Appendix A.6

Habitat Connectivity for Washington Ground Squirrel (*Urocitellus washingtoni*) in the Columbia Plateau Ecoregion

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Introduction

Washington ground squirrel, photo by Rich Finger

Washington ground squirrels (*Urocitellus washingtoni*) are endemic to the Columbia Plateau Ecoregion in Washington and northern Oregon. This species was formerly considered part of the genus *Spermophilus*, but was recently changed to *Urocitellus* (Helgen et al. 2009).

Like other species of *Urocitellus* inhabiting areas of seasonally harsh climates (Davis 1976; Michener 1984; Yensen & Sherman 2003), Washington ground squirrels have an annual cycle characterized by a relatively short active period when all foraging, social, and reproductive activity takes place. This is followed by a longer period of dormancy, when animals live off accumulated fat reserves while hibernating in underground burrows. The active period extends from late winter to early summer, when lush grasses and forbs are available for eating. Aboveground activity lasts about 4–4½ months for individual adult squirrels and 3 months for juveniles of the year, but is staggered over 5–5½ months within populations (Shaw 1921; Scheffer 1941; Carlson et al. 1980; Rickart & Yensen 1991). This overall pattern reflects the short growing season of the species' food plants (Shaw 1921; Bailey 1936; Boyer & Barnes 1999).

The ecological relationships of Washington ground squirrels have not been studied, but presumably resemble those documented in other species of *Urocitellus*. For example, Piute ground squirrels (*U. mollis*) are considered a keystone species because of their overall prominence in maintaining ecosystems (Van Horne et al. 1997). Washington ground squirrels likely fulfill a number of ecologically important roles. These include: (1) serving as prey for numerous predators; (2) affecting soil fertility and plant production through their burrowing (which loosens, mixes, and aerates soils) and feeding; and (3) providing burrow habitats for other species (e.g., burrowing owls [*Athene cunicularia*], rabbits, small mammals, snakes, lizards, and invertebrates).

Justification for Selection

The Washington ground squirrel was chosen as a focal species to represent the Shrubsteppe and Grassland vegetation classes in the Columbia Plateau Ecoregion of eastern Washington. It inhabits a range of ecological systems in those categories. Because this squirrel is endemic to the Columbia Basin, it is of high conservation interest.

The species scored an Excellent rating for all criteria used to assess and select focal species (See Appendix E). It was rated as vulnerable to loss of habitat connectivity from four of seven connectivity threats: land clearing, development, roads and traffic, and the presence of people and domestic animals. Washington ground squirrels appear to tolerate human proximity reasonably well except in situations where persecution, predation by pet cats and dogs, vehicle collisions, and continuing land development result in excessive mortality. Their movement scale is appropriate for the Columbia Plateau modeling effort based on known dispersal distances. They occur in colonies and as scattered individuals across the landscape and large-scale connectivity may be accomplished as a slow, multi-generational progression over the landscape.

The Washington ground squirrel is listed as a Species of Greatest Conservation Need in Washington due to habitat loss and human-related threats. It is listed as a federal and Washington State Candidate Species, and is state listed as Endangered in Oregon.

Distribution

Washington ground squirrels historically occupied shrubsteppe and grassland habitats across much of the Columbia Plateau region in eastern Washington and north-central Oregon. Higher elevations and somewhat moister conditions associated with the Palouse region and the foothills of the Blue Mountains limited distribution in the east and south, respectively. The species does not occur west or north of the Columbia River. The geographic distribution of Washington ground squirrels has declined dramatically in Washington during the past 150 years. Historical site records exist for 10 counties in the state, but the species is apparently now absent from Spokane, Whitman, Garfield, and probably Columbia counties (Wiles in prep.). In Oregon, Umatilla, Morrow, and Gilliam counties are inhabited (Verts & Carraway 1998). Elevation range extends from about 90 m in Oregon (Carlson et al. 1980) to about 900 m at Badger Mountain, Douglas County, Washington.

Most colony sites in Washington are now located in Grant, Douglas, and Adams counties, with fewer sites present in Franklin, Lincoln, and Walla Walla counties (Finger et al. 2007; WDFW 2011). Colonies exist on a variety of federal, private, state, and non-governmental organization lands (Finger et al. 2007). These include the state-owned Seep Lakes and Sagebrush Flat wildlife areas, the Bureau of Land Management's (BLM) Wenatchee Resource Area, the U.S. Fish and Wildlife Service's Columbia National Wildlife Refuge.

Habitat Associations

Washington ground squirrels are indigenous to the semiarid shrubsteppe and native grassland habitats of the Columbia Plateau Ecoregion. Major components of shrubsteppe communities are perennial bunchgrasses such as bluebunch wheatgrass (*Pseudoroegneria spicata*), Idaho fescue

(*Festuca idahoensis*), needle-and-thread (*Hesperostipa comata*), and Sandberg's bluegrass (*Poa secunda*); shrubs such as big sagebrush (*Artemisia tridentata*), threetip sagebrush (*A. tripartita*), and antelope bitterbrush (*Purshia tridentata*); and a diverse mixture of forbs (Daubenmire 1970; Franklin & Dyrness 1988; Crawford & Kagan 2001*a*). Native grasslands are dominated by short to medium-height bunchgrasses, especially bluebunch wheatgrass and Idaho fescue, with forbs and shrubs being lesser components (Daubenmire 1970; Franklin & Dyrness 1988; Crawford & Kagan 2001*b*). Land use practices and invasion by numerous exotic annual plants, especially cheatgrass (*Bromus tectorum*), have altered the composition and structure of plant communities in the region since the mid- to late 1800s. Certain landscape characteristics such as heavy grazing, lithosol soils, and dense, tall sagebrush are associated with low occurrence of ground squirrels (Finger et al. 2007).

Colonies of Washington ground squirrels occasionally border alfalfa (*Medicago sativa*), wheat (*Triticum* spp.), and other agricultural fields which can be highly attractive foraging sites (Wiles in prep.). Direct colonization of croplands is rare, probably because disking damages burrows and changes soil profiles, eliminates protective vegetative cover and food sources for animals during significant portions of the active season, or harms hibernating squirrels. In addition, where adequate resources exist, Washington ground squirrels are adaptable enough to inhabit or forage in a variety of disturbed anthropogenic habitats, such as in or around the edges of pastures, livestock feedlots, and grain elevators, highway roadsides, golf courses, railroads rights-of-way, mowed grass lawns at homes and school athletic fields, weedy or degraded vacant lots in towns, gardens, farmyards, and airfields (Carlson et al. 1980; Finger et al. 2007; R. Finger and G. Wiles, personal communication; Wiles in prep.).

Washington ground squirrels consume a wide variety of plants (Tarifa & Yensen 2004*a*, 2004*b*). They feed primarily on green vegetation during the early and middle active season, and then shift to a greater proportion of seeds during the month or two before hibernation. Seeds are important to the diet because they contain high amounts of fatty acids that are required for hibernation. Some of the most commonly recorded foods for the species include Sandberg's bluegrass (*Poa secunda*), cheatgrass (*Bromus tectorum*), the grass *Achnatherum* sp., silky lupine (*Lupinus sericeus*), wooly plantain (*Plantago patagonica*), and tiny trumpet (*Collomia linearis*; Tarifa & Yensen 2004*a*, 2004*b*).

Because Washington ground squirrels are burrowers, soil type and depth are important habitat factors. Occupied soil types are characterized as deep or moderate depth and well or excessively drained (Hosler 1983, 1984). Soil type is believed to influence rates of site abandonment and population recovery among Washington ground squirrels in Oregon (Marr 2001). In other similar species, nest burrows are preferentially built in areas of well-drained soils >1 m in depth (Alcorn 1940; Yensen et al. 1991).

Soils at occupied sites contain significantly reduced amounts of clay in comparison to unoccupied sites (Betts 1990). Reduced clay levels probably allow for easier digging by ground squirrels, although some clay is desirable for decreasing soil friability, thus enhancing the stability of burrows (Betts 1990; Greene 1999). Greene (1999) also detected significant soil differences at used and unused sites in Oregon. These included higher silt (50% at occupied vs. 22% unoccupied), lower sand (44% at occupied vs. 74% unoccupied), and lower clay (5% at occupied vs. 6% unoccupied sites) contents. On a soils triangle, occupied sites equate to loam/silt loam. Unoccupied sites equate to sandy loam. Soils with lower amounts of sand, and hence more silt, may also feature better burrow integrity (Greene 1999).

Sensitivity to Traffic

Data from WDFW (2011) show that Washington ground squirrels occupy a number of locations next to or near roads, which reflects the presence of suitable habitat in these locations. Animals living along roads are tolerant of passing vehicular traffic and are regularly seen crossing minor roads. However, these individuals are vulnerable to being struck by vehicles, as reported by observers who have witnessed small numbers of road-killed squirrels (Carlson et al. 1980; Sherman & Shellman Sherman 2006; Wiles in prep.). Much less information is known about the species' ability to cross larger roads with higher traffic volumes. Wider medians that exist in some four-lane highways may provide easier crossing opportunities. In Washington, at least one population of the closely related Townsend's ground squirrel (*U. townsendii*) has taken up residence in a highway median (M. Livingston and C. Sato, personal observation).

Washington ground squirrels have been observed using primitive dirt and two-track roads bordered by natural vegetation. Individuals have been observed traveling along such roads and burrowing in adjacent banks, and it is thought that the roads may sometimes function as travel corridors. In one study, dispersing squirrels exhibited selection for sites significantly closer to primitive roads than expected (Klein 2005). Burrows are occasionally placed directly in the tracks of lightly driven two-track roads and other trails (R. Finger and G. Wiles, personal communication).

Railroads—Railroad rights-of-way with remnant strips of natural vegetation along the tracks may similarly provide suitable habitat for Washington ground squirrels, including corridors for movement through areas of extensive agriculture. Although not mentioned in the literature for any ground squirrel species, railroad mortality may be quite low because the vibrations from oncoming trains may frighten animals away from the tracks (M. Livingston, personal communication).

Sensitivity to Development

The primary cause for the decline of Washington ground squirrels is thought to be habitat destruction, chiefly through conversion of shrubsteppe and native grasslands to intensive agriculture (e.g., irrigated croplands, dryland wheat, and intensive livestock grazing). Agricultural activities in the geographic range of Washington ground squirrels have targeted areas with deeper, more productive soils that were probably also preferred by the squirrels, eliminated reliable seasonal food sources, changed soil structure, and routinely destroyed burrows during soil tillage (Carlson et al. 1980; Betts 1990, 1999; Quade 1994; Vander Haegen et al. 2001). Extensive persecution of squirrels by farmers also occurred (Wiles in prep.).

Residential and other development also threatens Washington ground squirrels and their habitat (G. Wiles, personal communication). Several colonies have been lost, or partially destroyed by the construction of homes, apartments, and recreational fields since the 1990s (Betts 1999; G. Wiles, personal communication). Other colonies (e.g., in the towns of Warden and Soap Lake, Grant County) occur on the edges of residential neighborhoods and are vulnerable to future construction activities (R. Finger and G. Wiles, personal communication). For example, one such population in Warden occurs on an 8-ha plot bordered on three sides by homes, apartments, and streets. In most cases, especially those involving squirrels in or on the edges of towns, human development has expanded into the areas inhabited by squirrels. In other cases, animals colonize atypical sites near people probably because of the presence of nutritious food sources (e.g., irrigated lawns; G. Wiles, personal communication).

Many colonies in Washington occur in isolated fragments of suitable habitat (See Finger et al. 2007) with little or no chance of genetic interchange. This type of isolation further threatens the species by increasing its vulnerability to a variety of natural and manmade factors, such as: (1) reduced genetic diversity; (2) greater exposure of small colonies to destruction from predation or unpredictable catastrophic events such as fire, disease, or drought; (3) fewer opportunities for colonies to shift sites if the occupied habitat becomes unsuitable; and (4) reduced likelihood that colony locations will be re-populated through immigration if their squirrels become extirpated (Betts 1990; ODFW 1999; Wisdom et al. 2000).

Sensitivity to Energy Development

WIND ENERGY DEVELOPMENT

Numbers of wind power developments are increasing in the range of Washington ground squirrels, with nearly all being built on or proposed for sites in shrubsteppe habitat. Limited information is available on the impacts of wind power to this species or to similar ground squirrel species. However, projects could potentially harm some Washington ground squirrel populations by permanently removing suitable habitat in or adjacent to occupied sites, and by further fragmenting the species' distribution. Proximity to wind farms may have other possible direct and indirect impacts such as mortality from roads built on-site or the influence of turbine shadows altering behavior (e.g., squirrels might spend more time being vigilant for predators and less time foraging; L. Nelson and M. Livingston, personal communication).

However, some evidence exists that wind farms may not play a large role in resistance or habitat quality for Washington ground squirrels. Observations of a fairly extensive squirrel population at the Stateline Wind Farm along the Washington-Oregon border suggest that squirrel numbers have remained stable on the property following the initial installation of wind turbines in the early 2000s, when some animals were probably killed during construction work (K. Kronner, personal communication). Since then, squirrels appear to have co-existed without incident with the turbines and other facilities related to the project, and some occupy sites close to the towers. Washington ground squirrels have also been seen near turbines built on adjoining Washington Department of Natural Resources land (K. Kronner, personal communication).

TRANSMISSION LINES

No research has been done on sensitivity of Washington ground squirrels to transmission lines. In some cases, power transmission corridors may retain suitable habitat for squirrels. However, it is postulated that power transmission towers and lines could have an impact on the squirrels by providing predator perches (R. Finger and M. Livingston, personal communication).

Sensitivity to Climate Change

If climate change leads to drier conditions on the Columbia Plateau, the major impact for Washington ground squirrels could be changes in the phenology of important food plants. The species has a short active season lasting about 4–4½ months in adults, when mating, gestation, rearing of young, and accumulation of adequate body fat for hibernation must be achieved. If spring weather conditions become hotter and drier, some food plants may dry out prematurely and offer less opportunity for the squirrels to "fatten up" before hibernation. Without adequate fat reserves, the squirrels are more susceptible to mortality during hibernation. Van Horne et al. (1997) examined the effects of a severe drought on the related Piute ground squirrel and reported a significant decline in adult survival and almost no juvenile survival.

Drier conditions may also result in more frequent and hotter range fires, which would likely change habitat structure, reduce the availability of preferred food plants for Washington ground squirrels, and encourage the growth of cheatgrass (*Bromus tectorum*). Cheatgrass carries fire well and increases the natural fire hazard, changing fire recurrence intervals from 20 to 100 years for sagebrush or grassland ecosystems to 3 to 5 years for cheatgrass-dominant sites (Yensen et al. 1992; Ypsilantis 2003), eventually degrading natural habitats for ground squirrels.

Dispersal

Home range—Among ground squirrels in general, home ranges commonly measure <1 ha and vary with gender, season, and food availability (Yensen & Sherman 2003). In many species, the home ranges of males are largest during the mating period when males search for females in estrus, then become smaller as the active season progresses. By comparison, female home ranges are often smallest prior to the emergence of their litters and expand in size after the dispersal of pups (Yensen & Sherman 2003). Home-range sizes have also been found to vary with annual precipitation levels, which affect food availability, and the reproductive output of females (Harris & Leitner 2004). Both factors affect the amount of space required to meet the energy demands of individual squirrels.

Delavan (2008) examined home range sizes of adult Washington ground squirrels during much of their active season in Oregon. Mean home-range sizes were 1.4–3.7 times larger for males than females depending on the analysis method used, with males averaging 2.4–5.3 ha and females 0.9–3.7 ha. Considerable variation in size was noted among study sites. Some overlap in ranges and core areas was also detected. Mean home range was 3.3 ha (minimum, 0.3 ha; maximum, 7.7 ha) for males and 0.9 ha (minimum, 0.04 ha; maximum, 3.0 ha) for females using the 95% fixed kernel estimator method.

Delavan (2008) reported that some Washington ground squirrels shift their home ranges by distances of 70 to 228 m during portions of the active season. Thus, for these individuals, the location of any given activity site is not static. However, such shifts were not considered significant when examined at the colony scale.

Some researchers believe that the locations of some Washington ground squirrel aggregations move, or "drift," over periods of a few years (Goodman & Cummins 2003; Finger et al. 2007). The processes by which these changes occur, their extent, and whether they happen gradually or abruptly are poorly known. However, colonization of new areas by adults seems unlikely, given current knowledge of movements (Delavan 2008) and site tenacity by groups of closely related females (Sherman & Shellman Sherman 2006). Instead, drift may be caused by local annual variation in a combination of factors such as survival, reproduction, food availability, and juvenile dispersal, resulting in heavy localized mortality at particular sites and incremental population expansion into nearby unoccupied habitat. Drift may explain the abandonment, reoccupation, or discovery of new aggregation sites in some areas during survey efforts (Goodman & Cummins 2003). For example, Marr (2001) reported extensive change in the status of squirrel locations in the Boardman area of Morrow County, Oregon, during a four-year period, with only 30 of 67 sites still inhabited, 80 new sites present, and several sites reoccupied after abandonment. This type of movement has not been assessed for populations in Washington and is apparently not described in other species of ground squirrels.

Dispersal—Two types of dispersal have been reported in ground squirrels. Natal dispersal, in which immature animals permanently depart their birth site, is common in many species, with males comprising the majority of dispersers. A second type of dispersal, known as breeding dispersal, wherein individuals permanently depart their home range after breeding, has been reported less commonly.

Klein (2003, 2005) described natal dispersal patterns in juvenile male Washington ground squirrels living in Oregon and found that 72% of 95 radio-tracked individuals dispersed. Median and mean dispersal distances were 880 m and 991 m with a minimum distance of 40 m and a maximum distance of 3521 m recorded (Table A.6.1). About 90% of dispersal distances fell between 300 and 2200 m. Distances traveled did not differ significantly among sites or between the two study years. Young males dispersed at about 8 weeks of age (K. Klein, personal communication) and about 5 weeks after their litters emerged aboveground. Dispersal movements occurred rapidly and were generally completed in a few hours to several days. Dispersing individuals had higher survival rates during the main dispersal period than after settling into new home ranges.

Table A.6.1. Dispersal of Washington ground squirrels.

	Dispersal distance (m)			
Gender (n, if known)	*Minimum*	*Mean*	*Maximum*	*Citation*
Juvenile males[a]	40	991	3521	Klein 2005
Immature male (1)		761[b]		Delavan 2008
Immature males (2)	300–400		1300	Sherman & Shellman Sherman 2005
Immature males	<400			Sherman & Shellman Sherman 2006
Females			300	Goodman & Cummins 2003

[a]*72% of juvenile males from three sites.*
[b]*From point of dispersal (accounting for topography, distance was 851 m).*

In a study of habitat use by juvenile males following dispersal, Klein (2005) found that individuals settled disproportionately in locations dominated by annual grass or sagebrush, and avoided sites with low shrubs (mainly rabbitbrush [*Chrysothamnus viscidiflorus*] and snakeweed [*Gutierrezia* sp.]) or bunchgrass, albeit these latter vegetation types comprised only small portions of the three study areas. Sites with varying slopes and aspects were occupied in proportion to their availability. At two of three study areas, ground squirrels also showed strong selection for settling closer to primitive roads and in one area for settling nearer to historically known aggregation sites, especially those currently occupied. Dispersers preferred to settle in sites near other colonies. Squirrels at one of the sites exhibited selection for silt-loam soil texture.

Klein (2005) listed other factors that may influence dispersal distance such as availability of travel corridors, familiarity with habitat type, distance to other colonies, and extent of predation pressure. However, these factors did not appear to account for the rare long-distance dispersal noted in the study.

Sherman and Shellman Sherman (2006) also recorded frequent natal dispersal among juvenile male Washington ground squirrels, based on the extremely low recapture rates at birth sites between years and the arrival of untagged individuals at closely studied aggregations. They suggested that most dispersal in immature males may extend <0.4 km, based on their failure to recapture tagged animals at neighboring aggregations located 0.7–1.7 km away. Sherman and Shellman Sherman (2005) documented two young males moving straight-line distances of 1.3 km and 300–400 m while dispersing (Table A.6.1).

Sherman and Shellman Sherman (2005, 2006) reported possible examples of post-breeding dispersal among adult male Washington ground squirrels. Two examples occurred in late February or early March and involved individuals that arrived at and then soon departed specific study locations. The extent and frequency of these movements remain poorly known.

To what extent Washington female ground squirrels disperse from their birth ranges is poorly understood. Unpublished observations indicate that juvenile females may not disperse more than 300 m from their natal burrows (Goodman & Cummins 2003). Sherman and Shellman Sherman (2005, 2006) did not detect any dispersal among marked females during intensive observations in 2005, but found untagged adult and yearling females living at their study sites in 2006, indicating that some individuals in both age groups had relocated to new aggregations. Dispersal by females may be caused by competition for territories or other resources (Nunes et al. 1997).

Conceptual Basis for Columbia Plateau Model Development

Overview

Washington ground squirrels are open habitat specialists that occupy shrub and grassland habitats, as well as a variety of disturbed anthropogenic habitats (e.g., edges of pastures, highway roadsides, golf courses, mowed grass lawns, and weedy or degraded vacant lots in towns) having suitable foods, soils for burrowing, and protection from predators. The species is capable of traversing a variety of habitats if necessary, as long as suitable foods, soils for burrowing, and protection from predators is present. Despite this adaptability, Washington ground squirrels have been greatly impacted by habitat loss and degradation, and human persecution. This has resulted in a significant decline in overall abundance and the species' absence from areas of seemingly unaltered native habitat.

Movement routes used by Washington ground squirrels are expected to be influenced by desirable food sources, land-cover type, and human disturbance. Factors impeding movement throughout the landscape include agricultural and urban land use, predation, irrigation canals, and vehicular traffic, although the species does appear to occupy or gravitate toward certain types of human-altered landscapes in some instances. Energy development impacts on Washington ground squirrels are not well known.

Movement Distance

Movement patterns in Washington ground squirrels have been studied at the Boardman Naval Weapons Systems Training Facility in Oregon (Klein 2003, 2005; Delavan 2008) and the Seep Lakes Wildlife Area in Washington (Sherman & Shellman Sherman 2005, 2006). The longest dispersal distance recorded for this species was 3521 m (Klein 2005). This distance represents an outlier; about 90% of dispersal distances fell between 300 and 2200 m with a mean of 991 m.

When considering the selection of cost-weighted distance, connectivity can be viewed as a slow, multi-generational progression over the landscape. Because of this, considering movement over a temporal as well as spatial scale is more practical than focusing on an individual animal's capacity to move.

Habitat Concentration Areas

Habitat concentration areas (HCAs) for the Washington ground squirrel were modeled using habitat values set at 0.75 and higher and a home range radius of 250 m. Several HCAs were added for the Upper and Lower Crab Creek drainages (HCA numbers 1–5), where Washington ground squirrel occurrences have been recorded in native shrubsteppe (R. Finger, personal communication).

Resistance and Habitat Values for Landscape Features

We assigned resistance and/or habitat values to parameters associated with the following GIS data layers (Table A.6.2) to model connectivity for the Washington ground squirrel:

1) Land Cover/Land Use
2) Slope
3) Soil Texture
4) Soil Depth to First Restrictive Horizon
5) Housing Density
6) Roads
7) Railroads (Active and Inactive)
8) Irrigation Infrastructure

Table A.6.2. Landscape features and resistance values used to model habitat connectivity for Washington ground squirrel.

Spatial data and included factors	*Resistance value*	*Habitat value*
Landcover/Land use		
Grassland Basin	0	1.00
Grassland Mountain	90	0.00
Shrubsteppe	0	1.00
Dunes	15	0.10
Shrubland Basin	0	1.00
Shrubland Mountain	90	0.00
Scabland	0	0.50
Introduced upland vegetation—annual grassland	0	0.70
Cliffs—rocks—barren	30	0.00
Meadow	90	0.00
Herbaceous wetland	90	0.00
Riparian	90	0.10
Introduced riparian and wetland vegetation	90	0.20
Water	90	0.00
Aspen	90	0.00
Woodland	30	0.00
Forest	90	0.00
Disturbed	30	0.60
Cultivated cropland from ReGap NLCD	30	0.10
Pasture—hay from CDL	3	0.10
Non-irrigated cropland from CDL	30	0.10
Irrigated cropland from CDL	30	0.10
Highly structured agriculture from CDL	3	0.10
Irr Not Irr Cult Ag buffer 0 - 250m from native habitat	30	0.10
Irr Not Irr cult ag buffer 250 - 500m from native habitat	30	0.10
Pasture Hay Ag buffer 0 - 250m from native habitat	3	0.10
Pasture Hay Ag buffer 250 – 500m from native habitat	3	0.10
Slope (degrees)		
Gentle slope less than or equal to 20 deg	0	1.00
Moderate slope greater than 20 ° less than equal to 40 deg	0	0.70
Steep slope greater than 40 deg	75	0.00
Soil Texture		
Sand	0	0.00
Loamy sand	0	0.80
Sandy loam	0	0.90
Silt loam	0	1.00
Loam	0	1.00
Sandy clay loam	0	0.00
Silty clay loam	0	0.00
Clay loam	0	0.00
Silty clay	0	0.00
Clay	0	0.00
No soil	0	0.00
Soil Depth to First Restrictive Horizon		
0 – 20cm	0	0.10

Spatial data and included factors	*Resistance value*	*Habitat value*
>20 – 50cm	0	0.50
>50 – 100cm	0	1.00
>100cm	0	1.00
No soil	15	0.00
Housing Density census 2000		
Greater than 80 ac per dwelling unit	0	1.00
Greater than 40 and less than or equal to 80 ac per dwelling unit	0	0.80
Greater than 20 and less than or equal to 40 ac per dwelling unit	2	0.50
Greater than 10 and less than or equal to 20 ac per dwelling unit	4	0.30
Less than or equal to 10 ac per dwelling unit	15	0.10
Roads		
Freeway Center line	50	0.00
Freeway Inner buffer 0 – 500m	0	1.00
Freeway Outer buffer 500 – 1000m	0	1.00
Major Highway Center line	40	0.00
Major Highway Inner buffer 0 – 500m	0	1.00
Major Highway Outer buffer 500 – 1000m	0	1.00
Secondary Highway Center line	30	0.00
Secondary Highway Inner buffer 0 – 500m	0	1.00
Secondary Highway Outer buffer 500 – 1000m	0	1.00
Local Roads Center line	3	0.00
Local Roads Inner buffer 0 – 500m	0	1.00
Local Roads Outer buffer 500 – 1000m	0	1.00
Railroad Active		
Railroad Active Center line	0	0.00
Railroad Active Inner buffer 0 – 500m	0	1.00
Railroad Active Outer buffer 500 – 1000m	0	1.00
Railroad Inactive		
Railroad Inactive Center line	0	0.00
Railroad Inactive Inner buffer 0 – 500m	0	1.00
Railroad Inactive Outer buffer 500 – 1000m	0	1.00
Irrigation Infrastructure		
Irrigation canals	100	0.00

Modeling Results

Resistance Modeling

This discussion of habitat resistance for Washington Ground Squirrels excludes areas west and north of the Columbia River that are outside of the geographic range of the species (Fig. A.6.1). High resistance conditions occur over large portions of the species' range and are mainly due to widespread agriculture, which has replaced much of the squirrel's preferred shrubsteppe habitat. Areas of lowest resistance include: (1) the swath of scablands extending southward from southeastern Lincoln County through eastern Adams County into eastern Franklin and northern Columbia counties; (2) scablands running along upper Crab Creek and those extending south from Swanson Lakes Wildlife Area in Lincoln County, which continue west to extensive shrubsteppe habitat in northern Grant and southern Douglas counties; (3) shrubsteppe extending from the vicinity of Seep Lakes Wildlife Area in southern Grant County south to Columbia

National Wildlife Refuge in far western Adams County and then west through the Lower Crab Creek drainage and adjoining Saddle Mountains in southern Grant County; and (4) habitats along the Columbia River and adjoining area in northern Douglas County.

Habitat Modeling and Habitat Concentration Areas

While the Washington ground squirrel habitat map (Fig. A.6.2) provides a useful overview of modeled habitat quality, the habitat concentration areas (HCAs) derived from this map are used to delineate areas to connect during linkage modeling. The HCAs identify presumed areas of high quality habitat and are not intended to reflect the full range of the Washington ground squirrel (Fig. A.6.3). Fifty-six Washington ground squirrel HCAs were identified in Washington ranging from 494 to 28,246 ha. Mean HCA size was 4671 ha and the total area of all HCAs was 261,588 ha. Forty-one HCAs were identified in Oregon, ranging from 1289 to 69,914 ha. Mean HCA size was 7470 ha and the total area of all HCAs was 306,285 ha. These HCAs stretch across the range of Washington ground squirrels in the state and are relatively fragmented with the exception of a large block of habitat at the Boardman Naval Weapons Systems Training Facility.

(continued on page A.6-15)

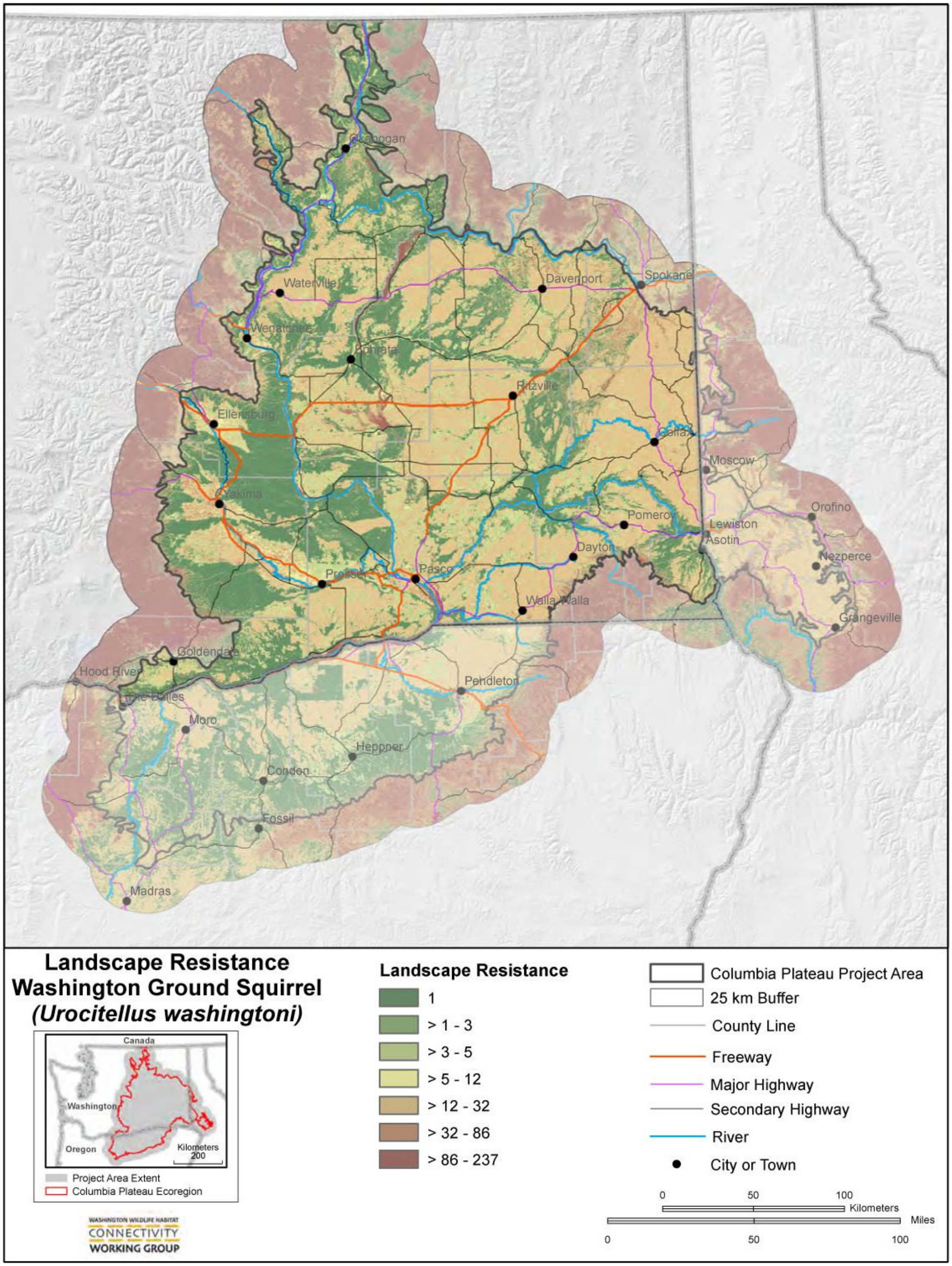

Figure A.6.1. Resistance map for Washington ground squirrel in the Columbia Plateau Ecoregion.

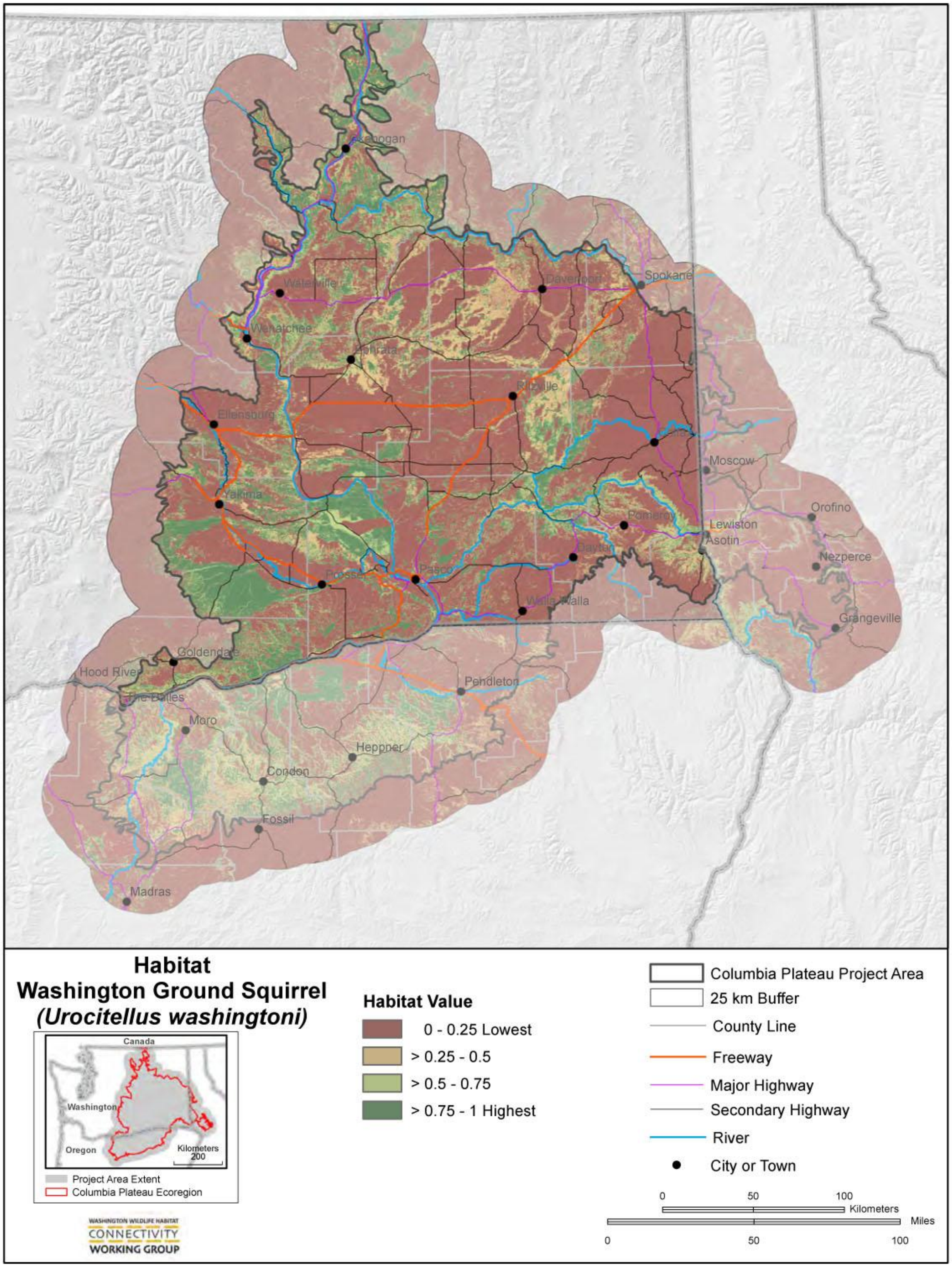

Figure A.6.2. Habitat map for Washington ground squirrel in the Columbia Plateau Ecoregion.

Cost-Weighted Distance Modeling

The cost-weighted distance map provides a view of the full range of areas that the model indicates as most suitable for potential movement of Washington ground squirrels away from HCAs (Fig. A.6.4; See Fig. A.6.5 for HCA identification). This map is most useful for understanding the potential for Washington ground squirrel movements outward from HCAs.

Linkage Modeling

There were 201 linkages modeled between the Washington ground squirrel HCAs (Fig. A.6.6.). Linkage lengths were not constrained during modeling. Least-cost distances for the Washington ground squirrel linkages ranged from <1 km to 191 km with a mean of 23 km, while Euclidean distances ranged from <1 km to 48 km with a mean of 9 km.

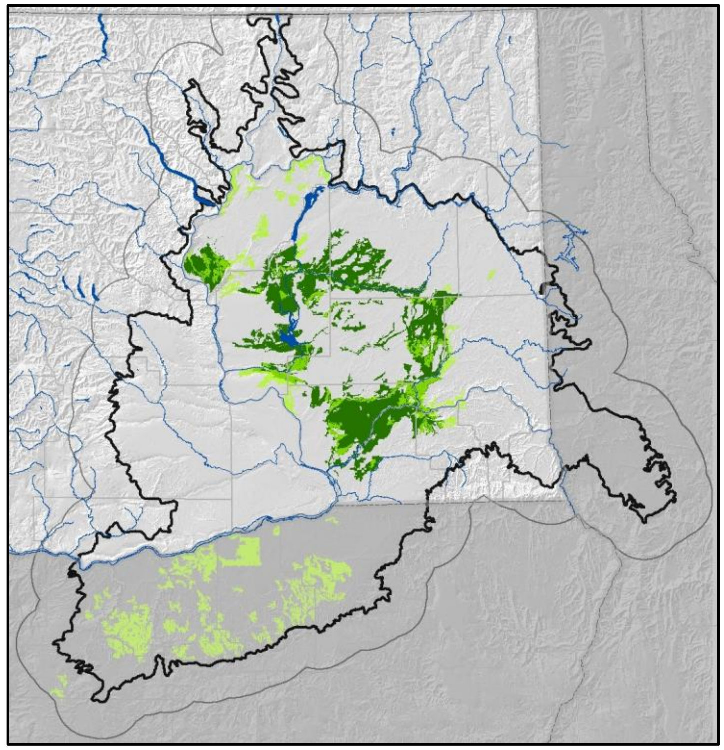

Figure A.6.3. Washington ground squirrel HCAs (light green) and GAP distribution (dark green) in the Columbia Plateau Ecoregion.

Linkage quality metrics (See Appendix B) indicate linkages between HCAs in Washington may be of lesser quality than those between HCAs in Oregon. For example, the cost-weighted/Euclidean mean (SD) for HCAs in Washington is 5 (9) whereas in Oregon the mean is 2 (2), less than half the value for Washington linkages. Similarly, the cost-weighted/non-weighted mean for Washington HCAs is 3 (5) whereas in Oregon the mean is 1 (1), representing one-third of the quality level indicated by the Washington value.

Many linkages are vulnerable to the degradation of shrubsteppe habitat or the expansion of agriculture. Some of the more fragile (i.e., long and narrow) and possibly important links are those connecting (1) HCAs in the Saddle Mountains, Wahluke Slope, and the area west of Esquatzel Coulee to HCAs in northern Franklin County; and (2) HCAs in southern Lincoln County to HCAs in eastern Adams County. Other essential links connect HCAs in Douglas, Grant, and southwestern Lincoln counties.

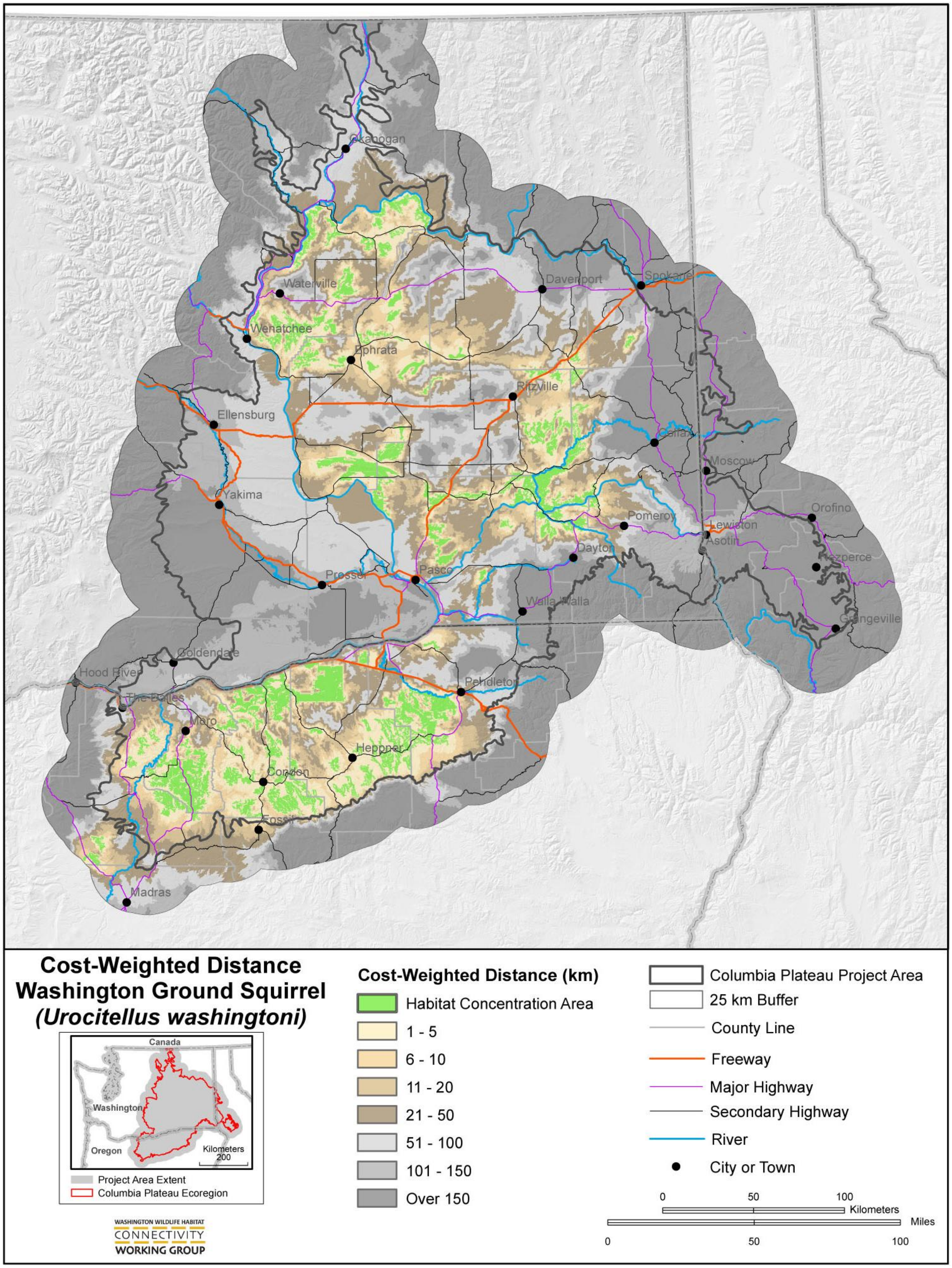

Figure A.6.4. Cost-weighted distance map for Washington ground squirrel in the Columbia Plateau Ecoregion.

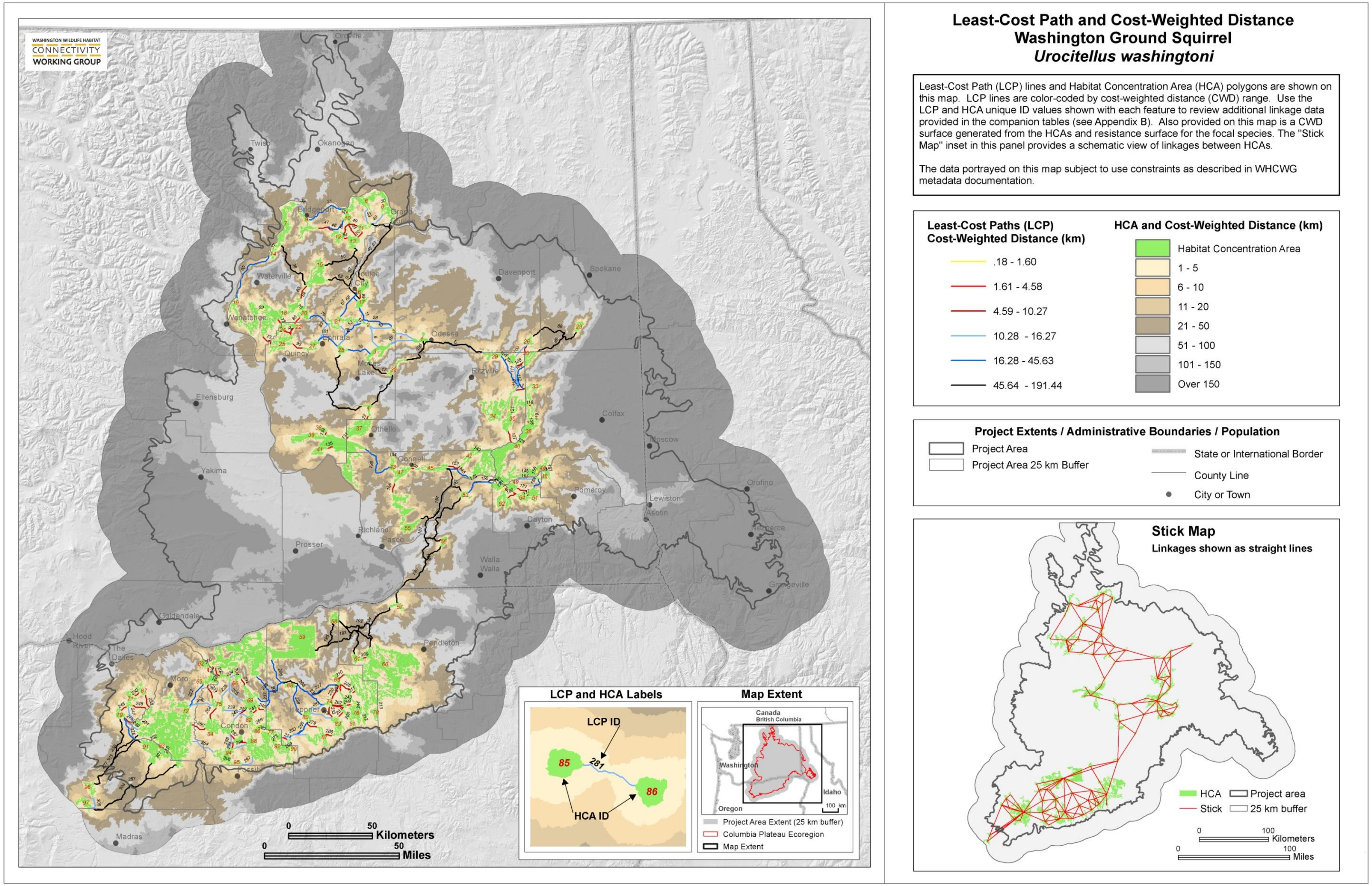

Figure A.6.5. Cost-weighted distance map with numbered HCAs (green polygons labeled with red numerals) and least-cost paths (lines labeled with black numerals) for Washington ground squirrel. Linkage modeling statistics provided in Appendix B.

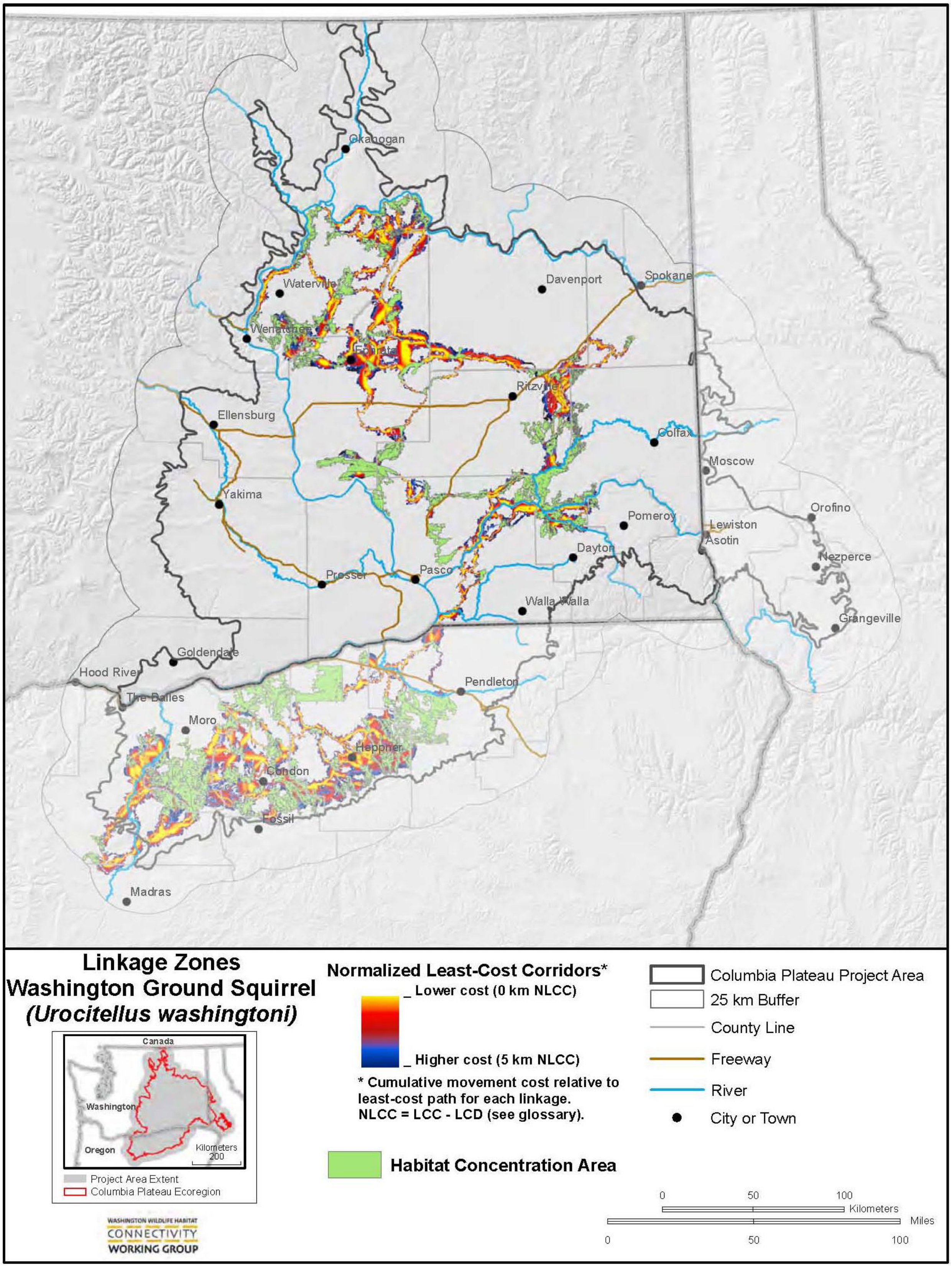

Figure A.6.6. Linkage map for Washington ground squirrel in the Columbia Plateau Ecoregion.

Key Patterns and Insights

Key patterns and insights for our connectivity analysis of Washington ground squirrel in the Columbia Plateau Ecoregion include:

- A significant part of Washington ground squirrel range is in Oregon. However, despite a colony straddling the border of the two states (east of Wallula Gap), populations in Oregon appear to be disconnected from those in Washington.
- Many of the sites occupied by Washington ground squirrels in Washington appear to be isolated from each other, which reflects the highly fragmented condition of the species' habitat.
- Agricultural conversion has displaced Washington ground squirrels from extensive areas with deep, silty soils, which are also preferred by squirrels, thereby leaving populations in habitats where soil texture or depth are marginal.
- As remaining shrubsteppe in the Washington ground squirrel's range is degraded or lost, populations will become further isolated.
- Washington ground squirrels appear to tolerate human proximity and some human-modified habitats reasonably well if adequate food and soil resources are present and there is limited mortality from persecution, predation by pet cats and dogs, vehicle collisions, and continuing land development.
- More intensive surveys in HCAs and other areas with suitable habitat may find populations previously overlooked.
- Techniques such as translocation have been used and they can be valuable tools, but are not a long-term solution for maintaining population viability.

Considerations and Needs for Future Modeling

It should be noted that much remains to be learned about the specific habitat requirements and movements of Washington ground squirrels. For several reasons, managers and researchers should exercise caution when interpreting the results of resource-use studies. Observations indicate that the species can occupy a fairly broad range of habitats within shrubsteppe and grassland. Because Washington ground squirrels have disappeared from much of their historical range and experienced extensive loss or alteration of native habitat, surviving populations may not occur in optimal habitat, which can result in misleading conclusions about habitat preferences. For example, agricultural conversion of lands and increasing urban development have probably eliminated the squirrels from many of the best portions of their range. This may be why they are often found near human-modified landscapes and may appear to have adapted to seemingly adverse conditions. Altered landscapes may be dispersal sinks, possibly leading to attrition of Washington ground squirrels in their range over time.

Opportunities for Model Validation

Although demography, distribution, occupancy, and behavioral studies have been conducted on Washington ground squirrels in Washington, no home range or dispersal studies have been done. Designing and implementing home range and dispersal studies are crucial to protecting the precarious linkages and remaining suitable habitat for the species. Home range and dispersal studies conducted in Oregon, on whose research these models were based, were all conducted on the same area of land in what is considered the best remaining habitat in Oregon. Landscape composition and topography, for instance, can be quite different in Washington, and currently occupied sites or suitable habitat is scattered across a wide expanse of Washington's portion of the Columbia Plateau Ecoregion.

Surveys should continue and become more frequent. Squirrel activity, habitat, and colonies have been discovered in unexpected places and more may exist in areas which have not been explored. Survey discoveries may also provide new opportunities to translocate squirrels in isolated areas to suitable habitat that may encourage colony growth and opportunities for dispersal.

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The completion of this document would not have been possible without Gary Wiles' (WDFW) contributions to the manuscript, editing, and insights. Rich Finger (WDFW) provided vital information on Washington ground squirrel biology and behavior, the history of the Washington ground squirrels in Washington, and habitat and occurrence information. He was instrumental in the modeling and guidance of the Washington ground squirrel section of this project. Thanks go to Kelly McAllister (WSDOT) for his thoughtful editing and review. Leslie Nelson (TNC), JA Vacca (BLM), and Jason Lowe (BLM) provided insight and guidance into the response of Washington ground squirrels to energy development and other threats. I am especially indebted to Kimberly Klein, independent scientist, and Jodie Delavan (USFWS) for providing valuable information about Washington ground squirrel phenology and movements. John Fleckenstein (Natural Heritage Program, DNR), Gail Olson (WDFW), and the participants in this project provided insight on habitat and on the process of this project.

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