Appendix A.1

Habitat Connectivity for Sharp-tailed Grouse (*Tympanuchus phasianellus*) in the Columbia Plateau Ecoregion

Prepared by Leslie Robb (Independent Researcher) and Michael A. Schroeder (WDFW)

Modeling and GIS analysis by Brian Cosentino (WDFW), Brian Hall (WDFW), Darren Kavanagh (TNC), Brad McRae (TNC), and Andrew Shirk (UW)

Introduction

Sharp-tailed Grouse photo by Gregg Thompson

The *Washington Connected Landscapes Project: Statewide Analysis* (WHCWG 2010) modeled connectivity for 16 focal species within Washington. This analysis incorporated data layers such as land cover/land use, elevation, slope, housing density, and roads at a 100-meter scale of resolution. Because of the generality of the layers and the relatively coarse scale of the statewide analysis, the approach was refined for a connectivity assessment of the Columbia Plateau Ecoregion, a part of the state with an extensive human footprint and many species that are declining in both distribution and abundance.

For the Columbia Plateau Ecoregion analysis we used additional data layers, better defined habitat variables, and a finer scale of resolution to examine connectivity issues for 11 focal species, including Sharp-tailed Grouse (*Tympanuchus phasianellus*). We use occurrence data to assess *current conditions* for connectivity for Sharp-tailed Grouse. We have chosen to apply this "fine filter" to the connectivity analysis because we have the opportunity to use survey and radio-telemetry data to develop the connectivity models. Using current survey data allowed us to assess connectivity for Sharp-tailed Grouse within and among known populations and thus help prioritize on-the-ground connectivity conservation efforts. Our intent is for this analysis to build upon what was learned at the statewide scale, to better inform conservation and management efforts for Sharp-tailed Grouse in the Columbia Plateau and to further our understanding of connectivity issues for other shrubsteppe dependent species.

Justification for Selection

Sharp-tailed Grouse were chosen as a focal species to represent the Shrubsteppe, Grassland, and Riparian vegetation classes in the Columbia Plateau Ecoregion of eastern Washington. Sharp-tailed Grouse have large home ranges, are capable of extensive movements, and use a mosaic of habitats within the Columbia Plateau Ecoregion. They scored an Excellent rating for all criteria used to assess and select focal species (See Appendix E).

Sharp-tailed Grouse were historically found throughout steppe, grassland, and mixed-shrub habitats of northern and central North America (Connelly et al. 1998). Populations were originally found in 21 states and 8 Canadian provinces. Numbers of Sharp-tailed Grouse have declined range-wide since the 1900s, especially in the eastern and southern portions of their range (Connelly et al. 1998). Primary factors attributed to this decline include, but are not limited to, conversion of native habitat to cropland, excessive grazing by livestock, herbicide treatments, removal of trees in riparian areas, invasion of conifers, urban development, and fire suppression (Giesen & Connelly 1993; Connelly et al. 1998).

There are seven recognized sub-species (one extinct) of Sharp-tailed Grouse in North America (Connelly et al. 1998); the subspecies found in Washington, Idaho, Oregon and British Columbia is the Columbian Sharp-tailed Grouse (*T. p. columbianus*; Aldrich & Duvall 1955). The distribution of Columbian Sharp-tailed Grouse has severely contracted range-wide and <10% of the historical range is currently occupied (Bart 2000). Range contraction has been particularly severe in Washington where Columbian Sharp-tailed Grouse inhabit <3% of their 79,865 km^2 historical range (Schroeder et al. 2000; Stinson & Schroeder 2010).

Sharp-tailed Grouse are classified as a game bird under Washington State law, but hunting has been closed since 1988 (Stinson & Schroeder 2010). They are listed as Threatened by the state of Washington, and are designated a Priority Species and their habitats Priority Habitats, by the Washington Department of Fish and Wildlife (WDFW) Priority Habitats and Species Program (Hays et al. 1998). In 1995, the U.S. Fish and Wildlife Service (USFWS) was petitioned to list Sharp-tailed Grouse as Threatened under the federal Endangered Species Act; the agency held that listing was not considered warranted (USFWS 2000). The Columbian subspecies was again petitioned for federal listing as Threatened or Endangered in 2004; the USFWS (2006) again determined that listing was not warranted. However, Bart (2000) in a status review for the USFWS predicted that without federal protection most of the small remnant populations of Columbian Sharp-tailed Grouse, like those in Washington, would likely be extirpated in a decade or two.

Distribution

The historical range of the Columbian subspecies of Sharp-tailed Grouse (hereafter Sharp-tailed Grouse) included central-interior British Columbia south to California, Nevada and Utah, east to western Montana, Wyoming, Colorado and possibly New Mexico (Aldrich & Duvall 1955; Bart 2000). Habitat loss and degradation are the primary factors responsible for population declines (Bart 2000). By the mid-1900s Sharp-tailed Grouse were extirpated from California, Nevada, and Oregon. Remnant populations (≤1000 birds) occur in Washington, Montana and Wyoming. Populations of ≥5000 birds occur in Idaho, Utah, Colorado, and British Columbia (Schroeder et al. 2000).

Beginning in the early 1990s, efforts were made to reestablish populations of Sharp-tailed Grouse in extreme northeastern Oregon and northeastern Nevada. Since the early 1900s, numbers of Sharp-tailed Grouse have declined an estimated 70% in British Columbia, especially in grassland habitats in the south-central interior. They have expanded their range and their numbers in the forested areas of the central interior in response to large-scale timber harvesting that has created suitable habitat. This increase is predicted to be temporary as clear cuts grow back (Leupin 2003).

Historical evidence indicates that Sharp-tailed Grouse were abundant and widely distributed in eastern Washington (Schroeder et al. 2000; Stinson & Schroeder 2010). Significant population declines were observed in the late 1800s and continued steadily throughout the 1900s; the overall estimated decline was 91.5% between 1954 and 1998 (Schroeder et al. 2000). Landscape scale changes between the 1900s and 1990s resulted in a decrease of grassland cover types from 25% to 1.3% and a minimum patch size decrease from 3765 ha to 299 ha (McDonald & Reese 1998). Buss and Dziedzic (1955) estimated that by 1920, 80% of Adams, Spokane, and Whitman counties were converted to farmland coinciding with the dramatic decline in Sharp-tailed Grouse from "abundance to virtual annihilation." Interestingly, when the researchers surveyed farmers in the region (approximately 200), the majority of respondents felt that over-hunting was the most important "decimating" factor leading to extirpation.

The current distribution of Sharp-tailed Grouse encompasses 2234 km^2 or 2.8% of their historical range in the state (Schroeder et al. 2000). There are approximately 900 Sharp-tailed Grouse in Washington (M.A.S) distributed among seven small, isolated populations in Okanogan, Douglas, and Lincoln counties (Hays et al. 1998; Schroeder et al. 2000; Stinson & Schroeder 2010). More than half (51.1%) of the active breeding complexes associated with these remnant populations are located on private land, 24.4% are on state or federal land, and 24.4 % are on the Colville Reservation (Schroeder et al. 2000).

Habitat Associations

General

Sharp-tailed Grouse use a variety of habitats in Washington including shrubsteppe, meadowsteppe, mountain shrub, and riparian/deciduous habitats (Hays et al. 1998). The presence of dense herbaceous vegetation and shrubs is of key importance. Plant species composition is secondary to structural characteristics of the habitat (Connelly et al. 1998). Grassland habitats provide breeding and nesting areas while deciduous trees and shrubs in upland and riparian areas provide essential food and cover in winter (Giesen & Connelly 1993). Historical densities of Sharp-tailed Grouse in Washington are believed to have been highest where steppe habitats were interspersed with riparian, forest-edge, and mountain-shrub habitats (Schroeder et al. 2000; Stinson & Schroeder 2010). Topographic features such as elevation and slope vary throughout the range. In Washington, Sharp-tailed Grouse are found at elevations of 300–1350 m but in other parts of their range occur as high as 2900 m (Hays et al. 1998). Slope tends to be used in proportion to availability. In southwestern Idaho, Saab and Marks (1992) noted that in summer birds used habitats with 0–47% slope, however most observations (>95%) were <30% slope.

Breeding

In spring, Sharp-tailed Grouse congregate on traditional sites termed leks for courtship and breeding. Leks are typically situated on elevated areas such as knolls or ridgetops, but lower sites are also used (Giesen & Connelly 1993). Leks are often located in disturbed areas or on sites with less vegetation than surrounding areas (Connelly et al. 1998). Factors important for nesting and brood rearing habitat include: (1) vegetation density, (2) vegetation height, and (3) diversity of forbs and bunchgrasses (Giesen & Connelly 1993). Abundance of forbs and insects, high shrub density, and interspersion of cover types are features of good brood habitat (Connelly et al. 1998).

Winter

In winter Sharp-tailed Grouse rely on deciduous trees and shrubs in upland and riparian areas for food and cover (Connelly et al. 1998). In western Idaho, Mark and Marks (1988) found 88% of all winter locations of Sharp-tailed Grouse were <50 m from mountain shrub or riparian cover types. In Washington winter habitat is variable as radio-marked birds were observed in wheat (19%), native grass (19%), big sagebrush (*Artemisia tridentata*, 19%), threetip sagebrush (*A. tripartita*, 15%), planted grass (7.7%), water birch (*Betula occidentalis*, 7.7%), antelope bitterbrush (*Purshia tridentata*, 3.8%), snowberry (*Symphoricarpos* sp., 3.8%), and rose (Rosa sp., 3.8%). Use of water birch appeared to be positively correlated with both snowy weather and poor habitat quality (Schroeder 1996). Sharp-tailed Grouse used riparian/mountain shrub more during winter (15.9% vs. 3.7%) mostly during high snow levels (McDonald 1998).

Agriculture

The Conservation Reserve Program (CRP) is a voluntary program (administered by the United States Department of Agriculture) that pays farmers to take agricultural lands out of production to achieve specific conservation objectives, one of which is to improve wildlife habitat. A review of prairie grouse and CRP lands concluded that more than any other species, Sharp-tailed Grouse responded positively (both populations and range) to CRP in 10 of 12 states where they occur. CRP is considered integral to conservation of Sharp-tailed Grouse in Colorado, Utah, and Idaho (Rodgers & Hoffman 2005). Bart (2000) believed termination or modification of the CRP so that it no longer supports Sharp-tailed Grouse would result in severe declines and extirpation of populations.

Radio-marked birds monitored on the Swanson Lakes Wildlife Area (SLWA) in Lincoln County used CRP lands more than expected by availability; 11 of 17 nests found at SLWA were situated in CRP (McDonald 1998). However, nest success was significantly lower (18%) in CRP lands planted mainly with crested wheatgrass (*Agropyron cristatum*) than in two other sites where cover type consisted of native bunch-grasses and forbs (38% and 47%; McDonald 1998). Lands enrolled in the Conservation Reserve Program in Washington may reduce resistance to movement in the landscape for Sharp-tailed Grouse by providing suitable habitat.

Standing wheat or spilled grain in fields is an important winter food source in some locations. Sharp-tailed Grouse are also known to use wheat fields in winter (Stinson & Schroeder 2010).

Sensitivity to Roads and Traffic

Vehicles and roads can be a source of mortality for Sharp-tailed Grouse (Stinson & Schroeder 2010). Buss (1984) recorded 18 road-killed Sharp-tailed Grouse along U.S. Highway 12 in eastern Montana during November in a year when there was an unusually high number of birds moving southward. Evidence from radio-marked birds introduced to the Scotch Creek Wildlife Area in Okanogan County indicates that Sharp-tailed Grouse crossed U.S. Highway 97 (Schroeder & Peterson 1998). Birds tended to cross the highway where it was situated in a valley between ridges (M.A.S.) suggesting that landscape resistance from highways may be mitigated by topography, and that crossing areas may be limited. The extent to which Sharp-tailed Grouse avoid roads is unknown and such behavior may vary with factors such as traffic volume and noise levels. For example, in winter months they are occasionally seen in deciduous shrubs and trees near local paved roads in Douglas County, Washington (M.A.S.).

Few studies have documented effects of anthropogenic noise on Sharp-tailed Grouse populations. However, a review of studies documenting the effects of paved roads on birds concluded that indirect effects, including noise, artificial light, barriers to movement, and edge habitats, may exert a greater effect on populations than direct effects of mortality, habitat loss, and fragmentation. Of these indirect effects, traffic noise has a greater impact on birds than other taxonomic groups possibly because birds rely on acoustic communication (Kociolek et al. 2011).

Sensitivity to Development

Initial declines of Sharp-tailed Grouse occurred in the early 1900s when much of eastern Washington was dramatically altered by livestock grazing, agriculture, and development. Since then numerous factors have contributed to the continued conversion, fragmentation, and degradation of habitat and isolation of populations (Stinson & Schroeder 2010). Sharp-tailed Grouse currently occupy small portions of Douglas, Grant, and Lincoln counties, about 3% of their historical distribution (Stinson & Schroeder 2010). Occupied range exists in higher elevation steppe habitats where ranching and farmland are the predominant land-use practices and human population densities are relatively low. Conversion of these areas to residential development, even at a low density, potentially decreases habitat suitability and connectivity among occupied areas (Stinson & Schroeder 2010).

Sensitivity to Energy Development

WIND ENERGY DEVELOPMENT

Wind power is an emerging land use issue contributing to the overall threat posed by energy development to Sharp-tailed Grouse populations. Impacts are largely unknown because development is so recent that immediate and lag effects have not been identified (Doherty et al. 2011; Knick et al. 2011). The consideration of time-lag effects is important: analysis of Greater Sage-Grouse (*Centrocercus urophasianus*) and oil and gas well development sites suggest that measurable affects on lek attendance by grouse can occur 2–10 years following activities associated with energy development (Harju et al. 2010). Studies of wind energy development and grouse are inconclusive possibly because grouse species demonstrate variable sensitivity to this type of disturbance. Zeiler and Grünschachner-Berger (2009) documented a strong decline of a local Black Grouse (*Lyrurus tetrix*) population during an 8-year period following construction of a wind energy facility consisting of 13 turbines. However, Greater Prairie-Chicken and Sharp-tailed Grouse continue to display at the Nebraska Public Power District Ainsworth Wind Energy facility (36 wind turbines) in Nebraska since construction in 2005 (Vodehnal 2011). Although there have been changes in lek persistence and attendance on the site these changes are difficult to evaluate relative to construction of the wind facility because of the lack of pre-construction surveys.

Direct and indirect effects of wind energy development on Sharp-tailed Grouse are largely unknown. Johnson and Holloran (2010) noted that five Sharp-tailed Grouse have been recorded colliding with wind turbines. Because of sensitivity of prairie grouse to anthropogenic disturbance, in a briefing paper for the USFWS Manville (2004) recommended avoiding placing wind turbines within 8 km of known leks.

TRANSMISSION LINES

Powerlines can be a source of mortality for Sharp-tailed Grouse (Stinson & Schroeder 2004). Pitman et al. (2005) seldom found Lesser Prairie-Chicken nests within 400 m of transmission lines even though the habitat was similar. Radio-tagged Greater Prairie-Chickens (*Tympanuchus cupido*; *n* = 216) and Lesser Prairie-Chickens (*T. pallidicinctus*; *n* = 463) avoided crossing a powerline right-of-way (Pruett et al. 2009b) even though this feature was within their home ranges. Changes in habitat use by Lesser Prairie-Chickens 1 year following construction of a 138 kV powerline indicated that monthly use areas were less likely to include powerlines than non-use areas. However, these data were limited to 1 year following construction and may not assess long-term effects as adult Lesser Prairie-Chickens exhibit strong site fidelity to breeding areas (Hagen et al. 2011).

Sensitivity to Climate Change

For sagebrush habitats global climate-change models predict more variable and severe weather events, higher temperatures, drier summer soil conditions, and wetter winter seasons in (Miller et al. 2011). The current distribution of sagebrush is predicted to decrease 12% for each degree of temperature increase (Neilson et al. 2005). A possible decrease in distribution of sagebrush, attributed to increased levels of atmospheric carbon dioxide, is predicted to favor cheatgrass (*Bromus tectorum*) expansion and exacerbate the fire cycle in cheatgrass-dominated systems (Miller et al. 2011). Impacts of global climate change have the potential to affect Sharp-tailed Grouse as the consequences of these changes interact with stresses that are already affecting populations. Climate induced stressors may have a greater affect on small isolated populations such as those in Washington (Stinson & Schroeder 2010). It is not known how climate change may affect parasites and disease. Sharp-tailed Grouse occupy a small fraction of their original distribution in Washington and many of these areas are higher elevation "islands" of habitat. Thus, any climate change impacts have potential to put the remaining range—and the species—at risk.

Dispersal

Little is known about natal dispersal (movement from hatch location to place of first breeding or attempted breeding) by juvenile Sharp-tailed Grouse. Seasonal movement information for Sharp-tailed Grouse is limited to data collected from radio-marked birds captured at leks and monitored throughout the year (Table A.1.1).

From spring through fall, Sharp-tailed Grouse move fairly short distances: females in Washington nested an average 1.3 km from the leks where they were captured (Schroeder 1994). Distances moved by Sharp-tailed Grouse are likely influenced by landscape features. For instance, Schroeder (1996) found seasonal distances moved by Sharp-tailed Grouse differed significantly by county in Washington, with migration distances largest in Lincoln County. By comparison, Boisvert et al. (2005) monitored Sharp-tailed Grouse on CRP and Mine Reclamation lands in northwestern Colorado: during winter, birds were a median distance of

21.5 km from lek sites where they were captured. The shorter distances moved by Sharp-tailed Grouse in Washington may be influenced by the fragmented nature of the populations (M.A.S.).

Sharp-tailed Grouse were released on the Scotch Creek Wildlife Area by WDFW in 1998 as part of a population augmentation project. Based on 1300 observations of 24 radio-marked individuals, birds moved an average of 12–17 km from the wildlife area during the initial weeks following release (Schroeder & Peterson 1998). Movement behavior suggested that the released birds "explored" potential habitat in the region. All the birds eventually returned to the wildlife area except for two females who moved 34 and 31 km respectively and established in the Tunk Valley and Siwash Creek areas of Okanogan County after "finding" local populations of Sharp-tailed Grouse. M.A.S. suggested that the released birds had a search distance of about 16 km and returned to the Scotch Creek Wildlife Area when they did not encounter other Sharp-tailed Grouse.

Table A.1.1. Seasonal movements of Sharp-tailed Grouse.

	Distance (km)			
Category/location	*mean*	*median*	*maximum*	*Citation*
Females				
hunter return juveniles/SD	21.6			Robel et al. 1972
breeding to winter range/WA	4.4			Schroeder 1996
breeding to winter range/CO	21.4			Boisvert et al. 2005
from capture, autumn/CO		1.5		Giesen 1997
from capture lek, spring/WA	2.0			McDonald 1998
from capture lek, spring/WA	1.0			McDonald 1998
from capture lek, winter/WA	2.3			McDonald 1998
from capture lek, winter/WA	5.6			McDonald 1998
from capture lek, winter/WA			11.5	McDonald 1998
Males				
hunter return juveniles/SD	13.6			Robel et al. 1972
breeding to winter range/WA	2.8			Schroeder 1996
breeding to winter range/CO	21.5			Boisvert et al. 2005
from capture lek, autumn/CO		0.6		Giesen 1997
from capture lek, spring/WA	0.6			McDonald 1998
from capture lek, spring/WA	0.7			McDonald 1998
from capture lek, winter/WA	2.8			McDonald 1998
from capture lek, winter/WA	1.0			McDonald 1998
from capture lek, winter/WA			9.7	McDonald 1998

Conceptual Basis for Columbia Plateau Model Development

Overview

Habitats used by Sharp-tailed Grouse are well documented (Connelly et al. 1998; Stinson & Schroeder 2010). Optimal habitat consists of a mosaic of shrubsteppe, meadowsteppe, mountain shrub, and riparian/deciduous plant communities. Grassland type habitats are used for nesting and brood rearing while deciduous trees and shrubs in upland and riparian areas are essential for food and cover in winter. What is less understood is how various habitat types, especially altered habitats, influence movement of Sharp-tailed Grouse through the landscape. Although Meints et al. (1992) and Ashley (2006) have constructed habitat suitability models for Sharp-tailed Grouse, there is a lack of specific modeling analyses examining anthropogenic disturbances and their affect on Sharp-tailed Grouse.

To characterize landscape resistance for Sharp-tailed Grouse we used, whenever possible, documented habitat associations. Behavioral responses to constructed habitat features, such as buildings and roads, are more difficult to document and most evidence comes from research on other species of prairie grouse. For instance, Greater Sage-Grouse, Lesser Prairie-Chickens, and Greater Prairie-Chickens (*T. cupido*) tend to avoid vertical structures in the landscape (Braun 1998; Pitman et al. 2005; Pruett et al. 2009a; Hagen et al. 2011). When information was lacking for Sharp-tailed Grouse, we relied upon the professional judgment and knowledge of grouse biologists to score resistance values. Housing density and roads were considered major factors contributing to landscape resistance to movement for Sharp-tailed Grouse.

Movement Distance

Based on Sharp-tailed Grouse movement information (see Dispersal and Movement Distance subsections) an unweighted Euclidean distance of 60 km was used to define the maximum corridor length in the normalized least-cost corridor analysis. A corridor width of 10 km CWD was selected for linkage modeling.

Habitat Concentration Areas

At the statewide scale of analysis we modeled connectivity among polygons of habitat that represented the known distribution for Sharp-tailed Grouse in Washington. For the Columbia Plateau analysis we have refined the definition and scale of the habitat concentration areas (HCAs) so that: (1) HCAs do not include potential barriers to movement, and (2) HCAs provide insight to potential patterns of movement at the finer scale of analysis, e.g. within the known distribution. We developed HCAs for Sharp-tailed Grouse using lek and nest locations rather than using a habitat value modeling approach. Sharp-tailed Grouse exhibit well-documented site fidelity to leks, annual lek surveys are standard protocol for monitoring populations in Washington and range-wide (Connelly et al. 1998; Stinson & Schroeder 2010), and leks represent important sites for breeding activity within populations that have also been used in other studies to model spatial connectivity (Knick & Hanser 2011). Additionally, females generally select nest sites in suitable habitats near the lek where they breed (Stinson & Schroeder 2010).

We developed HCAs for Sharp-tailed Grouse using WDFW survey data including: (1) locations of active breeding areas in 2011 (leks, n = 48), (2) 91 nest locations of resident radio-marked birds (not birds translocated from other states; nest locations from 1992 to 1997, we eliminated nest locations for females captured at leks that were active at the time of the original telemetry research, but are inactive now), and (3) 256 winter (December and January, 1992–1997) locations of radio-marked birds. The HCAs were created by moving outward a cost-weighted distance from lek locations until 95% of nest locations were included within the HCA (CWD = 5.2 km). The generated HCAs were determined to also include 89% of winter locations for radio-marked birds. We did not use winter locations to generate HCAs for the following reasons. First the ability to accurately locate radio-marked birds during winter was variable and was influenced by accessibility of a site increasing the bias of these data. Second, when we overlaid winter locations on the HCAs generated using nest locations, we determined that many of the winter locations that were outside HCAs were associated with leks that were active at the time of the original telemetry research, but are inactive now.

Resistance and Habitat Values for Landscape Features

We assigned resistance values to parameters associated with the land cover/land use, housing density, road, railroad, transmission line, and wind turbine GIS data layers (Table A.1.2) to model connectivity for Sharp-tailed Grouse. The lowest resistance value in Table A.1.2 was 0, indicating no additional resistance beyond the effect of distance alone. There was also an attempt to simplify other values to reflect general assumptions. Values from 1 to 4 (Table A.2.2) were used to reflect a relatively low cost of movement (2–5 times the minimal cost of travel across a unit of distance). The higher costs of travel were assigned values of 9, 19, 49, and 99. For all practical purposes, a value of 99 reflected a "barrier" to travel by Sharp-tailed Grouse. It should also be noted that many values were assigned a value of 0; either because of a lack of information or because any possible effect of the parameter was secondary to an identified, overriding factor. For example, we did not assign resistance to soil type, even though soil type may be correlated with the presence and movement of Sharp-tailed Grouse. However, because soil type is secondary to habitat, and habitat type was identified, parameterization of soil type would have been redundant. We also did not assign resistance to rare habitats for which very little information was available (e.g., Dunes). We assumed that the Pasture Hay class which included Conservation Reserve Program lands (See Appendix E) had no resistance to movement. Because Sharp-tailed Grouse will move into agricultural fields from native habitat, we assumed that there was no additional resistance to movement within the Agriculture 0–250 m buffer class. Freeways and Major Highways were the primary road classes contributing to movement resistance for Sharp-tailed Grouse in the landscape, and we assumed that traffic noise may contribute to resistance in road buffers.

(continued on page A.1-11)

Table A.1.2. Landscape features and resistance values used to model habitat connectivity for Sharp-tailed Grouse.

Spatial data layers and included factors	*Resistance value*	*Habitat value**
Landcover/Landuse		
Grassland_Basin	0	n/a
Grassland_Mountain	0	n/a
Shrubsteppe	0	n/a
Dunes	0	n/a
Shrubland_Basin	0	n/a
Shrubland_Mountain	4	n/a
Scabland	0	n/a
Introduced upland vegetation_Annual grassland	0	n/a
Cliffs_Rocks_Barren	0	n/a
Meadow	0	n/a
Herbaceous wetland	4	n/a
Riparian	0	n/a
Introduced riparian and wetland vegetation	0	n/a
Water	4	n/a
Aspen	0	n/a
Woodland	4	n/a
Forest	9	n/a
Disturbed	4	n/a
Cultivated cropland from RegapNLCD	4	n/a
Pasture Hay from CDL	0	n/a
Non-irrigated cropland from CDL	4	n/a
Irrigated cropland from CDL	4	n/a
Highly structured agriculture from CDL	4	n/a
Irrigated/Not Irrigated/Cultivated Crop Ag Buffer 0 – 250m from native habitat	0	n/a
Irrigated/Not Irrigated/Cultivated Crop Ag Buffer 250 – 500m from native habitat	4	n/a
Pasture Hay Ag Buffer 0 – 250m from native habitat	0	n/a
Pasture Hay Ag Buffer 250 – 500m from native habitat	0	n/a
Housing Density Census 2000		
Greater than 80 ac per dwelling unit	0	n/a
Greater than 40 and less than or equal 80 ac per dwelling unit	9	n/a
Greater than 20 and less than or equal 40 ac per dwelling unit	19	n/a
Greater than 10 and less than or equal 20 ac per dwelling unit	49	n/a
Less than or equal 10 ac per dwelling unit	99	n/a
Roads		
Freeway Centerline	24	n/a
Freeway Inner buffer 0 – 500m	4	n/a
Freeway Outer buffer 500 – 1000m	1	n/a
Major Highway Centerline	19	n/a
Major Highway Inner buffer 0 – 500m	3	n/a
Major Highway Outer buffer 500 – 1000m	0	n/a
Secondary Highway Centerline	9	n/a
Secondary Highway Inner buffer 0 – 500m	2	n/a
Secondary Highway Outer buffer 500 – 1000m	0	n/a
Local Roads Centerline	2	n/a
Local Roads Inner buffer 0 – 500m	0	n/a
Local Roads Outer buffer 500 – 1000m	0	n/a
Railroads Active		
Railroads Active Centerline	2	n/a
Railroads Active Inner buffer 0 – 500m	0	n/a
Railroads Active Outer buffer 500 – 1000m	0	n/a
Transmission Lines		

Spatial data layers and included factors	*Resistance value*	*Habitat value**
LessThan 230KV One Line Centerline	2	n/a
LessThan 230KV One Line Inner buffer 0– 500m	1	n/a
LessThan 230KV One Line Outer buffer 500 – 1000m	0	n/a
LessThan 230KV Two or More Lines Centerline	2	n/a
LessThan 230KV Two or More Lines Inner buffer 0 – 500m	1	n/a
LessThan 230KV Two or More Lines Outer buffer 500 – 1000m	0	n/a
Greater Than or Equal 230KV One Line Centerline	2	n/a
Greater Than or Equal 230KV One Line Inner buffer 0 – 500m	1	n/a
Greater Than or Equal 230KV One Line Outer buffer 500 – 1000m	0	n/a
Greater Than or Equal 230KV Two Lines Centerline	4	n/a
Greater Than or Equal 230KV Two Lines Inner buffer 0 – 500m	2	n/a
Greater Than or Equal 230KV Two Lines Outer buffer 500 – 1000m	0	n/a
Wind Turbine		
Wind turbine point buffer 45m radius	4	n/a
Buffer zone beyond point buffer 0 – 500m	2	n/a
Buffer zone beyond point buffer 500 – 1000m	0	n/a

**Habitat values were not used to model habitat concentration areas.*

Modeling Results

Resistance Modeling

The resistance surface for Sharp-tailed Grouse in the Columbia Plateau (Fig. A.1.1) is extensively fragmented by agriculture, roads, development, and powerlines. Parts of the Columbia Plateau that were historically occupied, such as Whitman County, currently have few areas with ease of movement (low resistance). Much of the central portion of the Columbia Plateau exhibits a checkering of small patches of low resistance habitat set in a matrix of higher resistance.

In the Okanogan Valley areas of low resistance are predominately located at higher elevations. Occupied areas in the Okanogan Valley are separated by a north–south band of high resistance associated with development along the Okanogan River and Highway 97; potential crossing areas may be limited here. Given the resistance to movement created by the Highway 97 corridor, we expect that connectivity for Sharp-tailed Grouse populations will be negatively impacted by continued development in this area.

The Methow Valley is narrow and constrained by high resistance habitat to the north, west, and east. The area of the Methow Valley extending from Carlton to Winthrop is extensively fragmented and generally of high resistance. The southern end of the Methow Valley is broader and is of low resistance.

In central Lincoln County, Upper Crab Creek forms an area of low resistance. There is low resistance habitat between this area and Douglas County near Coulee City and along the Columbia River. Movement potential between large areas of low resistance in Douglas County and central Lincoln County is reduced in part by extensive areas of cropland and high voltage powerline corridors that extend from Grand Coulee Dam south and southwest past Coulee City.

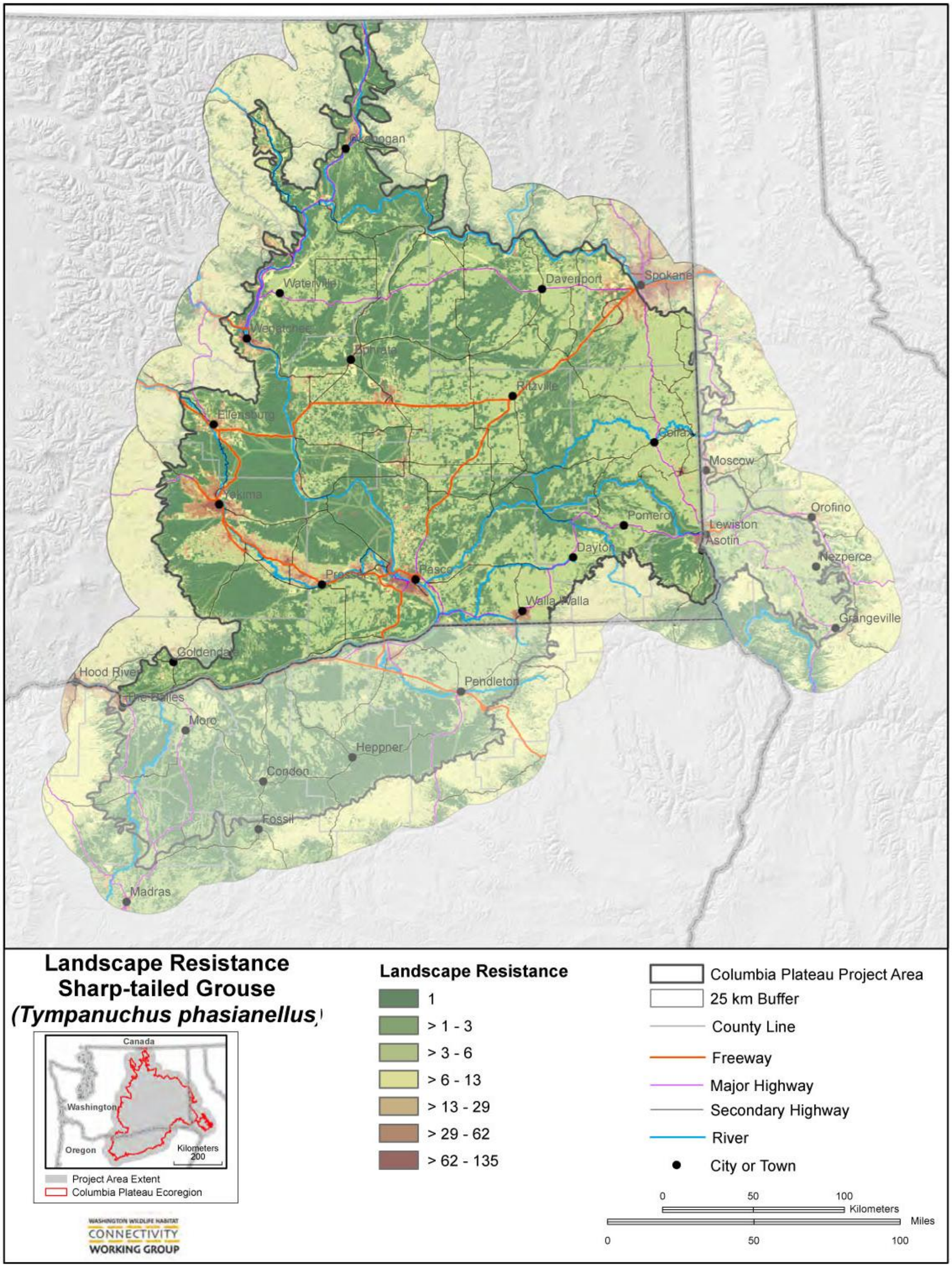

Figure A.1.1. Resistance map for Sharp-tailed Grouse in the Columbia Plateau Ecoregion.

In our model, shrubsteppe and grassland habitats were assigned low resistance for movement. The resistance surface shows many areas of the Columbia Plateau that have low resistance for movement but are not currently occupied. This is because it is difficult to use remote sensing information to map those components of shrubsteppe and grassland habitats critical for supporting viable populations of Sharp-tailed Grouse, such as perennial grass understory and winter habitat. However, the resistance map can still be extremely useful to identify potential areas for Sharp-tailed Grouse because it illustrates where in the landscape large blocks of low resistance habitat still remain, and how these areas relate to occupied range. This type of assessment helps inform the selection of translocation sites. Additionally, the mapped resistance surface provides direction for where to search for previously undiscovered leks in and near occupied range.

Habitat Modeling and Habitat Concentration Areas

Using known lek locations, we identified 15 HCAs (Fig. A.1.2) in the Columbia Plateau Ecoregion and buffer. Difference between the HCA locations and Gap range (Johnson & Cassidy 1997; Fig. A.1.2) illustrates the difficulty in using current habitat maps to identify areas of occupation for this species. Several HCAs were located along the ecoregional boundary in Okanogan County and northern Douglas County and two were in the buffer. The largest cluster of HCAs occurred in northern Douglas County and the adjacent area in Okanogan County (Douglas/ Okanogan Cluster). The Columbia Plateau Ecoregion is fairly narrow as it extends north following the Okanogan Valley and the boundary is irregular with occasional east–west "pockets" of habitat extending on either side. There was a tendency for Sharp-tailed Grouse HCAs to occur in these "pockets" of habitat on the east side of the valley. Most HCAs are in higher elevation sites and areas where farming and ranching are the predominant land uses and human population density is relatively low. The HCAs in Lincoln County and the most northerly HCA in Okanogan County are the most isolated. The distribution of HCAs on the landscape tends to be a linear and arranged in a "stepping stone" pattern with minimal clustering. For example, there is a north–south orientation of HCAs in Okanogan County and an east–west orientation of HCAs in northern Douglas and southern Okanogan counties. This pattern is cause for concern as loss of any HCAs in the "stepping stone" pattern will likely have a negative impact on overall connectivity of Sharp-tailed Grouse.

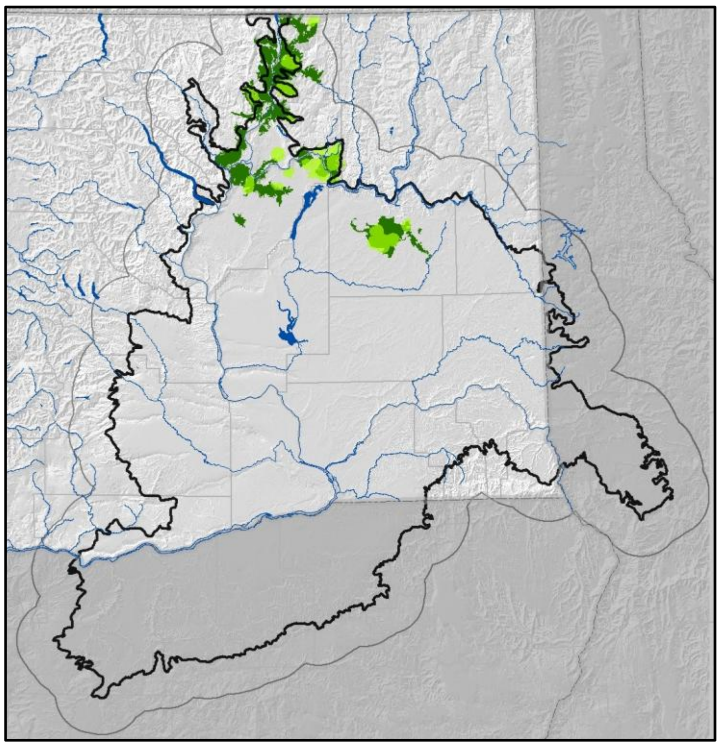

Figure A.1.2. Sharp-tailed Grouse HCAs (light green) and GAP distribution (dark green) in the Columbia Plateau Ecoregion.

Cost-weighted Distance Modeling

The cost-weighted distance map (Fig. A.1.3, see Fig. A.1.4 for HCA identification) illustrates interesting patterns for movement potential for Sharp-tailed Grouse in the Columbia Plateau. For instance, resistance to movement rapidly increases outside the ecoregional boundary except for the northernmost HCA 1, which is an area of high-elevation grassland that is outside the Columbia Plateau. The opportunity for movement from HCA 1 south to HCA 2 is limited and constrained by areas of high resistance. In the Okanogan Valley, the greatest potential for movement occurs north–south along the east boundary of the Columbia Plateau Ecoregion. Resistance accumulates rapidly east and west for HCAs near the ecoregional boundary in the Okanogan Valley primarily because of forest and/or development. The cost-weighted distance map suggests that opportunities for movement across the Okanogan Valley are limited. The single HCA on the west side of the Okanogan Valley, HCA 4, has an area of low resistance to the east where there is movement potential across the valley. Resistance accumulates rapidly to the south and southeast of this HCA.

Eight HCAs in southern Okanogan and northern Douglas counties form a loose cluster (HCAs 6–13). All are within the same 10 km CWD isocline. There is good potential for movement from this HCA cluster to HCAs immediately to the north but resistance to the southeast towards HCAs 14 and 15 in Lincoln County is high. The CWD map indicates that the area of lowest resistance to movement between these HCAs and the two in Lincoln County (HCAs 14, 15) follows the Columbia River. For the HCAs in Lincoln County resistance also accumulates slowly to the southwest through Upper Crab Creek. This is an area to consider searching for potential leks.

Linkage Modeling

We used a maximum Euclidean cut-off distance of 60 km for linkage modeling which resulted in a total of 27 linkages among 15 HCAs (Fig. A.1.5, see Fig. A.1.4 for HCA identification). Measures of linkage length and quality varied considerably (See Appendix B). In Euclidean distance linkages ranged from 0.4 to 54.4 km and averaged 17.1 km (SD 15.6). Linkage cost-weighted distances ranged from 1.3 to 80.5 km and averaged 26.2 km (SD 24.4).

Two linkage quality ratios were calculated for the Sharp-tailed Grouse modeling outputs: the ratio of cost-weighted distance to Euclidean distance (mean of 2.1 [SD 2.2], range 1.1–11.7) and the ratio of cost-weighted distance to least-cost path length (mean of 1.4 [SD 0.7], range 1.0–4.9). The ratio of cost-weighted distance to Euclidean distance indicates how hard it is to move between HCAs relative to how close they are together. The ratio of cost-weighted distance to least-cost path length indicates the average resistance encountered moving along the optimal path between a pair of HCAs.

Linkages connecting Sharp-tailed Grouse HCAs generally extend north–south and follow the northeastern boundary of the Columbia Plateau Ecoregion. Linkages are most numerous among the HCAs clustered in northern Douglas County and adjacent southern Okanogan County (Douglas/Okanogan cluster).

The linkage between the northernmost HCA in Okanogan County, HCA 1, and HCA 2 to the south, in Siwash Creek, has a constriction and is also fragmented by small areas of high resistance. The linkage between HCA 2 in Siwash Creek and HCA 3 to the south, in the Tunk Valley, has secondary corridors which provide alternative pathways for connectivity.

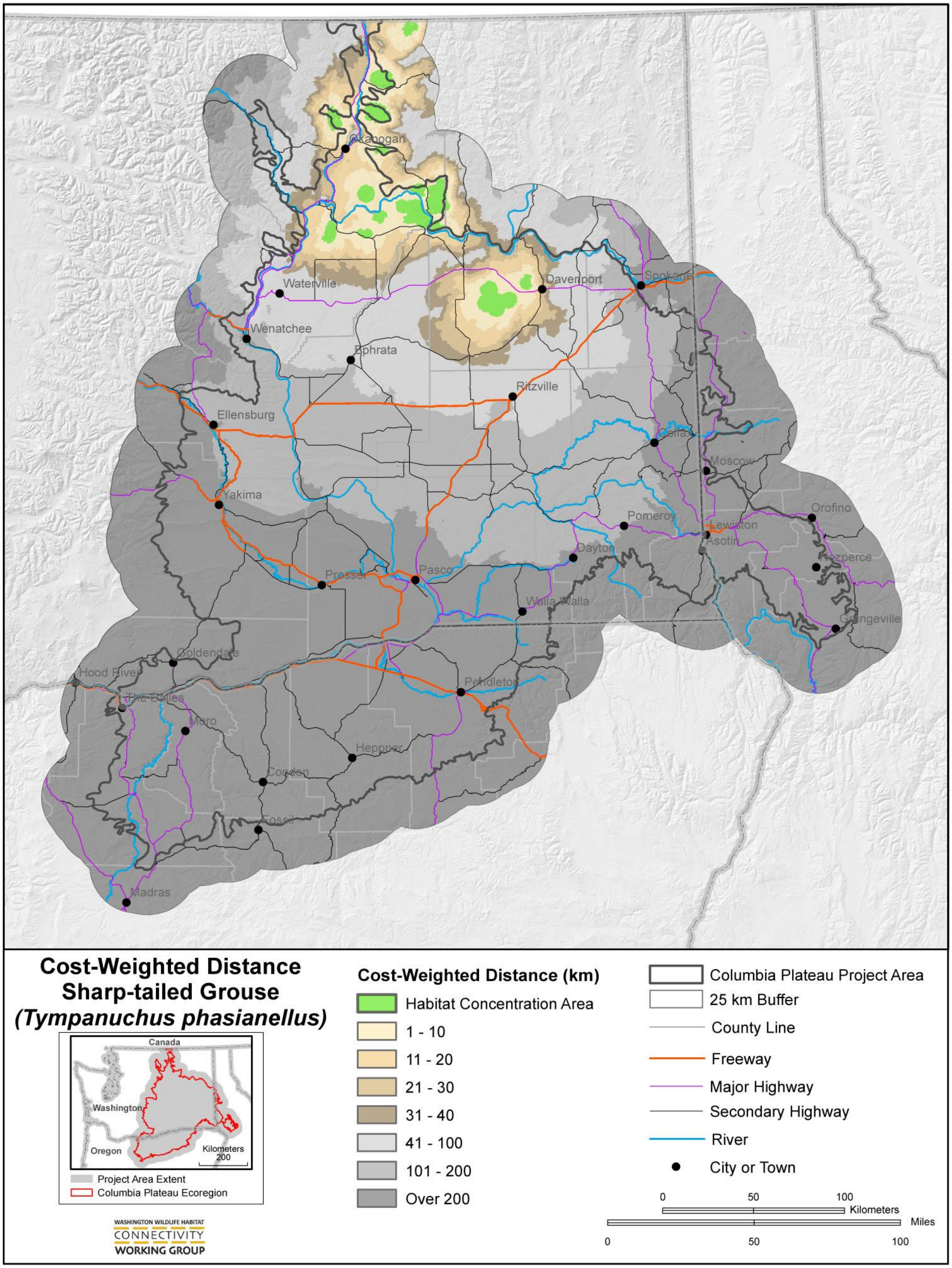

Figure A.1.3. Cost-weighted distance map for Sharp-tailed Grouse in the Columbia Plateau Ecoregion.

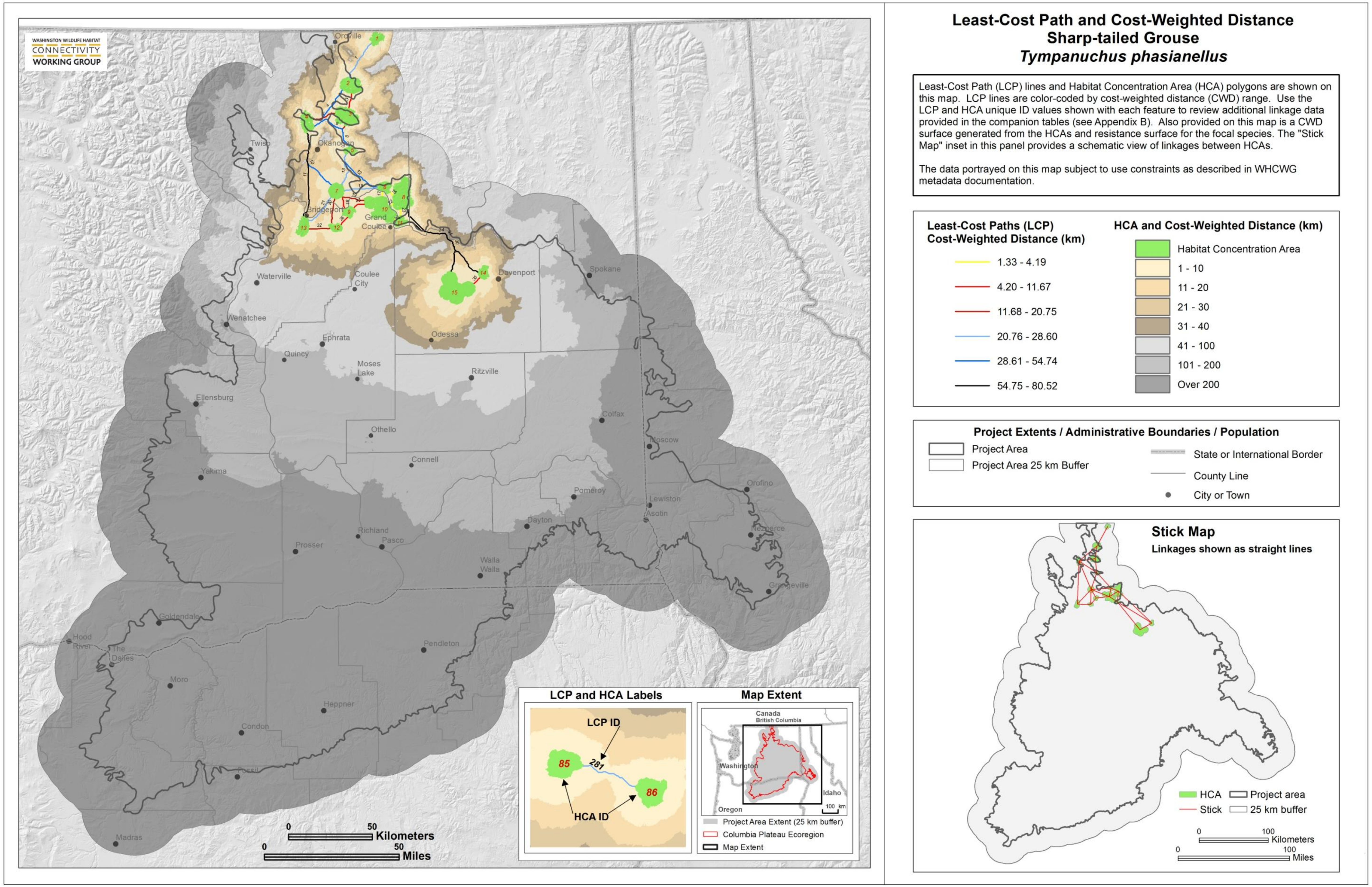

Figure A.1.4. Cost-weighted distance map with numbered HCAs (green polygons labeled with red numerals) and least-cost paths (lines labeled with black numerals) for Sharp-tailed Grouse. Linkage modeling statistics provided in Appendix B.

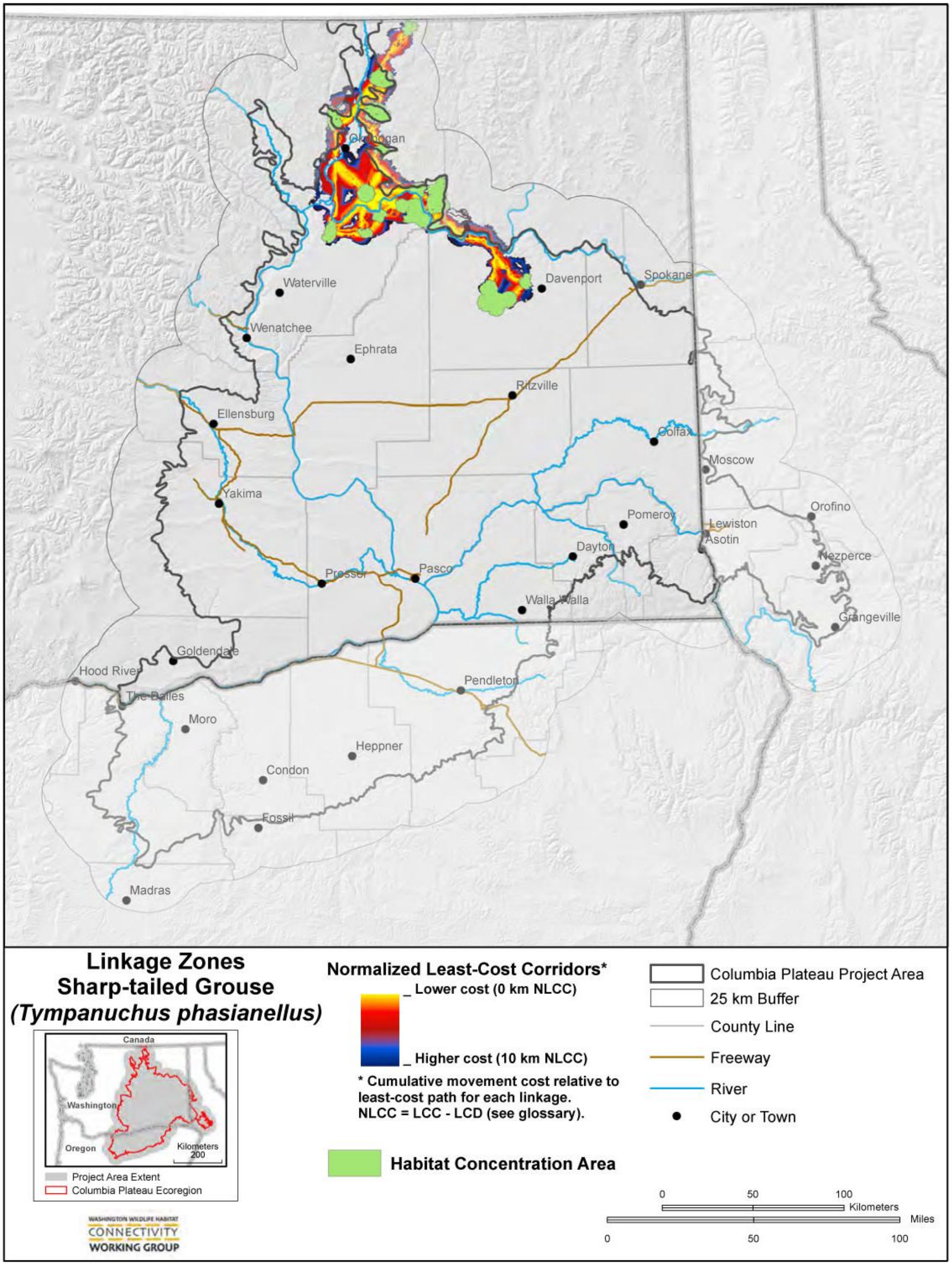

Figure A.1.5. Linkage map for Sharp-tailed Grouse in the Columbia Plateau Ecoregion.

Connectivity between the Douglas/Okanogan cluster (HCAs 6–13) and HCAs further north (HCAs 3, 4, 5) is variable. For example, HCA 13 is the furthest west in Douglas County and is linked to HCA 4 in western Okanogan County by a linkage that is narrow and constrained, and passes through a severe pinch point (Fig. A.1.6). The linkage extending from the centrally located HCA 7 in southern Okanogan County to HCA 4 also passes through this pinch point. Efforts to reduce resistance at this pinch point may be challenging since it is primarily created by agriculture, rural housing, and is near the town of Malott. An alternative route that could be evaluated for restoration potential is through the "red" part of the linkage west of the Okanogan River (Fig. A.1.6). This route passes close to the Chiliwist Wildlife Area, which was historically occupied by Sharp-tailed Grouse. Management emphasis for Sharp-tailed Grouse in the Chiliwist may increase the connectivity potential of this linkage by providing a stepping stone habitat.

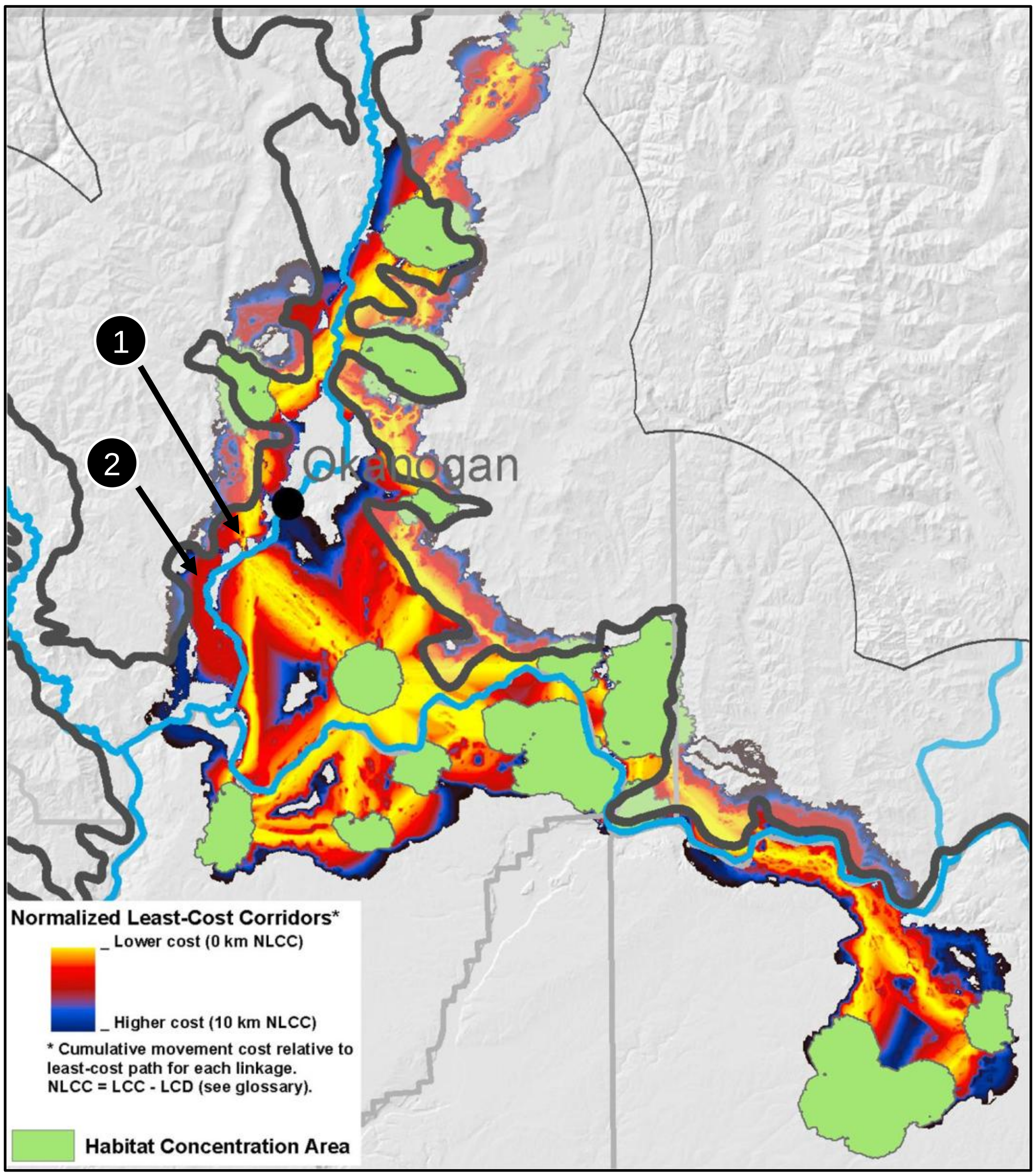

Figure A.1.6. Close up of the linkage map for Sharp-tailed Grouse (see Fig. A.1.5). Arrow labeled "1" indicates a pinch point. The arrow labeled "2" indicates a potential but more costly pathway.

The linkage that looks the best for connectivity between the Douglas/Okanogan cluster and HCAs to the north extends from HCA 7 to HCA 5. Habitat concentration area 7 has linkages to 7 other HCAs and is likely important for maintaining the overall linkage network. A second linkage from HCA 6 to HCA 5 connects the eastern part of the Douglas/Okanogan cluster (HCAs 6, 8, 10, 11) to HCAs further north but this linkage is considerably more constrained near its southern end. Some of the linkages between HCAs in the Douglas/Okanogan cluster are wide suggesting that there is high quality habitat for movement in these areas.

The linkage from HCAs 14 and 15 in Lincoln County and the nearest HCAs in Okanogan County (HCAs 8, 11) follows habitat along the Columbia River. This linkage has several areas where it is narrow and constrained and resistance increases rapidly to the south and west. An alternate pathway to the least-cost route occurs north of the Columbia River closely following the ecoregional boundary (Fig. A. 1.5), but it passes through higher resistance habitat. Resistance in this alternative pathway may be challenging to mitigate because the pathway passes through a forested area.

Comparative Insights between the Statewide and Ecoregional Connectivity Analyses

Although the statewide (WHCWG 2010) and Columbia Plateau analyses identified similar parts of the landscape important for connectivity of Sharp-tailed Grouse in Washington there were some important differences. The addition of powerline and wind-turbine data layers, the refinement of the agriculture land use class, and the increased resolution of the Columbia Plateau analysis were immensely valuable for understanding in greater detail the patterns highlighted by the statewide analysis. For example, the resistance surface for both analyses identified a similar pattern of low resistance to the northwest of Coulee City (Fig. A.1.7a and b). The native habitat in this area is intermixed with agriculture, predominately dryland wheat. In the Columbia Plateau analysis we recognized the value of those agricultural lands adjacent to suitable habitat. These areas are commonly used by Sharp-tailed Grouse and consequently we assigned them low resistance. This resulted in the Columbia Plateau resistance surface showing greater opportunity for movement in some parts of the landscape (Fig. A.1.7b).

The linkage modeling for Sharp-tailed Grouse in the Columbia Plateau Ecoregion (Fig. A.1.5) is valuable for understanding connectivity for this species. Our modeling in the statewide analysis used relatively large HCA polygons that represented the distribution of Sharp-tailed Grouse in Washington. We also included in the statewide analysis an HCA located in the Methow Valley that represented the WDFW Methow Recovery Unit for Sharp-tailed Grouse—a potential translocation site. For the Columbia Plateau analysis we used lek locations to refine our identification of HCAs because we were interested in understanding potential connectivity both within and between known populations. This approach, coupled with the greater detail in our data layers, allowed us to discern potential movement pathways on the landscape. This refined approach also illustrated that some of the populations we modeled in the statewide analysis (Fig. A.1.8a) may be more discontinuous than previously believed (Fig. A.1.8b). Exclusion of the HCA in the Methow Valley markedly changed those linkages in the western part of the network extending between HCAs in western Douglas County and western Okanogan County (Fig. A.1.8 a and b, circle "1"). Connectivity in this part of the network is more constrained in the ecoregional analysis and is likely a more accurate representation of potential movement pathways for Sharp-tailed Grouse. It was interesting to note that some of the HCAs we modeled in the ecoregional analysis occurred in linkage pathways identified in the statewide analysis (Fig. A.1.8a, b, circle labeled “2”). We feel that both scales of analyses are useful for understanding connectivity of Sharp-tailed Grouse in the state. The statewide analysis identifies the general patterns of connectivity, while the Columbia Plateau analysis provides the necessary detail to more fully understand these patterns. This added detail makes it much easier to consider potential restoration and conservation scenarios and the implementation of efforts to enhance or maintain connectivity for Sharp-tailed Grouse in Washington.

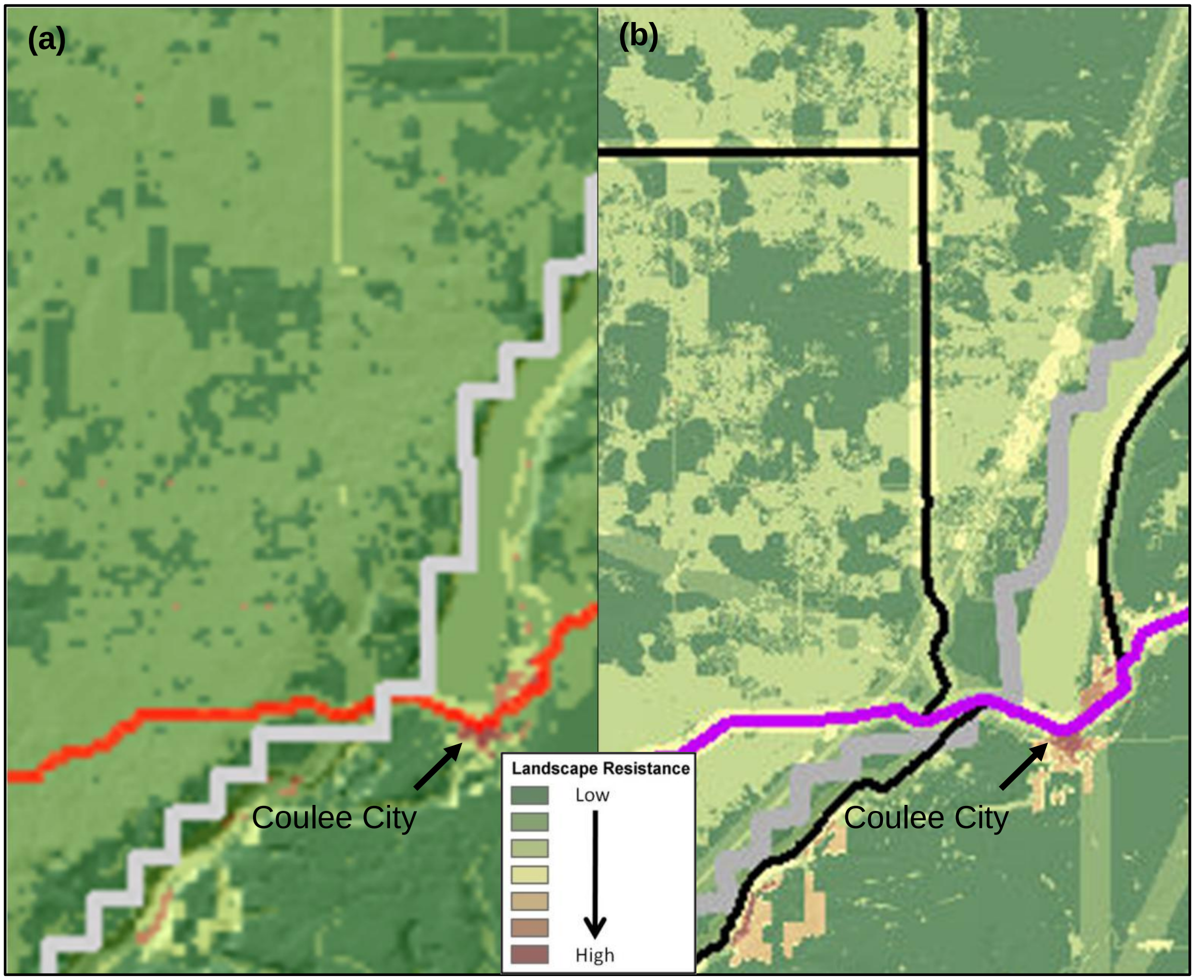

Figure A.1.7. Close up of the resistance surfaces generated for Sharp-tailed Grouse in (a) the statewide analysis, and (b) the Columbia Plateau analysis, near Coulee City, south of Banks Lake in Grant County, Washington. Note more areas of low resistance northwest of Coulee City in panel (b).

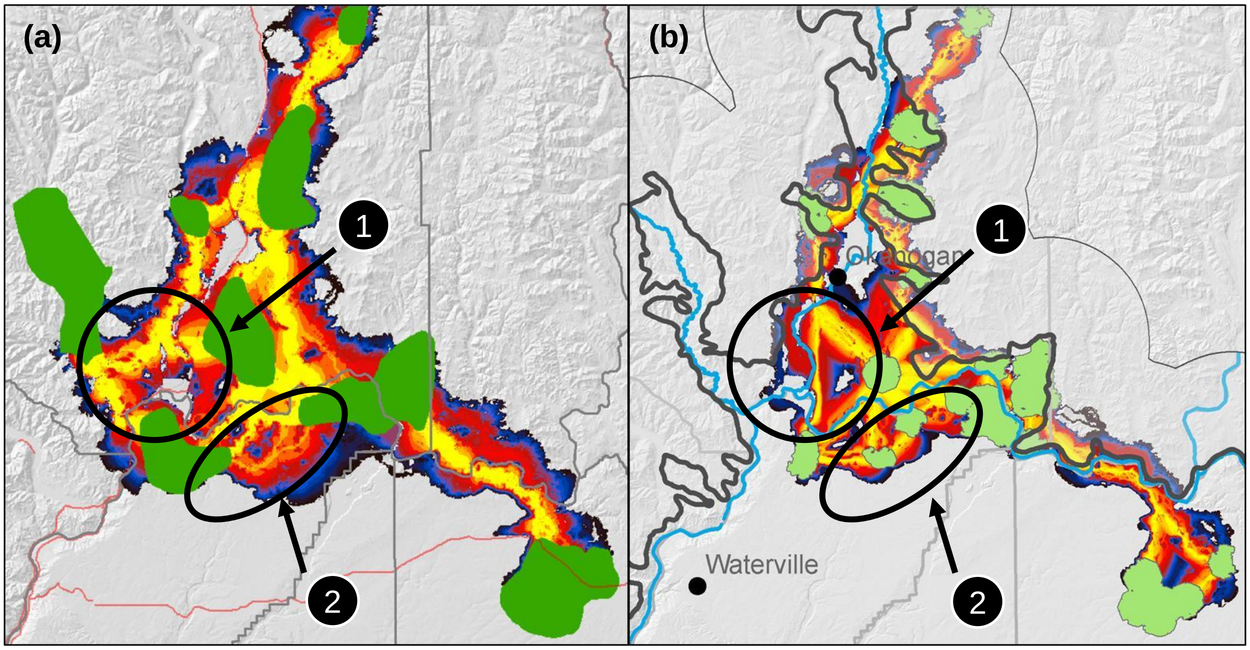

Figure A.1.8. Close up of linkages among HCAs (green polygons) for Sharp-tailed Grouse modeled in (a) the statewide analysis and (b) the Columbia Plateau Ecoregion analysis (b). Circle labeled "1" shows area where the linkage network markedly differs between the (a) statewide analysis and (b) the ecoregional analysis. Circle labeled "2" in the (a) statewide analysis identifies a potential movement pathway shown in orange, HCAs were located in this same area in (b) the Columbia Plateau analysis.

Key Patterns and Insights

Key patterns and insights for our connectivity analysis of Sharp-tailed Grouse in the Columbia Plateau Ecoregion include:

- Areas of low resistance are constrained and fragmented by agriculture, development, roads, powerlines, and wind turbines.
- The area of northern Douglas County and adjacent Okanogan County has good potential for movement among HCAs.
- Upper Crab Creek is an area of low resistance.
- Habitat concentration areas (HCAs) are located on the northern edge of the Columbia Plateau Ecoregion and several are on the boundary.
- HCAs in Lincoln County, the western side of the Okanogan Valley, and the northernmost HCA are peripheral and potentially at higher risk of becoming isolated.
- Development associated with U.S. Highway 97 in the Okanogan Valley creates a north–south band of resistance for movement.
- The HCAs in the Okanogan Valley are constrained by forest and development and are restricted to higher elevations.
- The dominant orientation of linkages is north–south.

- Only two linkages were modeled across the Okanogan Valley, one of which has a severe pinch point.
- The HCA in southern Okanogan County exhibits high centrality as it connects with seven other HCAs.

Considerations and Needs for Future Modeling

There are additional factors that may influence landscape resistance that were not considered in our model. A potential source for resistance in the landscape is noise from human activity. It has been suggested that birds in general may be sensitive to this type of disturbance because of the role vocalizations play in communication. In the shrubsteppe and grassland habitats of the Columbia Plateau disturbance from anthropogenic noise may impact a larger area than in forested landscapes where there is more vegetation to "absorb" sound. A recent study of Greater Sage-Grouse indicates that males tended to avoid leks with where noise was experimentally elevated (Blickley et al. in press). There are no studies that examine Sharp-tailed Grouse response to anthropogenic noise, and further research that addresses this type of disturbance is needed. Fences may also contribute to resistance, since both fence collisions and mortality have been documented for Greater Sage-Grouse (Stevens 2011) and it is possible that they might also impact Sharp-tailed Grouse. To look at either of these considerations (noise or fences), the GIS data layers would first need to be developed.

Leks, nests, winter locations, and cost-weighted distances outward from lek locations were used to determine HCAs. However, there is a need to improve assessment of occupied habitats in Washington. This modeling effort could be based on an assessment of areas of Sharp-tailed Grouse occurrence in relation to the available GIS layers developed for the Columbia Plateau Ecoregion. An improved habitat suitability model for Sharp-tailed Grouse would have benefits for future analyses, particularly with efforts to evaluate restoration and conservation scenarios. Especially important, and challenging, is for researchers to accurately map critical winter habitats.

We need to better understand the relationship between Euclidean and cost-weighted distances. What is the cost-weighted distance that a Sharp-tailed Grouse will move? And how do they make their decisions about moving forward, turning back, or seeking alternate pathways? These questions are extremely important to understand characteristics of a functional corridor and help inform connectivity conservation.

For this phase of the linkage modeling we used HCAs generated from lek locations. A next step is to model linkages among specific lek locations to further understand connectivity within populations. This analysis would help to (1) identify which leks are important for maintaining the lek linkage network, (2) identify potential areas where leks may be at risk of becoming isolated and therefore extirpated, and (3) inform implementation of conservation efforts to enhance and/or maintain connectivity within the population.

The models can be used to help inform numerous planning efforts. For instance, they can help:

1) Inform the impacts of restoration and conservation activities such as CRP by evaluating the location and abundance of CRP with respect to habitat suitability and connectivity for

Sharp-tailed Grouse. Ultimately this would help prioritize areas for implementation of Farm Bill programs. This same type of strategy could be used when considering alternatives for habitat acquisitions and/or easements.

2) Evaluate development options. For example, if there are alternatives for placement of powerlines or wind turbines, these alternatives can be compared on the basis of additional resistance they contribute to the landscape and the relative impact of this increased resistance to Sharp-tailed Grouse.

3) Evaluate different translocation options. These options can include the amount of potentially occupied habitat (the size of the potential HCA) and the quality of potential corridors between the translocation location and existing HCAs. Such an examination would provide the basis for systematically and quantitatively comparing potential translocation sites.

Opportunities for Model Validation

There are numerous opportunities to evaluate the assumptions and interpretations of the connectivity models developed for Sharp-tailed Grouse. Movement of radio-marked individuals can offer insight into movement capability with respect to landscape resistance. Additionally, movement data from Sharp-tailed Grouse translocated to sites in Washington may potentially be used to evaluate our connectivity models. It is common for grouse translocated to a new location to move away, sometimes a considerable distance, from the release site. Because these movements are through a landscape new to the birds, studying the pathways of the translocated grouse are especially valuable for gaining insight into aspects of connectivity. Occupied and extirpated range can also be used to evaluate resistance characteristics and corridor quality. Genetics can also be used to evaluate movement across landscapes and between HCAs.

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