Appendix A.3

Habitat Connectivity for Black-tailed Jackrabbit (*Lepus californicus*) in the Columbia Plateau Ecoregion

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Introduction

Black-tailed jackrabbit, photo by Mike Schroeder

This account describes components of black-tailed jackrabbit (*Lepus californicus*) life history that are relevant to an analysis of habitat sensitivity and connectivity in the Columbia Plateau Ecoregion. This effort started with the *Washington Connected Landscapes Project: Statewide Analysis* (WHCWG 2010) which modeled connectivity for 16 focal species within Washington State. This statewide 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 next step was to conduct a connectivity assessment of the Columbia Plateau Ecoregion. This ecoregion is the arid eastside portion of Washington State with several habitats—e.g., shrubsteppe and scabland—and many species that are declining in both distribution and abundance, due to the extensive human footprint, primarily agriculture, in the area. This ecoregion is very important since less than 50% of the historical shrubsteppe remains in Washington and it is entirely contained within the Columbia Plateau (Schroeder & Vander Haegen 2011).

To better define key wildlife corridors and crucial wildlife habitats in the Columbia Plateau Ecoregion than was done in the statewide analysis, we used additional data layers, better defined habitat variables, and a finer scale of resolution—a 30-meter scale, to examine connectivity issues for 11 focal species, including the black-tailed jackrabbit. The black-tailed jackrabbit was selected as a focal species to represent the shrub dominated habitats in the Columbia Plateau Ecoregion—shrub dominated shrubsteppe, shrub dominated scabland, and shrub dominated dune vegetation classes. The white-tailed jackrabbit (*L. townsendii*) was also selected as a focal species for this analysis and is addressed in its own species account (See Appendix A.4).

Justification for Selection

The black-tailed jackrabbit was selected as a focal species because it is a good representative of wildlife habitat and connectivity needs within the shrubsteppe vegetation type. Black-tailed jackrabbits are closely associated with this habitat in Washington and throughout their range. Specific habitats that were classified as prime habitat for black-tailed jackrabbits were

Shrubsteppe and Basin Shrubland; secondary habitats were Dunes, Mountain Shrubland and Scabland.

The major connectivity threats to jackrabbits are alteration and removal of habitat, development, roads and traffic, fire, energy development, irrigation and its infrastructure, and the presence of people and domestic animals. From many of these same factors jackrabbits also face increased mortality e.g., persecution from farmers, harassment by pets—especially domestic dogs, and increased predation by both native and non-native predators.

For jackrabbits, population monitoring is a challenge as no reliable census method exists; however, individual monitoring, is now fairly easy when using radio telemetry. Techniques that have been used to determine density include road counts, pellet counts, drive counts and transects. Their movement scale is appropriate for ecoregional modeling based on recorded dispersal distances.

Jackrabbits have been reported causing considerable damage to agricultural crops including lawn and pasture grasses, ornamental shrubs, orchards, grape vines, alfalfa (*Medicago sativa*), wheat (*Triticum* spp.), and potato plants (Best 1996). As a result jackrabbit populations were harvested heavily in the early 1900s. They were hunted throughout the year, in rabbit drives, organized hunts, trapping, snaring and poisoning (Bailey 1936). Hunters were paid by bounties (Best 1996). One rabbit drive reported killing approximately 20,000 black-tailed jackrabbits in California (Palmer 1897). Poisons were used particularly in the 70s and 80s. In Idaho, it was reported that 168,166 black-tailed jackrabbits were killed with strychnine applied to bait. Tiemeier (1965) reported that humans with motorized vehicles, spotlights, and guns, probably caused the greatest mortality. Jackrabbits are vulnerable to high mortality on roads. The number of carcasses found on highways range from <1/km to 130/km in Idaho (Williams & Nelson 1939; Best 1996).

Although jackrabbit populations are known to oscillate greatly in different years and in different habitat types with density estimates varying from 0.1 to 5.6 rabbit/ha (Best 1996), it appears that the jackrabbit population in Washington has been on a decreasing trend for at least the past 20 years. The most likely reason is loss of habitat. Historically, most of the land in the Columbia Plateau supported shrubsteppe vegetation communities (Daubenmire 1970). Large-scale clearing of land for agriculture began in the late 1800s and expanded when irrigation became widespread after damming of the Columbia River in the 1930s (National Research Council 1995). Using historical and current land cover maps from the Interior Columbia Basin Ecosystem Management Project (Quigley & Arbelbide 1997), McDonald and Reese (1998) estimated that the mean patch size of sagebrush (*Artemisia* spp.) decreased from 13,420 ha circa 1900s to 3418 ha in the 1990s, and the number of patches increased from 267 to 370 becoming smaller and much more fragmented.

There is also the additional stressor on the landscape of increased fire frequency that converts shrubsteppe to annual grasslands (Knick et al. 2003). The synergistic effect of livestock grazing, introduced plant species, and altered fire regimes have resulted in large scale alterations to the landscape including shifts in the composition of plant communities, loss of topsoil, and altered hydrology (West 1999). Once established, cheatgrass (*Bromus tectorum*), an introduced annual grass, provides a continuous fuel that results in larger, more frequent, and more complete burns, that in many cases preclude reestablishment of big sagebrush (*A. tridentata*; Whisenant 1990; West 1999). West (1999) estimated that 25% of the shrubsteppe region has been converted to exotic annual grasslands, and an additional 25% is at risk of transitioning. All of this has likely contributed to the widely observed decrease of black-tailed jackrabbit populations.

Accordingly, the black-tailed jackrabbit is considered a Priority Species by the Washington Department of Fish and Wildlife (WDFW) Priority Habitats and Species Program (WDFW 2008), a Species of Recreational, Commercial, and/or Tribal Importance, and is listed as a Washington State Candidate Species. In Washington State a species is given Candidate Species status "When populations are in danger of failing, declining, or are vulnerable, due to factors including, but not restricted to, limited numbers, disease, predation, exploitation, or habitat loss or change" (WDFW 2008). Due to these same factors they are also listed as a Species of Greatest Conservation Need in Washington (WDFW 2005). The Bureau of Land Management (BLM) also lists the black-tailed jackrabbit as Sensitive (Bureau of Land Management 2008). Refer to Table A.3.1 for the NatureServe (2011) ranking status of the black-tailed jackrabbit for the U.S.

Table A.3.1. Status of the black-tailed jackrabbit in the U.S. (NatureServe 2011).

	*NatureServe status by state**
U.S.	Arizona (S5), Arkansas (S1S2), California (S5), Colorado (S5), Florida (SNA), Idaho (S5), Kansas (S4S5), Massachusetts (SNA), Missouri (S1), Montana (S2), Navajo Nation (S5), Nebraska (S5), Nevada (S5), New Jersey (SNA), New Mexico (S5), Oklahoma (S5), Oregon (S4), South Dakota (S4), Texas (S5), Utah (S5), Virginia (SNA), Washington (S2S3), Wyoming (S5)

**S1= critically imperiled; S2 = imperiled; S3 = vulnerable; S4 = apparently secure; S5 = secure; SNR or SNA = not ranked or not applicable.*

Distribution

The black-tailed jackrabbit is the most common jackrabbit in the western U.S. (Flinders & Chapman 2003). The black-tailed jackrabbit's historical range encompasses an area from the Pacific Ocean on the west to Arkansas and Missouri on the east. In the north, it ranges from south-central Washington to South Dakota and in the southwest it is found throughout Baja California and well into south-central Mexico (Chapman & Flux 1990). They also have been successfully introduced into various eastern states (Dunn et al. 1982).

In Washington, the black-tailed jackrabbit is found east of the Cascade Mountains concentrated in the arid Columbia Plateau shrubsteppe and shrub dominated grassland habitats. Areas used by black-tailed jackrabbits include sagebrush (*Artemisia* spp.), rabbitbrush (*Chrysothamnus* spp.), and greasewood (*Sarcobatus vermiculatus*) dominated habitats as well as areas of mixed grassland and shrub (Johnson & Cassidy 1997). They generally occupy areas with more shrubs and less grass than white-tailed jackrabbits and are more tolerant of grazing by livestock (Best 1996); they do not readily move into areas of tall grass or forest where vision is obscured (Jones et al. 1983). Black-tailed jackrabbits are generally nocturnal and solitary (Flinders & Chapman 2003).

There are some indications that black-tailed jackrabbits are recent colonizers of Washington State (Couch 1927; Larrison 1976). Larrison (1976) reported that "…in the years preceding their sweep into Eastern Oregon and Washington…" Another early observation by Couch in 1927 also documents this colonization when he noted that this species moved a distance of forty miles from between 1908 and 1912, colonizing the area from western Walla Walla up to Grant County (Couch 1927).

Habitat Associations

General

The distribution of black-tailed jackrabbits in the western U.S. is closely linked to the distribution of sagebrush, particularly big sagebrush. Compared to white-tailed jackrabbits, black-tailed jackrabbits prefer areas with more shrub growth and less abundant and shorter grasses, often, where grazing has been severe (Best 1996). They do not readily move into areas of tall grass, where visibility is obscured. Associated plant species include: *Artemisia tridentata*, *Agropyron spicatum*, *Chrysothamnus viscidiflorus*, *Sitanion hystrix*, *Orzyopsis hymenoides*, and *Atriplex* spp. (French et al. 1965). Chew and Chew (1970) found 65% of the diet was shrub browse, and 30% was herbage. Although there are no studies for the white-tailed jackrabbit, a black-tailed jackrabbit pellet analysis on Hanford Reservation (Uresk et al. 1975) reported that no cheatgrass was found in the pellets, indicating this non-native plant has little or no forage value for jackrabbits.

Washington Gap analysis (Johnson & Cassidy 1997) noted that black-tailed jackrabbits are usually in sagebrush, rabbitbrush (*C. viscidiflorus*), and greasewood including areas of mixed grass and sagebrush and/or rabbitbrush, but generally not in pure grassland lacking shrub cover. They can also be found in and around inland sand dunes (Hallock et al. 2007). In Idaho, they are primarily associated with shrub cover dominated by *A. tridentata*. Their diet varies seasonally; they eat a higher percentage of shrubs in winter, forbs in spring, and mostly grasses with almost no shrub ingestion in summer (Grant 1987). They are known to also use juniper (*Juniperus osteosperma*), shadscale (*Atriplex confertifolia*) and greasewood for feeding and cover (Gross et al. 1974). Thompson and Gese (2007) found that presence of jackrabbits was positively correlated with shrub density ($r^2 = 0.33$, $p > 0.006$).

Agriculture

In Washington, large-scale clearing of land for agriculture began in the late 1800s and expanded when irrigation became widespread after the damming of the Columbia River in the 1930s (National Research Council 1995). A considerable portion of the study area is farmed—approximately 43% of the Columbia Plateau is farmland. Dryland wheat is the main crop in higher elevation zones, whereas irrigated orchards, vineyards, and row crops prevail at lower elevations. Grazing by livestock began in the ecoregion in the late 1800s and has continued to varying degrees (Quigley & Arbelbide 1997). Both species of jackrabbits may frequent agricultural land where they can become a pest of crops and fruit trees (Lechleitner 1958*a*; Flinders & Chapman 2003).

We generally lack an understanding of how dispersal costs and animal movements vary among crops in agroecosystems (Cosentino et al. 2011). These results suggest that estimating crop-specific dispersal costs and movement patterns may improve measures of landscape connectivity in agroecosystems (Cosentino et al. 2011). In the sagebrush-steppe, black-tailed jackrabbits typically inhabit shrub dominated areas during daylight for cover and make feeding forays into areas offering higher forage quality but less overhead cover at night (Johnson & Anderson 1984). Flinders and Hansen (1972) reported that agricultural crops used as food for jack rabbits included alfalfa and winter wheat. Research by Longland (1991) showed significantly less use of palatable feed by jackrabbits when distance from cover was only 5–10 m. However, in other studies black-tailed jackrabbits typically forage within a 300 m band adjacent to protective cover (Westoby & Wagner 1973; Roundy et al. 1985; McAdoo et al. 1987; Ganskopp et al. 1993).

In agricultural fields, especially those that have sparse cover, vulnerability increases for jackrabbits; however, plant cover increases through the growing season, resulting in the potential for more and/or longer forays by rabbits into agricultural crops. Marin et al. (2003) demonstrated that jackrabbits do integrate both resource levels and predation risk in their selection of habitats. Thus, as predicted by optimal foraging theory, jackrabbits are balancing foraging gains (resource levels) and costs (predation risk).

This may explain why jackrabbits have been observed using Conservation Reserve Program (CRP) fields more than other croplands (Schroeder & Vander Haegen 2006). The 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. Some of the habitat loss due to agriculture may be mitigated through conversion of cultivated agricultural lands to CRP. The vast majority of CRP in Washington occurs on land that was historically shrubsteppe. There are currently ~599,180 ha of CRP in eastern Washington, which is roughly 10% of the region’s total agricultural lands (USDA 2011). In general, the “usefulness” of CRP for wildlife 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 CRP program in Washington can reduce resistance to movement in the landscape for jackrabbits by providing suitable habitat.

Sensitivity to Development

Housing and other forms of development either destroy or fragment the preferred habitat of shrubland and shrubsteppe. Again, the primary impact of development is the loss of habitat, but it also carries the associated impacts of other factors—roads, distribution power lines, irrigation ditches, well sites, increased sound levels, and increased predation and harassment by pets, particularly dogs. While jackrabbits will often be seen in or near developed areas, e.g., Richland-Tri-Cities area, they are likely only there as relict or “sink” populations, surviving in the small patches of native vegetation and feeding on the new lawns and landscaping plants. There are now many sites in newly developed areas like Richland where jackrabbits were formerly observed but are no longer seen (M. Livingston, personal communication).

Sensitivity to Roads and Traffic

Vehicles collide with wildlife over one million times each year in the U.S., and the annual number of collisions has grown by 50% in the last 15 years. The number of jackrabbit carcasses on highways reported in 1939 by Williams and Nelson, ranged from <1/km to 130/km in Idaho (Best 1996). From 2009 to September 2011, 466 black-tailed jackrabbits were reported as road kills in California (Road Ecology Center 2011). It is evident that roads can be a major source of mortality for jackrabbits. The relatively high dispersal capacity of the black-tailed jackrabbit increases the likelihood that they will encounter roads during dispersal through landscapes with high road densities. However, there is little empirical information available defining the relative resistance of different types of roads and different levels of traffic volume for the jackrabbit. Potential impacts other than direct mortality may be increased predation due to lack of cover, additional perches for raptors, and an increase of both noise and light—light because jackrabbits are mainly nocturnal animals.

Black-tailed jackrabbits are known to use undeveloped roads for movement between habitat areas and will cross all roads, including major highways if encountered (Best 1996). It is on these high speed and high-volume roads that black-tailed jackrabbits are at high risk due to mortality associated with vehicles.

Sensitivity to Energy Development

WIND ENERGY DEVELOPMENT

Although no studies evaluating the sensitivity of jackrabbits to wind developments are available, it is probably relatively light. The amount of habitat destroyed by wind energy projects is relatively small and therefore only light impacts might be expected from direct habitat loss. Other impacts would be related to general habitat fragmentation, increased road traffic, potential increase of fire frequency, weed introduction, increased light, and increased predation. All of which are minor on a single project, but need to be looked at on a cumulative landscape level to determine actual impact. These effects, however, have not yet been documented. Energy development probably has little effect on jackrabbit dispersal.

TRANSMISSION LINES

Transmission lines can potentially increase jackrabbit mortality by providing perch sites for raptors in habitat that is generally more open than the surrounding native habitat. In addition, the vegetation under the transmission lines is often mowed or cleared on a regular basis eliminating cover for jackrabbits, again making them more vulnerable to predators.

Sensitivity to Climate Change

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). Projected climate change and associated consequences are recognized as potentially interacting with the stressors mentioned in earlier sections of this document that are already impacting jackrabbits (Miller et al. 2011). The current distribution of sagebrush is predicted to decrease 12% for each degree of temperature increase (Neilson et al. 2005). Climate change may potentially impact jackrabbits by amplifying effects of parasites and disease, e.g., *Pasteurella tularensis* and *Pasteurella pestis* (Bacon & Drake 1958).

The impact of climate change on fire cycles is speculative, but if it leads to increased fire intensity and a shorter fire return interval, the impact will likely be negative on the black-tailed jackrabbit because of the loss of shrub cover (Knick & Dyer 1997). Increased atmospheric CO^2 favors introduced species such as cheatgrass which puts more of the shrubsteppe ecosystem at risk to increased fire—frequency, extent, and intensity. All these consequences, especially when considered cumulatively, will have negative impacts on the black-tailed jackrabbit.

Dispersal

Black-tailed jackrabbit movements appear to be quite variable, with some studies showing little mobility while others show high mobility (Table A.3.2; Table A.3.3). Size of home range varies from 16 to 300 ha and density ranges from 0.1 to 2.8 rabbits/ha (Table A.3.2). Female black-tailed jackrabbits generally have larger home-range sizes than males. From a telemetry study in Utah, Smith (1990) reported the largest home ranges and noted that the shape of most home ranges tended to be elliptical. A similar elliptical shape was noted by Rusch (1965) and Donoho (1971). The literature suggests that no regular seasonal migration occurs; however, most recorded large movements are between fall and winter ranges and winter and spring ranges (Rusch 1965; Grant 1987; Smith et al. 2002).

Table A.3.2. Summary of spatial data available for black-tailed jackrabbits.

Home range (km^2)	*Radius (m)*	*Density (hare/ha)*	*Location*	*Telemetry used (yes/no)*	*Citation*
0.2	236	2.7	CA	no	Lechleitner 1958*b*
0.2	227		ID	no	French et al. 1965
2.6	906	0.1–0.3	CO	no	Donoho 1971
0.3			ID	no	Grant 1987
0.2	252		CA	no	Chapman & Flux 1990
1–3.0	977		UT	yes	Smith 1990
0.8	501	0.4–2.8	WA	yes	Major 1993
		0.1–1.0	UT	no	Gross et al. 1974
		1.2	AZ	no	Vorhies & Taylor 1933
		0.2	NV	no	Hayden 1966b
		0.9	UT	no	Woodbury 1955
		0.2–1.1	NM	no	Daniel et al. 1993
			UT	yes	Nelson & Wagner 1973
		0.3–1.0	NM	no	Lightfoot et al. 2010

Table A.3.3. Maximum dispersal distance reported for black-tailed jackrabbits.

Maximum dispersal distance (km)	*Mean dispersal distance (km)*	*Location*	*Telemetry used (yes/no)*	*Citation*
1.6		CA	no	Lechleitner 1958*b*
	12.0	UT	no	Porth 1995
45.0		ID	no	French et al. 1965
57.3	16.2	ID	yes	Grant 1987
35.0	11.0	UT	yes	Smith et al. 2002
17.0		UT	no	Rusch 1965
17.0	4.4	CO	no	Donoho 1971
8.0		WA	yes	Major 1993

Similar to home-range size and density black-tailed jackrabbit dispersal distance varies greatly, from 1.6 km to 57.3 km (Table A.3.3). In Idaho, dispersal movements occurred in approximately 18% of the population with the greatest distance being a 45 km movement over a 17-week period (French et al. 1965; Table A.3.3). From a very early observation in Washington, Couch (1927) reported that this species expanded its range 64 km from 1908 to 1912, colonizing the area from western Walla Walla County up to Grant County.

Conceptual Basis for Columbia Plateau Model Development

Overview

Black-tailed jackrabbits are found in the arid Columbia Plateau and prefer shrub dominated habitat. They do not utilize areas with tall grass-cover or areas with little shrub cover; however, they will use agricultural areas whenever adjacent to native habitat. As mentioned earlier, Washington Gap analysis (Johnson & Cassidy 1997) noted that black-tailed jackrabbits are in sagebrush and sometimes rabbitbrush, including areas of mixed grass and sagebrush and/or rabbitbrush, but generally not in grassland lacking shrub cover. They can also be found in and around inland sand dunes (Hallock et al. 2007). In Kansas the habitat model noted that the black-tailed jackrabbit is an animal of open country, that does not inhabit areas of tall grasses or forest where visibility is obscured. They prefer lowland areas where cover is the heaviest and heavily grazed grassland (Kansas State University 2001).

Knick and Dyer (1997) conducted GIS modeling of the black-tailed jackrabbit in Idaho and found that in winter, jackrabbits used smaller and less variable sizes of shrub patches and areas of higher spatial heterogeneity when compared to summer observations ($p < 0.05$) and that jackrabbits also used agricultural regions more during winter than summer. They also reported that areas that were repeatedly burned by military training activities were less likely to contain habitats used by jackrabbits (Knick & Dyer 1997).

In Washington, black-tailed jackrabbits typically inhabit areas of relatively flat topography but may use steep slopes. Although slope is a component of suitable jackrabbit habitat it is not likely to be a factor impeding movement or dispersal.

Black-tailed jackrabbits are at risk from the conversion of native shrubsteppe and grassland habitats for development and the other risks associated with development—road, railroads, powerlines, campgrounds, rest stops, landfills, irrigation canals, water and oil-gas wells, and human-induced fires.

On high-speed and high-volume roads black-tailed jackrabbits are at high risk due to mortality associated with vehicles; we therefore assumed that Freeway and Major Highway were the primary road classes contributing to resistance to movement for jackrabbit in the landscape.

With this background in mind, we began modeling the habitat for rabbits using the vegetation layer obtained from the National Land Cover Gap Analysis Project (See Appendix D). LandSAT imagery base data used in developing the layer was circa 2000.

Habitat Concentration Areas

Habitat concentrations areas (HCAs) are habitat areas that are expected or known to be important habitat for focal species. These areas are used as the focus locations for running dispersal and linkage models that identify connectivity pathways. A more technical definition of HCAs is that they are aggregations of habitat grid cells that are connected to each other by a species-specific home range diameter or short range dispersal distance. These aggregations must also meet a minimum size requirement appropriate for the species' movement capability and the extent of our analysis.

Due to a lack of sufficient local studies and occurrence points that were not on a road, the core habitat for black-tailed jackrabbits in Washington is not well defined. Because of this, models were developed to define HCAs. Our modeling effort for the jackrabbits consisted of defining the resistance and habitat values for different landscape features (see Resistance and Habitat Values for Landscape Features below) as well as movement capabilities and habitat patch size requirements. These were then used to model jackrabbit habitat, generate HCAs, and determine least cost corridors between HCAs. In order to ensure that the HCAs developed were prime habitat for black-tailed jackrabbits, a minimum habitat value of 0.8 was applied and a conservative estimate of 500 m was used for home range radius. Additionally, to ensure that HCAs would be appropriate for the species' movement capability and the extent of our analysis, a minimum HCA size of 25 km^2 was used.

During development several questions consistently arose. Are HCAs core habitat areas or core population areas? Is an area an HCA even if there have been no rabbit observations in the area and experts agree that there are no rabbits in the area? What if rabbits have been observed in the HCA in the past, but not currently? For the final model it was decided to remove those HCAs that were not currently occupied and did not have the necessary habitat to support colonization. These removals were based on local biologists' knowledge and familiarity with the areas in question.

The modeling process for black-tailed jackrabbit HCA identification involved the following steps:

1) A continuous habitat value map was generated by multiplying together all the landscape feature habitat values for an individual grid cell (30 m).
2) A continuous average habitat value map was then generated using a circular moving window with a radius of 500 m, an area equal to a home range size of 1 km^2.
3) Areas falling below an average habitat quality threshold of 0.8 were masked out, and the remaining areas of the habitat model were converted from a continuous into a binary habitat/non-habitat map based on a threshold of 0.8.
4) All cells within the home range movement (500 m) of a binary habitat cell were joined together to form HCAs. This was done using the resistance model and expanding designated habitat cells outwards up to a total cost-weighted distance of 500 m. This had the effect of joining nearby habitat cells together if the intervening landscape supports within-home-range movements.
5) Habitat concentration areas smaller than a 25 km^2 were then eliminated.

Movement Distance

The central objective of this ecoregional analysis was to explore connectivity opportunities across the Columbia Plateau. In this context, we selected 50 km as the maximum Euclidean distance between habitat concentration areas (HCAs) to model habitat linkages. This choice implies that an exchange of individuals could occur between populations separated by up to 50 km. This distance is just short of the maximum 57.3 km dispersal distance recorded in the literature for a jackrabbit (Table A.3.3). Our rationale for using the near maximum is based on the fact that the final HCA model selected included: (1) only the best habitat patches in the landscape—many patches of suitable habitat were excluded that can serve as stepping stones between HCAs; and (2) the capacity of jackrabbits to find and opportunistically inhabit stepping stone habitats—a mechanism that if spread across years, or even generations, affords long-distance movements between habitat concentration areas. This is an important reason to protect these travel corridors since if not protected or restored, these stepping stone habitats would be lost, further isolating HCAs.

Resistance and Habitat Values for Landscape Features

For many of the landscape features used in the modeling, specific information was not available in the literature regarding resistance to movement by the black-tailed jackrabbit. Therefore, the assignment of habitat values was often subjective and based on the professional judgment of local experts with extensive field experience who helped review and refine these assignments. For both groups of values—resistance values and habitat quality values—several iterations of assignment, implementation, and review were made before the resulting ecoregional maps conformed reasonably well to expert opinion about the distribution of black-tailed jackrabbit populations and the resistance each feature contributed to jackrabbit movement. We also used a database of known black-tailed jackrabbit observations as an appraisal of our habitat value assignments.

Land cover and land use—For the black-tailed jackrabbit their prime habitat is shrubsteppe and basin shrubland so these were assigned a habitat value of 1 (core habitat) and 0 or no resistance. Secondary habitats jackrabbits are known to occur in are Scabland, Shrubland Mountain, and shrubby edges of Dunes so these habitats were assigned habitat values of 0.8 (adequate habitat) and resistance values of 1 and 2 (Table A.3.4). All other habitat types were scored as marginal (<0.6) or non-habitat (0). Resistance values were all relative based on their ideal or prime habitat types, for example Introduced Upland Vegetation Annual Grassland and Grassland Mountain were given a resistance of 3 reflecting jackrabbit avoidance of grassland habitats and increased predation due to low shrub cover. Cliffs Rocks Barren habitats were assigned a resistance value of 10 indicating general avoidance of these areas—a 10 would equate to a jackrabbit travelling an extra 300 m to avoid these habitats compared to prime habitats. The highest resistances were assigned to Water (50) and Forest (100). Although jackrabbits are able to swim when forced to by predators, they normally avoid water, especially large wide bodies of water like the Columbia River. Forest habitats, except the early transition zones, are normally not occupied and not traversed.

Table A.3.4. Landscape features and resistance values used to model habitat connectivity for black-tailed jackrabbits.

Spatial data layers and included factors	*Resistance value*	*Habitat value*
Landcover/Landuse		
Grassland_Basin	2	0.6
Grassland_Mountain	3	0.4
Shrubsteppe	0	1.0
Dunes	2	0.8
Shrubland_Basin	0	1.0
Shrubland_Mountain	2	0.8
Scabland	1	0.8
Introduced upland vegetation_Annual grassland	3	0.4
Cliffs_Rocks_Barren	10	0.2
Meadow	7	0.2
Herbaceous wetland	4	0.2
Riparian	4	0.6
Introduced riparian and wetland vegetation	12	0.2
Water	50	0.2
Aspen	10	0.6
Woodland	15	0.2
Forest	100	0.0
Disturbed	100	0.0
Cultivated cropland from RegapNLCD	4	0.2
Pasture Hay from CDL	3	0.8
Nonirrigated cropland from CDL	5	0.6
Irrigated cropland from CDL	4	0.4
Highly structured agriculture from CDL	8	0.2
Irrigated/Not Irrigated/Cultivated Crop Ag Buffer 0 – 250m from native habitat	0	0.6
Irrigated/Not Irrigated/Cultivated Crop Ag Buffer 250 – 500m from native habitat	4	0.6
Pasture Hay Ag Buffer 0 – 250m from native habitat	0	1.0
Pasture Hay Ag Buffer 250 – 500m from native habitat	3	0.8
Elevation (meters)		
0 – 250m	0	1.0
250 – 500m	0	1.0
500 – 750m	1	0.8
750 – 1000m	3	0.6
1000 – 1250m	5	0.6
1250 – 1500m	10	0.4
1500 – 2000m	25	0.4
2000 – 2500m	50	0.2
2500 – 3300m	500	0.0
Slope (degrees)		
Gentle slope Less than or equal 20 deg	0	1.0
Moderate slope Greater than 20 less than equal to 40 deg	2	0.8
Steep slope Greater than 40 deg	10	0.0
Ruggedness		
Very gentle terrain (or surface water)	0	1.0
Gentle terrain	0	1.0
Moderate terrain	0	1.0
Rough terrain	0	1.0
Very rough terrain or escarpment	500	0.4
Housing Density Census 2000		
Greater than 80 ac per du	0	1.0
Greater than 40 and less than or equal 80 ac per du	0	1.0
Greater than 20 and less than or equal 40 ac per du	2	0.8
Greater than 10 and less than or equal 20 ac per du	5	0.4

Spatial data layers and included factors	*Resistance value*	*Habitat value*
Less than or equal 10 ac per du	500	0.0
Roads		
Freeway Centerline	200	0.0
Freeway Inner buffer 0 – 500m	3	0.6
Freeway Outer buffer 500 – 1000m	0	1.0
Major Highway Centerline	50	0.0
Major Highway Inner buffer 0 – 500m	2	0.8
Major Highway Outer buffer 500 – 1000m	0	1.0
Secondary Highway Centerline	10	0.4
Secondary Highway Inner buffer 0 – 500m	1	0.8
Secondary Highway Outer buffer 500 – 1000m	0	1.0
Local Roads Centerline	3	0.6
Local Roads Inner buffer 0 – 500m	0	1.0
Local Roads Outer buffer 500 – 1000m	0	1.0
Railroads Active		
Railroads Active Centerline	5	0.4
Railroads Active Inner buffer 0 – 500m	0	1.0
Railroads Active Outer buffer 500 – 1000m	0	1.0
Railroads Inactive		
Railroads Inactive Centerline	0	0.8
Railroads Inactive Inner buffer 0 – 500m	0	1.0
Railroads Inactive Outer buffer 500 – 1000m	0	1.0
Transmission Lines		
LessThan 230KV One Line Centerline	3	0.4
LessThan 230KV One Line Inner buffer 0– 500m	1	1.0
LessThan 230KV One Line Outer buffer 500 – 1000m	0	1.0
LessThan 230KV Two or More Lines Centerline	5	0.4
LessThan 230KV Two or More Lines Inner buffer 0 – 500m	2	1.0
LessThan 230KV Two or More Lines Outer buffer 500 – 1000m	1	1.0
Greater Than or Equal 230KV One Line Centerline	3	0.4
Greater Than or Equal 230KV One Line Inner buffer 0 – 500m	2	1.0
Greater Than or Equal 230KV One Line Outer buffer 500 – 1000m	1	1.0
Greater Than or Equal 230KV Two Lines Centerline	5	0.4
Greater Than or Equal 230KV Two Lines Inner buffer 0 – 500m	3	1.0
Greater Than or Equal 230KV Two Lines Outer buffer 500 – 1000m	1	1.0
Greater Than or Equal 230KV Two Lines no transmission line features	0	1.0
Wind Turbine		
Wind turbine pnt buffer 45m radius	16	0.2
Buffer zone beyond pnt buffer 0 – 500m	1	0.8
Buffer zone beyond pnt buffer 500 – 1000m	0	1.0
Irrigation Infrastructure		
Irrigation canals	60	0.0

Although a significant amount of jackrabbit habitat has been lost due to agriculture, certain agricultural crops provide forage for jackrabbits, such as alfalfa. As mentioned in previous sections, the black-tailed jackrabbit will typically forage within a 300 m band into cropland that is adjacent to protective cover (Westoby & Wagner 1973; Roundy et al. 1985; McAdoo et al. 1987; Ganskopp et al. 1993) which includes not only native habitat but CRP as well. Schroeder and Vander Haegen (2006) conducted a pellet study on shrubsteppe associated wildlife and found significantly higher number of jackrabbit pellet groups in CRP fields than non-CRP fields, and higher pellet counts in younger CRP than older CRP. The younger CRP fields were often planted with more native plants which may include one or more shrubby species. Because of this, we included the GIS generated agricultural buffer classes—irrigated/non-irrigated and pasture-hay, into our modeling process. The pasture-hay class was considered to approximate CRP lands. In addition, two different buffer distances were used; 0–250 m and 250–500 m. This allowed different resistance and habitat values to be modeled for the use of croplands adjacent to preferred jackrabbit habitat (Table A.3.4).

Elevation—Elevation became a major variable in the modeling of the black-tailed jackrabbit. After several runs of the model and attempted manipulations of the different vegetation classes it became apparent the classes within the land cover/land use layer did not have a fine enough resolution to differentiate the black-tailed jackrabbit and white-tailed jackrabbit habitat. The main differentiating features from the literature and from field observations appear to be: (1) shrub density or percent shrub cover; (2) percent grass cover; and (3) shrub and grass height.

Realizing this shortcoming, many modeling runs were done using different combinations of the resistance and habitat values for all of the other classes in the available layers (Appendix D). The elevation layer when used in combination with the land cover/land use layer produced the best fit of "good" black-tailed habitat and "good" white-tailed habitat. The use of the elevation classes to distinguish between these species and the "fit" of the HCAs produced were reviewed by local biologists and assessed with observation data.

Elevation is actually referred to indirectly if not directly in several jackrabbit citations (Lim 1987; Rickard & Poole 1989; Fitzner & Gray 1991; Best 1996; Knick & Dyer 1997; Kansas State University 2001). For example, black-tailed jackrabbits have been reported as relatively common at the Hanford Site in areas where a dense overstory of sagebrush is present particularly in the lower valleys, whereas observations of white-tailed jackrabbits have been rare and restricted to the higher elevations of Rattlesnake Mountain (Rickard & Poole 1989; Fitzner & Gray 1991; H. Newsome, personal communication). Severaid (1950) observed white-tailed jackrabbits more frequently on higher slopes and ridges, and black-tailed more frequently on valley floors (Lim 1987). A habitat model in Kansas noted that white-tailed jackrabbits prefer higher elevation areas than the black-tailed jackrabbit, where grass is the dominant canopy cover, rather than shrubs and less grazed grasslands used by the black-tailed jackrabbit (Kansas State University 2001). The Washington Gap analysis (Johnson & Cassidy 1997) noted that in California and Montana, the white-tailed jackrabbit ranges higher in elevation than the black-tailed jackrabbit, but may be sympatric in the higher valleys. In Washington they note that white-tailed jackrabbits tend to occur a little higher (on grassy hills and plateaus) than the black-tailed (more often in valleys), and the white-tailed goes farther north.

Using elevation as a correlate for vegetation is not a perfect solution, but does provide a reasonable approximation. The preferred elevation range for black-tailed jackrabbits was 0–500 m, a higher resistance and lower habitat value assigned to elevations above 500 m (Table A.3.4). In contrast, the preferred elevation range for white-tailed jackrabbits was 500–1250 m which were assigned no (0) resistance and a core habitat value of 1, with higher resistance and lower habitat values assigned to elevations below 500 m and above 1250 m (Table A.3.4).

Slope—A slope of less than 20 degrees was considered to have no effect on either prime habitat or on dispersal movements, thus it was given a habitat value of 1 and a resistance of 0 (Table A.3.4). Though it may seem counter intuitive to give slopes of less than 20 degrees a habitat value of 1, because the habitat model is based on multiplying the habitat values together, a value of 1 imparts no impact on a cell's final habitat value. Moderate slopes and ridges were evaluated to have about 2 times the resistance of flat ground but still would not eliminate prime habitat from being HCAs. Steep slopes of greater than 40 degrees were considered relatively difficult for jackrabbits to cross and were not considered as habitat.

Ruggedness—Only one class of the ruggedness layer was assigned a resistance > 0 for modeling jackrabbits and that was the most extreme—very rough terrain and escarpment, which was used as an analog for the very steep cliffs and slopes found throughout the channeled scablands and basaltic canyons. This class was implemented as a complete barrier for jackrabbits and was assigned a very high resistance value of 500 and a marginal habitat value of 0.4 (Table A.3.4).

Housing density—We considered the resistance of areas with lower housing densities (>40 acres per dwelling unit) to be dominated by other features, such as cover type, and were thus given a resistance value of 0 and a habitat value of 1. A high resistance value of 500 and a habitat value of 0 were assigned to housing density of less than 10 ac per dwelling unit, which includes industrial, suburban, urban developments.

Roads—Black-tailed jackrabbits are known to cross all roads, including freeways and major highways if encountered (Best 1996). It is on these high speed and high volume roads that black-tailed jackrabbits are at high risk of collision. For this reason a high resistance of 200 was assigned to the centerline of freeways and a resistance of 50 was assigned to the centerline of major highways (Table A.3.4). The increased resistance assigned to freeway and major highway buffers is due to the associated increase in structures making it more attractive to predators of the jackrabbit, especially raptors. Local roads and secondary highways were assumed as having minimal impact and given relatively low resistance values. While centerlines of roads, particularly freeways, are assigned the highest resistance values, jackrabbit movement is not prohibited by the presence of roads.

Railroads—Railroads were considered significantly lower resistance features than freeways and major highways due to the much lower frequency of potential collisions and also due to the lack of infrastructure of railways (Table A.3.4). Aside from the 30 m wide centerline class of Railroads Active Centerline, the remaining active railway classes were considered to have no resistance to jackrabbit movement or effect on habitat value. All classes within the Railroads Inactive layer were considered to have no effect on resistance or habitat value for jackrabbits.

Transmission lines—Transmission lines likely increase jackrabbit mortality by providing perch sites for raptors similar to that found for Greater Sage-Grouse (*Centrocercus urophasianus*) (Steenhof et al. 1993; Connelly et al. 2004; Beck et al. 2006). Increased predation may also occur due to the regular maintenance of many of these lines—mowing, clipping or herbicide applications—that eliminate protective cover. Other impacts would be related to general habitat fragmentation, increased road traffic, fire frequency, and weed introduction. Impact of the development phase is greater, but assuming contractors are sensitive to general wildlife needs, jackrabbits are minimally impacted (Table A.3.4).

Wind turbine—The impact of wind turbines is more than the towers themselves; it includes the associated access roads, vehicular traffic, and maintenance activities. Considering these additional factors, a resistance value of 16 and a habitat value of 0.2 were assigned to the wind turbine and immediate 45 m around it, values that would prevent an HCA forming on top of a turbine and reduce the likelihood of a linkage developing through a wind turbine (Table A.3.4). Buffer zones were considered of little impact for both dispersal movements and creation of HCAs.

Irrigation infrastructure—We also lacked specific information about the resistance of major irrigation canals. We feel that overall resistance of these canals is a combination of effects from the canal itself, seasonal usage, access roads, and maintenance activities that could include herbicide applications. Most large canals have adjacent, native-surface access roads and canal crossing at least every 13 km or so—an effort is being made to reduce this distance to maybe 6 km. These roads typically have very low traffic volumes, suggesting that the resistance of the access road component is probably lower than that of typical local roads. Considering the canals themselves, during the irrigation season (approximately April to September), high water velocity in these canals increases the landscape resistance due to harm from the water diversion infrastructure itself, the inability of jackrabbits to extract themselves from the canal, and the displacement to locations where potentially low habitat values could reduce survival. Because of these additional increases in potential injury and mortality, irrigation canals were given a higher resistance of 60 compared to 50 for water (Table A.3.4).

Modeling Results

Resistance Modeling

Resistance surface maps show the relative difficulty of movement across the varying landscape of the study area and are integral in the production of HCA, cost-weighted distance (CWD), and linkage maps. If a cell has a resistance value of 1 the cost to cross this cell is equal to that of the real world distance (30 m); if the cell has a value of 5 the cost to cross is 5 times as much. All resistance values for black-tailed jackrabbits are relative to the cost to move through a cell of ideal habitat (i.e., basin shrubland).

The resistance surface for movement of black-tailed jackrabbits in the Columbia Plateau (Fig. A.3.1) shows a landscape extensively fragmented by development, roads, powerlines, irrigation canals, and agriculture. Although the majority of the area would appear to have relatively low resistance with values less than 10, the cumulative cost of moving through it can quickly become very expensive for a jackrabbit who's average home range is 1 km^2 (a value equaling 1111 grid cells).

The areas that appear to have the lowest resistance for black-tailed jackrabbits in the east of the study area are Upper Crab Creek drainage in Lincoln and Grant county and Cow Creek drainage in Adams and Whitman county (e.g., scablands). In the southwest of the study area the low resistance areas appear to be centered on and in the large public land holdings e.g., Yakima Training Center (YTC), WDFW Colockum Wildlife Area and the Hanford Site, as well as tribal lands on the Yakama Reservation. In the northwest it is the glacial moraine in Douglas County and the Moses Coulee in Grant County.

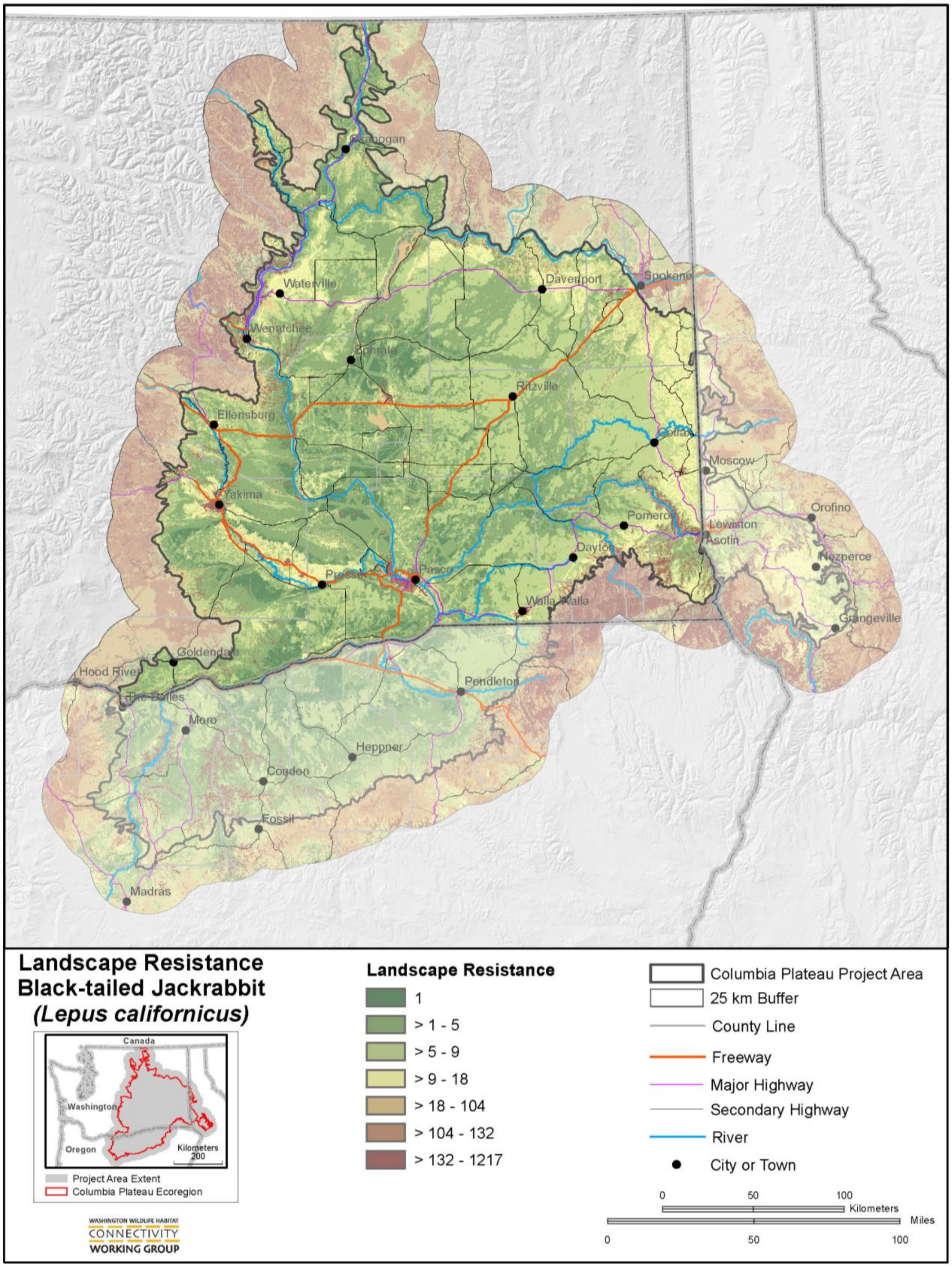

Figure A.3.1. Resistance map for black-tailed jackrabbit in the Columbia Plateau Ecoregion.

Given the resistance to movement created by features such as urbanization and roads we anticipate that connectivity of jackrabbit populations will be negatively impacted by continuing development. Additionally, long linear features (e.g., roads, powerlines, etc.) do not present alternative paths for crossing—either the rabbits must cross the feature and absorb the cost or remain isolated. For example, the Yakima Training Center is constrained by resistance from I-82 (east), I-90 (north), and powerlines (in all directions). Development along the I-82 corridor extending from Yakima south-east to the Tri-Cities paralleled by the Yakima River creates a linear feature of high resistance that greatly reduces connectivity between the Yakama Reservation and areas to the north and east.

Habitat Modeling and Habitat Concentration Areas

With little published literature and limited unbiased occurrence data, core habitat for black-tailed jackrabbit in Washington is not well defined. Having insufficient data, habitat concentration areas were modeled on habitat suitability (See Habitat Concentration Areas above).

During the modeling process, HCAs were formed using a combination of different parameters on many different runs. The HCA model produced using a minimum average habitat value (MAHV) of 0.8 (Fig. A.3.2) was selected as a base map and, although it was the considered the best model by expert review and fit with known data points, it still produced several HCAs that were undesirable and failed to create some that were. Undesirable HCAs were those either outside of the known range of black-tailed jackrabbit or occurring within the historical range but in an area where habitat no longer exists. The HCAs the model failed to create were few, but in areas of known black-tailed jackrabbit concentrations and/or areas that were judged to have excellent jackrabbit habitat. These missing HCAs were mapped when a MAHV of 0.75 was used (Fig. A.3.3 and Table A.3.5), however at the 0.75 level many more undesirable and extensive HCAs were created. Thus it was decided to use the 0.8 MAHV model as the base, and then “manually” remove the undesirable HCAs and manually add the missing HCAs to create the final HCA map (Fig. A.3.4).

The final HCA model was a conservative or lean model with a minimum number of HCAs—a total of 55, that were believed to have high quality habitat (most at .80 MAHV) and in most cases with an existing population of black-tailed jackrabbits. All HCA removals and additions were based on known jackrabbit populations, jackrabbit expert review, and local biologists’ knowledge of current habitat conditions and occurrence.

Table A.3.5. Additions and deletions of black-tailed jackrabbit HCAs made to produce final map.

	HCA ID	*MAHV*	*Map*
HCAs removed	1–6, 12, 25, 30, 33, 35, 37, 38, 43, 44, 47, 51	0.80	Fig. A.3.2
HCAs added	32, 39, 41, 53, 56	0.75	Fig. A.3.3

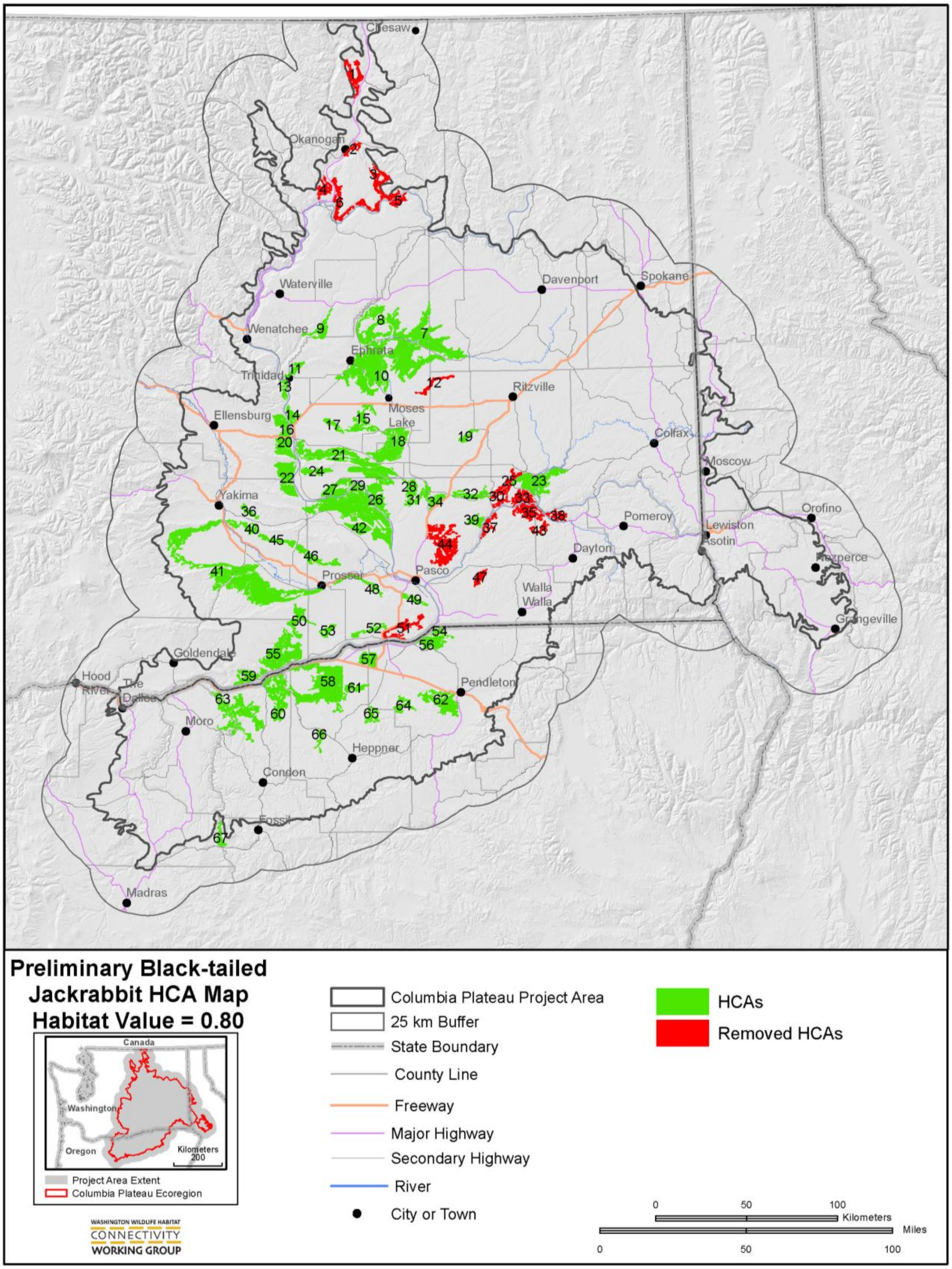

Figure A.3.2. Preliminary black-tailed jackrabbit HCA map using a habitat value of 0.80. Habitat concentration areas in red were removed to make the final HCA map based on local biologists' knowledge of the habitat and jackrabbit populations.

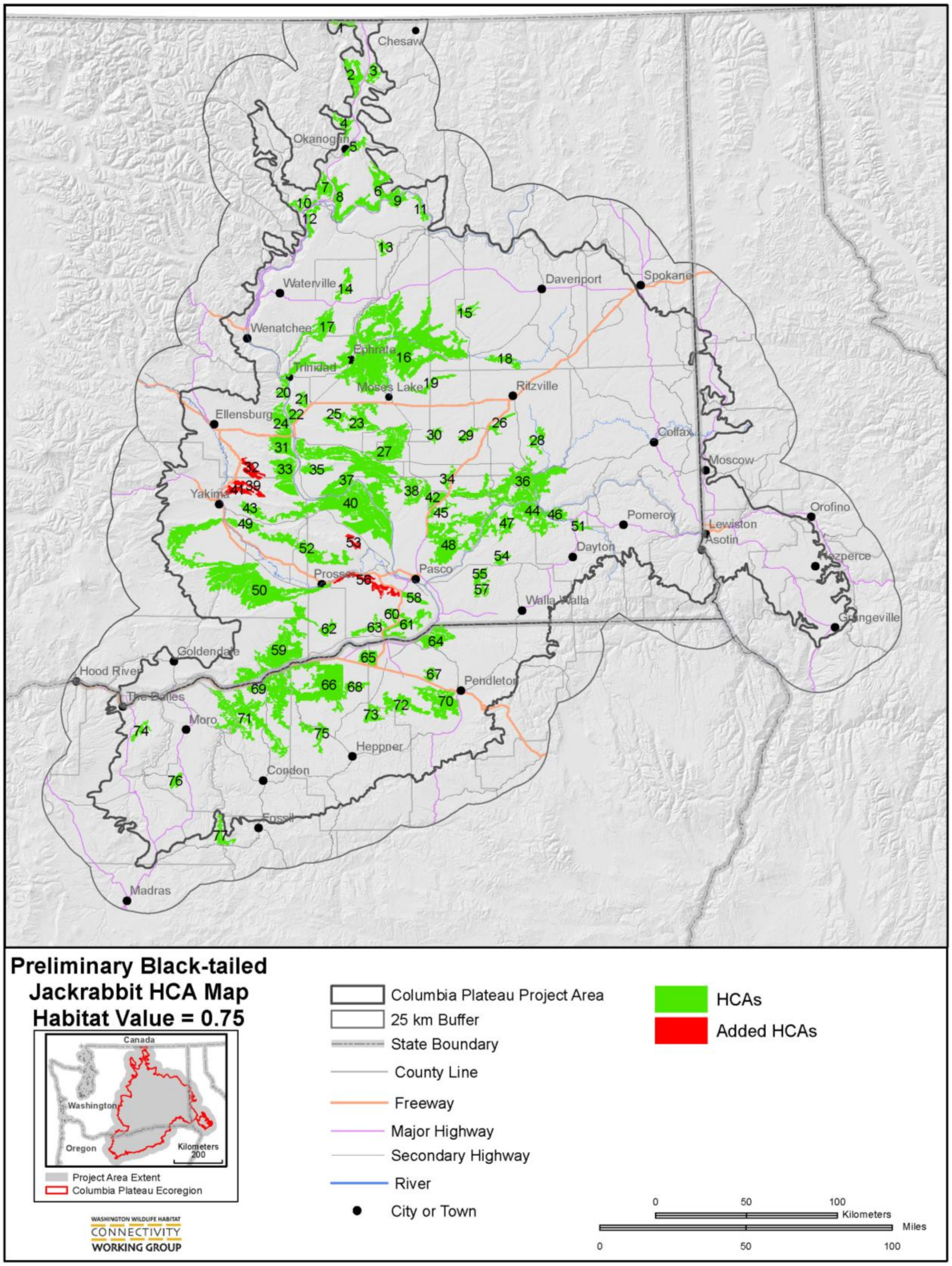

Figure A.3.3. Preliminary black-tailed jackrabbit HCA map using a habitat value of 0.75. Habitat concentration areas in red were those added to the final HCA map based on local biologists' knowledge of habitat and jackrabbit populations.

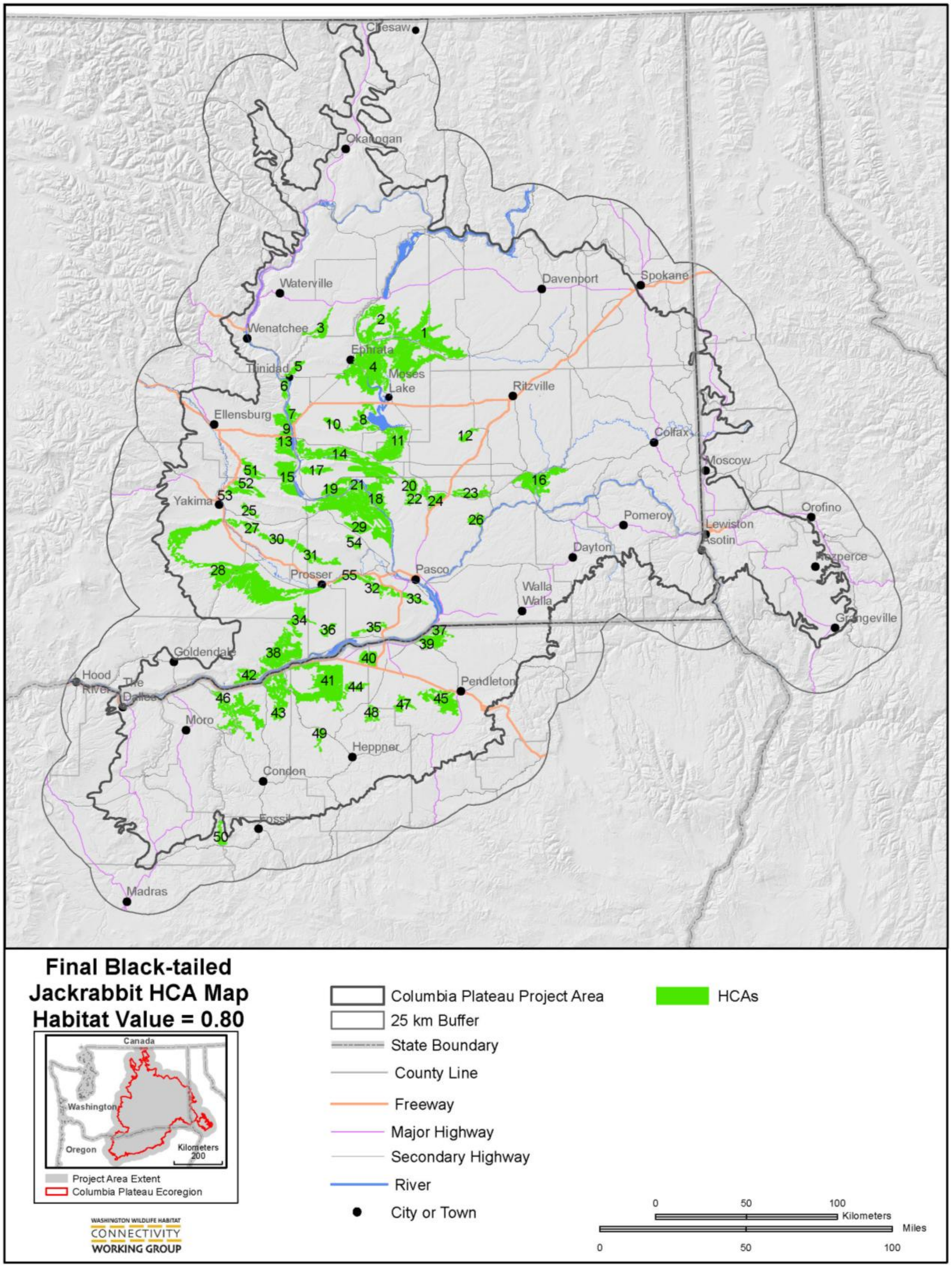

Figure A.3.4. Final black-tailed jackrabbit HCA map after additions and deletions.

In the Final HCA map (Fig. A.3.4), the 55 black-tailed jackrabbit HCAs, totaling 6923 km^2 are spread across the Columbia Plateau Ecoregion, but are mainly in three counties—Grant, Yakima, and Benton. The most sizeable HCAs on public lands are on the Hanford Reach National Monument (Hanford Site), Yakama Reservation, Yakima Training Center, Bureau of Reclamation, and some WDFW Wildlife Areas (Fig. A.3.5). In addition, many WA Department of Natural Resources (DNR) sections are located in the HCAs.

The final HCA map is a good representation of the distribution of remnant shrub-dominated habitat in the Columbia Plateau. Many of the areas left out are low quality habitat, most often expansive areas of irrigated agriculture such as that in southeastern Grant County, western Adams County, southern Franklin County, and the Yakima Valley in east-central Yakima County (Fig. A.3.4). In northwestern Benton County, a large "hole" with no HCAs is apparent. On closer inspection, this is probably due to a compounding of high resistance values and poor habitat due to slope and the high ruggedness across the Rattlesnake Hills area (Fig. A.3.6). Another large hole exists in the Yakima Valley area due to high resistance caused by a combination of development, I-82, the Yakima River, and little remnant habitat.

Some of the HCAs are quite small, for example, HCA 12 in Adams County and HCAs 33, 35, and 36 in southwestern Benton County (Fig. A.3.4; see Fig A.3.7). These small HCAs may be important because they are likely the last remnants of habitat in the area and provides the only link between other HCAs. Protection of these areas may be of high priority.

When comparing our final HCA map with the 1997 Washington Gap analysis (Johnson & Cassidy 1997) black-tailed jackrabbit range map (Fig. A.3.8) two features standout. First, all of the HCAs fall within the core range area of the 1997 Gap range, except for a very small overlap with the Gap peripheral range in the south of Yakima County. Second, our HCAs only cover a small extent of the Gap core range. This may indicate the loss of habitat for the jackrabbit in the Columbia Plateau but may also be a result of our effort to model only the best habitat, having better remote imagery data, improvements in modeling habitat based on remote imagery, as well as a loss of actual habitat on the ground.

Shortcomings of the use of elevations showed up in a number of conditions such as:

- changes in environmental conditions due to changes in latitude, specifically the identification of black-tailed jackrabbit HCAs in Okanogan County, these HCAs were manually removed since black-tailed jackrabbits have not at this time crossed the Columbia River north into Okanogan County;
- micro-climate conditions caused by a number of environmental factors such as soil, slope, aspect, and precipitation; and,
- human causal factors such as grazing, irrigation, irrigated crops, human landscaping.

Despite these shortcomings, the use of the elevation classes in our modeling effort to distinguish the jackrabbit species resulted in a good fit of the known jackrabbit range and also the field observations that are available.

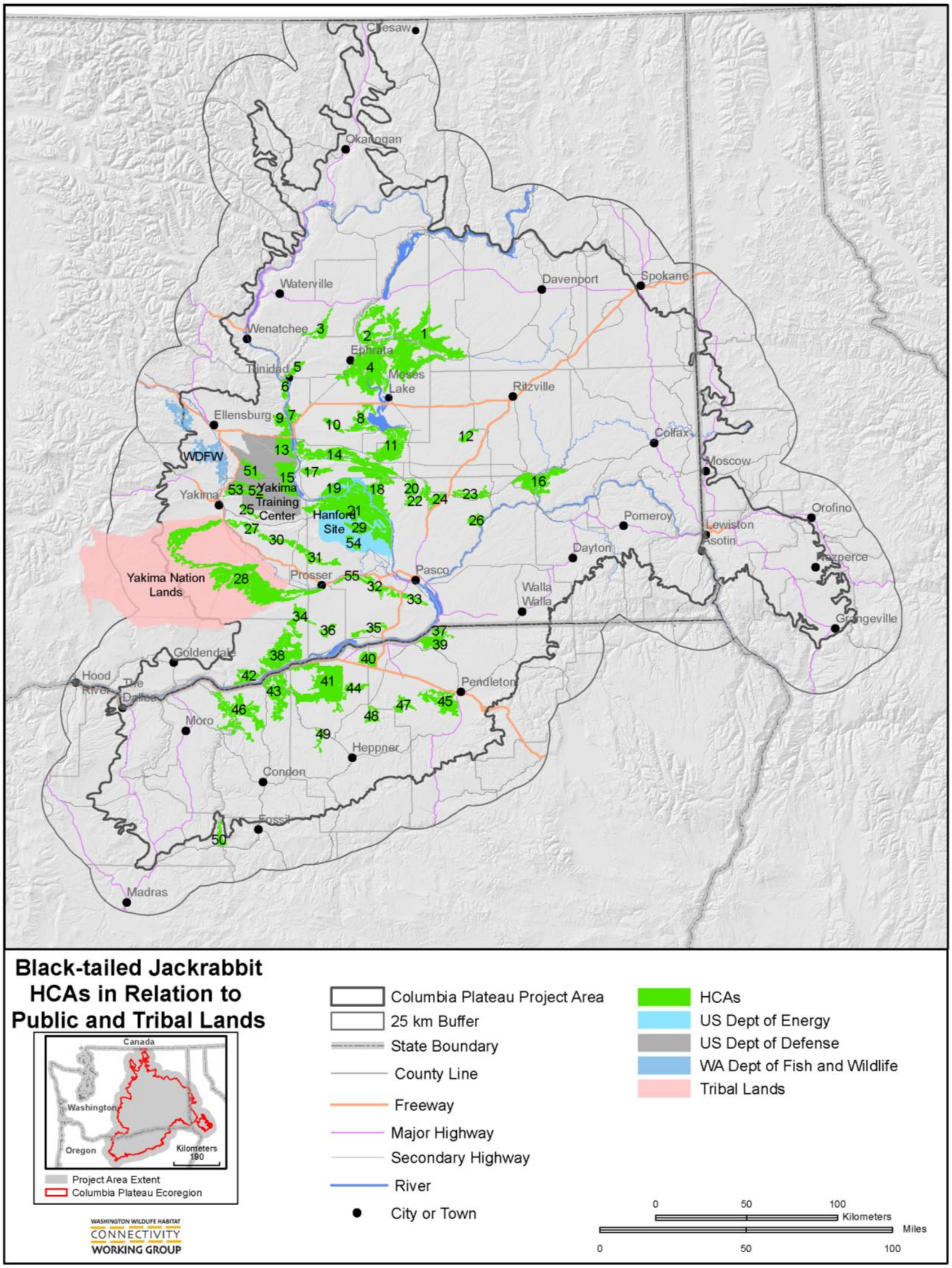

Figure A.3.5. Black-tailed jackrabbit HCAs in relation to public and tribal lands.

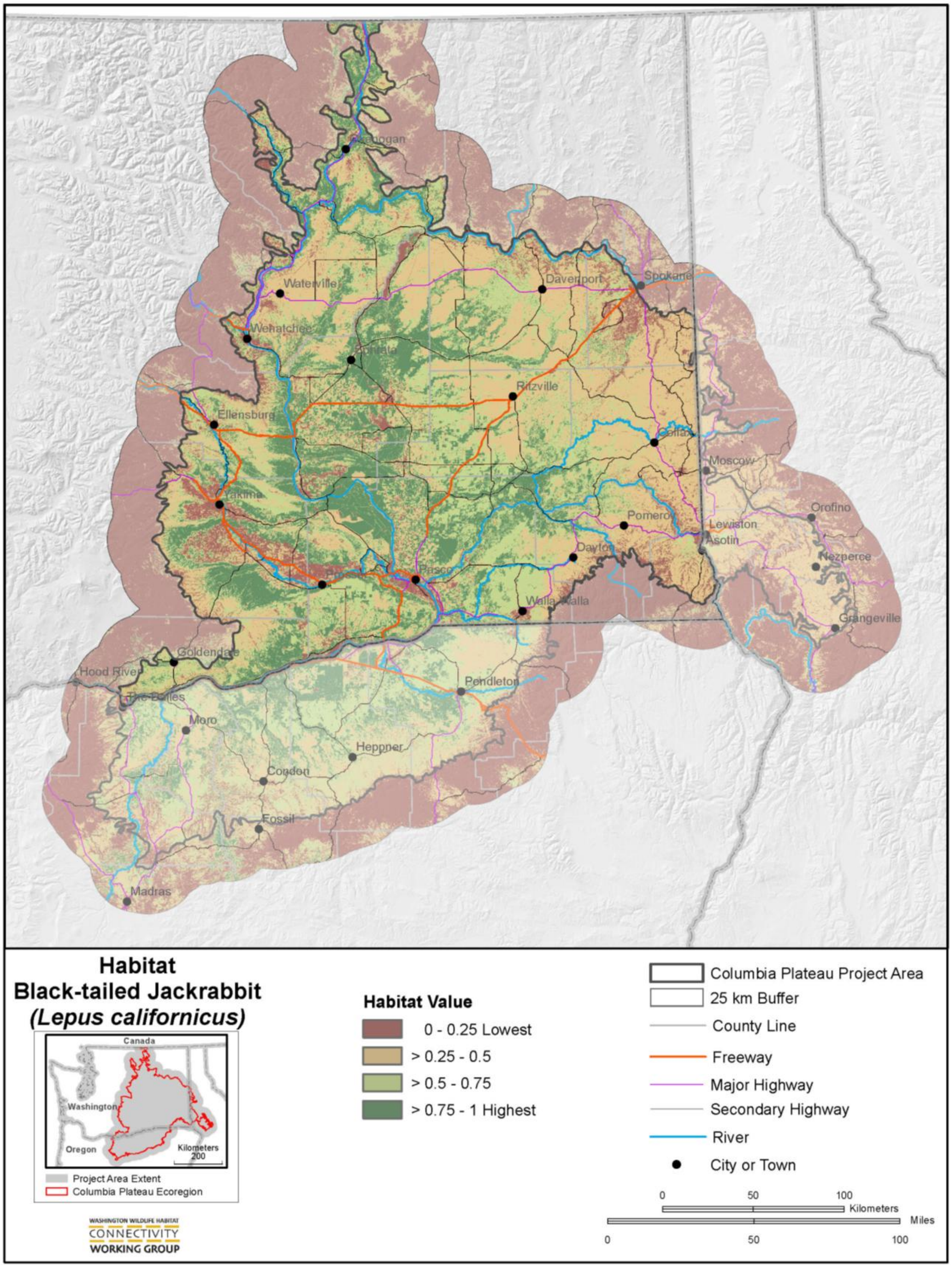

Figure A.3.6. Habitat map for black-tailed jackrabbit in the Columbia Plateau Ecoregion.

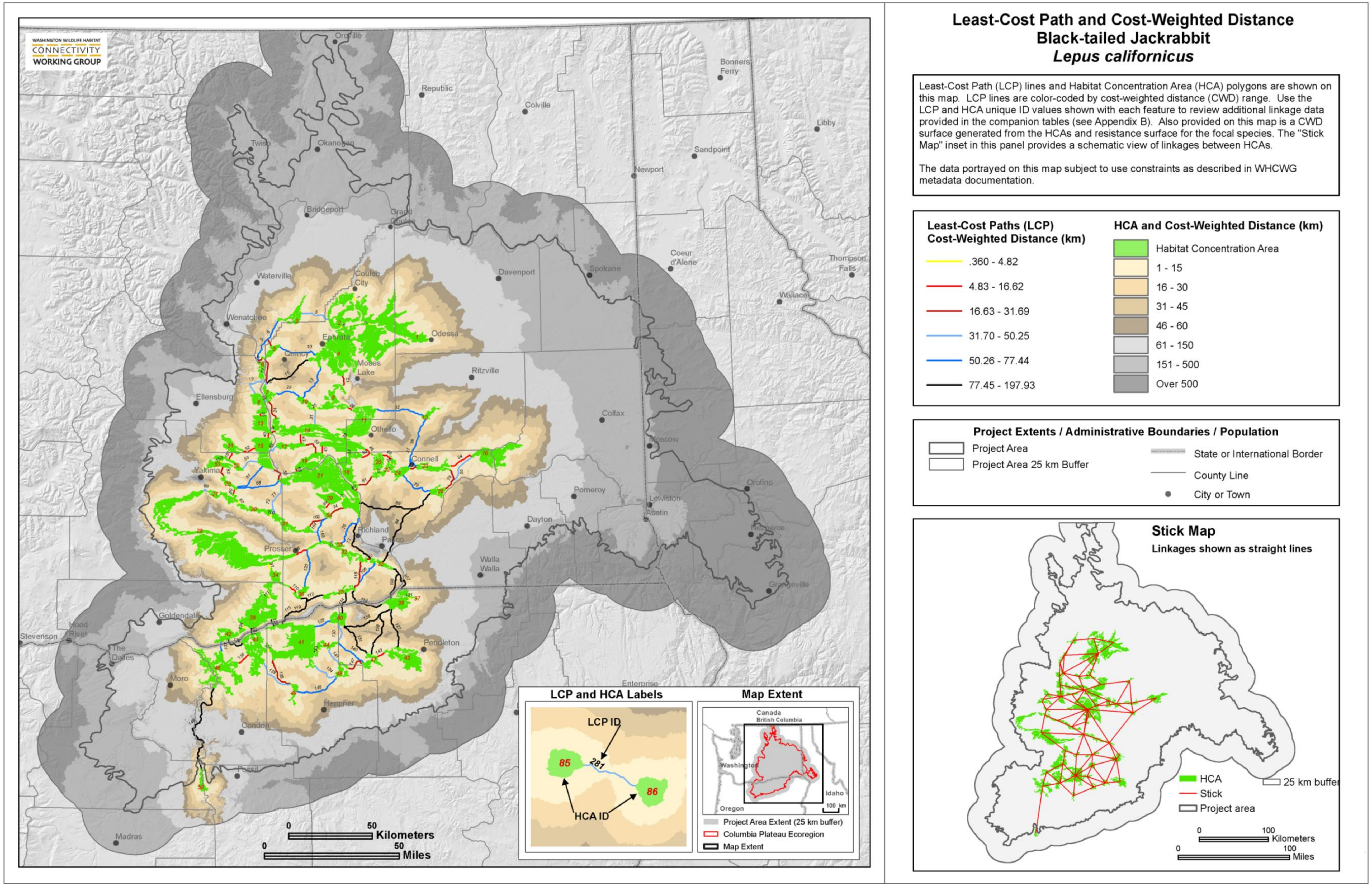

Figure A.3.7. Cost-weighted distance map with numbered HCAs (green polygons labeled with red numerals) and least-cost paths (lines labeled with black numerals) for black-tailed jackrabbit. Linkage modeling statistics given in Appendix B.

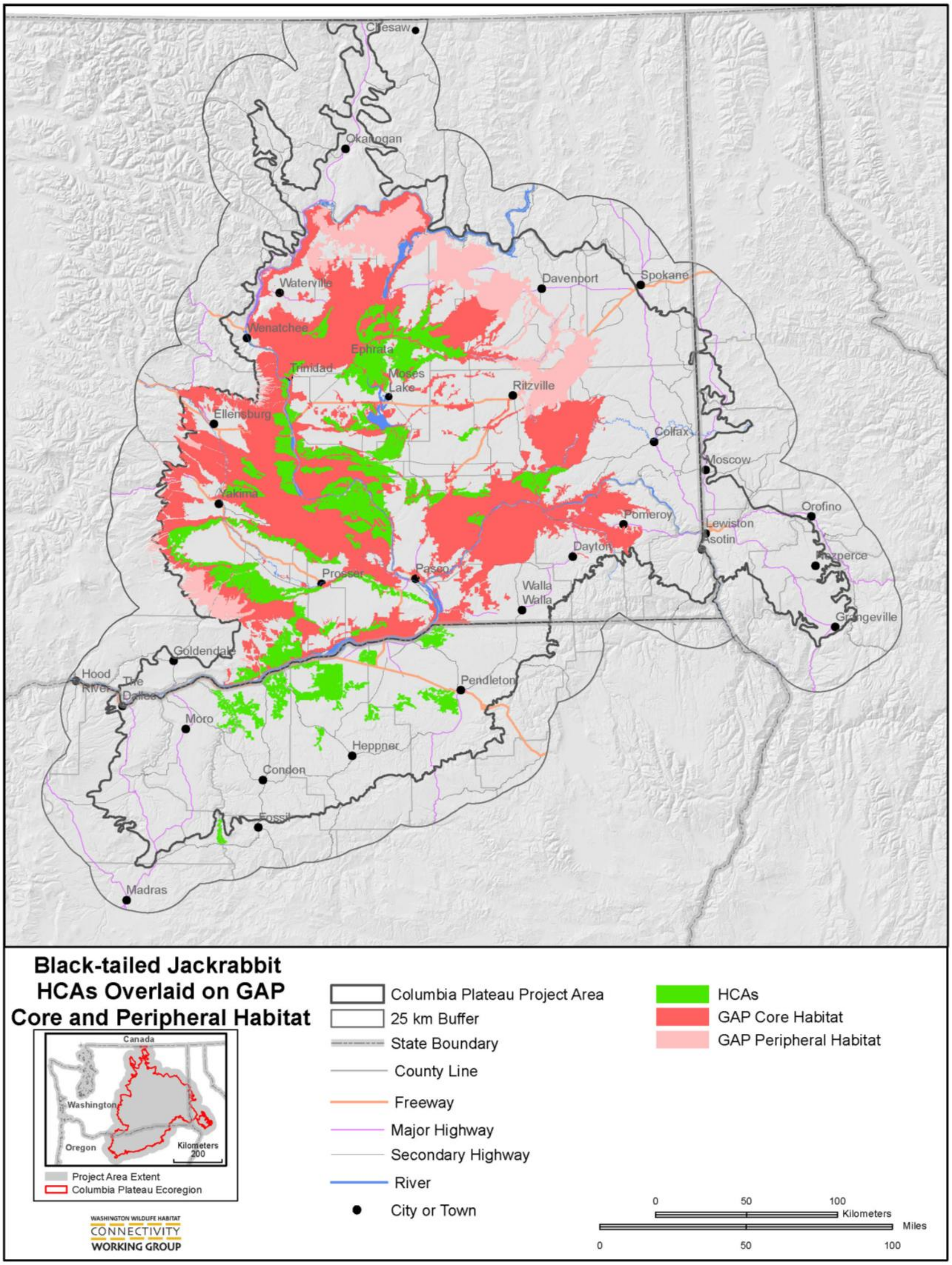

Figure A.3.8. Black-tailed jackrabbit HCAs (green polygons) overlaid on 1997 GAP ranges (core in light pink and peripheral in dark pink).

Cost-Weighted Distance Modeling

The cost-weighted distance (CWD) map (Fig. A.3.9) provides an estimate of the relative cost of movement across the landscape—the cumulative effect of features that impede the movement of the jackrabbit of any route taken from an HCA. This map is particularly useful for identifying barrier effects and broad areas that contribute to connectivity.

There are three significant "holes" or barriers in the black-tailed jackrabbit CWD map. One is in the southwest corner running almost east–west in Yakima County. This barrier is created by a number of different features paralleling one another—the Yakima River, I-82 Freeway, and development. Another is in southern Franklin County, this hole is caused by numerous features as well—I-82 and major Highways 395 and 12, development from the Tri-Cities area, an irrigation channel, and agricultural areas with little or no native vegetation nearby. The third is in Adams County and is a donut shaped barrier with HCA 12 sitting in the middle (Fig. A.3.10). This barrier is created in the north by the I-90 corridor, in the east and south by the Highway 395 corridor and dryland agriculture, and in the west by irrigated crop circles around Othello up to Moses Lake.

Other areas of resistance, but not as high as those described above, are found in western Grant County, eastern Yakima/northern Benton counties, and southern Benton County. In eastern Grant and southern Benton this is caused by large blocks of agriculture with little or no native habitat intermixed. In eastern Yakima/northern Benton, the area of high resistance is due mostly to elevation and ruggedness of the terrain.

Connectivity appears to be good north to south along the foothills of the Cascades; however a severe pinch point in this area is created by the Yakima River Valley and I-82 corridor. Connectivity in the lowlands between the HCAs in Grant, Franklin, and Benton counties also appears to be decent except for the break created by the I-90 corridor in central Grant. The Columbia River is the major barrier between the foothill and the lowland HCAs.

Linkage Modeling

One of the primary goals of this project was to determine and map connectivity across the Columbia Plateau for black-tailed jackrabbits (Fig. A.3.11; see Fig. A.3.7 for HCA identification). Cost-weighted distance methods were used to map least-cost corridors, identifying continuous swaths of land expected to encompass the best routes for species to travel between HCAs. Least-cost corridor links depict the path taken that provided the lowest resistance value in providing connectivity between an HCA pair. This technique allows users to identify which routes encounter more or fewer features that facilitate or impede movement while moving between two HCAs.

The final black-tailed jackrabbit HCA model was conservative. Therefore, between the final HCAs, there are many areas with good habitat and likely small populations of jackrabbits. With smaller and fewer HCAs across the landscape, as might be expected, linkage path lengths are quite high often exceeding dispersal distances reported in the literature. However, the maximum dispersal distance reported in the literature for the black-tailed jackrabbit is 57 km (Grant 1987) clearly within the range of the 50 km limit used in our modeling. This approach resulted in the desired effect of producing a maximum number of corridors across the landscape (i.e., all HCAs are connected to at least one other HCA). To verify these assumptions, we compared these “sparse” HCAs and their associated linkages to the more liberal mapping of HCAs as seen in Figure A.3.3 and verified that most if not all of the linkages fell across or near HCAs that were eliminated when higher quality habitat limits were implemented (0.8 rather than 0.75). This assumption is further validated when considering that other smaller areas of good quality habitat were also eliminated in the HCA formation when we imposed a 25 km^2 minimum HCA size on the landscape.

Linkages for the black-tailed jackrabbit were modeled between 55 HCAs and resulted in 109 discrete links, 90 of which were contained entirely or partially within Washington. Least-cost distances between all 109 linkages ranged from <1 to 73 km (<1–49 km Euclidean distance). The cost-weighted to Euclidean ratio ranged from 1 to 45 (Appendix B).

The barriers or “holes” discussed in the Cost-weighted Distance Modeling section above are just that—barriers. No linkages run across these barriers except in Adams County where HCA 12 was surrounded and there was no other option. Note that both links to HCA 12 are very narrow (i.e., these links are passing through high resistance landscape). Another issue illustrated by CWD and linkage mapping is the small and isolated island HCAs (low number of linkages and high distances) as mentioned earlier. These small islands are important since they indicate some of the last remnants of habitat left in the area and provide the only link between other HCAs.

There are no HCAs without linkages; all have some path under the 50 km cutoff. Several HCAs are only connected by 2 linkages, for example, HCAs 12, 16, and 51. These all appear as outliers and if lost would eliminate jackrabbit movement to large regions. Other areas that are of concern would be the east–west resistance along the Yakima Valley, Yakima River, and I-82 corridor. If the HCAs or the links to the HCAs in the YTC (HCAs 15, 51, 52, 53, and a portion of 13) and southwestern Hanford Site (HCAs 29 and 54) were lost the jackrabbit distribution would basically be broken into 2 subpopulations—one north and one south. Furthermore, loss of the narrow HCAs along the Yakima River, HCAs 27, 30, and 31 would further exacerbate this separation of jackrabbit distribution.

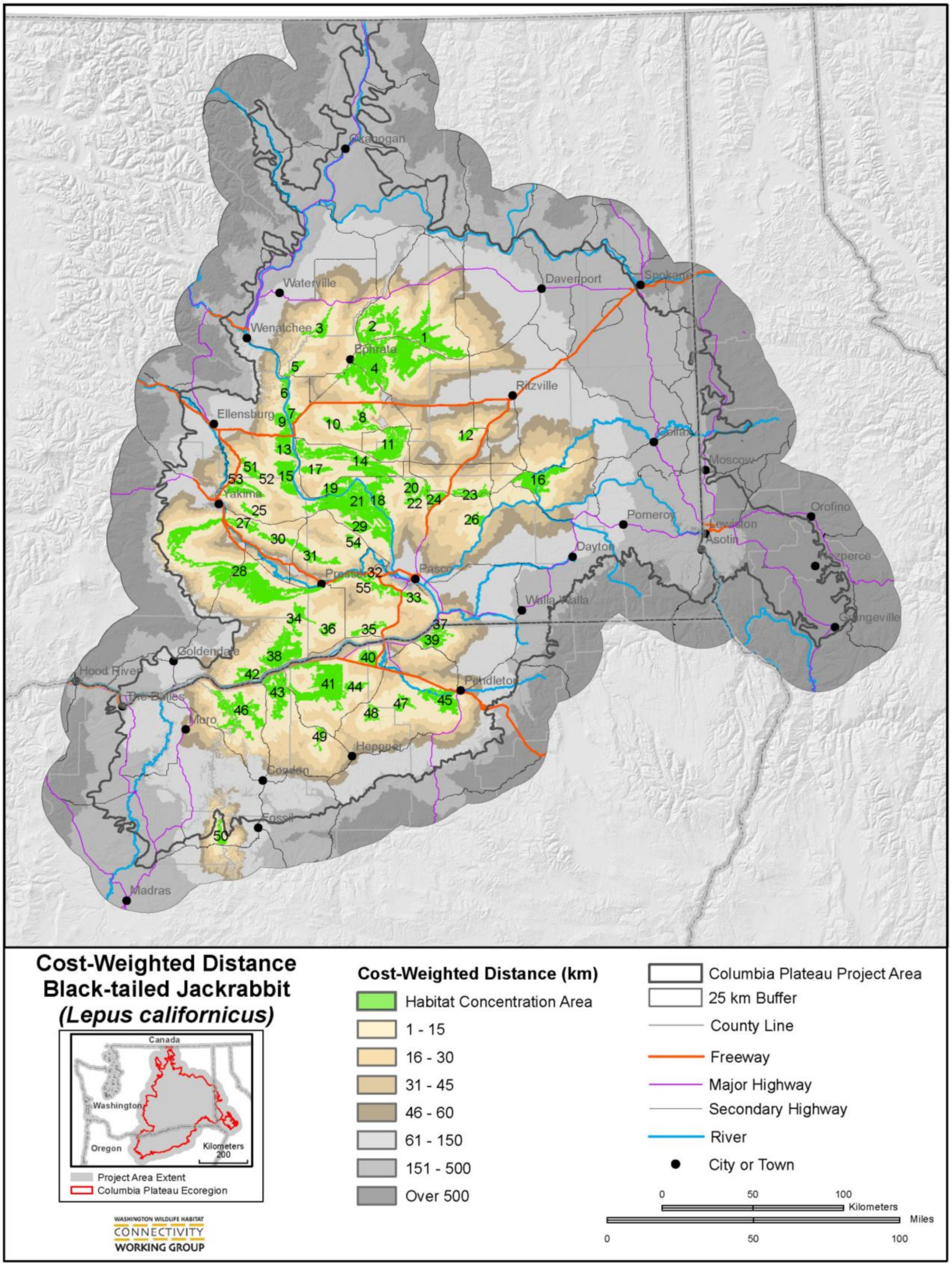

Figure A.3.9. Cost-weighted distance map for black-tailed jackrabbit in the Columbia Plateau Ecoregion.

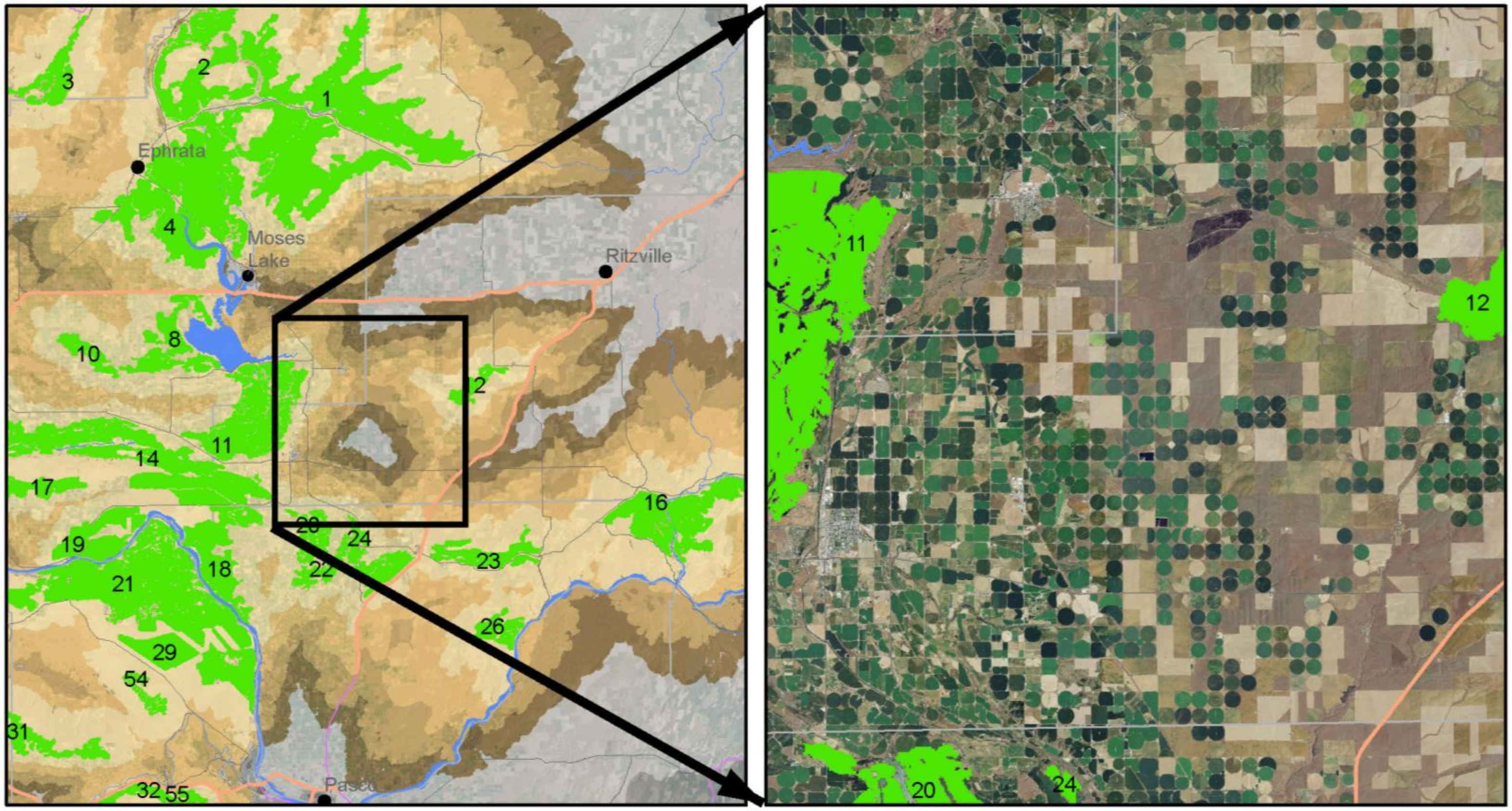

Figure A.3.10. An area in Adams County showing an aggregate of irrigated croplands which creates areas of high resistance to black-tailed jackrabbit movements.

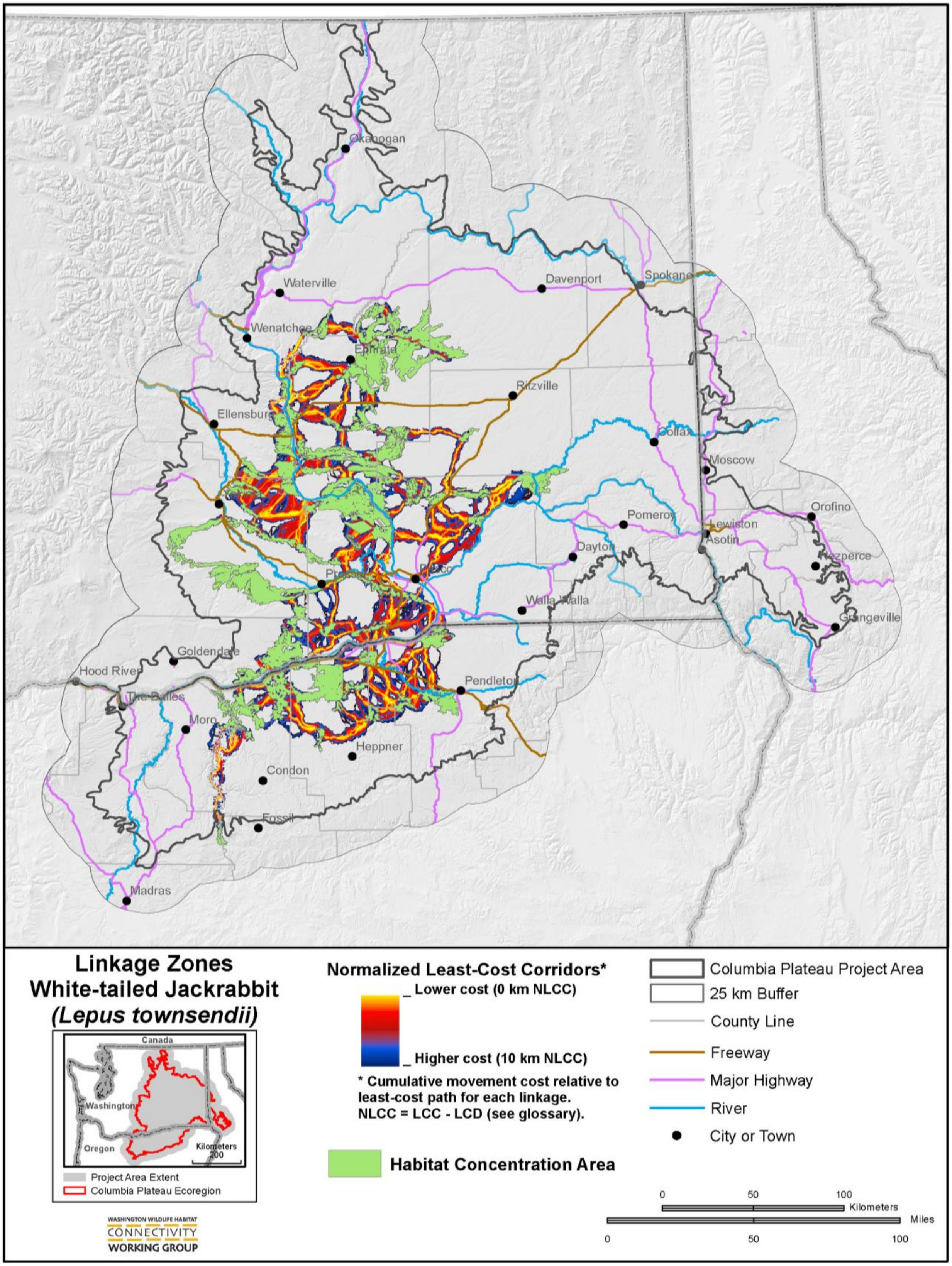

Figure A.3.11. Linkage map for black-tailed jackrabbit in the Columbia Plateau Ecoregion.

Comparative Insights between the Statewide and Ecoregional Connectivity Analyses

In the statewide analysis a larger home-range radius (2 km) and minimum HCA size (50 km^2) was used than in the ecoregional analysis, 500 m and 25 km^2 respectively. This resulted in larger and fewer HCAs in the statewide, 46 versus 55, than in the ecoregion (Fig. A.3.12). The difference would have been even greater except that in the ecoregional analysis several polygons were removed based on current black-tailed jackrabbit range, most notably the HCAs in Okanogan County (Fig. A.3.2; Fig. A.3.4). These HCAs were left in for the statewide analysis because there was a greater interest in mapping all potential habitats whether currently or even historically occupied.

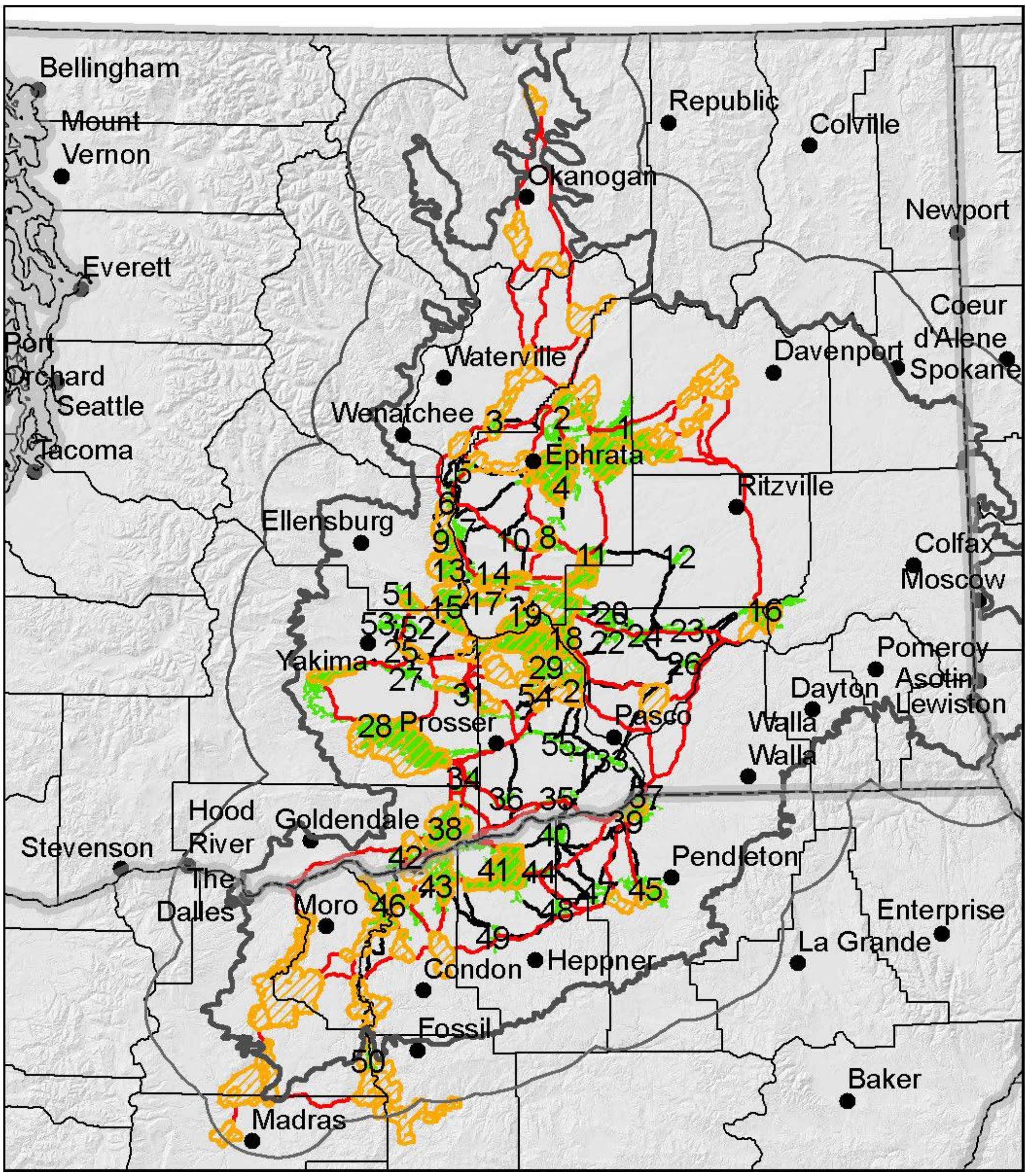

Figure A.3.12. Statewide HCAs (orange hashed areas) and LCPs (red lines) on top of Ecoregional HCAs (green polygons) and LCPs (black lines).

In the ecoregional analysis elevation was used to better distinguish between the white-tailed and black-tailed jackrabbit core range resulting in the absence of HCAs in northern Douglas County and in the north central Lincoln County when compared to the statewide analysis.

The elevation constraints, smaller home-range, and improved landscape layers also tended to reduce the size of the HCAs. There were a few cases where the improved landscape layers expanded the HCAs, and the addition of the agricultural buffers likely also helped expand some HCAs. Overall, the larger HCAs from the ecoregion analysis match up very closely with those from statewide analysis. However, nine smaller HCAs appear in the ecoregional analysis that were not mapped in the statewide analysis.

In the statewide analysis the black-tailed jackrabbit was considered to be a linkage dweller and all HCAs were connected during linkage modeling. In the ecoregional analysis the jackrabbit was not considered a linkage dweller, but we used 50 km (close to the largest 57 km dispersal observed in any study) for the maximum dispersal. This allowed for all HCAs to be connected.

Differences between HCAs make it difficult to compare the least-cost pathways identified in the two analyses, because the locations and number of HCAs determine where linkages are formed. In several cases the least-cost pathway modeled in the statewide analysis goes directly along a chain of smaller HCAs modeled in the ecoregional analysis; the best example of this is in northern Franklin County. However, the ecoregional least-cost pathways connecting these HCAs do not occur along similar paths as the statewide. Also, notably, several linkage pathways are missing entirely from the ecoregional analysis. One is in central Adams County connecting the HCA on the Snake River to those in central and southwest Lincoln County. The others are: east of Moses Lake connecting central Grant County to the Columbia River Refuge; in Walla Walla County connecting the Snake River HCAs to those in Oregon; and through the Yakima River Valley connecting the Rattlesnake hills to the Yakima Reservation (Fig. A.3.5; Fig A.3.12). Although these HCAs were identified in the statewide analysis, according to the ecoregional analysis these corridors are not important to black-tailed jackrabbits (but are most likely important for other sagebrush dependent species).

Comparing the total linkages for each project, there were 96 for the statewide and 109 in the ecoregion analysis. Least-cost paths differed in that the two longest least-cost path lengths for the statewide were 105 km and 113 km (when limited to Washington links only), while in the ecoregion they were smaller at 52 km and 56 km. This is likely due to the fact that the final Columbia Plateau Ecoregion model has better habitat data and allowed for smaller HCAs, and therefore does not have as many isolated HCAs as the statewide analysis.

The major barriers for jackrabbit dispersal in both analyses appear to be the Columbia and Snake rivers, Highways 90 and 82, and urban development in the Yakima Valley, Tri-Cities, and Moses Lake. Each analysis found different paths to cross or avoid these barriers; some of this again is likely due to differences in HCAs. Given the greater resolution of the ecoregion analysis and the incorporation of better data, one would believe that the linkage pathways from this analysis would be the most precise. However, it will require field surveys to truly determine and validate which of these analyses provide the best linkages required to maintain connectivity for black-tailed jackrabbits.

Key Patterns and Insights

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

- Areas of low resistance are constrained by development, freeways and major highways, rivers, and agriculture.
- Looking at the HCA map (Fig. A.3.4) and the black-tailed jackrabbit occurrence data (Fig. A.3.13) the primary concentration area appears to be in the “central” basin area, from Pasco in the southeast to the Yakima Training Center and up to southern Grant County.
- The I-82/Yakima River corridor between Yakima and the Tri-Cities is a barrier to north-south movement. Further development and expansion in this area either to the north or south will further widen this gap.
- It appears that what was once an area with many jackrabbit observations—to the west and across the Columbia River from Pasco—now has little, if any, prime jackrabbit habitat (Fig. A.3.13).
- When looking at all landscape impacts, roads and agriculture appear to impart the biggest impact on jackrabbit habitat.
- When reviewing the HCA maps and occurrence data that are split into recent (post-2000) and historical (pre-2000), there are a number of HCAs that have no recent observations (Fig. A.3.13). These include relatively large HCAs in both the north (HCAs 1, 2, and 4) and the south (HCA 38). If these areas are for some reason, “lost” to black-tailed jackrabbits, it would eliminate a large portion of the northeastern section of their range and also a portion of their range in southern Washington which serves as a corridor between Washington and Oregon.
- This analysis shows a reduced area of core range relative to the 1997 Gap Analysis project. This likely represents a true loss of habitat, but could also be due to an improvement in the available habitat data and the tools to analyze it.

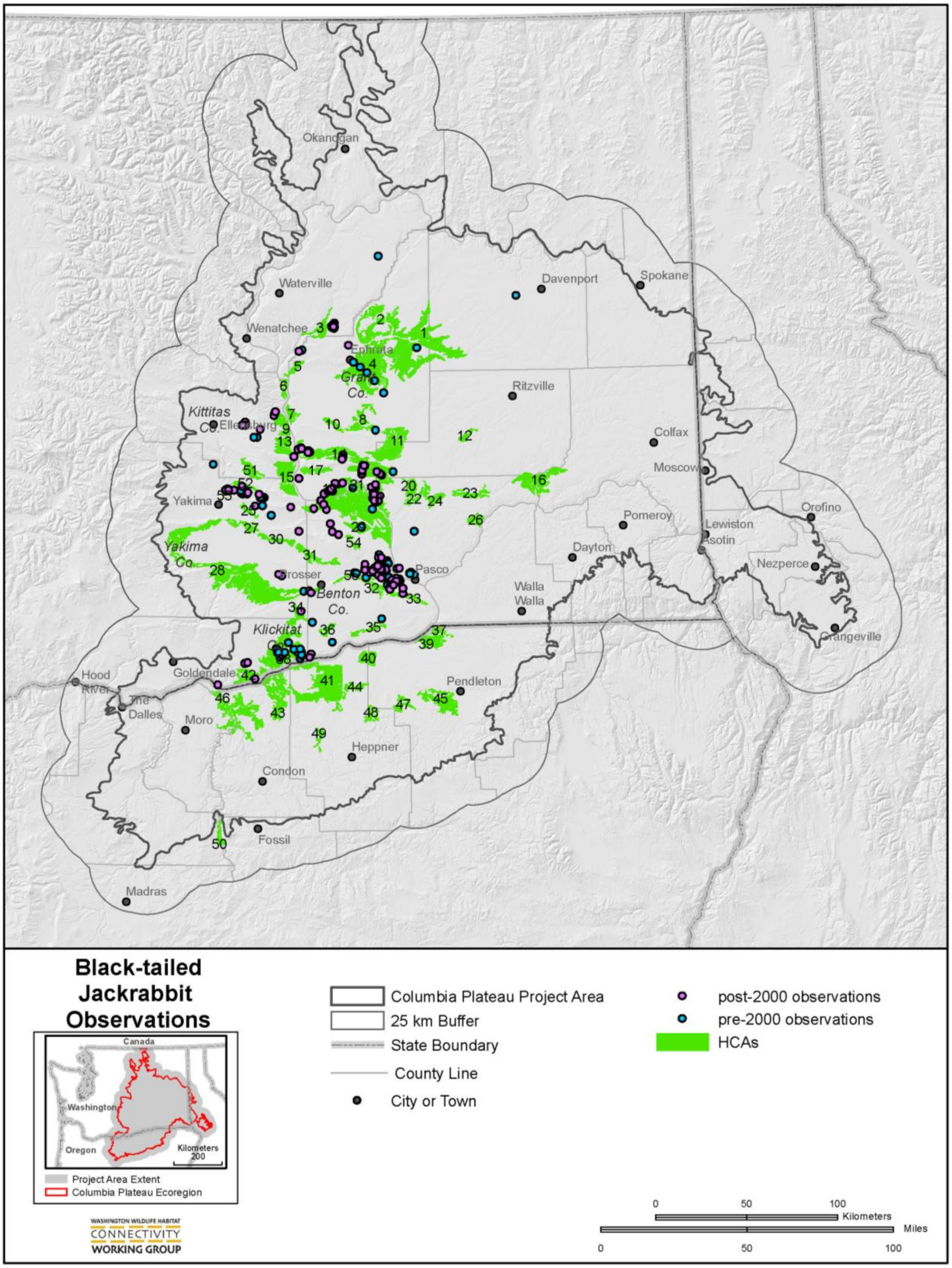

Figure A.3.13. HCAs showing both post-2000 (purple) and pre-2000 (blue), jackrabbit observations.

Considerations and Needs for Future Modeling

Due to these two projects it has become more obvious than ever that there is a general lack of studies and occurrence data for the black-tailed jackrabbit both in Washington and range-wide, especially when the “pest” or damage studies are excluded. The actual field data available for the black-tailed jackrabbit is limited and biased as many of the observations are along roadways. These are some of the biggest gaps in information realized by this project. There are also few, if any, scientific studies available to help and determine the impacts of many of the threats—e.g., land conversion, agriculture, roads, transmission lines, or wind power. Most of the impacts for these analyses were determined by gauging the direct habitat destruction that would take place, while the less direct impacts were evaluated using expert opinion.

As mentioned in the text, some of the shortcomings of the modeling were due to the detail of the vegetation classes. To more accurately map the distribution of the two jackrabbit species, a layer with vegetation classes that could distinguish shrub vs. grass cover, density and height would be needed.

We need to better understand the relationship between Euclidean and cost-weighted distances. What is the cost-weighted distance that a jackrabbit 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.

With these points in mind, future modeling should:

1) Collect more location data and population information to improve delineation of HCAs.
2) Conduct research prior to modeling to estimate jackrabbit movement capabilities and response to feature classes of interest.
3) Use more current and finer-scale vegetation data.

Opportunities for Model Validation

There are numerous opportunities to evaluate the assumptions and interpretations of the connectivity models developed. These include:

- The radio-marking of individuals to gain insight into movement capability of the jackrabbits with respect to landscape resistance.
- GPS transmitter marking of individuals would allow detailed information on movement pathways, distances traveled in different habitats, use of croplands, CRP, etc.
- Genetics could be used to evaluate movement across landscapes and between HCAs.
- Black-tailed jackrabbits are reported to out-compete white-tailed jackrabbits, but is there an upper limit of elevation, shrub cover, and/or other parameters that reverses this trend?

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