Appendix A.2

Habitat Connectivity for Greater Sage-Grouse (*Centrocercus urophasianus*) in the Columbia Plateau Ecoregion

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Introduction

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.

Greater Sage-Grouse, photo by Rob Bennetts.

For the Columbia Plateau Ecoregion analysis we used additional data layers, better defined habitat variables, and a finer resolution to examine connectivity issues for 11 focal species, including Greater Sage-Grouse (*Centrocercus urophasianus*). In this ecoregional analysis we use occurrence data to assess *current conditions* for connectivity for sage-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 Greater Sage-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 Greater-Sage Grouse in the Columbia Plateau and further our understanding of connectivity issues for other shrubsteppe dependent species.

Justification for Selection

Greater Sage-Grouse are considered a shrubsteppe obligate species because of their year round dependence on sagebrush (*Artemisia* spp.) dominated habitats for food and cover (Schroeder et al. 1999). Additionally, they are a landscape species which have large home ranges, are capable of extensive movements, and use a mosaic of habitat patch sizes within the sagebrush ecosystem (Connelly et al. 2004). Greater Sage-Grouse were chosen as a focal species to represent the Shrubsteppe and Grassland vegetation classes in the Columbia Plateau Ecoregion. They scored an Excellent rating for all criteria used to assess and select focal species (See Appendix E).

Considerable research has established that Greater Sage-Grouse are sensitive to disturbance from human activities, as well as the configuration, juxtaposition, and suitability of habitat in the landscape (Braun 1986; Lyon & Anderson 2003; Connelly et al. 2004; Aldridge 2005; Aldridge & Boyce 2007; Knick & Hanser 2011; Wisdom et al. 2011; Johnson et al. 2011). An analysis of Greater Sage-Grouse population trends and sagebrush habitat concluded that intensity of the human footprint was higher in areas where Greater Sage-Grouse were extirpated than areas still occupied (Connelly et al. 2004). Furthermore, the Columbia Basin Sage Grouse Management Zone (Stiver et al. 2006) has the highest human footprint intensity (Leu & Hanser 2011) of the seven management zones recognized for Greater Sage-Grouse range-wide.

A myriad of stressors threaten the persistence of Greater Sage-Grouse populations in Washington including habitat loss, degradation, and fragmentation of native shrubsteppe vegetation resulting from altered fire regimes, conversion of shrubsteppe to agriculture, urban development, energy development, grazing, mining, military activity, noise, powerlines, roads, fences, and encroachment by invasive plant species (Schroeder et al. 2003; Stinson et al. 2004). Loss of genetic diversity through population isolation is also a significant threat (Stinson et al. 2004) and evidence suggests that Greater Sage-Grouse populations in Washington have already undergone a genetic bottleneck (Benedict et al. 2003; Oyler-McCance et al. 2005). Global climate change models predict more variable and severe weather events, higher temperatures, drier summer soil conditions, and wetter winter seasons (Miller et al. 2011). It is predicted that projected climate change and associated consequences will potentially interact with, and could magnify, stressors such as disease (Walker & Naugle 2011) and habitat degradation and loss, that are already impacting Greater Sage-Grouse (Neilson et al. 2005; USFWS 2010; Miller et al. 2011).

Greater Sage-Grouse are listed as Threatened by the state of Washington and are considered a Priority Species by the WDFW Priority Habitats and Species Program (Hays et al. 1998; Schroeder et al. 2003; Stinson et al. 2004). In 2001, the USFWS determined that Greater Sage-Grouse in Washington constituted a distinct population segment (DPS) and that their listing under the federal Endangered Species Act was warranted but precluded by higher listing priorities (USFWS 2001). Petitions for listing Greater Sage-Grouse range-wide were filed in 2002 and 2003; in 2005 the USFWS determined that listing was not warranted. In 2008, a status review was initiated by the USFWS to address new information available since the 2005 finding. In March 2010 the USFWS determined that the range-wide listing of Greater Sage-Grouse under the federal Endangered Species Act was warranted but precluded due to higher listing priorities; range-wide they are considered a Candidate species with an assigned listing priority of 8 out of 12 (USFWS 2010).

Distribution

The historical distribution of Greater Sage-Grouse coincided with that of sagebrush in western North America (Schroeder et al. 1999; Schroeder et al. 2004). At one time, Greater Sage-Grouse populations were found in parts of 14 states in the western U.S. and three Canadian provinces (Connelly et al. 2004; Schroeder et al. 2004). Currently Greater Sage-Grouse occur in 11 states and two provinces with an estimated total range of 668,412 km^2, approximately 56% of the pre-settlement distribution of potential habitat (Schroeder et al. 2004).

Greater Sage-Grouse were once widely distributed throughout central and eastern Washington, parts of north-central and eastern Oregon, southern Idaho, and in the extreme southern portion of British Columbia within the Okanagan Valley (Campbell et al. 1990; Schroeder et al. 2000; Aldridge & Brigham 2003; Schroeder et al. 2004). Initial declines of Greater Sage-Grouse distribution in Washington were related to cultivation of shrubsteppe habitat, primarily for production of wheat, and continued as cultivation expanded throughout the Columbia Plateau (Schroeder et al. 2000). Between 1900 and 1940 Greater Sage-Grouse numbers declined in Oregon and by 1955 birds were extirpated from the northern parts of the state (Stinson et al. 2004). Habitat along the Snake River in Idaho likely once supported populations of Greater Sage-Grouse but is currently unoccupied (Schroeder et al. 2004); Greater Sage-Grouse continue to decline in the Snake River region (Connelly et al. 2004). The number of Greater Sage-Grouse in British Columbia was probably always low and they were considered extirpated in 1918 (Campbell et al. 1990; Aldridge & Brigham 2003).

The estimated range of Greater Sage-Grouse in Washington is approximately 4683 km^2 or 8% of the historical range (Schroeder et al. 2000). Connelly et al. (2004) concluded that populations in Washington declined at a rate of 4.8% per year from 1965 to 2003 and current estimates place the state population at 1165 birds (2011 estimate; M.A.S., unpublished data). Greater Sage-Grouse are found in two populations in Washington. One population is located in the Moses Coulee area in Douglas/Grant counties and one is on the U.S. Army's Yakima Training Center (YTC) in Yakima/Kittitas counties (Schroeder et al. 2000; Stinson et al. 2004). These populations are isolated from each other by approximately 50 km and from populations in Oregon and Idaho by about 250 km and 350 km, respectively.

Greater Sage-Grouse were extirpated from Lincoln County in 1987 (Hayes et al. 1998). In 2008 WDFW initiated a translocation project (project timeline from 2008 to at least 2011) to release Greater Sage-Grouse in the Swanson Lakes Wildlife Area, Lincoln County, in east-central Washington (Schroeder et al. 2008). It is too early to know if this translocation project is successful. Greater Sage-Grouse were also extirpated from the Yakama Reservation, though the timeline was likely at least 20 years earlier than for Lincoln County. Greater Sage-Grouse were translocated to the Yakama Reservation in 2006. Two leks were observed the year following translocation efforts (N. Burkepile, personal communication); one lek was believed to be active as recently as 2009. Although anecdotal observations of Greater Sage-Grouse have since been reported in this area, there have been no confirmed observations of breeding activity. Efforts are underway by the Yakama Nation Wildlife Resource Management Program to conduct another translocation of Greater Sage-Grouse in 2012 to lands they manage.

Habitat Associations

General

The distribution of Greater Sage-Grouse is closely allied to the distribution of sagebrush, particularly big sagebrush (*A. tridentata*) in the western U.S. Sagebrush habitat types demonstrate considerable variation across the range in terms of vegetative composition, fragmentation, topography, substrate, weather, and frequency of fire (Schroeder et al. 1999). Because Greater Sage-Grouse use a variety of habitat patches within a larger landscape, the juxtaposition and quality of these habitat types is critical.

In Washington, Greater Sage-Grouse habitat includes the shrubsteppe and meadowsteppe plant communities (Stinson et al. 2004). Shrubsteppe plant communities are characterized by bunchgrasses, big sagebrush, three-tipped sagebrush (*A. tripartita*), bitterbrush (*Purshia tridentata*) and forbs. Meadowsteppe habitat is characterized by dense grass and forb cover and fewer shrubs (Stinson et al. 2004). The quality of the shrubsteppe and diversity of the vegetation is critical. Many uncultivated areas are not suitable for Greater Sage-Grouse because of lack of sagebrush, perennial grasses, and forbs (Schroeder et al. 1999). Greater Sage-Grouse may use alfalfa (*Medicago sativa*), wheat (*Triticum* spp.), and crested wheatgrass but use of these altered habitats depends primarily on their configuration (proximity) with native habitat (Schroeder et al. 1999).

Greater Sage-Grouse in Washington are found in suitable habitat at 300–900 m elevation (Cadwell et al. 1997; Livingston 1998; Stinson et al. 2004). Greater Sage-Grouse in Oregon and Idaho are found at 1200–2400 m and 1200–2900 m elevation, respectively (WDFW 1995). Within suitable habitats, elevation does not seem to limit movements by Greater Sage-Grouse. Similarly, although slope is a component of suitable Greater Sage-Grouse habitat, it is not likely a factor impeding movement. On the YTC Greater Sage-Grouse prefer slopes <15% (Livingston 1998).

Breeding

Leks are traditional breeding areas where males congregate in the spring and perform courtship displays. They are typically situated near nesting habitat and close to relatively dense stands of sagebrush used for cover and feeding (Connelly et al. 2004). Leks tend to be located in natural openings such as ridge-tops, grassy swales, and dry stream channels as well as openings created by human disturbance, including cultivated fields, airstrips, gravel pits, roads, burned areas, and edges of stock ponds (Schroeder et al. 1999; Connelly et al. 2004).

Sagebrush/bunchgrass habitat is used for nesting (Stinson et al. 2004); nests tend to be situated under the tallest sagebrush within a stand (Connelly et al. 2000). Good quality brood habitat is characterized by abundant forbs, insects and high plant diversity (Connelly et al. 2000).

Winter

Winter habitat for Greater Sage-Grouse consists of large stands of good quality sagebrush that provide food and cover. Presence of sagebrush is essential for survival as it is 100% of the winter diet (Schroeder et al. 1999). Spatial distribution of Greater Sage-Grouse in winter is related to snow depth as sagebrush must be exposed to be accessible for forage (Connelly et al. 2004). Sagebrush stands with canopy cover 10–30% and heights of at least 25–35cm are considered minimal for winter habitat (Connelly et al. 2000).

Agriculture

The reduction in distribution of Greater Sage-Grouse range in Washington is largely a consequence of habitat loss due to conversion of shrubsteppe to cropland. Less than 50% of historical shrubsteppe remains in Washington and what is left is often degraded, fragmented, or isolated (Schroeder & Vander Haegen 2011). Interestingly, the Douglas/Grant population of Greater Sage-Grouse occupies a landscape highly fragmented by dryland agriculture, unlike most other populations in North America (Aldridge et al. 2008; Wisdom et al. 2011). The remnant patches of native shrubsteppe in this matrix often are of good quality for Greater Sage-Grouse while larger areas of intact shrubsteppe can be over-grazed by livestock.

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 improved wildlife habitat. Active CRP lands totaled approximately 594,212 ha (1,485,530 ac) for Washington State as of December 2011 (USDA 2011). The vast majority of CRP in the state occurs in eastern Washington; Douglas County alone has roughly 73,813 ha (184,533 ac). When Aldridge et al. (2008) modeled range-wide patterns of Greater Sage-Grouse populations the Douglas/Grant population exceeded the cropland thresholds, while also having lower than expected sagebrush habitat. They suggested that habitat loss may have been mitigated through conversion of cultivated agricultural lands to CRP. For example, in the Douglas/Grant population of Greater Sage-Grouse females nest in CRP more than expected by its availability. In general, the "usefulness" of CRP for Greater Sage-Grouse is influenced by maturity of the planting, species planted, presence of sagebrush, and juxtaposition to native habitat (Schroeder & Vander Haegen 2011). Lands enrolled in the Conservation Reserve Program in Washington can reduce resistance to movement in the landscape for Greater Sage-Grouse by providing suitable habitat.

Dryland wheat is the dominant agricultural crop within the distribution of the Douglas/Grant population of Greater Sage-Grouse. In spring, males often display in wheat fields that are adjacent to native shrubsteppe. These display sites are situated within 500 m of native habitat (M.A.S.), suggesting a threshold distance beyond which Greater Sage-Grouse are reluctant to move.

Sensitivity to Roads and Traffic

Roads can have a negative impact on Greater Sage-Grouse by directly increasing mortality through collisions with vehicles (Stinson et al. 2004; Aldridge and Boyce 2007). As well, disturbance and noise associated with roads may influence nest site selection, habitat use, and lek persistence (Lyon & Anderson 2003; Connelly et al. 2004; Holloran 2005; Hagen et al. 2011; Blickley et al. in press). Range-wide analysis of Greater Sage-Grouse lek count trends indicated lower trends on leks that had >20 km of interstate, federal, or state highways within 18 km and on leks nearer such highways (Johnson et al. 2011).

Yearling female Greater Sage-Grouse select nest sites further from oil and gas haul roads than adult birds. Additionally, the rate of decline in the number of males attending leks within 3 km of main haul roads increases with increased traffic (Holloran 2005). Although roads were not a barrier to movement by Lesser Prairie-Chickens (*Tympanuchus pallidicinctus*) roads were five times less likely in use vs. non-use ranges (Hagen et al. 2011). Pruett et al. (2009) documented an avoidance distance of 100 m by Lesser Prairie-Chickens (based on 15,071 locations of 463 radio-marked individuals) from Highway 283 in Oklahoma. Connelly et al. (2004) examined the distribution of 804 leks in southern Wyoming and found no leks within 2 km (4 km band) of I-80, and only nine leks 2–4 km from the interstate. Additionally, analysis of Greater Sage-Grouse populations between 1970 and 2003 indicated that leks within 7.5 km of I-80 appeared to decline at a higher rate than leks 7.5 to 15.0 km from I-80.

Few studies have documented effects of anthropogenic noise on Greater Sage-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 and 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). Habitat mitigation recommendations for renewable energy development recently proposed by the state of Oregon (whitepaper 2 August, 2011) use a noise propagation model whereby sound levels >40 decibels are considered to negatively impact Greater Sage-Grouse (Hagen 2011).

Sensitivity to Development

There is clear evidence that Greater Sage-Grouse are highly sensitive to the impacts of human related disturbance of sagebrush communities (Connelly et al. 2004; Johnson et al. 2011; Knick & Hanser 2011; Wisdom et al. 2011). A discriminate function analysis of range-wide data indicated that best discrimination between occupied and extirpated area was provided by five environmental variables including: sagebrush area, elevation, distance to transmission lines, distance to cellular towers, and land ownership (Wisdom et al. 2011). Occupied areas are those where there are still large tracts of sagebrush at higher elevations, primarily because lower elevation sites and private lands are more often developed. Aldridge et al. (2008) compared historical and occupied range and concluded that extirpation of Greater Sage-Grouse was most likely in areas containing <30 km^2 of sagebrush and human density greater than four people/km^2.

Settlement patterns by yearling Greater Sage-Grouse in Wyoming indicate that males avoid establishing territories on leks near infrastructure associated with natural-gas development (drill rigs, oil pads, haul roads), while females avoid nesting within 950 m of these features (Holloran et al. 2010). Evidence suggests that anthropogenic features such buildings may act as barriers to use of suitable habitat by Lesser Prairie-Chickens (Hagen et al. 2011). Occupied range in Washington occurs in areas where ranching and farming are the major land uses practices and human population density is low. Active leks in the Douglas/Grant population are on average 3.5 km from the nearest dwelling (M.A.S.).

Sensitivity to Energy Development

WIND ENERGY DEVELOPMENT

Wind power is an emerging land use contributing to the overall threat that energy development poses to Greater Sage-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 as analysis of oil and gas well development sites suggests 2–10 years between activity associated with energy development and measurable effects on lek attendance (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 (*Tympanuchus cupido*) and Sharp-tailed Grouse (*T. phasianellus*) 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.

Most available literature that investigates energy development and response of Greater Sage-Grouse examines impacts of oil and gas development. It is assumed that the potential impacts of oil and gas development, from direct habitat loss, fragmentation through roads and powerlines, noise, and increased human activity are similar for renewable energy development (Becker et al. 2009; USFWS 2010). Naugle et al. (2011) reviewed and synthesized the response of Greater Sage-Grouse to oil and gas energy development. All studies they reviewed reported negative impacts of energy development including: decreased male lek attendance, increased chick mortality, avoidance of otherwise suitable habitats, decreased nest initiation rates, and reduced survival. No studies reported any positive influence of development on populations or habitats. Development exceeding one drill pad/2.6 km^2 resulted in negative impacts to breeding populations and eight pads/2.6 km^2 exceeded the tolerance threshold for Greater Sage-Grouse. A review of the response of prairie grouse to energy development (oil, gas, and wind) reported moderate to large displacement effects and small to moderate demographic effects on populations (Hagen 2010).

Wind energy development within sage-grouse range in Washington was 2.2 gigawatts in 2009 and capacity is projected to increase to 5 to 10 gigawatts by 2030 (USFWS 2010). Concern that large vertical structures may negatively impact Greater Sage-Grouse prompted the USFWS to recommend that wind turbine construction maintain an 8 km buffer from active prairie grouse leks (Manville 2004). Wind turbines may cause mortality of Greater Sage-Grouse through collisions as has been documented for Black Grouse (Zeiler & Grünschachner-Berger 2009).

TRANSMISSION LINES

Powerlines can increase Greater Sage-Grouse mortality through collisions and by providing perch sites for raptors, which prey on grouse (Steenhof et al. 1993; Connelly et al. 2004; Beck et al. 2006). Mortality from collisions with powerlines is difficult to document. In Idaho Beck et al. (2006) monitored radio-marked juvenile Greater Sage-Grouse and recorded 33% of juvenile mortality (2 of 6) resulted from powerline collision. Greater Sage-Grouse and other species of prairie grouse tend to avoid vertical structures in the landscape. In Colorado, use of areas by Greater Sage-Grouse, as measured by pellet transects, increased as distance from powerlines increased, up to 600 m (Braun 1998). 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 (*T. cupido*; n = 216) and Lesser Prairie-Chickens (n = 463) avoided crossing a powerline right-of-way (Pruett et al. 2009) even though this feature was within their home ranges. Changes in habitat use by Lesser Priairie-Chickens 1 year post-construction of a 138 kV powerline indicated that monthly use areas were less likely to include powerlines than non-use areas. This study did not document a clear avoidance distance to the powerline possibly because of a lag effect, due to high site fidelity by adult birds, between the time of powerline construction and avoidance by Lesser Prairie-Chickens (Hagen et al. 2011).

In Washington, 19 of 20 leks (95%) documented within 7.5 km of 500 kV powerlines are now vacant while the vacancy rate for leks further away is 59% (22 of 37 leks; Schroeder 2008). A number of large powerlines cross the northern portion of the YTC through an area that has been rested from grazing since the early 1990s. The Wanapum-Wind Ridge powerline (230 kV Puget Sound Energy) runs east–west across the YTC approximately 5 miles south of I-90. The Pomona Wanapum (230 kV, Pacific Corp), Schultz-Wautoma (500 kV, Bonneville Power Administration—BPA), and Schultz-Vantage (500 kV, BPA) powerlines run northwest to southeast through the area bordered by I-90 to the north and the Wanapum-Wind Ridge powerline to the south. Although habitat north of the powerline appears suitable, there has been little documented use of this area by Greater Sage-Grouse. Additionally, radio-marked Greater Sage-Grouse released on the YTC have been documented crossing I-90 and the Columbia River but no birds have been documented crossing the powerlines (M. Livingston, personal communication). Pruett (2009) documented movement behavior of radio-marked Lesser Prairie-Chickens in relation to a powerline and a highway. These features were parallel to each other in the landscape and separated by approximately 1.5 km of habitat. Birds occasionally crossed the powerline and the highway but were rarely observed in the habitat between these features. It is possible that multiple powerline corridors may have a similar effect on patterns of movement and habitat use by Greater Sage-Grouse.

Sensitivity to Climate Change

Impacts of global climate change have the potential to affect Greater Sage-Grouse as the consequences of these changes interact with known stressors that are already affecting populations (USFWS 2010). The sagebrush ecosystem is characterized by hot dry summers and cold winters with most precipitation in winter and spring. Global climate-change models predict more variable and severe weather events, higher temperatures, drier summer soil conditions, and wetter winter seasons (Miller et al. 2011). The current distribution of sagebrush is predicted to decrease 12% for each degree of temperature increase (Neilson et al. 2005). Further decrease in distribution of sagebrush is attributed to increased levels of atmospheric carbon dioxide that is predicted to favor expansion of cheatgrass (*Bromus tectorum*) and exacerbate the fire cycle in cheatgrass dominated systems (Miller et al. 2011). Climate change may potentially impact Greater Sage-Grouse by amplifying effects of parasites and disease (Christiansen & Tate 2011; Walker & Naugle 2011). Greater Sage-Grouse occupy a small fraction of their original distribution in Washington. Thus, any climate change impacts have the potential to put the remaining range at risk. This issue is problematic because sage-grouse have nowhere to go since they are already at the northern extent of their distribution.

Dispersal

Little information is available regarding dispersal of juvenile Greater Sage-Grouse from their natal territory (hatch area) to location of first breeding (Connelly et al. 2004); one study in Colorado recorded juvenile females (n = 12) moving an average 8.8 km and males (n = 12) moving 7.4 km (Dunn & Braun 1985). These distances are considerably less than what has been recorded for Greater Sage-Grouse movements in Washington, where females often move 13 km between lek sites during a single breeding season. In at least two cases, females moved 27 km and 33 km between nest locations within the same nesting season (Schroeder & Robb 2003).

Three types of seasonal migration patterns have been defined for Greater Sage-Grouse: (1) non-migratory (individual movements <10 km between or among seasonal ranges); (2) one-stage migratory, birds move between two distinct seasonal ranges; and (3) 2-stage migratory, birds move among three distinct seasonal ranges (Connelly et al. 2000). Schroeder and Vander Haegen (2003) concluded that the Greater Sage-Grouse population in Douglas/Grant counties demonstrated the characteristics of all three patterns. Distance moved between traditional breeding and winter ranges averaged 16 km for females and 11 km for males; one female Greater Sage-Grouse moved 85 km (Table A.2.1; Schroeder & Vander Haegen 2003). Greater Sage-Grouse on the YTC are more localized on a seasonal basis (Livingston 1998), possibly because the YTC is surrounded by unsuitable habitat (Schroeder & Vander Haegen 2003).

Migratory corridors for Greater Sage-Grouse are determined by the seasonal patterns of Greater Sage-Grouse movement (Connelly et al. 2004) and the distribution of required habitats. Greater Sage-Grouse intensively monitored during seasonal migration followed shrubsteppe corridors at higher elevations, close to breeding habitat. Birds tended to deviate from a minimal "straight-line" route, instead choosing longer routes in or close to shrubsteppe vegetation (Schroeder & Vander Hagen 2003).

Based on occasional sightings, a few Greater Sage-Grouse may occur on the periphery of the current range (Stinson et al. 2004). However, genetic analysis indicates that the YTC population has only 1 haplotype and the Moses Coulee population 3 haplotypes (2 unique) compared to an average of 6.4 for other populations range-wide, reflecting little gene flow between these populations (Benedict et al. 2003; Oyler-McCance et al. 2005).

Table A.2.1. Seasonal movements of Greater Sage-Grouse.

	Distance (km)			
Category/location	*mean*	*median*	*maximum*	*Citation*
Females				
natal dispersal/CO		8.8		Dunn & Braun 1985
breeding to winter range/WA	16.0			Schroeder & Vander Haegen 2003
breeding to winter range/WA			85.0	Schroeder & Vander Haegen 2003
spring to summer range/ID	12.3			Connelly et al. 1988
winter to breeding range/ID			72.0	Connelly et al. 1988
winter to summer range/ID	32.7			Connelly et al. 1988
winter to summer range/ID	12.3			Connelly et al. 1988
winter to summer range/ID	8.8			Connelly et al. 1988
Males				
natal dispersal/CO		7.4		Dunn & Braun 1985
breeding to winter range/WA	11.0			Schroeder & Vander Haegen 2003
spring to summer range/ID	16.1			Connelly et al. 1988
winter to breeding range/ID			82.0	Connelly et al. 1988
winter to summer range/ID	48.6			Connelly et al. 1988
winter to summer range/ID	16.1			Connelly et al. 1988
winter to summer range/ID	31.5			Connelly et al. 1988
Unknown juveniles				
summer to winter range/ID	14.9			Connelly et al. 1988
Unknown adults				
summer to winter range/ID	11.3			Connelly et al. 1988

Conceptual Basis for Columbia Plateau Model Development

Overview

Connelly et al. (2004) modeled anthropogenic disturbance factors in sagebrush habitats throughout Greater Sage-Grouse range: variables included railroads, powerlines, roads, campgrounds, rest stops, landfills, irrigation canals, oil-gas wells, human-induced fires, agricultural land, and populated areas. These spatial data sets were used to develop a human footprint model. The Columbia Plateau in Washington had high human footprint influence compared to other parts of Greater Sage-Grouse range. Additionally, human footprint intensity was higher in areas where Greater Sage-Grouse were extirpated. Extirpation of Greater Sage-Grouse range-wide was most likely in areas having at least four people/km^2, 25% cultivated cropland or the presence of three or more severe droughts per decade. Extirpation was most often explained by the combined effects of peripherality (within 30 km of range edge) and lack of sagebrush cover, less than 25% within 30 km (Aldridge et al. 2008). A range-wide connectivity analysis of Greater Sage-Grouse leks concluded that the lowest level of connectivity occurs in the Columbia Basin Greater Sage-Grouse Management Zone (Washington), due to the small number of leks and the longer than average distance and few linkages among leks (Knick & Hanser 2011).

Habitats used by Greater Sage-Grouse are well documented (Schroeder et al. 1999; Connelly et al. 2004; Stinson et al. 2004). What is less understood is how various habitat types, especially altered habitats, influence movement of Greater Sage-Grouse through the landscape. Housing density, roads, powerlines, and wind turbines were considered major factors contributing to landscape resistance to movement of Greater Sage-Grouse in the Columbia Plateau Ecoregion.

To characterize landscape resistance for Greater Sage-Grouse, we used, whenever possible, documented habitat associations. Behavioral responses to man-made habitat features, such as buildings, roads, powerlines, and wind turbines are more difficult to document, and most evidence comes from research on other species of prairie grouse (See Habitat Associations). When information was lacking for Greater Sage-Grouse, we relied upon the professional judgment and knowledge of grouse biologists to score resistance values.

Movement Distance

Most Greater Sage-Grouse in Washington move less than 30 km between seasonal breeding and wintering areas (Table A.2.1; Schroeder & Vander Haegen 2003). Some birds have been recorded moving considerably further (as far as 85 km). These birds are the ones important for maintaining connectivity among/between (sub) populations. Based on daily and seasonal movement distances (Table A.2.1 and also see Dispersal), an unweighted Euclidean distance of 100 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 or "core" areas for Greater Sage-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, i.e. within the known distribution. We developed HCAs for Greater Sage-Grouse using lek and nest locations rather than using a habitat value modeling approach. Leks represent important sites for breeding activity within populations and as such are useful for spatial modeling of connectivity (Knick & Hanser 2011).

Greater Sage-Grouse exhibit well documented site fidelity to leks (Schroeder et al. 1999; Connelly et al. 2011), and annual lek surveys are standard protocol for monitoring populations in Washington and range-wide (Stinson et al. 2004; Garton et al. 2011). In the Douglas/Grant population, all but one visit by 22 radio-marked males was to the same lek where captured or first observed as an adult (a total of 207 visits). The average distance between the first nests of 82 females and the lek where a female was captured was about 7 km, the average distance to the nearest lek was 5 km (Schroeder 2001; Stinson et al. 2004). Movement occurs among lek locations as female Greater Sage-Grouse often visit more than one lek within and between breeding seasons, and yearling males visit more than one lek before establishing a breeding territory (Schroeder & Robb 2003).

We developed HCAs for Greater Sage-Grouse using WDFW survey data including: (1) locations of active breeding areas in 2011 (leks, n = 27), (2) 193 nest locations of resident radio-marked birds (not birds translocated from other states; nest locations were collected 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) 226 winter (December and January, 1992–1997) locations of radio-marked birds. The lek location for the Yakama Reservation was estimated from best available information; we included this observation because the Yakama Reservation has initiated a project to translocate Greater Sage-Grouse to this same general area in 2012. 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 = 12.6 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.2.2) to model connectivity for Greater Sage-Grouse. The lowest resistance value in Table A.2.2 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 Greater Sage-Grouse. It should also be noted that many values were assigned a value of 0 because of either 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/or movement of Greater Sage-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 (i.e., Dunes). We assumed that the Pasture Hay class which included CRP fields (See Appendix D) had no resistance to movement. To account for what may be a non-linear relationship of the distance Greater Sage-Grouse will move into agricultural fields from native habitat, we assumed that there was no additional resistance to movement within the Pasture Hay Ag Buffer classes. Freeways and Major Highways were the primary road classes contributing to resistance to movement for Greater Sage-Grouse in the landscape and we considered that traffic noise may contribute to resistance in road buffers.

(continued on page A.2-14)

Table A.2.2. Landscape features and resistance values used to model habitat connectivity for Greater Sage-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	4	n/a
Introduced riparian and wetland vegetation	4	n/a
Water	4	n/a
Aspen	4	n/a
Woodland	9	n/a
Forest	19	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	9	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	0	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	3	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	7	n/a
LessThan 230KV Two or More Lines Inner buffer 0 – 500m	3	n/a
LessThan 230KV Two or More Lines Outer buffer 500 – 1000m	0	n/a
Greater Than or Equal 230KV One Line Centerline	7	n/a
Greater Than or Equal 230KV One Line Inner buffer 0 – 500m	3	n/a
Greater Than or Equal 230KV One Line Outer buffer 500 – 1000m	0	n/a
Greater Than or Equal 230KV Two Lines Centerline	9	n/a
Greater Than or Equal 230KV Two Lines Inner buffer 0 – 500m	4	n/a
Greater Than or Equal 230KV Two Lines Outer buffer 500 – 1000m	1	n/a
Wind Turbine		
Wind turbine point buffer 45m radius	9	n/a
Buffer zone beyond point buffer 0 – 500m	4	n/a
Buffer zone beyond point buffer 500 – 1000m	1	n/a

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

Modeling Results

Resistance Modeling

The resistance surface for movement of Greater Sage-Grouse in the Columbia Plateau (Fig. A.2.1) is extensively fragmented by development (urbanization, housing, etc.), roads, powerlines, and agriculture. Many of the agricultural lands in eastern Washington exhibit a “checkering” pattern of small patches of low resistance habitat set in a matrix of higher resistance. The few large areas of low resistance are essentially “islands” of habitat bordered by resistant features of the landscape. The vast majority of the Columbia Plateau was historically occupied by Greater Sage-Grouse and most of the large blocks of low resistance habitat in the Columbia Plateau were occupied relatively recently (last 50 years). Given the resistance to movement created by features such as development and roads we anticipate that connectivity of Greater Sage-Grouse populations will be negatively impacted by continuing development pressure.

Areas occupied by Greater Sage-Grouse in Douglas County, the YTC, and central Lincoln County are bounded by areas of high resistance created by development, roads, powerlines, and agriculture—opportunities for movement outside the HCAs are limited. For example, the YTC in Yakima and Kittitas counties is constrained by resistance from development, I-82, I-90, and powerlines. A north–south band of low resistance habitat extends from the YTC through the Colockum Wildlife Area to the southern end of Douglas County. Although there is potential for movement along this band of low resistance, the northern and southern “ends” are extensively fragmented by powerlines, I-90, wind turbines, and development associated with housing and the Rock Island Dam.

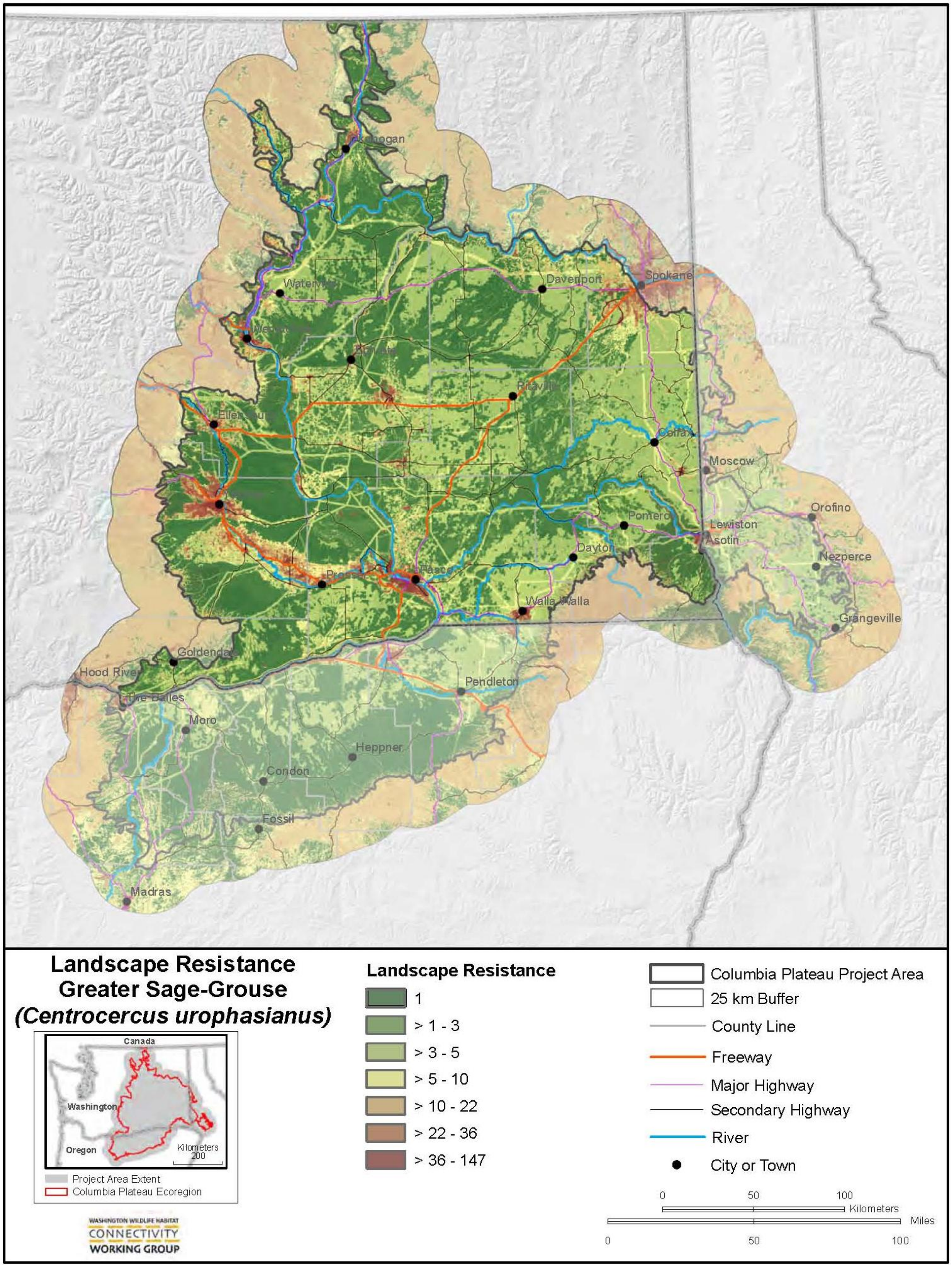

Figure A.2.1. Resistance map for Greater Sage-Grouse in the Columbia Plateau Ecoregion.

In central Lincoln County, the Crab Creek drainage forms an area of low resistance. There is low resistance habitat between this area and Douglas County near Coulee City. Movement potential between 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. Greater Sage-Grouse occupied the block of low resistance habitat in central Lincoln County until the late 1980s. Habitat acquisition and improvements by state and federal agencies supported a translocation project to reintroduce Greater Sage-Grouse to this area beginning in 2008. Prior to translocation the habitat had been improved for Greater Sage-Grouse but birds from Douglas County did not recolonize the area, perhaps in part due to its isolation and the lack of a suitable corridor.

Development along the I-82 corridor extending from Yakima southeast to the Tri-Cities creates a barrier to movement. There is a narrow, highly constrained east–west band of low resistance that extends along Ahtanum Ridge south and west of Yakima, crosses I-82, and connects to the Rattlesnake Hills east of Yakima. Potential for movement along this east–west band of low resistance looks dismal. The I-82 corridor essentially isolates low resistance habitat on the Yakama Reservation from areas to the north and east.

Because Greater Sage-Grouse are a shrubsteppe obligate species, this habitat was assigned low resistance for movement in our model. The resistance surface shows unoccupied areas of the Columbia Plateau that have low resistance. This is because it is difficult to use remote sensing information to map those components of shrubsteppe habitat critical for supporting viable populations of Greater Sage-Grouse, such as the perennial grass understory. However, the resistance map can still be extremely useful to identify potential areas for Greater Sage-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 leks in and near occupied range.

Habitat Modeling and Habitat Concentration Areas

Using known lek locations we identified 4 HCAs (Fig. A.2.2, see Fig. A.2.3 for HCA identification) for the Columbia Plateau. The HCAs included HCA 2 (Mansfield Plateau/Moses Coulee, in Douglas County), HCA 1 (Crab Creek drainage, Lincoln County), HCA 6 (Yakima Training Center, Kittitas and Yakima counties), and HCA 7 (Toppenish Ridge, Yakama Reservation in Yakima County). In general, HCAs were in the relatively intact areas of low resistance and high elevation habitat located on the "edge" of the Columbia Plateau Ecoregion boundary. HCA 2 has a highly irregular border reflecting the complex mix of shrubsteppe habitat and agriculture in this area. This HCA has a "boot" shape with a noticeable narrowing at the "ankle" due to agriculture (wheat fields) to the east and west. All the HCAs are isolated from each other by substantial distances. The difference between the HCA map and Gap range (Johnson & Cassidy 1997; Fig. A.2.2) illustrates the difficulty in using current habitat maps to identify areas of occupation for this species.

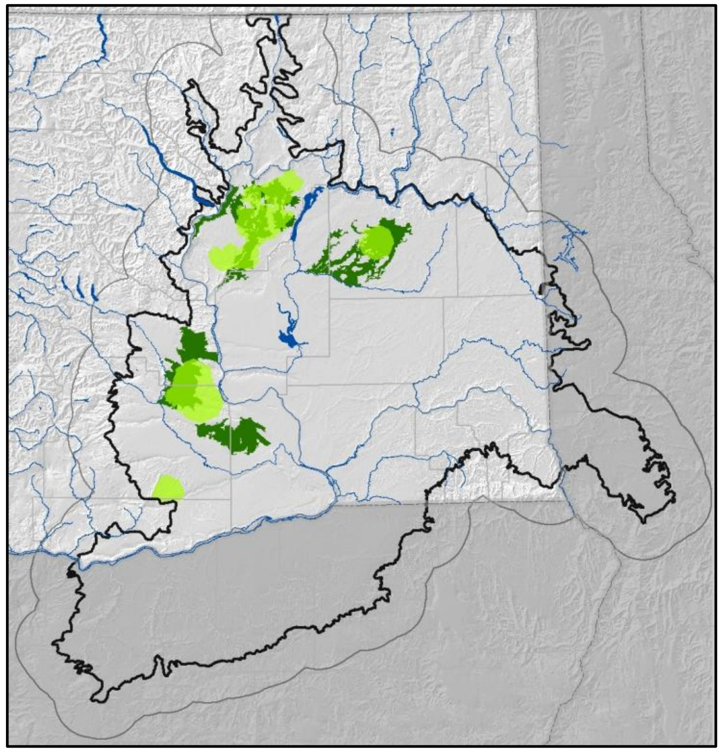

Figure A.2.2. Greater Sage-Grouse HCAs (light green) and GAP distribution (dark green) in the Columbia Plateau Ecoregion.

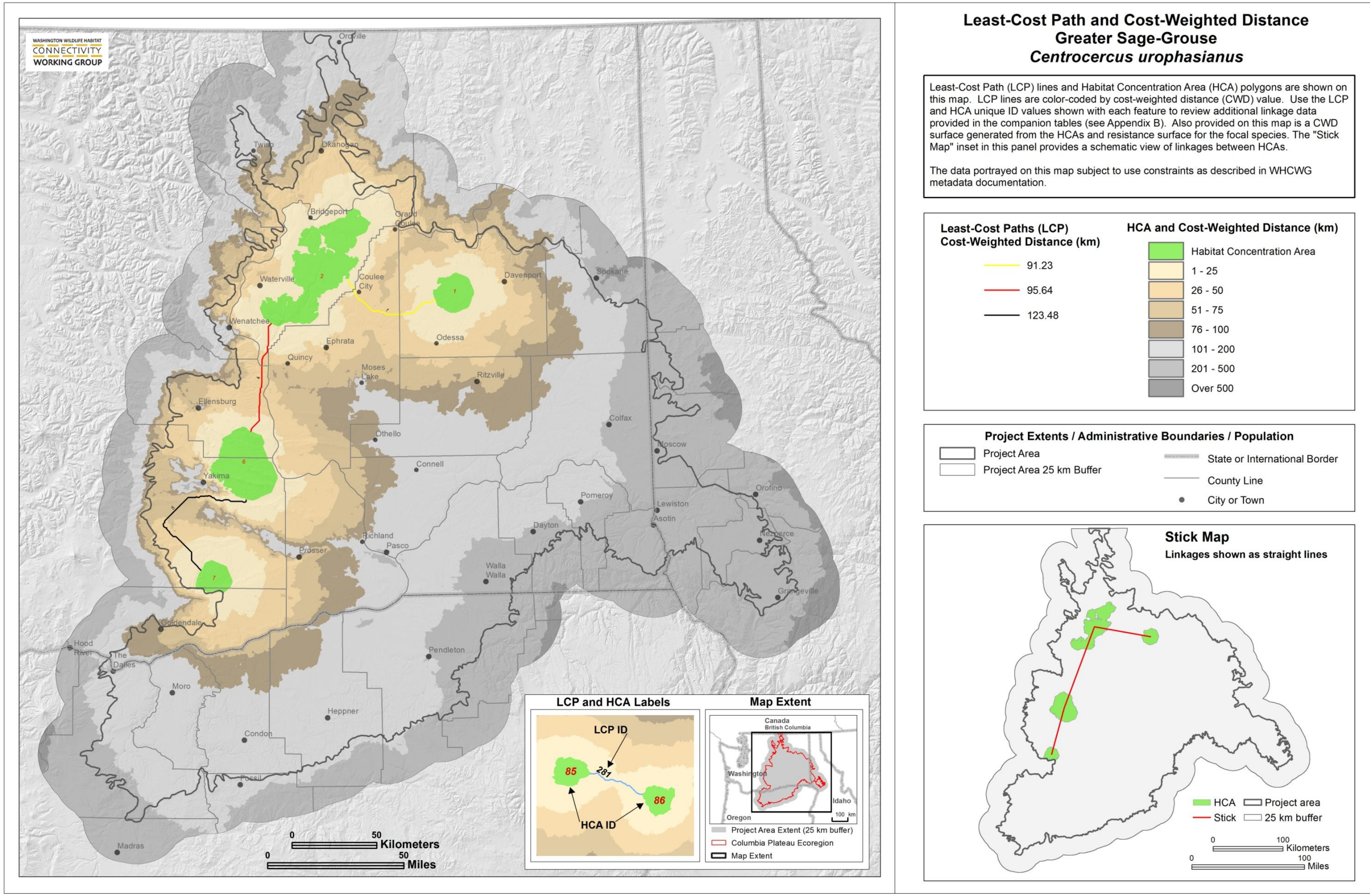

Figure A.2.3. Cost-weighted distance map with numbered HCAs (green polygons labeled with red numerals) and least-cost paths (lines labeled with black numerals) for Greater-Sage Grouse. Linkage modeling statistics provided in Appendix B.

Cost-Weighted Distance Modeling

The cost-weighted distance map (Fig. A.2.4) illustrates patterns for movement potential for Greater Sage-Grouse in the Columbia Plateau. In Lincoln County, HCA 1 has lower potential for movement to the northwest primarily because of agriculture. Movement potential is higher to the southwest of the HCA reflecting low resistance through the channeled scablands. The Mansfield Plateau/Moses Coulee HCA 2 is bordered by large powerlines and extensive areas of agriculture which contribute to the fairly rapid accumulation of resistance moving eastward from the HCA. The potential for movement between the Mansfield Plateau/Moses Coulee and YTC HCAs is greatest on the periphery of the ecoregion. The YTC HCA 6 is surrounded by interstate highways (I-90 and I-82), powerlines, development, and agriculture. Resistance accumulates rapidly to the south and east of this HCA. The Toppenish Ridge HCA 7 has potential for movement to the immediate east but is constrained to the north and west. This HCA is bordered by agriculture, forest, and I-82.

Linkage Modeling

We used a maximum Euclidean cut-off distance of 100 km for linkage modeling which resulted in a total of three linkages among four HCAs (Fig. A.2.5, see Fig. A.2.3 for HCA identification). Measures of linkage length and quality varied considerably (See Appendix B). In Euclidean distance linkages ranged from 40.1 to 62.4 km and averaged 49.8 km (SD 11.4). Linkage cost-weighted (CWD) distances ranged from 91.3 to 123.5 km and averaged 103.3 km (SD 17.4). The cost-weighted distances of all linkages were at the upper end of recorded dispersal distances for Greater Sage-Grouse.

Two linkage quality ratios were calculated for the Greater Sage-Grouse modeling outputs The ratio of cost-weighted distance to Euclidean distance (mean of 2.2 [SD 0.8], range 1.5–3.1) and the ratio of cost-weighted distance to least-cost path length (mean of 1.3 [SD 0.1], range 1.2–1.4). The ratio of cost-weighted distance to Euclidean distance indicates how hard it is to move between HCAs relative to how close they are. 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.

The three linkages identified for Greater Sage-Grouse in Columbia Plateau are all relatively long and problematic for connection of the current HCAs. For instance, the linkage between the Mansfield Plateau/Moses Coulee and Crab Creek HCAs (HCA 2 to HCA 1) follows the Upper Crab Creek drainage and associated shrubsteppe habitat. There are powerlines that increase resistance and a large area of cropland that virtually eliminates the most direct route between these HCAs. The least-cost pathway extends from the southeastern part of the Crab Creek HCA 1 and connects to the Mansfield Plateau/Moses Coulee HCA 2 immediately west of Coulee City. An alternate route passes through habitat between Soap Lake and Ephrata. The linkage between these two HCAs is relatively wide, suggesting opportunities for restoring additional pathways.

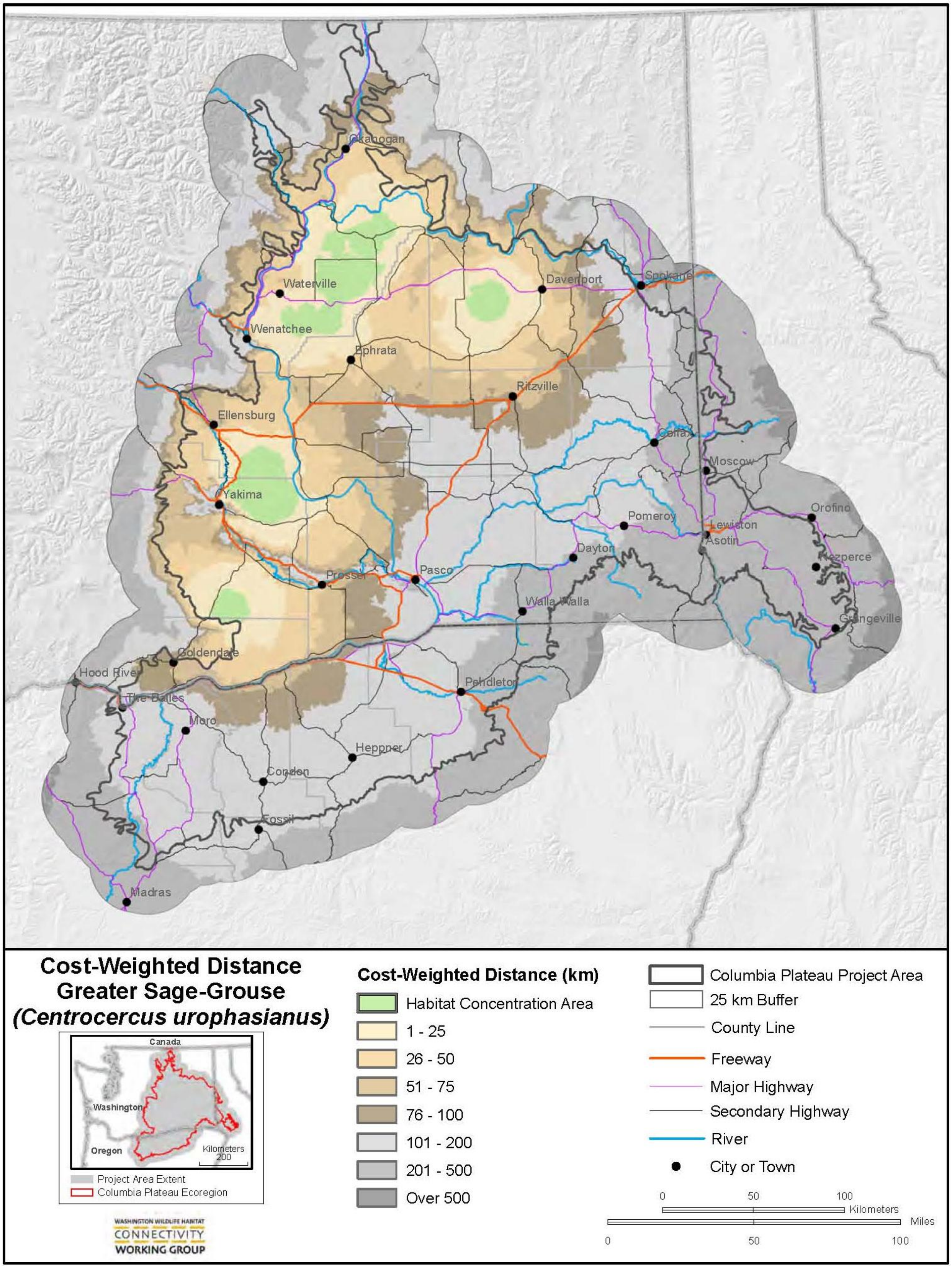

Figure A.2.4. Cost-weighted distance map for Greater Sage-Grouse in the Columbia Plateau Ecoregion.

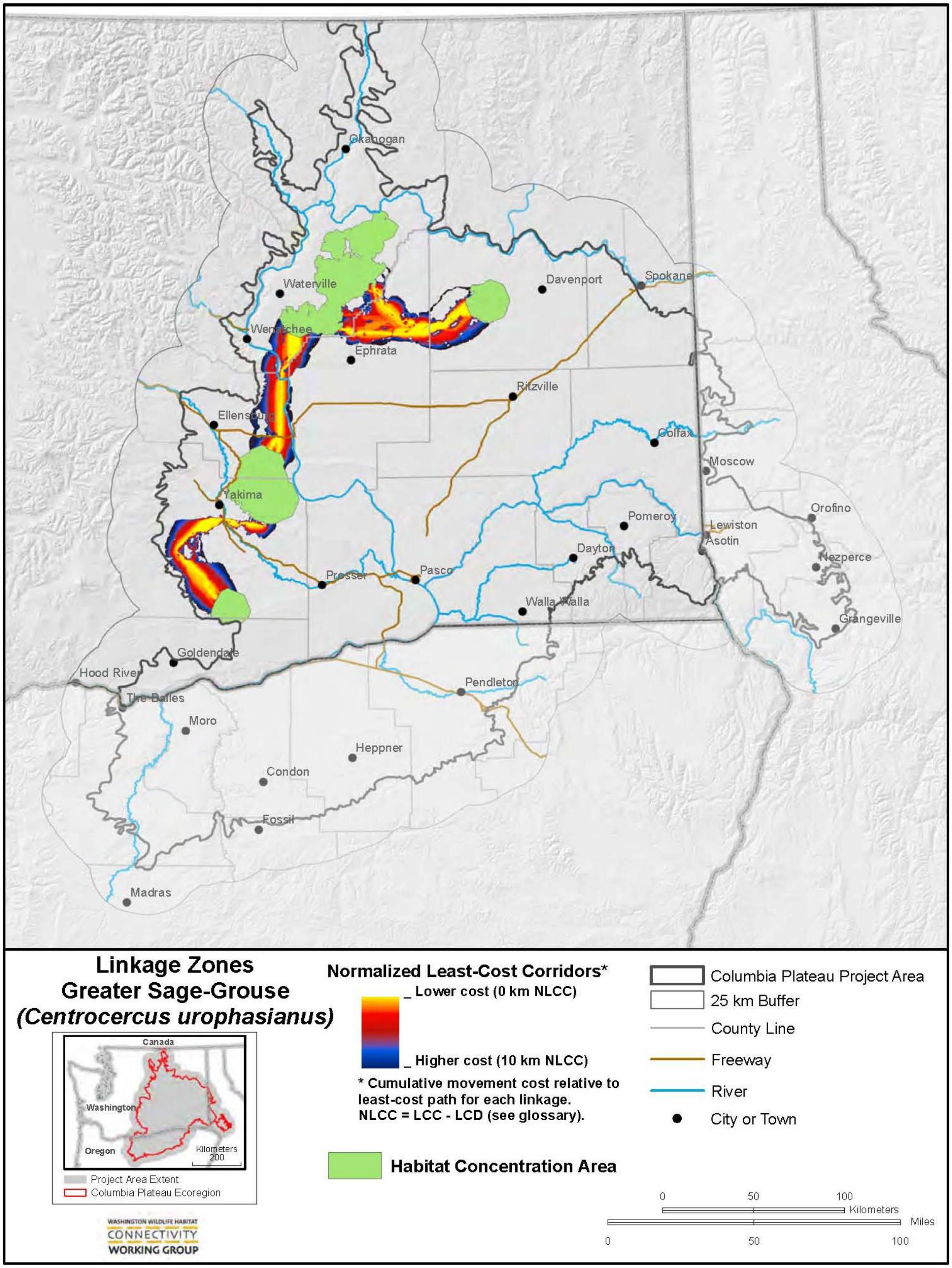

Figure A.2.5. Linkage map for Greater Sage-Grouse in the Columbia Plateau Ecoregion.

The most direct linkage connects the Mansfield Plateau/Moses Coulee HCA 2 and YTC HCA 6. Much of the habitat along this corridor is shrubsteppe that is protected within state-owned wildlife areas (e.g., Colockum Wildlife Area). Negative aspects of this linkage corridor include the relative steepness of the terrain, and disturbance associated with I-90, powerlines, and wind energy development. The least-cost pathway is good in the middle portion of the linkage but there are areas of concern at either end. To the north the least-cost pathway becomes narrow and constricted as it crosses the Columbia River near Rock Island Dam. Resistance accumulates rapidly on either side of the constriction because of development and powerlines. An alternate route of higher cost occurs to the west of this constriction. At the southern end, near where the linkage connects to YTC HCA 6, the corridor constricts to the west because of resistance from wind energy development.

The linkage between the YTC HCA 6 and Toppenish Ridge HCA 7 takes a significant detour from the straight line path due to I-82, development, and agriculture. A severe pinch point occurs on Ahtanum Ridge east and over Union Gap, but many other areas of the least-cost path are also highly constrained. This linkage looks to be tenuous at best with a high risk of being severed in multiple locations by further resistance in the landscape. The Euclidean distance of this linkage is 40 km and the cost-weighted distance is 123 km. The cost-weighted distance is at the upper end of dispersal distances (Table A.2.1) we have recorded for Greater Sage-Grouse in the state, suggesting that movement between these two HCAs may be challenging.

The most important HCAs for maintaining connectivity of Greater Sage-Grouse in the Columbia Plateau are the Mansfield Plateau/Moses Coulee HCA 2 and YTC HCA 6. Each of those HCAs has resident populations and potential connections with two other HCAs. Because the Mansfield Plateau/Moses Coulee HCA 2 supports the largest population of Greater Sage-Grouse in Washington, it may have the greatest potential to provide source birds for dispersal movements.

Overall, none of the linkages provide ideal connectivity between HCAs for Greater Sage-Grouse in the Columbia Plateau. This suggests that improvement of Greater Sage-Grouse connectivity within Washington would require expansion of the existing HCAs, development of new HCAs between the existing HCAs, and/or improving linkage quality.

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 Greater Sage-Grouse populations in the state, 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 analysis were immensely valuable in the Columbia Plateau assessment for understanding the patterns highlighted by the statewide analysis. For example, the resistance surface for both analyses identified the same area of low resistance running north–south between the YTC and Douglas County (Fig. A.2.6a and b). In the statewide analysis the resistance surface (Fig. A.2.6a, Box 1) looks good for movement in this area as most of the habitat is low resistance except for the east–west line of resistance created by I-90. The Columbia Plateau resistance surface for the same area (Fig. A.2.6b, Box 2) shows not only resistance from I-90 but additional resistance in this area from powerlines and wind turbines. The mapping of these additional features on the landscape is important. Greater Sage-Grouse have a highly restricted range in Washington and the area of low resistance highlighted in Figure A.2.6 forms part of the single linkage between the two resident populations in the state. The added detail provided by the Columbia Plateau analysis illustrates that overall resistance in this area is higher than previously thought and movement potential is most likely more constrained.

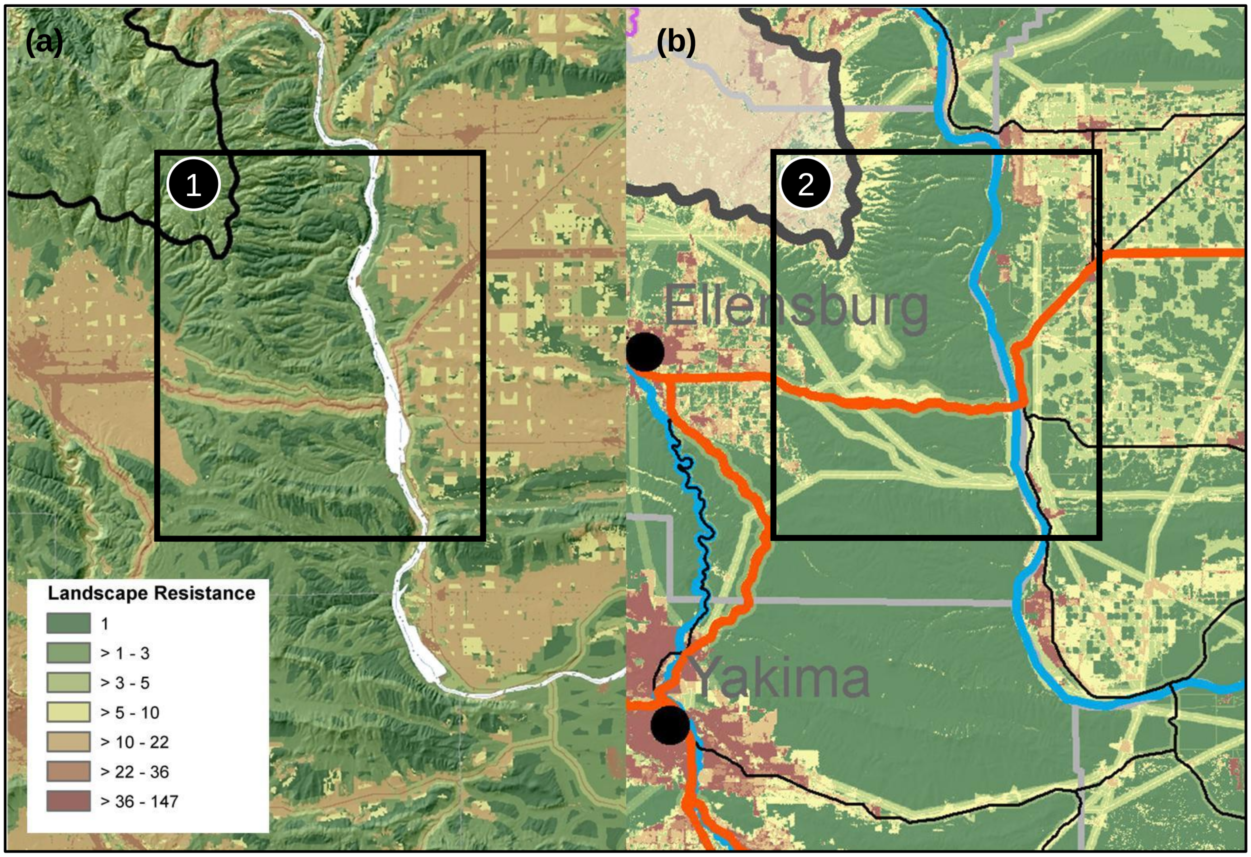

Figure A.2.6. A close up of the resistance surface for Greater Sage-Grouse generated by the (a) statewide analysis and the (b) Columbia Plateau Ecoregion analysis. The areas outlined by boxes are located between the Yakima Training Center (south) and the Mansfield Plateau/Moses Coulee (north).

The cost-weighted distance maps produced by the statewide and Columbia Plateau analyses show similar patterns of potential movement for Greater Sage-Grouse. The major difference is that movement potential is higher through some of the agricultural areas in the Columbia Plateau analysis. This difference is explained by our effort to model the value of agricultural lands adjacent to suitable native habitat as these areas are known to be used by Greater Sage-Grouse. The addition of the agriculture buffers in the model tended to reduce landscape resistance in some parts of the Columbia Plateau Ecoregion.

The statewide analysis identified two linkage pathways (Fig. A.2.7a) connecting the Yakima Training Center and the Yakama Reservation. The least-cost linkage connecting the HCAs in these locations was identified as the linkage though the Horse Heaven Hills crossing the Columbia River near Prosser then moving northwest through the Hanford Site. The alternate pathway to the north, and crossing at Union Gap south of Yakima, was of higher cost but still a potential linkage. The Columbia Plateau analysis (Fig. A.2.7b) identified this alternate linkage pathway as the least-cost route. In part this is because our HCAs are slightly different between the two analyses. But the least-cost path between the YTC and the Yakama Reservation HCAs identified in the statewide analysis is tenuous at best. It is more likely that the additional data layers and finer resolution of the ecoregional analysis is a better representation of the potential resistance to movement for Greater Sage-Grouse in this area.

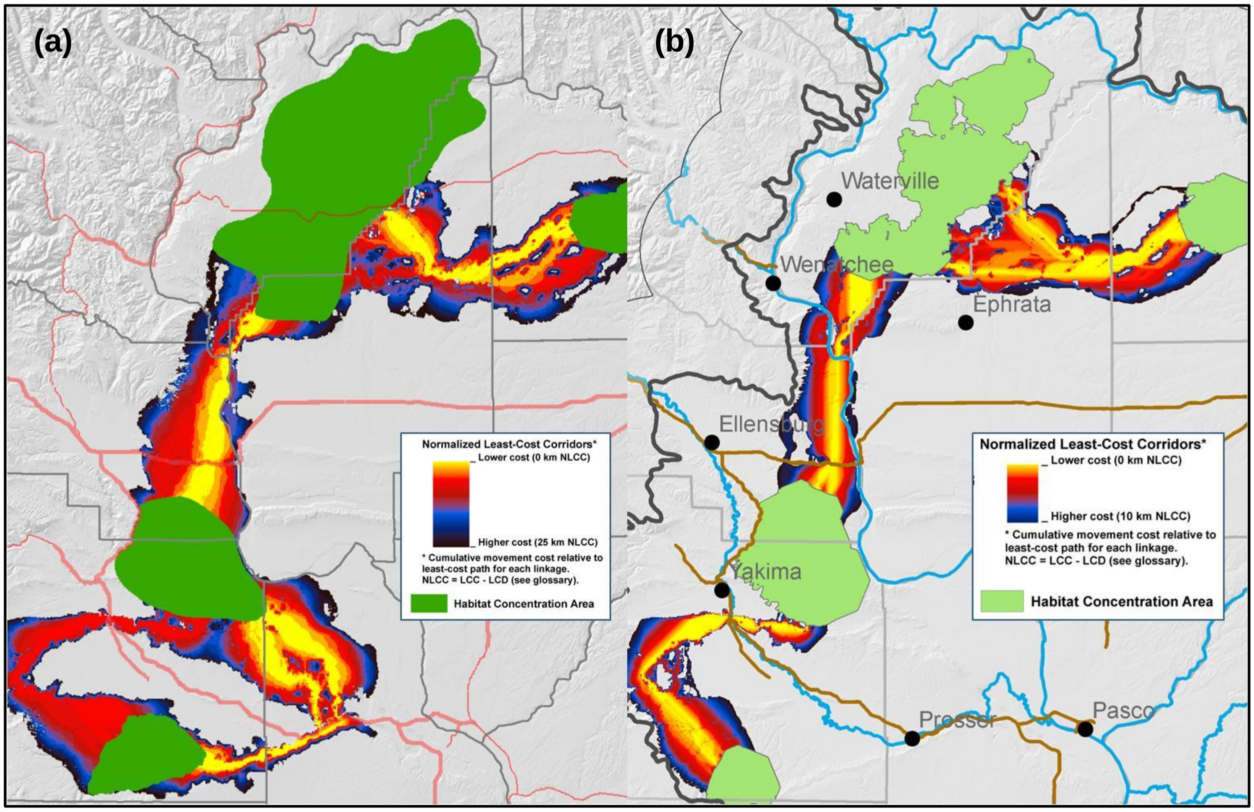

Figure A.2.7. A close up of the linkages modeled for Greater Sage-Grouse for the (a) statewide analysis and (b) Columbia Plateau Ecoregion analysis.

In summary, both scales of analyses are useful for understanding connectivity of Greater Sage-Grouse. 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 scenarios and the implementation of efforts to enhance or maintain connectivity for Greater Sage-Grouse in Washington.

Key Patterns and Insights

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

- A crescent of low resistance is formed by the areas of Upper Crab Creek, Moses Coulee, the Colockum Wildlife Area, and the Yakima Training Center.
- Areas of low resistance are constrained and fragmented by agriculture, development, roads, powerlines, and wind turbines.
- HCAs are peripherally located in the Columbia Plateau Ecoregion and are isolated.
- The Mansfield Plateau/Moses Coulee HCA narrows in the vicinity of U.S. Highway 2 due to agriculture (wheat fields) to the east and west.
- Linkages between individual HCAs are far in nonweighted Euclidean distance.
- The linkage network for Greater Sage-grouse is linear.
- A linkage pinch point between Mansfield Plateau/Moses Coulee and Yakima Training Center HCAs occurs near Rock Island Dam.
- Additional resistance in the linkage between Mansfield Plateau/Moses Coulee and the Yakima Training Center may negatively impact movement potential of Greater Sage-Grouse between these HCAs.
- The I-82 corridor between Yakima and the Tri-Cities is a barrier to movement.
- This Columbia Plateau analysis provides important detail for assessing connectivity of Greater Sage-Grouse in Washington.

Considerations and Needs for Future Modeling

Several additional factors that may influence landscape resistance were not considered in our model. A potential source for resistance in the landscape is anthropogenic noise. 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 seem to avoid leks with experimentally-elevated noise (Blickley et al. in press). In the last decade the single lek that has been abandoned was located about a half mile from a gravel crushing pit that operated through the spring breeding season (M.A.S.). Fences may also contribute to resistance as both fence collisions and mortality have been documented (Stevens 2011). For both of these considerations (noise and fences), the GIS data layers would need to be developed.

Leks, nests, and 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 Greater Sage-Grouse occurrence in relation to the available GIS layers developed for the Columbia Plateau

Ecoregion. An improved habitat suitability model for Greater Sage-Grouse would have benefits for future analyses, particularly with efforts to evaluate restoration and conservation scenarios.

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

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: (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 (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 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 Greater Sage-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. They can also help 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 the additional resistance they contribute to the landscape and the relative impact of this increased resistance to Greater Sage-Grouse. Finally, models can also be used to evaluate different translocation options including 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 Greater Sage-Grouse. Movement of radio-marked individuals can offer insight into movement capability with respect to landscape resistance. Additionally, movement data from Greater Sage-Grouse translocated to sites in Washington may potentially be used to evaluate our connectivity models. It is common for grouse that are translocated to a new location to move away from the release site, sometimes a considerable distance. Because these movements are through a novel landscape, translocated birds 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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