loss or damage to deciduous riparian habitat. Because livestock spend a disproportionate amount of time in riparian areas for water and shade, excessive grazing and trampling can reduce deciduous riparian shrubs and trees that provide important winter food and cover to sharp-tailed grouse (Kessler and Bosch 1982, Nielsen and Yde 1982, Marks and Marks 1987). Extensive, long-term suppression of riparian vegetation, bank alterations, and subsequent changes in hydrology as a result of livestock grazing can shift deciduous riparian species to upland shrubs like sagebrush and invasive grasses like bluegrass (*Poa* spp.), essentially limiting the amount of riparian winter habitat available to sharp-tailed grouse (Belsky et al. 1999).

In addition to indirect effects of livestock through grazing, livestock can negatively impact sharp-tailed grouse in several other ways. Grouse nests can be trampled by livestock, but trampling is rare and the impacts on seasonal survival from trampling are negligible (Crawford et al. 2004, McNew et al. 2012b). More commonly, grouse will avoid areas where livestock are in close proximity and continually disturbing the grouse, which may decrease lek attendance and increase nest abandonment (Nielsen and Yde 1982, Giesen and Connelly 1993, Crawford et al. 2004, Lupis et al. 2006). Trampling disturbance to soil and biological crusts, especially from heavy grazing, can aid in the establishment of invasive species including knapweeds, mustards (*Brassica* spp.), and cheatgrass (Stinson and Schroeder 2012), with resulting negative effects on nesting and brood-rearing habitat. Invasive species are often of little value to grouse, can displace important native food and cover species, and can increase the fire return interval, which could reduce important grass and shrub cover (see Invasive Species above). Anthropogenic structures associated with livestock grazing can also potentially affect sharp-tailed grouse. Fences, stock tanks, and feed storage sites attract predators, such as corvids, and provide perches for predators to prey on grouse and their nests (Coates et al. 2016). Fencing can also be a source of mortality via collisions but effects of collision mortality on the overall population is unknown (Freilich et al. 2003).

Overall, livestock grazing management should be considered at a landscape-scale and not at the pasture level (Aldridge et al. 2004). However, this can be difficult when working with multiple land owners with variable operations. Overall, using land for livestock grazing is more beneficial to plains sharp-tailed grouse habitat than development or cultivation, and the appropriate application of livestock grazing should be promoted for long-term grouse habitat management (Flake et al. 2010).

Anthropogenic Disturbances and Development

Cultivation

Hay and crop production is another land use within potential sharp-tailed grouse reintroduction sites in western Montana. The loss and fragmentation of native grassland or shrubland habitats reduces the amount and availability of nesting and brood-rearing habitat, and increase nest parasitism and predation (Coppedge et al. 2001, Haegen and Matthew 2007). Research has found: 1) a strong negative relationship between the proportion of cropland on the landscape and the density of sharp-tailed grouse leks (Runia 2009), 2) decreased lek attendance near tillage agriculture (Walker et al. 2007), and 3) that conversion of grassland to cropland is the main cause of prairie-grouse population declines (Kirsch et al. 1973, Connelly et al. 1998, Fuhlendorf et al. 2002).

Once in cultivation, hay or croplands provide relatively low quality habitat for breeding sharp-tailed grouse. Because land used for hay or crop production is generally mowed annually, it lacks adequate residual cover for nesting (Runia 2009). However, if croplands are indeed used by sharp-tailed grouse for nesting, farming activity such as cutting or plowing prior to fledging can cause high mortality rates of nests and chicks, and hayfields are often ecological traps for ground nesting grassland birds (Hillman and Jackson 1973). Noises and movements associated with land cultivation can decrease lek attendance and cause avoidance of these areas for nesting, conceivably reducing reproduction (Pitman et al. 2006, Stinson and Schroeder 2012). Windrows planted for crop protection could also negatively affect sharp-tailed grouse. An increase in the proportion of trees on the landscape can reduce the number of leks and displaying males, likely a result of grouse avoiding unsuitable nesting and brood-rearing habitats that could contain a higher predator density (Runia 2009).

Some land cultivation could provide marginal benefits to sharp-tailed grouse. Overall suitable habitat could be increased if windrows are planted with trees or shrub species that are high-quality winter habitat for sharp-tailed grouse. Similarly, some cultivated grains like wheat can provide a substantial food source to grouse in the winter if other foods are not available (Renhowe 1968, Meints et al. 1992). CRP lands that have been converted from cropland back to perennial grassland can support sharp-tailed grouse breeding, nesting, and brood-rearing (Runia 2009, Gillette 2014). However, nest and brood success of Columbian sharp-tailed grouse in Idaho were lower on CRP lands compared to native shrub-steppe habitats likely because of specific plant types used, leading to population declines (Gillette 2014). CRP lands may require additional management actions to improve nesting and brood-rearing habitats before they can be considered beneficial to sharp-tailed grouse conservation.

Energy Development

Currently, there are no energy developments on any of the potential sharp-tailed grouse reintroduction sites. However, future energy developments could have negative impacts to sharp-tailed grouse restoration and persistence in these areas. Little research has investigated the impact of energy developments on sharp-tailed grouse but many studies have focused on impacts of such developments on sage-grouse and greater prairie-chickens (Walker et al. 2007, Pruett et al. 2009, Holloran et al. 2010, Winder et al. 2014b, McNew et al. 2015).

Because prairie-grouse do not migrate long distances, there are few collision deaths associated with wind turbines and other tall structures (Pruett et al. 2009, Winder et al. 2014a). Instead, behavioral avoidance and depredation are the most significant impacts of energy development on sage-grouse and prairie-chickens (Walker et al. 2007, Doherty et al. 2008, Holloran et al. 2010, Taylor et al. 2013, LeBeau et al. 2014, Winder et al. 2014b, Winder et al. 2015). Male sage-grouse lek attendance and lek persistence can decrease at up to 3.2 kilometers from infrastructure related to coal-bed natural gas developments (Walker et al. 2007) and greater prairie-chicken lek persistence can be reduced for leks within 8 kilometers of a wind turbine (Winder et al. 2015). Such lek avoidance may be due to noise associated with energy development activities like drilling and vehicle traffic (Blickley et al. 2012) or may be due to tall structures that prairie-grouse perceive as a barrier because they have not evolved with similar tall structures in native grassland habitats (Walker et al. 2007, Pruett et al. 2009). Tall structures such as power lines and wind turbines that prairie-grouse perceive as a barrier can lead to habitat loss and fragmentation if they prevent access to suitable habitat (Doherty et al. 2008, Pruett et al. 2009). However, sharp-tailed grouse often use habitat near deciduous trees, especially in the winter, and therefore may not avoid tall structures to the same degree as other prairie-grouse. Studies have documented an avoidance of roads associated with energy development during lekking and nesting up to 100 meters but other studies have found little influence of roads on grouse space use for other prairie-grouse (Walker et al. 2007, Pruett et al. 2009).

Nest site selection and nest survival of prairie-chickens and sage-grouse were not affected by wind energy development (LeBeau et al. 2014, McNew et al. 2015). Although prairie-grouse may avoid suitable brood-rearing and summer habitats near wind energy developments, brood and female survival are not negatively influenced by such facilities (LeBeau et al. 2014). Nevertheless, wind power facilities have been shown to impact seasonal space use (Winder et al. 2015). Future energy developments in western Montana should consider the effects of development on prairie-grouse habitat selection and population dynamics. Impacts of energy developments on sharp-tailed grouse could be minimized by burying power lines, clustering tall structures like wind turbines, and maintaining a 8-km development-free buffer around leks (Manville 2004). Generally, energy development within potential restoration areas should be avoided.

Exurban Development

Exurban development including rural communities, ranchettes, and other human developments in the wildland-urban interface may have negative impacts on sharp-tailed grouse and their habitat (Fuhlendorf et al. 2002, Pitman et al. 2006, Gillan et al. 2013, Hovick et al. 2014). Similar to energy developments and grassland conversion to cropland, exurban developments can fragment a once-continuous landscape, create more edges, and increase predation risk. The development of roads, houses, landscaping trees, and power lines decreases large patches of suitable habitat which can cause habitat loss and local population declines of prairie-grouse (Fuhlendorf et al. 2002). However, broad-scale land changes, like the development of ranchettes that encompass a substantial part of the western Montana landscape, likely present a greater threat of habitat loss and habitat fragmentation to prairie-grouse (Fuhlendorf et al. 2002, Gillan et al. 2013). Residential development, even at low densities, can affect the connectivity of local sharp-tailed populations and limit recovery potential (Stinson and Schroeder 2012).

Avoidance of residential structures and activity has been documented in prairie-grouse (Pitman et al. 2006, Gillan et al. 2013, Hovick et al. 2014). Sage-grouse will avoid buildings by up to 150 m and will avoid power lines up to 600 m (Gillan et al. 2013). Similarly, lesser prairie-chickens will avoid nesting within 1 km of a building or within 400 m of a power line (Pitman et al. 2006). Nest success of lesser prairie-chickens was found to be related to an interaction between nest site vegetation and distance to anthropogenic features, where nests were less successful near anthropogenic features when placed within certain vegetation types (Pitman et al. 2006). Avoidance of exurban developments may be due to associated tall structures that accommodate predators, including corvids that thrive in urban settings (Pitman et al. 2006, Coates et al. 2016). Lek attendance and persistence can be greatly influenced by road traffic and anthropogenic structures (Blickley et al. 2012, Hovick et al. 2014). Site avoidance and habitat loss are large threats to species with high site fidelity, such as the sharp-tailed grouse, because they cannot migrate long distances to escape development (Hovick et al. 2014).

Fences pose a collision hazard for sharp-tailed grouse, but it is unknown how fence mortalities affect populations. Lesser prairie-chicken fence collisions in Kansas and Colorado were of little biological significance and most mortalities were attributed to predation (Robinson et al. 2016). Relatively low mortality (<11 %) of prairie-grouse will likely be compensatory mortality and have little effect on population survival (Sedinger et al. 2010). Generally, mortality has little influence on overall population dynamics and viability of sharp-tailed grouse. If possible, removing unnecessary fencing or marking fences could reduce collision mortalities, even if such mortalities do not significantly influence long-term population persistence. Removing unnecessary fencing or flagging fences could also benefit other rangeland wildlife species that experience fence mortalities such as deer, elk, pronghorn, and other upland birds.

Climate Change

The impacts of climate change on sharp-tailed grouse populations and their habitat in western Montana is uncertain. However, global research indicates that climate change has affected and will continue to affect many bird species (Carey 2009, Jiguet et al. 2010, Saino et al. 2011). Changes in temperatures as well as changes in the timing and amount of precipitation can cause a mismatch between peak food availability and breeding, which could lead to population decline (Carey 2009, Saino et al. 2011). Food availability and breeding mismatch impacts will be most pronounced for bird species that use day length instead of environmental factors like temperature or rainfall as a cue to begin migration or breeding (Carey 2009, Saino et al. 2011). Sharp-tailed grouse may be less likely to experience a mismatch between food availability and breeding because as a resident bird species, they experience some phonological plasticity in response to changing local conditions, such as earlier snowmelt in the spring (Carey 2009).

Other possible climate change impacts to sharp-tailed grouse include reduced nest or brood survival following intense late spring/early summer storms, less vegetation for food and cover due to warmer, drier summers, habitat loss from increased fire frequencies, and higher mortality from a greater impact of disease (Carey 2009, Stinson and Schroeder 2012). Conversely, increased fire frequencies could reduce conifer invasion in sagebrush-steppe and grassland habitats, increasing suitable habitat for sharp-tailed grouse (Stinson and Schroeder 2012). The combined effects of higher temperatures, changes in patterns of precipitation, more frost-free days, and higher atmospheric CO^2 levels on sagebrush-steppe vegetation and sharp-tailed grouse in the western United States are complex and difficult to predict (Siemann et al. 2011).

RESTORATION POTENTIAL

DESCRIPTION OF SITES

Blackfoot Valley

The Blackfoot Valley is one of the last known areas to support a population of sharp-tailed grouse in western Montana, but the species may now be extirpated from the region. There have been no formal population surveys or searches since 1994-2000, but three reliable but unverified observations of sharp-tailed grouse have been reported by landowners and agency personnel since that time (A. Wood, MTFWP, personal communication). Past research examining sharp-tailed grouse populations suggest that the Blackfoot Valley should be a primary focus in sharp-tailed grouse recovery west of the Continental Divide (Deeble 1996, Fitzpatrick 2003). Further, of the potential restoration sites, the Blackfoot Valley has the most complete data on past sharp-tailed grouse habitat use, lek counts and lek locations (Deeble 2000).

The 18,550-ha Blackfoot Valley restoration site is located within the upper Blackfoot River Watershed, near the towns of Ovando and Helmville, Montana. The majority of the reintroduction site is within Powell County, with a small portion occurring in Missoula County. The elevation ranges from a minimum of 1,218 m to a maximum of 1,458 m with a mean elevation of 1,286 m. Average annual precipitation is 38.8 cm with a mean annual temperature of 4.74ºC and annual mean minimum and maximum temperatures of -3.24 ºC and 12.7 ºC, respectively (PRISM Climate Group 2016).

The vegetation in the Blackfoot reintroduction site is dominated by a shrub-steppe plant community with an estimated mean annual production of 1,196 kg per ha that can range from

752 to 1,389 kg per ha depending on the year (Natural Resources Conservation Service Soil Survey Staff 2016c). The vegetation consists primarily of mountain big sagebrush, Idaho fescue, rough fescue (*Festuca campestris*), bluebunch wheatgrass, arrowleaf balsamroot (*Balsamorhiza sagittata*), western yarrow and yellow salsify (*Trapopogon dubius*). Douglas fir (*Pseudotsuga mensezii*), ponderosa pine (*Pinus ponderosa*) and Rocky Mountain juniper (*J. scopulorum*) have invaded some areas likely due to fire suppression in the valley (Deeble 1996).

The Blackfoot Valley is transected by the north fork and main fork of the Blackfoot River as well as several streams, lakes, and wetlands. Approximately 15% of the vegetation in the upper Blackfoot Valley is comprised of riparian species (Fitzpatrick 2003). Riparian vegetation communities are generally comprised of black cottonwood (*Populus trichocarpa*), quaking aspen, birch, hawthorn, rose, snowberry, and willow.

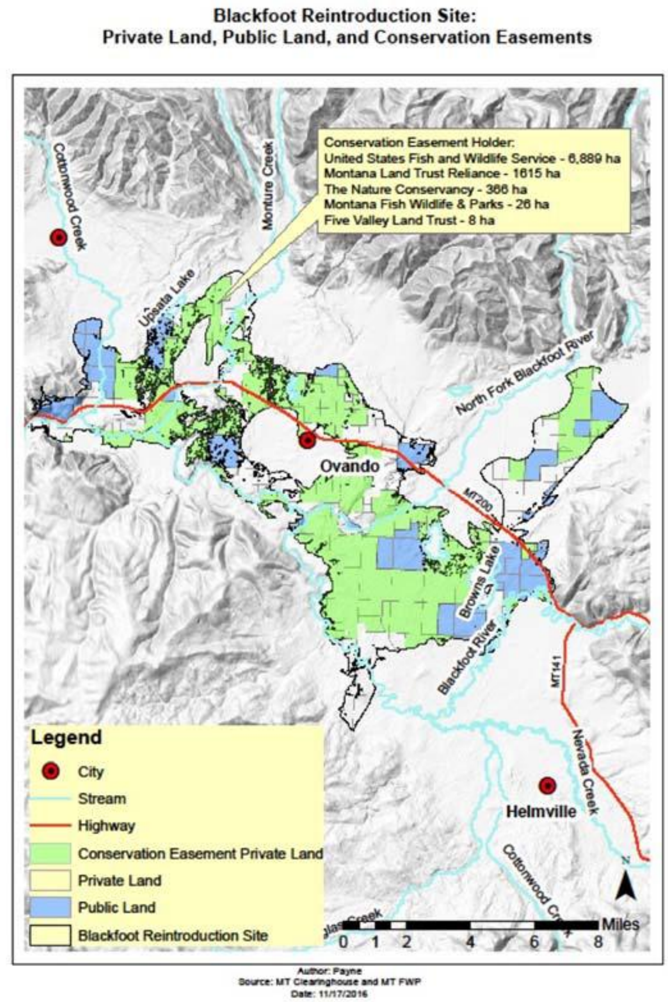


Figure 8: Land ownership and conservation easements at the potential sharp-tailed grouse restoration site in the Blackfoot Valley, MT.

The Blackfoot Valley reintroduction site is predominantly private land used for grazing cow/calf operations (14,804 ha). Large areas in the upper Blackfoot Valley have been converted to croplands, haylands, exotic grass pastures, and grazed rangelands (Deeble 1996). Lands in the upper Blackfoot Valley are not a priority for CRP enrollment (Deeble 1996, M. Merrill, Farm Service Agency, personal communication). Public lands consist of state trust lands, MTFWP, BLM, USFS, and USWS lands (3,746 ha; Figure 8). USFWS-owned lands present in the valley are managed to provide wildlife habitat, primarily for waterfowl production.

The Blackfoot Valley is home to a community-based conservation group, the Blackfoot Challenge, which has been identified as a national model for successful grassroots community conservation (Burnett 2013). The Blackfoot Challenge focuses on keeping working lands intact and preventing development, and has placed over 36,422 ha in conservation easements. Conservation easements in the Blackfoot reintroduction site are managed primarily by the USFWS and the Montana Land Trust Reliance, and account for 8,910 ha of private land in the

Blackfoot reintroduction area. Conservation easements managed by USFWS restrict development but do not have grazing restrictions (K. Urtl, USFWS, personal communication). MTFWP easements often require specific grazing management in the form of rotational grazing (*i.e.*, rest rotation; S. Eggeman, MTFWP, personal communication).

Potential predators of sharp-tailed grouse in the Blackfoot Valley include several carnivorous mammals including coyote, red fox, bobcat (*Lynx rufus*), mountain lion (*Puma concolor*), raccoon (*Procyon lotor*), striped skunk, western spotted skunk (*Spilogale gracilis*), and several members of the weasel family (*Mustelidae*), such as, badger (*Taxidea taxus*). Avian predators include falcons (*Falconidae*), hawks (*Accipitridae, Pandionidae,* and *Cathartidae*), owls (*Tytonidae* and *Strigidae*), and crows, ravens, and magpies (*Corvidae*).

Drummond

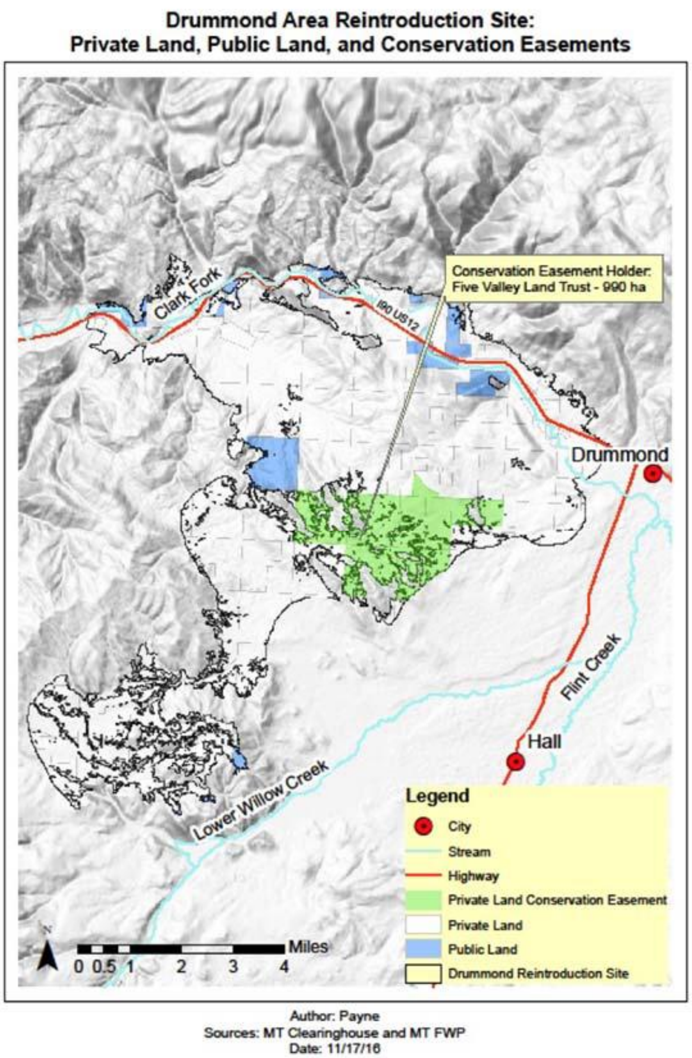


Figure 9: Land ownership and conservation easements at the potential sharp-tailed grouse restoration site near Drummond, MT.

The Drummond reintroduction site is located in the Flint Creek Valley along the Clark Fork River Watershed, near Drummond, MT. There are no known published sharp-tailed grouse survey data for the Drummond reintroduction site. However, available habitat conditions appear similar to those where sharp-tailed grouse historically occurred. Additionally, the habitat suitability index model, created by MTFWP, concluded that this region has potential habitat for sharp-tailed grouse reintroduction (Anderson and Farrar, unpublished manuscript).

The Drummond reintroduction site and surrounding suitable habitat encompasses 20,696 ha that is predominantly a working agriculture landscape focused on beef production (Figure 9). The reintroduction site and surrounding lands are located in Granite County. The elevation ranges from 1,142 m to 1,707 m with a mean elevation of 1,360 m. Average annual precipitation is 36.4 cm with a mean annual temperature of 5.4ºC and annual mean minimum and maximum temperatures of -2.1 ºC and 12.9 ºC, respectively (PRISM Climate Group 2016).

The vegetation in the Drummond reintroduction site is dominated by a shrub-steppe plant community with a mean annual production of 1,383 kg per ha that can range from 903 to 1,767 kg per ha depending on the year (Natural Resources Conservation Service Soil Survey Staff 2016a). The vegetation consists primarily of big sagebrush, Idaho fescue, bluebunch wheatgrass. However, large areas in the Flint Creek Valley have been converted to croplands, haylands, exotic grass pastures, and grazed rangelands. The Flint Creek Valley is transected by Flint Creek and several other streams and wetlands which drain into the Clark Fork River. Riparian vegetation communities are generally comprised of black cottonwood, quaking aspen, birch, hawthorn, rose, snowberry, and willow.

Land ownership is primarily comprised of private lands (10,874 ha). Public lands account for 642 ha and are managed by Montana Department of Natural Resources and Conservation (DNRC), Montana Department of Transportation (MDT), and the BLM. Private land conservation easements compose 990 ha, all of which are managed by the Five Valleys Land Trust and are focused on maintaining wildlife habitat on working farms and ranches.

Potential predators of sharp-tailed grouse at the Drummond site include several carnivorous mammals including coyote, red fox, bobcat, raccoon, striped skunk, and western spotted skunk, and several members of the weasel family including badger. Avian predators include falcons, hawks, owls, and Corvids.

Northern Bitterroot Valley

Although the northern Bitterroot Valley may have historically supported Columbian sharp-tailed grouse, the area is not known as historic plains sharp-tailed grouse habitat. However, historical delineation of Columbian and plains subspecies may have been erroneous (Warheit and Dean 2009), and the habitat suitability index model created by MTFWP concluded that this region may provide suitable habitat for sharp-tailed grouse reintroduction (Anderson and Farrar, unpublished manuscript).

The 8,609-ha Bitterroot Valley reintroduction site is located within the Bitterroot River Watershed near Florence and Lolo, MT. The majority of the reintroduction site is in Missoula County, with the southern portion adjoining Ravalli County. The elevation ranges from a minimum of 975 m to a maximum of 1,646 m, with an average of 1,104 m. Average annual precipitation is 40.2 cm with a mean annual temperature of 7°C. The annual mean minimum and maximum temperatures are -0.5°C and 14.2°C, respectively (PRISM Climate Group 2016).

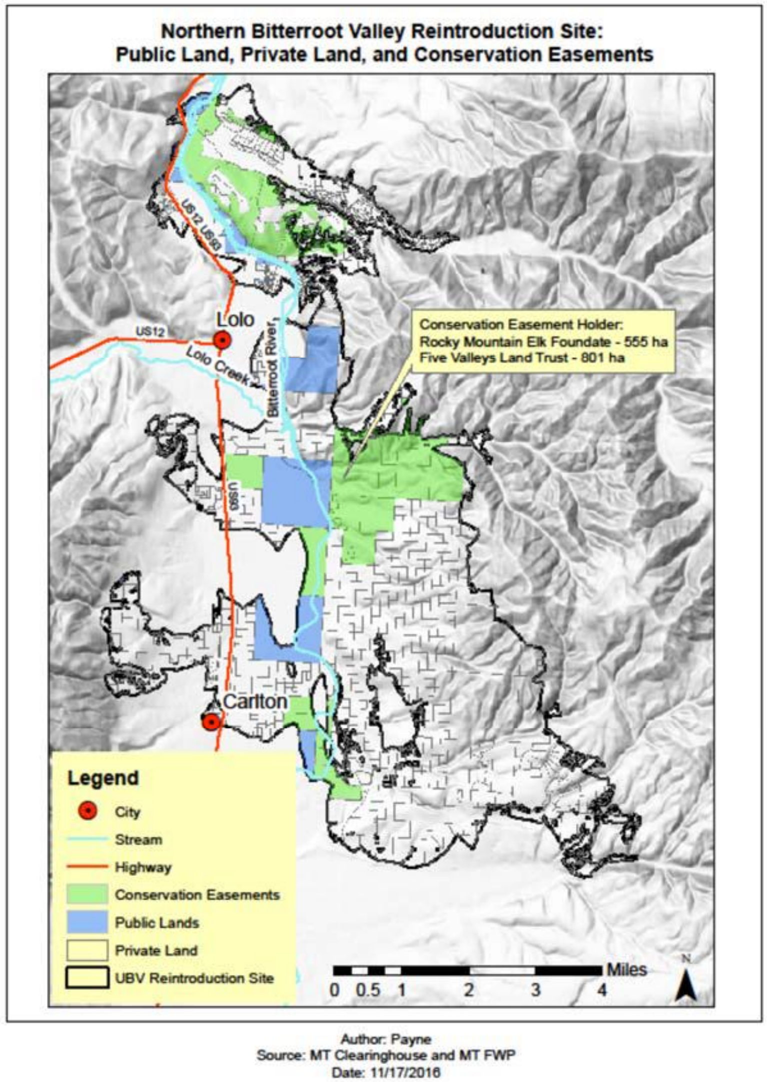


Figure 10: Land ownership and conservation easements at the potential sharp-tailed grouse restoration site in the northern Bitterroot Valley, MT.

The vegetation at the site is dominated by introduced tame forage grass species and small remnant areas of native grass/shrub communities. Additionally, noxious weeds such as Dalmatian toadflax (*Lineria dalmitica*) and spotted knapweed are present throughout the Bitterroot Valley. Mean annual production is 1,196 kg per ha, with a minimum of 844 kg per ha and maximum of 1389 kg per ha depending on the year (Natural Resources Conservation Service Soil Survey Staff 2016b). A field tour within the MPG Ranch noted vegetation communities primarily consisting of crested wheatgrass, intermediate wheatgrass, cheatgrass, bluebunch wheatgrass, arrowleaf balsamroot, lupine (*Lupinus spp.*), spotted knapweed, and wheat. Douglas fir, ponderosa pine, Rocky Mountain juniper, mountain mahogany (*Cercocarpus ledifolius*), serviceberry, and chokecherry were also present, but were generally limited to small riparian draws and mid-mountain elevations. Large areas in the Bitterroot Valley have been converted to croplands, haylands, exotic grass pastures, and grazed rangelands.

The Bitterroot Valley is transected by several other streams and wetlands which drain into the Bitterroot River. Riparian vegetation communities are generally comprised of black cottonwood, quaking aspen, birch, hawthorn, rose, snowberry, and willow. Within the Bitterroot Valley reintroduction site the following carnivorous mammals are present: coyote, red fox, bobcat, raccoon, striped skunk, and western spotted skunk. Several members of the weasel family are also present, including badger. Avian predators include: falcons, hawks, owls, crows, ravens and magpies also occur at the site.

The Bitterroot Valley site is dominated by private land (7,852 ha; Figure 10). The remaining 757 ha are public lands managed by the state of Montana, MTFWP, county government, and MDT. Conservation easements are contracted on 1,356 ha of private lands. The Bitterroot Valley has a mixture of working landscapes for agriculture, primarily cattle production, conservation for wildlife, and housing and industry development. Approximately 4,046 ha are managed for wildlife conservation at the MPG Ranch.

HABITAT ASSESSMENT SUMMARY

The Montana Department of Fish, Wildlife and Parks used the methods of Ashley (2006) for Columbian sharp-tailed grouse to identify the potential areas to target for ground-based surveys at potential restoration sites (Anderson and Farrar, unpublished manuscript). The model developed for Columbian sharp-tailed grouse was selected over a habitat suitability model for plains sharp-tailed grouse because it offered a more conservative evaluation of suitable habitat at potential restoration sites (Anderson and Farrar, unpublished manuscript).

The tools and extensions of ArcMap 10.1 (ESRI, Redlands, CA) were used to conduct a moving window analysis on digital maps from Montana Natural Heritage Program with 30-m pixel resolution, and 1.25 km scanning radius (5.9 km^2 area; Table 8). Cover type classifications were verified or modified by comparing Montana Natural Heritage Program assigned types to high-resolution aerial or satellite imagery to correct misclassifications. Pixel scores within 250 m of residential structures were set to zero to reflect low habitat suitability around human structures.

Each 30-m pixel received a score ranging from zero to 10, with a score of zero being least suitable, and a score of 10 being optimal habitat. Only pixels that contained a score of 5 or greater were included as potentially suitable habitat. These pixels were then grouped into polygons using GIS to identify 5,000-ha blocks with the highest overall habitat scores. The four largest areas of best potential habitat were selected for conducting ground-based surveys to validate the model by measuring the habitat suitability index (HSI) of each area. Each of the four polygons was assigned 90 randomly generated survey points in proportion to the amount of each potentially suitable cover type present: shrub, grass, and riparian.

Table 8. Sorting criteria used to identify habitat suitability for sharp-tailed grouse in Montana using GIS information from MTNHP.
(Anderson and Farrar, unpublished manuscript)

		Score criteria for each 30 meter cell			
GIS Layer	**Parameter Measured**	**0 Points**	**1 Point**	**2 Points**	**3 Points**
Agriculture	Percent Cover[1]	> 10%	≤ 10%	NA	NA
Grasslands	Percent Cover[1]	<10%	10% - 24%	25% – 40%	>40%
Riparian	Percent Cover[1]	<5%	5% - 10%	>10%	NA
Shrublands	Percent Cover[1]	<10%	10% - 24%	25% – 40%	>40%
Slope	Percent Cover[2]	≥20%	<20%	NA	NA

[1]Analysis distance equaled a 2.5 km diameter, circular moving window.
[2]Slope calculated for each cell.

GROUND-BASED HSI

Field survey methods were modified from the approach described in the Habitat Evaluation Procedures protocol created by the Columbia River Wildlife Mitigation Program (Ashley 2010). Only the portions of the Habitat Evaluation Procedures surveys related to the most important habitat components for sharp-tailed grouse nesting, brood-rearing, and wintering were used (Anderson and Farrar, unpublished manuscript). HSI scores were calculated in accordance to protocols developed by the Washington Department of Fish and Wildlife (WDFW) for rating the habitat requirements of Columbian sharp-tailed grouse nesting, brood-rearing, and wintering sites (Ashley 2006, Anderson and Farrar, unpublished manuscript). Anderson and Farrar (unpublished manuscript) broadly defined winter sites as any riparian area, any mast producing shrubland, or grain field that covered >5% of a given landscape; nesting and brood-rearing sites were not explicitly defined.

Within each of the four polygons designated as potential reintroduction sites, 33–53 ($\bar{x}$ = 38.14) points were surveyed per site. Winter habitat data were only collected at 2–9 ($\bar{x}$ = 4.5) points per site, except in the Bitterroot Valley where data were collected at 20 points. Each of the chosen survey points were visited once during nesting season (late April through May) and again during brood-rearing season (June) to measure the variables associated with those specific habitat types (Anderson and Farrar, unpublished manuscript). The few points surveyed for winter habitat were visited during June when foliage was available for identification of plant species. Although clumping of survey locations was not intended, individual points were selected based on ease of access, and proximity to other points to help increase sampling efficiency. This “clustering” of selected survey sites may cause a bias in the data and should be dealt with appropriately.

All variables (V1–V6) associated with calculating nesting and brood-rearing habitat suitability scores are defined in Anderson and Farrar (unpublished manuscript) as modified from Ashley (2006) and are listed in Table 9. Points with missing data for any of the variables were excluded from the analyses (Anderson and Farrar, unpublished manuscript).

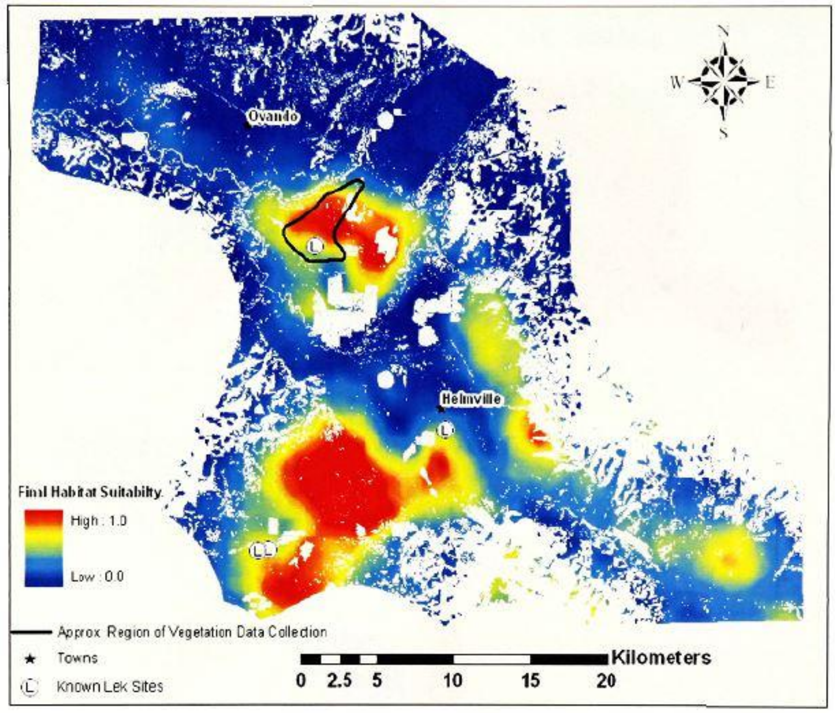


Figure 11: Suitable sharp-tailed grouse habitat (HSI>.75) in the upper Blackfoot Valley shown in yellow and red. (Fitzpatrick 2003)

FOCUS AREAS

Blackfoot Valley

Overview

Multiple studies have attempted to quantify the amount of suitable sharp-tailed grouse habitat in the upper Blackfoot Valley (Fitzpatrick 2003, Anderson and Farrar, unpublished manuscript). Anderson and Farrar (unpublished manuscript) found the upper Blackfoot Valley provides 18,550 ha of suitable sharp-tailed grouse habitat, based on vegetation cover and slope. However, an additional 12,000 ha of potentially suitable sharp-tailed grouse habitat exists to the east and southwest of Helmville, Montana (Figure 11). Fitzpatrick (2003) calculated that the upper Blackfoot Valley contains 56,223 ha of sharp-tailed grouse habitat; his estimate was based on the distribution of breeding and non-breeding habitat considered suitable according to habitat suitability indices (i.e., those > 0.75) developed by Meints et al. (1992; Figure 11).

Table 9. Sharp-tailed grouse nesting and brood-rearing habitat in western Montana.

		Upper Blackfoot Valley			Bitterroot Valley			Drummond				
	Vegetation Cover Class	**Area (ha)**	**Mean**	**±SD**	**Area (ha)**	**Mean**	**±SD**	**Area (ha)**	**Mean**	**±SD**	**Time of Measure**	**Source**
VOR (dm)[3]	Grassland[1]	21,998	1.0	0.52	-	-	-	-	-	-	Late-March to early-May 2003	Fitzpatrick 2003
	Altered Herbaceous[1]	5,610	0.53	0.72	-	-	-	-	-	-		
	Sagebrush < 20% canopy cover[1]	4,609	2.35	2.32	-	-	-	-	-	-		
	Sagebrush > 20% canopy cover[1]	3,480	3.75	2.75	-	-	-	-	-	-		
	Sagebrush, invading conifer <10%[1]	586	3.61	2.46	-	-	-	-	-	-		
V1 VOR (dm)[4]	Grassland[2]	9,368	0.27	0.26	4,134	0.29	0.29	7,128	0.25	0.09	Late-April to early-May and June 2015	Anderson and Farrar 2016
	Shrubland[2]	3,763	0.45	0.36	1,031	0.34	0.37	1,750	0.23	0.26		
	Deciduous/riparian[2]	-	-	-	1,194	0.56	0.41	371	0.11	0.09		
V3 Percent cover herbaceous; residual and current year's growth[5]	Grassland[2]	9,368	95.6	0.15	4,134	78.8	29	7,128	88.9	25		
	Shrubland[2]	3,763	91.6	0.21	1,031	76.1	34	1,750	83.4	33		
	Deciduous/riparian[2]	-	-	-	1,194	83.7	36	371	100.0	35		
V4 Percent cover forbs[5]	Grassland[2]	9,368	34.2	35	4,134	29.8	34	7,128	32.0	28		
	Shrubland[2]	3,763	29.1	27	1,031	33.4	32	1,750	24.0	29		
	Deciduous/riparian[2]				1,194	54.2	39	371	28.6	17		
V5 Percent cover noxious invasive species[5,6]	Grassland[2]	9,368	95.2	15	4,134	81.0	29	7,128	96.2	12		
	Shrubland[2]	3,763	99.9	1	1,031	72.3	33	1,750	98.9	5		
	Deciduous/riparian[2]	-	-	-	1,194	47.5	34	371	88.5	4		
V6 Percent equivalent optimum area providing nest/brood-rearing cover[7]	Grassland[2]	9,368	96.0	8	4,134	100.0	0	7,128	98.4	3		
	Shrubland[2]	3,763	100.0	0	1,031	100.0	0	1,750	97.9	4		
	Deciduous/riparian[2]	-	-	-	1,194	100.0	0	371	100.0	0		

[1]Land cover within habitat available to support sharp-tailed grouse in the upper Blackfoot Valley defined by Fitzpatrick (2003). Using the proportion of each nesting and brood-rearing vegetation class within total sharp-tailed grouse habitat, areas (ha) of these vegetation classes within the 56,223 hectares of available habitat were calculated (Fitzpatrick 2003).
[2]Land cover within suitable sharp-tailed grouse habitat defined by Anderson and Farrar (Unpublished manuscript).
[3]A Robel (1970) pole was used to estimate VOR of residual and new vegetation every 5 meters along a 25 meter transect for each cover class.
[4]Within the field-surveyed area: A Robel (1970) pole was used to estimate VOR of residual and new vegetation every 25 ft along a 300 ft transect. Measurements were taken at 90, 180, 270 and 360 degrees to the transect and averaged for every point.
[5]Within the field-surveyed area: Estimated using a 0.3-m² quadrat every 25 ft along a 300 ft transect.
[6]Invasive species included: spotted knapweed, leafy spurge (*Euphorbia esula*), hound's tongue (*Cynoglossum officinale*), Dalmatian toadflax, ventenata (*Ventenata dubia*), sulphur cinquefoil (*Potentilla recta*), and cheatgrass.
[7]Within the field-surveyed area: Percent of a 3.5 km buffer around each survey point that had a habitat suitability model score ≥5.

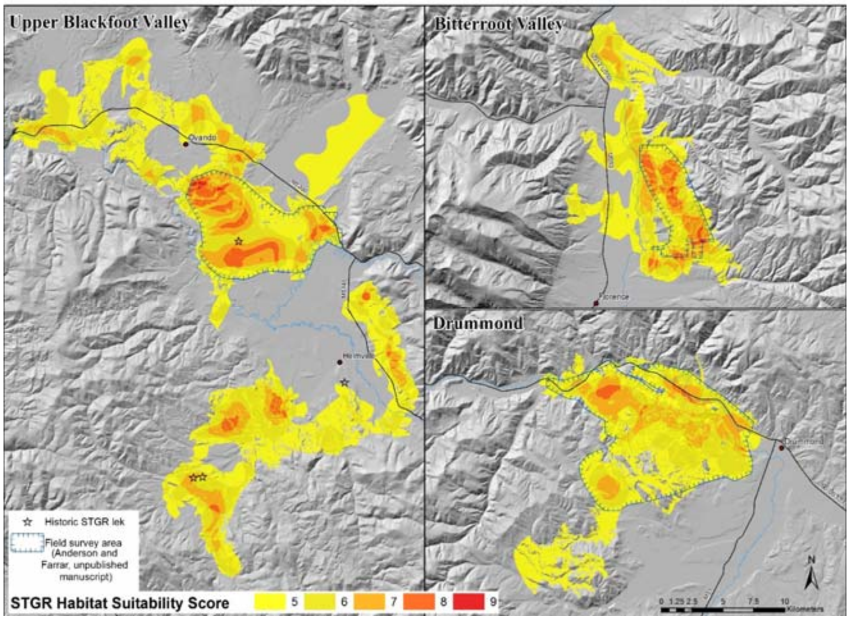


Figure 12: Potential suitable sharp-tailed grouse habitat and historic leks in western Montana.
(Deeble 2000, Anderson and Farrar, unpublished manuscript)

Breeding habitat

Habitat attributes important for sharp-tailed grouse nesting and brood-rearing in western Montana are summarized in Table 9. Anderson and Farrar (unpublished manuscript) measured habitat attributes within a contiguous 6,366-ha area with the highest overall habitat scores determined from a GIS-based screening (Figure 12). Neither the grass nor shrub cover types surveyed by (Anderson and Farrar, unpublished manuscript) provided the minimum residual cover of 1.0 dm deemed necessary for suitable sharp-tailed grouse breeding habitat. However, the residual cover in the upper Blackfoot Valley is similar to the residual cover of occupied sharp-tailed grouse sites east of the Continental Divide. Fitzpatrick (2003) found that vegetation in the upper Blackfoot Valley provided suitable residual cover (mean VOR ≥ 1.0 dm) at 42% of nesting and brood-rearing habitat types, and provided optimum residual cover (VOR > 2.5 dm) at only 20% of nesting and brood-rearing habitats. The remaining 38% of nesting and brood-rearing habitats had less than the minimum VOR measurement of 1.0 dm necessary to support successful sharp-tailed grouse breeding. Nest and brood-rearing habitat was found to be the most limiting factor to sharp-tailed grouse habitat suitability (Fitzpatrick 2003).

Nesting and brood-rearing habitat suitability scores, as defined by Ashley (2006), for field-surveyed areas west of the Continental Divide and occupied sites east of the Divide are summarized in Figures 13 and 14 (Anderson and Farrar, unpublished manuscript). The upper Blackfoot Valley nesting and brood-rearing HSI scores were similar to all the occupied sites ($p>0.05$) and were high relative to other unoccupied sites. Based on the methodology of Ashley (2006), Fitzpatrick

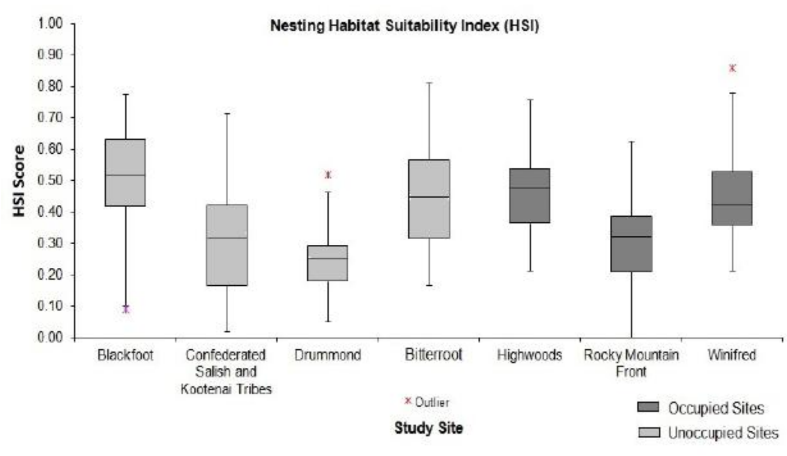


Figure 13: Sharp-tailed grouse nesting habitat suitability index scores in Montana.
(Anderson and Farrar, unpublished manuscript)

(2003) found that nesting and brood-rearing habitat suitability scores in the upper Blackfoot Valley averaged 0.3, and only 12,851 ha met the minimum nesting and brood-rearing habitat suitability value of 0.75 to support sharp-tailed grouse. Based on the assessments of Anderson and Farrar (unpublished manuscript) and Fitzpatrick (2003), ideal sharp-tailed grouse nesting and brood-rearing habitat in the Blackfoot Valley may be limited. Moreover, previous assessments of nesting and brood-rearing habitat conditions failed to consider the occurrence of conifer; prairie-grouse tend to avoid areas with > 10% conifer cover and areas with 1-10% cover act as ecological traps that significantly reduce productivity (Coates et al. in press, Severson et al. in press).

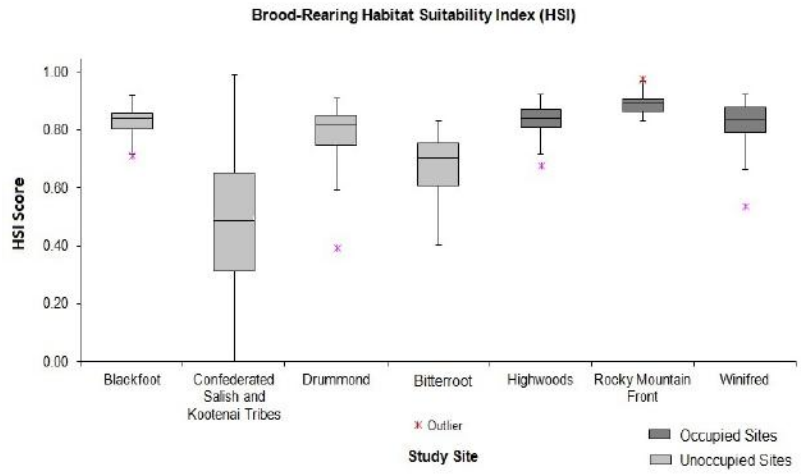


Figure 14: Sharp-tailed grouse brood-rearing habitat suitability index scored in Montana.
(Anderson and Farrar, unpublished manuscript)

Non-breeding habitat

Within areas deemed suitable habitat, there are 1,100 hectares of riparian cover types (i.e., winter habitat) at the Blackfoot Valley site (Anderson and Farrar, unpublished manuscript). Randomly selected nesting and brood-rearing habitat survey points in 2015 were 610 meters from riparian habitats on average. Based on the nine riparian points surveyed in the upper Blackfoot Valley in 2015, deciduous shrubs and trees averaged 41% cover in riparian areas. In contrast, deciduous shrub and tree cover for occupied sharp-tailed grouse sites east of the Continental Divide averaged 50–96%. Within a 3.5-km radius of the riparian survey points, deciduous shrub and tree cover averaged 71% in the upper Blackfoot Valley, which was relatively high compared to the occupied sharp-tailed grouse sites east of the Continental Divide (Anderson and Farrar, unpublished manuscript). Based on the deciduous shrub and tree composition and wheat availability scoring system of Anderson and Farrar (unpublished manuscript), riparian area survey locations had and average HSI score of 0.88

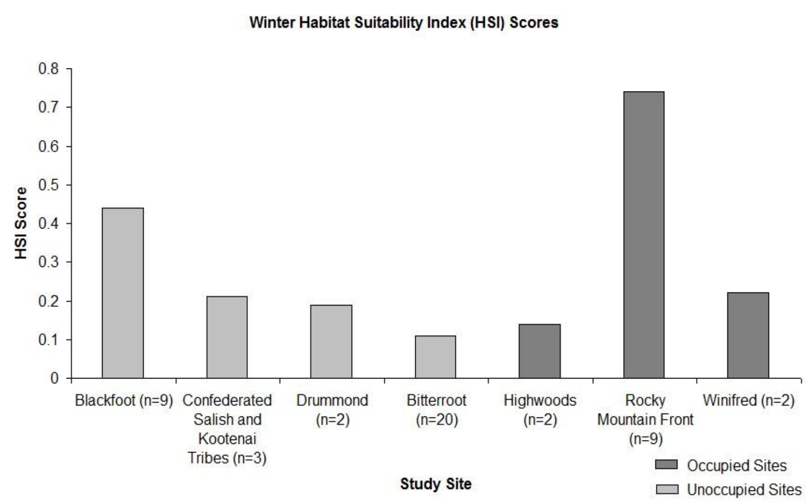


Figure 15: Sharp-tailed grouse winter habitat suitability index scored in Montana.
(Anderson and Farrar, unpublished manuscript)

out of 1.0, which was similar to occupied sites east of the Continental Divide.

Winter habitat suitability scores, as defined by Ashley (2006), for field-surveyed areas west of the Continental Divide and occupied sites east of the Divide are summarized in Figure 15 (Anderson and Farrar, unpublished manuscript). The upper Blackfoot Valley has higher sharp-tailed grouse winter habitat suitability relative to occupied sites east of the Divide and other potential sites west of the Divide. Fitzpatrick (2003) found that most of the upper Blackfoot Valley had a winter habitat suitability score of 0.75 or above (Meints et al. 1992). However, fine-scale species composition and food availability of riparian habitats were not considered and suitable winter habitat was likely overestimated (Fitzpatrick 2003). Comprehensive field surveys of riparian habitat have not recently been completed and other research has indicated a lack of quality winter forage in the upper Blackfoot Valley (Deeble 1996). Before reintroduction of sharp-tailed grouse, comprehensive, on-the-ground field surveys of riparian habitats should be completed to better quantify the quality and amount of winter habitat available in the upper Blackfoot Valley.

Drummond and Bitterroot

In contrast to the Blackfoot Valley site, relatively few sharp-tailed grouse habitat evaluations have occurred at the Drummond and Bitterroot sites. Estimates of the quantity and quality of suitable habitat are provided only by Anderson and Farrar (unpublished manuscript).

Breeding habitat

Habitat attributes important for sharp-tailed grouse nesting and brood-rearing in western Montana are summarized in Table 8. Nesting HSI scores among occupied sites east of the Continental Divide and the Drummond and Bitterroot sites were similar, although Drummond had the lowest average scores of the unoccupied sites (Anderson and Farrar, unpublished manuscript). Brood-rearing HSI scores in the unoccupied Drummond site and all occupied sites were statistically similar, and higher and less variable than scores at the unoccupied Bitterroot site (Anderson and Farrar, unpublished manuscript).

Non-breeding habitat

Due to small sample sizes, Anderson and Farrar (unpublished manuscript) were not able to conduct statistical comparisons of winter habitat conditions. However, they reported that winter habitat scores at the Bitterroot site were among the lowest for all unoccupied and occupied sites (Anderson and Farrar, unpublished manuscript). Anderson and Farrar (unpublished manuscript) subjectively noted that all the unoccupied areas are potentially capable of supporting birds overwinter.

GENETIC METRICS

Genetics of Small Populations

The persistence of a small population is determined by a combination of environmental, demographic, and genetic factors, and small populations can be particularly susceptible to stochastic events. Small populations are especially vulnerable to extreme weather events, fire or disease, which can have catastrophic effects on demographic and genetic population processes (Shaffer 1981). Small changes in sex ratios or age distributions can affect reproductive success and recruitment, which has implications for genetic diversity (Gilpin 1986).

Genetic health, including heterogeneity and allelic diversity, is important for any population, with particular considerations for small populations. While other considerations are typically more critical in the short-term, genetic diversity may be the decisive factor determining long-term population persistence and whether a population is capable of adapting to a changing environment (Lande and Shannon 1996). Genetic variation reduces the effects of deleterious alleles due to inbreeding and allows a population to better cope with both current and future environmental variability and change (Lande and Barrowclough 1987).

A variety of causes, including genetic drift, founder effects, genetic bottlenecks, and inbreeding, can lead to loss of genetic variation. Genetic drift is the random shift in allele frequencies over time, which results in only a subset of genes from previous generations being retained (Slatkin 1987). Founder effects result from the colonization of a new area by a small group of individuals that represent only a small proportion of the genetic diversity of the source population (Barton and Charlesworth 1984). Therefore, founder effects are particularly relevant for reintroduced populations if released birds only represent a small proportion of the source population. Genetic drift and founder effects both result in the loss of rare alleles. In reintroduction efforts, there is also a risk of releasing animals with genotypes that are not well suited for the new environment or do not contain the genes necessary for future adaptations.

Similar types of genetic bottlenecks may occur when a population is reduced by demographic or environmental processes below some level. A genetic bottleneck is the result of the reduction of a population to a very low level, with consequent loss of rare alleles and genetic variation (Allendorf 1986). For example, a population of greater prairie-chickens in Illinois that was reduced to very low numbers experienced a corresponding decrease in genetic diversity and reduction in fitness (Bouzat et al. 1998). Spatial structure and isolation of populations can also have a large influence on genetic health and population persistence (Bouzat et al. 1998, Johnson et al. 2003). Isolated populations require significantly more individuals to maintain genetic health compared to populations that have even minimal exchange with other populations (Lande and Barrowclough 1987).

Loss of genetic diversity is also caused by inbreeding. More frequent mating between relatives increases individual and population level homozygosity, and may be the most immediate threat from genetic processes affecting small populations (Keller and Waller 2002). Inbreeding depression can result in lower fecundity, survival, or a population that is less capable of adapting to changing environments (Gilpin 1986, Allendorf and Ryman 2002). Inbreeding depression has led to the decline and extinction of several wild grouse populations and has been linked to lower fertility in populations of the greater prairie-chicken (Bouzat et al. 1998). Furthermore, these genetic factors can reinforce each other and result in positive feedback loops between demographic, environmental and genetic factors, driving populations to extinction in what is termed an extinction vortex (Gilpin 1986).

Considering the many ways a loss of genetic variation can negatively impact small populations, careful monitoring and management is necessary to ensure long-term persistence of reintroduced populations. In one of the best-known cases of genetic rescue, an isolated population of greater prairie-chickens experienced population declines that were associated with reductions in genetic diversity and hatching success (Bouzat et al. 1998). However, these declines were both reversed with the introduction of individuals from a separate genetically diverse population, potentially saving the population from extinction (Westemeier et al. 1998). Together, the effects of a loss of genetic variation on long-term population persistence highlight the necessity of considering genetic implications when managing or introducing a small population.

Implications for reintroduction

Before reintroduction efforts begin, managers must consider whether source animals should come from a wild or captive-bred population. While using captive birds may have less of an impact on existing wild populations, captive-bred individuals may have been subjected to selection in captivity, which can reduce the fitness of reintroduced individuals. In previous translocations of prairie-grouse, wild-caught birds have been more successful than captive-bred individuals, although underlying causes for this are not restricted to genetics (Toepfer et al. 1990).

Two main considerations for reintroductions are to establish a population with adequate genetic variation and to minimize the loss of that variation over time (Jamieson and Lacy 2012). While genetic factors are not the most proximate threat to reintroduced populations, they are important for long-term population persistence. There are several issues to consider when planning a reintroduction. First, it is important that reintroduced individuals be genetically representative of the source population (Jamieson and Lacy 2012). This has implications for the number of separate populations used as sources and how many individuals are released. Generally, if potential source populations have only been separated in the last 150 years, there is unlikely to be significant genetic divergence and using individuals from the largest or closest population is a good strategy (Jamieson and Lacy 2012). In successful reintroductions of ptarmigan (*Lagopus* spp.), Braun et al. (2011) translocated birds from multiple mountain ranges to allow for maximum levels of genetic diversity. However, if the habitat targeted for reintroduction is very different from that of the source populations, it would be beneficial to release individuals from multiple source populations to optimize the population's chance of adapting to a different habitat (Young and Wood 2012).

The second major genetic consideration when planning a reintroduction is the number of individuals that should be released. With regards to genetic diversity, more individuals are typically better. However, this does not account for constraints related to obtaining new individuals, such as how many individuals can realistically be captured and what impact that will have on the source population. A reasonable goal is to retain at least 90% of the genetic variation found in the source population for 100–200 years (Soulé et al. 1986). In general, 20 genetic founders are considered adequate to establish a captive stock (Lacy 1989). For wild populations, the actual number of founders will be significantly smaller than the number of individuals released due to post-release mortality and dispersal (Jamieson and Lacy 2012). In addition, the proportion of genetic founders in the initial population would be lower for a polygynous lekking species, such as sharp-tailed grouse, than for monogamous species. No information exists on the genetic structure of sharp-tailed grouse populations in Montana. However, Tracy et al. (2011) found that for reintroductions of New Zealand passerines, twice as many individuals as were typically released were required to maintain genetic diversity (95% certainty that alleles at an initial frequency of 0.05 would be retained over 20 years). While fewer individuals may be sufficient to establish a population in the short-term, releasing more individuals is justifiable if it increases the long-term viability of the population.

Once a population has successfully established, monitoring should be conducted to detect any influences of inbreeding or declines in heterozygosity. If populations are isolated and small (i.e.,

<500 individuals), periodic assisted gene flow may be effective at slowing genetic deterioration (Jamieson and Lacy 2012). Movement of 1–10 individuals per generation is generally considered sufficient to prevent genetic isolation (Mills and Allendorf 1996).

POPULATION VIABILITY ANALYSIS

Use of species reintroductions in ecological restoration is increasingly common, but has been characterized by a lack of monitoring or standard metrics for success, which has reduced their utility to inform future efforts (Ewen and Armstrong 2007). Prairie-grouse, in particular, have proven difficult to restore to historic habitats, and a lack of documentation of previous efforts has limited the understanding of factors related to success (Toepfer et al. 1990, Snyder et al. 1999). Population viability analyses (PVA) are a common tool used to make decisions when managing wild populations (Beissinger and Westphal 1998). Standard uses of a PVA include estimating a population's extinction probability over a set time period, the minimum viable population (MVP), or the minimum dynamic area (MDA; Reed et al. 2003). The MVP is the number of individuals required for a population to have a given probability of persistence over a specified time period, while the MDA represents the smallest area of ideal habitat required to support a sustainable population (Reed et al. 2003). While these metrics can be useful, the optimal use of PVAs is to compare different management options, evaluating relative differences in extinction probability compared to a baseline scenario (Reed et al. 2002, Converse et al. 2013). In this regard, PVAs can augment knowledge from previous translocations by comparing different translocation and habitat improvement scenarios to inform future efforts.

The most common type of PVA is a stochastic single-population model, which uses Monte Carlo methods to sample from defined distributions of vital rates and project a population over a specified time period (Beissinger and Westphal 1998). Several components are required for a PVA, including a population model, estimates of demographic parameters and their variation, estimates of environmental variation (including both regular annual variance and extreme outliers known as catastrophes), and estimates of spatial and individual variation. Demographic parameters are estimates of the vital rates affecting population growth, ideally collected from the population of interest, are the most critical component of a PVA, and require the most justification for use (Pe'er et al. 2013). Estimates of variance, both demographic and environmental, are also important, because models that do not include variance will predictably overestimate population persistence (Beissinger and Westphal 1998). Spatial variation can be important to include when modelling multiple populations that are spatially segregated, such as in metapopulation models, while individual variation, or constant variation in survival or reproductive success among individuals, can influence the probability of population persistence, particularly in long-lived species (Reed et al. 2002).

While stochastic single-population models improve upon deterministic models by incorporating demographic and environmental stochasticity, they do have several limitations. First, a PVA is limited by the quality of the data involved in building the model (Beissinger and Westphal 1998, Pe'er et al. 2013). Vital rates are particularly difficult to measure precisely and the full range of vital rates needed for a PVA is rarely estimated from long-term field studies with adequate sample sizes, which often results in guesses for mean rates based on intuition or information from similar species (Beissinger and Westphal 1998). In addition, more complicated PVAs, including stochastic single-population models, require estimates of variance, which are difficult to obtain because vital rates must be observed over long periods of time to sample the full range of environmental variation (Ariño and Pimm 1995). A second drawback of PVAs is the inability to validate models, which precludes drawing any definitive conclusions from such models. Stochastic models cannot be validated as they project multiple populations over long time periods and it is both logistically impossible to follow multiple separate populations, and impossible to know which of the possible modeled trajectories a wild population will follow (Beissinger and Westphal 1998). A third limitation of PVAs is that they assume that the system is static, or that the species or its habitat will not change over the period for which population persistence is projected, which will rarely be valid, but can be relaxed with more complicated spatially-explicit models (Reed et al. 2002).

Despite their limitations, PVAs can still be useful when making management decisions regarding wild populations. Rather than estimating absolute rates of extinction, PVAs can be used to evaluate relative extinction probabilities to compare the outcomes of different management scenarios (Beissinger and Westphal 1998, Reed et al. 2002). In addition, extinction probabilities can be estimated over shorter time intervals (*i.e.,* no greater than 50 years) to minimize error propagation and reduce the effects of the assumption that the system is static (Pe'er et al. 2013). PVAs can be particularly useful to maximize success when planning a reintroduction by evaluating different management scenarios. We used life-history information from the published literature to conduct a population viability analysis of a reintroduced population of sharp-tailed grouse in western Montana. Our objectives were to 1) identify the minimum viable population for sharp-tailed grouse using the best available demographic information and stochastic population modeling, 2) identify the minimum dynamic area for sharp-tailed grouse and evaluate whether the three potential reintroduction sites identified by MTFWP provide adequate habitat and are suitable for sharp-tailed grouse reintroduction, 3) identify what management scenarios, with regards to both translocation protocols and habitat management, are necessary to establish a viable population of sharp-tailed grouse, and 4) determine whether a self-sustaining population of sharp-tailed grouse is possible in western Montana.

Method

We used program VORTEX (version 10; Conservation Breeding Specialist Group, Apple Valley, MN) to evaluate different management scenarios for the reintroduction of sharp-tailed grouse into western Montana. VORTEX is an individual-based Monte Carlo simulation package that can simulate the effects of deterministic forces, as well as demographic stochasticity, environmental variation including catastrophes, genetic stochastic events, and intrinsic population regulation (Lacy 1993), and has been used to evaluate population viability for many species (Lacy 2000). We modeled a single population without immigration and projected 1,000 population trajectories over 50 years for multiple management scenarios. Initial population size was set at 75 individuals (25 males, 50 females) and was based on a tradeoff between feasibility and cost of translocating prairie-grouse (Snyder et al. 1999). We defined success as a viable population with a 95% probability of persistence for 50 years (Temple 1992). The probability of extinction was considered the proportion of simulated populations within a given scenario with only one sex remaining after 50 years.

Baseline Model

Model parameters were estimated based on the best available information from published literature on prairie-grouse demographic rates and were averaged across studies. We estimated multiple demographic parameters with regards to reproduction and survival. We modeled a polygynous mating system with 20% mate monopolization (Robel 1970, Gratson et al. 1991). We set the maximum lifespan of birds to be 7 years, that both females and males can breed at one year of age, and that prairie-grouse reproduce until death (Gratson et al. 1991, Connelly et al. 1998). No density dependence in either reproductive effort or reproductive success was considered (Bergerud et al. 1988, Wisdom and Mills 1997, Roersma 2001). All females were assumed to reproduce under normal conditions, but the probability of nest initiation was reduced to 48% in the first year post-translocation (Coates et al. 2006). Sharp-tailed grouse only produce one brood per year, and we assumed a maximum clutch size of 17 and a 50:50 sex ratio at hatch (Connelly et al. 1998). We estimated average fecundity (F) at 3.5 offspring per female in the baseline model based on the reported vital rates from 15 published studies (Table 1) as:

$$F = \{(\mathrm{NEST} \times \mathrm{CS}_1 \times \mathrm{NSURV}_1) + [(1\text{-}\mathrm{NSURV}_1) \times \mathrm{RENEST} \times \mathrm{CS}_2 \times \mathrm{NSURV}_2]\} \times \mathrm{CPE} \times \mathrm{BSURV} \times \mathrm{FPC}$$

where:

NEST = nest initiation rate,
$\mathrm{CS}_{1,2}$ = Clutch size of first and renesting attempts, respectively,
$\mathrm{NSURV}_{1,2}$ = nest survival of first and second nesting attempts, respectively,
RENEST = renesting rate (proportion of females that renest after first nest loss),
CPE = chicks produced per egg laid (accounts for partial clutch loss or egg viability < 1),
BSURV = brood survival (the proportion of broods that produce at least one fledgling), and
FPC = fledglings produced per chick hatched (accounts for partial brood loss; McNew et al. 2012a).

Annual survival of mature birds was set at 0.50 based on a review of 10 published studies (Table 2). However, annual survival of translocated female greater sage-grouse was lower in the first year post-translocation, and based on these estimates, we set annual survival at 0.25 in the first year (Mathews et al. 2016). Juvenile survival was set at 0.40 based on three studies of greater sage-grouse and lesser and greater prairie-chickens (Beck et al. 2006, Pitman et al. 2006, McNew et al. 2012a). We modeled stochastic genetic effects using the default value of 6.29 lethal equivalents as the combined mean effect of inbreeding on fecundity and first year survival (O'Grady et al. 2006).

Demographic parameters can vary considerably due to normal annual variability in weather, habitat conditions, predation, or even disease (Moynahan et al. 2006, Hagen et al. 2009, McNew et al. 2011). Annual environmental variation in fecundity was conservatively set to 10% (McDonald 1998). Variation in annual survival rates of prairie-grouse can be significant and has ranged from less than 5% to more than 50% (Moynahan et al. 2006, McNew et al. 2012a, Davis et al. 2014). We set annual environmental variation in survival rates to 15% which we assumed to represent typical annual variability in survival rates (McNew et al. 2012, Gifford et al., in review).

In addition to the standard annual variation in demographic rates due to environmental stochasticity, we considered two types of potential catastrophes with different probabilities of occurrence. A catastrophe is a type of environmental variation that is not necessarily rare but is distinct from environmental stochasticity due to its extreme effects on demography that result in large population declines (Beissinger and Westphal 1998). First, we modeled an extreme winter with a 2% frequency (i.e., happens once every 50 years on average) based on annual snowfall data from NOAA. Survival during the extreme winter was estimated to be 34% compared to a normal year based on differences between survival rates in mild and severe winters for Columbian sharp-tailed grouse (Ulliman 1995). The second type of catastrophe considered was a cold wet spring and summer, which we estimated to have a 6% frequency based on mean temperature and total precipitation data from NOAA; we parameterized this catastrophe to reduce reproductive success by 34% (Erikstad and Andersen 1983, Smyth and Boag 1984, Bousquet and Rotella 1998).

We incorporated and evaluated the effects of different levels of habitat quality or quantity by testing scenarios at varying levels of carrying capacity as a proxy for the amount of available habitat. Based on the amount of suitable habitat identified by MTFWP and an average density of 5 birds per km^2 (Table 7), we ran each scenario at carrying capacities of 500, 1000, 2000, and 4000 individuals to model the effects of habitat quality and availability.

Management Scenarios

We adjusted vital rates of our baseline model to evaluate 7 additional management scenarios based either on translocation methods or habitat management (Table 10). Unless otherwise stated, all management scenarios were modeled at the four levels of carrying capacity described above. Three scenarios modeled different translocation techniques. First, we modeled translocating just yearlings (Scenario A) based on reported higher survival (0.67 vs 0.42) of yearling versus adult translocated sage-grouse (Mathews et al. 2016). Second, we modeled the effects of supplementation on population persistence by supplementing 10 grouse for the first five years at carrying capacities of 500 and 1000 for the baseline and juvenile translocation scenarios (Scenario B). Third, we modeled a genetic rescue (Scenario C) by supplementing 10 grouse every decade for the baseline and juvenile translocation scenarios (Mills and Allendorf 1996).

Six additional scenarios modeled the effects of different habitat management actions. First, we modeled the effects of predator removal for the first two years of translocation effort (Scenario D). For greater sage-grouse, raven removal increased nest survival by 73% (Coates and Delehanty 2004), so we adjusted the average annual fecundity to 4.7 offspring per female. Mammalian predator impacts on nest survival were not included because previous research found no effect of mesopredator trapping on nesting success (Wiens 2007). A second habitat management scenario involved two alternative methods to improve nesting habitat either through the removal of conifers (Scenario E) or improved grazing practices (Scenario F). Nest survival was increased 5.2% for a population of greater sage-grouse with the removal of conifers

Table 10. Management scenarios evaluated with population viability analysis.

Scenario	Type	Management Action	Affected Vital Rate	Adjusted Model Value (F=Fecundity, S=Survival)
Baseline				
A	Translocation	translocate yearlings only	post-release survival	S=0.42 in year 1
B	Translocation	supplement 10 grouse every year for 5 years	NA	
C	Translocation	genetic rescue of 10 grouse every 10 years	NA	
D	Habitat management	removal of ravens as nest predators	nest survival	F=4.7 in years 1-3
E	Habitat management	improve nesting habitat by decreasing conifer cover	nest survival	F=3.72
F	Habitat management	improve nesting habitat by improving grazing practices	nest survival	F=4.37
G	Habitat management	improve winter habitat by increasing shrub cover	adult survival	S=0.60
H	Habitat management	improve nesting and winter habitat by decreasing conifer cover and increasing shrub cover	nest and adult survival	F=3.72 and S=0.60
I	Habitat management	improve nesting and winter habitat by improving grazing practices and increasing shrub cover	nest and adult survival	F=4.37 and S=0.60
J	Habitat management + Translocation	improve nesting and winter habitat by improving grazing practices and increasing shrub cover + genetic rescue of 10 grouse every 10 years	nest and adult survival	F=4.37 and S=0.60

(Severson 2016) and 37% without heavy grazing in a population of black grouse (*Tetrao tetrix*; Baines 1996). We modeled both effects on fecundity separately. We also modeled the effects of winter habitat improvement as a 15% increase in shrub cover (Scenario G), which increased overwinter survival by 19% in a population of greater sage-grouse (Moynahan et al. 2006). Finally, we modeled improvements in both nesting and winter habitat by combining the increased overwinter survival due to greater shrub cover and the increased nest survival either due to conifer removal (Scenario H) or due to improved grazing practices (Scenario I).

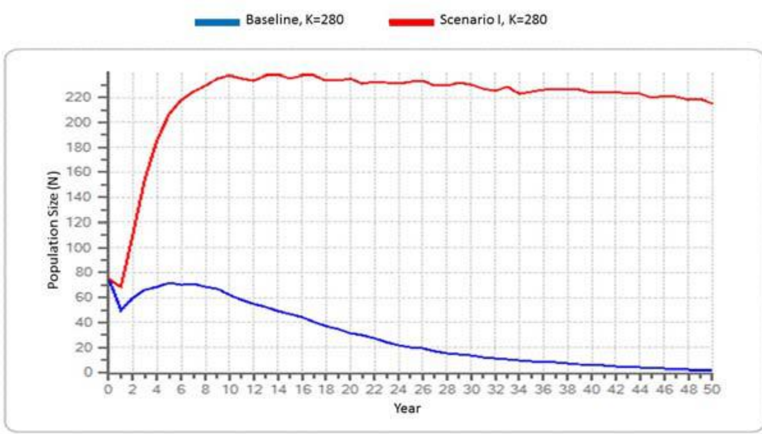


Figure 16: Population size (N) over time for the minimum viable population of sharp-tailed grouse in western Montana projected over 50 years.
The baseline scenario is shown for reference.

Results

Results of our VORTEX modeling exercise are summarized in Table 11. Additional scenario outputs are included in Appendix A.

Minimum Viable Population

Simulation results indicated that a viable population was only achieved under Scenario I with both improved reproductive success and overwinter survival. Following these results, carrying capacity was altered in Scenario I to test smaller population sizes of 200 and 280 individuals, both previously suggested to be sustainable (Toepfer et al. 1990, Temple 1992, Colorado Parks and Wildlife 2014). This yielded a minimum viable population of 280 sharp-tailed grouse in a landscape managed to improve sharp-tailed grouse demographic rates. The population increased 23% per year on average (r = 0.23). The population at year 50 was approximately 228 birds, but the population began a slow decline after approximately year 18 (Figure 16). The population size of 200 recommended by Toepfer et al. (1990) and Colorado Parks and Wildlife (2014) had a 93% probability of persistence for 50 years under Scenario I and was not considered a viable population by our *a priori* criteria. Increasing the carrying capacity (K) generally improved population persistence and reduced the amount of genetic diversity lost in each scenario. However, increasing K did not lead to a viable population in any scenario except in Scenario I. Larger carrying capacities under Scenario I also produced a population with a 95% probability of persistence for 50 years. The MVP of 280 individuals under Scenario I lost approximately 20% of its initial genetic diversity over the 50-year period while the larger carrying capacities under the same scenario lost approximately 10–15% of the initial genetic diversity (Table 11). The genetic effects on small populations likely negatively affected the viability the population at K=200 under Scenario I while a population of 280 individuals was large enough to reduce the negative genetic effects and produce a viable population.

Table 11. Stochastic VORTEX model outputs for each scenario of sharp-tailed grouse management ≥95% probability of persistence for 50 years in bold.

Scenario	Carrying capacity (K)	Mean growth rate (r)[a]	SD(r)	λ[b]	Probability of extinction[c]	Population size (N)[d]	Genetic diversity[e]
Baseline	200	-0.124	0.492	0.883	0.98	42	58
	280	-0.123	0.495	0.884	0.97	48	61
	500	-0.115	0.484	0.891	0.93	111	71
	1000	-0.128	0.443	0.880	0.94	168	75
	2000	-0.124	0.500	0.883	0.93	362	79
	4000	-0.127	0.502	0.881	0.94	836	77
A Translocate yearlings only	500	-0.106	0.433	0.899	0.91	106	69
	1000	-0.102	0.429	0.903	0.88	226	74
	2000	-0.096	0.424	0.908	0.87	403	79
	4000	-0.100	0.426	0.905	0.89	745	76
Ba Supplement 10 female grouse every year for 5 years; adults translocated	500	-0.054	0.486	0.947	0.79	115	71
	1000	-0.048	0.482	0.953	0.76	238	79
Bb Supplement 10 female grouse every year for 5 years; yearlings translocated	500	-0.047	0.464	0.954	0.78	117	75
	1000	-0.039	0.465	0.962	0.71	267	80
Ca Genetic rescue of 10 female grouse every 10 years; adults translocated	500	-0.063	0.501	0.939	0.70	81	74
Cb Genetic rescue of 10 female grouse every 10 years; yearlings translocated	500	-0.048	0.477	0.953	0.64	94	75
D Removal of ravens as nest predators for first two years	500	-0.100	0.485	0.905	0.93	102	71
	1000	-0.089	0.478	0.915	0.86	223	75
	2000	-0.087	0.484	0.917	0.85	463	78
	4000	-0.086	0.479	0.918	0.85	659	80
E Nesting habitat improvement: conifer removal	500	-0.090	0.490	0.914	0.88	144	72
	1000	-0.081	0.486	0.922	0.85	285	79
	2000	-0.079	0.481	0.924	0.83	553	79
	4000	-0.080	0.485	0.923	0.85	1044	81
F Nesting habitat improvement: improve grazing practices	500	0.000	0.483	1.000	0.62	205	75
	1000	0.018	0.481	1.018	0.57	471	81
	2000	0.013	0.481	1.013	0.59	988	82
	4000	0.035	0.480	1.036	0.52	1977	86
G Winter cover improvement: increase shrub cover	500	0.119	0.392	1.126	0.17	347	82
	1000	0.135	0.393	1.144	0.18	747	86
	2000	0.136	0.397	1.146	0.17	1524	88
	4000	0.142	0.394	1.152	0.17	3019	88
H Habitat improvements: Conifer removal and increase shrub cover	500	0.156	0.394	1.168	0.12	379	83
	1000	0.171	0.396	1.186	0.12	785	86
	2000	0.176	0.391	1.193	0.10	1609	88
	4000	0.173	0.397	1.189	0.14	3181	88
I **Habitat improvements: improved grazing practices and increase shrub cover**	200	0.208	0.403	1.231	0.07	153	72
	280[f]	0.235	0.396	1.265	**0.05**	228	79
	500	0.256	0.396	1.292	**0.03**	427	84
	1000	0.271	0.401	1.311	**0.05**	873	88
	2000	0.283	0.397	1.327	**0.04**	1787	90
	4000	0.289	0.398	1.336	**0.04**	3639	91
J **Improved grazing practices and increased shrub cover + Genetic rescue of 10 female grouse every 10 years; adults translocated**	280	0.261	0.396	1.298	**0.02**	241	83

[a] Mean exponential growth rate across all time steps; population decreases : r < 0, population increases: r > 0, population stable: r = 0

[b] Lamba based on stochastic mean growth rate (r)

[c] Probability of extinction is defined as the proportion of 1000 iterations in which the population goes extinct

[d] Population size (N) is the mean final population size for iterations (of 1000) in which the population does not go extinct

[e] Genetic diversity is defined as the mean expected heterozygosity, reflecting the number of alleles and their distribution within the population, remaining for iterations (of 1000) in which the population does not go extinct

[f] Minimum Viable Population (MVP)

Minimum Dynamic Area

Breeding densities of sharp-tailed grouse in ideal habitat was observed to be as high as 25 birds per km^2 (Hamerstrom 1939). However, a more realistic estimate of breeding density of sharp-tailed grouse, calculated as an average density reported for nine studies (Table 7) is 5 grouse per km^2. Assuming reintroduced grouse populations can be sustained at this density, the minimum dynamic area of breeding habitat for a viable population of 280 sharp-tailed grouse in western Montana is approximately 56 km^2 (5,600 ha). Based on current information, under Scenario I with initial habitat improvements, all three potential reintroduction sites in western Montana have sufficient habitat to support a minimum viable population of sharp-tailed grouse. If larger populations of 2,000 or 4,000 sharp-tailed grouse are desired to prevent the deteriorating effect of loss of genetic diversity on small populations, the MDAs for these larger populations are 402 km^2 (40,200 ha) and 804 km^2 (80,400 ha), respectively.

Management Actions

Translocation Methods

None of the original scenarios of translocation and supplementation (Baseline, A, B, & C) resulted in a viable population. Although supplementation improved the short-term genetic diversity, overall genetic diversity decreased 20–30% and the populations declined on average (r < 0; Figures 17 and 18, Table 11). Similarly, translocation of yearlings increased the size of the population initially relative to the baseline scenario, but the population decreased by 10% on average and approximately 20–30% of genetic diversity was lost (Table 11, Appendix A). Supplementation of 10 females every 10 years was not sufficient to produce a viable population, but under the MVP scenario (Scenario I + Scenario C= Scenario J), supplementation increased

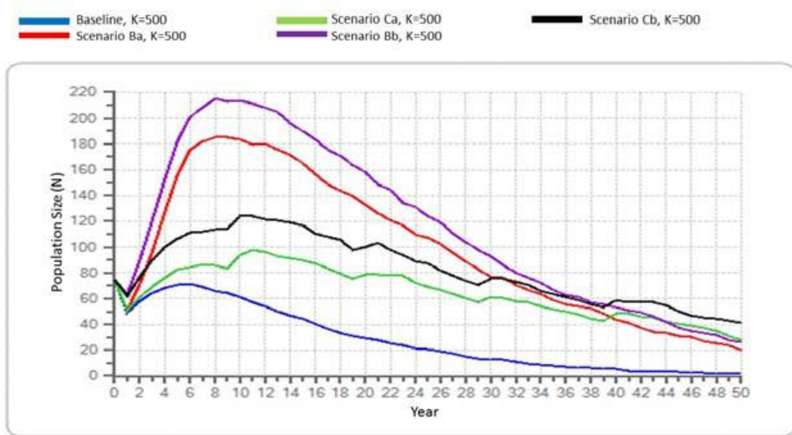


Figure 17: Population size (N) of sharp-tailed grouse populations under each supplementation scenario at K=500.
The baseline scenario is shown for reference.

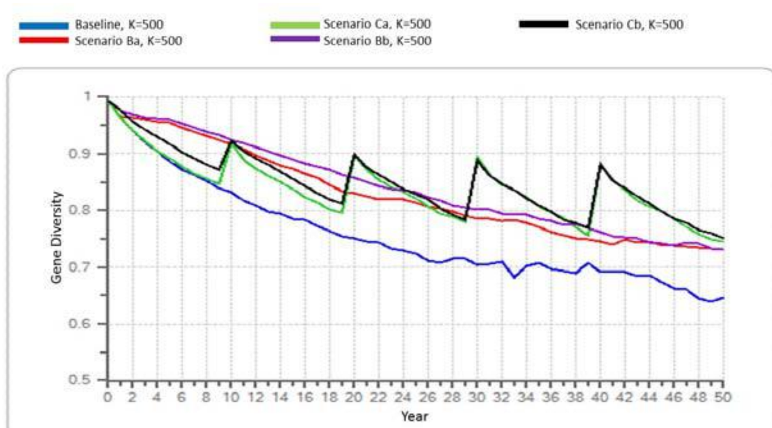


Figure 18: Genetic diversity of sharp-tailed grouse populations under each supplementation scenario at K=500.
The baseline scenario is shown for reference.

long-term genetic diversity and increased the population's probability of persistence (Figures 19 and 20, Table 11). habitat improvement plus supplementation scenarios (e.g., nesting and winter habitat improvements + supplementation of 10 females each year for the first 5 years) could be explored with an aim to maintain genetic diversity and alleviate concerns related to genetic effects on small populations.

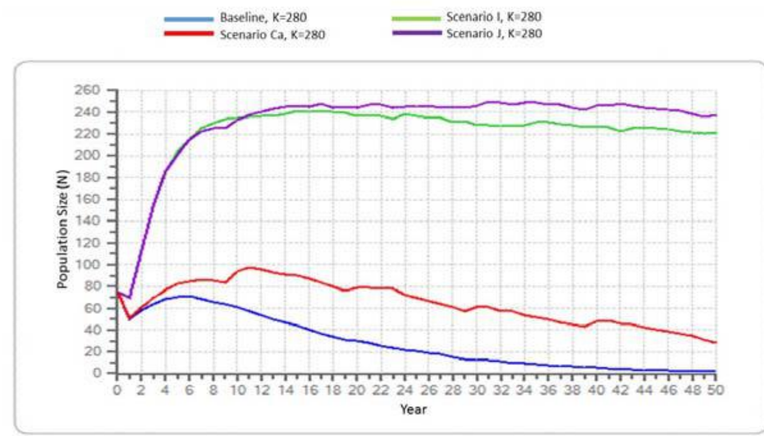


Figure 19: Population size (N) of sharp-tailed grouse populations under a supplementation scenario (Ca), a habitat improvement scenario (I), and a combination of supplementation and habitat improvement scenario (J) at K=280.
The baseline scenario is shown for reference.

Habitat Management

Simulation results indicated that the most limiting factor to population persistence was quality sharp-tailed grouse nesting and winter habitat. Predator removal in the first two years post-translocation did not result in a viable population of sharp-tailed grouse. Under this scenario, population size and persistence was only slightly higher than the baseline scenario and the population decreased by approximately 9% on average (Table 11). All habitat improvement scenarios except conifer removal produced a population that increased on average ($r > 0$) but not all populations persisted for 50 years. Nesting and winter habitat improvements including conifer removal, improved grazing practices, and improved shrub cover increased population persistence relative to other scenarios but did not produce a viable population. However, a combination of improved grazing practices and shrub cover improvements (Scenario I) produced a viable sharp-tailed grouse population (Figure 21).

Discussion

Based on our simulation results, a self-sustaining population of sharp-tailed grouse in western Montana may be possible with a minimum viable population of 280 individuals and a minimum dynamic area of at least 5,600 ha. However, improvements to nesting and winter habitat may be necessary to produce a viable population at the potential restoration sites. Previous studies have recommended similar minimum population sizes and similar minimum dynamic areas (3,000-4,000 ha; Toepfer et al. 1990, Temple 1992). Temple (1992) recommended that a population 280 grouse was sufficient in Wisconsin, but that multiple populations were required to avoid issues relating to genetic, demographic, and environmental stochasticity. Similar to our results, Temple (1992) found that the extinction probability rose sharply after the population dropped below 200 individuals. In contrast, Toepfer et al. (1990) recommended that 200 birds was sufficient, but this was mainly based on previous translocations that were poorly documented. Temple (1992) recommended that at least 4,000 ha of suitable were required to sustain a viable population, while Toepfer et al. (1990) suggested that populations be maintained in areas at least 3,000 ha in size, composed of at least 1,000 ha of undisturbed grass-shrub habitat. The minimum dynamic area from our analysis was based on the average of estimates of population density reported in the literature and represents the minimum area required if habitat is of a quality to support 5 grouse per km^2 at the reintroduction sites. If there is a significant gradient in habitat quality, with smaller areas of high quality habitat embedded in a larger unsuitable matrix, then the minimum area required to support a sharp-tailed grouse population will be larger.

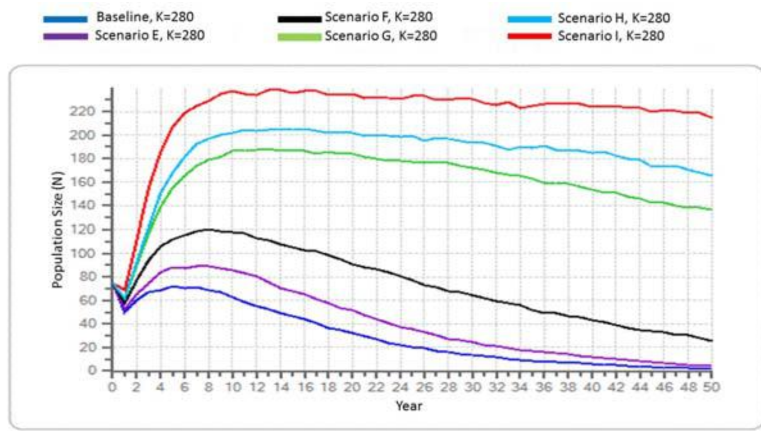


Figure 21: Population size (N) of sharp-tailed grouse populations under each habitat improvement scenario at K=280. The baseline scenario is shown for reference.

shown for reference.

Our results suggest that a population of 280 individuals may be able to withstand demographic and environmental variation to produce a viable population over 50 years; however, genetic factors should also be considered over a longer time frame. While demographic and environmental stochasticity can be more critical in the short-term, genetic variation may be the decisive factor determining whether a population persists in the long-term (i.e., >50 years) and is capable of adapting to a changing environment (Lande and Shannon 1996). The MVP of 280 individuals lost approximately 20% of its genetic diversity in 50 years. If genetic diversity is of concern, mangers should consider supplementation (like Scenarios B or C) or maintaining more quality habitat that can support a larger population (i.e., 500 individuals) of sharp-tailed grouse.

While a viable population is possible, significant habitat improvements, including improved nesting habitat conditions and winter shrub cover, with and without periodic supplementation

(Scenarios I & J) were the only scenarios that produced a viable sharp-tailed grouse population. While our results do not represent absolute rates of extinction, they do indicate that relative to other management actions and translocation techniques, a combination of nesting and winter habitat improvements will provide the best opportunity for producing a sustainable sharp-tailed grouse population. In a similar study of a reintroduction of hihi (*Notiomystis cincta*), an endangered bird species in New Zealand, Armstrong et al. (2007) successfully identified effective management actions using population modeling and found that a combination of several intensive habitat improvements increased the population growth rate more than one habitat improvement project alone. Likewise, several studies of translocations have found that having suitable habitat was the most important factor determining the success of the project (Griffith et al. 1989, Toepfer et al. 1990, Terhune et al. 2006). For example, in a translocation of northern bobwhite (*Colinus virginianus*) the quantity and quality of habitat was the most critical determinant of the project's success and relocating bobwhites to poor or submarginal habitat was not recommended (Terhune et al. 2006). Therefore, pre- and post-translocation management efforts should focus on improving or maintaining quality nesting and winter habitat through grazing management and shrub cover improvements.

With regards to translocation strategies, supplementation alone is unlikely to maintain a population of sharp-tailed grouse in western Montana. However, our results indicate that supplementation used in conjunction with habitat improvements could increase population persistence and genetic diversity. Also, translocation of only yearlings did not greatly improve population persistence but could result in a viable population if implemented along with habitat improvements. Similar to our findings, periodic supplementation reduced the modeled loss of genetic diversity in reintroductions of capercaillie in southern Scotland (Marshall and Edwards-Jones 1998). Supplementation of a pair of capercaillie every five years for 50 years following reintroduction resulted in a predicted viable population. Similarly, we observed improved genetic diversity when the restored population was supplemented periodically with 10 females.

Caveats

While our results have important implications for reintroductions of sharp-tailed grouse, there are several caveats of PVAs that are relevant to management. First, PVAs are only as good as the data that are used to build the underlying demographic models (Beissinger and Westphal 1998). While the demographic rates used in this study were based on the best available information from published literature and averaged across all studies, they were not collected from sharp-tailed grouse populations at the reintroduction sites in question. They do not represent actual habitat conditions at each restoration site; thus the population dynamics realized in a reintroduced population may be quite different. Further, using average demographic rates from the published literature should result in a viable population under normal circumstances, but even our baseline scenario declined and had a very low probability of persistence over 50 years, suggesting that reported demographic rates may have come largely from declining populations, which are often the primary focus of intensive studies. Therefore, the rates used here may not represent the full range of sharp-tailed grouse population dynamics. In addition, not all the demographic rates necessary for this study were available for sharp-tailed grouse. The demographic rates used as a substitute included those from similar species, including sage-grouse and prairie-chickens, which may exhibit different population responses to the translocation and habitat management scenarios examined here. Thus, our estimates of population viability are based on the best available information, but true population viability may be different. Reassessing viability as more information is available about sharp-tailed grouse in Montana will be important for better estimating the true sustainability of a reintroduced population.

Stochastic single-population models, like the one presented here, require estimates of variance, which are typically difficult to obtain (Beissinger and Westphal 1998). However, it is important to include estimates of variability because otherwise estimates of population persistence will be biased upward. The effects of environmental stochasticity are evident in the model outputs of all scenarios and both demographic and environmental variation cause sharp rises and falls in population size over time (Figures 14, 15, and 21). The effects of stochasticity are particularly relevant to small populations where there are fewer individuals to act as a cushion when population growth rates fall (Shaffer 1981). Incorporating estimates of environmental variation into subsequent sharp-tailed grouse population modeling and management decisions will be important for providing useful information on population viability.

Finally, PVAs have several limitations regarding the complexity of models that may restrict their ability to realistically represent natural systems (Reed et al. 2002). These limitations include not incorporating individual variation, not being spatially-explicit and assuming the environment is static. Failure to include individual heterogeneity assumes that fates of all individuals are generally similar and can significantly overestimate the importance of demographic stochasticity and, consequently, extinction risk (Fox and Kendall 2002). However, mean generation time for female sharp-tailed grouse is 1.5 years (Sisson 1976), so the inclusion of individual variation would likely have relatively little effect on our estimated probabilities of extinction. The assumption regarding a static environment over time and space may have more serious implications for the applicability of PVA results. A spatially static model does not allow for gradients of demographic rates across habitat quality. Our estimates of the minimum dynamic area are based on population densities in ideal habitat and assume that the habitat quality is consistent within restoration sites. Thus if there is significant variation in habitat quality within a restoration area, population projections will likely be overly optimistic. In addition, the model assumes that habitat conditions will not change over the time period for which population persistence is projected, which does not account for future habitat degradation or improvement.

Management Recommendations

Habitat Improvement

Based on the results of our population viability analysis, we recommend that sharp-tailed grouse nesting and winter habitat improvements be the focus of pre- and post-release management. Although current information indicates that all three potential reintroduction sites in western Montana potentially contain adequate amounts of habitat to support a viable population of sharp-tailed grouse, additional habitat surveys should be conducted to better quantify the amount, as well as the relative quality, of habitat available and identify target areas for improvement. If quality nesting and winter habitat is lacking, managers should aim to improve grazing practices and improve winter shrub cover in target areas prior to reintroduction in order to increase the probability of population persistence. Strategies to do so, including grazing management and conservation easements, are presented in the Habitat Improvements section of this document.

Adaptive Management

Post-release monitoring of sharp-tailed grouse habitat and demographic rates to enable adaptive management is vital to population recovery and future management success. Adaptive management involves both the development of predictive models and the subsequent updating of those models and related management and has been effective at facilitating species recovery in the past. Post-release monitoring will allow for estimates of population parameters based on the dynamics of sharp-tailed grouse at the reintroduction sites, which will improve the applicability of model estimates of population viability and will better identify the most effective management actions for specific sites. Adaptive management based on population monitoring, evaluation, and manipulation will be critical to the long-term success of sharp-tailed grouse populations in western Montana. Suggested post-release monitoring is outlined in the Monitoring and Research section of this document.

RECOVERY

RECOVERY GOALS AND OBJECTIVES

1) Restore and maintain a population of STGR in western Montana that has a 95% probability of persistence for 50 years.
    a) Identify the minimum population size required.
    b) Identify source populations that match similarly to the reintroduction site's habitat.
    c) Identify most effective methods for translocation.
    d) Identify release sites that minimize movements and maximize survival.
2) Identify management actions that improve probability of restoration success.
    a) Evaluate existing habitat conditions and suitability at the three potential restoration sites.
    b) Identify pre-release habitat and predator management methods to improve restoration success.
    c) Determine appropriate habitat management actions that improve long-term population persistence.
    d) Determine potential for private landowner, public agency, and NGO cooperation.
3) Evaluate necessary monitoring and research priorities/strategies following reintroduction.
    a) Short term
    b) Long term
4) Evaluate best management practices for restored populations of sharp-tailed grouse in western Montana.
    a) Habitat improvement practices.
    b) Source populations (i.e., which ones survived best).
    c) Conservation efforts through private landowners, public agencies, and NGOs.

5) Determine strategies for measuring success in terms of public and NGO perception and involvement.
    a) Wildlife viewing.
    b) Hunting opportunity when applicable.
    c) Involvement of local, regional, and national NGOs.

PRE-TRANSLOCATION HABITAT IMPROVEMENTS

Reintroduction sites that have high quality habitat improve the probability of success of translocation programs (Griffith et al. 1989). Thus, management actions that improve the quantity and quality of critical habitats are recommended prior to sharp-tailed grouse reintroductions.

Blackfoot Valley

Of the three potential restoration sites, the Blackfoot Valley had the highest habitat suitability index scores for both brood-rearing and nesting habitat (Anderson and Farrar, unpublished manuscript). Nevertheless, management actions that improve cover and reduce habitat fragmentation will increase the potential for successful restoration. To maximize nesting habitat, we suggest improvements to develop high quality grassland surrounding the historical and newly established lek sites. On average, female sharp-tailed grouse nest within 1.6 km of leks, suggesting that initial improvements of nesting and brood-rearing habitat should be focused within a mile of leks (Schroeder 1994, Robb and Schroeder 2012). Encroachment of Rocky Mountain juniper and Douglas fir into historically unoccupied areas has been documented in the Blackfoot Valley (B. Deeble, Big Sky Upland Bird Association, personal communication). Because prairie-grouse habitat quality declines with increased conifer cover, managers should focus efforts on removing conifers near historic lek sites and in otherwise highly suitable sharp-tailed grouse habitat (McNew et al. 2012b, Coates et al. in press). Grazing is the most influential land use at potential nesting and brood-rearing areas, and can positively or negatively affect grouse habitat depending on intensity, duration and timing. Grazing management that provides sufficient residual cover for nesting and brood-rearing habitat around lek sites is recommended to maximize potential nesting and brood-rearing cover for sharp-tailed grouse (Stinson and Schroeder 2012). Prior to reintroduction, these factors should be incorporated in the recommendations made for grazing the rangelands where sharp-tailed grouse leks are located.

Of the three potential reintroduction sites, the Blackfoot Valley had the highest winter habitat suitability index score (Anderson and Farrar, unpublished manuscript). Nevertheless, sample sizes for field-based winter habitat assessments were small. There are areas of deciduous shrubs to offer food and cover in the winter. However, within the Blackfoot Valley, much of the deciduous shrub community has likely been impacted by domestic and wild ungulate browsing and trampling (B. Deeble, personal communication). To enhance winter habitat, we suggest habitat improvements that increase the quantity and quality of deciduous shrubs through shrub exclosures and shrub planting in areas historically composed of deciduous shrub communities.

Northern Bitterroot Valley

Two pre-translocation habitat improvements may be required for successful sharp-tailed grouse reintroduction on the MPG Ranch. Improvements to the amount and type of nesting habitat will likely be necessary prior to a translocation program at the site. Field inspections suggested that much of the available nesting habitat within the MPG Ranch is composed predominately of crested wheatgrass, intermediate wheatgrass, and cheatgrass, which offer low-quality nesting habitat compared to native grasses (Stinson and Schroeder 2012). The MPG Ranch is actively restoring the non-native grass ranges with native species. Wildlife conservation is a focus of the MPG Ranch, and a strength of the northern Bitterroot site for sharp-tailed grouse restoration is MPG Ranch's motivated and capable staff of biologists and ecologists, and significant resources that can be applied to restoration.

Winter habitat suitability scores were the lowest amongst potential reintroduction sites as well as areas currently occupied by sharp-tailed grouse (Anderson and Farrar, unpublished manuscript). However, sample sizes for winter habitat quality were small and interpretation on winter habitat suitability should be made with caution. Nevertheless, improvements in deciduous shrub abundance in upland habitats would likely improve overwinter survival. The MPG Ranch is a grassland dominated landscape, with some shrub-bunchgrass draws scattered throughout the property. Preferred deciduous shrubs within upland habitats are generally lacking. Deciduous shrub habitats can account for up to 90% of winter use by sharp-tailed grouse (Nielsen and Yde 1982, Swenson 1985). Riparian habitats with abundant deciduous shrubs and trees are available, but overlap with relatively high exurban development that may result in avoidance or increased overwinter mortality. Sharp-tailed grouse home ranges increase in the winter, and the areas of exurban development surrounding the MPG Ranch may act as either a barrier to movement or increase risk of predation by wild and domestic predators (Fuhlendorf et al. 2002, Boisvert et al. 2005). It is possible that adjacent agricultural fields may be used by sharp-tailed grouse for foraging and riparian areas along the river corridor may be used as cover in the winter (Anderson and Farrar, unpublished manuscript). However, these habitats overlap or are in close proximity to exurban developments and that are known to be avoided by other species of prairie-grouse (Fuhlendorf et al. 2002); information on behavioral or demographic impacts of exurban development for sharp-tailed grouse is lacking.

Drummond

The Drummond reintroduction site ranked the lowest for nesting habitat suitability among the potential reintroduction sites identified (Anderson and Farrar, unpublished manuscript). The site is lacking in herbaceous or shrubby cover needed by sharp-tailed grouse for concealing their nests. Landowners interested in assisting with sharp-tailed grouse reintroduction should be informed of the best grazing systems for sharp-tailed grouse habitat. A rest-rotation or deferred grazing system may improve residual herbaceous cover (Kirby and Grosz 1995, Crawford et al. 2004, Lupis et al. 2006). However, we observed little nesting cover during a site visit even at a potential cooperating ranch where a rest-deferred-rotation system was in place. Annual precipitation is similar at Drummond and the Blackfoot Valley (31.45 cm and 31.3 cm respectively; National Oceanic and Atmospheric Administration Accessed 10/31/2016). However, the annual rangeland productivity was lower at the Drummond site (400–525 kg per ha) compared to the Blackfoot Valley (510–570 kg per ha) which could explain the higher nesting suitability score at the Blackfoot Valley (Natural Resources Conservation Service Soil Survey Staff Accessed 10/31/16, National Oceanic and Atmospheric Administration Accessed 10/31/2016). Reduced productivity at the Drummond site may be incapable of producing the density and height of herbaceous cover required by nesting sharp-tailed grouse, even under conservation-minded grazing and land management.

Landowner Cooperation

The reintroduction of sharp-tailed grouse in western Montana will require the cooperation of landholders at reintroduction sites and surrounding areas to improve habitat and monitor translocated sharp-tailed grouse. Approximately 70% of land for all three reintroduction sites is privately-owned, making outreach and cooperation with private landowners vital to a successful reintroduction program. Public lands managed by federal and state agencies (e.g.,BLM, USFWS, MTFWP; see Description of Sites) also occur at all potential sites and the recovery team will need to coordinate land management for successful habitat improvements.

An information packet should be produced and distributed to key landowners. The information packet should provide background information on sharp-tailed grouse, the reintroduction effort, and how landowners can participate in the reintroduction effort. Collaboration with interested private landowners, local NGOs, and federal and state agencies should be an initial focus to provide input and develop initial plans for restoration. Technical guidance should be made available to interested landowners for developing conservation plans and enrolling in programs and grants to mitigate the cost of developing conservation plans and implementing habitat improvements.

State and federal programs are available to private landowners to assist with habitat improvement and conservation planning costs. The Upland Game Bird Habitat Enhancement Program administered by MTFWP uses cost-sharing programs to reimburse landowners for habitat improvements that benefit upland bird populations. The Upland Game Bird Habitat Enhancement Program is often used for enhancing populations of upland game birds, but is also offered in regions where prairie-grouse are not likely to be harvested provided landowners allow reasonable access to properties under easement for harvest of other game birds (Deeble 1996). The Upland Game Bird Habitat Enhancement Program projects that benefit sharp-tailed grouse are conservation easements that require specified grazing practices, cost share programs for purchasing and installing shrubs for shelterbelts and winter cover, cost share programs for materials and labor to establish infrastructure needs for implementing specific grazing systems that are believed to benefit sharp-tailed grouse (e.g., rest-rotation), and cost share programs for seeds and seeding equipment to improve available nesting and brood cover.

The CRP managed by the Farm Service Agency has benefited upland game bird populations, including sharp-tailed grouse, in multiple states (Sirotnak et al. 1991, Stonehouse et al. 2013, Gillette 2014). Land in the reintroduction sites can qualify for CRP and the recent CRP Grassland Initiative, but may have a low national priority for funds (M. Merrill, personal communication). CRP provides an annual rental payment to remove cropland from production and plant native grasses, as well as a cost share up to 50% of costs. The CRP Grassland Initiative targets grazed rangeland and provides a cost-share up to 50% of fencing costs to support rotational grazing as well as annual rental payments establishing long-term vegetative cover. A Conservation Reserve Enhancement Program (CREP) targeting cropland along the Clark Fork River is currently being developed by the Farm Service Agency and the state of Montana that would benefit upland game birds (M. Merrill, personal communication). The CREP is a partnership between the state and federal government to address a specific conservation concern and provides annual rental payments to participants as well as cost-shares for implementation and incentives specific to the program agreement.

The Natural Resources Conservation Service administers two programs that may mitigate costs of habitat improvements for landowners. The Conservation Stewardship Program provides contract payments to landowners for implementing enhancements to their land that benefit wildlife. The Working for Wildlife Bundle through the Conservation Stewardship Program can increase payments to landowners, while providing enhancements for multiple resource concerns (Natural Resources Conservation Service Accessed 12/1/2016a). Enhancements covered by Conservation Stewardship Program that would benefit sharp-tailed grouse include increased riparian herbaceous cover, brush management (conifer removal), and implementing a grazing plan with an 18 month deferment on a native pasture. The Environmental Quality Incentive Program (EQIP) provides participating landowners up to 75% cost-share for completed practices and activities in their contract (Natural Resources Conservation Service Accessed 12/1/2016b). For a landowner to be able to participate in EQIP, the USDA Local Workgroup needs to determine that the land is in an area with a high priority resource concern. The Local Workgroup also determines what practices and activities will be eligible in the area. Some practices and activities for habitat improvements that can be covered through EQIP are conifer removal, shelterbelt establishment, and developing and implementing a prescribed grazing system.

The majority of conservation programs benefiting wildlife are cost-share programs where landowners cover a portion of the costs for habitat improvements. Expanding the reintroduction coalition to include NGOs could reduce this cost burden to landowners with funds to assist the landowner costs. In addition, NGOs and local conservation groups can assist with developing relationships and cooperation from landowners. NGOs can also bring awareness and enthusiasm to improve the success of reintroduction projects. The Blackfoot Valley Adopt-a-Swan program coordinated by the Blackfoot Challenge, may serve as a useful model for collaboration development and conservation delivery. A unique joint-venture grazing program is available within the Blackfoot Valley to local producers to partner with the USFWS. The program involves a producer exchanging their Animal Unit Months (AUMs) for AUMs available on USFWS lands. The exchanged AUMs are rested from livestock grazing on the producer's property for a specified contract period, allowing for wildlife habitat enhancement. Additionally, USFWS has opportunities for producers to purchase grazing AUMs (*e.g.* drought) as available (K. Urtl, personal communication).

Translocation and monitoring of sharp-tailed grouse requires the cooperation of private landowners. Landowner cooperation and awareness of continued monitoring efforts is essential for evaluating sharp-tailed grouse survival post-translocation. Periodic field tours, meetings, and mailings should be developed for landowners within reintroduction areas to share information regarding the restoration project and solicit landowner input on the recovery effort. Continued outreach can bring new and previously uninterested landowners into the project to improve sharp-tailed grouse habitat on their lands, increasing the total availability of sharp-tailed grouse habitat in the reintroduction area. Landowner working groups should be established early in the planning phase to ensure that landowners are full partners in the recovery effort.

Predator Management

Predation of nests, young, and adults is the primary demographic driver of prairie-grouse populations (McNew et al. 2012, Haukos and Boal 2016, Johnsgard 2016). The most common predators of sharp-tailed grouse are ravens, coyotes, and raptors (Bergerud and Gratson 1988).

Coyotes can prey upon all life stages of sharp-tailed grouse, ravens prey upon eggs, and raptors prey upon juveniles and adults. Due to the influence of predators on game bird populations, predator removal is sometimes promoted to improve population growth rates. However, predator control programs developed to improve upland bird egg, juvenile, and adult survival have had mixed results on short and long term success (Cote and Sutherland 1997, Orning 2013). The effects of predation on nests and adults is typically mediated by habitat conditions (McNew et al. 2012); thus habitat improvements that reduce the numerical or functional response of predators will yield greater population-level benefits in the long-term. Nevertheless, short-term predator removal can improve the initial success of translocation programs by reducing losses for naïve birds in novel landscapes (Coates and Delehanty 2004).

The demographic performance of translocated sharp-tailed grouse and the causes of losses of adults and offspring should be identified prior to beginning any predator-removal program. Biological evidence, such as tracks, feathers, fur, egg remains, or teeth imprints, can be used to implicate specific predators that are causing a significant impact on the reintroduced sharp-tailed grouse (Riley et al. 1998). Camera traps can be useful in identifying predators in a given area and their relative density (Coates et al. 2008). If demographic analyses reveal that specific predators are limiting the establishment of the reintroduced sharp-tailed grouse, then predator removal may be an option to improve short-term sharp-tailed grouse survival and reproduction. However, predator control is not intended to be a long-term method of maintaining a viable sharp-tailed grouse population (Cote and Sutherland 1997).

Coyotes

Coyotes can be a leading cause of depredation on all life-stages of prairie-grouse (Prugh et al. 2009). Habitat improvements that produce improved cover can reduce coyote predation of sharp-tailed grouse (DeLong et al. 1995). In Wyoming, Orning (2013) found removal of coyotes increased the breeding season survival of female greater sage-grouse by 36%, but did not increase overall annual survival. Current research has focused on short-term removal of predators; however, it is believed that long-term effects of coyote removal could increase densities of other mesopredators of sharp-tailed grouse (Prugh et al. 2009).

Other mammalian predators

Red foxes, badgers, skunks, raccoons, and other mesopredators have been known to prey upon sharp-tailed grouse at various life-stages (Bergerud and Gratson 1988). While there have been some efforts to remove these predators to improve upland bird populations, small sample sizes, low densities of these predators, and the short durations of these studies make it difficult to evaluate the potential effectiveness of predator removal on the long-term viability of a reintroduced population of sharp-tailed grouse (Lawrence 1982). As with coyotes, habitat improvements that increase cover could potentially reduce sharp-tailed grouse encounters with these predators (Schroeder and Baydack 2001).

Ravens and other corvids

Ravens are opportunistic and known to prey upon sharp-tailed grouse eggs. Removal of ravens has reduced nest depredation for many ground-nesting birds, including sharp-tailed grouse (Carlsen et al. 1989). Raven removal increased nest survival of greater sage-grouse from 43% to 74% (Coates and Delehanty 2004). Nevertheless, our population viability analysis predicted only a 9% increase in long-term viability of sharp-tailed grouse under an initial raven removal program occurring during the first two years of translocation efforts (see PVA section above). While ravens are the primary concern, other corvids such as crows and magpies are also known to prey upon sharp-tailed grouse eggs. Ravens and other corvids are protected under the Migratory Bird Treaty Act. Thus permits would need to be obtained from the USFWS prior to removal. The removal of conifers would result in reduction of perches available to ravens and likely reduce nest predation by corvids (Coates et al. in press).

Raptors

Raptors, including harriers, eagles, hawks, and owls, have been known to prey upon juvenile and adult sharp-tailed grouse (Bergerud and Gratson 1988). Raptors migrate through Montana in the early spring and late fall (Buskirk 2012). Migration of raptors may overlap with the lekking season when males are more conspicuous and more vulnerable to predation. Raptors are federally protected and cannot be removed without special permission from the U.S. Wildlife Service. Like corvids, habitat improvements that remove potential hunting perches (e.g., conifers, transmission lines) and improve nesting and loafing cover will reduce exposure to raptors. Raptors are protected under the Migratory Bird Treaty Act.

Other Predators

While gopher snakes (*Pituophis catenifer*) have been documented to prey upon upland bird eggs, there have been no formal recommendations to control their population (Coates et al. 2008).

Regardless of the predominate predators and predator density in the reintroduction sites, we recommend habitat improvements that increase cover to reduce sharp-tailed grouse exposure to predation (Aldridge 2005). Sharp-tailed grouse mortality should be monitored prior to implementing predator removals to evaluate whether predation is limiting to population growth and to identify the specific predators implicated. Although intensive removal programs have increased demographic performance and may improve the establishment of new populations of prairie-grouse, the continued intensive effort and expense limits practicality over the long-term and predator removal will not provide long-term solutions for declining populations (Prugh et al. 2009). Prairie-grouse evolved with predators and populations are capable of coexisting with common predators if adequate nesting and security cover is available.

SOURCE POPULATIONS

Sharp-tailed grouse, prairie chickens, and sage-grouse have the lowest performance for re-establishing populations of upland game birds (Toepfer et al. 1990). Low population establishment post translocation for re-introduction sites has been attributed to rapid dispersal rates following reintroduction (Patterson 1952, Ammann 1957, Jacobs 1959). It should be noted that the term dispersal in this section reflects translocation population dispersion away from the introduction site, and does not reflect natal dispersion of young. Source populations originate from two sources: wild or captive-bred stock (World Pheasant Association and IUCN/SSC Re-introduction Specialist Group 2009). The success of the source populations re-establishing depends on the amount and quality of habitat at the reintroduction site (Griffith et al. 1989) and the pre-existing adaptations within the source population (Houde et al. 2015).

Pen-reared Birds

Rapid dispersal of post-translocated wild-stock away from the introduction site is often the cause of the poor success of reestablishment programs (Patterson 1952, Ammann 1957, Jacobs 1959).

The use of pen-reared or captive-bred stock is a common approach to overcome dispersal problems as high rates of deaths or dispersal can be overcome by releasing large numbers of birds (Kurse 1973). However, daily movements of pen-reared birds are similar to wild stock (M. Morrow, U.S. Fish and Wildlife Service, personal communication, Toepfer 1988)USFWS. Pen-reared stock are generally more conspicuous to predators than wild stock, likely due to naïve behavior (Hessler et al. 1970, Roseberry et al. 1987). Mortality rates of pen reared birds 30-days post release have been documented as high as 90%, with 80% of those mortalities attributed to predation (Toepfer 1988).

Pen-rearing often selects for birds who fly poorly (Toepfer 1988). Flushing rate and flying distance for pen-reared stock can be reduced by as much as half those of wild stock (Toepfer 1988). Success of pen-reared bird reintroductions will likely improve if birds are given the opportunity to adapt behaviorally (*i.e.,* introduced to predators) and physiologically (*i.e.,* greater muscle development) prior to release (Toepfer et al. 1990). Predator removals prior to releasing pen-reared birds has been recommended to offset the reduced escape potential and survival of pen-reared birds. Pen-reared stock should be checked for overall health, infections, and contagious diseases (World Pheasant Association and IUCN/SSC Re-introduction Specialist Group 2009).

Pen-reared prairie-chickens are currently translocated annually through a captive breeding program at the Attwater Prairie Chicken National Wildlife Refuge. Post-release annual survival for released birds has averaged c.a. 0.20. Wild stock have higher survival rates post-translocation (>0.30) and therefore should be considered superior to pen-reared stock for translocation (M. Morrow, personal communication). In addition, the breeding and raising of pen-reared birds is expensive relative to the capture and movement of wild birds.

Pen-held Wild Birds

An alternative method to captive-bred stock is to hold wild-caught birds at the reintroduction site prior to release. Pen-held wild birds have previously been used to successfully establish a population of sharp-tailed grouse in Kansas (Rodgers 1992). Holding wild stock on the release site allows for greater familiarization of the introduction site, while still allowing a social hierarchy to function (R. Rodgers, Hays, Kansas, personal communication). When using pen-held stock, it is essential that the pen is predator-proofed. Additionally, human contact and disturbance should be minimized to ≤ 3 times per week (R. Rodgers, personal communication).

Potential negative aspects of pen-held wild birds include high financial and resource costs, as well as potential muscle atrophy and weight loss due to decreased flight movements while in captivity (Toepfer et al. 1990). However, sharp-tailed grouse fed a diet of milo and iceberg lettuce were able to put on weight during the pen holding stage before release (R. Rodgers, personal communication). Providing grain (cracked corn or milo) on the introduction site can hold females following release (R. Rodgers, personal communication).

Wild Birds

Wild birds have higher survival following release than pen-reared birds (Griffith et al. 1989, Fischer and Lindenmayer 2000). Wild prairie-chickens had very large movements in good habitat following initial release, likely related to orienting themselves in a new environment when searching for breeding and nesting areas (Toepfer 1988). Wild pheasant translocations also have greater success in establishing populations than pen-reared pheasants (Trautman 1982, Leif

1994, Musil and Connelly 2009). Prairie-chickens translocated and released in August had greater survival rates through December than those released in spring and remained within 2.5 km of the release site (80% and 33% respectively; Toepfer 1976;1988). In northeastern Nevada, female sharp-tailed grouse captured later in the season were more likely to nest at the reintroduction site than females captured in early spring, likely due to a greater chance of being inseminated prior to translocation (Coates and Delehanty 2006). Translocating wild stock will likely yield the greatest success for establishing populations and be most cost-effective.

Source Population Evolutionary and Habitat Match

Reintroduction programs often select only one source population that can sustain the removal of individuals, while being closest geographically to the reintroduction site (Soorae 2011). However, consideration of the evolutionary history and ecological similarity of source populations will increase the success of reintroduction programs (Houde et al. 2015). Examining for pre-existing adaption (*e.g.*, high fitness) or adaptive potential (*e.g.,* quick response to selection pressure) can provide greater insight to source populations that would lead to successful reintroduction. Reintroduction programs will have greater success if biologists select source populations with high fitness rather than populations with adaptive potential (Houde et al. 2015).

Two methods can be used to identify source populations with pre-existing adaptations: ancestor matching and environment matching (Houde et al. 2015). Ancestor matching is based on genetic similarity, such that those individuals that are genetically similar may possess genes similar to extirpated individuals. Genetic evaluations on sharp-tailed grouse in western Montana have concluded that sharp-tailed grouse were genetically similar to plains sub-species, and the Continental Divide was not likely a physical barrier for gene transfer (Warheit and Dean 2009). The recent increase in woody encroachment within western North America has had negative impacts on connectivity of bird populations (Bakker 2003), which may explain why sharp-tailed grouse populations in western Montana have not been sustained by immigration from populations east of the Divide that they were likely connected to prior to habitat manipulations (*e.g.*, fire suppression) associated with European settlement.

The nearest recorded location of plains sharp-tailed grouse is 56 kg east of the potential reintroduction sites (Deeble 1996). Conifer encroachment has likely reduced movement corridors for dispersing sharp-tailed grouse. Past travel corridors may explain the genetic relationship of western Montana sharp-tailed grouse to eastern Montana's plains sharp-tailed grouse. It is unlikely that sharp-tailed grouse in western Montana were receiving a genetic influx from sharp-tailed grouse from more western populations (Deeble 1996). Efforts for determining source populations should focus on plains sharp-tailed grouse within Montana following the suggestions of Houde et al. (2015).

Matching the environment of source populations to the reintroduction site should produce phenotypically similar individuals to the extirpated population (Houde et al. 2015). For example, vegetation cover types at the reintroduction and source population sites should be similar (Colorado Parks and Wildlife 2014). Comparing habitat characteristics between the source location and reintroduction site, and then selecting reintroduction sites that are most similar will likely improve translocation establishment. However, field studies are expensive and remotely sensed vegetation layers may be too coarse (30m × 30m resolution) to reliably identify similar source population habitat characteristics at landscape scales relative to sharp-tailed grouse population viability.

An alternative approach is to evaluate the best available vegetation layers (i.e., vegetation) in conjunction with annual herbaceous production, in which similar vegetation structure could be predicted between sites rather than species. Additionally, soil and climate could be modeled in relation to production to predict similar vegetation types. Production, soil, and climate data are available through the USDA's Web Soil Survey. The USFS's LANDFIRE vegetation map has produced geospatial data for plant structure height layer for the Northwest United States, which may provide additional insights for nesting and brood rearing habitat's grass/shrub height requirements (United States Forest Service 2014).

Ecological site descriptions can provide similar information with specific vegetation composition. Unfortunately, the Natural Resources Conservation Service field offices are currently producing ecological site descriptions across Montana; site descriptions are generally unavailable for the majority of the reintroduction sites. Possible alternatives for developing ecological site descriptions include field-based classification (Mueggler and Stewart 1980) or range site descriptions developed by the Natural Resources Conservation Service prior to ecological site descriptions. However, habitat would need to be mapped in the field to develop range site descriptions and habitat types for western Montana.

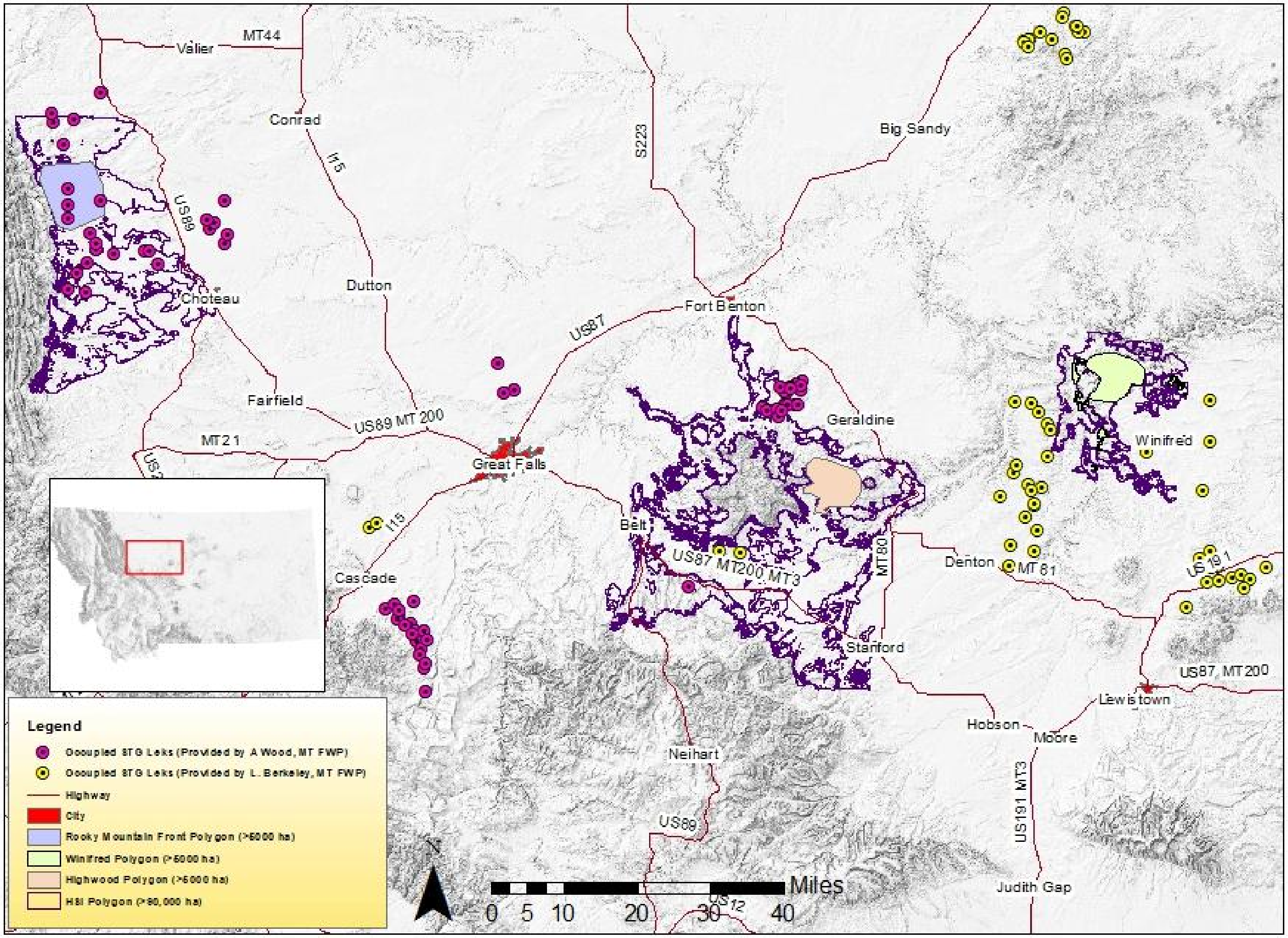
Selection Criteria for Source Population Sizes

To prevent detrimental effects of removing individuals from source populations, the following criteria should be considered. The criteria provided below is adapted from the *Colorado Parks and Wildlife Translocation Guidelines for Columbian Sharp-tailed Grouse* (Colorado Parks and Wildlife 2014). These criteria can be effectually applied to plains sharp-tailed grouse in Montana.

1) Only robust and healthy populations should be selected so that removal of birds will not adversely impact source populations. The recommended breeding size of a source population is ≥ 200 birds (Colorado Parks and Wildlife 2014). Biologists should avoid selecting small, declining, or fragmented populations, which are likely to have reduced genetic variation, increasing potential for inbreeding depression (Breed et al. 2013). Selecting from multiple source populations will likely result in a decrease in social cohesion (birds are unfamiliar with each other; Mathews et al. 2016). Keeping 5 to 8 females from the same congregate may maintain social cohesion.
2) Leks selected for trapping must have a running three-year average of ≥ 15 males per lek. Selection of larger leks reduces demographic and behavioral impacts of removing birds.
3) For each trapping event, only 30% of males and only 5-8 females should be removed from each lek.
4) Fall trapping may yield the greatest opportunity to collect juvenile males. Typically, these males are found on smaller leks. All lek candidates should be monitored prior to trapping to insure attendance and justify removal of those birds.
5) Trapping of females should occur during peak attendance during the spring. Trapping should only occur under suitable weather conditions.

6) Source populations should be considered when adjusting hunting season bag limits (Colorado Parks and Wildlife 2014).

Potential Source Populations



Author: Payne
Source: MT Clearinghouse and MT FWP
Date: 11/30/2016

Figure 22: Current lek locations of sharp-tailed grouse in eastern Montana that may be considered for source populations for translocations.

Potential Sources Populations

MTFWP biologists have identified three potential source populations in central Montana, each greater than 90,000 ha, that sustain robust and healthy sharp-tailed grouse populations. Habitat conditions at potential source populations in east-central Montana were assessed using the same HSI methods described previously for potential restoration sites, excepting: 1) only the three selected occupied sharp-tailed grouse sites (90,000 ha) were evaluated and habitat was not modeled across the whole of eastern Montana; 2) cover types were not verified within the three selected sites; and 3) residential structures were not excluded (Anderson and Farrar, unpublished manuscript). Of the three selected 90,000 ha sites, a 5,000-ha plot with the highest potential landscape scores was identified (Figure 22).

Examining the most recent sharp-tailed grouse lek counts for Montana, there are several potential source populations that coincide with the predicted landscape scores for the Rocky Mountain Front and Winfred polygons (Figure 22). Additional potential source populations are near the towns of Cascade, Denton, and Havre, Montana. However, these sites have not been evaluated for landscape suitability or habitat similarity to potential reintroduction sites.. Sufficient populations may also be present around Ulm and Raynesford, Montana, but additional leks will need to be located for within those regions (Figure 22). Habitat characteristics should be verified for potential source populations not yet identified by MTFWP before trapping and translocations begin.

Of the evaluated source populations, the Rocky Mountain Front site is geographically closest to the reintroduction site. The vegetation composition for the Rocky Mountain Front is likely more similar to that at reintroduction sites than at sites occurring further east. Nevertheless, vegetation across eastern Montana is generally more influenced by Intermountain flora rather than Great Plains flora (Lavin and Seibert 2011). Therefore, source populations farther east from the source populations evaluated by MTFWP should still be considered if it is determined that those sites have similar vegetative composition and structure as the reintroduction sites. Of the three potential source populations identified by MTFWP, the average HSI was greatest for the Rocky Mountain Front for brood-rearing and winter habitat, while nesting HSI scores were highest for the Highwood site (Anderson and Farrar, unpublished manuscript).

CAPTURE

Timing of Capture

The presence of males at established leks should reduce movements of translocated females away from release sites and increase the likelihood of breeding, nesting and brooding-rearing (Hoffman et al. 2015). Thus, we recommend that initial translocation efforts focus on establishing active leks at the restoration site. The first capture and release of sharp-tailed grouse should occur during the autumn and consist of ≥ 25 males trapped at source populations. Male sharp-tailed grouse are not sexually active in the autumn and are presumably under less physiological stress, suggesting they may be less susceptible to the stress of capture, handling, and relocation than during the spring lekking period (Hoffman et al. 2015). At least half of captured males should be equipped with radio-transmitters to enable tracking through the winter and subsequent breeding season (Schroeder et al. 2012, Hoffman et al. 2015). Spring tracking of males should identify new lek locations that will be used as the focal point for spring release of females. This approach will likely reduce the need for establishment of artificial leks using decoys and playback of tape-recorded calls and increase the likelihood that subsequently released birds stay at the site of release (Rodgers 1992, Hoffman et al. 2015).

The capture and release of female sharp-tailed grouse during the spring (Apr-May) increases the probability of a successful translocation (Snyder et al. 1999, Stinson and Schroeder 2012, Hoffman et al. 2015). Research has shown that female sharp-tailed grouse captured approximately 8 days following the start of lek visitation have a significantly higher probability of nesting at the desired release site following translocation (Coates and Delehanty 2006). The precise time period will likely vary between source populations and years. Lek surveys at source populations should be used to predict the time periods best suited to capture and relocate female sharp-tailed grouse the spring following the release of the males (see PVA section). The combined female:male sex ratio of fall and spring releases should approximate 2:1 (Hoffman et al. 2015). Additionally, translocations that include yearling sharp-tailed grouse increase the likelihood of population establishment (Mathews et al. 2016). Thus, if logistically possible, the capture and translocation of yearling sharp-tailed grouse should be prioritized. It should be noted that trapping success typically declines as breeding season progresses (Hoffman et al. 2015), therefore it is important to know when lek visitation by females starts and to adjust captures to commence before lek visitation declines.

Methods of Capture

Methods that have proven effective in capturing prairie-grouse include walk-in funnel traps (Hamerstrom and Hamerstrom 1973, Toepfer et al. 1987, Haukos et al. 1990), spotlighting (Drewien et al. 1967, Giesen et al. 1982), drop nets (Jacobs 1958), and cannon nets (Silvy and Robel 1967, Giesen et al. 1982). Walk-in funnel traps are a recommended method for capturing large numbers of sharp-tailed grouse during a short period of time (Haukos et al. 1990, Schroeder and Braun 1991). Walk-in traps function by placing “W” shaped drift fences composed of poultry fencing around and in travel corridors on leks, which funnel birds into holding cages located at each vertex of the fence (Figure 23; Haukos et al. 1990, Schroeder and Braun 1991). Walk-in traps have many advantages over other trapping techniques including: 1) trapping technique is passive resulting in minimal capture stress; 2) a permanent

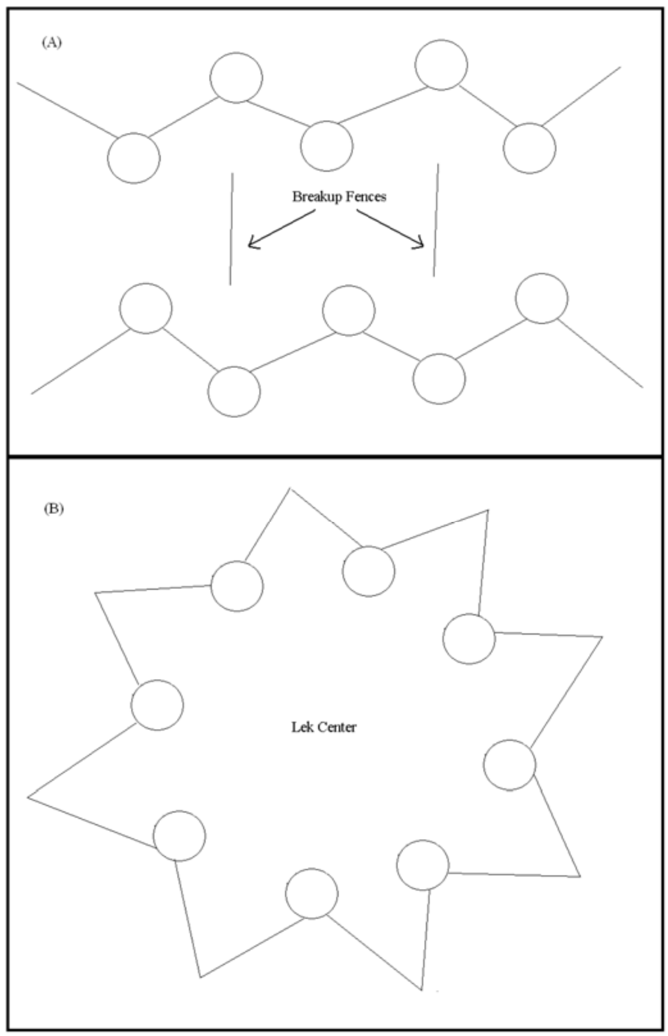


Figure 23: Walk-in trapping designs for capturing sharp-tailed grouse on leks.
As adapted from Williamson (2009).

site location can be used with little maintenance between relocations; 3) continuous observer presence is not required; and 4) the design takes advantage of prairie-grouse lek behavior allowing the whole lek area to be trapped (Haukos et al. 1990, Schroeder and Braun 1991). Advantages of walk-in traps allow multiple leks to be trapped simultaneously. Walk-in traps have been used to successfully trap prairie-grouse at leks during both the spring and autumn lekking periods, with greater overall success in the spring (Haukos et al. 1990, Schroeder and Braun 1991, Salter and Robel 2000). Additionally, walk-in traps result in a relatively high capture rates of female during the spring lekking period, while having high proportion of male captures in the autumn lekking period (Schroeder and Braun 1991, Salter and Robel 2000).

Spotlight trapping at night can be a successful method of trapping sage-grouse while birds are roosting near leks, typically during March–May (Giesen et al. 1982). Spotlight trapping typically requires a crew of two people, one to spotlight and disorient sage-grouse while the other uses a hand held net to capture the sage-grouse (Giesen et al. 1982). Spotlight captures typically result in a larger proportion of males and juveniles, due to juveniles being less wary than adults and the close association of males to leks (Giesen et al. 1982). Although spot-lighting has been successfully used to capture sage-grouse, it has limited success in the capture of sharp-tailed grouse due to differences in vegetation conditions at roosting sites (Cope 1992, Hoffman et al. 2015). Thus, spotlighting is recommended only as a supplementary method to walk-in trapping.

Drop nets have also been used to successfully capture sharp-tailed grouse. Drop nets allow for more targeted captures of sex and age classes. However, drop nets must be continuously monitored and activated by a technician. Drop nets have been used in both the spring and fall to capture prairie-grouse at leks, however, bait is often necessary for fall captures (Jacobs 1958), McNew et al. 2012a). Captures with drop nets typically leave prairie-grouse unharmed (Jacobs 1958). We recommend that drop nets be used as a supplementary method of capture and coupled with walk-in traps on leks. Drop nets could be strategically placed on the leks to increase autumn capture of males and spring capture of females.

Cannon nets can be highly effective when trapping at small leks during display and are advantageous in targeting specific captures by positioning the cannon to areas where females congregate or areas where males display (Haukos et al. 1990). However, cannon nets require continuous observation, cause high lek disturbance, and have a high frequency of escape, injury and mortality (Silvy and Robel 1967, Taylor 1978, Sell 1979, Haukos et al. 1990). In addition, cannon nets use regulated explosives that require special training and federal certification. Therefore, cannon nets are not recommended in the trapping of sharp-tailed grouse.

TRANSPORT

Immediately following capture and processing, sharp-tailed grouse should be safely transported to release sites. Cardboard poultry shipping boxes should be used to house and transport grouse from the capture sites to the release site (Rodgers 1992, Steen 1999, Braun et al. 2011). Transport boxes should have dividers for creating compartments sized for holding individual grouse and minimizing movement, along with having ample holes to allow for ventilation. Keeping individuals separated by the dividers in the transport boxes will reduce injuries (Steen 1999, Braun et al. 2011, Colorado Parks and Wildlife 2014, Hoffman et al. 2015). Holding two or more birds per box (in separate compartments) is thought to calm the birds by allowing them to see and hear one another. Boxes should be lined with unscented clay cat litter, clean fiber matting, clean straw, or other natural absorbent material to minimize the contact between the birds and feces (Baxter et al. 2008, Braun et al. 2011, Stinson and Schroeder 2012, Hoffman et al. 2015). These boxes can be readily sourced from online distributors such as FeatherEx (http://www.featherex.com) and/or Horizon Micro-Environments LLC (http://www.hm-e.net).

Slices of melon placed in shipping boxes during holding and transport will provide grouse with needed water and sugar that is thought to lower stress levels (Steen 1999). The drug estradiol cypionate (ECP) has been used in captive-held wild willow ptarmigan (*L. lagopus*) to reduce stress and increase subsequent survival (Martin and Wright 1993). However, further testing was suggested prior to use in other bird species (Martin and Wright 1993). Grouse will likely be transported late in the day or evening once the desired number and sex ratio of sharp-tailed grouse have been captured from source populations. An evening or night-time transport will aid in reducing stress, provided outside stressors such as human interaction, and anthropogenic noises are minimized (Baxter et al. 2008, Dickens et al. 2010). We recommend using a truck with an enclosed topper that can be ventilated or similar transportation that will shelter the captured sharp-tailed grouse from harsh weather and external noise as well as providing a smooth ride to reduce stress and injury during transport. Caution should be used if stacking transport boxes so that boxes aren't accidentally crushed, or fall over. Prior research involving the translocation of chukar (*Alectoris chukar*) indicated that birds experienced high levels of stress related to capture and transport (Dickens et al. 2010). Research indicates that a quick transport to the release sites is necessary for the maintaining the health of the captured grouse and reducing mortalities (Reese and Connelly 1997, Dickens et al. 2010, Braun et al. 2011, Colorado Parks and Wildlife 2014). Capture-related stress could potentially result in the loss of the flight-or-fight response and an impaired ability to successfully avoid predators (Dickens et al. 2010). Therefore, we recommend keeping the translocation distance and duration to a minimum.

RELEASE

A primary issue negatively impacting prairie-grouse reintroductions is the tendency of the released grouse to travel long distances from the release site (Toepfer et al. 1990, Dickens et al. 2009). To reduce initial movements away from release sites, biologists should use soft-release methods, capture and release only males in the fall and capture and release females late in the breeding season the following spring (Snyder et al. 1999, Coates and Delehanty 2006, Hoffman et al. 2015). Soft-release methods are three times more successful than hard-release methods for establishing grouse to novel areas (Snyder et al. 1999). Soft-release methods hold the captured grouse for a short time at the release site to allow them to acclimate and calm down prior to release. Sharp-tailed grouse should be released within 24 hours of capture if possible, with at least 3 hours of daylight to allow birds to become acclimated with the new surroundings (Gardner 1997, Hoffman et al. 2015). The amount of handling during capture, transport and release should be kept to a minimum to decrease exposure to handling stressors (Dickens et al. 2010, Hoffman et al. 2015). It is recommended that individual bird weights be taken at capture, then again post-transport to help assess the condition of the birds at release (Snyder et al. 1999). The post-transport weight can be assessed when the birds are being moved from the transport boxes to the release boxes, and birds should not be handled again once they are placed in the release boxes.

Rodgers (1992) developed specialized release boxes that were effective for sharp-tailed grouse translocations in Kansas that should prove useful for reintroductions in Montana. Release boxes should measure 165 × 32 × 18 cm, and should be constructed of exterior grade plywood. Boxes should be divided into 10 individual cells, with each cell measuring 30 × 15 × 15 cm, the size appropriate for holding one individual sharp-tailed grouse. The interior of the release boxes should be painted black to help darken cells and aid in calming the birds. Holes to allow air-flow should be drilled in the boxes. The top of the box should consist of two layers of black hardware cloth to prevent birds from hitting their heads on a hard plywood ceiling. The dual layered hardware cloth would be more durable than a single layer, and would also reduce light transmission into the box. The boxes must be designed so they can be opened remotely to reduce the likelihood of birds flushing due to human presence (Rodgers 1992, Colorado Parks and Wildlife 2014, Hoffman et al. 2015). The door should be 165 cm wide and 30 cm high with hinges attached to the backside 18 cm from the bottom (Figure 24). The hinges will attach to the front of the release box and allow the door to swing upward from the bottom allowing grouse to leave the box (Figure 24). The door will have a brace attached to each side at a 60° angle, and where the braces meet there should be a ring placed to attach the remote release rope to (Figure 24). A blind to hide biologists should be placed approximately 25 m away from the release boxes. Boxes and individual release ropes should be numbered, and ropes should be attached to the door of the respective release box (Rodgers 1992). The boxes should be staked down to

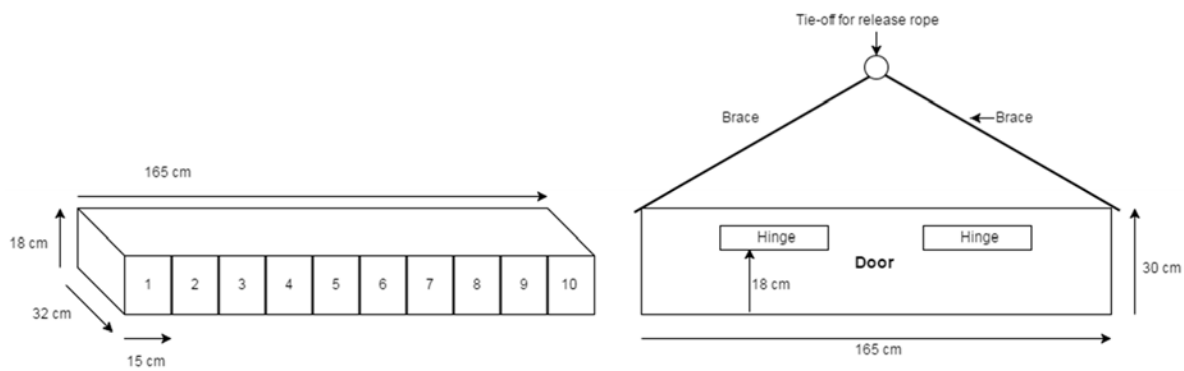


Figure 24: Diagram of a release box used to release sharp-tailed grouse remotely.

prevent them from tipping over prior to or during remote release.

Sharp-tailed grouse should be placed into the release boxes at least one hour before sunrise or immediately following transport (if < 3 hours until sunrise) to allow the birds to calm before being released (Rodgers 1992, Hoffman et al. 2015). Males and females should be placed into adjoining compartments so that upon release they will immediately see a member of the opposite sex (Rodgers 1992). Birds should be placed tail first into the cells, and cells 4 and 7 left empty to minimize the likelihood of sequential flushing (Rodgers 1992). As birds are placed into the cells, a piece of thin Masonite should be used to cover the opening until all birds are in their cells and the main door can be closed (Rodgers 1992). We caution against sharp-tailed grouse spending the night in the release boxes unless precautions are taken. Placing the sharp-tailed grouse into the release boxes for an overnight stay without human presence could potentially increase unnecessary exposure to weather and predators that can force entry into the boxes. At sunrise, a release box opening sequence of every other box, one-at-a-time, will help preclude flushing of released sharp-tailed grouse (Rodgers 1992). Each group of released sharp-tailed grouse should be afforded adequate time to move away from the release box before another box is opened (Rodgers 1992).

Using decoys placed at assumed historic leks or places where a lek is anticipated could help to attract and hold the released birds at the desired locations (Rodgers 1992). The playback of recorded sharp-tailed grouse breeding vocalizations may also help to keep the released sharp-tailed grouse at the desired sites (Rodgers 1992). The use of decoys will likely depend on the number of males that may have already been released previously and are currently active on leks. The use of supplemental feed has also previously been used to keep birds at the desired location (Rodgers 1992). Release operators should remain in the blind(s) until all the birds have stopped displaying, and release boxes should not be removed from the lek until release operators are certain they will not accidentally flush birds from the site (Rodgers 1992, Colorado Parks and Wildlife 2014, Hoffman et al. 2015).

POST-RELEASE MONITORING

In any ecological restoration effort, post-treatment monitoring is necessary to evaluate the ecological response of the restored or reintroduced species and the success of the program (Lake 2001). Success or failure of the reintroduction cannot be determined without monitoring the reintroduced sharp-tailed grouse population. Monitoring efforts include both long-term population monitoring and short-term demographic studies. Long-term monitoring of prairie-grouse populations is relatively inexpensive, while demographic studies of prairie-grouse are costly and require intensive effort. Full commitment is needed in both of these aspects to validate the reintroduction effort and assess the causes of success or failure (Colorado Parks and Wildlife 2014). Historically, attempted restorations of prairie-grouse were poorly monitored, and results of many restoration efforts have not been published or even well documented (Snyder et al. 1999). Whether the reintroduction is a success or a failure, publication of findings is important for developing the knowledge base for future restoration projects (World Pheasant Association and IUCN/Re-introduction Specialist Group 2009). This sharp-tailed grouse restoration project presents a unique opportunity to improve the knowledge base for future prairie-grouse reintroductions.

For the reintroduction of sharp-tailed grouse into western Montana, two main monitoring efforts should be established. First, short-term (3–4 year) monitoring of radio-marked sharp-tailed grouse should be coordinated to estimate parameters of population performance (e.g., fecundity, survival), as well as assess seasonal habitat selection and evaluate movements away from release sites (World Pheasant Association and IUCN/Re-introduction Specialist Group 2009). Demographic rates specific to the reintroduced population are needed to conduct site-specific population viability analyses required for adaptive management. Long-term (≥50 year) surveys of the reintroduced sharp-tailed grouse population should be implemented to monitor population trends and status (World Pheasant Association and IUCN/Re-introduction Specialist Group 2009).

Short-term Monitoring of Radio-marked Individuals

During capture and prior to release, sharp-tailed grouse should be radio-marked with necklace-style high-frequency VHF radio transmitters, so portable radio receivers paired with handheld antennas can be used to track and locate the sharp-tailed grouse. Radio-transmitters do not affect prairie-grouse survival or other demographic rates (Hagen et al. 2006). In a typical prairie-grouse demographic study, only females are radio-marked (Pitman et al. 2005, McNew et al. 2012a). For reintroduction efforts where leks are not yet established, male sharp-tailed grouse should be radio-marked the first fall of the reintroduction to help identify selected lek sites (Colorado Parks and Wildlife 2014). At least half of the fall-captured males should be radio-marked to help inform release locations the following spring (Colorado Parks and Wildlife 2014). Radio-transmitters are not thought to affect the displays of sharp-tailed grouse males, unlike other grouse species which rely more heavily on vocalizations during display (Amstrup 1980). Following the demographic study of the initial cohort of introduced sharp-tailed grouse, we suggest waiting at least 5 years before conducting additional demographic study of the offspring in order to minimize disturbance at newly established leks. If multiple permanent leks have been established after 5 years, conducting a second demographic study of restored population would provide metrics of population performance for a native cohort that is not naïve to the site. In addition, a second study to evaluate space use and habitat selection by the new native cohort of sharp-tailed grouse would provide valuable information to inform habitat management for the population.

In the first fall of reintroduction and the two subsequent spring releases, sharp-tailed grouse should be monitored closely immediately following initial release by gathering locations at least three times per week. Rapid dispersion and large movements from release sites have been documented in prairie-grouse, so monitoring their locations often during the period after release is necessary to ensure radio-marked birds are not lost (Hamerstrom and Hamerstrom 1951, Ammann 1957, as cited in Coates et al. 2006). Throughout the fall and winter seasons (Sep – Feb), reintroduced sharp-tailed grouse should be located at least one time per week (McNew et al. 2012a). Monitoring efforts to locate radio-marked sharp-tailed grouse should be conducted using the radio signals to triangulate bearings from ≥ 2 positions at distances greater than 100 m to minimize disturbance (McNew et al. 2012a). Because winter habitat is one of the most limiting factors in an area's ability to support a population of sharp-tailed grouse, habitat evaluations at occupied sharp-tailed grouse locations should be conducted (Marks and Marks 1987). Winter habitat selection can be assessed using triangulation or flush locations from radio-marked sharp-tailed grouse, integrated into various modeling techniques, such as resource selection functions (Boyce and McDonald 1999, Johnson et al. 2006, Manly et al. 2007).

During the breeding, nesting, and brood-rearing seasons (Mar – Aug), radio-marked sharp-tailed grouse should be located by triangulation ≥ 3 times per week (McNew et al. 2012a). Radio-marked males should be monitored for mortality, but do not necessarily need to be located if time or effort do not allow; the priority during the breeding season should be estimation of reproductive performance of females. When the mortality signal is emitted from any radio-marked sharp-tailed grouse, the radio-collar should be immediately located to evaluate cause of death. Mortality data can be used to inform estimates of adult survival, one of the necessary demographic rates used in a population viability analysis. Further, mortality data from radio-marked birds can be used in survival analyses to predict annual survival rates of the population (Pollock et al. 1989).

The nests of radio-marked females can be easily found during incubation by telemetry homing (Pitman et al. 2005, McNew et al. 2012a). Locations of nests should be taken with a handheld Global Positioning System unit. To estimate the stage of incubation, eggs should be floated in a cup of lukewarm water, and prairie-grouse incubation float curves should be used to estimate the date of nest initiation and clutch hatch date (McNew et al. 2009). When monitoring females on nests, if a female is away from her nest for three consecutive days, the nest should be inspected for success or failure. Nests should be classified as successful if ≥1 egg hatches, indicated by pipped eggshells, compared to a failed nest destroyed by predators, where eggs are either missing, punctured, or crushed (McNew et al. 2012a). For all failed nesting attempts, the female should be monitored closely to locate renesting attempts. All successfully hatched clutches should be monitored and located ≥3 times per week. To estimate brood survival, the female should be flushed at 14 days post-hatch at or before sunrise while she is brooding, and the number of chicks counted. If no chicks are present, locate and flush the female two days later to confirm brood failure (McNew et al. 2012a). Brood flushes can be conducted again at 24, 34, and 60 days post-hatch to estimate brood survival until fall breakup (Fields et al. 2006, McNew et al. 2012a).

Characteristics selected for by reintroduced sharp-tailed grouse must be identified to inform habitat management. To evaluate the effects of habitat conditions on nest site selection and nest survival, vegetation measurements must be taken at and in close proximity to the nest bowl, as well as at random points within a specified area of the nest. Important fine-scale habitat metrics to measure for prairie-grouse include visual obstruction, vegetation coverage, and shrub specific coverage (Canfield 1941, Daubenmire 1959, Robel et al. 1970, Pitman et al. 2005, Wambolt et al. 2006, McNew et al. 2012a). Although nest site scale vegetation conditions are often most important for nest site selection and subsequent survival, habitat assessments at larger spatial extents relative to demographic metrics of interest should also be considered. Habitat selection by breeding prairie-grouse is spatially-explicit, hierarchical, and occurs at multiple spatial scales (McNew et al. 2013). Analytical methods used to estimate nest success and annual fecundity are based on the demographic measurements collected during field sampling (Mayfield 1975, Johnson 1979, Sandercock 2006, Powell 2007, McNew et al. 2012a). The demographic rates estimated through short-term monitoring of radio marked sharp-tailed grouse should be used to inform an updated population viability analysis. Using the estimates of these rates from the specific reintroduced population will provide a much better evaluation of the viability of the population. An updated PVA can assist managers in identifying most appropriate habitat improvement strategies to benefit this specific reintroduced population.

During the first 4–5 years of the reintroduction effort, established leks should be closely observed via ground blind during peak attendance throughout the spring. Surveying leks and identifying uniquely color banded males can provide information on lek fidelity and territory establishment, and provide estimates of annual male survival (Gratson 1993, Hagen et al. 2005, Drummer et al. 2011).

Long-term Monitoring of Reintroduced Sharp-tailed Grouse

Long-term monitoring techniques are less expensive and require less effort than short-term demographic studies (World Pheasant Association and IUCN/Re-introduction Specialist Group 2009). Spring lek count surveys are the most cost-effective method to monitor prairie-grouse populations and provide relatively unbiased estimates of long-term population performance (Cannon and Knopf 1981, Reese and Bowyer 2007, South Dakota Department of Fish and Game 2010, Garton et al. 2011, Hoffman et al. 2015). Long term monitoring must have firm protocols and consistent survey effort each year, otherwise comparisons across years are inappropriate (Luukkonen et al. 2009, Hoffman et al. 2015). In the case of this restoration, long term monitoring protocols can be developed following three years of short-term monitoring, after leks have been established.

Annual spring lek surveys are the most commonly used method to monitor prairie-grouse, and can be used to identify active/inactive leks and peak annual lek attendance (South Dakota

Department of Fish and Game 2010). Generally, population estimates for sharp-tailed grouse are calculated by doubling the maximum count of males on leks in a the spring; this method assumes that all males attend leks and the sex ratio is at parity (Schroeder et al. 2008). Hierarchical models that account for imperfect detection can provide less biased estimates of population size (Royle and Dorazio 2008, McCaffery et al. 2016). In small areas like each of the potential restoration sites, annual lek monitoring may require little effort once established leks are located. To monitor established leks, blinds should be set up at leks 45 minutes before sunrise. The maximum number of male and female sharp-tailed grouse to visit the lek at any given time should be recorded. Each established lek should be visited ≥2 times during peak breeding season, at approximately 7 days apart. Within three years of reintroduction, annual survey routes should be established to identify new leks. To coordinate annual spring lek surveys, biologists should establish listening stations in areas where leks are present or near potential lek locations.

Listening stations should be located every c.a. 1.6 km (1 mile) along a selected route, where there is a good vantage point to see the surrounding landscape (South Dakota Department of Fish and Game 2010). Listeners should start at the first station 30 minutes before sunrise, and finish no later than 0730, spending 3 minutes at each station and recording whether or not a lek was detected and how many birds are present on the lek (South Dakota Department of Fish and Game 2010, Hoffman et al. 2015). Bearings to detected leks should be recorded from each station and distance estimated (Luukkonen et al. 2009). For leks that are not visible from the road, observers should search for the lek on foot, documenting the location and number of birds when the lek is located. Landowner cooperation will be important to allow surveyors access to private property. To maximize detection and assure annual survey consistency, surveys should not be conducted on mornings with high wind >15 kph or precipitation (Luukkonen et al. 2009, Hoffman et al. 2015). Surveying the route at least twice during peak lekking season is adequate (Schroeder et al. 2000). Sharp-tailed grouse occupancy and detection probabilities can be estimated using lek survey data from long-term monitoring (MacKenzie et al. 2002, Hagen 2003, Luukkonen et al. 2009, Garton et al. 2011, McNew et al. 2012a, Garton et al. 2016).

RESTORATION STRATEGIES AND TASKS

Our analyses of ecological and demographic requirements, suitability of available and potential habitat conditions, and population viability of sharp-tailed grouse indicated that population restoration in western Montana is possible with a concerted and sustained effort, and that the most suitable site for initial recovery efforts is the Blackfoot Valley site followed by the Northern Bitterroot site. We recommend the following strategies and actions to accomplish population restoration within the Blackfoot Valley and generally for any sharp-tailed grouse reintroduction.

1. **Enhance sharp-tailed grouse nesting and winter habitat conditions at the restoration site.**
    - 1.1. Reduce conifer coverage to < 4% in areas identified as potential nesting habitat and to < 1% in areas within 1.6 km of historical or potential lek sites.
    - 1.2. Reduce, modify, or mark existing fences within 1.6 km of historical or potential lek sites to increase visibility by sharp-tailed grouse.
        - 1.2.1. Generally, the removal of unused fencing will minimize collision fatalities. However, new fencing may be required to exclude livestock from riparian habitats and shrub plantings.

- 1.2.2. Fences can be modified by reducing the number of wires or lowering the top wire where feasible
- 1.2.3. Fences can be marked using strips of vinyl siding starter strips (Wolfe et al 2009).
- 1.2.4. Discourage the development of tall structures, such as power transmission lines and cellular towers that may serve as perches for avian predators and barriers to sharp-tailed grouse movements and habitat use.
- 1.2.5. Discourage the development or improvement of roads within the sharp-tailed grouse recovery area. Prairie-grouse often avoid primary roads and roads often facilitate the invasion of non-native vegetation (e.g., cheatgrass).

1.3. Ensure that grazing management of livestock is compatible with sharp-tailed grouse recovery goals.

- 1.3.1. Ensure that grazing management on public lands and appropriate conservation easements are compatible with sharp-tailed grouse habitat needs (see above). In general, management should be designed to increase herbaceous cover, improve the composition and diversity of native vegetation, and reduce or limit invasive and noxious plants.
- 1.3.2. Promote grazing systems that provide adequate herbaceous cover, especially residual nesting cover in the spring. Optimal nesting sites have visual obstruction readings (VOR; measured at height of 1 m and a distance of 4 m) of ≥ 25 cm (McDonald 1998, McNew et al. 2016). A good rule of thumb is that suitable nesting cover will obscure a football from view at a distance of 4 m.
- 1.3.3. Reduce or remove grazing in riparian areas and other winter habitats to ensure sufficient cover and food are available to the restored population during winter.
- 1.3.4. Ensure that a diverse forb community is maintained within 2 km of lek sites. Ideally, native forb cover should by ≥ 10% of total herbaceous cover.
- 1.3.5. Stocking rates and the timing and duration of grazing should be based on appropriate levels during periods of drought. Stinson and Schroeder (2012) recommend setting annual stocking rates that assume precipitation will be 75% of normal to ensure nesting and brood-rearing habitats are not overgrazed.

1.4. Manage wet meadow habitats on public lands and easements to improve nesting and brood-rearing habitat. Wet meadows provide abundance of succulent vegetation and invertebrates that prairie-grouse use during the summer.

- 1.4.1. Reduce or remove livestock from wet meadow and riparian habitats. Livestock select for these areas and habitat conditions typically decline rapidly if livestock are not managed appropriately. Damage can be reduced by reducing stocking rates, implementing rotational grazing methods, herding or fencing to exclude livestock from wet meadows and riparian areas, and providing water and minerals in upland areas away from sensitive lowlands. Wyman et al. (2006) and Knutson and Naef (1997) provide management guidelines that allow recovery of native vegetation in degraded areas where complete removal of cattle is not possible.

1.5. Protect shrub-steppe habitats. Sagebrush provides needed nesting cover for sharp-tailed grouse at drier sites where herbaceous cover may be limited. Native sage-steppe habitats within the restoration area should be protected.

- 1.5.1. Reduce the risk of fire in shrub-steppe habitats on public lands and promote the maintenance of these habitats on private lands. Reduction of cheatgrass from within and adjacent to these areas will reduce fire risk.

1.5.2. Control wildfires in shrub-steppe habitats.

2. **Develop working relationships with private landowners in the restoration area to promote land management and grazing practices that improve or maintain habitat value for sharp-tailed grouse prior to beginning sharp-tailed grouse restoration.**
   2.1. Private lands account for the majority of the sharp-tailed grouse restoration area. Assist landowners by providing information on management practices that benefit grouse. Partner with the Blackfoot Challenge and other local conservation groups and NGOs in developing and implementing programs to improve and maintain sharp-tailed grouse habitats. Source conservation cost-sharing programs or easements that benefit native habitat conservation and sharp-tailed grouse recovery, while enhancing forage and management for livestock. Explore means of providing incentives or assisting with landowner costs to appropriate conservation programs. Examples of several potential programs are described above.
   2.2. Use conservation easements or purchase development rights to assist landowners in maintaining intact native habitats. Provide assistance to protect large tracts of working rangelands from being sub-divided and developed. The USFWS, Partners for Fish and Wildlife program, has used these types of easements to protect large tracts of native habitats and preserve the rural economy at the Blackfoot Valley site.
   2.3. Consider acquisition of critical habitat if it provides the best option for protection if sellers are willing and the local community supports the purchase.
3. **Translocate and reintroduce sharp-tailed grouse to the restoration area according to the strategies described in the Recovery section of this document.**
   3.1. Select appropriate source populations for translocations.
      3.1.1. Released birds should come from source populations whose habitat conditions most closely resemble those at the restoration site.
      3.1.2. Source populations should be selected for high fitness and similar environmental conditions to the restoration site to ensure genetic similarity with the historical population at the restoration site.
      3.1.3. Tests of genetic similarity of source populations to museum specimens collected from the restoration site should be conducted to assist in selecting source populations
      3.1.4. More than one source population should be used to ensure sufficient genetic diversity in the founding population at the restoration site.
      3.1.5. Only robust source populations where lek sizes are $\geq$ 15 males should be used to avoid deleterious effects of bird removals on source populations.
      3.1.6. No more than 30% of males and $\leq$ 8 females should be removed from source leks.
   3.2. Initial translocations should occur in the first autumn of the restoration effort and focus on establishing leks with displaying males prior to the translocation of females the following spring. The presence of males at established leks should reduce movements of translocated females away from release sites and increase the likelihood of breeding, nesting and brooding-rearing. At least 25 males should be released at the restoration site during the initial fall translocation effort.
      3.2.1. Lek establishment at previously identified lek sites may be improved using decoys and recordings of displaying grouse during periods of release.
      3.2.2. At least half of the translocated males should be equipped with radio-transmitters in order to monitor movements and identify leks.

3.3. Females (≥ 25 per year for ≥ 2 years), preferably yearlings, should be translocated during the spring lekking period. Ideally, capture effort should be focused to occur 8 days after female lek attendance begins in order to maximize nesting at the restoration site.
3.4. Sharp-tailed grouse should be safely transported in divided poultry boxes to release sites as soon as possible.
3.5. Soft-release methods should be used to reduce initial movements away from release sites. We describe appropriate capture, transport, and release methods in the Recovery section above.

4. **Implement short-term demographic studies and a long-term population survey program to monitor restoration success and adaptive management, and inform future sharp-tailed grouse reintroductions.**
   4.1. A short-term (3–4 year) intensive study of the initial translocated cohort of sharp-tailed grouse should be implemented to estimate parameters of population performance (e.g., fecundity, survival), as well as assess seasonal habitat selection and evaluate movements away from release sites. Study designs reported in McNew et al. (2012, 2016) and Winder et al. 2015 would be appropriate.
      4.1.1. Demographic rates collected during the initial study should be used to update population viability analyses to inform adaptive management.
      4.1.2. A second demographic study should be conducted 5 years after the conclusion of the first study to provide population performance metrics for non-naïve birds produced at the restoration site.
   4.2. A long-term (≥50 year) population monitoring using standard lek survey protocols should be implemented to monitor population trends after population establishment.
5. **Use adaptive management to update preliminary population models to increase the probability of restoration success.**
   5.1. Post-release demographic monitoring should produce estimates of population parameters based on the dynamics of sharp-tailed grouse at the reintroduction sites, which will improve the applicability of model estimates of population viability and will better identify the most effective management actions.
   5.2. Our population viability analysis should be recalibrated with demographic rates collected for the restoration population to identify important demographic parameters and potential modifications of reintroduction protocols to improve population establishment and success.

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APPENDIX A

Figures in Appendix A display sharp-tailed grouse management scenario outputs using the program VORTEX (version 10; Conservation Breeding Specialist Group, Apple Valley, MN). Scenario descriptions and further results can be found in Tables 10 & 11.

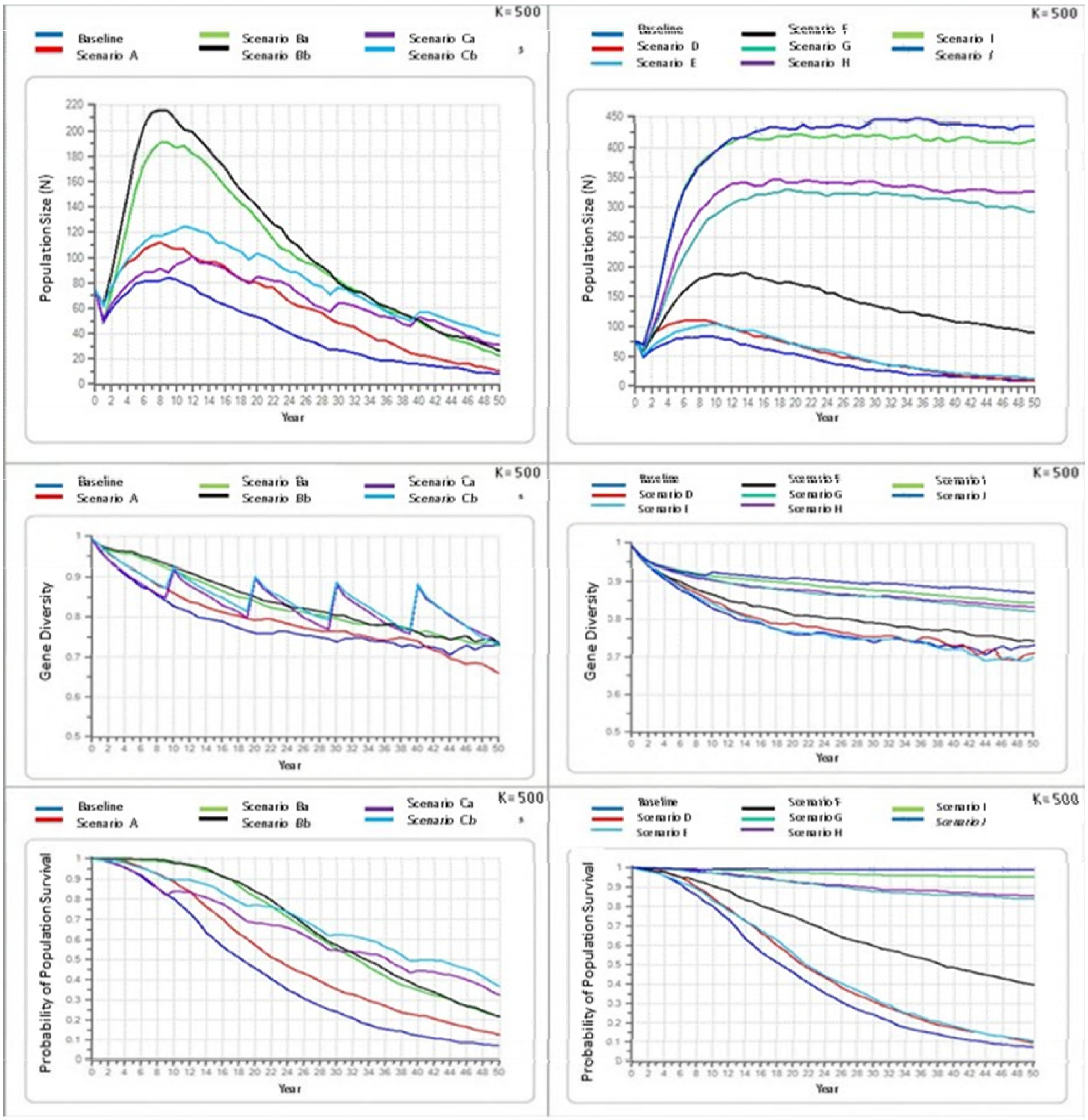

Figure A 1: VORTEX simulation results for all sharp-tailed grouse management scenarios with K=500.

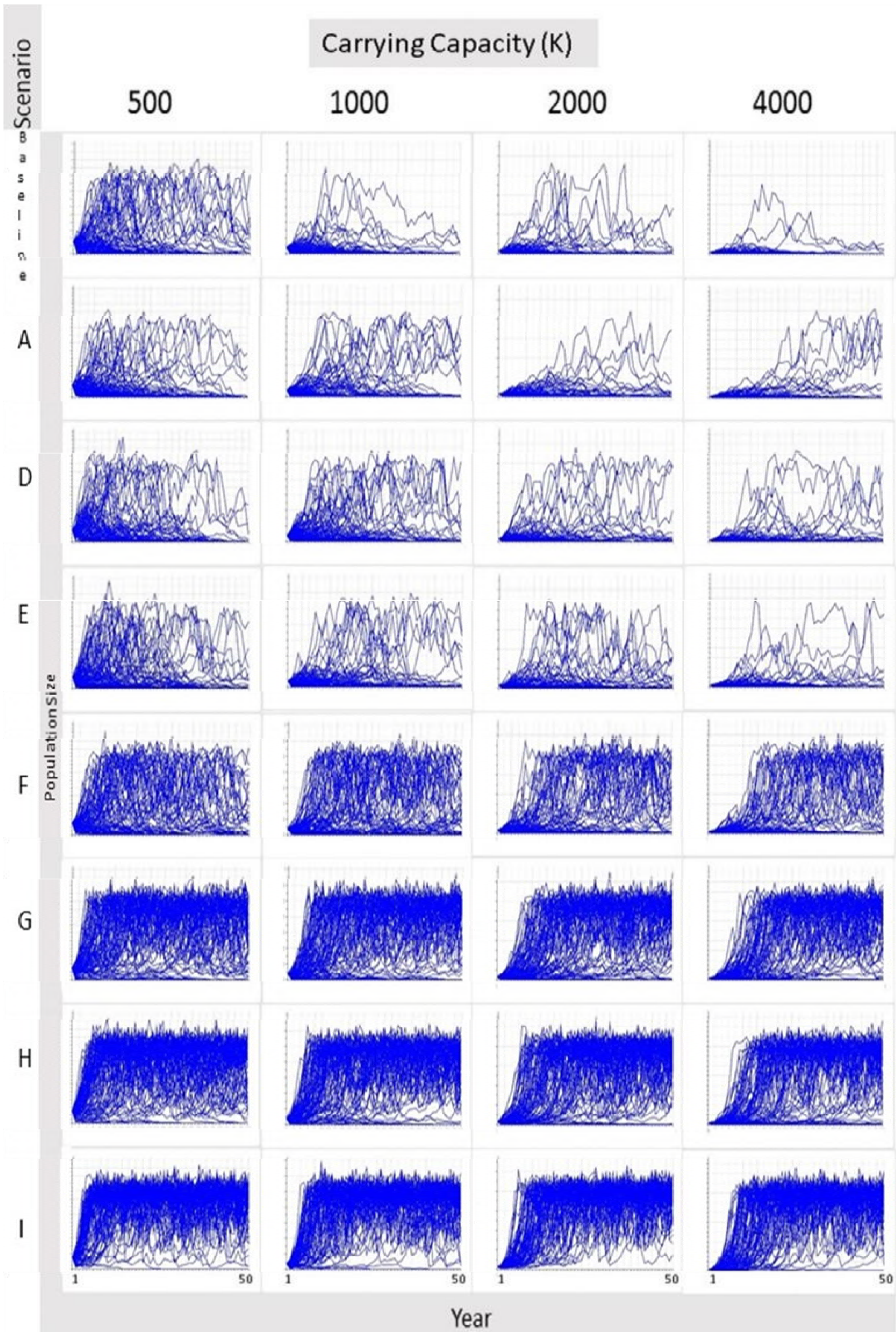

Figure A 2: VORTEX iteration results for each scenario of sharp-tailed grouse population management.

Each line represents one of the 1,000 iterations. Population sizes (N) are not specified but converge on the carrying capacity (K) if the population does not fall to 0 within the 50-year period.

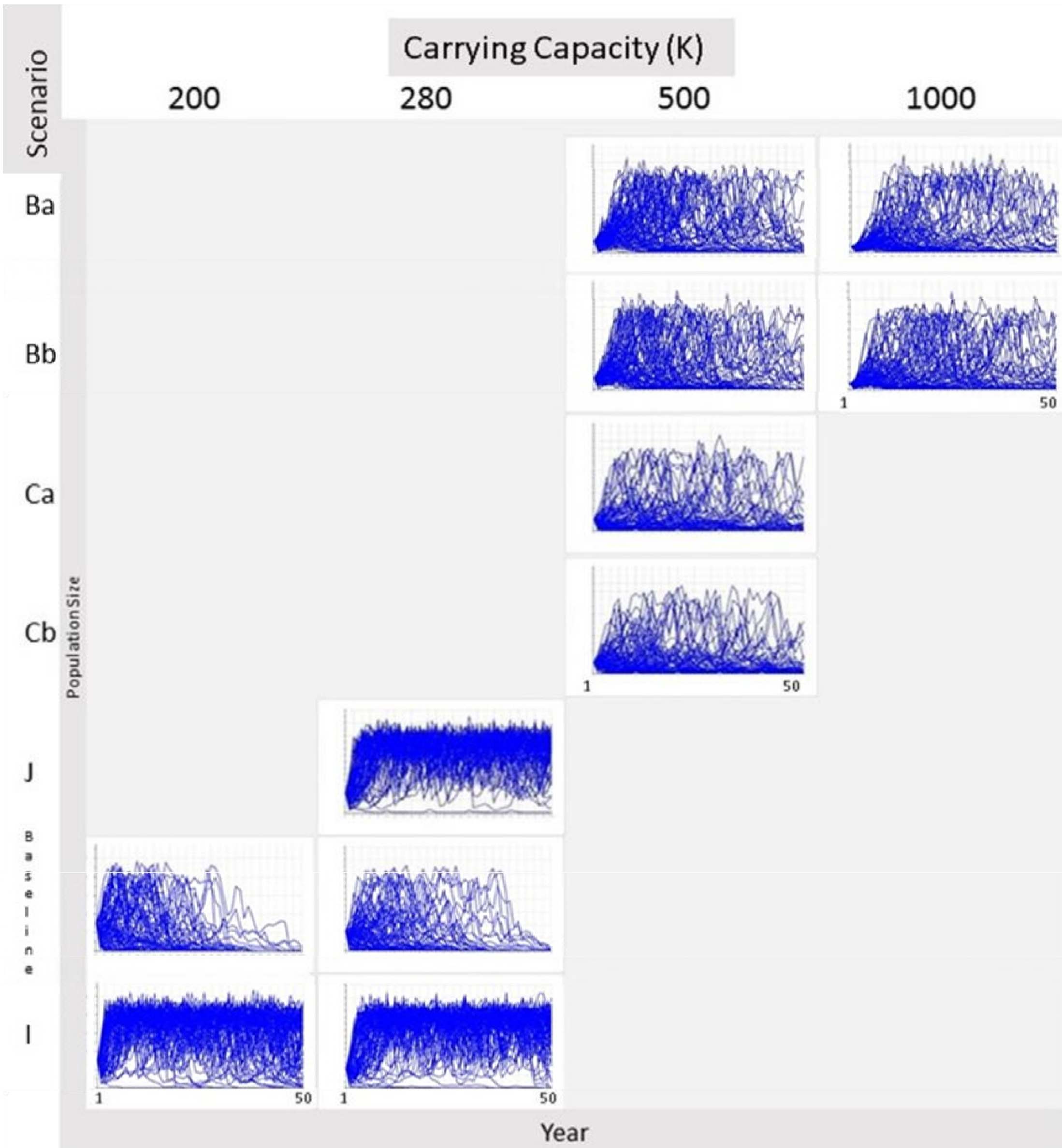

Figure A 3: VORTEX iteration results for each scenario of sharp-tailed grouse population management. Each line represents one of the 1,000 iterations.

Population sizes (N) are not specified but converge on the carrying capacity (K) if the population does not fall to 0 within the 50-year period.