MODELING COLUMBIAN SHARP-TAILED GROUSE LEK OCCUPANCY TO GUIDE SITE SELECTION FOR TRANSLOCATIONS AND SPECIES POPULATION RECOVERY

by

Stacey A. Plumley

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This Thesis for the Master of Environmental Studies Degree

by

Stacey A. Plumley

has been approved for

The Evergreen State College

by

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Dina Roberts, Ph. D.
Member of the Faculty

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Date

ABSTRACT

Modeling Columbian Sharp-tailed Grouse lek
occupancy to guide site selection for
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A fundamental step in conserving biodiversity is identification of existing habitat areas that could potentially sustain populations of target species. Animals can be translocated to suitable habitat to re-establish populations and expand the target species' range. Columbian Sharp-tailed Grouse (*Tympanuchus phasianellus columbianus*) (hereafter STG) were historically abundant in eastern Washington before native vegetation was converted to agriculture and livestock grazing in the early 20th century. Currently, there are only seven isolated STG populations in Washington that total less than 1,000 birds. This study identified potential habitat for STG translocations within their historical range in Washington. Two logistic regression models were used to compare the influence of environmental variables on STG occupancy at active (n = 40) and inactive lek complexes (n = 41). Each environmental variable was assessed at three scales from the leks: typical STG flight distance (1 km radius), spring/summer habitat area (3 km radius), and winter habitat area (10 km radius). Habitat identified by the first model was analyzed for habitat patch metrics at the three scales. The patch metrics, percent area of habitat and maximum habitat patch size, were included with the original environmental variables to develop the second model. Both models selected for mean elevation at two scales (10 and 1 km) and for road density (1 km). The first model also included percent grassland habitat (3 km) and the second model included percent habitat area (3 km). Ten potential habitat areas greater than 50,000 ha were identified. These areas were located on the periphery of the STG historical range, at higher elevations, similar to habitat locations of extant STG populations. Some potential habitat contained areas of agriculture, forest, and steep slopes–these areas would not be suitable for STG and further on-the-ground assessment is needed to determine the overall potential of the habitat.

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CHAPTER 1 LITERATURE REVIEW

INTRODUCTION

The current rate of species extinction due to human caused habitat loss, fragmentation, and degradation is at least 100 times the rate of extinction characterized by the fossil record (MEA 2005). According to the International Union for Conservation of Nature and Natural Resources' Red List of Threatened Species, 41% of amphibian, 25% of mammal, and 13% of bird species are at high risk for extinction (IUCN 2013). Many imperiled wildlife species and associated habitats are actively managed in an attempt to increase threatened populations and ensure their survival (Frankham, Ballou, and Briscoe 2002). In the U.S., the Endangered Species Act and state laws protect imperiled species and require actions to increase species' populations such as species monitoring, management, and habitat restorations (USFWS 2013).

In Washington State, Columbian Sharp-tailed Grouse (*Tympanuchus phasianellus columbianus*) (hereafter STG) is a state listed threatened species. STG were once an abundant game bird in eastern Washington until significant portions of their habitat were converted to agriculture and livestock grazing in the early 20th century (Yocom 1952). Currently, there are less than 1,000 STG in Washington occurring in seven isolated populations (Stinson and Schroeder 2012). Efforts to increase the overall population numbers in Washington have included habitat restoration and management, and translocation of birds from larger populations to augment existing populations (Schroeder et al. 2012; Stinson and Schroeder 2012). Additional translocations are planned to re-establish STG populations within their historical range in Washington but the best locations for the translocations still need to be identified (M. Schroeder, personal communication, October 8, 2013). This thesis research was undertaken to identify potential translocation sites by comparing the influence of environmental variables on STG occupancy at current habitat areas and historical, unoccupied habitat areas (Tack 2006; Aldridge et al. 2008).

The purpose of the literature review is to examine the relevant research related to this thesis beginning with a brief overview of human land use change and the subsequent negative impacts to wildlife populations. Efforts to protect and restore imperiled species in the U.S. with enactment of the Endangered Species Act and implementation of species recovery plans is discussed next. The last section of the literature review focuses on STG and how this species and its habitats are being managed in Washington to increase and restore healthy populations. The last section concludes with a review of STG habitat studies to summarize the current knowledge of the resource needs of the species and provide a foundation for this research.

In addition to the literature review, this thesis contains two other chapters. The second chapter is a complete account of the thesis research presented in a manuscript format including a brief summary of the literature review and the research methods and results, discussion, and management recommendations. The third chapter provides further analysis of two potential habitat areas in Okanogan County that were identified by the model and discusses ways to improve the STG model.

LOSS OF WILDLIFE BIODIVERSITY

Globally, the most direct driver of biodiversity loss in terrestrial ecosystems has been land use change resulting from the expansion of human populations and activities (Sala et al. 2000; Gaston, Blackburn, and Goldewijk 2003; Foley et al. 2005; MEA 2005). As humans settle new areas, native vegetation is converted to agriculture, pastures, or other uses to provide food, fuel, shelter, and other natural resources. (MEA 2005; Primack 2010). Today, agriculture and livestock pastures are the largest terrestrial land use, occupying approximately 40% of the global land surface (Ramankutty, Foley, and Olejniczak 2002; Asner, Elmore, Olander, Martin, and Harris 2004). Land use change destroys and degrades habitat for many wildlife species which can negatively impact their populations (Pimm and Raven 2000). In areas with higher habitat loss, species show declining trends in global abundance compared to species with increasing or stable trends for habitat (Donovan and Flather 2002). When habitat is lost from land use modifications, the quality of the remaining habitat is affected as it becomes fragmented into smaller patches that are surrounded by a matrix of different land uses such as agriculture or development (Wilcove, McLellan, and Dobson 1986; van den Berg, Bullock, Clarke, Langston, and Rose 2001). The amount of habitat in these patches is further reduced by edge effects, especially for specialist species that have specific habitat needs. Edge effects extend up to 100 m into habitat patches and include increased predation, increased numbers of invasive plant species, and additional changes to plant community structure from differences in moisture, temperature, and sunlight (Odell 2003; MEA 2005; Primack 2010).

Habitat loss and fragmentation may limit the ability of animals to move among habitat patches to find food, mates, shelter, and other resources they need (Crooks and Sanjayan 2006). A combination of the composition and configuration of the landscape, a wildlife species' ecological requirements, and its dispersal ability, determines how well an animal is able to move among habitat patches in a landscape (Crooks and Sanjayan 2006). This combination of factors establishes the structure of wildlife populations in fragmented landscapes. Frankham (2006) described several different wildlife population structures such as, source and sink, stepping stones, metapopulations, and isolated populations. Source and sink, stepping stones, and metapopulations are characterized by animals with medium to high dispersal abilities that are able to move among habitat patches. Source and sink wildlife populations structures are similar to a mainland and island structure where animals on the island migrate from the mainland. Stepping stones wildlife population structures consist of neighboring wildlife populations that are able to migrate among habitat patches. Metapopulation structure consists of random cycles of colonization, extinction, and recolonization of wildlife populations in small fragmented habitat areas. Larger subpopulations of wildlife species provide the source of migrants to recolonize the small areas of habitat. Dispersal among subpopulations is an important component of managing wildlife species in fragmented landscapes. Finally, some wildlife populations may become isolated on "islands" of habitat. These wildlife populations are unable to move among habitat patches because of the surrounding land use matrix, low dispersal abilities, and/or special habitat needs that prevent them from dispersing in highly fragmented landscapes (MEA 2005).

Small, isolated wildlife populations are at a greater risk for extinction due to the combined effects of habitat loss, low genetic diversity, and environmental variability or stochastic environmental events (Gilpin and Soule 1986; Pimm and Raven 2000; Frankham 2005). Isolated wildlife populations may be at a higher risk for developing low genetic diversity over time (Frankham 2006). Low genetic diversity can result in inbreeding depression which is characterized by low mating success, higher offspring mortality, and offspring that are weak or sterile (Frankham et al. 2002). In addition, low genetic diversity can negatively affect the ability of a population to adapt to short-term and long-term environmental change. Short-term environmental stochastic events such as changes in the number of predators, disease organisms, abundance of food, weather, etc, can lead to fluctuations in population size (Frankham et al. 2002; Frankham 2005; Primack 2010). Species that have larger population size and genetic diversity have a greater ability to recover from reductions in population size compared to small populations with low genetic diversity (Frankham et al. 2002; Frankham 2005; Primack 2010). Genetic diversity is also required for species to adapt to long-term environmental change, such as climate change, through evolutionary processes. Small populations with low genetic diversity have an increased risk of extinction since they have little ability to evolve to cope with long-term environmental change (Frankham et al. 2002; Primack 2010).

. EFFORTS TO PROTECT AND RESTORE WILDLIFE BIODIVERSITY

The U.S. Endangered Species Act

> "Under the Endangered Species Act, species may be listed as either endangered or threatened. 'Endangered' means a species is in danger of extinction throughout all or a significant portion of its range. 'Threatened' means a species is likely to become endangered within the foreseeable future" (USFWS 2013).

To maintain or restore wildlife biodiversity, imperiled species and their habitats are actively managed and protected under the U.S. Endangered Species Act (ESA) and/or similar state laws. The ESA prohibits the harm of listed species including harassing, wounding, killing, or capturing and also actions that significantly alter a species' habitat resulting in impairment of the species' ability to survive (USFWS 2013). The ultimate goal of the ESA is to recover a species so that it no longer needs protection (USFWS 2013). In pursuit of this goal, the ESA mandates that science based recovery plans are written for each listed species to determine and implement the steps needed to restore and ensure the long-term survival of the species (USFWS 2013). Wildlife populations that have experienced significant reductions in their statewide historical range may be state listed as threatened or endangered even if they are not listed under the ESA. For example, in Washington State, a species may be listed "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" (WAC 232-12-297). The intent of the law is to protect and ensure the survival of the listed species as free-ranging populations in Washington. In support of that goal, the law requires a recovery plan for all listed species that provides information on recovery goals for target populations and implementation strategies for reaching those goals. Implementation strategies can include: regulation, mitigation, acquisition, incentives and compensation mechanisms, public education, and species monitoring.

Habitat restoration, translocations, and habitat models

Implementation of the ESA and state recovery plans for listed species includes measures such as monitoring populations through field surveys, assessing existing habitat conditions, and restoring and managing the species' habitat (WAC 232-12-297; Stinson and Schroeder 2012; USFWS 2013). Land acquisitions may also be undertaken to increase habitat areas or improve connectivity of habitat patches (WAC 232-12-297; Stinson and Schroeder 2012). In addition, small populations that are isolated and have low genetic diversity may be augmented by translocated animals from larger, more genetically robust populations (Stinson and Schroeder 2012). Translocated animals can significantly increase genetic diversity and restore reproductive fitness to populations that exhibit inbreeding depression (Westemeier et al. 1998; Frankham et al. 2002).

Ongoing monitoring of wildlife populations provides information such as, population size, seasonal movement patterns, and nesting, foraging, and breeding habitat preferences (Giesen 1997; McDonald 1998; Boisvert, Hoffman, and Reese 2005; Goddard, Dawson, and Gillingham 2009; Stonehouse 2013). Information from monitoring can be used to create models that identify species' resource needs (Giesen 1997; Stonehouse 2013) and suitability of habitat (Goddard et al. 2009).

Habitat suitability models provide important information about species' resource requirements based on the characteristics, amount, and spatial arrangement of habitats that are selected by existing populations (Brambilla et al. 2009). Habitat suitability models are based on species' life stages and seasonal habitat requirements for food, cover, water, and reproduction (USFWS 1981). Recent habitat suitability models used a geographic information system (GIS) to combine geospatial data of species' locations with environmental parameters. These models can identify the ecological minimums that limit occupancy by comparing the differences between currently occupied habitat areas and unoccupied areas (Aldridge et al. 2008; Wisdom, Meinke, Knick, and Schroeder 2011; Knick, Hanser, and Preston 2013). Habitat suitability models can inform land management decisions about conservation or restoration efforts for habitat areas that are important for maintaining or increasing wildlife populations (Edgley 2001; Rittenhouse et al. 2008; Aldridge, Saher, Childers, Stahlnecker, and Bowen 2012; Stonehouse 2013). In addition, habitat areas can be assessed based on model outcomes to determine suitability for re-introducing wildlife populations in those areas (Ramsey, Black, Edgley, and Yorgason 1999; Edgley 2001; Fitzpatrick 2003).

COLUMBIAN SHARP-TAILED GROUSE

Columbian Sharp-tailed Grouse (hereafter STG) are one of six existing subspecies of Sharp-tailed Grouse in North America (Johnsgard 1973). STG are the smallest of the subspecies and have darker gray plumage, more pronounced spotting on the throat, and narrower markings on the underside (Figure 1) (Connelly, Gratson, and Reese 1998). They typically walk or fly short distances (0.4–0.8 km) but are capable of flying longer distances (3.2–4.8 km) (Stinson and Schroeder 2012). STG gather in the spring at leks where males engage in elaborate courtship displays to attract mates (Giesen and Connelly 1993; Stinson and Schroeder 2012). Male and female STG have high fidelity to leks, often returning to the same lek every spring although lek locations can also shift over time or be abandoned (Stinson and Schroeder 2012).

Figure 1. Photo of Columbian Sharp-tailed Grouse. By Michael A. Schroeder (WDFW).

Habitat range and population

Western North America

STG historically ranged from British Columbia, Washington, Oregon, California, Nevada, Idaho, Utah, Montana, Colorado, and Wyoming and were a plentiful and important game bird (Figure 2) (Yocom 1952; Aldrich 1963). Settlement and conversion of native vegetation to agriculture and livestock grazing in the early 20th century coincided with a massive reduction in STG populations and habitat range (Yocom 1952). Today, they are the rarest subspecies, having lost 90% of their historical range in Idaho, Utah, Wyoming, and Washington (Bart 2000). Three large populations that occur on the border between Colorado and Wyoming, Idaho and Utah, and within British Columbia comprise over 93% of all STG (Bart 2000). These three populations are reported to be either stable or increasing (Bart 2000). Small populations also exist in Washington and were re-introduced in Nevada and Oregon where they had previously been extirpated (Stinson and Schroeder 2012). Populations have also been extirpated from California and Montana (Stinson and Schroeder 2012).

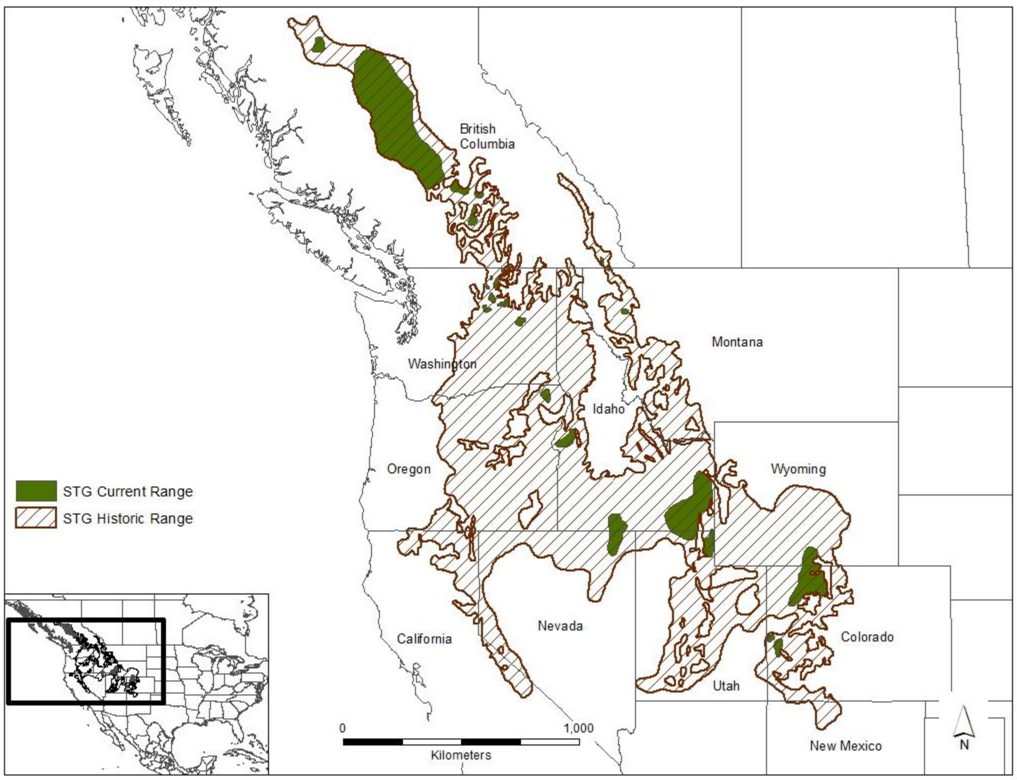

Figure 2. Current and historical range of Columbian Sharp-tailed Grouse in North America.

Washington

STG were historically abundant and widely distributed in the grassland steppe, meadow steppe, and the shrub-steppe ecosystems in eastern Washington (Figure 3) (Yocom 1952; Schroeder, Hays, Murphy, and Pierce 2000; Stinson and Schroeder 2012). The grassland steppe and meadow steppe ecosystems of the Palouse Prairie in southeastern Washington was characterized by deep, loess soils that supported native grassland vegetation dominated by Idaho fescue (*Festuca idahoensis*), bluebunch wheatgrass (*Agropyron spicatum*), and Sandberg bluegrass (*Poa secunda*) (Bunting, Kingery, and Schroeder 2003). The Palouse was rapidly settled and by 1895, most of the tillable land had been converted to agriculture (Stinson and Schroeder 2012). By the middle of the 20th century, STG had been extirpated from the Palouse region of eastern Washington (Stinson and Schroeder 2012). Native shrub-steppe vegetation communities in eastern Washington predominately contained big sagebrush (*Artemisia tridentata*) and three-tipped sagebrush (*Artemisia tripartita*) in association with bluebunch wheatgrass (*Agropyron spicatum*) (Daubenmire 1988). Shrub-steppe communities once covered most dryland areas of eastern Washington extending from the forest edge of the North Cascades to the Palouse Prairie (Dobler, Eby, Perry, Richardson, and Vander Haegen 1996). The shrub-steppe ecosystems also had substantial populations of STG historically before widespread conversion of the land to agriculture and livestock grazing in the early 20th century (Yocom 1952; Schroeder et al. 2000; Stinson and Schroeder 2012). Early settlers grew wheat using dryland farming techniques and livestock grazing occurred in areas that were not suitable for farming (Stinson and Schroeder 2012).

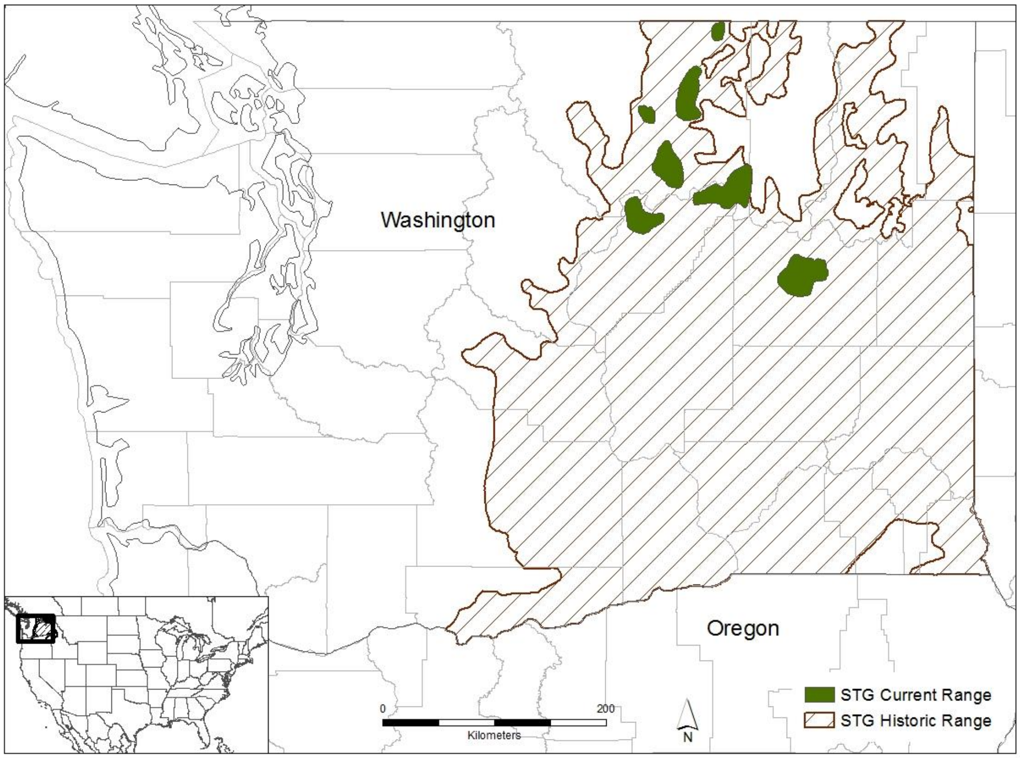

Figure 3. Current and historical range of Columbian Sharp-tailed Grouse in Washington.

The combination of agriculture, livestock grazing, and other land use change in eastern Washington greatly decreased and fragmented native shrub-steppe habitat. Sagebrush cover in the historical range of STG in Washington decreased from approximately 44.1% in 1900 to 15.6% by 1990 (McDonald and Reese 1998). Mean habitat patch size, comprised of sagebrush and grassland habitats, also decreased by 36%, from 4,474 ha in 1900 to 2,857 ha in 1990

(McDonald and Reese 1998). Currently, STG occur in seven isolated shrub-steppe habitats in Douglas, Lincoln, and Okanogan counties on a total area of approximately 217,300 ha or approximately 2.7% of their estimated historical range in Washington (Figure 3) (Schroeder et al. 2000; Stinson and Schroeder 2012). Estimated numbers of STG in Washington totaled 916 in 2013 (Table 1) (Stinson and Schroeder 2012).

Table 1. The distribution of current populations of Columbian Sharp-tailed Grouse in Washington.

Population	Est. Population Size (2013)	Area (ha)	Density
Chesaw	50	7,000	0.007
Crab Creek/Swanson Lakes	98	52,100	0.002
Dyer Hill	80	30,800	0.003
Greenaway Spring	60	34,000	0.002
Nespelem	438	51,300	0.009
Scotch Creek	54	7,900	0.007
Tunk Valley	136	34,200	0.004
Total	916	217,300	

The distance between existing STG populations ranges from 22.28 km to 46.19 km with a mean of 28.16 km. STG can move further than 20 km (Boisvert et al. 2005). However, the intervening matrix of croplands, roads, and transmission lines can make movement between highly fragmented habitat more difficult for STG (Robb and Schroeder 2012). Existing STG populations in

Washington are unable to readily disperse beyond their habitat areas to interbreed with other populations or find new sources of food or cover. Their small population size and isolation put them at risk of extirpation from Washington (Bart 2000; Stinson and Schroeder 2012).

Emerging threats

Wind energy development

In addition to habitat loss and fragmentation from agriculture and livestock grazing, wind energy development is an expanding land use in the arid lands of western U.S. that could negatively impact STG populations (Robb and Schroeder 2012; Stinson and Schroeder 2012). In eastern Washington, there are 1,527 existing turbines and 300 more under construction within the historical range of STG (Stinson and Schroeder 2012). Wind energy development includes turbines and associated infrastructure such as roads and transmission lines which can have direct and indirect impacts on STG populations. Wind turbines are a potential threat to STG populations through direct mortality from collisions (Manville 2004) and indirect effects over time (Harju, Dzialak, Taylor, Hayden-Wing, and Winstead 2010). Roads can negatively impact STG populations due to habitat fragmentation, road avoidance behavior, noise, and direct mortality (Manville 2004; Pruett, Patten, and Wolfe 2009; Robb and Schroeder 2012; Stonehouse 2013). Roads are also conduits for invasive plant species which can further degrade areas of native vegetation (Gelbard and Belnap 2003). Roads and transmission lines from energy development can be a source of direct mortality from collisions (Wolfe, Patten, Shochat, Pruett, and Sherrod 2007) and potentially increase habitat fragmentation from avoidance behavior (Manville 2004; Pruett et al. 2009; Stonehouse 2013). In addition, unimproved roads, transmission lines, and right-of-ways may increase predation of STG by providing corridors for mammalian predators and increase perching opportunities for raptors (Pitman, Hagen, Robel, Loughin, Applegate 2005; Wolfe et al. 2007).

Climate change

Climate change is predicted to exacerbate species extinction especially for species like STG that are already at high risk for extinction due to small population size, low dispersal ability, and special habitat needs (MEA 2005). Improving species ability to move through the landscape is the most often recommended adaptation strategy for climate change (Heller and Zavaleta 2009 and references therein). However, even with improved connectivity between habitat patches, species may be unable to migrate fast enough to adjust to climate change and may need to be translocated to more suitable habitat areas (Davis and Shaw 2001; Heller and Zavaleta 2009 and references therein). Climate change models are predicting significant change to sagebrush habitats including higher summer temperatures, more variable and severe weather events, and wetter winter seasons (Neilson, Lenihan, Bachelet, and Drapek 2005). Warming temperatures could reduce the distribution of sagebrush and change the vegetation composition to favor expansion of invasive species such as cheatgrass (*Bromus tectorum*) and woody vegetation which is more fire prone (Neilson et al. 2005). Big sagebrush in shrub-steppe ecosystems does not re-sprout after burning and must be re-colonized by seed (Stinson and Schroeder 2012). Reductions in the amount of sagebrush and/or more frequent fires could have significant impacts on STG and other shrub-steppe species (Connelly, Schroeder, Sands, and Braun 2000; Bunting et al. 2003).

Efforts to recover Columbian Sharp-tailed Grouse populations in Washington

Endangered Species Act listing

STG were petitioned for federal listing under the Endangered Species Act (ESA) in 1995. The U.S. Fish and Wildlife Service (USFWS) concluded that listing was not warranted because three extant, large populations of the species, located on the border between Colorado and Wyoming, Idaho and Utah, and within British Columbia, were not currently at increased risk of extirpation (USFWS 2000). They also cited the active management of populations by state and federal agencies such as, improving and restoring habitat and re-introducing birds to unoccupied areas within their historical range (USFWS 2000). In 2004, the Columbian subspecies was once again petitioned for federal listing but listing was not found to be warranted because of the existing metapopulations that "have persisted for the last several decades with no discernible downward trend" (USFWS 2006). However, Bart (2000), in a status review for the USFWS, predicted that most small populations of STG, like those in Washington, would likely be extirpated in a decade or two without federal protection.

Washington State listing

> "Threatened species are any wildlife species native to the state of Washington that are likely to become endangered within the foreseeable future throughout a significant portion of their range within the state without cooperative management or removal of threats" (WAC 232-12-297).

STG were listed as a state threatened species by the Washington Fish and Wildlife Commission in 1998 (Stinson and Schroeder 2012). A State of Washington Columbian Sharp-tailed Grouse Recovery Plan was completed in 2012. The Recovery Plan sets goals and objectives for recovery of STG in Washington and provides detailed, science-based information on their biology, life-cycle needs, and current population status. The goal of the Recovery Plan is to "restore and maintain healthy populations of Columbian Sharp-tailed Grouse in a substantial portion of the species' historical range in Washington" (Stinson and Schroeder 2012). STG will be considered for down-listing to a status of state sensitive when there is a 10-year period with a recognized metapopulation that averages greater than 2,000 birds and the total number of birds in Washington averages a minimum of 3,200 (Stinson and Schroeder 2012). Populations that are separate but genetically connected by periodic dispersers would be combined in assessing total numbers and the viability of the population for down-listing to state sensitive (Stinson and Schroeder 2012).

Conservation reserve program

The Conservation Reserve Program (CRP), administered by the U.S. Department of Agriculture, pays farmers to take their lands out of agricultural production to achieve conservation objectives, including reduced soil erosion and the provision of wildlife habitat (Rodgers and Hoffman 2005; Schroeder and Vander Haegen 2006). The CRP is a voluntary program established by the Federal Food Security Act of 1985 that generally targets marginal agricultural lands (Rodgers and Hoffman 2005). In eastern Washington, CRP land increased from 22,257 ha in 1986 to more than 607,028 ha in 2011 (Stinson and Schroeder 2012). Conservation goals for wildlife have been taken into consideration for newer CRP fields in Washington which have been planted with a mix of native grasses and forbs (Stinson and Schroeder 2012). Older fields are also being planted with native vegetation to provide important habitat for STG and other shrub-steppe species (Stinson and Schroeder 2012). However, the long-term status of CRP is uncertain because it is a voluntary program and dependent on congressional renewal, enrollments are affected by economic factors like the price of wheat (Stinson and Schroeder 2012). In the highly fragmented, agriculture dominated landscape of eastern Washington, CRP lands provide important habitat for STG (Schroeder and Vander Haegen 2006). If these lands were put back into crop production, STG population could be severely impacted and the risk of extirpation from Washington would likely increase (Bart 2000; Schroeder and Vander Haegen 2006).

Land acquisitions, habitat restorations, and translocations

Washington Department of Fish and Wildlife (WDFW) has been working toward meeting the Recovery Plan goal for STG by purchasing land, restoring habitat, and translocating birds to augment existing populations in eastern Washington. WDFW has purchased more than 16,187 ha in eastern Washington for the protection of STG (Stinson and Schroeder 2012; WDFW 2012). On WDFW Wildlife Areas that are managed for STG, riparian areas are being restored with plantings of native shrubs and trees and former agriculture fields have been planted with a mix of native grasses and forbs to improve habitat (Stinson and Schroeder 2012; WDFW 2012). Under the Washington State Acres for Wildlife Enhancement program (SAFE), WDFW biologists also work with area landowners to enhance older CRP fields with native plantings and to get additional acres enrolled in the CRP program (Stinson and Schroeder 2012; WDFW 2012). Despite habitat restoration, land acquisitions, and management of land for STG and other shrub-steppe species, STG populations continued to decline until 2005 (Schroeder et al. 2012). A genetic analysis of the STG population at Swanson Lakes Wildlife Area indicated that they had approximately 25% lower genetic diversity than birds from large populations in British Colombia (Warheit and Schroeder 2003). To increase population size and genetic diversity, 329 STG from British Columbia, Idaho, and Utah were translocated to four existing populations in eastern Washington from 2005 to 2012 (Schroeder et al. 2012). The translocated birds have experienced high mortality rates (47%) in the Swanson Lakes area but populations have increased overall at lek sites (Schroeder et al. 2012).

Population monitoring and habitat studies

Monitoring of STG populations in Washington has been ongoing since the 1950's (Stinson and Schroeder 2012). WDFW conducts annual surveys of all active STG leks and searches for new leks to assess overall population status (Schroeder et al. 2012). Currently, there are 39 active leks, while 87 lek sites documented since 1954 are now inactive (D. Stinson, personal communication, December 4, 2013). The locations of translocated STG are also monitored with radio collars (Stinson and Schroeder 2012). The location data from collared birds and field survey data have been used to identify the home ranges, resource use, and suitable habitat for STG in Washington (McDonald 1998; Stonehouse 2013).

Home ranges for STG include active leks and the surrounding spring and summer nesting/brood rearing habitat and winter habitat. Female STG typically stay within 1–2 km of leks in the spring and summer during nesting and brood rearing (Meints 1991; Meints, Connelly, Reese, Sands, and Hemker 1992; Giesen 1997; Boisvert et al. 2005; Stonehouse 2013) and males stay within 2 km of leks in the summer (Marks and Marks 1987; Boisvert et al. 2005; Stonehouse 2013). However, movements of up to 4.4 km from leks in the spring and summer have been observed in Washington (McDonald 1998). There is more variation in the distance STG move to winter habitat which may be based on the availability of suitable winter habitat (Giesen and Connelly 1993) or because of intraspecific competition between males and females (McDonald 1998). Maximum distance STG moved from nest and lek sites to winter habitat varied from 2 km in western Idaho (Marks and Marks 1988) to 11.5 km in Washington (McDonald 1998).

Meints (1991) observed movements of 20 km to winter habitats in southeastern Idaho and STG moved up to 41 km to find winter habitat in CRP and mine reclamation areas in Colorado (Boisvert et al. 2005).

STG require a mix of grass and shrub habitats near leks for nesting and brood rearing, and riparian or upland deciduous shrubs and trees within close proximity for escape cover in the spring, summer, and fall and for cover and forage in the winter (Marks and Marks 1987; Meints 1991, Meints et al. 1992; Giesen and Connelly 1993; Giesen 1997; McDonald 1998). Hofmann and Dobler (1988) surveyed winter habitat use by STG in Lincoln, Douglas, and Okanogan counties, Washington and estimated a density of 1 bird to 3 ha of riparian and deciduous habitat. Riparian and upland deciduous trees and shrubs are a vital component of STG habitat and are limited in shrub-steppe ecosystems due to excessive grazing and the effects of conversion to cropland on hydrology (Hofmann and Dobler 1988; Giesen and Connelly 1993; Stinson and Schroeder 2012). Marks and Marks (1987) reported that livestock grazing resulted in degradation to riparian vegetation from trampling, browsing, and rubbing.

STG will nest under grasses or shrubs in steppe, meadow-steppe, and shrub-steppe habitat types (Marks and Marks 1987; Meints 1991; McDonald 1998). In Colorado, females selected dense clumps of shrubs for nesting in mountain shrub habitats (Giesen 1997) and big sagebrush and low sagebrush in Idaho (Marks and Marks 1987; Meints 1991). In Washington and Montana, grassland habitat with sparse shrub cover was selected for nesting and nests were located under a variety of perennial grasses in Washington (Cope 1992;

McDonald 1998; Stonehouse 2013). CRP fields also provide suitable habitat for nesting and brood rearing (Meints 1991; Edgley 2001; McDonald 1998; Stonehouse 2013). In Washington, STG primarily selected grassy CRP fields for nesting under bunchgrasses and CRP fields with sparse shrub cover for lek locations (McDonald 1998; Stonehouse 2013).

STG diet includes grasses, seeds, forbs, and insects from spring through fall and berries, buds, and catkins of shrubs and trees during the winter (Evans and Dietz 1974; Marks and Marks 1987; Giesen 1997). Standing wheat or spilled grain in agricultural fields is also an important fall and winter food source in some locations (Meints 1991; Meints et al. 1992; McDonald 1998; Stinson and Schroeder 2012).

Additional environmental features such as land ruggedness, slope, elevation, and development also affect STG habitat selection. STG select less rugged areas (Stonehouse 2013), slopes that are less than 30%, and elevations between 300 m and 1350 m in Washington (Stinson and Schroeder 2012) and less than 2200 m in Idaho for their home ranges, nest, and lek sites (Marks and Marks 1987; Ramsey et al. 1999). STG also avoid roads, distribution lines, and trees (spring-summer) within their home ranges in Washington (Stonehouse 2013).

CONCLUSION

Habitat loss and fragmentation from human land use change have directly reduced the biodiversity of Earth’s terrestrial ecosystems and these declines continue to be dramatic (Sala et al. 2000; Gaston et al. 2003; Foley et al. 2005;

MEA 2005). Small, isolated populations in highly fragmented landscapes are at high risk for localized extirpation and species' extinction due to a combination of genetic and stochastic events that has been called a "vortex of extinction" (Gilpin and Soule 1986). Management of imperiled species and associated habitats may reverse declines and restore more resilient populations. Wildlife management strategies include habitat assessment, ecological restoration, land management, land acquisition, and translocations of animals from more robust populations to smaller populations in order to increase population size and genetic diversity (Stinson and Schroeder 2012).

Populations of STG in Washington declined significantly after the introduction and expansion of agriculture and livestock grazing in the early 20th century greatly reduced and fragmented their habitat (Yocom 1952). The existing small, isolated populations of STG in Washington are actively managed with the goal of restoring healthy populations within a substantial portion of their historical range (Stinson and Schroeder 2012). The Washington State Columbian Sharp-tailed Grouse Recovery Plan specifies that a habitat suitability model be developed to identify priority areas for habitat enhancement or restoration, and areas of suitable habitat for re-establishing additional STG grouse populations with translocations (Stinson and Schroeder 2012). Previous translocations of STG from larger populations appear to have stabilized and slightly increased STG populations in Washington (Schroeder et al. 2012). The next step is to identify areas of suitable habitat within their historical range in Washington and translocate birds to re-establish populations in those areas (Stinson and Schroeder 2012).

The goal of this study is to identify potential areas of STG habitat that may be suitable for future translocations by modeling the influence of biotic, abiotic, and anthropogenic variables on STG occupancy at active and inactive lek complexes (Tack 2006; Aldridge et al. 2008).

CHAPTER 2 ARTICLE MANUSCRIPT

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Modeling Columbian Sharp-tailed Grouse lek occupancy to guide site selection for translocations and species population recovery

ABSTRACT

A fundamental step in conserving biodiversity is identification of existing habitat areas that could potentially sustain populations of target species. Animals can be translocated to suitable habitat to re-establish populations and expand the target species' range. Columbian Sharp-tailed Grouse (*Tympanuchus phasianellus columbianus*) (hereafter STG) were historically abundant in eastern Washington before native vegetation was converted to agriculture and livestock grazing in the early 20th century. Currently, there are only seven isolated STG populations in Washington that total less than 1,000 birds. This study identified potential habitat for STG translocations within their historical range in Washington. Two logistic regression models were used to compare the influence of environmental variables on STG occupancy at active (n = 40) and inactive lek complexes (n = 41). Each environmental variable was assessed at three scales from the leks: typical STG flight distance (1 km radius), spring/summer habitat area (3 km radius), and winter habitat area (10 km radius). Habitat identified by the first model was analyzed for habitat patch metrics at the three scales. The patch metrics, percent area of habitat and maximum habitat patch size, were included with the original environmental variables to develop the second model. Both models selected for mean elevation at two scales (10 and 1 km) and for road density (1 km). The first model also included percent grassland habitat (3 km) and the second model included percent habitat area (3 km). Ten potential habitat areas greater than 50,000 ha were identified. These areas were located on the periphery of the STG historical range, at higher elevations, similar to habitat locations of extant STG populations. Some potential habitat contained areas of agriculture, forest, and steep slopes–these areas would not be suitable for STG and further on-the-ground assessment is needed to determine the overall potential of the habitat.

Key words: Columbian Sharp-tailed Grouse, Tympanuchus phasianellus columbianus, translocations, logistic regression, geographic information systems, GIS, habitat modeling

INTRODUCTION

Globally, the most direct driver of biodiversity loss in terrestrial ecosystems has been land use change from the expansion of human populations and human activities (Sala et al. 2000; Gaston et al. 2003; Foley et al. 2005; MEA 2005). Land use change destroys habitat for many wildlife species and fragments the remaining habitat into smaller patches that are surrounded by a matrix of different land uses such as agriculture or development (Wilcove et al. 1986; van den Berg et al. 2001). Habitat loss and fragmentation can limit the ability of animals to move among habitat patches to find food, mates, shelter, and other resources they need (Crooks and Sanjayan 2006). Species with low dispersal abilities or special habitat needs may be unable to move among habitat patches and become isolated in highly fragmented landscapes (MEA 2005). Small, isolated wildlife populations are at a greater risk for extinction due to the combined effects of habitat loss, low genetic diversity, short-term environmental variability, and long-term environmental change (Gilpin and Soule 1986; Pimm and Raven 2000; Frankham 2005).

Species recovery efforts for small wildlife populations include translocating animals from larger populations to increase the size and genetic diversity of small populations (Frankham et al. 2002; Stinson and Schroeder 2012). Translocations can also be used to re-establish wildlife populations in areas where they were previously extirpated. Populations of several grouse species have been successfully re-established including, Greater Sage-grouse (*Centrocercus urophasianus*) in Washington, Columbian Sharp-tailed Grouse (*Tympanuchus* *phasianellus columbianus*) in Idaho, Plains Sharp-tailed Grouse (*Tympanuchus phasianellus jamesi*) in Kansas, and Greater Prairie Chickens (*Tympanuchus cupido*) in Illinois and Iowa (Snyder, Pelren, and Crawford 1999). The first step to re-establishing wildlife populations is to identify potential habitat areas for translocations. One method to identify potential habitat is to create a habitat suitability model that combines geospatial data of environmental parameters with occupied and unoccupied habitat areas to identify variables that best predict for occupancy. The model parameters can be applied to the spatial data layers in a geographic information system (GIS) to map potential habitat areas (Aldridge et al. 2008; Wisdom et al. 2011; Knick et al. 2013). Landscapes can be assessed based on model outcomes to determine suitability for re-introducing wildlife populations in those areas (Ramsey et al. 1999; Edgley 2001; Fitzpatrick 2003). In addition, habitat models can inform land management decisions about habitat conservation or restoration of critical habitat areas that will maintain or increase wildlife populations (Edgley 2001; Rittenhouse et al. 2005; Aldridge et al 2012; Stonehouse 2013).

In Washington, Columbian Sharp-tailed Grouse (*Tympanuchus phasianellus columbianus*) (hereafter STG) is a state listed threatened species. STG were once an abundant game bird in eastern Washington until significant portions of their habitat were converted to agriculture and degraded by livestock grazing in the early 20th century (Yocom 1952). A conservative estimate by Washington Department of Fish and Wildlife (WDFW), assigned pre-settlement STG population size in Washington at greater than 100,000 birds (Stinson and

Schroeder 2012). Current estimated numbers of STG in Washington totaled 916 in 2013 (Stinson and Schroeder 2012).

Columbian Sharp-tailed Grouse (STG) are one of six existing subspecies of Sharp-tailed Grouse in North America (Johnsgard 1973). STG are the smallest of the subspecies and have darker gray plumage, more pronounced spotting on the throat, and narrower markings on the underside (Connelly, Gratson, and Reese 1998). STG gather in the spring at leks where males engage in elaborate courtship displays to attract mates (Giesen and Connelly 1993; Stinson and Schroeder 2012). Male and female STG have high fidelity to leks, often returning to the same lek every spring (Stinson and Schroeder 2012). Home ranges for STG include active leks and the surrounding nesting/brood rearing and winter habitat. Female STG typically stay within 1–2 km of leks in the spring and summer during nesting and brood rearing (Meints 1991; Meints et al. 1992; Giesen 1997; Boisvert et al. 2005; Stonehouse 2013) and males stay within 2 km of leks in the summer (Marks and Marks 1987; Boisvert et al. 2005; Stonehouse 2013). However, movements of up to 4.4 km from leks in the spring and summer have been observed in Washington (McDonald 1998). There is more variation in the distance STG move to winter habitat which may be based on the availability of suitable winter habitat (Giesen and Connelly 1993) or because of intraspecific competition between males and females (McDonald 1998). Maximum distance STG moved from nest and lek sites to winter habitat varied from 2 km in western Idaho (Marks and Marks 1988) to 11.5 km in Washington (McDonald 1998). Meints (1991) observed movements of 20 km to winter habitats in southeastern

Idaho and STG moved up to 41 km to find winter habitat in CRP and mine reclamation areas in Colorado (Boisvert et al. 2005).

A variety of seasonal habitats within close proximity are required by STG including dense grasses, forbs, or shrubs near leks for nesting and brood rearing in the spring and summer, and riparian or upland deciduous shrubs and trees for cover and forage in the winter (Marks and Marks 1987; Meints 1991, Meints et al. 1992; Giesen and Connelly 1993; Giesen 1997; McDonald 1998). Riparian and upland deciduous trees and shrubs are a vital component of STG habitat and are limited in shrub-steppe ecosystems due to excessive grazing and changes to hydrology from land use conversion to cropland (Hofmann and Dobler 1988; Giesen and Connelly 1993; Stinson and Schroeder 2012).

STG will nest under grasses or shrubs in steppe, meadow-steppe, and shrub-steppe habitat types (Marks and Marks 1987; Meints 1991; McDonald 1998). In Washington, grassland habitat with sparse shrub cover was selected for nesting and nests were located under a variety of perennial grasses in Washington (McDonald 1998; Stonehouse 2013). CRP fields also provide suitable habitat for nesting and brood rearing (Meints 1991; Edgley 2001; McDonald 1998; Stonehouse 2013). In Washington, STG primarily selected grassy CRP fields for nesting under bunchgrasses and CRP fields with sparse shrub cover for lek locations (McDonald 1998; Stonehouse 2013).

The diet of STG consists of grasses, seeds, forbs, and insects from spring through fall, and berries, buds, and catkins of shrubs and trees during the winter (Evans and Dietz 1974; Marks and Marks 1987; Giesen 1997). Standing wheat or spilled grain in agricultural fields is also an important fall and winter food source in some locations (Meints 1991; Meints et al. 1992; McDonald 1998; Stinson and Schroeder 2012).

Additional environmental features such as land ruggedness, slope, elevation, and human infrastructure also affect STG habitat selection. STG select less rugged areas (Stonehouse 2013), slopes that are less than 30%, and elevations between 300 m and 1350 m in Washington (Stinson and Schroeder 2012) and less than 2200 m in Idaho for their home ranges, nest, and lek sites (Marks and Marks 1987; Ramsey et al. 1999). STG also avoid roads, distribution lines, and trees (spring-summer) within their home ranges in Washington (Stonehouse 2013).

The Washington State Columbian Sharp-tailed Grouse Recovery Plan specifies that a habitat suitability model be developed to identify priority areas for habitat enhancement or restoration, and areas of suitable habitat for re-establishing additional STG populations with translocations (Stinson and Schroeder 2012). Previous translocations of STG from populations in British Columbia, Idaho, and Utah, have stabilized and slightly increased STG populations in Washington (Schroeder et al. 2012). The next step is to identify habitat areas that are suitable for establishing new STG populations within their historical range in eastern Washington (M. Schroeder, personal communication, October 8, 2013). This study compared the influence of environmental variables on the probability of occurrence at active and inactive STG lek complexes in eastern Washington to identify potential habitat areas for translocations.

METHODS

Study area

The study area encompasses the historical range of STG that is within the Columbia Plateau Ecoregion in eastern Washington (Figure 4). Pre-settlement habitats of this area included grassland steppe, meadow steppe, and shrub-steppe ecosystems (Yocom 1952; Schroeder et al. 2000; Stinson and Schroeder 2012) (Figure 4). The grassland steppe and meadow steppe ecosystems of the Palouse Prairie in southeastern Washington, were characterized by deep, loess soils that originally supported native grassland vegetation dominated by Idaho fescue (*Festuca idahoensis*), bluebunch wheatgrass (*Agropyron spicatum*), and Sandberg bluegrass (*Poa secunda*) (Bunting et al. 2003). By 1895, most of the tillable land in the Palouse had been converted to agriculture and STG were extirpated from the region by the middle of the 20th century (Stinson and Schroeder 2012). Native shrub-steppe vegetation communities in the Columbia Plateau region of eastern Washington predominately contained big sagebrush (*Artemisia tridentata*) and three-tipped sagebrush (*Artemisia tripartita*) in association with bluebunch wheatgrass (*Agropyron spicatum*) (Daubenmire 1988). Shrub-steppe communities once covered most dryland areas of eastern Washington extending from the forested slopes of the North Cascades to the Palouse Prairie (Dobler et al. 1996). This area also had substantial populations of STG historically before the area was settled in the early 20th century (Yocom 1952; Schroeder et al. 2000; Stinson and Schroeder 2012).

The combination of agriculture, livestock grazing, and other land use change in eastern Washington greatly decreased and fragmented STG habitat. Sagebrush cover in the historical range of STG in eastern Washington decreased from approximately 44.1% in 1900 to 15.6% by 1990 (McDonald and Reese 1998). Sagebrush and grassland habitat patch size also decreased by 36%, from a mean of 4,474 ha in 1900 to 2,857 ha in 1990 (McDonald and Reese 1998). The loss and fragmentation of sagebrush habitat has also increased the distance between patches and isolated extant populations of STG. Currently, STG occur in seven shrub-steppe habitat areas in Douglas, Lincoln, and Okanogan Counties that represent approximately 2.8% of their estimated historical range in Washington (Schroeder et al. 2000; Stinson and Schroeder 2012) (Figure 4).

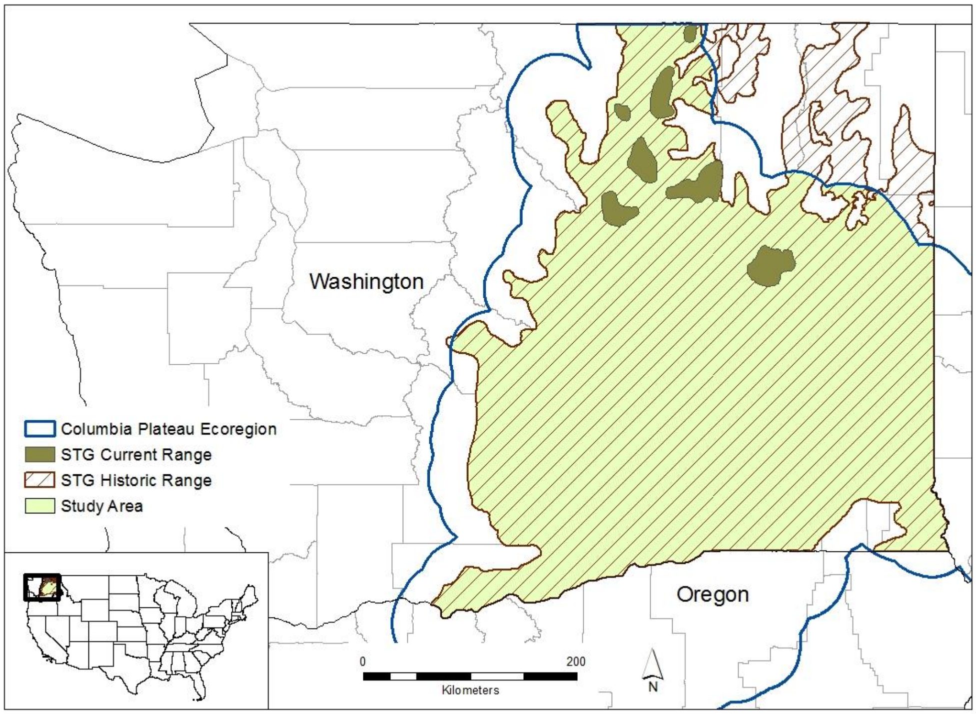

Figure 4. The study area. The study area was the historical range for STG in Washington that was included within the extent of the Washington Wildlife Habitat Connectivity Working Group's Columbia Plateau Ecoregion spatial data (Stinson and Schroeder 2012; WHCWG 2012b).

Land ownership within the historical and current range for STG is comprised of private, tribal, and public lands (Table 2). The majority of lands in STG historical (77.79%) and current (56.05%) range are privately owned. (Stinson and Schroeder 2012). Tribal lands are the next greatest area of land ownership within STG historic (8.51%) and current (28.12%) range, and the remaining land areas are owned by federal, state, and other public entities such as counties and universities (Stinson and Schroeder 2012). Within the current STG range, the Colville Confederated Tribes owns the largest area of land (28.10%), Washington State owns the next largest area including the Department of Fish and Wildlife (6.90%) and the Department of Natural Resources (4.80%), and the other areas of public land are owned by the U.S. Bureau of Land Management (4.08%) and the U.S. Forest Service (0.04%) (Stinson and Schroeder 2012).

Table 2. Land ownership within the historical and current range for Columbian Sharp-tailed Grouse in eastern Washington (Stinson and Schroeder 2012).

	Historic Range		Current Range	
Land Owner or Manager	Percent	Hectares	Percent	Hectares
Private	77.79	3,925,001	56.05	121,047
Federal	5.48	276,260	4.12	8,898
State	8.07	406,990	11.71	25,290
Tribal	8.51	429,168	28.12	60,718
Other Public	0.16	8,044	0.00	0
Total	100	5,045,463	100	215,953

Columbian Sharp-tailed Grouse database

Active and inactive STG lek complexes were used to predict the probability of occurrence by comparing the influence of the surrounding environmental parameters on occupancy (Appendix A). Lek complexes were comprised of clusters of leks that were no further apart than 1 km (Schroeder et al. 2000). Leks are small areas, usually on knolls or ridges, where males gather in the spring for elaborate courtship displays to attract mates (Giesen and Connelly 1993; Stinson and Schroeder 2012). Active and inactive lek complexes are a good indicator of occupancy because male and female STG have high fidelity to leks, often returning to the same lek every spring, although lek locations can shift over time or be abandoned (Stinson and Schroeder 2012). Additionally, annual surveys of leks by WDFW biologists have been conducted since 1954 and searches for new lek sites have been conducted since 1970 (Schroeder et al. 2000; Stinson and Schroeder 2012). Active lek complexes (1) were defined as those that had at least one male displaying in the spring of 2013 (n = 40). Inactive lek complexes (0) were selected to achieve approximately 50% prevalence (i.e., the frequency of occurrence) and included lek complexes that were abandoned between 1994 and 2012 (n = 41). Studies have found that datasets which have prevalence of 50% improved the predictive accuracy of a model (Manel, Williams, and Ormerod 2001; Liu, Berry, Dawson, and Pearson 2005).

Scale of analysis

Spatial scales were selected to represent the lifecycle habitat resource needs of STG. Environmental variables were analyzed at three radii distances from the lek complexes: 1, 3, and 10 km. One kilometer is a typical STG flight distance (Stinson and Schroeder 2012), three kilometers is the average distance from the lek that females move in the spring and summer for nesting and brood rearing (McDonald 1998; Stonehouse 2013), and ten kilometers is the average distance that male and female STG move from the lek to find suitable winter habitat (McDonald 1998).

Environmental variables

Environmental variables that were known to impact STG populations and other variables that may also influence STG occupancy of an area were selected for the analysis based on *a priori* knowledge from a thorough literature review. Candidate variables were divided into 3 broad categories: land cover, human infrastructure, and physical geography (Table 3).

All of the spatial data layers, except for precipitation and percent slope, were developed by the Washington Wildlife Habitat Connectivity Working Group (WHCWG) for modeling select species' habitat connectivity in the Columbia Plateau Ecoregion (WHCWG 2012b). WDFW provided the WHCWG layers for this study. WHCWG base layers were 30 m raster datasets and included land cover (Appendix B), freeways, major highways, secondary highways, local roads, four transmission line layers (< 230 KV, 1 line and 2 or more lines, and $\geq$ 230 KV, 1 line and 2 lines), ruggedness, soil depth, and elevation. The road density layer (roads/ha) was created by combining the four WHCWG's road category layers. Precipitation was derived from the PRISM 30-Year Normals dataset which is the average annual precipitation from 1981-2010 (PRISM 2014). The PRISM data was resampled from 800 m to 30 m. Percent slope was calculated from a 30 m Digital Elevation Model (DEM) using ArcGIS Spatial Analyst.

Individual raster layers for each environmental variable were created using a circular moving widow analysis at 1, 3, and 10 km radii. Percent area was calculated for land cover and road density and mean values were calculated for slope, elevation, ruggedness, soil depth, and precipitation. Individual Euclidean distance raster layers were created to measure distances to the nearest agriculture fields, pasture/hay fields, riparian/winter habitat, roads, and transmission lines. Geographic Information Systems (GIS) processing was performed using ArcGIS version 10.1 (ESRI 2012), Python 2.7 (Python 2010), and PythonWin 2.7.2 (Hammond 2011).

Table 3. Summary of GIS predictor variables used for Columbian Sharp-tailed Grouse modeling. Significant variables were determined by a univariate logistic regression analysis and are annotated for the scale(s) at which they were significant.

Variable Category	Name	Description	Units	Source
Land cover	ag$^{3\circ}$	Agriculture	percent	WHCWG (2012b)
	gr$^{13\circ}$	Grassland	percent	WHCWG (2012b)
	sh	Shrubland	percent	WHCWG (2012b)
	fr$^{\circ}$	Forest	percent	WHCWG (2012b)
	ph$^{\circ}$	Pasture hay (CRP)	percent	WHCWG (2012b)
	rw$^{\circ}$	Riparian/winter habitat	percent	WHCWG (2012b)
	igr	Introduced grassland	percent	WHCWG (2012b)
	d_ag*	Distance to ag	m	WHCWG (2012b)
	d_ph*	Distance to ph	m	WHCWG (2012b)
	d_rw	Distance to rw	m	WHCWG (2012b)

Table 3 (continued)

Variable Category	Name	Description	Units	Source
Infrastructure	rd[13°]	Road density	roads/ha	WHCWG (2012b)
	d_mh*	Distance to major highway	m	WHCWG (2012b)
	d_sch	Distance to secondary highway	m	WHCWG (2012b)
	d_lr*	Distance to local roads	m	WHCWG (2012b)
	d_lt_1	Distance to transmission line - less than 230KV 1 line	m	WHCWG (2012b)
	d_lt_2*	Distance to transmission line - less than 230KV 2 lines	m	WHCWG (2012b)
	d_ge_1	Distance to transmission line - greater or equal 230KV 1 line	m	WHCWG (2012b)
	d_ge_2	Distance to transmission line - greater or equal 230KV 2 line	m	WHCWG (2012b)
Physical Geography	prc[13°]	Precipitation	cm	PRISM (2014)
	slp[3°]	Slope	percent	DEM
	elv[13°]	Elevation	m	WHCWG (2012b)
	rug[°]	Ruggedness		WHCWG (2012b)
	sd[°]	Soil depth	cm	WHCWG (2012b)

The variable was significant in the univariate analysis: [1]1 km scale, [3]3 km scale, °10 km scale, and *distance

Model development

Two sets of models were developed (phase I and phase II) by comparing the influence of environmental variables on STG occurrence at active and inactive lek complexes in eastern Washington. The phase I and II models were developed using a purposeful selection approach to select the most parsimonious model from a set of candidate models (Hosmer, Lemeshow, and Sturdivant 2013). Both models were developed using logistic regression to analyze the influence of environmental variables at three scales, 1, 3, and 10 km radii distances from STG active and inactive lek complexes. The suitable habitat areas identified by the phase I model were analyzed using FRAGSTATS version 4 (McGarigal, Cushman, and Ene 2012) to calculate habitat fragmentation metrics. The phase II model included the original environmental variables and the habitat fragmentation variables from the phase I model in the statistical assessment.

First, a univariate analysis on each environmental variable, at each scale was conducted using Wald z statistic, $P < 0.25$ as the limit for inclusion in candidate models (Hosmer et al. 2013). Two active lek complexes, 64 and 65, were not used for the univariate analysis of variables at the 10 km scale because the radius included areas that were outside the extent of the available spatial data (Appendix A). All of the active and inactive lek complexes were used for the univariate analysis at the1 km and 3 km radii. In addition, lek complexes, 64 and 65 were excluded from distance analysis because they were within 6 km of the extent of the spatial data. The next closest lek complex was 27.06 km from the extent of the spatial data. Therefore, a 27 km maximum buffer was applied to the distance measurements.

All significant variables were assessed for correlation using Pearson's $r \geq |0.70|$ as the cutoff value (Aldridge et al. 2008). All uncorrelated variables that were significant in the univariate analysis were included in multivariable models (Table 3). The least significant variables were sequentially dropped from the model until all remaining variables were significant at Wald z statistic, $P < 0.10$

(Aldridge et al. 2008; Hosmer et al. 2013). All significant variables were also assessed for linearity with a visual assessment of a lowess smoothing scatterplot (Hosmer et al. 2013). Next, each uncorrelated variable that was not identified as being significant in the univariate analysis was added one at a time to identify variables that were important in combination with other variables (Hosmer et al. 2013). As variables were removed or added, P-values and the magnitude of change in the coefficient was monitored to identify interactions between variables and confounding variables for each candidate model (Hosmer et al. 2013). Multicollinearity of the candidate models was checked using variance inflation factors (VIF). Multicollinearity was considered a problem if VIF scores for individual covariates were greater than 10 (Chatterjee and Hadi 2012).

Model assessment and validation

The candidate models were assessed and a final model selected that surpassed the other models in more than one area. (Hosmer et al. 2013). Akaike Information Criterion (AIC) was used to compare the fit of the candidate models since they were derived from the same sample (Peng and So 2002). The overall goodness of fit was assessed using a Pearson's chi-square test which has a higher power for small sample sizes (Hosmer et al. 2013). A Receiving Operating Characteristic (ROC) curve was generated for each of the candidate models by plotting the sensitivity versus 1-specificity over all possible cut off points to assess the predictive ability of the models (Hosmer et al. 2013). The predictive ability of a model was considered outstanding at an ROC of ≥ 0.9, excellent at $\geq$

0.8, acceptable at ≥ 0.7, and poor at < 0.7 (Hosmer et al. 2013). The final step in assessing the candidate models was to check for overfitting of the model using k-fold cross validation (10-fold). All statistical analysis was conducted in STATA version 13 (StataCorp 2013).

Identifying potential Columbian Sharp-tailed Grouse habitat

The logistic regression model parameters for the final phase I and II models were applied to the spatial predictors for each model to derive a probability of occurrence map. Potential habitat areas were identified by applying the model's optimal threshold cutoff for occurrence, where sensitivity and specific intersected, to the occurrence map. Areas that had values greater than or equal to, the model's cutoff were identified as potential STG habitat.

RESULTS

Many of the variables were highly correlated ($r \geq |0.70|$) which limited the combinations of variables that could be assessed in the multivariate analysis. For example, mean elevation (10 km) was highly correlated with percent forest (10 km), mean precipitation (10 km), mean elevation (3 km), mean precipitation (3 km), and distance to pasture/hay fields. The only variables that were not highly correlated with at least one other variable at all scales were road density and mean soil depth.

Four phase I candidate models for STG occurrence were identified from the multivariate analysis (Table 4). The variables in the models were all statistically significant (P < 0.25) in the univariate analysis and not highly correlated (Hosmer et al. 2013). All of the candidate models had a two-way interaction between two of the variables that were significant at P < 0.05. The interaction terms and the main effects variables were retained in the final candidate models (Hosmer et al. 2013). Candidate model 2 was selected as the final phase I model because it had the lowest Akaike Information Criterion (AIC) score and was able to adequately discriminate between active and inactive lek complexes based on the ROC score (Figure 5). Model 2 also had the second lowest cross validation RMSE score which measures the difference between values predicted by a model and the values actually observed (Tack 2006; Aldridge et al. 2008; Hosmer et al. 2013).

Table 4. Phase I final candidate models selection criteria. Candidate models were compared for the best model fit with Akaike Information Criterion (AIC), predictive ability with Receiving Operating Characteristic (ROC) curve, goodness of fit with Pearson's chi-square test, and for over fitting with k-fold cross validation.

				Goodness of Fit		K-fold Cross Validation (10 fold average)	
Model	Log Likelihood	AIC	ROC	Pearson's chi2	Prob>chi2	RMSE	R2
1	-46.833	103.666	0.736	75.07	0.443	0.487	0.247
2	-45.217	100.434	0.761	76.74	0.391	0.470	0.234
3	-46.705	105.409	0.739	75.00	0.413	0.495	0.219
4	-45.311	102.621	0.770	77.93	0.325	0.469	0.247

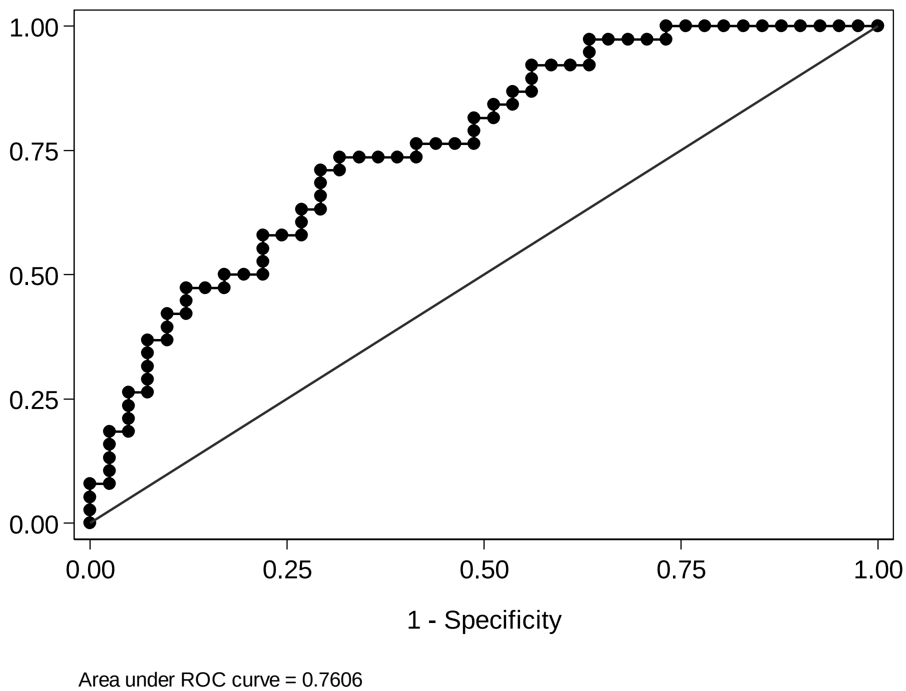

Figure 5. Phase I model Receiver Operating Characteristic curve.

The phase I model environmental variables that best predicted STG occurrence at active and inactive lek complexes included, mean elevation (10 km), percent area of native grass habitat (3 km), road density (1 km), and a two-way interaction between mean elevation (10 km) and percent area of grass habitat (3 km) (Table 5). The threshold for STG occurrence was estimated by plotting the final model sensitivity and specificity against probability cutoffs. The intersection of sensitivity and specificity is the optimal cutoff that minimizes false negatives and false positives in correctly identifying STG occurrence at lek complexes (Peng and So 2002). For this model, the optimal cutoff (0.51682) yielded 71.05% correct classifications for sensitivity and 70.73% for specificity (Figure 6).

Table 5. Phase I Columbian Sharp-tailed Grouse occurrence model Wald z statistic results. Estimated coefficients (β), standard errors (SE), intercepts (z), *P*-values (P) and 95% confidence intervals (95% CI).

Variable	β	SE	z	P	95 % CI	
Mean elevation (10 km)	0.030	0.011	2.650	0.008	0.008	0.052
% grassland (3 km)	36.376	15.948	2.280	0.023	5.118	67.635
Road density (1 km)	-94.705	41.235	-2.300	0.022	-175.524	-13.886
Interaction of elevation & grassland	-0.051	0.022	-2.310	0.021	-0.094	-0.008

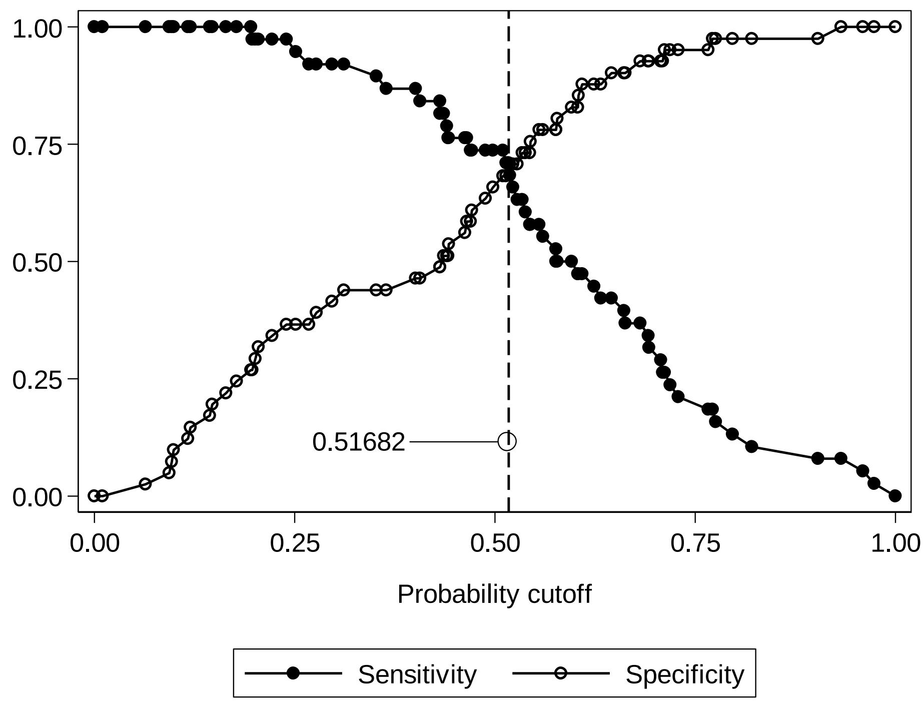

Figure 6. Phase I model overlay plot of sensitivity and specificity versus probability cutoffs. The proportion of lek complexes that were correctly classified as active or inactive is equal at the optimal cutoff where sensitivity and specificity intersect (Peng and So 2002). For this model, the optimal cutoff (0.521682) yielded approximately 71% correct classifications for both groups.

The phase I model logistic regression parameters were applied to the spatial data layers for each environmental variable in the model to create a probability of occurrence map. Probability of occurrence map raster values that were greater than or equal to, the phase I model probability cutoff (0.51682), were identified as potential STG habitat. The phase I model identified 315 potential habitat patches with a total area of 2,169,954 ha (Figure 7). The habitat patches had a mean area of 6,889 ha, a median area of 810 ha, and an area range of 0.81 ha to 466,182 ha.

Habitat patch metrics were calculated from the phase I model habitat areas. A circular moving window analysis was used to calculate percent habitat area and maximum patch area at 1, 3, and 10 km radii. Several of the variables were highly correlated ($r \geq |0.70|$), percent area (1 and 10 km) were both correlated with percent area (3 km), and maximum area (3 km) was correlated with maximum area (10 km). A univariate analysis of the habitat patch metrics resulted in significant values at $P < 0.25$ for percent habitat area (1, 3, and 10 km) and maximum patch area (1 km).

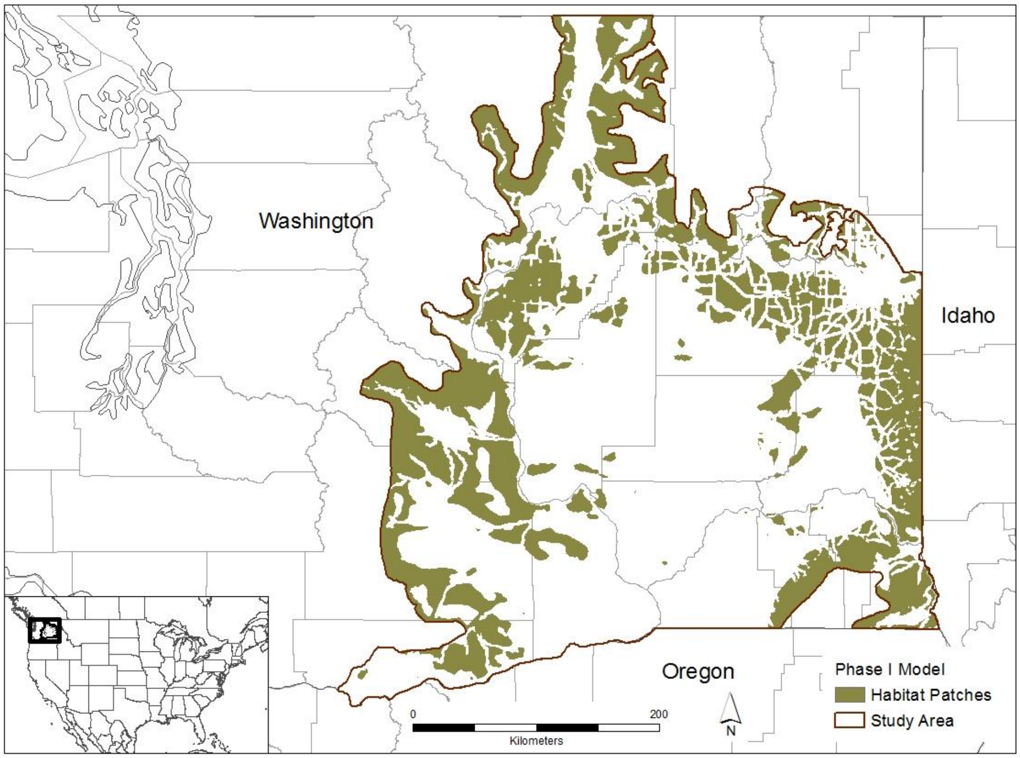

Figure 7. 315 Phase I model Columbian Sharp-tailed Grouse potential habitat patches with a total area of 2,169,954 ha.

A phase II model was developed from multiple logistic regression analysis of the original environmental variables and the phase I model habitat patch metrics. The phase II model variables were all significant ($P < 0.25$) in the univariate analysis and there were no significant interactions between the variables (Hosmer et al. 2013). The phase I and phase II models had very similar model verification test scores (Table 6). The phase I model had a slightly better (lower) AIC score but the phase II model had a slightly higher predictive ability (ROC = 0.765) (Figure 8) and cross-validation RMSE score.

Table 6. Phase I and phase II models verification test scores. The phase I model had a slightly higher AIC score but the phase II model had a slightly higher predictive ability (ROC = 0.765) and cross-validation RMSE score.

				Goodness of Fit		K-fold Cross Validation (10 fold average)	
Model	Log Likelihood	AIC	ROC	Pearson's chi2	Prob>chi2	RMSE	R2
Phase I	-45.217	100.434	0.761	76.74	0.391	0.470	0.234
Phase II	-46.705	100.532	0.765	77.23	0.471	0.469	0.240

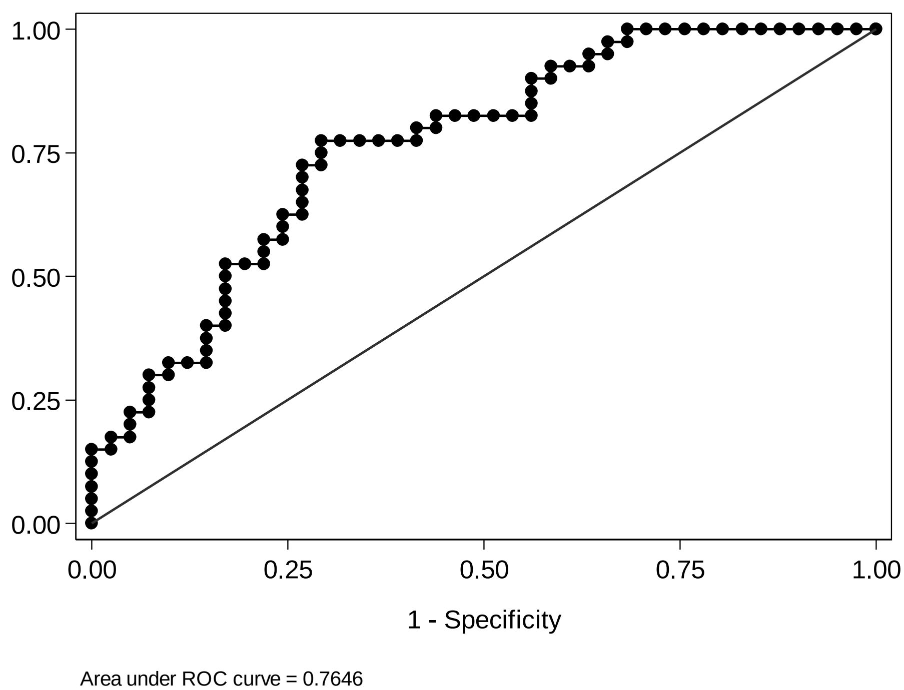

Figure 8. Phase II model Receiver Operating Characteristic curve.

The phase II model variables that best predicted STG occurrence at active and inactive lek complexes included percent area of suitable habitat (3 km), as defined by the phase I model, average elevation (1 km), and road density (1 km) (Table 7). Only one of the variables in the phase II model, road density, was also included in the phase I model. The phase II model optimal cutoff for sensitivity and specificity (0.49843) yielded 72.50% correct classifications for sensitivity and 73.17% for specificity (Figure 9).

Table 7. Phase II Columbian Sharp-tailed Grouse occurrence model Wald z statistic results. Estimated coefficients (β), standard errors (SE), intercepts (z), *P*-values (P) and 95% confidence intervals (95% CI).

Variable	β	SE	z	P	95 % CI	
% potential habitat (3 km)	1.879	0.809	2.320	0.020	0.294	3.465
Road density (1 km)	-69.536	40.738	-1.710	0.088	-149.380	10.309
Mean elevation (1 km)	0.005	0.002	2.000	0.045	0.000	0.010

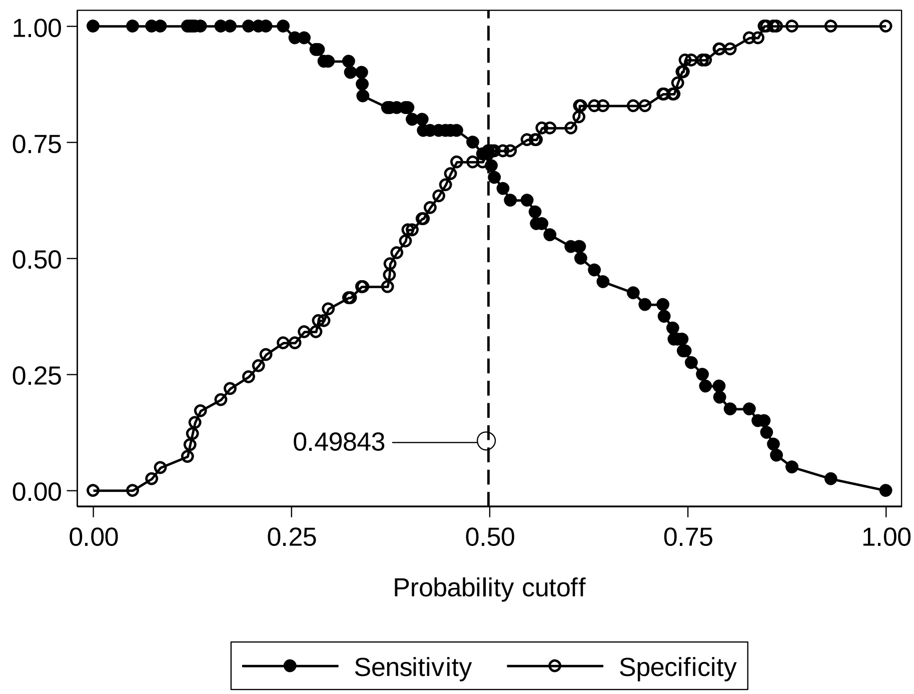

Figure 9. Phase II model overlay plot of sensitivity and specificity versus probability cutoffs. The optimal cutoff (0.49843), where sensitivity and specificity intersect, yielded approximately 73% correct classifications for both active and inactive leks.

A probability of occurrence map was created by applying the phase II model logistic regression parameters to the spatial data layers. The probability of occurrence map raster values that were greater than, or equal to, the phase II model probability cutoff (0.49843) were identified as potential STG habitat. The phase II model identified 316 habitat patches totaling 1,739,212 ha (Figure 10). The potential habitat had a mean area of 5,504 ha, a median area of 1,038 ha, and an area range from 0.09 ha to 190,019 ha.

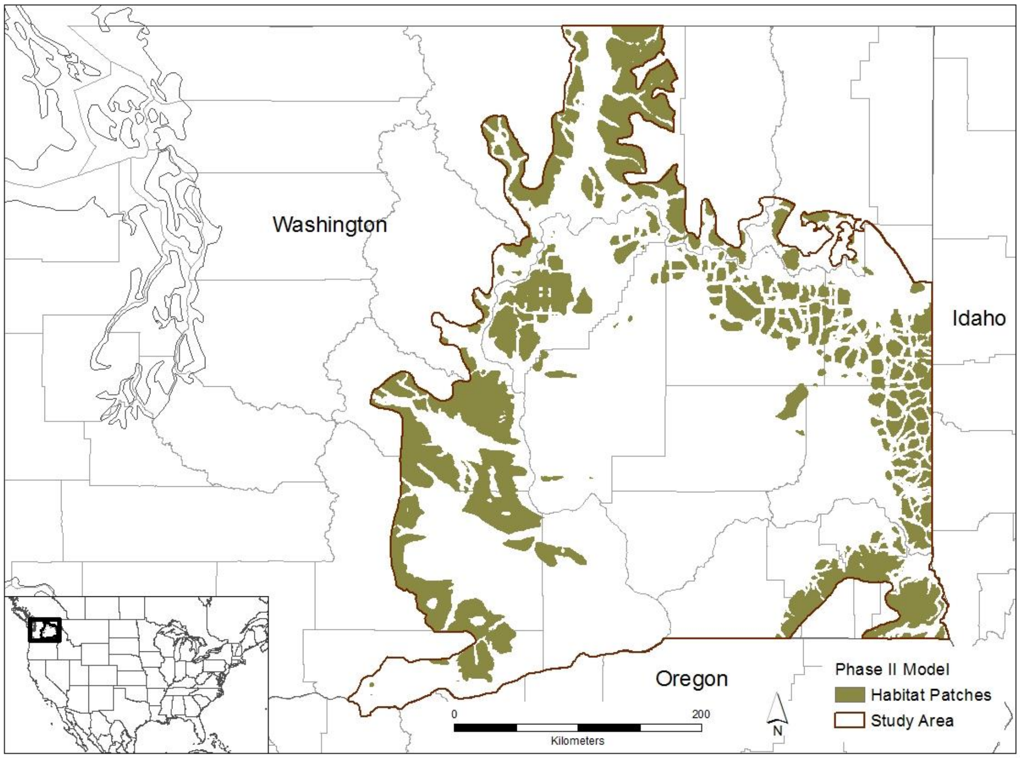

Figure 10. 316 Phase II model Columbian Sharp-tailed Grouse potential habitat patches with a total area of 1,739,212 ha.

DISCUSSION

Columbian Sharp-tailed Grouse population goals and habitat requirements

STG in Washington will be considered for down listing from state threatened to sensitive when there is one metapopulation that averages 2,000 birds, and an overall population that averages a minimum of 3,200 birds, for a 10 year period (Stinson and Schroeder 2012). An area greater than 400,000 ha of interconnected habitats of shrub-steppe, grassland, and CRP would be required to support 2,000 or more STG at densities of 0.005 birds/ha (Stinson and Schroeder 2012). The final model identified 10 habitat patches greater than 50,000 ha

(Figure 11). The largest habitat patch (190,017 ha) and another large patch (51,174 ha) were located in Okanogan County, in the northern portion of STG historical range, where extant STG populations are concentrated. These patches border the Okanogan-Wenatchee National Forest, WDFW Wildlife Areas, and are within the Colville Indian Reservation. Potential habitat in these areas should be the focus of STG range expansion efforts since they are located near the extant STG populations (Schroeder 1996; McDonald and Reese 1998)

Another cluster of habitat patches greater than 50,000 ha, were located on the western edge of STG historical range, predominately within Kittitas and Yakima Counties. These patches are located on the Yakima Training Center, WDFW's Colockum and LT Murray Wildlife Areas, the Yakama Indian Nation lands, and private lands. McDonald and Reese (1998) identified this area as having the largest grassland patches in the Columbia Plateau. Dobler et al. (1996) concluded that these large areas of remaining shrub-steppe on the Yakima Training Center, Hanford Nuclear Site, and the Yakama Indian Nation, may be the most suitable sites for species, like STG, that have evolved in expansive shrub-steppe habitats. These areas may have good potential for supporting STG populations since they are predominately located on public and sovereign tribal lands and are large, fairly intact areas of native habitat.

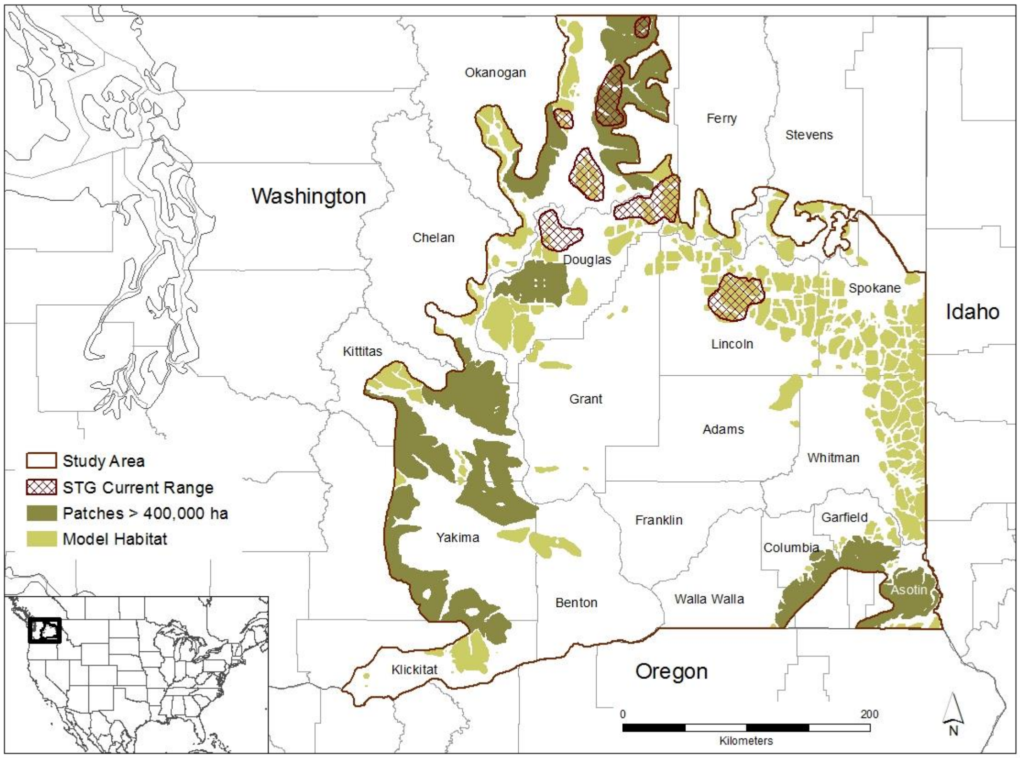

Figure 11. Ten habitat patches identified by the final model that were greater than 50,000 ha. Two patches are located in Okanogan County in the northern portion of STG historic range where the extant Columbian Sharp-tailed Grouse populations are clustered.

Final model selection

The final model was selected by comparing the suitability of habitat areas for STG that were identified by the phase I and II models. The habitat areas that were identified by the two models were both located on the periphery of STG historical range in higher elevation areas which is similar to the locations of the extant STG habitat areas. Overall, the potential habitat patches identified by the two models were very similar. The similarity was most likely due to the phase II model being developed with phase I model habitat patch metric variables. In addition, several of the environmental variables were the same (road density—1 km) or similar (mean elevation at different scales) for both models.

The main difference between the two model's habitat patches were the size and location of the patches and the phase I model had more habitat patches located in low precipitation areas. The phase II model habitat patches were smaller and more fragmented than the phase I model habitat. The road density (1 km) variable was included in both models and probably influenced the greater degree of habitat fragmentation for the phase II model potential habitat. Roads negatively impact STG populations due to habitat fragmentation, road avoidance behavior, noise, and direct mortality (Manville 2004; Pruett et al. 2009, Robb and Schroeder 2012; Stonehouse 2013). Road density is especially important within a 1 km radius of lek complexes because this area typically includes nesting and brood rearing habitat (McDonald 1998; Stonehouse 2013). The phase I model also had more habitat patches located in areas that received less than 23 cm of annual precipitation compared to the phase II model (Figure 12). Areas that receive less than 23 cm of annual precipitation are typically too dry to support the diversity of grasses, forbs, and deciduous trees and shrubs that STG need for nesting, brood rearing, and for winter forage and cover (Stinson and Schroeder 2012). Based on the phase I model having more habitat patches located in low precipitation areas, the phase II model was selected as the final model.

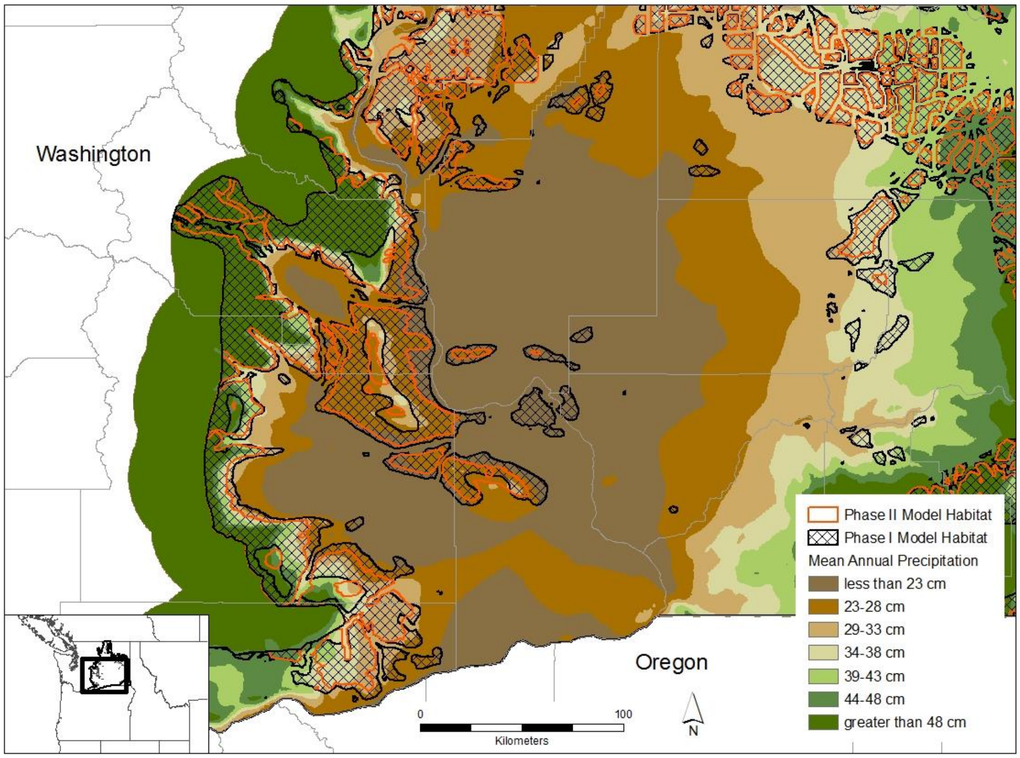

Figure 12. Mean annual precipitation and Columbian Sharp-tailed Grouse potential habitat identified by the phase I and II models. There were more phase I than phase II model patches in areas of low precipitation. Areas that receive less than 23 cm of average annual precipitation cannot support the grasses and diversity of vegetation that STG need for habitat.

Analysis of potential Columbian Sharp-tailed Grouse habitat

The extant STG populations in Washington are located in habitat areas on the northern periphery of their historic range with elevations that range from 289 m to 1,518 m ($\bar{x}$ = 748 m) and that receive 22.62 cm to 51.75 cm ($\bar{x}$ = 34.72 cm) of annual precipitation. The habitat areas identified by the final model follow this pattern of being located on the periphery of the Columbia Plateau region. Overall, compared to the current STG habitat areas, the model habitat areas were located in higher elevations, with a range from 348 m to 2,078 m ($\bar{x}$ = 858 m), and received higher amounts of annual precipitation, 20.77 cm to 192.48 cm ($\bar{x}$ = 45.49 cm). In Idaho, STG home ranges, nests, and lek sites were found at elevations less than 2,200 m which indicates that the upper end of the model habitat elevation may still be suitable for STG (Marks and Marks 1987; Ramsey et al. 1999). Minimum precipitation is a limiting factor for suitable STG habitat in the Columbia Plateau region. Most historical records indicate that STG occurred in areas with a minimum of 28 cm of precipitation or near rivers in areas with lower precipitation (Stinson and Schroder 2012). The Washington State Columbian Sharp-tailed Grouse Recovery Plan considers areas below 23 cm of precipitation as unsuitable habitat for STG (Stinson and Schroeder 2012).

A comparison of land cover within the extant STG habitat areas and the potential habitat areas identified by the final model, showed that current STG habitat areas had a higher percentage cover of grass and shrub habitat, introduced grassland, and pasture/hay fields, and a lower percentage cover of agriculture, forest, and riparian/winter habitat (Table 8). Percent area of pasture/hay fields (10 and 3 km) and percent area of shrub habitat (10 and 1 km) had negative linear relationships with the probability of occurrence in the univariate analysis. This means that as the percent area of those land cover types increased, the probability of STG occurrence decreased. This result may seem contradictory since studies have shown that STG select CRP fields, which are represented by the pasture/hay category, for nests and brood rearing sites and that native shrubs are also important habitat for STG in Washington (McDonald 1998; Stonehouse 2013). CRP fields that have been planted with native shrubs and grasses are an important component of STG habitat in Washington. However, many older CRP fields were planted with a monoculture of crested wheatgrass that does not provide suitable habitat for STG (Stinson and Schroeder 2012). The pasture/hay category does not distinguish between CRP fields that are beneficial or not beneficial to STG which is one possible explanation for why these areas were negatively associated with STG occurrence. Additionally, current information on the location of cropland enrolled in CRP was not readily available when the WHCWG land cover layers were being developed. A comparison of the National Agricultural Statistics Service Crop Data Layer (USDA-NASS), to an older 2007 CRP dataset, showed that most CRP fields were captured in the CDL pasture/hay class (Appendix C) (B. Cosentino, personal communication May 19th, 2014).

The negative linear relationship between shrub habitat and STG occurrence may be due to the selection of land cover classes that were included in the shrub category. The WHCWG land cover/land use layer classes that were selected to represent native shrub habitat were, shrubland—basin and scabland (Appendix C). The shrubland—basin class included taller shrubs such as big sagebrush (*Artemisia tridentata)* and sparse herbaceous cover that is found in the hotter, drier areas of the Columbia Plateau (WHCWG 2012a). The scabland class included areas of poor, rocky soils with sparse cover characterized by low or dwarf shrubs such as stiff sagebrush (*Artemisia rigida*) and buckwheat species (*Eriogonum sp.*) (WHCWG 2012a). Stonehouse (2013) found that STG in eastern

Washington predominately selected grass habitats with sparse shrub cover for their home ranges and lek sites, and built nests primarily under taller bunchgrasses. This type of vegetative cover is defined by the WHCWG shrub-steppe class (WHCWG 2012a). The shrub-steppe class was not included in the shrub category but in the grass habitat category for the model.

The final model also identified areas of potential STG habitat that were predominately agriculture such as the fragmented patches along the border with Idaho. The percent agriculture variable, at all scales, had a negative linear relationship with the probability of occurrence in the univariate analysis. Percent agriculture was not included as a variable in either the phase I or phase II models. However, there was a strong correlation between percent grass and percent agriculture. Percent grass (10 km) was highly correlated with percent agriculture (10 km) and percent grass (3 km). Percent grass (3 km), one of the variables in the phase I model, had a strong correlation (r = - 0.63) with percent agriculture (10 km). Likewise, percent grass (10 km) was strongly correlated (r = - 0.62) with percent agriculture (3 km). Even though agriculture was strongly correlated with percent grass, areas that were predominately agriculture were still identified as potential habitat which may be a function of the combination of the model variables. Overall, the final model selected for higher elevation areas with low road density based on the variables in the two models: road density (1 km), which occurred in both models, and average elevation (10 and 1 km), which also occurred in both models but at different scales.

Table 8. A comparison of percent area for different land covers within Columbian Sharp-tailed Grouse current range and the final model habitat areas.

	Percent Land Cover						
Habitat	Agriculture	Grass	Shrub	Forest	Pasture/ Hay	Riparian/ Winter	Intro Grass
Current Range	15.45	40.96	25.38	6.79	4.70	2.06	3.78
Final Model	21.84	36.76	8.45	23.41	4.13	3.00	2.10

Modeling considerations

The models were developed from geographic spatial data that contained inherent inaccuracies that were determined by the scale and age of the data, the number and quality of data sources, and other potential sources of error. The data that was used for this model came from several sources, each compiled at different times. All of the data that was used for the analysis had 30 m resolution except for the precipitation data from PRISM which was 800 m. Even at this relatively fine-scale resolution, the WHCWG (2012b) recommended that the 30 m raster data from the Columbia Plateau analysis be used for landscape level planning at scales of 1:100,000 or coarser.

Other important considerations in evaluating the results of the final model are the habitat conditions and small population dynamics of the extant STG populations that were the basis for model development. The models compared the influence of environmental variables at active and inactive STG lek complexes. However, the quality of current habitat at existing lek complexes was not evaluated. Current habitat conditions may not be ideal for extant STG populations compared to the quality of habitat in the Palouse Prairie and other areas in the Columbia Plateau that historically supported the highest densities of STG (Stinson and Schroeder 2012). Dobler et al. (1996), emphasized that the suitability of the remaining shrub-steppe habitat for wildlife has changed in eastern Washington since it is now predominately located in areas of poor, rocky soils which play an important role in determining the quality of vegetation cover. Historically, the best habitat for STG was the deep soil, high precipitation areas of the Palouse Prairie in southeastern Washington (Yocom 1952; Stinson and Schroeder 2012). This was the first area in Washington where STG were extirpated when the native vegetation was converted to farmland in the early 20th century (Dobler et al 1996). The remaining STG populations are located in the northern portion of their historic range in higher elevation areas that were less impacted by agriculture, orchard, and livestock grazing (Schroeder 1996). Average elevations (10 and 1 km) were two of the model variables that best predicted for STG occurrence based on their current locations. While the current conditions of these higher elevation areas provide more suitable habitat compared to the more modified areas in lower elevations, they also may be less suitable for winter habitat. This is reflected in the higher winter fatalities that are currently experienced by the remaining populations (Schroeder 1996). Historically, lower elevation areas in the Columbia Plateau had better winter weather conditions and more suitable riparian habitat (Schroeder 1996). Another factor to consider in the model development is small population dynamics. The extant STG populations in Washington are small and therefore, more likely to be adversely affected by random changes to environmental conditions, such as variations in food, extreme weather, predation, and disease (Primack 2010; Stinson and Schroeder 2012). Therefore, STG lek complexes may become inactive due to local extinctions of small populations from random environmental or other stochastic events that may not be directly related to the suitability of the existing habitat (Shaffer 1981).

MANAGEMENT RECOMMENDATIONS

On-the-ground assessment of the final model's two large potential habitat areas in Okanogan County should be conducted to evaluate potential areas for land acquisitions, habitat restoration, and future translocations to expand the range of STG. Existing areas of suitable habitat that are near extant STG habitat areas and at high risk for development in Okanogan County, should be prioritized for acquisition. Continued shrub-steppe habitat restoration on WDFW, Colville Tribal, and Okanogan National Forest lands should also be a high priority in these areas. Shrub-steppe habitat restoration for STG would also benefit many other shrub-steppe species such as, Greater Sage-grouse (*Centrocercus urophasianus*), sagebrush sparrow (*Artemisiospiza belli*), sage thrasher (*Oreoscoptes montanus*), and burrowing owls (*Athene cunicularia*). In addition to the potential suitable STG habitat in Okanogan County, further consideration should be given to the large, existing areas of shrub-steppe habitat located on the Yakima Training Center, WDFW's Colockum and LT Murray Wildlife Areas, and the Yakama Indian Nation lands. Habitat areas on the Yakima Training Center are already managed for an extant population of Greater Sage-grouse and may also be suitable for STG. Historical ranges for Greater Sage-grouse and STG overlapped in eastern Washington and currently, one population of STG and Greater Sage-grouse home ranges overlap by 72% on the WDFW Swanson Lakes Wildlife Area in Lincoln County (Stonehouse 2013). Overall, consideration should also be given to the current conditions of STG habitat that were the basis for model development and which may be suboptimal to pre-settlement habitats that supported the greatest densities of STG.

CHAPTER 3 ADDITIONAL RECOMMENDATIONS

FURTHER ANALYSIS OF POTENTIAL COLUMBIAN SHARP-TAILED GROUSE HABITAT IN OKANOGAN COUNTY

The final model identified ten potential habitat patches for STG that were greater than 50,000 ha. Two of these patches were located in Okanogan County, in the northern portion of STG historical range, where extant STG populations are concentrated. These areas should be the focus of shrub-steppe conservation, restoration, and population augmentation to expand the range of STG (Schroeder 1996; McDonald and Reese 1998). Both of the large habitat patches were adjacent to multiple smaller patches that were less than two kilometers apart. These smaller patches were combined with the two larger patches for a composite analysis of land cover and land ownership within those potential habitat areas (Figure 13). It is important to note that the smaller habitat patches were often separated from the next patch by a local road or secondary highway. These roads may create potential barriers to STG movement among the patches (Robb and Schroeder 2012).

Land cover

The two composite potential habitat patches in Okanogan County were located on the eastern and western periphery of STG historical range. The east habitat patch had a total area of 226,246 ha and could potentially support a population of 1,131 STG at a density of 0.005 birds/ha (Table 9). The west patch had a total area of 105,173 ha and could potentially support a population of 525

STG at the same density. However, both of these patches had a high percentage of forest cover that would not provide suitable habitat for STG. The east patch had 41% forest cover and the west patch had 51% forest cover. In addition, these habitat patches may contain rugged areas and steep slopes greater than 30% that would also not be suitable habitat for STG (Stinson and Schroeder 2012; Stonehouse 2013). Overall, both patches had less percent area of agriculture, native shrubland, pasture/hay fields, and introduced grass compared to the extant STG habitat. The east patch had a higher percent of grassland but the west patch had a much lower percent of grassland than extant STG habitat. Both patches had a higher percentage of riparian/winter habitats. The west patch had more than twice as much percent area of riparian/winter habitat compared to current STG habitat.

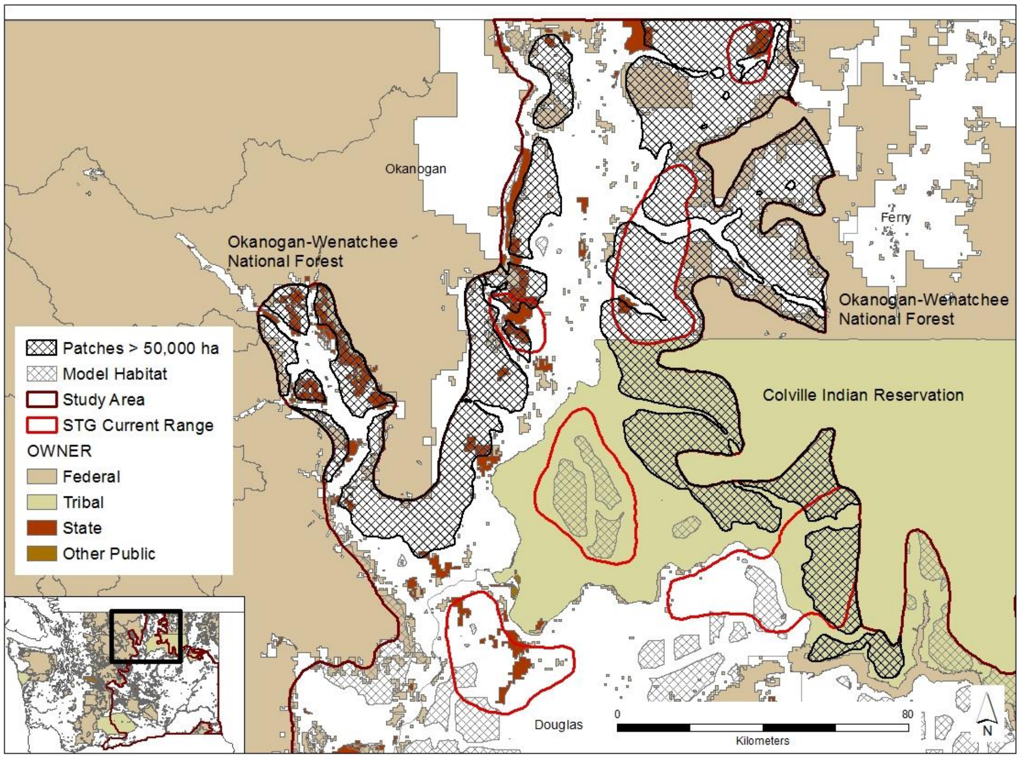

Figure 13. A composite of two model habitat patches in Okanogan County, greater than 50,000 ha, and adjacent habitat patches within two kilometers. These potential habitat patches are located on the eastern and western edge of STG historic range in Okanogan County in the area where extant STG populations are clustered.

Table 9. A comparison of percent land cover for current Columbian Sharp-tailed Grouse habitat range and two composite potential habitat areas in Okanogan County.

Habitat	Area (ha)	Percent Land Cover						
		Ag	Grass	Shrub	Forest	Pasture /Hay	Riparian /Winter	Intro Grass
Current Range	217,300	15.45	40.96	25.38	6.79	4.70	2.06	3.78
East Patch	226,246	0.35	42.83	8.97	41.31	0.12	3.87	2.17
West Patch	105,173	1.22	27.06	11.43	50.80	1.78	5.97	1.14

Land ownership

The two composite habitat patches are within ten recovery units identified in the Washington STG Recovery Plan (Stinson and Schroeder 2012). The Recovery Plan, in general, described the ten recovery units as potential STG habitat areas that were important for habitat connectivity, but also contained private lands that were at risk for development (Stinson and Schroeder 2012). The majority of the land in the west patch is privately owned (72.60%) whereas the east patch has slightly more land that is owned by federal and state agencies and the Colville Confederated Tribes (52.22%) (Table 10).

Table 10. A comparison of land ownership for the two composite potential habitat areas in Okanogan County.

	Land Ownership	Area (ha)	% Area
East Patch	Federal	33,972.12	15.02
	State	2,442.91	1.08
	Tribal	81,717.65	36.12
	Private	108,113.31	47.79
West Patch	Federal	14,971.39	14.24
	State	13,841.04	13.16
	Tribal	0.00	0.00
	Private	76,360.57	72.60

Challenges and opportunities

Land ownership and land use issues present some of the greatest challenges and opportunities for shrub-steppe habitat restoration in eastern Washington (Dobler et al. 1996). More than half (51%) of STG active lek complexes are located on private land (Schroeder et al. 2000). Connelly (2010), in an assessment of STG conservation needs in Okanogan County, concluded that private landowners were critical to the recovery effort for this species. However, shrub-steppe habitats on private land are vulnerable to current and new land use and land management practices including livestock grazing and development.

Livestock grazing in general, negatively impacts the quality of shrub-steppe habitats for STG. Intensive livestock grazing changes the structure and composition of shrub-steppe vegetation by increasing the spread of invasive grasses and woody vegetation, and decreasing native grasses and forbs that STG need for nesting and brood rearing (Stinson and Schroeder 2012). In addition, livestock grazing compacts soils and destroys the shrub-steppe soil crust which can be instrumental for survival of native grasses and forbs (Belnap et al. 2001). Livestock grazing that is very low intensity and that is timed to affect vegetation the least, may be sustainable in shrub-steppe habitats. However, further research and adaptive management strategies are needed to determine if there is an optimal threshold for grazing based on different plant communities, soils, precipitation, etc. (Beck and Mitchell 2000).

It is also important that remaining shrub-steppe habitat is not further divided into rural residential development (Connelly 2010). The Washington Recovery Plan for STG lists development as one of the factors affecting continued existence of STG in Washington (Stinson and Schroeder 2012). Four of the 10 Recovery Plan recovery units where the Okanogan County habitat patches are located are at high risk for development. Currently there are no federal or state regulations that protect STG or their habitats on private land (Stinson and Schroeder 2012).

Recommendations and conclusions

On-the-ground assessment of the potential habitat areas in Okanogan County should be conducted to identify relatively large intact shrub-steppe/grassland habitats. The number one priority should be to conserve and protect these habitats for STG and other shrub-steppe species. Dobler et al. (1996) emphasized that species tend to evolve in concert with their surroundings, and for shrub-steppe wildlife, like STG, this would mean species adapted to expansive landscape of steppe and shrub-steppe communities. Many shrub-steppe obligate and grassland species, like STG, are state or federal listed under the Endangered Species Act including, Greater Sage-grouse (*Centrocercus urophasianus*), which is a state threatened and federal candidate species, sagebrush sparrow (*Artemisiospiza belli*), sage thrasher (*Oreoscoptes montanus*), loggerhead shrike (*Lanius ludovicianus*), and burrowing owls (*Athene cunicularia*), which are state candidate species, and pygmy rabbit (*Brachylagus idahoensis*) which is a state and federal endangered species. Large, intact shrub-steppe habitats should be a priority for land acquisitions in Okanogan County for conservation to benefit these species. When land acquisitions are not possible, shrub-steppe habitats on private lands should be conserved and protected with long-range planning and policies adopted at the county level or in conjunction with governmental and non-governmental entities (Azarrad et al. 2011). Conservation incentive programs for private land owners such as, conservation easements that transfer development rights, and tax incentives are some options that are available to encourage shrub-steppe conservation (Azerrad et al. 2011).

Another high priority is continued shrub-steppe restoration and protection on WDFW, Colville Indian Reservation, Bureau of Land Management, and Okanogan National Forest lands that are within or adjacent to Okanogan County. When Greater Sage-grouse, which is currently a candidate species for protection under the ESA, is upgraded to a threatened or endangered status, there will be more funding opportunities for shrub-steppe habitat restoration on federal and state lands (USFWS 2013). Shrub-steppe habitat restoration and other population recovery efforts for Greater Sage-grouse could benefit STG since the two species can live sympatrically within the same habitat area. Currently there is one population of Greater Sage-grouse that is sympatric with a STG population in the vicinity of Swanson Lakes Wildlife Area in eastern Washington. Stonehouse (2013) found that the spring and summer habitat home ranges of the Swanson Lakes' Greater Sage-grouse and STG populations overlapped by 72%.

Finally, restoration of shrub-steppe habitats on private lands either through the CRP or other farmland conservation programs area also important for STG recovery. STG use restored CRP fields for nesting, brood rearing, and lek locations in eastern Washington (Stonehouse 2013). CRP lands currently comprise 4.7% of land cover in STG current range but only 0.12% of land cover in the east habitat patch and 1.78% in the west habitat patch in Okanogan County. There may be opportunities to increase the number of CRP acres that are enrolled in Okanogan County. Another farmland conservation program that could potentially be used to restore shrub-steppe habitat, is the Washington State Farmland Preservation Grants program (Azerrad et al. 2011). Cities, counties, nonprofit conservation organizations, and the State Conservation Commission can purchase conservation easements on farmland to help preserve farmland and protect wildlife through habitat restorations (Washington State Recreation and Conservation Office 2010; Azerrad et al. 2011).

IMPROVING THE COLUMBIAN SHARP-TAILED GROUSE MODEL

Developing the STG model was made possible by the availability of GIS data layers from the WHCWG (2012b) Columbia Plateau Ecoregional analysis. However, the extent of the WHCWG GIS data did not include areas in Ferry, Stevens, and Pend Oreille Counties in northeast Washington that were historically occupied by STG (Figure 4). In addition, the 10 km radius for two of the active lek complexes extended into Canada which was also not a part of the WHCWG GIS data. The difference between the extent of the WHCWG data and the STG historic range in Washington changed the way the model was created and applied. When the model was created, two of the active lek complexes' 10 km radii extended beyond the extent of the GIS data. As a result, only the 3 km and 1 km scales were used for the univariate analysis of the environmental variables for those two active lek complexes (n = 40) whereas the 10 km scale was not used for those two active lek complexes (n = 38). The model was applied to the WHCWG spatial layers to create a probability of occurrence map which excluded areas of STG historic range. These areas may contain suitable habitat for translocations. Expanding the extent of the WHCWG GIS data layers to include the entire STG historic range and areas of Canada should be considered especially if the WHCWG data layers are updated in the future or if another STG model is developed from the current layers.

In addition to expanding the extent of the spatial data layers and updating the layers, alternative modeling strategies should be considered for future STG models. One approach that may work well, since so many of the environmental variables were highly correlated, is a principal component analysis (PCA). A PCA would combine some of the variables together to create new variables that were no longer correlated but still retained the information from the original variables. The data in a PCA have to be normally distributed and independent. Autocorrelation between the lek complexes would have to be assessed to determine independence which may result in elimination of some of the leks complexes and a reduced sample size. This could be a potential drawback for this type of analysis since the sample size was already small.

Another approach to mapping suitable habitat for STG would be to create a fine-scale map of existing riparian/winter habitats using hydrology and vegetation maps in combination with near infrared National Agriculture Imagery Program (NAIP) orthophotos. STG rely on deciduous riparian trees and shrubs for cover and winter habitat (McDonald 1998) and these habitats can be a limiting factor for STG occupancy in the highly fragmented shrub-steppe ecosystem of the Columbia Plateau (Hofmann and Dobler 1988; Giesen and Connelly 1993; Stinson and Schroeder 2012). Habitats in the vicinity of mapped riparian/winter habitat could be assessed for suitability for STG using either *a priori* knowledge from the literature or modeling.

Optimal STG habitat could also be mapped based on the existing environmental conditions of areas that had the highest historic densities of STG, such as the deep soil, higher precipitation areas of the Palouse Prairie (Stinson and Schroeder 2012). These areas are now predominately cropland, however, a careful selection of environmental variables, and well documented historic occurrence of

STG in those areas, could provide support for land acquisition and habitat restoration on land that is better suited to STG.

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APPENDIX A LEK COMPLEX DATA

Lek ID	Lek Status	Last Year	Recent Count	Max Count
1	1	2013	11	30
2	0	2002	2	10
3	0	2012	1	7
4	0	1996	4	45
5	0	2011	2	2
6	0	1996	1	14
7	0	1994	1	5
8	0	2002	2	4
9	1	2013	6	22
10	0	1997	2	13
11	0	2005	5	14
12	0	1997	1	7
13	1	2013	5	14
14	0	2012	3	9
15	1	2013	18	18
16	1	2013	5	31
17	1	2013	4	25
18	0	2002	1	22
19	0	2009	1	28
20	1	2013	3	21
21	1	2013	20	20
22	0	2000	1	3
23	1	2013	21	21
24	1	2013	13	18
25	1	2013	3	7
26	1	2013	21	21
27	1	2013	19	40
28	0	2002	2	8
29	1	2013	24	26
30	1	2013	8	32
31	0	2002	3	9
32	0	1998	2	8
33	1	2013	7	7
34	0	1997	2	2
35	0	2002	15	15
36	0	1998	3	23
37	0	2005	1	10

Appendix A (continued)

Lek ID	Lek Status	Last Year	Recent Count	Max Count
38	1	2013	5	18
39	0	2012	10	16
40	0	2012	4	14
41	0	2011	1	3
42	1	2013	4	10
43	1	2013	26	26
44	0	1994	1	14
45	1	2013	7	15
46	1	2013	18	21
47	1	2013	11	11
48	1	2013	9	9
49	0	2012	11	12
50	1	2013	15	23
51	0	2005	2	8
52	0	2001	1	45
53	1	2013	13	13
54	1	2013	2	10
55	0	1997	1	1
56	0	2006	4	20
57	1	2013	28	32
58	0	2009	1	15
59	0	1998	2	4
60	0	2012	3	31
61	1	2013	12	13
62	0	1994	1	4
63	0	2007	2	24
64	1	2013	21	58
65	1	2013	4	11
66	1	2013	5	19
67	1	2013	3	10
68	1	2013	14	19
69	1	2013	12	20
70	0	1994	2	12
71	0	2011	3	9
72	1	2013	13	28
73	1	2013	3	13
74	1	2013	18	50
75	0	2012	2	28

Appendix A (continued)

Lek ID	Lek Status	Last Year	Recent Count	Max Count
76	0	1995	1	3
77	0	2002	1	4
78	1	2013	4	30
79	1	2013	1	22
80	1	2013	22	39
81	0	2011	2	4

APPENDIX B LAND COVER VARIABLE CATEGORIES

Variable Name	Land Cover Category	WHCWG (2012b) Land Cover/Land Use Class Name
gr	Grassland	Grassland - basin
		Grassland - mountain
		Shrubsteppe
		Meadow
sh	Shrubland	Shrubland - basin
		Scabland
rw	Riparian/winter habitat	Shrubland - mountain
		Herbaceous wetland
		Riparian
		Aspen
igr	Introduced grassland	Introduced upland vegetation -annual grassland
fr	Forest	Woodland
		Forest
ag	Agriculture	Nonirrigated cropland
		Irrigated/not irrigated cultivated agriculture buffer 0 - 250 m from native habitat
		Irrigated cropland
		Highly structured agriculture
		Cultivated cropland
		Irrigated/not irrigated cultivated agriculture buffer 250-500 m from native habitat
ph	Pasture/hay (CRP)	Pasture hay agriculture buffer 0-250 m from native habitat
		Pasture hay agriculture buffer 250-500 m from native habitat
		Pasture hay

APPENDIX C SOURCES AND DESCRIPTIONS OF LAND COVER CLASSES

NW GAP Class	WHCWG (2012a) Class Name
Columbia Basin Foothill and Canyon Dry Grassland	Grassland - Basin
Columbia Basin Palouse Prairie	Grassland - Basin
Columbia Plateau Steppe and Grassland	Grassland - Basin
Inter-Mountain Basins Semi-Desert Grassland	Grassland - Basin
Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland	Grassland - Basin
North Pacific Alpine and Subalpine Dry Grassland	Grassland - Mountain
North Pacific Dry and Mesic Alpine Dwarf-Shrubland, Fell-field and Meadow	Grassland - Mountain
North Pacific Herbaceous Bald and Bluff	Grassland - Mountain
North Pacific Montane Grassland	Grassland - Mountain
Northern Rocky Mountain Subalpine-Upper Montane Grassland	Grassland - Mountain
Rocky Mountain Alpine Fell-Field	Grassland - Mountain
Rocky Mountain Alpine Tundra/Fell-field/Dwarf-shrub Map Unit	Grassland - Mountain
Columbia Plateau Low Sagebrush Steppe	Shrubsteppe
Columbia Plateau Silver Sagebrush Seasonally Flooded Shrub-Steppe	Shrubsteppe
Inter-Mountain Basins Big Sagebrush Steppe	Shrubsteppe
Inter-Mountain Basins Montane Sagebrush Steppe	Shrubsteppe
Inter-Mountain Basins Semi-Desert Shrub Steppe	Shrubsteppe
Great Basin Xeric Mixed Sagebrush Shrubland	Shrubland - Basin
Inter-Mountain Basins Big Sagebrush Shrubland	Shrubland - Basin
Inter-Mountain Basins Mixed Salt Desert Scrub	Shrubland - Basin
Inter-Mountain Basins Curl-leaf Mountain Mahogany Woodland and Shrubland	Shrubland - Mountain
North Pacific Avalanche Chute Shrubland	Shrubland - Mountain
North Pacific Montane Shrubland	Shrubland - Mountain
Northern and Central California Dry-Mesic Chaparral	Shrubland - Mountain
Northern Rocky Mountain Montane-Foothill Deciduous Shrubland	Shrubland - Mountain
Northern Rocky Mountain Subalpine Deciduous Shrubland	Shrubland - Mountain
Columbia Plateau Ash and Tuff Badland	Scabland
Columbia Plateau Scabland Shrubland	Scabland

Appendix C (continued)

NW GAP Class	WHCWG (2012a) Class Name
Introduced Upland Vegetation - Annual Grassland	Introduced Upland Vegetation - Annual Grassland
North Pacific Bog and Fen	Meadow
Rocky Mountain Alpine-Montane Wet Meadow	Meadow
Rocky Mountain Subalpine-Montane Fen	Meadow
Rocky Mountain Subalpine-Montane Mesic Meadow	Meadow
Temperate Pacific Montane Wet Meadow	Meadow
Willamette Valley Wet Prairie	Meadow
Columbia Plateau Vernal Pool	Herbaceous Wetland
Inter-Mountain Basins Alkaline Closed Depression	Herbaceous Wetland
Inter-Mountain Basins Playa	Herbaceous Wetland
North American Arid West Emergent Marsh	Herbaceous Wetland
Temperate Pacific Freshwater Aquatic Bed	Herbaceous Wetland
Temperate Pacific Freshwater Emergent Marsh	Herbaceous Wetland
Columbia Basin Foothill Riparian Woodland and Shrubland	Riparian
Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland	Riparian
Inter-Mountain Basins Greasewood Flat	Riparian
Inter-Mountain Basins Montane Riparian Systems	Riparian
Introduced Upland Vegetation - Shrub	Riparian
Introduced Upland Vegetation - Treed	Riparian
Mediterranean California Foothill and Lower Montane Riparian Woodland	Riparian
North Pacific Lowland Riparian Forest and Shrubland	Riparian
North Pacific Montane Riparian Woodland and Shrubland	Riparian
North Pacific Shrub Swamp	Riparian
Northern Rocky Mountain Conifer Swamp	Riparian
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	Riparian
Rocky Mountain Lower Montane Riparian Woodland and Shrubland	Riparian
Rocky Mountain Subalpine-Montane Riparian Shrubland	Riparian
Rocky Mountain Subalpine-Montane Riparian Woodland	Riparian

Appendix C (continued)

NW GAP Class	WHCWG (2012a) Class Name
Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	Aspen
Rocky Mountain Aspen Forest and Woodland	Aspen
Columbia Plateau Western Juniper Woodland and Savanna	Woodland
Introduced Upland Vegetation - Perennial Grassland and Forbland	Woodland
North Pacific Broadleaf Landslide Forest and Shrubland	Woodland
North Pacific Maritime Mesic Subalpine Parkland	Woodland
North Pacific Oak Woodland	Woodland
North Pacific Wooded Volcanic Flowage	Woodland
Northern California Mesic Subalpine Woodland	Woodland
Northern Rocky Mountain Ponderosa Pine Woodland and Savanna	Woodland
Northern Rocky Mountain Subalpine Woodland and Parkland	Woodland
Northern Rocky Mountain Western Larch Savanna	Woodland
Willamette Valley Upland Prairie and Savanna	Woodland
East Cascades Mesic Montane Mixed-Conifer Forest and Woodland	Forest
East Cascades Oak-Ponderosa Pine Forest and Woodland	Forest
Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland	Forest
Mediterranean California Red Fir Forest	Forest
Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	Forest
North Pacific Dry Douglas-fir-(Madrone) Forest and Woodland	Forest
North Pacific Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest	Forest
North Pacific Lowland Mixed Hardwood-Conifer Forest and Woodland	Forest
North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest	Forest
North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest	Forest
North Pacific Mesic Western Hemlock-Silver Fir Forest	Forest

Appendix C (continued)

NW GAP Class	WHCWG (2012a) Class Name
North Pacific Mountain Hemlock Forest	Forest
Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	Forest
Northern Rocky Mountain Mesic Montane Mixed Conifer Forest	Forest
Rocky Mountain Lodgepole Pine Forest	Forest
Rocky Mountain Poor-Site Lodgepole Pine Forest	Forest
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Forest
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	Forest
Cultivated Cropland	Cultivated Cropland

USDA-NASS Crop Data Class	WHCWG (2012a) Class Name
Pasture/Hay	Pasture/Hay
Alfalfa	Pasture_Hay
Other Hay	Pasture_Hay
Clover/Wildflowers	Pasture_Hay
Pasture/Grass	Pasture_Hay
Caneberries	Highly Structured Agriculture
Hops	Highly Structured Agriculture
Cherries	Highly Structured Agriculture
Peaches	Highly Structured Agriculture
Apples	Highly Structured Agriculture
Grapes	Highly Structured Agriculture
Christmas Trees	Highly Structured Agriculture
Other Tree Nuts	Highly Structured Agriculture
Other Tree Fruits	Highly Structured Agriculture
Walnuts	Highly Structured Agriculture
Pears	Highly Structured Agriculture
Nectarines	Highly Structured Agriculture
Plums	Highly Structured Agriculture
Apricots	Highly Structured Agriculture
Blueberries	Highly Structured Agriculture
Corn	Irrigated Cropland

Appendix C (continued)

USDA-NASS Crop Data Class	WHCWG (2012a) Class Name
Soybeans	Irrigated Cropland
Sunflower	Irrigated Cropland
Sweet Corn	Irrigated Cropland
Mint	Irrigated Cropland
Flaxseed	Irrigated Cropland
Mustard	Irrigated Cropland
Sugarbeets	Irrigated Cropland
Potatoes	Irrigated Cropland
Other Crops	Irrigated Cropland
Misc. Vegs. & Fruits	Irrigated Cropland
Watermelons	Irrigated Cropland
Onions	Irrigated Cropland
Peas	Irrigated Cropland
Tomatoes	Irrigated Cropland
Herbs	Irrigated Cropland
Carrots	Irrigated Cropland
Asparagus	Irrigated Cropland
Greens	Irrigated Cropland
Strawberries	Irrigated Cropland
Squash	Irrigated Cropland
Dbl. Crop WinWht/Corn	Irrigated Cropland
Dbl. Crop Oats/Corn	Irrigated Cropland
Lettuce	Irrigated Cropland
Cucumbers	Irrigated Cropland
Pumpkins	Irrigated Cropland
Cabbage	Irrigated Cropland
Radishes	Irrigated Cropland
Sorghum	Nonirrigated Cropland
Barley	Nonirrigated Cropland
Spring Wheat	Nonirrigated Cropland
Winter Wheat	Nonirrigated Cropland
Rye	Nonirrigated Cropland
Oats	Nonirrigated Cropland
Speltz	Nonirrigated Cropland
Canola	Nonirrigated Cropland
Safflower	Nonirrigated Cropland
Rape Seed	Nonirrigated Cropland
Camelina	Nonirrigated Cropland

Appendix C (continued)

USDA-NASS Crop Data Class	WHCWG (2012a) Class Name
Dry Beans	Nonirrigated Cropland
Lentils	Nonirrigated Cropland
Sod/Grass Seed	Nonirrigated Cropland
Fallow/Idle Cropland	Nonirrigated Cropland
Triticale	Nonirrigated Cropland