Appendix A.5

Habitat Connectivity for Townsend's Ground Squirrel (*Urocitellus townsendii*) in the Columbia Plateau Ecoregion

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Introduction

Townsend's ground squirrel, photo by Ryan Shaw

Townsend's ground squirrels (*Urocitellus townsendii*) are endemic to the Columbia Plateau Ecoregion in Washington, west of the Columbia River. This species was previously taxonomically lumped with two other species (Piute ground squirrel, *U. mollis*, and Merriam's ground squirrel, *U. canus*) in the western U.S., which were collectively known as Townsend's ground squirrel. Hoffmann et al. (1993) and Thorington and Hoffmann (2005) recognized the three taxa as distinct species, noting their chromosomal differences and lack of hybridization. These species were formerly considered part of the genus *Spermophilus*, but were recently changed to *Urocitellus* (Helgen et al. 2009). Two subspecies of Townsend's ground squirrel are recognized. The subspecies *nancyae* lives east and north of the Yakima River, whereas the chromosomally distinct *townsendii* occurs west and south of the Yakima River.

Like other species of ground squirrels inhabiting areas of seasonally harsh climates (Davis 1976; Michener 1984; Yensen & Sherman 2003), Townsend's 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 to 5½ months within populations (Scheffer 1941). This overall pattern reflects the short growing season of the species' food plants.

Although the ecological relationships of Townsend's ground squirrels have not been studied, they 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). Townsend's 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

Townsend's ground squirrels were chosen as a focal species to represent the Shrubsteppe and Grassland vegetation classes in the Columbia Plateau Ecoregion of eastern Washington. They inhabit a range of ecological systems in those categories and they may also occupy dune areas stabilized by vegetation. They are also one of the few vertebrate species endemic to Washington State.

Townsend's ground squirrels scored an Excellent rating for all criteria used to assess and select focal species (See Appendix E). They were rated 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. The species appears 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 presumed dispersal distances. They generally 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.

Townsend's ground squirrel is considered as a Species of Greatest Conservation Need due to habitat loss and human-related threats. It is also listed as a federal Species of Concern and the subspecies *townsendii* is a state Candidate Species.

Distribution

Townsend's ground squirrels occur west of the Columbia River in south-central Washington. The species' historical range encompassed all of Benton County, the eastern portions of Yakima and Klickitat counties, and southeastern Kittitas County. Surviving populations now occur primarily in Benton and Yakima counties, with fewer sites in Kittitas and Klickitat counties. As already noted, the two subspecies of Townsend's ground squirrel occur on different sides of the Yakima River. This suggests that the river may function as a natural barrier to gene flow and overall population connectivity.

No detailed surveys have been conducted for Townsend's ground squirrels. The species is absent from much of its former range in the Yakima Valley (Johnson & Cassidy 1997). Remaining natural habitat may cover less than 10% of its historical range. Current knowledge of site use is biased by incomplete information on occurrence. Many recorded sites are located near roads or next to human-occupied areas, which greatly enhanced their detection.

Habitat Associations

Detailed information on the habitat preferences of Townsend's ground squirrel is lacking. Historically, the species would have occurred primarily in native shrubsteppe, grasslands, and large patches of sagebrush at the lower edges of forest. Field observations from recent decades indicate that a variety of human-modified habitats are now also occupied, including pastures, abandoned fields, orchards, vineyards, hop fields, canal banks, and adjacent to irrigated fields and springs (Johnson & Cassidy 1997; M. Livingston, personal communication). Generally, squirrel abundance appears to be higher in these habitats than in native plant communities (M. Livingston, personal communication). This may be due to the improved food availability at disturbed sites (Johnson & Cassidy 1997) and degradation of food resources at many sites with native plant communities. This species is also occasionally found living on the edges of vegetated dunes such as those on the western section of the Hanford Dunes complex.

Johnson (1977) examined the diet of Townsend's ground squirrels on the Arid Lands Ecology Reserve (near Hanford Site). Fourteen foods were identified in the analysis: *Poa sandbergii* (49% of the diet), *Achillea lanulosa* (11%), *Lupinus laxiflorus* (10%), *Astragalus purshii* (11%), *Descuriania pinnata* seed (8%), *Erigeron filifolius* (3%), *Antennaria dimorpha* (2%), *Salsola kali* (2%), *Artemisia tridentata* (2%), *Sisymbrium altissimum* (2%), unclassified forb (3%), *Balsamorhiza careyana* (<1%), *Lactula serriola* (<1%), lichen (<1%), and arthropod (<1%). Staple foods were almost entirely green vegetation. Rogers and Gano (1980) reported a similar diet.

Ground squirrels are generally considered to be selective feeders because they consume certain foods in greater abundance than their occurrence in the wild (Rogers & Gano 1980; Dyni & Yensen 1996; Van Horne et al. 1998). Diets are commonly dominated by a few plant species and supplemented with a number of additional minor food items (Johnson 1977; Rogers & Gano 1980; Yensen & Quinney 1992; Dyni & Yensen 1996; Van Horne et al. 1998). Dietary variation among seasons, years, and sites is frequently noted and likely reflects differences in the availability and nutritional qualities of plants (Frank 1992; Yensen & Quinney 1992; Dyni & Yensen 1996; Van Horne et al. 1998).

Because Townsend's ground squirrels dig extensive burrows, soil type and depth are important habitat factors. Little soils information is available for this species, although occupied soil types are presumably characterized as deep or moderate depth and well or excessively drained. The following information is taken from studies of Washington ground squirrels (*Urocitellus washingtoni*), justifiable because the two species are closely related and occupy adjoining regions with similar habitats. Soils at sites occupied by this species 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 sites), lower sand (44% at occupied vs. 74% unoccupied sites), and slightly lower clay content (5% at occupied vs. 6% unoccupied sites). Soils with lower amounts of sand, and hence more silt, may also feature better burrow integrity (Greene 1999). Soil type and elevation are postulated to influence rates of site abandonment and population recovery (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).

Agriculture

Townsend's ground squirrels occupy a number of locations in highly structured agricultural sites (i.e., orchards, vineyards, hop fields, etc.) with grassy ground cover in the Yakima and Moxee

Valleys. Some occupied sites of this type have estimated populations of >100 animals (M. Livingston, personal communication). In these situations, the major threat to the squirrels is control efforts by farmers. The banks of irrigation canals and ditches are also regularly inhabited.

The species is absent from large areas of uninterrupted agriculture (i.e., irrigated and non-irrigated cropland) where remnant patches of natural vegetation have been removed (Johnson & Cassidy 1997). This is probably caused by a combination of the loss of reliable seasonal food sources for the squirrels and to the routine destruction of burrows during soil tillage (Vander Haegen et al. 2001). Squirrels may be able to persist in areas where suitable rangelands border crop fields. In these situations, squirrels are able to maintain their burrows in the rangeland and enter the edges of the crop fields to forage.

The response of Townsend's ground squirrel to livestock grazing has not been reported, but may be similar to that in Washington ground squirrels. In this species, some grazing may be beneficial by opening dense vegetation and thereby enhancing visibility for predators (Tarifa & Yensen 2004*a*). However, excessive grazing pressure can reduce food availability and protective cover, thus perhaps lowering squirrel survival (Greene 1999; Tarifa & Yensen 2004*a*, 2004*b*).

Sensitivity to Roads and Traffic

Data from WDFW (2011) show that Townsend's ground squirrels occupy a number of locations next to or near roads, which reflects the presence of suitable habitat along roads. At these sites, animals are tolerant of passing automobiles. Townsend's ground squirrels have been observed using primitive dirt and two-track roads bordered by natural vegetation. Individuals have been reported 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 of the similar Washington ground squirrel, dispersers exhibited selection for sites significantly closer to primitive roads than expected (Klein 2005). Burrows of this species are occasionally placed directly in the tracks of lightly driven two-track roads and other trails (R. Finger and G. Wiles, personal communication).

Townsend's ground squirrels living next to roads are vulnerable to vehicular traffic, although no information is available on levels of mortality. They have been seen crossing back and forth over minor roads, but little is known about their ability to cross larger roads with higher traffic volumes. Wider medians that separate opposing directions of four-lane highways may provide easier crossing opportunities. At least one population of Townsend's ground squirrels resides in a highway median near the town of Prosser (M. Livingston and C.S., personal observation).

Railroads—Railroad rights-of-way with remnant strips of natural vegetation along the tracks may similarly provide suitable habitat for Townsend's 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 Townsend's 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). As noted for the similar Washington ground squirrel (Carlson et al. 1980; Betts 1990, 1999; Quade 1994; Vander Haegen et al. 2001), agricultural activities in the geographic range of Townsend's ground squirrel 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. Extensive persecution of squirrels by farmers also occurred. Nevertheless, as earlier discussed, Townsend's ground squirrels currently show an affinity for certain types of highly structured agriculture (i.e., orchards, vineyards, hop fields, etc) with grassy ground cover (M. Livingston, personal communication).

Destruction of habitat from residential and urban development is also an important threat to Townsend's ground squirrels. Colonies appear to survive fairly well where suitable habitat persists next to this type of development, although squirrels may be at greater risk to predation from cats and dogs, fragmentation of populations, and human persecution. A majority of current GIS occurrence points (WDFW 2011) show the squirrels occupying areas close to human activity, particularly along the Yakima River Valley, although survey effort to date has been biased towards roadsides and other accessible areas. There have been observations of squirrels occupying areas within town boundaries (M. Livingston, personal communication).

Sensitivity to Energy Development

WIND ENERGY DEVELOPMENT

Recent sightings of Townsend's ground squirrels have been recorded by conservation consultants hired by wind energy firms to survey possible locations for wind farms (K. Kronner, personal communication). As more potential wind farm locations are investigated, more location information for Townsend's ground squirrels may be gathered.

Relatively little is known about the impacts of wind power on Townsend's ground squirrels or similar species. Nearly all existing and proposed wind power sites in Washington are in native shrubsteppe habitat. Projects may negatively impact Townsend's ground squirrels by permanently removing suitable habitat in or adjacent to occupied sites, further fragmenting the species' distribution. Proximity to wind farms may have other possible direct and indirect impacts such as road infrastructure 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, observations of a fairly extensive population of Washington ground squirrels 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). Squirrels appear to co-exist without incident with the turbines and other facilities related to the project, and some occupy sites close to the towers.

TRANSMISSION LINES

No research has been done on Townsend's ground squirrel sensitivity 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 (M. Livingston, personal communication).

Sensitivity to Climate Change

If climate change leads to drier conditions on the Columbia Plateau, the major impact for the Townsend's ground squirrel 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 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 Townsend's ground squirrel, 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 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

There is little information on home-range size and dispersal in Townsend's ground squirrel. One study of home range exists for the species (range 435–77,021 m^2; Fuller 1971), but is probably unreliable because it determined movements only by direct observation. Home range included the area that squirrels confined themselves to at all times except during the breeding period. Because of the absence of reliable information for Townsend's ground squirrel, we instead provide descriptions of movements in two closely related species, Washington and Piute ground squirrels, which occur in similar habitats to Townsend's ground squirrel and likely have similar home range and dispersal patterns.

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 to 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.

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.5.1). 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.

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 from 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.

Table A.5.1. Dispersal of Washington ground squirrels.

Gender (n, if known)	*Dispersal distance (m)* *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).*

Sherman & 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.5.1).

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).

Olson and Van Horne (1998) reported on dispersal behavior in juvenile Piute ground squirrels. During two years of study, they found that 20 of 35 males and 1 of 16 females dispersed from their natal sites (Table A.5.2). Mean dispersal distance was 515 m, with a maximum distance of 1076 m. Dispersal distances did not differ between habitats, but dispersers tended to end up in the habitat type they started in. All dispersals occurred within a span of no more than 3 days.

Table A.5.2. Dispersal of juvenile Piute ground squirrels.

Year	*Dispersal distance (m)*			*Citation*
	Minimum	*Maximum*	*Mean*	
1993	204	1,005	505	Olson & Van Horne 1998
1994	146	1,076	520	Olson & Van Horne 1998

Conceptual Basis for Columbia Plateau Model Development

Overview

Although Townsend's ground squirrels occurred primarily in shrub and grassland habitats under historical conditions, they appear to be sufficiently adaptable to now inhabit a variety of human-altered habitats (e.g., pastures, abandoned fields, orchards, vineyards, hop fields, canal banks, and adjacent to irrigated fields and springs) offering suitable foods, soils for burrowing, and protection from predators. However, despite this adaptability, the species has been greatly impacted by habitat loss and degradation, and human persecution. It has presumably experienced a significant decline in overall abundance and is commonly absent from areas of relatively unaltered native habitat.

Movement routes used by Townsend's ground squirrels are expected to be influenced by desirable food sources, land-cover type, and human disturbance. Factors impeding movement throughout the landscape include urban and agricultural 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 Townsend's ground squirrels are poorly known.

Movement Distance

Because of the lack of movement information for Townsend's ground squirrels, we chose to use movement data for Washington ground squirrels to create the Townsend's ground squirrel model. 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. Expert opinion supported this decision to use this information in the model.

We did not set a maximum length limit for linking of HCAs for two reasons: (1) we wanted to understand the broad connectivity patterns across the landscape, recognizing linkage quality metrics would provide information; and (2) Townsend's ground squirrel connectivity can be viewed as a slow, multi-generational progression where habitat may be patchy between larger habitat patches.

Habitat Concentration Areas

Habitat concentration areas (HCAs) for the Townsend's ground squirrel were modeled using habitat values set at 0.85 and higher and a home range radius of 250 m.

Resistance and Habitat Values for Landscape Features

Data layers used to model resistance and/or habitat for Townsend's ground squirrel are presented in Table A.5.3 and include:

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) Transmission Lines
9) Wind Turbines
10) Irrigation Infrastructure

(continued on page A.5-13)

Table A.5.3. Landscape features and resistance values used to model habitat connectivity for Townsend's ground squirrel.

Spatial data layers and included factors	*Resistance value*	*Habitat value*
Landcover/Landuse		
Grassland Basin	0	1.00
Grassland Mountain	90	0.00
Shrubsteppe	0	1.00
Dunes	15	0.20
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	1	0.50
Irrigated/Not Irrigated/Cultivated Ag buffer 0 – 250m from native habitat	30	0.10
Irrigated/Not Irrigated/Cultivated 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		
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 Restricted Layer		
0 – 20cm	0	0.10
20 – 50cm	0	0.50

Spatial data layers and included factors	*Resistance value*	*Habitat value*
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 Centerline	50	0.00
Freeway Inner buffer 0 – 500m	0	1.00
Freeway Outer buffer 500 – 1000m	0	1.00
Major Highway Centerline	40	0.00
Major Highway Inner buffer 0 – 500m	0	1.00
Major Highway Outer buffer 500 – 1000m	0	1.00
Secondary Highway Centerline	30	0.00
Secondary Highway Inner buffer 0 – 500m	0	1.00
Secondary Highway Outer buffer 500 – 1000m	0	1.00
Local Roads Centerline	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
Transmission Lines		
LessThan 230KV One Line Centerline	0	0.70
LessThan 230KV One Line Inner buffer 0– 500m	0	0.80
LessThan 230KV One Line Outer buffer 500 – 1000m	0	1.00
LessThan 230KV Two or More Lines Centerline	0	0.70
LessThan 230KV Two or More Lines Inner buffer 0 – 500m	0	0.80
LessThan 230KV Two or More Lines Outer buffer 500 – 1000m	0	1.00
Greater Than or Equal 230KV One Line Centerline	0	0.70
Greater Than or Equal 230KV One Line Inner buffer 0 – 500m	0	0.80
Greater Than or Equal 230KV One Line Outer buffer 500 – 1000m	0	1.00
Greater Than or Equal 230KV Two Lines Centerline	0	0.70
Greater Than or Equal 230KV Two Lines Inner buffer 0 – 500m	0	0.80
Greater Than or Equal 230KV Two Lines Outer buffer 500 – 1000m	0	1.00
Greater Than or Equal 230KV Two Lines no transmission line features	0	1.00

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Spatial data layers and included factors	*Resistance value*	*Habitat value*
Wind Turbine		
Wind turbine point buffer 45m radius	0	0.90
Buffer zone beyond point buffer 0 – 500m	0	1.00
Buffer zone beyond point buffer 500 – 1000m	0	1.00
Irrigation Infrastructure		
Irrigation canals	100	0.00

Modeling Results

Resistance Modeling

This discussion of habitat resistance for Townsend's ground squirrels excludes areas east and south of the Columbia River that are outside of the geographic range of the species (Fig. A.5.1). The resistance surface for this squirrel demonstrates shrubsteppe and shrub grassland habitat as providing relatively free movement (Fig. A.5.1). Areas of lowest resistance are the Yakima Training Center, the Hanford National Monument (including the Arid Lands Ecology Reserve), much of the Yakama Reservation, and parts of eastern Klickitat County. Intensive agriculture poses the highest resistance, particularly areas of irrigated farmland between Yakima and Prosser, in the general vicinity of Ellensburg, and combined irrigated and dry farmland in southern Benton County. Hanford Dunes is also depicted as an area of high resistance; however, the western portion of the dunes is better vegetated and therefore has lower resistance.

Habitat Modeling and Habitat Concentration Areas

While the Townsend's ground squirrel habitat map (Fig. A.5.2) 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 Townsend's ground squirrel (Fig. A.5.3). Forty-eight HCAs were identified for Townsend's ground squirrel ranging from 1285 ha to 59,452 ha in size. Mean HCA size was 6000 ha and the total area of all HCAs was 290,729 ha. HCAs are well represented in the west-central and east-central portions of the species' range, as well as in parts of eastern Klickitat County, but are relatively sparse elsewhere. Several sizeable HCAs are located on public lands, including WDFW wildlife areas, the Yakima Training Center, and the Hanford National Monument (including the Arid Lands Ecology Reserve).

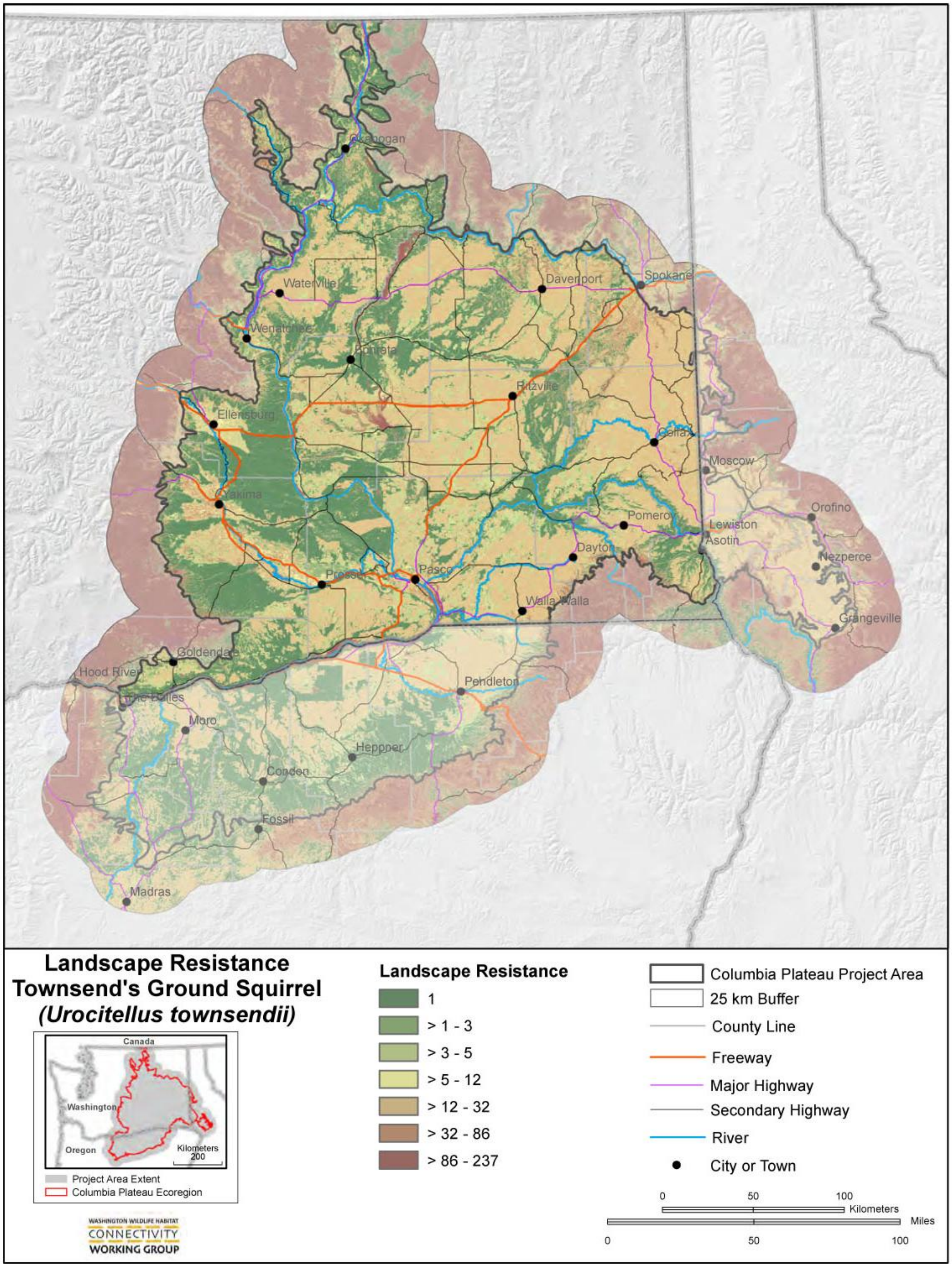

Figure A.5.1. Resistance map for Townsend's ground squirrel in the Columbia Plateau Ecoregion.

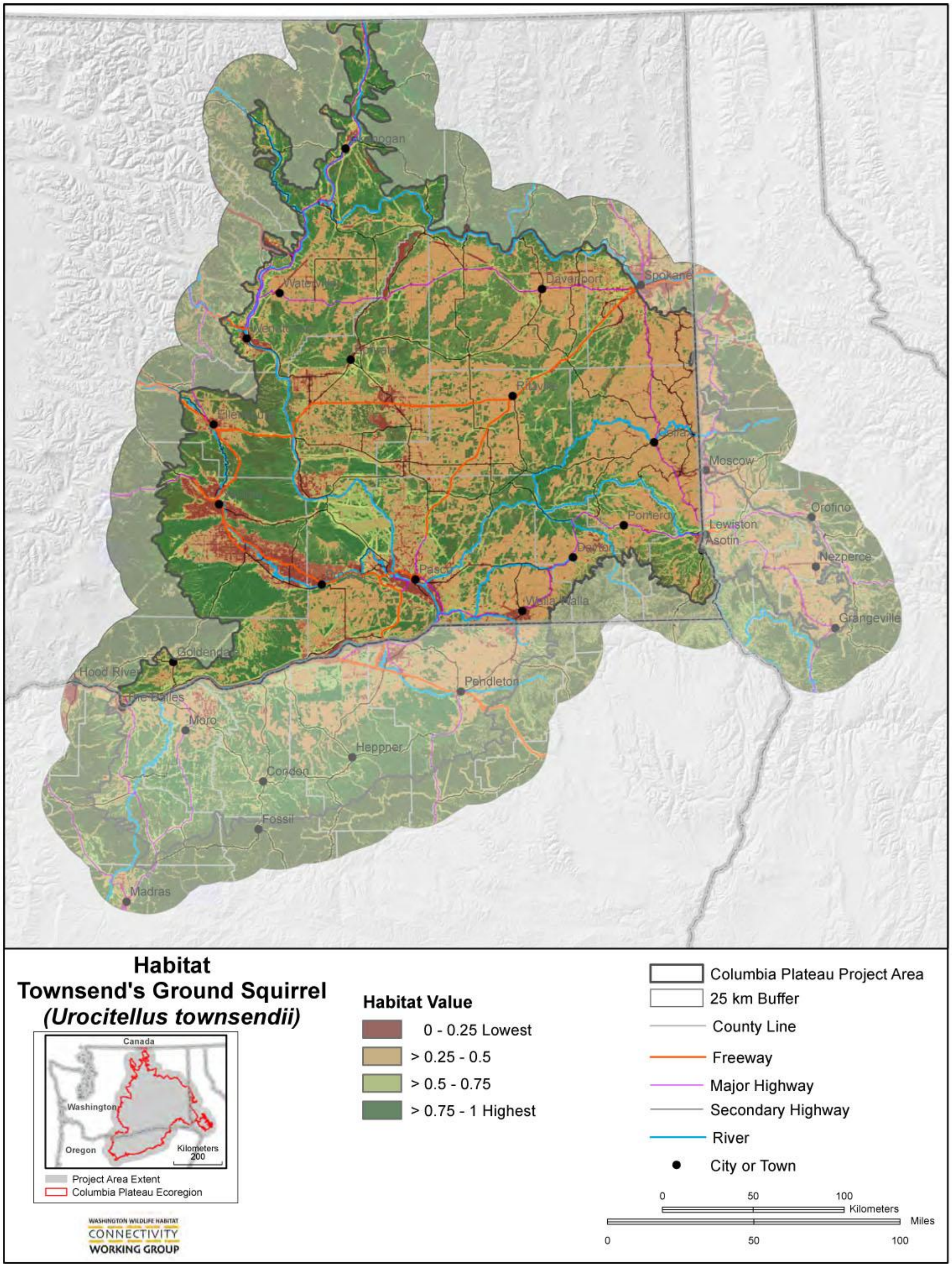

Figure A.5.2. Habitat map for Townsend's ground squirrel in the Columbia Plateau Ecoregion.

Cost-Weighted Distance Modeling

The cost-weighted distance map provides a view of the full range of areas the model indicates as most suitable for potential movement of Townsend's ground squirrels away from HCAs (Fig. A.5.4; see also Fig. A.5.5 for HCA identification). This map is most useful for understanding the full range of Townsend's ground squirrel movements outward from HCAs.

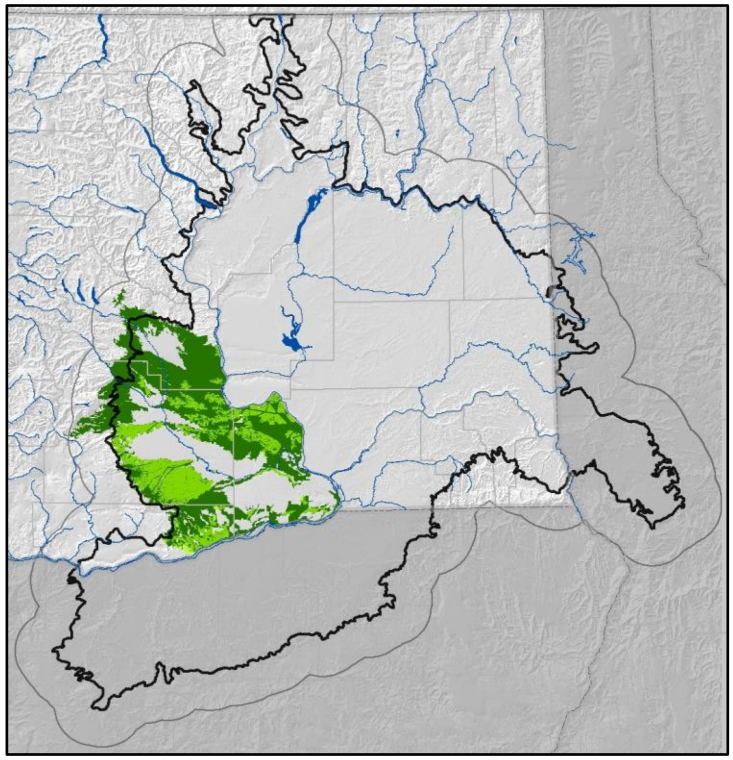

Figure A.5.3. Townsend's ground squirrel HCAs (light green) and GAP distribution (dark green) in the Columbia Plateau Ecoregion.

Linkage Modeling

There were 75 linkages modeled between the Townsend's ground squirrel HCAs (Fig. A.5.6.). Linkage lengths were not constrained during modeling. Least-cost distances for the Townsend's ground squirrel linkages ranged from <1 km to 50 km with a mean of 6 km, while Euclidean distances ranged from <1 km to 26 km with a mean of 3 km.

The results of the linkage model showed a number of strong connections through the matrix. Many corridors run through public lands that may be managed for long-term habitat protection, such as the Yakima Training Center, Hanford National Monument, and several WDFW wildlife areas (e.g., Sunnyside and Rattlesnake Slope wildlife areas). Linkages are generally broad in these public land areas (especially Hanford National Monument and the Yakima Training Center), reflecting the presence of extensive low resistance habitat. However, some corridors appear to be threatened and should be considered for future conservation action. Among these may be the links connecting HCAs in the eastern Horse Heaven Hills to those in southeastern-most Benton County, where expanded irrigated farming is occurring along the SR-395/I-82 corridor.

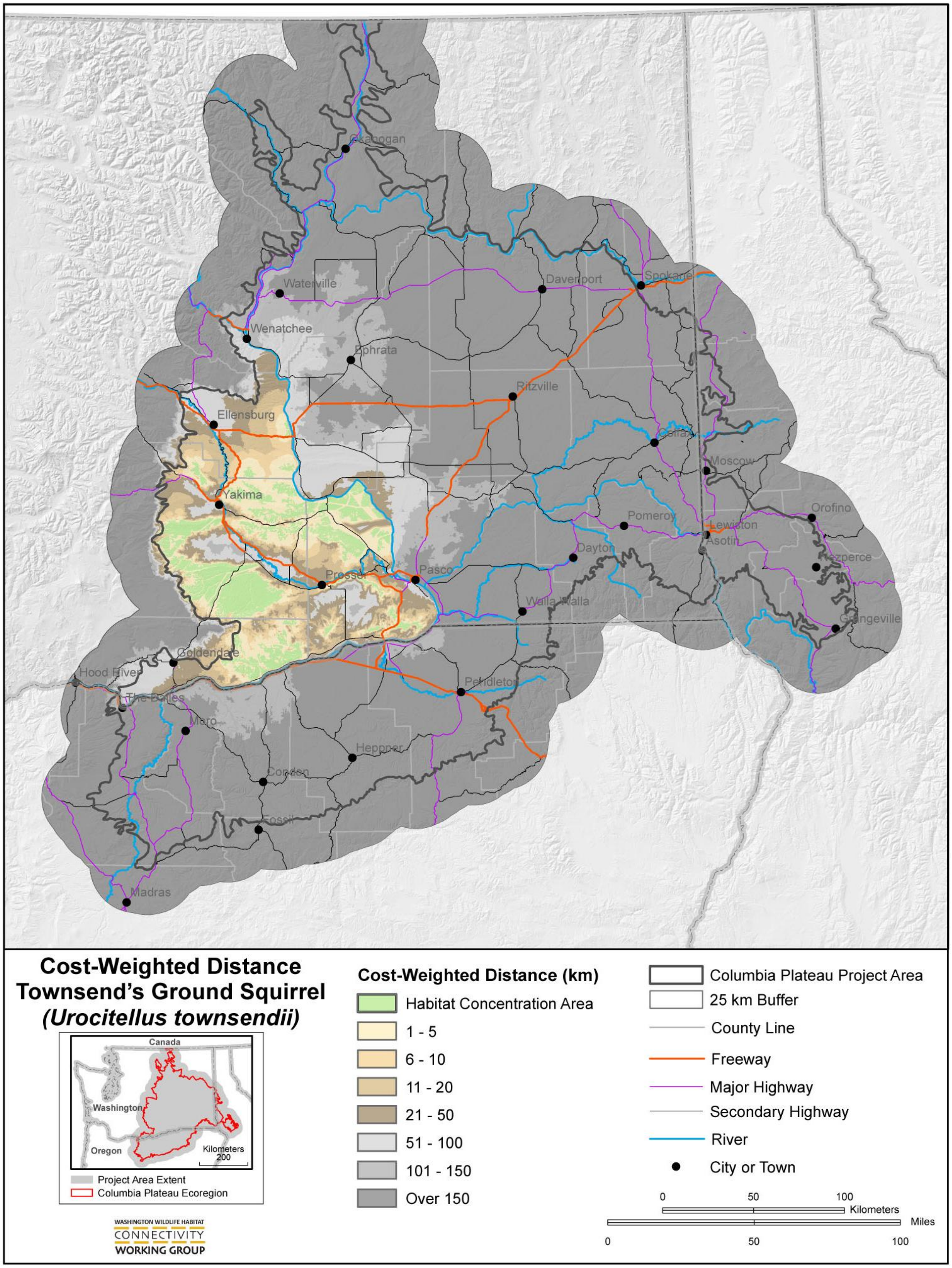

Figure A.5.4. Cost-weighted distance map for Townsend's ground squirrel in the Columbia Plateau Ecoregion.

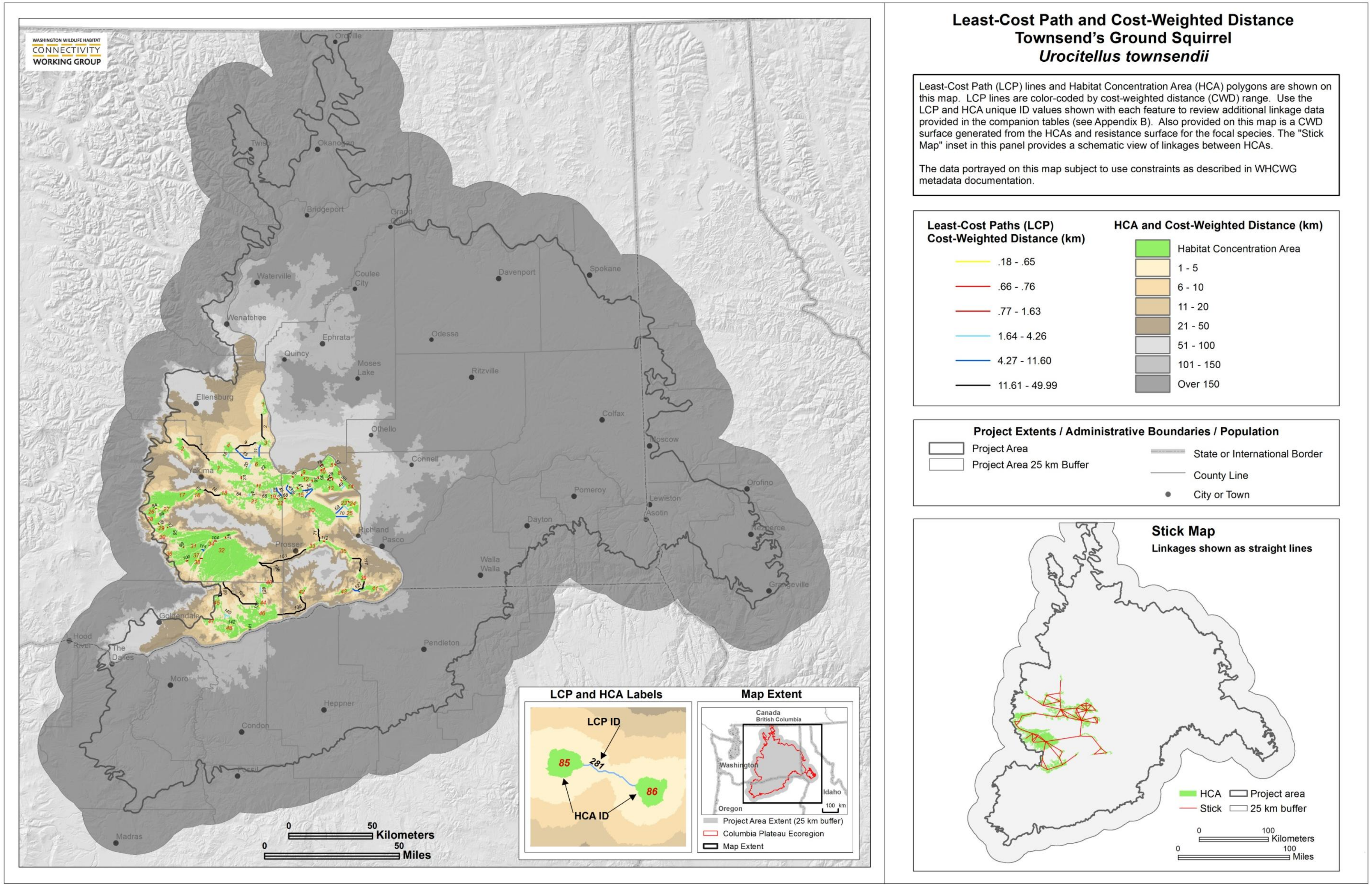

Figure A.5.5. Cost-weighted distance map with numbered HCAs (green polygons labeled with red numerals) and least-cost paths (lines labeled with black numerals) for Townsend's ground squirrel. Linkage modeling statistics provided in Appendix B.

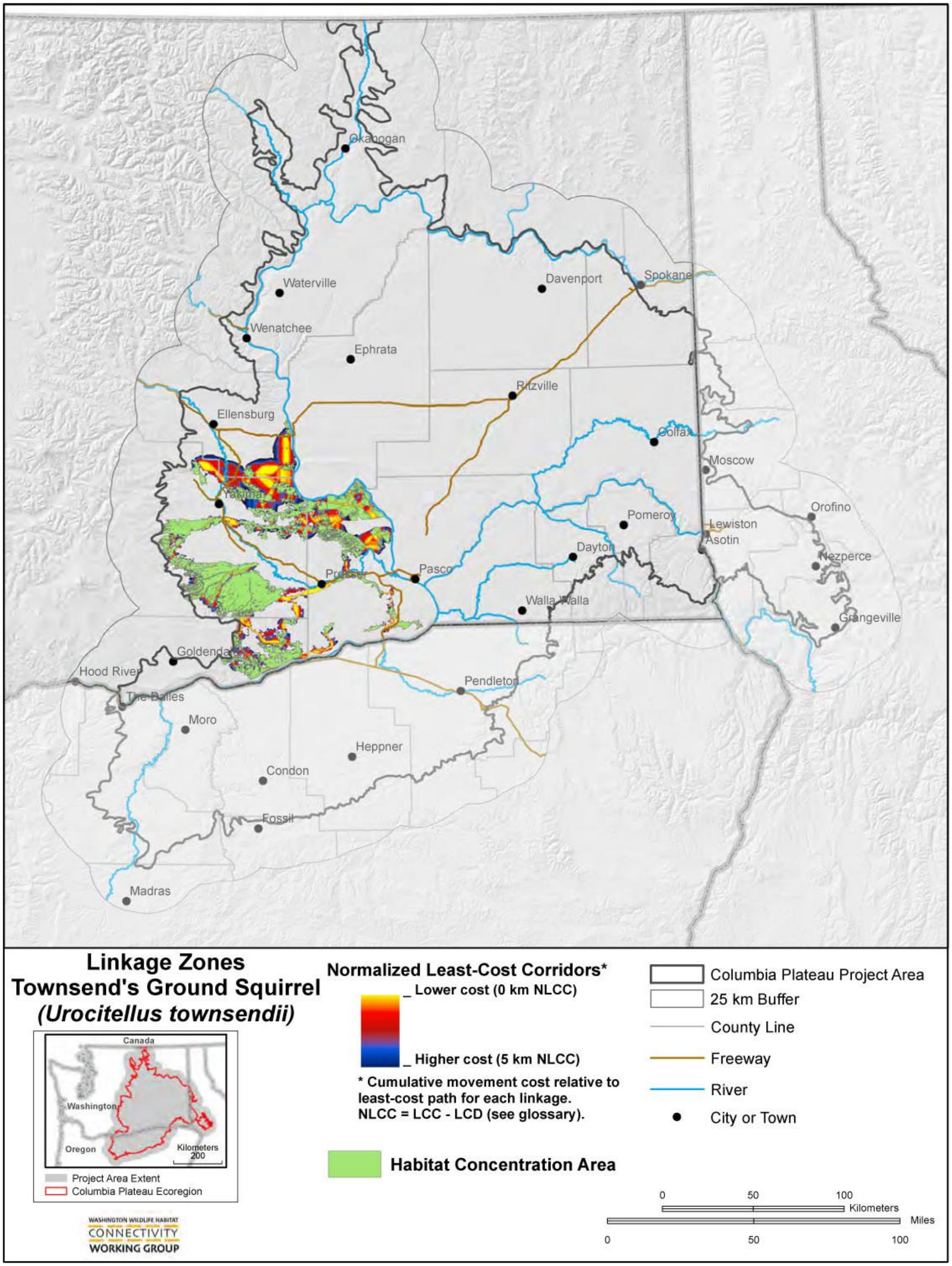

Figure A.5.6. Linkage map for Townsend's ground squirrel in the Columbia Plateau Ecoregion.

Key Patterns and Insights

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

- Information on the population status, habitat preferences, movements, and other aspects of the biology of Townsend's ground squirrel is inadequate and requires much further study. In particular, insufficient knowledge of habitat use patterns may result in some inaccurate conclusions relating to connectivity for this species.
- Townsend's ground squirrels appear to tolerate human proximity and some human-modified habitats (including some areas of highly structured agriculture) 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. At present, squirrel abundance generally appears higher in these habitats than in native plant communities.
- Main stressors for the species are loss of natural habitats to intensive dryland and irrigated agriculture and urban growth. Degradation of native shrubsteppe and grassland communities from undetermined causes may be another threat.
- Public lands, including the Yakima Training Center, the Hanford National Monument (which includes the Arid Lands Ecology Reserve), and several WDFW wildlife areas, support sizeable HCAs and associated linkages.
- The presence of Townsend's ground squirrels within all HCAs (and other areas with suitable habitat) is largely unknown.
- The two subspecies of Townsend's ground squirrel occur on different sides of the Yakima River, suggesting that the river is a natural barrier to gene flow and overall population connectivity. Our model, which did not constrain linkages using cost-weighted distance, shows linkages that cross the Yakima River in two locations. In view of the genetic patterns of the species, these linkages should be disregarded.

Considerations and Needs for Future Modeling

It should be noted that much remains to be learned about the specific habitat requirements and movements of Townsend's 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, both within and beyond shrubsteppe and grassland. Because Townsend's ground squirrels have disappeared from much of their historical range and experienced extensive loss or alteration of native habitat, surviving populations may give a misleading sense of habitat preferences. For example, agricultural conversion of lands and expanding urban development, have probably eliminated the squirrels from areas that were formerly most suitable. Altered landscapes may be dispersal sinks, possibly leading to attrition of Townsend's ground squirrels in their range over time.

Opportunities for Model Validation

Little scientific literature exists on Townsend's ground squirrels, which demonstrates the lack of knowledge about this species. Surveys are strongly needed to ascertain the presence of Townsend's ground squirrels in HCAs and other areas. Studies are required to learn more about the species' habitat use, movements, foraging, and behavior, as well as its response to energy development and other forms of land use change.

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