Chapter 3. Results and Discussion

This chapter describes results from focal species and landscape integrity analyses, as well as results from the integration of focal species and landscape integrity model outputs. Additional discussion can be found in subsequent chapters. Intended uses—and limitations—of our products are discussed in detail in Chapter 4, where we give guidance on interpretation and use of these products. Chapter 5 discusses our working group structure and process, which will be of interest to those involved in connectivity analysis efforts that follow ours. Finally, Chapter 6 looks ahead to future work we consider important to understanding and conserving connectivity, such as incorporating climate change, performing analyses at finer spatial scales, and validating our connectivity models.

3.1. Focal Species Overview

In this section we summarize results of focal species selection, identification of HCAs, and development of resistance surfaces, cost-weighted distance surfaces, and linkages. More detailed individual species accounts follow in Section 3.2.

3.1.1. Focal Species Selection

Sixteen species were ranked as excellent or acceptable for all of the criteria we applied. These consisted of thirteen mammals, two birds, and one amphibian (Table 3.1).

Table 3.1. Focal species selected to represent coarse-scale connectivity priorities in five broad vegetation classes. The vegetation class for which a species ranked well enough for selection is indicated with an "X." Additional vegetation classes where a species occurs are indicated with an "*".

Focal Species	*Semi-desert Habitats*	*Rocky Mt. Forests*	*Vancouverian Forests*	*Subalpine Forests*	*Alpine Habitats*
Sharp-tailed Grouse	X				
Greater Sage-Grouse	X				
American badger	X				
Black-tailed jackrabbit	X				
White-tailed jackrabbit	X				
Mule deer	X	X	*	*	*
Bighorn sheep	*	X			
Western gray squirrel		X	*		
American black bear		X	X	*	*
Elk	*	X	X	*	*
Northern flying squirrel		X	X		
Western toad		X	X	X	*
American marten		*	X	X	
Canada lynx				X	
Mountain goat		*	*	X	X
Wolverine				X	X

3.1.2. Focal Species Habitat Concentration Areas (HCAs)

In Washington, the number of HCAs identified for each species ranged from 4 for the Greater Sage-Grouse to 94 for the western toad (Table 3.2). Additionally, 131 landscape integrity core areas occurred wholly or partially in Washington. Focal species HCAs ranged in size from 24 km^2 (bighorn sheep) to 60,905 km^2 (mule deer).

Table 3.2. Number and size characteristics of focal species HCAs and landscape integrity core areas[a].

Focal species	*Number of HCAs project-wide*	*Number of HCAs Washington*	*HCA size (km^2) range*	*HCA size (km^2) mean (SD)*	*Total of all HCAs (km^2)*
Sharp-tailed Grouse	11	8	70-590	345 (195)	2761
Greater Sage-Grouse	8	4	521-3528	1428 (1428)	5711
American badger	36	16	204-1330	478 (408)	7654
Black-tailed jackrabbit	46	31	56-816	206 (187)	6372
White-tailed jackrabbit	68	38	55-2330	273 (411)	10,372
Mule deer	70	34	100-60,905	4594 (12,831)	156,186
Bighorn sheep	37	17	24-9521	767 (2270)	13,041
Western gray squirrel	34	26	50-589	196 (153)	5104
American black bear	94	27	239-7381	1966 (2218)	53,071
Elk	120	47	104-7176	1057 (1668)	49,680
Northern flying squirrel	229	41	50-7068	504 (1238)	20,648
Western toad	248	94	50-9079	420 (1044)	39,925
American marten	105	39	100-3576	535 (737)	20,865
Canada lynx	31	8	596-5916	1846 (1941)	14,769
Mountain goat	73	29	56-8023	180 (159)	5228
Wolverine	15	2	7199-16,299	11,749 (6435)	23,498
Landscape integrity[b]	349	131	41-9864	503 (1458)	65,841

[a] With the exception of "Number of HCAs project-wide," all statistics pertain to HCAs wholly or partially in Washington.
[b] Landscape Integrity medium sensitivity model.

3.1.3. Focal Species Resistance Surfaces

Across all focal species, resistance values ranged from 1–10,000, with most scores falling at the low end of that range (See Appendix B). Landscape elements assigned the highest average resistance scores included elevations over 3300 m, housing densities greater than one dwelling unit per ten acres, freeways, or urban/developed conditions. Landscape elements consistently assigned low resistance values included areas with few or no roads, low human population densities, and riparian vegetation.

3.1.4. Cost-Weighted Distance Surfaces

Cost-weighted distance maps (See Section 3.2) show the cumulative resistance—a measure of movement difficulty—encountered when moving to any point in our study area from the nearest HCA. They are particularly important because they simultaneously highlight areas that act as ***fracture zones***, suggest the best movement pathways between HCAs, and indicate the difficulty of moving between different HCA pairs (See Chapter 4 for more on interpreting our map products).

3.1.5. Focal Species Linkages

Descriptions of linkages for each focal species are provided in the individual species summaries (See Section 3.2). The number of identified linkages varied with number of HCAs (Table 3.3). The range of Euclidean distances traversed by these linkages ranged from <1 kilometer for several species up to 211 km for a wolverine linkage. Three metrics are useful for describing the quality of a linkage. The first is the cost-weighted distance, or weighted least-cost path (LCP) length. This is the total cumulative resistance encountered as an animal moves along the least-cost path, and values ranged from <1 kilometer weighted distance for western toads and white-tailed jackrabbits to 1322 km for a Canada lynx linkage. The second is the cost-weighted distance divided by the straight line or Euclidean distance, measured edge-to-edge, separating the HCA pair. The third is the cost-weighted distance divided by the non-weighted distance along the least-cost path (Table 3.3); this metric provides the average resistance encountered as animals move along the least-cost path between each HCA pair. For the second and third linkage quality metrics, an optimal linkage has a ratio equal to one. Poor quality linkages have high ratios, as seen in the high end of values for northern flying squirrel and American badger. Further discussion of these metrics and an illustration are provided in Chapter 4.

3.2. Individual Focal Species Background and Results

The focal species summaries that follow provide species-by-species presentations of model results prefaced by a general description of the conceptual basis for each model. Our focal species maps illustrate a spectrum of connectivity conditions for each species, often ranging from highly functional linkages among HCAs to complete lack of connectivity due to natural or human features that fragment habitat. Thus, close inspection of the maps can provide insights into current connectivity conditions in different parts of Washington State. The landscape patterns and the functional implications of the modeling results build progressively through the maps of HCAs, landscape resistance, cost-weighted distance, and linkages (See Appendix A for detailed species narratives).

3.2.1. A Note About Habitat Concentration Areas and GAP Distributions

We identified HCAs for each focal species based on habitat associations documented in the scientific literature and advice from species experts. For focal species that are widespread and relatively abundant, our HCAs represent the 'best of the best habitat' available (as for American marten). For threatened and endangered species, HCAs sometimes include suitable but currently vacant habitat within the species' historical range (as for Sharp-tailed Grouse). We've included Washington State Gap Analysis Project range maps (Cassidy et al. 1997) overlaid with our HCAs for each species to illustrate the relationship between a species' known range and our definition of HCAs. Some of our maps reflect improved knowledge of species' distributions since the Gap Analysis Project was published in 1997. The western gray squirrel, Greater Sage-Grouse, and Sharp-tailed Grouse HCAs include areas believed to be vacant but considered important for species recovery and improved range-wide connectivity. Mountain goat HCAs do not include the Olympic Mountains where this species was introduced.

Table 3.3. Number, length and quality characteristics of focal species and landscape integrity linkages[a].

Focal Species	*Number of Linkages Project-wide*	*Number of Linkages WA*	*Euclidean Dist (km) mean (SD) range*	*LCP Length (km) mean (SD) range*	*Non–weighted LCP length (km) mean (SD) range*	*LCP/Euclidean mean (SD) range*	*LCP/non-weighted mean (SD) range*
Sharp–tailed Grouse	12	12	21(10) 8–40	39(19) 12–70	30(15) 9–55	2(1) 1–4	1(<1) 1–2
Greater Sage–Grouse	5	3	41(15) 30–58	106(37) 80–149	74(12) 63–87	3(2) 2–5	1(<1) 1–2
American badger	54	30	32(26) <1–84	115(84) 1–301	48(37) <1–125	35(161) 1–889	10(41) 1–228
Black–tailed jackrabbit	96	75	23(24) <1–90	67(66) 2–245	32(31) <1–113	11(45) 1–312	4(15) 1–127
White–tailed jackrabbit	131	81	27(30) <1–147	89(178) <1–1124	37(44) <1–222	6(24) 1–213	4(14) 1–128
Mule deer	148	86	19(28) <1–130	56(66) 1–241	24(35) 1–169	4(5) 1–37	3(2) 1–19
Bighorn sheep	50	22	30(34) <1–112	336(333) 1–971	38(44) <1–145	17(18) 9–94	11(7) 3–34
Western gray squirrel	40	35	10(12) <1–49	59(62) 2–199	14(18) <1–73	33(65) 1–137	10(10) 1–26
American black bear	185	44	11(10) 1–32	116(110) 4–363	12(12) 1–40	12(7) 6–51	11(4) 6–32
Elk	295	98	24(30) 1–137	80(69) 2–235	31(37) 1–166	6(5) 1–29	5(4) 1–25
Northern flying squirrel	295	49	6(7) <1–31	37(32) 2–122	9(10) <1–38	49(186) 3–1167	17(50) 2–253
Western toad	420	180	10(9) <1–36	18(14) <1–50	12(10) <1–40	3(7) 1–58	2(4) 1–34
American marten	137	53	8(7) <1–29	97(86) 4–297	9(8) <1–36	15(13) 5–100	11(5) 5–32
Canada lynx	49	13	36(39) <1–107	416(432) 7–1322	50(49) <1–134	15(7) 4–27	10(5) 3–18
Mountain goat	166	71	27(27) <1–134	38(43) <1–171	29(30) <1–151	1(1) 1–7	1(1) 1–6
Wolverine	24	4	91(90) 1–211	574–(273) 319–938	110(103) 2–244	61(110) 4–226	49(88) 4–182
Landscape integrity[b]	741	277	14(18) <1–110	870(1034) 424–6270	20(27) <1–150	97(87) 1–239	74(76) 1–266

[a] With the exception of "Number of Linkages Project-wide," all statistics pertain to linkages wholly or partially in Washington.
[b] Landscape integrity medium sensitivity model.

3.2.2. Sharp-tailed Grouse (*Tympanuchus phasianellus*)

3.2.2.1. INTRODUCTION

Historical evidence indicates that Sharp-tailed Grouse were widely and abundantly distributed in eastern Washington (Schroeder et al. 2000b; Stinson & Schroeder 2010). Significant population declines were observed in the late 1800s and continued steadily throughout the 1900s, primarily as a result of habitat loss and degradation. The current distribution in the state encompasses about 3% of the historical range (Schroeder et al. 2000b). There are an estimated 800 Sharp-tailed Grouse in Washington distributed among seven small, isolated populations in Okanogan, Douglas, and Lincoln counties (Stinson & Schroeder 2010). Sharp-tailed Grouse are listed as Threatened in Washington and are designated a Priority Species, and their habitats Priority Habitats, by the WDFW Priority Habitats and Species Program (Hays et al. 1998b).

Sharp-tailed Grouse, photo by Marc Hallet.

Grassland habitats provide breeding and nesting areas for Sharp-tailed Grouse while deciduous trees and shrubs in upland and riparian areas provide essential food and cover in winter (Giesen & Connelly 1993). The presence of dense herbaceous vegetation and shrubs is of key importance. Plant species composition is secondary to structural characteristics of the habitat (Connelly et al. 1998). Factors important for nesting and brood-rearing habitat include vegetation density and height, and diversity of forbs and bunchgrasses (Geisen & Connelly 1993).

Sharp-tailed Grouse were selected as a focal species because their connectivity needs reflect those of wildlife in the Semi-desert vegetation class. They were considered vulnerable to loss of habitat connectivity attributed to development.

3.2.2.2. MODEL CONCEPTUAL BASIS

Habitat concentration areas were identified using WDFW distribution information for Sharp-tailed Grouse. These areas were defined using extensive surveys, active lek locations, movements of radio-marked birds, observations of birds year-round, and distribution of occupied habitat. Washington Department of Fish and Wildlife has identified the Methow Recovery Unit as having high conservation potential for re-introduction of Sharp-tailed Grouse (Stinson & Schroeder 2010). This area was also included and identified from WDFW mapping products.

To characterize landscape resistance for Sharp-tailed Grouse we used, whenever possible, documented behavior and habitat associations. When information was lacking we relied upon the professional judgment and knowledge of expert grouse biologists to score resistance values. Urban development, human population density and roads were considered major factors contributing to landscape resistance for Sharp-tailed Grouse.

Little is known about dispersal by juvenile Sharp-tailed Grouse. Gratson (1988) recorded natal dispersal for one Sharp-tailed Grouse in Wisconsin; a juvenile female nested 1.4 km from the range it used as a chick. Seasonal movement information for Sharp-tailed Grouse is limited to data collected from radio-marked birds captured at leks (traditional breeding sites) and monitored throughout the year. From spring through autumn Sharp-tailed Grouse move fairly short distances; females in Washington nested an average 1.3 km from the leks where they were captured (Schroeder 1994). Boisvert et al. (2005) monitored Sharp-tailed Grouse on Conservation Reserve Program (CRP) and mine reclamation lands in northwestern Colorado. During winter birds were a median distance of 21.5 km from lek sites where they were captured. The relatively short distances moved by Sharp-tailed Grouse in Washington may be influenced by the fragmented nature of the habitat and associated populations (M. Schroeder, personal communication).

3.2.2.3. MODEL RESULTS

Habitat Concentration Areas — Eight HCAs for Sharp-tailed Grouse are small and clustered in the north-central part of Washington in Okanogan County, within the Okanogan Valley, and in parts of northern Douglas and Lincoln Counties (Fig. 3.1). Area of HCAs ranged from 70 km^2 to 590 km^2 (Table 3.2).

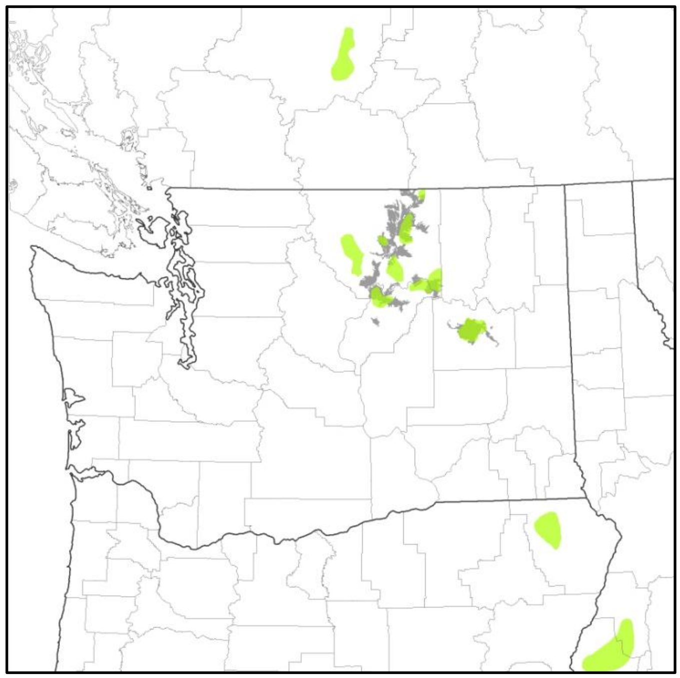

Figure 3.1. Sharp-tailed Grouse HCAs (green) and GAP distribution (gray).

Resistance Surface — The Sharp-tailed Grouse resistance surface (Fig. 3.2) shows a band of resistance due to U.S. Highway 97 running north-south through the HCA cluster within the Okanogan Valley. In general, HCAs are situated away from developed areas and high traffic-volume roads in higher elevation “islands” of habitat. Areas of least resistance tend to be fragmented and reflect the distribution of native shrubsteppe. The HCA in the Methow Valley in Okanogan County is surrounded by habitat of high resistance except for its southern border. In general, the resistance surface suggests that there are few options for additional HCAs in the state as many of the areas of low resistance are fragmented by agriculture, highways and development.

Cost-weighted Distance — There are fairly good conditions for movement among most of the centrally located HCAs in Washington (Fig. 3.3). Movement between the HCA in Lincoln County and the HCA on lands of the Colville Confederated Tribes in Okanogan County is limited to one fairly small area that skirts the Columbia River. The Methow Valley HCA is separated from the closest HCA in Okanogan County (on the Scotch Creek Wildlife Area) by an area of high resistance. Conditions for movement look relatively good among the HCAs in Douglas and Okanogan Counties. Agriculture, urban areas and highways create areas of highest resistance.

Notably, the cost-weighted distance map for Sharp-tailed Grouse has some interesting parallels with the chronology of range contraction map presented in the WDFW 2010 Sharp-tailed Grouse

Draft Recovery Plan (Stinson & Schroeder 2010). The outline of dark brown surrounding the HCAs is similar to the distribution of Sharp-tailed Grouse circa 1980 and the light gray 41–100 km cost-weighted distance extent is similar to Sharp-tailed Grouse distribution circa 1930.

Linkage Modeling — Modeled linkages between HCAs were considered when the least-cost distance between a pair of HCAs was less than 80 km (Fig. 3.4). This resulted in linkages between 12 discrete pairs of HCAs within Washington (Table 3.3). Linkage distances between HCAs were as follows: Euclidean distance (mean of 21 km [SD 10], range 8–40 km), weighted least-cost path distance (mean of 39 km [SD 19], range 12–70 km), and non-weighted least-cost path distance (mean of 30 km [SD 15], range 9–55 km).

Two linkage quality ratios were calculated for the Sharp-tailed Grouse modeling outputs: the ratio of cost-weighted distance to Euclidean distance (mean of 2.0 [SD 0.9], range 1.3–4.1) and the ratio of cost-weighted distance to least-cost path length (mean 1.3 [0.2], 1.1–1.6). The low ratio averages for linkage quality measures suggests that conditions for movement between HCAs are fairly good for Sharp-tailed Grouse. Linkage ratios were highest between HCAs separated by Highway 97 and between HCAs separated by forest.

Two of the HCAs (one in northern Okanogan County and one in Lincoln County) are peripheral and only connect to one other HCA. Disruption or increased resistance of these linkages would increase the likelihood of isolation of these HCAs. One of the HCAs connects to five others. The ***centrality*** of this particular HCA suggests that its loss or disruption would have a negative impact on a substantial portion of the population.

Most of the linkage corridors are within the movement capability of Sharp-tailed Grouse. However, each of the HCAs is occupied by relatively few birds, less than 100 individuals. Although linkages exist among the HCAs, it is not clear how movement behavior by Sharp-tailed Grouse might be influenced by low population size and past history of isolation.

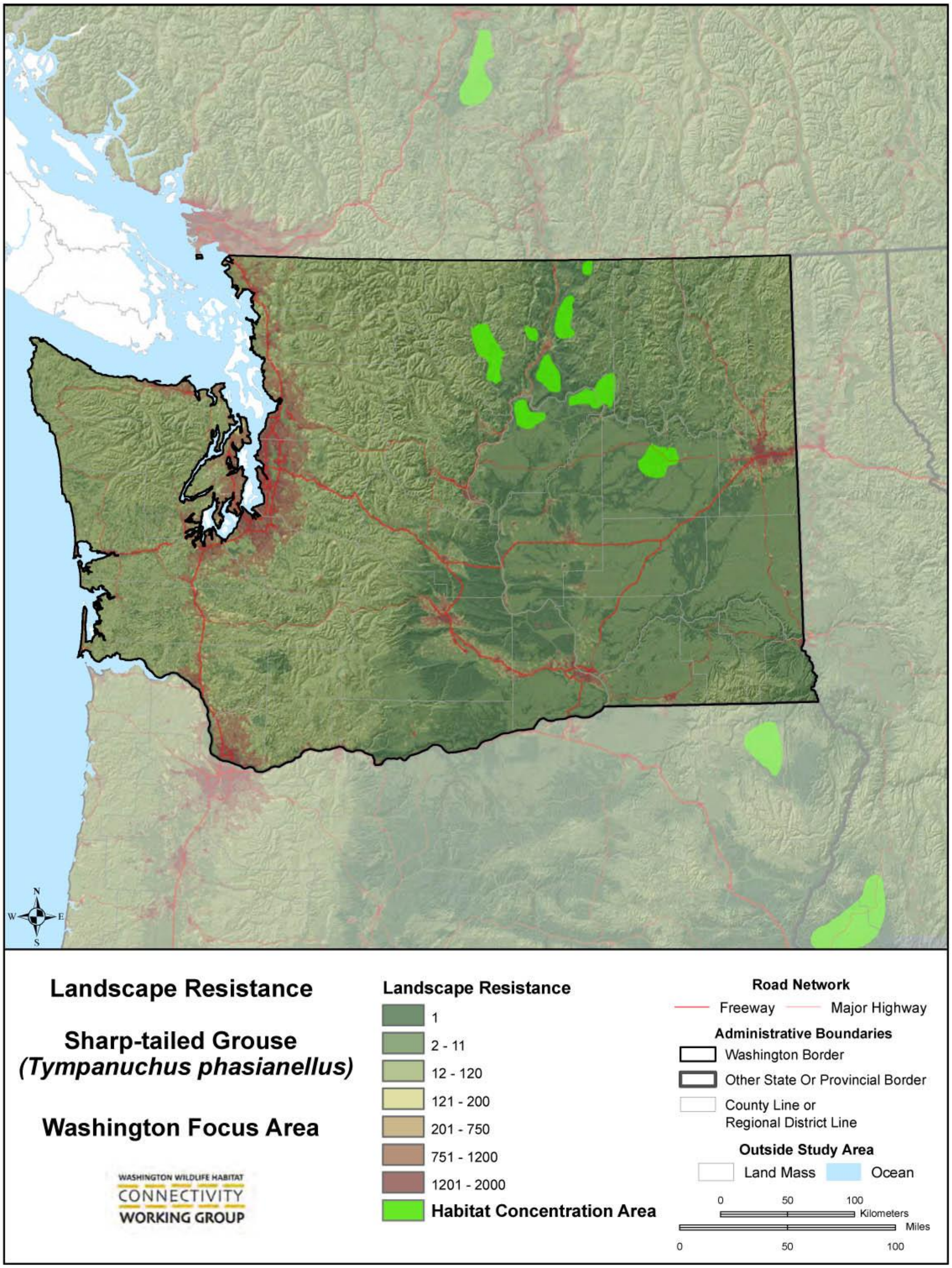

Figure 3.2. Landscape resistance for Sharp-tailed Grouse.

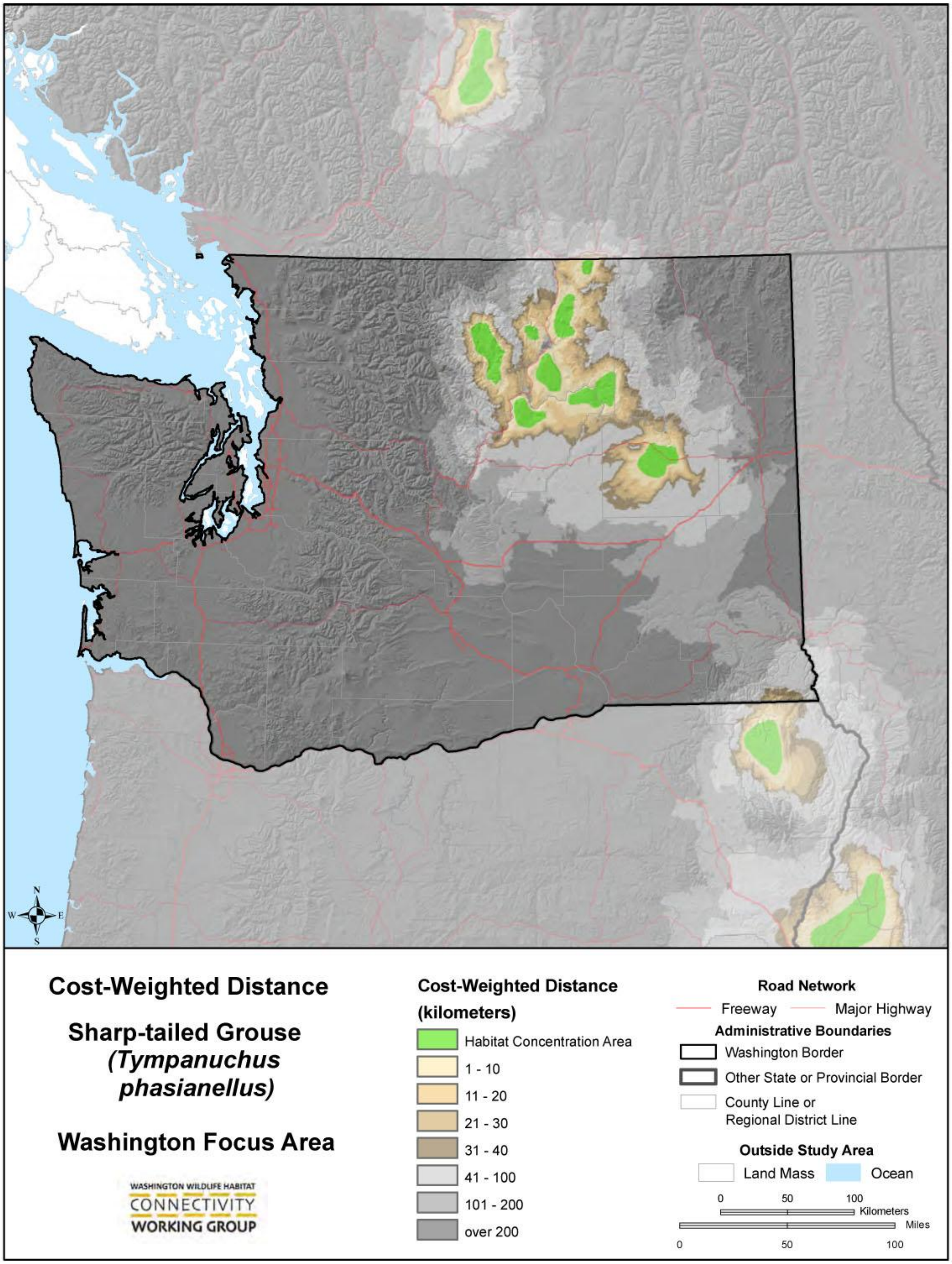

Figure 3.3. Cost-weighted distance for Sharp-tailed Grouse.

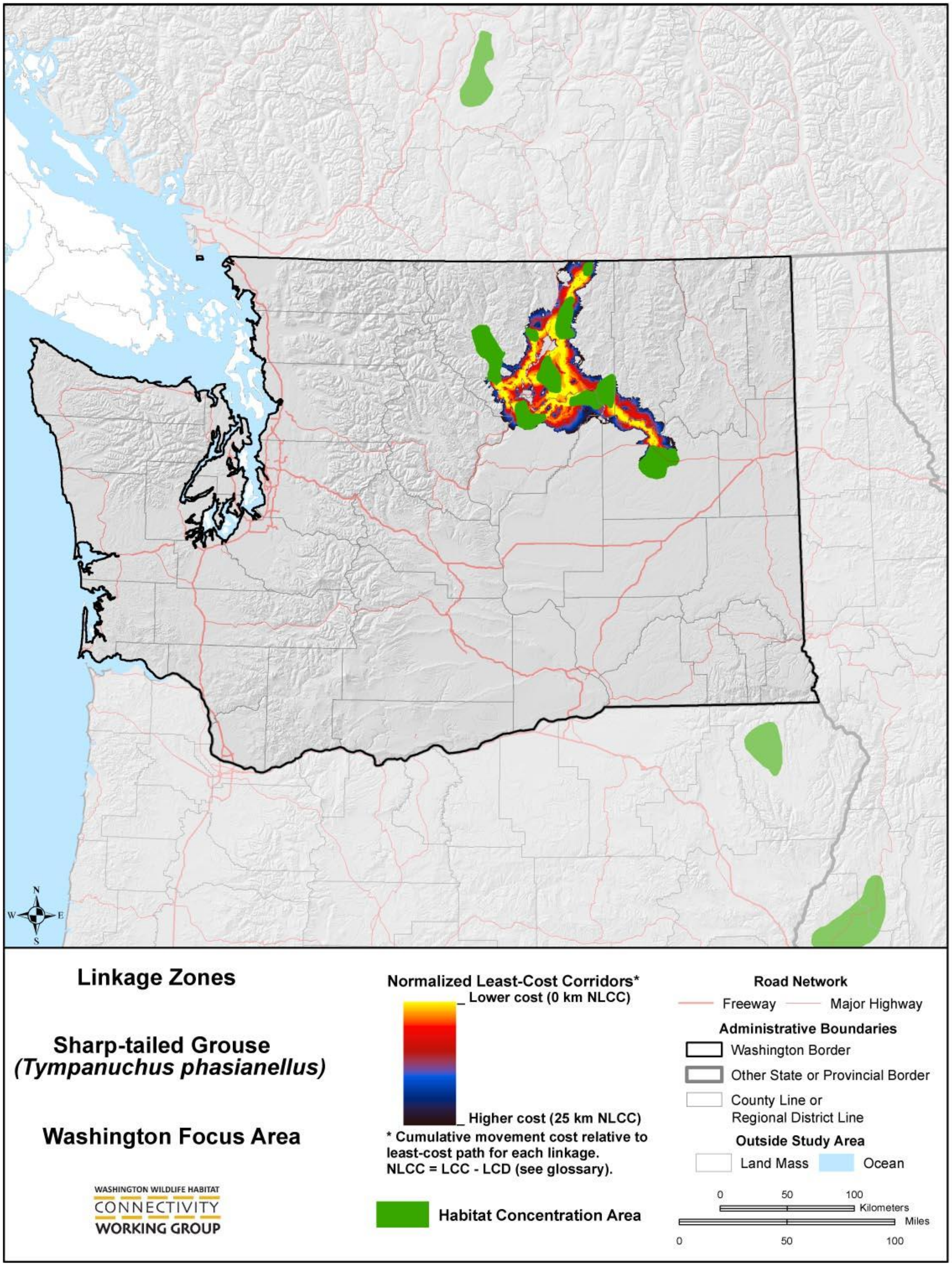

Figure 3.4. Sharp-tailed Grouse linkages.

3.2.3. Greater Sage-Grouse (*Centrocercus urophasianus*)

3.2.3.1. INTRODUCTION

Spectacular breeding displays and dependence on sagebrush habitats make Greater Sage-Grouse icons of the West. They were once widely distributed throughout central and eastern Washington (Schroeder et al. 2000a) but declined as shrubsteppe habitat was cultivated, primarily for production of wheat. Only about 8% of the historical range in the state is occupied and the total number of birds is around 1100 (Schroeder et al. 2000a; M. Schroeder, personal communication). There are two geographically distinct populations in Washington. One population is located in the Moses Coulee area in Douglas/Grant counties and one is on the U.S. Army's Yakima Training Center (YTC) in Yakima/Kittitas counties (Schroeder et al. 2000a; Stinson et al. 2004). These populations are isolated from each other by 50 km and from populations in Oregon and Idaho by about 250 km and 350 km. Greater Sage-Grouse are listed as Threatened in the state of Washington and are considered a Priority Species by the WDFW Priority Habitats and Species Program (Hayes et al. 1998a; Stinson et al. 2004). Greater Sage-Grouse are a federal Candidate species with regard to listing under the U.S. Endangered Species Act (USFWS 2010).

Greater Sage-Grouse, photo by Rob Bennetts.

Greater Sage-Grouse have large home ranges, are capable of extensive movements, and use a mosaic of habitat patch sizes within the sagebrush ecosystem. They are shrubsteppe obligate species because of their year-round dependence on sagebrush (*Artemisia* spp.) dominated habitats for food and cover (Schroeder et al. 1999). The quality of shrubsteppe habitat is critical as many uncultivated areas are not suitable because of lack of sagebrush, perennial grasses and forbs (Schroeder et al. 1999). Winter habitat for Greater Sage-Grouse consists of large stands of good quality sagebrush. Presence of sagebrush is essential for its survival, comprising roughly 100% of the winter diet (Schroeder et al. 1999).

Greater Sage-Grouse were selected as a focal species because they are a landscape species whose habitat connectivity needs reflect those of wildlife in the Semi-desert vegetation class. They were considered vulnerable to loss of habitat connectivity from three of the four main connectivity threats: (1) development, (2) roads and traffic, and (3) presence of people and domestic animals.

3.2.3.2. MODEL CONCEPTUAL BASIS

Within the assessment boundary, HCAs for Greater Sage-Grouse were mostly defined by extensive surveys; occupied areas were identified by active lek locations, movements of radio-marked birds, observations of birds year-round, and distribution of occupied habitat (Stinson et al. 2004). Additional areas recognized by WDFW as having high conservation potential for re-establishing Greater Sage-Grouse populations were also included as HCAs and delineated by WDFW management units (Stinson et al. 2004).

Recent studies have examined the impact of the human footprint on Greater Sage-Grouse habitat and population persistence (Connelly et al. 2004; Aldridge et al. 2008; Knick & Hanser 2010). Greater-sage Grouse are highly sensitive to development and disturbance from human activity.

We assigned resistance values to landscape features based on published literature of Greater Sage-Grouse habitat use, behavior and movements. When information was lacking we relied upon the professional judgment of expert reviewers to provide guidance when developing the model. Greater Sage-Grouse in Washington tend to move less than 30 km between seasonal breeding and wintering areas (Schroeder & Vander Haegen 2003). Some birds move considerably further distances. These birds are the ones important for maintaining connectivity among/between populations.

3.2.3.3. MODEL RESULTS

Habitat Concentration Areas — While there is overlap between our HCAs and the predicted GAP distribution (Fig. 3.5) they differ somewhat for a few reasons: (1) we were able to use WDFW population distribution data when identifying our HCAs, (2) Greater Sage-Grouse are known to use Conservation Reserve Program lands which are considered agricultural, and (3) shrubsteppe quality is an important factor determining habitat for Greater Sage-Grouse.

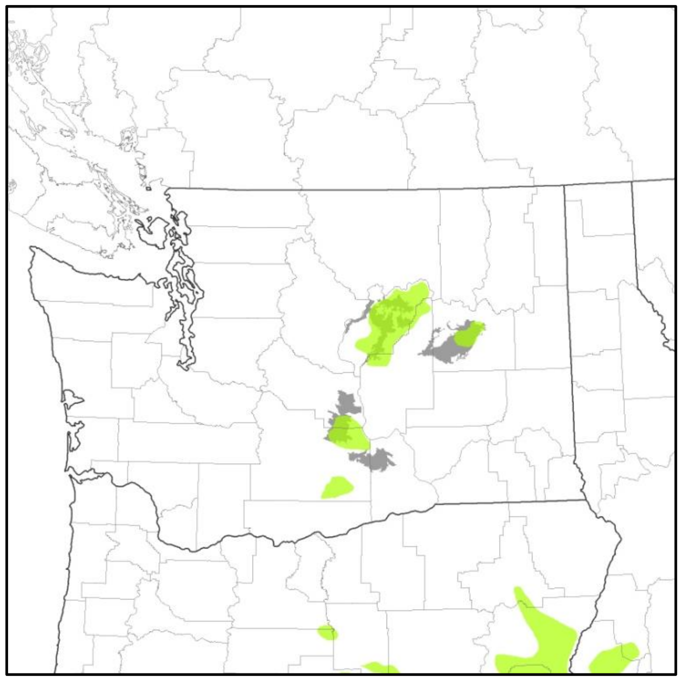

Figure 3.5. Greater Sage-Grouse HCAs (green) and GAP distribution (gray).

The HCAs in Douglas/Grant counties and on the YTC in Yakima and Kittitas counties are based on WDFW GIS distribution data of Greater Sage-Grouse populations. The HCA furthest east in Lincoln County is the Swanson Lakes Wildlife Area (SLWA) and represents the area occupied by a small re-introduced population of Greater Sage-Grouse. The most southerly HCA in Washington is located in Yakima County on Yakama Nation lands and is based on the WDFW Toppenish Ridge Greater Sage-Grouse management unit. Greater Sage-Grouse have been re-introduced to this area however there is currently no known population. All of the HCAs for Greater Sage-Grouse are situated in shrubsteppe habitats and the HCA in Douglas County also has substantial cropland in CRP. The HCAs for Greater Sage-Grouse ranged from 521 km^2 to 3528 km^2 in area.

Resistance Surface — The modeled resistance surface for Greater Sage-Grouse indicates variable conditions for movement of Greater Sage-Grouse among HCAs (Fig. 3.6). The HCA in Yakima County on Yakama Nation lands is separated from the YTC HCA by a band of high resistance due to urban development and freeway infrastructure along the route of Interstate 82 (I-82). Conditions for movement look fairly good between the YTC and Douglas/Grant HCAs however the band of low resistance between these HCAs is relatively narrow. The Columbia River marks a north-south “border” in the resistance surface between these HCAs; the area to the west of the Columbia River has lower resistance than the land to the east. Habitat west of the Columbia River is predominately shrubsteppe while east of the river is mostly agriculture.

Although I-90 creates a band of high resistance running east-west between the YTC and Grant/Douglas HCAs it is not likely an insurmountable barrier to movement. The resistance surface indicates fairly good conditions for Greater Sage-Grouse movement between the Swanson Lakes HCA and the Douglas/Grant HCA, particularly on the southern end of each HCA.

Cost-weighted Distance — Potential for movement exists among the four HCAs in Washington. Conditions for movement are probably best between the HCA in Douglas/Grant counties and the HCA in Lincoln County (Fig. 3.7), although there is an area of high resistance extending north-south between these two HCAs. The connection between the HCA in Douglas/Grant counties and the HCA in the YTC in Yakima County follows native shrubsteppe habitat (See Fig. 3.6) and is influenced by areas of high resistance to the east and west due to development, agriculture and the Columbia River, as well resistance from I-90. Interstate 82 between Yakima and Richland creates a significant barrier to movement between the YTC and Yakama Nation lands HCAs.

Linkage Modeling — Linkages were modeled when the least-cost distance between a pair of HCAs was less than 200 km cost-weighted distance. This created three linkages within Washington (Fig. 3.8). Linkage distances between HCAs were as follows: Euclidean distance (mean of 41 km [SD 15], range 30–56 km), weighted least-cost path distance (mean of 106 km [SD 37], range 80–149 km), and non-weighted least-cost path distance (mean of 74 km [SD 12], range 63–87 km).

Two linkage quality ratios were calculated for the Greater Sage-Grouse modeling outputs. The ratio of cost-weighted distance to Euclidean distance (mean of 2.9 [SD 1.8], range 1.6–5.0) and the ratio of cost-weighted distance to least-cost path length (mean of 1.4 [SD 0.3], range 1.1–1.7). The ratio of cost-weighted distance to Euclidean distance indicates how “hard” it is to move between HCAs relative to how close they are. The ratio of cost-weighted distance to least-cost path length indicates the average resistance encountered moving along the optimal path between a pair of HCAs. The highest ratio values were for the linkage between the YTC HCA and the Yakama Nation HCA. The lowest ratio values were for the linkage between the YTC HCA and the HCA in Douglas/Grant counties.

The linkage between the YTC HCA and the HCA on Yakama Nation lands is highly constrained on the southern end as it passes through an area of high resistance. Local biologists have indicated that our land-cover base layer may not adequately address the increased development that has occurred in this area within the last few years. It is likely that the constrained part of the linkage, which passes through the Horse Heaven Hills area near I-82, no longer exists.

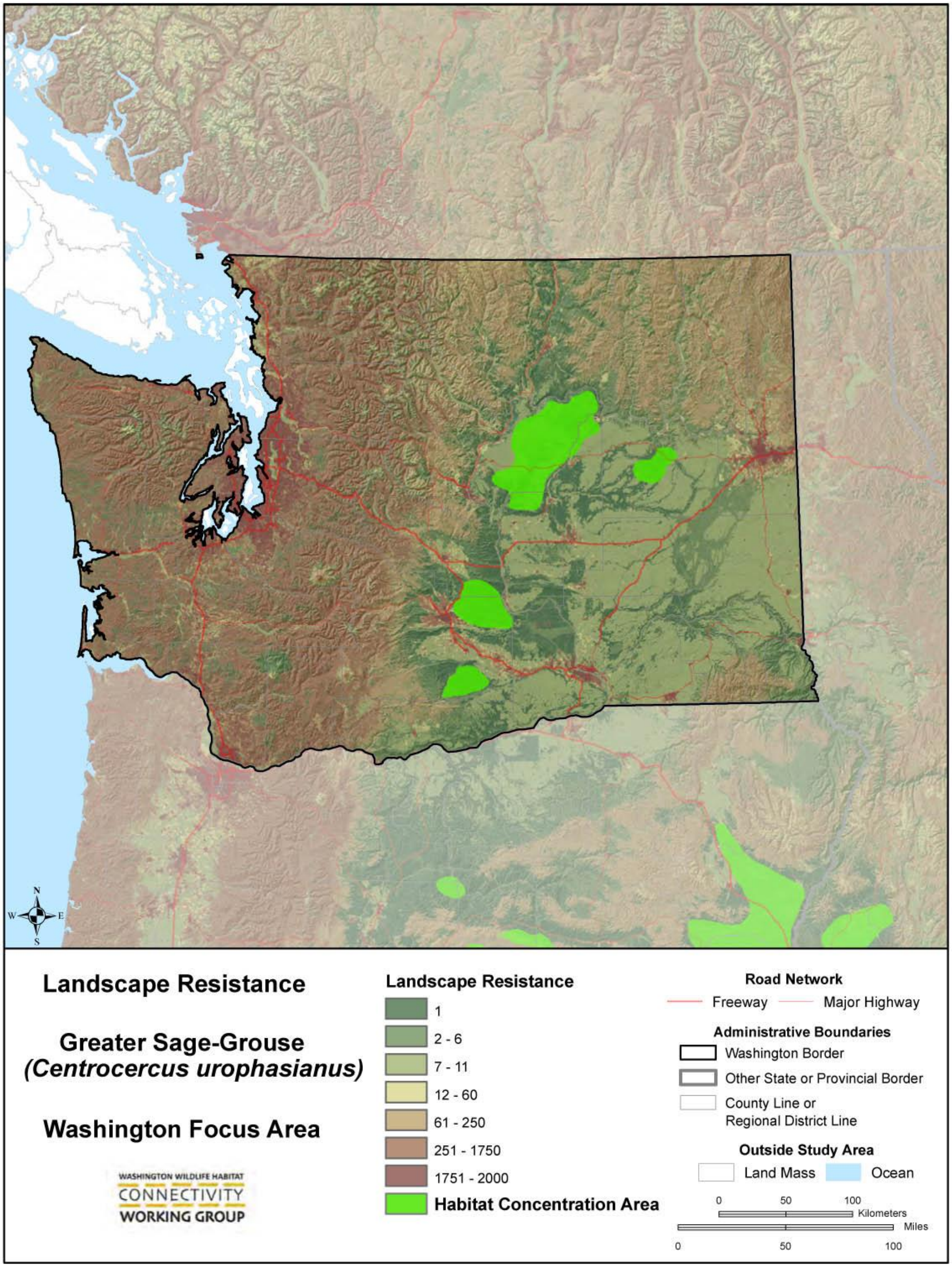

Figure 3.6. Landscape resistance for Greater Sage-Grouse.

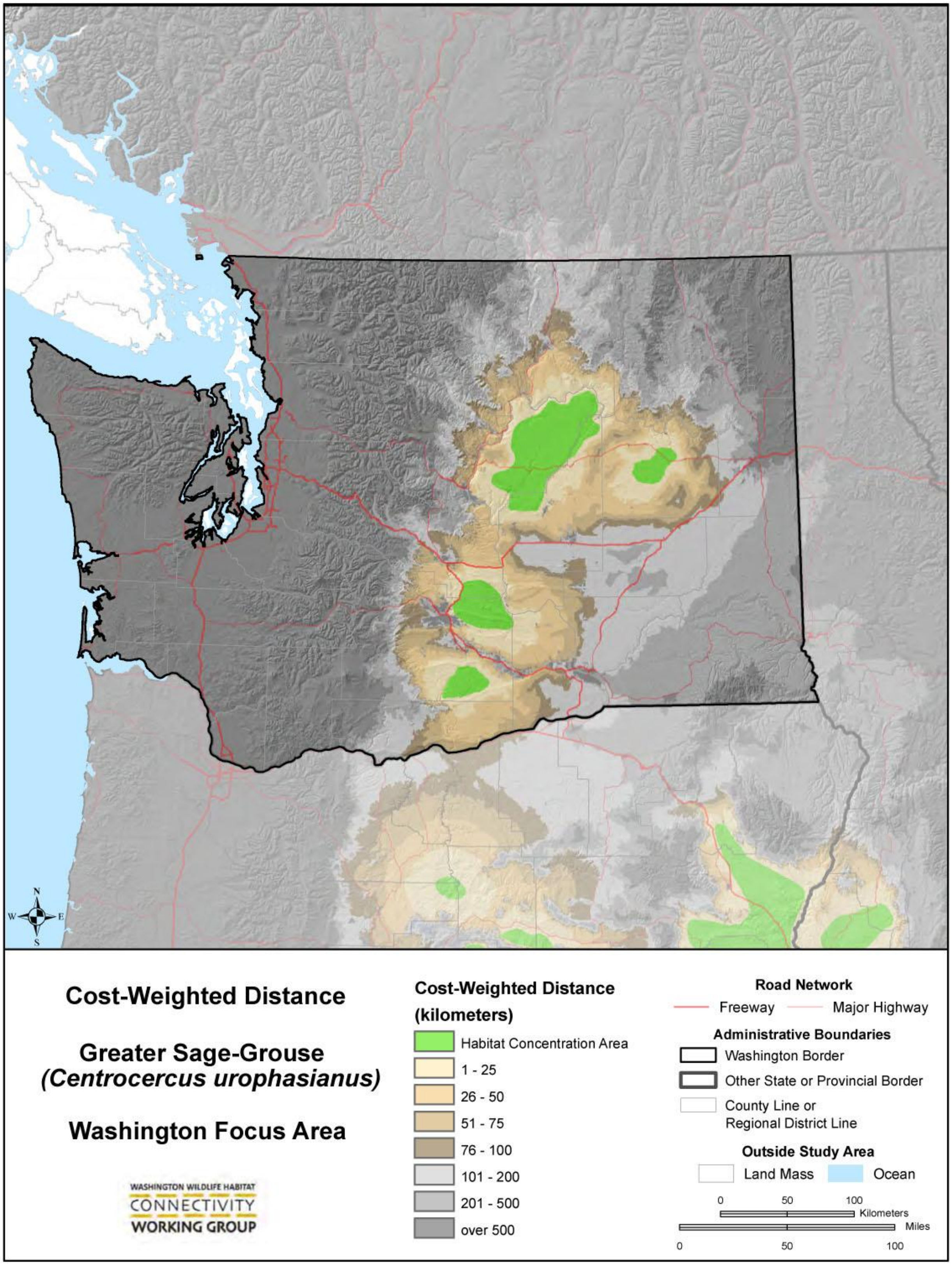

Figure 3.7. Cost-weighted distance for Greater Sage-Grouse.

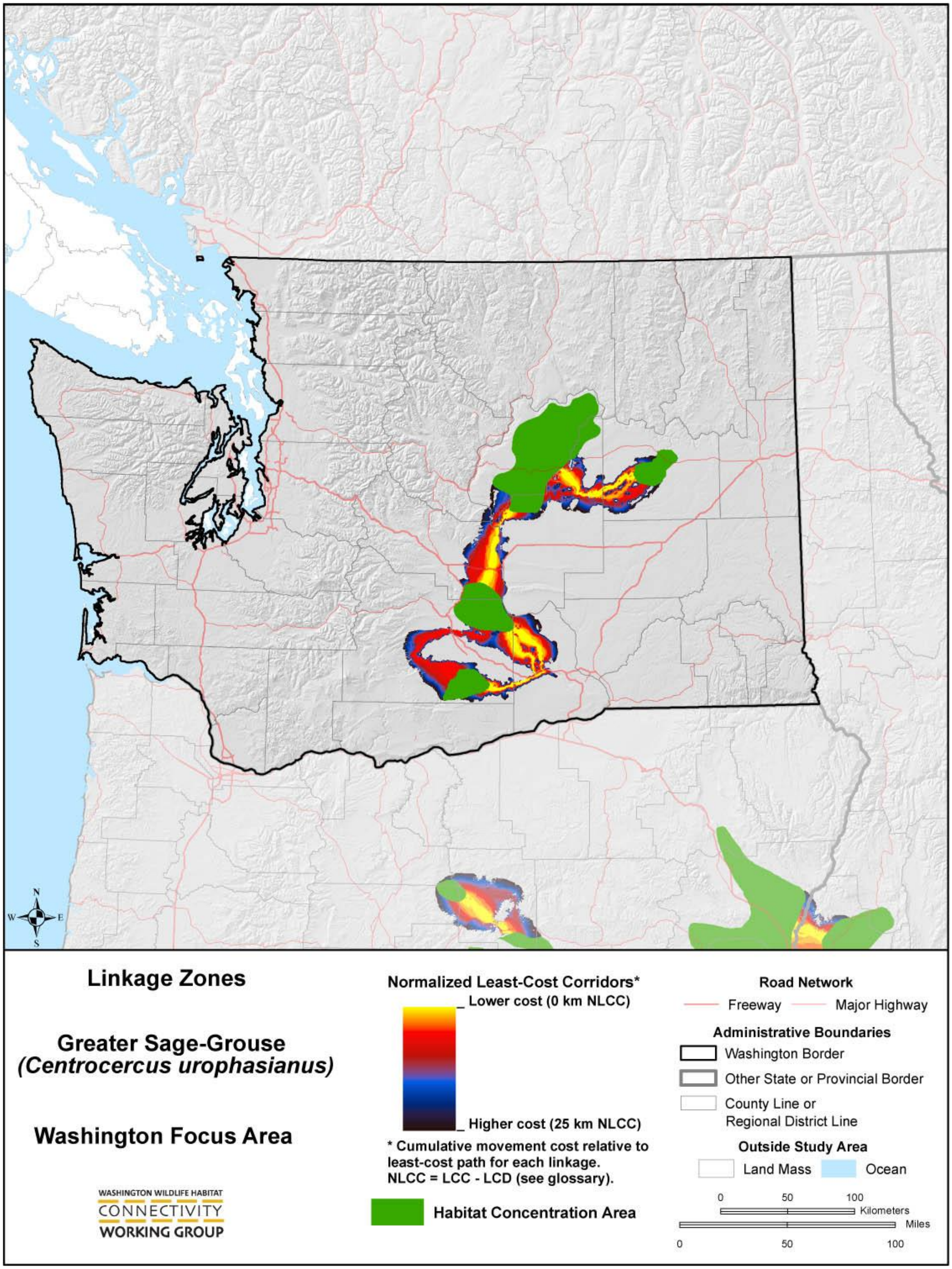

Figure 3.8. Greater Sage-Grouse linkages.

3.2.4. American Badger (*Taxidea taxus*)

3.2.4.1. INTRODUCTION

The American badger ranges from British Columbia, Canada to southern California and across the western United States. In Washington, it is an eastside species. South of Vantage (Kittitas County), its range extends up valleys penetrating the East Cascades and across the southern part of the state. North of Vantage, the western edge of its range is east of the Methow Valley in Okanogan County. In the northeast it occurs primarily in the Okanogan Highlands and in the bottoms of the major river drainages (Johnson & Cassidy 1997).

American badger, photo by Sunny Walter.

The American badger was selected as a focal species because its connectivity needs reflect those of wildlife in the Semi-desert vegetation class. Badgers are open habitat specialists that occupy shrub/grassland and occasionally open forest habitats. All recorded badger observations in the state are in dry-shrub or grassland habitat, or on the fringes of agricultural lands, with the exception of one observation in the Kettle Mountains which was likely a dispersing animal (WDFW 2010). American badgers require deep soils and adequate fossorial, or burrowing prey (Messick & Hornocker 1981). Optimal soil types are silty and sandy loams (Apps et al. 2002; Eldridge 2004; Diamond 2006). Soil conditions explain the presence and abundance of badger prey species. Thus, they are important to badgers as well (Lindzey 1976; T. Kinley, personal communication). However, badgers are capable of traversing a variety of habitats that fall outside their core habitat requirements (Messick & Hornocker 1981; Newhouse & Kinley 2000; T. Kinley, personal communication).

Badgers are vulnerable to loss of habitat connectivity from three of the four main connectivity threats: development, roads and traffic, and the presence of people and domestic animals. Although badgers are fairly tolerant of human activity, they face increased risk of mortality from vehicle traffic and persecution by people. They are listed as a Species of Greatest Conservation Need in Washington due to habitat loss and human-related threats.

3.2.4.2. MODEL CONCEPTUAL BASIS

Resistance values for landscape features were derived from descriptions in the literature of badger habitat and movements. In cases where little published information was available we relied upon the professional judgment of expert reviewers. Movement routes used by badgers are expected to be influenced by availability of rodent prey, land-cover type, and human disturbance (persecution and vehicle traffic). Factors impeding their movement throughout the landscape include vehicle traffic, urban land-uses, and human population density.

Home range size of American badgers varies from about 9 km^2 for males and 6 km^2 for females in eastern Washington (Paulson 2007) to 69 km^2 in highly fragmented habitat in British Columbia (Newhouse & Kinley 2000). In general, home range size is correlated with prey density, female availability and habitat features (Hoodicoff & Larsen 2009). The longest recorded dispersal distances for an American badger are 110 km for a juvenile male and 52 km for a juvenile female (Messick & Hornocker 1981). However, these distances are believed to be considerably less than what a badger is capable of moving (Messick & Hornocker 1981). We chose a maximum weighted distance of 301 km for linkages. This distance provides a best-fit model based on cost-weighted corridor maps and HCA modeling, as well as recorded Washington occurrence points.

3.2.4.3. MODEL RESULTS

Habitat Concentration Areas — Sixteen American badger HCAs were identified in Washington, ranging from 204 to 1330 km^2 in size (Fig. 3.9). Mean HCA size was 478 km^2; total area of all HCAs was 7654 km^2 (Table 3.2). The HCAs delineate the limits of what is considered badger habitat, from the foothills of the East Cascades, north through the Okanogan Valley, and east to the agricultural areas of eastern Adams County. Some of the shrubsteppe and grassland areas in the central Columbia Basin did not show up as HCAs because of the large minimum patch size used to identify HCAs. These areas of native habitat were intermixed with agricultural lands. American badger HCAs in most cases, include recorded occurrence points. Several sizeable HCAs are located on public lands, including WDFW wildlife areas, Yakama Tribal lands, the Yakima Training Center, and the Hanford site (which includes the Arid Lands Ecological Reserve).

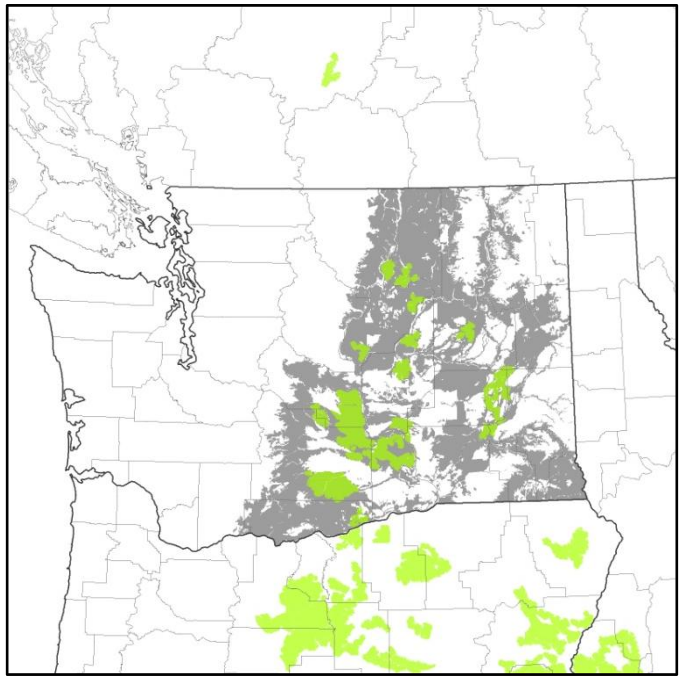

Figure 3.9. American badger HCAs (green) and GAP distribution (gray).

Resistance Surface — The resistance surface for badgers (Fig. 3.10) demonstrates relatively free badger movement throughout their range with the exception of urban areas. Interstate 90 and the Columbia River impose increased resistance to badger movements but are not impermeable barriers for badgers, which will cross highways and swim across rivers.

Cost-weighted Distance — The badger cost-weighted distance map provides a view of the full range of areas the model indicates as most suitable for badger movements away from HCAs (Fig. 3.11). This map is most useful for understanding the full range of badger movement through landscapes beyond least-cost corridors produced by the linkage model output.

Linkage Modeling — Linkages were modeled when the least-cost distance between a pair of HCAs was less than 301 km. This resulted in linkages being modeled between 30 discrete pairs of HCAs in Washington (Fig. 3.12). Least-cost distances for these 30 linkages ranged from 1 km to 301 km with a mean of 115 km, while Euclidean distances ranged from <1 km to 84 km with a mean of 32 km). The ratio represented by the least-cost distance divided by the Euclidean distance had a range of 1 to 889 with a mean of 35 (Table 3.3). The results of the linkage model for badgers generally showed strong connections throughout the HCA matrix. Many corridors run through public lands that may be managed for long-term habitat protection. The major interruption to connectivity occurs at I-90 between Vantage and Kittitas, which separates two HCAs that otherwise would have been combined.

Some other ***pinch points*** occur in corridors running: (1) just northwest of the Potholes Reservoir where the corridor squeezes between I-90 and irrigated agriculture; (2) north/south along the Grand Coulee, where it is constrained by the Columbia River on one side and development on the other; and (3) along the Wahluke Slope, where it winds between agricultural lands and developed lands. Because the minimum patch size for the HCAs is large, smaller patches of suitable and occupied habitat, as well as the linkages connecting them to others, were not accounted for.

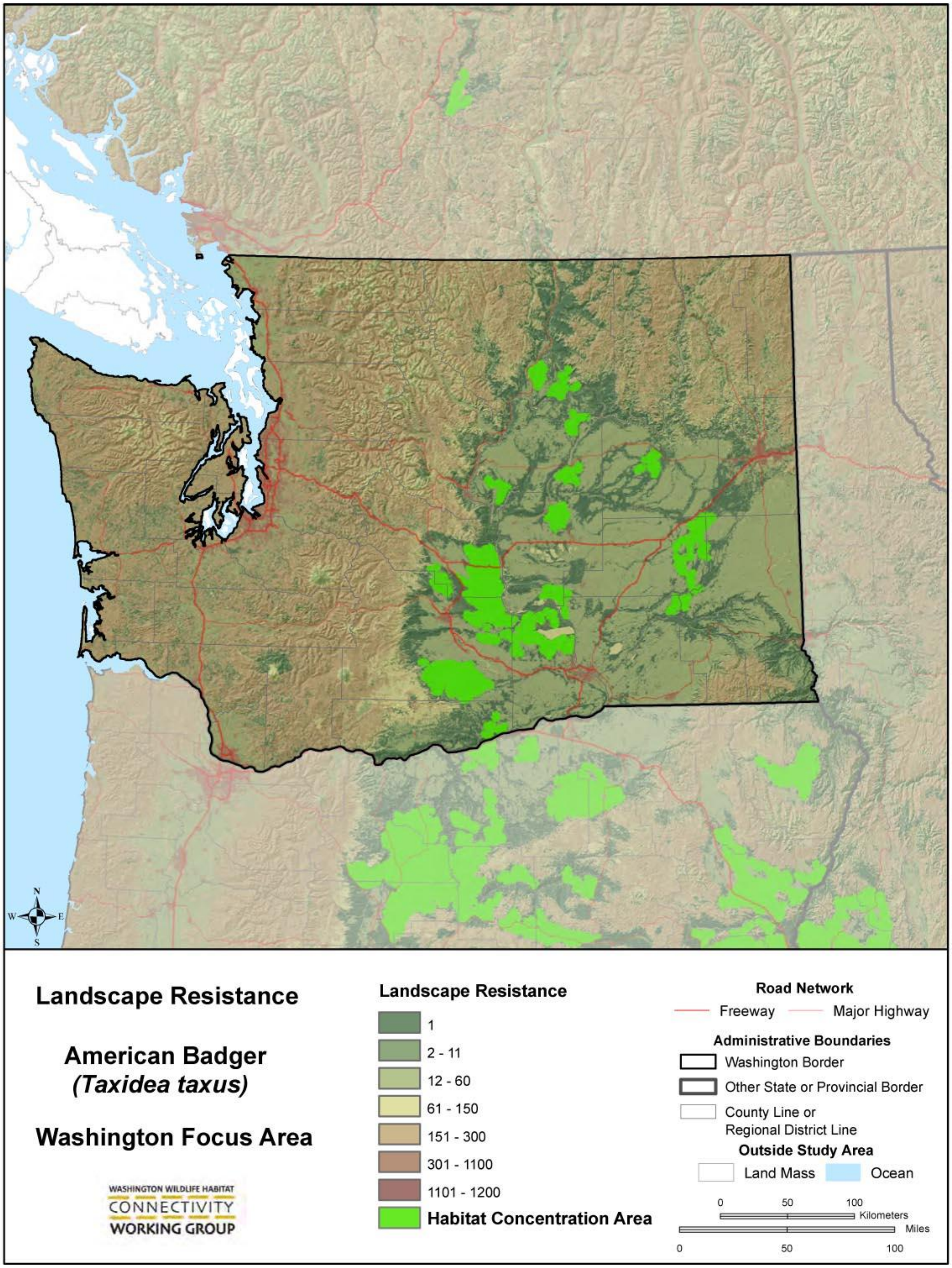

Figure 3.10. Landscape resistance for American badgers.

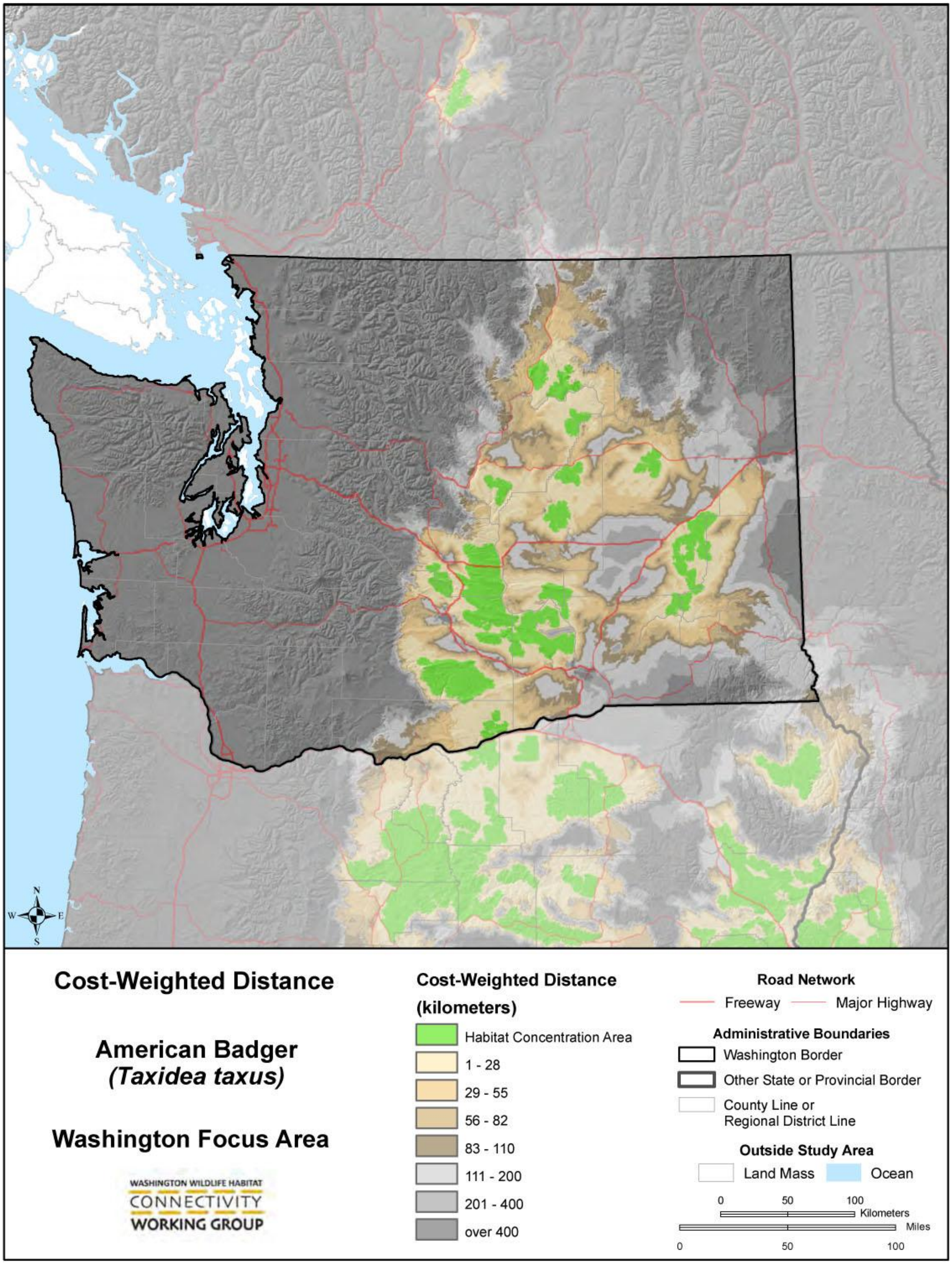

Figure 3.11. Cost-weighted distance for American badgers.

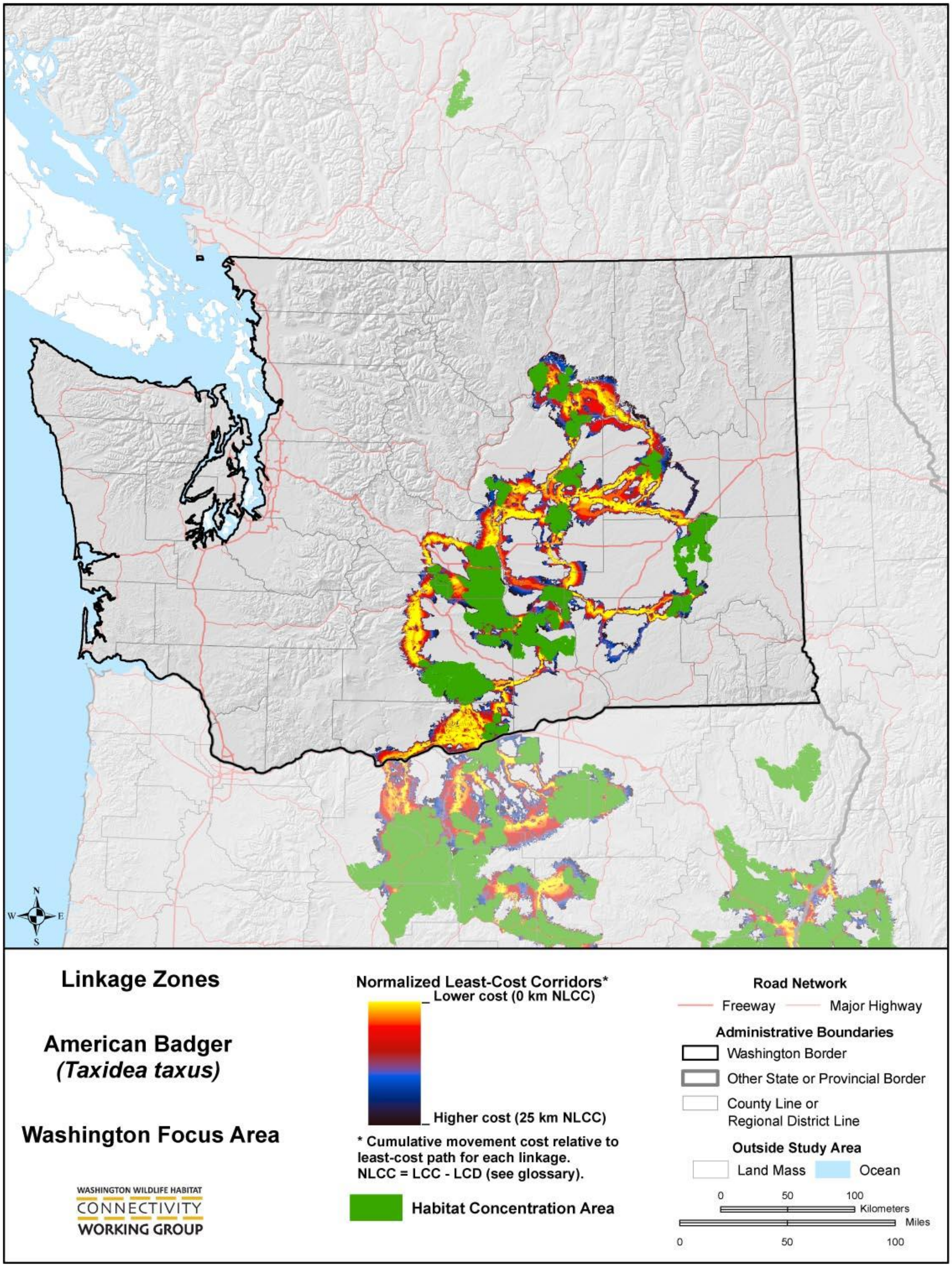

Figure 3.12. American badger linkages.

3.2.5. Black-tailed Jackrabbit (*Lepus californicus*)

3.2.5.1. INTRODUCTION

Black-tailed jackrabbit, photo by Mike Schroeder.

The black-tailed jackrabbit is the most common jackrabbit in the western U.S. (Flinders & Chapman 2003). Their range extends from southern-central Washington to South Dakota and southward into Baja California and well into south-central Mexico (Chapman & Flux 1990). They also have been successfully introduced into various eastern states. In central Washington, east of the Cascade Mountains, black-tailed jackrabbit distribution is concentrated in the arid Columbia Plateau shrubsteppe and grassland habitats, and extending south into Oregon. Areas used by black-tailed jackrabbits include sagebrush and rabbitbrush (*Chrysothamnus* sp.) dominated habitats as well as areas of mixed grassland and shrub (Johnson & Cassidy 1997). They tend to occupy areas with more shrubs and less grass than white-tailed jackrabbits and are more tolerant of grazing by livestock (Best 1996). Their diet varies seasonally, consisting of a higher percentage of shrubs in winter, forbs in spring, and mostly grasses with almost no shrub ingestion in summer (Grant 1987). Black-tailed jackrabbits are generally nocturnal and solitary (Flinders & Chapman 2003). Population monitoring is a challenge as no reliable census method exists for all population levels.

Black-tailed jackrabbits are highly mobile. Size of home range varies from 20–300 ha (Lechleitner 1958; Harestad & Bunnell 1979; Smith 1990). 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). Grant (1987) reported a black-tailed jackrabbit moving about 57 km during early winter; in this study, distances travelled averaged 16.2 km with a range of 2.2–57.3 km. Early observations in Washington indicate that this species moved a distance of forty miles from 1908–1912, colonizing the area from western Walla Walla up to Grant County (Couch 1927).

The black-tailed jackrabbit was selected as a focal species because its connectivity needs reflect those of wildlife in the Semi-desert vegetation class. They are vulnerable to loss of habitat connectivity from all four major connectivity threats: clearing and vegetation removal, development, roads and traffic, and the presence of people and domestic animals. Additionally, they are at considerable risk for increased mortality from vehicle traffic, persecution, and harassment by pets. The black-tailed jackrabbit is listed as a Species of Greatest Conservation Need in Washington due to habitat loss and human-related threats.

3.2.5.2. MODEL CONCEPTUAL BASIS

Due to lack of studies, published literature, and occurrence data for black-tailed jackrabbits, the core habitat in Washington was not well defined. Habitat concentration areas were therefore modeled based on habitat suitability. Grid cells were either designated as habitat (resistance values equal to 1) or non-habitat (resistance values >1), based on assigned resistance values. A GIS moving window analysis was then applied to generate a habitat density surface, with each cell representing the proportion of habitat around it. Habitat concentration areas were defined as areas that were at least 50 km^2 and composed of cells that had ≥75% good habitat (resistance value of 1) within 2 km.

Resistance values were derived from habitat descriptions from the literature, with shrubsteppe habitat assigned the lowest values. Resistance parameter values for non-habitat conditions such as agricultural lands, developed landscapes, and roads were based on expert opinion.

3.2.5.3. MODEL RESULTS

Habitat Concentration Areas — The 31 black-tailed jackrabbit HCAs are located throughout the Columbia Plateau shrubsteppe habitat in Washington, from the Columbia River north, with the northern most HCA modeled in Okanogan County (Fig. 3.13; Table 3.2). The modeling process resulted in HCAs occurring outside of the historical range of black-tailed jackrabbits, specifically within the Okanogan Highlands. These HCAs were retained on the statewide map due to the availability of suitable habitat in sufficient quantities to support black-tailed jackrabbits. The most sizeable HCAs are located on the Hanford Reach National Monument, Yakama Tribal Lands, YTC, WDFW Swanson Lakes Wildlife Area and on other state and federal public lands throughout the historical extent of the Columbia Plateau where larger tracts of shrubsteppe lands still exist.

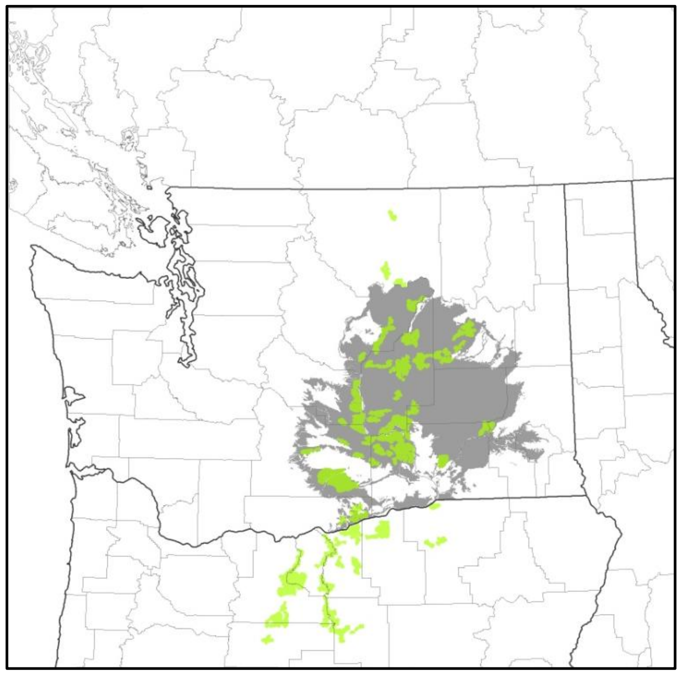

Figure 3.13. Black-tailed jackrabbit HCAs (green) and GAP distribution (gray).

Resistance Surface — The black-tailed jackrabbit resistance surface indicates good conditions for movement within their distributional range east of the Cascades in shrubsteppe dominated habitat (Fig. 3.14). The resistance values were used as representative of habitat values and matched up relatively well with known occurrence data for jackrabbits. While roads are assigned resistance values derived from the road type and distance, jackrabbit movement itself is not deterred by the presence of roads, though jackrabbits are definitely at risk from mortality associated with vehicles.

Cost-weighted Distance — The cost-weighted distance map (Fig. 3.15) illustrates the full range of areas suitable for movement between HCAs. Black-tailed jackrabbit HCAs appear highly connected (i.e., the cost-weighted distance between them is low) within the available shrubsteppe habitat in the Columbia Plateau.

Linkage Modeling — Linkages were modeled between 75 discrete pairs of HCAs within or partially within Washington. Least-cost distances between these 75 linkages ranged from 1 to 90km (1 to 90 km Euclidean distance). The Euclidean to cost-weighted ratio ranged from 1 to 312 (Table 3.3).

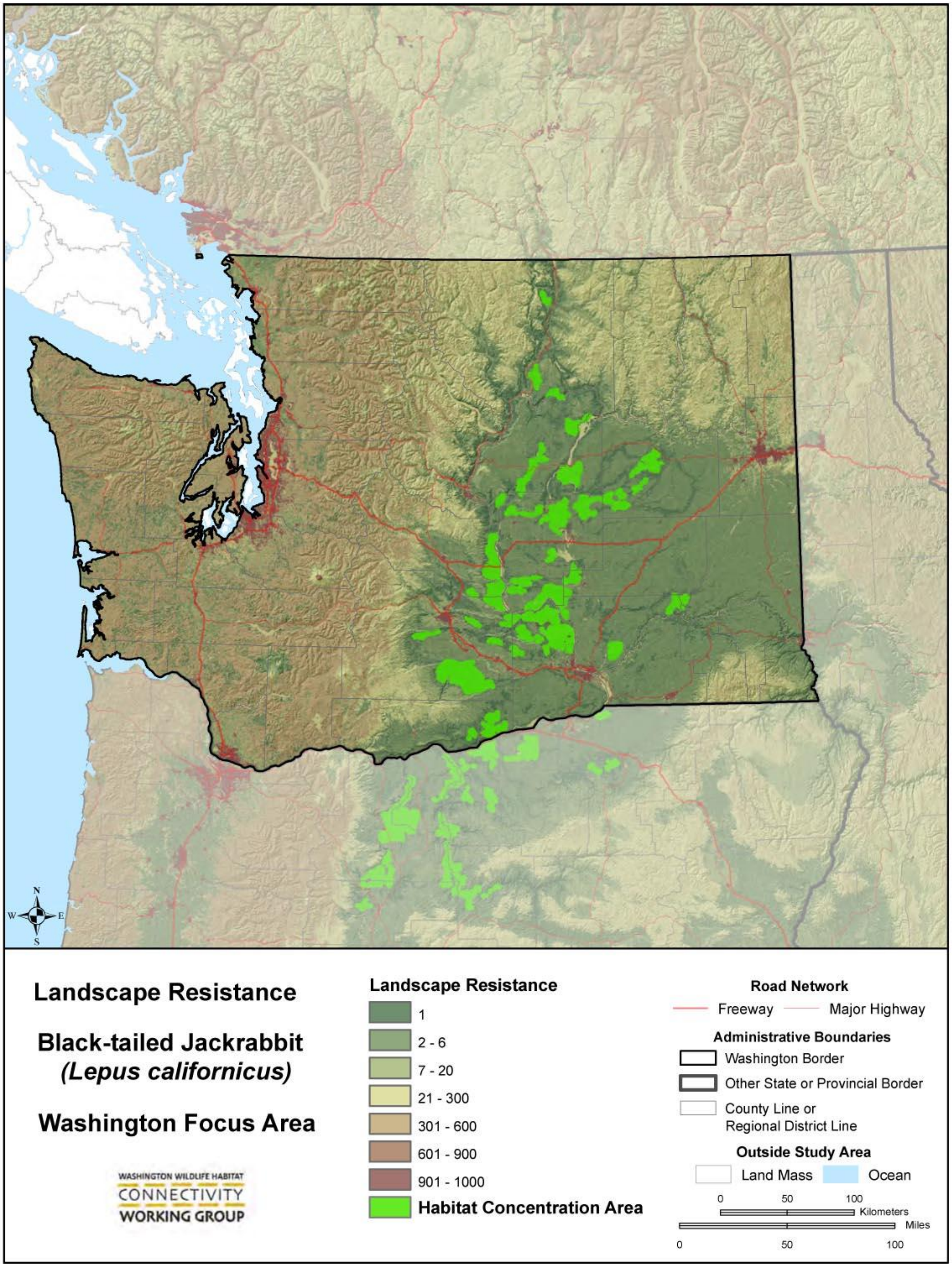

Figure 3.14. Landscape resistance for black-tailed jackrabbits.

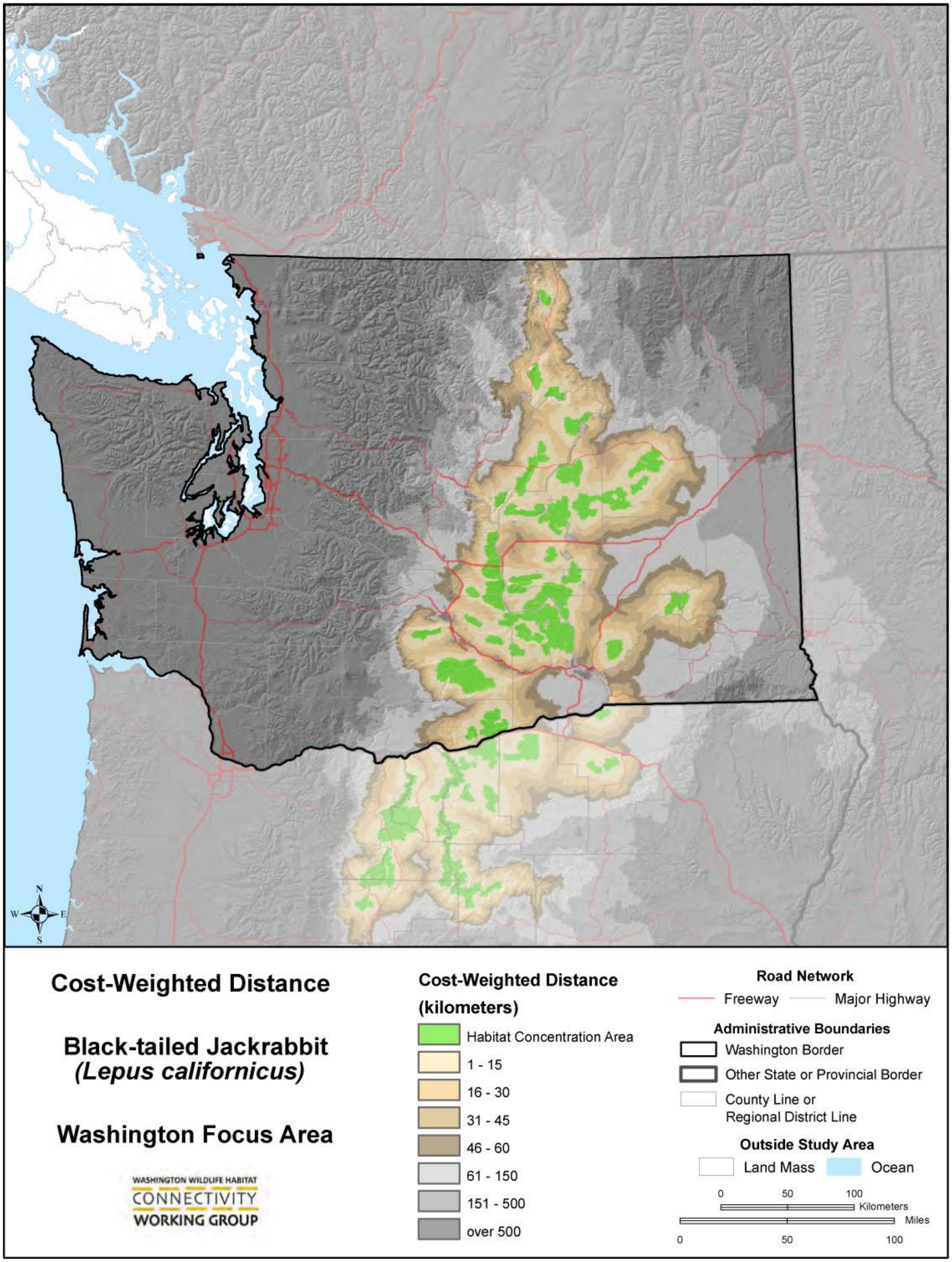

Figure 3.15. Cost-weighted distance for black-tailed jackrabbits.

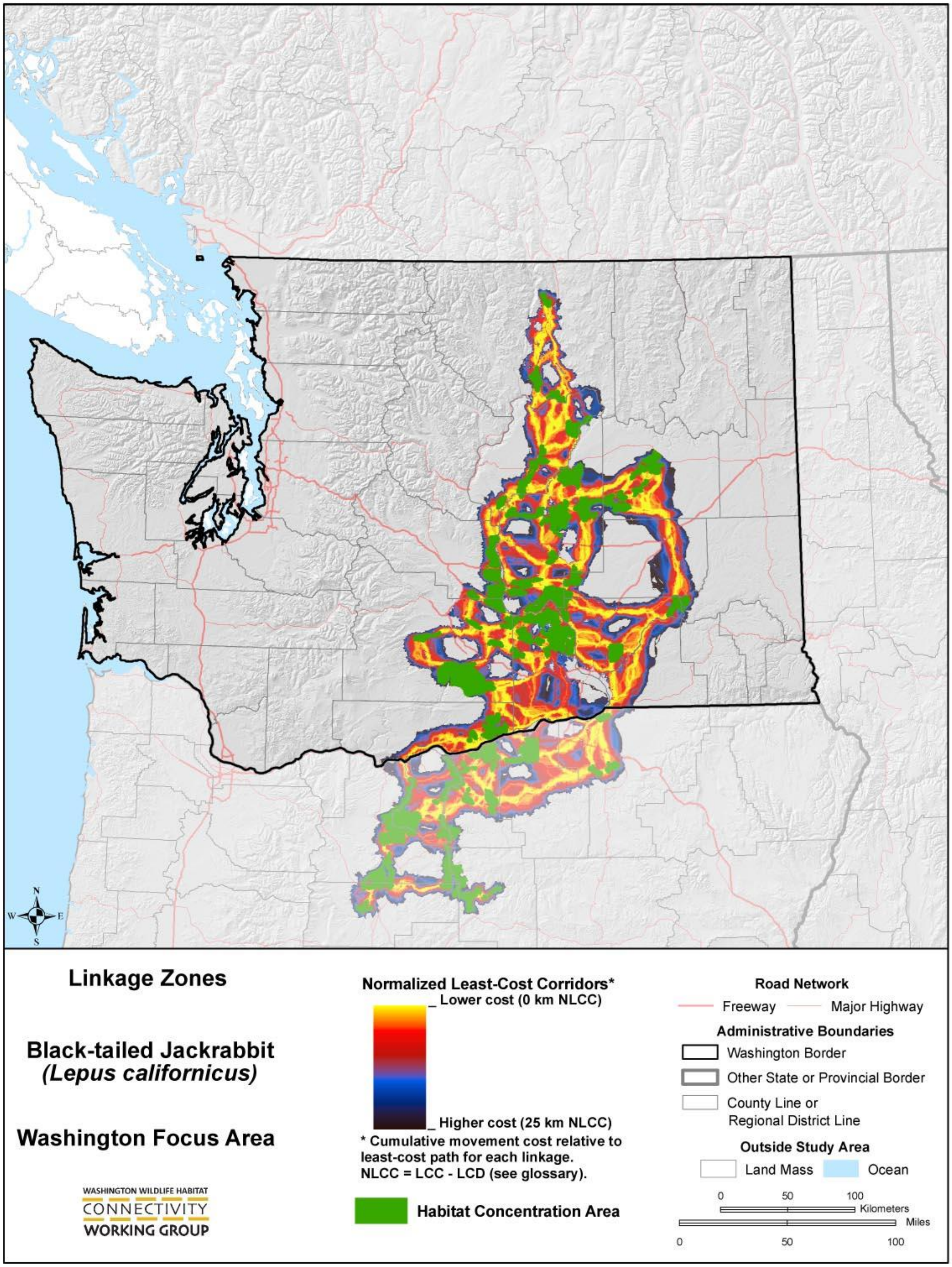

Figure 3.16. Black-tailed jackrabbit linkages.

3.2.6. White-tailed Jackrabbit (*Lepus townsendii*)

3.2.6.1. INTRODUCTION

White-tailed jackrabbit, photo by Doug Backlund.

The white-tailed jackrabbit is an ecologically important species affecting habitats and serving as prey for a wide variety of raptors and mammalian predators (Flinders & Chapman 2003). Its range extends from the prairies of the mid-western states and Canadian provinces westward to the Rocky Mountains, Cascades and Sierra Nevada mountain ranges and southward to the northern borders of Utah and New Mexico. Most populations are declining due to factors such as, habitat loss, degradation, fragmentation, competition with black-tailed jackrabbits, and unregulated hunting (Flinders & Chapman 2003). In Washington, it is found throughout the arid Columbia Plateau. White-tailed jackrabbits are largely nocturnal which makes population monitoring a challenge; no reliable census method exists for all population levels. The white-tailed jackrabbit is listed as a Washington State Candidate species.

In parts of its historical range, where cultivation, drought or overgrazing have affected the habitat, white-tailed jackrabbits have been replaced by black-tailed jackrabbits (Armstrong 1972). In areas where the two species overlap they use different habitats: black-tailed jackrabbits occur primarily in sagebrush habitats with open grass while white-tailed jackrabbits are most common in bunchgrass habitats with less shrub cover (Anthony 1913; Couch 1927). White-tailed jackrabbits generally prefer more open habitat than black-tailed jackrabbits; and in Washington they occur at somewhat higher elevations, in habitats such as grassy hills and plateaus (Johnson & Cassidy 1997). Dalquest (1948) found white-tailed jackrabbits on arid, hilly bunchgrass sites during the summer and in lower sagebrush valleys during winter. Dalquest (1948) also noted that as bunchgrass decreased due to overgrazing so did numbers of white-tailed jackrabbits.

The white-tailed jackrabbit was selected as a focal species because its connectivity needs reflect those of other species in the Semi-desert vegetation class. White-tailed jackrabbits scored high for all four major connectivity threats: clearing and vegetation removal, development, roads and traffic, and the presence of people and domestic animals. White-tailed jackrabbits are at considerable risk for increased mortality from vehicle traffic, persecution, and harassment by pets.

3.2.6.2. MODEL CONCEPTUAL BASIS

Resistance values for landscape features were derived from descriptions in the literature of white-tailed jackrabbit habitat and seasonal movements. In cases where little published information was available we relied upon the professional judgment of expert reviewers. Urban land-use and roads were considered top factors impeding movement of white-tailed jackrabbits through suitable landscape.

Due to a lack of scientific studies and occurrence data, core habitat areas for white-tailed jackrabbits were not well defined. We modeled habitat concentration areas (HCAs) based on habitat suitability whereby grid cells in a moving window were designated as either habitat or non-habitat based on resistance values assigned to landscape features for the white-tailed jackrabbit; resistances values of 1 were selected as white-tailed jackrabbit habitat while those greater than 1 were designated as non-habitat. We then calculated the proportion of habitat within a circular moving window while passing over the resistance surface. To establish the size of the moving window we used literature describing patterns of white-tailed jackrabbit movement. Home range of the white-tail is reported as 2 to 3 km in diameter (Seton 1928; Jackson 1961), but information is scant. We used a home range of 2 km in the model. A habitat density threshold (proportion of the moving window that is white-tailed jackrabbit habitat) of 85% was applied. Habitat areas were then expanded outwards up to a total cost-weighted distance equal to a home-range movement radius of 2.0 km. This had the effect of joining nearby habitat cells if the intervening landscape supported within-home range connectivity. Small habitat patches less than 50 km^2 were eliminated because they were unlikely to support a viable population of jackrabbits.

3.2.6.3 MODEL RESULTS

Habitat Concentration Areas — The 38 white-tailed jackrabbit HCAs are located throughout the Columbia Plateau grassland and shrubsteppe habitat (Fig. 3.17). White-tailed jackrabbits tend to occur at higher elevations than the black-tailed jackrabbits, and their distribution extends up the Okanogan drainage into B.C. The most sizeable HCAs are located on the Hanford Reach National Monument, Yakama Reservation, Yakima Training Center, WDFW Swanson Lakes Wildlife Area in Lincoln County and on other State and Federal public lands throughout the historical extent of the Columbia Basin, where larger tracts of grassland and shrubsteppe lands still exist.

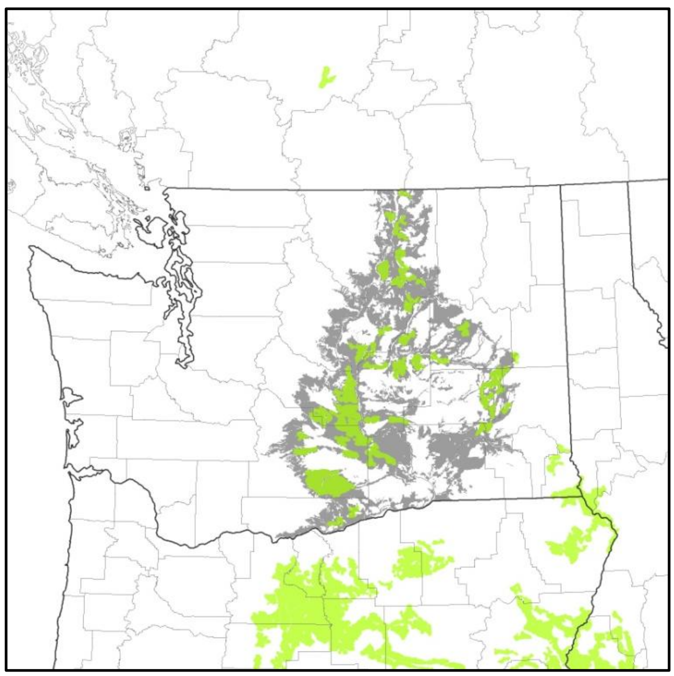

Figure 3.17. White-tailed jackrabbit HCAs (green) and GAP distribution (gray).

Resistance Surface — The white-tailed jackrabbit resistance surface indicates good conditions for movement within their distributional range east of the Cascades in grassland shrub-dominated habitat (Fig. 3.18). While centerlines of roads, particularly major highways, are assigned the highest resistance values, jackrabbit movement is not deterred by the presence of roads. The resistance values were used as representative of habitat values and matched up relatively well with known occurrence data for jackrabbits.

Cost-weighted Distance — The white-tailed jackrabbit cost-weighted distance map illustrates the full range of areas suitable for movement between HCAs (Fig. 3.19). Looking at the map, white-tailed jackrabbit HCAs appear highly connected (i.e., the cost-weighted distance between them is low) within the available shrubsteppe and grassland habitat in the Columbia Plateau.

Linkage Modeling — Linkages were modeled between 81 discrete pairs of HCAs within or partially within Washington. Least-cost distances for these 81 linkages ranged from <1 to 147 km (Table 3.3). The Euclidean to cost-weighted ratio ranged from 1 to 213 km. The results of the least-cost corridor model for white-tailed jackrabbit show strong connections throughout the HCA matrix; corridors are often associated with shrubsteppe habitats (Fig. 3.20). Corridors from HCAs in southeastern Washington follow the Snake River drainage. Connections in eastern Washington between the lower Rock Creek drainage and the Potholes follow patchy areas of shrubsteppe cover. Corridors between HCAs flow around areas of cultivated cropland.

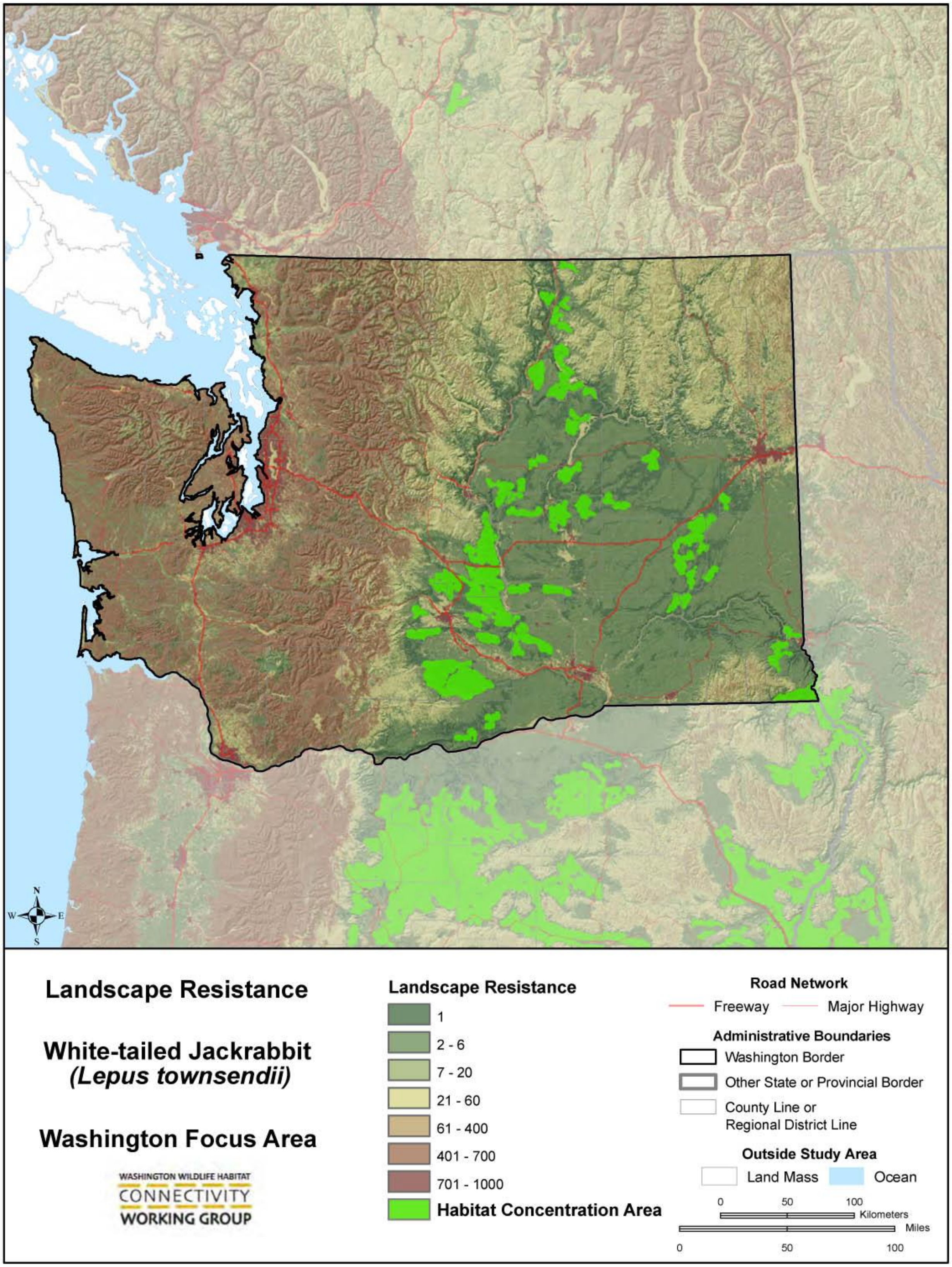

Figure 3.18. Landscape resistance for white-tailed jackrabbits.

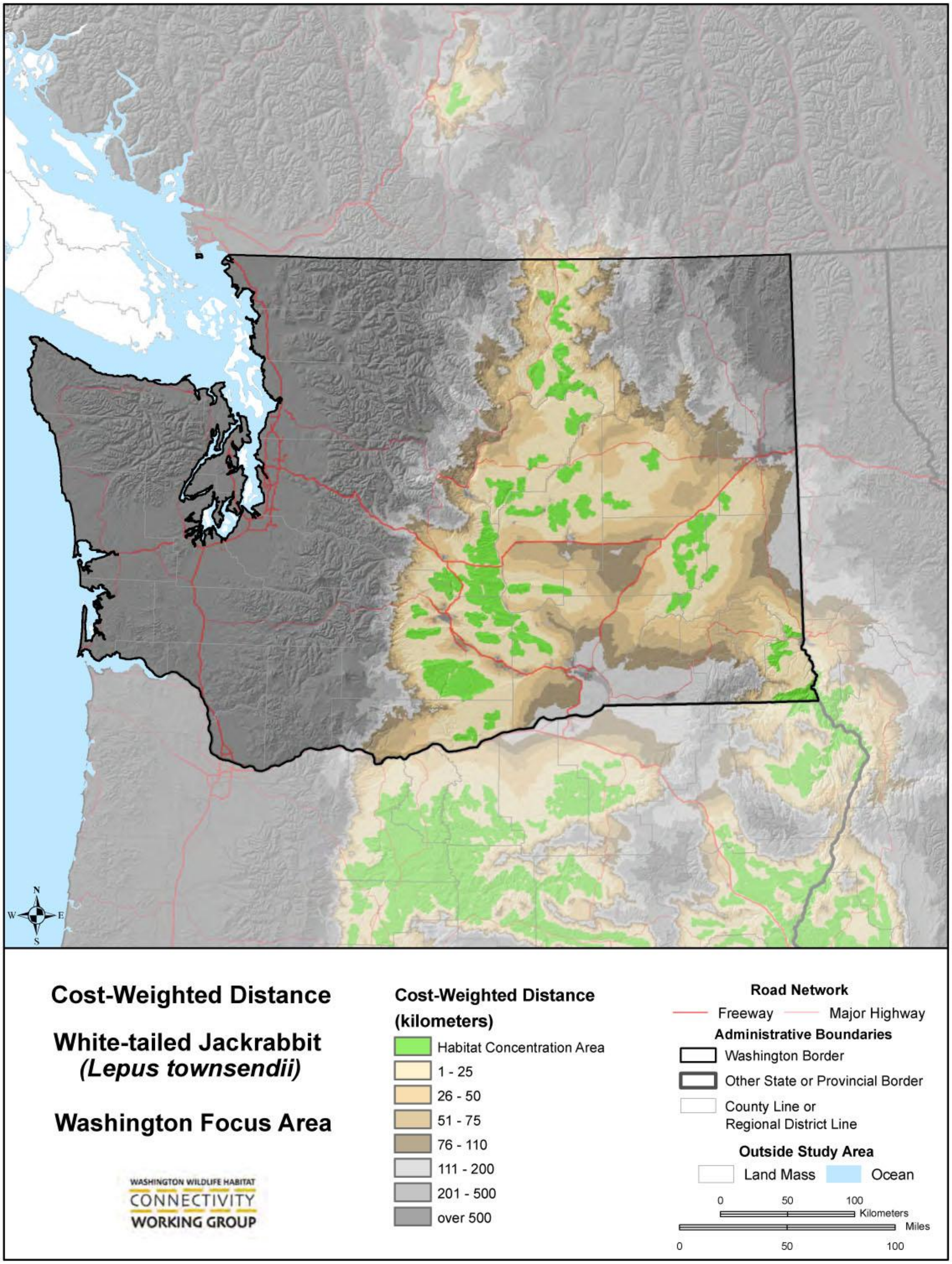

Figure 3.19. Cost-weighted distance for white-tailed jackrabbits.

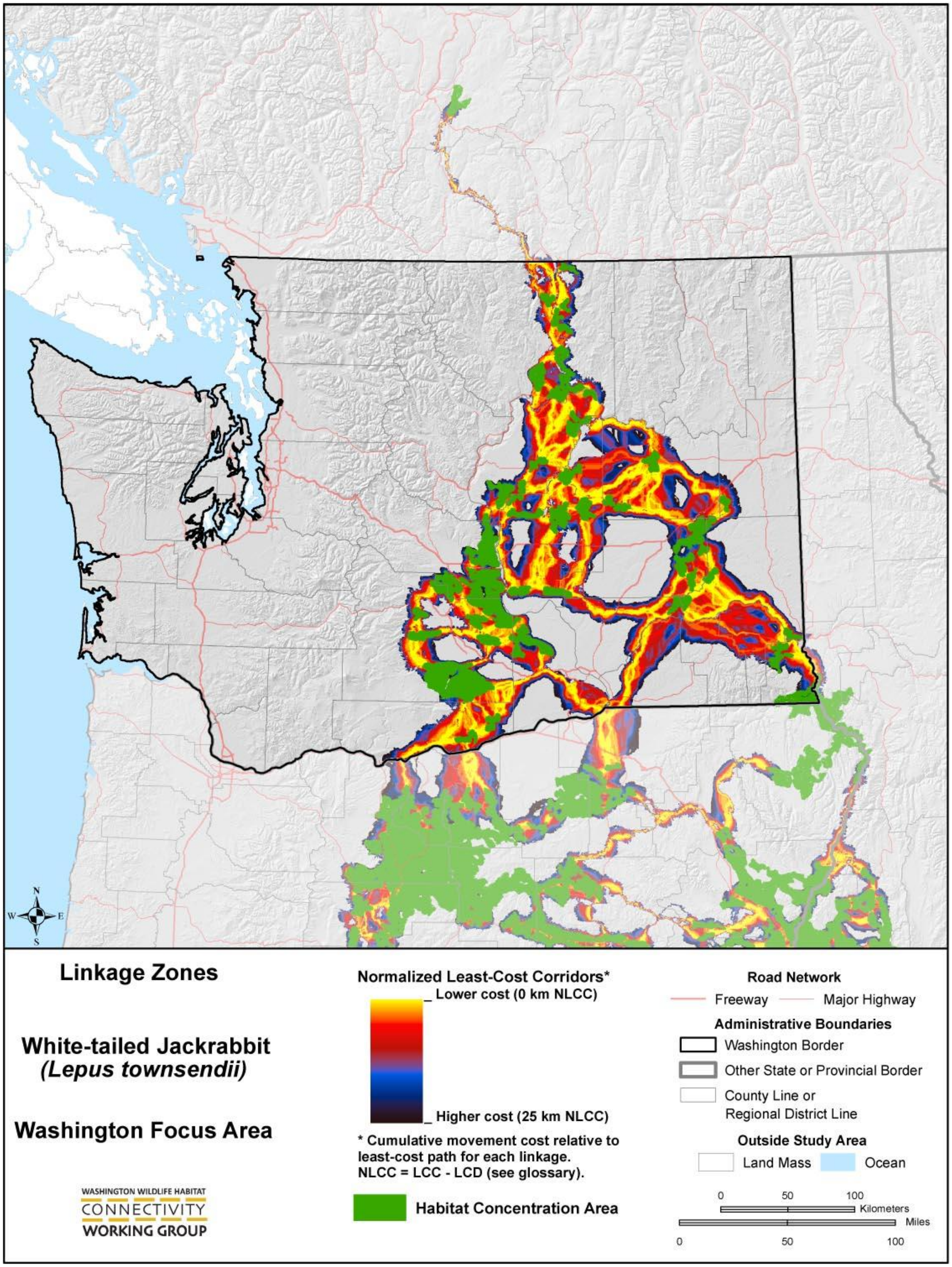

Figure 3.20. White-tailed jackrabbit linkages.

3.2.7. Mule Deer (*Odocoileus hemionus*)

3.2.7.1. INTRODUCTION

Mule deer are found throughout much of western North America, extending as far east as Nebraska, Kansas, and western Texas. In Washington, two subspecies of mule deer are recognized: black-tailed deer (*Odocoileus hemionus columbianus*), found primarily west of the crest of the Cascade Mountains, and Rocky Mountain mule deer (*Odocoileus hemionus hemionus*), which are widespread east of the crest of the Cascades. Only the larger agricultural blocks of the Columbia Plateau fail to support robust populations, due to a lack of adequate forest or shrub cover (Johnson & Cassidy 1997).

Black-tailed deer, photo by Kelly McAllister.

Mule deer are important members of the wildlife community, serving a number of key ecological functions as herbivores and prey for large carnivores such as cougars (*Felis concolor*) and wolves (*Canis lupus*). Some local populations are migratory, exploiting productive mountain meadow habitat in summer but retreating to low-elevation valleys in winter. As such, migratory mule deer often move long distances on a seasonal basis. Mule deer were selected as good representatives of connectivity needs in the Semi-desert and Northern Rocky Mountain Forest vegetation classes.

3.2.7.2. MODEL CONCEPTUAL BASIS

Mule deer require a mosaic of habitat types of different age classes to meet their life history requirements. They use forest, woodland, brush, and meadow habitats, reaching their highest densities in open pine forests, riparian strips within arid and agricultural lands, and along edges of meadows and grasslands. They also occur in open scrub, young chaparral, and low-elevation coniferous forests. A variety of brush cover and tree thickets interspersed with meadows and shrubby areas are important for food and cover. Thick cover can provide escape from predators, shade in the summer, or shelter from wind, rain and snow. Varying slopes and topographic relief are important for providing shade. Fawning occurs in moderately dense shrub, forest, riparian or meadow edge cover. Meadows are particularly important as fawning habitat.

Habitat concentration areas were identified based on habitat suitability scores that were used to build the GIS resistance surface. Apparently suitable habitat was eliminated from consideration if it fell outside of documented mule deer range (North American Mule Deer Foundation, unpublished data). A GIS moving window analysis was used to identify areas with the highest concentrations of suitable habitat. Only patches of 100 km^2 or greater were retained as HCAs.

The GIS moving window analysis used movement data from published research. Home range estimates vary from 39 ha to 3379 ha. Harestad and Bunnell (1979) calculated mean home range from several studies as 285 ha. Doe and fawn groups have smaller home ranges, averaging 100–300 ha, but can vary from 50 to 500 ha. Bucks usually have larger home ranges and are known to wander greater distances. A recent study of 5 different sites throughout California recorded home range sizes from 49 to 1138 ha.

Where deer are seasonally nomadic, winter and summer home ranges tend to largely overlap in consecutive years. Elevational migrations are observed in mountainous regions in response to extreme weather events in winter, or needs for shade or perennial water in summer. Distances travelled between winter and summer ranges vary from 8.6 to 29.8 km. Robinette (1966) observed natal dispersal distances ranging from 97 to 217 km.

3.2.7.3. MODEL RESULTS

Habitat Concentration Areas — Seventy mule deer HCAs were identified in the entire project area of which 34 were wholly or partially in Washington. The Washington HCAs ranged from 100 to 60,905 km^2 in size (Fig. 3.21; Table 3.2). Mule deer HCAs are extensive over much of the project area. However, landscapes within the arid Columbia Plateau and urbanized Puget Trough had few HCAs. Much of the Idaho Panhandle and extreme northeastern Washington were not included in an HCA because they were not mapped as significant mule deer range by the Mule Deer Foundation.

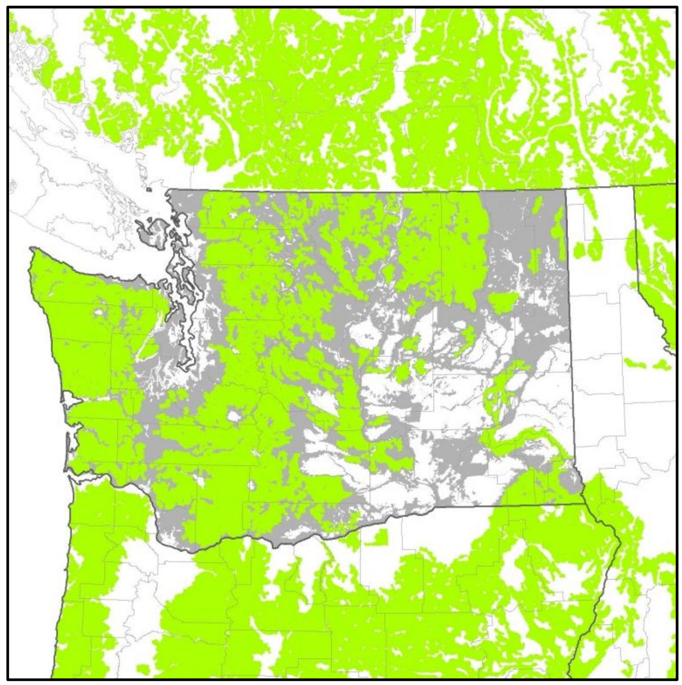

Figure 3.21. Mule deer HCAs (green) and GAP distribution (gray).

Resistance Surface — The mule deer resistance surface indicates good conditions for deer movements in all of the more mountainous regions of the project area as well as some areas of the Columbia Plateau where native shrub cover is plentiful (Fig. 3.22). Heavily urbanized areas and busy road corridors contributed to barriers.

Cost-Weighted Distance — The mule deer cost-weighted distance map indicates that connectivity is good throughout much of the project area (Fig. 3.23). Movement between HCAs appears reasonably likely even in the arid Columbia Plateau where HCAs tend to be more widely separated.

Linkage Modeling — Linkages were modeled when the least-cost distance between a pair of HCAs was less than 250 km. This resulted in linkages being modeled between 86 discrete pairs of HCAs wholly or partially in Washington (Fig. 3.24). Straight-line Euclidean distances between HCAs ranged from <1 to 130 km. Weighted least-cost distances for these 86 linkages ranged from 1 to 241 km.

In western Washington, the more significant linkages included a corridor connecting the Olympic Mountains with the Tahuya Peninsula. This linkage follows the south shore of Hood Canal from the Skokomish River to the Belfair vicinity. Others link Fort Lewis and the Vail Tree Farm to the Capital Forest, following paths that cross several busy highways, including I-5. Another important linkage across I-5 was identified north of the Toutle River. Eastern Washington's linkages include several that link identified HCAs in Klickitat County. These linkages are associated with Rock Creek, Alder Creek and Pine Creek. Other important corridors correspond with Moses Coulee and East Foster Creek and the breaks of the Columbia River near Chelan. Modeled corridors cross I-90 both east and west of Sprague Lake. Several HCAs in the high elevations of Pend Oreille and Steven's Counties, and adjacent areas in British Columbia and Idaho, are joined by modeled corridors. In southeastern Washington, the Tucannon and Snake Rivers contribute to a linkage that connects to an extensive arid-lands HCA associated with Cow Creek to the Blue Mountains.

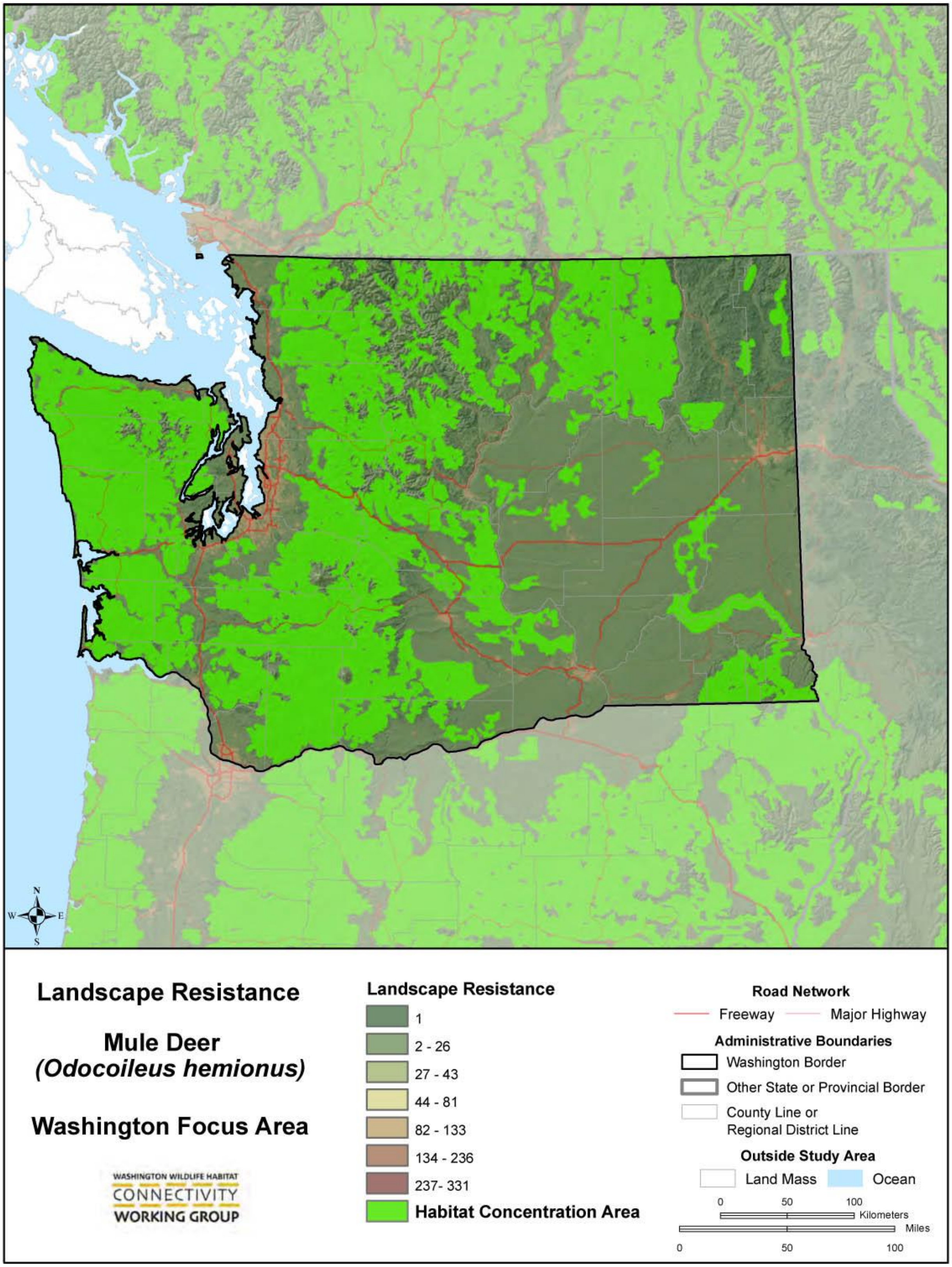

Figure 3.22. Landscape resistance for mule deer.

Figure 3.23. Cost-weighted distance for mule deer.

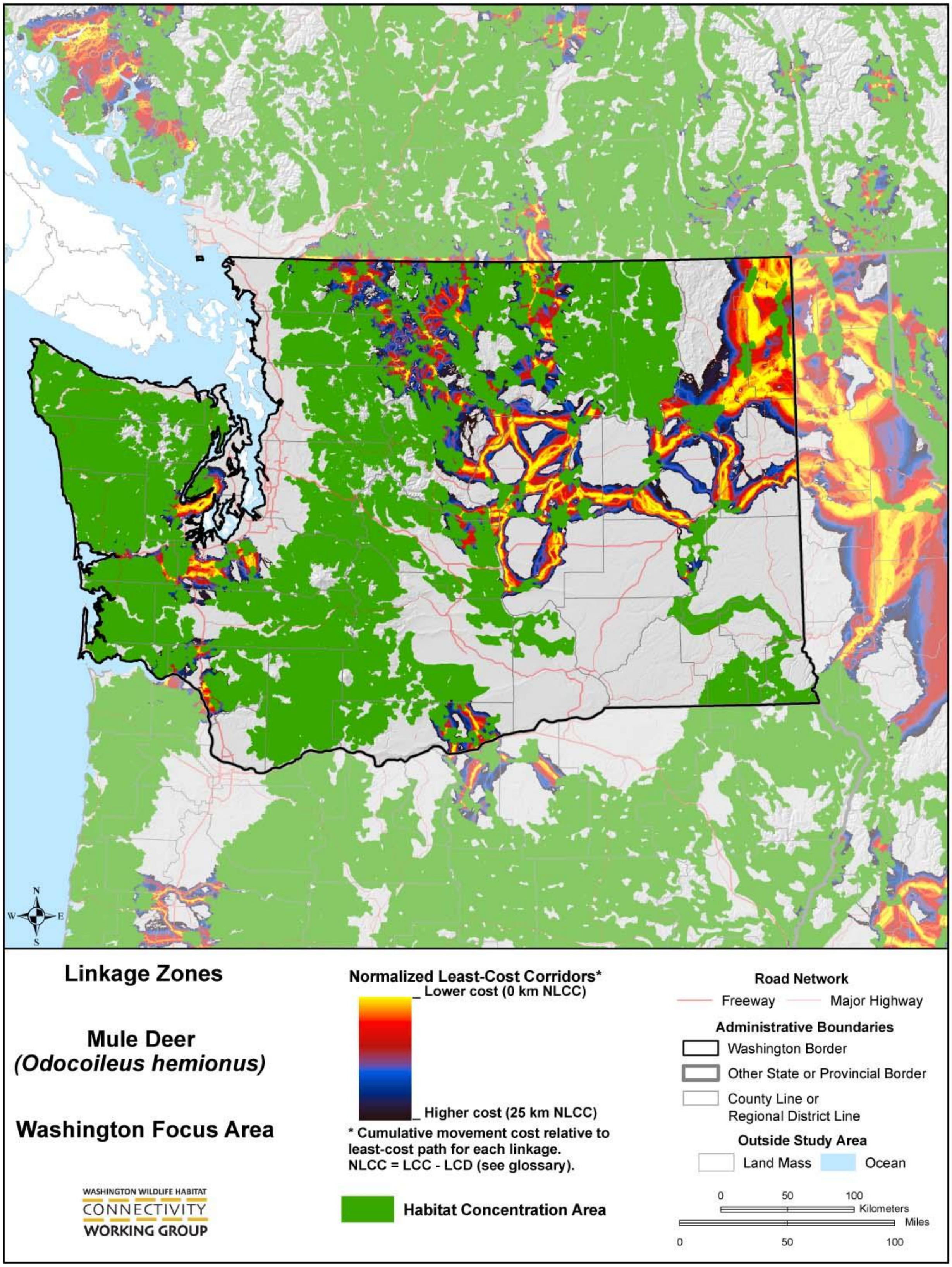

Figure 3.24. Mule deer linkages.

3.2.8. Bighorn Sheep (*Ovis canadensis*)

3.2.8.1. INTRODUCTION

Bighorn sheep have a history of active management in Washington State. The species was extirpated from the state and had to be re-introduced. Most of the herds were gone before 1900. The last known survivors, on Chopaka Mountain, died in 1925 (Johnson 1999a). Historically, bighorn sheep occurred on the eastern slopes of the Cascades from the Canadian border south to the Columbia River and in the Selkirk Mountains. Bighorn sheep were extirpated from the Selkirks by the late 1800s (Johnson 1999b).

Bighorn sheep, photo by Mike Schroeder.

As a result of considerable efforts to re-establish populations, bighorn sheep are now distributed across eastern Washington in 19 herds, each with a limited geographic range. There are approximately 1000–1500 bighorn sheep statewide. Bighorn sheep were selected as a focal species to represent the Rocky Mountain Forests vegetation class.

3.2.8.2. MODEL CONCEPTUAL BASIS

Habitat concentration areas for bighorn sheep were identified using a GIS layer of herd ranges compiled for the western U.S. and Canada. Herd ranges and HCAs were limited to south-central British Columbia, eastern Washington, northern and central Idaho, and the Blue Mountains in northeastern Oregon and southeastern Washington. A total of 37 HCAs were identified within the project area.

Dispersal rates in female bighorn sheep have been reported to be very low (Festa-Bianchet 1991; Jorgenson et al. 1997). Epps et al. (2005) reported that the distance between populations of bighorn sheep appeared to be a prevailing natural barrier, as evidenced by the strong correlation between genetic diversity and gene flow with distance. They estimated a "barrier effect distance" to be about 40 km.

3.2.8.3. MODEL RESULTS

Habitat Concentration Areas — Thirty-seven HCAs were identified within the project areas, 17 were wholly or partially within Washington. The HCAs covered about 13,041 km^2 and ranged in size from 24 km^2 to 9521 km^2 (Fig. 3.25).

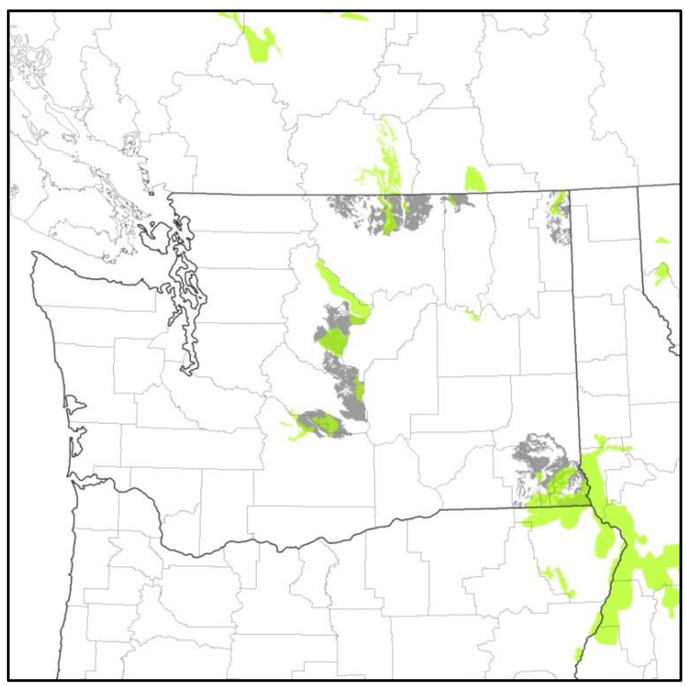

Figure 3.25. Bighorn sheep HCAs (green) and GAP distribution (gray).

Resistance Surface — The bighorn sheep resistance surface indicates limited conditions for bighorn movements in the project area (Fig. 3.26).

Cost-weighted Distance — There are a number of gaps between the HCAs as bighorn sheep populations are generally not well connected (Fig. 3.27). Barriers to connectivity include highways, roads, trails, and areas of human disturbance.

Linkage Modeling — Linkages were modeled where the least-cost distance between a pair of HCAs was less than 1000 km. This resulted in 22 linkages being modeled between HCAs (Fig. 3.28). The mean Euclidean distance of the linkages was 30 km and ranged from <1 to 112 km. The mean cost-weighted distance of the linkages was 336 km and the ratio of cost-weighted to Euclidean distance ranged from 9 to 94.

Linkages occur between bighorn sheep populations in the Tieton, Mount Clemens, and Umtanum herds. However these populations are likely isolated from populations further north. Linkages occur between bighorn sheep in the Chelan Butte and Lake Chelan herds. Linkages also occur between the Tucannon River/Wooten and Cottonwood Creek herds in the Blue Mountains. The Quilomene, Swakane, Lincoln Cliffs, and Vulcan Mountains herds are isolated and the potential linkages are intended to identify areas where finer-scale modeling will be important to determine the feasibility of providing habitat connectivity. It may also be useful in determining where future bighorn sheep re-introductions could occur to facilitate ***metapopulation*** function.

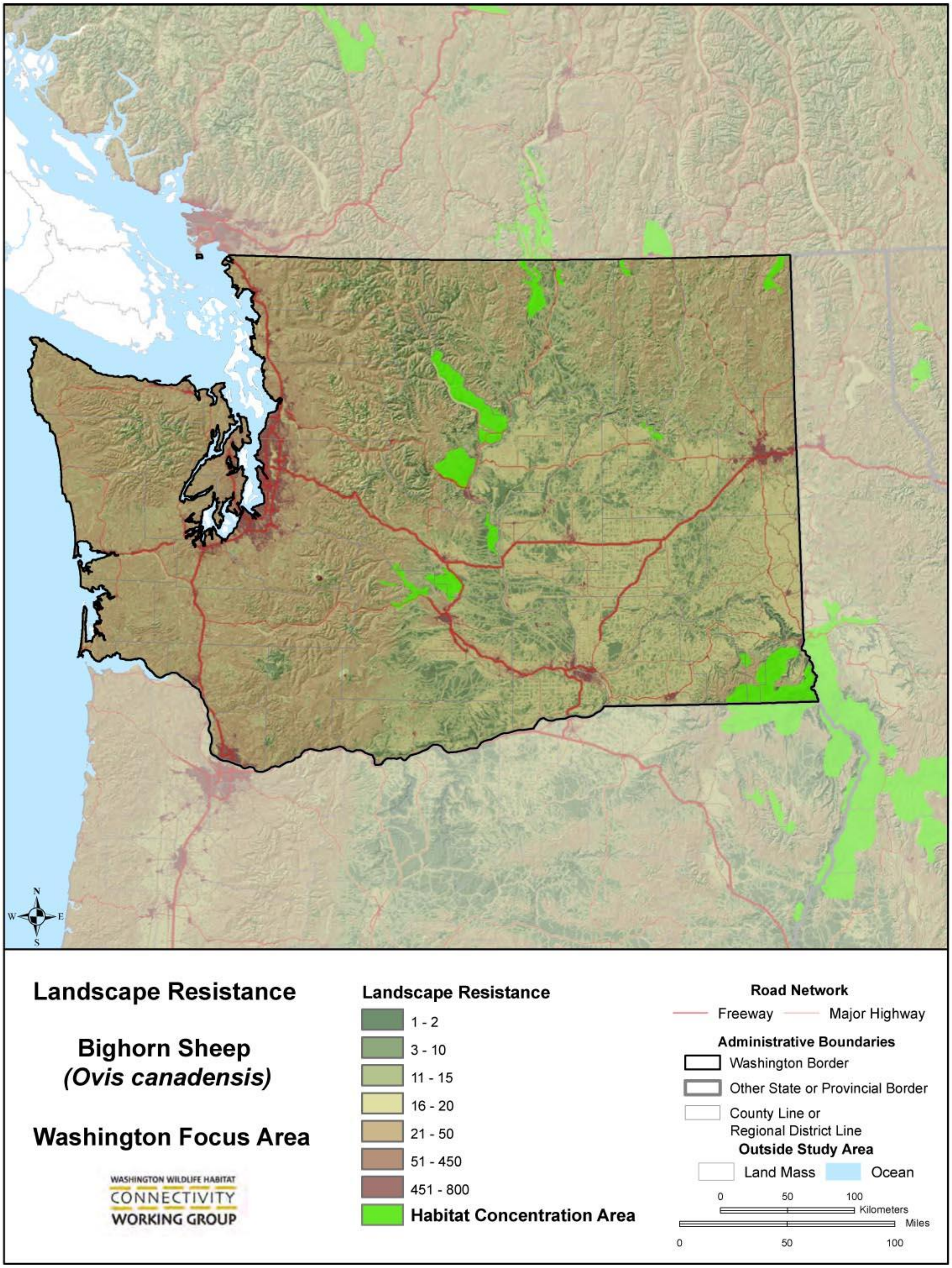

Figure 3.26. Landscape resistance for bighorn sheep.

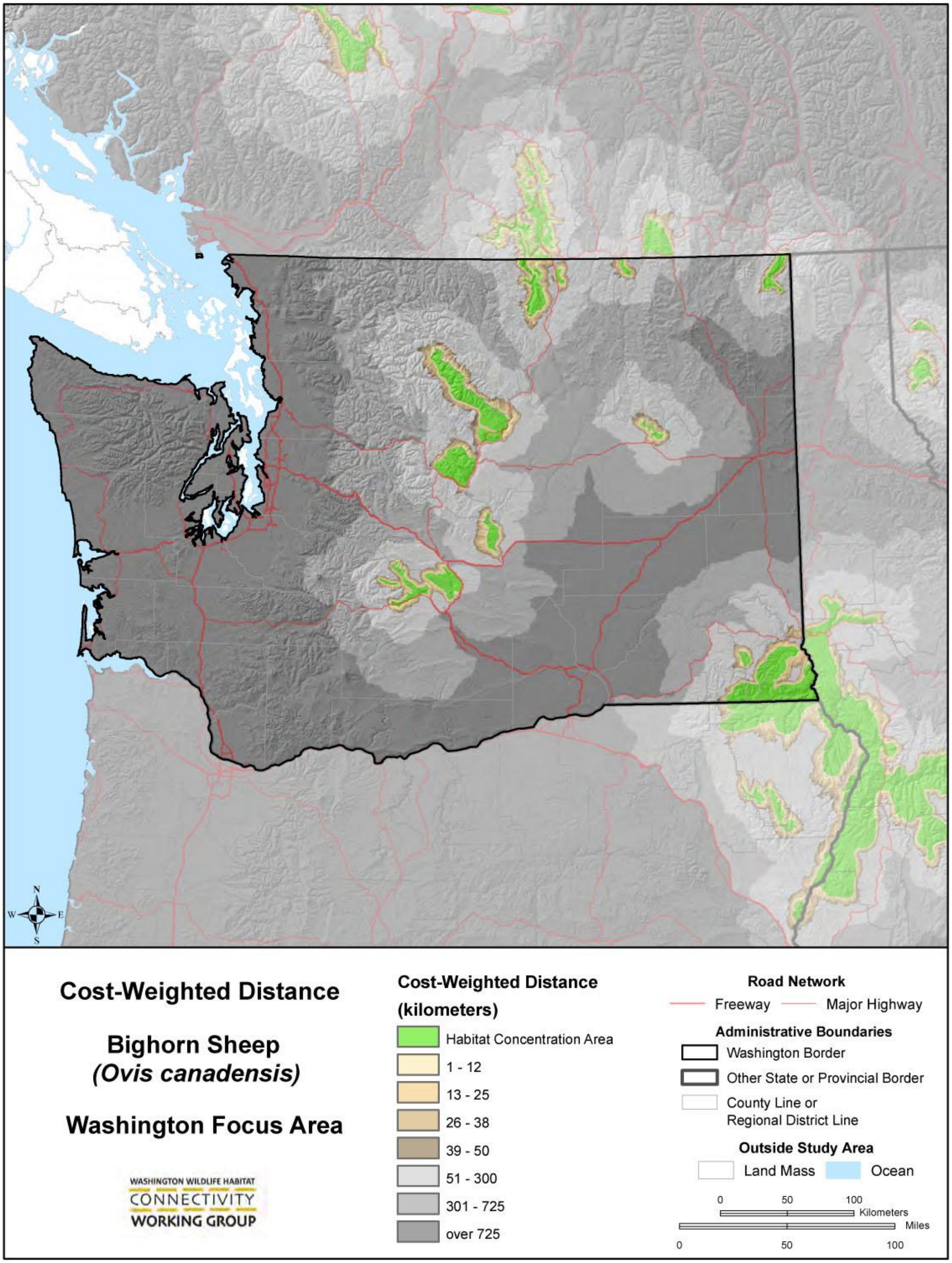

Figure 3.27. Cost-weighted distance for bighorn sheep.

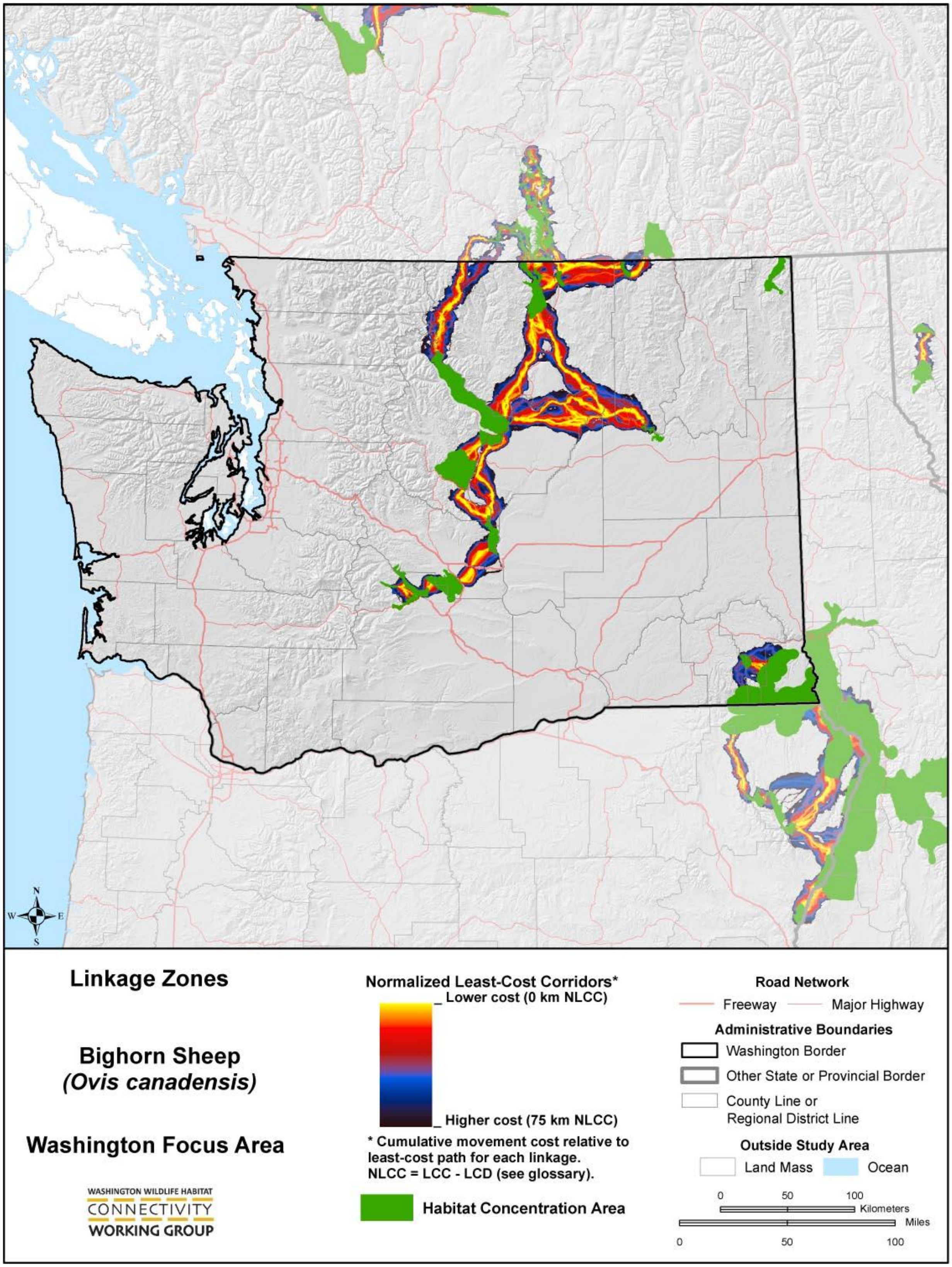

Figure 3.28. Bighorn sheep linkages.

3.2.9. Western Gray Squirrel (*Sciurus griseus*)

3.2.9.1. INTRODUCTION

The western gray squirrel is Washington's largest native tree squirrel. Washington State lists this squirrel among the state's Threatened species. Its numbers and geographic range have diminished and, in much of its western Washington range, it has been replaced by the non-native eastern gray squirrel (*S. carolinensis*). Western gray squirrels range from north-central Washington south to the southern border of California. Within Washington, their range consists of three geographically distinct areas: South Puget Sound (primarily Joint Base Lewis-McChord), Klickitat County extending into Yakima County, and the Lake Chelan and Methow Valley region.

Western gray squirrel, photo by Rod Gilbert.

The western gray squirrel was selected as a focal species because it is a good representative of wildlife habitat connectivity needs within the Rocky Mountain Forests vegetation class. The species was considered vulnerable to loss of habitat connectivity from all four overarching connectivity threats: land clearing and vegetation removal, development, roads and traffic, and the presence of people and domestic animals. Western gray squirrels inhabit mast-producing conifer-hardwood forest types such as, in Washington, transitional forests of ponderosa pine (*Pinus ponderosa*), Oregon white oak (*Quercus garryana*), Douglas-fir (*Pseudotsuga menziesii*), and various riparian tree species. Most occupied forest habitats contain pine or oak, though the presence of both is not essential. Suitable conditions are often found close to edges between forest and grass or shrub-dominated landscapes. In these areas fire often contributes to a sparse or open understory and may be influential in maintaining the vigor of mast-bearing trees and shrubs.

3.2.9.2. MODEL CONCEPTUAL BASIS

Habitat concentration areas were identified from known occupied habitat, areas with concentrations of ponderosa pine or Oregon white oak forests, within the historical range of the species. A GIS moving window analysis was applied to identify areas with the greatest concentrations of suitable habitat.

Resistance parameters were derived, primarily, from literature describing suitable habitat characteristics and, therefore, forested conditions received the lowest resistance values. Resistance parameters for non-habitat conditions such as roads, agriculture, and developed areas were based on professional judgment and vetted with experts attending a workshop in Cle Elum, Washington on 10 November 2009.

To establish the size of the GIS moving window used to identify HCAs, available information on western gray squirrel movement scale was used. Western gray squirrels regularly move 4–5 km in brief time intervals. Juveniles have been tracked dispersing an average of 2862 m from their natal site (Vander Haegen et al. 2005). The longest recorded movement distance was noted for an adult squirrel fitted with a radio collar in Chelan County. This animal moved 19.2 km in a two-week time span (M. Vander Haegen, personal communication).

3.2.9.3. MODEL RESULTS

Habitat Concentration Areas — Western gray squirrel HCAs were identified in concentrations of habitat that included the three widely separated populations at South Puget Sound, Klickitat/Yakima, and Methow/Chelan. Additional areas of concentrated oak or ponderosa pine forest were identified along the eastern foothills of the Cascade Mountains where forests begin to give way to shrubsteppe environments (Fig. 3.29). A total of 26 HCAs, wholly or partially within Washington, were identified. Some of these HCAs are not known to be occupied by western gray squirrels, including those identified on the Colockum Wildlife Area and in the Entiat and Chelan Mountains.

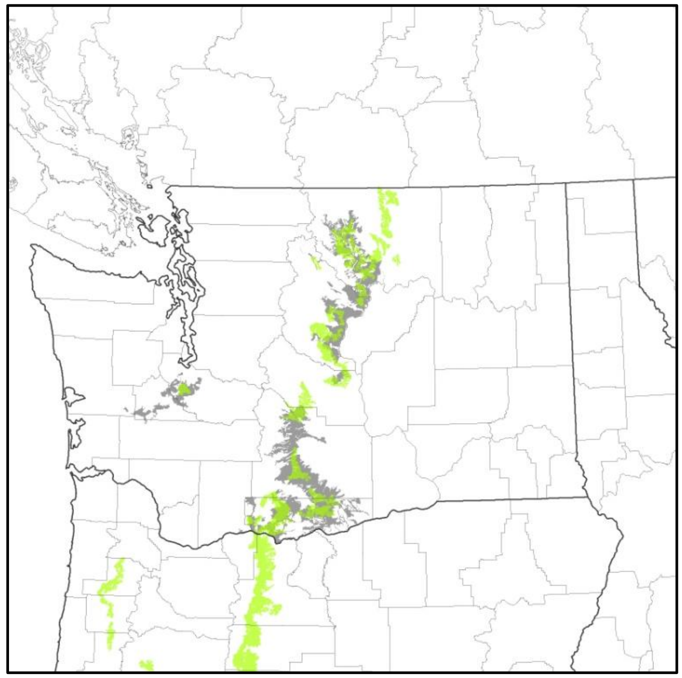

Figure 3.29. Western gray squirrel HCAs (green) and GAP distribution (gray).

Resistance Surface — The western gray squirrel resistance surface (Fig. 3.30) indicates good conditions for squirrel movements along the north-south axis of the Cascade Mountain foothills, particularly in riparian corridors. The South Puget Sound HCA is surrounded by largely impermeable conditions suggesting that this population may remain isolated from all others for the foreseeable future.

Cost-weighted Distance — The western gray squirrel cost-weighted distance map shows reasonably good conditions for animals to move between HCAs in Klickitat County and those on the Yakama Nation lands (Fig. 3.31). However, conditions deteriorate further north, on Cowiche Mountain and the south side of the Tieton River and U.S. Highway 12. Further north, the Kittitas Valley is another formidable barrier, with the best conditions for squirrels occurring at the western end of the valley. U.S. Highway 2, near Cashmere, and Lake Chelan are the remaining significant barriers to connectivity along the north-south axis of the east slope Cascade Mountains.

Linkage Modeling — Linkages were modeled when the least-cost distance between a pair of HCAs was less than 200 km (well beyond the dispersal capability of individual squirrels but potentially achievable over multiple generations by squirrels that live in a corridor). For linkages wholly or partially within Washington, this resulted in linkages being modeled between 35 discrete pairs of HCAs (Fig. 3.32). Least-cost distances for these 35 linkages ranged from 2 to 199 km. Linkage quality metrics indicate that connections between HCAs are sometimes many times more costly than the closest straight line route, with ratios up to 137. Along the least costly path, least-cost to non-weighted distance ratios were less severe, reaching 26 at the upper extreme, with an average of 10.

The South Puget Sound HCA was beyond the maximum cutoff for linking to any other western gray squirrel HCA and, for all practical purposes, will remain isolated. The model suggests that presently unoccupied habitat north of State Route 410 could be linked to squirrel populations to the south via a corridor that cuts across the Oak Creek Wildlife Area west of Naches. Another corridor, further north, crosses I-90 west of Thorp and makes a connection to potentially suitable habitat on the Colockum Wildlife Area. Additional linkages are identified crossing U.S. Highway 2 west of Cashmere and through the Entiat Mountains between Tillicum Creek and Mosquito Ridge. The last major barriers to connecting the squirrel population in the Klickitat/Yakima region with the squirrel population in the Chelan/Methow region, is Lake Chelan and the developed area around the town of Chelan. The model indicates the best opportunities for connecting populations through the Lake Chelan area are paths that skirt the Columbia River at the lower end of the lake and that follow closely along the shoreline at the upper end.

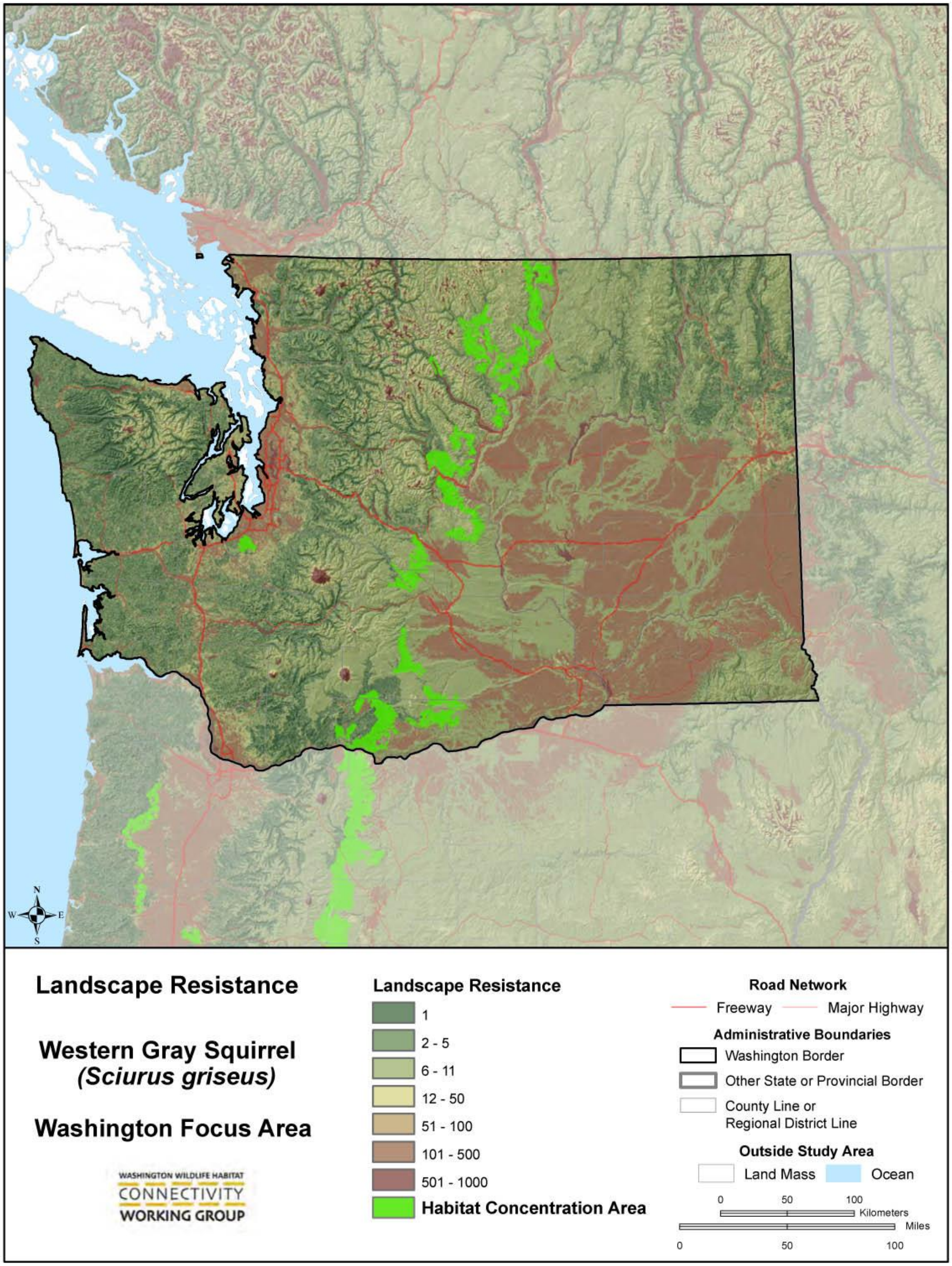

Figure 3.30. Landscape resistance for western gray squirrels.

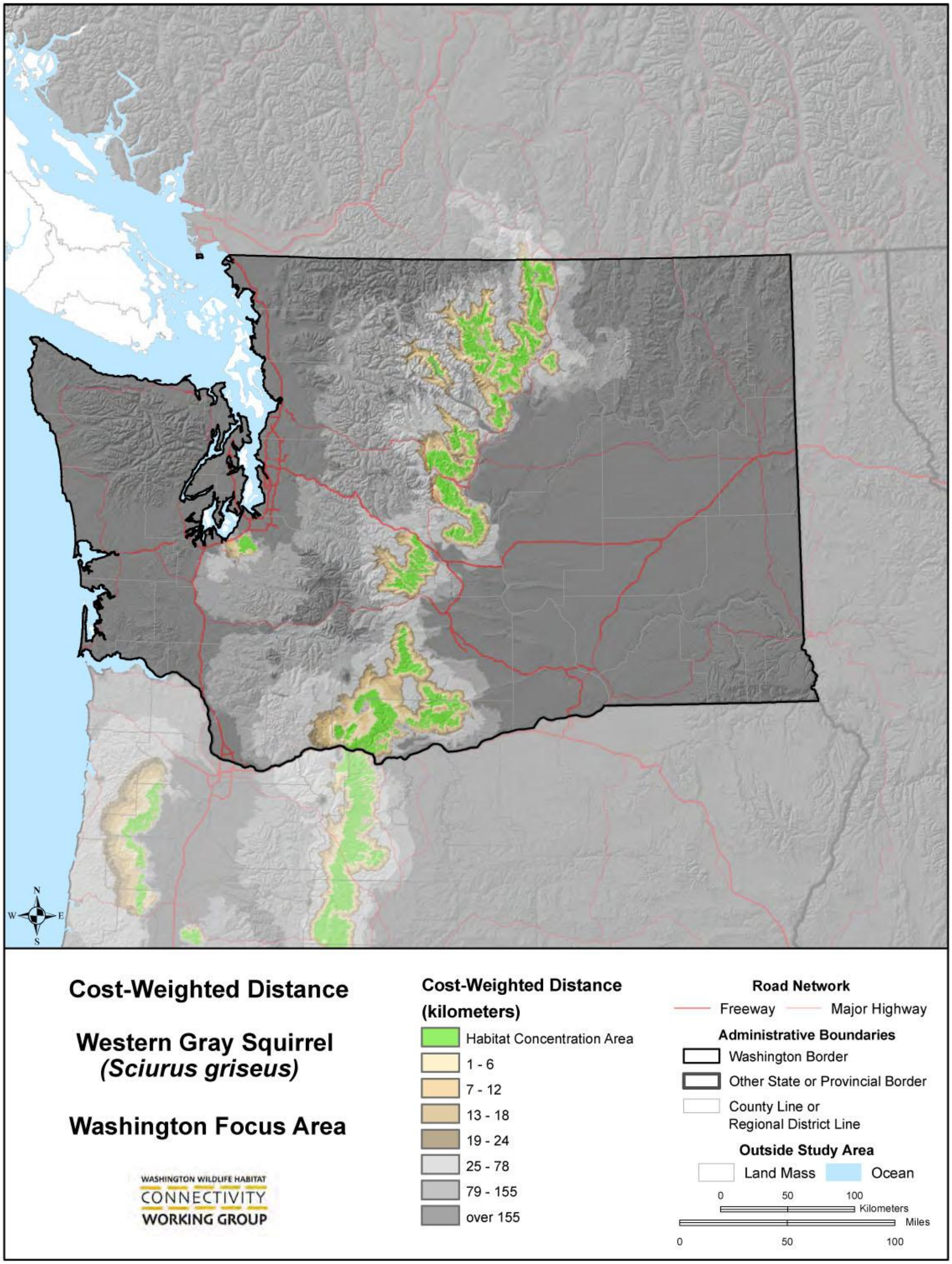

Figure 3.31. Cost-weighted distance for western gray squirrels.

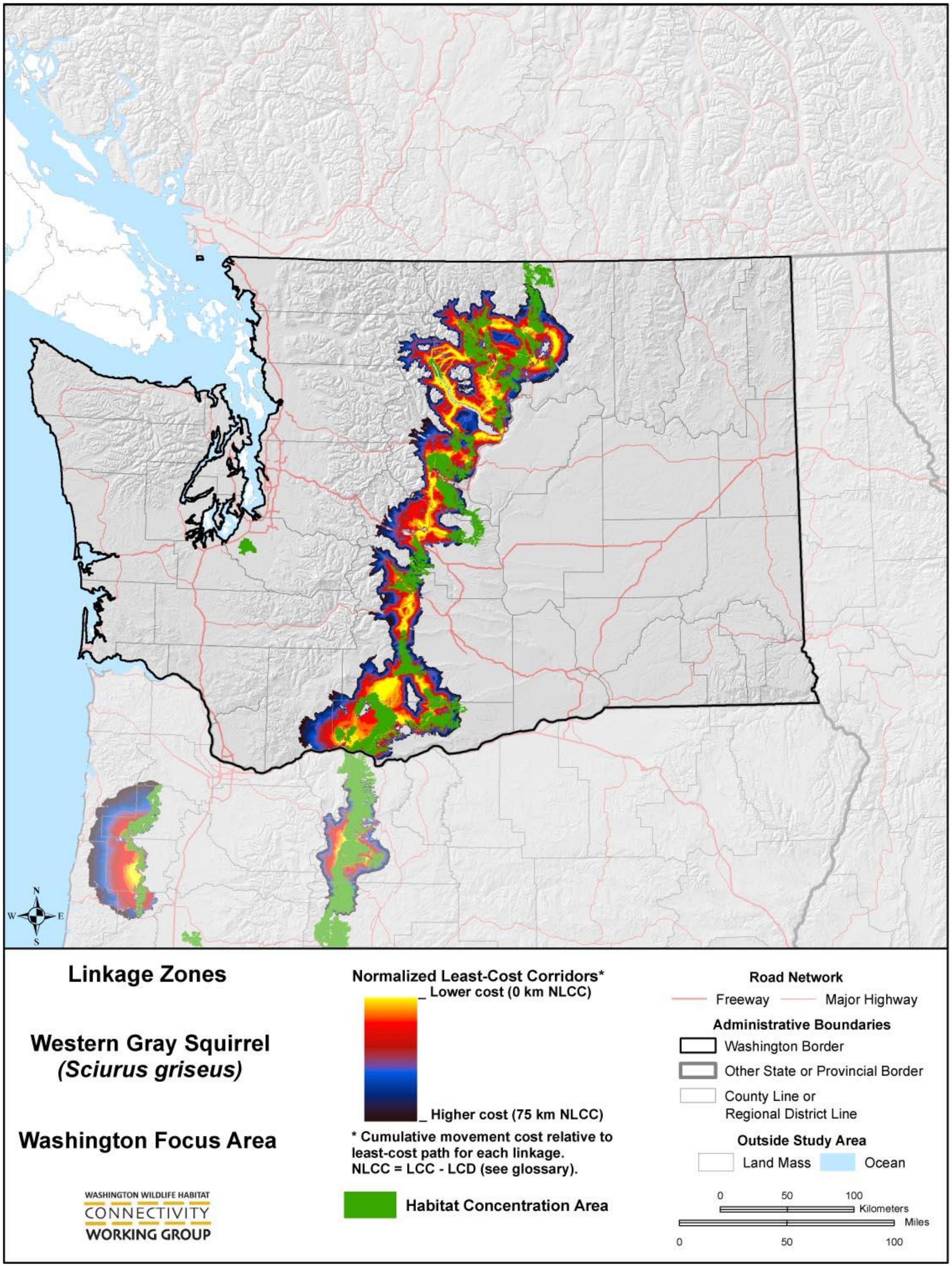

Figure 3.32. Western gray squirrel linkages.

3.2.10. American Black Bear (*Ursus americanus*)

3.2.10.1. INTRODUCTION

Throughout North America, American black bears are symbolic of wild environments (Hummel et al. 1991). They seldom get along well in areas with lots of people; not because they can't, but often because they aren't allowed to. Despite conflicts with humans, the species is very successful and currently occupies much of its historical range in the project area. American black bears were selected as a focal species due to their broad distribution within the assessment area, association with forested habitats, and wide-ranging space-use patterns.

Black bear, photo courtesy of USFWS.

American black bears have large home ranges and exhibit relatively high sensitivity to landscape fragmentation (Beier & Noss 1998). Cushman et al. (2009) evaluated the potential for American black bears to be used as a surrogate for the federally Threatened grizzly bear (*Ursus arctos*) in the identification of regional conservation corridors. They found considerable overlap in areas identified as important corridors for American black bears when compared to areas that others identified as important "linkage zones" for grizzly bears (Mietz 1994; Sandstrom 1996; Waller & Servheen 2005).

3.2.10.2. MODEL CONCEPTUAL BASIS

Habitat concentration areas were identified using a resistance value of ≤6, a home range radius of 2.6 km, a moving window threshold of 0.5, and a minimum patch size of 200 km^2. Habitat concentration areas were areas of at least 200 km^2 (roughly equivalent to average female home range size [see Appendix A] and multiplied by 10, which equals 214 km^2) composed of forest or higher elevation non-forest habitats, with distances from main open roads (paved or Forest Service Level 3, 4 or 5) of at least 500 m.

Information from published habitat connectivity models (Singleton et al. 2002; Cushman et al. 2006) was modified with local research on resource selection (Koehler & Pierce 2003; Lyons et al. 2003; Gaines et al. 2005) to derive resistance values.

3.2.10.3. MODEL RESULTS

Habitat Concentration Areas — There are 27 HCAs well distributed throughout the known distribution of American black bears within the project area (Fig. 3.33). Habitat concentration areas for American black bears cover 53,071 km^2 of the assessment area and range in size from 239 km^2 to 7381 km^2. Areas that are within the distribution of American black bears but are not included within HCAs include southwestern Washington where high concentrations of human activities, such as roads, resulted in high resistance values. Other notable gaps in the distribution of HCAs occurs along the Okanogan and Upper Columbia River valleys where a combination of low-elevation dry vegetation types, rivers, highways, and other human activities precluded inclusion within an HCA. These patterns are relatively consistent with those presented for the general forest carnivore model by Singleton et al. (2002) and represent a reasonable approximation of the distribution of high quality habitat for American black bears across the project area.

Resistance Surface — The American black bear resistance surface generally indicates that good conditions for black bear movements occur throughout their habitat in the project area. Human development and natural factors such as low elevations and dry habitats contributed to barriers (Fig. 3.34).

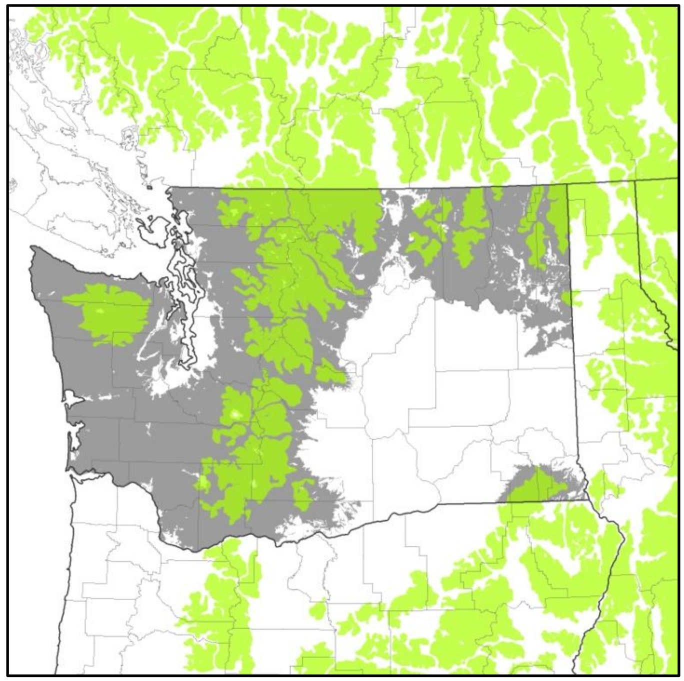

Figure 3.33. American black bear HCAs (green) and GAP distribution (gray).

Cost-weighted Distance — The American black bear cost-weighted distance map indicates that connectivity is good throughout much of the project area, with the exception of the Puget Trough, southwestern Washington, and the arid lands of the Columbia Plateau (Fig. 3.35).

Linkage Modeling — Linkages were modeled when the least-cost distance between a pair of HCAs was less than 400 km. This resulted in 44 linkages being modeled between HCAs (Fig. 3.36). The mean Euclidean distance of the linkages was 11 km and ranged from 1 to 32 km. The mean cost-weighted distance was 116 km and the ratio of cost-weighted/Euclidean distance ranged from 6 to 51 km.

The HCAs that occur along the Cascade Mountains extend from south-central British Columbia to the central Cascades of Oregon. In general there is a relatively high level of connectivity north-south throughout the Cascades due to sizeable areas of wilderness, national parks, national forests, state wildlife areas, and other public lands. However, there are some interruptions in this pattern that are important for consideration in conservation planning. A noticeable gap in north-south habitat connectivity for American black bears occurs along the Columbia River Gorge where a combination of human (highways, dams, trains, towns) and natural factors (low-elevation dry habitats) interact. Another gap in habitat connectivity occurs along the I-90 corridor where efforts are currently underway to improve habitat connectivity for a wide array of terrestrial and aquatic species. Finally, careful planning along the Highway 2 corridor and finer-scale linkage modeling will be important to conserve or enhance this linkage.

Our modeling effort did not yield a potential habitat corridor for American black bears between the Olympic and Cascades Mountains. Singleton et al. (2002) modeled a linkage through southwestern Washington between the Olympic and Cascade Mountains, but based on the actual and weighted distance concluded that the southwest Washington landscape is an effective barrier for forest carnivores. Another east-west potential linkage was modeled in Oregon between Redmond and Madras. This potential linkage includes public lands such as the Crooked River National Grassland and Ochoco National Forest. It is bisected by Highways 97 and 26. This is the only potential linkage within the project area that could connect the Cascades with the Blue Mountains. It is unknown whether this potential linkage currently functions to provide connectivity for American black bears. Finer-scale linkage modeling will be needed to better determine the function of this linkage.

Potential linkages were also modeled between the North Cascades and the Selkirk Mountains across northeastern Washington. This area has been identified as important for connecting populations of carnivores that occur in the Rocky Mountains and the Cascades Mountains (Singleton et al. 2002; Singleton et al. 2004). The valleys associated with the Okanogan, Upper Columbia, and Pend Oreille Rivers occur within the potential linkages between HCAs in this area. Along these valley bottoms occur towns, highways, and agricultural lands. Public lands, mostly the Okanogan and Colville National Forests, may function as stepping-stone habitats and increase the ***permeability*** of this landscape for bears and other carnivores (Singleton et al. 2002; Singleton et al. 2004). Finer-scale linkage modeling would be useful in identifying locations where potential linkages could be conserved or enhanced.

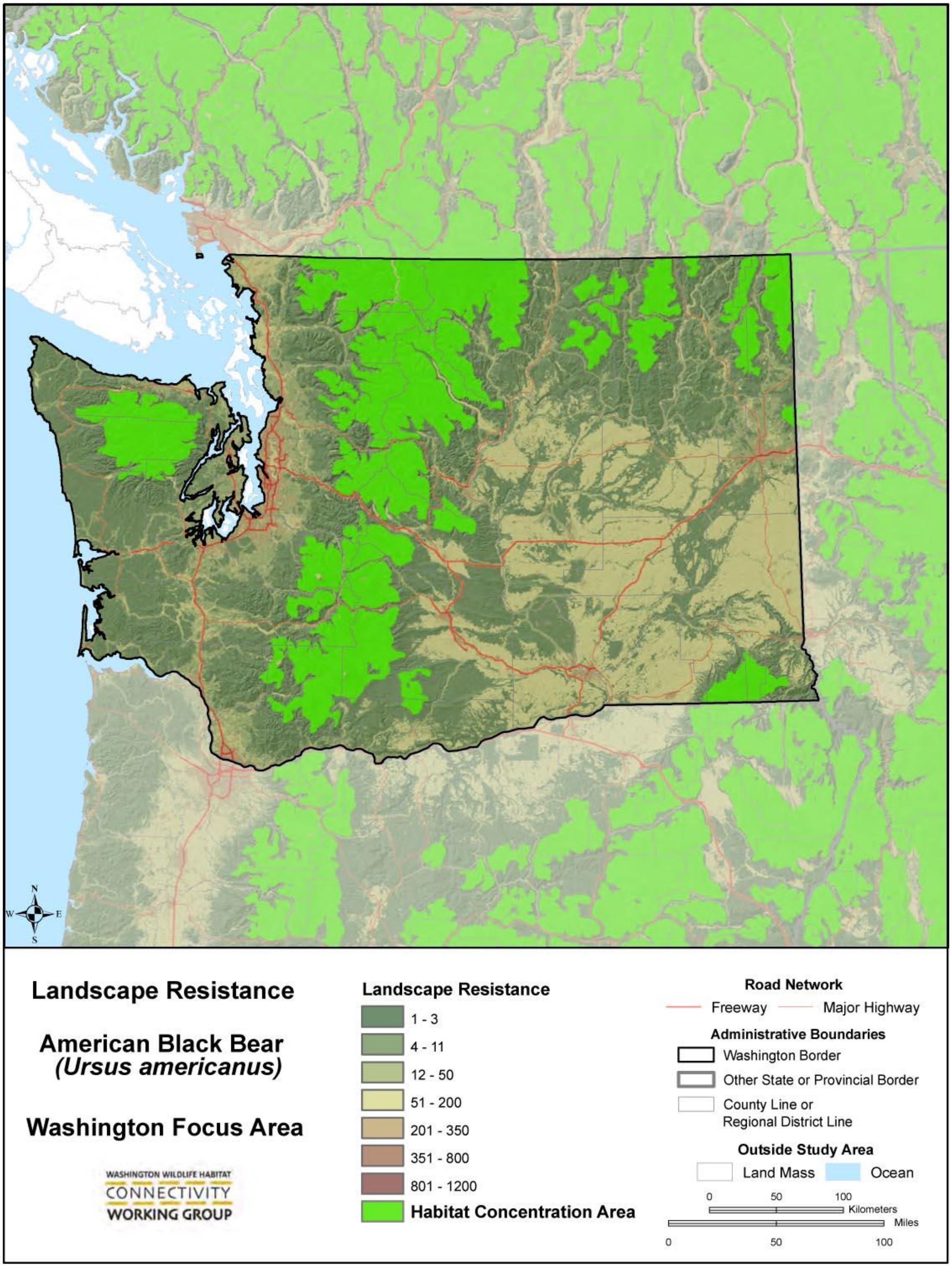

Figure 3.34. Landscape resistance for American black bears.

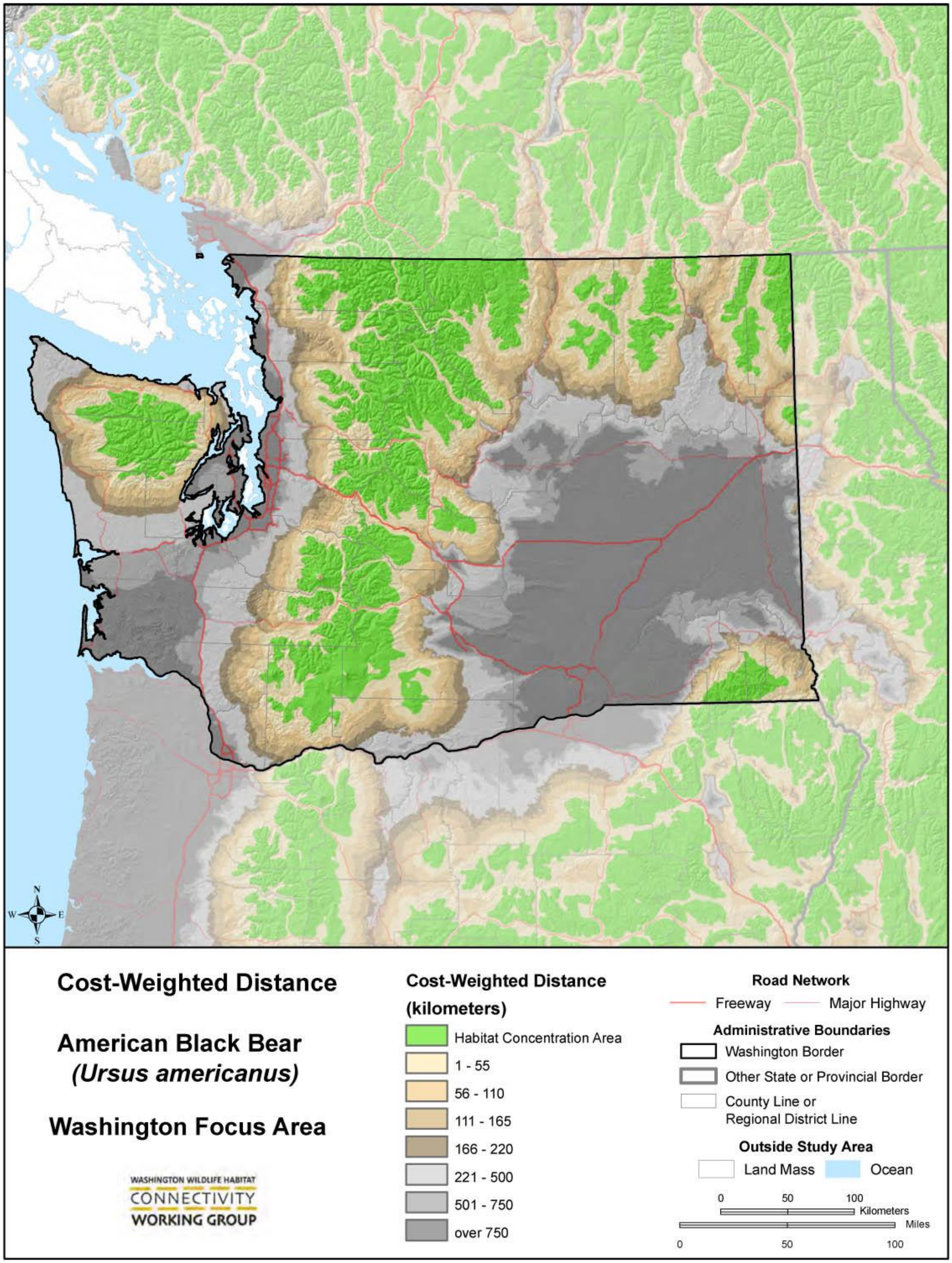

Figure 3.35. Cost-weighted distance for American black bears.

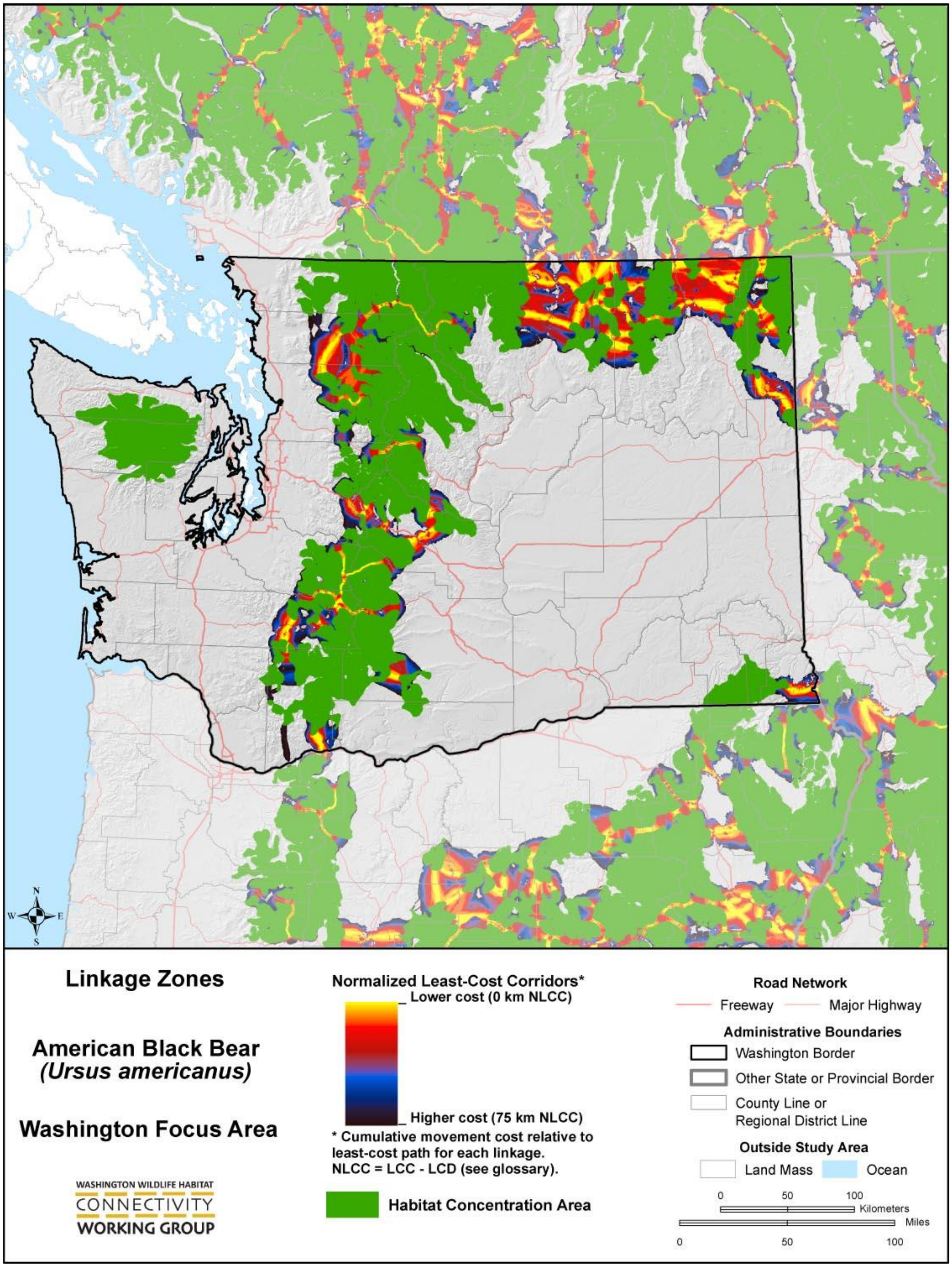

Figure 3.36. American black bear linkages.

3.2.11. Elk (*Cervus elaphus*)

3.2.11.1. INTRODUCTION

Elk, photo by Kelly McAllister.

Elk are among the more visible and culturally important wildlife in Washington State. There are avidly pursued by hunters and highly valued by Native American Tribes for subsistence and ceremonial uses. Elk also figure prominently in damage to private property, primarily agricultural crops and fencing. Simply viewing elk is considered a privilege by many. Their value and the nature of their interactions with people are multi-faceted. In Washington, elk are classified as a big game animal. One population, the Nooksack elk population, is a Species of Greatest Conservation Need.

Elk are additionally important as members of the wildlife community, serving a number of key ecological functions as herbivores and prey for large carnivores such as cougars and wolves. In the Pacific Northwest, elk are common to abundant in most mountainous regions and are present in many low-lying valleys, particularly during winter. The only extensive areas with few to no elk are the arid desert regions. Elk are associated with a wide variety of habitat conditions including forest habitats spanning the full range of moisture conditions and even shrubsteppe environments where there are no trees within the herd's range. In general, though, elk are associated with open woodlands or a mosaic of mature forest, meadow, and early successional forest conditions. They avoid dense, unbroken forests, largely due to a lack of adequate forage. Elk can be found in coniferous swamps, clear cuts, aspen-hardwood forests, and coniferous-hardwood forests. They are found over a wide range of elevations. In our project area, they occur from sea level to nearly 3000 m, with the highest elevations occupied seasonally, when snowpack allows.

Some local populations are migratory, exploiting productive mountain meadow-habitat in summer but retreating to low-elevation valleys in winter. As such, migratory elk often move long distances on a seasonal basis. Telemetry studies of the migratory Yakima elk herd (S. McCorquodale, personal communication) indicate that the average distance between winter and summer home ranges is about 30 km. Most of the Yakima elk had winter and summer activity centers that were separated by ~25–40 km. Maximum distances between winter and summer activity centers were in the range of 70–80 km. Elk are known to move as much as 100 km between seasonally important habitats (Boyce 1991).

3.2.11.2. MODEL CONCEPTUAL BASIS

The Department of Fish and Wildlife's Landscape Priority Habitats and Species Project characterized elk as having high sensitivity to the effects of roads and development. Elk are known to be affected by development, roads and traffic, and the presence of people and domestic animals.

Elk HCAs were largely identified based on vegetative cover conditions that indicated adequate forage and cover within the typical daily movement range of an individual elk. Areas outside of documented elk range were eliminated from consideration as were highway corridors and areas of human population density greater than one dwelling unit per 40 acres.

To characterize the suitability of the landscape for elk movements, resistance parameters were developed from descriptions of optimal elk habitat conditions and features of the landscape that are avoided. Since road avoidance is a recurring theme in the elk literature, this aspect of elk behavior was built into the model.

While there is ample information on elk habitat associations and preference, there is little published information on conditions suitable for elk movements, with the exception of research in Arizona to determine the barrier effect of highways (Dodd et al. 2007). Scoring resistance for landscape attributes that fell short of documented preferred conditions was based on professional judgment with the knowledge that elk will move through a wide variety of conditions that offer little or nothing in the form of security cover or forage.

3.2.11.3. MODEL RESULTS

Habitat Concentration Areas — Elk HCAs are well-distributed throughout the project area but considerably less extensive than known elk range (Fig. 3.37). Some areas with significant numbers of elk (for example, the Willapa Bay area) were not included in HCAs due to high road densities. Elk numbers are sometimes high in areas where human population densities or agricultural land uses make it difficult for the numbers to be sustained over time. These areas were not included in HCAs.

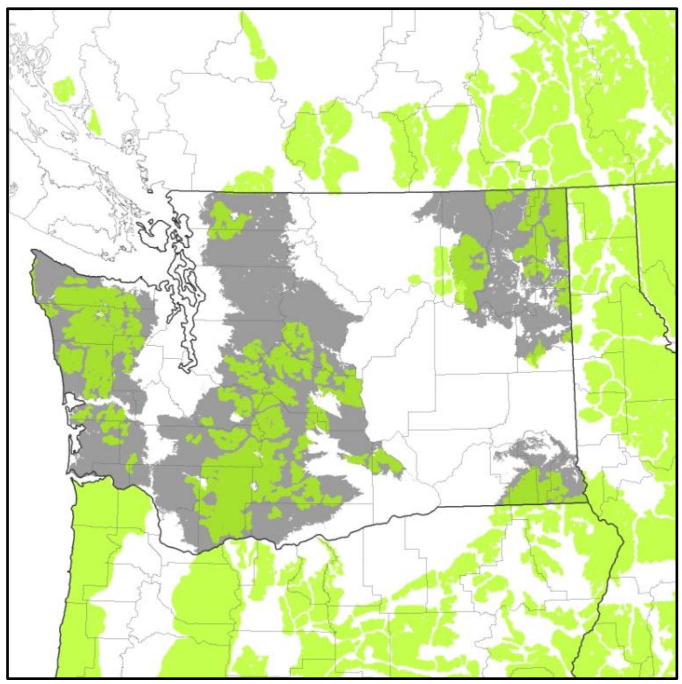

Figure 3.37. Elk HCAs (green) and GAP distribution (gray).

Resistance Surface — The elk resistance surface indicates good conditions for elk movements throughout much of the project area, with the exception of most of the arid Columbia Plateau and all areas affected by extensive development or conveying busy roads (Fig. 3.38).

Cost-weighted Distance — The elk cost-weighted distance map provides a view of the full range of areas most suitable for elk movements away from HCAs (Fig. 3.39). This map is most useful for understanding the full range of elk movement landscapes beyond least-cost corridors produced by the linkage model output.

Linkage Modeling — Linkages were modeled when the least-cost distance between a pair of HCAs was less than 250 km. This resulted in linkages being modeled between 98 discrete pairs of HCAs (Fig. 3.40). Straight-line, Euclidean, distances between HCAs ranged from 1 to 137 km. Weighted least-cost distances between HCAs averaged 80 km with a range from 2 to 235 km.

There are a number of large gaps or significant interruptions between HCAs for elk. The I-5-Puget Trough fracture is one of them. Here, substantial development and the state's busiest interstate threaten to isolate coastal elk from those of the interior Cascade Mountains. Linkage model outputs suggest several locations where conserving or restoring conditions suitable for elk movements could serve to keep populations connected. Similar, though perhaps less severe, interruptions to connectivity occur in the Chehalis bottomlands, where U.S. Highway 12 connects Olympia with Grays Harbor, and in the Cascade Mountains, where I-90 passes west to east. In the Chehalis bottomlands, outputs from the models indicate where to look to maintain a corridor between the Olympics and the Willapa Hills. Good locations for maintaining connectivity in the Cascade Mountains are indicated between North Bend and Snoqualmie Pass. Unfortunately, the best identified corridor across I-90 on the east slope of the Cascades is currently blocked by a fence constructed for the purpose of preventing elk movements onto the interstate and into agricultural lands where they are likely to damage private property.

Model outputs suggest the central and north Cascade Mountains provides ample suitable conditions for connecting elk of the south Cascades with elk in the Nooksack herd of Whatcom and Skagit Counties. Multiple linkages are also suggested as connections between elk in British Columbia and those in the U.S., including those in and around lands managed by the Colville Confederated Tribes. Similarly, elk associated with the Arid Lands Ecology Reserve on the Hanford Department of Energy site might be well served by conserving suitable conditions for movements to and from the Colockum Wildlife Area and Cascade foothills areas of the upper Yakima River drainage.

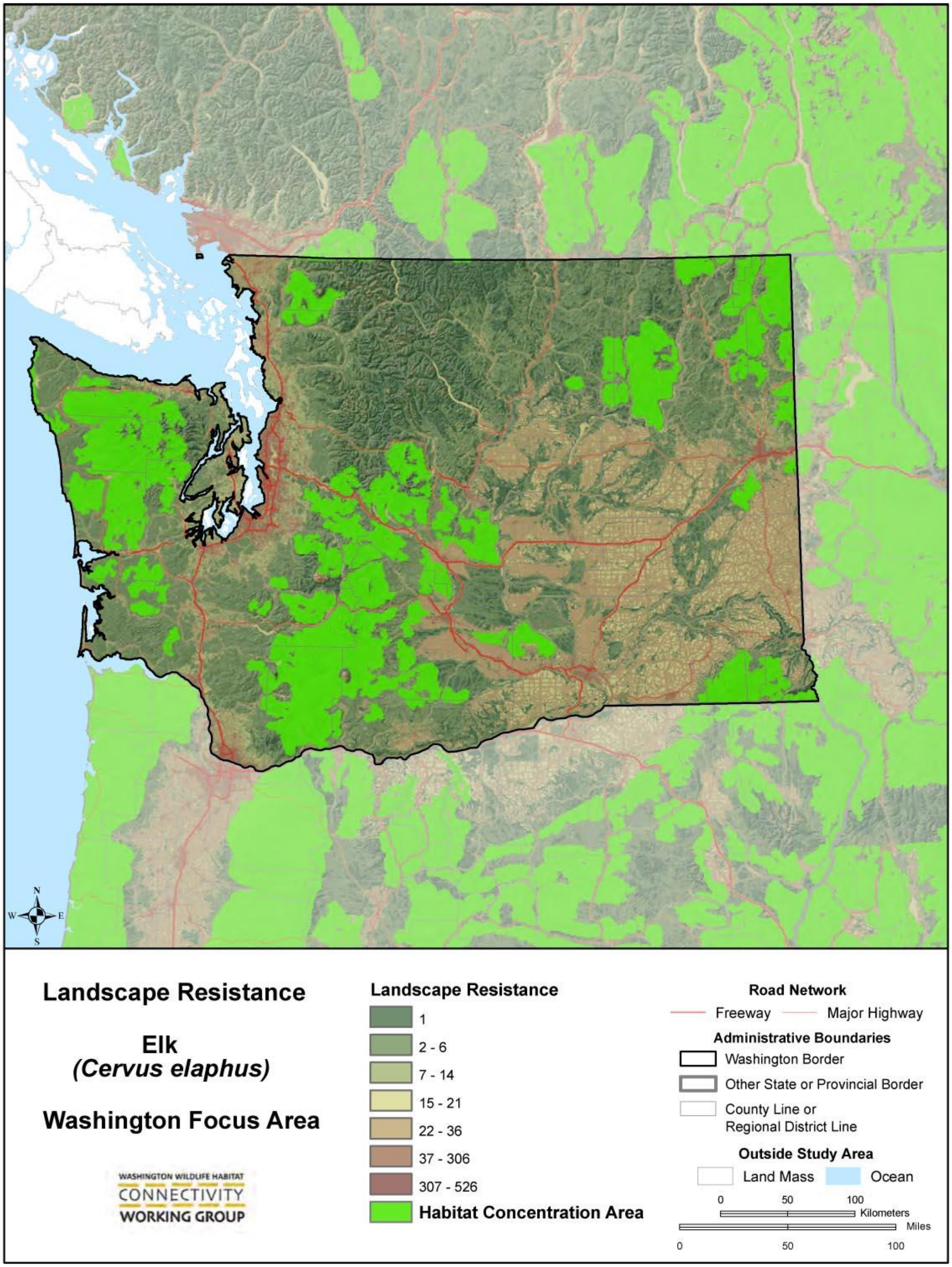

Figure 3.38. Landscape resistance for elk.

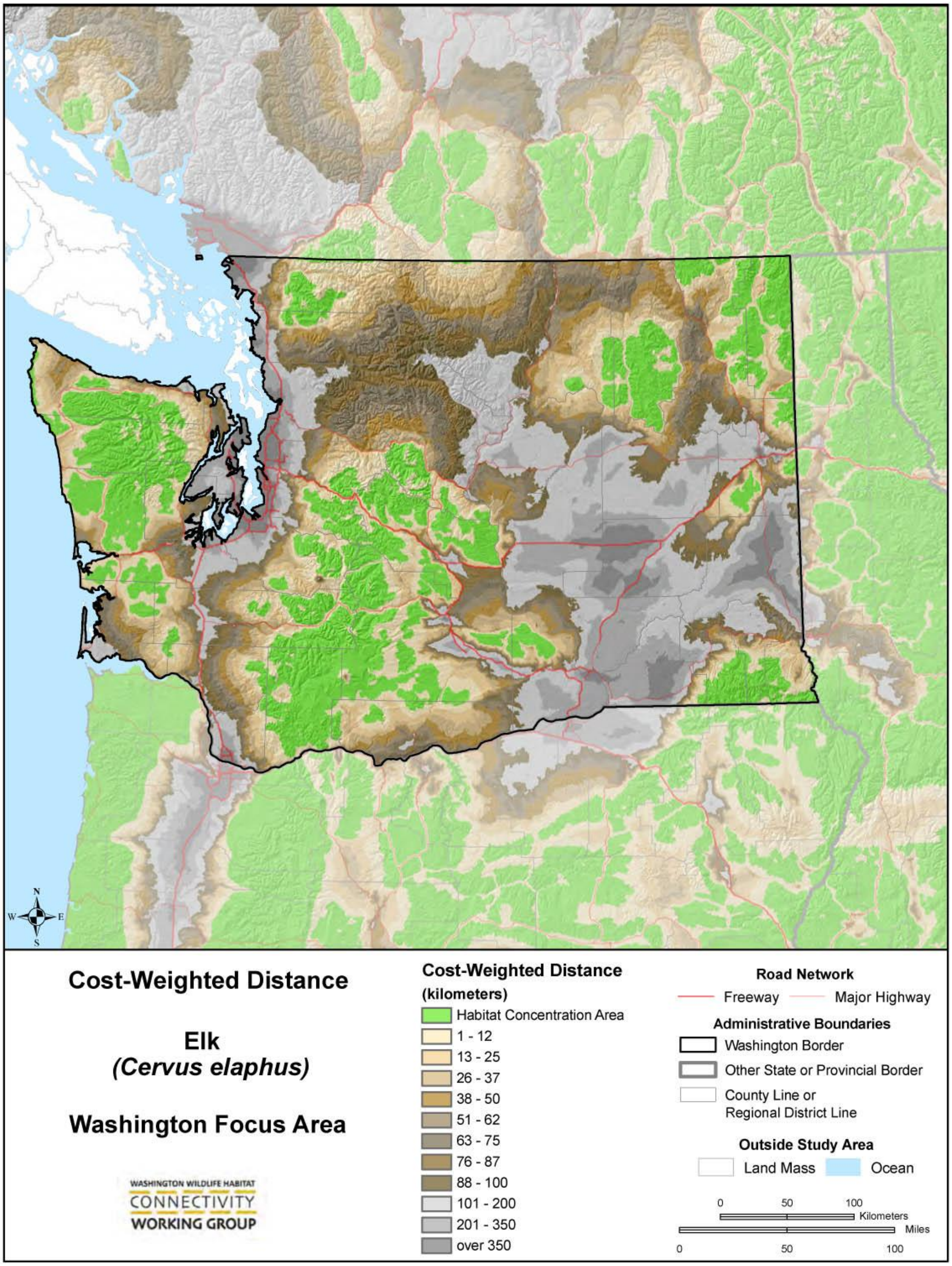

Figure 3.39. Cost-weighted distance for elk.

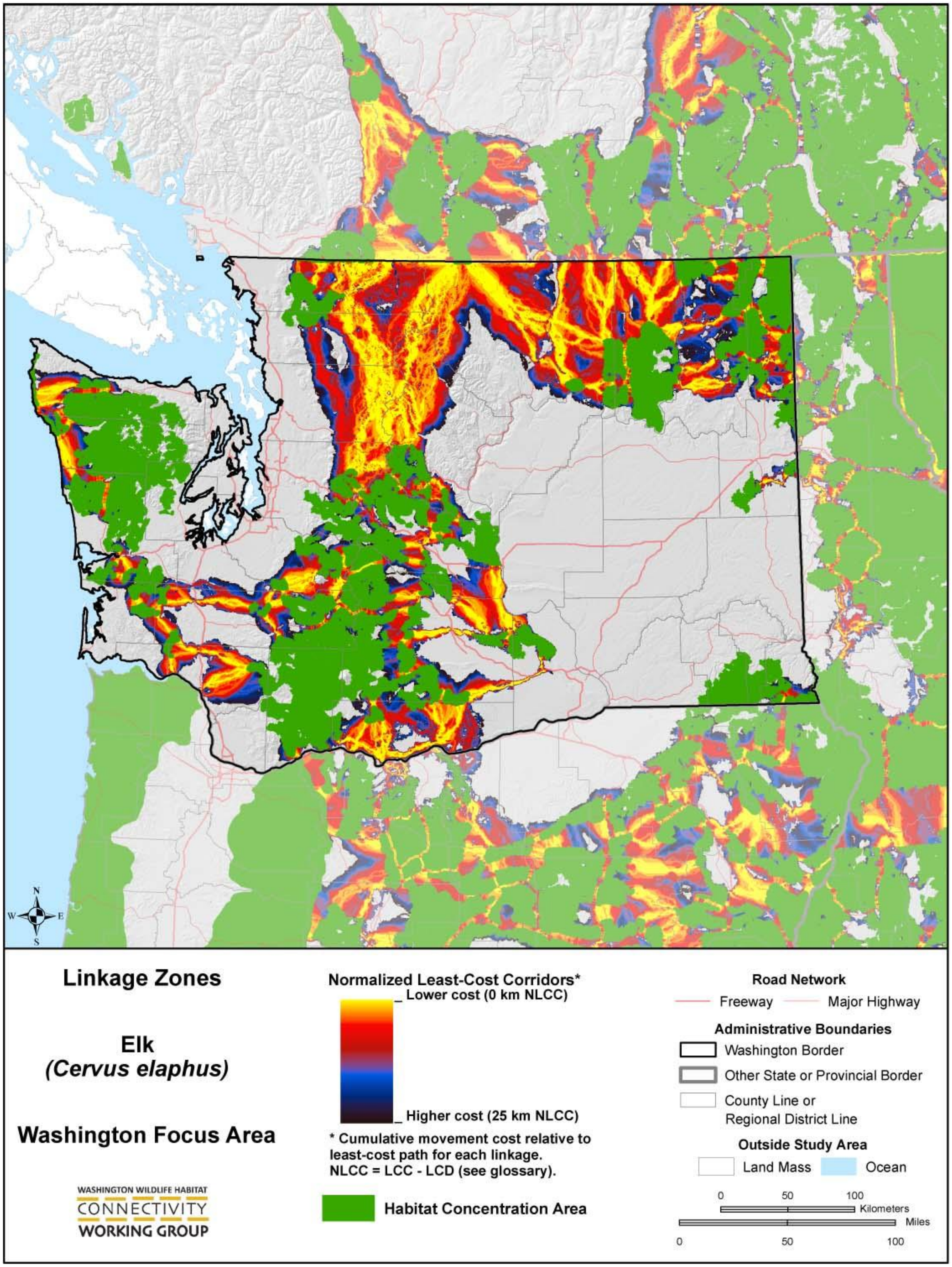

Figure 3.40. Elk linkages.

3.2.12. Northern Flying Squirrel (*Glaucomys sabrinus*)

3.2.12.1. INTRODUCTION

Northern flying squirrel, photo courtesy of WDFW.

Northern Flying Squirrels play a critical role in the ecology of Pacific Northwest forests. They are important in the diet of Northern Spotted Owls (*Strix occidentalis*). They also help disperse fungal spores (underground fungi are a major part of their diet) that aid trees in their absorption of nutrients from the soil. In Washington, the northern flying squirrel occurs in all coniferous and mixed forest types within its range. It is absent from the San Juan Islands, as well as Guemes, Cypress, and Lummi Islands, and does not occur in conifer 'islands' in the Palouse. Interestingly, it has adapted to urban areas in Washington; populations occur in the cities of Walla Walla, Seattle, Dayton, and Tacoma (Johnson & Cassidy 1997).

The northern flying squirrel was selected as a focal species because it is a good representative of wildlife connectivity habitat needs within the Vancouverian and Rocky Mountain Forest classifications. Flying squirrels are vulnerable to loss of habitat connectivity from all four of the main connectivity threats: land clearing and vegetation removal, development, roads and traffic, and people and domestic animals.

Forests that support high densities of northern flying squirrels are generally characterized as having dense multi-layered mid and over-story canopies, low to moderate amounts of understory, and few canopy gaps (Wilson 2010). These characteristics are typically found in mature and old-growth forests but can also be found in some younger forests (Rosenberg & Anthony 1992; Buck & Woodworth 2008). Older forests that lack one or more of these characteristics have been found to support few or no squirrels (Carey 1995; Wilson 2010). Across its range, squirrel abundance has been associated with large-diameter trees, large snags, coarse-woody debris (particularly decayed logs), and fungi (Carey et al. 1999; Smith 2007). These associations may have more to do with the structural complexity of a forest than a specific need for these individual components (Wilson 2010).

3.2.12.2. MODEL CONCEPTUAL BASIS

We used published literature and input from expert reviewers to develop resistance surfaces used to evaluate dispersal habitat suitability and HCAs. Riparian and forested areas with >70% canopy cover were assigned the lowest resistance values; agriculture, sparsely vegetated, grass and shrub-dominated habitats the highest.

Home range size of northern flying squirrels in the Pacific Northwest varies from 2.5–5.8 ha and tends to be influenced by forest structure and composition (Martin & Anthony 1999; Lehmkuhl 2006). Dispersal rate and distance for northern flying squirrels may depend on population density in a given source site and on habitat quality, however few studies address this topic. In a study in Alaska, northern flying squirrel juveniles dispersed 0.8–1.1 km in a landscape of complex old growth islands in the Tongass National Forest; some juveniles moved 1–2 km and readily crossed two-lane roads. One juvenile moved about 7 km in 48 hrs however it is unclear whether this was a dispersal or circuit movement (Smith et al. 2010). The largest home range documented is 11.2 ha in unlogged coniferous forest in Canada (Holloway & Malcolm 2007). Dispersal events for northern flying squirrels likely reflect a slow, generational progression across the landscape. Corridor width and a dense multi-layered canopy may be key factors affecting how far and how safely an individual squirrel can disperse (T. Wilson, personal communication).

3.2.12.3. MODEL RESULTS

Habitat Concentration Areas — Forty-one northern flying squirrel HCAs were identified for Washington, ranging from 50 to 7068 km^2 in size, with a mean of 504 km^2. Northern flying squirrel HCAs are patchy and elongated, and generally follow higher altitude, north-slope drainages and valleys (Fig. 3.41). The total area of all HCAs was 20,648 km^2 (Table 3.2). HCAs on the Olympic Peninsula are largely centered in the Olympic National Park. Others follow relatively undisturbed areas along the North and South Cascades, with a rather wide gap at I-90 and above Keechelus, Kachess, and Cle Elum Lakes, resuming to the south around Mount Rainier. In the northeastern part of Washington, HCAs are scattered, few and far between. Southeast Washington, in the Blue Mountains, an especially convoluted HCA follows the Wenaha Tucannon Wilderness into the Umatilla National Forest.

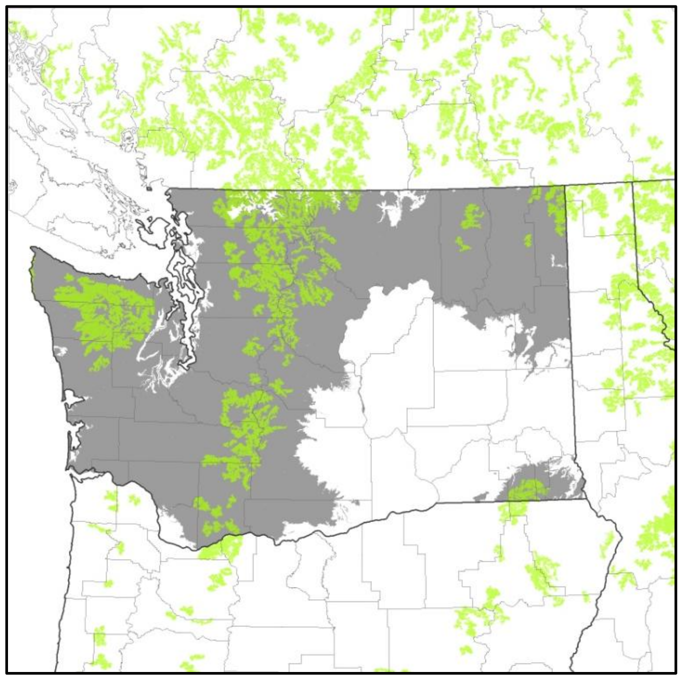

Figure 3.41. Northern flying squirrel HCAs (green) and GAP distribution (gray).

A number of HCAs for this model may no longer represent core squirrel habitat. The vegetation layer used in the model dates from 2001 and, since then, forestry activity has altered the landscape. For example, one HCA, located just south of Olympic National Park, has been heavily clear-cut. The number and extent of HCAs in the northeastern part of the state are probably under-represented due to the minimum size requirements of the HCA identification model, and recent changes in the landscape.

Resistance Surface — The northern flying squirrel resistance surface shows reasonable conditions for squirrel movements throughout the species' range in the project area, with the exception of the arid Columbia Plateau and all areas affected by extensive development, heavy forestry, or road systems. However, some areas shown on the map as low resistance (e.g., the Willapa Hills) are currently poorly suited to squirrel occupation and movement, due to recent timber harvest (Fig. 3.42).

Cost-weighted Distance — The northern flying squirrel cost-weighted distance map provides a view of the full range of areas most suitable for squirrel movements away from HCAs (Fig.

3.43). This map is most useful for understanding the full range of squirrel movement landscapes beyond least-cost corridors produced by the linkage model output.

Linkage Modeling — Linkages were modeled when the least-cost distance between a pair of HCAs was less than 126 km. This maximum distance was chosen based on a subjective evaluation of the pairs of HCAs we wanted to link and takes into account slow, multi-generational dispersal over fragmented landscapes to depict the most viable linkages likely to be functional over coming decades. This resulted in linkages being modeled between 49 discrete pairs of HCAs within or partially within Washington (Fig. 3.44). Least-cost distances for these 49 linkages ranged from 2 km to 122 km with a mean of 37 km, while Euclidean distances ranged from <1 km to 31 km. The ratio represented by the least-cost distance divided by the Euclidean distance had a range of 3 to 1167 with a mean of 49 (Table 3.3). This ratio is an indication of corridor quality, and can be thought of as representing the additional cost of moving along a corridor composed of less than optimal dispersal habitat (e.g. a corridor with a ratio of 2.0 would be, conceptually, twice as difficult to traverse per unit distance than a corridor consisting entirely of optimal dispersal habitat, which would have a ratio of 1.0).

Corridors provide fairly good linkages throughout the North Cascades and South Cascades; however, I-90 poses a significant interruption. On the Olympic Peninsula, two very strong corridors connect HCAs on Olympic National Park lands across the Olympic Experimental State Forest. Two corridors also join the large Olympic National Park HCA to a small one to the south, located in the Olympic National Forest. In the northeastern part of Washington, HCAs are scattered and few. A cluster exists in Pend Oreille County, but these have few linkages; pinch points occur at Sullivan Lake and along Box Canyon Dam. No linkages appear in the Blue Mountains HCA; despite its fractured appearance, it is a single connected HCA.

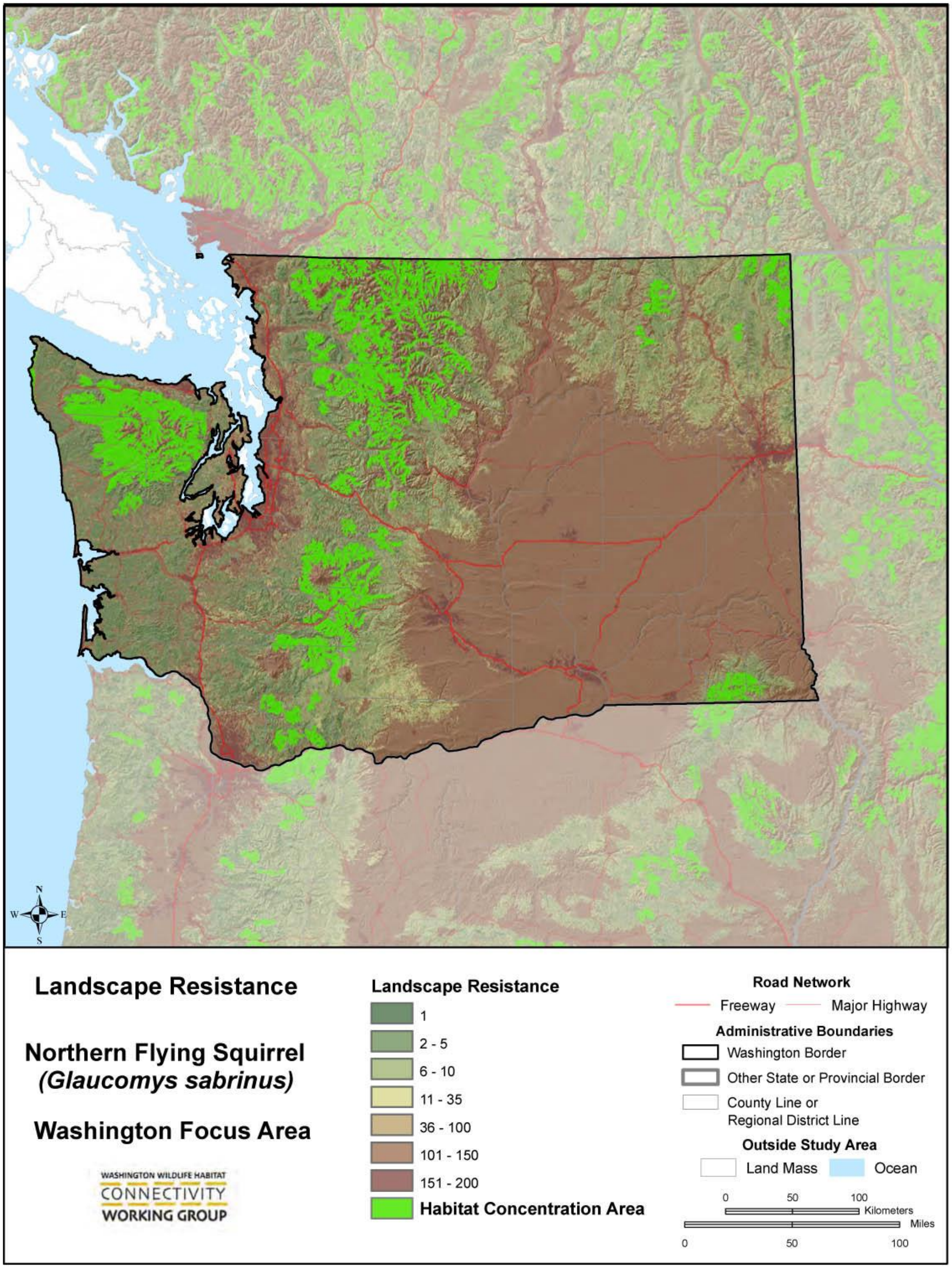

Figure 3.42. Landscape resistance for northern flying squirrels.

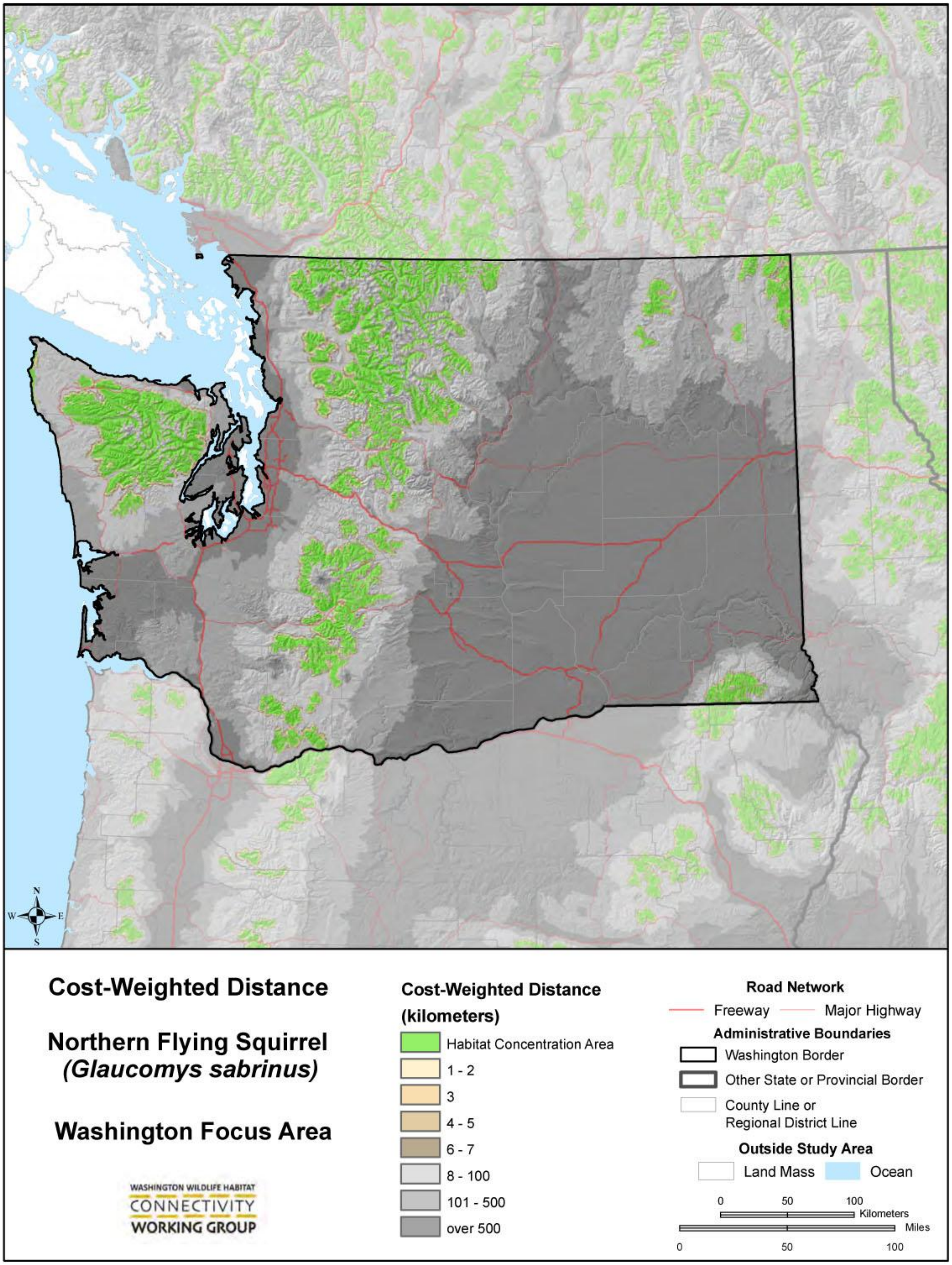

Figure 3.43. Cost-weighted distance for northern flying squirrels.

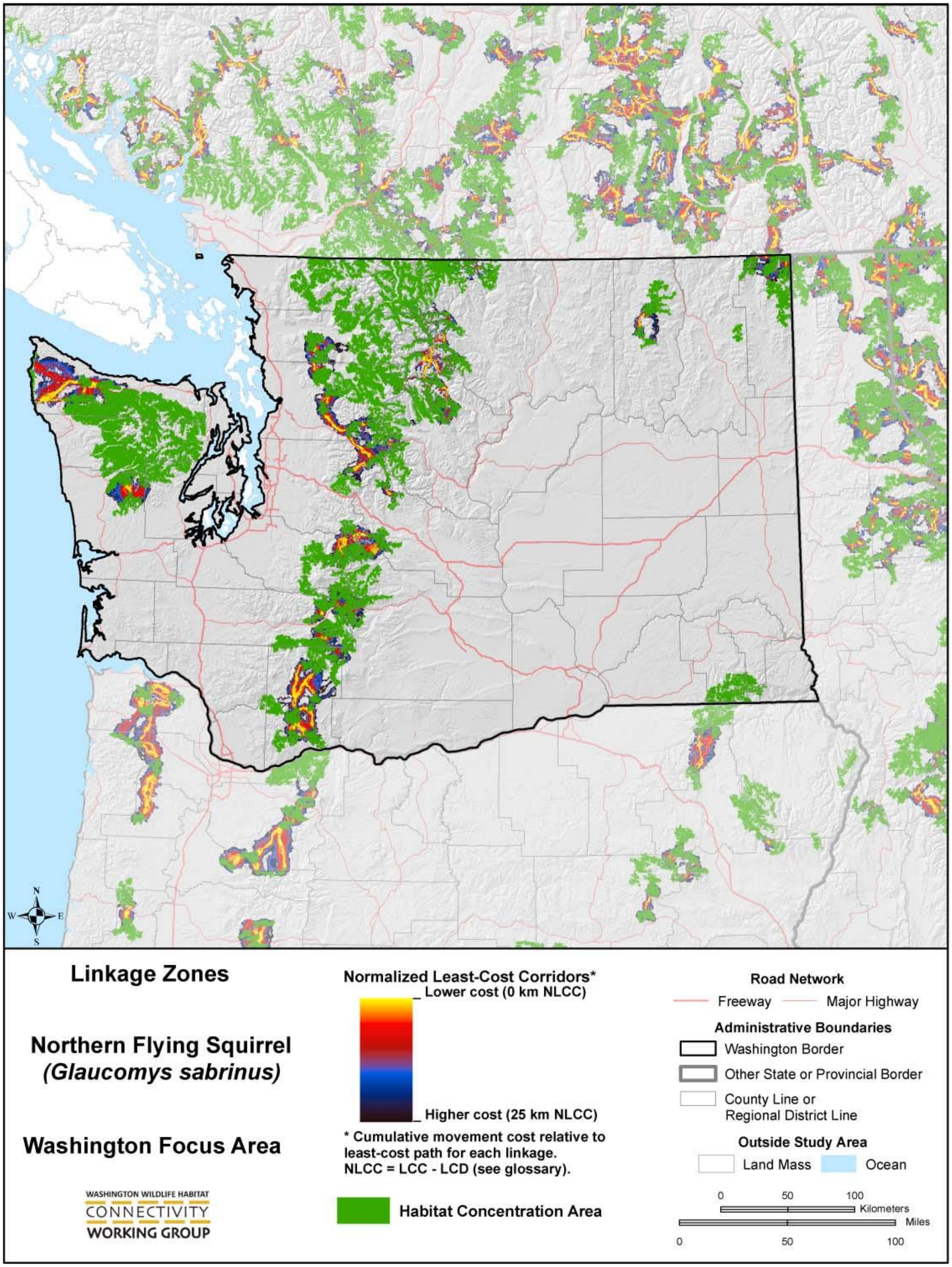

Figure 3.44. Northern flying squirrel linkages.

3.2.13. Western Toad (*Anaxyrus boreas*)

3.2.13.1. INTRODUCTION

Western toad, photo by Joanne Schuett-Hames.

Western toads are pond-breeding amphibians that move during the year to access aquatic breeding areas as well as terrestrial habitats. Seasonal movements of 1 to 3 km appear to be common (Bartelt et al. 2004; Bull 2006; Lynch 2006; Deguise 2007), and movement of 13 km in less than one month has been documented (Schmetterling & Young 2008). The reliance on aquatic habitats that occur in association with terrestrial habitats makes the toads important as an umbrella species for other pond-breeding amphibians with similar life history needs. Western toads are found across much of Washington from low to high elevations with the exception of much of the non-forested arid lands in eastern Washington (Leonard et al. 1993). The toad populations have been declining, for instance, in the Puget Sound Region, and in Mount Rainier National Park (Leonard et al. 1993; Adams [date unknown]). This species has a state conservation status of Candidate and nationally is a federal Species of Concern.

Populations of pond-breeding amphibians such as the western toad operate at multiple scales. These scales are: (1) the individual breeding pool or stream, (2) the breeding pool or stream with surrounding upland habitat, (3) neighboring breeding locations and upland habitat, and 4) clusters of neighboring populations in a regional framework where the focus is on long-term connectivity of metapopulations at a regional scale (after Compton et al. 2007). The latter scale is the focus for this statewide modeling effort.

Western toads were selected as a focal species because they are a good representative of habitat connectivity needs of wildlife with similar life history needs in the three forest vegetation classes (Rocky Mountain, Vancouverian, and Subalpine Forests; Table 3.1). In addition, the toad's broad coverage across the landscape, reliance on connectivity between populations, and in particular, its association with wetlands and aquatic systems led to inclusion in the statewide analysis.

3.2.13.2. MODEL CONCEPTUAL BASIS

Estimates of landscape resistance to dispersal were derived from expert opinion and literature regarding western toad movement and habitat characteristics. Road traffic, human population density, and urban land use are top factors impacting ***landscape permeability*** for this species and relevant GIS factors were given the highest resistance values.

We modeled western toad HCAs through steps that began with identification of potential breeding habitat based on wetlands, river, and waters data layers. We classified breeding habitat as having a value of 1 and all other areas as having a value of 0. We next ran a 2 km moving window to calculate the average proportion of breeding habitat within the window; this step begins the linking of breeding areas to complementary terrestrial habitats. We then removed any habitat grid cells where the breeding habitat density was <0.05, thus eliminating areas where breeding habitat was scarce. We ran a 2 km cost-weighted distance out from the remaining breeding habitat to link neighboring populations. This became our preliminary HCA map. We completed our map by removing small HCAs (<50 km^2), and HCAs in eastern Washington shown to be outside of the western toad range based on Dvornich et al. (1997).

3.2.13.3. MODEL RESULTS

Habitat Concentration Areas — We identified a total of 248 western toad HCAs across much of the toads range within Washington as well as into British Columbia, Idaho, Oregon, and Montana: 94 of the HCAs are within or intersect Washington (Fig. 3.45; Table 3.2). Within Washington the Olympic Peninsula encompasses the densest HCA pattern; HCAs are also scattered through the Willapa Hills, the Cascade Mountain Range, the upper Columbia River and Pend Oreille River valleys, and along portions of the Snake River and Blue Mountains in southeast Washington. The HCAs are convoluted shapes that tend to follow river valleys, other large water features such as Lake Roosevelt, and areas of dense wetlands and streams. Washington includes toad HCAs that span boundaries with all neighboring jurisdictions.

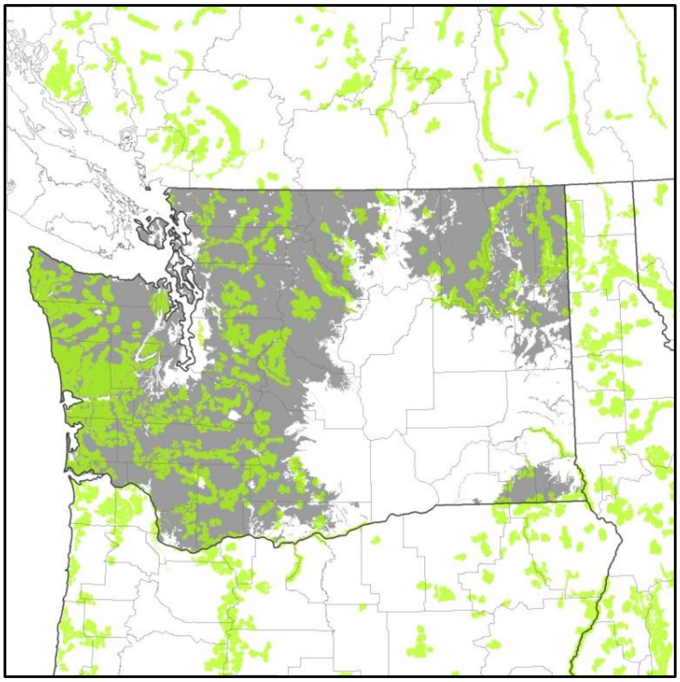

Figure 3.45. Western toad HCAs (green) and GAP distribution (gray).

Notably, few HCAs were identified in highly developed areas such as much of the Puget Sound region, and HCAs were fragmented by freeways and major highways. The Salish Sea islands are inhabited by western toads but were not within our study boundaries, and thus do not have HCAs. In addition, a lack of consistent wetland, water, and riparian data layers across boundaries with neighboring states and British Columbia has likely reduced the accuracy of HCA patterns across our borders.

We found the toad HCA sizes and extents to be highly sensitive to breeding habitat density values. Lower values provided substantially more habitat in HCAs and conversely more stringent values collapsed down the sizes and extent of the HCAs. We chose to use the value of ≥ 0.05 which produced a result where many known toad location points and known population areas were included, but such that discrete HCAs would be an effective size for linkage modeling.

Resistance Surface — The western toad resistance surface results (Fig. 3.46) within the toad distribution area broadly parallel the HCA results. Areas of least resistance tend to occur outside of developed areas and away from highway corridors.

Road traffic is among the most significant factors affecting survival of anurans including toads (van Gelder 1973; Heine 1987; Hels & Buchwald 2001; Lynch 2006). In this model we intentionally applied small values to secondary highways and local roads resistance factors. Had we done otherwise the coarse road data we used for this statewide scale analysis would have indicated much of the landscape as inhospitable. At finer scales of modeling, obtaining and using road layers that include traffic data will provide greater options for this factor and should allow for enhanced model performance.

Cost-weighted Distance — The western toad cost-weighted distance map (Fig. 3.47) indicates all areas within a 20 km cost-weighted distance of HCAs in brown colors. These areas are likely to be accessible to toads; thus there appears to be a very high level of accessibility across much of the toad's range in Washington, and across borders to Oregon, Idaho, and British Columbia. Within Washington only three HCAs appear to be isolated. Two are in the Puget Sound region: freeways and high use roads, urban/developed lands, and agriculture are factors in this isolation. The third isolated HCA is in north-central Washington, east of the Okanogan River. Our map layers may be under-representing good habitat in this area and future efforts should more carefully consider layer accuracy.

Linkage Modeling — We modeled linkages when the least-cost distance between a pair of HCAs was ≤50 km cost-weighted distance. This provided 420 linkages across the full mapped area, of which 180 were fully within Washington or spanned between Washington and neighboring jurisdictions (Fig. 3.48; Table 3.3). Within Washington linkages were mapped to all but the two isolated HCAs within the Puget Sound region.

Considering all 180 linkages within or spanning Washington, the ranges in linkage lengths were: Euclidean distance, 0–36 km (mean of 10 km [SD 9]); least-cost path distance, 0–40 km (mean of 12 km [SD 10]); and 0–50 km (mean of 18 km [SD 14]; Table 3.3). Generally, the larger extents of these ranges appear reasonable for a species such as the western toad which may be a ***linkage dweller***, i.e., a species that can disperse between habitat areas by living and dispersing through a linkage over the course of multiple generations.

The western toad linkage modeling outputs include ratios for two combinations of linkage measurements, the cost-weighted distance to Euclidean distance (range 1–58, mean of 3 [SD 7]), and the cost-weighted distance to least-cost path distance (range 1–34, mean of 2 [SD 4]; Table 3.3). In particular, low means for both ratios appear to indicate many toad linkages are generally hospitable for movement.

Cost-weighted distance to least-cost path ratios for the Washington western toad linkages were ≤2 for 79% (n = 143) of linkages, and ≤3 for 96% (n = 173) of linkages providing an indication that a majority of the linkages are likely favorable to movement by toads. Another 2% (n = 3) of linkages had ratios >3 to 10, and 2 incurred extremely high ratios of >10 to 35. While on-the-ground assessment is necessary to clarify the relationship of these ratios to the ability of toads to successfully move through the linkage areas, the range of ratios appears to include excellent to poor conditions, and may reflect a range of conservation needs from maintaining good conditions to restoring degraded conditions.

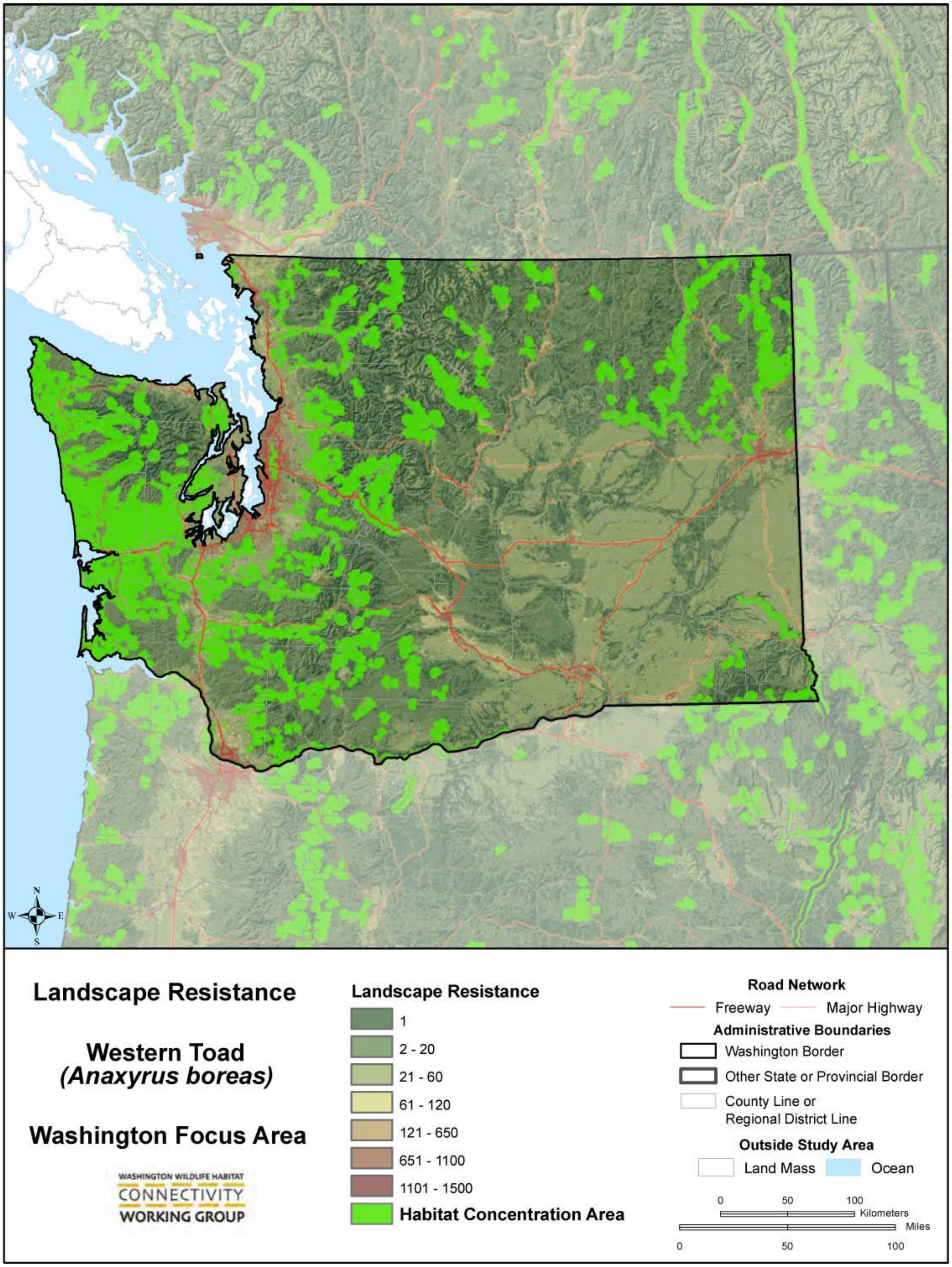

Figure 3.46. Landscape resistance for western toads.

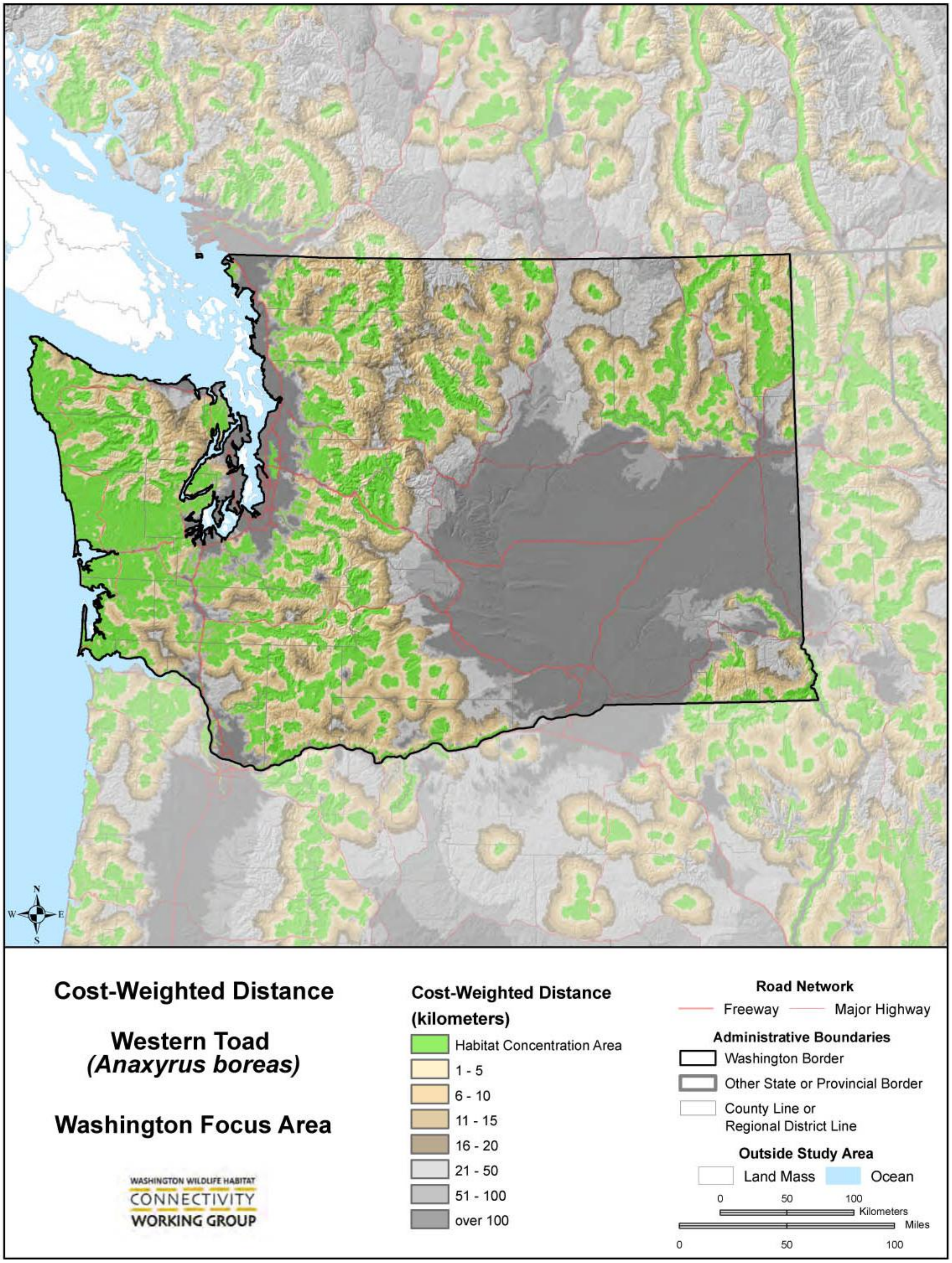

Figure 3.47. Cost-weighted distance for western toads.

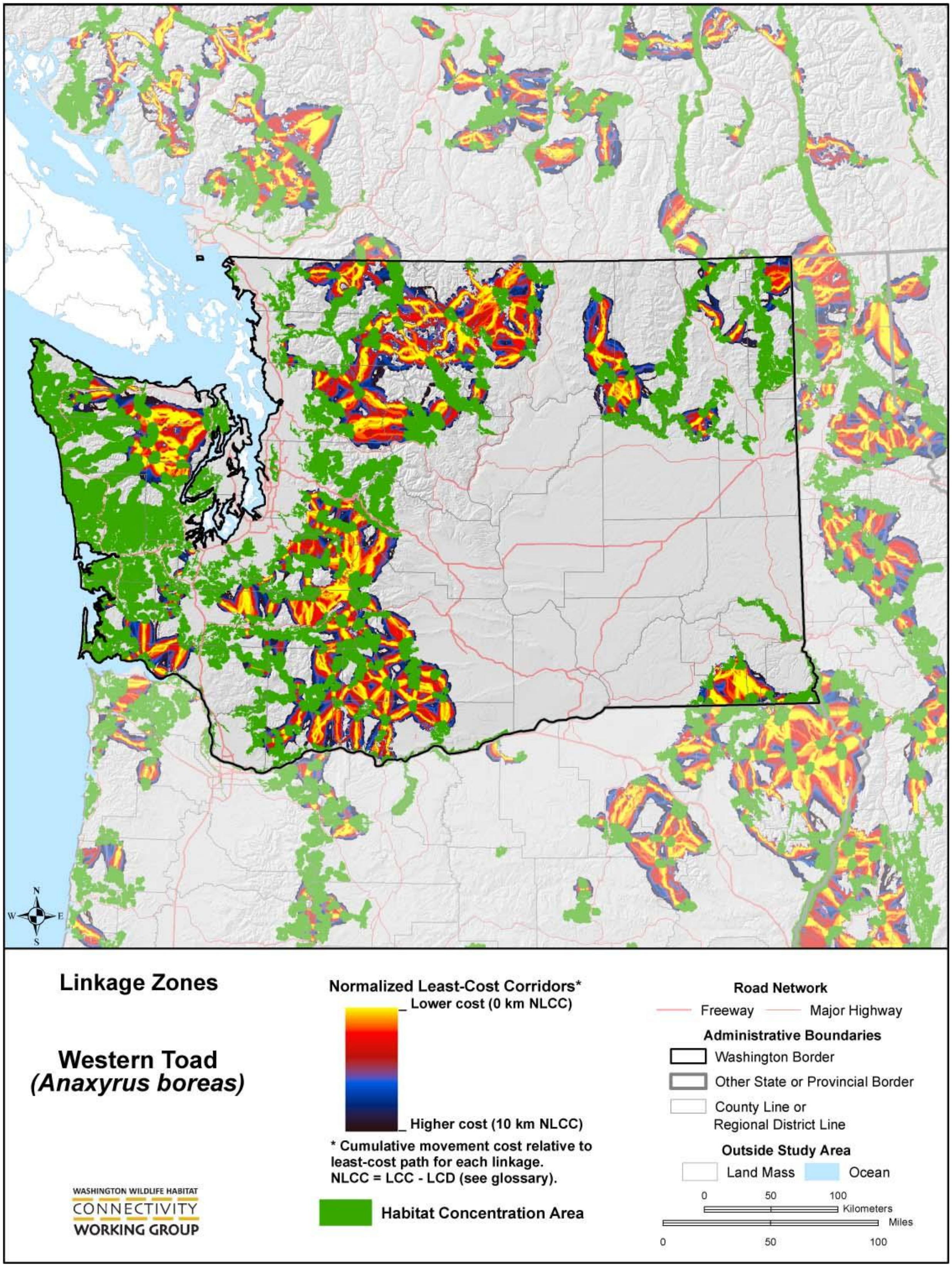

Figure 3.48. Western toad linkages.

3.2.14. American Marten (*Martes americana*)

3.2.14.1. INTRODUCTION

American marten are a boreal species with a relatively wide distribution across the forested portions of the assessment area (Johnson & Cassidy 1997), though observations are relatively rare within the lower elevation dry forests of eastern Washington (Bull et al. 2005; Munzing & Gaines 2008). The presence of abundant snags and coarse woody debris is an important feature of the habitat, especially in winter, as it provides access to prey beneath the snow and resting places (Bull & Heater 2000).

American marten, photo courtesy of WDFW.

Marten prefer riparian habitats throughout their range (Martin 1987; Buskirk et al. 1989; Anthony et al. 2003) and habitats near water (Bull et al. 2005). Percentage of the landscape in openings, such as forest clear cuts, is a primary factor in determining habitat quality; home range quality decreases as percentage of openings exceeds 25% (Hargis & Bissonette 1997; Hargis et al. 1999). Marten population reductions of 67% were reported following removal of 60% of timber (Soutiere 1979), and 90% with 90% timber removal (Thompson 1994). Trapping is a major source of mortality for marten especially in forested areas with road development (Hodgman et al. 1994; Thompson 1994).

The American marten was selected as a focal species for the Subalpine and Vancouverian Forest vegetation classes because of its relatively wide distribution and association with late-successional (mature and old-growth) forests. This species is considered vulnerable to loss of habitat connectivity from two of the four overarching connectivity threats: development, and roads and traffic. Marten are a species of management focus on national forest lands (USDA-FS 2006) and are considered a Species of Greatest Conservation Need in Washington State (WDFW 2005).

3.2.14.2. MODEL CONCEPTUAL BASIS

Habitat concentration areas for American marten were identified using late-successional forest excluding low-elevation dry forests of eastern Washington and in the Blue Mountains (Bull et al. 2005; Munzing & Gaines 2008), and areas that are >50 m from a road. Bull & Heater (2001) presents the best home range estimates for marten in the assessment area. They reported marten home range sizes of 27.2 km^2 for males and 14.2 km^2 for females. The minimum area for a marten HCA was determined by multiplying the female home range by 10 to equal 140 km^2. The resistance value cutoff was ≤8. Within home range movement distance (female) was 5 km based on dispersal and home range information.

Resistance parameters were derived, primarily, from literature describing marten habitat associations and behavior. In cases where information was lacking, we relied upon the professional judgment of species experts to score values. Wet forest and wetland vegetation types were assigned the lowest resistance values; urban areas, water bodies, and freeway roads the highest.

Snyder and Bissonette (1987) reported limited use by marten of patches <15 ha. Patches used by resident marten were 18 times larger (median = 27 ha) than patches that were not used (median = 1.5 ha) and were closer to adjacent forest preserves (Chapin et al. 1998). Median size of largest forest patch in marten home ranges was 150 ha for females and 247 ha for males (Chapin et al. 1998). Potvin et al. (2000) recommended that uncut forest patches be >100 ha to maximize core area and to minimize edge.

3.2.14.3. MODEL RESULTS

Habitat Concentration Areas — We identified 39 HCAs (Fig. 3.49) that were well distributed throughout the known and modeled habitat distribution for marten within or partially within Washington (Johnson & Cassidy 1997). Habitat concentration areas covered about 20,865 km^2 of the project area and ranged in size from 100 km^2 to 3576 km^2.

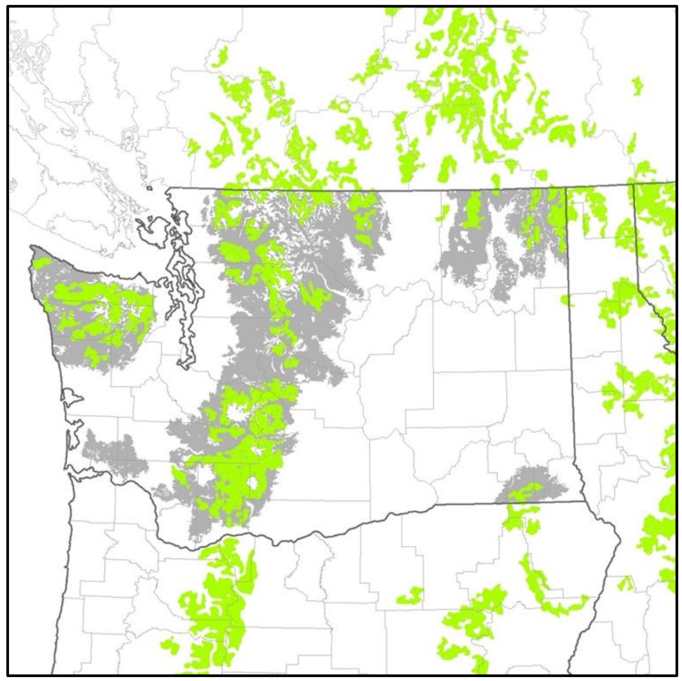

Figure 3.49. American marten HCAs (green) and GAP distribution (gray).

Resistance Surface — The American marten resistance surface for the project area indicates relatively good connectivity throughout most of its range (Fig. 3.50). Natural (low-elevation forests, grasslands and shrublands) and human created features (highways, dams, towns, and railways) contribute to areas of high resistance.

Cost-weighted Distance — The American marten cost-weighted distance map indicates that connectivity in the project area is reasonable for marten movements along the North Cascades/South Cascades with the exception of I-90, and throughout the Olympic Peninsula with the exception of U.S. Highway 101 (Fig. 3.51). The I-5 corridor and associated human development poses a potential barrier between the Olympic Peninsula and the southern Cascades HCAs. Connections between HCAs in the northeastern part of the state are patchy. The Blue Mountains HCA is surrounded by largely impermeable conditions suggesting that this population will remain isolated from all others in the project area.

Linkage Modeling — Linkages were modeled when the least-cost distance between a pair of HCAs was less than 300 km (Fig. 3.52). This resulted in 53 linkages, in Washington, between HCAs. The mean Euclidean distance of the linkages was 8 km and ranged from <1 to 29 km. The mean cost-weighted distance was 97 km and the ratio of cost-weighted/Euclidean distance ranged from 5 to 100.

The distribution of HCAs and their associated potential linkages resulted in seven hypothetical metapopulations of marten across the project area. These include the Olympics in which there were potential linkages between HCAs but no linkages to HCAs in the Cascades. There were three areas in the Cascades that appeared as hypothetical metapopulations, one occurring in the Cascades of Oregon, separated from HCAs in southern Washington by natural (low-elevation forests, grasslands, and shrublands) and human created features (highways, dams, towns, and railways). Another hypothetical metapopulation was identified in the southern Cascades of Washington. These HCAs are separated from those in the North Cascades by I-90, indicating the importance of efforts to restore habitat connectivity. Habitat concentration areas in the North Cascades include those in north-central Washington and south-central British Columbia. Potential linkages between HCAs across the Highway 2 corridor will be important to consider at a finer scale. Additionally, there are potential linkages across gaps in HCAs from the head of Lake Chelan westward across the North Cascades, likely a result of high elevation mountains and glaciers.

The HCAs in south-central British Columbia showed linkages to each other and to the Kettle Range in Washington. The HCAs in this area are separated from HCAs in the North Cascades by the Okanogan Valley to the west and HCAs in northeastern Washington by the Upper Columbia River.

Habitat concentration areas in northeast Washington have potential linkages to northern and central Idaho. Habitat concentration areas in the Blue Mountains of southeastern Washington and northeastern Oregon showed some linkages but are largely isolated from each other.

Figure 3.50. Landscape resistance for American marten.

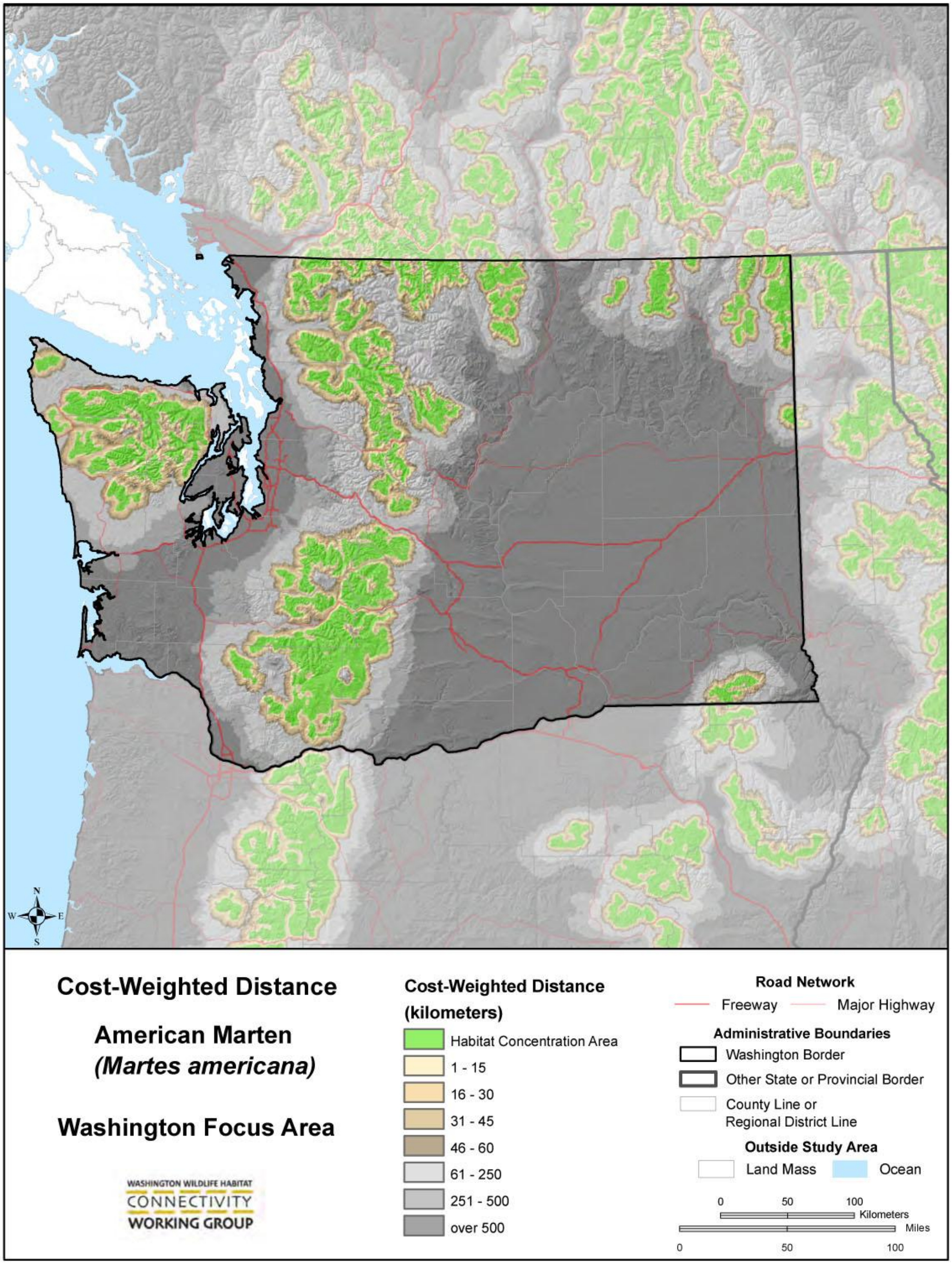

Figure 3.51. Cost-weighted distance for American marten.

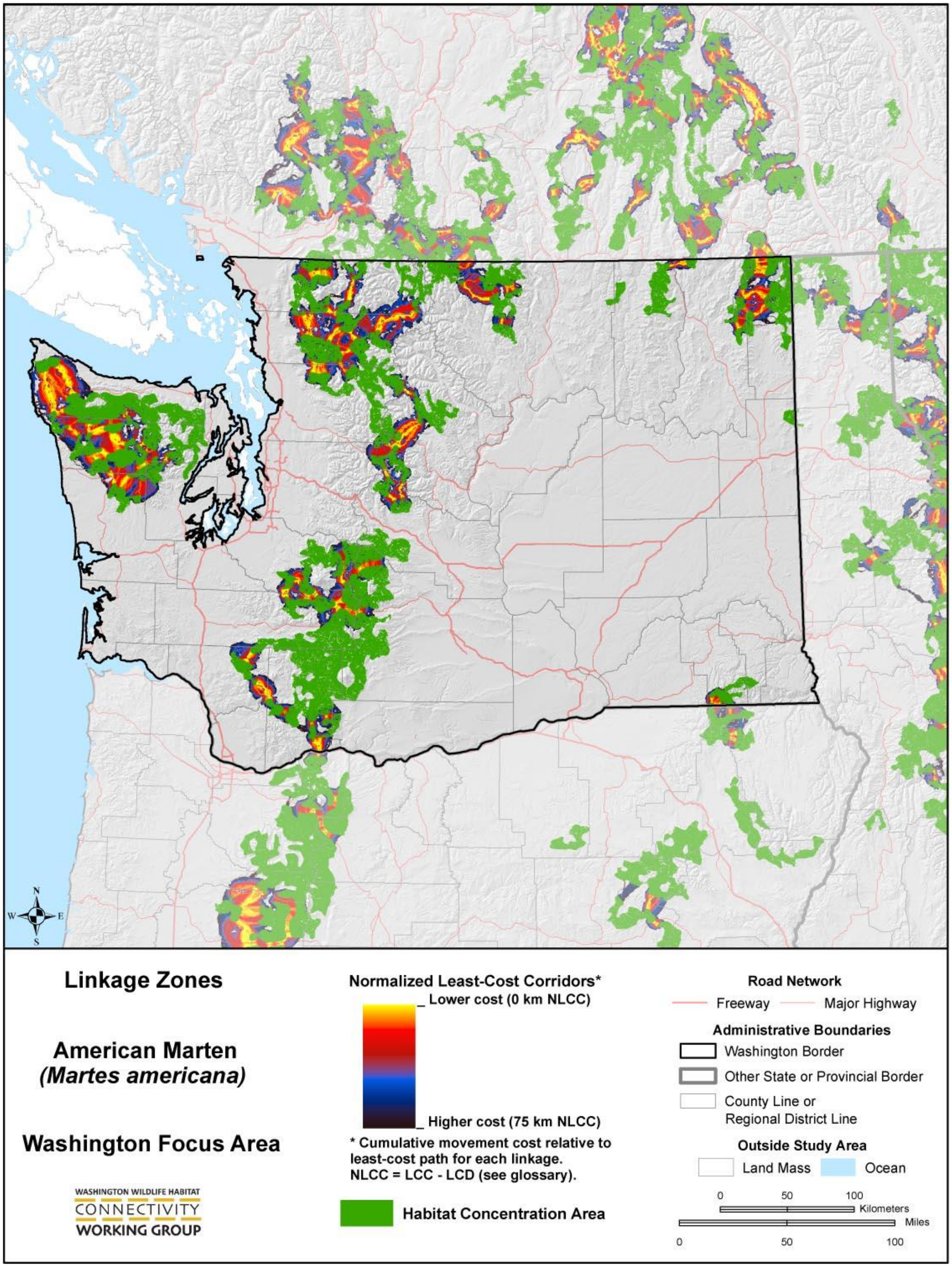

Figure 3.52. American marten linkages.

3.2.15. Canada Lynx (*Lynx canadensis*)

3.2.15.1. INTRODUCTION

Canada lynx, photo courtesy of WDFW.

Canada lynx occur in most boreal forest habitats in North America, including the upper elevation coniferous forests of the Rocky Mountains and Cascade Ranges (Aubry et al. 2000). In Washington, Canada lynx are primarily found in high-elevation forests in the north-central and northeast parts of the state including areas in Okanogan, Chelan, Ferry, Stevens, and Pend Oreille counties (Stinson 2001). The distribution of Canada lynx within the state has been stratified into core, secondary and peripheral habitat areas based on known records of their occurrences (USFWS 2005). The Canada lynx is state and federally listed as a Threatened Species.

The Canada lynx was selected as a focal species for the Subalpine Forest vegetation class due to its association with boreal forests (Koehler & Aubry 1994; Aubry et al. 2000; Koehler et al. 2008; Maletzke et al. 2008). Canada lynx were considered vulnerable to loss of habitat connectivity from all four major connectivity threats: land clearing and vegetation removal, development, roads and traffic, and the presence of people and domestic animals.

Key habitat components include foraging habitat for Canada lynx where understory stem densities and structure provide forage and cover for snowshoe hare (*Lepus americanus*), a major prey species (Koehler 1990; Agee 2000; Hodges 2000). In Washington, Canada lynx select for Engelmann spruce (*Picea englemanni*) and subalpine forest, moderate canopy cover, flat to moderate slopes, and relatively high elevations. They select against Douglas-fir and ponderosa pine forest, forest openings, recent burns, sparse canopy and understory, and relatively steep slopes (Koehler et al. 2008; Maletzke et al. 2008). Throughout their range, Canada lynx are absent or uncommon in dense, wet forests along the Pacific coast (Aubry et al. 2000).

3.2.15.2. MODEL CONCEPTUAL BASIS

We used published literature and input from expert reviewers to develop resistance surfaces used to evaluate dispersal habitat suitability. This spatial information was then used to identify concentrations of high quality Canada lynx habitat referred to as habitat concentration areas (HCAs). The distribution of HCAs within the U.S. portion of the assessment area was constrained by the location of core and secondary areas identified by the USFWS (2005), which were based on Canada lynx distribution. We calculated a weighted average home-range size of 60.4 km^2 (data for female Canada lynx; Brainerd 1985; Brittell et al. 1989; Koehler 1990; Apps 2000; Squires & Laurion 2000). We used the following criteria to identify HCAs for Canada lynx: a resistance value <8, home range radius of 4.4 km, minimum patch size of 400 km^2 and a habitat threshold of 0.5.

Intra-home range movements vary seasonally and depend on the availability of prey, mainly snowshoe hare. Daily movement distances range 2.6–10 km (Parker et al. 1983; Ward & Krebs 1985). Movements of 15–40 km beyond home-range boundaries have been documented in

Montana (Squires & Laurion 2000). However, this type of movement was not documented in a study in north-central Washington (Koehler 1990). In more northerly habitats Canada lynx can move up to 1000 km during periods of prey scarcity (Mech 1980; Slough & Mowat 1996; Poole 1997).

3.2.15.3. MODEL RESULTS

Habitat Concentration Areas — Thirty-one HCAs were identified for Canada lynx within the northern and eastern portions of the project area; 8 HCAs were wholly or partially within Washington (Fig. 3.53). These occurred within core and secondary areas identified for Canada lynx recovery (USFWS 2005) and within the highest quality Canada lynx habitat in the remainder of the project area. Habitat concentration areas covered a total of 14,769 km^2 of the project area and ranged in size from 596 km^2 to 5916 km^2. Habitat concentration areas occurred primarily within the North Cascades, Kettle Range, and Selkirk Mountains. The pattern of HCAs for Canada lynx are similar to those identified by Singleton et al. (2002) except that we constrained the distribution of HCAs by the core and secondary areas (as described above).

Figure 3.53. Canada lynx HCAs (green) and GAP distribution (gray).

Resistance Surface — The Canada lynx resistance surface generally indicates limited conditions for movements throughout the project area (Fig. 3.54). Human activities and low-elevation forest along the Okanogan River, Upper Columbia River, and Pend Oreille River valleys constitute the main barriers for connectivity.

Cost-weighted Distance — The Canada lynx cost-weighted distance map indicates that connectivity of habitats north-south is relatively good (Fig. 3.55). However, gaps exist between the southernmost HCAs where the distribution of Canada lynx habitat becomes more naturally fragmented.

Linkage Modeling — Potential linkages were modeled for Canada lynx when the least-cost distance between a pair of HCAs was <1350 km (Fig. 3.56). This resulted in 13 potential linkages between pairs of HCAs within or partially within Washington. The mean Euclidean distance of the linkages was 36 km and ranged <1–107 km. The mean cost-weighted length of the linkages was 416 km and the ratio of cost-weighted/Euclidean distance ranged from 4 to 27.

The connectivity of habitats for Canada Lynx north-south is relatively good. However, gaps exist between the southernmost HCAs where the distribution of Canada lynx habitat becomes more naturally fragmented. In addition, gaps in HCAs occur along the Similkameen River valley and along the Fraser and Thompson River valleys. These river valleys contain low-elevation forests and human activities. Similar results were found by Singleton et al. (2002).

The east-west connectivity between the North Cascades, Kettle Range, and Selkirk Mountains is interrupted by the Okanogan River, Upper Columbia River, and Pend Oreille River valleys which include low-elevation forests and human activities. The upper elevation forests associated with the Kettle Range and Selkirk Range may provide important stepping-stone habitats that could increase the permeability of the landscapes between the Rocky Mountains and the North Cascades. Our assessment shows relatively long and narrow linkages across the Okanogan Valley on the U.S. side, and long but broader linkages in British Columbia. It is interesting to note that several of the linkages identified in Singleton et al. (2002) for Canada lynx are also identified in this assessment (e.g., the potential linkage across the Okanogan Valley near the town of Riverside). These potential linkages are likely important for the long-term conservation of Canada lynx (Singleton et al. 2002; Schwartz et al. 2002) and a finer-scale assessment will be important to identify specific areas for the restoration or maintenance of these linkages.

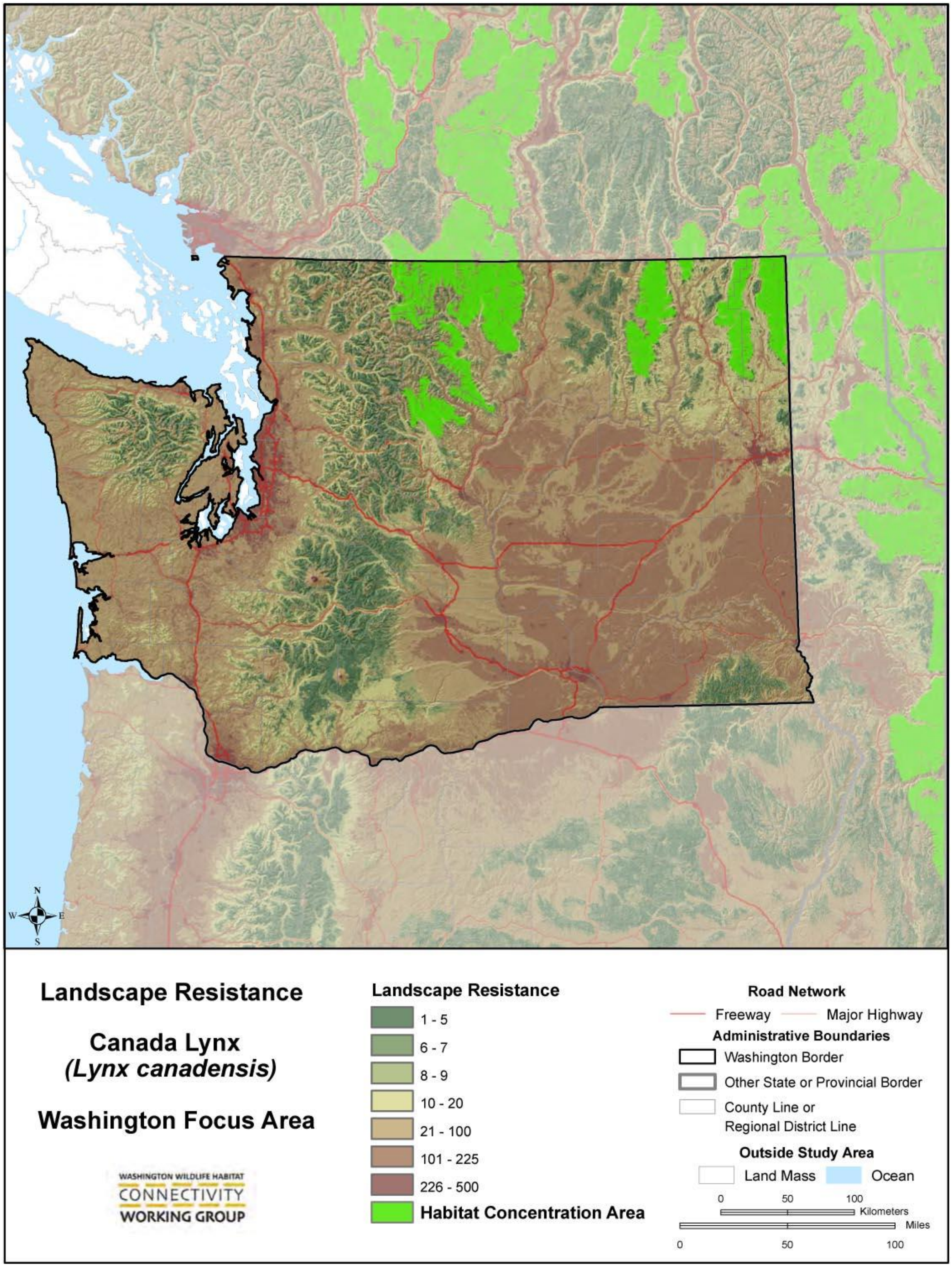

Figure 3.54. Landscape resistance for Canada lynx.

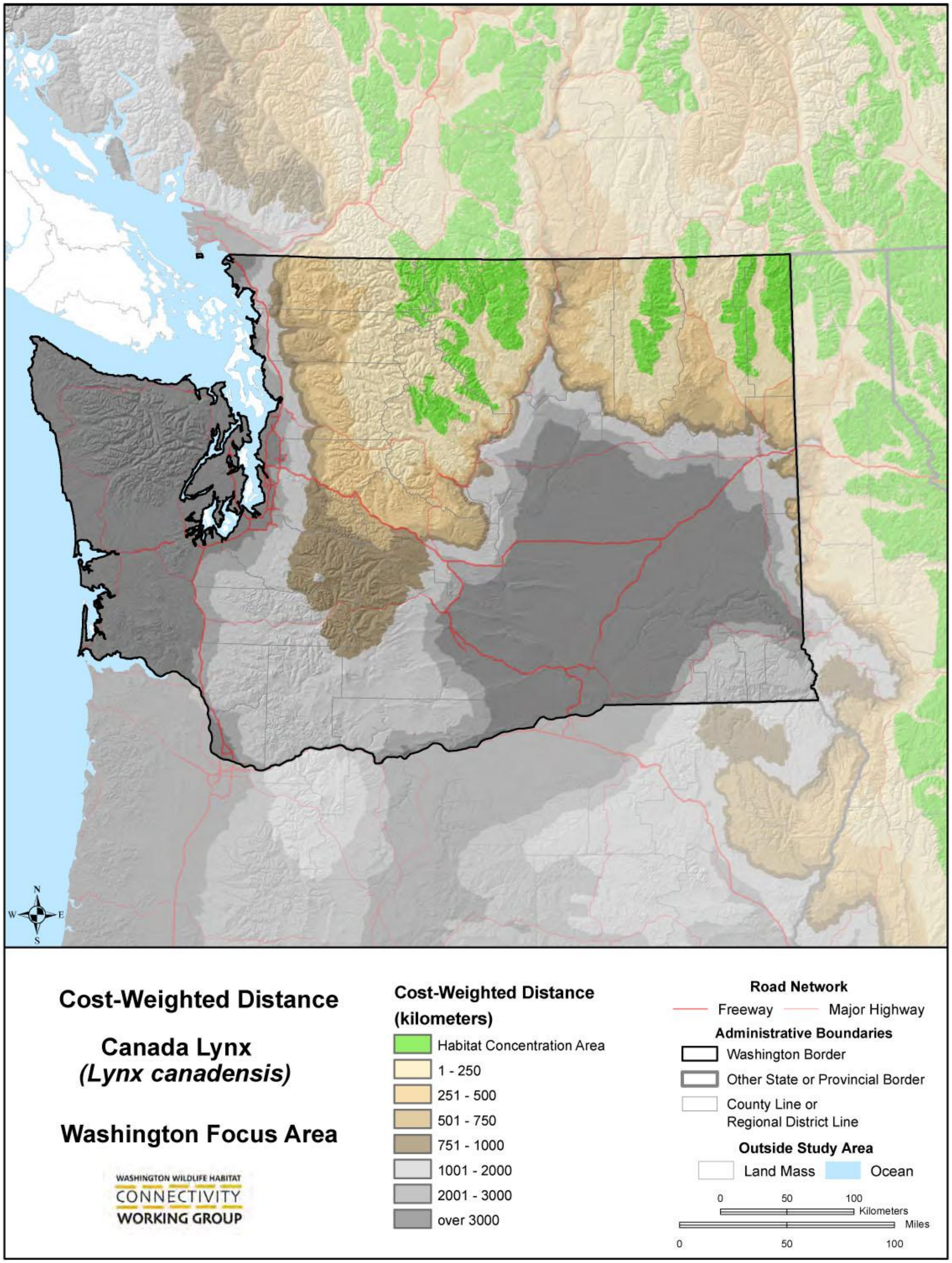

Figure 3.55. Cost-weighted distance for Canada lynx.

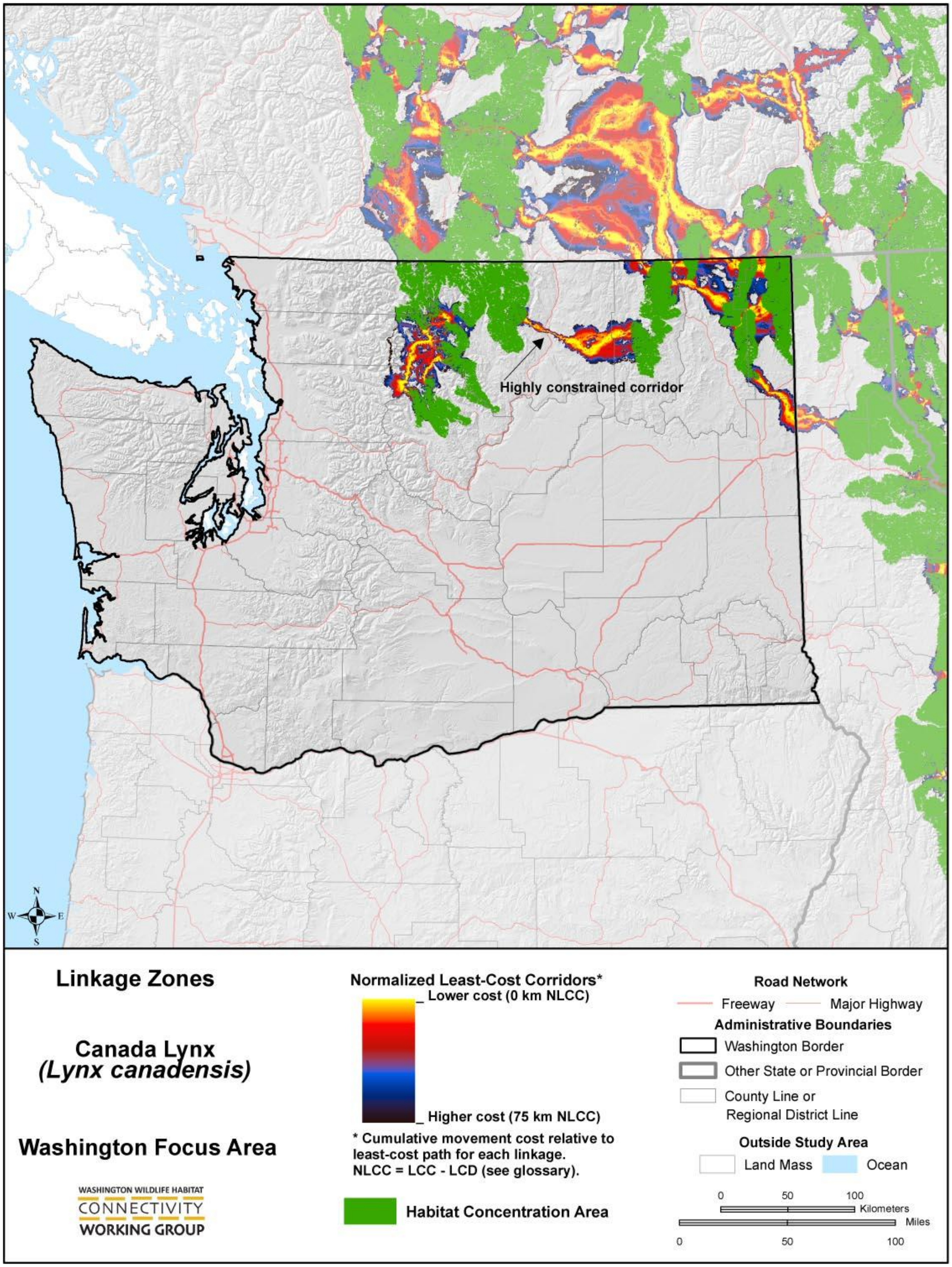

Figure 3.56. Canada lynx linkages.

3.2.16. Mountain Goat (*Oreamnos americanus*)

3.2.16.1. INTRODUCTION

Mountain goat, photo by Cliff Rice.

Mountain goats live in some of the most inhospitable alpine and subalpine terrain in North America where they are associated with cliffs or rocky ledges on which they depend to escape predators (Côté & Festa-Bianchet 2003). In Washington, the native population of mountain goats numbered about 8500 in 1961 (excluding populations in Mount Rainier National Park and Yakama Nation lands). Numbers have declined over the past several decades to about 2500 individuals. Although harvest of mountain goats is now strictly limited some areas of formerly occupied range in the state remain sparsely populated. Populations in Washington are patchily distributed among islands of habitat that are linked together by dispersal. Mountain goats are capable of long-distance movement (>50 km) through areas of relatively poor habitat (Fielder & Keesee 1988). Recent studies describing habitat (Wells 2006), genetic structure, and gene flow (Shirk et al. 2010) reveal that connectivity between mountain goat populations in the north and south Cascades is greatly reduced due to the effect of I-90.

Mountain goats were selected as a focal species because their habitat connectivity needs are representative of wildlife in the Subalpine Forests and Alpine vegetation classes. They were considered vulnerable to loss of habitat connectivity from three of the four main connectivity threats: development, roads and traffic, and the presence of people and domestic animals

3.2.16.2. MODEL CONCEPTUAL BASIS

Mountain goat HCAs for Washington were defined by aerial surveys and expert knowledge of populations in the state. Habitat concentration areas for portions of British Columbia, Idaho, Oregon, and Montana that fell within the study area were also identified by surveys. Resistance values were derived from published literature; where information was lacking we relied on the professional judgment of expert reviewers. Aside from I-90, primarily geographic distance but also highways, urban and agricultural areas, very high and low elevations, and bodies of water reduce ***landscape connectivity*** for this species (Shirk et al. 2010). Mountain goats are sensitive to human-caused disturbances in the landscape such as roads and development and avoid populated areas.

3.2.16.3. MODEL RESULTS

Habitat Concentration Areas — Most mountain goat HCAs exist within large cores of remote mountainous terrain that are less impacted by anthropogenic landscape changes relative to the lower elevations of the Puget Trough and Columbia Basin (Fig. 3.57). This reflects the adaptation of mountain goats to habitats generally devoid of high human population densities or expansive anthropogenic landscape changes. However, lowland areas and mountain passes between HCAs, in some cases, have been modified in ways that profoundly influence habitat connectivity. HCAs for this species form three large clusters representing the population of Washington, the Coast Range of British Columbia, and the interior North American population of the Rockies. The Olympic peninsula, which is inhabited by a sizeable non-native mountain goat population, was not considered an HCA in this study.

Resistance Surface — The mountain goat resistance surface was parameterized based on a study linking elevation, land cover, and roads to mountain goat gene flow in the Cascade Range, Washington (Shirk et al. 2010; Fig. 3.58). Based on this study, mountain goats appear capable of efficiently dispersing through lower elevation forested environments unless major roads, water bodies, and high human population densities are present. This is reflected in the resistance surface, where large cores of mountainous habitat have very low resistance while major roads, large lakes, and urban areas offer high resistance. We assigned resistance due to human population density entirely to the housing density (acres per dwelling unit) rather than the urban class of the land cover layer.

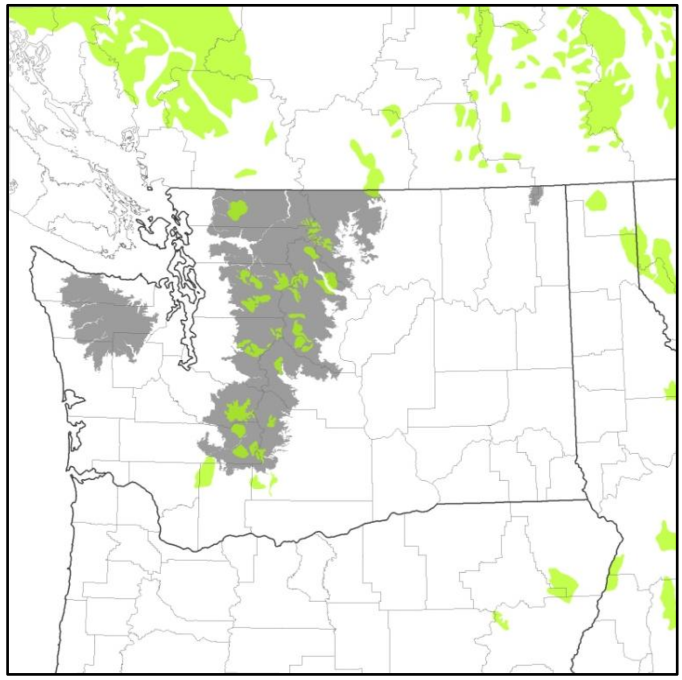

Figure 3.57. Mountain goat HCAs (green) and GAP distribution (gray).

Cost-weighted Distance — Habitat concentration areas appear highly connected (i.e., the cost-weighted distance between them is low) within the north and south Cascades (Fig. 3.59). Due to the very high resistance of I-90, the cost-weighted distance increases rapidly when crossing this major transportation corridor. This is congruent with the observation that mountain goats in the Cascade Range form two genetic sub-populations clearly delineated by I-90. A similarly strong barrier appears to rapidly increase cost-weighted distance when crossing the Fraser Valley between the Washington Cascade Range and Coast Range of British Columbia. Resistance due to a combination of distance, roads, and development in the Okanogan Valley also increase the cost-weighted distance between the interior North American population in the Rockies and the Washington Cascade mountain goat population.

Linkage Modeling — Linkages between mountain goat HCAs were limited to cost-weighted distances of less than 217 km. This criterion yielded a total of 166 linkages (71 within Washington) between the 73 mountain goat HCAs (29 within Washington) forming a large regional network (Fig. 3.60). The length and quality of linkages varied considerably across the study area. Linkage cost-weighted distances ranged from 0.3 km to 197 km (mean of 41 km [SD 47]). In Euclidean distance, linkages ranged from 0.2 km to 169 km (mean of 29 km [SD 31]). These values differ slightly from the linkage statistics reported in Table 3.3 because they summarize linkages across the full study area rather than Washington alone.

The ratio of the linkage Euclidean distance to cost-weighted distance ranged from 1 to 7 (mean of 1 [SD 1]; Table 3.3). This ratio is an indication of linkage quality, and can be thought of as a multiplier representing the additional cost of moving along a linkage due to suboptimal dispersal habitat (e.g. a linkage with a ratio of 2.0 would be, on average, twice as difficult to traverse per unit distance than a linkage consisting entirely of optimal dispersal habitat, which would have a ratio of 1.0).

Most of the mountain goat HCAs within the study area are in large cores of remote mountainous terrain that are less affected by anthropogenic landscape changes relative to the lower elevations of the Puget Trough and Columbia Basin. An exception occurs where major highways bisect the range. Empirical genetic data indicates that I-90 fragments the Washington mountain goat population into two distinct subpopulations (Shirk et al. 2010). This sharp boundary is reflected in the linkage models that connect HCAs on either side of I-90. For these connections, the cost-weighted distance is greater than 150 km, yet the Euclidean distance between these HCAs is only 43 km. This disparity can be quantified by taking the ratio of the Euclidean linkage length to the cost-weighted distance, which in the case of linkages crossing I-90 is 3.5 or greater. By comparison, most HCAs within the large cores of remote mountainous habitat have a ratio approaching 1:1 (the ratio which would occur if the entire linkage was in optimal dispersal habitat).

Major fracture zones occur across I-90, the Fraser Valley, and the Okanogan Valley. In addition to the fracture zone across I-90, the mountain goat linkage models predict similar fracture zones coinciding with other major highways. The connection which spans the Fraser River valley between the north Cascades and the Coast Range of British Columbia, for example, has a total cost-weighted distance of 189 km and a Euclidean to cost-weighted distance ratio of 4.5. This linkage crosses the Trans-Canada highway, a major river, agricultural lands, and areas with high human population density. It also becomes restricted to a narrow pinch point in the vicinity of Hope, B.C.

The connection between the North Cascades and the western sub-ranges of the Rockies involves several stepping-stone HCAs. Among these, the more northerly of two linkages spanning the Canadian portion of the Okanogan Valley appears costly according to our model (though not on par with the I-90 or Fraser Valley linkages) due to a combination of high human population density, significant water bodies, and highways. This linkage has a total cost-weighted distance of 56 km and a ratio of 2.1. It is also significantly constrained by a pinch point in the vicinity of Penticton, B.C. An alternative but longer route (96 km cost-weighted distance) exists to the south, but the distance ratio of 1.2 suggests it is comparatively more favorable to dispersal per unit of Euclidean distance. This more southerly route crosses the Okanogan in the vicinity of Oliver, British Columbia.

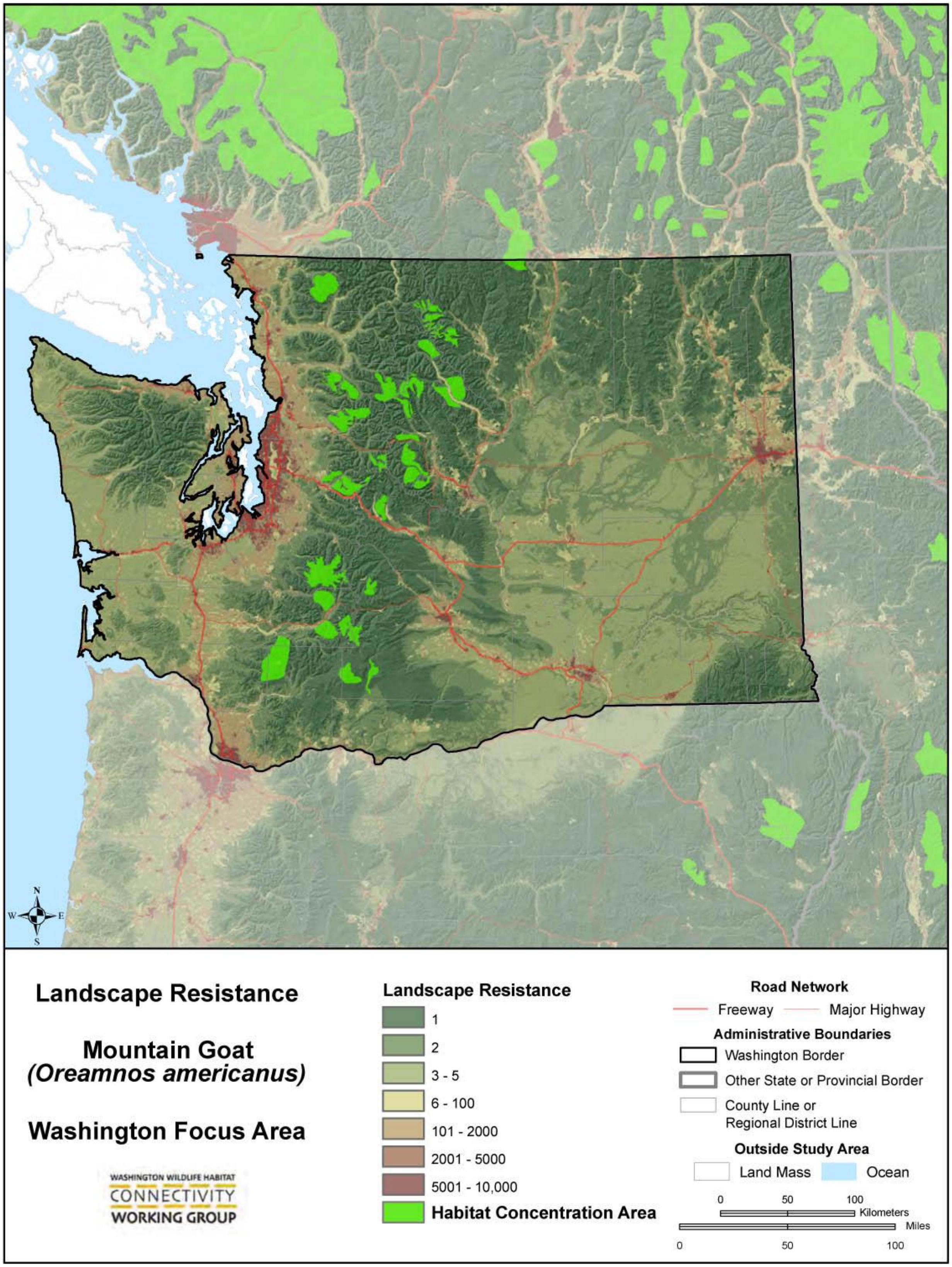

Figure 3.58. Landscape resistance for mountain goats.

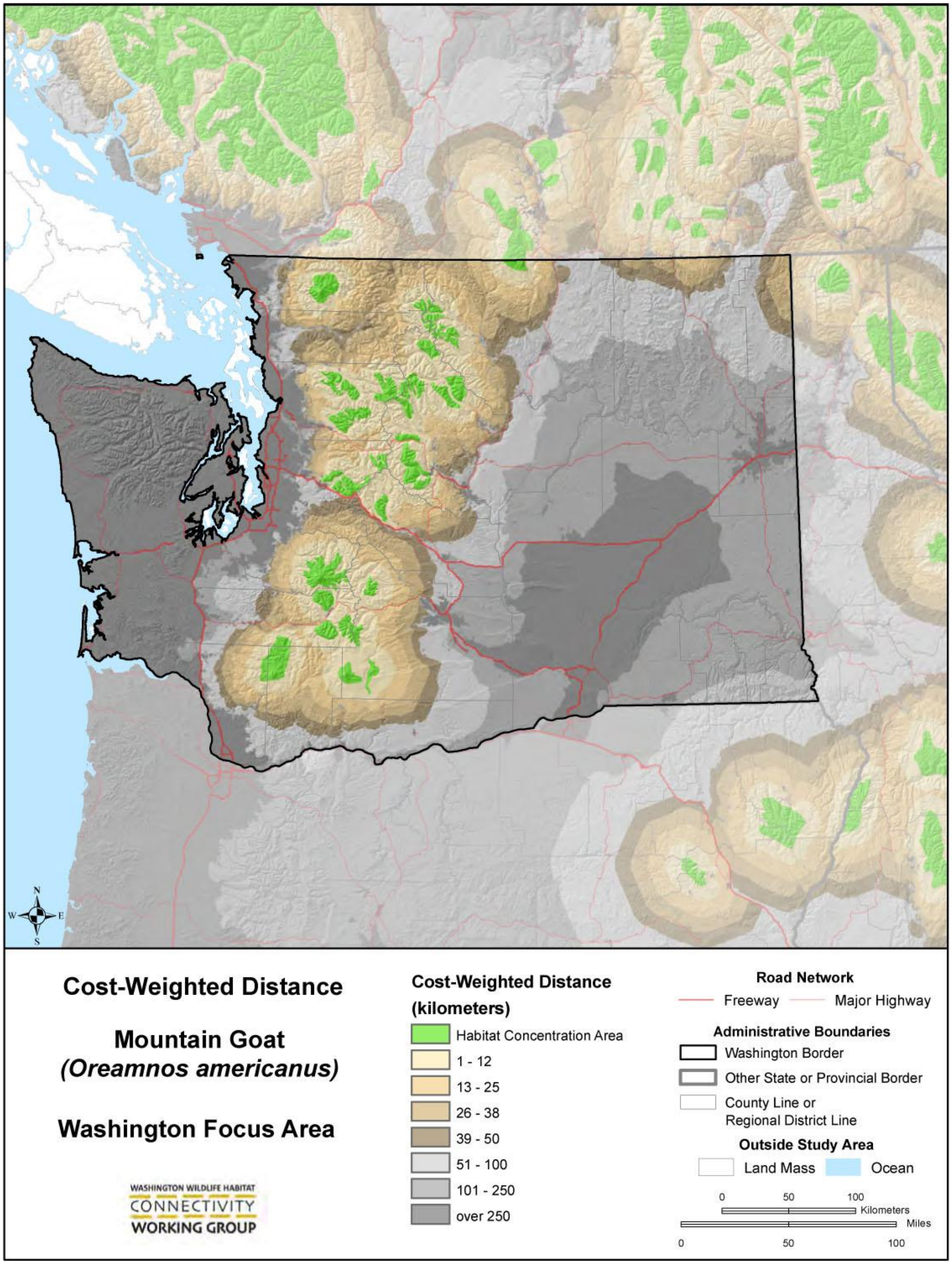

Figure 3.59. Cost-weighted distance for mountain goats.

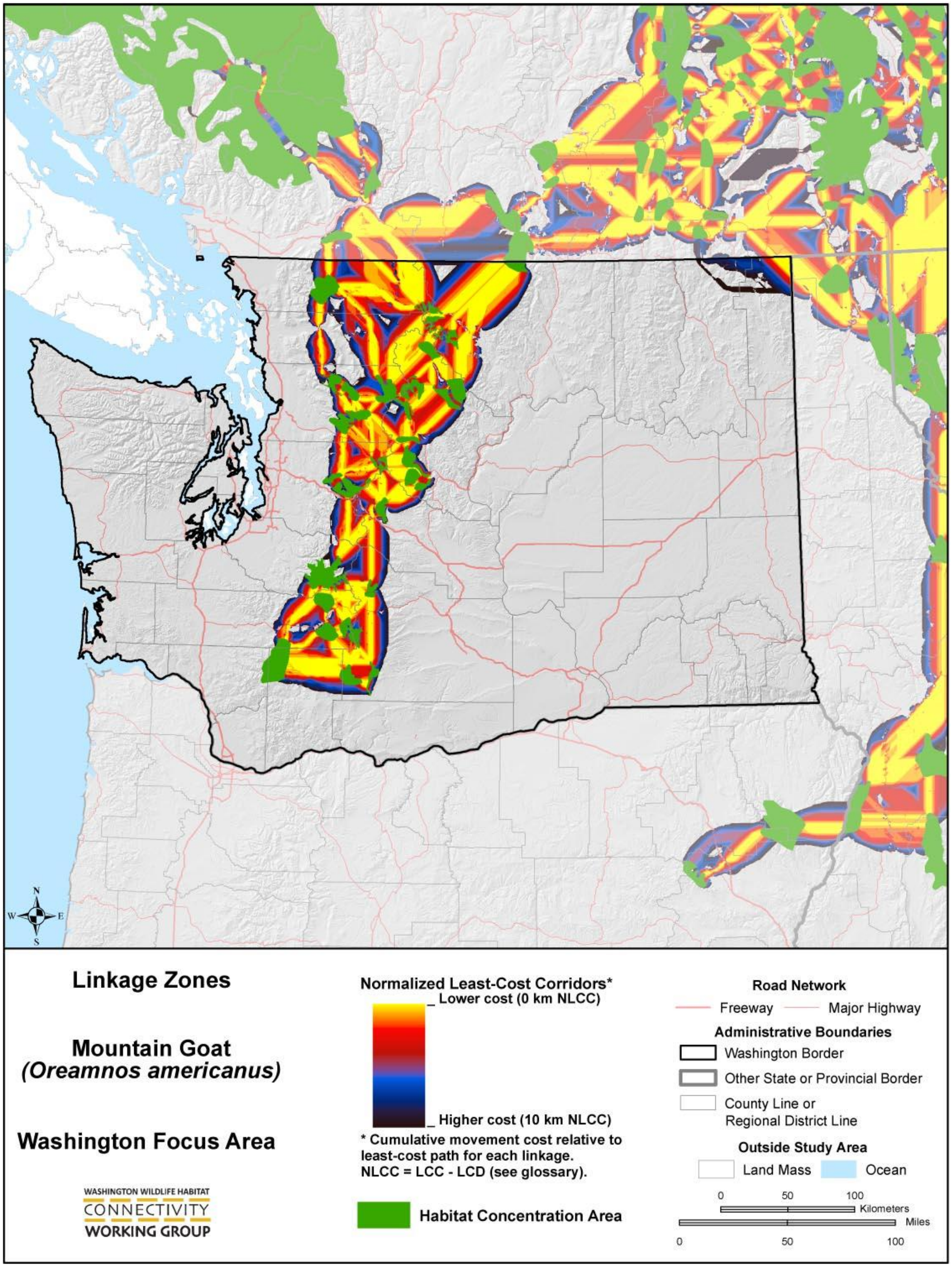

Figure 3.60. Mountain goat linkages.

3.2.17. Wolverine (*Gulo gulo*)

3.2.17.1. INTRODUCTION

Wolverine, photo by Anna Yu.

At far northern latitudes, wolverine habitat occurs virtually everywhere, but in Washington, the subalpine life-zone necessary for wolverine presence is restricted to a high-elevation band, resulting in a naturally fragmented distribution (Copeland & Yates 2008). Populations in the Cascades and Rocky Mountains have been described as peninsular extensions of a more widespread population in Canada (Banci 1994). In Washington, Oregon, and Idaho, wolverine sightings suggest the species' current distribution is clustered in the Cascade Ranges of Washington and Oregon, and the northern Rocky Mountains of Idaho (Edelmann & Copeland 1999). The pattern of wolverine distribution in Washington has varied through time. Before 1919, wolverine presence was reported often in the Cascade Range and northern parts of Washington State (Johnson 1977). From 1919 to 1959 reports were rare, but increasing reports in the 1960s and 1970s suggested re-colonization was occurring (Johnson 1977). Wolverines have not been reliably reported from the Olympic Peninsula and coastal areas to the south (Johnson 1977). Recent work suggests breeding is occurring in the North Cascades of Washington (Rohrer et al. 2008).

Wolverines are predators and scavengers that currently reproduce only in isolated, high-elevation habitats within our analysis area. Although wolverines seem to prefer to move through higher elevation areas (Copeland & Yates 2008; Schwartz et al. 2009; Copeland et al. 2010) they show a remarkable capacity for long-distance dispersal across a variety of forested and unforested habitat types. Wolverines also avoid human developments within their home ranges (May et al. 2006) and during dispersal (Packila et al. 2007). Thus the wolverine represents breeding habitat specialists that are sensitive to human disturbance and dispersal habitat generalists that are highly mobile. The wolverine tends to have large spatial requirements, making it well suited for evaluating landscape permeability at large extents and coarse scales such as this statewide assessment (Begley & Long 2009).

We selected the wolverine as a focal species to represent species that breed in subalpine and alpine habitats. The wolverine rated "excellent" for all selection criteria as a representative of the Subalpine Forests and Alpine vegetation classes. The association between wolverines and areas of persistent spring snow cover suggests the wolverine is also representative of species sensitive to climate changes that influence snow depth and persistence (Brodie & Post 2010; Copeland et al. 2010). Finally, the wolverine is a rare carnivore that is a candidate for listing under the Endangered Species Act. It is currently a Species of Concern in Washington State.

3.2.17.2. MODEL CONCEPTUAL BASIS

We derived estimates of landscape resistance to wolverine dispersal from the literature, especially past efforts to model wolverine habitat quality and connectivity. We also used results from telemetry studies and genetic analyses to infer the relative resistance of different landscape features. Because our inferences about landscape resistance were primarily based on professional judgment, and were only circumstantially supported by data or observations, we generally assigned resistance coefficients in bins that corresponded to low, medium, and high levels of resistance.

We delineated wolverine HCAs using a model that combined low cumulative landscape resistance with spring snow depth. Our evaluation criteria for candidate spatial models of HCAs included: (1) conformance with known activity areas of radio-collared wolverines in the North Cascades of Washington, (2) concordance between our proposed HCAs and areas found to be high quality habitat in previous modeling efforts, and (3) the degree to which our proposed HCA models captured patches of concentrated sighting records. We developed the GIS layer describing spring snow depth using data from the Snow Data Assimilation System (SNODAS) and a broader effort to estimate monthly snow depth across North America (Brown et al. 2003). To be included in an HCA, areas had to have an average snow depth on May 1 that was greater than 1 m and a cumulative resistance score of 10 or less, considering the full suite of layers we used to estimate landscape resistance.

To identify areas with concentrated habitat, we used a circular moving window analysis. We considered the average home-range diameter (19.42 km) of a female wolverine to reflect a typical within-territory movement distance. We merged habitat areas that were less than this distance apart. We found it challenging to determine a minimum size for HCAs. The difficulties were largely associated with an inherent conflict: should we emphasize the role of smaller patches of habitat that could serve as stepping stones for dispersing wolverines (about 100 km^2) or focus on larger patches of high quality habitat that were more likely to sustain populations of wolverines through time (10,000 km^2). We compromised at a smallish patch size of 400 km^2 that we felt was appropriate for both of the focal species in our analysis that are wide-ranging carnivores (wolverine and Canada lynx).

3.2.17.3. MODEL RESULTS

Habitat Concentration Areas — Modeling produced a network of 15 HCAs across the analysis area (Fig. 3.61). HCAs were concentrated in three groups: (1) the Coast Range of British Columbia, northwest of the Lillooet River; (2) the Cascade Range from Manning Provincial Park south to I-90, and from I-90 south to the Mount Adams area; and (3) in the Selkirk and Purcell Mountains of British Columbia. More isolated HCAs were located in the Monashee Mountains of British Columbia, in the Rocky Mountains of Idaho and Montana, and in the Wallowa Mountains and the Oregon Cascades near Mount Hood. In the Cascade Range, HCAs overlapped well with the GAP model of potential wolverine distribution (Johnson & Cassidy

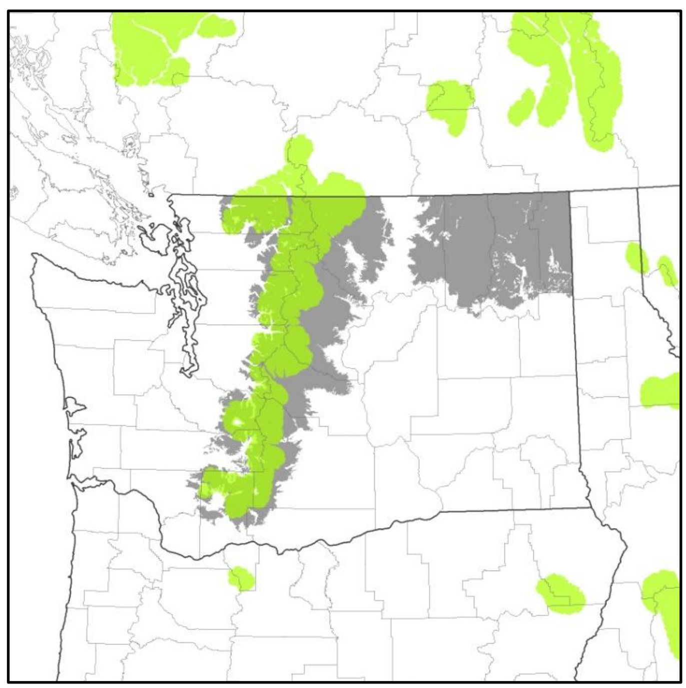

Figure 3.61. Wolverine HCAs (green) and GAP distribution (gray).

1997). HCAs generally cover less area, because they are focused on deep-snow areas near the crest (Fig. 3.61). In northeastern Washington, however, GAP modeling indicated a large area of potential wolverine habitat, but our analysis did not produce any HCAs. This divergence results from the lack of spring snow cover in large enough patches to meet our HCA criteria.

Resistance Surface — Our assignment of resistance values to different landscape features generated a resistance surface in which much of the undeveloped, forested, landscape had low resistance for wolverine dispersal (Fig. 3.62). Densely developed areas, agricultural lands, open water, volcanic peaks, and freeways and major roads were features we assigned a high level of resistance. This resulted in a pattern is which lowland areas and valley bottoms typically had moderate to high resistance, and mountainous areas had low resistance.

Cost-weighted Distance — The combination of high wolverine mobility and apparent willingness to traverse a variety of natural cover types enable wolverines to access most of the analysis area (Fig. 3.63). Cumulative resistance of highly developed areas in the Puget Trough and areas of intensive agriculture on the Columbia Plateau are likely to preclude wolverine dispersal through these areas. River valleys with residential development, transportation infrastructure, open water, and agriculture, such as the Okanogan River valley, represent areas where cost-weighted distance accumulates rapidly. Opportunities for crossing these valley bottoms is likely limited only to remnant patches of natural habitat aligned perpendicular to the long axis of the valley. Mountain passes with transportation infrastructure show a similar pattern of rapid accumulation of cost-weighted distance.

Linkage Modeling — Using 1500 km as the threshold of maximum cost-weighted distance for linkages led to all HCAs in the analysis area being linked (Fig. 3.64). These linkages form an arch that extends from Mount Hood in Oregon, up the Cascade Range of Washington, across southern British Columbia to the Monashee, Selkirk, and Purcell Mountains, and then back south along the Rocky Mountains between Idaho and Montana. A spur links the northwest Cascades to the Coast Range of British Columbia. This overall pattern suggests that existing linkages in the Cascade and Rocky Mountains are relatively good, while the linkage between them is tenuous.

Four linkages were mapped that exceeded 150 km in Euclidean distance. Two of these linkages extend from the Monashee and Selkirk Mountains in British Columbia to the Cabinet Mountains on the border between Idaho and Montana (Euclidean distances of 211 and 168 km). The remaining two long linkages connect an HCA located south of I-90 in the St. Joe portion of the Idaho Panhandle National Forest to an HCA east of McCall, Idaho, and another HCA in the Wallowa Mountains of Oregon (Euclidean distances of 167 and 197 km). We display these linkages to err on the side of inclusiveness, to highlight areas with tenuous linkages, and to acknowledge the remarkable dispersal capacity of wolverines. In the case of linkages from St. Joe to the south, additional shorter linkages may be available to the east (Brock et al. 2007), but the boundary of our analysis area prevented these from being displayed.

Considering all 24 linkages we identified among HCAs, the mean linkage length was 82 km in Euclidean distance and 476 km in cost-weighted distance. Thus, most linkages in the analysis area are on the high end of dispersal distances typical of wolverines. The longest linkage we mapped, from the Monashee Mountains to the Cabinet Mountains, was 211 km long in Euclidean distance and only 938 km in cost-weighted distance, a ratio of about 4.5. This low ratio suggests that habitat with relatively low resistance to wolverine dispersal is available throughout this long linkage. In contrast, the linkage across I-90 in the Cascade Mountains is only 1.4 km in Euclidean distance, but has a cost-weighted distance of 319 km. This high ratio of cost-weighted distance to Euclidean distance (226) reflects the high resistance to wolverine movement of an interstate highway with high traffic volume.

The mean ratio of cost-weighted distances to straight-line Euclidean distances between HCAs was about 10, when the anomalous I-90 linkage was excluded. Similarly, the mean ratio of cost-weighted distances to the non-weighted distance of the least-cost path was about 7. Both ratios suggest that wolverines have access to relatively direct routes that also have relatively high habitat suitability when moving among HCAs. Transportation infrastructure and associated development resulted in linear zones that increased resistance and led to more circuitous linkages.

Our estimates of resistance associated with major highways led to most of State Highway 2 across the Cascade Range being modeled as an obstacle to wolverine movement. In some locations, however, the combination of a narrow highway right-of-way with adjacent, low-resistance habitat resulted in our modeling approach annealing habitat north and south of Highway 2 into one large HCA. These habitat linkages are limited, but the resolution of the maps presented here is not fine enough to clearly display these linkages or to show that the highway is mostly a narrow, linear discontinuity in the HCA. We believe our modeling of the Highway 2 corridor is a reasonable representation of current conditions. The right-of-way is currently about 50 m wide and nighttime traffic volumes are relatively light, suggesting that there may be opportunities for wolverines to cross at select locations with relatively low risk of being deterred by traffic or harmed in a collision. Increases in traffic volume or expansion of the right-of-way could make Highway 2 much more resistant to wolverine movements. Several other major roads in our analysis area likewise have the potential to increase resistance in wolverine linkages.

Wolverine habitat is not as well connected in the Rocky Mountains as it is in the Cascade Mountains. In the Cascade Range, increased resistance is confined to areas around major highways and freeways crossing the range, especially I-90, which bisects the range into northern and southern HCAs. We expect that wildlife crossing structures currently being built as part of I-90 expansion near Snoqualmie Pass will improve connectivity across this freeway. In the Rocky Mountains, transboundary linkages between British Columbia and Idaho and Montana are relatively long and confined by a combination of developed valley bottoms, reservoirs, highways, and active forestry. Additional connections may be available east of our analysis area, but within our area, increased patchiness of persistent spring snow and more widely distributed resistance factors contribute to more fragmentation of wolverine habitat in the Rocky Mountains relative to the Cascade Range.

Other noteworthy impediments to wolverine dispersal in our analysis area include the Okanogan River valley and the Fraser River valley in southern British Columbia, and the Columbia River. We believe that the linkage between the Cascade and Rocky mountains in southern British Columbia is important to the persistence and expansion of the wolverine population in Washington State. This connection is tightly constrained to a narrow band of low resistance habitat across the Okanogan River valley north of Osoyoos, indicating a tenuous linkage that is unlikely to support high rates of successful dispersal. The Fraser River valley similarly constrains an otherwise relatively robust linkage between the Cascade Range and the Coast Range. This is another linkage that likely has important demographic consequences for the wolverine population in Washington. The recent detection of a wolverine that was trapped in the Washington Cascades at a location in the Lilooet Range, west of the Fraser River (C. Raley, personal communication), suggests this linkage is still functional. The Columbia River is a substantial barrier to movement between the Washington Cascade Range and an HCA around Mount Hood in Oregon. Our linkage modeling suggests that a relatively narrow corridor of low resistance habitat converges on the Columbia near Hood River, Oregon.

Given the association of wolverines with persistent spring snow and cool temperatures, climate change is likely to constrain both HCAs and linkages for wolverines in the future. We suspect these changes could lead to future discontinuities in wolverine habitat in the Cascade Range, further fragmentation of habitat in the Rocky Mountains, and northward shift of habitat in British Columbia.

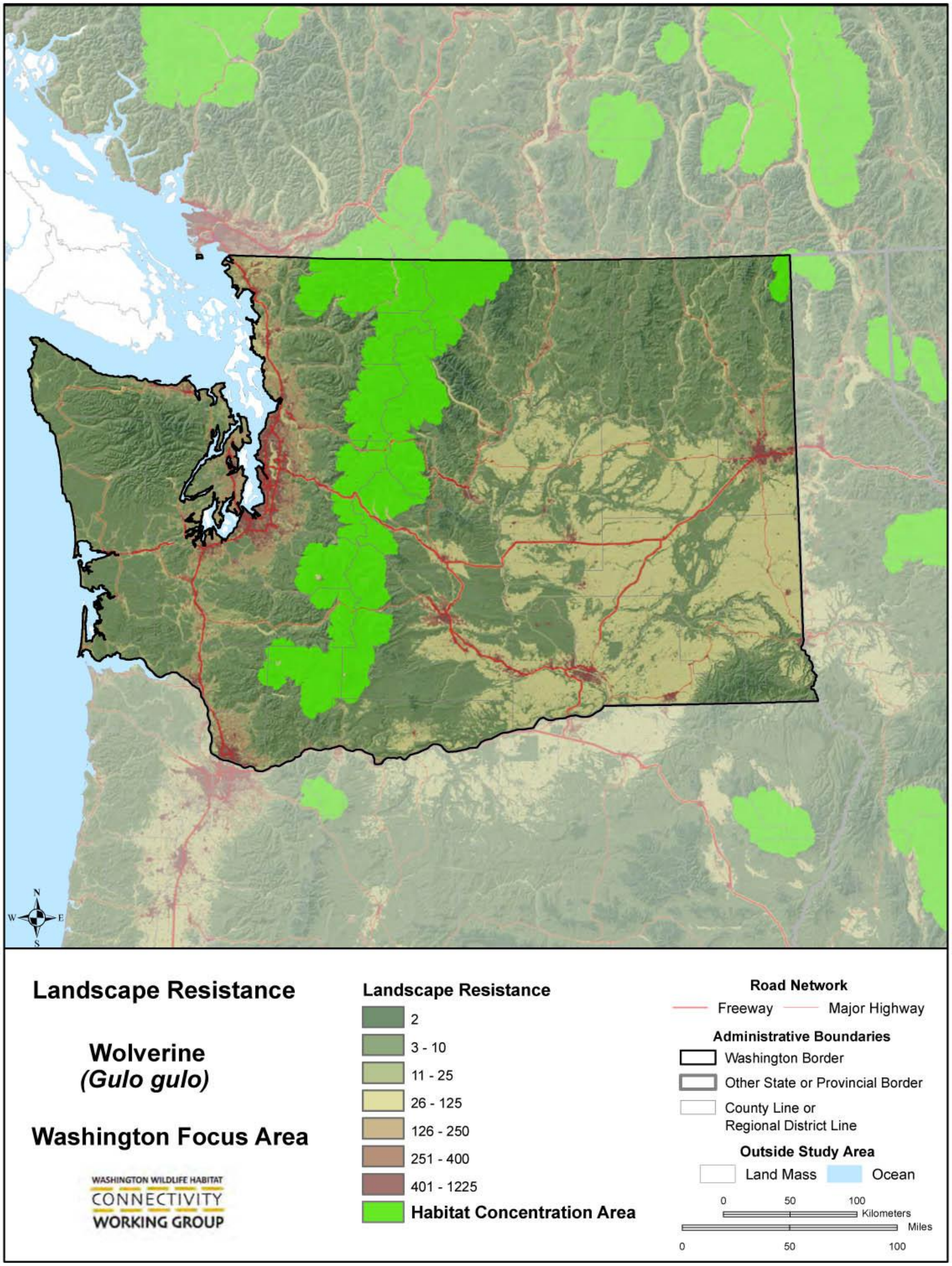

Figure 3.62. Landscape resistance for wolverines.

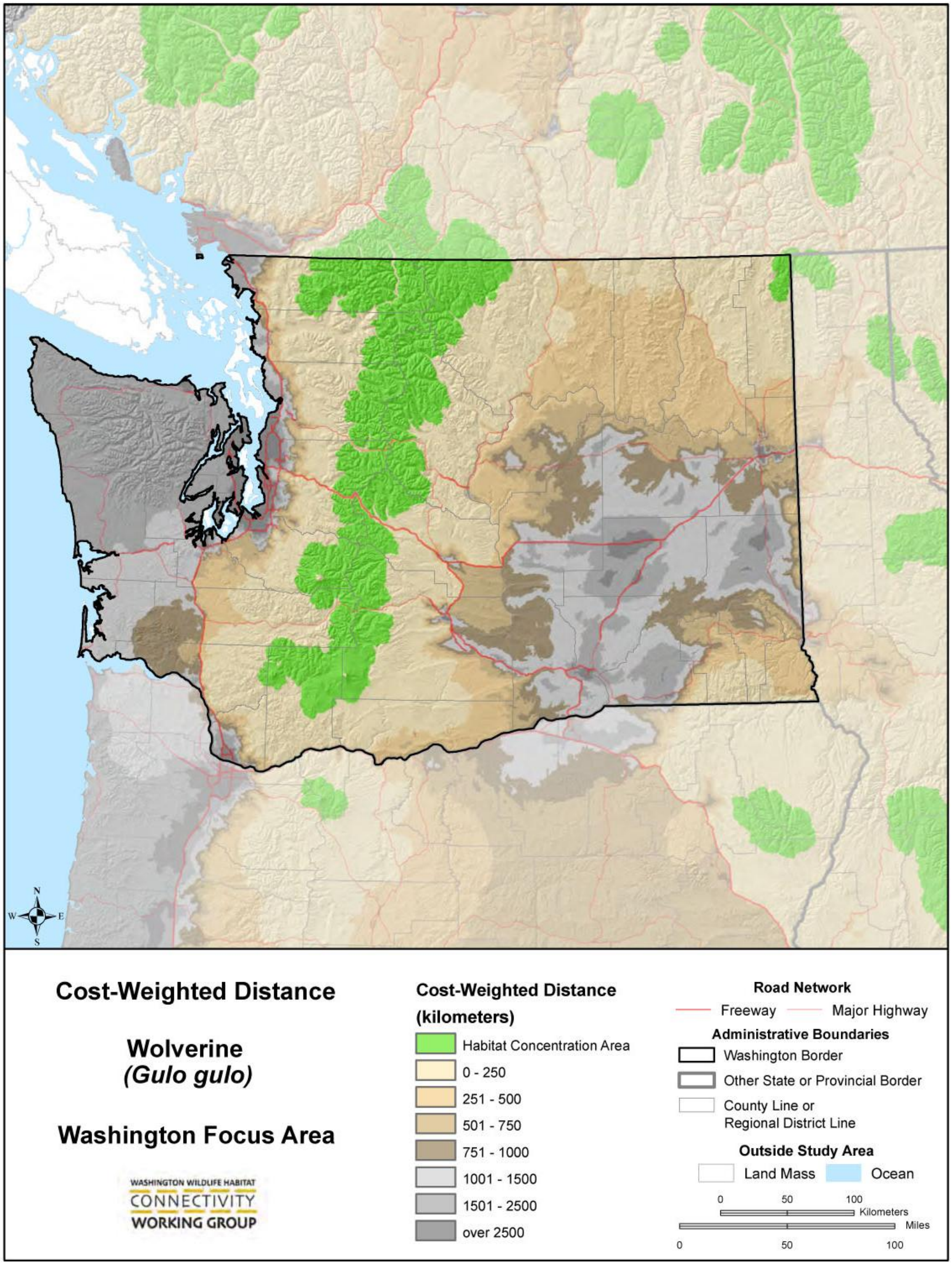

Figure 3.63. Cost-weighted distance for wolverines.

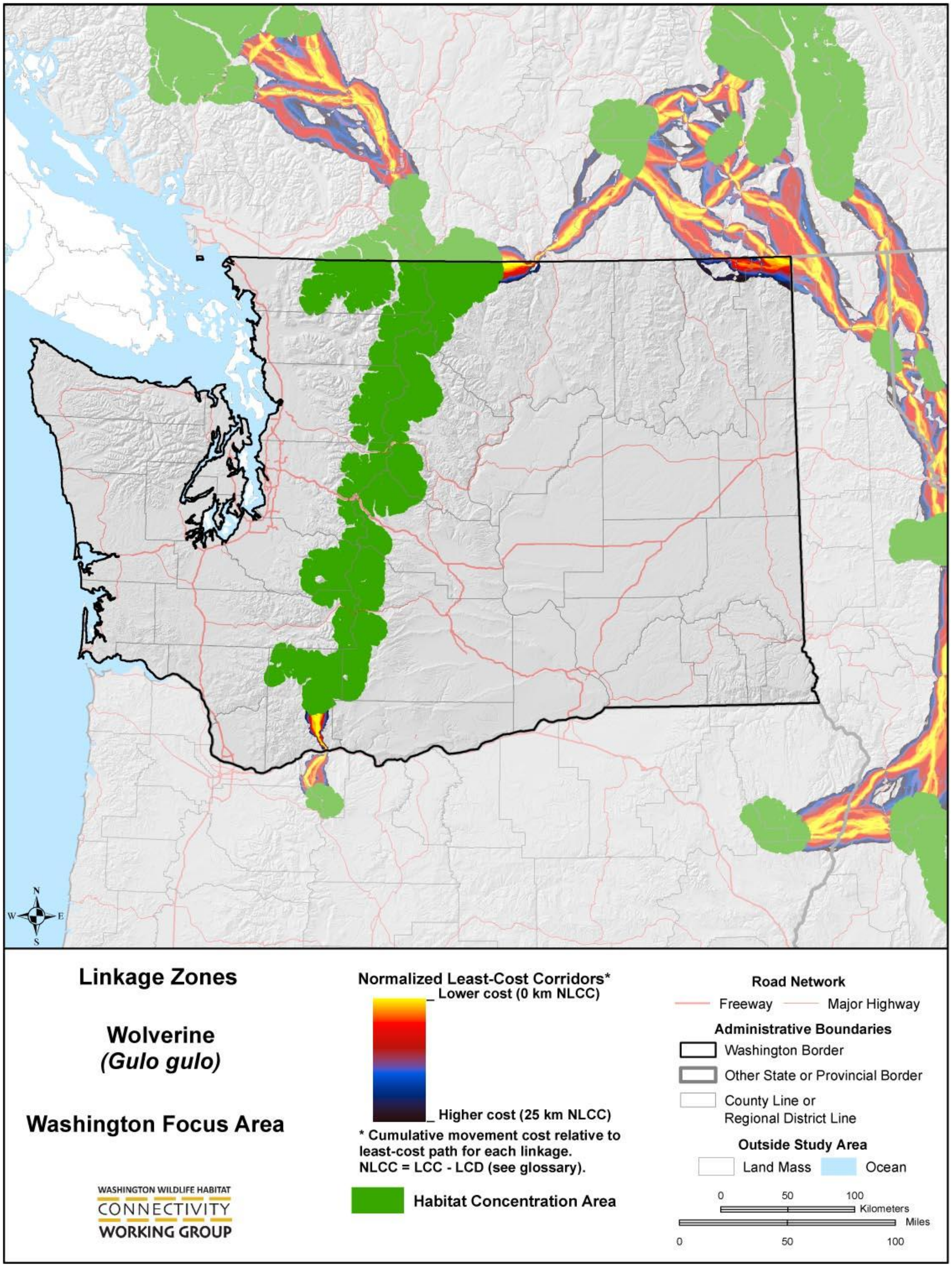

Figure 3.64. Wolverine linkages.

3.3. Landscape Integrity Results

The areas identified as having the highest levels of landscape integrity in Washington were located in the Cascade and Olympic Mountains (Fig. 3.65). Areas where integrity was consistently low or where high integrity lands were severely fragmented were found in the Puget Sound lowlands, the arid lands of the Columbia Plateau, and in southwestern Washington.

3.3.1. Landscape Integrity Core Areas

Our map of landscape integrity core areas (Fig. 3.66) shows the distribution of large, contiguous blocks of land with high integrity scores. The largest core areas show a high degree of overlap with large blocks of public and tribal ownership: in Washington, these large core areas cover much of the Olympic Mountains and North Cascades, along with significant portions of Washington's central and south Cascades. Other reasonably large core areas, wholly or partially within Washington, corresponded with the Selkirk Mountains in the northeast corner of the state, Yakama Nation lands in south-central Washington, and the Blue Mountains in the southeast corner of the state. Smaller core areas were well-distributed in the western Columbia Plateau ecoregion. A few significant core areas were identified in the Willapa Hills of southwest Washington, much of northeastern Washington, and the eastern half of the Columbia Plateau ecoregion. The Puget Trough was poorly represented by core areas, with a few small core areas identified along the foothills of the Cascades, Kitsap Peninsula and Fort Lewis Military Reservation. All of the GAP protected lands with status codes 1 & 2 that met minimum size requirements of 10,000 ac (4047 ha) were captured in our core area network (USGS 2010).

3.3.2. Landscape Integrity Linkages

As described in Section 2.4.2, we modeled landscape integrity linkages using four different resistance surfaces, representing varying levels of resistance associated with different ecological sensitivity to human-induced changes on the landscape. The resulting four connectivity maps identified similar linkage networks, despite their differing cost surfaces (Fig. 3.67). Because linkage locations are largely determined by the locations of core areas, areas with many small core areas in close proximity have many short linkages, as seen in north-central Washington and north-central Oregon. There are few linkages within the Puget Trough and Willamette Basin regions, as well as in southeastern Washington, corresponding to few or no core areas in these regions. However, these core-devoid regions are crossed by longer linkages, such as those connecting the Coast Range to the Cascades in northern Oregon and southern Washington, or those connecting the clusters of core areas in the Columbia Plateau.

The models of low, medium, and high sensitivity to human influences differed in several respects. All models used the same 349 core areas, but because we discarded linkages that passed through intermediate core areas (See Appendix D), the number of linkages varied between models (Fig. 3.67; Appendix E). Because it had the lowest resistance values, the low sensitivity model tended to identify broader, more direct linkages, while the high sensitivity model linkages tended to be more constrained, tracing narrow routes through areas of least human impact.

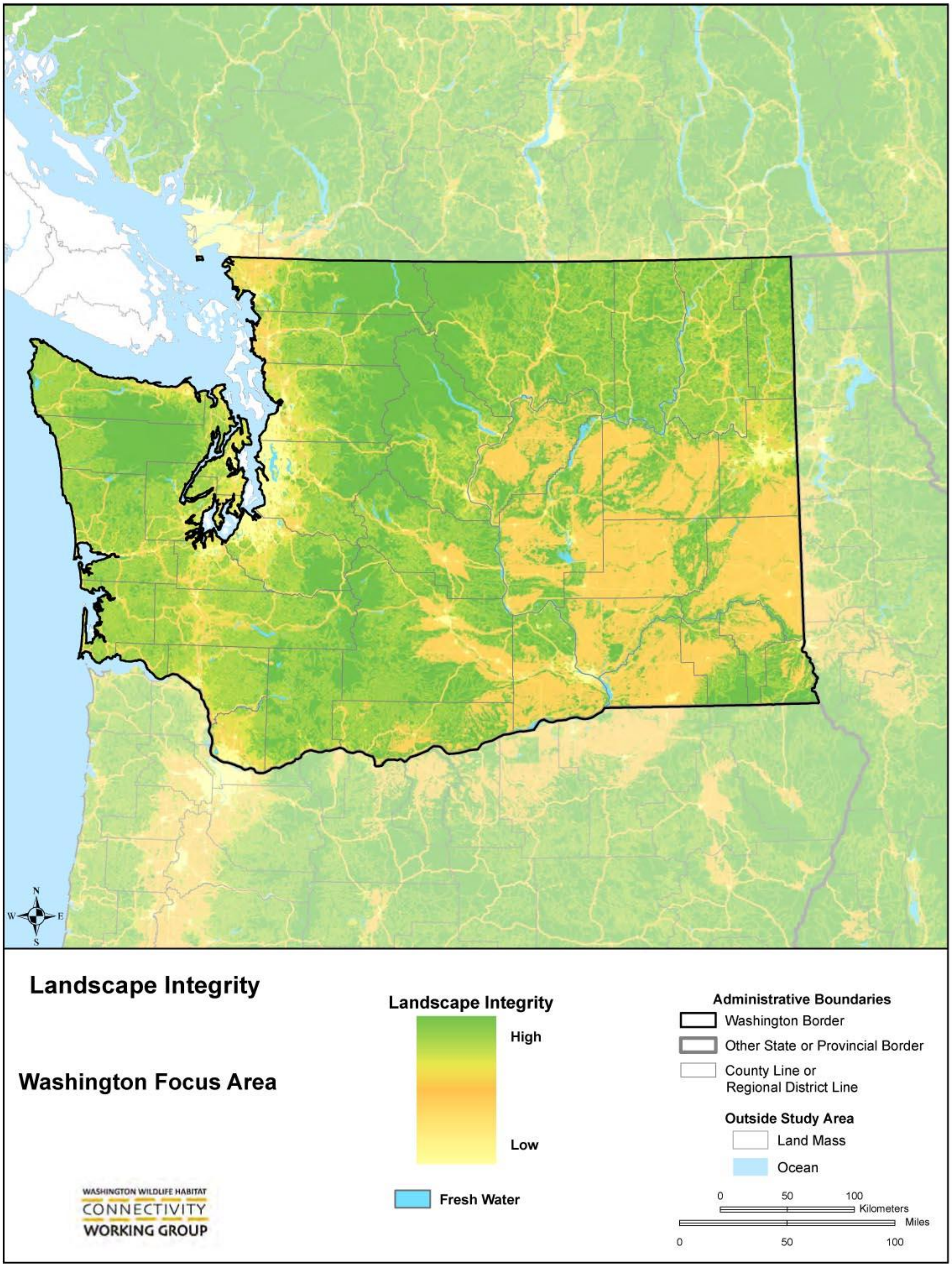

Figure 3.65. Landscape integrity map. Areas of highest landscape integrity have the least human footprint (e.g., natural land-covers, low housing density, and minimum roads).

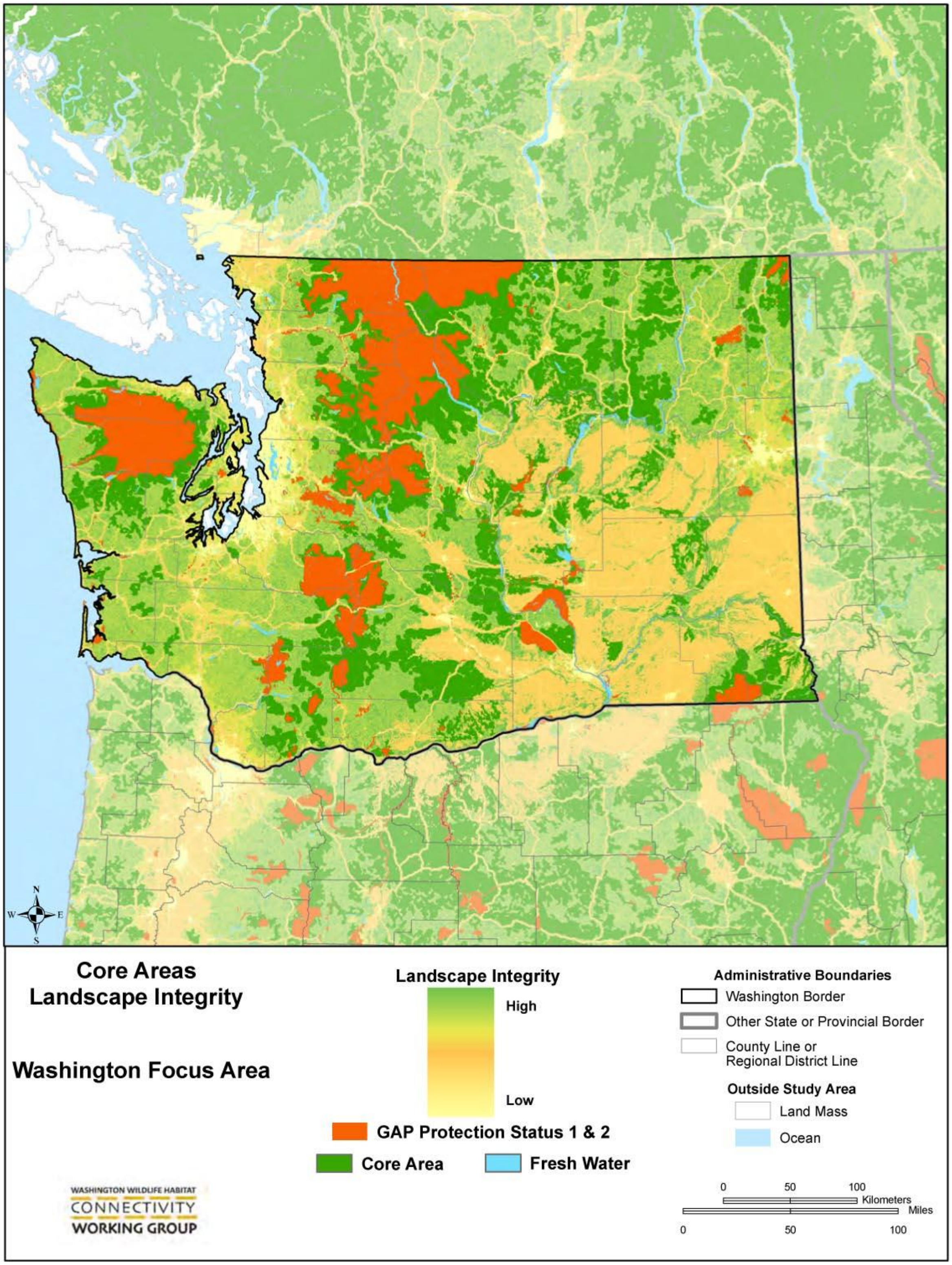

Figure 3.66. Landscape integrity core areas. Core areas were defined by large areas of high landscape integrity values (0.9). All core areas were equal to or larger than 10,000 acres (4047 ha) with local road density ≤10% in all ecoregions, except in Pacific Northwest Coast and Willamette Valley – Puget Trough – Georgia Basin, where local road density thresholds were 20% and 30% respectively.

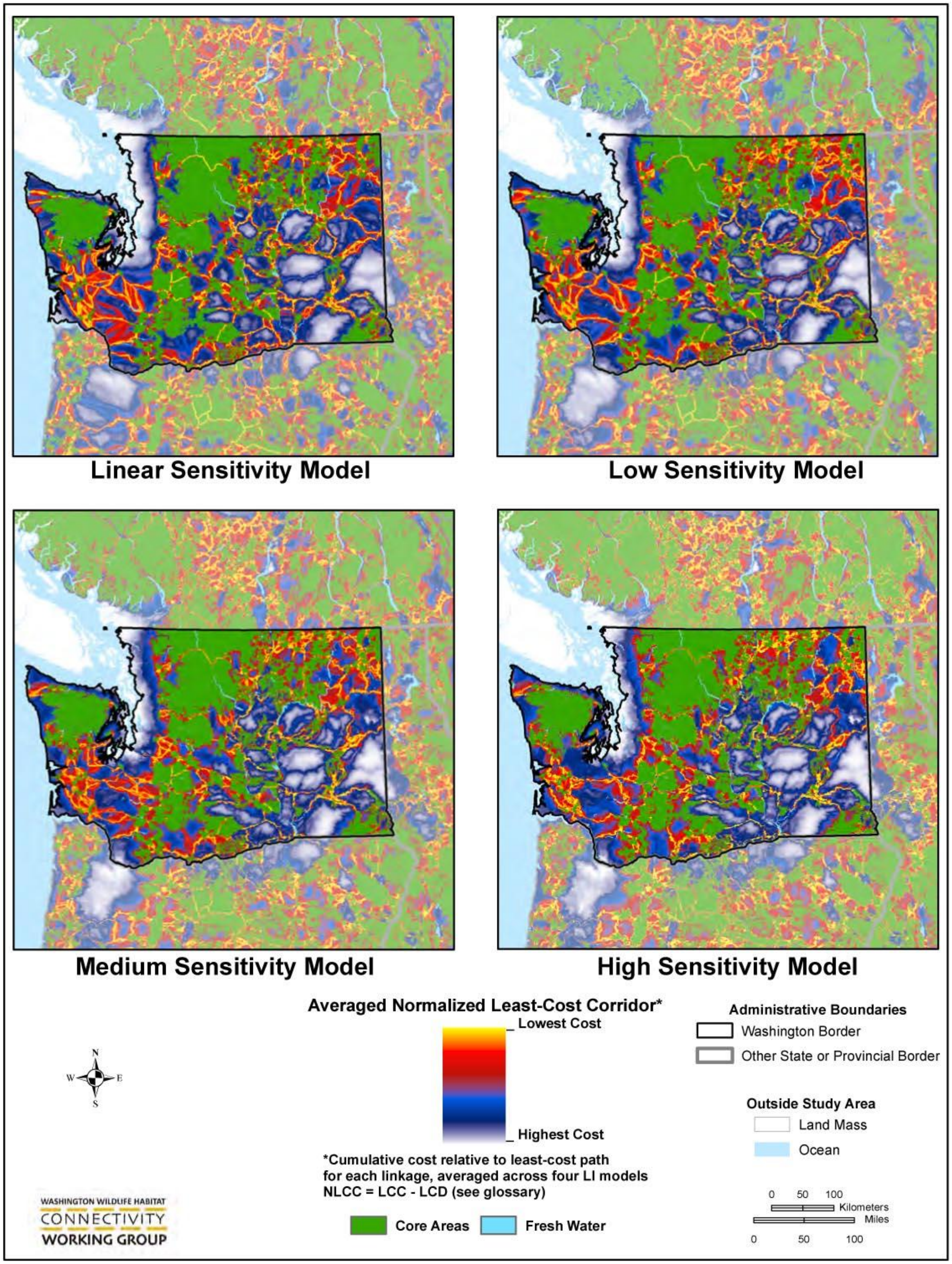

Figure 3.67. Landscape integrity linkage maps derived from four resistance models. Cost values indicate relative ease of movement within each linkage.

The overall composite landscape connectivity map (See Section 2.6.3) identified areas important for connectivity when all sensitivity models were considered. Areas with high linkage values (low normalized least-cost corridor scores) on the composite map had high linkage values for all four models, and areas with lowest linkage values had low values for all four models (Fig. 3.68).

A few patterns emerged from comparing connectivity values across the four resistance models. First, most linkages were similar across all four models. In general, there was more contrast in connectivity values associated with higher-sensitivity models than lower-sensitivity models, where more lands were identified with moderate connectivity values. In some areas, linkage locations differed significantly among the models (e.g., Fig. 3.69). Lower sensitivity models resulted in multiple pathways with similar cost-weighted distance values between core areas. Higher sensitivity models tended to restrict the number and width of corridors between core areas to only those with the highest landscape integrity values. The composite model identified areas that were important to all sensitivity models (Fig. 3.70).

Overlaying the best 30% of each connectivity map (i.e., the 30% with the lowest normalized least-cost distances for each sensitivity model) revealed that most (61%) of these were shared among three or four models (Fig. 3.71). Areas associated with only a single model accounted for 22% of the best 30% of the connectivity landscape; 16% of the linkage network was important for two models.

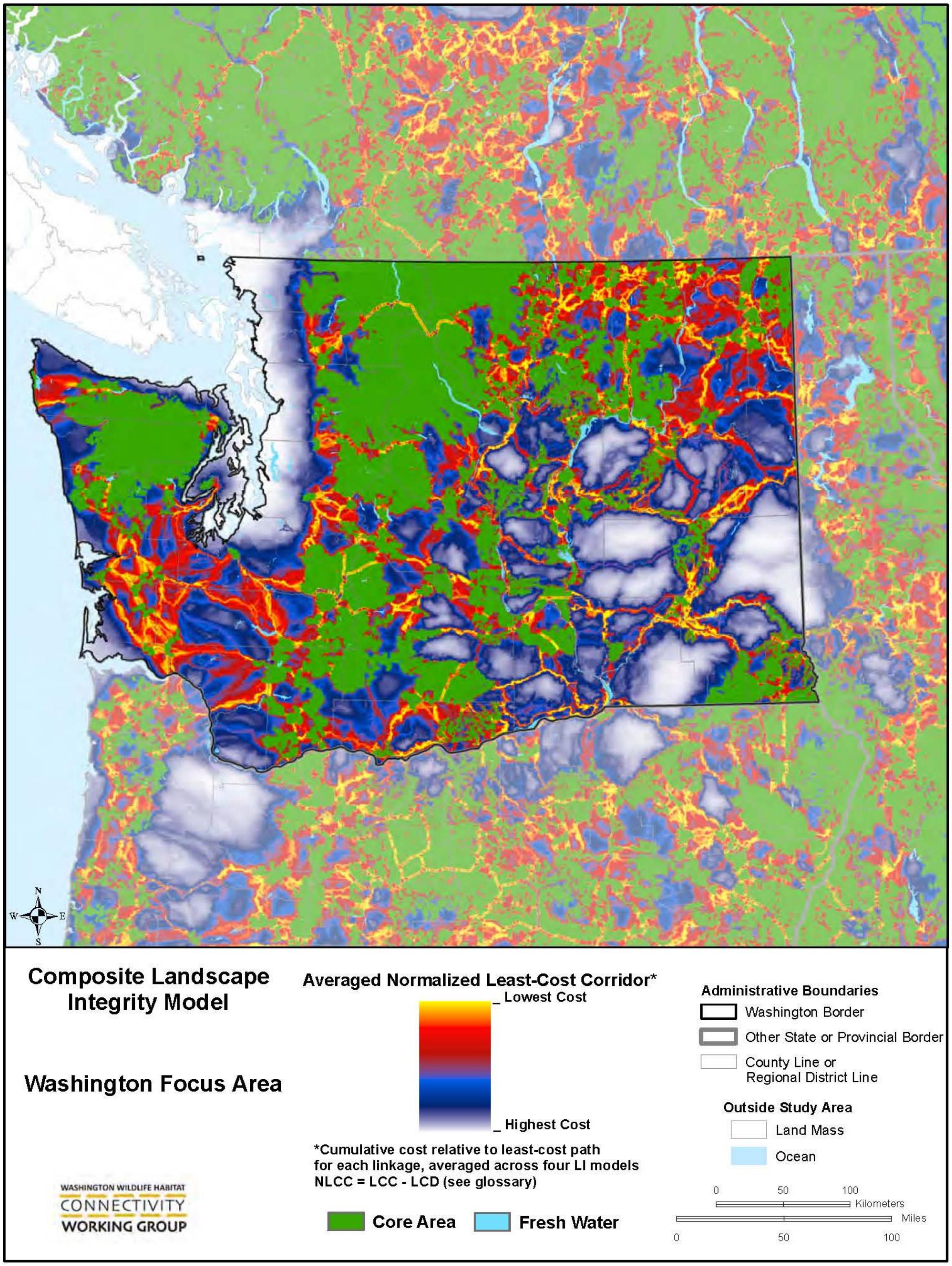

Figure 3.68. Composite landscape integrity linkage map which combines four sensitivity models. Cost values indicate relative ease of movement within each linkage.

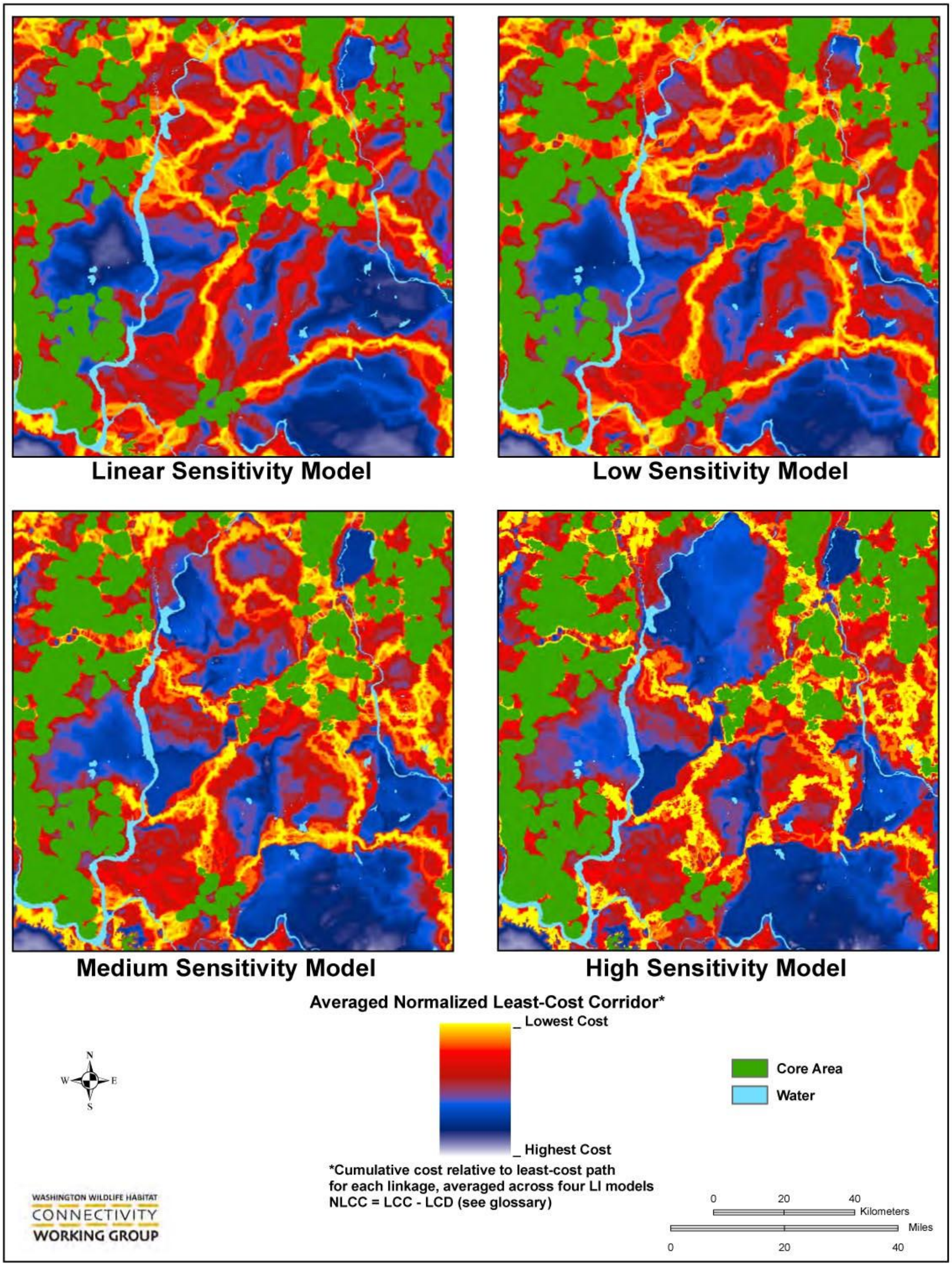

Figure 3.69. Landscape integrity connectivity areas in Kettle Falls/Republic area in northeastern Washington. These maps compare four different resistance models, representing a range of ecological flow sensitivity to human-altered landscapes.

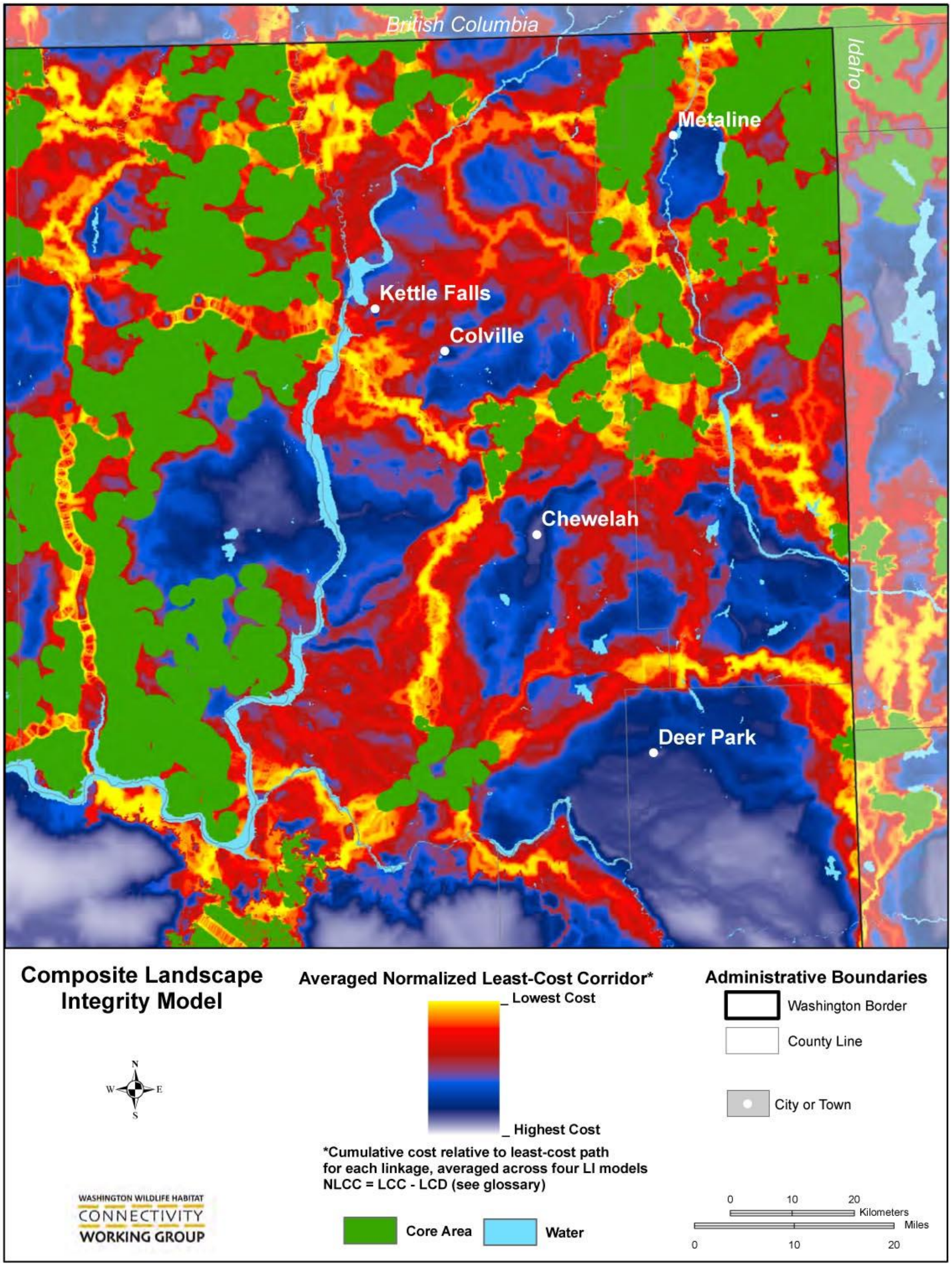

Figure 3.70. Composite landscape integrity connectivity areas in Kettle Falls/Republic area in northeastern Washington. This map is a composite of four different resistance models, representing a range of ecological flow sensitivity to human-altered landscapes.

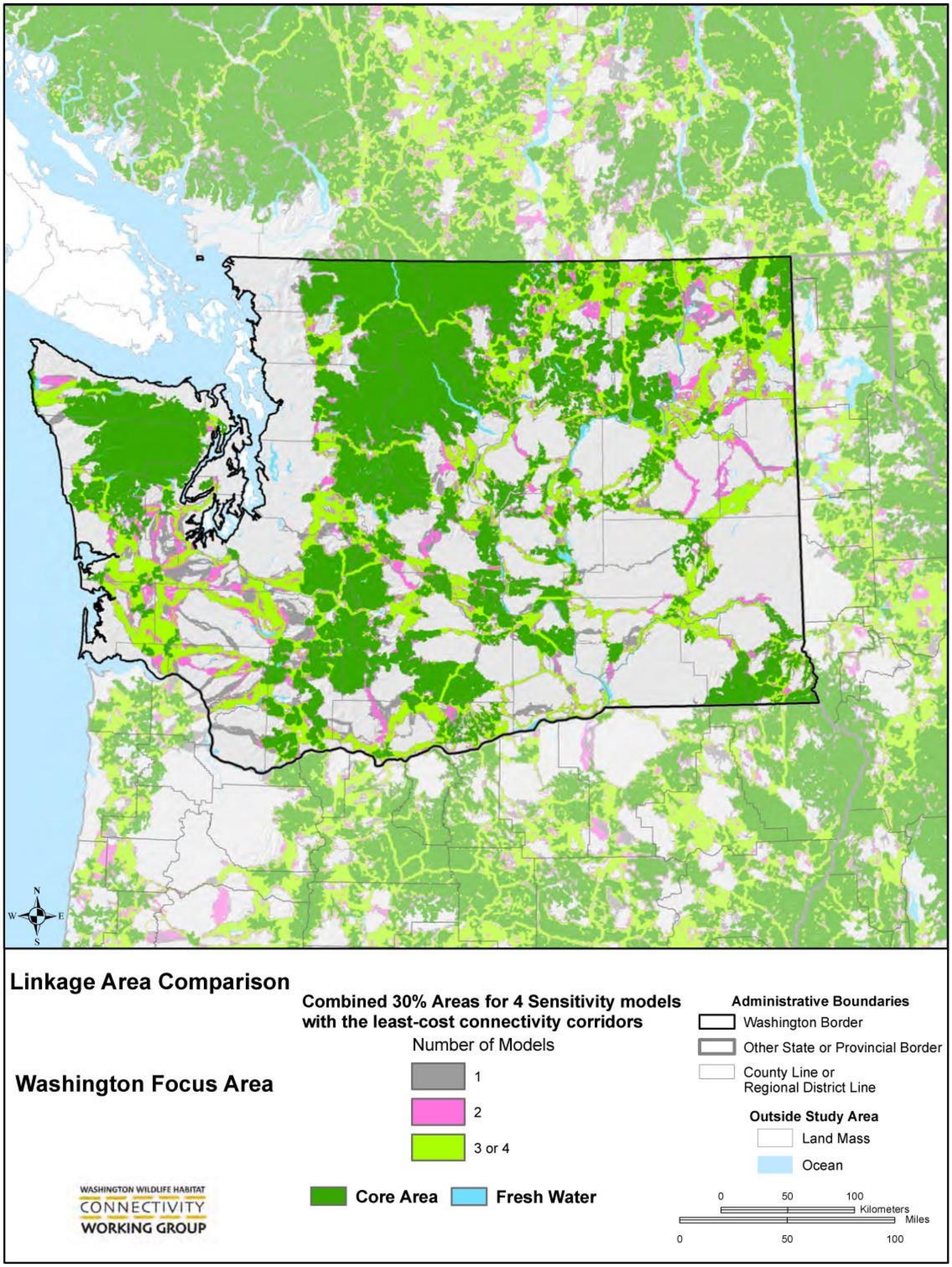

Figure 3.71. Comparison of linkage areas important for wildlife connectivity among four different models representing different sensitivities (linear, low, med, high) to human-altered landscapes.

3.4. Integration of Focal Species and Landscape Integrity Networks

Landscape integrity results were both concordant with, and complementary to, the focal species results. For example, both landscape integrity and focal species analyses revealed a strong pattern of habitat fragmentation in the Columbia Plateau ecoregion. These analyses also identified an extensive and widely distributed array of natural core areas that can form the base for future conservation of arid lands wildlife. Functional connectivity for many arid lands species may still occur, but it is unlikely to be resilient to much additional fragmentation. One way the landscape integrity results complemented the focal species results was that they were 'wall-to-wall,' allowing comparison of connectivity conditions across our entire study area in a single map.

Our systematic sampling across Washington allowed us to quantify the level of overlap between the focal species and landscape integrity networks. Overlap patterns were very similar between the wide, moderate, and narrow networks (See Section 2.6.4), so we only include the results for the narrow network here. The degree of overlap between the narrow linkage networks ranged from 0.9% of the black bear network falling within the Greater Sage-Grouse network, to 99.6% of the flying squirrel network falling within the mule deer network (Table 3.4). The degree of overlap between the landscape integrity network and the focal species networks ranged from 98.5% of the flying squirrel network falling within the landscape integrity network, to 69.1% of the Greater Sage-Grouse network falling within the landscape integrity network (Table 3.4).

Our results also indicated a high level of correspondence between the landscape integrity network and the union of all 16 focal species networks. The landscape integrity network captured 87% of the area that was within more than two focal species networks (Table 3.5).

Table 3.4. Network correspondence between narrow focal species (by code*) and medium sensitivity landscape integrity networks. Table entries show proportions of each row network contained within each column network; for example, 70% of the western toad network falls within the elk network. LI_LCC represents landscape integrity network.

	ANBO	CEEL	CEUR	GLSA	GUGU	LECA	LETO	LYCA	MAAM	ODHE	ORAM	OVCA	SCGR	TATA	TYPH	URAM	LI_LCC
ANBO	1	0.7	0.01	0.31	0.23	0.02	0.04	0.11	0.32	0.94	0.24	0.05	0.12	0.02	0.03	0.47	0.76
CEEL	0.59	1	0.04	0.33	0.28	0.06	0.12	0.15	0.36	0.94	0.26	0.06	0.13	0.08	0.04	0.58	0.88
CEUR	0.08	0.34	1	0.04	0.04	0.66	0.75	0.04	0.04	0.75	0.04	0.06	0.07	0.61	0.29	0.04	0.69
GLSA	0.74	0.91	0.02	1	0.49	0.02	0.02	0.21	0.77	1	0.46	0.05	0.06	0.02	0.02	0.86	0.99
GUGU	0.67	0.96	0.02	0.6	1	0.02	0.02	0.21	0.6	0.99	0.76	0.03	0.08	0.02	0.02	0.98	0.98
LECA	0.07	0.27	0.39	0.03	0.03	1	0.78	0.03	0.03	0.7	0.03	0.05	0.05	0.58	0.13	0.03	0.69
LETO	0.11	0.43	0.33	0.02	0.02	0.59	1	0.02	0.02	0.8	0.02	0.11	0.1	0.59	0.17	0.05	0.76
LYCA	0.54	0.82	0.03	0.43	0.34	0.03	0.03	1	0.48	0.98	0.37	0.09	0.18	0.03	0.04	0.97	0.95
MAAM	0.69	0.92	0.01	0.71	0.45	0.01	0.01	0.22	1	0.99	0.39	0.03	0.06	0.01	0.01	0.85	0.93
ODHE	0.54	0.64	0.06	0.25	0.2	0.1	0.16	0.12	0.27	1	0.19	0.05	0.12	0.11	0.05	0.43	0.76
ORAM	0.72	0.9	0.02	0.58	0.78	0.02	0.02	0.23	0.53	0.98	1	0.06	0.11	0.02	0.03	0.95	0.98
OVCA	0.43	0.62	0.09	0.18	0.09	0.12	0.35	0.18	0.13	0.87	0.17	1	0.38	0.16	0.1	0.41	0.87
SCGR	0.54	0.65	0.04	0.1	0.12	0.06	0.14	0.17	0.12	0.94	0.17	0.18	1	0.1	0.13	0.43	0.78
TATA	0.09	0.42	0.42	0.03	0.03	0.68	0.9	0.03	0.03	0.86	0.03	0.08	0.11	1	0.18	0.04	0.84
TYPH	0.26	0.46	0.4	0.06	0.06	0.31	0.51	0.08	0.06	0.84	0.08	0.1	0.27	0.36	1	0.17	0.84
URAM	0.62	0.91	0.01	0.49	0.45	0.01	0.02	0.27	0.52	0.98	0.43	0.06	0.13	0.01	0.02	1	0.95
LI_LCC	0.53	0.72	0.07	0.29	0.23	0.12	0.18	0.14	0.3	0.91	0.23	0.07	0.12	0.13	0.06	0.5	1

*Species codes: ANBO = western toad; CEEL = elk; CEUR = Greater Sage-Grouse; GLSA = northern flying squirrel; GUGU = wolverine; LECA = black-tailed jackrabbit; LETO = white-tailed jackrabbit; LYCA = Canada lynx; MAAM = American marten; ODHE = mule deer; ORAM = mountain goat; OVCA = bighorn sheep; SGCR = western gray squirrel; TATA = American badger; TYPH = Sharp-tailed Grouse; and URAM = American black bear.

Table 3.5. Proportion of sample points within focal species and medium sensitivity landscape integrity networks. Table entries show sample point proportions that are in or out of the landscape integrity network; and varying numbers of focal species networks.

	Number of focal species										
	0	1	2	3	4	5	6	7	8	9	10
Out of LI network	0.2	0.08	0.07	0.04	0.02	0.01	0	0	0	0	0
In LI network	0.01	0.03	0.05	0.1	0.09	0.09	0.1	0.06	0.04	0.01	0

The hierarchical cluster analysis dendrogram for all of the focal species and landscape integrity networks indicates that splitting the networks into three groups captured much of the variation in the data. The scree plot further supports the conclusion that much of the variation in spatial concordance is explained by clustering into three groups (Figure 3.72). The trio of focal species groups with similar linkage network patterns were the shrubsteppe associates (Sharp-tailed Grouse, Greater Sage-Grouse, black-tailed jackrabbit, white-tailed jackrabbit, American badger), the montane associates (Canada lynx, wolverine, mountain goat, black bear, northern flying squirrel, American marten), and the generalists (western toad, mule deer, elk, bighorn sheep, western gray squirrel). The landscape integrity network (LI_LCC) consistently clustered with the generalists and was most similar to the mule deer network.

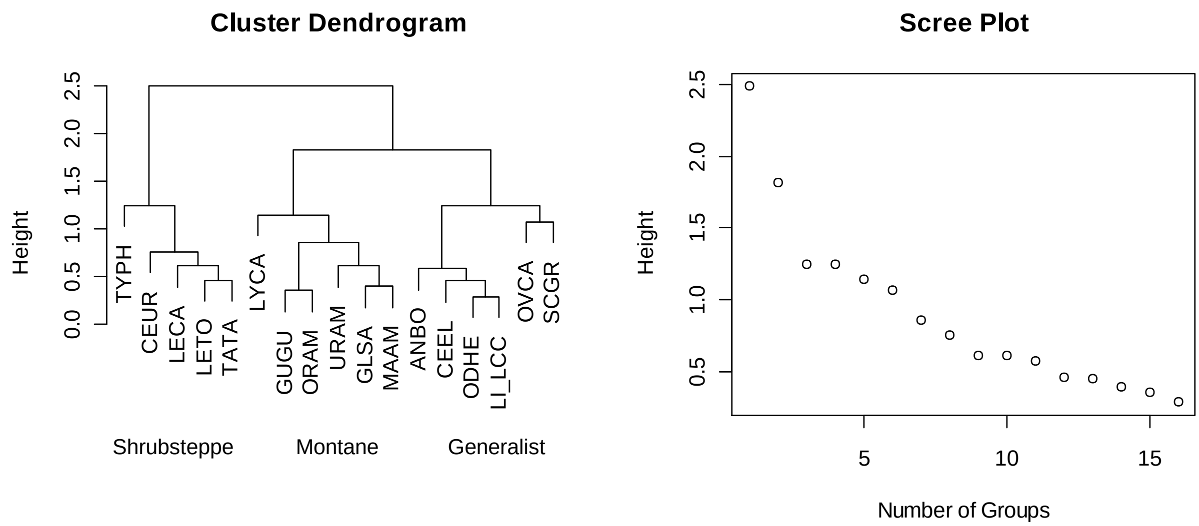

Figure 3.72. Hierarchical cluster analysis dendrogram showing three guilds, and scree plot.

3.4.1. Connected Landscapes Networks – Overviews by Species Guild

The results of this project are best represented by the maps and output data layers, in their entirety (See Chapter 4). The geographic coverage is vast, the range of species and landscape integrity is broad, and patterns in any individual map are relatively complex. However, there is value in comparing and contrasting the networks produced for focal species guilds and landscape integrity models.

The networks for the three identified species guilds were distinctly different. The networks for the generalist and montane species guilds are generally broadly connected, with the interruptions fitting the traditional view of "fracture zones," i.e., linear features that pose significant barriers to animal movement (Figs. 3.73 and 3.74). In contrast, the network representing the shrubsteppe species guild looks more like a series of broad linkages connecting isolated blocks of intact natural habitat (Fig. 3.75). Reflecting these differences, the results that follow highlight features of fracture zones and linkages among the three guilds.

Networks in the range of the generalist species guild — Relatively broad, well-connected landscapes typified much of the generalist species network (Fig. 3.73). A few important interruptions to the network were associated with fracture zones that were sometimes heavily developed and traversed by busy highways. Some of the more important fracture zones were associated with I-5 between Olympia and Vancouver, the Chehalis River bottomlands along U.S.

12, I-90 between North Bend and Cle Elum, the Methow River bottomlands between Winthrop and Twisp, U.S. 97 between Okanogan and the Canadian border, State Route 395 and the Colville River valley from Deer Park to Kettle Falls, and U.S. 12 from Morton to Naches.

Networks in the range of the montane species guild — In the more mountainous and forested regions of the state, where fragmentation from human-created barriers was less extensive and often confined to relatively narrow linear areas, the montane species networks were almost entirely represented within the landscape integrity network (Fig. 3.74). The identified narrow fracture zones often have similar conditions on both sides, and modeled corridors for focal species and landscape integrity varied in their selected crossing locations. In the Canadian Rocky Mountains ecoregion in the northeast corner of Washington State, linkage overlaps often reflected the most suitable lands, in private ownership, providing connectivity between blocks of publicly-owned or Native American Tribal lands that were strongly represented in multiple species' HCAs and the landscape integrity network.

Networks in the range of the shrubsteppe species guild — The range of the shrubsteppe focal species guild corresponds with the Columbia Plateau ecoregion and the semi-arid vegetation class used for focal species selection. This is a distinctive region within Washington, with arid conditions resulting in vegetation, wildlife communities, and land uses that are unlike most of the rest of the state. Natural vegetation communities and their associated wildlife are more extensively fragmented here as well (Fig. 3.75). The remaining sizeable blocks of native vegetation and limited human footprint contribute to a well-defined linkage network. This pattern is apparent in both focal species and landscape integrity networks. A prominent feature of the shrubsteppe species network is a south-to-north tending complex of linkages and HCAs that results from our models suggest is suitable for either four or five of the region's focal species (Fig. 3.76). This linkage network starts, on the south end, in the Horse Heaven Hills and the Yakama Indian Reservation. From the Prosser vicinity, it tends north through the Rattlesnake Hills and the Yakima Training Center, then follows the west bank of the Columbia River, broadly, to a river-crossing point that lands on the east side of the Columbia at the mouth of Moses Coulee. Moving east, the network forks, one leg continuing east and northeast to Swanson Lakes, and the other following the west side of Banks Lake north to East Foster Creek, then up the Okanogan Valley to the town of Okanogan. While portions of this network represent the best conditions available for animals to move through, conditions for many species may still be quite poor. However, this is undoubtedly an important network for maintaining connectivity for many species. A significant portion of this network is composed of channeled scablands, with soils too shallow for productive farming. Significantly, this network extends almost from the southern border of Washington to its northern border, providing connectivity that may be important to the shifting ranges of plants and animals as climate changes.

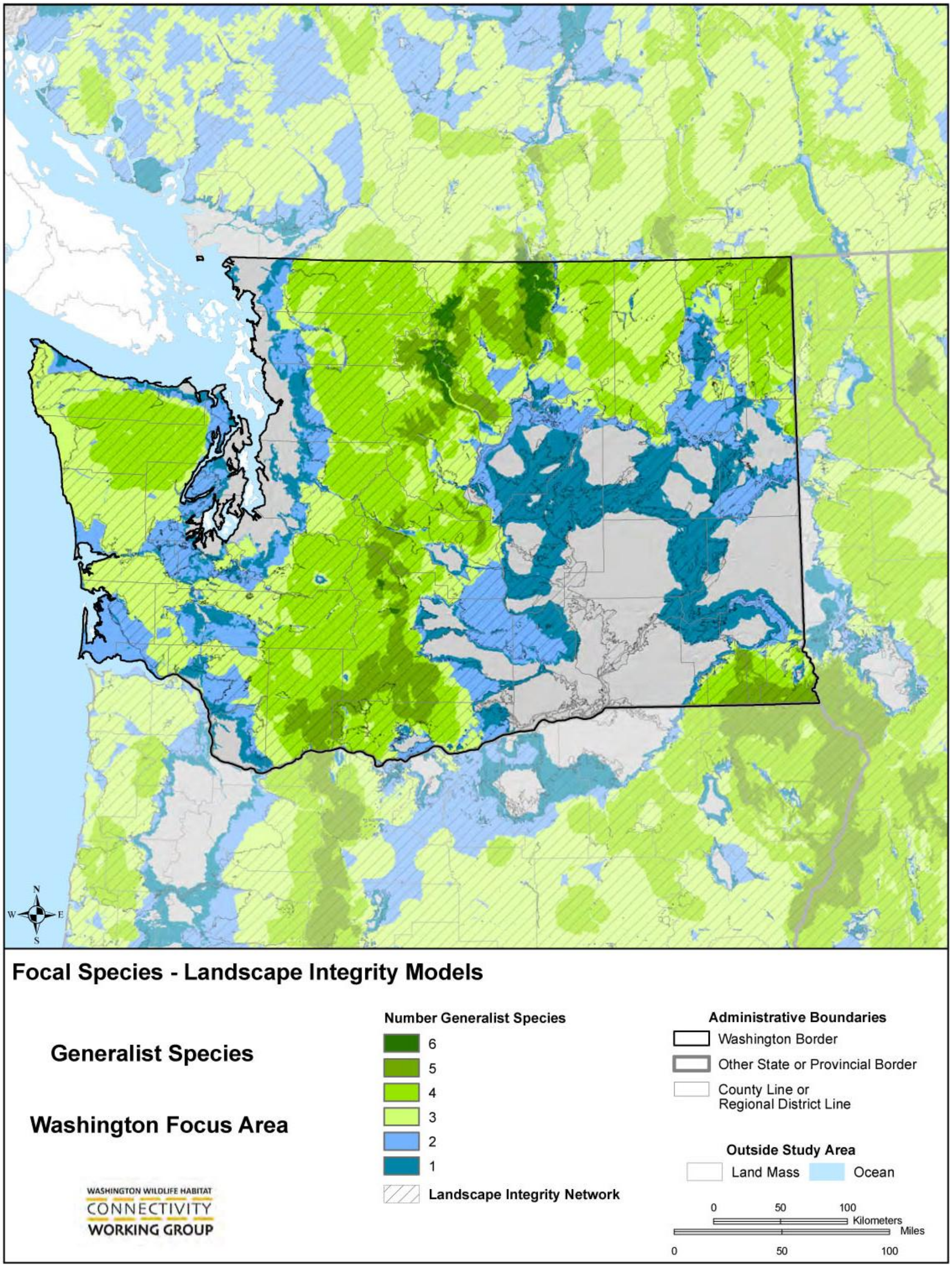

Figure 3.73. Composite focal species and landscape integrity map for generalist connectivity guild. Includes species that can inhabit a variety of habitats such as mule deer and western toads.

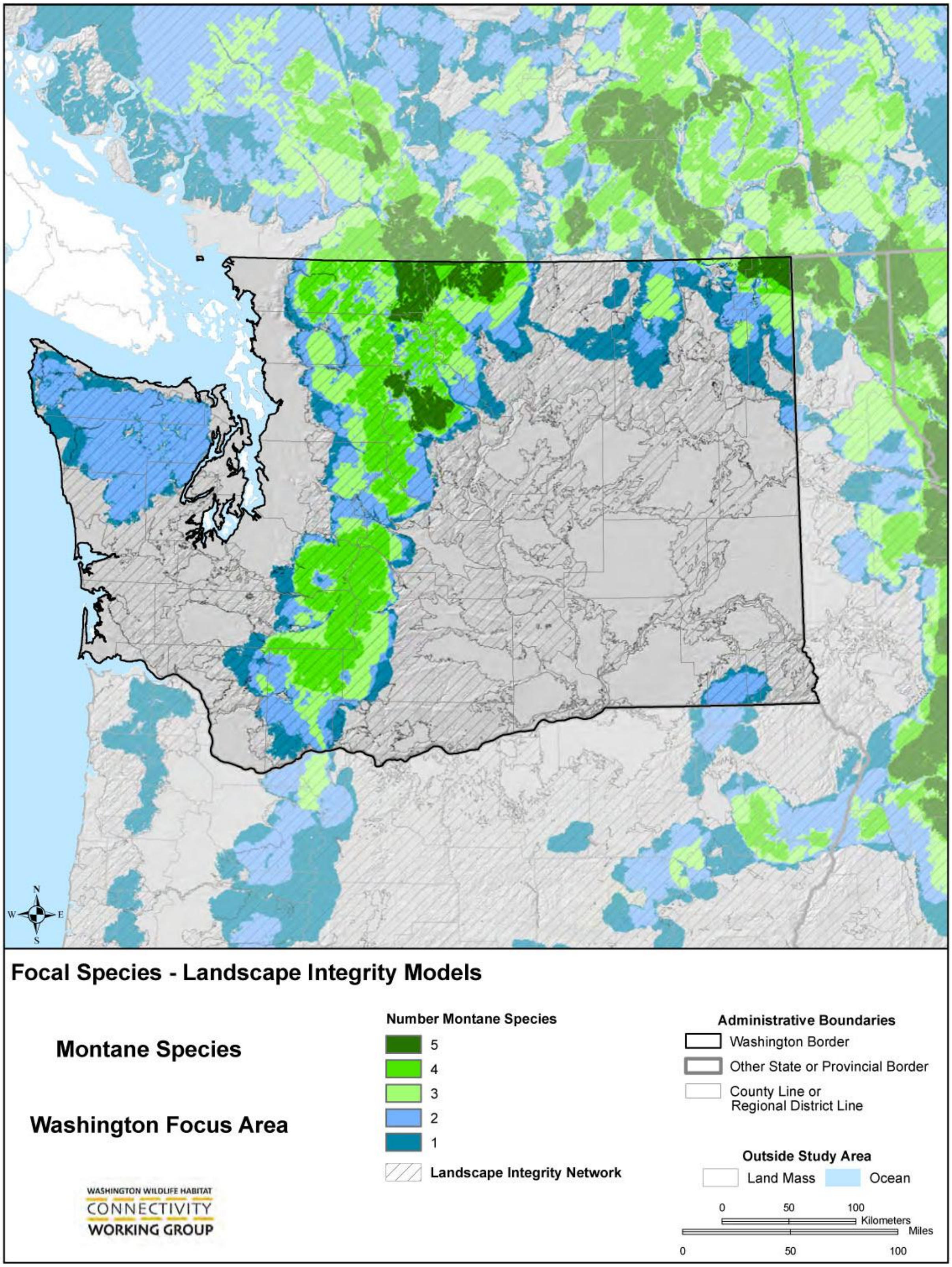

Figure 3.74. Composite focal species and landscape integrity map for montane connectivity guild. Includes species found in forests and mountainous areas such as American black bears and wolverines.

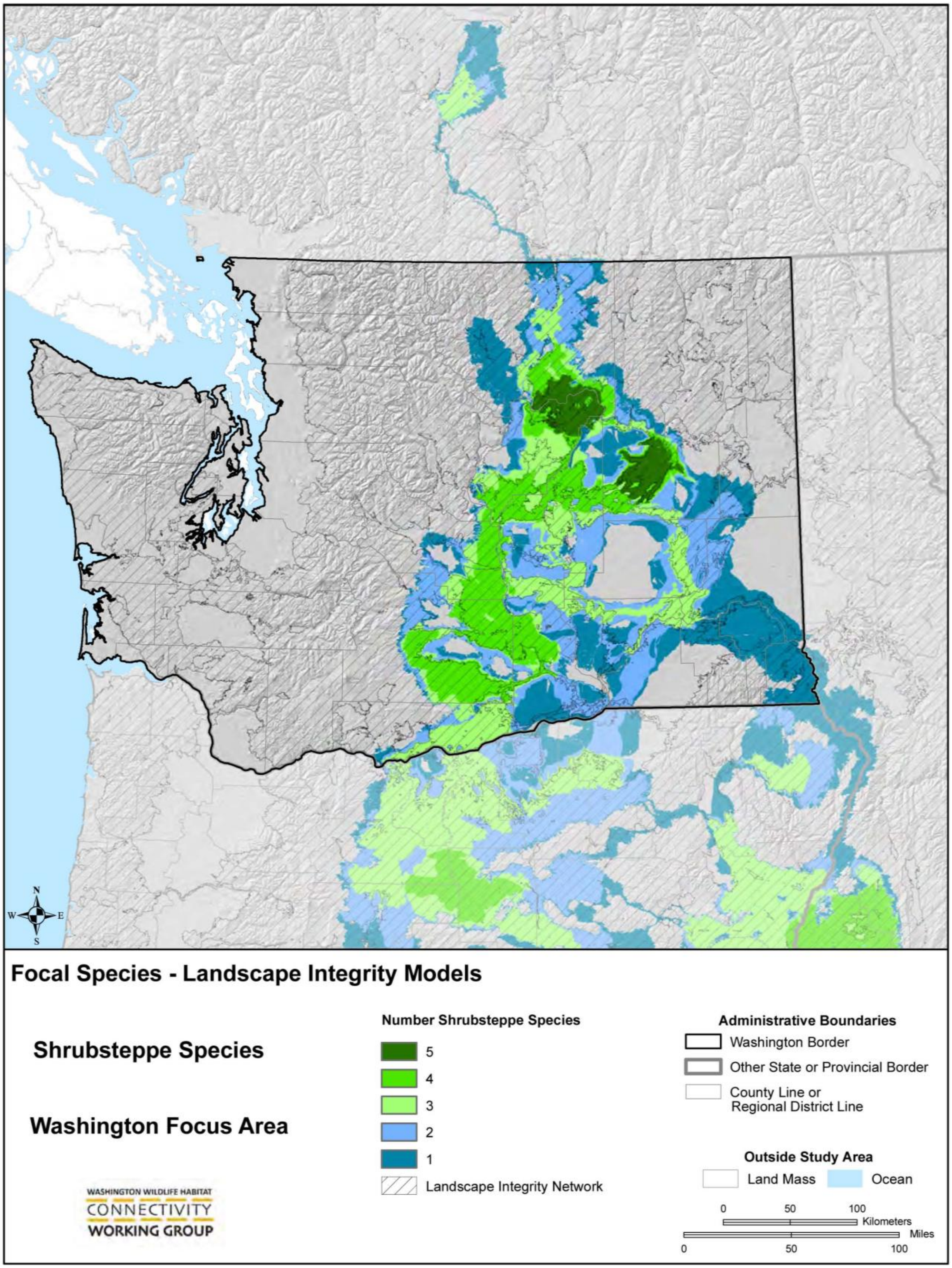

Figure 3.75. Composite focal species and landscape integrity map for shrubsteppe connectivity guild. Includes arid lands species such as American badgers and white-tailed jackrabbits.

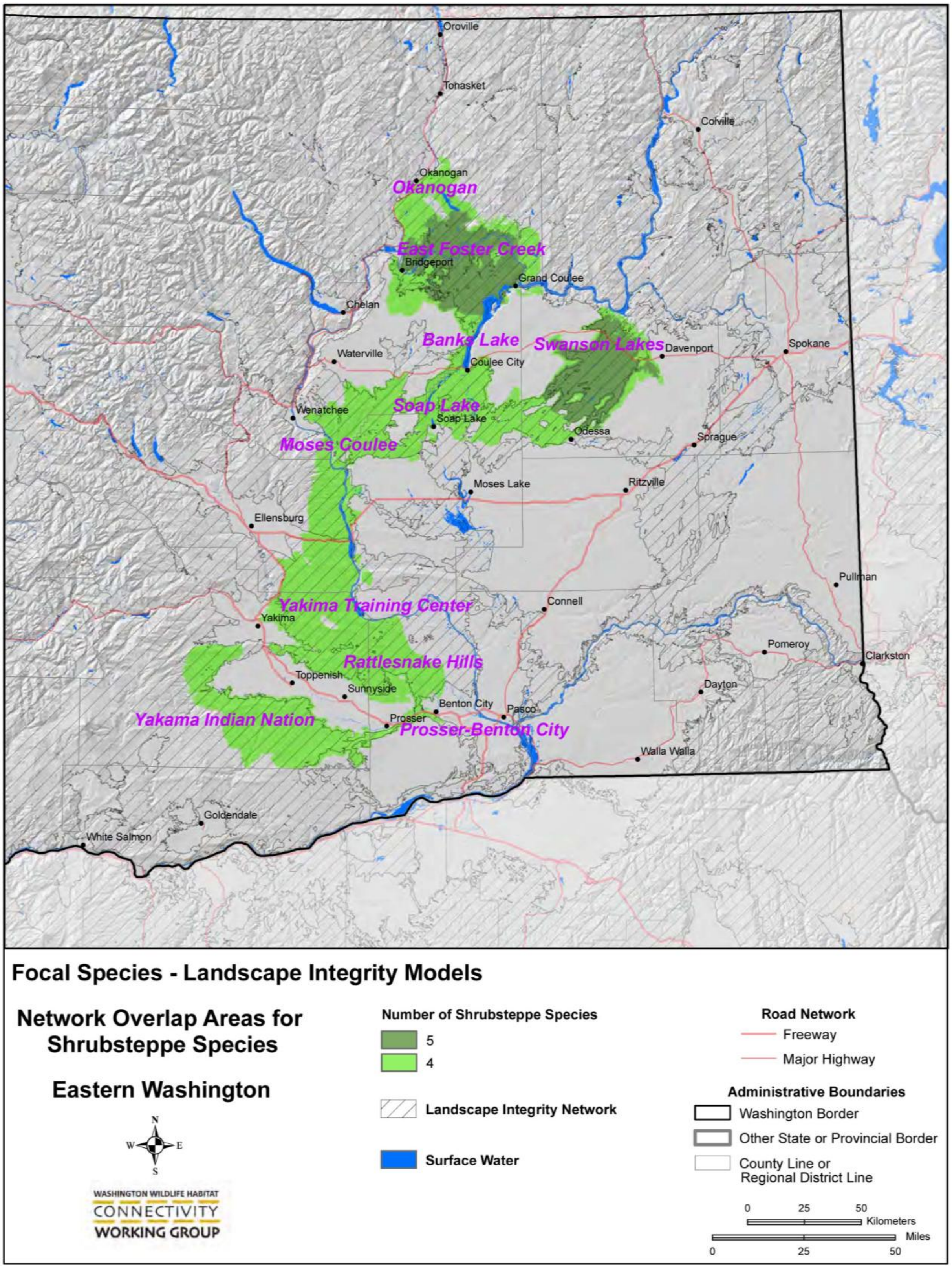

Figure 3.76. Shrubsteppe species and landscape integrity networks with overlap of four to five focal species shown in green.

3.4.2. Identifying Linkages for Broader Arrays of Species

We intended our analyses to identify areas important for a broad array of species and ecological processes. We designed our modeling approaches accordingly; for example, our focal species selection process was designed to identify those species that could serve as conservation umbrellas (Roberge & Angelstam 2004; Beier et al. 2008), representing the connectivity needs of a diverse suite of species.

Our network correspondence analyses revealed that focal species could be grouped into three major connectivity guilds (generalist, montane, and shrubsteppe), within which there is substantial network overlap (Fig. 3.72, Table 3.4). Further examination of linkage networks should help us understand how well these linkage networks serve non-focal species as well. We need to know, for example, if portions of networks identified for multiple focal species have greater ecological value than portions identified for a single species.

We included landscape integrity analyses in part to evaluate their ability to cost-effectively identify networks that are important for many species while requiring fewer data and resources than focal species models (Chapter 2). Such approaches (e.g., Spencer et al. 2010) are relatively new and there is a critical need to understand how well they perform relative to more arduous focal species-based approaches. Thus far, the quantitative comparisons between our focal species and landscape integrity results are limited to correspondence and cluster analyses of one landscape integrity network with all focal species networks. The landscape integrity network showed a high degree of overlap with most of the focal species linkage networks, containing between 69% (black-tailed jackrabbit and Greater Sage-Grouse) to 99% (for northern flying squirrel) of individual species' networks. This promising result must be balanced with the fact that the medium sensitivity landscape integrity network we used for comparison covers 58% of our project area (Figs. 3.73–3.75). More detailed analyses are needed to fully understand how conservation plans based on integrity compare with those based on focal species. We invite and eagerly anticipate such analyses, which should strengthen future connectivity modeling efforts. We briefly discuss plans for pursuing such analyses in Chapter 6.

3.4.3. Linkages to Lands Outside of Washington

Connections to important habitat blocks beyond Washington's borders sometimes met the needs of multiple species. Some of the readily apparent network connections across state borders were associated with:

1) The Selkirk Mountains linkage to British Columbia.
2) The Kettle River Range into the Granby River area, a connection to British Columbia.
3) The Similkameen/Chopaka Mountain connection west of the Okanogan River valley, a connection to British Columbia.
4) The Pasayten Wilderness connection to British Columbia.
5) The North Cascades National Park connection to Manning Provincial Park in British Columbia.

6) The Colville National Forest linkage south through Mount Spokane and to the Idaho Panhandle.

7) The linkage to the Idaho Panhandle from the Lamont & Turnbull National Wildlife Refuge, extending east into Idaho just south of Spokane.

8) The linkage from Washington's Blue Mountains to Oregon and Idaho along the Grand Rhonde and Snake Rivers.

9) The shrubsteppe species linkage between Washington and Oregon, just east of the big bend of the Columbia River and south of Wallula.

3.5. Key Findings

The statewide analysis confirmed many of the patterns that spurred the formation of the WHCWG. For example, habitat connectivity is clearly compromised in areas with extensive urban development and agriculture, such as the Puget Trough-Willamette Valley ecoregion in western Washington and the Columbia Plateau ecoregion in eastern Washington. I-5 and associated development between Olympia and the Columbia River create a substantial barrier to east-west movement of wildlife. Similarly, I-90 creates a major disruption to north-south wildlife movement in the Snoqualmie Pass area, which has been recognized by WSDOT as a priority for implementing wildlife-friendly crossing structures. Many important habitat areas and connecting landscapes are found on public lands, such as those in the Cascade and Olympic Mountains. Private lands also contribute important habitat areas, and frequently help link wildlife habitats on public lands.

More importantly, the analysis also yielded new insights, which should both inform connectivity conservation efforts in Washington and advance best practices for connectivity assessments elsewhere. Below we briefly summarize some of our major findings:

- Two different analysis approaches (focal species and landscape integrity) identified broadly consistent habitat connectivity patterns in Washington. Initial quantitative comparisons of these approaches is promising; more detailed analyses are needed to fully understand how conservation plans based on integrity would compare with those based on focal species. Nonetheless, the landscape integrity approach can complement individual species-based approaches by providing seamless, 'wall-to-wall' connectivity maps across large regions.

- Synthesis of the focal species modeling results highlighted three distinct linkage networks: the generalist species network, montane species network, and the shrubsteppe species network. Within each network, there was considerable overlap in habitat areas and linkages across species. This finding should facilitate future efforts to plan for multiple species conservation.

- Previously undocumented patterns of potential habitat connectivity for shrubsteppe species within the Columbia Basin were highlighted in this analysis. We believe these should be a priority for further attention due to the heavily fragmented nature of the area.

Similarly, the potential importance of the Okanogan Valley was highlighted because it provides habitat connectivity values for all three linkage networks described above.

- We identified broad-scale landscape patterns that may provide the best opportunities for restoring habitat connectivity in several areas where it has been highly compromised, such as along I-5 south of Olympia.

- Additional work is needed in southwestern Washington to adequately map connectivity patterns due to the complex patterns of land ownership and land use history (including an emphasis on commercial timber production) in that area.

- Automation of our core area and linkage modeling methods facilitated collaboration between modelers and focal species experts, and fostered iterative model development. We will be releasing our GIS tools (See Appendix D) following publication of this report. Other lessons relevant to best practices for connectivity assessments are discussed in Chapter 5.