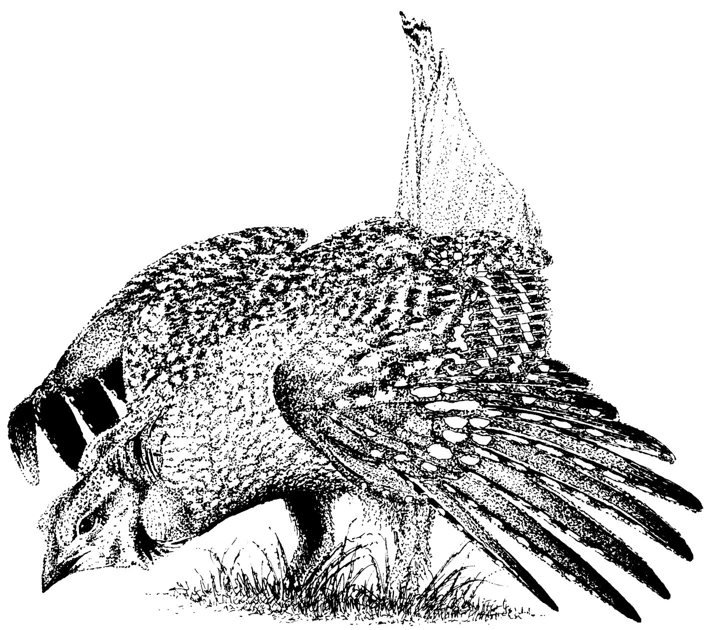
DRAFT
Columbian Sharp-tailed Grouse Recovery Plan



Derek W. Stinson and Michael A. Schroeder

Washington Department of Fish and Wildlife
600 Capitol Way North
Olympia, Washington 98501-1091

May 2010

In 1990, the Washington Wildlife Commission adopted procedures for listing and de-listing species as endangered, threatened, or sensitive and for writing recovery and management plans for listed species (WAC 232-12-297, Appendix A). The procedures, developed by a group of citizens, interest groups, and state and federal agencies, require preparation of recovery plans for species listed as threatened or endangered.

Recovery, as defined by the U.S. Fish and Wildlife Service, is the process by which the decline of an endangered or threatened species is arrested or reversed, and threats to its survival are neutralized, so that its long-term survival in nature can be ensured.

This is the Draft Washington State Recovery Plan for the Columbian Sharp-tailed Grouse. It summarizes the historical and current distribution and abundance of sharp-tailed grouse in Washington and describes factors affecting the population and its habitat. It prescribes strategies to recover the species, such as protecting the population and existing habitat, evaluating and restoring habitat, potential reintroduction of sharptails into vacant habitat, and initiating research and cooperative programs. Target population objectives and other criteria for reclassification are identified.

As part of the State's listing and recovery procedures, the draft recovery plan is available for a 90-day public comment period. Please submit written comments on this report by 7 September 2010 via e-mail to TandE-wildlife@dfw.wa.gov , or by mail to:

Endangered Species Section Manager
Washington Department of Fish and Wildlife
600 Capitol Way North
Olympia, WA 98501-1091

This report should be cited as:

Stinson, D. W., and M. A. Schroeder. 2010. Draft Washington State Recovery Plan for the Columbian Sharp-tailed Grouse. Washington Department of Fish and Wildlife, Olympia. 150+ viii pp.

Photos in text by authors unless otherwise credited.
Back cover and title page illustration by Darrell Pruett

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

ACKNOWLEDGEMENTS

Funding for the recovery plan has been provided by the State Wildlife Grants program through the U.S. Fish and Wildlife Service and Washington's personalized vehicle licence plate program. Recovery activities have benefitted from the involvement of a multi-agency work group with participation by Bureau of Land Management (BLM), the Colville Confederated Tribes, Yakama Nation, Coeur d'Alene Tribe, Spokane Tribe, and Washington Department of Fish and Wildlife (WDFW). The wildlife program of the Colville Confederated Tribes, in particular, has been an important partner in sharp-tailed grouse recovery activities for many years, and their interest and involvement is much appreciated.

Comments by Rick Hoffman, Christian Hagen, Jack Connelly, Leslie Robb, Jason Lowe, Nancy Williams, Marc Hallet, Jeff Heinlen, Mike Finch, Dale Swedberg, Peter Coates, and Colleen Stinson improved the draft. Brian Cosentino assisted with creating GIS products and analysis. Joe Higbee graciously allowed us to use his photos of plains sharp-tailed grouse for Plate 1. Darrell Pruett created the pen and ink illustrations. Sharon Brewer and Ruth Keller, Washington State Library assisted with retrieving needed literature. Tony Apa provided a copy of his dissertation.

EXECUTIVE SUMMARY

The Columbian sharp-tailed grouse was once probably the most abundant game bird in Washington. The Columbian is the rarest of six subspecies of sharp-tailed grouse, a close relative of prairie-chickens. Their historical range extended from southern British Columbia, south along the eastern slope of the Cascade and Sierra Nevada mountain ranges to northeastern California, and east to Colorado and Utah. Only small portions of this area still support populations. This plan updates the information in the 1998 status report (Hays et al. 1998), identifies population recovery objectives, and outlines activities needed to recover a viable population of sharp-tailed grouse in Washington.

Population status. Columbian sharp-tailed grouse were an abundant and important game bird in eastern Washington at the time of Euro-American settlement. They declined dramatically with the spread and intensification of agriculture and livestock grazing, until by the 1920's, sharp-tailed grouse were extinct in much of their historical range in Washington. Harvest levels were reduced after 1920 and the hunting season for sharp-tailed grouse was closed from 1933–1953, but short seasons were opened from 1954–1987. The population continued to decline after 1950, perhaps a time-lagged response to past habitat loss, but probably also due to intensive livestock grazing on remnant patches of shrub/meadow steppe, and continued loss of woody riparian winter habitat. The loss of active leks over time indicates a trend in reduced population, range, and the resulting isolation of subpopulations of sharp-tailed grouse in the state. Of the 114 leks documented between 1960 and 2006, 82 (71.9%) are currently vacant; 33 (40.2%) of the vacant leks are in portions of the historical range that are no longer occupied. The remaining 49 vacant leks reflect declines in density within occupied portions of the historical range (Schroeder 2006). Leks in Douglas, Okanogan, and Lincoln counties became inactive at similar rates (66%, 72%, and 63%, respectively) from 1954–1994 (Schroeder 1994). The sharp-tailed grouse was listed as a state Threatened species by the Fish and Wildlife Commission in 1998.

The analysis of annual changes in attendance at leks indicated that the average instantaneous rate of population change was -5.4% (SE = 3.4%) per year between 1970 and 2006. The overall population declined almost continually between 1970 and 2006, particularly during the 1970s, when the estimated population declined from about 5,000 to about 3,000 birds. The overall estimated decline was 86% between 1970 and 2006. The current distribution of sharp-tailed grouse covers approximately 2,234 km^2, approximately 2.8% of their historical range in Washington. Sharp-tailed grouse persist in seven scattered populations in Lincoln County, the Colville Indian Reservation, northern Douglas County, and valleys and foothills east and west of the Okanogan River in Okanogan County. The estimated sharp-tailed grouse breeding population in 2009 was 712 birds.

Habitat requirements. Good sharp-tailed grouse habitat contains perennial bunchgrasses, forbs, and key species of deciduous shrubs. Historically, the most important areas for sharp-tailed grouse were probably the Palouse, Wheatgrass/Fescue, Three-tip Sagebrush, and Big Sage/Fescue vegetation zones. The highest densities of sharp-tailed grouse were probably in the more mesic grassland and steppe types where annual precipitation averages at least 11 inches.

During spring and summer in Washington, grassland cover types and CRP fields seem to be preferred, while shrub, riparian, and bitterbrush habitats may be used primarily as escape cover. Leks are often on knolls or ridge tops with short vegetation and good visibility. Females generally select nest sites <2 km from the lek. Nesting and brood-rearing habitat quality depends on height and density of vegetation. Residual native grasses and forbs conceal the nest and provide shelter for the brood during spring and early summer. Roersma (2001) considered a 1:1:1 ratio of cover in shrubs, grasses, and forbs to be ideal. Brood-rearing habitat contains diverse cover of shrubs, forbs, and bunchgrasses, where insects are abundant; females often raise broods within 1 km of their nests. In late summer and fall, sharp-tailed grouse broods may move to riparian areas where there is green vegetation, berries, and shade. Visual obstruction appears to be the most important vegetation variable defining selected from random sites, and successful from unsuccessful nests. Optimal nesting habitat has residual vegetation averaging at least 25 cm high (Meints et al.1992, McDonald 1998). Habitat may be suitable for nesting with an average of >15 cm, as long as many microsites with higher cover (>25 cm) are present.

In Washington, critical winter habitats are riparian areas with deciduous trees and shrubs that provide cover, berries, seeds, buds, and catkins when the ground is snow-covered. The most important trees and shrubs include serviceberry, chokecherry, water birch, rose, hawthorn, snowberry, big sagebrush, cottonwood, and aspen. Some areas with suitable nesting and brood-rearing habitat may remain unused because the area lacks adequate winter resources.

The sharp-tailed grouse decline in Washington was primarily a result of loss and degradation of habitat. The Palouse prairie and the steppe habitats of the Columbia Basin and surrounding areas have been largely replaced with cultivated fields, and most of the woody riparian vegetation needed for wintering has been destroyed. A shortage of nesting, brood rearing, and wintering habitat are important factors limiting population recovery.

Recovery strategies. Restoring sufficient habitat for recovery will require a sustained effort involving many partners, and will not be possible without cooperation from many landowners. Sharp-tailed grouse often move up to 20 km to meet their year-round habitat needs, without regard to ownership boundaries. Cooperation is needed among private landowners, public and non-government agencies, and Native American tribes on managing habitat to ensure productivity of sharp-tailed grouse populations and facilitate recovery. Partnerships with individuals and organizations with goals for sustainable agriculture, Palouse prairie restoration, climate stabilization, ranch and rangeland preservation, water quality, soil erosion, as well as wildlife conservation may be helpful to restore sufficient habitat and intervening lands to compatible uses.

The U.S. Department of Agriculture's Conservation Reserve Program (CRP) is currently the main financial incentive for private landowners to provide sharp-tailed grouse habitat. The CRP program has been important in providing habitat for sharp-tailed grouse in Washington, and in other states. Idaho and Utah have provided birds from populations dependent on CRP for translocation projects in Washington. Within the historical range of sharp-tailed grouse with greater than 9 inches annual precipitation, Washington farmers have over 800,000 ac enrolled in CRP. However, enrollment is a voluntary contract and re-enrollment is affected by commodity prices. The CRP program is dependent on re-authorization in the federal Farm Bill every five years. When CRP lands supporting sharp-tailed grouse are placed back into grain production, significant declines in the current sharp-tailed grouse populations will result.

The remaining (sub)populations in Washington are small, isolated from one another, and will not persist unless they are able to increase in size. Habitat restoration and enhancement and population augmentation using birds from other states is ongoing and has prevented extirpation of one subpopulation in Okanogan County. Genetic monitoring may be used in the future to identify local populations most in need of augmentation.

Enhancement of habitat in occupied areas and, where possible, re-establishing habitat connections between occupied areas is essential for recovery. Many CRP fields enrolled in the 1980s–90s were seeded to crested wheatgrass, smooth brome, or other exotic grasses, and provide little habitat value to sharp-tailed grouse compared to native grassland; fields in this condition on Washington Department of Fish and Wildlife lands are being reseeded with native seed mixes as funds become available. Based on environmental factors, existing landcover, and land ownership, the Methow Valley seems to have the greatest current potential for re-establishing a sharp-tailed grouse population, but additional areas need to be identified and prioritized to focus habitat restoration efforts. Prescribed burns may be useful for improving habitat in three-tip sagebrush communities, or meadow steppe where excessive woody vegetation or conifers have invaded. Prescribed fire is not recommended in dry Wyoming big sagebrush shrub-steppe. Historical fire frequencies in Palouse prairie and grasslands in eastern Washington are largely unknown.

Recovery goal and objectives. The goal of the recovery program is to restore and maintain healthy populations of Columbian sharp-tailed grouse in a substantial portion of the subspecies' historical range in the state. The best way to achieve this recovery goal is to restore a 'viable population.' In other words, a population large enough to maintain genetic variability over time, and to withstand annual variation in food supplies, predation, diseases, and habitat quality. Small populations are subject to erosion of genetic diversity and as such are at high risk of decline and eventual extinction.

The Columbian sharp-tailed grouse will be considered for down-listing from State Threatened status when Washington has at least one population that has averaged >2,000 birds for a 10-year period, and when the total of all sharp-tailed grouse subpopulations in Washington averages >3,200 birds for a 10-year period. Meeting recovery objectives will require improvements in habitat availability and quality, increases in population numbers and expansion of occupied areas. Once these recovery objectives are achieved, the species will be evaluated for down-listing from State Threatened to Sensitive.

INTRODUCTION

The Columbian sharp-tailed grouse (*Tympanuchus phasianellus columbianus*) has experienced widespread declines and has been eliminated from many portions of its historical range. Washington once had tens of thousands, but with the conversion of grassland and shrub habitat to cropland their numbers have dwindled to <1,000 birds. Sharp-tailed grouse were last hunted in Washington in 1987. The sharp-tailed grouse was added to the state list of threatened species in 1998. This plan updates the information in the 1998 status report (Hays et al. 1998), identifies population recovery objectives, and outlines activities needed to recover a viable population of sharp-tailed grouse in Washington.

Sharp-tailed grouse are culturally significant to Native Americans in eastern Washington, and to Native Americans throughout the Great Plains, Great Lakes states, and Canada (Connelly et al. 1998). They are the subject of many legends and inspired 'chicken dances' that remain an important tradition at annual powwows. The Colville Confederated Tribes have long been a partner with Washington Department of Fish and Wildlife (WDFW) in efforts to restore sharp-tailed grouse abundant populations in north central Washington. Additional tribal partners, including the Spokanes, Couer d'Alenes, and Yakamas have done, or are currently conducting evaluations of the habitat potential to support reintroduced populations on their reservations.

This recovery plan is organized in two parts. The first part reviews the biology of sharp-tailed grouse, the status of populations and habitat in Washington, and factors affecting their populations. The second part presents recovery objectives, explains the rationale behind them, and outlines recovery strategies and tasks needed to attain the objectives.

TAXONOMY

Sharp-tailed grouse belong to the Order Galliformes, Family Phasianidae (pheasant-like birds), and Subfamily Tetraoninae (grouse). The species was originally described as *Tetrao Phasianellus* in 1758 by Linnaeus, but was later placed in the monotypic genus *Pedioecetes* by Baird in 1858 (American Ornithologists' Union 1998, Connelly et al. 1998). *Pedioecetes* was later synonymized with *Tympanuchus*, recognizing the similarities between sharp-tailed grouse and prairie-chickens (Hudson et al. 1966, Short 1967, American Ornithologists' Union 1983). The ancestors of sage-grouse (*Centrocercus* spp.), ptarmigans (*Lagopus* spp.), sharp-tailed grouse, and prairie-chickens were forest dwelling species, and of these groups, *Tympanuchus* diverged from forest-dwelling forms most recently (Drovetski et al. 2006). Genetic differences between sharp-tailed grouse and prairie-chickens are small suggesting recent speciation, possibly during the late Pleistocene (Ellsworth et al. 1994, 1995, Johnson et al. 2003). Sharp-tailed grouse lack the elongated neck feathers of prairie-chickens, but have elongated central tail feathers (Connelly et al. 1998); male sharp-tailed grouse also have violet air sacs instead of the orange or yellow of prairie-chickens. Rare hybrids of matings between sharp-tailed grouse and greater prairie chickens (*T. cupido*), dusky grouse (*Dendrogapus obscurus*), or greater sage-grouse (*C. urophasianus*) have been reported (Cockrum 1952, Eng 1971). Three sharp-tailed grouse x greater sage-grouse hybrids were observed on a sage-grouse lek in Colorado in 2002 (Hoffman and Thomas 2007). Aldridge et al. (2001) noted that of nine reported observations of hybridization between sharp-tailed grouse and greater sage-grouse, five occurred in Canada in the previous 13 years; they expressed concern for the genetic health of the small and declining greater sage-grouse populations in Canada if hybridization was becoming more common.

The sharp-tailed grouse in Washington are Columbian sharp-tailed grouse (*T. p. columbianus*). The

Columbian subspecies was first described by Lewis and Clark in 1805 (Bent 1963). In 1815, Ord classified the species, *Phasianus columbianus*, as the Columbian pheasant, because of its resemblance to pheasants. There are five other extant subspecies of sharp-tailed grouse: *T. p. phasianellus* (northern sharp-tailed grouse); *T. p. kennicotti* (northwestern sharp-tailed grouse); *T. p. caurus* (Alaskan sharp-tailed grouse); *T. p. campestris* (prairie sharp-tailed grouse); and *T. p. jamesi* (plains sharp-tailed grouse) (Johnsgard 1973). The New Mexico sharp-tailed grouse (*T. p. hueyi*) was found only in a portion of northeastern New Mexico and went extinct in 1952 (Dickerman and Hubbard 1994). Spaulding et al. (2006) suggest that applying the name Columbian sharp-tailed grouse only to birds west of the Rocky Mountains would restrict it to birds with a common evolutionary origin, and that sharp-tailed grouse in western Colorado should perhaps be considered part of the plains subspecies (*T. p. jamesi*). However, the western Colorado birds are much more similar to *T. p. columbianus* in terms of habitat, size, and plumage, than to *jamesi*, which are found at lower elevation in eastern Colorado (R. Hoffman, pers. comm.), suggesting additional analysis is needed. Warheit and Dean (2009) indicate that the birds in western Montana are molecularly more similar to plains sharp-tailed grouse than to birds in Idaho and Utah, and the Continental Divide did not appear to have been a barrier to historical gene flow. They suggested that the monophyly of Columbians needs to be further examined.

The subspecies endemic to Washington was named "Columbian," because Lewis and Clark mentioned its abundance on the "plains" of the Columbia River. Throughout this report, "sharp-tailed grouse" refers to any of the six subspecies of sharp-tailed grouse, unless otherwise stated. Other common colloquial names used for sharp-tailed grouse include "sharptails," "prairie chicken" (more accurately applied to *T. pallidicinctus* and *T. cupido*), "fire grouse," and "pin-tailed grouse" (Hart et al. 1950, Evans 1968:1).

DESCRIPTION

The tail of the sharp-tailed grouse is wedge-shaped, with the two middle tail feathers extending beyond the other tail feathers roughly 5 cm (2 in), creating the characteristic sharp tail. Sharp-tailed grouse are generally cryptically colored. The upperparts are heavily barred with dark brown, blackish, and buff; underparts are pale with dark brown V-shaped markings, and the undertail coverts are white (Connelly et al. 1998). The white underparts are conspicuous when sharp-tailed grouse fly. The crown feathers are somewhat elongated and form a slight crest when erected. The legs of sharp-tailed grouse are feathered (Connelly et al. 1998), which is characteristic of all grouse.

Males have a pink to pale violet 'air sac' (cervical apterium) on each side of the neck, though they are not as obvious as those of male sage-grouse. The air sacs and yellow combs above the eyes are enlarged during breeding display. Females lack air sacs, but do have yellow combs, though they are not as conspicuous as in males. Adult male and female sharp-tailed grouse are nearly identical in plumage, except that females have crosswise bars on the two middle tail feathers (Fig. 1), whereas males have longitudinal bars (Edminster 1954, Henderson et al. 1967). Females also have alternating buff and dark-brown crosswise bars on top of the head, whereas males have dark-brown crosswise bars edged in buff (Henderson et al. 1967). Feathers from the top of the head are black with a buff or tan edge in males and have bold black and buff horizontal bands in females (Northern Prairie Wildlife Research Center 2006). Sharp-tailed grouse are lighter brown than greater sage-grouse or dusky grouse (Hjorth 1970). Sharp-tailed grouse have short feathers above their air sacs, whereas sage-grouse and ruffed grouse (*Bonasa umbellus*) have elongated feathers (Hjorth 1970). In the spring, juveniles can often be distinguished in the hand from adults by the worn ninth and tenth primaries; adults have gone through a molt and these primaries show little wear (Fig. 2).

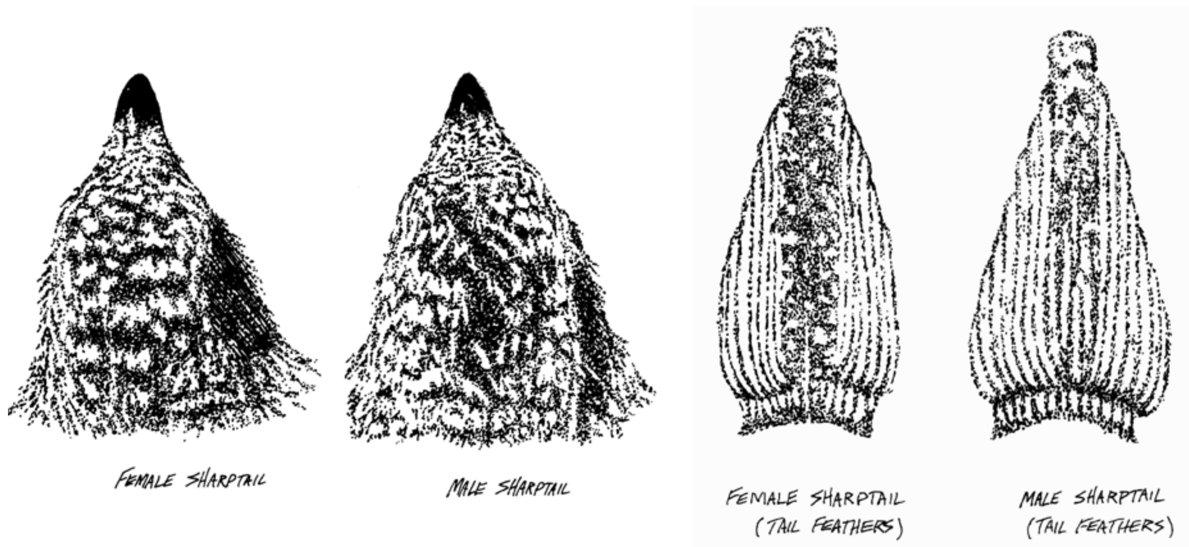


Figure 1. Feather differences used to distinguish male and female sharp-tailed grouse (illustration by Darrell Pruett, after Henderson et al. 1967).

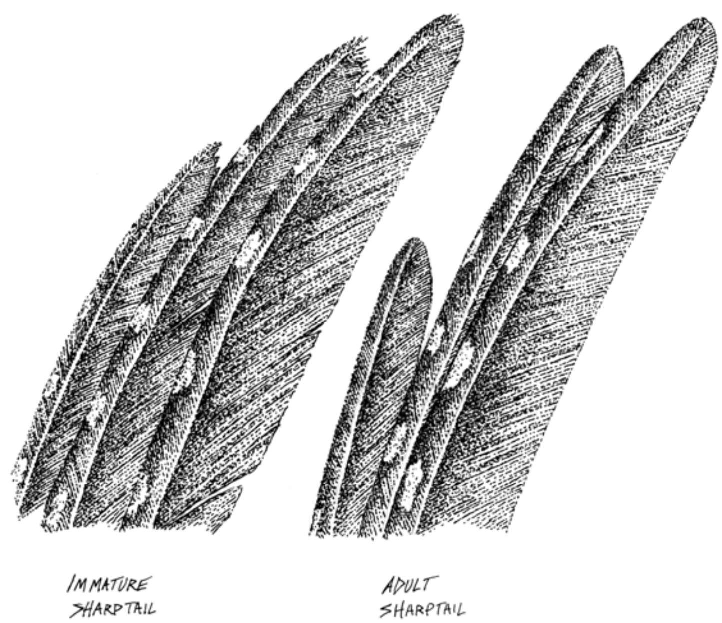


Figure 2. Outer primaries of juvenile (left) showing wear not usually evident in adults (right) (illustrated by Darrell Pruett).

Columbian sharp-tailed grouse have upperparts that are ruddy brown, with a buffy throat with moderate to heavy spotting, and bold V-shaped markings on the underparts that are narrower and darker than in other subspecies (Dickerman and Hubbard 1994, Connelly et al. 1998). Columbians have the shortest wings of all the sharp-tailed grouse subspecies (Connelly et al. 1998).

Adult sharp-tailed grouse average 41–47 cm (16–18.5 in) in total length (Connelly et al. 1998). Sharp-tailed grouse body mass is generally highest in late winter and it declines through the summer and fall (Giesen 1992, Collins 2004). Males are heavier than females by about 10% within each age class and season (Table 1). Adult males also have greater body mass than yearling males in spring (Giesen 1992). Sharp-tailed grouse are similar in size and weight to ruffed grouse (Rusch et al. 2000), much smaller than adult sage-grouse (male = 2,800 g, females = 1,500 g; Schroeder et al. 1999) and somewhat smaller than sooty grouse (*Dendragapus fuliginosus*; males ≈ 1,273 g, females ≈ 839 g; Zwickel 1992).

Table 1. Mean weight of Columbian sharp-tailed grouse in Washington (M. Schroeder, unpubl. data).

Sex/age class		*n*	Weight (g)	Range	SD
Males					
	Adult	130	755	671–909	44
	Yearling	80	710	606–812	37
Females					
	Adult	34	691	591–790	45
	Yearling	19	641	569–705	36

GEOGRAPHICAL DISTRIBUTION

North America

Sharp-tailed grouse have occupied the western and northern United States and Canada since at least the late Pleistocene Epoch, no later than 23,000 years ago (Snyder 1935, American Ornithologists' Union 1957, Spaulding et al. 2006). *T. phasianellus* bones dated to the late Pleistocene have been recovered from Oregon, Nevada, Texas, Tennessee, Virginia, and Pennsylvania (Lundelius et al. 1983, *in* Spaulding et al. 2006). The historical range of sharp-tailed grouse encompassed 6 Canadian provinces, 2 territories, and 21 states (Aldrich 1963, Johnsgard 1973). Sharp-tailed grouse have declined in western North America since the late 19th century (Hart et al. 1950, Miller and Graul 1980, Kessler and Bosch 1982), and have disappeared from 8 of the 21 states they formerly occupied (Johnsgard 1973, Miller and Graul 1980).

The Columbian subspecies ranged from central British Columbia south across eastern Washington, Oregon, Idaho, and northwestern Montana, south into northern California and Nevada, and east into Utah, western Wyoming and western Colorado (Fig. 3; Aldrich and Duvall 1955, Aldrich 1963, Miller and Graul 1980). The subspecific identity of sharptails in the Rocky Mountains is currently unsettled and requires additional analysis (Spaulding et al. 2006, Warheit and Dean 2009, R. Hoffman, pers. comm.). Currently, Columbian sharp-tailed grouse occupy <10% of their historicalrange in Idaho, Utah, Wyoming, and Washington; approximately 15% in Colorado, and 78% in British Columbia (Bart 2000, Leupin 2003). They were extirpated from California, Montana, Oregon, and Nevada. They were recently reintroduced to Nevada and Oregon, but the outcome of these projects are uncertain.

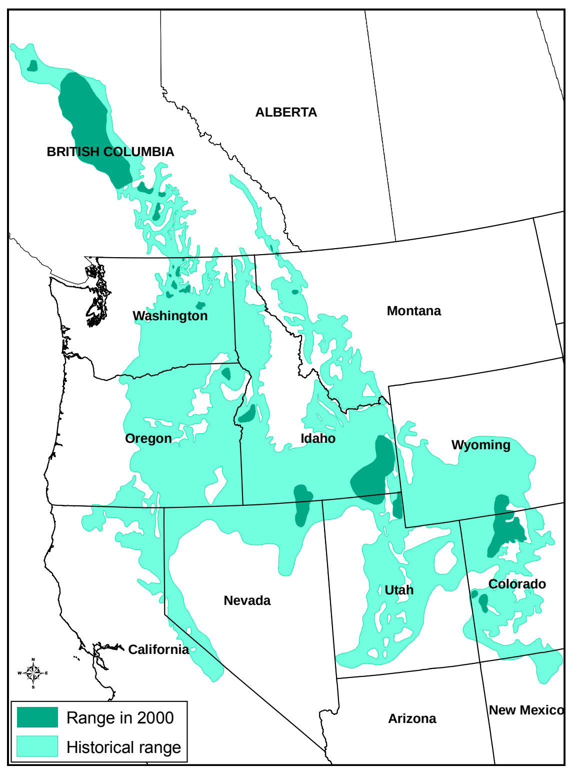


Figure 3. Historical and current range of the Columbian sharp-tailed grouse.

Washington

Columbian sharp-tailed grouse historically were widely distributed in eastern Washington (>75,000 km^2 area; Schroeder et al. 2000). They likely ranged from the Canadian border at Oroville, south to the Oregon border, as far west along the Columbia River as The Dalles, Oregon, and the eastern Cascade foothills, and east to the Idaho state line (Fig. 4). Sharp-tailed grouse inhabited most of the prairies in the Columbia Plateau and the stream valleys emptying into the Columbia River (Dawson and Bowles 1909, Darwin 1918, Yocom 1952, Schroeder et al. 2000). Sharp-tailed grouse were more abundant in grassland (steppe and meadow steppe; Daubenmire 1970), and less abundant in sagebrush communities. In 1836, John K. Townsend reported that sharp-tailed grouse were "occasionally seen in this vicinity," of Fort Vancouver in present-day Clark County, about 129 km (80 miles) down-river from The Dalles, and suggested they were probably "only a straggler here," because they were considered rare by the local Native Americans, some of who were unfamiliar with the bird (Jobanek and Marshall 1992:9).

By the 1950's, sharp-tailed grouse were mostly restricted to Lincoln, northern Grant, Douglas, and Okanogan counties (Yocom 1952, Buss and Dziedzic 1955), with scattered sightings from Adams, Asotin, Klickitat, Spokane, Stevens, and Whitman counties (Yocom 1952, Weber and Larrison 1977). The current range of Columbian sharp-tailed grouse in Washington consists of seven small isolated populations in Douglas, Lincoln, and Okanogan counties (Fig. 4). Sightings of sharp-tailed grouse were reported in Asotin County in the mid-1980s, but these may have been birds dispersing from Idaho subsequent to a translocation conducted by Idaho Department of Fish and Game. Sharp-tailed grouse found outside Douglas, Lincoln, and Okanogan Counties are likely transient birds that periodically occupy patches of remaining shrub/meadow steppe. Sharp-tails currently inhabit only about 2.8% of the estimated 79,865 km^2 historical range in Washington at the start of Euro-American settlement (Schroeder et al. 2000).

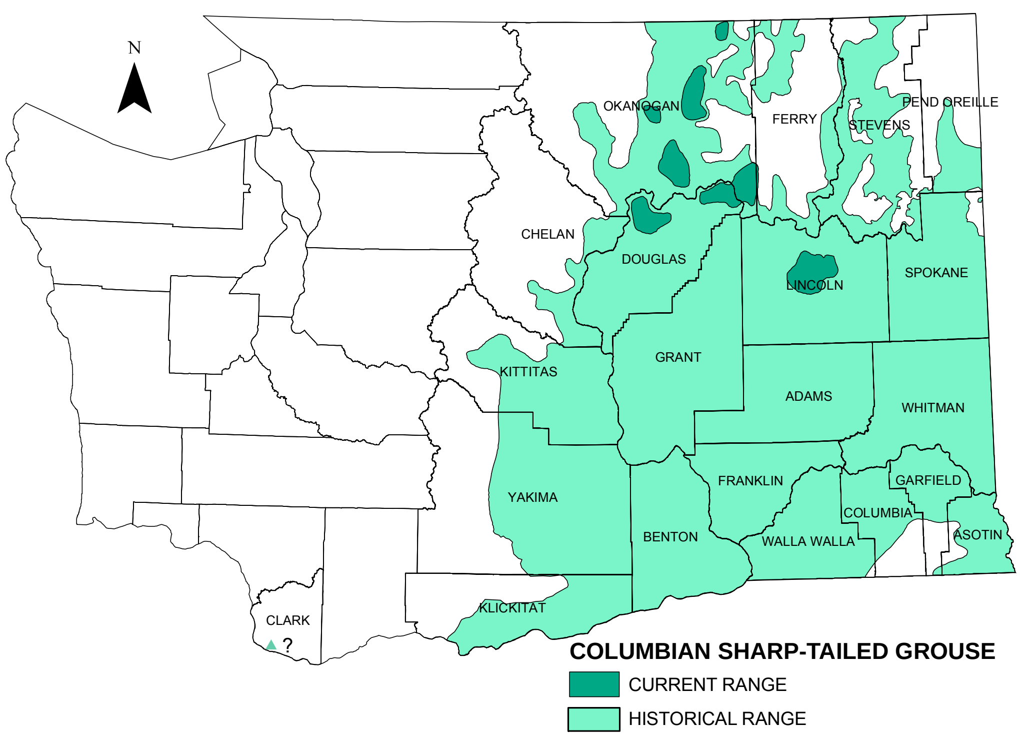


Figure 4. Historical and current range of Columbian sharp-tailed grouse in present-day counties in Washington; ? = historical record by Townsend in 1836 (modified from Schroeder et al. 2000).

NATURAL HISTORY

General Behaviors

Sharp-tailed grouse usually walk but they generally fly when they are disturbed, moving long distances, or are foraging in trees and shrubs (Hart et al. 1950). Sharp-tailed grouse typically fly 2 to 15 m (5–50 ft) above the ground, flapping their wings for approximately 30 to 50 m (98–164 ft) and then alternating between gliding and short bursts of wing beats. Average flight speed is about 30 to 35 mph (48–56 km), but they can attain speeds up to 46 mph (74 km)(Hart et al. 1950). Sharp-tailed grouse often fly 0.4–0.8 km, (¼–½ mi) but flights of 3.2 –4.8 km (2–3 miles) are not unusual (Hart et al. 1950). When flushed, sharp-tailed grouse issue a series of rapid calls that Lumsden (1965) described as "*tuckle…tuckle…tuckle*" or "*tuk…tuk…tuk*" (or *whucker-whucker-whucker*, Connelly et al. 1998); he characterized this as an alarm call because it is sometimes uttered from the top of a tree when they are approached. Variations of "cluck" or clucking calls are used as contact calls by feeding birds and by the female during brood-rearing (Kermott and Oring 1975, Connelly et al. 1998).

Sharp-tailed grouse typically forage in the early morning, when not attending leks, and again in the late afternoon, and spend the middle part of the day loafing (Connelly et al. 1998, Conover and Borgo 2009). Flocks typically spend time during the day at favored spots to which they return frequently (Hamerstrom and Hamerstrom 1951). As night approaches they move to a different location to roost, though the habitat may be very similar to the open grass-forb habitat of their daylight loafing sites (Gratson 1988, Conover and Borgo 2009). In fall or winter they may roost in shrubs or trees more often (Gratson 1988, Connelly et al. 1998).

Seasonal aggregations. Sharp-tailed grouse are usually found singly or in small groups during the summer. During summer in North Dakota, Kermott (1982) had great difficulty finding and flushing male sharp-tailed grouse, which hid in the grass. Sharp-tailed grouse aggregate into larger flocks from fall until spring. Sharp-tailed grouse may gather in flocks to share information, search for food, and guard against predators while foraging (Gratson 1988). Habitat, the availability of cereal crops, or snow depth may influence the size of flocks (Hart et al. 1950, Gratson 1988, Meints 1991, Weddell et al. 1991b). Meints (1991) observed concentrations of >200 sharp-tailed grouse foraging in grain fields in Idaho. Lord (1866 *in* Hammerstrom and Hammerstrom 1951) reported that west of the Canadian Rockies flocks aggregate, "about the middle of September and on into October …until they gradually accumulate into hundreds…." In Washington, Weddell et al. (1991b) found larger flocks in riparian areas (up to 19 birds) than in uplands (7 birds). J. Olson (pers. comm.) recently observed a flock of 38 at Scotch Creek Wildlife Area). Historically, larger flocks may have been common in Washington; a flock estimated at 250 birds was reported in McLaughlin Canyon in Okanogan County in 1954 (Weddell et al. 1991b). In Idaho, Marks and Marks (1987a) reported winter flock size up to 32 birds; 80% were within 2 km (1.2 mi) of leks. Meints (1991) observed winter flocks of 5–22 birds. Leupin (2003) reported winter flocks of 7–72 birds in British Columbia. In Utah, large sharp-tailed grouse flocks disbanded in winter but formed again in spring, usually near leks, after snow receded (Marshall and Jensen 1937, Hart et al. 1950). Gratson (1988:182) reported that flock size of prairie sharp-tailed grouse in Wisconsin declined when availability of ground foods decreased and when snow depth exceeded 18 cm (7 in) and birds began using snow burrows.

Snow burrows. Many grouse species, including sharp-tailed grouse use snow burrows for roosting during periods of deeper snow. Snow burrows allow sharp-tailed grouse to roost in relative safety from predators and conserve energy by adding insulation and reducing exposure to wind (Evans and Moen 1975). In Washington, sharp-tails used snow burrows when there was >28 cm (11 in) of uncrusted snow

(McDonald 1998). Burrows averaged 73 cm (*n* = 16, range 28−180 cm; 29, 11–70 in) in length. Marks and Marks (1987a) reported that burrows used by sharp-tailed grouse in Idaho were up to 1 m long and radiated from the entrance in random directions. They suggested it would be difficult for a mammalian predator to isolate the location of a grouse and capture it before the bird escaped. When flushed, sharp-tailed grouse will burst out of the snow creating an exit hole away from the entrance. In Wisconsin, snow burrows were used both at night and during the day; night burrows averaged 2.4 m long (7.9 ft, *n* = 57), and day burrows averaged 1.4 m (4.6 ft, *n* = 101) (Gratson 1988: 180–181). During midwinter, birds remained in their burrows through the night, left them to feed in the morning, then made new burrows and remained in them until leaving to forage again the following morning.

Territorial and Mating Behavior

Male sharp-tailed grouse gather on dancing grounds where they engage in specialized behavioral displays to attract females in hopes of mating. These communal dancing grounds, called leks, are also characteristic of mating behavior in sage-grouse and prairie chickens. In lek mating systems, females mate with established territorial males at a lek, the male territory contains no resources needed by the female, and males do not contribute to parental care (Bradbury and Gibson 1983). All North American grouse species, except ptarmigan, are polygynous, that is, a male may mate with many females.

Sites used for leks by sharp-tailed grouse are typically small in area (0.01–0.1 ha, or up to ¼ ac) on open elevated knolls or ridges with good visibility. Leks may shift location over time or cease to exist with population declines or changes in vegetation, but many persist in the same location for many years. Although most leks consist of only one location, one lek in eastern Washington seemed to move on an annual or biannual basis among >10 locations (Schroeder 2006). Movements of lek locations appear to be more common with smaller leks.

At the beginning of the breeding season, male sharp-tailed grouse establish small territories on a lek. The mating season generally begins about the same time each year depending on snow conditions, food and habitat availability (Oedekoven 1985, Giesen 1987). In Colorado, males returned to the breeding range in mid- to late March, and females began arriving in early April (Collins 2004). In Wyoming, most females appeared on leks when snow covered <10% of the area (Oedekoven 1985). Males congregate at leks before dawn to perform courtship displays. Kermott (1982) was able to predict the arrival of males by measuring the intensity of incident light in the eastern sky with a light meter. Courtship display occurs both in the morning and early evening. Displaying begins about 45–60 min before sunrise (Marshall and Jensen 1937, Kermott 1982), but local sunrise is affected by topography. The morning display period on the lek is variable, but typically lasts 2−4 hours; an overcast sky tends to prolong the display period (Kermott 1982). Early in the season before females begin visiting leks, morning display periods in Manitoba averaged 107 $\pm$ 6.4 min per morning; after females began visiting, the display period increased to 252.8 $\pm$ 4.9 min (Caldwell 1976). Weather, particularly heavy or steady precipitation, or disturbance by predators or humans on a lek, cause sharp-tailed grouse to temporarily stop displaying and mating, or leave the lek (Marshall and Jensen 1937, Hart et al. 1950, Rogers 1969, Farrar 1975, Caldwell 1976, Baydack and Hein 1987). Rain at night that continues into morning often prevents the morning display session (Kermott 1982). Males return in the evening and display during the 1–3 hours before dark. The dawn and dusk display schedule may be an adaptation to avoid diurnal predators and conditions reducing sound transmission (i.e. wind and thermal turbulence; Sparling 1983).

Leks may contain 2–40 males (Connelly et al. 1998), but 8−12 males is more typical (Johnsgard 1973).

Plate 1. Territorial and courtship displays of sharp-tailed grouse: top row, left to right: Face-off, and Aeroplane posture of Dance; Middle: Running parallel, and Upright Advance; bottom: Flutter Jump, and right, male approaches a female. Photos of plains sharp-tailed grouse by Joe Higbee at Benton Lake National Wildlife Refuge in Montana.

Caldwell (1976) suggested that the spacing of nests or male territorial aggression may impose an upper limit of 30–35 birds on leks; one lek in Washington contained 58 birds in 2009, although some of these birds were females (J. Olson, pers. comm.). Males typically lose weight during this period because they spend less time foraging during the lekking season (Caldwell 1976).

The most conspicuous displays performed on the lek territories are the Flutter Jump and the Aeroplane display (Plate 1). Male sharp-tailed grouse produce six different vocalizations associated with courtship or territorial aggression on leks, including *coo, gobble* ,*whine*, *chatter* or *cackle*, *chilk*, *cha* and *cork* calls (Lumsden 1965, Hjorth 1970, Kermott and Oring 1975, Sparling 1983). A *cackle* vocalization by females while approaching a lek often elicits a bout of Flutter Jumps by males, in which they jump or make short flights of 3−10 m, 1−3 m in the air (Lumsden 1965). In the Aeroplane display (Hjorth 1970) or Tail-rattling (Lumsden 1965), the male moves forward, often turning or circling, rapidly stamping its feet in short steps and with its wings outstretched. Displaying males erect their tail and expose white tail undercoverts, extend their neck, inflate lavender air sacs, and erect their yellow superciliary combs. The tail is rapidly wiggled side-to-side producing a rattling and rustling sound while simultaneously the foot stomping produces a dull drumming sound. Each foot hits the ground about 10 times per second (Hjorth 1970). The wings are vibrated and the stomping and tail movements are synchronized, so that the rectrices of either side are alternately spread and closed. The dance is punctuated by occasional fanning of the tail while uttering vocalizations (Hjorth 1970). Performance of the Aeroplane display is often highly synchronous among males, with two or more adjacent birds starting and stopping the display simultaneously, and sometimes with all the males present dancing and 'freezing' simultaneously (Hjorth 1970). The amount of dancing may increase 10 fold in the presence of females with the Aeroplane display oriented toward the females (Hjorth 1970).

Aggressive behavior between males on leks is most visible at territorial boundaries (Hjorth 1970). Boundary encounters sometimes escalate to fights when males jump in the air and try to peck and kick each other and beat each other with their wings; pecks are aimed at the head and shoulders (Hjorth 1970, Connelly et al. 1998). Fighting rarely ends in injuries more serious than scratches, but males have been known to be mortally wounded (Connelly et al. 1998).

Female visits to the lek peak in early April in Washington (Schroeder 1994), in March in western Idaho (Marks and Marks 1987a), and in mid-May in Wyoming (Oedekoven 1985), but peaks vary year-to-year with the weather. Female visits to leks in southern British Columbia peak in mid- to late April (Leupin 2003). Females leave the lek soon after mating (Johnsgard 1973). The peak of breeding activity lasted about a week in North Dakota (Kermott 1982). There may be a second low peak in visits by re-nesting females in May or early June.

For sharp-tailed grouse, and lekking species in general, the relative importance of female choice vs. competition among males in determining mating success has been the subject of debate (Bradbury and Gibson 1983, Bergerud 1988a, Schroeder 1991, Tsuji et al. 1992, 2000, Gratson et al. 1991, Gratson 1993). Females show a marked preference for mating with males occupying central territories (Lumsden 1965, Evans 1969, Hjorth 1970, Kermott 1982). About half the females remate the same day, or a few days later (Landel 1989, Gratson et al. 1991). Tsuji (1996) suggested that females mate successfully only once, but recent evidence indicates that females often mate successfully multiple times and with more than one male (Coates 2001). Females may visit a lek 1−10 times and may attend more than one lek (Landel 1989). In Manitoba, males on two small leks (9 males) were less active and spent less time on the lek than males on two large leks (20, 30 males; Caldwell 1976); females visited small leks, but were less likely to breed there than on large leks (0 vs. 11 observed copulations).

Territorial position and dancing intensity correlates with mating success. Males with central territories were responsible for 76% of the copulations in Alberta (Rippin 1970). On a North Dakota lek, 13% of males performed 93% of observed copulations, and one male performed almost 50% (20 of 41); only one copulation during three seasons involved a peripheral male (Kermott 1982). Of 47 territorial males on four leks in Manitoba, 23 (49%) were not observed to breed, and nine (19%) did 75% of the breeding (Gratson et al. 1991).

Sexton (1979) documented off-lek copulation involving a male that was displaying singly, and reported the existence of a non-territorial segment of the population in his Alberta study area. He speculated that non-lekking males may mate with subordinate females and make an unrecognized contribution to recruitment in the population. The low number of copulations observed, even on large leks with females present suggest that off-lek copulations may be common (R. Hoffman, unpublished data).

Hens sometimes chase other females away while on the lek, but territorial behavior has not been clearly documented in females. Robel (1970) reported that dominant female greater prairie-chickens prevented, or at least delayed, subordinate females from mating on leks. Kermott (1982) observed female-female aggression on a sharp-tailed grouse lek and speculated that a dominance hierarchy may exist among females. Females have been observed calling while perched in shrubs or small trees in nesting areas, which suggests females may defend a nesting territory from other females (M. Schroeder, pers. obs.). Caldwell (1976:100) also mentioned hearing cluck calls from good nesting habitat in late May, and he suggested that it may warn other females away from her intended nesting site. Caldwell (1976) noted that all the nests discovered were $\geq$157 m apart. Kermott (1982) described a first stage of the mating period during which females gathered near leks and often cackled from elevated perches, but he did not associate the female vocalization with defense of nesting areas.

Display and mating decrease toward the end of May (Evans 1968, Oedekoven 1985). In late summer to early fall, males return to leks, but initially do not display. As fall mornings become chilly, attendance becomes more regular and dancing occurs and increases in intensity (Hjorth 1970). In Alberta, lek activity tapers off by early November, but males may display on warm sunny days throughout the winter (Hart et al. 1950, Evans 1968, Hjorth 1970, Oedekoven 1985). Females rarely visit leks outside the spring mating period. Kermott (1982) suggested that fall and winter displaying may allow adult males to reassert their ownership of territories with a new generation of competitors, and gives juvenile males an opportunity to acquire a peripheral territory in anticipation of the spring competition.

Reproduction

Nesting and incubation. Gratson (1988:185) observed that females had large home ranges during the period before mating and egg-laying. He suggested that females were investing time and energy in selecting suitable nest sites by moving through potential nesting habitat, and selecting potential mates by visiting multiple leks. Male sharp-tailed grouse do not assist in building nests, incubation, or raising chicks. Nests (Fig. 5) are a small depression in the ground loosely lined with dry grass, leaves, moss, and a few feathers (Hart et al. 1950, Leupin 2003). In Washington, females nested an average of 1.6 km (1 mi; SD = 0.44) from a lek (Schroeder 1996).

In Washington, average starting date of incubation was 8 May for all nest attempts, including renests (range 14 April–22 June; Schroeder 1996). Eggs are olive to dark buff-brown and often finely speckled with spots of brown and lavender and measure about 43 x 32 mm (Hart et al. 1950, Evans 1968, Connelly et al. 1998). In a study on the Swanson Lakes Wildlife Area and the Colville Reservation, initial clutch size averaged 12.2 (range 11–14, n = 17; McDonald 1998). Initial clutches of Columbian sharp-tailed grouse averaged 11.9 eggs in Idaho (range 10–13, n = 18), 10.9 eggs in Utah (range 3–17, n = 127), and

11.2 eggs (range 8–13, *n* = 4?) in British Columbia (Hart et al. 1950, Meints 1991, Connelly et al. 1998, Leupin 2003; Table 2). There was no difference in clutch size between adult and yearling females in Colorado (Boisvert 2002, Collins 2004). If the initial clutch is lost to predation during laying or early in incubation, females often renest. McDonald (1998) estimated that 73% of 22 females that lost their initial clutch renested; two females renested twice (Schroeder 1996). Clutch sizes of renests were slightly smaller (mean = 9.5 eggs, range 8-12 eggs, *n* = 10; McDonald 1998). Apa (1998) reported that one radio-tagged female renested after losing a brood. Gratson (1989) reported one case of intraspecific nest parasitism (a female added her clutch to a nest built by, and containing eggs, of another female) out of 120 nests in a four year period in Manitoba. In Washington, 94.5% of 183 eggs contained a viable embryo (McDonald 1998).

Figure 5. Successful sharp-tailed grouse nest on Swanson Lakes Wildlife Area in northeastern Washington *(Photo by Ben Maletzke)*.

The incubation period for sharp-tailed grouse usually begins after the last egg is laid. It has been reported as 21–26 days (Connelly et al. 1998, Boisvert 2002), and duration may vary with environmental conditions. Females are attentive to the clutch during incubation. The female typically leaves the nest to feed for 30–45 minutes in the morning and again in the evening, but rarely wanders more than 200 m from the nest (Hart et al. 1950, Connelly et al. 1998). Females typically lose weight during incubation because foraging time is drastically curtailed (Caldwell 1976). Caldwell (1976) indicated that 5 incubating females spent 95.7 $\pm$ 1.5% of each day on the nest; two females lost about 5 grams/day. Median hatch date in Washington was about May 30 (8 May + 22days, *n* = 67; Schroeder 1996). Peak of hatch occurred in early and late June in Idaho (Marks and Marks 1987a), 20 May–11 June in British Columbia (Leupin 2003), and late May to early June in Utah (Hart et al. 1950); median hatch date was 13 June (31 May–19 June) in Idaho (Apa 1998).

Nest success (% nests that hatch $\geq$1 egg) varies year-to-year probably due to weather, age structure of females, predator densities, and changes in nesting cover (McDonald 1998). In Washington, nest success averaged 43% (*n* = 67), but renesting resulted in 65% of females hatching a clutch (Schroeder 1996). Nest success was 32 % (n = 127) in Utah (Hart et al.1950), and 42% (*n* = 71) and 63% (*n* = 119) in Colorado (Boisvert 2002, Collins 2004). Nest success was 72% (18/25), and female success 86% (% females that hatch $\geq$1 egg, 18/21; Meints 1991) in southeastern Idaho. Meints (1991) noted that only half of the eggs in 2 renests hatched. Bergerud (1988b) reported that nesting success is higher for adults than yearling females in steppe grouse, so the percentage of yearlings in a population can affect recruitment. However, Apa (1998) and Collins (2004) reported that initial nest success and female success did not differ between yearlings and adult sharp-tailed grouse in their studies.

Table 2. Reproductive parameters reported in Columbian sharp-tailed grouse in Washington, Idaho, Utah, and Colorado.

State/ Reference	Initial clutch size (*n*)	% Nesting effort (*n*)[a]	% Nest success[b] (*n*)	% Renest effort[c] (*n*)	% Female success[d] (*n*)	% Brood success[e]	Brood size[f] >45 days, or as noted	% Chick survival (*n*)
Washington								
Schroeder (1994)	10.4 (5)[g]	-	60 (10)	66 (3)	100 (6)	-	5.2 (*n* = 3; 45–75 days)	54.2 (48)
McDonald (1998)	12.2 (17)	>88 (34)[h]	41 (54)	73 (22)	49 (45)	50	2.5 (45 days)	12 (234)
Idaho								
Marks and Marks (1987a)	10.8 (5)[g]	-	71 (7)	-	-	-	-	-
Apa (1998)	10.4 (28)	100 (48)	51(47)	-	58 (38)	-	-	-
Meints (1991)	11.9 (19)	100 (20)	72 (25)	66 (3)	86 (21)	53 (to 28 days)	4.1 (*n* = 16; at 28 days)	
Utah								
Hart et al. (1950)	11 (127)[g]	-	37 (110)	-	-	-	4.6 (28–60 days)	-
Colorado								
Giesen (1987)	10.8 (10)[g]	-	62 (13)	-	-	-	-	-
Boisvert (2002)	10.2 (39)	1999: 100 (29) 2000: 97 (33)	42 (71)	1999: 20(15) 2000: 28(31)	45.9 (61)	1999: 64 2000: 85	4.4 (49 days)	1999: 49 2000: 47
Collins (2004)	10.4 (71)	2001: 100 (60) 2002: 97 (61)	63 (119)	2001: 69(13) 2002: 36(25)	71 (121)	58 (*n* = 79)	2.7–4.2 (49 days)	2001: 44.8 (125 m)[i] 13.3 (308 s) 2002: 19.7 (183 m) 14.2 (169 s)

[a]Percent females that attempted to nest.
[b]Percent nests that hatch ≥1 egg
[c]Percent females that renested after surviving the loss of initial clutch.
[d]Percent females that hatch ≥1 egg.
[e]Females that rear ≥1chick to ≥45 days, or as noted.
[f]Brood counts for females that did not lose entire brood.
[g]Includes renests.
[h]Percent confirmed; female behavior suggested effort was 100%.
[i] m = reclaimed mine; s = native shrub-steppe

Brood rearing. Sharp-tailed grouse raise one brood each year. Eggs hatch over a period of a few hours and the chicks are precocial and leave the nest soon thereafter (Hillman and Jackson 1973). A newly hatched brood that is disturbed often walks about peeping, but after two days the brood will hide and remain silent. When disturbed, the female may feign injury to lead the intruder away, flopping along the ground for >50 meters, and then fly off and walk back to her brood (Hart et al. 1950). Chicks may not be able to thermoregulate on their own until over 2 weeks of age (Bergerud and Gratson 1988: 546).

Females remain with their brood all summer. Females often move their brood to open areas containing succulent vegetation and insects (Hart et al. 1950, Gratson 1988). In Washington, females remained <1 km (0.6 mi) from their nest site during early spring, and 0.5 km (0.3 mi) during early summer (Schroeder 1996). Broods in Utah traveled only about 46 m (50 yd) from their hatch site by the end of their first month (Hart et al. 1950). When the chicks are able to fly only short distances, they usually walk and freeze or hide rather than fly when disturbed (Hart et al. 1950). Chicks flew up to 27 m (30 yd) at eight or nine days old (Christenson 1970), and 50 m (45.5 yd) at one month of age in North Dakota. At two months of age they attained half the mass of adults (McEwen et al. 1969) and were fairly strong fliers (Hart et al. 1950). By three months of age, the size, habits, and flight abilities of sharp-tailed grouse are well developed and juveniles are not easily distinguished from adults. In August, sharp-tailed grouse broods may join other broods in what Bergerud and Gratson (1988:585) call "gang broods" that presumably improve vigilance and avoidance of predators. The female generally leaves the brood first, before the juveniles disband in the fall (Caldwell 1976, Gratson 1988).

Adoption. Adoption has been reported in 150 bird species (Avital et al. 1998), with the most commonly reported situation being brood amalgamation. Brood amalgamation is fairly common in waterfowl, but little is known about the frequency or circumstances of adoptions in grouse. Adoption may be relatively common in Galliformes because of their precocial young and lack of territoriality in brood habitat (Wong et al. 2009). The apparently altruistic nature of adoption has generated several hypotheses about its potential adaptive advantage (Avital et al. 1998). Two hypotheses that apply to the sharp-tailed grouse female mentioned by Brown (1967a) include that unsuccessful yearling birds may adopt to get practice and improve their future chances of success, or a failed breeder might be unable to resist adopting because of high levels of hormones. Other hypotheses mentioned by Wong et al. (2009), include that chicks may seek out foster parents when they are abandoned, or separated; parents may be unable to distinguish their own from other young, and thus are not able to avoid the costs of protecting a larger brood. Adoption could benefit the foster parents by improved predator detection, or by exposing the unrelated young to greater risk to predation at the perimeter of the brood (Wong et al. 2009); the so-called 'selfish herd' effect. The phenomenon of adoption in broods may have potential for augmenting populations in certain circumstances.

Brown (1967a) reported that a radio-tagged yearling sharp-tailed grouse female adopted two, 1½ week-old chicks a week after losing her near-term clutch to predation. Twenty days later the same female had adopted two additional younger chicks and she reared this brood of four chicks of two ages for over 40 days. Maxson (1978) reported a case of two successive adoptions by female ruffed grouse with adjacent home ranges, and Keppie (1977) documented four cases in spruce grouse (*Falcipennis canadensis* aka *Canachites* spp.) in which broods were adopted after the female died. These adoptions plus the switching of broods by individual chicks totaled 4% of marked juveniles. All the spruce grouse juveniles that switched were ≥11 days old and all joined another brood in the immediate vicinity (Keppie 1977). All broods orphaned after 40 days post-hatch generally remained together without a female. Keppie (1977) also noted 10 reports in the literature in which the author suspected adoptions or brood switching; these included cases involving Attwater's prairie-chicken (*T. c. attwateri*), greater sage-grouse, ruffed grouse, sooty grouse, dusky grouse, and white-tailed ptarmigan (*Lagopus leucura*). Wong et al. (2009) reported adoption rates (% broods with adopted chicks) of 13% (n = 16) and 4% (n = 27) in white-tailed ptarmigan at two study areas, and 14% (n = 29) in rock ptarmigan (*L. mutus*). Adoption has also been reported in Merriam's wild turkey (*Meleagris gallopavo merriami*), and northern bobwhite (*Colinus virginianus*; Mills and Rumble 1991, DeMaso et al. 1997, Faircloth et al. 2005).

Chick survival and recruitment. Chick survival during the first two months after hatch is important for maintaining sharp-tailed grouse populations. Three interrelated important mortality factors affecting sharp-tailed grouse chicks are predation, chilling during cold wet weather, and starvation (Bergerud (1988b:610). Most grouse species experience a high loss of chicks before 2–3 weeks of age, in part because young chicks cannot fly or maintain their internal body temperature (Bergerud 1988b, Dobson et al. 1988). Bergerud (1988b:609) reviewed 10 studies of sharp-tailed grouse and noted that only 2 of 10 reported a chick mortality rate of >40%. Chick survival until fall was 66% in Colorado (Giesen 1987) and 50% in Idaho (Marks and Marks 1987a), and 34% (± 0.07, n = 283) to 35 days for plains sharp-tails in British Columbia (Goddard and Dawson 2009). Hart et al. (1950) reported that during a 1937–39 study in Utah, mean brood size was 8.7 (n = 150). In 1948, mortality was highest the first month after hatch. Broods <1 month old averaged 8.5 chicks; broods 1–2 months-old dropped in size to 4.6 chicks. Chick survival was 56% from <1 month to >2 months (Hart et al. 1950).

Reproductive output in two Washington study areas in 1995–96 was affected most by chick survival up to 45 days post-hatch; nest depredation played a lesser, though important role (McDonald 1998). During the 2-year study, 36 radio-tagged females produced only 28 chicks to 45 days of age. Only half of the females that succeeded in hatching a clutch successfully reared at least one chick to 45 days. Chick survival was low in McDonald's study, with mean brood sizes of 2.5 and 2.6 chicks, excluding females that lost their entire brood (McDonald 1998). McDonald (1998) noted that mean brood size was 1.07 and 1.63 chicks, if it included females that lost entire broods. Most studies report the average size of broods encountered during flush counts, and do not include females that lost entire broods. The failure to quantify the loss of entire broods means that chick mortality is under-represented in many estimates (Bergerud 1988b:609). Brood success (or brood survival: proportion of broods in which at least 1 chick survived brood rearing period) reported for Columbian sharp-tailed grouse ranged from 0.44 to 0.85 (Table 2). For plains sharp-tailed grouse, brood success was 0.48 (n = 21) during 2 seasons in Montana (Bousquet and Rotella 1998); 0.18 for 1 season in North Dakota (Christenson 1970), 0.32 (n = 22) during 2 seasons in southern Alberta (Roersma 2001), and 0.67 (± 0.09, *n* = 27) during 2 seasons in British Columbia (Goddard and Dawson 2009).

Renesting plays an essential role in reproductive output of a population, especially in years when early nest predation is high or inclement weather severely reduces the survival of broods from initial nests (McDonald 1998). In 1995, only 1 chick was reared to 45 days of age from 6 successful initial nests on the Colville Reservation study area, but 5 chicks were recruited from 2 renests (McDonald 1998). Half of the 28 chicks reared to 45 days were from renests. Sixty percent of 15 successful initial nests failed to produce any chicks to 45 days; during 1995, 3 females had clutches hatch at the same time and rainy conditions persisted for the first week during which the females were depredated. In Colorado, 21% of 707 chicks from initial nests survived to 7 weeks, while chick survival for 108 chicks from renests was 10.3% (Collins 2004). Survival of chicks in broods of adult females was higher than for chicks in broods of yearling females (21.7, *n* = 677 vs. 9.3%, *n* = 108;p = 0.003) (Collins 2004).

Boisvert (2002) reported that brood size decreased from 9.2 to 4.3 chicks during the first 49 days. Collins (2004) reported chick survival of 45% and 20% in mine reclamation areas, and 13% and 14% in shrub-steppe in 2001 and 2002, respectively. Brood sizes at 49 days were 4.2 in mine reclamation and 2.7 in shrub-steppe. Collins (2004) believed chick survival in shrub-steppe during his study was not adequate to sustain the population. Brown (1961) reported the mean brood size of one quarter-grown chicks was 7.7, but declined to 3.8 for chicks that were approximately 80% of adult size in Montana.

Manzer and Hannon (2008) reported that most chick mortality (81%) occurred in the first 15 days and that periods of heavy rain could result in significant mortalities, but losses due to exposure were relatively low (13%) in most years. Following 3 days of heavy rain, they found a female with her brood of 6 all dead apparently from exposure; they suggested that seasons with prolonged heavy rain during the early brood period could result in high mortality. Roersma (2001) also reported female and brood mortalities during prolonged periods of cold rain, with 3 of 8 monitored broods lost to exposure. Bousquet and Rotella (1998) reported that of 11 broods that failed to produce any chicks to 56 days of age, 10 lost all chicks in the first 3 weeks. They did not determine causes of chick mortality, but most losses corresponded with cold, wet weather. Goddard and Dawson (2009) reported 6 of 27 broods were lost, all in the first 14 days. The most important variables affecting chick survival to 35 days were, in order of importance: 1) weather during days 0–7; 2) hatch date; 3) weather during 10 days pre-hatch; 4) distance moved during day 0–7; 5) female body condition; and 6) female age. Wet weather during days 0–7 negatively affected chick survival, while wet weather within the 10 days prior to hatching positively affected survival, probably due to increased cover and abundance of forbs and insects, which improved food availability in the post-hatch period (Goddard and Dawson 2009).

Survival and Sources of Mortality

Adult survival and longevity. Most annual survival rates reported are for hunted populations of sharp-tailed grouse; rates reported in other states ranged from 17% to 42% (Connelly et al. 1998), however, hunting mortality may be at least partially additive. Robel et al. (1972) reported annual survival of 28.5% from a South Dakota study area where hunting mortality was estimated to be >20%. Estimates of survival from unhunted populations of Columbian sharp-tailed grouse in Washington and Colorado also varied widely (Table 3). Schroeder (1996) reported annual survival of 121 radio-marked birds in Washington was 57 % (95% CI = 45.7–68.5). For an unhunted population in Colorado, Collins (2004) reported annual survival of 32.7% in 2001–02, and 44.8% in 2002–03. Collins (2004) and Boisvert (2002) both reported no difference in survival rates of adults and yearlings, and no difference in survival rates between the sexes in mine reclamation lands. Boisvert (2002) reported annual survival of 20% in

Table 3. Annual survival of Columbian sharp-tailed grouse in Washington, Idaho, and Colorado.

State/location	Reference	% annual survival (*n*, sex)	Method
Washington	McDonald (1998)[a]	54.6 (19m, 19f)	Kaplan-Meier (Pollock et al. 1989)
Washington	Schroeder (1996)[a]	57.1 (74m, 47f)	Kaplan-Meier product limit
Idaho	Ulliman (1995)	86 (1992, *n* = 14)[b] 29 (1993, *n* = 14)[b]	Fate of all birds known
Colorado	Collins (2004) [b]	32.7 (2001–02, *n* = 80 f) 44.8 (2002–03, *n* = 67 f)	Kaplan-Meier, staggered entry
Colorado	Boisvert (2002) [c]	20 (40m, 45f)	Kaplan-Meier, staggered entry

[a]Non-hunted population.
[b]Over-winter survival.
[c]Hunting mortality was 2%; there was no hunting in mine reclamation.

1999 for sharp-tailed grouse in mine reclamation and lands enrolled in the Conservation Reserve Program (CRP) in Colorado. Grouse hunting occurred in the CRP habitat, but only 2% of mortality was attributed to hunting.

McDonald (1998) analyzed a subset of the Washington data from 1995-96 on the Colville Indian Reservation and Swanson Lakes Wildlife Area. He reported that survival for those years and sites pooled was 54.6 ± 0.84% (*n* = 38, 19 males, 19 females). There appeared to be a spike in mortality during nesting and brood rearing; 64% of female that died were nesting or brood-rearing (*n* = 14); 5 of 22 females were killed within 49 days of hatching a brood (McDonald 1998). Manzer and Hannon (2008) reported that survival of plains sharp-tailed grouse females during the reproductive period (1 May – 13 August) was low (53 ± 0.05%; 95% CI; 44–63%, *n* = 111), and accounted for most (82%) of their annual mortality. Hagen et al. (2007b) also noted a peak in mortality of females during nesting or early brood-rearing in lesser prairie-chickens. McDonald (1998) noted that females are reluctant to abandon a brood until the chicks are able to thermoregulate on their own, making them more vulnerable to predators during the 3 weeks following hatch. Collins (2004) noted that males suffered less mortality than females during the nesting and brood-rearing period; male mortality was highest during the breeding season when they were attending leks. Boisvert (2002) noted that mortality was relatively high during the breeding and nesting period, but not during the brood rearing/summer period; she reported that survival of radio-tagged birds was highest during the summer/brood-rearing and winter periods. Hagen et al. (2005a) suggested that a decline in survival rates between yearling males and adult males is a general feature of grouse demography, and not limited to lekking species.

The period of highest mortality for sharp-tailed grouse seems to vary with the severity of the winter. Ulliman (1995) reported that over-winter survival of sharp-tailed grouse in Idaho varied from 86% in a mild winter to 29% in a severe winter. Attwell (1977) provides an account of thousands of sharp-tailed grouse being killed by being trapped under crusted snow in the Klickitat Valley during the severe winter of 1861–62.

Robel et al. (1972) reported that the percentage of banded plains sharp-tailed grouse recaptured in subsequent years in a South Dakota study area was 12.2, 3.5, 1.1, 0.3, and <0.1% for the first through fifth years, respectively. The maximum life span reported for sharp-tailed grouse is 7.5 years (Arnold 1988).

Predation. Predation is an important factor in the population dynamics of prairie grouse (Schroeder and Baydack 2001). Raptors, corvids, and mammals can affect nest success, juvenile survival, and survival of breeding-age birds. Species that gather on leks to display and breed are more conspicuous to predators, and grouse may display at dawn and dusk to avoid diurnal predators, such as hawks (Hartzler 1974). Predation rate is often considered a function of habitat quality and distribution, grouse population and density, as well as predator behavior and population dynamics (Schroeder and Baydack 2001). A shortage of habitat can make it more difficult for birds to escape predators. Habitat degradation can affect visibility of nests and birds on leks, and affect the foraging and travel time to reach feeding sites. Habitat fragmentation can force birds into marginal areas and increase the density and diversity of predators (Schroeder and Baydack 2001). A higher density of birds or nests in limited habitat patches may increase the risk of detection by predators. The population dynamics of predators is often influenced by the populations of their primary prey species, which are often rodents or lagamorphs. Lower abundance of primary prey may require greater travel for predators and increase chance encounters with grouse, or cause predators to focus more on finding grouse or nests (see Predation in altered landscapes and communities).

Determining the species responsible for predation can be difficult due to similarities in nest remains and subsequent scavenging (Lariviere 1999, Bumann and Stauffer 2002), so assignment to a specific predator species, or even taxonomic group, particularly in the older literature should be interpreted with caution. Boisvert (2002) attributed 74% of mortalities to predation, including 41% to mammals and 33% to raptors. Collins (2004) used radio collars with a mortality sensor and recovered most dead grouse within 24 hours; he assigned cause to 54 % of 172 mortalities. He attributed 61% to mammals, 36% to birds (3% to necklace mounted radio transmitter). Radio transmitters were retrieved from the nests of a golden eagle (*Aquila chrysaetos*), great horned owl (*Bubo virginianus*), and a red-tailed hawk (*Buteo jamaicensis*). Other raptors observed at fresh kills included northern goshawk (*Accipiter gentilis*), and Cooper's hawk (*Accipiter cooperi*). Two females appeared to have been killed by bobcats (*Lynx rufus*, Collins 2004).

Marks and Marks (1987b) attributed 22 of 31 mortalities to predation, 86% to avian predators and 14% to mammals; cause of death could not be assigned for 9 birds. They observed or found evidence that predators included goshawks, a golden eagle, and a great horned owl. McDonald (1998) did not provide percentages, but also noted that most nest predation appeared to be by common ravens (*Corvus corax*), with coyotes the next most frequent nest predator in his Washington study. Both McDonald (1998) and Hart et al. (1950) mentioned that gulls (*Larus* spp.) may be responsible for mortalities of chicks or eggs. Meints (1991) listed 36 known mortalities of sharp-tailed grouse in southeastern Idaho; of these 66.6% was attributed to hunting, 19.4% to avian predators, 5.5% to mammals, and 8.3% to unknown causes. Manzer and Hannon (2008), in a study of plains sharp-tailed grouse in Alberta, attributed 72% of chick mortalities to 30 days post-hatch, and 96% of female mortalities during the reproductive period (1 May to 13 August) to predation. They reported that the odds of a female having a successful nest were 8 times greater in landscapes with <3 corvids/km^2 than in areas with >3 corvids/km^2 (Manzer and Hannon 2005).

Predators of sharp-tailed grouse eggs include striped skunk (*Mephitis mephitis*), ground squirrels (*Spermophilus* spp.), black-billed magpies (*Pica pica*), American crow (*Corvus brachyrhynchos*), and common raven (Connelly et al. 1998). Coates et al. (2008) used video cameras at greater sage-grouse nests and reported that predation by common ravens and American badgers (*Taxidea taxus*) often could not be distinguished based on signs, suggesting that the predation rates attributed to various predators based on sign in earlier studies are inaccurate. They also noted that though ground squirrels and other rodents often visited nests and ate egg shells at depredated and successful nests, they depredated none, and their small gape suggested they were probably incapable of breaking sage-grouse eggs. Collins (2004) noted that 6 entire clutches disappeared in shrub-steppe habitat. He suspected that gopher snakes (*Pituophis catenifer*) or prairie rattlesnakes (*Crotalus viridus*) were responsible, because they appeared to be much more abundant in shrub-steppe than in mine reclamation areas. Egg predation by snakes in grassland and shrub habitats may be much more frequent than previously thought (Davison and Bollinger 2000). Coates et al. (2008) noted, however, that badgers and ravens also occasionally consumed entire sage-grouse eggs, leaving no eggs or shells behind.

Additional predators of eggs, chicks, and adults include mink (*Mustela vison*), red fox (*Vulpes vulpes*), peregrine falcon (*Falco peregrinus*), gyrfalcon (*Falco rusticolus*), long-eared owl (*Asio otus*), rough-legged hawk (*Buteo lagopus*), and northern harrier (*Circus cyaneus*) (Connelly et al. 1998, Schroeder and Baydack 2001).

McDonald (1998) noted that predation on 3 females with young broods occurred during a long period of rain and noted other studies of ring-necked pheasants (*Phasianus colchicus)* and greater prairie-chickens that suggested a correlation between predation and precipitation, possibly due to increased olfactory detectability of birds by mammal predators in moist air. Lehman et al (2008) noted that precipitation increased the hazard of nest mortality for Merriam's turkey; they hypothesized that coyotes use olfaction to find incubating females during wet periods.

Hunting. The sharp-tailed grouse season was closed in Washington in 1988. The current frequency of illegal and accidental shooting in the pursuit of other upland gamebirds is not known. Two radio-collared sharptails were shot during an intensive study in the early 1990s, and three separate poaching incidences occurred in the late 1970s (M. Hallet, pers. comm.). Sharptails are vulnerable at times during winter when budding along rural roads. Any mortality to small populations in Washington would be significant.

Wildlife management theory during most of the mid- 20th Century held that hunting mortality was completely compensatory with hunting replacing part of the natural mortality that would be expected to occur over winter (Connelly et al. 2005). There was believed to be a "doomed surplus" of individuals that could be harvested each year without affecting the spring breeding population (Errington 1956). Hunting also was believed to be self-limiting because hunting effort would lessen when success declined with the game population. Some studies seemed to confirm these theories, and populations of some species remained robust despite substantial annual harvest. In the past 30 years, an increasing number of studies have shown that hunting mortality is often at least partially additive to natural mortality, particularly in increasing populations that are below carrying capacity. This is particularly true for sage-grouse that are longer-lived, have low over-winter mortality, and have a lower reproductive capacity than other game birds (Connelly et al. 2003, Reese et al. 2005). Hunting mortality of gamebirds also may be having a greater impact on populations than historically, because, as noted by Applegate et al. (2004), "…land use, and the landscape has changed drastically in the last 60 years." Even the northern bobwhite, with the ability to produce two or even three broods per season (Brennan 1999) can have populations reduced by additive hunting mortality (Roseberry 1979, 1981, Williams et al. 2004a).

In 10 studies involving 8 species of grouse, Bergerud (1988c) concluded that hunting increased annual mortality by adding to rather than replacing natural mortality during winter, but may be partly compensatory to natural mortality during breeding periods when birds are spread out. Connelly (1989) noted that most of the studies cited by Bergerud (1988c) reported a harvest of >20% of the population, a level more likely to be partly additive than lightly harvested populations.

There have been no experimental studies of sharp-tailed grouse designed to test whether, or when, hunting mortality is additive to natural mortality. Historically, hunting, especially market hunting, likely impacted sharp-tailed grouse populations before it was regulated (Yocum 1952). Farming practices and the conversion of habitat to cropland have undoubtedly been the more important factor in Washington (Buss and Dziedzic 1955, Schroeder at al. 2000), and elsewhere. However, hunting mortality likely impacted local populations and may have sped the retreat of sharp-tailed grouse range. The effect of hunting mortality on the breeding population may vary with population size, timing, weather, and the quality and extent of available habitat. Marks and Marks (1987a) believed sharp-tailed grouse could be over-harvested because they concentrate near leks during fall and in flocks during winter. Marks and Marks (1987a) supported maintaining a closed season on small, isolated populations of sharp-tailed grouse. Connelly et al. (2005) noted that Idaho changed their sharp-tailed grouse season to begin later in the fall to relieve hunting pressure during the fall lekking period.

Diseases and parasitism. Numerous parasites have been found in sharp-tailed grouse (Appendix C), but very little is known about their effect on grouse populations (Peterson 2004). Sharp-tailed grouse parasites include ticks (Acarina), chiggers (Trombidiidae), lice (Mallophaga), tapeworms (Cestoda), round worms (Nematoda), hippoboscid flies (*Ornithomyia anchineuria*), and mites (*Ornithonyssus sylviarum*) (Bernhoft 1969, Boddicker 1967, Dick 1981). Boddicker (1967) reported consistent and heavy parasite loads in sharp-tailed grouse in South Dakota; males and chicks had the highest number of parasites. Five-week old chicks were infested with ticks, chiggers, lice, tapeworms and nematodes (Hillman and Jackson 1973). Parasite levels were lowest from December to March (Hillman and Jackson

1973). Ectoparasites cause irritation and may result in reduced breeding activity in males or egg production of females (Hillman and Jackson 1973, Peterson 2004), although Tsuji et al. (2001) found no correlation between ectoparasite burdens and position on the lek in male sharp-tailed grouse in Ontario. Tsuji and DeIuliis (2003) reported no difference in nematode egg load between males on central than on peripheral territories on leks. Boddicker (1967) believed parasites seldom caused direct mortality of sharp-tailed grouse, but could affect populations that are stressed, such as during severe weather or when food is scarce.

Brown (1967b) reported the incidence of hematozoan (*Plasmodium* sp.) infections in two populations of plains sharp-tailed grouse in eastern Montana, 1961–1966. The incidence and intensity of *Plasmodium* parasitemia was variable between study sites, years, seasons, and age and sex classes. The highest incidence was in 1965 when 36% of 180 grouse were infected; this declined to 16.8% (n = 285) in 1966. Incidence of infection did not seem to be related to grouse density, but survival data suggested longevity was associated with absence of latent *Plasmodium* infection. One male had a low intensity latent infection when on a central territory on the lek; after losing his central territory, a blood test indicated that the intensity of infection had increased dramatically (Brown 1967b).

The intermediate host of some nematodes and avian tapeworms include grasshoppers and isopods, species more prevalent in summer when sharp-tailed grouse are eating more animal matter. Young birds tend to eat a higher percentage of animal matter and have more tapeworms (Peterson 2004). Some haematozoans are transmitted through black flies and midges, or hippoboscid flies.

The cecal nematode *Heterakis gallinarum* has been documented in sharp-tailed grouse from Wisconsin and South Dakota (Peterson 2004); it is widespread in domestic chickens, and also infects other grouse, pheasants, quail, turkeys, and chukars (*Alectoris chukar*) (Mississippi State University 1997, Beyer and Moritz 2000). *H. gallinarum* can transmit the protozoan *Histomonas meleagridis*, the agent that causes histomoniasis or 'blackhead disease'. Blackhead is an acute and chronic disease that produces lesions in the caeca and liver. Domestic chickens and pheasants are relatively resistant to the disease, but their droppings can transmit the disease to gamebirds when cecal worm eggs, which remain infective for 3 years, are ingested; transmission may also occur through earthworms (Lund and Chute 1972, Beyer and Moritz 2000, McDougald 2005). Infected game birds can have high rates (75%) of mortality (Peterson 2004). Blackhead has not been reported in sharp-tailed grouse, but it may have been a factor in the extinction of the heath hen (*T. c. cupido*; Johnsgard 2002). Peterson (2004) questions the wisdom of perpetuating ring-necked pheasants in areas with at-risk populations of prairie grouse.

Coccidia, such as *Eimeria* spp. are protozoans that can cause severe anemia, weight loss and mortality, particularly in chicks; they can be a serious problem for birds in captivity, but the significance of intestinal coccidians for free-living sharp-tailed grouse is unknown (Peterson 2004).

Several micro-organisms have been reported in sharp-tailed grouse, and some can cause epizootics that result in significant mortality that could eliminate small isolated populations (Peterson 2004). Disease outbreaks could result from "spill-over" from an epizootic in migratory waterfowl or domestic poultry.

Some studies indicate that population cycles in some species of grouse may be related to parasitic infections (e.g. red grouse, *Lagopus lagopus scoticus;* Moss et al. 1996, Hudson et al. 1998,Watson et al. 1998, 2000). Peterson (2004) stated that research is needed to determine whether parasites regulate or have the potential to regulate prairie grouse populations (sage-grouse, sharp-tailed grouse, and prairie-chickens). Batterson and Morse (1948) mentioned accounts of a crash in sage-grouse populations in Oregon when dead and dying grouse were prevalent. Population crashes were attributed to low reproduction caused by widespread serious infections in females with a cecal roundworm, *Trichostrongylus tenuis*. Northern populations of sharp-tailed grouse may exhibit cyclic fluctuations (see Populations cycles), and disease is one of the factors hypothesized as a causal factor.

West Nile virus, a disease new to North America, is affecting many bird populations. It is transmitted primarily between mosquitoes and birds in a bird-to-mosquito cycle (Kilpatrick et al. 2007). After being bitten by an infectious mosquito, most birds and mammals become infected. Many die within 4–8 days, but if they survive, the antibodies confer long-lasting protection from reinfection. West Nile virus has not been reported in sharp-tailed grouse, but has been reported in greater prairie-chickens and sage-grouse (Center for Disease Control, http://www.cdc.gov/ncidod/dvbid/westnile /birdspecies.htm). It has been reported in other bird species in Washington, including in Spokane County, and in mosquitoes in Grant County, but not yet in Lincoln or Okanogan counties. West Nile virus began causing mortalities of sage-grouse in other western states in 2003. Arthropod sampling in Wyoming indicated the most likely vector was the mosquito, *Culex tarsalis* (Naugle et al. 2005). The virus caused a high rate of mortality in a greater sage-grouse population in Wyoming (Naugle et al. 2004), and lab experiments confirmed that greater sage-grouse were highly susceptible to infection, and it is usually fatal (Clark et al. 2006). At study sites in Wyoming, Montana, Colorado, and California where sage-grouse were being monitored, survival of females was 10% lower at 4 sites with confirmed West Nile virus mortalities, than at 8 sites with no West Nile virus detected (Naugle et al. 2005). Radio marked sage-grouse in the Powder River Basin of Wyoming experienced 25% mortality from West Nile in 2003, but the percentage dropped to 10% and 2% in the cooler summers of 2004 and 2005; mortality increased again in the warmer summer of 2006 (USGS National Health Center 2006). If West Nile virus affects sharp-tailed grouse in significant numbers, the consequences for small populations could be very serious.

Collisions. Sharp-tailed grouse are sometimes injured or killed by flying into powerlines and fences (Aldous 1943). In Utah, Hart et al. (1950) found the bodies of 20 sharp-tailed grouse ≤91 m (100 yd) from newly erected telephone lines. Marking wires and fences with flagging or plastic markers may help minimize accidents. We have no information to suggest that accidents are currently an important source of mortality for sharp-tailed grouse in Washington, but at least one translocated greater sage-grouse was killed by a collision with a fence (M. Atamian, pers. comm.). As noted by Wolfe et al. (2007), most grouse killed or injured in collisions with fences would not be detected without intensive monitoring. Wolfe et al. (2007) reported that fences accounted for 33% of 260 mortalities for which a cause could be assigned of radio-tagged lesser prairie-chickens during a 5 year period in Oklahoma and New Mexico. The proportion of mortalities from collisions was higher in Oklahoma (42%) than in in New Mexico (14%); females were three times more likely to die as a result of collisions in Oklahoma due to a much higher density of fences, powerlines and roads (Patten et al. 2005). Females seemed to be more susceptible than males, and 2 females were found dead on their nest after being injured in collisions. Additional birds were injured and unable to fly and extremely vulnerable to predation. Moss (2001) estimated that mortalities of female capercaillie (*Tetrao urogallus*) from fence collisions in Scotland were largely responsible for an 18% annual decline, and without fence deaths the female population could have increased 6% per year; he predicted the capercaillie would again be extinct in Scotland. It is unknown whether sharp-tailed grouse are as susceptible to fence collisions as sage-grouse, prairie-chickens or capercaille.

Roads can be a source of occasional mortality (Aldous 1943). Automobiles were responsible for 2 of 10 cases of mortality in a Montana study not associated with trapped birds on leks (Brown 1961). Buss (1984) recorded 18 sharp-tailed grouse killed on a Montana highway during an unusual southward movement in November 1978. He believed that many more dead birds were likely removed by scavengers.

Cultivation. Agricultural fields can be a dangerous attraction to sharp-tailed grouse. Females occasionally build nests in grain stubble or cultivated fields, but the nests are destroyed by plowing and both females and chicks are sometimes killed (Hart et al. 1950, Hillman and Jackson 1973). Hart et al. (1950) reported that in Utah during 1937–1939, 4.7% of females and 1% of juveniles in 150 broods were killed by farm implements. Plowing destroyed 82% of 35 nests in stubble fields and mowing destroyed 53% of 67 nests in alfalfa (Hart et al. 1950). Bernhoft (1969) indicated one brood was likely killed by the removal of cover by haying at a time of severe weather; he suggested that haying in early July was an important limiting factor in southwestern North Dakota. Historically, when summer fallow came into widespread use, the plowing and burning of stubble fields in spring destroyed many nests and led to the rapid decline of sharp-tailed grouse in agricultural areas of Washington (Dice 1918, Myers 1948, Buss and Dziedzic 1955). This remains a problem in Washington, but it's not known how widespread. A lek was discovered by a farmer in Okanogan County in 2009 while cultivating a field; the birds returned to display after the field was tilled, but it's not known if any nests were present in the surrounding area and destroyed during plowing (J. Heinlen, pers. comm.).

Most recent studies indicate females usually select grassland for nesting, alfalfa or hay fields are sometimes used, but stubble fields are only occasionally used for nesting (Christenson 1970, Bernhoft 1969, Meints 1991, Giesen 1997, McDonald 1998). However, hayfields that are cut for hay attract nesting females and mowing can destroy eggs and young chicks (Bernhoft 1969).

Insecticides and toxins. Pesticides sprayed on or near areas occupied by sharp-tailed grouse may cause mortality. McEwen and Brown (1966) studied the effects of dieldrin and malathion on sharp-tailed grouse, two insecticides used for grasshopper control. Dieldrin is a highly toxic and persistent organochlorine pesticide that is no longer approved for use in the United States. Sharp-tails were administered dosages of 170–300 mg/kg malathion, and 6 of 19 birds died; the LD_{50} appeared to lie between 200 and 240 mg/kg (McEwen and Brown 1966). Grouse exposed to sublethal insecticide intake may be more vulnerable to predation because alertness and flight capability were negatively affected (McEwen and Brown 1966).

Greater sage-grouse died after feeding, roosting, and loafing in alfalfa fields sprayed with dimethoate (Blus et al. 1989). In 1985, predators were attracted to the dead and incapacitated grouse. Of about 200 grouse that were present when a field was sprayed, 63 were later found dead. Based on a sample of 43 radio-tagged birds, there was a 25% probability of dying from pesticide poisoning during the 72 day study. Sage-grouse that occupied potato fields sprayed with methamidophos also died or suffered adverse affects (Blus et al. 1989). Dimethoate and methamidophos are organophosphate insecticides used on a variety of crops. Sub-lethal doses of insecticide may increase the rate of mortality from diseases or parasites. Bobwhite quail fed the insecticide Sevin at rates of single doses from 2.5 to 50 μg were more susceptible to the parasites that carry blackhead disease and experienced high rates of mortality (Zeakes et al 1981, *in* Peterle 1991).

All birds are susceptible to lead poisoning and although it has not been diagnosed in sharp-tailed grouse, several gamebird species have been poisoned by spent lead shot, including ruffed grouse, chukar, gray partridge (*Perdix perdix*), ring-necked pheasant, and quail (*Callipepla squamata*, *Colinus virginianus*; Locke and Friend 1992, Walter and Reese 2003, Fisher et al. 2006, Schulz et al. 2006, Pain et al. 2009).

Demographics, Density, and Population Dynamics

Bergerud (1988b:578) listed six parameters that affect the number of grouse each year: percentages of females nesting and re-nesting; clutch size; nesting success; chick survival in summer; juvenile survival in winter; and, the mortality rate of adults. Normally, all female sharp-tailed grouse attempt to nest. If the mortality rate in winter remain relatively constant, the size of the population each year would depend on reprodcutive success (Bergerud 1988b).

Sex ratio. There is no evidence that sharp-tailed grouse sex ratios at hatch differ from 1:1, and no clear evidence of a consistent bias of sex ratios in juveniles or adults based on trapping or hunter harvest. There may however, be local or regional differences by sex in mortality rates due to predation or harvest. Bergerud (1988b:624) states that adult male:female ratio is commonly 55:45, but the data from the 4 studies cited do not seem to support this generalization. The studies with the largest sample sizes have the most even sex ratios (51 and 52% male; Kobriger 1981, Robel et al. 1972). In one study, the pooled sample was 52% male, but Robel et al. (1972) reported that the trapped birds favored males (57%) in one study area and females in the other (58%), suggesting differential trapability, or mortality. Giesen (1997) reported that among 93 adults killed, 54.8% were females, but the sample was not adequate to be statistically significant, and he concluded there was no evidence that sex ratios of harvested birds differ markedly from 1:1 (Geisen 1997).

Population density. In Washington, Hofmann and Dobler (1988a) estimated a winter density of about one sharp-tailed grouse per 3 ha (7.4 ac) in 340 ha of riparian and deciduous habitat within 5 km of active leks in Lincoln, Douglas, and Okanogan counties. In Colorado, Rogers (1969) used lek counts to estimate an overall spring density of 22–32 ha/bird in good habitat, to 86–259 ha/bird in low quality habitat. In Idaho, Ulliman (1995) estimated density of 77–186 ha/bird for the Curlew Valley, and 67–128 ha/bird in the Pocatello Valley. Ulliman (1995) calculated densities for the Curlew Valley of 74–162 ha/bird in 1974 after a mild winter, and 52–802 ha/bird in 1975 after a harsh winter, based on data in McArdle (1977). Several studies of plains and prairie sharp-tailed grouse report densities ranging from 4–370 ha/bird (Ulliman 1995).

Population cycles. Regular cycles of abundance and scarcity have long been recognized in northern populations of grouse, snowshoe hares (*Lepus americanus*), and their predators, but there is no consensus on their cause. Among grouse species, this roughly 10-year cycle is most pronounced in northern populations of ruffed grouse and ptarmigan (Bergerud 1988b, Lindstrom 1994). Sharp-tailed grouse do not exhibit clear cycles of abundance in Washington, but may have historically when they were much more abundant.

Cyclic populations are found in areas of extensive blocks of habitat and at northern latitudes where there are fewer predator species. In areas that formerly exhibited cyclic populations of ruffed grouse, but have undergone extensive habitat change or fragmentation, such as in New York, New Brunswick, and Maine, cycles have dampened or disappeared (Bergerud 1988b, Moss and Watson 2001). Habitat fragmentation can result in dispersal into sink habitats, and increases in generalist predators (Moss and Watson 2001). Bergerud (1988b) summarized data showing that a boundary between cyclic and noncyclic populations of sharp-tailed and ruffed grouse runs along the southern boundary of aspen parkland habitat from Alberta to Minnesota. For example, populations of sharp-tailed grouse in relic blocks of habitat scattered among agricultural lands in Manitoba do not cycle (Bergerud 1988b). However, lek count data from the Crex Meadows area in Wisconsin appears to exhibit a cycle (Evrard et al. 2000), apparently contradicting the pattern reported by Bergerud (1988b). Williams et al. (2004b) analyzed 27 long-term data sets for ruffed grouse, sharp-tailed grouse, and greater prairie-chickens and concluded that population cycles collapsed from north to south due to a lengthening of the cycle period. They state this result was in contrast to studies that suggest cycles in Europe shortened from north to south and eventually collapsed in southern populations (Williams et al. 2004b).

Diet

Plants comprise most of the diet of sharp-tailed grouse year-round. All sharp-tailed grouse consume insects, particularly grasshoppers, ants, and beetles, when available, but insects comprise only a small proportion of the diet of adults. In Washington, the spring diet of sharp-tailed grouse included grass blades, sagebrush buttercup (*Ranunculus glaberrimus*), common dandelion flowers (*Taraxacum officinale*), beetles, and grasshoppers (Jones 1966). Jewett et al. (1953) noted that in the Palouse region of Washington, sharp-tailed grouse congregated in canyons in winter, feeding on hawthorn fruits (*Crataegus douglasii*). Lord (1866:303-304) stated that the principal summer and fall foods of sharp-tailed grouse near Fort Colville, in present day Stevens County, were common snowberry (*Symphoricarpos albus*), kinnikinnik (*Arctostaphylos uva-ursi*), rose (*Rosa* spp.), and huckleberries (*Vaccinium* spp.). He also mentions finding wheat, insect larvae, grass seeds, and small wildflowers in their crops. Jones (1966) reported that sharp-tailed grouse consumed fewer insects than other species of prairie grouse. However, chicks in the first few weeks of life rely heavily on insects for food (Hart et al. 1950, Parker 1970, Bernhoft 1969, Johnsgard 1983). Chicks primarily consumed insects, particularly grasshoppers and beetles (and unidentified insects) until 4 to 5 weeks of age in Utah (Hart et al. 1950). Bernhoft (1969) reported a decline in the percent insect material in the diet of 56 immature sharp-tailed grouse in North Dakota from 100% at 2 weeks of age, to 26% at 11 weeks. Invertebrates provide much higher concentrations of methionine and cystine than vegetation, amino acids that are critical to plumage development (Hurst 1972, Wise 1982). Feeding experiments in gray partridge showed that growth and feather development is drastically slowed when fed a diet lacking insects (Potts 1986).

Recent studies indicate the importance of diet on survival. Goddard and Dawson (2009) reported that female body condition was a factor, although a minor one, in the probability of survival of their chicks during the first 14 days post-hatch. Juvenile lesser prairie-chickens that were heavier than average at 50-60 days, were more likely to survive the winter in Kansas (Pitman et al. 2006), and invertebrate biomass in brood habitat has been linked with juvenile body mass in lesser prairie chickens (Hagen at el. 2005b), and red grouse (Park et al. 2001). Gregg and Crawford (2009) reported a direct link between food resources, namely Lepidoptera larvae and slender phlox (*Phlox gracilis*), and survival of greater sage-grouse chicks and broods. Evidence from gray partridge and rock ptarmigan (*Lagopus muta*) suggest that maternal nutrition affects egg quality or clutch size (Rands 1988). The availability of preferred insects during the first 20 days post-hatch is an important factor in survival of gray partridge chicks and subsequent breeding densities (Rands 1988). Fertilization of plots led to increased production of larger broods and smaller territories in red grouse; whether as a result of improved female body condition, or if immigration and improved nesting cover were also important was unclear (Rands 1988).

In Idaho, fruit from shrubs and trees found in mountain and riparian habitat were consumed by sharp-tailed grouse during summer (Marks and Marks 1987a). The availability of forbs and perennial bunchgrasses declines during summer and when droughts occur (Sauer and Uresk 1976). However, stream drainages generally contain fruits and berries year-round; these drainages are important foraging areas for sharp-tailed grouse in late summer and during droughts (Hofmann and Dobler 1988b). Other foods eaten in the spring and summer include clover (*Trifolium repens*), goldenrod (*Solidago* spp.), Canadian hawkweed (*Hieracium canadense*), corn (*Zea mays*), gromwell (*Lithospermum* spp.), smartweed (*Polygonum* spp.), alfalfa, creeping barberry (*Mahonia repens*), yellow salsify (*Tragopogon dubius*), wheat, yarrow (*Achillea millefolium*), dock (*Wyethia amplexicaulus*), ants, and moths (Connelly et al. 1998).

Sharp-tailed grouse consume more agricultural grains, insects, and weed seeds during fall than other seasons (Marshall and Jensen 1937, Hart et al. 1950, Jones 1966). Jones (1966) listed grasshoppers, dandelion seeds, and grass leaves among important foods in fall. Based on 85 crops collected from hunter bags in northeastern Montana during 1976 and 1979, Mitchell and Riegert (1994) noted that samples were 34% grasshoppers by volume in 1976 when grasshopper populations were extraordinarily high, compared to 7% in 1979. Grasshoppers consumed were primarily *Melanoplus* spp, but included 22 species of Acrididae. Juniper cones (*Juniperus* spp.) and rose hips (*Rosa woodsii*) were the most abundant plant items consumed in 1976 by frequency and volume. Silver buffaloberry fruits (*Shepherdia argentea*) and skunkbush sumac (*Rhus aromatica*) were not detected at all in 1976, but were the most abundant plant items in 1979 (Mitchell and Riegert 1994). Yde (1977) obtained 103 crops from plains sharp-tailed grouse in September in northeastern Montana. Grasshoppers made up about 45% of the combined samples, but juvenile sharp-tailed grouse ate more than adults (56% vs. 30%). Most of the plant material was buffaloberry fruits the first year, and juniper berries (*Juniperus horizontalis*) the second year when buffaloberrries were not available (Yde 1977). Brown (1967a) noted that important items consumed in September in Montana included seed pods of prickly lettuce (*Lactuca serriola*), yellow salsify, and waste grain; later in the fall, fruits of chokecherry (*Prunus virginiana*) and serviceberry (*Amelanchier alnifolia*) were important, and in winter, buds, especially serviceberry were essential.

The winter diet of Columbian sharp-tailed grouse consists of: the buds of deciduous trees and shrubs, particularly serviceberry, chokecherry, hawthorn, water birch (*Betula occidentalis*), and quaking aspen (*Populus tremuloides*); fruits of hawthorn, juniper, wild rose, and snowberry; green vegetation at seeps (Jones 1966, Marks and Marks 1987a, Hofmann and Dobler 1988a, Leupin 2003). In Washington, Zeigler (1979) reported that the buds and branches of water birch were very important food items for sharp-tailed grouse during winter, but other species seemed to be preferred where available (M. Schroeder, pers. obs.). Hart et al. (1950) noted that in late fall and early winter in Utah, waste grains were an important part of the diet, but as snow accumulated, buds of serviceberry, chokecherry, and willow (*Salix* spp.), and rose fruits became more important. Marks and Marks (1987a) recorded feeding observations during 3 winters in western Idaho. Sharp-tailed grouse fed extensively on hawthorn fruits in December 1983- January 1984; the following winter (1984-85), the hawthorn fruits had been eaten by grasshoppers that were extremely abundant in late summer, so grouse fed on buds, particularly serviceberry and chokecherry. Grouse also fed on buds during 1985-86 when the hawthorn crop failed for unknown reasons. Serviceberry seemed to be preferred while bittercherry buds (*P. emarginata*), though abundant, were rarely eaten. Schneider (1994) reported sharp-tailed grouse eating midge galls (Diptera: Ceridomyiidae) in sagebrush and Russian olive fruits in the Curlew Valley of Idaho during winter; the crop of one bird contained >300 galls. Birds that remained in CRP fields during a mild winter in southeastern Idaho, likely survived on alfalfa, salsify, draba (*Draba* spp.), and other forbs, grasses and grains (Schneider 1994). Other fall and winter foods listed by Connelly et al. (1998) included sunflower (*Helianthus* spp.), goldenrod, and dock.

During cold conditions (<20° F) in Washington in 1996 or 1997, sharp-tailed grouse used snow burrows in unharvested food plots of wheat, barley, and triticale (M. Finch, pers. comm.). During a mild winter in which birds remained in CRP fields, birds selected grasses and forbs with higher than average fat, sodium, and potassium content (Schneider 1994). CRP fields provided foods with more protein, macro and trace elements, and less fiber, while shrub forages provided lower ash and higher gross energy. It was unknown why some birds moved into riparian and mountain shrub habitat, despite the availability of CRP that seemed to contain higher quality forage (Schnieder 1994), but the shrub habitats may have provided greater security cover.

Evans and Dietz (1974) analyzed the energy available from several foods in the winter diet of sharp-tailed grouse. They found that fruits of hawthorn, Russian olive, silver buffaloberry, and frozen snowberry provided a positive nitrogen balance indicating storage of protein in the body, while plains cottonwood buds (*Populus deltoides*), Wood's rose, and air-dried snowberry would not allow birds to maintain their weight. Hawthorn fruits were low in metabolizable energy and crude protein, but sharp-tailed grouse can maintain or gain weight on them because of the large quantity that they will consume. Silver buffaloberry was the best native food tested, being high in energy, it was readily eaten, and persisted on shrubs throughout the winter (Evans and Dietz 1974). Silver buffaloberry is not native to Washington; russet buffaloberry (*S. canadensis*) occurs in the Okanogan County in Washington; although reported to be eaten by grouse, it has not been reported in sharp-tailed grouse diets (Connelly et al. 1998).

Home Range, Seasonal Movements, and Dispersal

Home range. Home range size depends on topography, vegetative cover, season, and availability of food (Table 4). Sharp-tailed grouse have relatively small home ranges in the spring and summer (Giesen and Connelly 1993), but ranges are much larger in poor quality habitat. In Washington, spring home ranges of 3 males were 11 to 46 ha (27–114 ac) (Hofmann and Dobler 1988b). In Idaho, median home range size of 15 sharp-tailed grouse from spring to fall was 147 ha (364 ac) (Marks and Marks 1987a); they noted that home ranges were >2 times larger in an area that was heavily grazed, compared to a lightly grazed unit. Median home ranges were much larger in shrub-steppe than in mine reclamation areas in Colorado, particularly during a drought year (Collins 2004).

Daily and seasonal movements. Sharp-tailed grouse in Wisconsin moved up to several hundred meters between feeding and loafing areas and night roosts even though cover was similar (Gratson 1988). Sharp-tails also moved roost locations on successive nights, and generally moved to a new location each day and night. Gratson (1988:188–189) speculated that these movements were an adaptation to confound hunting efforts of predators. Daily movements of both sexes were <300 m during summer (Gratson 1988). Median daily winter movements of Columbian sharp-tailed grouse in southern Idaho were 221 m for females and 286 m for males (Ulliman 1995). Sharp-tailed grouse in Utah moved shorter distances on a daily basis in spring and summer than in fall and winter because food and cover are readily available near leks, nests, and brood-rearing areas (Hart et al. 1950). In summer, daily movements were <100 m to 400 m (methods, *n* and sex not given) in Utah (Hart et al. 1950), and < 100 m for broods of radio- marked females in Idaho (Meints et al. 1992). Apa (1998) reported that median daily movement of females with broods in the Curlew Valley, Idaho was 86 m/day (37–154 m, *n* = 13), and 98 m/day (52–340 m, *n* = 7) for females without broods.

From the spring through the autumn, most sharp-tailed grouse remained close to the lek where they were captured. Female sharp-tailed grouse often nest within 2 km of their lek of capture (Gratson 1988, Meints 1991, Giesen 1997, Apa 1998, McDonald 1998, Collins 2004, Boisvert et al. 2005). In Washington, all 54 radio-tagged females moved <3.5 km from their lek of capture to their nest site, except for two females that moved 6.7 km and 7.0 km (McDonald 1998). The mean distance from a female's initial nest to her renest was 1,121 m (range 55–3150 m, *n* = 14). Nesting success seemed to affect the distance between nests of successive years. In 1996, 3 females nested an average of 403 ± 28 m (range 358–453) from their 1995 successful nest, but 4 females nested an average of 2,521 ± 1,492 m (range 414–6,912) from their previous unsuccessful nests, but the sample sizes were small and the difference was not statistically significant (McDonald 1998).

In one Colorado study, 96% of females raised their brood within 1.4 km of where they nested (Boisvert et al. 2005). Boisvert et al. (2005) reported that 85% of birds remained within 2.0 km of the lek of capture, and 90% of females located on nests were found within 2.5 km of the lek of capture. During the summer-fall period, 96% of males remained within 2.0 km of their lek (Boisvert et al. 2005). In an earlier Colorado study, >90% of telemetry locations of 38 grouse during April–December were within 2.0 km, and 95% were within 3 km of the lek of capture (Giesen 1997); males remained closer to leks in the spring and summer than did females. Females with broods occasionally make long distance movements,

Table 4. Seasonal home range sizes of Columbian Sharp-tailed Grouse.

Season / Location and study	*N* and sex or age[a]	Median home range (ha)	Estimation method
Year-round			
Lincoln County, Washington			
Atamian (unpubl.data)[b]	26f	1,110[c]	100% minimum convex polygon
	42m	1,480[c]	
	50a	1,260[c]	
	18y	1,540[c]	
Spring			
North-central Washington			
Hofmann and Dobler (1988b)	3m	22.4	100% minimum convex polygon
Spring-fall			
Western Idaho			
Marks and Marks (1987a)	13m, 2f	147	100% minimum convex polygon
Northwestern Colorado			
Geisen (1987)	13m, 7f	80	100% minimum convex polygon
Collins (2004)			95% fixed kernal, least squares cross-validation
Shrub-steppe, 2001	18f	246	
Shrub-steppe, 2002	25f	1,168	
Mine reclamation, 2001	13f	75	
Mine reclamation, 2002	14f	69	
Summer-fall			
Northwestern Colorado			
Boisvert (2002)			95% fixed kernal, least squares cross-validation
Mine reclamation	34[d]	75	
CRP	20[d]	112	
Pooled	54	86.3	
Winter			
Northwestern Colorado			
Boisvert (2002)	6f	185	95% fixed kernal, least squares cross-validation
	5m	337	
Southeastern Idaho			
Ulliman (1995)			90% Epanechnikov adaptive kernal
1992	3f	44	
1992	6m	140	
1993	8f	177	
1993	3m	313	

[a]m = male, f = female, a = adult, y = yearling.
[b]This data is from translocated birds released in Lincoln County.
[c]Mean home range
[d]Sex not specified by habitat; estimate included 18 males, 36 females.

for example, a brood suddenly moved 28 km in its fifth week after hatch (Schiller 1973); Bergerud and Gratson (1988) suggest that such sudden movements may result from an encounter with a predator. One banded bird in North Dakota moved 93 km (58 miles) in 22 months (Aldous 1943). Robel et al. (1972) reported that a banded juvenile female moved 148.8 km.

Sharp-tailed grouse do not regularly migrate south of their breeding range, but exhibit a limited migration in which some birds move between breeding and wintering sites, and others remain near breeding sites throughout the year. The lack of consistent southward or downslope movements, suggested that sharp-tailed grouse were not seeking milder climatic conditions for wintering. Movements to wooded wintering areas were downslope in some locations, and upslope in others. Several studies reported that sharp-tailed grouse travel an average of 1.6 to 8 km from leks to winter sites (Janson 1950, Hamerstrom and Hamerstrom 1951, Marks and Marks 1987a, Gratson 1988, Meints 1991). In Washington, sharp-tailed grouse moved up to 14 km (8.5 miles) between breeding and wintering ranges (Schroeder 1994), but the average was 2.8 km for 41 males and 4.4 km for 28 females (Schroeder 1996). In Idaho, Marks and Marks (1988) located most sharp-tailed grouse in winter ≤2 km (1 mi) from the lek used in spring, and Ulliman (1995) reported that only 16% of birds moved >4 km from their lek of capture. Meints et al. (1992) considered the area ≤6.5 km (4 mi) around each lek as potential wintering area. Movements in winter are likely affected by weather and its affect on food availability (Hart et al. 1950); during a mild winter with little snow, sharp-tailed grouse in southeast Idaho remained in CRP fields instead of moving to more typical wintering habitat (Schneider 1994).

McDonald (1998) noted that females (n = 6) on the Colville Reservation moved longer distances (up to 11 km; 5.5 vs. 1.0 km) than males (n = 2) to winter habitat that appeared no better than winter habitat much closer to their summer range; however, sample sizes were small. McDonald's (1998) observations agreed with that of Ulliman (1995) and Collins (2004), who both speculated that females may move further to avoid competition with male sharp-tailed grouse or to avoid predators that would be attracted to large winter flocks, particularly when feeding in the upper branches of deciduous shrubs. They suggested that sharp-tails may disperse across available wintering habitat to improve survival.
Giesen and Connelly (1993) suggested that where winter foods are limited, Columbian sharp-tailed grouse are forced to move further to winter habitats. In a Colorado study, however, Boisvert et al. (2005) reported that 87% of radio-marked birds wintered >10 km from where they were trapped (median 21.5 km, range 3.1– 41.5 km, n = 30) despite the abundance of suitable wintering habitat near breeding sites; there was no difference between sexes in the distances moved.

Seasonal migrations of some distance by sharp-tailed grouse apparently occurred historically, but either no longer occur in southern subspecies, or distances are shorter (<34 km, 21 mi,) due to habitat changes (Connelly et al. 1998). Long distance movements may still occur in northern subspecies, but there are few data (Connelly et al. 1998). Hamerstrom and Hamerstrom (1951) reviewed available data on seasonal movements and noted that, "Fifty to a hundred years ago… there were conspicuous seasonal movements between breeding and wintering areas." Hamerstrom and Hamerstrom (1951) concluded that seasonal movements between summer and wintering areas are shorter than they were historically because the breeding habitat on prairies further from wintering habitat has largely been eliminated by agriculture. Dawson and Bowles (1909) noted that the availability of haystacks and grain in stubblefields allowed at least some sharp-tailed grouse in Washington to forego the seasonal movement to wooded draws.

Spectacular one-way mass movements of sharp-tailed grouse have been reported. Snyder (1935, *in* Tsuji and DeIuliis 2003) and Cade and Buckley (1953) describe two cases of autumn mass emigration. Hamerstrom and Hamerstrom (1951), Buss (1984), and Cade and Buckley (1953) recount what Buss (1984) called "the great 1932 sharp-tail exodus" from the vicinity of James and Hudson bays originally described by Snyder (1935). Small (4 birds) and large flocks (>100 birds) moved steadily through the western James Bay region for 3 consecutive weeks (Snyder 1935). Snyder (1935) mentioned evidence of two other such mass emigrations that occurred in 1865 and 1896 in the same region. The 1932 movement occurred at a time when large areas of habitat had been defoliated by the birch skeletonizer moth (*Bucculatrix canadensisella*) (Buss 1984). Cade and Buckley (1953) describe a mass emigration in Alaska in 1934. Sharp-tailed grouse populations were very high in the vicinity of Fairbanks and College, Alaska in the early 1930s. One day in October 1934, a huge number of grouse suddenly arose en masse and flew off to the south; the flock was estimated to be 2–3 mi long by ½ mi wide. Rowan (1948, *in*

Hamerstrom and Hamerstrom 1951) also described a mass flight in Alberta in 1942. Buss (1984) describes an apparent southward movement of sharp-tailed grouse observed along 436 km of U.S. Highway 12 in Montana in November 1978.

Natal dispersal. Natal dispersal distance, or the distance between site of hatching to the site of first breeding, has important implications for connectivity of populations and gene flow. For female sharp-tailed grouse, natal dispersal distance would be the distance between their natal nest to their initial nest the following spring, and for a male, it would be the distance from hatch site to the lek where it established a territory. In most avian species, median distances of natal dispersal are greater for females than males (Clarke et al. 1997). Several studies report distances moved by sharp-tailed grouse to wintering areas, but none report natal dispersal distances. However, data from lesser prairie-chickens are consistent with most species; 17 of 27 juvenile males moved 0.0–0.7 km, and 3 of 5 females moved >3.2 km between their autumn/winter range and their first breeding area (Copelin 1963). Jamison (2000) reported that two males banded as chicks were captured on a lek in autumn 2.2 and 2.3 km from their hatch sites. Data from sage-grouse, ruffed grouse, dusky grouse, spruce grouse, and white-tailed ptarmigan also indicate that natal dispersal distances are typically greater for females (Dunn and Braun 1985, Schroeder 1985, Small and Rusch 1989, Clarke et al. 1997).

Fidelity to leks and wintering areas. Most male sharp-tailed grouse return to the same lek or lek complex in the fall and again the following spring (Evans 1969, Bergerud 1988a, Giesen and Connelly 1993). Males exhibit greater fidelity to leks than females (Boisvert 2002). Males probably return to the same lek because they are familiar with the site and rival males there, and because they want to maintain or improve their territorial positions (Giesen 1987, Bergerud 1988a). Adult males may occasionally establish new leks, as leks are abandoned because of habitat changes, decline of local populations, or other unknown reasons (Rippin and Boag 1974, Sexton and Gillespie 1979, Gratson 1988, Berger and Baydack 1992).

Columbian sharp-tailed grouse in Colorado seemed to show some fidelity to traditional winter areas. Four grouse monitored for 2 winters in Colorado, returned to the same area, and observations of radioed birds subsequent to the study suggested use of traditional winter ranges (Boisvert et al. 2005). Birds captured from the same breeding population moved to the same general wintering area during successive winters (Collins 2004). The median distance between the home range centers for 3 of 6 sharp-tailed grouse monitored in successive winters was 2.4 km (Collins 2004).

Ecological Relationships

Interspecific competition. Little information is available on the impact of interspecific competition in grouse species. In Washington, the range of Columbian sharp-tailed grouse overlaps those of dusky grouse and greater sage-grouse. Sharp-tailed grouse also share range with non-native gamebirds, including gray partridge, chukar, California quail (*Callipepla californica*), ring-necked pheasant, and wild turkey. Potential competition for nesting and wintering sites and interference with reproduction may be the most likely forms of competition. Introduced gamesbirds may also support a higher year-round density of predators that could prey on sharp-tailed grouse.

Vance and Westemeier (1979) expressed concern about disruption of prairie-chicken leks by aggressive pheasant cocks and Sharp (1957) noted that daily attacks by ring-necked pheasants drove prairie-chickens from long-established leks. Vance and Westemeier (1979) state that pheasant disturbance may be especially harmful to small leks, including the incipient leks of a reintroduction project. However, Sharp (1957) stated that sharp-tailed grouse defeated the larger cock pheasants in all encounters observed. He noted that from its aggressive crouch position, the sharp-tailed grouse darts under a pheasant to grab tail or rump feathers and hangs on stubbornly, frightening the pheasant into retreat (Sharp 1957).

The historical ranges of Columbian sharp-tailed grouse and greater sage-grouse overlapped in eight states, including Washington. R. Hoffman (pers. comm.) notes that it is common to find both species together in Colorado. Klott and Lindzey (1990) studied the habitat use of greater sage-grouse and sharp-tailed grouse broods in shrub-steppe in southcentral Wyoming. They found that sage-grouse and sharp-tailed grouse broods used somewhat different habitats; they do not state whether they ever found both species present at the same site, at the same time, or separated in time. Sharp-tailed grouse used mountain shrub and sagebrush/snowberry habitats found in the transition zone between sagebrush/grass and forest. Sharp-tailed grouse broods used sites with greater forb diversity, taller snowberry and sagebrush, and greater snowberry and grass cover than those used by sage-grouse (Klott and Lindzey 1990).

In the Curlew Valley of Idaho, Apa (1998) reported that there was minimal, or no competition for nesting habitat between greater sage-grouse and sharp-tailed grouse. Sage-grouse and Columbian sharp-tailed grouse partitioned nesting habitat somewhat by topographic and vegetation characteristics; sharp-tailed grouse did not nest on slopes >19%, whereas sage-grouse nested on slopes up to 30%; steeper slopes tended to be at higher elevations. Aside from the tolerance for steeper slopes, sage-grouse required higher sagebrush canopy cover; they nested under larger sagebrush plants and in areas of taller sagebrush. All but one sage-grouse (n = 38) nested under shrubs, primarily sagebrush, whereas 49% of sharp-tailed grouse nested under shrubs. Sharp-tailed grouse nests were found throughout the gradient of shrub canopy cover. The difference in use of slopes disappeared during brood rearing as sage-grouse used steeper slopes less, but sharp-tailed grouse broods moved to areas with higher cover values. Sharp-tailed grouse brood use was concentrated in areas with medium to high grass cover and taller sagebrush; sage-grouse broods used sites with lower grass cover. The broods of both species used sites with twice the cover of forbs (8%) as independent sites. If situations occur where forbs are limiting, interspecific competition for brood habitat could exist and limit the less competitve species (Apa 1998).

At the more mesic, higher elevation portion of the Columbian sharp-tailed grouse's range, there is overlap with dusky grouse during summer. R. Hoffman (pers. comm.) has observed dusky grouse males displaying on sharp-tailed grouse leks, where they were ignored by the sharptails. Dusky grouse occur in steppe communities out to 2+ km from the forest edge, and the two species seem to have very similar summer diet and brood-rearing habitat needs (Zwickel 1992). There is substantial seasonal overlap in the occurrance of sharp-tailed and dusky grouse in northern Douglas and Okanogan counties. Niche relationships between dusky and sharp-tailed grouse have not been studied. Dusky grouse are seasonal migrants that move to conifer forest for the winter.

Livestock and wild ungulates can negatively affect winter habitat by browsing deciduous woody cover. Even where livestock are excluded, efforts to restore woody riparian shrubs in Washington for sharp-tailed grouse winter habitat have often failed unless shrubs are protected from deer by fencing. Braun et al. (1991) described an apparent competitive relationship between elk and white-tailed ptarmigan in Colorado for willow.

Nest parasitism by ring-necked pheasants. Ring-necked pheasants have been documented parasitizing nests (i.e. adding eggs to a sharp-tailed grouse clutch) of plains sharp-tailed grouse. Pheasant parasitism of prairie-chicken nests can lead to the female abandoning her own clutch when the pheasant eggs hatch because pheasant eggs require only 23 days to hatch, while greater prairie-chicken eggs require 25 days (Vance and Westemeier 1979, Deeble 1996). Parasitism of greater prairie-chicken nests by pheasants in Illinois reduced egg hatchability (Westemeier et al. 1998b). Nest parasitism by pheasants may be less of a problem for sharp-tailed grouse beacause their incubation period is 21–23 days, although Boisvert

(2002) reported incubation of up to 26 days at a high elevation study area. Westemeier et al. (1998b) state that extirpations of remnant prairie-chicken populations attributed to interactions with pheasants have been reported in Wisconsin, Illinois, Indiana, and Michigan. Declines of other species attributed to interactions with pheasants include black grouse (*Tetroa tetrix*) and gray partridge. Westemeier et al. (1998b) speculated that suppressed hatchability of fertile host eggs may have been a factor. They do not recommend managing for pheasants in areas supporting remnant flocks of prairie-chickens. Only 3 of 75 lesser prairie-chicken nests were parasitized by pheasants in a southwestern Kansas study; 2 nests hatched eggs, but no pheasant chicks survived >9 days (Hagen et al. 2002). Hagen et al. (2007a) reported that pheasants and lesser prairie-chickens in the Kansas study area were largely spatially separated, with pheasants exhibiting a strong affinity for edge habitats while prairie-chickens were closely tied to large blocks of native prairie. They concluded that pheasants were having no measurable effects on nesting and brood-rearing habitat use or productivity of lesser prairie-chickens in southwestern Kansas. They cautioned, however, that additional habitat loss or fragmentation might favor pheasants and lead to nest site competition, nest parasitism by pheasants, and disease transmission that would negatively impact prairie-chickens (Hagen et al. 2007a).

Sharp-tailed grouse as prey in grassland communities. The historical abundance of sharp-tailed grouse on grasslands in Washington suggest that eggs, young chicks, and adult sharp-tailed grouse were an important seasonal prey of many species and were a significant part of grassland communities.

HABITAT REQUIREMENTS

Vegetation and precipitation zones. Good sharp-tailed grouse habitat contains perennial bunchgrasses, forbs, and key species of deciduous shrubs, typically in steppe, (shrub-steppe and meadow steppe), mountain shrub, and riparian deciduous habitats. Meadow steppe is a descriptive term for plant communities that are dense at ground level, support many grasses and forbs, and have few shrubs. Meadow steppe is barely dry enough to exclude trees and generally has meadow characteristics (Franklin and Dyrness 1973, Daubenmire 1970). Typical meadow-steppe communities in Washington have several grasses, including bluebunch wheatgrass (*Pseudoroegneria spicata*) and Idaho fescue (*Festuca idahoensis*) (Daubenmire 1970). Shrub-steppe communities in Washington contain a conspicuous, but discontinuous, layer of big sagebrush (*Artemisia tridentata*), three-tipped sagebrush (*A. tripartita*), or bitterbrush (*Purshia tridentata*), and various perennial grasses and forbs (Daubenmire 1970). Of the vegetation zones mapped by Cassidy et al. (1997), the most important for sharp-tailed grouse were probably the Palouse,

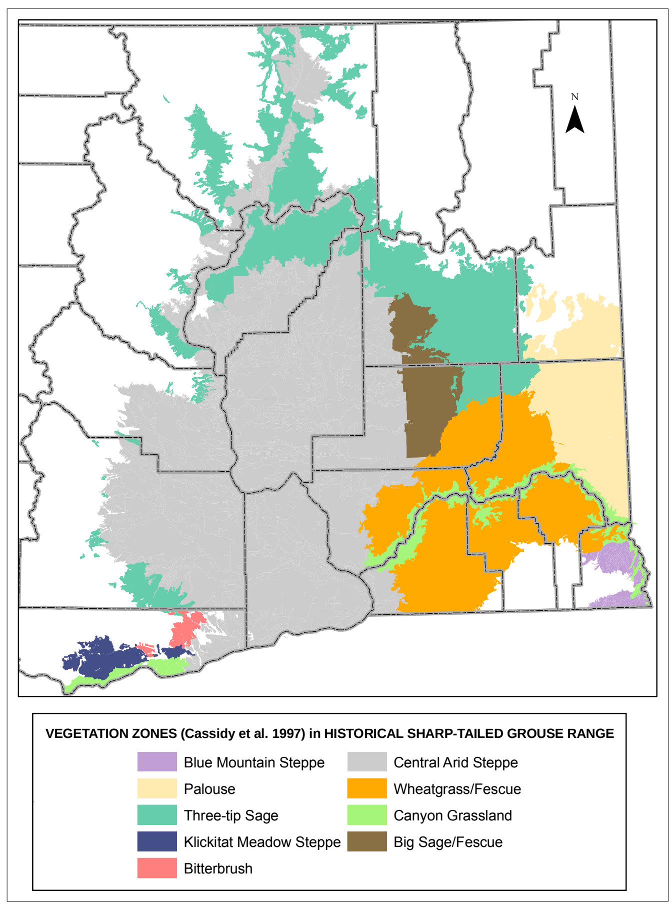


Figure 6. Steppe Vegetation Zones (Cassidy et al. 1997) in the historical range of Columbian Sharp-tailed Grouse in Washington.

Wheatgrass/Fescue, Three-tip Sagebrush, Big Sage/Fescue, and Central Arid Steppe (Fig. 6). The highest densities of sharp-tailed grouse were probably in the more mesic grassland and meadow steppe types. Most historical records are from areas that average ≥11 inches of annual precipitation (Fig. 7). The Palouse and Wheatgrass/Fescue zones were largely converted to cropland long ago, but may provide excellent potential for habitat restoration.

Dice (1916) reported that in Walla Walla and Columbia counties, sharp-tails were most abundant in bunchgrass prairie, and he included them as "reported--resident" in the sagebrush habitat of western Walla Walla County. Some of the Central Arid Steppe, or Wyoming Big Sage-Warm Potential Vegetation Type (Bunting et al. 2002), is likely too dry and monotypic to support the high vegetative diversity needed for year-round use by sharp-tailed grouse, except where it includes wetlands, springs, or other sites with more mesic grassland and shrubs. These drier areas may support seasonal use, but generally in much lower density. With the exception of a few historical records from the Yakima Valley, we have very few records for the driest areas of the Columbia Basin (<11" precip zone), and most of these are near rivers. Hillman and Jackson (1973) indicated that "prime" sharp-tailed grouse habitat in South Dakota occurred in the 15−19" precipitation zones.

Productive sharp-tailed grouse habitat contains perennial bunchgrasses that are well developed, and many species of forbs and shrubs (Oedekovan 1985, Marks and Marks 1987a, Meints 1991). They primarily choose habitat based on height and density of vegetation, and secondarily on species composition (Kirsch1969, Hofmann and Dobler 1988b, Stralser 1991). Sharp-tailed grouse often use areas near edges where two habitats meet, especially when the area contains a mixture of vegetative species and structure (Marks and Marks 1987a, Meints et al. 1992, Stralser 1991). McDonald (1998) concluded that seasonal habitat use by sharp-tailed grouse seems to be driven by the preferences and availability of foods. Grasses and forbs are important and preferred foods and birds are found where they are available. When grass and forbs were not available, sharp-tailed grouse fed on wheat. Where wheat was not available, or when it became covered with snow, sharp-tails shifted to riparian shrubs to feed on the catkins of water birch.

Mountain shrub communities are important Columbian sharp-tailed grouse habitats in Colorado, Wyoming, Idaho, and Utah, particularly in winter. Giesen and Connelly (1993) define mountain shrub as upland communities dominated by >1 deciduous shrub species including serviceberry, snowberry, common chokecherry, and Gambel oak (*Quercus gambelii*). Little of this upland habitat exists today in Washington, where sharptails depend on riparian deciduous trees and shrubs during winter (McDonald 1998). Sharp-tailed grouse historically probably used the shrub communities on north slopes and other relatively moist sites in the Palouse region, that included Douglas hawthorne, chokecherry, snowberry, and roses (*Rosa woodsii, R. nutkana*) (Daubenmire 1970, Aller et al. 1981). These shrub communities were of the *Festuca idahoensis-Symphoricarpus albus* and *Crataegus douglasii-Symphoricaprus albus* habitat types (Daubenmire 1970).

Slope, aspect, and elevation. Sharp-tailed grouse are found at elevations of 300 to 1,350 m (984 –4,429 ft) in Washington, but >2,900 m (9,000 ft) in Colorado (Evans 1968). Hart et al. (1950) reported that sharp-tailed grouse were found on rolling hills and benchland, extremely steep ground was seldom used in Utah. Hart et al. (1950) suggested that topography had little effect on sharp-tailed grouse except as it affects vegetation, snow cover, agriculture, and the siting of leks. Apa (1998) reported that none of 51 sharp-tailed grouse nests found in the Curlew Valley of southeastern Idaho were on slopes >19%. In western Idaho sharp-tailed grouse used slopes of up to 47% during summer, but 95% of use was on slopes <30%; slopes were used in proportion to availability 2 out of 3 years (Marks and Marks 1987a, Saab and Marks 1992). Birds generally only used the portions of steep slopes fairly close to flat areas at the top or bottom of slopes. Nine nests were found on gentle slopes, and nest placement showed no preference for

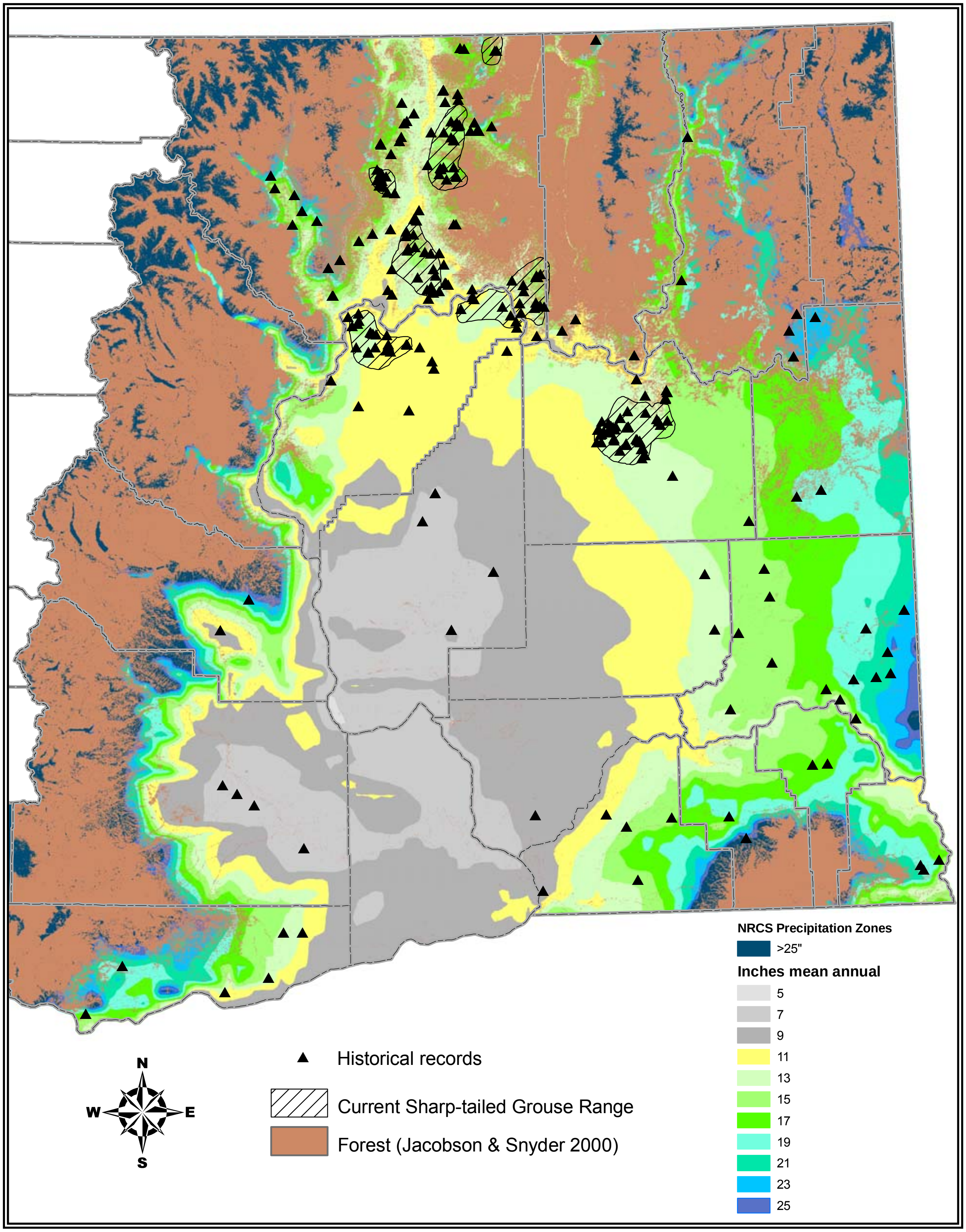


Figure 7. The historical and recent distribution of Columbian sharp-tailed grouse in Washington in relation to mean annual precipitation (Washington Department of Fish and Wildlife and Natural Resources Conservation Service data).

aspect (Marks and Marks 1987a). Radio-tagged birds showed no strong preference for aspect; northern aspects were selected and western aspects avoided during two years, but southern aspects were selected during one of three years. Giesen (1997) noted that sharp-tailed grouse in Colorado most often used areas with high shrub densities, generally on north and east slopes, but he did not test for selection of aspect. Sharp-tailed grouse seem to show preference for northern aspects in some study areas probably due to greater vegetation growth, residual cover, and moisture. Conover and Borgo (2009) reported that sharp-tailed grouse in Idaho selected loafing sites on windward slopes or ridgetops where wind velocity, updrafts, and turbulence would make them more difficult to be find for olefactory predators.

Water. Sharp-tailed grouse do not usually drink water or make movements to available surface water, but apparently rely on dew and succulent vegetation for moisture (Oedekoven 1985, Prose 1987). Saab and Marks (1992) saw no evidence that sharp-tailed grouse sought free water. Sharp-tailed grouse were rarely found near open water in Idaho, even in summer (Parker 1970, Marks and Marks 1987a, Saab and Marks 1992). Mesic sites that maintain green vegetation during summer may be important sources of moisture (Connelly et al. 1998). Sharp-tailed grouse may obtain water by eating snow in winter (Aldous1943).

Spring, Summer, and Fall Habitat

During spring and summer, sharp-tailed grouse in Washington primarily use grassland habitats; shrubby habitats are used primarily as escape cover. CRP, grass/forb, and grass/shrub cover types accounted for >80% of female locations and >65% of male locations, while these cover types accounted for only 11% of the landscape; sagebrush was used less than expected (McDonald 1998). In western Idaho, mountain shrub, riparian, and bitterbrush habitats were used primarily as escape cover during spring and summer (Saab and Marks 1992). As summer progressed, the use of grass/shrub and riparian/mountain shrub cover types increases, as grass and forbs dry out, and fruits become available (Saab and Marks 1992, McDonald 1998). An increase in the use of shrubs like sagebrush may reflect a need for shade in the hottest summer period.

Lek Sites. The focal point of the breeding season is the lek. Male sharp-tailed grouse prefer sites that are flat and open with good visibility that enables them to see predators and be seen by females while displaying (Hart et al. 1950, Zeigler 1979). Leks probably rarely form or persist unless suitable nesting habitat is nearby; females generally select nest sites <2 km from the lek at which they breed. Most leks are located on elevated ground, such as knolls and ridge tops (Fig 8), where vegetation is short (Rippen 1970, Zeigler 1979, Oedekoven 1985, Boisvert 2002), and the site may contain thin, rocky soils or clay pan (Rogers 1969). In addition to knolls or ridges, sharp-tailed grouse may establish leks on roads, airport runways, cropland, or native rangeland grazed by livestock (Hart et al. 1950,

Figure 8. Columbian sharp-tailed grouse habitat on Scotch Creek Wildlife Area, Washington.

Rogers 1969, Hillman and Jackson 1973, Oedekoven 1985). In southeastern Idaho, 58% of 50 leks were in CRP, 22% in sagebrush, 8% in pasture, 8% agricultural fields, and 4% in mountain shrub (Ulliman 1995).

Figure 9. Columbian sharp-tailed grouse habitat in the Greenaway Springs area, Colville Indian Reservation, Washington.

Nesting habitat. Females generally select nest sites near the lek at which they breed. In Washington, females nested an average of 1,387 (*n* = 37) and 1,886 m (*n* = 17) from their lek of capture on the Colville Indian Reservation and Swanson Lakes Wildlife Area (WLA), respectively (McDonald 1998). These means were not statistically different, but the median distances (855 vs. 2,134 m) indicated that females tended to nest closer to the lek on the Colville Reservation. McDonald (1998) suggested that this was probably due to higher quality and quantity of nesting habitat near leks on the reservation. In southeastern Idaho, Meints (1991) reported that 16 initial nests averaged 1.2 km from the lek of capture, and Apa (1998) reported a median of 1.4 km for 41 initial nests.

Whether an area is suitable for nesting and brood rearing depends on the amount, height, and density of vegetation, especially forbs and grasses. Much of the cover available at nest initiation is residual cover from the previous growing season (Meints et al. 1992). Grasses and forbs conceal the nest and provide shelter for the brood during spring and early summer (Marks and Marks 1987a, Meints et al. 1992, Giesen and Connelly 1993). Sharptails occasionally nest in agricultural fields when native vegetation is lacking (Hart et al. 1950, Zeigler 1979).

Figure 10. Columbian sharp-tailed grouse habitat in the Nespelem area, Colville Indian Reservation, Washington.

On the Swanson Lakes WLA and Colville Indian Reservation (Figs 9, 10), most females selected nest sites in homogenous grasslands or CRP (McDonald 1998). Of 17 nests on the Swanson Lakes WLA, 11 were in CRP, and 5 in grass/forb; no nests were found in sagebrush cover type, though it accounted for >80% of the available cover. On the Colville Reservation, 33 of 37 nests were in grass/forb; 3 were in grass/shrub, 1 in CRP, and 0 in sagebrush cover type (defined as >9% of available cover, McDonald 1998). Most nests were located at the base of a bunchgrass, or between two bunches; four nests were under sagebrush (McDonald 1998). In the Curlew Valley of Idaho, about half the nests were under shrubs, and one fourth each under forbs and grass; plant form chosen did not affect nest success (Apa 1998).

In contrast, Meints (1991) and Marks and Marks (1987a) reported the use of shrub habitats by Columbian sharp-tailed grouse in areas that were also predominantly shrubland in Idaho. The cover provided by shrubs, and the associated residual grass was essential for early spring nesting by plains sharp-tailed grouse in southern Alberta (Roersma 2001). Roersma (2001) described prime nesting areas as shrub cover with adequate amounts of grasses and forbs, with cover being 25–30 cm in height. He considered a 1:1:1 ratio of cover in shrubs, grasses, and forbs to be ideal.

Sharp-tailed grouse consistently nest in areas with higher cover compared to independent sites (Apa 1998, McDonald 1998, Boisvert 2002, Collins 2004). In Washington, females selected nest sites with greater overhead cover, higher visual obstruction, and litter cover, and less bare ground within 5 m of the nest than occurred randomly in available cover types (McDonald 1998). All cover variables were higher, and there was less bare ground at successful compared to unsuccessful nests. Similar to findings of Meints (1991) and Marks and Marks (1987a), 'visual obstruction' appeared to be the most important vegetation variable defining selected from random sites, and successful from unsuccessful nests (McDonald 1998). In the Curlew Valley of Idaho, nesting areas averaged 62% shrub cover; grass cover and sagebrush height were important variables predicting nest locations (Apa 1998).

Visual obstruction readings (VOR) are the height of a cover pole obstructed by vegetation (to the nearest 5 cm [2 in]) (Robel et al. 1970). VOR is often reported for the nest bowl, for the nesting cover around the nest, and paired random locations in the same cover type. VOR data can be confusing, because researchers have varied in sampling details, such as the height (observer's eye level) and distance from the nest that VOR was recorded. The timing of data collection is also important because the vegetation is taller later in the nesting season (Collins 2004). VOR at the nest site is indicative of the type of site suited for nesting, but data from a wider area of nesting cover may be more helpful to managers. Researchers also may not report any indication of variance, which can be important. For example, two fields may both have a mean VOR of 15 cm, but one supports nesting because of many sites with >30 cm, but the other does not because there is little variation to provide good nest sites (Table 5). In a habitat suitability index model (HSI) for the Columbian sharp-tailed grouse, Meints et al. (1992) reported mean VOR of residual vegetation for fields used for nesting and brood rearing in Idaho collected in June at a distance of 4 m from a predetermined point, and 1 m above the ground, as suggested by Robel et al. (1970). VOR for various types of nest/brood cover ranged from 19–57 cm, but they concluded that optimal for nesting and brood rearing habitat in Idaho was ≥25 cm (10 in), with suitability declining to zero at 10 cm. In Washington, McDonald (1998) reported that VOR measured 5 m from the nest and at paired random sites at a distance of 50-100 m within the same nesting cover type as the associated nest (p 45; McDonald does not state the height at which recorded, but cites Robel et al. 1979, suggesting 1 m was used). Data were collected 10-86 days after nest termination. Mean VOR at nest sites was 23.7 cm vs. 16.6 at random sites; there was no difference between nest and random points at distances of 5–20 m. VOR was higher at successful nests (27.9 cm) vs. unsuccessful nests (23.6 cm) at 0–5 m, and at 10–20 m from the nest (19.2 cm vs. 15.5 cm).

Brood-rearing habitat. Brood-rearing occurs during late spring and summer. Brood-rearing habitat contains diverse cover of shrubs, forbs, and bunchgrasses, where insects are abundant. In Washington,

Table 5. Visual obstruction (VOR; mean+SD), height of herbaceous vegetation, and forb cover in Columbian sharp-tailed grouse nesting and brood-rearing habitats.

Parameter	Vegetation measurement (cm)	Observation details	State	Study
VOR	23.7	All nests; 0–5 m, from 1 m height; 10-86 days after nest termination (successful nests: 27.9)	WA	McDonald (1998)
	16.6	Paired random sites		
	19.3+0.33	Within 20 m radius from nests from 1 m height		
	16.5+0.33	Paired random sites in same cover type		
	25+1.6	Nest and brood habitat; 4 m from 'nest point', 1 m height; June, mean of 4 study areas	ID	Meints (1992)
	29.9+12.6	1999: 1 m from nests at 1.5 m height,	CO	Boisvert (2002)
	12+7.9	Paired random sites in same cover type		
	33.3+14.6	2000: 1 m away from nests at 1.5 m height		
	10.0+6.8	Paired random sites in same cover type		
	49.9+15.2	1999: Brood-rearing sites,		
	44.1+18.3	Paired random sites in same cover type,		
	54.3+26.5	2000: Brood-rearing sites,		
	43.8+22.1	Paired random sites in same cover type,		
	48.9+21.1	Nests, 2.5 m away from 1.5 m height, in shrubsteppe or mountain shrub	CO	Collins (2004)
	43.6+29.7	Brood-rearing sites, 2.5 m away from 1.5 m height, in shrubsteppe		
Grass height	26.8+8.7	Successful nests	ID	Meints (1991)
	18.4+2.0	Unsuccessful nests		
	25.6, 41.9	Brood-rearing sites, 2 years		
	21.9+12.2	Nests sites in shrubsteppe or mountain shrub	CO	Collins (2004)
	19.1+5.7	Paired random sites in same cover type		
	24.8+8.1	Brood-rearing sites in shrub-steppe		
	19.2+6.1	Paired random sites in shrub-steppe		
	68, 93.5	Nests, 2 study years	CO	Boisvert (2002)
	84.7,64.6	Brood-rearing sites, 2 years		
Forb height	44, 31.6	Nests, 2 study years		
	11.2+3.6 9.9+2.8	Brood-rearing and random sites, shrub-steppe or mountain shrub	CO	Collins (2004)
Grass and forb height	53+7	Nest sites	ID	Apa (1998)
	40+7	20 m radius from nests		
% Forb cover	12.7+5.3%	Nest sites	WA	McDonald (1998)
	12.8+5.3%	Paired random sites in same cover type		
	15+5.8%	Brood-rearing sites	CO	Collins (2004)
	9.9+5.8%	Paired random sites in same cover type		

>75% of brood locations were in grass/forb (Colville Reservation), or grass/forb and CRP (Swanson Lakes WLA) cover types (McDonald 1998). Summer habitat in Colorado contained >70% shrub cover (Giesen 1987); most successful females raised broods within 1 km of their nests, indicating that they selected nest sites in or adjacent to suitable brood habitat (Boisvert 2002, Collins 2004). Brood-rearinghabitat in the Curlew Valley of Idaho was very similar to nesting habitat, except with greater cover values. Brood-rearing habitat also contained shrubs, forbs, and bunchgrasses in Idaho (Marks and Marks

1987a), Utah (Marshall and Jensen 1937, Hart et al. 1950), and Wyoming (Klott and Lindzey 1990). Females prefer to raise broods in areas with abundant forbs and diverse vegetation because these area contain abundant insects that chicks depend on for food (Bernhoft 1969, Marks and Marks 1987a, Klott and Lindzey 1990, Meints 1991). Some studies report an association of broods with habitat edges (Klottand Lindzey 1990, Meints 1991), but others found no relationship (Boisvert 2002).

Apa (1998) reported that brood-rearing areas had twice the forb cover (8%) of independent sites. Forbs typically found at brood sites included: fleabanes (*Erigeron* spp.), poverty weed (*Iva axillaris*), s tansyasters (*Machaeranthera* spp.), goldenrod, agoseris (*Agoseris* spp), hawksbeard (*Crepis* spp.), prickly lettuce (*Lactuca serriola*), skeleton plant (*Lygodesmia juncea*), common dandelion, and yellow salsify. Klott and Lindzey (1990) reported that key variables in distinguishing areas used by sharp-tailed grouse broods compared with greater sage-grouse broods, was the presence of oniongrass (*Melica* spp.) and sulphur-flower buckwheat (*Eriogonum umbellatum*).

Summer habitat used by females with broods may be different than habitat used by males or females without broods. In Idaho, Marks and Marks (1987a) reported that both male and female sharp-tailed grouse used areas containing more shrubs than random sites during summer, and McArdle (1977) found most grouse (77%) were in areas with 20 to 40% shrub canopy cover. In late summer and fall, sharp-tailed grouse females with broods in Colorado moved to riparian areas or mountain shrub cover type, where there was green vegetation, berries, and shade (Giesen 1987); green vegetation may be important sources of moisture.

Winter Habitat

Habitats with deciduous trees and shrubs are essential during winter because they provide cover, berries, seeds, buds, and catkins when the ground is snow-covered. In Washington, critical winter habitats are frequently in riparian areas. Some areas with suitable nesting and brood-rearing habitat may remain unused because the area lacks adequate winter resources. Standing wheat or spilled grain in fields is an important winter food source in some locations; standing wheat is important when spilled grain is covered by snow.

Sharp-tailed grouse often use winter habitat relatively close (≤6.5 km) to summer areas (Meints et al. 1992), but in some locations move >20 km to winter (Boisvert et al. 2005). Habitats with deciduous trees and shrubs located in riparian (Fig. 11) or mountain foothill areas provide essential food and cover for Columbian sharp-tailed grouse during winter (Marks and Marks 1988, Meints 1991, Giesen and Connelly 1993, Ulliman 1995). Ulliman (1995) concluded that riparian shrub habitat comprised only 2% of his study area, but received a disproportionate amount of use in most winters. The most important shrubs were serviceberry, chokecherry, and quaking aspen. Sharp-tailed grouse moved to deciduous trees and shrubs as snow depth increased in Idaho (Marks and Marks 1987a, 1988; Meints 1991, Ulliman 1995), Montana (Swenson 1985), Utah (Marshall and Jensen 1937), Colorado (Boisvert 2002), and Washington (Weddell et al. 1991b, McDonald 1998). During winter, sharp-tailed grouse often roost in woody vegetation (mostly shrubs) or under the snow (snow burrows) when deep, soft snow exists (Oedekoven 1985; Swenson 1985; Marks and Marks 1987a, 1988). Although snow depth that affected food availability caused grouse to move, they seemed otherwise unaffected by weather and cold temperatures, and they did not seem to select sites based on slope, aspect, or elevation (Ulliman 1995).

In Washington, sharp-tailed grouse winter in a variety of cover types (Schroeder 1996). Use of CRP, grass/forb, and grass/shrub cover types declined in winter and use of sagebrush and riparian/mountain shrub increased (McDonald 1998). On the Swanson Lakes WLA, the riparian/mountain shrub habitat

Figure 11. Deciduous winter habitat on Poween Creek on the Colville Indian Reservation.

(7.8% of detections) and wheat fields (17.7%) were only used during winter; the wheat fields used included wheat left standing for wildlife. Use of sagebrush was much higher than in other seasons (47% vs. 18%), but its importance is likely over-represented because many detections of birds in sagebrush were actually in snow burrows adjacent to riparian or mountain shrub where foraging likely occurred (McDonald 1998). Riparian and mountain shrub habitats were also used more in winter than other seasons (15.9 vs. 3.7%) on the Colville Indian Reservation (McDonald 1998). Water birch, rose, chokecherry, and big sagebrush are important species (Zeigler 1979, Hofmann and Dobler 1988a, Weddell et al. 1991b). Zeigler (1979) and Hofmann and Dobler (1988a) considered water birch the most important species, but Schroeder (1996) noted that use of water birch seemed to be correlated with snowy weather and poor habitat condition, and that monitored birds rarely used it.

During a mild winter, sharp-tails in the Pocatello Valley of Idaho remained in CRP and ate forbs (Schneider 1994, Ulliman 1995), but moved to riparian and mountain shrub habitats when snow was deeper the next winter. During the same mild winter (1993), sharp-tailed grouse remained in the Curlew Valley and foraged on midge galls in sagebrush and Russian olive fruits (Schneider 1994), although these birds may have lost weight subsisting on this diet (Ulliman 1995). Sharp-tailed grouse in Ulliman's (1995) study made no use of wheat fields during winter. Sharp-tailed grouse in Wyoming moved to ridges, hilltops, and steeper slopes blown free of snow during late fall; during December to March they were observed in mixed shrubland and woody riparian habitat (Oedekovan 1985).

POPULATION STATUS

North America

Bendire (1892) considered sharp-tailed grouse one of the most abundant gamebirds of the Pacific Northwest. They were reported to be exceedingly abundant in eastern Oregon in the 1860s (Olson 1976).

Although they were found in extraordinary numbers, populations began declining in much of their range in the late 19th century. A pioneer in Utah stated, "there were tens of thousands of these chickens until about 1875 when they began to dwindle" (Hart et al. 1950). Dr. W.W. Henderson of Utah State believed it would be possible to see 10,000, but noted that enormous numbers were killed and wasted (Hart et al. 1950). Populations in Idaho were said to be declining rapidly in 1917 (Rust 1917). In Nevada, sharp-tailed grouse were common in northern portions of the state, but they began declining around 1900 and the last record was in 1952; the success of a recent reintroduction project is uncertain (Starkey and Schnoes 1979, Bart 2000, Coates et al. 2006). Sharp-tailed grouse were common in the Modoc region of northern California, but were extinct by the late 1920s. Grinnel et al. (1918; *in* Starkey and Schnoes 1979) attributed their disappearance to the "incessant pursuit by man".

Columbian sharp-tailed grouse were declining rapidly in Oregon by 1899, and the last verified sighting was in 1967. They were extinct in Oregon for over 20 years until reintroduced into Wallowa County in northeastern Oregon during the 1990s (Bart 2000, Coggins 2003). A total of 357 birds from Idaho and Utah were released during 1991–1997, 2001–2002, 2006–2008 (Crawford and Snyder 1994, Coggins 2003, C. Hagen, pers. comm.). Numbers have remained low; September flush counts fluctuated between 24–56 birds between 2001–2007 (ODFW 2007). The amount of wintering habitat in the area may be limiting this population (C. Hagen, pers. comm.).

Columbian sharp-tailed grouse currently occupy about 8% of their historical range. The subspecies may have gone extinct in Montana within the last 5 years (Hoffman and Thomas 2007). Considering only public lands, Bart (2000) estimated that Columbian sharp-tailed grouse were imperiled on 91–95% of their current range. Bart (2000) estimated the total range-wide population at 56,000–62,000, with most of these birds in Idaho (40,000), Utah (5,100), Colorado (4,760; if these are considered *columbianus*), and British Columbia (4,700–9,600). They are separated into 15–20 isolated populations, with bird numbers declining in 8, and 6 had fewer than 50 birds (Bart 2000). Very small populations without augmentation and recovery programs will likely go extinct within 10–20 years. Many of the local populations in the U. S. depend on lands enrolled in CRP, and the main populations in British Columbia are in clearcuts and dependent on timber harvest schedules maintaining habitat on the landscape.

Washington: historical distribution and abundance

Distribution and abundance during early Euro-American settlement. Historically, the Columbian sharp-tailed grouse was an important game bird to Native Americans and Euro-American settlers in eastern Washington (Darwin 1918, Post 1938, Buss and Dziedzic 1955, Yocum 1952). Lewis and Clark indicated that sharp-tailed grouse were locally common to abundant on the lower Snake and Columbia rivers as far west as The Dalles in 1806; Lewis wrote "they associate in large flocks in autumn & winter" (Zwickel and Schroeder 2003). David Douglas reported that at the trading post near Kettle Falls in 1826, dusky and sharp-tailed grouse were "so plentiful that they formed a principal part of food" (Douglas 1914:63). On 6 July 1834, John Kirk Townsend killed 22 sharp-tailed grouse during a morning's hunt near present-day Wallula (Townsend 1987). George Suckley reported that they were "exceedingly abundant wherever there is open country and a sufficiency of food" (Suckley 1860:224).

An account by an early pioneer in the Palouse of southern Spokane County noted that in 1873 the family obtained hogs and cattle to supplement their diet of game, noting that, "prairie chicken and grouse populations remained stable" (Hergen 1990). Garret Kincaid who lived in the town of Palouse in Whitman County remarked that when his family arrived in 1877 there were "thousands of prairie chickens" in the area, but they soon declined with settlement and cultivation of the prairie (Kincaid and Harris 1979). Correspondance of early settlers in the steppe foothills of the Blue Mountains also indicate that they subsisted on sharp-tailed grouse (G. Green, pers. comm.). Orville Payne, who lived on the

South Fork Touchet River, 5 mi southeast of Dayton, Columbia County, recalled that in about 1890, hundreds of sharp-tailed grouse came down to the creek bottoms after a heavy snow, and some flocks covered an acre (Buss and Dziedzic 1955). Kuykendall (1984:82) reported similar observations of flocks on Pataha Creek in Garfield County in the early 1880s, and noted that "prairie chickens" were "found in all parts of this and surrounding counties in almost limitless numbers, except in higher timbered sections." Earl Larrison noted that old settlers claimed that in the 1880s and 1890s, it was nothing to fill up the bed of a wagon with sharp-tailed grouse in a single day's hunt (Larrison and Sonnenberg 1968). In late fall and early winter, in the Big Bend country, they "…congregated in great flocks, sometimes several hundred birds could be seen in a single flock (Myers 1948:236). In the 1930s, H. Lee Hanford saw about 500 to 600 sharp-tailed grouse during the winter in the water birch in an area that is now includes the Bridgeport Unit of the Wells Wildlife Area in Douglas County (M. Hallet, pers. comm.). Darwin (1918; *in* Merker 1988) states, "Walla Walla, Whitman, Spokane, Asotin, Garfield, Columbia, Lincoln, Ferry, and Stevens counties all … boasted of their great prairie chicken shooting…". Large flocks of sharp-tailed grouse were also found throughout the Klickitat Valley in the 1860s or 1870s (Ballou 1938:171, Attwell 1977).

Based on museum specimens, historical accounts, and available habitat (Appendix B), sharp-tailed grouse were abundant, with the highest densities in the grasslands, meadow steppe, more mesic shrub-steppe habitats, and the edges between steppes and pine forest. There are few records from the drier Wyoming big sagebrush (*A. t. wyomingensis*) habitats of the central Columbia Basin, but they were apparently present in local areas, especially in river valleys, like the Yakima, and in the more mesic Big Sage/Fescue and Three-tip Sage vegetation zones (Cassidy et al. 1997). Snodgrass (1904) led a collecting trip from Pullman to Yakima, and back, and reported that sharp-tailed grouse were abundant along the Touchet River in Walla Walla County, but were, "Not seen in any of the sagebrush regions of Franklin or Yakima [Yakima included Benton County at that time] Counties," Snodgrass (1904) noted, however, that sage-grouse were found throughout the entire sagebrush region. He describes large areas of the lower Columbia Basin as sand desert devoid of vegetation; these areas were later irrigated by the Columbia Basin Project. Dice (1916) also reported that sharp-tailed grouse were most abundant in bunchgrass prairie and noted that they were only "reported" for the sagebrush habitat of western Walla Walla County.

Initially, agriculture and logging may well have been beneficial to sharp-tailed grouse because there was an apparent temporary increase in their populations (Yocom 1952, Jewett et al. 1953, Smith 1986). However, sharp-tailed grouse may have simply been more concentrated near farms when wheat fields provided a new seasonal food source, but before widespread habitat loss (Merker 1988). Many sharp-tailed grouse used waste grain as a seasonal food and aggregated around haystacks during fall and winter.

The number of sharp-tailed grouse that inhabited Washington at the time of Euro-American settlement will never be known precisely, but a conservative estimate suggests the population numbered in the tens of thousands. Sharp-tailed grouse densities likely varied widely, but were probably highest in the deep soil, high precipitation areas of the Palouse prairie, and lower in shrub-steppe.

Columbian sharp-tailed grouse densities were estimated for "good habitat" in Colorado (0.013-0.019 birds/ac; Rogers 1969), and the Curlew and Pocatello valleys of Idaho which receive 13–18" annual precipitation (0.002–0.008 birds/ac; Ulliman 1995). However, >75% of the Curlew Valley was seeded with one to three species of non-native grasses and one or two species of forbs, and nest success was lower in non-native vegetation than in native vegetation (Apa 1998). Some density estimates for prairie sharp-tailed grouse are considerably higher. Edminster (1954) cites a 1930 estimate for Wisconsin by Aldo Leopold of 0.02 birds/ac, and estimates from Drummond Island, Michigan, during spring of 0.022 birds/ac, and 0.056 birds/ac during fall, by Amman. Gratson (1988) reported a spring density of 0.008 for a Wisconsin study area. Symington and Harper (1957) reported a density of 0.039–0.063 birds/ac in favorable habitat of the Sand Hills region of Saskatchewan.

The historical range in Washington, with steep slopes and low precipitation areas removed (slopes ≥40%, and precipitation zones ≤9"), totaled about 12.5 million acres; perhaps another 2 million ac was forest, emergent wetland or otherwise unsuitable. There were some birds in lower precipitation areas that we have left out of the range polygon (e.g. near Wallula), but these may have been only in river valleys. Assuming a density of 0.02 birds/ac for the 3.5 million ac that is now cropland (probably the most productive), and 0.002 birds/ac for the remaining 7 million ac of shrub-steppe and grassland, yields a total of 85,000 birds. Though populations were dramatically reduced by the 1950s, Schroeder et al. (2000), projecting rate-of-change from data from recent decades, suggested there were perhaps 10,000 sharp-tailed grouse in Washington in 1954 at a time when most of the habitat and, all the best habitat, had already been lost, so this estimate may be reasonable.

Population decline. Sharp-tailed grouse remained abundant in the early stages of Euro-American settlement, but with high rates of harvest and increasing cultivation, declines became obvious by 1897 (Buss and Dziedzic 1955). By 1900 there were hundreds or thousands of farms in the Palouse, and in Douglas, Spokane, and Lincoln counties, and the valleys of northeastern Washington (Yocum 1952). In Whitman County, from 1879 to 1893 the hunting season was 1 August–1 January with a daily bag limit of 20 sharp-tailed grouse (Buss and Dziedzic 1955). By 1897, population declines resulted in the state legislature shortening the sharp-tailed grouse season statewide to August - November; in 1903, daily bag was reduced to 10 birds (Buss and Dziedzic 1955). In 1909, Whitman County further reduced the season to October–December with a daily bag limit of 5; in 1913 the county shortened the season again to 15 September –1 November. The county closed the season in 1919 (Buss and Dziedzic 1955).

The range of sharp-tailed grouse in Washington contracted with the intensification of agriculture, in a somewhat predictable pattern (Fig. 12). Myers (1948:236) noted that after 1910, each succeeding year saw numbers diminished further. The last record of sharp-tailed grouse in the upper Columbia Valley is the 1915 report of "three pairs" by E. A. Blakely near Kettle Falls (Jewett (1953). Farming of the narrow valleys and unregulated hunting likely eliminated sharp-tailed grouse from these areas relatively quickly. Additionally, Dzeidzic (1951: 40) suggested that the use of poisoned grain placed along fencerows to control ground squirrels may have severely impacted the sharp-tailed grouse population. In the Palouse, one period of steep population decline was 1910–1920, when burning and plowing of wheat stubble during the nesting season became common practice. One Palouse farmer found 16 sharp-tailed grouse nests after he burned 150 ac of stubble; he saw no sharp-tailed grouse on his farm after 1915 (Yocum 1952, Buss and Dziedzic 1955). Sharp-tailed grouse remained along the Snake River breaks and in the more rocky scablands of western Whitman County into the 1950s. The sparse sharp-tailed grouse populations in the drier portions of the Columbia Basin may have depended on winter habitat elsewhere, and been reduced along with it. The spread of irrigated cropland with the Columbia Basin Project may have eliminated remnant populations.

Prior to 1933, counties set their own hunting seasons. For a period of time, Okanogan, Ferry and Stevens counties maintained a season of 2–6 weeks with a bag limit of 5/day, and Klickitat County maintained a season from 1–10 September, with a bag of 3/day until 1924 (Buss and Dziedzic 1955). In 1933, a moratorium was placed on sharp-tailed grouse hunting statewide. The intensification and increased mechanization of farming continued to eliminate native vegetation until 1945 when practically all available land was under cultivation (Buss and Dziedzic1955). The last sharp-tailed grouse records from Klickitat County are from the 1940s. They may have still been present in southwest Stevens County in the early 1950s (Yocum 1952).

In 1953, a 2-day season on sharp-tailed grouse was re-opened in three counties with daily and possession limits of one and two, respectively. Harvest data for sharp-tailed grouse were never tallied separately from other grouse species, so harvest figures are unavailable. In 1954, the daily limit increased to two, the possession limit increased to four, and in Okanogan County, the season increased to 8 days. The illegal kill of sharp-tailed grouse by hunters seeking other species, and by orchard owners may have been significant during this period (J. Patterson, pers. comm., *in* Hayes et al. 1998).

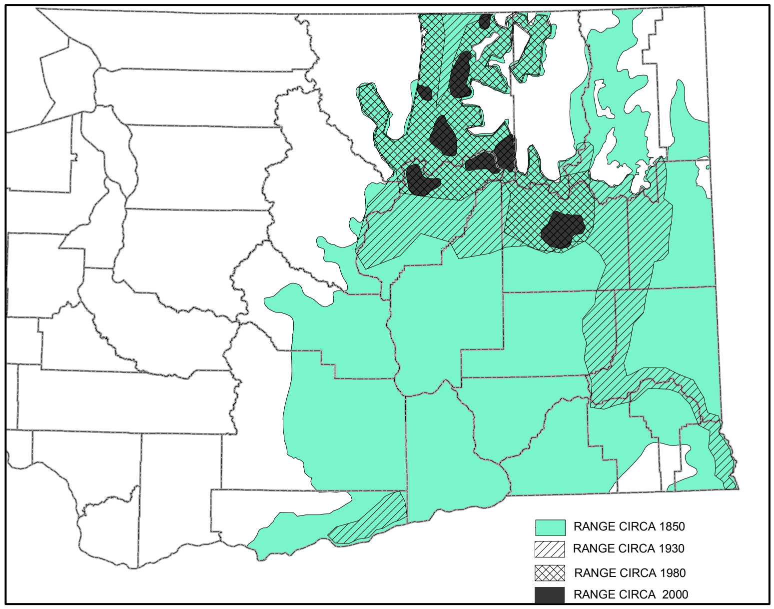


Figure 12. Approximate chronology of the range contraction of Columbian sharp-tailed grouse in Washington (based on Yocum 1952, Zeigler 1979, Merker 1988, Schroeder et al. 2000, and historical records in Appendix B).

The Deer Park Airport lek in northwestern Spokane County was last active in 1964 (Zeigler 1979). According to Steve Judd, biologist on the Colville Reservation for many years, sharp-tailed grouse were abundant in the eastern portions of the reservation in the 1940s, and were still present through the 1970s. At least one sharp-tailed grouse lek persisted in the Methow Valley into the 1980s, and there were occasional individuals sighted in the 1990s.

All of eastern Washington was re-opened for sharp-tailed grouse hunting in 1965, presumably because of conventional dogma about compensatory mortality and hunting effort being self-limiting, and daily and possession limits remained at two and four until 1976. Possession limits were reduced to two in 1977. All counties except Lincoln were closed to sharp-tailed grouse hunting in 1985 because of population declines. Seasons were closed statewide in 1988.

Some early attempts were made to restore local populations with translocation of birds from other areas. According to Dr. Phil Wright, University of Montana, who helped with the capture, there was a translocation of Columbian sharp-tailed grouse from the National Bison Range in Montana to eastern Washington "about 1930" (M. Schroeder, notes on a conversation 21 June 1994); no other details are known. In 1954, there was also a translocation of sharp-tailed grouse from the Tunk Valley in Okanogan County, where 200 sharp-tailed grouse were congregated at a haystack, to Turnbull National Wildlife Refuge, Spokane County. Neither project affected the long-term outcome for the local populations.

Washington: population status 1960–2009

There was little attempt to monitor sharp-tailed grouse populations in Washington until 1954 when annual lek counts began on a limited number of leks in Okanogan County (Zeigler 1979). Lek counts expanded to Lincoln and Spokane counties in 1959. Surveys of leks prior to 1970 typically consisted of a single count of the birds attending a lek during the breeding season; methods were not standardized. Most of the leks surveyed between 1954 and 1969 were opportunistically visited by members of bird-watching organizations and WDFW personnel, consequently they provide limited information on population levels or trends, but do indicate the presence of birds in areas. WDFW and the Colville Confederated Tribes standardized methods and expanded surveys between 1970 and 1989 to include multiple (≥2) visits to specific leks and additional searches for new and/or previously undiscovered leks. Biologists surveyed many more leks after 1987, and The Nature Conservancy assisted with surveys and the compilation and reporting of data in the early 1990's (Hofmann and Dobler 1989, Weddell et al. 1990, 1991a, Weddell and Johnston 1992a,b). Increased survey effort, greater frequency and standardization of lek counts, and the discovery of satellite leks (new locations near a primary lek) resulted in a higher number of birds counted on leks statewide from 1970 to 1996 (Hays et al 1998). Since the early 1990s, WDFW and Colville Confederated Tribes have attempted to visit all leks that have been active in recent years on ≥2 occasions each spring.

One hundred fourteen active leks were documented in Washington between 1960 and 2006. From 1977 to 1986, the number of active leks declined 42% from 54 to16 (Hofmann and Dobler 1989). The loss of active leks over time indicates a trend in reduced population, range, and the resulting isolation of subpopulations of sharp-tailed grouse in the state. Hofmann and Dobler (1989) reported that many leks, though still active, exhibited a decline in the number of birds attending. On every lek with at least 7 years of data, the number of birds counted declined, and the longer the period, the greater the decline (Hofmann and Dobler 1989). The decline was experienced at both the state and county level. From 1980 to 1989, the Lincoln County population estimate declined from 1,500 to 150 birds (Hickman 1989). Active leks in Douglas, Okanogan, and Lincoln counties disappeared at similar rates (66%, 72%, and 63%, respectively) from 1954 to 1994 (Schroeder 1994). Of the 114 leks documented between 1960 and 2006, 82 (71.9%) are currently vacant; 33 (40.2%) of the vacant leks are in portions of the historicalrange that are no longer occupied. The remaining 49 vacant leks reflect declines in density within occupied portions of the historicalrange (Schroeder 2006).

Attendance numbers for leks were analyzed using the highest number of birds observed on a single day for each lek complex for each year. [Some leks shift location up to a few hundred meters year-to-year, and over time mapped locations form a cluster of points that Schroeder et al. (2000) call a “lek complex”; for simplicity, we use the term, ‘lek.’] Maximum attendance of birds at leks is often used to evaluate sharp-tailed grouse populations (Hart et al. 1950, Rogers 1969, Parker 1970, Marks and Marks 1987a, Giesen and Braun 1993, Ritcey 1995, Connelly et al. 1998). The best surveys of sharp-tailed grouse require a relatively complete count of birds on all leks in a region. Rates of population change were analyzed by comparing the total number of birds counted at all leks surveyed in consecutive years (Schroeder et al. 2000, Connelly et al. 2004). Because sampling was occasionally biased by size andaccessibility of leks, leks not counted in consecutive years or on both ends of a specific 2-year interval were excluded from the sample for that specific interval. The 2006 population was estimated by multiplying lek attendance numbers for each lek complex by 2; this technique assumes that lek counts include mostly males and that the male:female sex ratio is approximately 1:1. Annual rates of population change were then used to estimate annual spring populations backward between 2006 and 1970 (Fig. 13). Because a few leks believed to be active in 2006 were not surveyed, the last counts available for these leks (1998–2002) were used in the analysis of 2006 estimates (after being modified with the estimated annual rates of population change).

The analysis of annual changes in attendance at leks indicated that the average instantaneous rate of population change was -5.4% (SE = 3.4%) per year between 1970 and 2006. These annual changes were used to ‘back-estimate’ the population; the estimated population in 1970 was 4,093. The overall population declined almost continually between 1970 and 2006, particularly during the 1970s, when the estimated population declined from about 5,000 to about 3,000 birds. The overall estimated decline was 85.8% between 1970 and 2006.

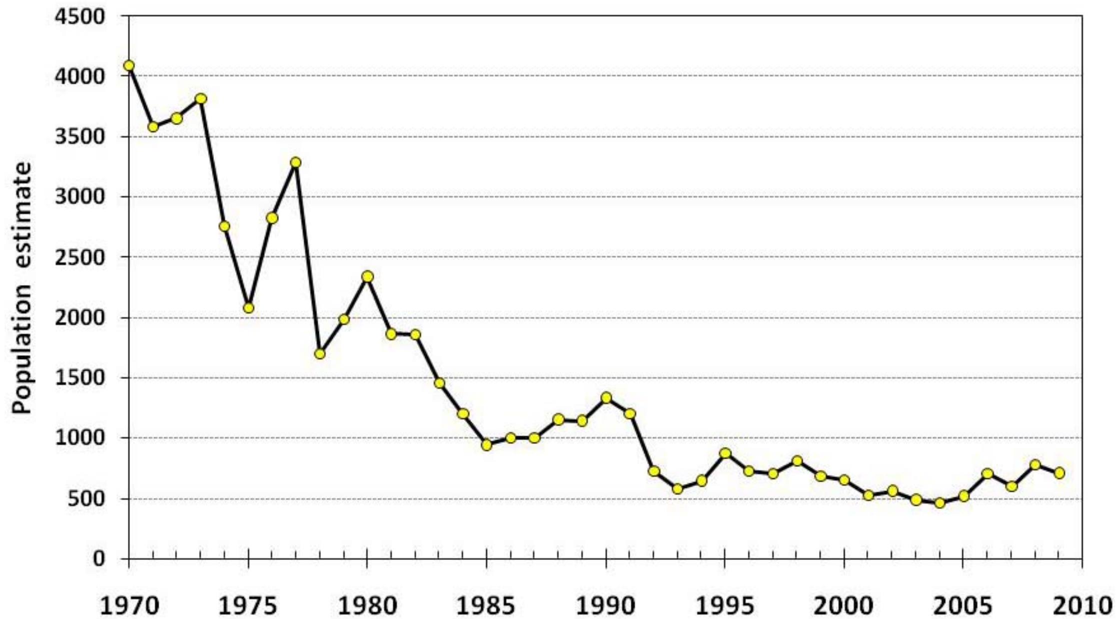


Figure 13. Estimated total population of Columbian sharp-tailed grouse in Washington, 1970-–2009.

This analysis has inherent sources of bias and is limited by the lack of complete historical survey information, and therefore population numbers should be considered estimates. A few females are probably counted as males, but there may also be some males not attending a lek. Confidence intervals for these estimates cannot be readily calculated. The principle assumption is that changes in lek counts reflect changes in population size. The discussion and analyses above only look at leks that were active (birds present) in any year. The reduced monitoring when active leks became inactive limited the analysis.

Applegate (2000) objected to the use of lek surveys to estimate a statewide population, and stated that they were best used for detecting trends. An intensive banding or telemetry mark-resight study as described by Clifton and Krementz (2006) would likely provide a more accurate estimate, but would require a large financial expenditure. Currently in Washington, all known leks are counted systematically each spring using standardized methods, and efforts are made to find new leks. Because the sharp-tailed grouse season is closed in Washington, the results do not affect decisions about harvest. The telemetry study by Clifton and Krementz (2006) found that lek surveys consistently underestimated the local population of greater prairie-chickens in Kansas, this may also be true for sharp-tailed grouse. However, the large magnitude of the downward trends in the distribution and abundance of sharp-tailed grouse in Washington indicate that overall conclusions are not likely to be altered by biases associated with lek counts, including lek movement and detectability, variability in lek attendance, and poorly defined male:female sex ratios.

Based on the distribution of active leks, sharp-tailed grouse appear to persist in seven relatively isolated populations that are separated by at least 20 km (Fig. 14). The distribution of sharp-tailed grouse has declined about 97% from historical levels and the overall abundance declined about 89% since 1970. The current distribution of sharp-tailed grouse covers approximately 2,234 km^2, approximately 2.8% of the historical distribution: Chesaw (70 km^2 area east of Oroville); Tunk Valley (342 km^2 area southeast of Tonasket); Scotch Creek (79 km^2 area northwest of Omak); Greenaway Spring (340 km^2 area southeast of Okanogan); Dyre Hill (308 km^2 area south of Brewster); Nespelem (513 km^2 area north of Grand Coulee); and Swanson Lakes (521 km^2 area west of Davenport). Most of the populations appeared to decline between 1970 and 2006. Greenaway Spring had no known leks in 2004–2008, but leks may have moved and gone undetected. The population in the Horse Springs Coulee area west of Tonasket, (Schroeder et al. 2000), is now believed to be extinct. The remaining seven populations of Columbian sharp-tailed grouse in Washington totaled about 712 birds in 2009.

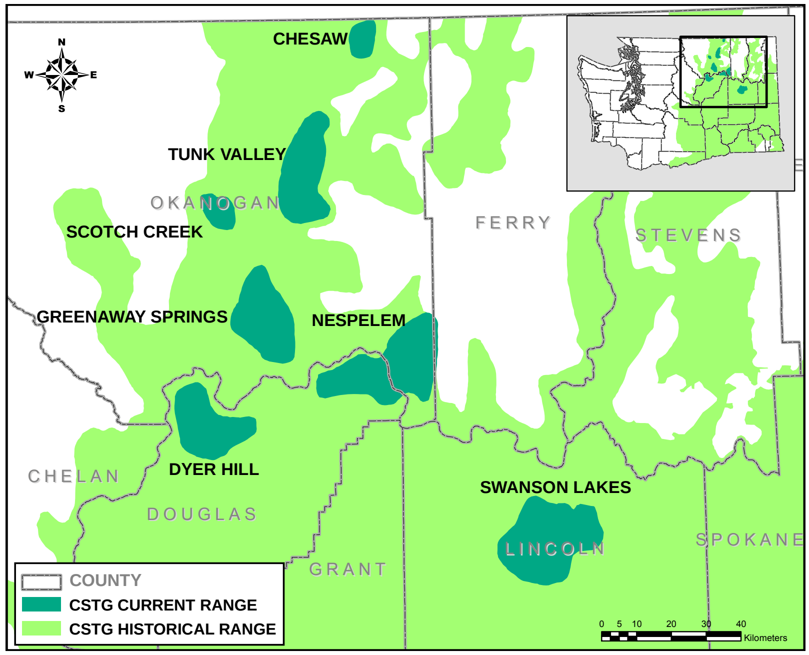


Figure 14. The location of areas in Washington currently occupied by Columbian sharp-tailed grouse.

Populations in Washington may be too small to persist (Hamerstrom et al. 1957; Bouzat et al. 1998; Westemeier et al. 1998a). Two of the populations occupy areas <100 km^2 (Chesaw, Scotch Creek). A substantial portion of the habitat between existing populations consists of wheatfields, orchards, and reservoirs associated with dams. Although much of the habitat on state, federal, and tribal land is currently managed to benefit sharp-tailed grouse, it is critical to expand management efforts to incorporate both public and private lands into management areas that are large enough to support viable populations (Hamerstrom et al. 1957; Westemeier et al. 1998a).

Population augmentation: 1998–2009

Sharp-tailed grouse from healthy populations outside the state have been translocated to Washington to improve the vigor of local populations (Schroeder et al. 2008). Since 1998, a total of 274 sharp-tailed grouse have been translocated and released in areas where populations have been declining. During 1998–2000, 63 birds were released on the Scotch Creek Wildlife Area. Birds for this translocation were obtained from the Rockland area in southeastern Idaho (51 birds) and the Colville Indian Reservation in Washington (12 birds). From 2005–2009, an additional 215 birds from Idaho, Utah, and British Columbia, were released at sites in Okanogan, Douglas, and Lincoln County. Additional releases are planned for coming years to stabilize existing populations and eventually establish additional populations.

HABITAT STATUS

Past

> *On the slopes above the Palouse River were service berries, wild currants, and gooseberries in great abundance; the "luxuriant bunch grass" that grew everywhere provided excellent feed for the surveyors' horses."* Theodore Kolecki, U.S. Army topographer (Mullan, 1863)

Reduction in the population and range of sharp-tailed grouse in Washington is primarily attributed to habitat loss. The story of sharp-tailed grouse habitat in eastern Washington is one of destruction and degradation, initially by livestock grazing, then by widespread conversion to cropland and agricultural intensification, and finally the continued degradation by livestock and invasive plants of the untillable remainder.

The term 'Palouse' is used to refer to a geographic region of southeastern Washington and adjacent Idaho that historically supported meadow-steppe vegetation; in Washington it includes Whitman County, southeastern Spokane, and northern Garfield, Columbia, and Asotin counties. Daubenmire (1942) used the term "Palouse grassland" as an ecological term that included the grasslands further west in Walla Walla County. More recently the vegetation of these regions has been termed Pacific Northwest Bunchgrass grassland, which is further divided into Palouse Grassland and Canyon Grassland (Weddell and Lichthardt 1998). We use the term 'Palouse' in the geographic sense, and use 'Palouse prairie' or 'Palouse grassland' to refer to the meadow-steppe vegetation of the region.

Before Euro-American settlement. Before settlers arrived in the early 1800's, much of eastern Washington was covered with sagebrush/bunchgrass vegetation representative of shrub-steppe or native bunchgrasses/deciduous shrubs representative of the more mesic meadow-steppe (Daubenmire 1970). The Palouse region was characterized by bunchgrass prairies on dune-like hills of wind deposited loess up to tens of meters deep (200 ft) (Cook and Gilmore 2004). The prevailing southwest winds resulted in steeper northeastern slopes where snow was deeper and shrubs, particularly Douglas hawthorn, snowberry, and *Rosa* spp. became established. Precipitation ranges from about 16" at the western end to 22" at the Idaho state line. Deciduous shrubs in draws, northeast slopes, and riparian areas likely provided abundant buds and fruits for sharp-tailed grouse, including fruits from hawthorn, serviceberry, snowberry, rose, and chokecherry, and buds of birch, willow, aspen, dogwood, and others.

Within the shrub-steppe zone, sagebrush coverage ranged from 5 to 26% and perennial grass coverage ranged from 69 to 146% (sampling method accounts for overlapping plants) on undisturbed sites (Daubenmire 1970). Sharp-tailed grouse may have been more migratory in these drier areas where fewer deciduous shrubs for winter food were available. Few large ungulates inhabited these areas since the last glaciation and the vegetation evolved without intense grazing (Daubenmire 1970, Shinn 1980, Mack and Thompson 1982). Shallow streams meandered through meadows, and during spring flood, likely ran almost siltless (Victor 1935).

Human impacts in these areas were fairly modest; Native Americans made seasonal movements to harvest camas and other roots, berries, salmon and other fish, and there was almost no permanent human presence on the uplands of Palouse prairie (Meinig 1995, Black et al. 1999, Weddell 2002b). Native Americans likely also burned some areas periodically or annually to improve yields of food plants (Marshall 1999).

Horses, which were obtained by Native Americans in the Pacific Northwest around 1730, were the first large animals to graze eastern Washington in large numbers for at least several thousand years (Harris and Chaney 1984). Spanish horses that were brought to New Mexico spread to northwest tribes through trade, and by the early 19th century the Yakama and Nez Perce tribes had substantial herds (Haines 1938, *in* Hessburg and Agee 2003). These horse herds grazed on the grasslands of the plateau during the summer and were wintered in the canyons (Tisdale 1986). Historical accounts by early Euro-American explorers and settlers of the large horse herds, led Hessburg et al. (2003) to speculate that localized damage from over-grazing may have already been occurring before Euro-American settlement. Tisdale (1986) indicated, however, that he observed no evidence of widespread heavy use or damage to the canyon grasslands from that period.

Free-range era. The earliest Euro-Americans present in eastern Washington were fur traders and then missionaries; somewhat later ranchers and the U.S. Army established outposts. Cattlemen were the first Euro-American settlers in the Palouse region; they introduced cattle in 1834 and sheep in the 1880's. The number of horses increased between 1830 and 1880 (Daubenmire 1970). In addition to the lack of adaptation of the vegetation to grazing by large ungulates, the historical impact of livestock was aggravated by the high numbers of animals, the poor distribution of cattle in steeper terrain, and grazing during the spring and early summer when the native plants were particularly sensitive to damage (Tisdale 1986). Young (1943) reported that the result of prolonged over-grazing of Palouse grassland was the elimination of Idaho fescue, and domination of the site by Sandberg bluegrass (*Poa secunda*) and cheatgrass. Where steppe vegetation was grazed excessively, the density and canopy cover of native grasses was reduced allowing adapted alien species to invade (Daubenmire 1970). Botanist John Leiberg lamented,

> "We will never know the complete flora of these regions…sheep and cattle are rapidly destroying the native plants and by the time private explorations reach these regions the flora will have been totally exterminated" (Leiberg 1896, *in* Weddell 2001a).

The range in the Klickitat and Yakima areas was seriously overgrazed by 1879. In 1880, 72,000 head of cattle were driven to Wyoming from Washington Territory (Meinig 1995: 286). In the Palouse and Walla Walla regions, ranching became restricted to the western margins and along the Snake River. The range cattle industry peaked in the 1870s and largely came to an end in the 1880s (Meinig 1995). The southern portion of the Big Bend, from Crab Creek to Pasco lingered as a free range area and in the mid-1880s, along with the scablands became important sheep areas. By 1890, the free range era was "virtually past" (Meinig 1995: 292).

Euro-American settlement. The Walla Walla River valley was one of the first areas to be settled by Euro-Americans in eastern Washington. In 1859, valley bottoms in present-day Walla Walla County were being settled by farmers and ranchers (Mullan 1863). After Native American unrest was resolved by treaties and the Homestead Act was passed in 1862, small farms proliferated and valleys were rapidly settled by homesteaders. From 1860–1870 the human population of Walla Walla County grew from 1,300 to >5,000 (Robbins and Wolf 1994). The discovery of gold near the headwaters of the Palouse River in present-day Idaho and in the Caribou region of British Columbia created a market for farm goods, particularly flour and beef, though transport was limited to river boat, wagons, and cattle drives. Cattle drives to the mining districts peaked in 1862-1866, and totaled about 20,000 head each year; these tapered off with the gold and increasing self-sufficiency of the mining districts (Meinig 1995). Free range livestock had about vanished in southeastern Washington by 1880 (Dziedzic 1951).

North of the Snake River, settlement along Union Flat Creek occurred in 1869; Whitman County was organized in 1871; Spokane County received the first settlers in the 1870s (Dziedzic 1951, Meinig 1995). In the latter 1870s, the Palouse country was being rapidly settled (Meinig 1995). Settlement of the area called the 'Big Bend country', including present-day Lincoln, Douglas, Grant and Okanogan counties, followed somewhat later. Douglas County settlement increased rapidly from 1883-1890 (Dziedzic 1951). In the Palouse and Walla Walla areas, the bottomlands were farmed first and the uplands left for pasture; settlers were doubtful that the loess hills could grow wheat, but through experimentation the hills of loess proved to be perfectly suited to growing wheat and were less susceptible to spring frosts than the valleys (Kaiser 1961, Meinig 1995). Initially, spilled grain provided a new food source for sharp-tailed grouse (Yocom 1952). Considerable native vegetation remained at this time due to the need for much pasture for horses and the limits of farm technology and transport for agricultural goods. Railroads, which began to service the Palouse in 1885, alleviated the problem of transporting grain to larger markets outside the

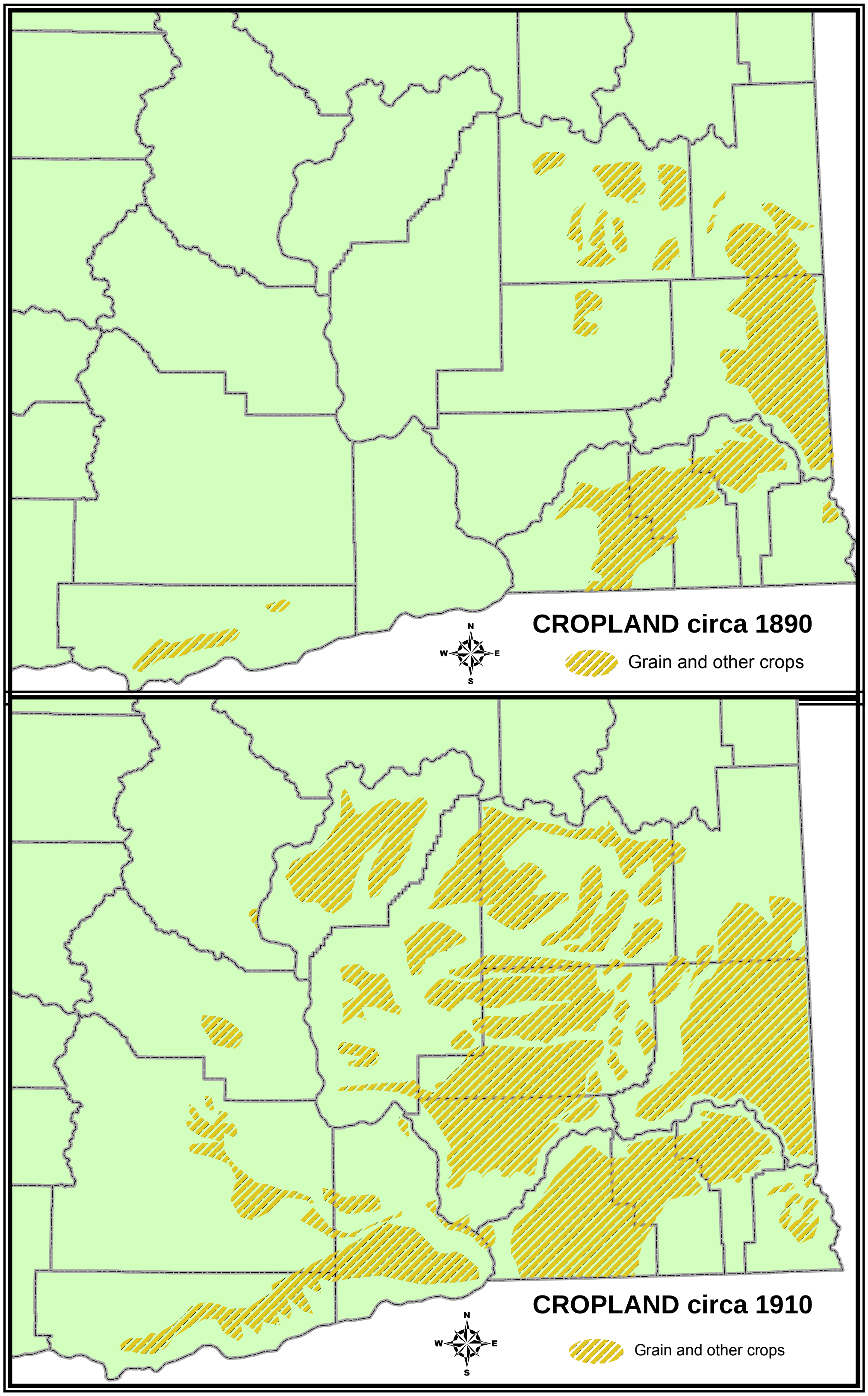


Figure 15. Rapid conversion of steppe habitat to cropland in eastern Washington, 1890–1910 (county boundaries are present-day; modified from Meinig 1995).

region.

By 1895, most of the tillable land in the Palouse had been converted to cropland, and in 1912, only small isolated tracts of well-developed prairie remained intact (Fig.15; Weddell 2001a). By 1920, 80% of the Palouse region available for agriculture was cultivated (Buss and Dziedzic 1955). The early development of dryland farming required large herds of horses, which grazed freely on rangelands when they were not being used for farming (Harris and Chaney 1984). Areas that were too steep or rocky to plow continued to be grazed, and most eventually were degraded to non-native vegetation, including annual bromes (*Bromus tectorum. B. japonicus, B. brizaeformis*) in the drier areas and Kentucky bluegrass (*Poa pratensis*) in moister areas.

The long drought that began in the early 1930s, along with livestock grazing had a dramatic effect in northern Douglas County. According to H. Lee Hanford, a longtime farmer and rancher in the area, when his father settled in the Bridgeport area about 1900, the area was lush grassland that produced up to 1.5 tons/ac of of grass hay; there was no sagebrush and little bitterbrush. Wilfred Shaw (pers. comm. to M. Schroeder), also indicated that the grass-dominated vegetation allowed horse-drawn combines to be used to cut native hay in the area. The drought led to abandonment of fields and large numbers of feral horses. These factors were believed to have led to the present condition of predominantly sagebrush cover. However, it is possible that climate factors may also have been involved in this change in vegetation.

The intensification of agriculture. The 20th century saw increasing intensification of agriculture and elimination of most remaining sharp-tailed grouse habitat (Dziedzic 1951, Yocom 1952). The first horse-drawn combine was introduced in 1888 (Meinig 1995). They were not uncommon in areas of level ground by 1900, but the early models were large unwieldy monsters that required 32 horses and 5 men, and were ill-suited to the small hilly Palouse farms (Meinig 1995). Smaller models became available about 1910. Prior to the combines, wheat was harvested with headers or binders; stubble from a binder was short and easily tilled in, but headers left tall stubble that had to be burned (Jennings et al. 1990). Sharp-tailed grouse began using stubble fields for nesting, but burning of fields in spring resulted in the destruction of nests (Yocom 1943, Myers 1948). In the 1920s, combines were becoming widely used, and by 1930, 90% of Palouse wheat was harvested by combine (Jennings et al. 1990, Black et al. 1999). The introduction of tractor farming and combines in the 1920's and 1930's eliminated the need for horses and allowed some recovery of rangeland but improved equipment allowed the plowing of steeper slopes and resulted in most of the untilled pasture land being converted to cropland (Buss and Dziedzic 1955, Black et al. 1999).

Mechanization also enabled farmers to remove riparian habitat from drainage basins that separated small fields. Small fields were combined into large fields that were seldom used by sharp-tailed grouse. From 1920 to 1950, small numbers of sharp-tailed grouse continued to occupy scattered patches of shrub/meadow steppe where cultivation was not practical (Hudson and Yocom 1954, Merker 1988). However, continued excessive livestock grazing on these patches contributed to the continued decline of sharp-tailed grouse (Merker 1988). Brushy draws and creek bottoms were replaced by ditches and gullies. Pastures and fencerows formed of brush that had provided food and cover were eliminated (Yocom 1952).

From 1947 to 1982, 301,500 ha (744,705 ac) of brush control occurred under the federal Agricultural Conservation Program and the Columbia Basin Project in Washington (Pedersen 1982). This included 88,393 ha (218,331 ac) of sagebrush chemically or mechanically treated and 213,120 ha (526,406 ac) converted to irrigated cropland and facilities. Twenty percent [60,800 ha (150,176 ac)] of all brush control occurred in Douglas, Lincoln, Kittitas, and Yakima counties; Douglas and Lincoln counties were core areas for sharp-tailed grouse. Shrub control was used primarily to remove sagebrush on 12,360 ac on 138 farms in Lincoln and Spokane Counties between 1947 and 1967 (Adkins 1968). Although significant, the amount of sagebrush removed under federal programs was small compared to sagebrush removed by private landowners (Pedersen 1982).

Dams along the Columbia River resulted in additional loss of habitat due to flooding and indirect loss of habitat from expansion of irrigated farming. Hydropower development of the Columbia Basin and Snake River in the 20th century provided the irrigation water and the barge transportation that facilitated grain shipment for export markets that promoted the continued conversion of shrub-steppe and the drier grasslands to cropland (Cook and Gilmore 2004). The completion of Grand Coulee Dam in 1942 resulted in the inundation of 70,000 ac, including an estimated 32,000 ac of sharp-tailed grouse habitat for a potential loss of 2,800 birds (Howerton et al. 1986). Since 1951, the Columbia Basin Project has brought irrigation water to 671,000 ac (http://www.usbr.gov/dataweb/html/columbia.html).

Loss of riparian deciduous and meadow habitats. Botanist John Leiberg noted that with settlement, camas meadows were used as hay fields (Leiberg 1897, *in* Servheen et al. 2002). The original extent of seasonal wet meadows and riparian vegetation is uncertain because much was lost before anyone was interested in quantifying it, but historical records suggest that camas meadows were common (Servheen et al. 2002, Weddell [no date], Weddell 2002b). Terrain analysis, soil survey data, and General Land Office records for two subwatersheds in eastern Whitman County suggest that seasonally moist meadows may have comprised 13% of the study area (Servheen et al. 2002). Loss of riparian habitat and shrubland continued in the 20th century. Dzeidzic (1951) noted that farmers around Pullman said that springs that were once present "everywhere" began drying up "about 20 years ago." Various county and U.S. Department of Agriculture programs encouraged the draining of wetlands and removal of shrubs to maximize production and control weeds. The removal of riparian shrubs continued in the 1940s-1960s because they were considered a weed harbor, supposedly had soil holding value inferior to grass, and were considered an unnecessary evil by county extension agents (Dzidezic 1951). During this period, a Whitman County weed control supervisor stated that his objective was to remove all the trees from the county road right-of-ways, including waterways. This was done by spraying with the herbicide 2,4-D, which killed all broad-leaved vegetation (Dzeidzic 1951).

Adkins (1968) summarized the activities of the USDA Agricultural Conservation Program (ACP) between 1943–1967 that impacted wildlife in Spokane, Lincoln, and Whitman counties. These practices included land clearing, channel clearances, underground drainage, and competitive shrub control. Under the land clearing practice, about 12,000 ac of habitat was destroyed on 964 farms in Whitman and Spokane counties; this practice was terminated in 1954 after objections by Washington Department of Game. Approximately 448 miles of stream were channelized on 487 farms, over 6,525 rods of tile were installed and 20,980 ac were drained on 1,508 farms, primarily in Whitman County. Draining and stream channelization were still being ongoing in the early 1970s (J. Connelly, pers. comm.).

An examination of aerial photos for an 875 ha area near Viola, Idaho, indicated that 61% of the riparian areas that existed in 1940 were gone by 1989; "stringers of riparian vegetation shrunk to thin broken tendrils, and shrub vegetation virtually disappeared" (Black et al. 1999).

Intensive grazing and agricultural development resulted in greater damage during flood events. According to H. Lee Hanford, a flash flood ravaged through the Dyer Hill area of Douglas County on 31 August 1922, and destroyed a large wet meadow in Fye Draw (M. Hallet, pers. comm.). This meadow area likely had tremendous riparian habitat providing winter food and cover for sharp-tailed grouse, but it was drained due to the down-cutting (Fig. 16), and the area is now shrubsteppe with a few scattered trees in the draws.

Figure 16. Down-cutting in Fye Draw near West Foster Creek in Douglas County.

Winter riparian habitat continued to be removed throughout areas occupied by sharp-tailed grouse. At the time of Euro-American settlement, birch was abundant in Okanogan County, and "thrived in every draw and bottomland area" (Don Chalmers, pers. comm., *in* Zeigler 1979). Birch was cut to clear land, for firewood, and to develop springs, and cutting continued through much of the 20th century. For example, Zeigler (1979) documented a 51% decline in water birch and aspen from 1945 to 1977 in Johnson Creek, Okanogan County. During this period, riparian deciduous "budding" habitat declined 26% in four areas measured from aerial photos (Zeigler 1979). In addition, 13% of landowners contacted in Okanogan County were planning to remove water birch or aspen (Zeigler 1979). Hofmann and Dobler (1988a) also reported the loss of water birch at two locations in Okanogan County in less than 3 months of observation. Sharp-tailed grouse no longer used these areas after water birch was removed (Hofmann and Dobler 1988a). A habitat assessment of several areas in Okanogan Couty in 1996 reported that sharp-tailed grouse winter forage was poor to non-existent on most sites and nesting cover was marginal due to past or current grazing practices (Ashley and Berger 1997). Water birch may have represented the last remnants of winter budding habitat, because water birch is considered to have only poor to fair palatability rating for cattle and is only lightly browsed (Uchytil 2006). Sharp-tailed grouse in Washington seem to only use water birch when other deciduous species are unavailable (M. Schroeder, pers. obs.)

The destruction of prairie vegetation on Palouse hills exposed the loess soils to extraordinary erosion, and accelerated run-off increased the energy and erosion potential of area streams (Victor 1935). Larger streams with basalt or granite beds used the increased energy to widen their channels and many smaller streams underwent rapid head erosion advancing 20–100 feet per year (Victor 1935). Victor (1935) recalled that pioneer roads often followed stream grades and crossed and re-crossed smaller streams, but many crossings became too deep and required a bridge. For example, Deadman Creek in Garfield County was crossed at any point by wagon in 1880, but in 1935 it was 25 feet deep and 100 feet wide. Over 4 million cubic yards of soil had been eroded from a seven mile stretch of this gully and moved toward the Snake River. When head erosion proceeded through wet meadows, the water table became lowered. Meadows and streams that were formerly too wet to farm and provided riparian and meadow habitat became dry enough to plant wheat, often about 10–12 years after the surrounding land was converted (Victor 1935).

Present

Columbian sharp-tailed grouse habitat in eastern Washington has been drastically reduced in quantity and quality. Since Euro-American settlement, about 94% of the grasslands and most of the wetland of the Palouse Bioregion have been converted to cropland, hay, or pasture (Black et al. 1999). In agricultural areas like the Palouse, clean farming practices that include burning, herbicide, and tilling roadbed to roadbed, leaves few fencerows and little untilled ground of any kind (Black et al. 1999). McDonald and Reese (1998) used Interior Columbia Basin Management Project data (Quigley et al. 1996) with a 100 ha pixel resolution, to determine that cropland and hay/pasture accounted for 51% of the total land area of 20 million acres in a more generalized sharp-tailed grouse historicalrange map from Tirhi (1995). They estimated that the extent of grassland was diminished from 44 to 1.3%, and mean grassland patch size declined from 3,765 to 299 ha (9303 to 739 ac). Sagebrush cover types declined from 44.1 to 15.6% (McDonald and Reese 1998).

Current landcover. We examined land cover in historical sharp-tailed grouse range using 2001 National Land Cover Data, with the driest areas (≤9" annual precipitation) and steep slopes (≥40%) removed from the analysis (Fig. 17). Although this area still includes some unsuitable area (open water, coniferous forest, and rock total ≈ 16%), it focuses on that portion of sharp-tailed grouse range that was likely most important both historically, and for recovery projects in the future. In this landscape of roughly 12.5 million ac, nearly one third is in cultivated crops or pasture/hay and about 4% has been converted to other human-related development.

The main cover types that potentially provide suitable habitat, including shrublands, grassland, and CRP total about 47% in the historical range; these cover types total almost 80% in currently occupied areas (Table 6). Minor types that likely contain some essential winter and brood-rearing habitat (deciduous

Table 6. Current landcover[a] of areas in the historical (modified for slope and precipitation[b]) and current ranges of Columbian Sharp-tailed Grouse in Washington.

	Historical Range		Current Range[c]	
Land Cover Class Name	**Percent**	**Acres**	**Percent**	**Acres**
Shrub/scrub	33.12	4,129,750	69.09	368,685
Cultivated crops	30.13	3,760,691	9.72	51,872
Grassland/herbaceous	6.71	881,443	6.42	34,234
Conservation Reserve Program	7.12	836,276	4.37	23,295
Conifer forest	14.44	1,799,867	5.18	27,619
Emergent herbaceous wetlands	0.80	100,021	2.06	10,976
Developed, open space	2.30	287,037	1.07	5,702
Open water	1.79	223,251	0.93	4,976
Pasture/hay	1.67	208,582	0.70	3760
Developed, low intensity	1.03	128,394	0.14	759
Developed, medium intensity	0.37	45,716	0.02	88
Developed, high intensity	0.06	7,834	<0.00	6
Woody wetlands	0.31	39,084	0.17	908
Deciduous forest	0.12	15,229	0.13	713
Mixed forest	0.02	2,654	0.01	33
Barren land (rock/sand/clay)	0.02	2,805	<0.00	7
Total	100	12,468,637	100	533,633

[a]Based on 2001 National Land Cover Data.
[b]Areas with 9" or less of annual precipitation, or >40% slope were deleted from the historical range polygon.
[c]Includes the 15,000 ac Horse Springs Coulee area, where sharp-tailed grouse may now be extinct.

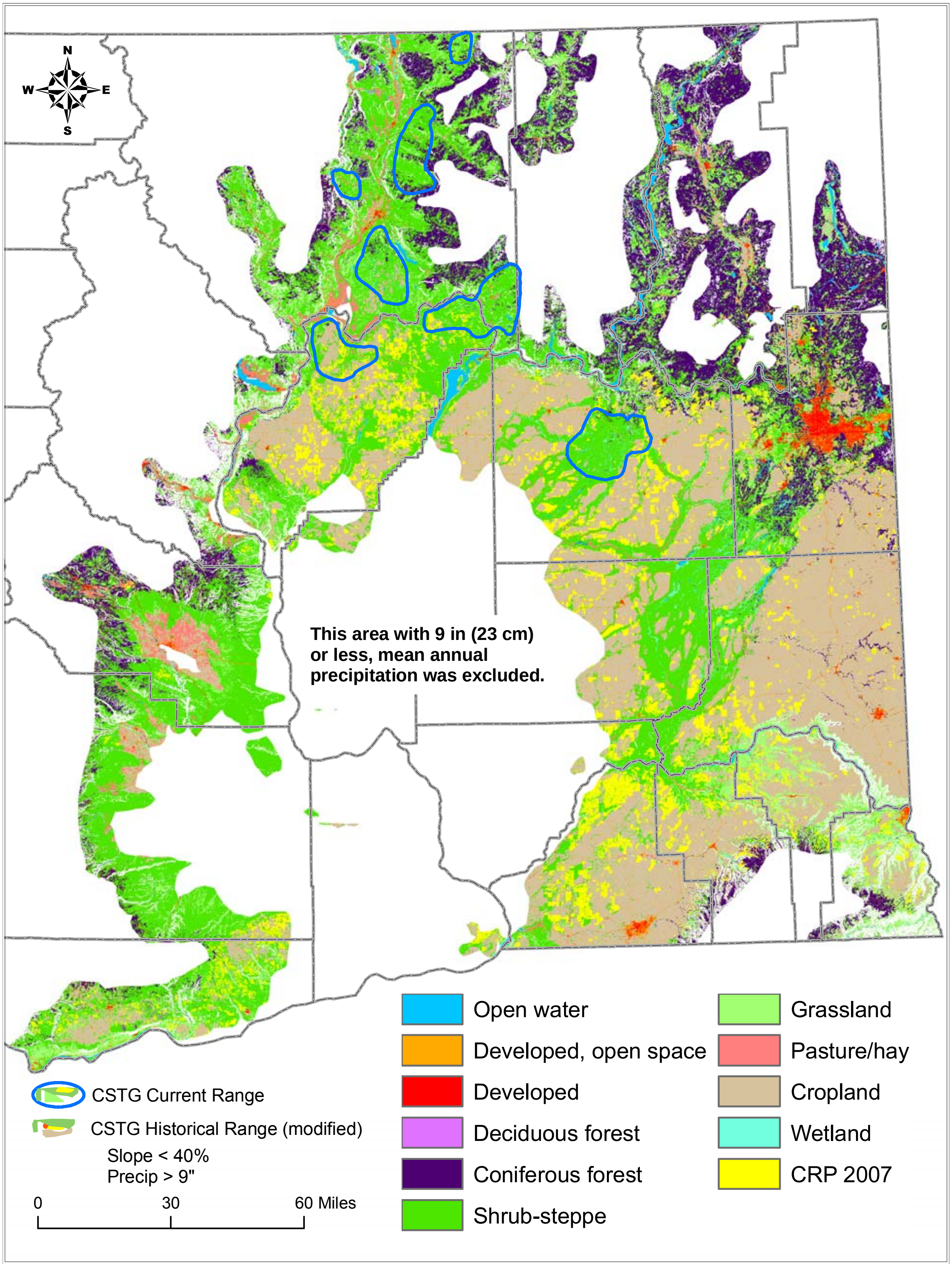


Figure 17. National Landcover (2001 data) and Conservation Reserve Program lands (2007 data) in the historical range of Columbian Sharp-tailed Grouse (steep slopes and low precipitation zones removed) in Washington.

forest, emergent wetland, woody wetland) total 1.2%. Grassland and CRP, possibly the most important cover types, account for 6.7 and 7%, respectively of the historical range. Shrub/scrub accounts for 33% of the area, however, large portions of this type are in the 11" precipitation zone and have thin rocky soils. Furthermore, it is degraded by excessive grazing and highly fragmented by agriculture and steep slopes. Some areas that may otherwise be suitable for sharp-tailed grouse lack the riparian deciduous cover needed in winter.

Most of the largest areas of uncultivated native grassland that remain are Canyon Grassland along the breaks of the Snake and Grand Ronde rivers, though they too have been degraded by grazing except where inaccessible or too far from water for cattle (Tisdale 1986, Weddell 2001a). Although these grasslands were not plowed due to their steepness, slopes of 45–70 % predominate in these canyons (Tisdale 1986), so these areas may be only marginally suitable for sharp-tailed grouse which seem to prefer slopes of <30% (Marks and Marks 1987a, Saab and Marks 1992). Although considerable steppe vegetation exists on shallow soils of the channeled scablands, these areas have generally been degraded by a long history of livestock grazing.

Although 32% of the historical area is in cropland or hay fields, portions could be restored to provide sharp-tailed grouse habitat. CRP is a federal program that pays landowners that have highly erodible crop land, or land of high conservation value to establish vegetative cover for a minimum of 10 years. Payments to individual landowners or land managers are described in a signed contract, which specifies a date of termination for the contract. Many acres of cropland in the counties that compose historical sharp-tailed grouse range were enrolled in CRP beginning in the late 1980's. In recent years the CRP program has increased its emphasis on the restoration of native vegetation and wildlife benefits. CRP, particularly in Lincoln and Douglas counties, provides essential habitat for supporting existing populations. The CRP benefits sharp-tailed grouse by establishing perennial vegetation, and allowing the reinvasion of sagebrush and other shrub species. In Lincoln County, sharp-tailed grouse used CRP land for nesting, brood rearing, foraging, and thermal and escape cover (Stralser 1991, McDonald 1998). Of 17 nests located in Lincoln County in 1995, 11 were on CRP lands (McDonald 1998).

The Palouse prairie, perhaps the historical center of abundance of Columbian sharp-tailed grouse in Washington, is considered one of the most endangered ecosystems in the United States; only about 0.1% of these grasslands remain in a relatively natural state (Noss et al. 1995; Lichtardt and Moseley 1997, Weddell and Lichhardt 1998). Palouse prairie vegetation is largely restricted to small privately-owned remnants in the corners of fields or rocky areas that were not converted to cropland or pasture, and are surrounded by cropland, degraded by weed invasions, and threatened by residential development (Weddell and Lichthardt 1998).

Agricultural drainage, erosion, stream downcutting, and invasion by exotic vegetation has eliminated, or dramatically altered the moist meadow communities in the Palouse (Weddell 2002a, b). Many intermittent streams are now cropland, and many perennial streams that formerly had wide wet meadows are now intermittent and deeply incised. Wet areas have been drained, riparian shrubs removed, and the streams channelized (Victor 1935, Adkins 1968, Black et al. 1999). A recent characterization of the South Fork Palouse River Watershed (72% in Washington, remainder in Idaho) indicated 82% was cropland and 8% was urban or roads; rangeland and riparian/wetlands comprised only 2% each (Resource Planning Unlimited, Inc. 2002a). Of these riparian habitats, an estimated 88% of riparian areas are directly affected by agriculture, grazing, or development; 98% of wetlands have been drained or altered. A similar characterization of the North Fork Palouse River Watershed indicated that 96% was agricultural land, and <2% was riparian, and rangeland is not listed (Resource Planning Unlimited, Inc. 2002b).

Assessments of the North and South Fork Palouse River watersheds indicated that about 98% of wetlands were drained or altered by drainage ditches, subsurface drain tiles, trees and shrub removal, and straightening of the natural watercourse. Many small intermittent streams are now managed as drainage ditches where vegetation has been removed and tillage occurs to the waters edge (Resource Planning Unlimited, Inc. 2002a,b).

Where riparian vegetation exists, native vegetation has been largely replaced by reed canarygrass (*Phalaris arundinacea*), one of the most noxious grass invaders in North America (Servheen et al. 2002 Lavergne and Molofsky 2006). It now dominates many moist and wet sites that have not been cultivated, forming dense monotypic stands throughout the Palouse prairie (Weddell 2002a). Although the species was native to parts of the west, it was not collected in the Palouse until 1917, and the invasive type may be a hybrid between the native and a non-native cultivar (Merigliano and Lesica 1998).

In addition to the degradation by reed canarygrass and Kentucky bluegrass in riparian and wet meadow sites, sharp-tailed grouse habitat in many upland locations has been invaded by noxious weeds including cheatgrass, Scotch cottonthistle (*Onopordum acanthium*), Canada thistle (*Cirsium arvense*), jointed goatgrass (*Aegilops cylindrical*), yellow starthistle (*Centaura solstitialis*), and diffuse and spotted knapweed (*Centaura diffusa*, *C. bibersteinii*) (Ashley and Stovall 2004a,b). White bryony (*Bryonia alba*), or wild hops, is a fast growing vine that forms dense mats. Like kudzu (*Pueraria montana*) in habit, bryony covers and eventually kills shrubs like Douglas hawthorne and is particularly destructive in the limited upland habitat remaining in the Palouse landscape.

The current range of sharp-tailed grouse includes small portions of Douglas, Lincoln, and Okanogan counties. These areas contain higher percentages of steppe than the current landcover of the historical range polygon (Table 6). However, these occupied areas are relatively small (60–500 km^2), isolated from one another, and largely degraded (Schroeder et al. 2000). Stralser (1991) described the habitat around active and inactive leks in Lincoln County; the habitat around two abandoned leks had been degraded by shrub reduction treatments, high levels of annuals, and CRP that had been planted with exotic grasses. Habitat degradation by feral horses has become a problem on the Colville Indian Reservation in recent years. Two long established leks were abandoned as a result of feral horses congregating on the sites.

Land ownership. Sharp-tailed grouse management is complicated by land ownership. Ashley and Stovall (2004a) reported that most (85%) of Eastside (Interior) Grasslands in the southeast Washington ecoregion can be characterized as having no conservation protection status, and only 3% are characterized as having medium or high protection status; no grassland in the Palouse Subbasin was characterized as having high protection status. About 78% of the modified historical range polygon and 56% of the current range are private lands (Fig. 18). An important 4% of the current range is in CRP. However, CRP is a voluntary program and inherently unstable because landowners consider ending their enrollment when the price of wheat is high.

Of the publically-owned land, WDNR manages the largest portion of the historical range at 5.8% (>700,000 ac) (Table 7). However large portions of this are timberland on the eastern edge of the Cascades in Yakima, Kittitas and Chelan counties; another portion is 'school' sections scattered throughout eastern Washington and managed to generate funds for public schools; these lands and other DNR lands in steppe are typically leased for cropland, or for livestock grazing, and sharp-tailed grouse management is not a high priority. The next largest landowner is the Colville Confederated Tribes at 5%; the Colville Reservation has the largest remaining blocks of habitat, and has supported the largest remaining sharp-tailed grouse population in recent years. Together with the Yakama Nation, Spokane, Kalispel, and Umatilla tribes, tribe-owned lands total 8.5% of the polygon (≈1 million ac), although most of these lands also are affected by livestock grazing, and fragmentation by agriculture and development.

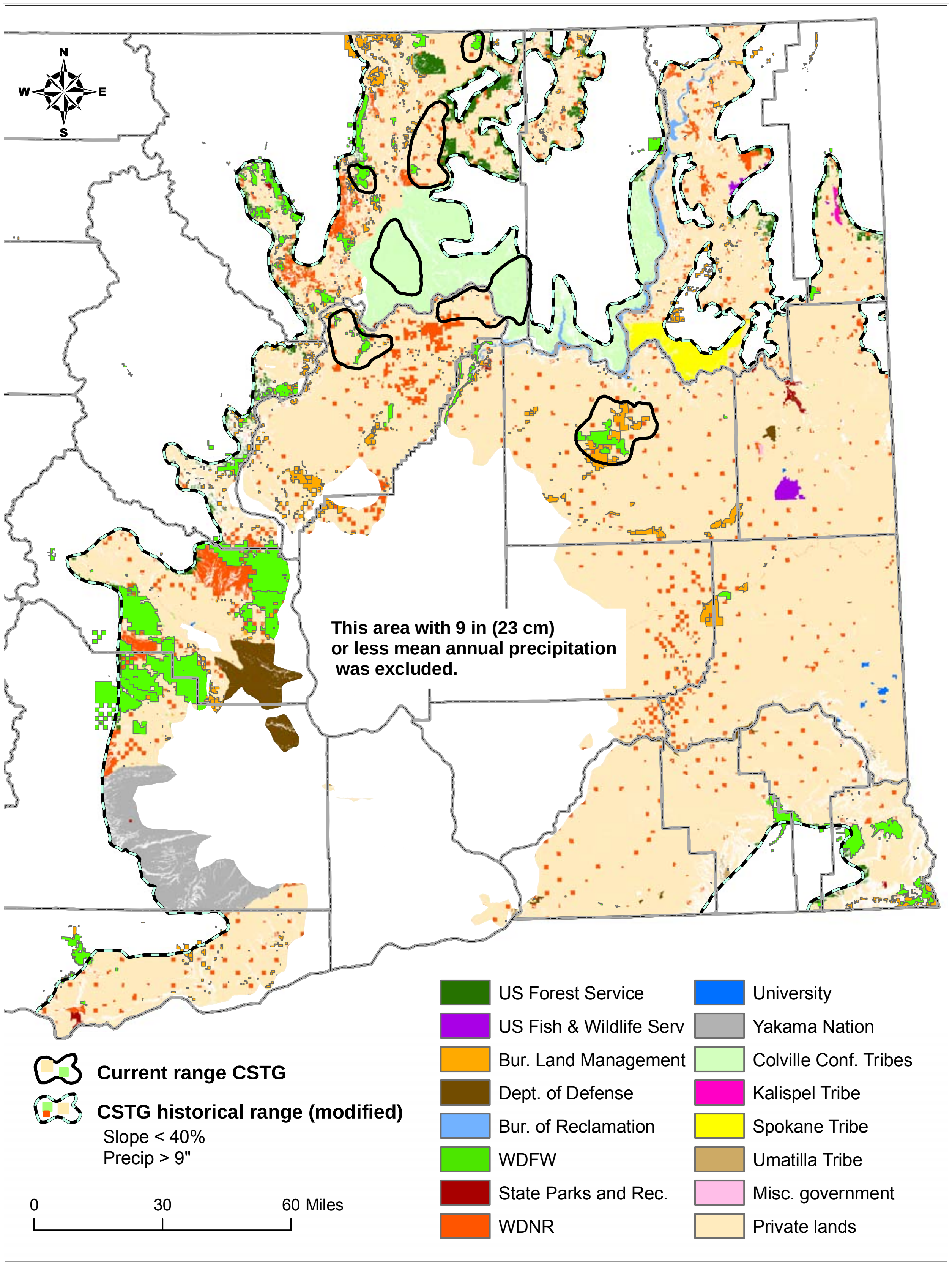


Figure 18. Land ownership or administration in the historical range (steep slopes and low precipitation zones removed) and current range of Columbian Sharp-tailed Grouse in Washington (from WDNR Major Public Lands data, 2007).

Table 7. Ownershipa of areas in the historical and current ranges of Columbian Sharp-tailed Grouse in Washington.

	Historical range[b]		Current range[c]	
Land Owner or Manager	**Percent**	**Acres**	**Percent**	**Acres**
Private	77.79	9,698,889	56.05	299,114
Colville Confederated Tribes	5.09	635,089	28.1	150,037
Dept. Fish and Wildlife	2.15	268,035	6.9	36,834
Dept. of Natural Resources	5.78	720,830	4.8	25,655
US Bureau of Land Management	1.47	183,455	4.08	21,753
US Forest Service	1.54	192,747	0.04	234
Yakama Nation	2.62	327,130	-	-
US Dept of Defense	1.48	184,228	-	-
US Bureau of Reclamation	0.79	98,510	-	-
Spokane Tribe	0.72	90,060	-	-
US Fish & Wildlife Service	0.19	23,713	-	-
State Parks & Recreation	0.13	16,829	<0.0	4
Counties	0.07	8,229	-	-
University	0.05	5,905	-	-
Kalispel Tribe	0.04	4,806	-	-
Confederated Umatilla Tribes	0.03	3,413	-	-
Other miscellaneous public	0.05	5,742	-	-
Total	100	12,467,657	100	533,631

[a]Based on Washington Department of Natural Resources, Major Public Lands data, 2007.
[b]Areas with 9” or less of annual precipitation, or ≥40% slope were deleted.
[c]Includes Horse Springs Coulee area where sharp-tailed grouse may be recently extirpated.

WDFW owns about 2% (>268,000 ac); however, much of this land is concentrated in areas that are probably marginal for sharp-tailed grouse. The foothills of the Cascades in Kittitas County tends to have thin rocky soils and steppe is fragmented by forest and steep slopes. The Wooten, Asotin, and Chief Joseph Wildlife Areas in the foothills of the Blue Mountains and the Grande Ronde Canyon support some potential habitat, and there are a few sharp-tailed grouse records from the 1950s near Hell’s Canyon; however, these lands may be too fragmented by steep slopes to support significant populations, and are isolated from any existing sharp-tailed grouse population.

In addition to 28% of current range on the Colville Reservation, the most important public lands supporting current populations include WDFW lands in Douglas and Okanogan counties, and the combined WDFW and BLM lands in Lincoln County; WDFW and BLM lands total 11% of the current range. Areas that may have historically supported the greatest numbers of sharp-tailed grouse, including Whitman and Klickitat counties, have little public lands dedicated to conservation, although they have significant acreage enrolled in CRP contracts. Exceptions include the Columbia Hills in Klickitat County, and Revere WLA in Whitman County.

Habitat status summary. The most productive steppe habitat areas with deeper soils have been converted to agriculture. A large portion of the remaining habitat is shrub-steppe on shallow lithosols, which affects productivity of vegetation, and consequently sharp-tailed grouse. Habitat quality is difficult to measure on a large scale, but declining quality of steppe habitats in eastern Washington is believed to have been a significant factor in local declines of sharp-tailed grouse. In addition to the direct loss of meadow steppe habitat by conversion to cropland, sharp-tailed grouse habitat has been lost and degraded through: 1) the destruction of deciduous riparian vegetation needed for winter food and cover; 2) livestock grazing, particularly, historical over-grazing by cattle, sheep, and horses; 3) loss of riparian vegetation and seasonally wet meadows due to alteration of hydrology by agriculture; 4) invasive exotic grasses and forbs; and 5) fragmentation of native habitat into small, isolated patches; and 6) invasion by conifers. In additon to these factors, shrub-steppe habitat also has been degraded by wildfires in Wyoming big sage areas and removal of sagebrush. Management for sharp-tailed grouse is difficult because much of the landscape, including lands between the existing populations, is privately owned cropland, orchards, or rangeland. Although CRP has been important in maintaining and restoring local sharp-tailed grouse populations both here, and in other states, it is a voluntary program, and could be discontinued in the future. CRP and restoration efforts on WDFW wildlife areas have shown that farmland can be restored to usable condition for sharp-tailed grouse, and strategically located cropland could be the focus of acquisition efforts. However, funding acquisition of cropland can be more difficult because grant programs like Washington Wildlife and Recreation Program (WWRP) give higher priority to funding proposals for areas with intact native vegetation, and local officials often oppose taking cropland out of production.

CONSERVATION STATUS

Sharp-tailed grouse are listed as a game bird by WDFW, although the season has been closed since 1988. By policy, sharp-tailed grouse were considered a Candidate species for listing as Sensitive,Threatened, or Endangered by the WDFW between 1991–1998. Sharp-tailed grouse were listed by the Washington Fish and Wildlife Commission as Threatened in April 1998. Sharp-tailed grouse are designated a priority species and their habitat a priority habitat by the WDFW Priority Habitats and Species (PHS) Program.

The U.S. Fish and Wildlife Service (USFWS) considers the Columbian sharp-tailed grouse to be a 'Species of Concern'. The USFWS was petitioned to list the Columbian Sharp-tailed Grouse as a threatened or endangered species under the federal Endangered Species Act in 1995 and 2004 (Carlton 1995, Banerjee 2004). In response to the 1995 petition, USFWS conducted a status review (Bart 2000), and concluded that listing was not warranted (USFWS 2000). They also concluded that the 2004 petition did not provide substantial information indicating that listing was warranted (USFWS 2006).

BLM classifies the Columbian sharp-tailed grouse as a Sensitive Species. The BLM Manual (6840.06), states:

> "Actions authorized by the BLM shall further the conservation of …Bureau sensitive species….Bureau sensitive species will be managed consistent with species and habitat management objectives in land use and implementation plans to promote their conservation and to minimize the likelihood and need for listing under the ESA."

MANAGEMENT ACTIVITIES IN WASHINGTON

Species monitoring. Since the 1950's, WDFW has conducted lek surveys of sharp-tailed grouse each spring to assess population status, trends, hunting seasons and bag limits. Searches for newly established leks are conducted periodically. The Colville Confederated Tribes Fish and Wildlife Department has monitored active leks on the Colville Reservation in recent years; in addition they used radio telemetry to monitor the movements, habitat use, and nesting success of birds released during augmentation, and additional birds captured on the reservation (Berger et al. 2005, Gerlinger 2005). WDFW attempts to visit all other leks that have been active in recent years on ≥2 occasions each spring during the breeding season. The BLM periodically inventories potential breeding and wintering habitats, especially on new land acquisitions. The WDFW, BLM, and Colville Tribe have also been monitoring radio-tagged birds that have been released during translocation efforts.

Management plans. Sharp-tailed grouse habitat management plans for the Tracy Rock area that later became the Swanson Lakes WLA were developed as part of Bonneville Power Administration (BPA) wildlife mitigation for Grand Coulee Dam (Ashley 1992, Cope and Berger 1992). A statewide management plan for sharp-tailed grouse was developed by the WDFW in 1995 (Tirhi 1995); that plan is replaced by this recovery plan. The Colville Confederated Tribes completed a sharp-tailed grouse management plan in 2005 (Berger et al. 2005). The plan outlines tasks to increase sharp-tailed grouse populations, including habitat restoration, elimination of unmanaged grazing in occupied areas, monitoring of birds and habitat, translocation of birds within the reservation, and genetic augmentation with birds from outside Washington. The BLM develops Allotment Management Plans for all parcels with occupied grouse habitat that describe the grazing system and permitted use of the allotment while addressing any local issues and providing for multiple uses.

Habitat acquisition. The WDFW has been acquiring habitat for sharp-tailed grouse with funding from the Bonneville Power Administration (BPA) and the Washington Wildlife and Recreation Program (WWRP). Additional lands have been acquired over the years with funds from the U.S. Fish and Wildlife Service through the Federal Aid in Wildlife Restoration (Pittman-Robertson Act) or Endangered Species Act-Section 6 programs. A total of over 40,000 ac has been purchased by WDFW in Okanogan, Lincoln, and Douglas counties primarily, or partly, for the protection and conservation of sharp-tailed grouse (Table 8). However, >25,000 ac are historical sharp-tailed grouse areas where populations need to be restored. Additional acquisitions that were aimed primarily at protecting mule deer winter range contribute to protecting sharp-tailed grouse habitat or surrounding area.

In 1974, WDFW entered into an agreement with Douglas County Public Utilities District for wildlife mitigation for the construction and operations of Wells Dam. The utility purchased 5,723 ac and gave WDFW title; WDFW also leases an additional 1,550 ac from WDNR in the Indian Dan Canyon area, and BLM has 180 ac within the fenced boundary of the Wells Wildlife Area. The Wells WLA initially totaled 7,800 ac, recently 370 ac were added to the Central Ferry Canyon Unit. The West Foster Creek and Central Ferry Canyon units support small sharp-tailed grouse populations and the Indian Dan Canyon Unit has habitat and recent sightings of sharptails (Hallet 2006). Washburn Island is managed by WDFW, but is owned by Douglas County Public Utility District.

In 1991, WDFW began acquiring land with funding from WWRP to protect sharp-tailed grouse populations in Okanogan County (Olson 2006). These lands now total 22,860 ac, and include the Scotch Creek, Tunk Valley, Pogue Mountain and Chesaw units of the Scotch Creek WLA. Acquisitions in the last several years include 320 ac added to the Tunk Valley Unit, and the 6,300 ac Charles and Mary Eder Unit. Additional WDFW lands in Okanogan County that were primarily purchased to protect mule deer winter range, but that also preserve historical sharp-tailed grouse habitat include the Sinlahekin, Chiliwist, and Methow Wildlife Areas (Fig. 19). Many homesteads and ranches in the foothills around the Methow Valley were acquired, including >12,000 ac from 1941−1959, >4,700 ac 1972−73, and 14,000 ac in the 1990s. The most recent acquisitions include 2,160 ac, and an easement on 613 ac in 2003, 600 ac in 2004–05, and 584 ac in 2007. Other recent acquisitions include 193 ac acquired in 2006, and 838 ac in 2008 in the Horse Springs Coulee area west of Tonasket that will be managed as part of the Sinlahekin WLA.

Table 8. Columbian Sharp-tailed Grouse occurrence and area of Washington Department of Fish and Wildlife lands in northcentral Washington.

Wildlife Area / **Management Unit**	**Sharp-tailed grouse occurrence[a]** Breeding	Wintering	**Acres[b]**
Scotch Creek Wildlife Area			
Scotch Creek Unit	√	√	8,694
Chesaw Unit	√	√	4,351
Tunk Valley Unit	√	√	1,399
Pogue Mountain Unit	x	x	1,146
Charles & Mary Eder Unit	x	?	6,300
Chiliwist Wildlife Area	x	√	4,889
Sinlahekin Wildlife Area[c]			14,000
Wells Wildlife Area			
West Foster Creek Unit	√	√	1,050
Central Ferry Canyon Unit	√	√	1,908
Indian Dan Canyon Unit		√	4,412
Sagebrush Flat Wildlife Area			
Bridgeport Unit	√	√	3,905
Methow Wildlife Area			
Methow Unit	x		14,800
Rendezvous Unit	x		4,225
Big Buck Unit	x		5,150
Swanson Lakes Wildlife Area	√	√	21,000

[a]Symbols: √ = sharp-tailed grouse known to be present; x = historicalrecords of presence, but not observed in recent years; ? = uncertain.
[b]Lands owned or managed by WDFW.
[c] Most of the Sinlahekin is probably not suitable for sharp-tailed grouse.

In 1990 an area in Lincoln County near Tracy Rock was identified as a potential area to mitigate impacts to sharp-tailed grouse from Grand Coulee Dam (Ashley 1992). The proposal was approved by BPA and the Northwest Power Planning Council and 10,399 ac were acquired in 1993. Additional acreage was acquired later, including 8,300 ac in 1995, 295 ac in 1996, and 792 ac in 1997. WDFW also leased 1,280 ac from WDNR. The area became known as the Swanson Lakes WLA and currently totals about 21,000 ac. Acquisitions by BLM in the Twin Lakes, Telford, and Hawk Creek areas brought the combined total BLM/WDFW in the area to >53,000 ac. This has facilitated management compatible with sharp-tailed grouse and greater sage-grouse on an area large enough to justify a sage-grouse reintroduction project.

The Sagebrush Flat WLA was approved as a wildlife mitigation project in 1992 by BPA and the Northwest Power Planning Council to partially address adverse impacts caused by the construction of Chief Joseph and Grand Coulee hydroelectric dams (Peterson 2006). Since 1991 ten separate purchases have contributed land. The Bridgeport Unit in northern Douglas County is the most important for sharp-tailed grouse, and acquisitions added 2,362 ac to the unit in 2005, and 200 ac in 2007. During the 1990s, BPA also funded the purchase of three ranches totalling 16,100 ac for the Hellgate project on the Colville Indian Reservation (Ashley and Berger 1997).

A recent acquisition in a potential reintroduction area is the 2008 purchase of 516 ac on Swale Creek in

Klickitat County. Although the primary purpose was for a pheasant release area, this purchase adds to an aggregation of public lands that should be evaluated for its potential as a reintroduction area. Along with the Columbia Hills Natural Area Preserve managed by DNR (3,594 ac), and the Dalles Mountain Ranch portion of Columbia Hills State Park (3,338 ac), publically managed land totals over 7,500 ac. The potential risks to reintroduced sharp-tailed grouse from disease and accidental hunting mortality associated with pheasant releases would need to be evaluated, but state park or DNR land could perhaps be the sharp-tailed grouse release site, reducing the potential for these mortality factors. There is also significant private acreage (>1,000 ac) in CRP to the northeast of these public lands. However, the density of homes on private lands may increase and become incompatible with sharp-tailed grouse, and the area is attractive for wind turbine development.

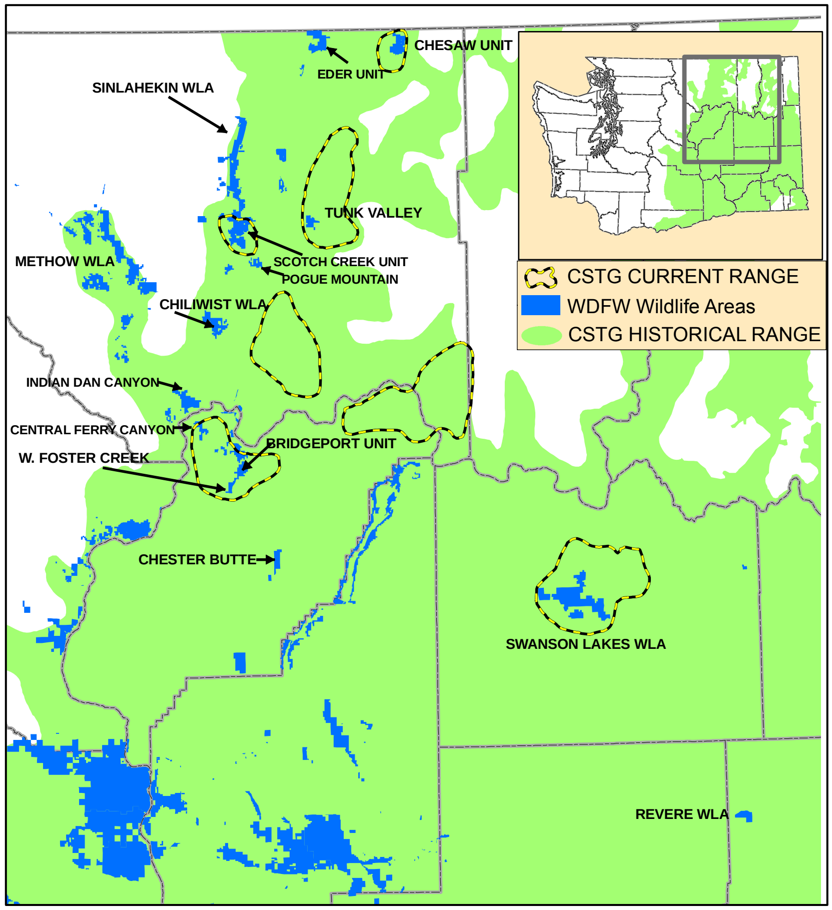


Figure 19. Washington Department of Fish and Wildlife lands and areas currently occupied by Columbian Sharp-tailed Grouse in north central Washington.

The Revere Wildlife Area, 2,291 ac of steppe and wetlands along Rock Creek in western Whitman County was acquired in 1992 with funds from the U.S. Army Corp of Engineers through the Lower Snake River Fish and Wildlife Compensation Plan. The Revere WLA together with 15,446 ac of BLM lands provide a nucleus for a potential reintroduction area that should be evaluated.

Habitat assessment, restoration and enhancement. Habitat assessments using variations of Habitat Suitability Index models for Columbian sharp-tailed grouse have been done to quantify habitat values. Assessments based on its condition before and after enhancements have been conducted on WDFW wildlife areas most often with funding from Bonneville Power Administration. Habitat assessment has also been done by the Colville Confederated Tribes Fish and Wildlife Department (Gerlinger 2005), and Spokane Tribe Wildlife Program (B.J. Kieffer, pers. comm.), and is currently underway on the Coeur d'Alene Indian Reservation in Idaho, adjacent to Whitman County (G. Green, pers. comm.).

Habitat on wildlife areas is being enhanced through restoring native vegetation to former agricultural fields, and older CRP fields where non-native grasses were used. Restoration involves establishing a more diverse mix of native grasses and forbs. Apa (1998) reported sharp-tailed grouse nest success was higher in native vegetation than in older CRP that was largely crested wheatgrass (100%, n = 6 vs. 45%, n = 42; $p = 0.006$). Riparian areas are enhanced through shrub and tree plantings. Weed control has been

Figure 20. Restored former wheat field on the Chesaw Unit, Scotch Creek Wildlife Area, Washington

done on thousands of acres to promote native vegetation, and is a perennial activity. The bulk of the funding for habitat restoration has come from the BPA and the Washington Wildlife Recreation Program through the Recreation and Conservation Office.

Habitat enhancement on the Scotch Creek WLA since 1991 included restoring native steppe vegetation on 2,772 ac of former cropland (Fig. 20), and the planting of >100,000 trees and shrubs in riparian areas, moist draws and north slopes (Olson 2006, 2007, 2008). During 2007–2008, 105 ac of former agricultural fields were seeded to native vegetation, and 500 water birch were planted. In addition, 60 mi of boundary fence have been erected, and 20 miles repaired to exclude trespass cattle; 34 miles of interior fences have been removed. Lek counts on the Chesaw Unit indicate a recent increase in the population, but the timing suggests that factors in addition to habitat restoration may be responsible (Fig 21).

In 1986 and 1987, 500 acres of former cropland on the West Foster Creek and Central ferry Canyon units of the Wells WLA was restored to shrub-steppe. From 2000–2006, an additional 65 acres were restored to shrub-steppe, and >29,000 trees and shrubs were planted on the Wells WLA (Fig 22; Hallet 2001–2007). On the Bridgeport Unit of the Sagebrush Flat WLA, several thousand stems of willow and 400 shrubs were planted in riparian sites in 2006, and 110 ac of former cropland were restored in recent years; 400 trees were planted in 2007 (Peterson 2007, 2008).

Many shrub plantings were done on the Methow WLA in the 1950s–60s; these saw high mortality from drought and deer damage, but many still survive (Romain-Bondi 2006, 2008). Later projects included 4,000 shrubs with drip lines that were damaged by porcupines in 1988, and 1,200 in 1992 that suffered deer damage. Habitat enhancement work in 2006–2008 included seeding native vegetation on 140 ac of former cropland, laying plastic to control reed canarygrass, planting 275 shrubs, and fencing a riparian site, most often with the help of volunteers, and removal of 9 mi of old fencing. Volunteers helped seed 15 ac with native forbs. Some former cropland on the WLA that has not yet been replanted with native vegetation is a high priority to improve habitat.

Figure 22. Water birch, rose and other shrubs planted in a deer exclosure near West Foster Creek, Wells Wildlife Area.

On Swanson Lakes WLA and adjacent BLM lands, from 1991–2006, 1,650 ac of cropland and non-native crested and tall wheatgrass was restored to native-like grassland. Cattle grazing has been largely eliminated on Swanson Lakes WLA; 41,900 shrubs and trees were planted in riparian zones during 1996–97, 58 mi of new fence and 38 mi of fence was repaired to exclude cattle, and 53 mi of unneeded interior fence were removed (KWA Ecological Sciences, Inc. 2004). Recent habitat enhancement included 70 ac of crested wheatgrass restored with native-like seed mix, and 1,360 riparian shrubs and trees were planted, irrigated and fenced to prevent deer damage (Anderson 2006, 2007, 2008). In 2007, 113 ac of former wheat field was planted to native vegetation. Reseeding of an additional 500 ac of old CRP is a high priority for sharp-tailed grouse recovery. The Lincoln County Conservation District has also completed several riparian habitat restoration projects in the Crab Creek drainage (KWA Ecological Sciences, Inc. 2004).

Habitat enhancement has been ongoing in recent years on the Colville Indian Reservation. A recent sharp-tailed grouse management plan included the expectation of planting 2,500 shrub and trees, and 50,000 bunchgrass plugs annually for 5 years (Berger et al. 2005).

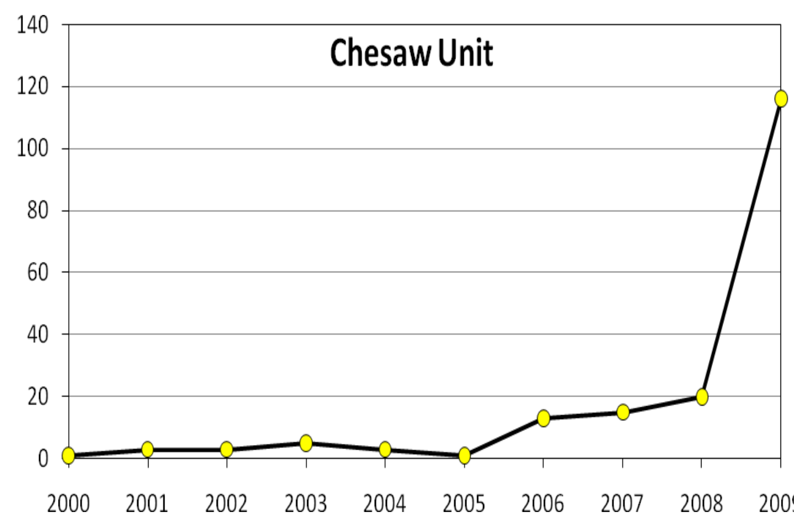


Figure 21. Population estimates for the Chesaw Unit of the Scotch Creek Wildlife Area, Washington.

WDFW is actively working to increase the benefits of CRP lands to sharp-tailed grouse. The WDFW works with landowners and federal agencies to extend current CRP contracts and promote new contracts, such as the new Douglas County sage and sharp-tailed grouse SAFE program , while requiring vegetative plantings beneficial to wildlife, such as native forbs, grasses, and sagebrush.

Population augmentation. In the early 1950s, sharp-tailed grouse were trapped in Okanogan County and released on Turnbull National Wildlife Refuge in Spokane County. In the early 1960s, sharp-tailed grouse from Okanogan County were released on the Wooten Wildlife Area. Neither of these releases was successful at re-establishing local populations (Hays et al. 1998).

More recent translocations were conducted to improve the genetic health of populations, and have been conducted with the cooperation of other states. Microsatellite data indicate that the Swanson Lakes population exhibits lower genetic diversity than larger populations near Nespelem and in a population of plains sharp-tailed grouse in Alberta (Warheit and Schroeder 2003). The small isolated populations in Washington may have lost some of their intrinsic ability to respond positively to habitat improvements because they have endured severe 'bottlenecks' in abundance (Westemeier et al. 1998a, Bellinger et al. 2003, Johnson et al. 2003). There appeared to be little genetic differentiation among all populations of Columbian sharp-tailed grouse (Spaulding et al. 2006). Based on genetic

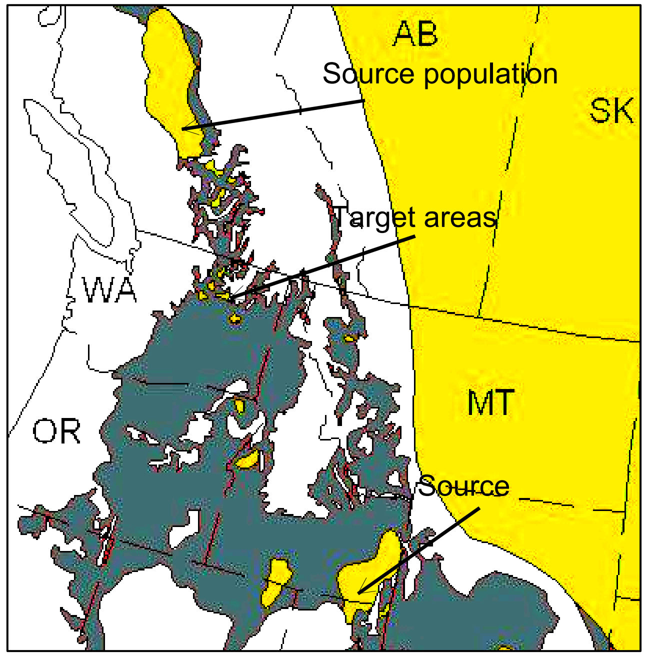


Figure 23. Location of source populations and target areas for 2005–2009 translocations of Columbian sharp-tailed grouse in Washington.

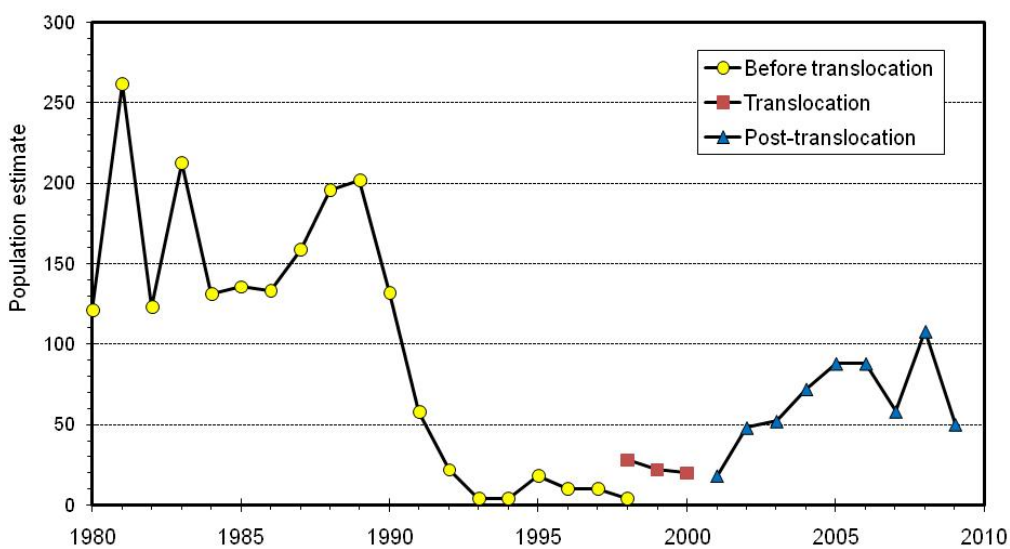


Figure 24. Population estimates for the Scotch Creek Wildlife Area before, and since, the 1998-2000 augmentation project using birds from outside the area.

sampling of Columbian sharp-tailed grouse from Utah, British Columbia, Idaho, and Washington, any population within these areas appears to be a genetically appropriate source population for augmenting Washington populations (Fig. 23).

Since 1998, a total of 274 sharp-tailed grouse have been translocated and released. During 1998–2000, 63 birds from southeastern Idaho (51 birds) and the Colville Indian Reservation in Washington (12 birds) were released on the Scotch Creek Unit (Fig. 24). Prior to the translocation, surveys indicated that 4 grouse remained on the one remaining lek in the area, and 2 nests found contained infertile eggs. After the three year translocation project, the population increased to approximately 100 birds using 3 leks in 2005. The population response to the augmentation was consistent with the hypothesis that the population suffered from poor genetic health prior to the translocations. A flock of 38 birds was observed on 7 December 2008, the largest observed since 1983 (J. Olson, pers. comm.). The decline apparent in 2006–2007 may have resulted from poor recruitment due to cold wet spring weather.

Additional translocations conducted during 2005–2009 included 61 birds released on the West Foster Creek unit (Dyer Hill area, Douglas County), 88 at Swanson Lakes Wildlife Area in the Crab Creek area, Lincoln County (Fig. 25), and 66 on the Colville Indian Reservation (Schroeder et al. 2008). The birds were captured from populations in Idaho (98), Utah (78), and British Columbia (40). Populations at all three recent release sites increased slightly between 2005 and 2006, but results are difficult to assess at this early stage of the augmentation process. Future projects may involve reintroductions of sharp-tailed grouse to unoccupied portions of the historical range. WDFW is currently evaluating potential sites for future reintroduction and augmentation projects.

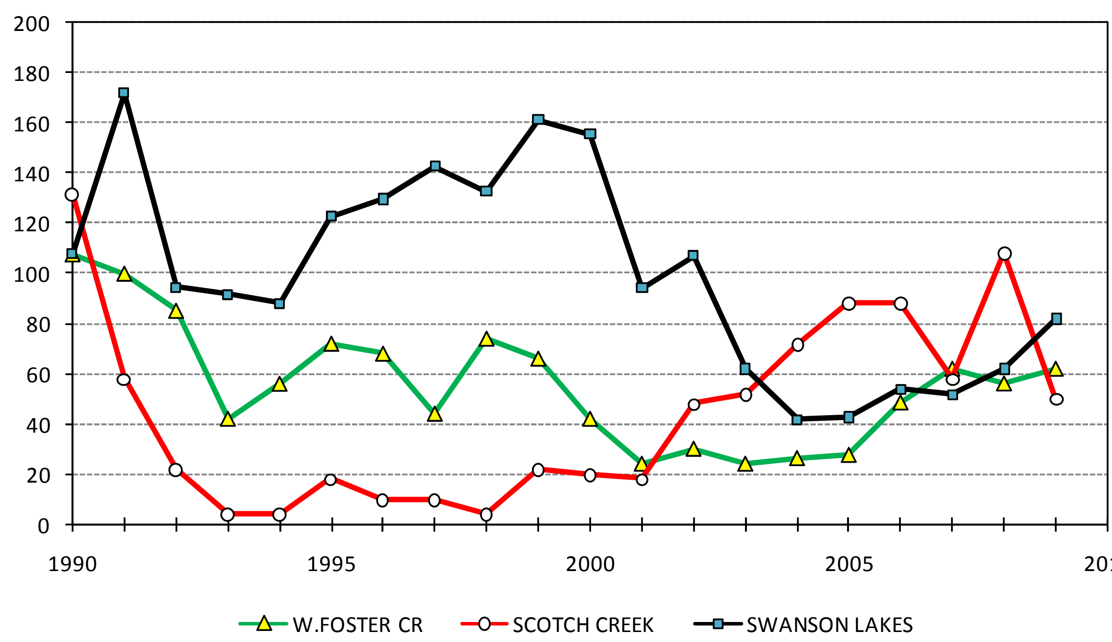


Figure 25. Population estimates for three translocation release areas in Washington.

Research. Early papers, reports, and theses that investigated the distribution, diet, and status of sharp-tailed grouse in eastern Washington include Dziedzic (1951), Yocom (1952), Buss and Dziedzic (1955), Jones (1966), and Zeigler (1979). In the 1980s, Hofmann and Dobler investigated wintering densities, home range, habitat use, and spring movements of Columbian sharp-tailed grouse in Okanogan, Douglas, and Lincoln counties, and lek histories (Hofmann and Dobler 1988a, b; Hofmann and Dobler 1989). Merker (1988) reviewed the sharp-tailed grouse situation in Washington and made recommendations for their conservation.

Research in the 1990s produced three theses from Eastern Washington University, and one from University of Idaho. Stralser (1991) quantified habitat characteristics around active and inactive leks in Lincoln County. Paulson (1996) described the impacts of livestock grazing on woody riparian vegetation in areas used by sharp-tailed grouse in Lincoln County. WDFW and the Washington Falconer's Association supported a thesis project that investigated captive rearing and release of hand-reared versus parent-reared chicks to evaluate the potential for use of captive rearing in reintroduction projects (Merker 1996). WDFW funded a thesis project at the University of Idaho that examined seasonal habitat use and movements, nesting ecology, productivity, and survival of sharp-tailed grouse in Washington (McDonald 1998). McDonald and Reese (1998) examined the landscape changes in the historicalrange of sharp-tailed grouse and their distribution in Washington, and provided recommendations about where to augment populations.

The Nature Conservancy obtained funding to conduct extensive lek searches, lek surveys, and fall surveys in Washington during 1990–1992 (Weddell et al. 1990, Weddell et al. 1991a, Weddell and Johnston 1992a, b). They also produced reports on winter habitat (Weddell et al. 1991b), and a review of biology and conservation (Weddell 1992).

WDFW conducted a research project during 1992-1996 titled *Productivity and Habitat Use of Sharp-tailed Grouse in North-central Washington* (Schroeder 1996), that focused on habitat-use, population status, and estimating rates of mortality and recruitment. Additional projects resulted in a paper on the decline of sharp-tailed grouse in Washington (Schroeder et al. 2000), and reports on genetics (Warheit and Schroeder 2001, 2003), and ongoing translocation projects (Schroeder et al. 2008). WDFW personnel contributed to a paper on range-wide genetic analysis of Columbian sharp-tailed grouse (Spaulding et al 2006), and the subspecific identity of sharp-tailed grouse in western Montana (Warheit and Dean 2009).

Coordination and partnership. WDFW coordinates with several agencies on habitat management issues for sharp-tailed grouse. The Fish and Wildlife Program of the Colville Confederated Tribes has been a cooperator with WDFW on sharp-tailed grouse research, translocation projects, and conservation for many years. WDFW, BLM, and WSU, with the help of volunteers, are cooperating in monitoring the sharp-tailed grouse and sage-grouse released in Lincoln County. WDFW, Colville Confederated Tribes, and BLM co-sponsored the 24th Biennial Western Agencies Sage and Columbian Sharp-tailed Grouse Technical Committee Meeting in Wenatchee in 2004. WDFW was also a co-sponsor of the 16th Western Sage and Sharp-tailed Grouse Technical Committee Meeting in Moses Lake in 1989.

Translocations have been possible because of the cooperation of wildlife agencies in British Columbia, Idaho, Utah, and Oregon. Washington State Department of Agriculture has been assisting with disease testing of translocated birds.

The WDFW is continuing to work with the Natural Resources Conservation Service (NRCS) and Farm Service Agency (FSA) to extend current CRP contracts, promote new contracts in areas inhabited by sharp-tailed grouse or where potential reintroductions could occur, and improve the benefits of CRP lands to wildlife. The Eastern Washington Shrub-steppe and Palouse Prairie State Acres For Wildlife Enhancement (SAFE) projects are new initiatives within the CRP program that give special consideration to wildlife (http://www.fsa.usda.gov/Internet/FSA_File /fs_safe.pdf). The shrub-steppe SAFE project is a special partnership between FSA, WDFW, and the Colville Confederated Tribes with a goal of enrolling

5,200 ac to benefit shrub-steppe birds. The Palouse Prairie SAFE project is a partnership between FSA and WDFW with the goal of enrolling 2,000 ac to increase habitat for wildlife by re-establishing prairie vegetation. Foster Creek, Lincoln County, and other conservation districts in recent years have helped facilitate the protection and restoration of riparian habitat.

Funds for sharp-tailed grouse research, habitat acquisition and enhancement, monitoring, and planning in Washington have been provided by many programs and cooperators including, Federal Aid in Wildlife Restoration, State Wildlife Grants, Washington Wildlife and Recreation Program, Bonneville Power Administration, Douglas County Public Utility District, Tribal Wildlife Grants, and the Charlotte Martin Foundation through The Nature Conservancy.

Information and education. The WDFW provides the public and other agencies with the most appropriate methods for managing sharp-tailed grouse habitat through the Department's PHS Management Recommendations (Schroeder and Tirhi 2003; http://wdfw.wa.gov/hab/phs/vol4/birdrecs.htm).

FACTORS AFFECTING CONTINUED EXISTENCE

The primary factors affecting the continued existence of sharp-tailed grouse in Washington relate to habitat loss and alteration and the precarious nature of small, geographically isolated subpopulations. Two of the major factors that contributed to the decline of sharp-tailed grouse and their habitat in Washington, conversion to agriculture and improper grazing by livestock, are still threats today. The voluntary nature of CRP, in particular creates uncertainty about habitat availability on private lands in the future. The conversion of habitat to rural residential and commercial development, and wind energy development have become important threats in recent years. The removal of shrubs as part of agricultural practices reduces the quantity and quality of winter habitat, and there is potential for additional degradation of shrub and meadow steppe breeding habitat as a result of livestock management. The remaining subpopulations are small and relatively isolated from one another, which increases their risk of extinction.

Adequacy of Existing Regulatory Mechanisms

Sharp-tailed grouse were protected from hunting with the closure of the hunting season by the Washington Fish and Wildlife Commission in 1988. Populations have stayed at low levels or continued to decline since the season closure. House Bill-1309 (Washington State Legislature 1993) requires the WDFW and WDNR to develop goals to preserve, protect, and perpetuate wildlife and fish occupying shrub-steppe (and shrub/meadow) habitat or lands that are classified agricultural lands, rangelands, or woodlands used for grazing. However, there are no existing state or federal regulatory mechanisms that directly protect sharp-tailed grouse habitat on private lands. Washington's Growth Management Act requires counties to develop critical area ordinances to address protection of critical wildlife habitat, but counties vary in how far along they are in that process, how well ordinances address habitat, and how effectively they are enforced. Ongoing development of private lands is precluding options for restoring populations in some areas.

Small Population Size, Isolation, and Genetic Health

The persistence of small populations can be affected by environmental, demographic, and genetic factors.

Environmental events, such as droughts or disease can decimate small populations. Chance shifts in sex ratios or age distributions can affect breeding and recruitment, and small populations can rapidly lose the genetic diversity needed for adaptation to changing environments (Foose et al. 1995). Genetic and demographic factors can interact so that a small population continues to decline in what has been called an extinction vortex (Fig. 26). None of the existing subpopulations in Washington currently exceed a few hundred birds. An increasing number of studies indicate that goals to maintain viable populations of vertebrates need to be in the order of several thousands, rather than hundreds (Reed et al. 2003), although much smaller populations may sometimes persist for some time (Pacheco 2004). Sharp-tailed grouse populations seem to naturally fluctuate with weather, habitat condition, predation and disease. This natural variability puts smaller populations at greater risk of local extinction.

Population isolation could affect the continued existence of sharp-tailed grouse in Washington. Many authors indicate that long-term survival (>100 years) of isolated populations requires many more individuals than populations that occasionally exchange genetic material with other populations (Lande and Barrowclough 1987, Dawson et al. 1987, Grumbine 1990). The remaining sharp-tailed grouse in Washington exist as seven subpopulations separated by >20 km. Limited data from radio-marked birds suggest that movements sufficient to allow regular interchange of individuals among the populations in north-central Washington may be rare. The negative effects of habitat change are amplified when populations become isolated. For example, dispersal by juveniles is typically advantageous in widespread and connected populations. However, it may become detrimental in isolated populations if dispersing juveniles are a net loss to the population and there is no compensating immigration.

Genetic health (represented by adequate genetic heterogeneity and allelic diversity) is an important consideration for species reduced to small populations, and is an important issue for sharp-tailed grouse in Washington. In a review of rare mammals, Garner et al. (2005) report that based on microsatellite markers, there has been a pervasive and consistent loss in genetic diversity in populations that face a demographic threat. They concluded that by the time species receive official conservation status (i.e., listing as threatened or endangered), they have already lost a substantial portion of their genetic variation. Warheit and Schroeder (2003) reported that data suggest that historically, the Columbian sharp-tailed grouse existed in very large populations with extensive gene flow across large geographic areas. Washington populations of sharp-tailed grouse may be showing symptoms of isolation; the Swanson Lakes population was approximately 25% lower in gene diversity and allelic richness than birds in Alberta, the most diverse population. A wide variety of genetic problems can occur with small isolated populations and can interact with demographic and habitat problems leading to a population's extinction (Gilpin and Soule 1986, Lacy 1987, Reed and Frankham 2003). The decline in allelic diversity associated with small population size is often expressed by reduced resistance to disease (Allendorf and Ryman 2002).

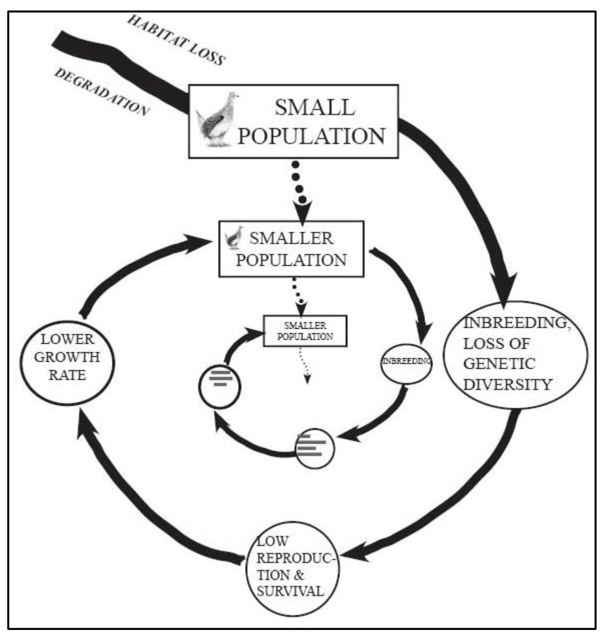


Figure 26. Extinction vortex (Frankham et al. 2002).

Poor genetic diversity can result in weak immune systems, low hatchability of eggs, and reduced ability to adapt. Inbreeding depression has contributed to declines and extinctions of several species in the wild (Brook et al. 2002). Inbreeding has been reported to affect male fitness in black grouse (Höglund et al. 2002). Bellinger et al. (2003) reported the loss of genetic variation in greater prairie-chickens following a population bottleneck in Wisconsin. Westemeier et al. (1998a) and Bouzat et al. (1998) reported reduced heterogeneity and fertility in a declining, remnant population of greater prairie-chickens in Illinois. Johnson et al. (2003) reported that genetic variation was significantly reduced in isolated populations of <2,000 greater prairie-chickens. Fertility, hatching rate, and the population size of the Illinois population increased following augmentation with birds from large healthy populations (Westemeier et al. 1998a). The small populations of sharp-tailed grouse at Scotch Creek and Dyer Hill both exhibited an increase following augmentation projects in recent years (Schroeder et al. 2008), but it is too early to tell if this indicates the start of a sustained increase as a result of improved genetic health.

Habitat Quantity, Condition, and Continued Loss

> "It is not enough to simply improve habitat; former habitat must be restored. Simply put, prairie grouse require prairie and lots of it." Silvy et al. (2004)

The predominant reason for the isolation and small size of remnant sharp-tailed grouse populations is the loss of habitat. McDonald and Reese (1998) reported dramatic declines in mean patch size of sagebrush, grassland, and herbaceous wetlands in the historicalrange of sharp-tailed grouse in Washington. In addition to the issues of demographic and genetic isolation, habitat fragmentation creates or exacerbates other impacts to sharp-tailed grouse, including increased predation in habitat patches (Schroeder and Baydack 2001), increased potential for encroachment by noxious weeds, and increased impacts of herbicides and insecticides sprayed on adjacent cropland. Bousquet and Rotella (1998) attributed the high nest success (74%) in their study partially to the lack of fragmentation of the grassland in their Montana study area. Isolated populations also would be more susceptible to temporary disturbances like fire.

Schroeder et al. (2000) noted that the portion of the sharp-tail's historical range that is unoccupied was 38% cropland, while occupied areas were 11.3% cropland; Dyer Hill, which was 12% CRP, was an exception to this pattern. Most of the remaining habitat with native vegetation is in areas with thin or rocky soils that are poorly suited to cultivation; this includes extensive 'scablands' that were stripped of soil by repeated ice age floods resulting from the catastrophic draining of Lake Missoula (USDI/GS 1976). These areas with thin soils have typically been used for livestock grazing, and in most cases the native vegetation suffers the effects of historical over-grazing. It is uncertain if management efforts can result in these lands becoming highly productive for sharp-tailed grouse. It may be essential to also restore habitat on former cropland with deep soils. McCleery et al. (2007) and Silvy et al. (2004) report that lesser prairie-chicken recovery efforts have been focused on proximate factors and shinnery oak habitat because that is where relict populations occur. However, shinnery oak is likely marginal habitat, and the preferred prairie habitat was converted to cropland long ago. Deep soils and historical prairie habitats need to be included for sharp-tailed grouse recovery in Washington.

Sharp-tailed grouse in Douglas and Okanogan counties, and to a lesser degree in Lincoln County, are now generally restricted to habitats, mostly in higher elevation areas, where the impacts of grazing and conversion to wheat and orchards have not been as severe (Schroeder 1996). Lower elevation areas historically provided important winter habitiat. Relatively high winter mortality resulting from declining quantity and quality of winter habitat may be an important factor causing continuing decline in the sharp-tailed grouse population in Washington (Schroeder 1996). Protecting and enhancing high quality habitat where sharp-tailed grouse continue to concentrate and restoring key wintering sites are vital to conservation of sharp-tailed grouse in Washington.

Habitat quality has improved on WDFW and Bureau of Land Management lands in Lincoln, Douglas, and Okanogan counties, where they are actively managed for sharp-tailed grouse. Keeping private lands enrolled in CRP is also important to improve habitat quality in Lincoln and Douglas counties. Habitat quality on private and tribal lands will depend on the intensity of grazing, and the extent of fragmentation by residential development. Habitat condition appears to have improved in the Methow Valley in recent years due to reduced grazing pressure, but many sites have been lost to residential development. Habitat restoration is needed to provide habitat connections between subpopulations of sharp-tailed grouse where possible, and to increase populations to a level at which genetic health, wildfires, and episodic weather extremes are no longer a major concern.

Habitat loss to subdivision of farms and ranches. The need to increase and connect populations is essential for recovery, but exists with a backdrop of continued habitat loss and degradation. Ranches and farmland, particularly in Okanogan, Lincoln, and Spokane counties, are being subdivided and sold (Hallet 2006, Swedberg 2006, J. Anderson, pers. comm., S. Fitkin, pers. comm.). Okanogan County is a favored location for vacation homes. Conversion of ranches and farmland to residential areas, even though of relatively low density, probably results in unsuitable conditions for sharp-tailed grouse because of greater density of fences, roads, traffic, structures, heavily grazed horse pastures, dogs, cats, and corvids. Residential development will affect the ability to connect subpopulations and limit options for sharp-tailed grouse recovery. It is unlikely that WDFW alone can acquire enough lands to restore viable populations. WDFW should develop partnerships with land trusts and other organizations to negotiate and fund conservation easements that will keep large ranches intact and provide financial stability that will facilitate ranching operations compatible with sharp-tailed grouse conservation.

In addition to the effect that habitat fragmentation can have on genetics as a result of isolating small populations, features characteristic of fragmentation, such as roads and fences, can affect grouse survival. Patten et al. (2005) described differences in survival and reproduction between populations of lesser prairie-chicken in Oklahoma and New Mexico which have a 10-fold difference in parcel size. Oklahoma had much smaller farms and a higher density of fences, powerlines, and roads that affected female survival. Females in Oklahoma exhibited larger clutch sizes and higher renest rates, but on average they nested fewer years. Patten et al. (2005) suggested that the habitat difference and lower female survival rate had resulted in an evolutionary change in life history strategy, with an unfortunate artifact of reducing the likelihood of population persistence. A population model suggested the Oklahoma population was more susceptible to year-to-year environmental variations such as weather because females concentrated their reproductive effort into one year (Patten et al. 2005).

Use of herbicides to control shrubs. The loss of deciduous trees and shrubs by chemical control was associated with declining sharp-tailed grouse populations in Washington (Zeigler 1979) and Utah (Hart et al. 1950). Chemical treatment of vegetation in sharp-tailed grouse habitat is detrimental due to the direct loss of vegetation (McArdle 1977, Blaisdell et al. 1982, Kessler and Bosch 1982, Oedekoven 1985, Klott 1987). Herbicide treatments are a useful tool to open dense areas and provide more open habitat in the Great Lakes states where precipitation is much higher and succession to forest is reducing sharp-tailed grouse habitat (Amman 1963). Use of herbicides to control sagebrush and other vegetation, however, may cause additional reductions in sharp-tailed grouse in Washington. Stralser (1991) reported that two leks that had been abandoned in Lincoln County, were surrounded by habitat that had been degraded by brush control using herbicides and fire, and had higher coverage of annuals than two active leks that had more intact shrub-steppe habitat and more native perennial vegetation.

Human-related disturbance. Sharp-tailed grouse are vulnerable to disturbance when aggregated at leks and in riparian winter habitat. Noise, machinery, livestock, and human presence related to farming, roads, and recreation can flush birds off of leks, and if frequent can affect mating activity. There is also increasing interest by bird watchers and photographers seeking permission to visit leks (Jim Olson, pers. comm.). Baydack and Hein (1987) conducted experimental disturbances, including parked vehicles, propane exploders, scarecrows, leashed dogs, snow fencing, and human presence on sharp-tailed grouse leks in Manitoba. The found that the attraction of males to the lek was sufficiently strong that after flushing, that they usually returned to the lek quickly despite ongoing disturbance, unless it included human presence. However, though the number of males returned to normal, females never attended a lek during treatments, limiting reproductive opportunities for both sexes. They concluded that though grouse may continue to be observed on a lek during disturbance, the lek may actually be reproductively inactive. However, trapping of males and females on leks for translocation projects indicates that females are at least somewhat tolerant of the presence of traps on a lek and a vehicle parked adjacent (Schroeder et al. 2008). Increases in human activity related to rural development, orchards, and vinyards likely would degrade habitat by limiting use by sharptails.

Livestock Grazing

> "Current information thus suggests that within the United States grazing, and secondary effects such as change in fire frequency and invasion of exotics, were the primary cause of extirpation of Columbian sharp-tailed grouse…on roughly 75% of the historic range." (Bart 2000)

Livestock grazing is an important factor affecting sharp-tailed grouse populations (Evans 1968, Kessler and Bosch 1982, Bart 2000). Although many studies report negative impacts of livestock grazing, keeping large private ranches intact may be essential for sharp-tailed grouse recovery. Livestock grazing may be compatible with sharp-tailed grouse in uplands if habitat characteristics needed for breeding and nesting can be consistently maintained (Giesen and Connelly 1993). Whether this is possible on any particular site probably depends on many factors including the grazing history of the site, site condition, precipitation zone, year-to-year precipitation, livestock involved, stocking rate, season, intensity, frequency, and duration of grazing.

Although habitat conversion was a more important factor in the historicaldecline in Washington, the degraded condition of remaining habitat due to past heavy grazing is still an important factor affecting populations and sharp-tailed grouse recovery. In experiments designed to investigate grazing and grouse, Baines (1996) and Calladine et al. (2002) reported that grazing reductions on moors in northern England were associated with more successful breeding and higher densities of black grouse; the heavily grazed moors were essentially sink habitat where grouse populations were supported by immigration. With the exception of Kirby and Grosz (1995), there have been no experimental studies designed to investigate the effects of grazing on sharp-tailed grouse populations. However, there have been many experimental studies on the effects of grazing on native vegetation, and many correlative studies have documented low use and productivity, or absence of sharp-tailed grouse associated with heavy grazing (Brown 1966, 1968, Parker 1970, Hillman and Jackson 1973, Kirsch et al. 1973, Marks and Marks 1987a, Klott and Lindzey 1990,).

Improperly managed livestock grazing is reported to: 1) affect sharp-tailed grouse reproductive success through reduction of key food plants and insects available to females and broods (Hoffman and Thomas 2007); 2) decrease available nesting cover and reduce residual vegetation making females, nests, and chicks more vulnerable to predation (Schroeder and Baydack 2001, Flanders-Wanner et al. 2004, Manzer 2004); and 3) degrade riparian and upland shrub winter habitat. These impacts can eliminate local populations (Zeigler 1979, Kessler and Bosch 1982, Giesen and Connelly 1993, Hoffman and Thomas 2007). In Montana, Brown (1968) reported that the reduction in habitat due to intensive livestock grazing resulted in the elimination of plains sharp-tailed grouse in particular areas. Sharp-tailed grouse were observed shifting use to ungrazed areas following livestock use of traditional sites (Brown 1968). Brown

(1966) noted a clear relationship between cover provided by residual vegetation, and numbers of male sharp-tailed grouse and the establishment of new leks. He also noted that females appear to be more sensitive to the amount of cover; males outnumbered females up to 4:1 on areas with little residual cover, but females often outnumbered males 3:1 near newly established leks in heavy standing herbage with good shrub interspersion. Apa (1998) suggested that any management practice, including livestock grazing, that reduced nesting and security cover within 2 km of leks would make females and eggs more vulnerable to predation. Marks and Marks (1987a) compared two study areas; one, where sharp-tailed grouse were rare, had been severely modified by livestock and agricultural development. Compared to the area with more sharp-tailed grouse, it had less vertical and horizontal plant cover, lower diversity of forbs and shrubs, lower canopy closure of plants that decrease with grazing, and fewer and more severely damaged mountain shrub and riparian areas. Compared to random sites, grouse locations had higher proportions of species that decrease with overgrazing (Saab and Marks 1992). Sharp-tailed grouse preferred microhabitats with more bluebunch wheatgrass and arrowleaf balsamroot, which both decrease with increases in grazing intensity, and were critical for cover during a drought year (Saab and Marks 1992). Kirsch et al. (1973) reported that lightly to moderately grazed grasslands in North Dakota were of limited value for sharp-tailed grouse and no leks were located on hay fields or heavily grazed pastures without adjacent 'retired' cropland. They recommended suspension of annual grazing and a management regime of prescribed burning.

Additional effects of livestock include trampling of nests and behavioural avoidance by grouse. Nielsen and Yde (1982) reported that sharp-tailed grouse in Montana appeared to avoid association with cattle; only 3 of 1,279 observations were within 150 m of cattle. McDonald (1998) reported that at least two sharp-tailed grouse nests were trampled by livestock during his study in Washington. Livestock grazing during drought generally reduced grasshopper populations in southern Idaho rangeland (Fielding and Brusven 1995). Grasshoppers are an important food of growing chicks (Hart et al. 1950, Bernhoft 1969, Mitchell and Riegert 1994).

Indirect impacts of livestock ranching sometimes include spraying, burning, and mechanical treatments of sagebrush, seeding of crested wheatgrass to increase livestock forage and an increase in noxious weeds (Beck and Mitchell 2000). Somewhere between 2 and 4.8 million ha of sagebrush habitats were altered by sagebrush control activities by 1975 (Beck and Mitchell 2000). Additional effects of ranching on habitat include fences that can be a source of sharp-tailed grouse mortality (Hart et al. 1950), and roads that fragment habitat; roads and livestock also facilitate the spread of weeds that eventually require the use of herbicides that can impact native forbs and shrubs (Freilich et al. 2003).

Cattle are the most common livestock affecting sharp-tailed grouse habitat in Washington, but sheep and horses have affected habitat quality in some areas. Two leks on the Colville Indian Reservation have moved or been eliminated in recent years because increasing numbers of feral horses congregated on the sites; horses seem to use ridgetops chosen by sharp-tailed grouse for leks, with unfortunate results. Exclosures at springs and meadows in Nevada had notably greater plant species richness, percent cover, and abundance of grasses and shrubs than horse-grazed springs; there were 6.7 times the number of shrubs in plots protected from horse grazing (Beever and Brussard 2000). Exclosures in mountain rangeland exhibited maximum vegetation heights 2.8 times greater than vegetation grazed by horses and 4.5 times greater than vegetation grazed by horses and cattle (Beever and Brussard 2000).

Sheep may compete directly with grouse for forbs (Miller and Eddleman 2000, Pedersen et al. 2003). Herds of sheep or goats often occur at much higher densities on the landscape than native ungulates were historically, which makes them more likely to cause serious damage. Laycock (1967) reported that heavy spring grazing in three-tipped sagebrush by sheep near Dubois, Idaho, caused rapid deterioration of range. Sagebrush production increased 85%, production of grasses and forbs decreased 50%, and some forbs decreased >85%. Heavy grazing by sheep only in late fall allowed the site to remain in good condition from 1924–1949. Further experimentation found that late fall sheep grazing reduced the density of sagebrush, but maintained a healthy understory. Grasses and forbs were not damaged because they are dormant in late fall (Laycock 1967). Fall grazing, however, decreases residual herbaceous cover needed for nesting cover by sharp-tailed grouse the subsequent spring.

Livestock grazing in Columbia Basin shrub-steppe. The impacts and merits of livestock grazing in arid and semi-arid western ranges has been much reviewed and debated from various perspectives (Fleischner 1994, Vavra et al. 1994, Belsky et al. 1999, Donahue 1999, Jones 2000, Curtin 2002). One key consideration, sometimes overlooked in the discussions (Knight 2002), is that native shrub-steppe vegetation in the Columbia Basin, characterized by an understory of bunchgrasses and a biotic crust (Belnap et al. 2001), reflects a recent evolutionary history without high numbers of large herbivores (Tisdale 1961, Daubenmire 1970, Shinn 1980, Mack and Thompson 1982). Although elk (*Cervus canadensis*), deer (*Odocoileus hemionus*), and bighorn sheep (*Ovis canadensis*) were at least seasonally or locally present, and bison (*Bos bison*) were at least sporadically present in modest numbers, grazing by large ungulates seems to have played little part in the evolution of shrub-steppe organisms in Washington prior to the influences of Euro-Americans. In a worldwide review of the effects of grazing by large herbivores, Milchunas and Lauenroth (1993) concluded that an evolutionary history that included grazers in the local environment is the most important factor in determining negative impacts of grazing on an ecosystem. This suggests that the impact of livestock grazing in the Columbia Basin would be different than in other regions; it is not clear that any level of grazing benefits sharp-tailed grouse in the region.

In general, heavy grazing in sagebrush steppe decreases perennial forbs and grasses, often increases the dominance of introduced annuals, and may increase the dominance of unpalatable woody species (Miller et al. 1994, Anderson and Inouye 2002). The herbaceous plants of the Palouse and sagebrush communities are sensitive to defoliation in the late spring and early summer, when heavy grazing reduces their vigor and coverage (Tisdale 1961, Crawford et al. 2004). Tisdale (1986) reported that standing crop from nine depleted Canyon Grassland sites averaged 6% perennial grass (mostly Kentucky bluegrass), 57% annual grasses and 37% forbs (mostly exotic annuals). Bluebunch wheatgrass produced <1% of the total. In contrast, relatively undisturbed sites had 70% native perennial grasses, 19% perennial forbs, 5% annual grasses, and 5% annual forbs (mostly native).

Trampling impacts to the biotic crust may affect the ability of native vascular plants to sustain and recover from disturbance (Belnap et al. 2001). As Anderson et al. (1982) stated, "prolonged grazing during seasons of low precipitation, high temperature and persistent wind is almost certain to destroy even well developed biotic crusts." Yeo (2005) reported differences at exclosure sites in Idaho he attributed to the exclusion of livestock, including the reductions of bare ground and evident soil erosion, while principle forage cover, screening cover, and cover of lichens and algae all increased.

Grazing in spring and summer habitat. Many shrub-steppe areas in Washington, though currently lightly or moderately grazed, have little perennial grass or forb cover, a legacy of past over-grazing. In west-central Idaho, Saab and Marks (1992) found sharp-tailed grouse using home ranges in areas that were least modified by livestock grazing, and they considered Columbian sharp-tailed grouse as an indicator of good range condition in mesic shrub-steppe. Kirby and Grosz (1995) monitored nest success of plains sharp-tailed grouse in rotationally grazed pastures and adjacent nongrazed area in North Dakota. They reported that nests/100 ac in the nongrazed area was double that in the grazed pastures, and the number of successful nests/100 ac was 1.0 in grazed compared to 1.3 in nongrazed areas (significance not stated). The percent of nests that were successful was higher ($P < 0.05$, Mayfield method, 36 days exposure), however, in the grazed pastures (44%) than in nongrazed (26%) pastures; they could not explain the higher nest success in the grazed pastures, but hypothesized that the reduced cover and high human activity made the grazed pastures unattractive to mammalian predators. There was also a lower density of nests in the grazed pastures, affecting the success of predators searching for them.

Mattise (1978) concluded that deferred rotation grazing was more detrimental to plains sharp-tailed grouse than season-long grazing on his North Dakota study area. The season-long pastures were unevenly grazed and on average contained taller vegetation, while the deferred pastures were uniform and over-utilized and did not provide the cover needed for sharp-tailed grouse nesting and brood-rearing (based on visual obstruction data reported by Kohn 1976). Nielsen and Yde (1982) noted that male sharp-tailed grouse did not shift to rested areas, and showed considerable behavioral attachment to areas near leks. Roersma (2001) speculated that periodic grazing after the nesting season was beneficial for plains sharp-tailed grouse in southern Alberta because it rejuvenated the vegetation and prevented the accumulation of excessive litter.

In Wyoming, key variables for sites used by broods was presence of oniongrass and sulphur-flower buckwheat, both of which decrease with grazing (Klott and Lindzey 1990); areas used were diverse in forb and grass species, therefore grazing pressure that reduces species diversity would be detrimental. In Colorado, Hoffman (2001) reported a higher density of leks and greater number of males per lek on CRP and mine reclamation lands than on grazed shrub-steppe. Collins (2004) reported higher sharp-tailed grouse productivity on ungrazed mine reclamation land than on grazed shrub-steppe.

Livestock grazing of riparian habitat. Perhaps the most important negative impact of livestock on sharp-tailed grouse habitat in Washington has been the destruction of riparian deciduous habitat. Livestock spend a disproportionate amount of time in riparian areas, particularly in summer and fall, because of the available water, green forage, shade and lower temperature (Kauffmen and Krueger 1984). Excessive grazing can eliminate streambank vegetation resulting in channel widening, channel aggradation, and lowering of the water table (Kauffman and Krueger 1984, Armour et al. 1991). Lowering of the water table can result in the replacement of riparian vegetation with upland vegetation and exotic weeds (Belsky et al 1999) (Fig. 27). Trampling, browsing, and rubbing decrease the deciduous trees and shrubs needed for food and shelter in winter (Parker 1970, Nielsen and Yde 1982, Kessler and Bosch 1982, Marks and Marks 1987a).

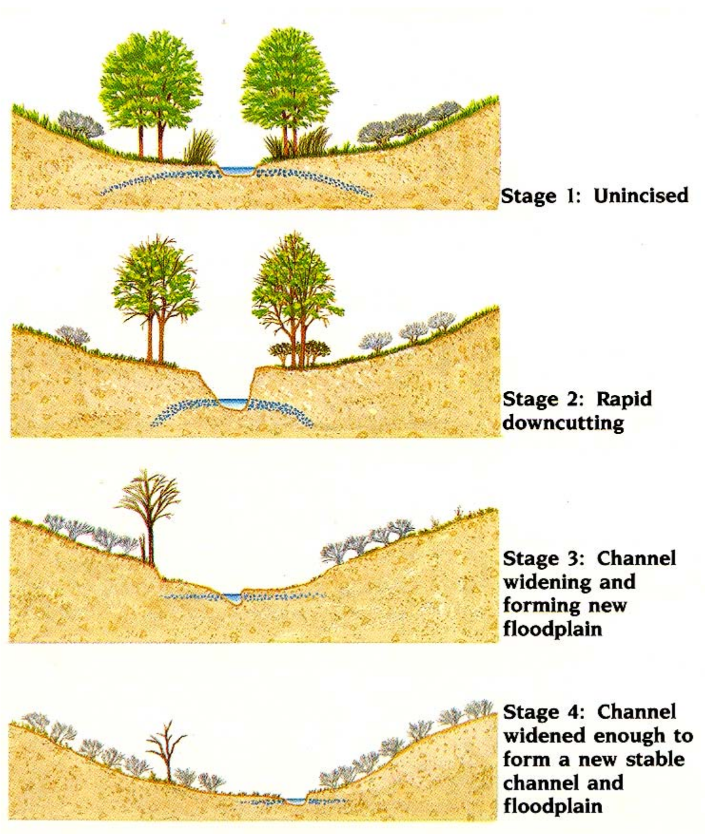


Figure 27. Potential degradation of stream channel and riparian vegetation of prolonged heavy grazing (*from* Chaney et al. 1993).

Loss of deciduous cover is especially severe near riparian areas; this cover provides critical foraging areas and escape cover for sharp-tailed grouse throughout the year (Zeigler 1979, Marks and Marks 1987a). In many eastern Washington riparian areas, the regeneration of shrubs, such as hawthorn, snowberry, chokecherry, serviceberry, black cottonwood (*Populus balsamifera trichocarpa*), aspen, willows, and water birch, has been suppressed by decades of grazing (Franklin and Dyrness 1973, Paulson 1996). Deciduous species have often been replaced by sagebrush and rabbitbrush and grazing-resistant exotics such as bluegrass, thistles (*Cirsium* spp.), teasel (*Dipsacus fullonum*), common dandelion and reed canarygrass (Chaney et al. 1993).

Paulson (1996) investigated the effects of 17 years of intensive grazing on riparian habitat in Lincoln County. Riparian stands of aspen and birch were common on the study area before the number of AUMs were increased by 50% in 1974. Density and canopy cover of trees and shrubs >5ft were >3 times greater in the ungrazed section of the creek than in the intensively grazed area. Paulson (1996) noted that the most obvious missing element was the 5–10 ft layer. Seedlings and saplings of aspen, birch, willow, and hawthorn were extremely rare, and no chokecherry and serviceberry were found in the grazed area. Paulson (1996) suggested: 1) zero grazing was the fastest way to restore sharp-tailed grouse wintering habitat; 2) early spring would have less impact on riparian trees and shrubs than summer or fall grazing; 3) cattle should be removed when consumption of key trees and shrubs is observed; and 4) careful monitoring of grazing intensity may be more important than the grazing system employed.

Livestock damage can be reduced by improved grazing methods, herding or fencing livestock away from streams, reduced stocking rate, salt and alternative water sources, and increasing rest (Belsky et al. 1999, Kauffman and Krueger 1984, Wyman et al. 2006). Changes in livestock distribution with new water sources can lead to the degradation of remnant high quality areas that had been lightly grazed or ungrazed due to distance from water. Often the best prescription for riparian habitat restoration is a long period of rest from livestock grazing (Ohmart 1994, Belsky et al. 1999). Reduction or elimination of grazing will often result in rapid recovery of herbaceous vegetation and shrubs if seed sources are present (Rickard and Cushing 1982). In some cases, however, recovery of native vegetation may be extremely slow due to the degraded physical condition of the stream, dominance of exotic vegetation, and lack of native seed sources (Clary et al 1996). Control of reed canarygrass may be required before woody vegetation can recover. In areas dominated by reed canarygrass, grazing can be used to reduce canarygrass vigor and allow the establishment of more desirable native species (Antieau 2004). On Turnbull National Wildlife Refuge, areas of canarygrass that were grazed showed 40% more sedge and rush composition than areas that were excluded from grazing (Bennington 1972). Wyman et al. (2006) and Knutson and Naef (1997) provide management strategies that can be used to minimize impacts and allow recovery of native vegetation where complete removal of livestock from a riparian area is not possible.

Summary: livestock grazing. Sharp-tailed grouse habitat damaged by livestock and agriculture needs to be restored and managed to provide adequate breeding, nesting, and winter food and cover. Residual vegetation of nest/brood cover should average ≥25 cm (10 in) in height (visual obstruction reading using a Robel pole; Meints et al. 1992, McDonald 1998); sites that average <10 cm (4 in) are not considered suitable for sharp-tailed grouse nest/brood cover. Management should also take care to maintain a diverse native forb component, ideally comprising ≥10% of vegetative cover. Although livestock grazing has the potential to have major negative impacts to sharp-tailed grouse, it is probably essential to keep large ranches and farms intact because conservation agencies may not be able to acquire enough land to fully recover sharp-tailed grouse grouse. When ranches are subdivided and subsequently developed, habitat loss is permanent. It will be important to work with ranchers to develop management that is compatible with maintaining good sharp-tailed grouse habitat and facilitate any incentives that become available.

Predation in altered landscapes and communities

Predation is the most important proximate cause of mortality for sharp-tailed grouse and the rate of predation is affected by the quality of habitat. Grouse have long coexisted with predators and have developed adaptations and strategies to improve their chances of survival, such as camouflage, flocking, distraction displays, reduced scent emission of incubating females (Reynolds et al. 1988), and roost site selection (Conover and Borgo 2008). However, long-term declines in ground-nesting waterfowl, gamebirds, and songbirds have led to hypotheses about increased nest predation, likely related to changes in habitat and predator communities (Reynolds and Tapper 1996, Nelson 2001, Sovada et al. 2001, Brennan and Kuvlesky 2005). Although predator control was standard practice on the moors and estates of Europe and the United Kingdom (Opermanis et al. 2005, Baines et al. 2008, Park et al. 2008), in North America, predation on grouse has more often been addressed through habitat improvement, which is considered a more economical, efficient, and effective long-term strategy than direct control of predator populations (Schroeder and Baydack 2001).

Altered landscapes and predator communities. Population declines in many bird species have been attributed to higher rates of nest predation in fragmented habitats. However, this and several related hypotheses about the mechanisms responsible have not been adequately tested (Chalfoun et al. 2002). Chalfoun et al. (2002) noted in a review that avian predators more often respond positively to fragmentation than mammalian predators, and that higher rates of avian predation may result from increased predator abundance rather than increased foraging efficiency or other effects. Greenwood et al. (1995) reported that nest success of ducks in the prairie potholes region of Canada decreased 4% for every 10% increase in cropland, suggesting that populations were not stable where cropland exceeded 56% of available habitat.

The landscape of eastern Washington has been dramatically altered by agriculture and human development (McDonald and Reese 1998). Several studies of simulated or real nests report higher nest predation rates in smaller habitat patches of grassland or shrubland (Burger et al. 1994, Vander Haegen et al. 2002, Herkert et al. 2003). When available habitat is comprised of small patches, it limits the search area for predators to find nests (Phillips et al. 2000), and the higher predation rates may limit reproductive success and drive local populations to act as sinks (Pulliam 1988). Vander Haegen et al. (2002) reported that real and simulated songbird nests in a fragmented shrubsteppe/cropland landscape were nine times more likely to be depredated (mostly by common ravens or black-billed magpies), than those in continuous landscapes. Vander Haegen (2007) reported that the reproductive success of shrub-steppe passerines was lower in landscape fragmented by agriculture. Small isolated tracts of grassland tend to be visited often by numerous predators, especially red foxes (Sovada et al. 2000, Phillips et al. 2003). Small isolated patches were of marginal benefit to ducks unless they were managed to reduce predation. Fragmented agricultural landscapes may also support abundant rodents, insects, pigeons (*Columba livia*) and Eurpoean starlings (*Sturna vulgaris*) that in-turn attract predators that then opportunistically prey on grouse (Rich 1986, Reynolds and Tapper 1996, Moulton et al. 2006). For example, in studies in the United Kingdom, fox predation had a significant impact on gray partridge, even though the fox population was largely supported by rabbits (*Oryctolagus cuniculus*) and hares (*Lepus europaeus*) (Reynolds and Tapper 1996). The impact of weasels (*Mustela nivalis*) on eggs and young of songbirds varied with the abundance voles, their main prey (Dunn 1982). The presence of introduced ring-necked pheasants and California quail in Washington, particularly where supported by winter feeding stations, may support a greater density of resident predators, such as great horned owls, than was historically present. Also, introduced gamebirds may allow seasonal migrants, such as northern goshawks and rough-legged hawks to linger in the area longer than otherwise, and occasionally take sharp-tailed grouse.

Manzer and Hannon (2005) reported that concealment cover was the most important variable for explaining sharp-tailed grouse nest success, and the relationship was strongest when analyzed at the 50 m scale. Nests were four times more likely to succeed in areas with <10% cropland (included hay fields) and with <35% total cropland and sparse grassland when analyzed at the 1,600 m scale. However, chick and hen survival was not statistically lower in the more fragmented landscapes (Manzer and Hannon

2008); predation accounted for 72% of chick mortality, and 82% of hen mortality with mammals taking the largest part in each case.

In addition to problems associated with fragmented habitat, habitat changes have also led to changes in predator communities. The numbers of a few predators are lower today than they were historically (e.g., wolves, possibly badgers), but populations of many predators of nests and birds that benefit from human-associated food and nesting structures are higher than they were historically. For example, human altered landscapes provide resource subsidies to corvids, such as ravens, that have led to increased reproduction and survival (Boarman 2003, Webb et al. 2004). Ravens nest on transmission towers, railroad tressels, highway overpasses, and abandoned farm buildings; they will feed on roadkill, livestock afterbirth and carcasses, and at landfills (Coates et al. 2007). Common ravens opportunistically feed on prairie grouse eggs and young (Schroeder and Baydack 2001), and the population of ravens has tripled in North America in the past 40 years (Sauer et al. 2008). Coates and Delehanty (2010) reported that daily survival rate of greater sage-grouse nests in Nevada was directly related to local abundance of common ravens. Anthropogenic food sources, even isolated ones, contribute to population increases of crows and ravens in highly settled areas. Marzluff and Neatherlin (2006) reported that American crow abundance and survivorship was higher, and both crows and ravens fledged more young/pair, within 1 km of human settlements and campgrounds on the Olympic Peninsula of Washington. The rate of predation on simulated nests was related to corvid abundance. Human-associated food sources were used during 75% of foraging bouts, and crows and ravens were recorded traveling >30 km to access these food sources.

Black-billed magpies most often nest in riparian thickets of deciduous trees and shrubs and shrubby draws (Trost 2000), but also in trees and shrubs planted around farms. Vander Haegen (2007) noted that magpies were more abundant in landscapes fragmented by agriculture in eastern Washington. Magpies will respond to increased food availability by increasing densities, clustering nests near the resource patch and abandoning territorial defense (Stone and Trost 1991). In winter they sometimes aggregate at feedlots, garbage dumps and grain elevators (Stinson 2005). Jones and Hungerford (1972) reported that magpies were the primary predator of simulated nests in southern Idaho. Magpies and American crows have increased in Washington in recent decades (Sauer et al. 2008). Manzer and Hannon (2005) found higher magpie and crow densities in landscapes with higher proportions of cropland and sparse grassland; sharp-tailed grouse nests were eight times more likely to succeed in landscapes with lower densities of corvids.

Several duck species declined from 1955–1991in the North American prairie pothole region (Sovada et al. 2001). Predation has a major impact on ducks, and nest success has declined for at least five species since the 1930s (Greenwood et al. 1995, Beauchamp et al. 1996). Sovada et al. (2001) noted that habitat changes have resulted in increases in raccoons, red fox, and Franklin's ground squirrel; red-tailed hawk, great-horned owl, American crows, and black-billed magpies have expanded their ranges. A related hypothesis, "meso-predator release", is the idea that the removal of top mammalian carnivores, such as gray wolf, results in increases in abundance, distribution, or changes in behavior of mid-sized predators (Crooks and Soule 1999, Prugh et al. 2009). This has subsequent impacts on populations of birds and other prey because mesopredators typically occur in higher densities, and are often more tolerant of human presence than top carnivores. Mesopredator release can be difficult to disentangle from the effects of habitat changes, and it is more often demonstrated within a taxonomic family, such as canids (Prugh et al. 2009).

Foxes (*Vulpes* spp) were absent from the Columbia Basin in the 19th century, though there are a few records from the Holocene; the Cascade red fox (*Vulpes vulpes cascadensis*) is endemic in Washington, but is restricted to the Cascade Mountains (Aubry 1984, Lyman 1991). In the early 20th century, however, non-native red foxes from eastern states were released for hunting in western Washington lowlands, and foxes escaped from fur farms, including farms in Kittitas and Stevens counties (Aubry 1984). Red foxes are well adapted to a fragmented agricultural landscape, are more tolerant of human activity, and can occur in higher densities than the native mountain foxes (Kamler and Ballard 2002, Gosselink et al. 2003). Non-native red foxes are now established in the lowlands of Kittitas and southern Chelan counties (Aubry 1984), and Lincoln County (M. Finch, pers. comm.); red foxes have been sighted in all the counties of eastern Washington (Aubry 1984, D. Volsen, M. Finch, P. Wik, P. Fowler, pers. comm.). Red foxes are seen in forested portions of Okanogan County but have not been seen in the steppe regions where sharp-tailed grouse are present (J. Heinlen, pers. comm.). Coyotes are known to prey on red foxes, and where common, may largely exclude foxes from areas, like the shrub-steppe areas in Washington (Voigt and Earle 1983, Sargeant et al. 1987). Coyotes harass and will prey on foxes which may be part of the reason foxes select human associated habitat such as rural residences and abandoned farmsteads (Dekker 1983, Gosselink et al. 2003). Red foxes are a primary mammalian predator of ground-nesting birds, and are known to have a greater impact than coyotes on nest success (Sovada et al. 1995, Riley and Schultz 2001). Lewis et al. (1999) reported that non-native red foxes have the potential to impact 24 threatened or endangered species in California. Sovada et al. (2000) suggested that higher duck nest success in larger patches may have resulted from the presence of coyotes suppressing activity of foxes and skunks. Pieron and Rohwer (2010) reported that duck nesting success has improved in the prairie pothole region as a result of a decline in red foxes and increase in coyotes subsequent to an outbreak of sarcoptic mange. Non-native red foxes and other predators associated with human habitations represent another form of habitat degradation for sharp-tailed grouse.

Predator control. Predator control to increase prairie grouse populations has rarely been used in North America, but it has long been used for grouse management in Europe (Schroeder and Baydack 2001). Although losses to predation are sustainable in large populations, predation losses can have a more significant impact on small populations. Predator control programs were standard management practice on many estates in the UK and Europe to increase upland gamebirds (Reynolds and Tapper 1996, Park et al. 2008). Several studies evaluated the effectiveness of predator control to address widespread declines in ducks and pheasants, particularly in the prairie regions of the U.S. and Canada. Removal of nest predators has been shown to temporarily improve nest success, juvenile survival, and/or population size in ground nesting birds, including grouse (Lawrence 1982, Kauhala et al. 2000, Coates and Delehanty 2004, Baines et al. 2008), ring-necked pheasants (Chesness et al. 1968, Trautman et al. 1974, Riley and Schultz 2001), gray partridge (Tapper et al. 1996), ducks (Greenwood and Sovada 1996, Garrettson and Rohwer 2001, Chodachek 2004, Pearse and Ratti 2004, Kauhala 2004, Opermanis et al. 2005, Pieron and Rohwer 2010), and sandhill cranes (Littlefield 2003).

There have been many tests of predator removal to improve duck nesting success, but few predator removal studies in North American in which grouse populations were monitored (Schroeder and Baydack 2001). Coates et al. (2007) used the avicide, CPTH (DRC-1339), in chicken eggs to remove common ravens in Utah. CPTH has low risk to non-target species. Coates and Delehanty (2004) reported that sharp-tailed grouse nest success improved from 42% prior to raven removal, to 75 % during removal; data on sage-grouse nest success prior to removal was not available, but was expected to be about 43%, compared to 73.6% during removal. Lawrence (1982) controlled mammal predators in the range of Attwater's prairie-chicken; 'success' of artificial nests was 82% in the treated area, and 33% where predators were not controlled. Batterson and Morse (1948) conducted an experimental control of ravens in Oregon; sage-grouse nest success was 35% where ravens were removed and 3% where no removal occurred.

Projects that removed the most frequent predator, such as the two raven removal studies cited above have more often been successful. Harding et al. (2001) reported that red fox removal had strong positive effects on the population of the endangered California Clapper rails (*Rallus longirostris obsoletus*).

Cessation of removal of northern harriers on a Scottish moor, resulted in halving the pre-shooting density of red grouse (Baines et al. 2008). In Latvia, harrier removal increased duck nest success, and success declined for three years after removal ceased (Opermanis et al. 2005).

However, some predator removal projects that removed a single species failed, either because the targeted species was not the primary nest predator, or it resulted in increased nest predation by other species. Slater (2003) did not detect a difference in sage-grouse nest success or predation rates between an area with ongoing coyote control and an area without coyote control; badgers appeared to be responsible for most of the nest predation in both study areas (Slater 2003). Clark et al. (1995) reported that removal of American crows did not result in increased duck nest success on treatment plots. Removal of mink was not correlated with duck nesting success, but harrier predation increased when mink were removed (Opermanis et al. 2005). In a South Dakota study, reduction of red fox numbers alone increased pheasants only 19% after 5 years, but where foxes, badgers, raccoons, and skunks had all been reduced, pheasant numbers quadrupled; minor improvement in nest success suggested that predator reduction increased chick and adult survival (Trautman et al. 1974). Dion et al. (1999) reported that removal of mammalian predators of duck nests (raccoons, striped skunk, and red fox) in North Dakota resulted in no effect on survival of natural and simulated songbird nests, and it resulted in compensatory predation by ground squirrels. Parker (1984) reported that removal of hooded crows (*Corvus corone cornix*), ravens, and black-billed magpies in Norway did not improve nest success of willow ptarmigan or black grouse, apparently due to compensatory predation by ermine. Henke and Bryant (1999) reported that reduction of coyote numbers by 50% by aerial gunning in western Texas resulted in an increase in relative abundance of badgers, bobcats, and gray foxes (*Urocyon cineroargenteus*). Coyote reduction has also often been followed by increased red fox densities (Gosselink et al. 2003).

Projects that involved intensive predator removal from large or isolated treatment areas were more likely to demonstrate an effect because of immigration and/or recruitment of predators on smaller treatment areas. Frey et al. (2003) reported that removal of foxes, raccoons, striped skunks, mink, and badger with traps, snares, and gassing of dens, consistently resulted in twice the number of ring-necked pheasants seen in large treated plots (41.5 km^2), but no difference in small treated plots (10.4 km^2). Similar results have been reported in other studies with large treatment plots (Balser et al. 1968, Chesness et al. 1968, Trautman et al. 1974, Garrettson and Rohwer 2001, Pieron and Rohwer 2010), and failure on small plots (Steen and Haugvold 2009). Sargeant et al. (1995) reported that removal of mammalian predators did not produce a significant increase in duck hatch rate on relatively small treatment tracts (61−301 ha). They also noted that trappers were restricted to 8 hrs/day, were responsible for multiple sites, and were restricted to certain methods (e.g., no snares on part of the area, padded jaw legholds of certain sizes). They suggested that the use of skilled trappers that are given more flexibility in schedule, methods, and less need for travel between plots are more likely to be effective. Studies by Chodachek (2003) and Pieron and Rohwer (2010) that implemented these suggestions reported improvement in nest success; Chodachek (2003) used 20 small sites (259 ha), demonstrating that repeated removal on small sites can successfully increase duck nesting success. Marcstrom et al. (1989) reported a doubling of black grouse and capercaillie chick production on islands with intensive predator control, compared to islands without control.

Though predator removal projects can be dramatically successful in increasing bird populations, the benefits are short-lived. Where red foxes were removed in California, high proportion of immigration seemed to be occurring and they suggested that trapping focus on limiting movement (Harding et al. 2001). Although the effects of predator removal may persist for a few years, the benefits usually disappear fairly quickly (Sovada et al. 2001, Frey and Conover 2007, Baines et al. 2008). Predator removal projects are also costly. Musil and Connelly (2009) indicated that it cost $13.87/animal removed in their Idaho study. Chesness et al. (1968) reported a cost of $4.50 per pheasant chick hatched in excess of that expected without predator removal. Trautman et al. (1974) reported that the reduction of foxes with professional control agents cost $30/mi^2 and reduction of several mammal species cost $41/mi^2; control methods included trapping, shooting, and strychnine baits. Chodachek (2003) indicated that the cost of predator removal in her study was 16–$20/fledged duckling. Costs of $10–20/bird is justified if needed to protect a threatened species during the early phases of recovery, particularly reintroduced birds translocated and released at great expense, but could not be sustained indefinitely.

Predator control may reduce nest predation and increase the post-breeding population, but it does not always increase breeding populations in subsequent seasons because winter food and cover, or other factors may be limiting the spring population (Reynolds et al. 1988, Cote and Sutherland 1997). Musil and Connelly (2007) reported that predator removal increased survival of male wild pheasants but did not increase nest success or survival of hens (wild or pen-reared). Although more difficult to document, several studies have shown increases in breeding populations. Tapper et al. (1996) reported that removal of foxes, carrion crows, (*Corvus corone*) and magpies during the critical gray partridge nesting period increased August counts by 75%; breeding stock in year following removal was 36% larger than in years that did not follow predator control, and after three years, produced a 2–6 fold difference in breeding density.

Frey and Conover (2007) reported that removal of mammals during two years (fox, raccoon, skunk, mink, feral cats, badger) at Bear River Migratory Bird Refuge in Utah, resulted in the number of nests increasing from 12 nests/year prior to control, to 322 nests, the second year after removal had stopped; apparent nest success rate increased from 0 to 31%. Pearse and Ratti (2004) reported that predator removal increased mallard juvenile survival from hatch to 30 day by 60%; nest success increased 170%. On the site without predator removal, 3 hens were killed and 16 entire broods were lost; where predators were removed, 0 hens were killed and 3 broods lost. Based on a productivity model, the increased brood survival would be expected to increase recruitment (Pearse and Ratti 2004). Garretson and Rohwer (2001), Frey et al. (2003), and Baines et al. (2008) also reported indications of increases in the breeding population in addition to improved nest success.

Management strategies to address predation may include restoration and protection of more nesting and wintering habitat to optimal conditions, reduction of human-related food resources and nesting structures that support predators, and potentially, to remove predators in certain situations. Improvements in understanding of how predators use the landscape and how predator communities interact would increase effectiveness of all these actions (Phillips et al. 2003). Jimenez and Conover (2001) noted that the success of any management technique will likely depend on the predator community present, topography, area size, management goals and constraints, and other factors unique to each situation. Messmer et al. (1999) indicated that, though the public is skeptical of predator control to increase game bird and waterfowl populations, the public would likely be more supportive of limited, surgically applied control activities to protect threatened populations of rare native species. Columbian sharp-tailed grouse populations in Washington are found in relatively small isolated areas, and reintroduction to re-establish additional local populations is an important recovery strategy. Protection of an incipient population of birds reintroduced with great effort and expense warrants considering all the options, and limited predator control may need to be considered. There is no information on the long term impacts of predator control on the behavior, genetics, and the abundance of grouse (Schroeder and Baydack 2001), and predator control would not be a long-term management strategy. Predator control can be relatively expensive, its benefits short-lived, and it can generate strong opposition.

Selective and non-removal management of predators. Improving sharp-tailed grouse nesting and security cover within two km of leks where it is degraded may lead to improved nesting success and survival of females (Apa 1998). Several studies have reported higher greater sage-grouse nest success associated with higher cover values (Coates and Delehanty 2010). Improved cover will help reduce predation by visual predators, but may be ineffective for mammals which tend to use the sense of smell. Foraging behavior of some predators may limit the effectiveness of cover improvements, for example, American crows are known to watch hen behavior to find nests in dense cover (Jimenez and Conover 2001). Coates and Delehanty (2010) observed higher rates of predation by badgers on sage-grouse nests with higher visual obstruction by understory vegetation; they suggested that the nest predation was incidental to badger hunting for ground squirrels (*Urocitellus* spp.). Vickery et al. (1992) reported that skunk predation on threatened grassland bird nests was incidental, and that their foraging behavior was consistent with skunks searching for invertebrates, not for nests, which were rare.

Another habitat management approach that can help reduce the local distribution and abundance of grouse predators, is the reduction of the human-related food and cover resources supporting predators. Den sites and nesting structures, such as large isolated trees, rock piles, culverts, abandoned buildings, and machinery can be removed, or modified to make them unusable by predators. Boarman (2003) and Marzluff and Neatherlin (2006) recommended reducing anthropogenic food sources (dumps, garbage, livestock carcasses, etc.) to reduce the number of crows and ravens. Frey and Conover (2007) noted that the benefit of removing mammalian predators would be more effective and long-lasting if non-native carp carcasses did not provide an abundant food source in the area.

Coyotes may be an important predator of sharp-tailed grouse eggs, chicks, and females (Hart et al. 1950, McDonald 1998), but coyotes may play an important role in limiting the presence of non-native red foxes in occupied sharp-tailed grouse areas (Sovada et al. 2001, Gosselink et al. 2003); based on home range sizes, one coyote may displace five pairs of non-native red foxes (Sergeant et al. 1987). American badgers may have a similar effect on striped skunk (Sovada et al. 2001), so removal of coyotes or badgers could have unintended consequences.

Individual predators can become lifetime specialists on one prey type, and continue to prey on gamebirds regardless of nest density (Reynolds et al. 1988). Boarman (2003) suggested selective removal of offending ravens from special target areas, and Coates et al. (2007) reported that CPTH-treated egg baits can be effective, with low risk of secondary poisonings. Connelly et al. (2000b) suggested this technique for sage-grouse where corvids are identified as the dominant nest predator and nest success is <25%. Amar et al. (2004) reported that habitat structure could be used to predict which harriers take red grouse on a Scottish moor; 78% of grouse deliveries occurred to only 50% of harrier nests. Improved understanding of grouse predation on critical nesting and wintering areas may be useful to facilitate targeted removal of individual predators or nest structures. Non-lethal capture and translocation of individual predators is an option in some cases. Small numbers of great horned owls that were preying on reintroduced sage-grouse in Lincoln County were captured and released some distance away during 2008-2009.

Providing alternative food for predators have generally been unsuccessful in increasing nest success of ducks (Greenwood et al. 1998, Jimenez and Conover 2001), although supplemental food increased early nest success of ducks by reducing nest depredation by skunks during a 1-year study (Crabtree and Wolfe 1988). Numerical responses or immigration of the target species and other predators would probably limit the effectiveness of supplemental food. Turner et al. (2008) reported that supplemental feeding of northern bobwhites attracted red-tailed hawks by increasing density of rodents, which may have negative effects on quail.

Isolating nesting areas with fencing can be effective in some circumstances (Reynolds and Tapper 1996), but would be impractical for widely spaced sharp-tailed grouse nest sites. Sterilization and release of predators has been suggested, but is at an experimental phase of development. It would likely be very expensive and not eliminate predation by the resident predators. Conditioned taste aversion has potential, particularly for egg predators; taste aversion is also experimental, and would likely be expensive and be effective only in limited situations (Reynolds and Tapper 1996).

Dependence on the Conservation Reserve Program

Nearly 80% of the historical range of sharp-tailed grouse in Washington is privately owned lands. This has affected and will continue to affect the future of sharp-tailed grouse in Washington. The Conservation Reserve Program was established by the 1985 Farm Bill. Soil conservation was the original focus of CRP, but the perennial vegetation provided benefits to wildlife, particularly ground-nesting birds (Gray and Teels 2006). Land enrolled in CRP contracts in Washington has increased from 55,000 ac in 1986, to over 1.5 million ac on 5,000 farms in FY2007 (FSA 2007). Rodgers and Hoffman (2005) reported that sharp-tailed grouse, and Columbian sharp-tailed grouse in particular, had increased in number and in distribution in 10 of 12 states as a result of the CRP program. Populations in southeastern and western Idaho increased sharply with the establishment of grasslands through the CRP, with over 80% of 172 new leks in 1995–98 in CRP fields (Rodgers and Hoffman 2005). Sharp-tailed grouse distribution increased 400% in Utah after the CRP re-established connections between isolated populations. The increase of sharp-tailed grouse in southeastern Idaho and Utah has made possible the translocations to augment Washington populations that are essential to early sharp-tailed grouse recovery efforts.

About 7% of the historical range in Washington is in CRP (Table 6), and in 2006 accounted for 4% of land in areas currently occupied. Although CRP provides a modest portion of the landscape, it provides important nesting habitat in several areas, and almost the only habitat in portions of the historicalrange. The quality of a CRP field depends on the type of vegetation planted and the length of time the field has been enrolled in CRP. Early plantings of CRP fields in Washington consisted mostly of monocultures of introduced grasses, usually crested wheatgrass, which provides poor habitat (McDonald 1998). In Douglas County, sagebrush has recolonized many CRP fields, which has increased the quality of habitat for sharp-tailed grouse. In recent years, CRP fields have been planted with a diverse mix of native grasses and forbs, and many older CRP fields are being improved with native species.

Another, at least short-term benefit of the establishment of perennial vegetation, is carbon sequestration. Conversion of prairies to cropland in the 19th century released huge amounts of carbon to the atmosphere because prairie plants have a large biomass of roots underground (Montgomery 2007). Re-establishing prairie removes carbon dioxide from the atmosphere during root growth, so the carbon sequestration value of CRP, particularly in prairies, may help the program survive future budget reductions.

The 2008 Farm Bill extended CRP enrollment through September 2012; however, nationally the program will be reduced by 7 million ac by 2012. In Douglas County, approximately 33.4% of recognized cropland is enrolled in CRP as of 2008. That amount will be reduced to a cap of 25% by September 2010 unless the county can secure a new acreage limitation waiver. The USDA announced the approval of a new SAFE program to support sage and sharp-tailed grouse in Douglas County, that allocates up to 38,000 ac, however, acreage above 25,000 will require the cap be lifted. This SAFE may be very helpful for maintaining the sharptail population in northern Douglas County, depending on the location of acreage enrolled.

In areas with little public land, such as Whitman County, CRP provides most of the steppe habitat, and any future recovery would depend heavily on private lands. Given that CRP is a voluntary program and dependent on congressional renewal in farm bills, the long-term status of these areas is uncertain. The commodity price of wheat has fluctuated dramatically in the past year; on 25 February 2008, the price of

March spring wheat on the Minneapolis Grain Exchange spiked to $24/bu, the highest price ever (Scherer 2008). Lobbyists with the American Bakers Association were meeting with officials and congressmen with a goal, "to free up land that has been set aside for conservation purposes". The price fell back to around $4.75 in November. The high prices in 2007 and early 2008 led to concerns that many CRP contracts would not be renewed, or some farmers would seek early release from contracts (Streifeld 2008), drastically affecting wildlife conservation efforts. Large federal deficits also raise some doubt about whether CRP will continue to be funded indefinitely.

The re-conversion of CRP habitat to cropland in Douglas, and Okanogan counties could cause further declines in sharp-tailed grouse numbers, and negatively impact recovery in additional areas. Over 90,000 ac of contracts will expire in Washington in 2010, and nearly 175,000 ac will expire in 2011. A widespread reduction of CRP contracts would also affect populations in Idaho and Utah that have been sources for translocations to Washington, and are among the largest remaining populations of Columbian sharp-tailed grouse. Uncertainty about CRP's future increases the value of acquisitions of perpetual easements and fee title purchase for conservation by public agencies, land trusts, and conservation groups.

Fire and Altered Fire Regimes

The effects of fire on sharp-tailed grouse habitat in Washington vary with the vegetation type and are not well understood. In the more mesic meadow steppe habitats where grasses and fire-tolerant shrubs predominate, habitat can recover quickly and fires may be benign or beneficial to sharp-tailed grouse. In the largely forested regions of eastern North America, fire is essential for maintaining open habitat and sharp-tailed grouse populations respond positively (Connelly et al. 1998). Furtman (2005) noted that the prairie sharp-tailed grouse was called what translates to "firebird," by the Ojibwe due to its association with fire-created clearings in the forest. Hamerstrom (1982) believed that fire suppression was the most important factor in the decline and extinction of the heath hen.

In drier shrub-steppe areas, wildfire is believed to be a serious threat to sage-dependent species, such as sage-grouse (Fischer et al 1996, Connelly et al. 2000a), because big sagebrush does not resprout after fire and must re-colonize a burn by seed; fires can eliminate the shrub layer for a long period of time and often facilitate the spread of cheatgrass (Wambolt et al. 2001). Burns that leave patches of shrubs may be less detrimental to sharp-tailed grouse than sage-grouse which depend on sagebrush for food. Damage from fires where three-tip or mountain sagebrush predominates is less long-lasting because precipitation is higher and three-tip usually resprouts after fire.

Historical fire regimes in Washington sharp-tailed grouse habitat. Many studies that report historical fire frequency in the inland Northwest, used fire scars in trees and forest age structure, but the relationship between fire frequency in pine and adjacent shrub-steppe has not been determined. Fire is less likely to ignite and burn in sagebrush than in ponderosa pine (Weddell 2001b, Baker 2006). There are numerous historical accounts of fires in the understory of pine forest, but fewer data on fire frequency, whether a result of human or lightning ignition, in steppe and prairie habitats. Historical accounts of the landscape, fires, Native American burning, studies of charcoal deposits, and what can be surmised based on the fire tolerances of vegetation, provide some information about historical fire frequency in steppe of eastern Washington (Agee 1994, Weddell 2001b, Welch 2005).

The abundance of sagebrush and bitterbrush reported by early European explorers in eastern Washington suggests that fire was infrequent in this vegetation type because Wyoming big sagebrush and bitterbrush, the dominant shrubs in most shrub-steppe communities, are killed by fire (Daubenmire 1970). Some sagebrush-bunchgrass communities, particularly stiff sage (*Artemisia rigida*), contain sparse and discontinuous vegetation that does not sustain fires (Tisdale and Hironaka 1981). Fire return intervals in shrub-steppe vary depending on precipitation. Areas with higher precipitation regenerate plants and shrubs that can act as fuel for the next fire more quickly (Tisdale and Hironaka 1981), although the window of time when conditions are dry enough to burn is more brief (Welch and Criddle 2003, Welch 2005). Drier areas may have exceeded 200 years between fires. Baker (2006) reviews evidence that suggests pre-Euro-American fire rotations were 100–240 years in Wyoming big sagebrush, and 70–200 years or more in mountain big sagebrush. He concluded that though fire is an important natural disturbance in sagebrush, it does not occur as often as suggested in the past, and given the long rotations, fire exclusion has had little effect on most sagebrush areas.

Daubenmire (1970:8) concluded that fire did not have a major influence in shaping the distribution of vegetation types or species in eastern Washington, and they were entirely related to characteristics of soil and climate. Tisdale (1986) reached similar conclusions about the Canyon Grasslands, represented in Washington along the Snake and Grand Ronde River canyons. Sauer (1950) believed that no grassland on deep soil existed except those that had been maintained by reccurring fires, mostly set by humans. However, extensive grassland ecosystems existed for long periods before humans invaded the North American continent (Vale 2002:297).

Native American prescribed burning in eastern Washington. Stewart (2002) mentioned the tribes that "admitted" using fires for hunting game, to open up the forest, and improve pasture included the Klikitats, Kalispels, Coeur d'Alenes, Umatillas, Spokans, and Nez Perce. Anderson (2002) states that Stewart's (2002) monograph gives the false impression that Native Americans burned everywhere, "which is clearly not the case." Shinn (1980) believed that aboriginal burning in the inland Northwest was a widespread and long-standing practice, but he noted that given the varied physiography of the region, fire was probably not used everywhere with equal regularity. Whitlock and Knox (2002) reported close correlation between climate and fire frequency in the Pacific Northwest during long prehistoric periods. They concluded that, "prehistoric peoples locally altered the landscape, but there is no strong evidence that their activities created new vegetation types at a regional scale" (p. 224). Barrett et al. (2005) stated,

> "A myth of human manipulation everywhere in pre-Columbus America is replacing the equally erroneous myth of a totally pristine wilderness. …the case for landscape-level fire use by American Indians has been dramatically over-stated and overextrapolated."

Interviews of many elders during the 20th century indicate that Native Americans in eastern Washington and surrounding areas historically burned local areas to increase yield of important food plants, including camas, lomatiums, and berries (Hunn and Selam 1990, Boyd 1999, French 1999). Fire was used to concentrate game, clear the understory along trails, improve forage for elk, deer, and horses, and clean campsites of vegetation, snakes and vermin (Barrett and Arno 1999). They also may have used fire to gather crickets, lizards, acorns, and sunflower seeds (Shinn 1980, Boyd 1999, Marshall 1999). Locations where burning was used included the Klikitat Trail, Methow Valley, and Cayuse Mountain in southern Spokane County. One Methow elder, upon returning to the Methow Valley in 1979 after a long absence, recounted how they used to take care of the land by burning every fall, but "now it is a jungle" (Boyd 1999:1). The Klikitats, Nez Perce, and Spokans are known to have used fire to improve food patches (Marshall 1999, Norton et al. 1999, Ross 1999). Ross (1999) reported that Spokans fired the grassland near Cayuse Mountain to capture wild horses. The need for improving forage for expanding horse herds may have provided motivation to intensify and expand burning activities by Native Americans during the 18th and 19th centuries (Robbins 1997, *in* Hessburg and Agee 2003). Charcoal deposits indicate that light surface fires became more frequent at Blue Lake, Nez Perce County, Idaho about 700 years ago as Nez Perce activity increased (Smith 1983, *in* Weddell 2001b).

Though fire was used to manage vegetation at specific sites, it is not clear whether larger landscapes in steppe were intentionally burned. Shinn (1980) noted that 65% of 30 fires recounted in historical sources were attributed to Native American burning. This included reports from the Grande Ronde Valley, the upper Walla Walla watershed, and Hells Canyon; it is unclear how many of these fires were in steppe verses ponderosa pine forest. Baker (2002:53–54) points out, however, that historicalaccounts that attribute ignition to Native Americans, unless an eye-witness account, are unreliable, because of racial biases and historical ignorance of lightning as a frequent ignition source. Baker (2002:56) also noted that the importance of lightning as an ignition source in grasslands was underestimated until the 1970s. Charcoal deposits in lake sediments from a study area in northern Douglas and southern Okanogan counties indicate that between 500 and 1,500 years ago, fires occurred on average every 148 years (range 94–232 years; Scharf 2002). This return interval is more consistent with natural ignition sources rather than aboriginal burning, and consistent with estimates suggested by Baker (2006). Charcoal deposits of the more recent 500 years were much reduced, perhaps indicating a reduction in fire size (Scharf 2002).

Weddell (2001b) concluded from the various types of evidence that Native Americans in the northern intermountain region apparently did set fires in steppe environments, but with unknown frequency. It appears that fires were infrequent in the drier shrub-steppe. Native Americans apparently did burn certain areas in the foothills (e.g., Methow), but it is uncertain if Native Americans burned large portions of the Palouse prairie or other areas of more mesic steppe with any regularity and thus whether fire should be considered an important potential tool for maintaining sharp-tailed grouse habitat in these areas.

Wildfire as a threat in shrub-steppe. Althougth fire may be beneficial in some vegetation types, it is also a potential threat to local sharp-tailed grouse populations. Fire has been used to alter large blocks of sagebrush rangelands to reduce shrubs and encourage grasses, which may be ineffective (Welch 2005). In Lincoln County, three large prescribed fires and one chemical control of sagebrush in the 1980's were done in areas containing active leks. Merker (1988) believed these fires were directly responsible for the decline and elimination of local populations of both sharp-tailed grouse and sage-grouse. A large fire during the nesting season on Martha’s Vineyard in 1916 was also disastrous for the only remaining population of heath hen (Johnsgard 2002). McArdle (1977) found less use by sharp-tailed grouse in burned areas compared to other vegetation manipulations. Likewise, Hart et al. (1950) reported Columbian sharp-tailed grouse abandoning a lek site following a fire, which also caused accelerated erosion, loss of nests, and loss of winter food and cover.

Burns in drier shrub-steppe may affect sharp-tailed grouse and sage-grouse similarly. Burns in Wyoming big sagebrush appeared to have no value for nesting and brood-rearing sage-grouse (Fischer et al.1996, Wambolt 2001, Byrne 2002). Connelly et al. (2000) and Wambolt et al. (2002) both concluded that the effects of fires were largely negative on sage-grouse and urged managers to refrain from burning in low precipitation (<26 cm, 10”) sagebrush areas. Modeling by Pedersen et al. (2003) suggested that small infrequent fires would have a positive effect, but frequent (e.g., every 17 years) large fires would lead to the extinction of a sage-grouse population. The effect of burns in more mesic sagebrush areas which are more important for sharp-tailed grouse are more ambiguous. Burns in mountain sage appear to have benefited sage-grouse in one study (Pyle and Crawford 1996), but had generally negative effects in other studies (Nelle et al. 2000, Byrne 2002). The long fire rotation of 70–200 years in mountain big sagebrush suggested by Baker (2006) indicates that fire exclusion has had little effect; Baker (2006) concluded that there is insufficient basis for prescribed burning to restore a mosaic thought to be important to wildlife.

Grazing, crust disturbance, and range fires since European settlement have resulted in the domination of several million acres of the drier shrub-steppe region by cheatgrass, a non-native species from Eurasia (Tisdale and Hironaka 1981). Cheatgrass is highly flammable and forms a continuous carpet of finetextured fuel, and its presence has greatly increased the incidence of wildfire in the sagebrush-grass region (Whisenant 1990, Billings 1994, Mosley et al. 1999). Burning may also facilitate invasion by noxious weeds. Cheatgrass is not as invasive in the Three-tip Sagebrush and Mountain Big Sagebrush Mesic West potential vegetation types (Bunting et al. 2002), which may be more important to sharp-tailed grouse in Washington than the drier Wyoming big sagebrush vegetation types. The invasion by cheatgrass in Wyoming big sage areas, which is accelerated with fire and increases fire frequency, requires that fire prevention receive greater emphasis in management. A healthy community of native bunchgrasses and forbs will survive a fire and only the sagebrush component may need to be restored. Burned areas where cheatgrass is a significant component, however, may need immediate restoration if a community of sagebrush and native perennials is to be maintained on the site.

Effects and potential benefits of fire in meadow steppe and prairie. Prescribed fire is considered a potential tool to improve vegetation in restoring Palouse prairie (Weddell and Lichthardt 2001). Burning of heather moorlands increased red grouse density due to improved food quality for adults, resulting in either immigration or improved survival of breeding birds (Rands 1988). Fire is considered to improve site productivity and species composition, and reduce litter; however there are few data on the fire regime of the Palouse, and the effects of burning there. Native perennial bunchgrasses can be damaged by fire because they grow from meristematic tissue in the form of buds near the soil surface, and new growth occurs as lateral shoots, rather than underground rhizomes like turf-forming grasses. Since they lack rhizomes, bunchgrasses reproduce by seed. These characteristics make them susceptible to fire damage during the growing season (Weddell 2001b). Bluebunch wheatgrass and squirreltail (*Elymus elymoides*) have an open, low density growth form that burns quickly and suffers less lasting damage, but species that grow in tight clumps, like Idaho fescue and needle and thread (*Hesperostipa comata*), can generate higher temperatures and may smolder for hours resulting in more damage (Weddell 2001b). However, native bunchgrasses are dormant during the summer-early fall dry period and suffer little damage from late summer burning; fires that occur when they are actively growing in fall through spring are more damaging. Most fires mentioned in 30 historical accounts in the inland Northwest were in late summer or fall (Shinn 1980), when lightning caused fires are more likely to occur. Fire sets back succession and reduces diversity of soil crust organisms and can facilitate establishment of disturbance adapted, mostly non-native species. Bowker et al. (2003) reported that burning reduced the density of lichens and mosses, but there was no difference in lichen and moss species composition between burned and unburned plots; they hypothesized that Palouse prairie soil crusts are relatively resistant to wildfire.

Under some circumstances, burning can improve sharp-tailed grouse habitat. Fires in grasslands generally increase forbs, and fires in shrublands generally increase grass and forb cover at the expense of shrubs (Agee 1994). Fires in Idaho fescue communities may have created conditions that favored plant diversity; balsamroot, lupines (*Lupinus* spp.), and yarrow (*Achillea millefolium*) are favored by burning (Agee 1994). Burning dense sagebrush and thickly wooded areas was found to improve sharp-tailed grouse habitat in Utah (Hart et al. 1950), North Dakota (Kirsh et al. 1973), Colorado (Rogers 1969), and Wyoming (Oedekoven 1985). Several important winter foods are often top-killed, but resprout readily after fire, including Douglas hawthorn, serviceberry, chokecherry, snowberry, and aspen (Giesen and Connelly 1993, Habeck 1991, Howard 1997, Keyser et al. 2005). Snowberry and other low shrubs of meadow steppe resprout and may return to their pre-burn condition within three years (Weddell 2001b). Native bunchgrasses, snowberry, chokecherry, and native rose are recovering well on the Chiliwist subsequent to three wildfires which killed bitterbrush which is little used by sharp-tailed grouse (Swedberg 2006). Sexton and Gillespie (1979) reported that sharp-tailed grouse returned to a traditional

Figure 28. Pine invasion in the Siwash Valley, Okanogan County.

lek site from a new lek in Manitoba immediately after a fire that removed residual grass but did not affect woody vegetation; the fire apparently had reduced the vegetation to a more favorable height for displaying birds. Modern fire suppression policies may have allowed conifers to invade in some areas to the detriment of sharp-tailed grouse populations. Juniper has expanded into some sagebrush steppe areas in Oregon and northern California; Washington does not have much juniper, but ponderosa pine and Douglas-fir have invaded and increased in density in steppe habitat in some areas, such as the Siwash Valley (Fig. 28). Giesen and Connelly (1993) indicated that prescribed burning may be effective in maintaining suitable habitats in these situations. Baker (2006) suggests that conifer invasion of sagebrush areas is not generally due to fire exclusion, but to other factors, such as overgrazing. D. Swedberg (pers. comm.) however, notes there are areas of conifer encroachment on the Sinlahekin WLA where grazing does not occur.

In Washington, prescribed fire is not recommended in dry Wyoming big sagebrush shrub-steppe, but the risks of burning should not eliminate consideration of burning as a potential habitat improvement tool in meadow steppe or prairie. Prescribed burns may be useful for improving habitat in three-tip sagebrush communities, or meadow steppe where excessive woody vegetation or conifers have invaded. Prescribed burns should be carefully considered and planned. A wildfire in recent years on the Scotch Creek WLA did not appear to have improved habitat for sharp-tailed grouse (J. Olson, pers. comm.). Opportunities for prescribed burning may be limited and would be controversial due to real or perceived risks. Any prescribed burns should be considered experiments with careful evaluation of sharp-tailed grouse use and habitat value before and after the burn.

Diseases

Diseases have the potential to be an important factor in the persistence of small populations. Disease is not known to be an important mortality factor for Washington populations, but mortalities due to disease may be difficult to document. Mortalities of telemetered birds are necropsied when a cause of death is not apparent. However, birds that are depredated may have become vulnerable due to poor health. Birds that are translocated and released (both sharp-tailed grouse and sage-grouse) are sampled for avian influenza, mycoplasma, and Salmonella Pullorum-typhoid, to reduce the chance of introducing disease to the local population. Sage-grouse that were tranlocated in the fall were also tested for West Nile Virus.

West Nile Virus. West Nile virus, a disease new to North America, is affecting many bird populations.

West Nile virus has caused high mortality in local greater sage-grouse populations in some locations (Naugle et al. 2005). Other native grouse species have tested positive for West Nile, including greater prairie-chicken and ruffed grouse (Center for Disease Control, see: http://www.cdc.gov/ncidod/dvbid/westnile/birdspecies.htm). It is unknown if the observed declines in bird populations will continue, or if species will adapt and recover (Kilpatrick et al. 2007). Positive tests for West Nile in sharp-tailed grouse have not been reported, but there is little reason to expect they would not be susceptable. West Nile has been detected in other bird species in Spokane County, and in mosquitoes in Grant County. Given their small size and habitat associations, the likelihood of finding a grouse that died from the disease is remote unless they were being intensively monitored with telemetry. If West Nile virus causes mortalities in significant numbers in Washington, the impact on small populations could be very serious. Large populations would presumably be more likely to have birds that survive and pass on their ability to resist the disease to offspring. Diseases are among many factors that affect a species' ability to persist as small isolated populations.

Histomoniasis. Histomoniasis or 'blackhead' has not been reported in Columbian sharp-tailed grouse, but most diseases in free-ranging wild birds go undetected. Pheasants are considered a 'carrier' because they are largely unaffected by the disease, but can transmit the disease organism, and the disease organism can persist in earthworms (Lund and Chute 1972, McDougald 2005, Davidson and Doster n.d.). None of WDFW Wildlife Areas that are currently important in supporting sharp-tailed grouse populations are established regular pheasant release sites (Eastern Washington Pheasant Enhancement Program; http://wdfw.wa.gov/wlm/game/water/ewapheas.htm). However, the Chiliwist WLA is a pheasant release site and it historically supported sharp-tailed grouse, and may support some seasonal use. Of lesser importance to sharp-tailed grouse, Chelan Butte Unit of the Sagebrush Flats WLA and two parcels of the Sinlahekin WLA along the Okanogan River are also release sites. The habitat potential of Chelan Butte and the Chiliwist WLA should be evaluated, as well the risk posed to sharp-tailed grouse by pheasant releases. The disease issues raised by pheasant releases need to be recognized, and policies established to reduce risks to other species, especially sharp-tailed grouse.

Wind Energy Projects and Utility Infrastructure

There are an increasing number of wind energy projects completed, under construction, or proposed in eastern Washington. There are currently about 1,000 turbines, but that number may double in the next few years. In considering impacts of wind farms on wildlife, most of the focus has been on collision impacts to flying birds and bats (Anderson et al. 1999, Erickson et al. 2002). Among 21 studies of avian moratlies at wind energy projects, upland birds were the third most frequently killed bird group. Although pheasants, gray partridge, and chukar accounted for most of the mortalities, 5 sharp-tailed grouse were among the birds killed (Johnson and Halloran 2010).

For prairie grouse, another important issue that has unitl recently received inadequate funding and research attention is the potential for habitat loss and fragmentation due to behavioral avoidance of towers (Pruett et al. 2009). Prairie grouse and other grassland birds generally avoid areas with human disturbance and tall structures (Leddy et al. 1999, Hagen et al. 2004, Manville 2004, Pruett et all. 2009). This avoidance may be an instinctive response to tall structures that reduces the bird's vulnerability to avian predators. It is not known if birds avoid the vicinity of turbines due to disturbance from noise, motion, or human activity, or if the area is avoided because tall structures are perceived as potential raptor perches. Noise that can disrupt mating communication may also be a factor for lekking species. Interim guidance provided by the USFWS states, "Avoid placing turbines in habitat known to be occupied by prairie grouse...In known habitat, avoid placing turbines within 5 miles of known leks..." (USFWS 2003, Manville 2004).

Wind energy projects include roads, powerlines, and some level of chronic disturbance. Powerlines, wire fences, and roads are all known to cause sharp-tailed grouse mortalities. All of these structures destroy, fragment, and degrade habitat and make it more hazardous for sharp-tailed grouse to move within otherwise suitable habitat and between habitat patches (Fig. 29). The concerns about behavioral avoidance of wind turbines are also true about electrical transmission lines and any other tall structures. Sage-grouse seemed to abandon leks near major transmission lines in Douglas County and on the Yakima Training Center. In California, sage-grouse abandoned leks within 1.4 mi of new powerlines and lek attendance was reduced up to 3 mi away (Manville 2004). In radio-telemetry studies, prairie chickens avoided suitable habitat within ½ mi of residences, well-traveled roads, and compressor stations, and none of the 200 marked birds nested or were ever located within 1 mi of a coal-fired generating station (Robel 2002). In Oklahoma, there were no telemetry locations of greater prairie-chickens within 100 m, and almost none within 1 km of a 69 kv powerline; of 74 nests found in the study, only 1 nest was within 2 km of the powerline (at 1.8 km)(Pruett et al. 2009). Pruett et al. (2009) suggested that tall structures have a greater impact on prairie-chicken movements than do heavily-traveled roads. Smaller distribution lines that do not have tall towers may primarily be a concern as a collision hazard and raptor perches. In an Oklahoma study, power-line collisions resulted in 4 of 128 (3.1%) and 4 of 75 (5.3%) of mortalities in lesser and greater prairie-chickens, respectively (Pruett et al. 2009).

Grassland nesting passerines, waterfowl, and wading birds are known to avoid wind turbines (Winkelman 1990, Leddy et al. 1999). Robel (2002) predicted that prairie-chickens would not nest or rear broods within at least 1 mile of wind turbines which will render otherwise suitable habitat unusable. However, Toepfer (abstract 2005) reported that prairie-chickens did not avoid a site with a small 3 turbine complex in Minnesota. A study of greater prairie chickens and the potential effects of wind turbines is currently underway in Kansas.

Figure 29. Access roads being prepared for wind turbines in Klickitat County.

Sharp-tailed grouse, though closely related to prairie-chickens use habitat near trees and bud in deciduous shrubs and trees in winter, suggesting that behavioral avoidance of tall structures may not be as important an issue for sharp-tailed grouse, as it seems to be for prairie-chickens and sage-grouse. However, any further loss and fragmentation of remaining sharp-tailed grouse habitat is a significant concern.

Climate Change

The impacts of climate change on sharp-tailed grouse and their habitat in Washington are uncertain. There is compelling evidence that climate change has affected many bird species (Crick 2004). Many species seem to be responding to the increase in global average temperature of 0.6 C with altered phenology, distribution, or density (Root et al. 2005). Many more obvious and significant changes can be expected with the much greater temperature increases predicted by 2100.

Recent models generally predict a modest increase in precipitation in the winter and a modest decrease in summer in Washington (Miles and Lettenmaier 2007). The longer growing season and reduced summer precipitation may result in an increase in area of aridity, suggesting that the drier edge of sharp-tailed grouse range may exhibit a retreat. However, drier, nonirrigated cropland that is currently marginal for dryland agriculture may become less suited for agriculture (Miles and Lettenmaier 2007) and therefore become available for conservation programs. An increase in fire frequencies could reduce invasion by pine forest into steppe habitats apparent in pairs of historical and recent photos from areas of the Okanogan (http://wdfw.wa.gov/lands/wildlife_areas/sinlahekin/gallery/sinlahekin_historical.php). Increased CO_2 may affect plant chemical and nutrient composition and affect wildlife in ways that are not yet understood. Some studies indicate that there may be a reduction of protein value of forage (Inkley et al. 2004), which could affect sharp-tailed grouse reproduction or brood survival. In general, the stresses associated with climate change and instability are predicted to have greater impact on small isolated populations, and increases the importance of restoring sharp-tailed grouse populations as much as possible to faciliate adaptation to climate change induced stresses. Climate change may also affect the impact of diseases on sharp-tailed grouse populations.

RECOVERY

Recovery Goal

The goal of the recovery strategy is to restore and maintain healthy populations of Columbian sharp-tailed grouse in a substantial portion of the species' historical range in the state.

Recovery Objectives

The Columbian sharp-tailed grouse will be considered for down-listing from State Threatened status when:

1) Washington has at least one population that has averaged >2,000 birds for a 10-year period.

and

2) The total number of sharp-tailed grouse in Washington has averaged $\geq$3,200 birds for a 10-year period.

The Columbian sharp-tailed grouse will be considered for up-listing from State Threatened to State Endangered if:

1) The total population falls to <400.

Rationale and Assumptions

Healthy populations would be large enough to readily recover from fluctuations due to disease, drought, and extremes in weather and to adapt to some degree of changes in habitat. This will require greatly increasing the number and distribution of sharp-tailed grouse in the state.

Effective population size and viable populations. A desirable goal of species recovery is to restore a 'viable population'. There is no universally accepted definition of what constitutes a 'viable' population in the scientific literature, but generally a minimum viable population is the smallest size at which populations can maintain genetic variability over time. It also relates to the ability of a population to withstand fluctuations in population and recruitment associated with annual variation in food supplies, predation, disease and habitat condition. Most conservation biologists agree that a population of a few thousand or more is desirable for long-term persistence (Frankham et al. 2002, Reed et al. 2003). Smaller populations are subject to erosion of genetic diversity and are at higher risk of decline and eventual extinction as a result.

Population sizes of sharp-tailed grouse are difficult to estimate, but it is the 'effective population size' that determines whether the population is large enough to maintain genetic health and avoid inbreeding. The effective population (N_e) is the proportion of a population (N) that can be expected to pass on their genetic information from one generation to the next (Frankham et al. 2002). To estimate the minimum viable population size for Columbian sharp-tailed grouse in Washington, the effective population size needs to be determined (Reed et al. 1986). N_e is affected by fluctuations in population size, variance in litter size, and unequal sex ratio (Frankham 1995). Two characteristics of sharp-tailed grouse that would reduce N_e is population fluctuations and their lek mating system in which a minority of males do most of the breeding. Dramatic population fluctuations are a well-established feature of the population dynamics of grouse and strongly influence the effective size of a population (Lindstrom 1994, Frankham 1995, Vucetich and Waite 1998, Watson et al. 2000, Williams et al. 2004). In a metapopulation model for prairie sharp-tailed grouse in Wisconsin, Akcakaya et al. (2004) assumed that each male could mate with up to 10 females, and that the population exhibited a 10-year cycle, based on data in Evrard et al. (2000).

Allendorf and Ryman (2002) recommended retaining at least 95% of the heterozygosity in a population over 100 years. They suggested that the population size required to meet this criteria should not be a goal, but the lower limit below which genetic factors may reduce the likelihood of the population's persistence. If the generation interval for sharp-tailed grouse is about 2 years, then an N_e of 450–500 would be required to retain 95% of genetic heterozygosity for 100 years (Allendorf and Ryman 2002). In general, an N_e of about 500 is considered the minimum expected to maintain the species evolutionary potential (Frankel and Soulé 1981, Frankel 1983, Reed et al. 1986, Frankham et al. 2002:530).

The census population (N) needed to achieve N_e of 500 is often calculated from the ratio of N_e to N. The relationship between N and N_e is unknown for sharp-tailed grouse because of the lack of sufficient census data and understanding of demography and population dynamics. Frankham et al. (2002) reviewed estimates of N_e from 192 studies of a wide variety of taxa. Estimates of N_e for populations with long term census data averaged 11% of the census population (N_e/N)(Frankham et al. 2002: 240). Studies of birds have reported N_e/N ratios ranging from 0.05 to 0.74, but most of these studies involved monogamous species. Sharp-tailed grouse are polygynous and the estimated ratio for the only polygynous species studied (white-winged wood duck, *Cairina scutelata*) were the lowest values (0.05–0.09) reported. Grouse populations also seem to fluctuate somewhat dramatically, so the N_e /N is likely to be near the low end of this range. The N_e/N ratio for sharp-tailed grouse has not been estimated, but Schroeder (2000) estimated the N_e/N ratio at 0.156 for sage-grouse in Washington from 41 years of survey data. This suggested that a breeding population of 3,200 sage-grouse would provide an N_e of 500 to maintain genetic diversity and be considered a minimum viable population. Additional research would be needed to develop and estimate of the N_e/N ratio for sharp-tailed grouse. Since N_e is often 0.10 to 0.3 of N, Lynch and Lande (1998) concluded that the actual population sizes necessary for the maintenance of genetic integrity must be "in excess of a few thousand."

Poor genetic health may be reflected in declining productivity and hence in declining population size, regardless of other factors such as habitat. Johnson et al. (2003) reported that genetic variation was significantly reduced in isolated populations of <2,000 greater prairie-chickens, and recommended that managers attempt to maintain populations of >2,000 birds. They contrasted Minnesota, where habitat is contiguous throughout 5 counties and the population has remained around 2,000 for 25 years, with Wisconsin, where a population of 2,000 is declining in number and genetic diversity because it is split among 4 increasingly isolated wildlife areas. This suggests that recovery of sharp-tailed grouse should include one or more populations of >2,000 birds.

The amount of area needed to support a breeding population of >2,000 grouse depends on the quality of habitat. Ulliman (1995) estimated densities in the Curlew and Pocatello valleys of Idaho, a landscape of wheat fields, CRP, and grassland, as ranging from 0.002–0.008 birds/ac. Density in the current range of sharp-tailed grouse in Washington (410, 000 ac of shrub-steppe, grassland, CRP; from Table 5) approach the low end of this range (0.002 birds/ac). If habitat improvements increased the density of birds on WDFW and Colville reservation lands to 0.008, and 0.002 on the remaining area, the current range could support 2,100 sharp-tailed grouse. A reintroduction to the Methow Valley and may support 200 or more, but increasing the total population to >3,000 birds will require restoring additional lands. If a Palouse prairie reserve of sufficient size were established, it could potentially support a higher density (≈ 0.01–0.02 birds/ac), although it would be isolated from current populations.

The current range is fragmented into 7 subpopulations, all separated by >20 km and may be genetically isolated. Ideally, the subpopulations would be connected by periodic dispersers moving between them and the combined total of the subpopulations could be considered in evaluating viability. Toepfer et al. (1990) reported that historical evidence indicates that isolated populations of prairie grouse <200 birds do not persist. Therefore, a high priority must be to restore and enhance habitat to increase all subpopulations to >200 birds, and to restore habitat where possible to establish connections between existing subpopulations. The amount of immigration needed to connect populations genetically is not known, but generally movement of 1–10 individuals per year is enough to prevent genetic isolation (Mills and Allendorf 1996); this assumes that these dispersing individuals breed successfully and movement is not in one direction. An interim strategy may include maintaining genetic connectivity between the separate populations by a program of translocations and genetic monitoring.

Meeting recovery objectives will require improvements in habitat quality, increases in population numbers and expansion of occupied areas. Once the recovery objectives are achieved, the species will be evaluated for down-listing from Threatened to Sensitive. A state Sensitive species is defined as a species "...that is likely to become endangered or threatened in a significant portion of its range within the state without cooperative management or removal of threats" (WAC 232-12-297). Once the Columbian sharp-tailed grouse is down-listed to Sensitive, a management plan would be prepared outlining management needs and objectives to de-list the species. Recovery objectives may be modified as more is learned about the habitat needs, dispersal capabilities, and population dynamics of sharp-tailed grouse. Data on vital rates, dispersal and population dynamics, as well as a better understanding of habitat needs and habitat capability, are necessary to more accurately assess what population sizes are needed and possible to achieve with existing habitat and habitat that could be restored.

Translocation and Reintroduction

The capture, movement, and release, or 'translocation' of wild-trapped or captive-reared wildlife is an increasingly common conservation practice, and has long been done with game birds. However, projects to establish populations of prairie grouse (sharp-tailed grouse, prairie-chickens, and sage-grouse) have had low success rates, in part due to the species' tendency to disperse away from the release site (Toepfer et al. 1990), or projects failed because they were limited to small numbers of birds or short in duration. Pen-reared birds are not as mobile, are costly, and tend to be much more vulnerable to predators (Toepfer et al. 1990, Merker 1996). Toepfer et al. (1990) noted that the amount of quality habitat is the ultimate factor determining success of a translocation. They recommended protecting or restoring habitat sufficient to support a population of ≥200 birds, which they estimated this would require >1,000 ha of undisturbed grass-shrub habitat within a radius of 3.1 km. However, a greater amount of less fragmented cover is desirable, and dry areas would likely require more area.

Translocation of sharp-tailed grouse to augment existing populations has been conducted successfully in Washington, Idaho, and Kansas (Snyder et al. 1999, Schroeder et al. 2008). Augmentation projects that release birds at active leks of an existing population have had greater success than attempts to re-establish a population. Populations have been re-established after extirpation in Idaho, Nevada, Colorado, and Kansas; success of a project in Oregon is being evaluated. Successful reintroductions of prairie-chickens have been done in Iowa, Illinois, Minnesota, and Missouri (Hoffman et al. 1992, Snyder et al. 1999, Toepfer et al. 2005:abstract).

Rodgers (1992) described a method using an artificial lek with decoys, playback of vocalizations, and remotely opened release boxes, that was used to re-establish a population of plains sharp-tailed grouse in Kansas. The mock lek was established to encourage released birds to remain at the site, and prevent the dispersal that often caused the failure of earlier projects. Sharp-tailed grouse were kept in captivity for an average of 40 days and fed commercial grains and lettuce before release (Rodgers 1992). Schneider (1994) speculated, however, that an abrupt change in diet when sharp-tailed grouse are released may be stressful, and he warned it may result in higher mortality in reintroductions that involve periods of captivity. Crawford and Snyder (1994) experimented with this technique in the early years of a reintroduction project in Oregon. They suggested that the decoys did not seem to retain birds at the site, but the vocalization playback might be important, although it may also interfere with vocalizations of released birds.

Snyder et al. (1999) reviewed past translocation projects involving sharp-tailed grouse or prairie-chickens in North America. They categorized projects as either "soft-release" or "hard release," apparently based on the criteria whether birds were released from remotely-operated boxes. Coates et al. (2006) uses the term for releases using a mock lek as well as the remotely opened boxes, as described by Rodgers (1992). Musil (1989) experimented with anesthetizing sage-grouse and placing them under a sagebrush as a "soft release" technique. The term "soft release" is more commonly used in the literature for translocations involving days or weeks of transitional confinement and/or supplemental feeding of longer duration that allows animals time to adjust to the new environment, and gain an attachment to the site (Scott and Carpenter 1987, Griffith et al. 1989, Teixeira et al. 2006). However, more elaborate soft-release schemes often involve captive-reared animals. We suggest that releases that do not involve confinement for >36 hours and supplemental feeding should be referred to as a 'hard release,' to be more consistent with literature on translocation/reintroduction of other taxa. The term 'moddified hard release' could be applied when techniques are used to reduce panic flushing, such as remotely opened boxes, or decoys.

Snyder et al. (1999) concluded that the common features of successful sharp-tailed grouse and prairie-chicken translocation projects were: 1) a total of >100 birds were released; 2) projects were of long duration (i.e., several seasons); 3) birds were moved in spring, although the number of projects in other seasons was small (n = 9); and 4) projects used remotely operated settling boxes when releasing birds (Snyder et al. (1999). Reese and Connelly (1997) reviewed translocations of sage-grouse. They recommended translocations only after careful evaluation of the release area for year-round habitat, that birds be captured at leks in March or April, transported quickly, and released via a "soft release" technique (groups released from a holding pen from a hidden location).

Coates et al. (2006) conducted a reintroduction of Columbian sharp-tailed grouse in Nevada, using the mock lek technique described by Rodgers (1992), and released birds from a box with separate compartments. They recommended closely monitoring birds during the initial year to fine-tune release site location based on female selection of nesting habitat. They were uncertain about whether the mock lek was important, but concluded that habitat quality of the release area was a critical factor affecting the retention of nesting females. A predator control program was directed at coyotes and ravens in the release area, but they did not test the effect on survival of released birds. Coates and Delehanty (2006) reported that females captured later in the lek visitation period had a higher nest-attempt rate, and they hypothesized females that were inseminated prior to capture at source leks may be more likely to nest following release than females that are not inseminated prior to capture.

No recent reintroduction of sharp-tailed grouse has been attempted in Washington, but a translocation to a site on Scotch Creek WLA with a lek that had declined to only four males appears to have successfully augmented the local population. Additional translocations are ongoing (Schroeder et al. 2008). Reintroductions in Washington should benefit from the experiences of previous reintroductions in other areas.

Under the current WDFW protocol for grouse translocations, birds are transported individually in boxes that are small enough to contain the bird's movement. The bottom of each box is lined with clay cat litter to reduce contact between feces and the birds' feet. Sharp-tailed grouse are captured on leks in spring, and processed soon after capture. Samples of blood and other body fluids are taken for disease testing and genetic analysis. The birds are banded and radio collars attached. Birds are transported by truck and/or aircraft to the release site soon after processing. Birds are released within 24 hours of capture whenever possible to minimize weight loss and stress, however, if it is already dark upon arrival at the release site, birds are held overnight and released at sunrise the following morning. Special settling boxes, modified from Musil (1989), are used to allow the birds some time to calm down before being released. Birds are placed in a settling box for at least 20 minutes before the box is opened with a cord from a hide, allowing the birds to exit on their own. The usefulness of this technique has not been confirmed by controlled studies, but it is hoped that it may minimize stress and the chances of panic flushes that could ultimately result in longer movements away from the release area. Past efforts suggest that such modified hard release techniques may contribute to project success (Snyder et al. 1999).

Management Beyond Recovery

The recovery objectives are intended to recover Columbian sharp-tailed grouse populations to the point where there is little concern about the persistence of the species in the state. Ideally, sharp-tailed grouse populations will continue to increase to the point where a limited harvest can be permitted without concern about impacts to the population, and management will continue to facilitate expansion of sharp-tailed grouse populations. The sharp-tailed grouse is classified as a game bird in Washington, and should the species recover sufficiently that it is de-listed from sensitive status, its management would return to the Game Division of WDFW. A game management plan would be prepared that outlines additional management strategies and identifies population levels sufficient to allow limited harvest.

Recovery Area

The recovery area (Fig. 30) focuses on portions of the historical range of sharp-tailed grouse that still support sharp-tailed grouse, or have the greatest potential to support sharp-tailed grouse, taking into account mean annual precipitation, slope, and current vegetation and the potential for habitat restoration. We identified the Methow Unit for its potential to support a reintroduced population based on a preliminary assessment, but a more in-depth analysis is needed. We have included much of southeastern Washington and the Klickiat region in "other potential recovery areas". The Palouse and the Wheatgrass/Fescue Zones (Cassidy et al. 1997) of southeastern Washington are now largely cropland, with a small percentage in CRP, but they may have historically supported the highest density of sharp-tailed grouse in the state. The annual precipitation and deep soils of these areas would probably be productive for sharp-tailed grouse and facilitate restoration projects. What the region lacks is a nucleus of public land with deep soil that could serve as an obvious focal point for efforts to aggregate easements, conservation grant projects, acquisitions, and habitat restoration. In future revisions of the recovery area map, southeastern Washington, may be further subdivided to help focus and prioritize habitat work to facilitate future reintroduction projects. Some parts of the recovery area may be removed in the future if habitat assessments suggest they have little potential to contribute significantly to recovery.

Columbian Sharp-tailed Grouse Recovery Area

State highways	Developed	Pasture/hay
County	Deciduous forest	Cultivated cropland
CSTG Historical range (mod.)	Forest	Wetland
Open water	Shrub/scrub	CRP 2007
Developed, open space	Grassland	

Management Priority

33 = Priority 1: Occupied by sharp-tailed grouse.

33 = Priority 2: Units important for providing habitat to connect existing populations.

33 = Priority 3: Units with high potential to support reintroductions.

33 = Priority 4: Units that may provide habitat for populations to expand

= Priority 5: Other potential recovery areas.

= Sharptail recovery units

Sharp-tailed grouse Recovery Units

1. Similkameen	9. Chiliwist	17. Hellgate Canyon
2. Chesaw	10. Methow	18. Roosevelt
3. Sinlahekin	11. W. Foster Creek	19. Spokane River
4. Siwash	12. Chelan Butte	20. Wilson Creek
5. Tunk Valley	13. Badger Mountain	21. Swanson Lakes
6. Scotch Creek	14. Withrow Moraine	22. Crab Creek
7. French Valley	15. E. Foster Creek	
8. Greenaway Springs	16. Nespelem	

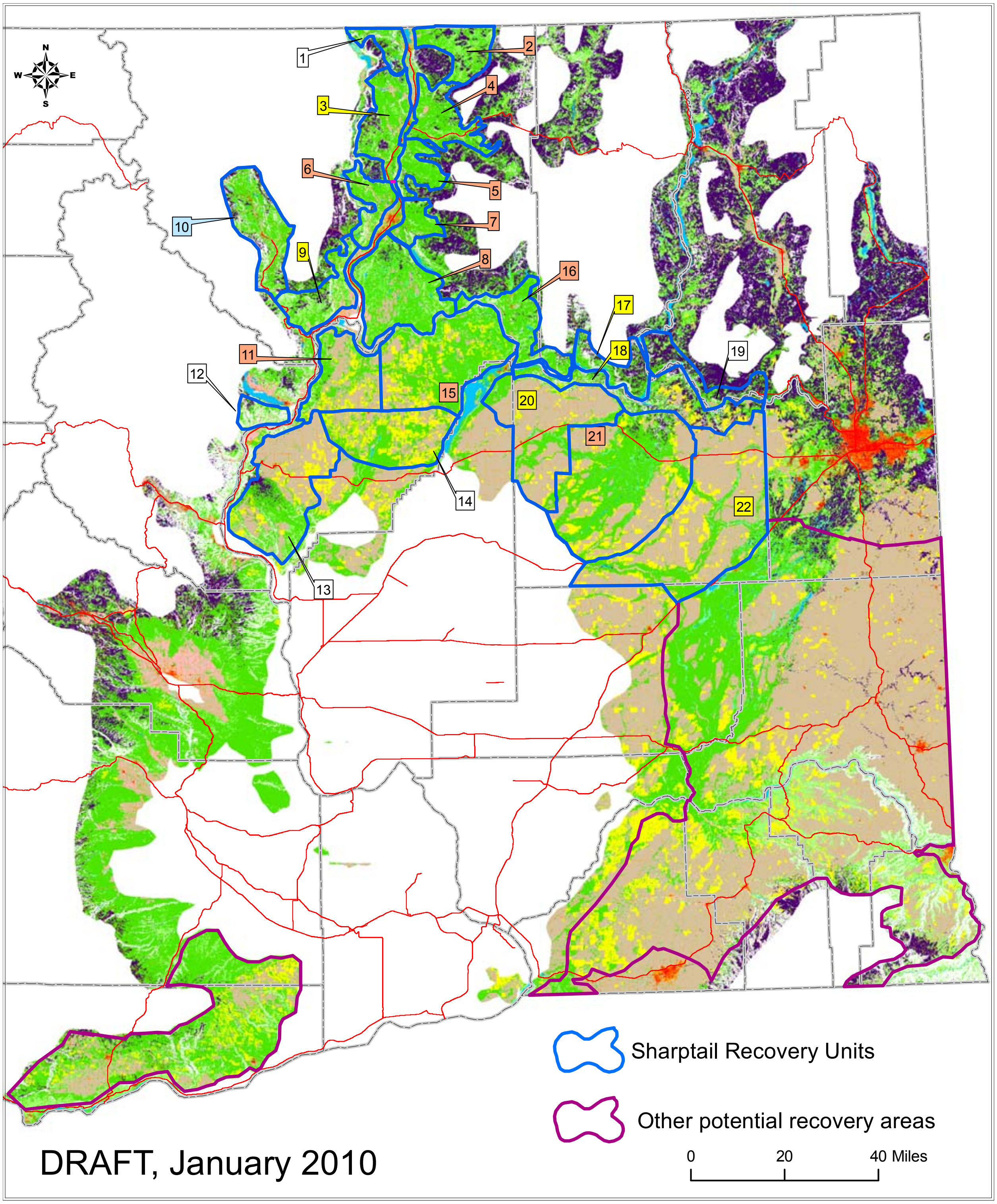


Figure 30. Columbian Sharp-tailed Grouse Recovery Area and Recovery Units (DRAFT) and landcover in the historical range of sharp-tailed grouse (modified) in Washington.

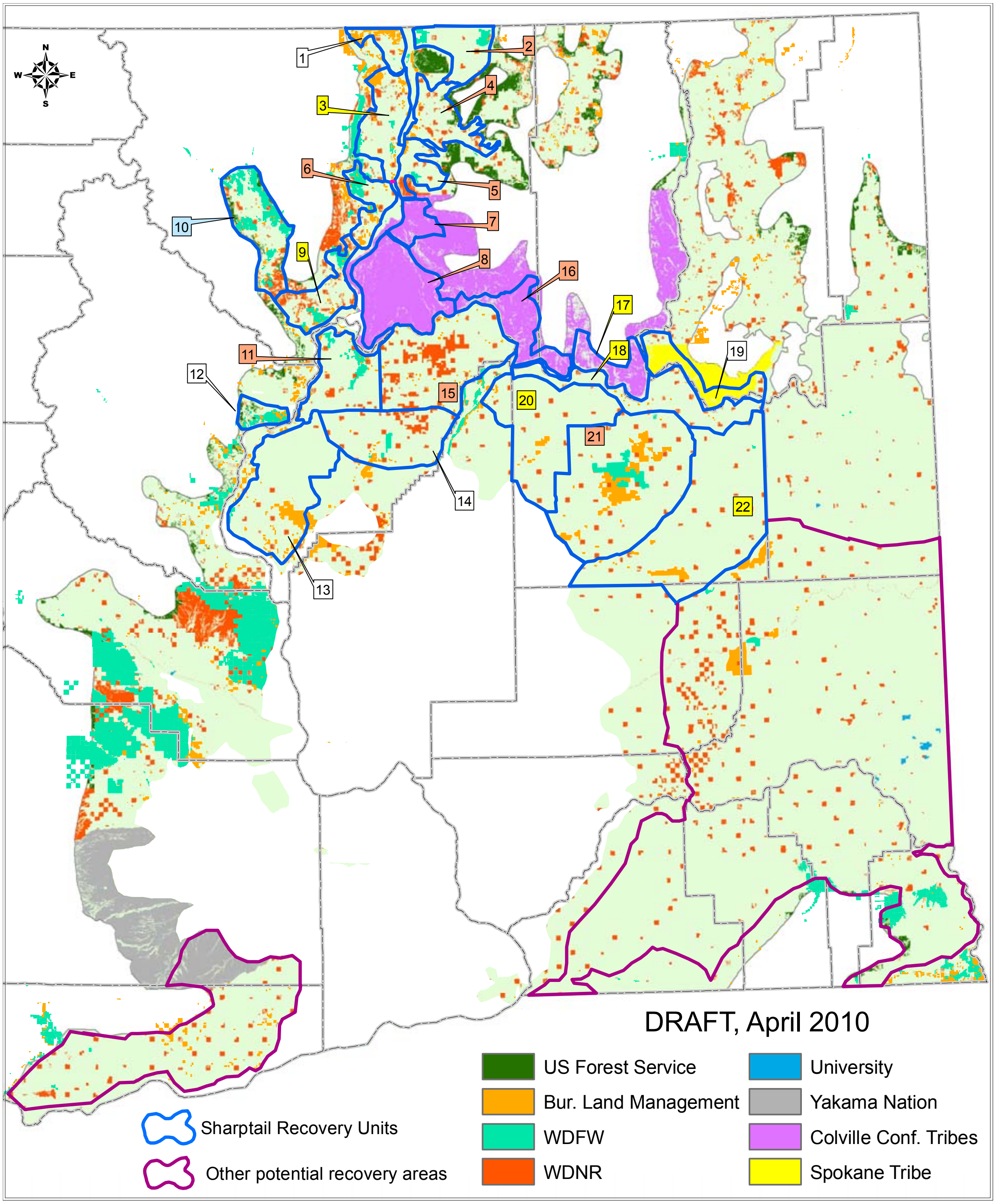


Figure 31. Columbian Sharp-tailed Grouse Recovery Units and important public and tribal lands in Washington.

RECOVERY STRATEGIES AND TASKS

1. Protect sharp-tailed grouse populations.

1.1. Reduce the collision and predation hazards posed by poles, wires, and fences.

Fences and powerlines pose a collision hazard to grouse and provide perches for avian predators. Minimize proliferation of perch sites for raptors and corvids within occupied sharp-tailed grouse areas and where reintroductions occur. New powerlines and utilities should use existing corridors or be located so as to minimize collision risk and damage to habitat. Existing powerlines should be buried or poles modified with perch guards to prevent use as raptor perch sites. Because burial of powerlines is expensive (≥$30,000/mi), only lines that clearly pose a hazard to sharp-tailed grouse would likely be buried as funds are available.

1.1.1 Promote removal of fences, powerlines, cables, and poles that are no longer in use.

1.1.2 Mark existing fences by attaching vinyl markers to the wires to increase visibility and attach perch guards to poles in areas occupied by sharp-tailed grouse.

Mark existing fences using pieces of vinyl undersill trim available from hardware and building material retailers (Fig. 31), or a heavy duty reflective tape on smooth wire. In 2008, material cost is about $270/mile of fence, and volunteers may be available for cutting and installation. Where necessary, remove vegetation along fences to improve visibility.

Figure 32. Fence near West Foster Creek marked with vinyl markers, and (inset) heavy duty reflective tape to use on smooth wire.

1.1.3 <u>Minimize proliferation of additional corridors for power lines, towers, and fences, except where needed to exclude livestock.</u>

1.2 Identify and minimize other human-related and natural sources of mortality.

Identify major mortality factors, both human-related and natural, for local populations through intensive monitoring and research activities.

1.2.1 <u>Document incidents of illegal and accidental shooting of sharp-tailed grouse and evaluate the need for remedies</u>.

The frequency of accidental shooting of sharp-tailed grouse during upland bird seasons is unknown. Shooting mortality may occur occasionally on public lands where sharp-tailed grouse co-occur with ring-necked pheasants, gray partridge, dusky grouse, chukar, and California quail. Incidents should be documented to help determine if additional education or local enforcement is needed. Two radio-tagged sharp-tailed grouse were shot during the 1990s, and a radio-collared sage-grouse female released on Swanson Lakes was shot in October 2009 (Fig 33).

Figure 33. X-ray of female sage-grouse found dead on Swanson Lakes WLA in October 2009, revealing shotgun pellets.

1.2.2 <u>Minimize accidental and illegal killing of sharp-tailed grouse</u>.

Figure 34. Warning sign used on wildlife areas to reduce accidental shooting by upland bird hunters.

Signs on wildlife areas warn of the presence of sharptails and their protected status (Fig. 34), and WLA staff provide information to hunters to minimize the potential for mis-identification (J. Anderson, pers. comm.). Accidental killing of sharp-tailed grouse during legal hunting of other upland bird species may be a significant problem, especially where local sharptail populations are low and hunting pressure is great. Lands that support sharp-tailed grouse populations should not be used as pheasant release sites. Steps should be taken such as increased hunter education, changes in pheasant stocking, or restrictions on local access during upland game seasons when sharp-tailed grouse are vulnerable. Local upland gamebird hunting closures should be considered.

1.2.3 Minimize accidental destruction of nests by trampling by cattle and horses, and during haying, tilling, etc .

Where shaptials are known to be nesting, avoid haying from 1 April – 30 June. Share information about sharp-tailed grouse use areas with landowners and help them avoid destruction of nests and young chicks. Avoid livestock grazing on portions of wildlife areas that support nesting and early brood-rearing sharp-tailed grouse.

1.2.4 Minimize the risk of exposing sharp-tailed grouse to histomoniasis or other diseases by reducing overlap of sharp-tailed grouse and pheasants releases .

Pheasants are considered a nearly ideal carrier of histomoniasis ('blackhead'), which can devastate populations of grouse and wild turkeys (Davidson and Doster n.d., Beyer and Moritz 2000, Peterson 2004, McDougald 2005). Pheasants should not be introduced on sites supporting sharp-tailed grouse, or on areas where sharp-tailed grouse reintroductions are being considered. Areas where infected birds have been released can remain contaminated for a long period of time.

1.2.5 Assess the potential impacts of wild turkeys on sharp-tailed grouse.

Assess the risks of disease transmission, or competitive interactions between sharp-tailed grouse and introduced wild turkeys.

1.2.6 Reduce sources of disease vectors, such as mosquitoes.

New guzzlers and other manmade water sources should not be established because they may increase mosquitoes that spread West Nile Virus. Junk, such as old tires, that hold water provides potential mosquito breeding sites and should be removed.

1.3 Reduce predation by human subsidized predators.

1.3.1 Where feasible, eliminate poles, posts and nesting structures, unused equipment, and refuse from steppe and grassland habitats.

In occupied sharp-tailed grouse areas, reduce or eliminate unused structures that provide nesting, denning, and perching sites for predators. Fence posts and farm equipment, abandoned buildings and associated trees can provide nesting sites, hunting perches, or hiding places for predators, including hawks, owls, corvids, and other predators.

1.3.2 Promote removal of human-related food sources of corvids, raptors, and carnivores.

Reduce the availability of garbage, livestock carcasses, and bird feeding stations that can support or concentrate predators that prey on sharptails opportunisically.

1.4 Protect sharp-tailed grouse from human-related disturbance.

1.4.1 Identify any human-related disturbance factors and avoid disturbing activities such as gravel crushing, ORV use, and recreation near leks (≈ 2 km).

Disturbing activities are those that cause the birds to flush or alter their behavior for a substantial length of time. Persistent disturbing activities are a more serious problem; farming activities, unless actually on a lek site, on one or two days of the breeding season are not likely to be a significant problem. Repeated or chronic disturbances are most harmful between the hours of 0500 and 0900 during March-April, but chronic disturbance during fall, should also be avoided near leks. While not a major impact to grouse populations, disturbance to sharp-tailed grouse nesting and foraging may result from noisy activities, recreational development, or repeated disruption of leks. For example, a lek in Douglas County was abandoned after a rock-crushing operation began nearby. If areas are identified where humans seriously inhibit lekking, work with birding groups and landowners to minimize and mitigate impacts. Restrict off-road vehicles, snowmobiles, camping, site visits, etc, and close roads or limit area access as necessary to protect lek areas from disturbance.

1.4.2 Treat lek locations as sensitive data.

Locational information for sharp-tailed grouse is considered sensitive under WDFW policy # 5210, and exempt from public disclosure (RCW 42.56.430). Lek location information is not released by WDFW except under conditions defined in policy 5210. In order to minimize disturbance from frequent visitation, land managers with leks should not disclose lek locations or encourage viewing at leks. Agency personnel should do nothing that increases viewing disturbance. Landowners should be encouraged to limit viewing activities to long-range observation from vehicles on county roads, except activities required for agency lek counts. As populations recover, consider establishing a designated lek to provide controlled viewing and photographic opportunities.

2. Protect sharp-tailed grouse habitat.

2.1 Update planning documents and policies to protect sharp-tailed grouse habitat on state, federal, and tribal lands.

2.1.1 Update WDFW Wildlife Area Management Plans with current sharp-tailed grouse management needs.

2.1.2 Identify public lands important for sharp-tailed grouse conservation and recovery and provide that information to managing agencies.

2.1.3 As opportunities arise, work with WDNR, tribes, and BLM to protect sharp-tailed grouse habitat.

2.2 Ensure compatibility of grazing management on public lands in the sharp-tailed grouse recovery area.

2.2.1 Where grazing occurs on public lands in sharp-tailed grouse recovery areas, manage grazing so that the habitat characteristics needed for breeding and wintering are consistently maintained.

Where shaptails are known to be nesting, avoid livestock grazing from 1 April – 30 June. In general, management should be designed to increase herbaceous cover, improve the composition and diversity of native vegetation, and limit the spread of noxious weeds. Whatever method is used to set stocking levels, the key consideration is that the habitat characteristics required for sharp-tailed grouse be maintained. Successful nest sites in Washington had a VOR of 27.9 cm; random sites 50–100 m away from nests (successful and unsuccessful) in the same cover type had a VOR of 16.6 cm (McDonald 1998). Optimal nesting habitat would have mean VOR of residual vegetation (measured from a height of 1 m, 4 m from the pole) of ≥25 cm (Meints et al.1992). Nesting cover with mean herbaceous vegetation height of >20 cm may be suitable, as long as numerous sites with higher (>30 cm) cover are present. On degraded sites, grazing could be part of an interim phase of a long-term restoration plan to reduce fire hazard on annual grassland or to control cheatgrass. Some sites degraded to annual grassland will not recover sufficiently through grazing changes or livestock exclusion to be suitable for sharp-tailed grouse until the site is revegetated with native species. Salt grounds should not be located on sites used annually by grouse. New livestock water developments should not be located at sites used by grouse unless designed to improve habitat for sharptails and reduce existing damage by livestock.

Grazing levels should be based on predicted use during periods of drought (i.e., less than 75% of average moisture during a period of ≥6 months). If it is determined through assessment, monitoring, and observation that sharp-tailed grouse habitat needs are not being met and livestock are a significant contributing factor, changes in grazing management should be made immediately to correct deficiencies. Remove grazing pressure if the area is degraded and restoration is unlikely under an altered grazing strategy, if there is increasing encroachment by noxious weeds, or where it is otherwise incompatible with use by sharp-tailed grouse.

2.2.2 Ensure that grazing leases on WDFW lands managed in part for sharp-tailed grouse are compatible with their habitat needs.

In some locations, WDFW lands have been managed to benefit mule deer in ways that may have negatively affected sharp-tailed grouse. Cattle grazing on the Chiliwist Wildlife Area is used to suppress grass and increase shrubs for mule deer winter forage (Swedberg 2006). Sharp-tailed grouse were present historically on the Chiliwist, but no known leks have been found in recent years. The Chiliwist is in an important location between sharp-tailed grouse populations on Scotch Creek WLA and the northern Douglas County population; it is also over the Loup Loup Summit from the Methow and is west of the Greenaway Springs population on the Colville reservation. Grazing on the Chiliwist should be evaluated relative to sharp-tailed grouse habitat condition. Livestock grazing should not occur during the nesting and brood-rearing season on WLA managed for sharptailed grouse. Grazing during the remainder of the year should be managed to maintain adequate residual spring nesting cover, and diverse herbaceous vegetation.

2.2.3 Fence public lands when necessary to to manage livestock to protect and restore sharp-tailed grouse habitat.

New fencing may be needed to keep livestock from adjacent ownership out, and to protect shrub plantings and vegetation in riparian zones and wet meadows from deer and livestock. Livestock should be excluded from riparian habitat, except where and when it can be very closely monitored, and the livestock removed before woody deciduous vegetation is damaged. Fences in areas with potential use by sharp-tailed grouse should be equipped with markers to increase their visibility and fences that are no longer needed should be removed.

2.3 Manage riparian habitats on public lands to support sharp-tailed grouse wintering.

Recovery of riparian and meadow vegetation may require careful monitoring and management of grazing or exclusion of livestock; where no deciduous shrubs remain, recovery may require plantings. Where reed canarygrass is dominant moderate grazing may be helpful to increase plant diversity.

2.3.1 Avoid damage to wet meadows by road development and human disturbance.

2.3.2 Control reed canarygrass to restore woody vegetation.

2.4 Discourage expansion of road systems on public lands in management units.

2.4.1 Avoid adding new roads, ORV trails, or right-of-ways that would destroy or fragment habitat or isolate populations.

2.4.2 Avoid improvements such as grading and widening of existing unpaved roads that receive little use.

2.4.3 Promote closures of unnecessary roads or those that are negatively impacting habitat quality.

Close roads on public lands not needed for management, and that conflict with sharp-tailed grouse conservation.

2.5 Facilitate management of private agricultural and range lands that is compatible with the conservation of sharp-tailed grouse.

2.5.1 Promote the protection of remnant areas of Palouse prairie and steppe.

2.5.2 In dry shrub-steppe areas, discourage burning of CRP and vegetation along the edges of farm fields and roadsides where remnant patches of shrub-steppe may be burned in the process.

2.5.3 Discourage use of insecticides and herbicides in grouse brood-rearing habitats and spraying practices that result in the accidental or incidental spraying of remnant areas of native steppe .

Incidental spraying of shrub-steppe can be due to the close proximity of remnants to croplands and road right-of-ways. It can also be exacerbated by regulations which make disposal of left-over chemicals difficult (may result in some chemicals being 'dumped' over open shrub-steppe habitat).

2.5.5 Work with range managers interested in sharp-tailed grouse conservation to use range management practices that result in increased habitat value for grouse.

Private rangeland accounts for a significant portion of the sharp-tailed grouse recovery area in Washington. Assist ranchers by providing information on range management practices that benefit grouse. For mixed ownerships and leases on public lands, work collaboratively through Coordinated Resource Management (CRM) or other processes to develop management solutions. Encourage retention of residual grass cover to provide for sharp-tailed grouse nest concealment, and healthy communities of native perennial grasses and the associated forb and shrub communities.

2.5.6 Discourage development of additional springs and underground water wells for livestock, unless it can be shown that the result will benefit sharp-tailed grouse by protecting wet meadow or riparian habitat.

2.5.7 Encourage the development, and provide technical assistance for, Habitat Conservation Plans that include protection of sharptail habitat on private lands.

2.5.8 Explore means of providing incentives to protect and enhance sharptail habitat on private lands.

2.6 Protect essential sharp-tailed grouse habitat through easements, cooperative agreements, and acquisitions.

The priorities for acquisitions or easements are:

a) Areas that contain important habitat currently occupied by sharp-tailed grouse;
b) Locations adjacent to occupied areas that can be enhanced or restored to allow a sharp-tailed grouse population to increase or that provide potential corridors connecting isolated populations;
c) Areas that will increase and consolidate public, land trust, and/or The Nature Conservancy holdings in areas that have been identified for reintroduction projects; and
d) Areas that are at risk of an alternate land use (such as development) that would isolate or fragment habitat and substantially impair recovery.

2.6.1 Use conservation easements, or purchase of development rights (PDR) agreements to keep large ranches intact and protect sharp-tailed grouse habitat.

Conservation easements have been used effectively to protect and manage blocks of private land, while preserving rural economies. PDRs are being used throughout the western states by governments, nongovernmental organizations, and agricultural producers to maintain land in large blocks and allowing landowners to continue ranching. This approach to habitat protection and management should be considered for its potential to protect large blocks of contiguous sharp-tailed grouse habitat. Cooperative agreements may also be used to develop management and protection strategies for sharp-tailed grouse habitat.

2.6.2 Consider acquisitions of important habitat if there are willing sellers and when it provides the best option to protect and/or restore critical habitats.

Identify important parcels of sharp-tailed grouse habitat on private land that may be at risk of development or loss. Where there are willing sellers, consider acquisitions that result in protection of key areas and/or better habitat connectivity of sharp-tailed grouse habitat. Facilitate protection and management by adding them to conservation lands, such as county land trusts, The Nature Conservancy, state research natural areas and natural area preserves, and state wildlife areas.

2.7 Provide data and technical advice to conservation districts, counties and regulatory agencies to increase protection of sharp-tailed grouse habitat on private lands.

Work with counties and conservation districts in eastern Washington to protect shrub-steppe and meadow steppe habitats important to sharp-tailed grouse. Encourage recognition of occupied sharp-tailed grouse areas, shrub-steppe, and prairie habitats as important and worthy of inclusion in critical area designations and updates of county ordinances under the state's Growth Management Act. Provide PHS management recommendations (Schroeder and Tirhi 2003) and maps to landowners and regulatory agencies.

2.7.1 Provide technical assistance to counties to minimize the effects of development on sharp-tailed grouse habitat.

Review and comment on proposed revisions of critical area and clearing and grading ordinances. Encourage counties to adopt clear standards of protection for sharp-tailed grouse habitat.

2.7.2 Update PHS maps as needed to include sharp-tailed grouse nesting, brood-rearing, and winter habitat.

2.7.3 Provide technical assistance to counties to minimize the effects of roadside spraying and road maintenance on sharp-tailed grouse habitat, including woody riparian vegetation.

2.8 Protect shrub-steppe habitat by reducing the risk of wildfires.

Not all sharp-tailed grouse habitat is seriously affected by wildfires, but sagebrush in drier shrub-steppe can require decades to recover, even when seed sources are present. Climate change may increase the incidence of wildfires. However, prescribed fire may be useful in restoring some grassland communities.

2.8.1 Reduce fire risk in shrub-steppe on WDFW lands and encourage appropriate fire management measures on other public lands.

2.8.2 Work with owners of private lands near and adjacent to WDFW and other public lands essential to sharp-tailed grouse at high risk of damaging fires to reduce risk of fires.

3. Enhance sharp-tailed grouse habitat.

The first priorities for enhancement or restoration are:
a) Areas that are currently occupied by sharp-tailed grouse;
b) Areas adjacent to existing populations that provide potential corridors connecting isolated populations or for expanding occupied areas; and
c) Areas that have been identified for reintroduction projects.

Habitat restoration should use mixtures of locally adapted varieties of native grasses, forbs, sagebrush and other shrubs when available. Avoid seeding with nonnative species whenever possible, although alfalfa may be an exception (Rodgers and Hoffman 2005). Also, some situations may necessitate non-natives that can compete with noxious weeds. Suppress cheatgrass and noxious weeds. Apa (1998) suggested that following control of the exotic understory, a diverse mix ($\geq$10 species of grasses, forbs, and shrubs) be seeded to maintain >10% forb and 10–20% grass cover. Use the best available techniques for the situation, which may include fallow procedures that reduce problems associated with noxious weeds or the selective use of herbicides to reduce the competitive advantage of noxious weeds over planted vegetation.

3.1 Evaluate habitat capability using vegetation maps, and sharp-tailed grouse habitat models to identify focus areas for restoration.

Analyze habitat condition in areas targeted for recovery starting with occupied areas, and working outward to adjacent areas intended for connecting populations, and establishing new populations. A Habitat Suitability Index model could be tested and used to evaluate habitat.

3.1.1 Analyze current habitat conditions and identify and prioritize areas for habitat restoration.

3.1.2 Identify and prioritize areas for restoration to increase and expand existing populations, support connectivity between existing populations, and support reintroductions.

Areas that may be priorities for work include former CRP fields acquired by BLM and WDFW that have become a monoculture of crested wheatgrass. The Nature Conservancy has used volunteers to cut conifer seedlings that are invading grassland they own in the Siwash Valley, but additional work is needed. In some locations, lands have been managed to increase woody shrubs to benefit mule deer winter range, but this may have negatively affected sharp-tailed grouse. Habitat on the Chiliwist WLA should be evaluated for ways that the habitat can be improved for sharp-tailed grouse, such as prescribed burns.

3.2 Enhance sharp-tailed grouse habitat on WDFW lands.

3.2.1 Restore upland sharp-tailed grouse areas, including older CRP fields, grain and hay fields to meadow steppe using native grasses, forbs, and selected shrubs.

Current priorities for restoration include older CRP fields on Swanson Lakes Wildlife Area and old wheat fields in the Fraser Creek area of the Methow WLA

3.2.2 Restore riparian deciduous shrubs, including seviceberry, chokecherry, hawthorn, *Rosa* spp., aspen, and water birch.

3.2.3 Use cutting and removal, or conduct experimental prescribed burns to control conifer invasion and improve habitat for sharp-tailed grouse in meadow steppe/grassland communities, where appropriate.

Habitat on the Chiliwist and Sinlahekin WLAs might benefit from prescribed burns to reduce woody vegetation. Native bunchgrasses, *Rosa* sp., chokecherry, and snowberry, all are recovering well after wildfires on the Chiliwist WLA (Swedberg 2006).

3.3. Facilitate sharp-tailed grouse habitat enhancement on other public and conservation lands.

3.3.1 As opportunities occur, assist BLM, WDNR, TNC, and land trusts in the restoration of healthy grasslands and riparian deciduous shrubs to improve sharp-tailed grouse habitat values in the recovery area.

3.3.2 Facilitate funding for habitat management for sharp-tailed grouse on other conservation lands.

3.4 Encourage and facilitate habitat enhancement on private lands through the use of incentives, such as Farm Bill conservation programs, to benefit sharp-tailed grouse.

Assist landowners and conservation districts by providing information, advice, or materials for implementing incentive programs available for habitat protection and restoration. Continue working with the Farm Service Agency and the Natural Resources Conservation Service to enroll and re-enroll landowners in CRP and the Palouse Prairie and Eastern Washington Shrub-steppe, and Douglas County sage and sharp-tailed grouse SAFE programs. Interested landowners should be assisted in applying for grants intended to protect natural resources, restore habitat, and conserve wildlife on private lands. In addition to CRP, grant programs authorized in the 2008 Farm Bill that may be used to enhance sharp-tailed grouse habitat include the Grassland Reserve Program, Wildlife Habitat Incentives Program, Environmental Quality Incentives Program, and the Conservation of Private Grazing Lands Program. Additional types of incentives, such as direct payments for sharp-tailed grouse production, should be explored.

3.4.1 Identify the best local opportunities for enhancing sharp-tailed grouse habitat and assist landowners interested in incentive programs.

3.4.2 Assist with securing grants for conservation easements, purchase of development rights, or habitat protection and restoration through 2008 Farm Bill programs such as CRP, SAFE, Wildlife Habitat Incentives Program and Grassland Reserve Program.

3.4.3 Provide technical assistance or materials to landowners, such as cost-share for seed mixes that enhance sharp-tailed grouse habitat value of plantings above the minimum requirements of Farm Bill conservation programs.

4. Inventory and monitor sharp-tailed grouse populations.

4.1 Monitor the status of known sharp-tailed grouse populations.

4.1.1 Conduct annual lek counts.

Use established protocols to conduct annual lek counts, unless or until, a more reliable monitoring technique is developed, tested, and proven to be more efficient.

4.1.2 Conduct surveys for leks that have moved and new leks.

Finding all leks is important to maintain the consistency of trend information and population estimates. Potential habitat should be periodically surveyed for lek complexes at least every three years. Potential habitat can be defined by the quality and distribution of the habitat in relation to known populations of birds. Areas close to existing lek complexes should be searched for new, shifting, or satellite lek sites. When a known lek becomes inactive, surveys should be conducted the same year to determine if and where the lek moved. Adjacent inactive lek complexes should be surveyed once every 3 to 5 years to determine if they are still inactive. One or more new lek locations on the Colville Indian Reservation were detected by a tribal biologist in 2008 by helicopter, which may be an efficient means of finding leks when funds are available (R. Whitney, pers.comm.).

4.1.3 Collect feather, blood, or other samples as needed to monitor genetic health of populations.

4.2 Coordinate cooperative surveys, monitoring, and data collection and maintenance.

4.2.1 Coordinate data exchange and cooperative survey efforts with the Colville Confederated Tribes, BLM, and other cooperators.

Coordinate monitoring and survey efforts, as needed.

4.2.2 Maintain a statewide database of sharp-tailed grouse survey efforts and detections.

The Wildlife Survey Data Management (WSDM) section at WDFW, Olympia, currently maintains a statewide database of survey information on sharp-tailed grouse. To be fully effective, area surveyed, along with positive and negative results, should be reported. Work with cooperators to solicit data on sharp-tailed grouse surveys and results. Compile observations of wintering sites from agencies, landowners, and birders, to identify critical winter cover and potential areas for planting shrubs.

4.3 Estimate population size and monitor population trend.

Sharp-tailed grouse population estimates are based on numbers of males at lek complexes. Despite potential biases and sources of error, it is currently the only cost effective method available to estimate grouse population sizes, and monitor trends over time. Number of males attending lek complexes should be analyzed using the highest number observed on a single day for each complex each year. This conservative technique will permit comparison with other sharp-tailed grouse populations in North America. Total population size should be estimated by multiplying the total numbers of males at all lek complexes by 2. This assumes all males are counted and the male:female ratio is approximately 1:1. All count data should be retained indefinitely, regardless of whether they are high counts or not. This will permit quantifying survey variability and perhaps additional analysis.

With the assistance of cooperating agencies, monitor sharp-tailed grouse populations in Washington with periodic surveys according to the protocols developed. Annual rates of population change should be estimated by comparing the maximum number of males counted at all lek complexes in consecutive years. Because sampling will occasionally be biased by effort and/or size and accessibility of lek complexes, sites not counted in consecutive years should be excluded from the sample for a given interval.

5. Augment existing populations and establish new populations.

Translocations of sharp-tailed grouse will be used to augment existing populations or to re-establish populations in historical locations where none currently exist. Reintroduction of birds into unoccupied habitat will be necessary to re-establish additional populations in Washington. Sharp-tailed grouse should only be reintroduced where they were present historically and where habitat in the release region is available in sufficient quantity, quality, and configuration to support a population year-round. Release sites will most often be locations with significant public land and cooperative adjacent private landowners. Release sites that provide opportunities for further population expansion into additional uninhabited areas are preferable.

5.1 Identify and prioritize local populations in need of augmentation.

Use lek count and genetic data to determine when local populations may need augmentation to persist while habitat enhancement is ongoing.

5.2 Identify and prioritize locations within the recovery area with the greatest potential to support reintroduced populations.

Evaluations should include assessments of habitat and landscape capability for supporting a sharp-tailed grouse population.

5.2.1 <u>Evaluate the feasibility of reintroductions in the Methow Valley.</u>

Sharp-tailed grouse were more recently in the Methow, and WDFW has 31,000 ac around the valley. Although the habitat is somewhat fragmented with steep slopes and private lands, some habitat restoration has been done since the extinction of the local population and vegetation appears to be in better condition than 10 years ago (M. Schroeder, pers. obs.). The matrix of private lands is threatened by development, although some is under conservation easements.

5.2.2 Evaluate the feasibility of reintroducing sharp-tailed grouse to southeastern Washington, Klickitat County, or in other parts of the historical range of sharp-tailed grouse in Washington

Assess habitat capability for establishing a population through reintroduction and maintaining the population through time. Focus areas may include Whitman County, southern Spokane County, or areas in Asotin, Columbia, Garfield, or Walla Walla counties. The Revere WLA and adjacent BLM lands together total >15,000 ac in western Whitman, and eastern Adams counties, that should be evaluated. The Escure Ranch appears to have suffered from a long history of sheep grazing before it was acquired by BLM. However, if conditions can be improved, the area might provide a focus area for additional work with private landowners (Farm Bill, easements, etc.).

The results of ongoing habitat modeling underway on the Coeur d'Alene Indian Reservation, just across the Idaho state boundary may influence consideration of a potential focus area in eastern Whitman County. If results of that study are encouraging, a cooperative cross-boundary project will be considered that could help increase the size of available habitat and the re-introduced population through a combined effort. The Columbia Hills area southwest of Goldendale has a nucleus of public lands, but a preliminary assessment suggested that conflicts with residential and/or wind power development might be problematic. The Yakama Nation also has some good grassland habitat, although limited in extent, and has expressed interest in eventually evaluating the potential for a reintroduction there (N. Burkepile, pers. comm.).

5.3 Evaluate and modify protocols used for the capture, transport, and release of sharp-tailed grouse during translocation projects as needed for reintroduction.

5.4 Conduct augmentations or reintroductions as needed.

5.4.1 Develop augmentation/reintroduction plans for local areas where needed.

Develop reintroduction plans with cooperators. The plans should include the number, timing, and sources for grouse, monitoring and any temporary predator control.

5.4.2 Where predation is problematic, conduct limited, local predator control prior to releases and/or during initial stages of reintroduction projects.

When feasible, raptor perches and habitat features attractive to predators should be eliminated from reintroduction sites.

5.4.3 Conduct translocations of grouse.

5.4.4 Monitor the survival and productivity of translocated individuals.

Monitor released individuals with radio telemetry as needed to assess survival and reproduction. Ideally, monitoring should be intensive enough to be able to identify the reasons for project success or failure. Monitor movement, habitat use, productivity, survival, and size of the population..

5.5 Evaluate success of augmentation projects.

The success or failure of re-introduction and augmentation efforts should be evaluated. Monitor the size, trend, and genetic health of populations to determine whether additional translocations, habitat improvements, release locations, or improved translocation methodologies are necessary

6. Conduct research necessary to conserve and restore sharp-tailed grouse populations.

6.1 Investigate the life history, demographics, and population dynamics of sharp-tailed grouse in Washington.

6.1.1 Investigate survival, productivity, and sources of mortality to identify vulnerable life stages and suggest means of improving survival of sharp-tailed grouse.

6.1.2 Investigate dynamics of sharp-tailed grouse populations to facilitate estimates of minimum viable populations and modeling of extinction risks.

6.2 Conduct research to improve understanding of habitat needs, sharp-tailed grouse seasonal movements, and dispersal.

6.2.1 Evaluate the nutritional value of water birch for sharp-tailed grouse.

6.2.2 Develop a landscape model of year-round habitats that can be used to evaluate potential reintroduction areas.

6.3 Develop methods of monitoring and improving the genetic health of sharp-tailed grouse populations.

6.3.1 Develop needed techniques and conduct genetic analysis of sharp-tailed grouse populations necessary to monitor success of translocations and the use of DNA for demographic monitoring.

Develop protocols for using feathers or other samples to monitor the genetic health of populations to determine if, when, and where translocations are needed and to determine the effectiveness of translocations for increasing genetic diversity.

6.4 Improve methods of restoring and maintaining sharp-tailed grouse habitat in Washington, including planting and prescribed burns.

6.4.1 Improve methods of restorating native vegetation and controlling weeds.

Document seed mixes, plant varieties, methods of controlling weeds and deer damage, and exchange information among managers to improve success and efficiency of habitat improvement projects.

6.4.3 Evaluate the effectiveness of prescribed burns to control conifer invasion, maintain grassland, and improve habitat for sharp-tailed grouse in meadow steppe/grassland communities.

Prescribed burns should be carefully evaluated, and the response of any sharp-tailed grouse population present should be monitored. Burns may be detrimental in some locations; Apa (1998) indicated that sagebrush control would be detrimental to sharp-tailed grouse brood habitat.

6.5 Estimate the minimum viable population of sharp-tailed grouse and develop spatially explicit viability assessment for the species in Washington when feasible.

When sufficient data is available on sharp-tailed grouse demography, genetics, and population dynamics, estimate the $N:N_e$ ratio and revise/update estimates of minimum viable population, and viability of Washington's subpopulations.

7. Review and revise recovery and conservation planning documents for sharp-tailed grouse populations in Washington.

7.1 Revise recovery objectives, recovery area map, and strategies for the sharp-tailed grouse as needed.

Use research results and new information to update and revise the sharp-tailed grouse recovery plan.

8. Coordinate and cooperate with other agencies, landowners and private groups in the conservation, protection, and restoration of sharp-tailed grouse in Washington.

8.1 Provide technical advice to the Natural Resources Conservation Service and the Farm Service Agency for the implementation of Farm Bill programs (CRP, SAFE, GRP, WHIP, etc.) at the local, state and national level to facilitate sharp-tailed grouse conservation in Washington and to ensure the wildlife conservation benefits intended by Congress.

8.1.1 Identify priority areas in Washington where Farm Bill programs have the greatest potential to benefit sharp-tailed grouse.

8.1.2 Provide technical advice on planting requirements and management practices to enhance or restore potential sharp-tailed grouse habitat.

8.1.4 Review and comment during rule-making at the national level to ensure that Farm Bill programs continue to benefit sharp-tailed grouse in Washington and elsewhere.

8.2 Facilitate meetings and information exchange of a technical interagency working group as needed to implement recovery actions for sharp-tailed grouse.

8.2.1 Facilitate information exchange and cooperation with the BLM, WDNR, Colville Confederated Tribes, Spokane Tribe, Coeur d'Alene Tribe, and Yakama Nation concerning management of sharp-tailed grouse and restoration of habitats .

8.3 Facilitate information exchange with the Palouse Prairie Foundation, NRCS, TNC, land trusts, and other organizations involved in developing methods of restoring Palouse prairie and other grassland habitats.

9. Develop public information and education programs.

9.1 Minimize incidental hunting mortality by providing identification materials to hunters.

9.2 Develop an education and outreach strategy to gain support for sharp-tailed grouse recovery.

Resources should address species identification, habitat and management conflicts, opportunities for habitat enhancement, habitat loss and degradation, and other threats.

9.2.1 Develop and disseminate information, education and interpretation materials.

9.2.2 Develop educational materials on grouse identification, conservation, and habitat management.

Materials should be designed for target audiences, such as landowners, school-aged children, or elected officials. For example a brochure was designed to provide information to landowners and residents of other states where we have obtained sharp-tailed grouse for translocation. The brochure is designed to help maintain support for cooperative translocation projects.

9.2.3 Identify media sponsors and public outreach and education partners to increase public knowledge and cooperation with recovery actions.

9.2.4 As populations recover, establish a controlled access, public-viewing/photo blind at a lek.

9.3 Periodically update and revise WDFW's Priority Habitats and Species (PHS) management recommendations for the sharp-tailed grouse.

PHS recommendations represent "best management practices" used to protect sharp-tailed grouse habitat. These were recently updated (Schroeder and Tirhi 2003), but will need to be periodically updated to promote good stewardship of sharp-tailed grouse and their habitat.

10. Secure funding for recovery activities.

10.1 Secure federal and nongovernmental foundation grants to conduct research, reintroductions, public education, and other recovery activities.

10.2 Seek grants and partnerships for habitat acquisiton, restoration and enhancement.

Secure funding for acquiring and restoring sharp-tailed grouse habitat, purchase of development rights, and exploring direct payment incentive programs through federal, state, and private sources. Develop cooperative propoposals with other conservation organizations, land trusts, and agencies. Grants intended to improve conditions for salmon by restoring stream banks, could use tree and shrub species of value for sharp-tailed grouse winter habitat. Explore partnering with Palouse prairie organizations to seek sponsors to establish and restore a reserve of sufficient size to support a sharptail population.

CONCLUSIONS

The Columbian sharp-tailed grouse was once the most abundant gallinaceous bird in steppe and prairie habitats of eastern Washington. Their numbers declined dramatically with the conversion of most of the Palouse prairie and arable shrub-steppe to cropland. Their decline continued with the degradation of habitat that came with drying of moist meadows, the elimination of woody riparian vegetation, over-grazing of native bunchgrasses, and general agricultural intensification. Declines of remnant populations have continued in recent years with continued degradation of habitat, isolation of small populations, and probably a resulting decline in genetic health. Recovery of sharp-tailed grouse in Washington will require that larger populations become established through connecting existing populations and re-establishing additional populations. Data from prairie-chickens and conservation genetics suggest that persistence for the next few decades may require at least one population of 2,000 birds, and long-term persistence may require a total population of at least 3,200 birds. Maintaining genetic connectivity may require periodic translocations between subpopulations if habitat connections cannot be re-established.

Restoring sufficient habitat for recovery will require a sustained effort involving many partners, and will not be possible without cooperation with many landowners. Partnerships with individuals and organizations with goals for sustainable agriculture, Palouse prairie restoration, climate stabilization, ranch and rangeland preservation, water quality, soil erosion, as well as wildlife conservation may be helpful to restore sufficient habitat and intervening lands to compatible uses.

IMPLEMENTATION SCHEDULE

Identified below are the agencies, WDFW involvement, task priorities, and estimates of annual expenditures needed for sharp-tailed grouse recovery (Table 8). Cost estimates do not mean that funds have been designated or are necessarily available to complete the recovery tasks. **Implementation of recovery strategies is contingent upon availability of sufficient funds to undertake recovery tasks.**

The following conventions are used:
Priority 1: Actions needed to prevent the extinction of the species in Washington.
Priority 2: Actions to prevent a significant decline in population size or habitat quality, or some other significant negative impact short of extirpation.
Priority 3: All other actions necessary to meet recovery objectives.

Table 9. Implementation schedule and preliminary cost estimates for implementation of recovery tasks.

Priority	Recovery Task	Duration in years	Potential Cooperators[a]	Est. Annual Cost ($1000's)	DFWShare[b]
1	1.1 Reduce collision hazards posed by fences, poles.	5	WDFW, BLM, VO	25	30
2	1.2 Identify and minimize human-related and natural sources of mortality	5	WDFW, UN, BLM	tbd[c]	50%
2	1.3 Reduce predation from human-subsidized predators	ongoing	WDFW	tbd[c]	90%
2	1.4 Protect sharp-tailed grouse from disturbance	ongoing	PL, WDFW, DNR		80%
1	2.1 Update planning documents to protect sharp-tailed grouse habitat on state, federal, and tribal lands.	ongoing	WDFW, DNR, BLM, CCT, WSP	20	50%
2	2.2 Ensure compatibility of grazing on public lands in sharp-tailed grouse recovery area.	ongoing	BLM, WDFW, DNR	10	5
1	2.3 Manage riparian habitats on public lands to support sharp-tailed grouse wintering.	ongoing	WDFW, BLM, DNR	10	6
2	2.4 Discourage expansion of road systems on public lands in management units.	ongoing	C, WDFW, BLM, DNR	5	4
2	2.5 Facilitate management of agricultural and rangelands that is compatible with sharp-tailed grouse.	ongoing	NRCS, BLM, PL, CD	tbd[c]	50%
1	2.6 Protect essential sharp-tailed grouse habitat through easements, cooperative agreements, and acquisitions.	10	RCO, USFWS, BLM, TNC, PL	tbd[c]	50%
2	2.7 Provide technical assistance to counties and regulatory agencies to protect sharp-tailed grouse and habitat.	ongoing	WDFW	5	5
2	2.8 Protect shrub-steppe habitat by reducing the risk of wildfires.	ongoing	DNR, C, PL	tbd[c]	
2	3.1 Evaluate habitat capability to identify focus areas for restoration.	2	WDFW, BLM, CCT	tbd[c]	30%
2	3.2 Enhance grouse habitat on WDFW lands.	ongoing	WDFW, VO	40	35
2	3.3 Facilitate sharptail habitat enhancement on public lands.	ongoing	WDFW, BLM, DNR, CCT, VO	tbd[c]	5
2	3.4 Encourage and facilitate habitat enhancement on private lands.	ongoing	NRCS, FSA, PPF, VO, CD	10	30
2	4.1 Monitor the status of sharp-tailed grouse populations.	annually	WDFW, BLM, CCT	15	80
2	4.2 Coordinate cooperative surveys, monitoring, and data.	ongoing	WDFW, CCT, BLM	2	2

Priority	Recovery Task	Duration in years	Potential Cooperators[a]	Est. Annual Cost ($1000's)	DFWShare[b]
2	4.3 Estimate population and monitor trends.	annually	WDFW	2	2
2	5.1 Identify populations augmentation needs.	ongoing	WDFW	5	5
2	5.2 Identify areas with potential to support reintroduced populations.	cyclic	WDFW	30	30
2	5.3 Evaluate protocols used for the capture, transport, and release of sharp-tailed grouse as needed for reintroduction.	5	WDFW	2	2
1	5.4 Conduct augmentations and reintroductions.	10/cyclic	WDFW, BLM, CCT, OS	30	25
2	5.5 Evaluate success of augmentation projects	10/cyclic	WDFW, BLM, CCT, OS	5	5
2	6.1 Investigate life history, demographics, and population dynamics of sharp-tailed grouse.	10	WDFW,BLM,VO,CCT,UN	40	20
2	6.2 Conduct research on habitat needs, seasonal movements, and dispersal.	10	WDFW, CCT, BLM, UN	15	8
2	6.3 Develop methods of monitoring and improving the genetic health of sharp-tailed grouse populations.	5	WDFW	4	4
3	6.4 Improve methods for restoring and maintaining sharp-tail habitat, including planting and prescribed burns.	5	WDFW, CCT, UN	tbd[c]	
3	6.5 Estimate the minimum viable population of sharp-tailed grouse and develop spatially explicit viability assessment for Washington.	1, when feasible	WDFW,	5	99
3	7.1 Revise recovery objectives, maps, documents as needed.	1	WDFW,	5	5
2	8.1 Provide technical advice to NRCS, FSA for the implementation of Farm Bill programs at local, state, and national level to facilitate sharp-tailed grouse conservation.	ongoing	WDFW	10	10
3	8.2 Facilitate/participate in sharptail working groups.	2	WDFW, CCT, TG,	2	2
3	8.3 Facilitate information exchange with the Palouse Prairie Foundation, NRCS, TNC, and other organizations involved in restoring Palouse prairie and shrub-steppe.	ongoing	WDFW	1	1
2	9.1 Provide identification material to hunters to minimize incidental hunting mortality.	ongoing	WDFW, CCT	1	1
3	9.2 Develop an education and outreach strategy.	1	WDFW	tbd[c]	
3	9.3 Periodically update PHS maps and management recommendations for the sharp-tailed grouse.	1	WDFW	10	10
	10.1 Secure funding for research, translocations, education, etc.	ongoing	WDFW, CCT, BLM	5	3
	10.2 Secure funding for habitat acquisition, improvement	ongoing	WDFW, CCT, BLM, TNC, VO	5	4

[a]Acronyms for cooperators: BLM = USDI Bureau of Land Management; C = counties; CCT = Colville Confederated Tribes; CD= Conservation districts; WDFW = Washington Department of Fish and Wildlife; DNR= Washington Department of Natural Resources; FWS = USDI Fish and Wildlife Service; OS = otherstates or provinces; PL = private landowners; PPF = Palouse Prairie Foundation; RCO = Recreation and Conservation Office; TG = tribal government, including Spokane Tribe, Coeur d'Alene, Yakama Nation, etc.; TNC = The Nature Conservancy; UN = university researchers; VO = non-governmental and volunteer organizations (such as Audubon Society chapters, Backcountry Horsemen, Inland Northwest Wildlife Council, Methow Conservancy, Washington Falconers, Wenatchee Sportsmen, etc.).

[b] Thousands, or %; anticipated WDFW share of cost if funds are available.

[c]Cost estimate to be determined.

REFERENCES CITED

Addison, E. M., and R. C. Anderson. 1969. *Oxyspirura lumsdeni* n. sp. (Nematoda: Thelaziidae) from Tetroanidae in North America. Canadian Journal of Zoology 47: 1223–1227.

Adkins, J. 1968. The detrimental effects of certain A.C.P. practices on wildlife in Lincoln, Spokane, and Whitman Counties. Federal Aid project W-41-D. Washington Department of Game. Olympia.

Agee, J. K. 1994. Fire and weather disturbances in terrestrial ecosystems of the eastern Cascades. *from* Hessberg, P. F. (ed.) Eastside Forest Ecosystem Health Assessment, Vol. III: Assessment. U.S.D.A. Forest Service, Pacific Northwest Research Station. PNW-GTR-320.

Akcakaya, H. R., V. C. Radeloff, D. J. Mladenoff, and H. S. He. 2004. Integrating landscape and metapopulation modeling approaches: viability of the sharp-tailed grouse in a dynamic landscape. Conservation Biology 18: 526–537.

Aldrich, J. W., and A. J. Duvall. 1955. Distribution of American gallinaceous game birds. U.S. Department of Interior, Fish and Wildlife Service Circular 34: 1–23.

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

Aldridge, C. L., S. J. Oyler-McCance, R. M. Brigham. 2001. Occurrence of Greater Sage-grouse x Sharp-tailed Grouse hybrids in Alberta. Condor 103: 657–660.

Aldous, S. E.1943. Sharp-tailed grouse in the sand dune country of north-cental North Dakota. Journal of Wildlife Management 7: 23–31.

Allendorf, F. W., and N. Ryman. 2002. The role of genetics in population viability. Pp 50-85, in S.R. Beissinger and D. R. McCullough (eds.) Population viability analysis. University of Chicago Press, Chicago, IL. 577 pp.

Aller, A. R., M. A. Fosberg, M. C. LaZelle, A. L. Falen. 1981. Plant communities and soils of north slopes in the Palouse region of eastern Washington and northern Idaho. Northwest Science 55(4): 248–262.

Amar, A., B. Arroyo, S. Redpath, and S. Thirgood. 2004. Habitat predicts losses of red grouse to individual hen harriers. Journal of Applied Ecology 41:305–314.

American Ornithologists' Union. 1957. Check-list of North American birds, fifth edition. American Ornithological Union. Washington, D.C. 691 pp.

American Ornithologists' Union. 1983. Check-list of North American birds, sixth edition. American Ornithological Union, Washington, D.C. 877 pp.

American Ornithologists' Union. 1998. Check-list of North American birds, seventh edition. American Ornithological Union. Washington, D.C. 829 pp.

Ammann, G. A. 1963. Status and management of Sharp-tailed Grouse in Michigan. Journal of Wildlife Management 27:802–809.

Anderson, J. 2006. Swanson Lakes Wildlife Area Management Plan (Draft). Washington Dept. Fish and Wildlife. 40 pp.

Anderson, J. 2007. Swanson Lakes Wildlife Area. 2007 management plan update. Washington Dept. Fish and Wildlife. 6 pp.

Anderson, J. 2008. Swanson Lakes Wildlife Area 2008 management plan update. Washington Department of Fish and Wildlife. 6 pp.

Anderson, D. C., K. T. Harper, and S. R. Rushforth. 1982. Recovery of cryptogamic soil crusts from grazing on Utah winter ranges. Journal of Range Management 35: 355–359.

Anderson, J. E., and R. S. Inouye. 2001. Landscape-scale changes in plant species abundance and biodiversity of a sagebrush steppe over 45 years. Ecological Monographs 71: 531–556.

Anderson, M. K. 2002. An Ecological Critique. p. 37-64 *in* O.C. Stewart. Forgotten Fires: Native Americans and the Transient Wilderness. University of Oklahoma Press, Norman. 364 pp.

Anderson, R., M. Morrison, K. Sinclair, Dale Strickland. 1999. Studying Wind Energy/Bird Interactions: A Guidance Document. Avain subcommittee, National Wind Coordinating Committee, Washington, D.C. 88 pp

Antieau, C. J. 2004. Biology and management of reed canarygrass, and implications for ecological restoration. Washington Department of Transportation, Seattle, WA. unpublished report.

Apa, A. D., 1998. Habitat use and movements of sympatric sage and Columbian sharp-tailed grouse in southeastern Idaho. Ph.D. dissertation, University of Idaho, Moscow. 199 pp

Applegate, R. D. 2000. Use and misuse of prairie chicken lek surveys. Wildlife Society Bulletin 28:457–459.

Applegate, R. D., C. K. Williams, and R. R. Manes. 2004. Assuring the future of prairie grouse: dogmas, demagogues, and getting outside the box. Wildlife Society Bulletin 32:104–111.

Armour, C. L., D. A. Duff, and W. Elmore. 1991. The effects of livestock grazing on riparian and stream ecosystems. Fisheries 16(1): 7–11.

Arnold, T. W. 1988. Life histories of North American game birds: a reanalysis. Canadian Journal of Zoology 66:1906–1912.

Ashley, P. 1992. Grand Coulee Dam Wildlife Mitigation Program Sharp-tailed grouse Programmatic Management Plan, Tracy Rock Vicinity, Lincoln County, Washington. Washington Dept. Fish and Wildlife, Prepared for Bonneville Power Administration, Division of Fish and Wildlife, Portland, Oregon, under agreement no. CE-B179-91BP18504, Phase One Project No. 91-061. 88 pp.

Ashley, P., and M. Berger. 1997. Columbia River wildlife mitigation habitat evaluation procedures report: Scotch Creek Wildlife Area, Berg brothers, and Douglas County Pygmy Rabbit Projects. Report prepared for U.S. Dept of

Energy, Bonneville Power Administration, Portland, OR, Project Number 95-056. 115 pp.

Ashley, P. and S. H. Stovall. 2004a. Southeast Washington Subbasin Planning Ecoregion Wildlife Assessment. Columbia River Basin Fish and Wildlife Program, Northwest Power and Conservation Council, Portland, Oregon. 640 pp.

Ashley, P. and S. H. Stovall. 2004b. Draft Okanogan Subbasin Wildlife Assessment and Inventory. Columbia River Basin Fish and Wildlife Program, Northwest Power and Conservation Council, Portland, Oregon. 86 pp

Attwell, J. 1977. Early history of Klickitat County. Tahlkie Books, Skamania, Washington. 279 pp.

Aubry, K. B. 1984. The recent history and present distribution of the red fox in Washington. Northwest Science 58: 69–79.

Avital, E., E. Jablonka, and M. L. Lachmann. 1998. Adopting adoptions. Animal Behaviour 55: 1451-1459.

Babero, B. B. 1953. Studies on the helminth fauna of Alaska. XVI. A survey of the helminth parasites of ptarmigan (*Lagopus* spp.) Journal of Parasitology 39:538–546 (*not seen, in* Peterson 2004).

Baines, D. 1996. The implications of grazing and predation management on the habitats and breeding success of black grouse *Tetrao tetrix*. Journal of Applied Ecology 33: 54–62.

Baines, D., S. Redpath, M. Richardson, and S. Thirgood. 2008. The direct and indirect effects of predation by Hen Harriers *Circus cyaneus* on trends in breeding birds on a Scottish grouse moor. Ibis 150(Suppl. 1): 27–36

Baker, W. L. 2002. Indians and Fire in the Rocky Mountains: the Wilderness Hypothesis Renewed. Pp 41–76, *in*: T. R. Vale, editor. Fire, Native Peoples, and the Natural Landscape. Island Press, Washington, D.C., 315 pp.

Baker, W. L. 2006. Fire and restoration of sagebrush ecosystems. Wildlife Society Bulletin 34(1):177–185.

Ballou, R. 1938. Early Klickitat Valley Days. Goldendale Sentinel, Goldendale, Washington.

Balser, D.S., Dill, H.H. & Nelson, H.K. 1968: Effect of predator reduction on waterfowl nesting success. Journal of Wildlife Management 32: 669–682.

Banerjee, R. 2004. Petition to List Columbian sharp-tailed grouse (*Tympanuchus phasianellus columbianus*) as threatened or endangered under the Endangered Species Act. Forest Guardians. Santa Fe, Mew Mexico. 70 pp.

Barrett,S. W. and S. F. Arno. 1999. Indian fires in the Northern Rocky Mountains: ethno history and ecology. P. 50–64. *in* R. Boyd, editor. Indians, fire, and the land. Oregon State University Press, Corvallis, Oregon. 313 pp.

Barrett, S. W., T. W. Swetnam, and W. L. Baker. 2005. Indian Fire Use: Deflating the legend. Fire Management Today 65(3):31–33.

Bart, J., 2000. Status assessment and conservation plan for Columbian Sharp-tailed Grouse. Forest and Rangeland Ecosystem Science Center, U. S. Geological Survey, Boise, Idaho. 58 pp.

Batterson, W. M., and W. B. Morse. 1948. Oregon Sage Grouse. Oregon Fauna Series No. 1. Oregon State Game Commission, Portland, Oregon. 29 pp.

Baumgartner, F. M. 1939. Studies on the distribution and habits of the Sharp-tail Grouse in Michigan. Transactions of the 4th North American Wildlife Conference Pages. 485–490.

Baydack, R. K., and D. A. Hein. 1987. Tolerance of Sharp-tailed Grouse to lek disturbance. Wildlife Society Bulletin 15: 535–539.

Beauchamp, W. D., R. R. Koford, T. D. Nudds, R. G. Clark, and D. H.Johnson. 1996. Long-term declines in nest success of prairie ducks. Journal of Wildlife Management 60:247–257.

Beck, J. L., and D. L. Mitchell. 2000. Influences of livestock grazing on sage grouse habitat. Wildlife Society Bulletin 28:993–1002.

Beever, E.A., and P. F. Brussard. 2000. Examiningin ecological consequences of feral hors grazing using exclosures. Western North American Naturalist 60(3): 236–254.

Bellinger, M. R., J. A. Johnson, J. E. Toepfer, and P. Dunn. 2003. Loss of genetic variation in Greater Prairie-Chickens following a population bottleneck in Wisconsin, U.S.A. Conservation Biology 17:717–724.

Belnap, J., J. H. Kaltenenecker, R. Rosentreter, J. Williams, S. Leonard, D. Eldredge. 2001. Biological Soil Crusts: Ecology and Management. Technical Ref. 1730–2. USDI, BLM and USGS. 110 pp.

Belsky, A.J., A. Matzke, S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. Journal of Soil and Water Conservation 54(1):419–431.

Bendire, C. E. 1892. Life Histories of North American Birds. U.S. National Museum Special Bulletin 1. Washington, D.C.

Bennington, W. L. 1972. Comparison of the vegetational composition of grazed and protected sites on Turnbull NWR. Master's Thesis. Eastern Washington State University, Cheney, Washington. 41 pp.

Bent, A. C. 1963. Life Histories of North American Gallinaceous Birds. Dover Publications, New York, New York 490 pp +93 plates.

Berger, R. P., and R. K. Baydack. 1992. Effects of aspen succession on sharp-tailed grouse, *Tympanuchus phasianellus*, in the Interlake Region of Manitoba. Canadian Field-Naturalist 106: 185–191.

Berger, M. T., R. P. Whitney, R. A. Gerlinger, and D. J. Antoine. 2005. Colville Confederated tribes Columbian Sharp-tailed Grouse Management Plan (Draft). Colville Confederated Tribes, Fish and Wildlife Department, Nespelem, Washington. 37 pp.

Bergerud, A. T. 1988a. Mating systems in grouse. Pages 439–472 *in* A. T. Bergerud and M. W. Gratson, editors. Adaptive strategies and population ecology of northern grouse. University Minnesota Press, Minneapolis.

Bergerud, A. T. 1988b. Population ecology of North American grouse. Pages 578–685 *in* A. T. Bergerud and M. W. Gratson, editors. Adaptive strategies and population ecology of northern grouse. University Minnesota Press., Minneapolis.

Bergerud, A. T. 1988c. Increasing the Numbers of Grouse.

Pages 686–731 *in* A. T. Bergerud and M. W. Gratson, editors. Adaptive strategies and population ecology of northern grouse. University Minnesota Press., Minneapolis.

Bergerud, A. T., and M. W. Gratson. 1988. Survival and breeding strategies of grouse. Pages 473–577 *in* A. T. Bergerud and M. W. Gratson, editors. Adaptive strategies and population ecology of northern grouse. University Minnesota Press, Minneapolis.

Bernhoft, L. S. 1969. Reproductive ecology of female sharp-tailed grouse (*Pedioecetes phasianellus jamesi* Lincoln) and food habits of broods in southwestern North Dakota. M.S. Thesis, University North Dakota, Grand Forks. 96 pp

Beyer, R. S., and J. S. Moritz 2000. Preventing blackhead disease in turkeys and game birds. Kansas State University, Agricultural Experiment Station and Cooperative Extension Service. EP-69, March 2000. (http://www.oznet.ksu.edu).

Billings, W. D. 1994. Ecological impacts of cheatgrass and resultant fire on ecosystems in the western Great Basin. pp 22–30, *in* S.B. Monsen and S.G. Kitchen, editors. Proceedings of Symposium on Ecology, Management, and Restoration of Intermountain Annual Rangelands, Boise, ID, May 18–22, 1992. USDA Forest Service. INT-GTR-313, Ogden, Utah.

Black, A. E., J. M. Scott, E. Strand, R. G. Wright, P. Morgan, C. Watson. 1999. Biodiversity and Land-use History of the Palouse Bioregion: Pre-European to Present. Chapter 10, *in* T. D. Sisk, editor. Perspectives on the land-use history of North America: a context for understanding our changing environment. U. S. Geological Survey, Biological Resources Report USGS/BRD/BRS 1998-0003 (rev. Sept 1999). 104 pp.

Blaisdell, J. P., R. B. Murry, and E. D. McArthur. 1982. Managing intermountain rangelands-sagebrush-grass ranges. U.S. Dept. Agriculture, Intermountain Forest and Range Experiment Station. General Technical Report GTR INT-134.

Blus, L. J., C. S. Staley, C. J. Henny, G. W. Pendleton, T. H. Craig, E. H. Craig, and D. K. Halford. 1989. Effects of organophosphorus insecticides on sage grouse in southeastern Idaho. Journal of Wildlife Management 53:1139–1146.

Boarman, W. I. 2003. Managing a subsidized predator population: reducing common raven predation on desert tortoises. Environmental Management 32(2): 205–217.

Boddicker, M. L. 1967. Characteristics of parasite infestations in sharp-tailed grouse. Seventh Prairie Grouse Technical Council, 12–14 September, Effingham, Illinois.

Boddicker, M. L., and E. J. Hugghins. 1965. Some parasites of sharp-tailed grouse in South Dakota. Transactions of the Annual Summer Conference, Central Mountains and Plains Section of the Wildlife Society 10:19. (*Not seen, in* Peterson 2004).

Boisvert, J. H. 2002. Ecology of Columbian Sharp-tailed Grouse associated with Conservation Reserve Program and reclaimed surface mine lands in northwestern Colorado. M. S. Thesis, University of Idaho, Moscow. 184 pp.

Boisvert, J. H., R. W. Hoffman, and K. P. Reese. 2005. Home range and seasonal movements of Columbian sharp-tailed grouse associated with Conservation Reserve Program and mine reclamation. Western North American Naturalist 65: 36–44.

Boughton, R.V. 1937. Endoparasitic infestations of grouse, their pathogenicity and correlation with metero-topographical conditions. Minnesota Agriculture Experiment Station, Technical Bulletin No. 121 (*not seen, in Peterson 2004*).

Bousquet, K. R., and J. J. Rotella. 1998. Reproductive success of sharp-tailed grouse in central Montana. Prairie Naturalist 30: 63–70.

Bouzat, J. L., H. H. Cheng, H. A. Lewin, R. L. Westemeier, J. D. Brawn, and K. N. Paige. 1998. Genetic evaluation of a demographic bottleneck in the greater prairie chicken. Conservation Biology 12: 836–843.

Bowker, M. A., J. Belnap, R. Rosentreter, and B. Graham. 2003. Wildfire-resistant biological soil crusts and fire-induced loss of soil stability in Palouse prairies, USA, Applied Soil Ecology 26: 41–52.

Boyd, R. 1999. Introduction. Pages 1–30, *in* R. Boyd, editor. Indians, fire, and the land. Oregon State University Press, Corvallis, OR. 313 pp.

Bradbury, J. W., and R. M. Gibson. 1983. Leks and mate choice. Pages 109–138 *in* P. Bateson, editor. Mate choice. Cambridge University Press, New York. 462 pp.

Braun, C. E., D. R. Stevens, K. M. Giesen, C. P. Mecher. 1991. Elk, white-tailed ptarmigan, and willow relationships: a management dilemma in Rocky Mountain National Park. Transactions North American Wildlife and Natural Resources Conference 56:74–85.

Brennan, L. 1999. Northern Bobwhite (*Colinus virginianus*) *I* The Birds of North America, No. 397. (A. Poole and F. Gill, editors). The Birds of North America, Inc. Philadelphia, Pennsylvania.

Brennan, L. A. and W. P. Kuvlesky Jr. 2005. North American grassland birds: an unfolding conservation crisis? Journal of Wildlife Management 69(1): 1–13.

Brook, B. W., D. W. Tonkyn, J. J. O'Grady, and R. Frankham. 2002. Contribution of inbreeding to extinction risk in threatened species. Conservation Ecology 6(1): 16 [online] URL: http://www.consecol.org/vol6/iss1/art16.

Brown, R. L. 1961. Sharp-tailed grouse population study. Small Game Research Project, Federal Aid in Wildlife Restoration Project W-91-R-3, Montana Fish and Game Department, Helena. 33 pp.

Brown, R. L. 1966. Responses of sharp-tail grouse breeding populations to annual changes in residual grassland cover. Proceedings Annual Conference Western Association State Game and Fish Commissions 46:219–222.

Brown, R. L. 1967a. Female sharp-tailed grouse ecology study. Small Game Research Project, Federal Aid in Wildlife Restoration Project W-91-R-8, Job II-E.1, Montana Fish and Game Department, Helena. 6 pp.

Brown, R. L. 1967b. Sharp-tailed grouse blood parasite study. Small Game Research Project, Federal Aid in Wildlife Restoration Project W-91-R-8, Job II-E.2

Montana Fish and Game Department, Helena. 10 pp.
Brown, R. L. 1968. Effects of land use practices on sharp-tailed grouse. Federal Aid in Wildlife Restoration Project W-91-R-9, job II-F, Montana Fish and Game Department., Helena.
Bumann, G. B., and D. F. Stauffer. 2002. Scavenging of ruffed grouse in the Appalachians: influences and implications. Wildlife Society Bulletin 30: 853–860.
Bunting, S. C., J. L. Kingery, M. A. Hemstrom, M. A. Schroeder, R. A. Gravenmier and W. J. Hann. 2002. Altered Rangeland Ecosystems in the Columbia Basin. USDA FS Pacific Northwest Research Station and USDI BLM. General Tech. Report PNW-GTR-553. 71 pp.
Burger, L. D., L. W. Burger Jr, J. Faaborg. 1994. Effects of fragmentation on predation on artificial nests. Journal of Wildlife Management 58: 249–254.
Buss, I. O. 1984. Comments on an apparent sharp-tailed grouse movement in eastern Montana. Northwest Science 58: 151–152.
Buss, I. O., and E. S. Dziedzic. 1955. Relation of cultivation to the disappearance of the Columbian sharp-tailed grouse in southeastern Washington. Condor 57:185–187.
Byrne, M. W. 2002. Habitat use by female greater sage grouse in relation to fire at Hart Mountain National Antelope Refuge, Oregon. M.S. Thesis, Oregon State University. 57 pp.
Cade, T. J., and J. L. Buckley. 1953. A mass emigration of Sharp-tailed Grouse from the Tanana Valley, Alaska, in 1934. Condor 55:313.
Caldwell, P. J. 1976. Energetic and population considerations of sharp-tailed grouse in the aspen parkland of Canada. Ph. D. Dissertation. Kansas State University, Manhattan, Kansas. 113 pp.
Calladine, J., D. Baines, and P. Warren. 2002. Effects of reduced grazing on population density and breeding success of black grouse in northern England. Journal of Applied Ecology 39: 772–780
Carlton, D.C. 1995. Petition for a rule to list the Columbian Sharp-tailed Grouse *Tympanuchus phasianellus columbianus* as "threatened" or "endangered" in the conterminous United States under the Endangered Species Act, 16 USC. Sec 1531 et seq (1973) as amended. Biodiversity Legal Foundation. Boulder, Colorado. 52 pp.
Cassidy, K.M. 1997. Land cover of Washington State: description and management. Volume 1, *in* K. M. Cassidy, C. E. Grue, M. R. Smith, and K. M. Dvornich, editors. Washington State Gap Analysis—Final Report. Washington Cooperative Fish and Wildlife Research Unit, University of Washington, Seattle. 260 pp.
Chalfoun, A.D., F. R. Thompson III, M. J. Ratnaswamy. 2002. Nest predators and fragmentation: a review and meta-analysis. Conservation Biology 16(2): 306–318.
Chaney, E., W. Elmore, and W.S. Platts. 1993. Livestock grazing on western riparian areas. Northwest Resource Information Center, Inc., Eagle, Idaho. Prepared for U.S. Environmental Protection Agency. 45 pp.
Chesness, R.A., M. M. Nelson, and W. H. Longley, 1968. The effect of predator removal on pheasant reproductivesuccess. Journal of Wildlife Management 32:683–697.
Chodachek, K. 2003. Evaluation of repeated removal of mammalian predators on waterfowl nest success and density. M.S. Thesis. Louisiana state University, Baton Rouge.27 pp.
Christenson, C. D. 1970. Nesting and brooding characteristics of sharp-tailed grouse (*Pediocetes phasianellus jamesi* (Lincoln) in southwestern North Dakota. M.S. Thesis, University of North Dakota, Grand Forks. 53 pp.
Clark, L., J. Hall, R. McLean, M. Dunbar, K. Klenk, R. Bowen, and C. A. Smeraski. 2006. Susceptibility of greater sage-grouse to experimental infection with West Nile virus. Journal of Wildlife Diseases 42(1): 14–22.
Clark, R.G., D.E. Meger, J.B. Ignatiuk. 1995. Removing American crows and duck nesting success. Canadian Journal of Zoology 73(3): 518–522.
Clarke, A. L., B. Saether, and E. Roskaft. 1997. Sex biases in avian dispersal: a reappraisal. Oikos 79: 429–438.
Clary, W. P., N. L. Shaw, J. G. Dudley, V. A. Saab, J. W. Kinney, L. C. Smithman. 1996. Response of a depleted sagebrush steppe riparian system to grazing control and woody plantings. USDA Forest Service, Intermountain Research Station, Research Paper INT-RP-492.
Clifton, A. M., and D. G. Krementz. 2006. Estimating numbers of greater prairie-chickens using mark-resight techniques. Journal Wildlife Management 70:479–484.
Coates, P.S. 2001. Movement, survivorship, and reproductive behavior of Columbian sharp-tailed grouse translocated to Nevada. M.S. thesis, University of Nevada, Reno, NV. 110 pp.
Coates, P. S., J. W. Connelly, and D. J. Delehanty. 2008. Predators of greater sage-grouse nests identified by video monitoring. Journal of Field Ornithology 79: 421–428.
Coates, P. S., and D. J. Delehanty. 2004. The effects of raven removal on sage grouse nest success. Proceedings of the Vertebrate Pest Conference 21:17–20.
Coates, P. S., and D. J. Delehanty. 2006. Effect of date on nest-attempt rate of translocated sharp-tailed grouse *Tympanuchus phasianellus*. Wildlife Biology 12:277_ 283.
Coates, P. S. and D. J. Delehanty 2010. Nest predation of greater sage-grouse in relation to microhabitat factors and predators. Journal of Wildlife Management 74(2): 240–248.
Coates, P. S., J. O. Spencer, and D. J. Delehanty. 2007. Efficacy of CPTH-treated egg baits from removing ravens. Human-Wildlife Conflicts 1(2):224–234.
Coates, P. S., S. J. Stiver, and D. J. Delehanty. 2006. Using sharp-tailed grouse movement patterns to guide release-site selection. Wildlife Society Bulletin 34: 1376–1382.
Cockrum, E. L. 1952. A check-list and bibliography of hybrid birds in North America north of Mexico. Wilson Bulletin 64: 140–159.
Coggins, V. L. 2003. Sharp-tailed Grouse. Pages 183– 184 *in* D. B. Marshall, M. G. Hunter, and A. L. Contreras, editors. Birds of Oregon: a general reference. Oregon State University Press, Corvallis, OR. 768 pp.
Collins, C.P. 2004. Ecology of Columbian Sharp-tailed Grouse breeding in coal mine reclamation and native

upland cover types in northwestern Colorado. M. S.Thesis, University of Idaho, Moscow. 201 pp.

Connelly, J. W. 1989. Book reviews: Adaptive strategies and population ecology of northern grouse. Edited by Arthur T. Bergerud and Michael W. Gratson. University of Minnesota Press, Minneapolis. 1988. Journal of Wildlife Management 53: 857–858.

Connelly, J. W., J. H. Gammonley, and J. M. Peek. 2005. Harvest Management. Pages 658–690 *in* C. Braun, editor. Techniques for wildlife investigations and management. The Wildlife Society, Bethesda, Maryland. 974 pp.

Connelly, J. W., M. W. Gratson, and K. P. Reese. 1998. Sharp-tailed Grouse (*Tympanuchus phasianellus*). The Birds of North America, No. 354. (A. Poole and F. Gill, editors. The Birds of North America, Inc. Philadelphia, Pennsylvania.

Connelly, J. W., S. T. Knick, M. A. Schroeder, and S. J. Stiver. 2004. Conservation Assessment of Greater Sage-grouse and Sagebrush habitats. Western Association of Fish and Wildlife Agencies. Cheyenne, WY. (irregular pagination).

Connelly, J. W., K. P. Reese, R. A. Fischer, and W. L.Wakkinen. 2000a. Response of a sage grouse population to fire in southeastern Idaho. Wildlife Society Bulletin 28:90–96.

Connelly, J. W., K. P. Reese, E. O. Garton, M. L. Commons-Kemner. 2003. Response of greater sage-grouse *Centrocercus urophasianus* populations to different levels of exploitation in Idaho, USA. Wildlife Biology 9: 255–260.

Connelly, J. W., M. A. Schroeder, A. R. Sands, C. E. Braun. 2000b. Guidelines to manage sage grouse populations and their habitats. Wildlife Society Bulletin 28:967–985.

Conover, M. R., and J. S. Borgo. 2009. Do sharp-tailed grouse select loafing sites to avoid visual or olfactory predators? Journal of Wildlife Management 73: 242–247.

Cook, T., and S. Gilmore. 2004. Palouse Subbasin Management Plan. Palouse-Rock Lake Conservation District, St. John, Washington. Irregular pagination.

Cope, M. G., and M. T. Berger. 1992. Tracy Rock Sharp-tailed Grouse and Douglas County Pygmy Rabbit Site Specific Management Plan. Washington. Washington Department Fish and Wildlife, Prepared for Bonneville Power Administration, Division of Fish and Wildlife, Portland, Oregon, Project No. 91-061. 57 pp.

Copelin, F. F. 1963. The lesser praire chicken in Oklahoma. Technical Bulletin No. 6. Oklahoma Wildlife Conservation Department, Oklahoma City. 58 pp.

Cote, I. M., and W. J. Sutherland. 1997. The effectiveness of removing predators to protect bird populations. Conservation Biology 11:395–405.

Cowan, A. B., and T. J. Peterle. 1957. *Leucocytozoon bonazae* Clarke in Michigan Sharp-tailed Grouse. Journal of Wildlife Management. 21:469–471.

Crabtree, R. L., and M. L.Wolfe. 1988. Effects of alternate prey on skunk predation of waterfowl nests. Wildlife Society Bulletin 16: 163–169.

Crawford, J. A., and J. W. Snyder. 1994. Habitat use, movements, and reproduction by translocated Columbian sharp-tailed grouse in eastern Oregon: preliminary report, 1991–1994. Department of Fisheries and Wildlife, Oregon State University, Corvallis. 20 pp.

Crawford, J. A., R. A. Olson, N. E. West, J. C. Mosley, M. A. Schroeder, T. D. Whitson, R. F.. Miller, M. A. Gregg, and C. S. Boyd. 2004. Ecology and management of sage-grouse and sage-grouse habitat. Journal of Range Management 57: 2–19.

Crick, H. Q. P. 2004. The impact of climate change on birds. Ibis 146(Supplement 1): 48–56.

Crooks K. R., and M.E. Soulé. 1999. Mesopredator release and avifaunal extinctions in a fragmented system. Nature 400: 563–566.

Curtin, C. G., 2002. Livestock grazing, rest, and restoration in arid landscapes. Conservation Biology 16:840–842.

Darwin, L. H. 1918. Third and fourth annual reports of the state game warden to the governor of the state of Washington, 3/1/15–2/28/17, Lamborn. Olympia, Washington.

Daubenmire, R. F. 1942. An ecological study of the vegetation of southeastern Washington and adjacent Idaho. Ecological Monographs 12: 53–79.

Daubenmire, R. F 1970. Steppe vegetation of Washington. Washington Agricultural Experiment Station, Technical Bulletin 62, Washington State University, Pullman. 131 pp.

Davidson, W.R., and G.L. Doster. (no date). Blackhead disease does not really cause black heads. National Wild Turkey Federation. Wildlife Bulletin No. 25. 4 pp.

Davison, W. B., and E. Bollinger. 2000. Predation rates on real and artificial nests of grassland birds. Auk 117: 147–153.

Dawson, W. L., and J. H. Bowles. 1909. Birds of Washington. Vol. 2. Occidental Publishing Co., Seattle, Washington. 997 pp.

Dawson, W. R., J. D. Ligon, J. R. Murphy, J. P. Myers, D. Simberloff, and J. Verner. 1987. Report of the scientific advisory panel on the spotted owl. Condor 89:205–229.

Deeble, B. D. 1996. Conservation of Columbian sharp–tailed grouse, with special emphasis on the upper Blackfoot Valley, Montana. M.S. Thesis, University of Montana, Missoula.

Dekker, D. 1983. Denning and foraging habits of red foxes, *Vulpes vulpes*, and their interactions with coyotes, Canis latrans, in Central Albert, 1972-1981. Canadian Field-Naturalist 97(3): 303-306.

DeMaso, S. J., A. D. Peoples, S. A. Cox, and E. S. Parry. 1997. Survival of northern bobwhite chicks in western Oklahoma. Journal of Wildlife Management 61: 846-853.

Dice, L. R. 1916. Distribution of the land vertebrates of southeastern Washington. University of California Publications in Zoology 16(17): 293–348.

Dice, L. R. 1918. The birds of Walla Walla and Columbia counties, southeastern Washington. Auk 35: 40–51.

Dick, T. A. 1981. Ectoparasites of sharp-tailed grouse, *Pediocetes phasianellus*. Journal of Wildlife Diseases 17:229–235.

Dickerman, R. W., and J. P. Hubbard. 1994. An extinct subspecies of Sharp-tailed grouse from New Mexico. Western Birds 25:128–136.

Dion, N., Hobson, K. A., Larvie`re, S., 1999. Effects of removing duck-nest predators on nesting success of grassland songbirds. Canadian Journal of Zoology 77, 1801–1806.

Dobson, A. P., E. R. Carper, and P. J. Hudson. 1988. Population biology and life-history variation of gamebirds. Pages 73–97, in P. J. Hudson and M. R. W. Rands, editors. Ecology and Management of Gamebirds. BSP Professional Books, Oxford, UK. 263 pp.

Donahue, D. L. 1999. The Western Range Revisited. University of Oklahoma Press, Norman, OK. 388 pp.

Douglas, D. 1914. Journal kept by David Douglas during his travels in North America, 1823–1827. Willam Wesley & Son, for the Royal Horticultural Society, London. 364 pp.

Downen, L. 1977. Covered Wagon Days in the Palouse Country. Ye Galleon Press, Fairfield, Washington (reprint of articles originally published in Pullman Herald). 32 pp.

Drovetski, S. V., S. Rowher, N. A. Mode. 2006. Role of sexual and natural selection in evolution of body size and shape: a phylogenetic study of morphological radiation in grouse. Journal of Evolutionary Biology 19: 1083–1091.

Drouin, T. E. and J. L. Mahrt. 1979. The prevalence of *Sarcocystis* Lankester, 1882, in some bird species in western Canada, with notes on its life cycle. Canadian Journal of Zoology 57:1915–1921.

Dunn, E. 1982. How mice affect weasel predation on titmice Mammal Review 12: 154 (*not seen, in* Reynolds and Tapper 1996).

Dunn, P. O., and C. E. Braun. 1985. Natal dispersal and lek fidelity of Sage Grouse. Auk 102:621–627.

Dziedzic, E. S. 1951. Land-use and wildlife on farms in southeastern Washington. M. S. Thesis, State College of Washington, Pullman. 76 pp.

Edminster, F. C. 1954. American Game Birds. Charles Scribner's Sons, New York, New York.

Elison, G. W. 1980. Food habits study of Rock Ptarmigan (*Lagopus mutus*) on Amchitka Island, Alaska. M. S. Thesis. Washington State University.

Ellsworth, D. L., R. L. Honeycutt, N. J. Silvy, K. D. Rittenhouse, and M. H. Smith. 1994. Mitochondrial-DNA and nuclear-gene differentiation in North American prairie grouse (Genus *Tympanuchus*). Auk. 111:661–671.

Ellsworth, D. L., R. L. Honeycutt, and N. J. Silvy. 1995. Phylogenetic relationships among North American grouse inferred from restriction endonuclease analysis of mitochondrial DNA. Condor 97:492–502.

Emerson, K. C. 1951. A list of Mallophaga from gallinaceous birds of North America. Journal of Wildlife Management 15:193–195.

Eng, R. L. 1971. Two hybrid sage grouse x sharp-tailed grouse from central Montana. Condor 73:491–493.

Erickson, W., G. Johnson, D. Young, D. Strickland, R. Good, M. Bourassa, K. Bay, K. Sernka. 2002. Synthesis and Comparison of Baseline Avian and Bat Use, Raptor Nesting, and Mortality Information from Proposed and Existing Wind Developments. Prepared for Bonnevile Power Administration, by West Inc., Cheyenne, WY. 124 pp.

Errington, P. L. 1956. Factors limiting higher vertebrate populations. Science 124:304–307.

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

Evans, K. E. and D. R. Dietz. 1974. Nutritional energetics of sharp-tailed grouse during winter. Journal of Wildlife Management 38: 622– 629.

Evans, K. E. and A. N. Moen. 1975. Thermal exchange between sharp-tailed grouse (*Pediocetes phasianellus*) and their winter environment. Condor 77: 160–168.

Evans, R. M. 1969. Territory stability in sharp-tailed grouse. Wilson Bulletin 81: 75–78.

Evrard, J. O., J. E. Hoefler, and P. A. Kooiker. 2000. The history of sharp-tailed grouse in the Crex Meadows Wildlife Area. Passenger Pigeon 62: 175–183.

Faircloth, B. C., W. E. Palmer, and J. P. Carroll. 2005. Post-hatching brood amalgamation in northern bobwhites. Journal of Field Ornithology 76: 175–182.

Farrar, I. 1975. Prairie grouse (sharp-tailed grouse) Nebraska natives: their past, present and future. Nebraska Game and Parks Commission, Lincoln.

Fields, T. L., G. C. White, W. C. Gilgert, R. D. Rodgers. 2006. Nest and brood survival of Lesser Prairie-chickens in west central Kansas. Journal of Wildlife Management 70: 931–938.

Fielding, D. J., and M. A. Brusven. 1995. Grasshopper densities on grazed and ungrazed rangeland under drought conditions in southern Idaho. Great Basin Naturalist 55:352–358.

Fischer, R. A., K. P. Reese, and J. W. Connelly 1996. An investigation on fire effects within xeric Sage Grouse habitat. Journal of Range Management 49:194–198.

Fisher, I. J., D. J. Pain, and V. G. Thomas. 2006. A review of lead poisoning from ammunition sources in terrestrial birds. Biological Conservation 131: 421–432.

Flakas, K. G. 1952. Wildlife pathology study. Wisconsin Wildlife Research 10:69–80.

Flanders-Wanner, B. L., G.C. White, L. L. McDaniel. 2004. Weather and prairie grouse: dealing with effects beyond our control. Wildlife Society Bulletin 32: 22–34.

Fleischner, T. L. 1994. Ecological costs of livestock grazing in western North America. Conservation Biology 8: 629– 644.

Foose, T. J., L. de Boer, U. S. Seal, and R. Lande. 1995. Conservation management strategies based on viable populations. Pp 273–294, in, J. D. Ballou, M. Gilpin, and T. J. Foose, editors. Population Management for Survival and Recovery: Analystical methods and strategies in small population conservation. Columbia University Press, New York, NY. 375 pp.

Frankel, O. H. 1983. The place of management in conservation. Pages 1–14 *in* C. M. Schonewald-Cox, S. M. Chambers, B. MacBryde, and L. Thomas, editors. Genetics and conservation. Benjamin/Cummings

Publishing, Menlo Park, California

Frankel, O. H., and M. E. Soulé. 1981. Conservation and evolution. Cambridge Univ. Press, Cambridge, Mass. 327 pp.

Frankham, R. 1995. Effective population size/adult population size ratios in wildlife: a review. Genetical Research 66:95–107.

Frankham, R., J. D. Ballou, and D. A. Briscoe. 2002. Introduction to Conservation Genetics. Cambridge University Press, Cambridge, U.K. 617 pp.

Franklin, J. F., and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. U.S.D.A. Forest Service General Techical Report, PNW-8. 417 pp.

Freilich, J. E., J. M. Emlen, J. J. Duda, D. C. Freeman, and P. J. Cafaro. 2003. Ecological effects of ranching: a six-point critique. BioScience 53(8): 759–765.

French, D. 1999. Aboriginal control of huckleberry yield in the Northwest. Pages 31–35 *in* R. Boyd, editor. Indians, fire, and the land. Oregon State University Press, Corvallis. 313 pp.

Frey, S. N., and M. R. Conover 2007. Influence of population reduction on predator home range size and spatial overlap. Journal of Wildlife Management 71(2):303–309.

Frey, S.N., S. Majors, M. R. Conover, T. A. Messmer, D. L. Mitchell 2003. Effect of predator control on ring-necked pheasant populations. Wildlife Society Bulletin 31(3):727–735.

FSA (Farm Service Agency) 2007. Conservation Reserve Program: summary and enrollment statistics, FY2007. Farm Service Agency, U.S. Department of Agriculture, Washingotn, D. C. available at the FSA website at http://www.fsa.usda.gov/.

Furtman, M. 2005. Sharp-tailed grouse on the edge. Grouse Partnership News 6(1) 12–14.

Garner, A., J. L. Rachlow, and J. E. Hicks. 2005. Patterns of genetic diversity and its loss in mammalian populations. Conservation Biology 19: 1215–1221.

Garrettson, P. R., and F. C. Rohwer. 2001. Effects of mammalian predator removal on production of upland-nesting ducks in North Dakota. Journal of Wildlife Management 65:398–405.

Gerlinger, R. 2005. Sharp-tailed Grouse restoration; Colville Tribes restore habitat for sharp-tailed grouse, 2003–2004 Annual report, project No. 200103000, (BPA Report DOE/BP-00006927-2). Bonneville Power Administration, Portland, OR. 17 pp.

Gibson, G. G. 1967. *Spledidoflilaria pectoralis* n.sp. (Filarioidea: Onchocercidae) from tetraonid birds in northwestern North America. Canadian Journal of Zoology 45: 1135–1147.

Giesen, K. M. 1987. Population characteristics and habitat use by Columbian sharp-tailed grouse in northwest Colorado. Final Report, Federal Aid in Wildlife Restoration Project W-152-R, Colorado Division Wildlife, Denver.

Giesen, K. M.. 1992. Body mass of Columbian sharp-tailed grouse in Colorado. Prairie Naturalist 24:191–196.

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

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

Giesen, K. M., and J. W. Connelly. 1993. Guidelines for management of Columbian sharp-tailed grouse habitats. Wildlife Society Bulletin 21:325–333.

Gilpin, M. E., and M.E. Soule. 1986. Minimum viable populations: processes of species extinction. Pages 19 – 34 *in* M. E. Soule, editor. Conservation biology: the science of scarcity and diversity. Sinauer, Sunderland, Massachusetts.

Goddard, A. D., and R. D. Dawson. 2009. Factors influencing the survival of neonate sharp-tailed grouse *Tympanuchus phasianellus*. Wildlife Biology 15: 60–67.

Gosselink, T.E., T. R. Van Deelen, R. E. Warner, and M. G. Joselyn. 2003. Temporal habitat partitioning and spatial use of coyotes and red foxes in east-central Illinois. Journal of Wildlife Management 67(1): 90–103.

Gratson, M. W. 1988. Spatial patterns, movements, and cover selection by sharp-tailed grouse. Pages 158–192 *in* A. T. Bergerud and M. W. Gratson, editors. Adaptive strategies and population ecology of northern grouse, Volume 1. University Minnesota Press, Minneapolis.

Gratson, M. W. 1989. Intraspecific nest parasitism by Sharp-tailed Grouse. Wilson Bulletin 101:126–127.

Gratson, M. W. 1993. Sexual selection for increased male courtship and acoustic signals and against large male size at sharp-tailed grouse leks. Evolution 47: 691–696.

Gratson, M. W., G. K. Gratson, and A. T. Bergerud. 1991. Male dominance and copulation disruption do not explain variance in male mating success on Sharp- tailed Grouse (*Tympanuchus phasianellus*) leks. Behaviour 118:187–213.

Gray, R. L., and B. M Teels. 2006. Wildlife and fish conservation through the Farm Bill. Wildlife Society Bulletin 34: 906–913.

Green, R. G., and J. E. Shillinger. 1932. A natural infection of the sharp-tailed grouse and the ruffed grouse by *Pasteurella tularensis*. Proceedings of the Society for Experimental Biology and Medicine 30:284–287.

Greenwood, R. J., D. G. Pietruszewski, and R. D. Crawford. 1998. Effects of food supplementation on depredation of duck nests in upland habitat. Wildlife Society Bulletin 26(2): 219–226.

Greenwood, R. J., A. B. Sargeant, D. H. Johnson, L. M. Cowardin, and T. L. Shaffer. 1995. Factors associated with duck nest success in the prairie pothole region of Canada. Wildlife Monographs 128: 1–57.

Greenwood, R. J., and M. A. Sovada. 1996. Prairie duck populations and predation management. Transactions of the North American Wildlife and Natural Resources Conference 61:31–42.

Gregg, M. A., and J. A. Crawford. 2009. Survival of greater sage-grouse chicks and broods in the northern Great Basin. Journal of Wildlife Management 73(6): 904–913.

Griffith, B., J. M. Scott, J. W. Carpenter, and C. Reed. 1989. Translocation as a species conservation tool: status and strategy. Science 245:477–480.

Grinnell, J., H. C. Bryant, and T. I. Storer. 1918. The Game Birds of California. University of California Press, Berkeley. (*not seen, in* Starkey and Schnoes 1979).

Gross. A. O. 1930. Progress report of the Wisconsin prairie chicken investigation. Wisconsin Conservation Commission, Madison. 112 pp.

Grumbine, R. E. 1990. Viable populations, reserve size, and federal lands management: a critique. Conservation Biology 4: 127–134.

Habeck, R. J. 1991. Crataegus douglasii. In: Fire Effects Information System, [Online].U.S. Department of Agriculture, Forest Service,Rocky Mountain Research Station, Fire Sciences Laboratory Available: http://www.fs.fed.us/ database/feis/ [24 March 2008].

Hagen, C. A., B. E. Jamison, R. J. Robel, and R. D. Applegate. 2002. Ring-necked pheasant parasitism of Lesser Prairie-chickens in Kansas. Wilson Bulletin 114: 522–524.

Hagen, C. A., B. E. Jamison, K. M. Giesen, and T. Z. Riley. 2004. Guidelines for managing Lesser Prairie-Chicken populations and their habitats. Wildlife Society Bulletin 32:69–82.

Hagen, C. A., J. C. Pitman, B. K. Sandercock, R. J. Robel, and R. D. Applegate. 2005a. Age-specific variation in apparent survival rates of male Lesser Prairie-chickens. Condor 107: 78–86.

Hagen, C. A., J. C. Pitman, R. J. Robel, T. M. Louhgin, and R. D. Applegate. 2007a. Niche partitioning by lesser prairie-chicken *Tympanuchus pallidicintus* and ring-necked pheasant *Phasianus colchicus* in southwestern Kansas. Wildlife Biology 13 (supplement 1): 34–41.

Hagen, C. A., J. C. Pitman, B. K. Sandercock, R. J. Robel, and R. D. Applegate. 2007b. Age-specific survival and probable causes of mortality in female Lesser Prairie-chickens. Journal Wildlife Management 71: 518–525.

Hagen, C. A., G. C. Salter, J. S. Pitman, R. J. Robel, and R. D. Applegate. 2005b. Lesser prairie-chicken brood habitat in sand sagebrush: invertebrate biomass and vegetation. Wildlife Society Bulletin 33(3):1080–1091.

Haines, F. 1938. The northward spread of horses among the Plains Indians. American Anthropology 40: 429–437 (*not see, in* Hessberg and Agee 2003).

Hallet, M. 2000–2007. Wells Wildlife Mitigation Program. Annual Reports. Washington Department of Fish and Wildlife, prepared for Douglas County Public Utility District.

Hallet, M. 2006. Wells Wildlife Area management plan. Washington Department of Fish and Wildlife, Olympia. 72 pp.

Hamerstrom, F. 1982. Death of a Firebird. Defenders 57(3):37–39 (reprinted in Grouse Partnership News 6(2005, no.1):37–38.)

Hamerstrom, F. N., O. E. Mattson, and F. Hamerstrom. 1957. A guide to prairie chicken management. Wisconsin Conservation Department Technical Wildlife Bulletin 15. 128 pp.

Hamerstrom, F. N. Jr., and F. Hamerstrom. 1951. Mobility of the sharp-tailed grouse in relation to its ecology and distribution. American Midland Naturalist 46:174–226.

Harding, E. K., D. F. Doak, and J. D. Albertson. 2001. Evaluating the effectiveness of predator control: the non-native red fox as a case study. Conservation Biology 15(4): 1114–1122.

Harris, G. A., and M. Chaney. 1984. Washington State grazing land assessment. Washington Range Land Commission and Washington State University Cooperative Extension Service, Pullman.

Hart, C. M., O. S. Lee, and J. B. Low. 1950. The sharp-tailed grouse in Utah. Publication 3, Utah Department Fish and Game, Salt Lake City. 79 pp..

Hartzler, J. E. 1974. Predation and the daily timing of sage grouse leks. Auk 91:532–536.

Hays, D. W., M. J. Tirhi, and D. W. Stinson. 1998. Washington state status report for the sharp-tailed grouseed grouse. Washington Department of Fish and Wildlife, Olympia. 57 pp.

Henderson, F.R., F.W. Brooks, R.E. Wood, and R.B. Dahlgren. 1967. Sexing of prairie grouse by crown feather patterns. Journal of Wildlife Management 31:764–769.

Henke, S. E., and F. C. Bryant. 1999. Effects of coyote removal on the faunal community in western Texas. Journal of Wildlife Management 63(4):1066–1081.

Hergen , N. 1990 (year uncertain). Gateway to the Palouse: a story about the Spangles and other settlers on a new frontier. Palouse Press, Spangle, Washington.

Herkert, J. R., et al. 2003. Effects of prairie fragmentation on the nest success of breeding birds in the midcontinental United States. Conservation Biology 17:587–594.

Hessburg, P. F., and J. K. Agee. 2003. An environmental narrative of Inland Northwest United States forest, 1800–2000. Forest Ecology and Management 178: 23–59.

Hickman, J. 1989. Columbian sharp-tailed grouse lek biology in Lincoln County, Washington. Proceedings 16th Western Sage and Sharp-tailed Grouse Workshop, Moses Lake, Washington.

Hillman, C. N., and W. W. Jackson. 1973. The sharp-tailed grouse in South Dakota. Technical Bulletin 3, South Dakota Department Game, Fish and Parks, Pierre, South Dakota

Hjorth, I. 1970. Reproductive behavior in Tetraonidae, with special reference to males. Viltrevy 7:185–596.

Hoffman, R. W. (technical editor) 2001. Northwest Colorado Columbian Sharp-tailed Grouse Conservation Plan. Northwest Colorado Columbian Sharp-tailed Grouse Work Group and Colorado Division of Wildlife, Fort Collins, Colorado. 79 pp.

Hoffman, R. W., W. D. Snyder, G. C. Miller, and C. E. Braun. 1992. Reintroduction of Greater Prairie-Chickens in northeastern Colorado. Prairie Nat. 24:197–204.

Hoffman, R. W., and A. E. Thomas. 2007. Columbian Sharp-tailed Grouse (*Tympanuchus phasianellus columbianus*): A Technical Conservation Assessment. Species Conservation Project.USDA Forest Service, Rocky Mountain Region, 131 pp. [online]: http://www.fs.fed.us/r2/projects/scp/assessments/columbiansharptailedgrouse.pdf [accessed 2 November 2007].

Hofmann, L., and F. Dobler. 1988a. Observations of wintering densities and habitat use by Columbian sharp-tailed grouse in three counties of eastern Washington. Unpublished report, Washington Department Wildlife, Olympia.

Hofmann, L., and F. Dobler 1988b. Spring movements, home range size, and habitat use by Columbian sharp-tailed grouse in eastern Washington. Unpublished report, Washington Department of Wildlife, Olympia.

Hofmann, L., and F. Dobler 1989. A history and inventory of sharp-tailed grouse (*Tympanuchus phasianellus columbianus*) dancing grounds in eastern Washington. Unpublished report, Washington Department of Wildlife, Olympia.

Höglund, J., S. B. Piertney, R. V. Alatalo, J. Lindell, A. Lundberg, and P. T. Rintamäki. 2002. Inbreeding depression and male fitness in black grouse. Proceedings of Royal Society, Biological Science 269: 711–715.

Howard, J. L. 1997. Amelanchia alnifolia. In: Fire Effects Information System, [Online].U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Available: http://www. fs.fed. us /database/feis/ [24 March 2008].

Howerton, J., J. Creveling, and B. Renfrow. 1986. Wildlife protection, mitigation and enhancement planning for Grand Coulee Dam. Final Report. Washington Department of Game, Olympia, Washington. Project No. 86–74. Prepared for Bonneville Power Administration, U. S. Department of Energy.

Hudson, P. J., A. P. Dobson, and D. Newborn. 1998. Prevention of population cycles by parasite removal. Science 282: 2256–2258.

Hudson, G. E., R. A. Parker, J. V. Berge, and P. J. Lanzillotti. 1966. A numerical analysis of the modifications of the appendicular muscles in various genera of gallinaceous birds. American Midland Naturalist 76:1–73.

Hudson, G. E., and C. F. Yocom. 1954. A distributional list of the birds of southeastern Washington. State College Washington Research Studies. 22:17.

Hunn, E. S., and J. Selam. 1990. Nch'I-Wana, "The Big River": Mid-Columbia Indians and their land. University of Washington Press, Seattle. 378 pp.

Hurst, G.A. 1972. Insects and bobwhite quail brood management. Pages 65–82 *in* J. A. Morrison and L. C. Lewis, editors. Proceedings of the First National Bobwhite Quail Symposium. Oklahoma State University, Stillwater, Oklahoma (*not seen, in* Fields et al. 2006).

Inkley, D. B., M.G. Anderson, A. R. Blaustein, V. R. Burkett, B. Felzer, B. Griffith, J. Price, and T. L. Root. 2004. Global climate change and wildlife in North America. Wildlife Society Technical Review 04-2. The Wildlife Society, Bethesda, Maryland, USA. 26 pp.

Jamison, B. S. 2000. Lesser prairie chicken chick survival, adult survival, and habitat selection and movements of males in fragmented rangelands of southwestrn Kansas. M. S. Thesis. Kansas State University, Manhatten, Kansas.

Janson, R. G. 1950. Prairie grouse banding returns, 1947 to 1950. Federal Aid in Wildlife Restoration Project W-17-R-5, South Dakota Department Game, Fish and Parks, Pierre, SD.

Jennings, M. D., B. C. Miller, D. F. Bezdicek, and D. Granastein. 1990. Sustainability of dryland cropping in the Palouse: an historical view. Journal of Soil and Water Conservation 451:75–80.

Jewett, S. G., W. P. Taylor, W. T. Shaw, and J. W. Aldrich. 1953. Birds of Washington State. University of Washington Press, Seattle. 768 pp.

Jimenez, J. E., and M. R. Conover. 2001. Ecological approaches to reduce predation on ground-nesting gamebirds and their nest. Wildlife Society Bulletin 29(1): 62–69.

Jobanek, G. A., and D. B. Marshall. 1992. John K. Townsend's 1836 report of the birds of the lower Columbia River region, Oregon and Washington. Northwestern Naturalist 73:1–14.

Johnsgard, P. A. 1973. Grouse and quails of North America. University of Nebraska Press, Lincoln, NE. 553 pp.

Johnsgard, P. A. 1983. Grouse of the world. University of Nebraska Press, Lincoln, NE.413 pp.

Johnsgard, P. A. 2002. Grassland grouse and their conservation. Smithsonian Institution Press, Washington, D. C. 157 pp.

Johnson, G., and M. Halloran. 2010. Greater sage-grouse & wind energy devlopment: a review of the issues. West, Inc. and Wyoming Willdife Consultants, Pinedale, WY, for Renewable Northwest Project. 78 pp.

Johnson, J. A., J. E. Toepfer, and P. O. Dunn. 2003. Contrasting patterns of mitochondrial and microsatellite population structure in fragmented populations of greater prairie-chickens. Molecular Ecology 12: 3335–3347.

Jones, A. 2000. Effects of cattle grazing on North American arid ecosystems: a quantitative review. Western North American Naturalist 60:155–164.

Jones, R. E. 1966. Spring, summer, and fall foods of the Columbian sharp-tailed grouse in eastern Washington. Condor 68:536–540.

Jones, R. E. and K. E. Hungerford. 1972. Evaluation o fnesting cover as protection from magpie predation. Journal of Wildlife Management 36(3): 727–732.

Kaiser, V.G., 1961. Historical land use and erosion in the Palouse—a reappraisal. Northwest Science 35:139–153.

Kamler, J. F., W. B. Ballard. 2002. A review of native and nonnative red foxes in North America. Wildlife Society Bulletin 30: 370–379.

Kauffman, J. B. and W. C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications…a review. Journal of Range Management 37(5): 430–438.

Kauhala, K. 2004.Removal of medium-sized predators and the breeding success of ducks in Finland Folia Zool. 53(4): 367–378.

Kauhala, K., P. Helle, and E. Helle. 2000: Predator control and the density and reproductive success of grouse populations in Finland. Ecography 23: 161–168.

Kennedy, C. H. 1914. The effects of irrigation on bird life in the Yakima Valley, Washington. Condor 16: 250–255.

Kellogg, V. L. 1899. List of the biting lice (Mallophaga) taken from birds and mammals of North America. Proceedings of the United States National Museum 22(1183): 39–100.

Keppie, D. M. 1977. Inter-brood movements of juvenile Spruce Grouse. Wilson Bulletin 89:67–72.

Kermott, L. H. 1982. Breeding behavior in the sharp-tailed grouse. Ph.D. Dissertation, University of Minnesota, Minneapolis. 134 pp.

Kermott, L. H., and L. W. Oring. 1975. Acoustical communication of male sharp-tailed grouse (*Pediocetes phasianellus*) on a North Dakota dancing ground. Animal Behaviour 23: 375–386.

Kessler, W. B., and R. P. Bosch. 1982. Sharp-tailed grouse and range management practices in western rangelands. Pages 133–146 *in* J. M. Peek and P. D. Dalke, editors. Proceedings Wildlife-livestock Relationships Symposium, Coeur d'Alene, Idaho, 20–22 April., Forest, Wildlife and Range Experiment. Station, Proceedings 10, University of Idaho, Moscow, ID. 614 pp.

Keyser, T. L., F. W. Smith, and W. D. Shepperd. 2005. Trembling aspen response to a mixed-severity wildfire in the Black Hills, South Dakota, USA. Canadian Journal Forest Research 35: 2679–2684.

Kincaid, G. D., and A. H. Harris 1979. Palouse--in the making. (reprint of serial originally published in the Palouse Republic in 1934) Rosalia Citizen-Journal, Rosalia, Washington. 56 pp.

Kilpatrick, A. M., S. L. LaDeau, and P. P. Marra. 2007. Ecology of West Nile virus transmission and its impact on birds in the western hemisphere. Auk 124(4):1121–1136.

Kirby, D. R., and K. L. Grosz. 1995. Cattle grazing and sharp-tailed grouse nest success. Rangelands 17(4): 124–126.

Kirsch, L. M. 1969. Prairie grouse and land-use. Proceedings 8th Conference Prairie Grouse Technical Council, 9–11 September, Woodward, Oklahoma.

Kirsch, L. M., A. T. Klett, and H. W. Miller. 1973. Land use and prairie grouse population relationships in North Dakota. Journal of Wildlife Management 37:449–453.

Klott, J. H. 1987. Use of habitat by sympatrically occurring sage grouse and sharp-tailed grouse with broods. M. S. Thesis, University of Wyoming, Laramie.

Klott, J. H., and F. G. Lindzey. 1990. Brood habitats of sympatric sage grouse and Columbian sharp-tailed grouse in Wyoming. Journal of Wildlife Management 54:84–88.

Knight, R. L. 2002. The Ecology of Ranching. Pages 123–144, *in* R. L. Knight, W. C. Gilgert, and E. Marston. editors. Ranching west of the 100th meridian: culture, ecology, and economics. Island Press. Washington, D.C. 259 pp.

Knutson, K. L., and V. L. Naef. 1997. Management recommendations for Washington's Priority Habitats: riparian. Washington Department of Fish and Wildlife, Olympia. 181 pp.

Kobriger, G. D. 1980. Habitat use and brooding Sharp-tailed Grouse in southwestern North Dakota. North Dakota Outdoors 43(1):2–5.

Kobriger, G. D. 1981. Prairie grouse population data. North Dakota State Game and Fish Department. Report B-318, Project W-67-R-21, Jobs B-V-1-5. 30 pp.

Kohn, S. C. 1976. Sharp-tailed grouse nesting and brooding habitat in southwestern North Dakota. M. S. Thesis, South Dakota State University, Brookings, SD. 41 pp + appendices.

Kuykendall, E.V. 1984. History of Garfield County. Reprint of a serial published in the East Washingtonian, 1948–49. Ye Galleon Press, Fairfield, Washington. 183 pp.

KWA Ecological Sciences, Inc. 2004. Appendix C. Telford/Swanson Lakes Wildlife Area Assessment and Inventory (Draft). Crab Creek Subbasin Plan. Prepared for Washington Department Fish and Wildlife and Lincoln County Conservation District, 50 pp.

Lacy, R. C. 1987. Loss of genetic diversity from managed populations: interacting effects of drift, mutation, immigration, selection, and population subdivision. Conservation Biology 2:143–158.

Lande R., and G. F. Barrowclough. 1987. Effective population size, genetic variation, and their use in population management. Pages 87–123, *in* M.E. Soule, editor. Viable populations for conservation. Cambridge University Press, Cambridge, UK. 189 pp.

Landel, H. 1989. A study of female and male mating behavior and female mate choice in the sharp-tailed grouse, *Tympanuchus phasianellus jamesi*. Ph.D. Dissertation. Purdue University, West Lafayette, Indiana. (*Not seen, in* Connelly et al. 1998)

Lariviere, S. 1999. Reasons why predators cannot be inferred from nest remains. Condor 101: 718–721.

Larrison, E.J. 1942. Strange behavior of a sharp-tailed grouse. Murrelet 23(3): 79

Larrison, E. J., and K. G. Sonnenberg. 1968. Washington birds: their location and identification. The Seattle Audubon Society, Seattle, Washington. 258 pp.

Lavergne, S., and J. Molofsky. 2006. Control strategies for the invasive reed canarygrass (*Phalaris arundinacea* L.) in North American wetlands: the need for an integrated management plan. Natural Areas Journal 26: 208–214.

Lawrence, J. S. 1982. Effect of predator reduction on the reproductive success of Attwater's Prairie-Chicken. M.S. Thesis. Texas A & M University, College Station, Texas.

Laycock, W. A. 1967. How heavy grazing and protection affect sagebrush-grass ranges. Journal of Range Management 20:206–213.

Leddy, K. L., K. F. Higgins, and D. E. Naugle. 1999. Effects of wind turbines on upland nesting birds in conservation reserve program grasslands. Wilson Bulletin 111:100–104.

Lehman, C. P., M. A. Rumble, L. D. Flake, and D. J. Thompson. 2008. Merriam's turkey nest survival and factors affecting nest predation by mammals. Journal of Wildlife Management 72: 1765–1774.

Leiberg, J. 1896. Letter to Professor Charles V. Piper dated 5 July. On file *in* Manuscripts, archives, and special collections of the Washington State University Library. Pullman, WA (*not seen, in* Weddell 2001a).

Leiberg, J. 1897. General report on a botanical survey of the Coeur d'Alene Mountains in Idaho during the summer of 1895. Contributions from the U.S. Herbarium 5, No. 1.

Leupin, E. E. 2003. Status of the Sharp-tailed Grouse (*Tympanuchus phasianellus*) in British Columbia.

Wildlife Bulletin No. B-104. B. C. Ministry of Water, Land and Air Protection. Biodiversity Branch, Victoria, British Columbia. 25 pp.

Lewis, J. C., K. L. Sallee, and R. T. Golightly Jr. 1999. Introduction and range expansion of nonnative red foxes (*Vulpes vulpes*) in California. American Midland Naturalist 142(2): 372–381.

Lichthardt, J., R. K. Moseley. 1997. Status and Conservation of the Palouse Grassland in Idaho. Idaho Department of Fish and Game, Boise, Idaho. 30 pp+ appendices.

Lindstrom, J. 1994. Tetraonid population studies – state of the art. Annales Zoologica Fennici. 31:347–364.

Littlefield, C. D. 2003. Sandhill crane nesting success and productivity in relation to predator removal in southeastern Oregon. Wilson Bulletin 115:263–269.

Locke, N. L., and M. Friend. 1992. Lead poisoning of avian species other than waterfowl. Pages 19–22 *in* D. J. Pain, editor. Lead poisoning in waterfowl. International Waterfowl and Wetlands Research Bureau, Gloucester, UK

Lyman, R.L. 1991. The Holocene history of the red fox (*Vulpes vulpes*) in eastern Washington. Northwest Science 65(1): 22–26.

Lord, J. K. 1866. The Naturalist in Vancouver Island and British Columbia. Vol. 1. Richard Bently, London, UK

Lumsden, H. G. 1965. Displays of the Sharp-tailed grouse Grouse. Ontario Department of Lands and Forests, Technical Series research Report No. 66. 68 pp.

Lund, E. E., and A. M. Chute. 1972. The ring-necked Pheasant (*Phasianus colchicus torquatus*) as a host for Heterakis gallinarum and Hostomonas meleagridis. American Midland Naturalist 87: 1–7.

Lundelius, E. L, R. W. Graham, E. Anderson, J. Guilday, J. A. Holman, D. W. Steadman, and S. D. Webb. 1983. Terrestrial vertebrate faunas. Pages 311–353 *in* H. E. Wright Jr, and S. C. Porter, editors. Late-Quaternary environments of the United States. University of Minnesota Press, Minneapolis, Minnesota. (*not seen, in* Spaulding et al. 2006).

Lynch, M., and R. Lande. 1998. The critical effective size for a genetically secure population. Animal Conservation 1: 70–72.

Mack, R. N., and J. N. Thompson. 1982. Evolution in steppe with few large, hooved mammals. American Naturalist. 119:757–773.

Manville, A. M., II. 2004. Prairie grouse leks and wind turbines: U.S. Fish and Wildlife Service justification for a 5-mile buffer from leks: additional grassland songbird recommendations. Peer-reviewed briefing paper, Division of Migratory Bird Management, U.S. Fish and Wildlife Service, Arlington, Virginia. 17 pp.

Manzer, D. L. 2004. Sharp-tailed grouse breeding success, survival, and site selection in relation to habitat measured at multiple scales. Ph.D. Dissertation, University of Alberta, Edmonton. 158 pp.

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

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

Marcstrom, V., R.E. Kenward, and E. Engren. 1989. The impact of predators on boreal tetranoids during vole cycles: an experimental study. Journal of Animal Ecology 57: 859–872. (*not seen, in* Steen and Haugvold 2009).

Marks, J. S., and V. S. Marks. 1987a. Habitat selection by Columbian sharp-tailed grouse in west-central Idaho. U.S. Department of Interior, Bureau Land Management, Boise District, Idaho.

Marks, J. S., and V. S. Marks. 1987b. Influence of radio collars on survival of sharp-tailed grouse. Journal of Wildlife Management 51:468–471.

Marks, J. S., and V. S. Marks. 1988. Winter habitat use by Columbian sharp-tailed grouse in western Idaho. Journal of Wildlife Management 52:743–746.

Marshall, W. H., and M. S. Jensen. 1937. Winter and spring studies of sharp-tailed grouse in Utah. Journal of Wildlife Management 1:87–99.

Marshall, A. G. 1999. Unusual Gardens: the Nez Perce and wild horticulture on the eastern Columbia Plateau. Pages 173–187, *in* D. D. Goble and P. W. Hirt, editors. Northwest lands, Northwest peoples: readings in environmental history. University of Washington Press, Seattle. 552 pp.

Marzluff , J. M., and E. Neatherlin. 2006. Corvid response to human settlements and campgrounds: causes, consequences, and challenges for conservation. Biological Conservation 130: 301–314.

Mattise, S. N. 1978. Effects of grazing systems on sharp-tailed grouse habitat. M.S. Thesis, South Dakota State University, Brookings, SD.

Maxson, S. J. 1978. Evidence of brood adoption by Ruffed Grouse. Wilson Bulletin 90: 132–133.

McArdle, B. A. 1977. The effect of sagebrush reduction practices on sharp-tailed grouse use in southeastern Idaho. M.S. Thesis, Utah State University, Logan.

McCleery, R. A., R. R. Lopez, N. J. Silvy. 2007. Transferring research to endangered species management. Journal of Wildlife Management 71(7): 2134–2141.

McDonald, M. W. 1998. Ecology of Columbian sharp-tailed grouse in eastern Washington. M. S. Thesis. University of Idaho, Moscow. 125 pp.

McDonald, M. W, and K. P. Reese. 1998. Landscape changes within the historical distribution of Columbian sharp-tailed grouse in eastern Washington: Is there hope? Northwest Science 72:34–41.

McDougald, L. R. 2005. Blackhead disease (histomoniasis) in poultry: a critical review. Avian Diseases 49: 462–476.

McEwen, L. C. and R. L. Brown. 1966. Acute toxicity of dieldrin and malathion to wild sharp-tailed grouse. Journal of Wildlife Management 30:604–611.

McIntosh, A. 1937. Two new avian liver flukes with a key to the species of the genus *Athesmia* Looss, 1899 (Dicrocoeliidea). Proceedings of the Helminthological Society of Washington 4:21–23.

Meinig, D. W. 1995. The great Columbia plain: a historical geography, 1805–1910. University of Washington Press, Seattle. 576 pp.

Meints, D. R. 1991. Seasonal movements, habitat use, and productivity of Columbian sharp-tailed grouse in southeastern Idaho. M.S. Thesis, University of Idaho, Moscow.

Meints, D. R., J. W. Connelly, K. P. Reese, A. R. Sands, and T. P. Hemker. 1992. Habitat suitability index procedures for Columbian sharp-tailed grouse. Forest, Wildlife and Range Experiment Station Bulletin 55, University of Idaho, Moscow. 27 pp.

Merigliano, M.F., and P. Lesica. 1998. The native status of reed canarygrass (*Phalaris arundinacea* l.) in the inland Northwest, U.S.A. Natural Areas Journal 18: 223–230.

Merker, C. 1988. The Columbian sharp-tailed grouse in the state of Washington. Unpublished report, Washington Wildlife Cooperative, Rochester, Washington.

Merker, C. R. 1996. Reintroduction of the Columbian Sharp-tailed Grouse (*Tympanuchus phasianellus columbianus* Ord) using captive-reared young. M.S. Thesis. Eastern Washington University, Cheney, Washington. 48 pp.

Messmer, T. A., M. W. Brunson, D. Reiter, and D. G. Hewitt. 1999. United States public attitudes regarding predators and their management to enhance avian recruitment. Wildlife Society Bulletin 27:75–85.

Milchunas, D. G., and W. K. Lauenroth. 1993. Quantitative effects of grazing on vegetation and soils over a global range of environments. Ecological Monographs 63: 327–366.

Miles, E. L., and D. P. Lettenmaier. 2007. HB 1303 Interim Report: a comprehensive assessment of the impacts of climate change on the state of Washington. Unpublished report of the JISAO CSES Climate Impacts Group, University of Washington Seattle. 53 pp.

Miller, R. F., and L. L. Eddleman. 2000. Spatial and temporal changes of sage grouse habitat in a sagebrush biome. Oregon State University Agricultural Experiment Station Technical Bulletin 151. Corvallis, OR.

Miller, G. C., and W. D. Graul. 1980. Status of sharp-tailed grouse in North America. Pages 18–28 *in* P. A. Vohs, Jr. and F. L. Knopf., editors. Proceedings Prairie Grouse Symposium. Oklahoma State University, Stillwater, Oklahoma.

Miller, R. F., T. J. Svejcar, and N. E. West. 1994. Implications of livestock grazing in the intermountain sagebrush region: plant composition. Pages 101–146, *in* M. Vavra, W. A. Laycock, and R. D. Pieper, editors. Ecological implications of livestock herbivory in the West. Society for Range Management, Denver, CO. 297 pp.

Mills, L. S., and F. W. Allendorf. 1996. The one-migrant-per-generation rule in conservation and management. Conservation Biology 10: 1509–1518.

Mills, T. R., and M. A. Rumble. 1991. Poult adoption in Merriam's wild turkey. Wilson Bulletin 103: 137–138.

Mississippi State University 1997. Protozoan poultry diseases. College of Agriculture and Life Science. http://www.msstate.edu/dept/poultry/disprot.htm.

Mitchell, G. J., and P. W. Riegert. 1994. Sharp-tailed Grouse, *Tympanuchus phasianallus*, and grasshoppers: food is where you find it. Canadian Field-Naturalist 108: 288–291.

Montgomery, D. R. 2007. Dirt: the erosion of civilizations. University of California Press, Berkeley, CA.

Morely, L. C., and P. W. Wetmore. 1936. Discovery of the organism of ulcerative enteritis. Transactions of the North American Wildlife Conference 1: 471–472.

Morgan, B. B., and F. N. Hamerstrom, Jr. 1941. Notes on the endoparasites of Wisconsin pinnated and sharp-tailed grouse. Journal of Wildlife Management 5:194–198.

Mosley, J. C., S. C. Bunting, and M. E. Manoukian. 1999. Cheatgrass. pp 175–188, *in* R. L. Sheley and J. K.Petroff, editors. Biology and management of noxious rangeland weeds. Oregon State University Press, Corvallis. 438 pp.

Moss, R. 2001. Second extinction of capercaillie (*Tetrao urogallus*) in Scotland? Biological Conservation 101(2): 255–257.

Moss, R., and A. Watson. 2001. Population cycles in birds of the grouse family (Tetraonidae). Advances in Ecological Research 32: 53–111.

Moss, R., A. Watson, and R. Parr. 1996. Experimental prevention of a population cycle in Red Grouse. Ecology 77:1512–1630.

Moulton, C. E., R. S. Brady, and J. R. Beltoff. 2006. Association between wildlife and agriculture: underlying mechanisms and implications in burrowing owls. Journal of Wildlife Management 70: 708–716.

Moyles, D. L. J., and D. A. Boag. 1981. Where, when, and how male sharp-tailed grouse establish territories on arenas. Canadian Journal of Zoology 59:1576–1581.

Mullan, Captain J., 1863. Report on the Construction of a Military Road from Fort Walla Walla to Fort Benton. General Printing Office. Reprint 1994, by Ye Galleon Press, Fairfield, Washington. 183 pp.

Musil, D. D., 1989. Movements, survival, and habitat use of sage grouse translocated to the Sawtooth Valley, Idaho. M.S. Thesis. University of Idaho, Moscow. 72 pp.

Musil, D. D., and J. W. Connelly. 2009. Survival and reproduction of pen-reared vs. translocated wild pheasants *Phasianus colchicus*. Wildlife Biology 15(1):80–88.

Myers, C. E. 1948. Memoirs of a hunter. Shaw and Borden Co., Spokane, Washington.

Naugle, D. E., C. L. Aldridge, B. L. Walker, T. E. Cornish, B. J. Moynahan, M. J. Hollaran, K. Brown, G. D. Johnson, E. T. Schmidtman, R. T. Mayer, C. Y. Kato, M. R. Matchett, T. J. Christiansen, W. E. Cook, T. Creekmore, R. D. Falise, E. T. Rinkes, M. S. Boyce. 2004. West Nile virus: pending crisis for greater sage-grouse. Ecology Letters 7: 704–713.

Naugle, D. E., C. L. Aldridge, B. L. Walker, K. E. Doherty, M. R. Matchett, J. McIntosh, T. E. Cornish, M. S. Boyce. 2005. West Nile virus and sage-grouse: What more have we learned? Wildlife Society Bulletin 33(2): 616–623.

Nelle, P. J., K. P. Reese, and J. W. Connelly. 2000. Long-term effects of fire on sage grouse habitat. Journal of Range Management 53:586–591.

Nelson, H. K. 2001. Impact of predation on avian recruitment: an introduction. Wildlife Society Bulletin 29(1): 2–5.

Nielsen, L. S. and C. A. Yde. 1982. The effects of rest-rotation grazing on the distribution of sharp-tailed grouse. Pages 147–165, *in* J. M. Peek and P. D. Dalke, editors. Proceedings Wildlife-livestock Relationships Symposium, Coeur d'Alene, Idaho, 20–22 April., Forest, Wildlife and Range Experiment. Station, Proceedings 10, University of Idaho, Moscow, ID. 614 pp.

Northern Prairie Wildlife Research Center. 2006. Upland Game Identification: A Basic Guide for Aging and Sexing the Bird in your Hand, Sharp-tailed Grouse. USDI, Geological Survey. (http://www.npwrc.usgs.gov /resource/birds/upland/stgrouse.htm)

Norton, H. H., R. Boyd, and E. Hunn. 1999. The Klikitat Trail of south-central Washington: a reconstruction of seasonally used resource sites. pp 65–93 *in* R. Boyd, editor. Indians, fire, and the land. Oregon State University Press, Corvallis, OR. 313 pp.

Noss, R. F., E. T. La Roe III, and J. M. Scott. 1995. Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. U.S. Department of the Interior, National Biological Service, Washington, D.C. 58 pp.

ODFW (Oregon Department Fish and Wildlife). 2007. Special Projects: Re-introducing Columbia sharp-tailed grouse. (http://www.dfw.state.or.us/resources/ hunting/upland_bird/projects/

Oedekoven, O. O. 1985. Columbian sharp-tailed grouse population distribution and habitat use in south central Wyoming. M. S. Thesis, University of Wyoming, Laramie.

Ohmart, R. D. 1994. The effects of human-induced changes on the avifauna of western riparian habitats. Studies in Avian Biology 15:273–285.

Olson, B. 1976. Status Report: Columbian Sharp-tailed Grouse. Oregon Wildlife, April, p 10.

Olson, J. 2006. Scotch Creek Wildlife Area management plan (Draft). Washington Department of Fish and Wildlife, Olympia. 70 pp.

Olson, J. 2007. Scotch Creek Wildlife Area 2007 management plan update. Washington Department of Fish and Wildlife, Olympia. 6 pp.

Olson, J. 2008. Scotch Creek Wildlife Area 2008 management plan update. Washington Department of Fish and Wildlife, Olympia. 6 pp.

Opermanis, O., A. Mednis, I. Bauga. 2005. Assessment of compensatory predation and re-colonisation using long-term duck nest predator removal data. Acta Universitatis Latviensis 691, Biology : 17–29

Pacheco, L. F. 2004. Large estimates of minimum viable population sizes. Conservation Biology 18:1178–1179.

Pain, D. J., I. J. Fisher, and V. G. Thomas. 2009. A global update of lead poisoning in terrestrial birds from ammunition sources. *In* R. T. Watson, M. Fuller, M. Pokras, and W. G. Hunt, editors. Ingestion of lead from spent ammunition: implications for wildlife and humans. Available online from The Peregrine Fund, Boise, Idaho. http://www.peregrinefund.org/Lead_conference/2008Pb Conf_Proceedings.htm. [6 March 2009]

Park, K. J., K. E. Graham, J. Calladine, C. W. Wernham. 2008. Impacts of birds of prey on gamebirds in the UK: a review. Ibis 150(supple. 1): 9–26.

Park, K. J., P. A. Robertson, S. T. Campbell, R. Foster, Z. M. Russell, D. Newborn, and P. J. Hudson. 2001. The role of invertebrates in the diet, growth, and survival of red grouse (*Lagopus lagopus scoticus*) chicks. Journal of Zoolofy 254: 137–145.

Parker, H. 1984. Effect of corvid removal on reproduction of willow ptarmigan and black grouse. Journal of Wildlife Management 48(4): 1197–1205.

Parker, T. L. 1970. On the ecology of the sharp-tailed grouse in southeastern Idaho. M. S. Thesis, Idaho State University, Pocatello, Idaho.

Patten, M. A., D. H Wolfe, E. Shochat, and S. K. Sherrod. 2005. Habitat fragmentation, rapid evolution and population persistence. Evolutionary Ecology Research 7: 235–249.

Paulson, G. C., 1996. Livestock grazing: effect on woody riparian plant communities used by wintering Columbian sharp-tailed grouse (*Tympanuchus phasianellus columbianus*), Lake Creek, Washington. M. S. Thesis. Eastern Washington University, Cheney, Washington.

Pearse, A. T., and J. T. Ratti. 2004. Effects of predator removal on mallard duckling survival. Journal of Wildlife Management 68(2): 342–350.

Pedersen, W. T. 1982. Sage grouse status, distribution, movement, seasonal use of habitat, and habitat status in eastern Washington. Federal Aid in Wildlife Restoration Project W-70-R-21, Study VI, Job 1 and 2. Washington Department of Fish and Wildlife, Olympia.

Pedersen, E. K., J. W. Connelly, J. R. Hendrickson, and W. E. Grant. 2003. Effect of sheep grazing and fire on Sage-Grouse populations in southeastern Idaho. Ecological Modeling 165:23–47.

Peterle, T. J. 1954. The sharp-tailed grouse in the upper peninsula of Michigan. Ph.D. Dissertation, University.of Michigan, Ann Arbor.

Peterle, T.J. 1991. Wildlife Toxicology. Van Nostrand Reinhold, New York. 322 pp.

Peterson, D. 2006. Sagebrush Flat Wildlife Area management plan (draft). Washington Department of Fish and Wildlife, Olympia. 55 pp.

Peterson, D. 2007. Sagebrush Flat Wildlife Area 2007 management plan update. Washington Department of Fish and Wildlife, Olympia. 8 pp.

Peterson, D. 2008. Sagebrush Flat Wildlife Area 2008 management plan update. Washington Department of Fish and Wildlife, Olympia. 9 pp.

Peterson, M. J. 2004. Parasites and infectious diseases of prairie grouse: should managers be concerned? Wildlife Society Bulletin 32: 35–55.

Phillips, M. L. , W. R. Clark, M. A. Sovada, D. J. Horn, R. R. Koford, R. J. Greenwood. 2003. Predator selection of prairie landscape features and its relation to duck nest success. Journal of Wildlife Management 67(1): 104–114.

Pieron, M. R., and F. C. Rohwer. 2010. Effects of large-scale predator reduction on nest success of upland nesting ducks. Journal of Wildlife Management 74(1):124–132.

Pitman, J. C., C. A. Hagen, B. E. Jamison, R. J. Robel, T. M. Loughin, R. D. Applegate. 2006. Survival of juvenile

lesser prairie-chickens in Kansas. Wildlife Society Buletin 34(3): 675–681.
Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53: 7–15.
Post, R. H. 1938. The Sinkaietk or Southern Okanogan of Washington: the subsistence quest. In W. Cline, R.S. Commons, M. Mandelbaum, R.H. Post, and V.W. Walters. The Sinkaietk or Southern Okanogan of Washington. L. Spier, editor. General Series in Anthropology 6, Contributions from the Laboratory of Anthropology 2. George Banta Publishing, Menasha, Wisconsin. 262 pp.
Potts, G. R., 1986. The Partridge: pesticides, predation and conservation. Collins Professional and Technical Books, London, UK. 274 pp.
Prose, B. L. 1987. Habitat suitability index models: Plains Sharp-tailed Grouse. US Dept. Interior, US Fish and Wildlife Service Biological Report 82(10.142). 31pp.
Pruett, C. L., M. A. Patten, and D. A. Wolfe. 2009. Avoidance behavior by prairie grouse: implications for development of wind energy. Conservation Biology 23: 1253–1259.
Prugh L.R. C. J. Stoner, C. W. Epps, W. T. Bean, W. J. Ripple, A. S. Laliberte, J. S. Brashares. 2009. The rise of the mesopredator. BioScience 59(9): 779–791.
Pulliam, H. R. 1988. Sources, sinks, and population regulation.American Naturalist 132:652–661.
Pyle, W. H. and J. A. Crawford. 1996. Availability of foods of sage grouse chicks following prescribed fire in sagebrush-bitterbrush. Journal of Range Management 49:320–324.
Quigley, T.M., R.W. Haynes, and R.T. Graham, editors. 1996. Integrated scientific assessment for ecosystem management in the interior Columbia Basin and portions of the Klamath and Great Basins. General Technical Report PNW-GTR-382. USDA Forest Service, Pacific Northwest Research Station, Portland, OR. 303 pp.
Rands, M. R. W. 1988. Habitat quality and gamebird population ecology. Pp 134–158, *in* P. J. Hudson and M. R.W. Rands, editors. Ecology and Management of Gamebirds. BSP Professional Books, Oxford, U.K.
Reed, J. M., P. D. Doerr, and J. R. Walters. 1986. Determining minimum population sizes for birds and mammals. Wildlife Society Bulletin 14:255–261.
Reed, D. H., and R. Frankham. 2003. Correlation between fitness and genetic diversity. Conservation Biology 17:230–237.
Reed, D. H., J.J. O'Grady, B.W. Brook, J.D. Ballou, and R. Frankham. 2003. Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. Biological Conservation 113: 23–34.
Reese, K. P., and J. W. Connelly. 1997. Translocation of sage grouse *Centrocercus urophasianus* in North America. Wildlife Biology 3: 235–241.
Reese, K. P., J. W. Connelly, E. O. Garton, M. L. Commons-Kemner. 2005. Exploitation and greater sage-grouse *Centrocercus urophasianus*: a response to Sedinger and Rotella. Wildlife Biology 11: 377–381.
Resource Planning Unlimited, Inc. 2002a. North Fork Palouse River Watershed Characterization: Final report. Prepared for Palouse Conservation District, Pullman, Washington.
Resource Planning Unlimited, Inc. 2002b. South Fork Palouse River Watershed Characterization: Final report. Prepared for Palouse Conservation District, Pullman, Washington.
Reynolds, J. C., P. Angelstam, and S. Redpath. 1988. Predators, their ecology and impact on gmaebird populations. Pages 73–97, *in* P. J. Hudson and M. R. W. Rands, editors. Ecology and Management of Gamebirds. BSP Professional Books, Oxford, UK. 263 pp.
Reynolds, J. C., and S. C. Tapper 1996. Control of mammalian predators in game management and conservation. Mammal Review 26(2–3): 127–155.
Rickard, W. H., and C. E. Cushing. 1982. Recovery of streamside woody vegetation after exclusion of livestock grazing. Journal of Range Management 35(3): 360–361.
Riley, T. Z., and J. H. Schultz. 2001. Predation and ring-necked pheasant populations. Wildlife Society Bulletin 29(1): 24–32.
Rippin, A. B. 1970. Social organization and recruitment on the arena of sharp-tailed grouse. M. S. Thesis, University of Alberta, Edmonton.
Rippin, A. B., and D. A. Boag. 1974. Recruitment to populations of male sharp-tailed grouse. Journal of Wildlife Management 38: 616–621.
Ritcey, R. 1995. Status of the sharp-tailed grouse in British Columbia. Report No. WR-70, British Columbia Ministry of Environment, Land, and Parks, Victoria, B.C. 40p.
Rich, T. 1986. Habitat and nest-site selection by burrowing owls in the sagebrush steppe of Idaho. Journal of Wildlife Management 50: 548–555.
Ritzville High School freshman class 1978. Hunting in the Carico [Karikul] Hills area. Page 53, *in* The Golden Years. Ritzville High School, Ritzville, WA.
Robel, R. J. 1970. Possible role of behavior in regulating greater prairie chicken populations. Journal of Wildlife Management 34: 306–312.
Robel, R. J. 2002. Expected impacts on greater prairie-chickens of establishing a wind turbine facility near Rosalia, Kansas. Prepared for Zilkha Renewable Energy, Houston, TX. 31 pp.
Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationship between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295–297.
Robel, R., F. R. Henderson, and W. W. Jackson. 1972. Some sharp-tailed grouse population statistics from South Dakota. Journal of Wildlife Management 36:87–98.
Robbins, W. G. 1997. Landscpaes of Promise: the Oregon Story, 1800–1940. University of Washington Press, Seattle, WA. 392 pp. [*Not see, in* Hessburg and Agee (2003)].
Robbins, W. G., and D. W. Wolf. 1994. Landscape and the intermontane northwest: an environmental history. General Technical Report PNW-GTR-319. Portland, Oregon: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 32 pp.
Rodgers, R. D. 1992. A technique for establishing Sharp-

tailed Grouse in unoccupied range. Wildlife Society Bulletin 20:101–106.

Rodgers, R. 2003. Wind Power Generation: Biological Concerns. Wind Energy Symposium April 10, 2003. Ft. Hays State University, Hays, KS. (available at: www.fhsu.edu/econ/wind_energy.shtml

Rodgers, R. D., and R.W. Hoffman. 2005. Prairie grouse population response to Conservation Reserve Program grasslands: an overview. Pages 120–128 *in* A. W. Allen and M. W. Vandever, editors. The Conservation Reserve Program—Planting the Future: Proceedings of a National Conference, Fort Collins, Colorado, June 6–9, 2004. U.S. Geological Survey, Biological Resources Division, Scientific Investigation Report 2005–5145. 248 pp.

Roersma, S. J. 2001. Nesting and brood rearing ecology of Plains Sharp-tailed Grouse (*Tympanuchus phasianellus jamesi*) in a mixed-grass/fescue ecoregion of southern Alberta. M. S. Thesis, University of Manitoba. 124 pp.

Rogers, G. E. 1969. The sharp-tailed grouse in Colorado. Colorado Game, Fish and Parks Technical Publication 23, Denver, CO.

Romain-Bondi, K. 2006. Methow Wildlife Area management plan (draft). Washington Department of Fish and Wildlife, Olympia. 98 pp.

Romain-Bondi, K. 2007. Methow Wildlife Area. 2007 management plan update. Washington Department of Fish and Wildlife, Olympia. 12 pp.

Romain-Bondi, K. 2008. Methow Wildlife Area 2008 management plan update. Washington Department of Fish and Wildlife, Olympia. 13 pp.

Root, T. L., J. T. Price, K. R. Hall, S. H. Schneider, C. Rosenzweig, and J. A. Pounds. 2005. The impact of climate change on wild animals and plants: a meta-analysis. Pages 1115–1118 *in* C. J. Ralph and T. D. Rich, editors. Bird conservation implementation and integration in the Americas: proceedings of the Third Interantional Partners in Flight Conference. USDA Forest Service. General Technical Report, PSW-GTR-191.

Roseberry, J. L. 1979. Bobwhite population responses to exploitation: real and simulated. Journal of Wildlife Management 43: 285–305.

Roseberry, J. L. 1981. Bobwhite population responses: a reply. Journal of Wildlife Management 45: 1054–1056.

Ross, J. A. 1999. Proto-historical and historical Spokan prescribed burning and stewardship of resource areas. Pages 277–291 *in* R. Boyd, editor. Indians, fire, and the land. Oregon State University Press, Corvallis, OR. 313 pp.

Rowan, W. 1948. The ten-year cycle, outstanding problem of Canadian conservation. University of Alberta, Dept. of Extension. (*not seen, in* Hamerstrom and Hamerstrom 1951).

Rusch, D. R., S. Destephano, M. C. Reynolds, and D. Lauten. 2000. Ruffed Grouse (*Bonasa umbellus*). *In* The Birds of North America, No. 515. (A. Poole and F. Gill, eds.). The Birds of North America, Inc. Philadelphia, Pennsylvania.

Rust, H.J. 1917. An annotated list of birds of Fremont County, Idaho, as observed during the summer of 1916. Condor 19:29–43.

Saab, V. A., and J. S. Marks. 1992. Summer habitat use by Columbian sharp-tailed grouse in western Idaho. Great Basin Naturalist 52(2): 166–173.

Sargeant, A. B., S. H. Allen, and J. O. Hastings. 1987. Spatial relations between sympatric coyotes and red foxes in North Dakota. Journal of Wildlife Management 51:285–293.

Sargeant, A. B., M. A. Sovada, and T. L. Shaffer. 1995. Seasonal predator removal relative to hatch rate of duck nests in waterfowl production areas. Wildlife Society Bulletin 23:506–513.

Sauer, C. O. 1950. Grassland climax, fire, and man. Journal Range Management 3:16–21.

Sauer, R. H., and D. W. Uresk. 1976. Phenology of steppe plants in wet and dry years. Northwest Science 50:133–138.

Sauer, J. R., J. E. Hines, and J. Fallon. 2008. The North American Breeding Bird Survey, Results and Analysis 1966–2007. Version 5.15.2008. USGS Patuxent Wildlife Research Center, Laurel, MD

Saunders, G. B. 1935. Michigan studies of sharp-tailed grouse grouse. Transactions of the American Game Conference 21: 342–344 (*not seen, in* Peterson 2004).

Scharf, E. A. 2002. Long-term interactions of climate, vegetation, humans, and fire in Eastern Washington. Ph.D. Dissertation, University of Washington, Seattle. 382 pp.

Scherer, R. 2008. Wheat prices hit record high. Christian Science Monitor, February 27, 2008.

Schneider, J. W. 1994. Winter feeding and nutritional ecology of Columbian sharp-tailed grouse in southeastern Idaho. M. S. Thesis. University of Idaho, Moscow, ID.

Schroeder, M. A. 1985. Behavioral differences of female spruce grouse undertaking short and long migrations. Condor 87: 281–286.

Schroeder, M. A. 1991. Movement and lek visitation by female greater prairie-chickens in relation to predictions of Bradbury's female preference hypothesis of lek evolution. Auk 108:896–903.

Schroeder, M. A. 1994. Productivity and habitat use of sharp-tailed grouse in north-central Washington. Upland Bird Job Progress Report, Federal Aid in Wildlife Restoration. Washington Department of Fish and Wildlife, Olympia.

Schroeder, M. A. 1996. Productivity and habitat use of sharp-tailed grouse in north-central Washington. Upland Bird Job Progress Report, Federal Aid in Wildlife Restoration. Washington Department of Fish and Wildlife, Olympia.

Schroeder, M. A. 2000. Minimum viable populations for greater sage-grouse in Washington. Job Progress Report. Upland Bird Research. Washington Department of Fish and Wildlife.

Schroeder, M. A. 2006. Distribution, abundance, and translocation of Columbian sharp-tailed grouse in Washington. *In* Job Progress Report: project #3, Upland Bird Population Dynamics and Management, Federal Aid in Wildlife Restoration. Washington Department of

Fish and Wildlife, Olympia.
Schroeder, M. A., and R. K. Baydack. 2001. Predation and the management of prairie grouse. Wildlife Society Bulletin 29:24–32.
Schroeder, M. A., D. W. Hays M. A. Murphy, and D. J. Pierce. 2000. Changes in the distribution and abundance of Columbian Sharp-tailed Grouse in Washington. Northwestern Naturalist 81: 95–103.
Schroeder, M., M. Atamian, H. Ferguson, M. Finch, D. Stinson, M. Berger, and R. Whitney. 2008. Re-establishment of Viable Populations of Columbian Sharp-tailed Grouse in Washington: Progress Report. Washington Departemnt of Fish and Wildlife. 23 pp. (http://wdfw.wa.gov/wlm/research/papers/sharp-tailed grouse_grouse/columbian_sharp-tailed grouse08.htm).
Schroeder, M. A., and M. Tirhi. 2003. Sharp-tailed Grouse. Pages 16-1 – 16-10, *in* E. Larsen, J. M. Azerrad, N. Nordstrom, editors. Management Recommendations for Washington's Priority Species, Volume IV: Birds. Washington Department of Fish and Wildlife, Olympia, Washington.
Schroeder, M. A., J. R. Young, and C. E. Braun. 1999. Sage grouse (*Centrocercus urophasianus*). The Birds of North America No. 425. A. Poole and F. Gill, editors. The Birds of North America, Inc., Philadelphia, Pennsylvania, USA.
Schulz, J. H., J. J. Millspaugh, A. J. Bermudez, X. Gao, T. W. Bonnot, L. G. Britt, M. Paine. 2006. Acute lead toxicosis in mourning doves. Journal of Wildlife Management 70: 413–421.
Scott, J. M., and J. W. Carpenter. 1987. Release of Captive-reared or translocated endangered birds: what do we need to know? Auk 104: 544–545.
Servheen, G., P. Morgan, B. Weddell, P. Gessler, P. McDaniel. 2002. Wetlands of the Palouse prairie: historical extent and plant composition. Final Report, EPA Westlands Grant No. CD-980545-01-0. Idaho Operations Office, Environmental protection Agency, Boise, Idaho. 17 pp.
Sexton, D. A. 1979. Off-lek copulation in Sharp-tailed Grouse. Wilson Bulletin 91: 150–151.
Sexton, D. A., and M. M. Gillespie. 1979. Effects of fire on the location of a Sharp- tailed Grouse arena. Canadian Field-Naturalist. 93:74–76.
Sharp, W. M. 1957. Social and range dominance in gallinaceous bird—pheasants and prairie grouse. Journal of Wildlife Management 21: 242–244.
Shillinger, J. E. 1942. Diseases of wildlife and their relationship to domestic livestock. Pages 1217–1225 *in* Keeping livestock healthy. Yearbook of Agriculture 1942. USDA, Washington, D.C. (*not seen, in* Peterson 2004).
Shillinger, J. E., and L. C. Morley. 1937. Diseases of upland game birds. U.S. Department of Agriculture, Farmers Bulletin No. 1781.
Shinn, D. A. 1980. Historical perspectives on range burning in the inland Pacific Northwest. Journal of Range Management 33(6):415–423.
Short, L. L., Jr. 1967. A review of the genera of grouse (Aves: Tetraoinidae). American Museum Natural History Novitiates No. 2289. 39pp.
Silvy, N. J., M. J. Peterson, and R. R. Lopez. 2004. The cause of the decline of pinnated grouse: the Texas example. Wildlife Society Bulletin 32(1): 16–21.
Slater, S. J. 2003. Sage-grouse (*Centrocercus urophasianus*) use of different-aged burns and the effects of coyote control in southwestern Wyoming. M.S. Thesis, University of Wyoming, Laramie. 177 pp.
Small, R. J., and D. H. Rusch. 1989. The natal dispersal of Ruffed Grouse. Auk 106:72–79.
Smith, C. A. 1983. A 4300 year history of vegetation, climate, and fire from Blue Lake, Nez Perce County, Idaho. M.S. thesis. Washington State University, Pullman.(*not seen, in* Weddell 2001b)
Smith, J. 1986. Bunch Grass Pioneer. Ye Galleon Press, Fairfield, WA. 78 pp.
Snodgrass, R. E. 1904. A list of land birds from central and southeastern Washington. Auk 21: 223–233.
Snyder, L. L. 1935. A study of the sharp-tailed grouse. Biol. Ser. Number 40. Univ. Toronto Press, Toronto.
Snyder, J. W., E. C. Pelren, and J. A. Crawford. 1999. Translocation histories of prairie grouse in the United States. Wildlife Society Bulletin 27:428–432.
Sovada, M. A., R. M. Anthony, and B. D. J. Batt. 2001. Predation on waterfowl in arctic tundra and prairie breeding areas: a review. Wildlife Society Bulletin 29(1): 6–15.
Sovada, M. A., A. B. Sargeant, and J. W. Grier. 1995. Differential effects of coyotes and red foxes on duck nest success. Journal of Wildlife Management 59:1–9.
Sovada, M. A., M. C. Zicus, R. J. Greenwood, D. P. Rave, W. E. Newton,R. O. Woodward, and J. A. Beiser. 2000. Relationships of habitat patch size to predator community and survival of duck nests. Journal of Wildlife Management 64:820–831.
Sparling, D. W. 1983. Quantitative analysis of prairie grouse vocalizations Condor 85: 30–42.
Spaulding, A. W., K. E. Mock, M. A. Schroeder, and K. I. Warheit. 2006. Recency, range expansion, and unsorted lineages: implications for interpreting natural genetic variation in the sharp-tailed grouse (*Tympanuchus phasianellus*). Molecular Ecology 15: 2317–2332.
Stabler, R. M, P. A. Holt, and N. J. Kitzmiller. 1966. *Trypanosoma avium* in the blood and bone marrow from 677 Colorado birds. Journal of Parasitology 52: 1141–1144.
Stabler, R. M, and N. J. Kitzmiller. 1976. *Plasmodium (Giovannolaia) pedioecetii* from gallinaceous birds of Colorado. Journal of Parasitology 62: 539–544.
Stabler, R. M, N. J. Kitzmiller, and C. E. Braun. 1974. Hematozoa from Colorado birds, IV Galliformes. Journal of Parasitology 60: 536–537.
Starkey, E. E., and R. A. Schnoes. 1979. The Columbian sharp-tailed grouse: with special reference to their potential reintroduction to Lava Beds National Monument. *in* R. M. Linn, editor. Proceedings First Conference on Scientific Research in the National Parks. National Park Service Transactions and Proceedings Series 5:497–500.
Steen, J. B., and O. A, Haugvold. 2009. Cause of death in

willow ptarmigan *Lagopus l. lagopus* chicks and the effect of intensive, local predator control on chick production. Wildlife Biology 15(1): 53–59.

Stewart, O. C. 2002. Forgotten Fires: Native Americans and the Transient Wilderness. University of Oklahoma Press, Norman. 364 pp.

Stinson, D. W. 2005. Black-billed Magpie, page 265, *in* T. R. Wahl, B. Tweidt, and S. G. Mlodinow, editors. Birds of Washington: status and distribution. Oregon State University Press, Corvallis. 436 pp.

Stone, E. and C. H. Trost. 1991. The effects of supplemental food on nest dispersal in Black-billed Magpies. Condor 93:452–454

Stralser, T. 1991. A description of habitats surrounding Columbian sharp-tailed grouse leks in Lincoln County, Washington. M. S. Thesis, Eastern Washington University, Cheney.

Streitfeld, D., 2008. As prices rise, farmers spurn conservation program. The New York Times. 9 April 2008.

Suckley, G. 1860. Railroad route explorations and surveys. Thirty-sixth U.S. Congress, vol. 12, book 2:223–224.

Sullivan, S. L. 1988. Status reviews of some important animals of the shrub-steppe of Washington. Washington Department of Wildlife, Olympia. 126 pp.

Swales, W. E. 1934. *Rhabdometra odiosa* (Leidy, 1887) Jones, 1929, a cestode parasite of *Pedioecetes phasianellus* in Quebec. Journal of Parasitology 20: 313–314. (*not seen, in* Peterson 2004).

Swedberg, D. 2006. Chiliwist Wildlife Area management plan (draft). Washington Department of Fish and Wildlife, Olympia. 101 pp.

Swenson, J. E. 1985. Seasonal habitat use by sharp-tailed grouse, *Tympanuchus phasianellus*, on mixed-grass prairie in Montana. Canadian Field-Naturalist 99:40–46.

Symington, D. F. and T. A. Harper. 1957. Sharp-tailed grouse in Saskatchewan. Conservation Bulletin No. 4. Saskatchewan Department of Natural Resources.

Tapper, S. C., G. R. Potts, and M. H. Brockless. 1996. The effect of an experimental reduction in predation pressure on the breeding success and population density of grey partridge *Perdix perdix*. Journal of Applied Ecology 33: 965–978.

Teixeira, C., C. Schetini de Azevedo, M. Mendl, C. F. Cipreste, and R. J. Young. 2007. Revisiting translocation and reintroduction programmes: the importance of considering stress. Animal Behaviour 73: 1–13.

Thompson, T. R., K. P. Reese, and A. D. Apa. 2007. Dispersal Ecology of Greater Sage-grouse in northwestern Colorado: evidence from genetic and demographic methods. Progress Report. Colorado Division of Wildlife. 43 pp. Available online at http://wildlife.state.co.us/Research/Birds/GreaterSageGrouse/ [12 April 2009].

Tirhi, M. J. 1995. Washington State Management Plan for the Sharp-tailed Grouse. Game Division, Washington Department of Fish and Wildlife, Olympia. 99 pp.

Tisdale, E. W. 1961. Ecologic changes in the Palouse. Northwest Science 35: 134–138.

Tisdale, E. W. 1986. Canyon Grasslands and associated shrublands of west-central Idaho and adjacent areas. College of Forestry, Wildlife, and Range Sciences Bulletin No. 40, Forest, Wildlife and Range Experiment Station contribution No. 284, University of Idaho, Moscow. 42 pp.

Tisdale, E. W. and M. Hironaka. 1981. The sagebrush-grass region: a review of the ecological literature. College of Forestry, Wildlife, and Range Sciences Bulletin No. 33, Forest, Wildlife and Range Experiment Station contribution No. 209, University of Idaho, Moscow. 31 pp.

Toepfer, J. E. 2005. "Anecdotal" observations of prairie chickens and wind generators in northwestern Minnesota. (abstract) Page 17 *in* Proceedings of 26th Prairie Grouse Technical Council, Valentine, Nebraska, September 2005. Available online at http://www.ngpc.state.ne.us/wildlife/programs/pgtc/ [8 June 2007]

Toepfer, J. E., R. L. Eng, and R. K. Anderson. 1990. Translocating prairie grouse: what have we learned? Transactions North American Wildlife and Natural Resources Conference 55: 569–579.

Toepfer, J. E., D. R. Trauba, and S. C. Vacek. 2005. Restoring prairie chickens to west central Minnesota-Progress report. (abstract) Pages 18–19 *in* Proceedings of 26th Prairie Grouse technical Council, Valentine, Nebraska, September 2005. Available online at http://www.ngpc.state.ne.us/wildlife/programs/pgtc/ [8 June 2007]

Townsend, J. K., 1987. Across the Rockies to the Columbia. University of Nebraska Press, Lincoln, NB. Originally published in 1839, as Narrative of a Journey across the Rocky Mountains to the Columbia River. H. Perkins, Philadelphia. Reprint of abridged version published in vol. 21, Early Western Travels. 1905. R. G. Thwaites, editor.

Trautman, C. G., L. F. Fredrickson, and A. V. Carter. 1974. Relationship of red foxes and other predators to populations of ring-necked pheasants and other prey, South Dakota. Transactions of the North American Wildlife Conference 39:241–252.

Trost, C. H. 1999. Black-billed Magpie (*Pica pica*). Birds of North America, No. 389. A. Poole and F. Gill, editors. The Birds of North America, Inc. Philadelphia, PA. 28 pp.

Tsuji, L. J. S. 1996. Do female sharp-tailed grouse, *Tympanuchus phasianellus*, copulate only once during a breeding season? Canadian Field-Naturalist 110:535–536.

Tsuji, L. J. S., and G. DeIuliis. 2003. Endoparasites of Northern Sharp-tailed Grouse *Tympanuchus phasianellus phasianellus*, as related to age and position on the lek. Arctic 56: 266–270.

Tsuji, L. J. S., G. DeIuliis, R. I. C. Hansell, D. R. Kozlovic, and M. B. Sokolowski. 2000. Non-random mating in classical lekking species: seasonal and diurnal trends. International Journal of Biometerology 44: 134–140.

Tsuji, L. J. S., J. D. Karagatzides, and G. Deiluis. 2001. Ectoparasites in lekking sharp-tailed grouse, *Tympanuchus phasianellus*. Canadian Field-Naturalist

115:210–213.
Tsuji, L. J. S., D. R. Kozlovic, M. B. Sokolowski. 1992. Territorial position in Sharp-tailed Grouse leks: the probability of fertilization. Condor 94: 1030–1031.
Turner, A. S., L. M. Conner, R. J. Cooper. 2008. Supplemental feeding of northern bobwhite affects red-tailed hawk spatial distribution. Journal of Wildlife Management 72(2): 428–432.
Twedt, C. M. 1974. Characteristics of sharp-tailed grouse display grounds in Nebraska Sandhills. Ph.D. Dissertation, University of Nebraska, Lincoln.
Uchytil, R. J. 1989. Betula occidentalis. In: Fire Effects Information System, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory.Available: http://www.fs.fed.us/ database/feis/ [26 May 2006].
Ulliman, M. J. 1995. Winter habitat ecology of Columbian sharp-tailed grouse in southeastern Idaho. M. S. Thesis. University of Idaho, Moscow, ID.
USFWS (U. S. Fish and Wildlife Service) 2000. 12-Month finding on a petition to list the Columbian sharp-tailed grouse as Threatened. Federal Register 65(197): 60391–60396.
USFWS (U. S. Fish and Wildlife Service) 2003. Interim Guidelines to Avoid and Minimize Wildlife Impacts from Wind Turbines. United States Department of the Interior, U. S. Fish and Wildlife Service, Washington, D.C.
USFWS (U. S. Fish and Wildlife Service) 2006. 90-Day finding on a petition to list the Columbian sharp-tailed grouse as Threatened or Endangered. Federal Register 71(224): 67318–67325.
USGS National Health Center. 2006. West Nile virus in greater sage-grouse. Wildlife Health Bulletin #06-08.
USDI/GS 1976. The Channeled Scablands of eastern Washington: the geologic story of the Spokane floods. U. S. Department of Interior, Geological Survey. USGS, INF-72-2 (R-1). 25 pp.
Vale, T. R. 1975. Presettlement vegetation in the sagebrush grass areas of the intermountain west. Journal of Range Management 28:32–36.
Vale, T. R. 2002. Reflections. Pages 295–301 *in* T. R. Vale, editor. Fire, native peoples, and the natural landscape. Island Press, Washington, D.C., 315 pp.
Vance, D. R., and R. L. Westemeier. 1979. Interactions of pheasants and prairie chickens in Illinois. Wildlife Society Bulletin 7:221–225.
Vander Haegen, W. M. 2007. Fragmentation by agriculture influences reproductive success of birds in a shrubsteppe landscape. Ecological Applications, 17(3): 934–9471
Vander Haegen, W. M., M. A. Schroeder, and R. M. DeGraaf. 2002. Predation on real and artificial nests in shrubsteppe landscapes fragmented by agriculture. Condor 104:496–506.
Webb, C. W., W. I. Boarman, and J. T. Rotenberry. 2004. Common raven juvenile survival in a human- augmented landscape. Condor 106:517– 528.
Vavra, M., W. A. Laycock, and R. D. Pieper, editors. 1994. Ecological implications of livestock herbivory in the west. Society for Range Management, Denver, CO. 297 pp.
Vickery, P. D., M. L. Hunter Jr, J. V. Wells. 1992. Evidence of incidental nest predation and its effect on nests of threatened grassland birds. Oikos 63: 281–288.
Victor, E. 1935. Some effects of cultivation upon stream history and upon the topography of the Palouse region. Northwest Science 9: 18–19.
Voight, D. R., and B. D. Earle. 1983. Avoidance of coyotes by red fox families. Journal of Wildlife Management 47: 852– 857.
Vucetich, J. A., and T. A. Waite. 1998. Number of censuses required for demographic estimation of effective population size. Conservation Biology 12:1023–1030.
Walter, H., and K. P. Reese. 2003. Fall diet of chukars (*Alectoris chukar*) in eastern Oregon and discovery of ingested lead pellets. Western North American Naturalist 63: 402–405.
Wambolt, C. L., A. J. Harp, B. L. Welch, N. Shaw, J. W. Connelly, K. P. Reese, C. E. Braun, D. A. Klebenow, E. D. McArthur, J. G. Thompson, L. A. Torell, J. A. Tanaka. 2002. Conservation of greater sage-grouse on publc lands in the western U.S.: implications of recovery and management policies. PACWPL-Policy Paper SG-02-02. Policy Analysis Center for Western Public Lands, Caldwell, ID. 41 pp.
Wambolt, C. L., K. S. Walhof, and M. R. Frisina. 2001. Recovery of big sagebrush communities after burning in south-western Montana. Journal of Environmental Management 61: 243–252.
Warheit, K. I. and C. A. Dean. 2009. Subspecific identification of sharp-tailed grouse (*Tympanuchus phasianellus*) samples from Montana. Report submitted to: Big Sky Upland Bird Association, Montana Departemnt of Fish, Wildlife and Parks, and Confederated Salish aned Kootenai Tribes. Washington Department of Fish and Wildlife, Olympia. 17 pp.
Warheit, K. I. and M. A. Schroeder. 2001. Genetic survey of Columbian sharp-tailed grouse: apreliminary study. Final Report, Washington Department of Fish and Wildlife, Olympia. 16 pp.
Warheit, K. I. and M. A. Schroeder. 2003. Genetic survey of Columbian sharp-tailed grouse populations in western North America: summary of microsatellite results. Draft report, Washington Department of Fish and Wildlife, Olympia. 17 pp.
Washington State Legislature. 1993. House Bill 1309. First Special Session, Washington State Legislature, Olympia.
Watson, A., R. Moss, and S. Rae. 1998. Population dynamics of Scottish rock ptarmigan cycles. Ecology 79:1174–1192.
Watson, A., R. Moss, and P. Rothery. 2000. Weather and synchrony in 10-year population cycles of rock ptarmigan and red grouse in Scotland. Ecology 81:2126–2136.
Webb, C. W., W. I. Boarman, and J. T. Rotenberry. 2004. Common raven juvenile survival in a human- augmented landscape. Condor 106:517– 528.
Weber, J. W., and E. J. Larrison. 1977. Birds of southeastern Washington. University Idaho Press, Moscow.
Weddell, B. J., (n.d.) The historical significance of camas

meadows for native peoples in Idaho. *Draba* Consulting, Pullman, Washington. Report prepared for U.S. Environmental Protection Agency. 20 pp.

Weddell, B. J. 1992. Biology and conservation of the sharp-tailed grouse, with special reference to the Columbian sharp-tailed grouse in Washington. Unpublished report, The Nature Conservancy, Seattle, Washington.

Weddell, B. J., 2001a. Changing perspectives in nineteenth century written descriptions of Palouse and Canyon Grasslands. Bureau of Land Management, Cottonwood District, Cottonwood, Idaho. Technical Bulletin 01-13

Weddell, B. J., 2001b. Fire in steppe vegetation of the northern intermountain region. Bureau of Land Management, Cottonwood District, Cottonwood, Idaho. Technical Bulletin 01-14. 24 pp.

Weddell, B. J., 2002a. Historical vegetation of seasonally moist depressions in the South Fork of the Palouse River watershed. Draba Consulting, Pullman. 17 pp. Appendix 5, *in* Servheen, et al. (2002).

Weddell, B. J., 2002b. The causes and consequences of loss of a culturally significant resource: seasonally moist meadows in the Palouse region. Draba Consulting, Pullman. 14 pp.

Weddell, B. J., and S. Johnston 1992a. Fall surveys of Columbian sharp-tailed grouse in Douglas and Okanogan Counties, Washington, 1991. Unpubl. report, The Nature Conservancy, Seattle, Washington.

Weddell, B. J., and S. Johnston 1992b. Results of Columbian sharp-tailed grouse lek surveys and searches in Douglas and Okanogan Counties, Washington, Spring 1991. Unpubl. report, The Nature Conservancy, Seattle, Washington.

Weddell, B. J., S. Johnston, S. Lannoy, and M. Stalmaster 1991a. Columbian sharp-tailed grouse lek surveys in Douglas, Lincoln, and Okanogan Counties, Washington, 1991. Unpubl. report, The Nature Conservancy, Seattle, Washington. 36 pp +appendix.

Weddell, B. J., S. Johnston and J. Martin. 1991b. Sharp-tailed grouse winter habitat inventory in Douglas, Lincoln, and Okanogan counties, Washington, 1990–1991. Unpubl. rep., The Nature Conservancy, Seattle, Washington. 33 pp.

Weddell, B. J., and J. Lichthardt. 1998. Identification of conservation priorities for and threats to Palouse Grassland and Canyon Grassland Remnants in Idaho, Washington, and Oregon. Technical Bulletin No. 98-13, Prepared for Bureau of Land Management, Cottonwood, ID. 57 pp.

Weddell, B. J., and J. Lichthardt. 2001. Restoration of Palouse and Canyon Grasslands: a review. Pages 1–6, in B. J. Weddell, editor. Restoring Palouse and Canyon Grasslands: putting back the missing pieces. Technical Bulletin No. 01-15, Prepared for Bureau of Land Management, Cottonwood, ID. 10 pp.

Weddell, B. J., L. J. Salzer, and S. Johnston 1990. Columbian sharp-tailed grouse lek surveys in Douglas, Lincoln, and Okanogan Counties, Washington, Spring 1990. Unpubl. report, The Nature Conservancy, Seattle, Washington. 63 pp.

Wehr, E. E. 1938. A new species of crop worm, *Gongylonema phasianella*, from the sharp-tailed grouse. Pages 523–526 in Livro Jubilar do professor Lauro Travassos: editado para commemorar o 25 anniversario de suas actividades scientificas (1913–1938). Typographica do Instituto Oswaldo Cruz, Rio de Janeiro, Brazil. (*not seen, in* Peterson 2004).

Welch, B. L. 2005. Big sagebrush: a sea fragmented into lakes, ponds, an dpuddles.Gen. Tech. Report RMRS-GTR-144. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO. 210 p.

Welch, B. L., and C. Criddle. 2003. Countering misinformation concerning big sagebrush. Research Paper RMRS-RP-40. USDA Forest Service Rocky Mountain Research Station, Ogden, Utah. 28 pp.

Westemeier, R. L., J. D. Brown, S. A. Simpson, T. L. Esker, R. W. Jansen, J. W. Walk, E. L. Kershner, J. L. Bouzat, K. N. Piage. 1998a. Tracking the long-term decline and recovery of an isolated population. Science 282:1695–1698.

Westemeier, R. L., J. E. Buhnerkempe, W. R. Edwards, J. D. Brawn, S. A. Simpson. 1998b. Parasitism of greater prairie-chicken nests by ring-necked pheasants. Journal of Wildlife Management 62:854– 863.

Westemeier, R. L., S. A. Simpson, and D. A. Cooper. 1991. Successful exchange of prairie-chicken eggs between nests in two remnant populations. Wilson Bulletin 103: 717–720.

Wetmore, P.W. 1939. A species of Plasmodium from the sharp-tailed grouse infective to other birds. Journal of Wildlife Management 3: 361–365.

Whisenant, S. G., 1990. Changing fire frequencies on Idaho's Snake River Plains: ecological and management implications. Pages 4–10 *in* E. D. McArthur, E. V. Romney, S. D. Smith, P. T. Tueller, compilers. Proceedings–Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management. USDA Forest Service Intermountain Research Station. GTR INT-276. Ogden, UT.

White, E. M., and G. F. Bennett. 1979. Avian Haemoproteidae. 12. The haemoproteids of the grouse family Tetraonidae. Canadian Journal of Zoology 57: 1465–1472.

Whitlock, C., and M. A. Knox. 2002. Prehistoric burning in the Pacific Northwest: human versus climatic incluences. Pages 195–228 *in* T.R. Vale, editor. Fire, native peoples, and the natural landscape. Island Press. Covelo, CA. 315 pp.

Williams, C. K., F. S. Guthery, R. D. Applegate, and M. J. Peterson. 2004a. The northern bobwhite decline: scaling our management for the twenty-first century. Wildlife Society Bulletin 32:861–869.

Williams, C. K., A. R. Ives, R. D. Applegate, and J. Ripa. 2004b. The collapse of cycles in the dynamics of North American grouse populations. Ecology Letters 7: 1135–1142.

Winkelman, E. 1990. Impact of the wind park near Urk, Netherlands, on birds: bird collision victems and disturbance of wintering fowl. International Ornithological Congress. 20: 402–403.

Wise, D. R. 1982. Nutrition of wild Red Grouse (*Lagopus*

lagopus scoticus). Ibis 119:1–9. (*Not seen, in* Fields et al. 2006).

Wolfe, D. H., M. A. Patten, E. Shochat, C. L. Pruett, S. K. Sherrod. 2007. Causes and patterns of mortality in lesser prairie-chickens *Tympanuchus palladicinctus* and implications for management. Wildlife Biology 13 (Supplement 1): 95–104.

Wong, M. M. L., B. C. Fedy, S. Wilson, and K. M. Martin. 2009. Adoption in Rock and White-tailed Ptarmigan. Wilson Journal of Ornithology. 121: 638–641.

Wyman, S., D. Bailey, M. Borman, S. Cote, J. Eisner, W. Elmore, B. Leinard, S. Leonard, F. Reed, S. Swanson, L. Van Riper, T. Westfall, R. Wiley, and A. Winward. 2006. Riparian area management: Grazing management processes and strategies for riparian-wetland areas. Technical Reference 1737-20. BLM/ST/ST-06/002+1737. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, Colorado. 105 pp.

Yde, C. A. 1977. Distribution and movements of sharp-tailed grouse during spring and summer in relation to rest-rotation grazing. Federal Aid in Wildlife Restoration Job 1, project W-120-R. Final report. Montana Fish and Game Department. 78 pp.

Yeo, J. J. 2005. Effects of grazing exclusion on rangeland vegetation and soils, east central Idaho. Western North American Naturalist 65(1): 91–102.

Yocom, C. F. 1943. The Hungarian partridge *Perdix perdix* in the Palouse Region, Washington. Ecological Monograph 13:167–202.

Yocom, C. F. 1952. The Columbian sharp-tailed grouse (*Pediocetes phasianeillus columbianus*) in the state of Washington. American Midland Naturalist 48:185–192.

Young. V. A. 1943. Changes in vegetation and soil of Palouse prairie caused by overgrazing. Journal of Forestry 41: 834–838.

Zeakes, S. J., M. F. Hansen, and R. J. Robel. 1981. Increased susceptibility of bobwhites (*Colinus virginianus*) to *Histomonas meleagridis* after exposure to Sevin insecticide. Avian Disease 25: 981–987.

Zeigler, D. L. 1979. Distribution and status of the Columbian sharp-tailed grouse in eastern Washington. Federal Aid in Wildlife Restoration Project W-70-R-18. Washington Department of Game, Olympia.

Zwickel, F. C. 1992. Blue Grouse (*Dendragapus obscurus*). The Birds of North America, No. 15 (A. Poole, P. Stettenheim, and F. Gill, editors). The Academy of Natural Sciences, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington, D.C.

Zwickel, F. C., and M. A. Schroeder. 2003. Grouse of the Lewis and Clark Expedition, 1803–1806. Northwestrn Naturalist 84: 1–19.

PERSONAL COMMUNICATIONS

Juli Anderson, Manager
Swanson Lakes Wildlife Area
Washington Department of Fish and Wildlife

Mike Atamian, Assistant District Wildlife Biologist
Washington Department of Fish and Wildlife
Spokane Valley, Washington

Nathan Burkepile, Wildlife Biologist
Wildlife Resource Management
Yakama Indian Nation
Toppenish, Washington

Jack Connelly, Principal Wildlife Research Biologist
Idaho Department of Fish and Game
Pocatello, Idaho

Scott Fitkin, District Wildlife Biologist
Washington Department of Fish and Wildlife
Wintrop, Washington

Pat Fowler, District Wildlife Biologist
Washington Department of Fish and Wildlife
Walla Walla, Washington

Gerry Green, Wildlife Mitigation Biologist
Coeur d'Alene Tribe
Plummer, Idaho

Greg Green, wildlife biologist
Ebasco Environmental
Bellevue, Washington

Christian Hagen, Sage-grouse Conservation Coordinator
Oregon Department of Fish and Wildlife
Bend, Oregon

Marc Hallet, Manager
Wells Wildlife Area
Washington Department of Fish and Wildlife

Jeff Heinlen, Assistant District Wildlife Biologist
Washington Department of Fish and Wildlife
Wintrop, Washington

Richard W. Hoffman, wildlife biologist
Colorado Department of Wildlife (retired)
Fort Collins, Colorado

Jim Olson, Manager
Scotch Creek Wildlife Area
Washington Department of Fish and Wildlife

Dale Swedberg, Manager
Sinlahekin Wildlife Area
Washington Department of Fish and Wildlife

Richard Whitney, Wildlife Biologist
Fish and Wildlife Dpartment
Colville Confederated Tribes
Nespelem, Washington

Paul Wik, Assistant District Wildlife Biologist
Washington Department of Fish and Wildlife
Clarkston, Washington

Appendix A. Washington Administrative Codes.

WAC 232-12-297 Endangered, threatened, and sensitive wildlife species classification.

PURPOSE

1.1 The purpose of this rule is to identify and classify native wildlife species that have need of protection and/or management to ensure their survival as free-ranging populations in Washington and to define the process by which listing, management, recovery, and delisting of a species can be achieved. These rules are established to ensure that consistent procedures and criteria are followed when classifying wildlife as endangered, or the protected wildlife subcategories threatened or sensitive.

DEFINITIONS

For purposes of this rule, the following definitions apply:

2.1 "Classify" and all derivatives means to list or delist wildlife species to or from endangered, or to or from the protected wildlife subcategories threatened or sensitive.

2.2 "List" and all derivatives means to change the classification status of a wildlife species to endangered, threatened, or sensitive.

2.3 "Delist" and its derivatives means to change the classification of endangered, threatened, or sensitive species to a classification other than endangered, threatened, or sensitive.

2.4 "Endangered" means any wildlife species native to the state of Washington that is seriously threatened with extinction throughout all or a significant portion of its range within the state.

2.5 "Threatened" means any wildlife species native to the state of Washington that is likely to become an endangered species within the forseeable future throughout a significant portion of its range within the state without cooperative management or removal of threats.

2.6 "Sensitive" means any wildlife species native to the state of Washington that is vulnerable or declining and is likely to become endangered or threatened in a significant portion of its range within the state without cooperative management or removal of threats.

2.7 "Species" means any group of animals classified as a species or subspecies as commonly accepted by the scientific community.

2.8 "Native" means any wildlife species naturally occurring in Washington for purposes of breeding, resting, or foraging, excluding introduced species not found historically in this state.

2.9 "Significant portion of its range" means that portion of a species' range likely to be essential to the long term survival of the population in Washington.

LISTING CRITERIA

3.1 The commission shall list a wildlife species as endangered, threatened, or sensitive solely on the basis of the biological status of the species being considered, based on the preponderance of scientific data available, except as noted in section 3.4.

3.2 If a species is listed as endangered or threatened under the federal Endangered Species Act, the agency will recommend to the commission that it be listed as endangered or threatened as specified in section 9.1. If listed, the agency will proceed with development of a recovery plan pursuant to section 11.1.

3.3 Species may be listed as endangered, threatened, or sensitive only when populations are in danger of failing, declining, or are vulnerable, due to factors including but not restricted to limited numbers, disease, predation, exploitation, or habitat loss or change, pursuant to section 7.1.

3.4 Where a species of the class Insecta, based on substantial evidence, is determined to present an unreasonable risk to public health, the commission may make the determination that the species need not be listed as endangered, threatened, or sensitive.

DELISTING CRITERIA

4.1 The commission shall delist a wildlife species from endangered, threatened, or sensitive solely on the basis of the biological status of the species being considered, based on the preponderance of scientific data available.

4.2 A species may be delisted from endangered, threatened, or sensitive only when populations are no longer in danger of failing, declining, are no longer vulnerable, pursuant to section 3.3, or meet recovery plan goals, and when it no longer meets the definitions in sections 2.4, 2.5, or 2.6.

INITIATION OF LISTING PROCESS

5.1 Any one of the following events may initiate the listing process.

5.1.1 The agency determines that a species population may be in danger of failing, declining, or vulnerable, pursuant to section 3.3.

5.1.2 A petition is received at the agency from an interested person. The petition should be addressed to the director. It should set forth specific evidence and scientific data which shows that the species may be failing, declining, or vulnerable, pursuant to section 3.3. Within 60 days, the agency shall either deny the petition, stating the reasons, or initiate the classification process.

5.1.3 An emergency, as defined by the Administrative Procedure Act, chapter 34.05 RCW. The listing of any species previously classified under emergency rule shall be governed by the provisions of this section.

5.1.4 The commission requests the agency review a species of concern.

5.2 Upon initiation of the listing process the agency shall publish a public notice in the Washington Register, and notify those parties who have expressed their interest to the department, announcing the initiation of the classification process and calling for scientific information relevant to the species status report under consideration pursuant to section 7.1.

INITIATION OF DELISTING PROCESS

6.1 Any one of the following events may initiate the delisting process:

6.1.1 The agency determines that a species population may no longer be in danger of failing, declining, or vulnerable, pursuant to section 3.3.

6.1.2 The agency receives a petition from an interested person. The petition should be addressed to the director. It should set forth specific evidence and scientific data which shows that the species may no longer be failing, declining, or vulnerable, pursuant to section 3.3. Within 60 days, the agency shall either deny the petition, stating the reasons, or initiate the delisting process.

6.1.3 The commission requests the agency review a species of concern.

6.2 Upon initiation of the delisting process the agency shall publish a public notice in the Washington Register, and notify those parties who have expressed their interest to the department, announcing the initiation of the delisting process and calling for scientific information relevant to the species status report under consideration pursuant to section 7.1.

SPECIES STATUS REVIEW AND AGENCY RECOMMENDATIONS

7.1 Except in an emergency under 5.1.3 above, prior to making a classification recommendation to the commission, the agency shall prepare a preliminary species status report. The report will include a review of information relevant to the species' status in Washington and address factors affecting its status, including those given under section 3.3. The status report shall be reviewed by the public and scientific community. The status report will include, but not be limited to an analysis of:

7.1.1 Historic, current, and future species population trends.

7.1.2 Natural history, including ecological relationships (e.g., food habits, home range, habitat selection patterns).

7.1.3 Historic and current habitat trends.

7.1.4 Population demographics (e.g., survival and mortality rates, reproductive success) and their relationship to long term sustainability.

7.1.5 Historic and current species management activities.

7.2 Except in an emergency under 5.1.3 above, the agency shall prepare recommendations for species classification, based upon scientific data contained in the status report. Documents shall be prepared to determine the environmental consequences of adopting the recommendations pursuant to requirements of the State Environmental Policy Act (SEPA).

7.3 For the purpose of delisting, the status report will include a review of recovery plan goals.

PUBLIC REVIEW

8.1 Except in an emergency under 5.1.3 above, prior to making a recommendation to the commission, the agency shall provide an opportunity for interested parties to submit new scientific data relevant to the status report, classification recommendation, and any SEPA findings.

8.1.1 The agency shall allow at least 90 days for public comment.

8.1.2 The agency will hold at least one public meeting in each of its administrative regions during the public review period.

FINAL RECOMMENDATIONS AND COMMISSION ACTION

9.1 After the close of the public comment period, the agency shall complete a final status report and classification recommendation. SEPA documents will be prepared, as necessary, for the final agency recommendation for classification. The classification recommendation will be presented to the commission for action. The final species status report, agency classification recommendation, and SEPA documents will be made available to the public at least 30 days prior to the commission meeting.

9.2 Notice of the proposed commission action will be published at least 30 days prior to the commission meeting.

PERIODIC SPECIES STATUS REVIEW

10.1 The agency shall conduct a review of each endangered, threatened, or sensitive wildlife species at least every five years after the date of its listing. This review shall include an update of the species status report to determine whether the status of the species warrants its current listing status or deserves reclassification.

10.1.1 The agency shall notify any parties who have expressed their interest to the department of the periodic status review. This notice shall occur at least one year prior to end of the five year period required by section 10.1.

10.2 The status of all delisted species shall be reviewed at least once, five years following the date of delisting.

10.3 The department shall evaluate the necessity of changing the classification of the species being reviewed. The agency shall report its findings to the commission at a commission meeting. The agency shall notify the public of its findings at least 30 days prior to presenting the findings to the commission.

10.3.1 If the agency determines that new information suggests that classification of a species should be changed from its present state, the agency shall initiate classification procedures provided for in these rules starting with section 5.1.

10.3.2 If the agency determines that conditions have not changed significantly and that the classification of the species should remain unchanged, the agency shall recommend to the commission that the species being reviewed shall retain its present classification status.

10.4 Nothing in these rules shall be construed to automatically delist a species without formal commission action.

RECOVERY AND MANAGEMENT OF LISTED SPECIES

11.1 The agency shall write a recovery plan for species listed as endangered or threatened. The agency will write a management plan for species listed as sensitive. Recovery and management plans shall address the listing criteria described in sections 3.1 and 3.3, and shall include, but are not limited to:

11.1.1 Target population objectives.

11.1.2 Criteria for reclassification.

11.1.3 An implementation plan for reaching population objectives which will promote cooperative management and be sensitive to landowner needs and property rights. The plan will specify resources needed from and impacts to the department, other agencies (including federal, state, and local), tribes, landowners, and other interest groups. The plan shall consider various approaches to meeting recovery objectives including, but not limited to regulation, mitigation, acquisition, incentive, and compensation mechanisms.

11.1.4 Public education needs.

11.1.5 A species monitoring plan, which requires periodic review to allow the incorporation of new information into the status report.

11.2 Preparation of recovery and management plans will be initiated by the agency within one year after the date of listing.

11.2.1 Recovery and management plans for species listed prior to 1990 or during the five years following the adoption of these rules shall be completed within five years after the date of listing or adoption of these rules, whichever comes later. Development of recovery plans for endangered species will receive higher priority than threatened or sensitive species.

11.2.2 Recovery and management plans for species listed after five years following the adoption of these rules shall be completed within three years after the date of listing.

11.2.3 The agency will publish a notice in the Washington Register and notify any parties who have expressed interest to the department interested parties of the initiation of recovery plan development.

11.2.4 If the deadlines defined in sections 11.2.1 and 11.2.2 are not met the department shall notify the public and report the reasons for missing the deadline and the strategy for completing the plan at a commission meeting. The intent of this section is to recognize current department personnel resources are limiting and that development of recovery plans for some of the species may require significant involvement by interests outside of the department, and therefore take longer to complete.

11.3 The agency shall provide an opportunity for interested public to comment on the recovery plan and any SEPA documents.

CLASSIFICATION PROCEDURES REVIEW

12.1 The agency and an ad hoc public group with members representing a broad spectrum of interests, shall meet as needed to accomplish the following:

12.1.1 Monitor the progress of the development of recovery and management plans and status reviews, highlight problems, and make recommendations to the department and other interested parties to improve the effectiveness of these processes.

12.1.2 Review these classification procedures six years after the adoption of these rules and report its findings to the commission.

AUTHORITY

13.1 The commission has the authority to classify wildlife as endangered under RCW 77.12.020. Species classified as endangered are listed under WAC 232-12-014, as amended.

13.2 Threatened and sensitive species shall be classified as subcategories of protected wildlife. The commission has the authority to classify wildlife as protected under RCW 77.12.020. Species classified as protected are listed under WAC 232-12-011, as amended. [Statutory Authority: RCW 77.12.020. 90-11-066 (Order 442), § 232-12-297, filed 5/15/90, effective 6/15/90.]

Appendix B. Historical distribution and abundance of Columbian sharp-tailed grouse in Washington.

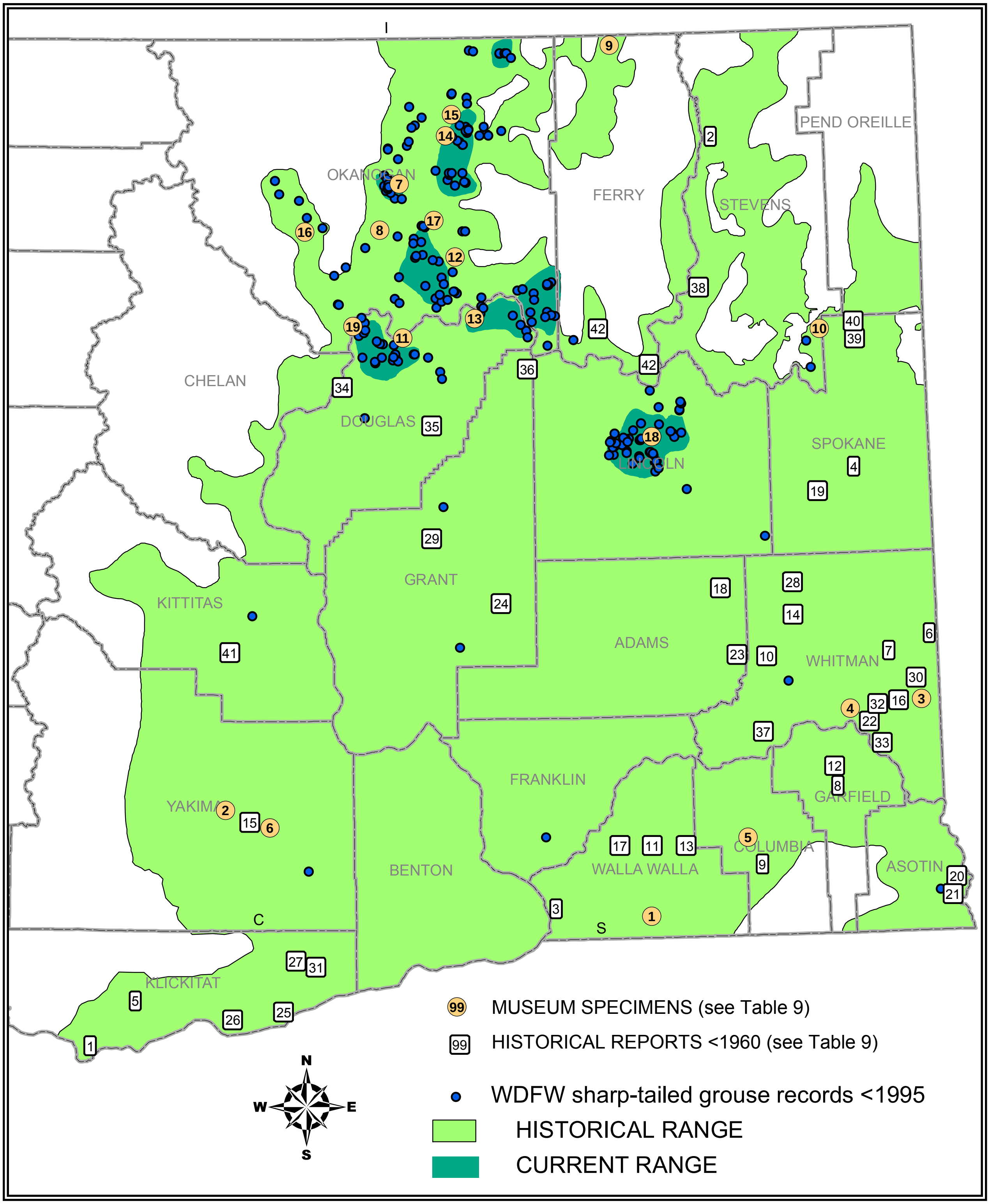


Figure 35. Historical specimens, reports, WDFW records, and approximate historical range of Columbian Sharp-tailed Grouse in Washington (see Table 10, next page) for corresponding information).

Appendix B. Historical distribution and abundance (cont'd)

Table 10. Historical specimen records and selected reports of distribution and abundance of sharp-tailed grouse in Washington (see Fig 35).

Map Point	Location	County	Year	Notes	Source or specimen number
Specimens (orange numbers on map)					
1	Fort Walla Walla	Walla Walla	1880	Female	CMNH # 62153
	Fort Walla Walla	Walla Walla	1881	Female	CMNH # 62151
	Walla Walla	Walla Walla	?	Male	ANSP # 24304
	?	Whitman	1884	Egg (12)	CAS # 6959
2	Yakima	Yakima	1887	Eggs	UWBM# 3676
	Yakima	Yakima	1905	Male	AMNH 751239
3	Pullman	Whitman	1895		WSUCM # 420
	Pullman	Whitman	1895	Female	WSUCM # 681
4	Almota	Whitman	1895	Male	USNM # 141363
5	Dayton	Columbia	1897	Eggs (9)	SMUPS # 13571
	Dayton	Columbia	1897	Eggs (10)	CM # 899
	Dayton	Columbia	1897	Eggs (15)	WFVZ
	Dayton	Columbia	1897	Egg (10)	WFVZ
	Dayton	Columbia	1898	Eggs (8)	WFVZ
	Dayton	Columbia	1898	Egg	USNM # B43523
6	Toppenish	Yakima	1897		USNM # 157956
7	Conconully	Okanogan	1897		USNM # 157955
	Conconully	Okanogan	1897	Male	USNM # 157957
8	Okanogan	Okanogan	1906	Male	USNM # 270794
9	Danville	Ferry	1907	Female	USNM # 271895
	Danville	Ferry	1908	Female	USNM # 271896
10	Loon Lake	Stevens	1909	Female	No number assigned
11	Bridgeport	Douglas	1910	Female	WSUCM # 40-3
	?	Douglas	1952	Female	WSUCM # 53-22
	?	Douglas	1952	Male	WSUCM # 53-23
	?	Douglas	1952	Female	WSUCM # 53-24
	Bridgeport	Douglas	1973	Female	UWBM # 33950
	Bridgeport	Douglas	1975	Female	UWBM # 31342
12	Omak Lake	Okanogan	1953	Male	UWBM # 12175
13	Del Rio	Douglas	1953	Male	WSUCM # 54-115
14	Tonasket	Okanogan	1954	Female	WSUCM # 54-73
	Tonasket	Okanogan	1954	Female	WSUCM # 54-74
15	Mosquito Creek	Okanogan	1954	Male	WSUCM # 54-113
	Mosquito Creek	Okanogan	1954	Male	WSUCM # 54-114
16	Twisp	Okanogan	1960	Male	WSUCM # 61-214
	Riverside	Okanogan	1961	Male	SMUPS # 07052
17	Riverside	Okanogan	1961	Male	SMUPS # 07054
	Riverside	Okanogan	1961	Female	SMUPS # 07051
	Riverside	Okanogan	1961	Female	SMUPS # 07053
18	T24N R34E S4	Lincoln	1975		UWBM # 33419

Map Point	Location	County	Year	Notes	Source or specimen number
	T24N R34E S4	Lincoln	1975	male	UWBM # 33420
19	Central Ferry Canyon	Douglas	1979	male	UWBM # 33090
	Central Ferry Canyon	Douglas	1979	female	UWBM # 33091
	River	?	?		USNM # 429140
	Sinyakwateen	Okanogan	?		USNM # 022011
Historical Reports, prior to 1960 (white numbers on map)					
1	Dallesport vicinity	Klickitat	1805	Lewis & Clark Expedition shot 2	Zwickel and Schroeder (2003)
	Dallesport vicinity	Klickitat	1855	Young chicks	Suckley (1860)
2	Kettle Falls vicinity	Stevens	1826	Abundant	Douglas (1914)
	Kettle Falls vicinity	Stevens	1860	Vast numbers in stubble fields	Lord (1866:304)
	Kettle Falls vicinity	Stevens	1915	3 nests	Jewett (1953:215)
3	Wallula	Walla Walla	1834	Shot 22 in 1 day	Townsend (1987[1839])
4	Spangle	Spokane	1873	Frequent part of settler's diet	Hergen (1990?:93)
5	Klickitat Valley	Klickitat	1861	Thousands	Attwell (1977)
	Klickitat Valley	Klickitat	1860-70s	Large flocks in every part of the valley	Ballou (1938)
6	Palouse River near Palouse	Whitman	1877	Thousands	Kincaid and Harris (1979)
7	Colfax	Whitman	1880	Many	Downen (1977)
8	Pomeroy vicinity	Garfield	1880s	Found in almost limitless numbers; great flocks in cottonwoods along Pataha Crk after heavy snow	Kuykendall (1984)
9	S. Touchet River, 5 mi SE Dayton	Columbia	1890	Hundreds came to creek bottoms after heavy snow	O. Payne (Buss and Dziedzic 1955)
10	Rock Creek	Whitman	1902	Abundant, last single record 1947	F. Weidrich (Yocum1952)
11	Touchet Creek	Walla Walla	1903	Abundant	Snodgrass (1904)
12	[county]	Garfield	1903	A few seen	Snodgrass (1904)
13	Prescott vicinity	Walla Walla	1906	Abundant	Dice (1918)
14	Cherry Creek	Whitman	1908	Very numerous	W. Hegler (Yocum 1952)
15	Yakima Valley	Yakima	1909	Common, but absent by 1914	Kennedy (1914)
16	Pullman vicinity	Whitman	1910	50-75 birds on ranch, none after 1915	L.Hall (Buss and Dziedzic 1955)
	Pullman vicinity	Whitman	1941	2 seen	H. Eastlick (Yocum 1952)
17	Eureka	Walla Walla	1914	"A number seen in the grain fields and bunchgrass hills"	Dice 1918
18	Karakul Hills	Adams	1920s	Common	Ritzville H.S. Freshman class (1978)
19	Turnbull Slough	Spokane	1933	75; common in	Yocum (1952)

Map Point	Location	County	Year	Notes	Source or specimen number
				1930s	
20	Snake Riv. Breaks E of Anatone	Asotin	1938	2 seen	E&F. Hendrickson (Yocum 1952)
21	Anatone vicinity: 4-5 mi E, 4 mi S	Asotin	1936-40	A brood and small numbers seen	Yocum (1952)
22	Almota	Whitman	1939	17 seen; a few persisted to 1941	J. Drolet (Yocum 1952)
23	Twelve Mile Slough	Adams	<1940	Present unitl about 1940	Yocum (1952)
24	Moses Lake	Grant	1940	Small group present past several years	Larrison (1942)
25	Columbia breaks, Sundale-Roosevelt	Klickitat	1940	Flock of 6 seen; a few present N of Sundale	Yocum (1952)
26	Goodnoe Hills	Klickitat	1940	Flock of 10-15	H. Bryant (Yocum 1952)
27	Wood Gulch	Klickitat	1940	A flock seen	Yocum (1952)
28	Rock Lake	Adams	1941	3 seen S end of lake	Yocum (1952)
29	Ephrata, 1 mi S	Grant	1942	1 male along highway	Larrison (1942)
30	Whelan	Whitman	1942	5 seen around farm in summer	R. Held (Yocum 1952)
31	Alder Crk, 7 mi SE Bickleton	Klickitat	1945	A small flock	N. Mattsen (Yocum 1952)
32	Almota Cr/Little Almota Cr.	Whitman	1949	Flock of 10	E. Larrison (Yocum 1952)
	Almota, NE of	Whitman	1949	About 25 seen	Yocum (1952)
33	Wawawai	Whitman	1949	Pair flushed several dates	D. Earp, A, Canaris (Yocum 1952)
34	Columbia breaks, S to Waterville	Douglas	1952	A few present	R. Schwindel (Yocum 1952)
35	Jameson Lake	Douglas	1952	A few present	R. Schwindel (Yocum 1952)
36	S of Electric City	Grant	1952	Present in scablands E side Grand Coulee	R. Schwindel (Yocum 1952)
37	Hay vicinity	Whitman	1952	A few still present	Yocum (1952)
38	Hunters and Cedonia	Stevens	1950s	May be present	Yocum (1952)
	Snake River breaks		1954	A few still present	Hudson and Yocum (1954)
39	Deer Park Airport	Spokane	1959	Lek of 50; dwindled to2 in 1964, last active	Zeigler (1979)
40	Eloika Lake	Spokane	Late 1950s	Small lek	Zeigler (1979)
41	Ellensburg	Kittitas	?		A. Fisher (Jewett et al. 1953)
42	Colville Reservation, eastern part	Ferry	1940-70s	Abundant in 1940s, present through 1970s	S. Judd (Merker 1988)

[a]Museum abbreviations: AMNH = American Museum of Natural History, New York, New York; ANSP = The Academy of Natural Sciences, Philadelphia, Pennsylvania; CAS = California Academy of Sciences, San Francisco; CM = The Carnegie Museum of Natural History, Pittsburgh, Pennsylvania; CMNH = The Cleveland Museum of Natural History, Cleveland, Ohio; SMUPS = Slater Museum, University of Puget Sound, Tacoma; USNM = Smithsonian Institution National Museum of Natural History, Washington, D.C.; UWBM = University of Washington, Burke Museum, Seattle; WFVZ = Western Foundation of Vertebrate Zoology, Camarillo, California;

Appendix C. Parasites documented in sharp-tailed grouse (modified from Peterson 2004).

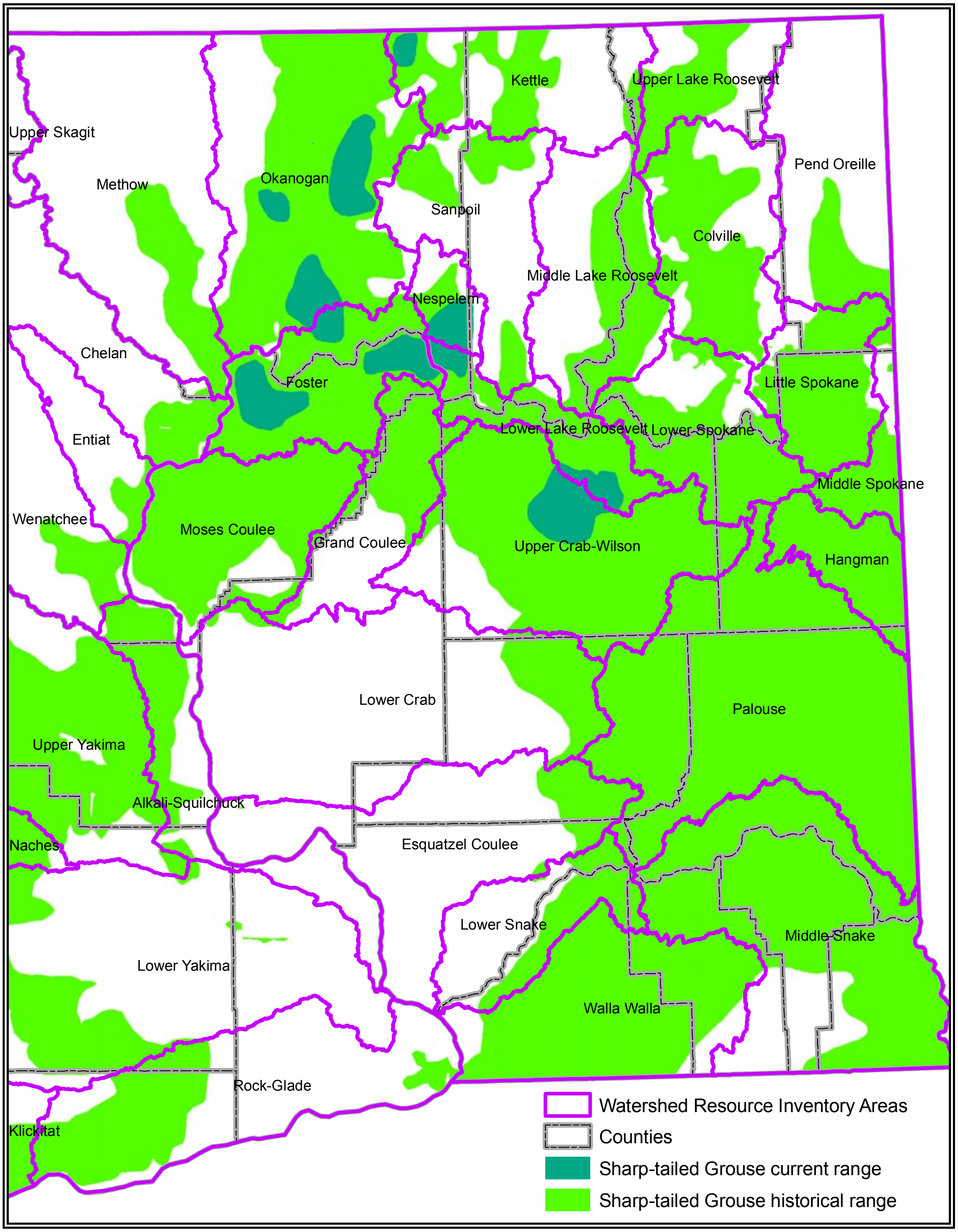
Parasite	Locations	Intermediate host or vector	References
Mallophaga (lice)			
Amyrsidea sp.	MB, WI		16, 30
A. perdicis	SD		20
Goniodes sp.	ON, WI		2, 31
G. nebraskensis	MB, MT, NE, ND, SD, ON, WA		16, 20, 30
Lagopoecus gibsoni	MB		30
Lagopoecus perplexus	ON, SD, WA		1, 14, 16, 20
Mites			
Ornithonyssus sylviarum	MB		30
Unidentified sp.	SD		20
Ticks			
Haemaphysalis sp.	MN		3
H. chordeilis	MB, SD		20, 30
H. leporispalustris	MB, MI, SD, WI		2, 10, 20, 30
Diptera (Hippoboscidae?)			
Ornithoyia anchineuria	MB		30
Nematodes			
Ascaridia galli	MN, WI		12, 13
Capillaria contorta (crop)	WI		13
Cheilospirura spinosa (gizzard)	SD, WI	Grasshoppers	12, 13
Cyrenia colini (proventriculus)	SD, WI	Grasshoppers (*Melanoplus* spp.)	12, 20
Dispharynx nasuta	SD	Isopods (*Porcellio scabes*, *Armadillidium vulgare*)	20
Gongylonema phasianella	NE	Arthropod?	8
Heterakis gallinarum	SD, WI	Earthworms or direct	12, 13
Oxyspirura petrowi (eyeworm)	MI, SD	Insect?	5, 12, 23
Physoloptera sp.	MN, SD		12, 25
Splendidofilaria pectoralis	BC, AK	Black flies or biting midge?	22
Subulara strongylina (caecum)	SD, WI		12, 13, 20
Cestodes (tapeworms)			
Choanotaenia infundibulum	MN, WI		12, 13
Raillietina centrocerci	ND, SD		20, 24, 25
R. variabilis	ND, WI		2, 15
Rhabdometra nullicollis	MN, ND, SD, WI		2, 12, 13, 15
R. odiosa	QC		4
Trematodes			
Agamodistomum sp.	MN	Gastropods	12
Athesmia wehri	MT	Gastropods	7
Brachylaima furcatum	AK	Gastropods	17
Echinostoma revolutum	SD	Gastropods	25
Hematozoa			
Leucocytozoon sp.	MI		5, 10
L. bonasae	MI, WI	Blackflies & midges	18, 19
Plasmodium pediocetii	ND, CO		11, 14
Trypanosoma avium	CO	Blackflies	21, 26
Haemoproteus mansoni	?	Midges & hippoboscids	29
Other protozoans			
Eimeria dispersa (coccidia)	MN, WI		12, 13
Eimeria angusta (coccidia)	MN, WI		12, 13
Histomonas maleagridis (flagellated protozoan)	?	*Heterakis gallinarum* direct or via earthworms	32 (assumed)

	Parasite	Locations	Intermediate host or vector	References
	Sarcocystis sp.	AB	Unknown vertebrate	28
Bacteria				
	Francisella tularensis (etiological agent of tularemia)	MN	*H. leporispalustris* (tick)	3
	Clostridium colinum (causes ulcerative enteritis)	Captive birds		6
	Mycoplasma sp.	?		32 probable
	Clamydophila psittici	?		32 probable
Fungi				
	Trichophyton sp. (ringworm)	SD		25

References:

1 Kellogg 1899
2 Gross 1930
3 Green and Shillinger 1932
4 Swales 1934
5 Saunders 1935
6 Morely and Wetmore 1936
7 McIntosh 1937
8 Shillinger and Morely 1937
9 Wehr 1938
10 Baumgartner 1939
11 Wetmore 1939
12 Boughton 1937
13 Morgan and Hammerstrom 1941
14 Shillinger 1942
15 Aldous 1943
16 Emerson 1951
17 Babero 1952
18 Flakas 1952
19 Cowan and Peterle 1957
20 Boddicker and Hugghins 1965
21 Stabler et al. 1966
22 Gibson 1967
23 Addison and Anderson 1969
24 Bernhoft 1969
25 Hillman and Jackson 1973
26 Stabler et al. 1974
27 Stabler and Kitzmiller 1976
28 Drouin and Marht 1979
29 White and Bennett 1979
30 Dick 1981
31 Tsuji et al. 2001
32 Peterson 2004

Appendix D. Watershed Resource Inventory Areas and historical and current sharp-tailed grouse range in Washington.



WASHINGTON STATE STATUS REPORTS AND RECOVERY PLANS

Status Reports

2007	Bald Eagle	√
2005	Mazama Pocket Gopher, Streaked Horned Lark, and Taylor's Checkerspot	√
2005	Aleutian Canada Goose	√
2004	Killer Whale	√
2002	Peregrine Falcon	√
2000	Common Loon	√
1999	Northern Leopard Frog	√
1999	Olympic Mudminnow	√
1999	Mardon Skipper	√
1999	Lynx Update	
1998	Fisher	√
1998	Margined Sculpin	√
1998	Pygmy Whitefish	√
1998	Sharp-tailed Grouse	√
1998	Sage-grouse	√
1997	Aleutian Canada Goose	√
1997	Gray Whale	√
1997	Olive Ridley Sea Turtle	√
1997	Oregon Spotted Frog	√
1993	Larch Mountain Salamander	
1993	Lynx	
1993	Marbled Murrelet	
1993	Oregon Silverspot Butterfly	
1993	Pygmy Rabbit	
1993	Steller Sea Lion	
1993	Western Gray Squirrel	
1993	Western Pond Turtle	

Recovery Plans

2007	Western Gray Squirrel	√
2006	Fisher	√
2004	Sea Otter	√
2004	Greater Sage-Grouse	√
2003	Pygmy Rabbit: Addendum	√
2002	Sandhill Crane	√
2001	Pygmy Rabbit: Addendum	√
2001	Lynx	√
1999	Western Pond Turtle	√
1996	Ferruginous Hawk	√
1995	Pygmy Rabbit	√
1995	Upland Sandpiper	
1995	Snowy Plover	

√ These reports are available in pdf format on the Department of Fish and Wildlife's web site: http://wdfw.wa.gov/wlm/diversty/soc/concern.htm.
To request a printed copy of reports, send an e-mail to wildthing@dfw.wa.gov or call 360-902-2515.