WASHINGTON CONNECTED LANDSCAPES PROJECT: CASCADES TO COAST ANALYSIS

WASHINGTON WILDLIFE HABITAT CONNECTIVITY WORKING GROUP

JULY 2022

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Washington Wildlife Habitat Connectivity Working Group

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Mission Statement of the

Washington Wildlife Habitat Connectivity Working Group

Promoting the long-term viability of wildlife populations in Washington State through a science-based, collaborative approach that identifies opportunities and priorities to conserve and restore habitat connectivity

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Cascades to Coast Analysis Team

Coordinators: Thomas Miewald, Dan Craver and Alan Yanahan (U.S. Fish and Wildlife Service)

Modeling Team: James Begley (Washington Conservation Science Institute), Erin Butts (U.S. Fish and Wildlife Service), Peter Singleton (U.S. Forest Service), Jeffrey Azerrad (Washington Department of Fish and Wildlife), Glen Kalisz (Washington State Department of Transportation), Brian Stewart (Conservation Northwest), Mark Teske (Washington Department of Fish and Wildlife)

Landscape Integrity Team: John Gallo (Conservation Biology Institute), Erin Butts (U.S. Fish and Wildlife Service), Thomas Miewald (U.S. Fish and Wildlife Service), and Kai Foster (Conservation Biology Institute)

Document Lead Authors: Sonia A. Hall (SAH Ecologia LLC), Peter Singleton (U.S. Forest Service), Brian Stewart (Conservation Northwest), Glen Kalisz (Washington Department of Transportation), Jeffrey Azerrad (Washington Department of Fish and Wildlife), Alan Yanahan (U.S. Fish and Wildlife Service)

Technical Editor: J.C. Armbruster (Conservation Northwest Volunteer Writer)

Cartography Team: Alan Yanahan (U.S. Fish and Wildlife Service), Brian Stewart (Conservation Northwest), Glen Kalisz (Washington Department of Transportation), Keiko Betcher (Conservation Northwest), Peter Singleton (U.S. Forest Service), Jeni Bennett (The Evergreen State College)

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Contents

SECTION B - Case Studies: Using the Connectivity Models

SECTION C - Focal Species' Accounts (TO BE ADDED SOON)

Washington Connected Landscapes Project: Cascades to Coast Analysis

SECTION A

Connectivity Analysis and Synthesis

Photo courtesy of Ted Grudowski and Conservation Northwest.

Chapter 1. Introduction to the Cascades to Coast Analysis

The Pacific Northwest is diverse, with landscapes ranging from conifer-covered mountainsides rising toward alpine meadows, craggy summits and snow-covered volcanoes; arid high plateaus of shrub steppe dotted with meadows and streams in the inland areas; and rich, productive valleys surrounded by dense, moist forests, blending into extensive coastlines along the Pacific Ocean. This richness and diversity supports agriculture, recreation, natural resource-based industries, and attracts people and a range of industries to the region. The growing population that is involved in these activities needs infrastructure to travel, stay connected, and to support their economic and other endeavors.

As the climate changes, the Pacific Northwest may have relative advantages to other regions in the North America. These advantages could increase the pressure on our natural ecosystems and working lands through population growth, the need for additional production of goods, as well as the direct and indirect impacts of climate change in the region. Maintaining and restoring a robust network of resilient and connected lands is key to ensuring that the Pacific Northwest's beauty and diversity can persist, and sustain the goods and services that it offers.

A number of private and public partnerships have formed over the last decade to address the need for connectivity at the scale necessary to respond to current changes (Figure 1). This includes the Washington Wildlife Habitat Connectivity Working Group (WHCWG) that formed in 2007 as an open, collaborative, science-based effort to produce tools and analyses that identify opportunities and priorities to provide habitat connectivity in Washington and surrounding habitats. To address issues of wildlife habitat connectivity within Washington and adjacent lands, the WHCWG adopted a multi-scale approach, starting with a broad-scale, statewide analysis of connectivity in Washington State and adjacent areas, the *Washington Connected Landscapes Project: Statewide Analysis* (WHCWG 2010). The *Statewide Analysis* confirmed many of the patterns that spurred the formation of the WHCWG.

In southwestern Washington and the Olympic Peninsula, the *Statewide Analysis* confirmed that many important habitat areas and connecting landscapes are found on public lands in the Cascade and Olympic Mountains, and that private lands also contribute important habitat areas, and frequently help link wildlife habitats on public lands. However, the *Statewide Analysis* also highlighted that habitat connectivity is compromised in areas with extensive urban development and agriculture, and that Interstate 5 (I-5) and the associated development between Olympia and the Columbia River create a substantial barrier to movement of wildlife between the Olympic and Cascades Mountains. Yet key findings of the *Statewide Analysis* included broad-scale landscape patterns that may provide the best opportunities for restoring habitat connectivity across I-5 between Olympia and Vancouver. The authors recognized, however, that southwest Washington was different from other parts of the state due to the complex patterns of land ownership, land use history, and the dynamic nature of change in this landscape. Therefore, additional work was needed in southwestern Washington to adequately map connectivity patterns in a way and at a scale that can inform actions in this region.

Figure 1. Examples of collaborative efforts in Washington State that highlight the importance of connected networks of lands to respond to current and future changes.

In 2018, the Cascades to Coast Landscape Collaborative (CCLC) was formed, convening farm and forest owners, non-governmental organizations, Tribes, industry, local, state, and federal governments in a self-directed collaborative practicing landscape conservation through spatial mapping and bringing people together. The CCLC is focused on lands and waters between the Pacific Coast and the Cascade Mountains in the states of Washington and Oregon. Early on, the CCLC understood that the places where wildlife feed, reproduce, and raise their young need to be connected to allow animals to adapt to changing conditions on the landscape. Effectively maintaining and restoring habitat connectivity requires science and information about species and their life history needs, as well as the current status and projections for land use and changing conditions throughout the region. Therefore, the CCLC became an enabler and supporter of the WHCWG's next phase in the *Washington Connected Landscapes Project:* this *Cascades to Coast Analysis*. The CCLC also supported a similar effort in Oregon State, led by the Oregon Department of Fish and Wildlife, to obtain information on connectivity priorities across their whole region of interest.

This report presents the findings of an ecoregional-scale assessment of habitat connectivity across southwest Washington and the Olympic Peninsula. This analysis complements the *Statewide Analysis* by providing more detailed information on current patterns of habitat connectivity, and guidance on areas and linkages important to maintaining existing connectivity, as well as priorities for investments that can improve connectivity where needed. We envision this analysis serving as a foundation for conversations among entities and stakeholders in particular places on what actions they can take and how those actions could enhance connectivity locally and regionally.

Goal

Our goal for the *Cascades to Coast Analysis* is to identify connected habitat networks that highlight areas important for conserving and restoring conditions that promote desirable wildlife movements for the broadest possible range of native species across this landscape. This includes identifying locations where there are bottlenecks to major animal movements. Though major wildlife bottlenecks are one of the more extreme examples of places requiring immediate action, this analysis also identifies other areas important to maintaining and enhancing wildlife connectivity.

Through a series of outreach meetings in 2018 and 2019 the team heard from a range of stakeholders some of the potential uses of the analysis, including to support:

- City and county growth planning,
- Land management planning by state and federal agencies (e.g., Federal Forest Plan revisions, the U.S. Fish and Wildlife Service's Comprehensive Conservation Planning for National Wildlife Refuges),
- Investment in crossing structures by transportation agencies,
- Investment in priority easement or land acquisition by land trusts or other non-governmental organizations (NGOs),
- Investments in conservation on private working lands made by timber corporations, small family forest owners, ranchers, and dairy farmers, whose working lands can also provide habitat connectivity for wildlife,
- Understanding how Tribal lands and territories contribute to species conservation, and
- Decisions by biodiversity advocate organizations and individuals on how they can support and encourage action across the landscape that contributes most to improving connectivity and climate-smart conservation.

We anticipate that this analysis will provide a strong foundation for prioritizing conservation efforts, guiding development of detailed linkage design at the local scale, and encouraging future validation of connectivity models.

The Cascades to Coast Region

Much of western Washington is experiencing some of the fastest growth in the western United States. This growth is layered on top of an already relatively large human population—Washington ranks the smallest of all eleven western states in land area, but the second most populous. This growth is leading to significant change and land conversion across much of this landscape. Southwestern Washington in particular has seen some of the fastest rates of population growth in the state, contributing to significant land conversion, mostly from forest and farmlands to development.

The Cascades to Coast project area runs from the crest of the Cascade Mountains in the east to the Pacific Coast in the west (Figure 2). The area includes southwestern Washington (from Pierce County to Clark and Skamania Counties) and the entire Olympic Peninsula. Our project area overlaps significantly with the Washington portion of the Cascades to Coast Landscape Collaborative's region, while extending northward to relevant boundaries.

Many wildlife species in the region are designated by Washington Department of Fish and Wildlife as Species of Greatest Conservation Need. While this landscape may still provide connectivity for many species, future changes in land use, human population growth, and the potential effects of a changing climate underscore the need for a better-connected landscape—one that allows for continued movement of wildlife within and between the Cascades and the Coast.

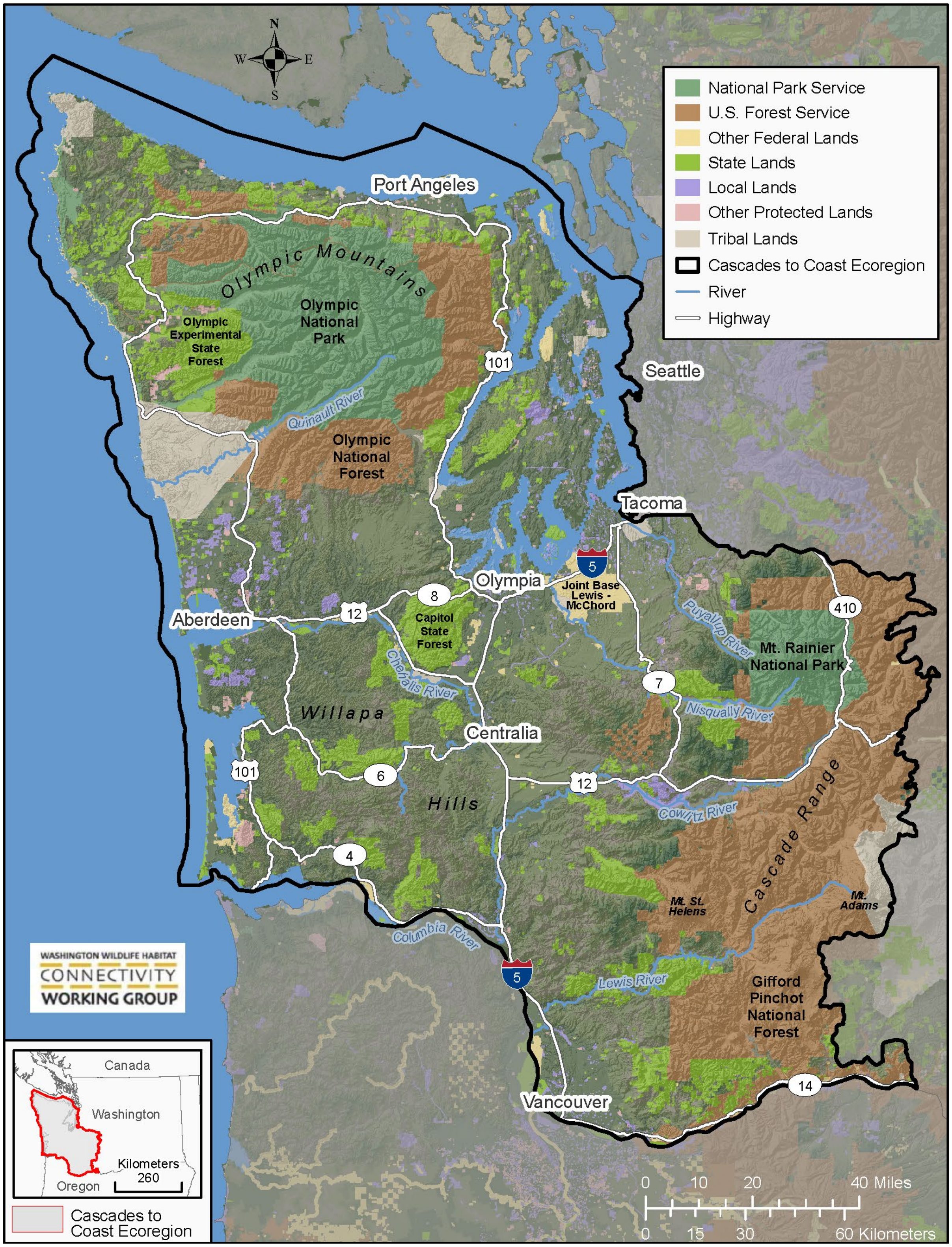

Figure 2. The Cascades to Coast region showing common geographic features and place names.

How This Report Is Organized

The report is divided into three sections. Section A of this report contains four chapters. Chapter 1 (this chapter) provides an introduction to the project and the region. In Chapter 2, we provide an overview of the methodological approaches used to model connectivity across the Cascades to Coast region. This chapter focuses on providing an overview of the approaches and rationale for the decisions we made. The tools and methods used are similar to those used in the WHCWG's previous work (WHCWG 2010, 2012), related analyses (Gallo et al. 2019). Readers should refer to those reports and the documentation for the tools used (e.g. LinkageMapper; McRae and Kavanagh 2011) for a more detailed description of methods. In Chapter 3, we describe key patterns and insights drawn from the synthesis and interpretation of connectivity models for five focal species (Section C) and for landscape integrity (Gallo et al. 2019). This synthesis includes (a) summaries of key connectivity patterns for each species and landscape integrity, (b) an assessment of connectivity patterns across the region for all habitats and species, based on a composite of the individual linkage networks, (c) a discussion of opportunities for maintaining and restoring connectivity across the region, and (d) a vision for a connected Cascades to Coast region in Washington State. Finally, Chapter 4 provides conclusions and recommendations, and outlines future work around understanding and conserving connectivity in the Cascades to Coast region.

Section B contains five case studies intended to illustrate, via a series of concrete examples, different ways that these connectivity models can and are being used to inform connectivity conservation actions on the ground Finally, Section C contains accounts of the background and modeling information for each of the five focal species. Each species' account provides natural histories, modeling overviews, connectivity mapping products, and description of results and key insights for a particular focal species: cougar, western gray squirrel, mountain beaver, Pacific fisher and American beaver. Each of these species' accounts also include a comprehensive set of maps resulting from the connectivity modeling, including a map of the species' Habitat Concentration Areas (HCAs), resistance to movement, cost-weighted distance, and linkages between HCAs.

Chapter 2. Analytical Approach for the Cascades to Coast Analysis

This Cascades to Coast Analysis follows the approach outlined in the Washington Connected Landscapes Project: Statewide Analysis (WHCWG 2010) and the Washington Connected Landscapes Project: Analysis of the Columbia Plateau Ecoregion (WHCWG 2012). As in both of these analyses, two main approaches are combined to model patterns of habitat connectivity that are representative of the needs of a wide array of species with different movement characteristics and habitat requirements in the region (Krosby et al. 2015). One of these approaches, based on landscape integrity, is intended to function as a coarse filter, capturing and representing the needs of many species across the region. The landscape integrity approach seeks to identify the best available routes to maintain movement for wildlife and ecological processes across the landscape by modeling connectivity across large, contiguous areas that retain high levels of naturalness (that is, limited human impact). However, its results do not assess specific ecological functions, can be difficult to validate, and are challenging to communicate. We therefore complemented this approach with a focal species approach to modeling connectivity (Krosby et al. 2015).

In the focal species approach, the modeling is centered on five carefully selected focal species, and the habitat and connectivity needs of each of those five species are modeled individually. The strength of this approach lies in the consideration given to the ways that each focal species assessment contributes to our understanding of connectivity across the region, hence the care taken in selecting these species. In addition, species-specific connectivity models are more intuitive, and can be interpreted and communicated more easily. It is also easier for those with expertise on the needs and movement capabilities of different species to assess the extent to which a particular model can inform the needs of other species with similar characteristics and needs. The challenge for the focal species approach lies in the need, theoretically, to develop models for all species of interest, a potentially long list. Hence our two-pronged approach that also includes landscape integrity modeling.

Finally, how do individual species models inform the regional patterns of functional connectivity across the whole landscape, for all species? Synthesizing and integrating the results across focal species and landscape integrity is therefore part of this analysis as well. By taking this two-pronged strategy to model connectivity, including both landscape integrity and focal species models, and then integrating the two, we gain the advantages associated with both approaches while addressing shortcomings associated with using each approach alone.

Focal Species Selection

We selected five species to represent the connectivity needs of a broader assemblage of wildlife, as well as the major vegetation classes across the Cascades to Coast region, and the threats to wildlife connectivity and persistence expected in this region. The process to select these five focal species mirrored the process used in previous analyses (WHCWG 2010, 2012). Starting from a list of 188 Species of Greatest Conservation Need known to occur in the region, the team followed a systematic, multi-step, collaborative process to narrow down the list and ultimately focus on five species. The team first focused on 21 species through initial consideration of the extent of each species' range within the project area, the scale and mode of movement of each species, and the availability of data to support connectivity modeling, as well as ensuring representation of species associated with the main habitat types found in the Cascades to Coast region (obtained from the LANDFIRE Existing Vegetation Type dataset; Johnson and O'Neill 2001, NatureServe 2018):

- Open water, riparian, wetlands
- Coastal Forest
- Mixed Conifer-Hardwood Forest
- Grassland, Prairie, Oak Woodland, Savanna
- Bays, Estuaries, Coastal Dunes
- Montane Mixed Conifer Forest and Alpine Forest

Eleven wildlife biologists from agencies with interests across the region scored these 21 species based on criteria meant to assess whether each species could be considered a good focal species for habitat connectivity modeling. The criteria that guided this process included their association with particular habitats or seral stages, their sensitivity to barriers to connectivity, and other factors (Table 1).

The team and invited experts used these scores as the basis for discussions in a workshop setting that resulted in the selection of five focal species. During this process, the group explicitly decided (1) not to select focal species for Bays, Estuaries and Coastal Dunes; (2) not to select species for the Mixed Conifer-Hardwood Forest habitat type, as those species would be covered by species representing the Coastal Forest, particularly those associated with early seral stages; (3) to combine the Montane Mixed Conifer and Alpine Forest habitat type with the Coastal Forest habitat type; and (4) to select different focal species representing early and late seral Coastal Forests. The five focal species selected by the team and invited experts were:

- **Cougar** (*Puma concolor*), selected as a generalist species that uses a variety of habitats,
- **Western gray squirrel** (*Sciurus griseus*), selected to represent species using grassland, prairie and oak woodland habitats,
- **Mountain beaver** (*Aplodontia rufa*), selected to represent early stage Coastal Forests,
- **Pacific fisher** (*Pekania pennanti*), selected to represent late seral stage Coastal Forests, and
- **American beaver** (*Castor canadensis*), selected to represent Riparian and Wetland habitats.

The specific basis for selection of each species is described in more detail in that species' account (Section C).

Modeling Habitat Value, Resistance to Movement, and Connectivity

The conceptual approach to modeling connectivity was essentially the same as the one used in the *Analysis of the Columbia Plateau Ecoregion* (WHCWG 2012). The connectivity model for landscape integrity or for each focal species was developed through a series of steps that transform spatially explicit data layers (see *Data Used to Model Connectivity*, below) into a map of core areas and a map of resistance values, which were then combined and processed to identify the linkages and associated corridors between core areas (equivalent to the HCAs for specific species; Figure 3).

Table 1. *Criteria and ranking guidance used by contributing wildlife biologists to score the 21 species under consideration as potential focal species for the Cascades to Coast connectivity analysis.*

Threatened by land clearing or vegetation removal?	*Respond "yes" if this is a significant or population-level threat. Examples of things to consider: ● Results in loss of habitat functions such as reduced security cover or forage; ● Results in inhospitable environment (e.g., desiccating conditions for amphibians); ● Results in increases in competition with or harm from other species, predators, or invasive exotics.*
Threatened by development?	*Respond "yes" if this is a significant or population-level threat. Examples of things to consider: ● Obstacles to movement created by buildings and associated infrastructure; ● Harm to or avoidance from habitat due to noise, lighting, lack of forage or prey; ● Increases in competing species, predators, and invasive exotics as a result of development.*
Threatened by roads or traffic?	*Respond "yes" if this is a significant or population-level threat. Examples of things to consider: ● Creation of inhospitable conditions (e.g., desiccating conditions for amphibians); ● Creation of an obstacle or physical barrier; ● Fatal attraction (e.g., attraction of snakes to warm road surface); ● Increased mortality due to vehicle collisions; ● Behavioral avoidance (e.g., roads avoidance).*
Threatened by people or domestic animals?	*Respond "yes" if this is a significant or population-level threat. Examples of things to consider: ● Legal and illegal harvest; ● Harassment/disturbance; ● Disease transmission; ● Intolerance to the presence of people or vice versa (a rancher's intolerance of wolves on their pasture).*
Climate Sensitivity (1-10)	*RANK 1 to 2: Unaffected or scantily influenced by factors associated with climatic changes. Species exhibits little physiological or phenological sensitivity to climatic factors. More of a generalist species with few dependencies (e.g., on specific habitat types or prey). Dependencies that exist are insensitive to climate change. RANK 3 to 4: Influenced by factors associated with climatic changes, but to a low degree and may not be noticeable. Species may exhibit some slight sensitivity to climatic factors in terms of physiology, phenology, and/or ecological relationships (e.g., habitat needs or prey). RANK 5 to 6: Though not significantly influenced by factors associated with climatic changes, the effects are noticeable. Species exhibit some sensitivity to climatic factors in terms of physiology, phenology, and/or ecological relationships. RANK 7 to 8: Likely to experience a significant influence from factors associated with climatic changes, with potential implications to long-term persistence. Significant sensitivity to climatic factors in terms of physiology, phenology, and/or ecological relationships. RANK 9 to 10: Substantially influenced by factors associated with climatic changes, with major implications to species long-term persistence. Species exhibits substantial physiological sensitivity to climatic factors AND/OR the species is more of a specialist with critical dependencies (e.g., on specific habitat types or prey) that are significantly affected by climate change.*

Mobility (1-10)	*VERY LOW MOBILITY, Rank 1 to 2 (e.g., lands snail, sedentary salamander species)* *LOW MOBILITY, Rank of 3 to 4 (e.g. Western Gray Squirrel)* *MODERATE MOBILITY, Rank of 5 to 6 (e.g., Black-tailed Deer, Coyote)* *HIGH MOBILITY, Rank of 7 to 8 (e.g., Elk)* *VERY HIGH MOBILITY, Rank of 9 to 10 (e.g. Gray Wolf, Wolverine, or Cougar)*
Susceptibility to barriers (1-10)	*A rank of 1 represents a species with the greatest ability to move through most (if not all) types of human altered landscapes. These species can easily move through or around any type of human-altered landscape or barrier.* *A rank of 10 represents a species with the least ability to move through most (if not all) types of human altered landscapes. Most types of habitat alterations, no matter the intensity, are a barrier to movement.*
Type of barrier sensitivity	*Examples include:* *● Canopy gaps over a certain size;* *● Water bodies above a certain size/depth/flow rate;* *● Fencing;* *● Roads of a given size/traffic volume.*
Aquatic & Terrestrial linkage?	*Does the species depend on both aquatic and terrestrial habitats to fulfill its life history needs?*
Association with specific seral stages?	*Is the species generally associated with a specific seral stage (i.e. early, mid, late)? If so, which stage?*
Association with other structural habitat components?	*Does the species depend on any other (abiotic) structural habitat components? Please describe them and indicate if each habitat component can be mapped across the species' range (with an emphasis on components that can be mapped at the regional scale).*
Particular socioeconomic consideration	*Please elaborate what the socioeconomic considerations are, if applicable to the species. For example:* *● The species is considered a "pest".* *● The species is culturally important.* *● The species is economically important.*
Data Availability?	*Please respond to the following questions to the best of your ability:* *● Is there enough information on the species to support modeling efforts?* *● Do we know enough about conditions that promote or deter movement?* *● Are the species' movement choices based on features that can be modeled?* *● Are there Habitat Suitability Models for this species?*

STEP 1: Develop habitat surface. Through a literature search and consultation with species experts, numerical values representing habitat value were assigned to different vegetation types and applied to a vegetation data layer. Similarly, natural and man-made features occurring across the landscape, such as highways and other roads, rivers and streams, or developed areas, were also assigned values depending on whether they offer habitat value for each species. These assigned values were used as attributes in the spatial data layers for that landscape feature. The values range from 0 (no habitat value) to 1 (perfect habitat value). For example, the habitat value for fisher of evergreen forest is 1 (best possible habitat), while that of deciduous forest is 0.5; mid-density developed areas have a habitat value of 0.1. For western gray squirrel, evergreen forests have a habitat value of 0.75, while both deciduous forests and mid-density developed areas both have no habitat value (score of 0); oak woodlands are the best habitat, with a score of 1. The habitat value in one grid cell is obtained by overlaying the different input data layers, and integrating the impact

each layer has on habitat value for that species. The end product of this first step is a habitat surface for the whole region where each grid cell (30 m x 30 m) has a value between 0 (no habitat value) and 1 (best habitat value).

STEP 2: Develop resistance surface. The assignment of values and the output of this second step are analogous to those used in developing habitat surfaces. The main difference is that the values assigned to each vegetation type and landscape feature was based on how easy or hard it is for the species to move through a grid cell with those vegetation and landscape features. For example, both cougar and mountain beaver have resistance values of 1 to 5 for most terrestrial natural vegetation classes. However, high intensity developed areas pose more resistance to cougar movement (resistance value of 100) than to the smaller mountain beaver (resistance value of 30). In this case, the end product is a resistance surface for the whole region where each grid cell has a value between 1 (the species experiences no resistance to moving through that cell) to a maximum value that is species specific (for example, the maximum resistance for mountain beaver is 651, such that moving through a grid cell with that resistance value equates to moving through 651 grid cells that pose no particular resistance—beyond the distance traveled—to that species).

STEP 3: Delineate Habitat Concentration Areas. Modeling linkages first requires a map of areas that you are interested in connecting. For each species, the team delineated Habitat Concentration Areas (HCAs), which are areas that have habitat characteristics suitable for supporting breeding individuals or populations of the focal species. In this analysis, the delineation of these HCAs was based on identifying the highest densities and extents of clusters of grid cells in the habitat surface that had high habitat value for that species. The output of this step is a map showing HCAs of varying sizes scattered across the region.

STEP 4. Develop cost-weighted distance surface. An intermediate step in connectivity modeling requires the development of a cost-weighted distance surface. This step quantifies how hard it is for the species of interest to move outward from each HCA by adding the resistance values (obtained from the resistance surface) as it moves away from a particular HCA. The output of this step, therefore, is a map showing the HCAs, and the cost-weighted distance values in the areas between the HCAs. These appear as concentric bands expanding out from each HCA, similar to the contours of a topographical map around mountain peaks. These bands are not perfectly concentric, as their values are weighted by the resistance values in each added cell, showing areas with steeper changes in cost-weighted distance, and areas with gentler changes in cost-weighted distance.

STEP 5. Identify least-cost paths and associated linkages. The final step in modeling connectivity uses the cost-weighted distance surface to identify the shortest path, in cost-weighted terms, between adjacent HCAs. This shortest path is called the least-cost path, is one grid cell in width, and extends from the edge of one HCA to the edge of the adjacent one. The linkage associated with each least-cost path is a wider corridor with the least-cost path at its center. The width of the linkage is determined based on how cost-weighted distance accumulates outward from the least-cost path, to a cost-weighted distance threshold of 5 km of cost-weighted distance. The end product of this step, and therefore of the connectivity modeling process as a whole, is a map showing the HCAs, and the variable width linkages between them. Additional analyses can then be done to explore attributes of these linkages, which can make them more or less important in conserving connectivity across the region. The team carried out some of these analyses to inform the prioritization (results available with data layers for download at https://waconnected.org/coastal-washington-analysis/).

Applying this approach to the landscape integrity model

The same conceptual approach described in the five steps above was used to develop the connectivity model based on landscape integrity. The main difference is in the way parameters were assigned to develop the habitat and resistance surfaces, as well as some differences in the input layers used. In the landscape integrity case, the resistance surface was developed first, based on how impacted a grid cell is by human activities, or the level of integrity in that grid cell. So for example, all native habitat types are considered to pose no resistance, whether they are bare rock or forested (though note adjustment described in the next paragraph for the habitat surface). Roads, buildings, energy infrastructure, and other datasets are then layered on and assigned resistance values based on guidance obtained from the literature or expert opinion. Once this basic resistance surface was developed, two modifications were made: (1) resistance was reduced where crossing structures (e.g. bridges or large culverts) exist across I-5, US 12 and State Route (SR) 8; and (2) resistance within protected areas was reduced slightly, with the intent of favoring linkages—and therefore conservation opportunities—across protected areas, everything else being equal (see Gallo et al. 2019 for details).

The landscape integrity habitat surface was developed by basically inverting this resistance surface. That is, areas with low human impact, which were assigned low resistance to movement, were considered good habitat, and vice versa. The main adjustment made to the habitat surface was to ensure that steep areas, which would have higher resistance, were actually considered wild or intact areas, and so had high values in the habitat surface. Core areas were delineated in a similar fashion to species' HCAs, and the development of the cost-weighted distance surface and identification of least-cost paths and associated linkages follows the same process outlined above for the species-specific analyses.

Data Used to Model Connectivity

The team assembled 10 GIS data layers to characterize the wildlife habitat quality and resistance to movement of all grid cells in the Cascades to Coast region. A key layer focuses on vegetation classes, which in this case was developed by combining land cover data with another layer containing attributes related to the structural condition and size class of forests. Types of agriculture were also added in from other data sources (Table 2). Other layers were obtained, or developed by combining different data sources, to characterize the following features across the landscape: highways and roads, highway crossings (across I-5, US 12 and SR 8), railroads, trails, rivers and streams, energy infrastructure (natural gas pipelines, wind turbines and transmission lines), buildings, and topography (slope and elevation) (Table 2).

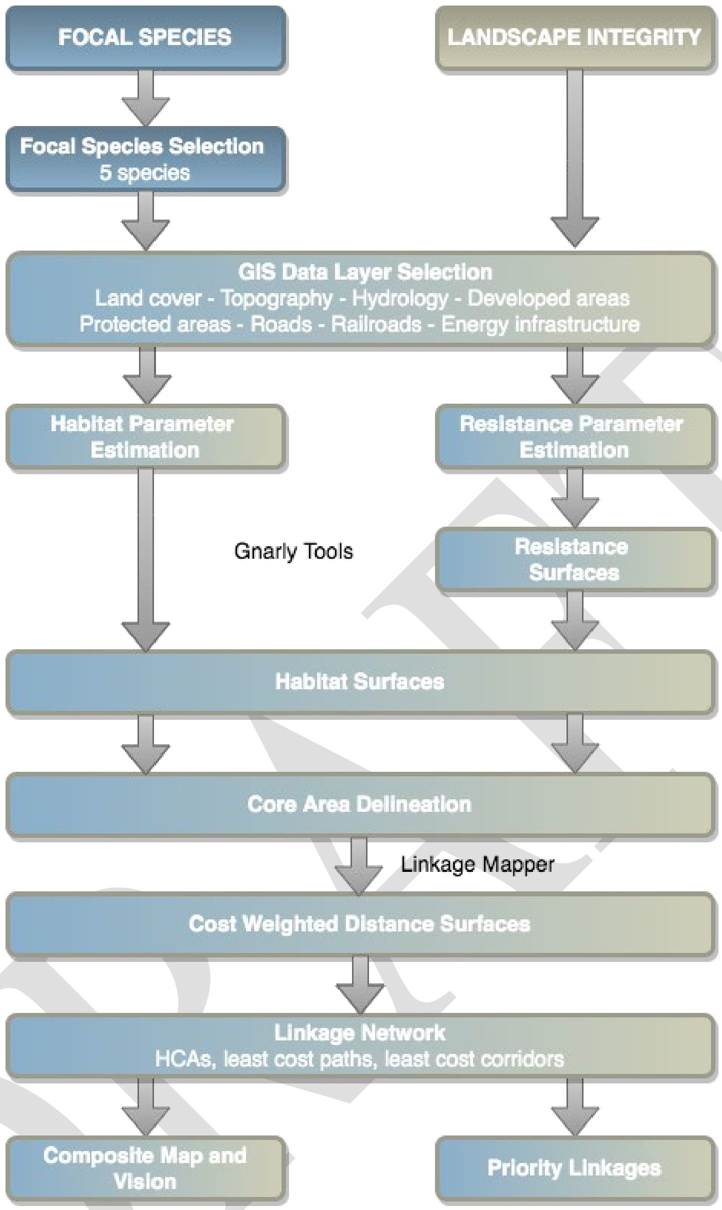

Figure 3. *Flow of the Cascades to Coast Analysis.*

For some types of data, such as highways, roads and buildings, the team buffered features so that the layers used for habitat and resistance modeling could incorporate not only the effects of the physical features themselves but also effects that extend beyond those features. For example, each highway was coupled with a buffer, whose width was dependent on the species of interest, throughout which the resistance to movement for that species declined linearly as the distance from the center of the highway increased. The intent was to allow species models to incorporate effects beyond the direct footprint of the highway, such as visual impacts, noise, vibrations, or disturbance of the vegetation by weeds or other processes. As with the *Statewide Analysis* and the *Analysis of the Columbia Plateau Ecoregion* (WHCWG 2010, 2012), not all data layers were used for all focal species or landscape integrity models. All base layers were compiled using an Albers

Conical Equal Area map projection with a 30 m square grid cell size.

Landscape Integrity Modeling

Landscape integrity can provide a measure of the relative degree of human disturbance on the landscape. When the team began the Cascades to Coast connectivity analysis, they discussed two alternative approaches to connectivity modeling. Before selecting the approach we finally used, and that is described in this report, the team compared landscape integrity models developed using each of these two approaches. The results of this comparison (and additional analyses that were not mirrored in the focal species analyses) are described in detail by Gallo et al. (2019), as is the rationale for using the linkage modeling approach—rather than a circuit theory approach—for the full Cascades to Coast analysis. The landscape integrity analysis discussed in this report, and used in the development of the synthesis analyses that integrated these results with the focal species connectivity models, is based on the following products developed by Gallo et al. (2019): (1) landscape resistance surface that includes using data on I-5, US 12 and SR 8 crossings and protected areas that were expected to reduce the resistance to movement of those areas (called Resistance Surface with Protected Area Benefits in Gallo et al. 2019, Stewart 2019), (2) landscape integrity core areas, delineated using a habitat surface developed from the resistance surface, with some modifications (see Gallo et al. 2019) and (3) linkages among core areas, using the resistance surface with reduced resistance values in protected areas, which essentially increases the likelihood that linkages will go through protected areas, everything else being equal.

Focal Species Modeling

For each focal species, we prepared a detailed account of the connectivity modeling analysis (see Section C). These accounts discuss the biology and ecology of the focal species in the context of their habitat needs, their movement abilities and the connectivity across the landscape. Each account also describes the rationale for the selection of each species and for the specific modeling decisions that informed the habitat, resistance and connectivity modeling steps for that species. The accounts also include connectivity modeling results and maps, accompanied by interpretation and insights drawn from the connectivity patterns for that particular species. Modeling products for each focal species include: (1) a habitat surface, (2) a resistance surface, (3) a map of HCAs, which represent the important habitat areas to connect, (4) a cost-weighted distance (CWD) surface, which reflects the cumulative cost of resistance as species move outward from HCAs, and (5) modeled linkages, or the movement pathways between HCAs. We also calculated linkage statistics, such as linkage length and quality metrics, which we used for the prioritization (see below), and allow users to evaluate the linkage quality and degree of connectivity between specific HCA pairs (linkage statistics are available with the data layers for download at https://waconnected.org/coastal-washington-analysis/).

***Table 2**. Summary of GIS spatial data layers used for habitat, resistance and connectivity modeling for focal species and landscape integrity analyses in the Cascades to Coast region.*

Data layer	*Summary**
Land Cover/ Land Use	We used data from multiple sources. Our main source was NOAA's Coastal Change Analysis Program (CCAP) data, whose land cover classes are consistently and accurately derived through remote sensing (accessed July 2018 at www.coast.noaa.gov/ccapftp). Other datasets were burned into the base CCAP data. We used the LEMMA data from the Forestry Sciences Lab, Oregon State University (accessed at https://lemma.forestry.oregonstate.edu/data/structure-mapsto) to integrate information on forest structure and size class. The LEMMA data was also used to identify dune pixels, since dune systems are not present in the CCAP land cover data. The USDA's Cropland Data Layer (CropScape – Cropland Data Layer (CDL) obtained from the USDA National Agricultural Statistics Service, accessed at https://nassgeodata.gmu.edu/CropScape/) from 2015 was also overlaid on the CCAP base raster to further classify CCAP cultivated areas.
Protected Areas	We used the Protected Areas Database of the United States updated by the Conservation Biology Institute (PAD-US (CBI Edition) Version 2.1; https://databasin.org/datasets/f10a00eff36945c9a1660fc6dc54812e/) and the National Conservation Easement Database (NCED; https://www.conservationeasement.us/).
Slope	We used the LANDFIRE 2.0.0 dataset, obtained from the U.S. Geological Survey, U.S. Department of the Interior (accessed August 2018 at https://www.landfire.gov/version_comparison.php).
Streams and Rivers	We used hydrological lines for rivers and streams obtained from the NHDPlus Region 17 dataset (accessed from https://www.usgs.gov/core-science-systems/ngp/national-hydrography).
Building Footprints	We obtained the Building Footprint Impact Gradient derived from Microsoft's 2018 data for the U.S. (accessed at https://github.com/Microsoft/USBuildingFootprints).
Roads	Highways (obtained from http://www.wsdot.wa.gov/mapsdata/geodatacatalog/Maps/noscale/DOT_TDO/FunctionalClass/FunctionalClass_SR.htm) were derived from Washington State Department of Transportation Highways data layer. We then used Washington Department of Natural Resources Roads data (obtained from https://data-wadnr.opendata.arcgis.com/datasets/dnr-proprietary-roads-statewide) for the spatial mapping of roads, and the Open Street Map (OSM) data (downloaded from http://download.geofabrik.de/north-america.html) for attributes of the roads. We did this because the OSM has a much richer mapping of different road types across the landscape.
I-5 Crossings	Data for the Interstate 5 Crossings were obtained from a M.Sc. thesis (Stewart 2019). The data include 20 crossing locations each ranked A (passable, could be improved), C (If improved could more easily passable), or F (impermeable) for six different species guilds.
Railroads	We also used Washington State Department of Transportation data to map active and abandoned railroads and rail banks (Railroads in Washington State, accessed at https://www.wsdot.wa.gov/mapsdata/geodatacatalog/default.htm).
Transmission Lines, Gas Pipelines and Wind Turbines	First, we used transmission line data from an interagency team including the Oak Ridge National Laboratory (ORNL) Geographic Information Science and Technology (GIST) Group, the Los Alamos National Laboratory (LANL), the Idaho National Laboratory (INL), and the National Geospatial-Intelligence Agency (NGA) Homeland Security Infrastructure Program (HSIP) (accessed at https://hifld-geoplatform.opendata.arcgis.com/datasets/electric-power-transmission-lines/data). We used U.S. Energy Information Administration data on natural gas liquid pipelines (accessed at https://hifld-geoplatform.opendata.arcgis.com/datasets/natural-gas-liquid-pipelines). We identified the locations of wind turbines using the U.S. Geological Survey's United States Wind Turbine Database (accessed at https://eerscmap.usgs.gov/uswtdb/data/).

* For more details on these data layers and how they were combined, please see Gallo et al. (2019), from which much of these summary descriptions were obtained and slightly modified for this table.

Linkage Networks' Synthesis Analysis

The focal species and landscape integrity approaches identify habitat concentration areas and core habitats, respectively, and areas of the landscape important for connecting them. As in the Statewide Analysis and the Analysis of the Columbia Plateau Ecoregion (WHCWG 2010, 2012), we consider that a linkage network consists of the combination of all the habitat concentration areas and the linkages modeled for a particular focal species, or core areas and modeled linkages for landscape integrity (WHCWG 2010). These networks are useful individually, informing decisions pertaining to maintaining and restoring connectivity for the particular focal species (or species considered similar enough in terms of habitat and movement needs), or for maintaining connectivity between relatively intact habitat areas. However, to explore the overall patterns of connectivity across the region, and identify those areas important for maintaining and restoring connectivity for all species of interest—which are too many to model individually—it is important to synthesize the information contained in each linkage network across focal species and landscape integrity. We therefore developed a composite of the six resulting linkage networks, to explore broader-scale patterns of connectivity from the Cascades to the Coast, with the goal of identifying priority areas for connectivity conservation or restoration.

This composite is a map that simply overlays all five focal species networks and the landscape integrity network, and highlights those areas where the greatest number of linkages in the linkage networks overlap. The scientific guidance for how wide linkages need to be to functionally connect two core areas is still uncertain. The team took a fairly conservative approach to defining linkage widths, and though these decisions appear to make sense, they are somewhat arbitrary. In this analysis, linkages for each focal species were defined as extending up to 5 km of cost-weighted distance from the least-cost path, while the landscape integrity linkages extended up to 150 km of cost-weighted distance from the least-cost path. These values defined linkages of similar geographical width by compensating for the higher resistance values used in the landscape integrity model. In addition to providing a basis for a synthetic product to explore connectivity across the Cascades to Coast region, these six linkage networks were also the basis for prioritizing linkages across the main fracture zones—areas of reduced permeability between HCAs or core areas—in the region.

Prioritizing Linkages Across Key Fracture Zones

Whether to inform efforts to conserve and enhance connectivity for one species or for the landscape overall, there is a need to identify specific linkages that provide the best opportunities for maintaining or improving wildlife's ability to move in response to current needs and future changes. It is important, however, to identify such priority linkages across the whole landscape, rather than focus on a handful of highest priorities that may co-exist in the most fragmented portion of the region. It is also important to identify priority linkages for each species, as well as those areas that are part of priority linkages for multiple species. The approach we took to prioritizing linkages was applied in two ways. First, we identified priority linkages for each focal species, and then these species-specific linkages were synthesized into a composite map (analogous to the linkage networks' synthesis analysis). Second, we first identified the main fracture zones across the whole Cascades to Coast region, and then prioritized linkages across each of these main fracture zones.

For each focal species and for landscape integrity, highways are central landscape features where permeability is reduced, leading to the occurrence of fracture zones. We therefore used highways as the focus for identifying priority linkages connecting different Habitat Concentration Areas within each linkage network. In this way, we identified nine major fracture zones along highways, which divided the landscape into 14 habitat blocks (Figure 4). Along each major fracture zone we identified the locations where least-cost paths in each network cross the highway, and then prioritized these crossing locations based on the following criteria:

- *Linkage length*: the length of the linkage's least-cost path (LCP), where shorter lengths were considered higher priority.
- *Cost/Euclidean ratio*: dividing the linkage's LCP cost-weighted distance length by the Euclidean distance between the connected HCAs provides a measure of permeability of the linkage. More permeable linkages (lower Cost/Euclidean ratio) were considered higher priority.
- *Linkage centrality*: The circuit flow centrality calculated by the Centrality Mapper tool in Linkage Mapper (McRae 2012) provides a measure of how central a particular linkage is to the whole network. Linkages with higher centrality were considered higher priorities.
- *Value of connected HCAs*: Linkages connecting higher habitat value HCAs, quantified as the HCA area weighted by habitat suitability, were considered higher priority.

Using non-parametric rankings, we identified the five highest priority linkages within each fracture zone for each linkage network (five focal species' and the landscape integrity network). For each of these priority linkages, we delineated a polygon that captured the segment of the linkage (5 km cost-weighted distance from the least-cost path) that crossed the relevant highway, plus a 1-mile (1.6 km) buffer along that highway. Similar to how we developed the composite map of linkage networks, we overlapped these priority linkage polygons to identify priority crossing areas important for multiple species and landscape integrity.

Focusing on those polygons that were priority linkages in two or more linkage networks, we categorized them based on traffic volume (a surrogate for the risk wildlife face) and the potential for loss of connectivity. We consider priority polygons with high traffic volumes as priorities for enhancing or restoring connectivity. Priority polygons with low traffic volumes are priorities for conserving existing connectivity. Priority polygons with medium traffic volumes may need further evaluation to see if they currently function as effective linkages, and therefore should be conserved, or if their functionality is compromised (for some or all species), and investments to improve connectivity are needed.

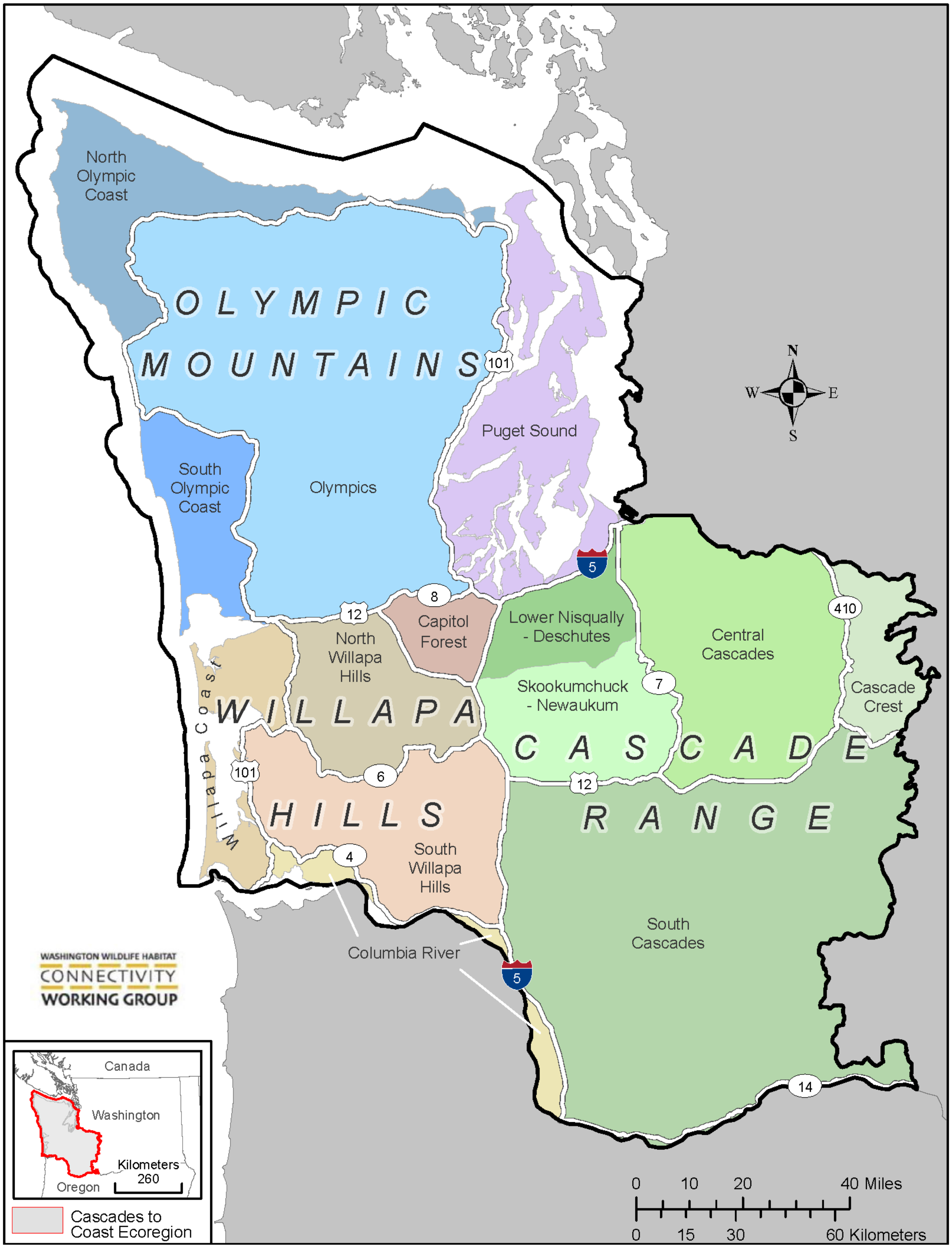

Figure 4. Highways representing the main fracture zones in the Cascades to Coast region, and the landscape units these fracture zones define. The colors on the map characterize the three main topographical areas in this region: Olympics (shades of blue), Willapa Hills (shades of brown), and Cascade Range (shades of green).

Interpreting and Applying the Connectivity Models[1]

By modeling core areas and linkages important for an array of wildlife species we are creating a vision for a connected landscape across the Cascades to Coast region in Washington State. These results are intended to help prioritize connectivity conservation both across the region and locally. It is important for users to understand the strengths and weaknesses of this connectivity analysis so that the results can be interpreted correctly and used effectively. We identify some of the strengths and weaknesses here and encourage the reader to refer to the *Statewide Analysis* and the *Analysis of the Columbia Plateau Ecoregion* reports (WHCWG 2010, 2012) for a more in-depth discussion.

The Cascades to Coast connectivity analysis: (1) creates a vision of a connected landscape by modeling habitats and linkages for an array of wildlife species and landscape integrity, (2) provides information to help agencies and organizations incorporate connectivity into conservation efforts while meeting organizational goals and priorities, (3) delivers the foundation for finer-scale linkage design analyses that can guide actions to enhance connectivity in particular linkages, and (4) affords opportunities for validation of model assumptions and predictions.

There are limitations to the analysis, which include: (1) errors and limitations in spatial data, (2) reduced applicability outside the project area, (3) incomplete assessment of important habitats or linkages, (4) insufficient detail to prioritize habitats or linkages at a finer scale, and (5) lack of adequate field data to validate all model assumptions. Despite these limitations, this analysis is a powerful tool that provides a solid foundation for actions to create or enhance connected landscapes as well as opportunities for future work.

This analysis is a landscape modeling effort that reflects our best estimate of modeled pathways for potential wildlife movement across the Cascades to Coast region in Washington State. We provide a great deal of information in this analysis and rely on readers to select from this array the information that is most pertinent to their specific interests and applications. We encourage users to delve into the focal species and landscape integrity resistance and habitat surfaces, HCAs and core areas, cost-weighted distance surfaces, and linkage networks that they consider most relevant to their questions and objectives. There are a great many ways to use these analysis products to address a wide variety of potential applications (see Case Studies in Section B). Our composite network analysis is one way of integrating different types of information. Other approaches to integration are possible, and we hope readers will develop and share new ideas about how to synthesize the information we provide to promote practical connectivity conservation.

[1] The guidance and limitations of the *Cascades to Coast Analysis* are very similar to those of the *Analysis of the Columbia Plateau Ecoregion*. We would therefore like to acknowledge the authors of Chapter 1 in WHCWG 2012, as this section is a slightly modified version of the *Interpretation* and *Application* sections in that document.

Chapter 3. Key Findings of the Cascades to Coast Analysis

The *Washington Connected Landscapes Project's Statewide Analysis* (WHCWG 2010) analyzed habitat connectivity across Washington State and into surrounding areas using the same two approaches that we used in this *Cascades to Coast Analysis*: a landscape integrity approach, which evaluates the overall impact of the human footprint on a landscape's habitats and connectedness (Gallo et al 2019), and a focal species approach, where a small set of species are carefully selected to represent the needs and movement abilities of a much wider array of terrestrial fauna. The *Statewide Analysis* concluded that, at the broad-scale landscape patterns the analysis captured, the results highlighted the best opportunities for restoring habitat connectivity across the I-5 corridor south of Olympia. However, the *Statewide Analysis* also emphasized that additional work was needed in southwestern Washington to adequately map connectivity patterns, as this region—which we now call the Cascades to Coast region—is characterized by complex patterns of land ownership and land use history, which were not fully captured in the *Statewide Analysis*. This report describes the connectivity patterns across the Cascades to Coast region that arise when considering such finer detail information, and can thereby inform priority areas for connectivity conservation and restoration in this region.

Key Connectivity Patterns for Focal Species

The habitat characteristics across the region and the habitat needs of each species together determine where Habitat Concentration Areas for that species exist in the Cascades to Coast region. Similarly, the resistance to movement that different landscape features pose for each species varies, and determines the existence, characteristics and value of different linkages between HCAs. Therefore, each species has a unique linkage network that highlights the most important areas for conserving and restoring conditions that promote desirable wildlife movements for that species and others with similar habitat needs and movement abilities.

Connectivity Patterns for Cougar

Key patterns arising from the connectivity analysis for cougar highlight that the primary barriers to cougar movement, at all scales, are major highways and development. We identified four main fracture zones due to these barriers: between Tacoma and Vancouver due to I-5, between Olympia and Aberdeen due to US 12 and SR 8, the Lower Nisqually-Deschutes area due to SR 507, 510 and 702, and between Napavine to White Pass, due to US 12.

The I-5 Tacoma to Vancouver fracture zone is one of the largest barriers to cougar movement within the Cascades to Coast region, disconnecting the Willapa Hills and Capitol Forest to the west from the South Cascades, Lower Nisqually-Deschutes and Skookumchuck to the east. Four linkages cross I-5 (Beaver and Scatter Creeks, the Great Wolf Lodge, the Centralia Mall, and the Toutle River), and represent some of the only remaining potential wildlife linkages bridging this fracture zone (Figure 5). The US 12-SR 8 Aberdeen to Olympia fracture zone is a major barrier to cougar movement between the Olympic Peninsula to the north and Willapa Hills and Capitol Forest to the south. There are five primary linkages crossing this fracture zone (west and east of

Central Park, Sylvia Creek, the Satsop River, and Oakville; Figure 5). In the Lower Nisqually-Deschutes area, linkages weave across SR 507, SR 510 and SR 702 between towns; however, these connections are tenuous and threatened by future development and sprawl. Finally, the US 12 Napavine to White Pass fracture zone is less of a barrier to cougar movement than the highways described above, due to the moderate to low traffic volumes. Areas east of Randle are broadly permeable, with core habitat close to both sides of the highway. Four linkages west of Randle also cross the highway around Riffe and Mayfield Lakes (Figure 5).

Connectivity Patterns for Western Gray Squirrel

Most of the western gray squirrel habitat within the Cascades to Coast region is located within a broad swath between Spanaway and Grand Mound, bounded by I-5 and associated developed areas on the north and west, SR 507 on the south, and SR 7 on the east. Habitat patches in the northeastern portion of this swath (mostly located within Joint Base Lewis-McChord) are broadly connected by relatively permeable landscapes (Figure 6). The HCAs and the open interspaces between them on JBLM combine into a matrix of oak woodlands, dry upland conifer forest and prairie that forms a unique and regionally significant unbroken tract of habitat for species dependent on prairie-oak ecosystems, including western gray squirrel.

Habitat patches outside JBLM, particularly to the southwest, are smaller and more isolated (Figure 6). Highways, including I-5, SR 507, and SR 510, are important impediments to western gray squirrel movement near JBLM. The model identified two linkages across each of these highways. Though some or all of these linkages may currently not be functional for western gray squirrel, they could be important for other oak prairie-associated species such as Mazama pocket gopher, streaked horn lark, Oregon vesper sparrow, or a host of butterfly species.

The majority of occupied western gray squirrel habitat is restricted to JBLM. The fracture zones dominated by highways and development determine that opportunities to expand occupied habitat is limited. However, the connectivity model shows some areas where permeability could be enhanced to increase the chances for squirrels to move to areas that are currently inaccessible, such as those southeast of SR 507 or southwest of SR 510. These opportunities could occur through conservation efforts (e.g., restoration and acquisitions) in strategic locations. Because western gray squirrel was selected as a focal species representative of these oak-prairie landscapes, such efforts could ultimately assist in conserving and enhancing other important species that use these habitats.

Connectivity Patterns for Mountain Beaver

Key patterns arising from the connectivity analysis for mountain beaver highlight the impact major highways have on habitat connectivity for this species in the Cascades to Coast region. The low and mid-elevations of the western Olympic Peninsula, Willapa Hills, and southern Cascades contain abundant habitat that is generally well-connected. Permeability is constrained along I-5, US 12 west, US 12 east and other highways by urban and suburban development, agricultural land use, roads, and other anthropocentric features, defining the main fracture zones for mountain beaver. The connectivity model does identify linkages across these fracture zones, and these can provide areas of focus for maintaining or restoring connectivity for mountain beaver and other species with similar habitat needs and movement abilities (Figure 7).

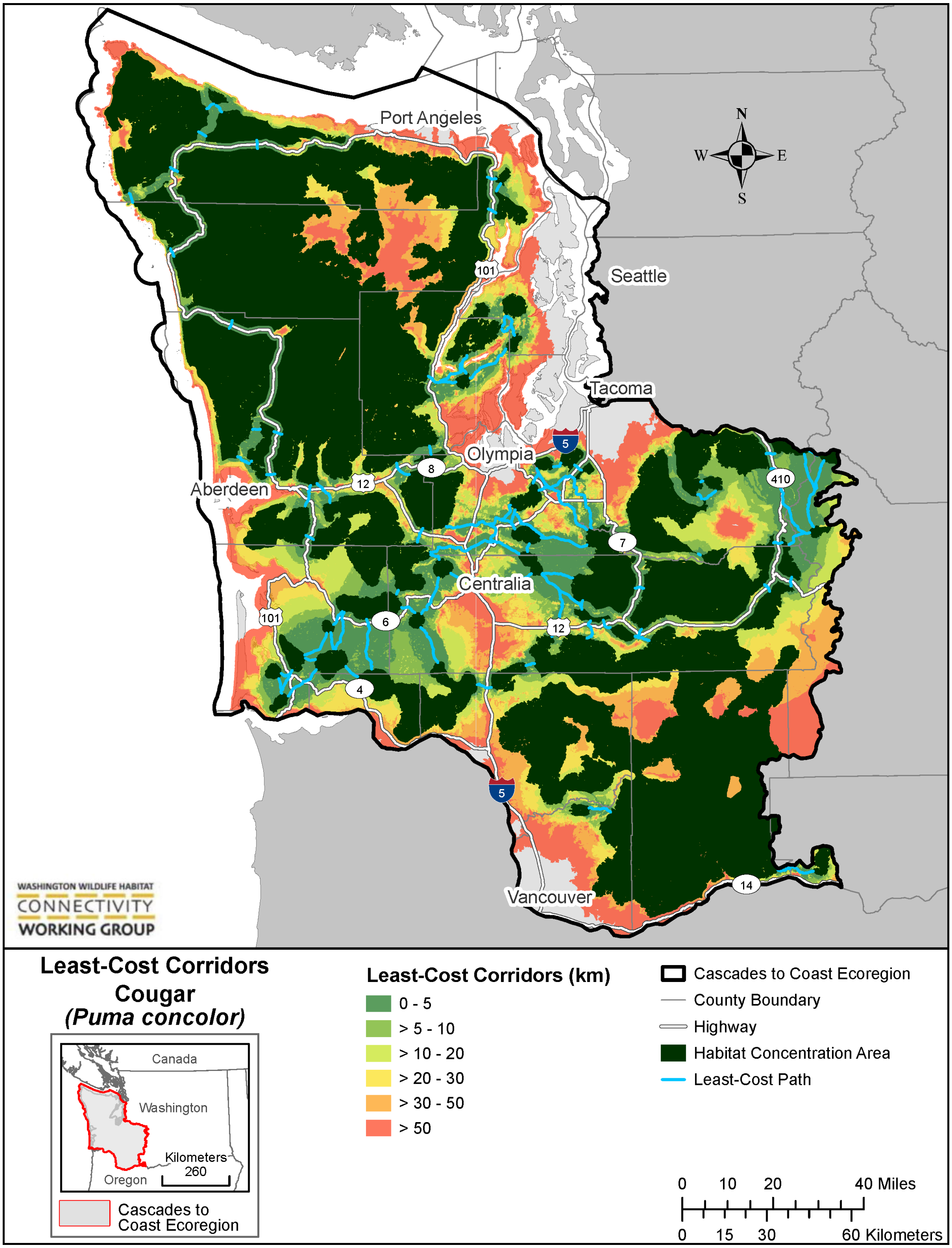

Figure 5. Cougar habitat connectivity model, including Habitat Concentration Areas, least-cost paths and least-cost corridors.

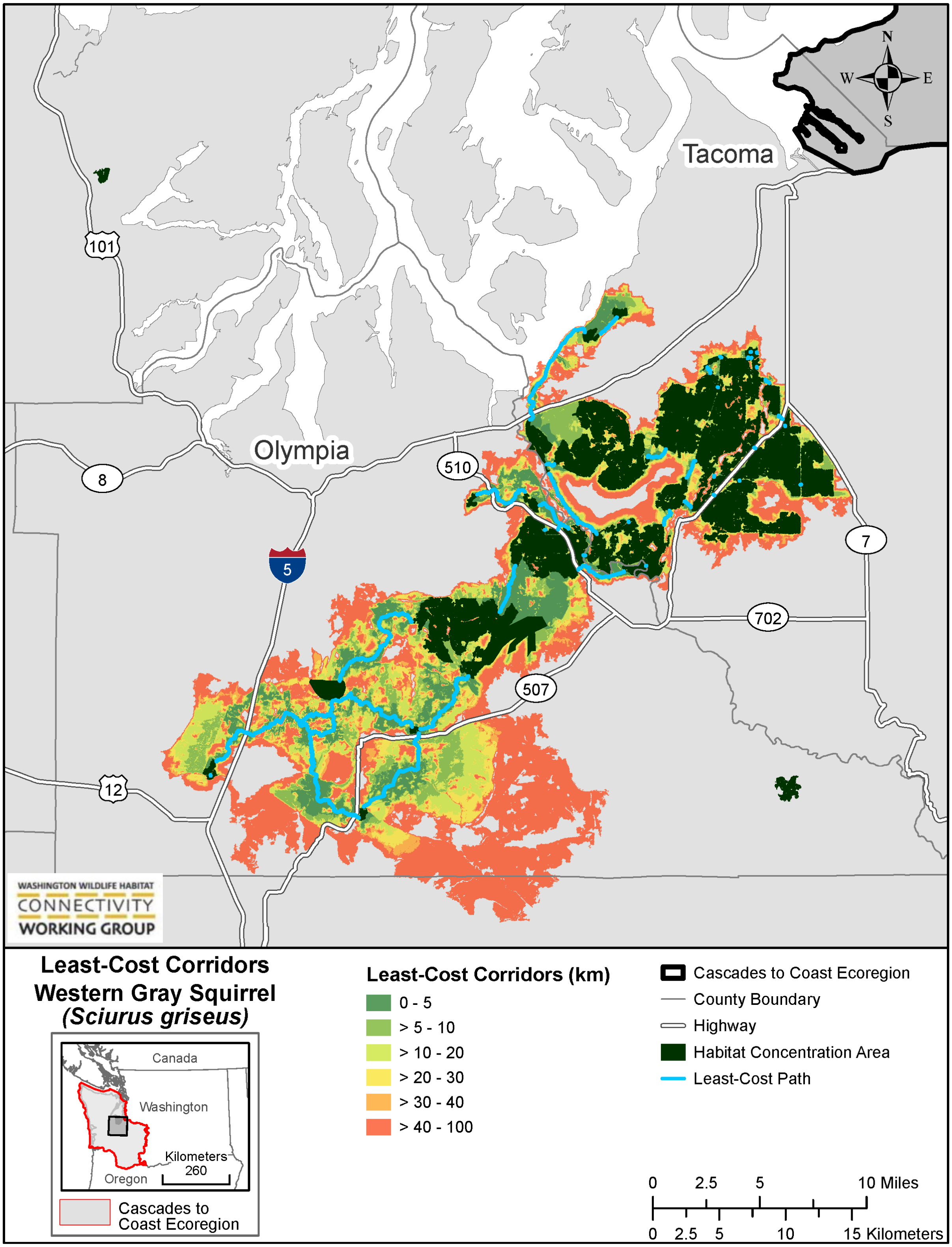

Figure 6. *Western gray squirrel habitat connectivity model, including Habitat Concentration Areas, least-cost paths and least-cost corridors.*

Across US 101 on the Olympic Peninsula, the highest priority linkages are south of the Queets River. These linkages are highly permeable and connect large blocks of habitat on public lands to the east with Quinault Tribal lands to the west (Figure 7). Other high priority linkages cross SR 8 and US 12. South of Aberdeen, high priority linkages across US 101 occur north of Raymond and at the mouth of the Naselle River. Important linkages cross the SR 6 Raymond to Chehalis fracture zone near the Walker and Fork Creeks, the Fern and Patton Creeks, and the Chehalis River (Figure 7). Other linkages cross the SR 4 Willapa to Longview fracture zone, the I-5 Tacoma to Vancouver fracture zone, and the US 12 Napavine to White Pass fracture zone. Most of these linkages, however, are long and have moderate to low permeability, suggesting that they may require restoration efforts to provide functional connectivity for mountain beaver (Figure 7).

In addition, no Habitat Concentration Areas exist in the interior and eastern Olympic Peninsula, and in higher elevations of the Cascades, likely due to elevation and steepness of the mountains (Figure 7).

Connectivity Patterns for Pacific Fisher

Habitat for Pacific fisher is abundant in the mountains of the Olympic Peninsula and the Cascades Range, though Habitat Concentration Areas are mostly irregularly-shaped and sometimes long, narrow and circuitous (Figure 8). Key to a robust network that connects these two mountainous areas are a few relatively small, scattered HCAs in the Willapa Hills, as well as an array of linkages that allow fishers to move from the Cascades, through these scattered HCAs, to the Olympic Mountains and vice versa (Figure 8).

There are two main linkages across I-5 that connect the Cascades to the Willapa Hills, one at Castle Rock and the other near the Cowlitz River. There is also a third linkage further north that connects the Olympic Peninsula to the Cascades through a series of stepping-stones that include Capitol State Forest and forests around Joint Base Lewis-McChord (Figure 8). Due to the relatively shorter lengths of the linkages through JBLM and the Capitol State Forest and the directness of this route between the Cascades and the Olympics, this northern linkage is likely to be particularly important for fishers to cross the I-5 fracture zone. It is worth noting, however, that fishers moving across I-5 will also need to cross SR 8. The fisher connectivity model suggests all movement—whether from JBLM or the Willapa Hills—is likely to be funneled through one main linkage that crosses the US 12-SR 8 fracture zone between Elma and McCleary (Figure 8).

Although not every area currently occupied by fishers is incorporated in Habitat Concentration Areas (HCAs) and not every HCA will remain the same over time, especially where logging activity leads to a shifting mosaic of habitat across the landscape, the overall landscape patterns provided by the fisher connectivity model offer valuable information to biologists, planners, and stakeholders as reintroduction and monitoring of fisher in the Cascades to Coast region continues.

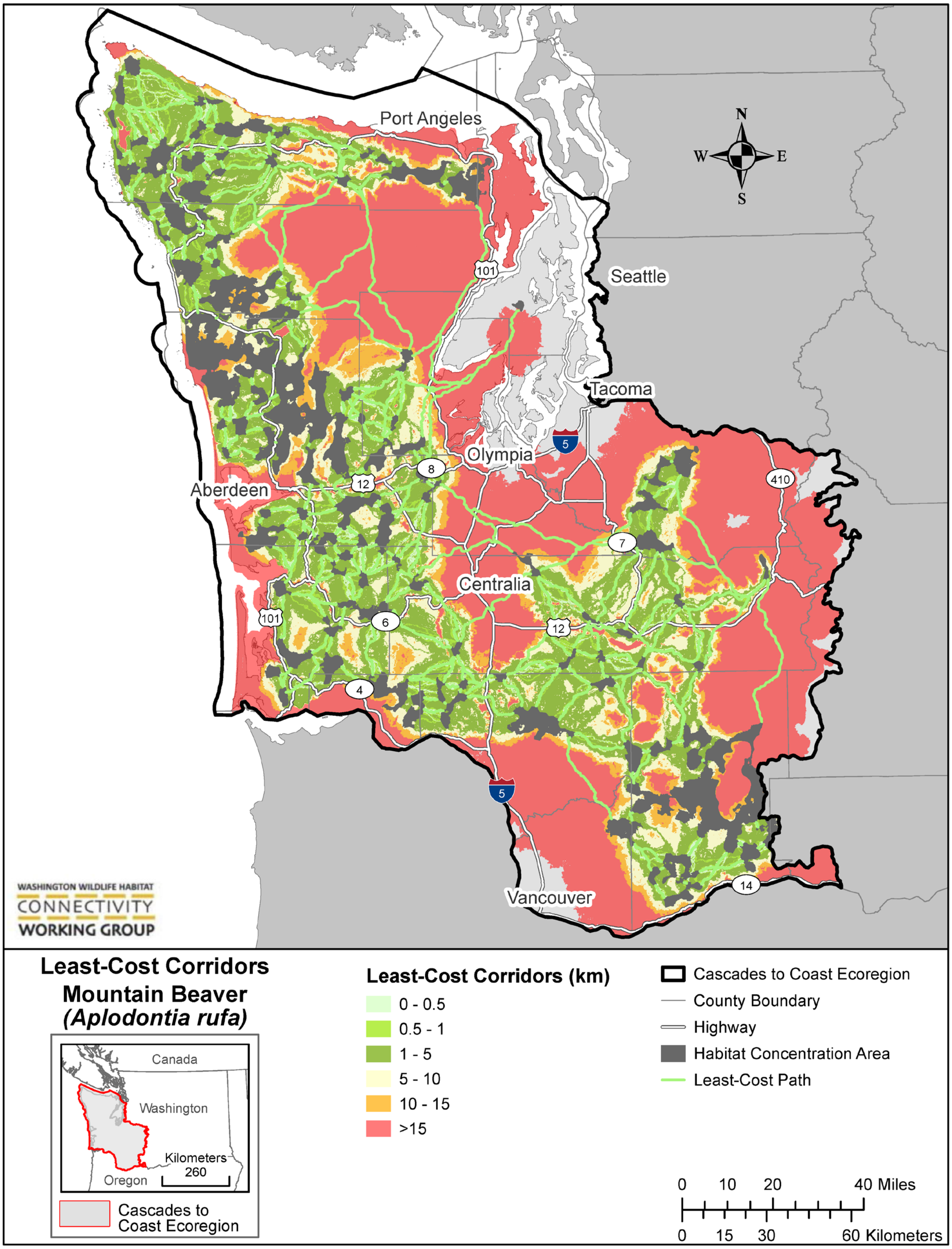

Figure 7. Mountain beaver habitat connectivity model, including Habitat Concentration Areas, least-cost paths and least-cost corridors. The color ramp is slightly different to other maps in this report due to the reduced range of values.

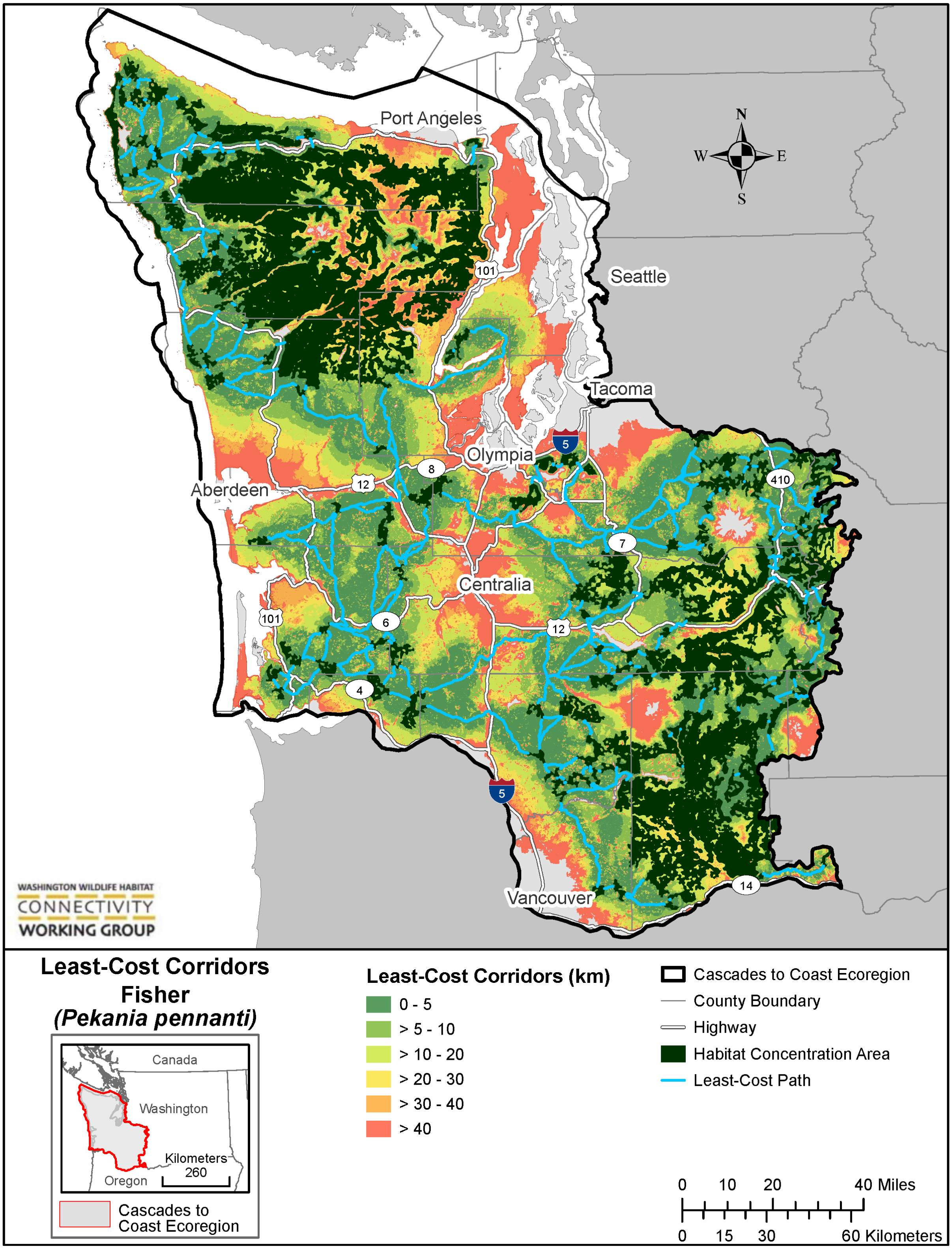

Figure 8. *Pacific fisher habitat connectivity model, including Habitat Concentration Areas, least-cost paths and least-cost corridors. The color ramp is slightly different to other maps in this report due to the reduced range of values.*

Connectivity Patterns for American Beaver

The densest assemblages of Habitat Concentration Areas (HCAs) were found in the Chehalis Basin south of US 12, followed by the southern Olympic foothills, along the Olympic coast, and portions of the Willapa Hills (Figure 9). However, networks of linkages exist throughout coastal and southwest Washington. Heavy development and urban sprawl create high levels of resistance for beavers. In many cases, these occur along linear road features, making these roads and highways some of the most important impediments to beaver movement across the region.

Fracture zones that affect connectivity for beavers include areas along I-5, US 101, US 12, SR 8 and to a lesser extent SR 6 on the west side of I-5, and SR 508 and SR 507 on the east side. However, viaducts and underpasses that maintain water throughout the year may be permeable to American beavers. Therefore, some linkages across these major highways may not be complete barriers to beaver movement, as there are many large waterways that pass under them. Examples include the Nisqually River underpass, Scatter and Prairie Creeks in Thurston County, the Skookumchuck River and Salzer Creek by Centralia, the Toutle, Cowlitz, Coweeman and Lewis Rivers in Lewis County, or the Wynoochee and Satsop Rivers under US 12 (Figure 9).

Due to topography, slope, and development, the south Cascades have many HCAs that are not well connected to the Willapa Hills and Chehalis Basin (Figure 9). Finding functional corridors that move to and from these locations will be key for creating a network of beaver habitat and linkages. In addition, though the beaver habitat connectivity maps show that much of the potential beaver habitat is structurally connected, these patterns may not reflect current beaver population distribution and functional connectivity due to historical and current management patterns. This potentially offers planners, practitioners, and stakeholders a roadmap for conservation, relocation, and conflict mitigation.

Key Landscape Integrity Connectivity Patterns

The connectivity analysis for naturalness in the region carried out by Gallo and colleagues (Gallo et al. 2019) provided insights into the connectivity patterns for landscape integrity across the Cascades to Coast region. The main portion of the landscape that has large core areas (analogous to the species-specific Habitat Concentration Areas) is the Olympic Peninsula, in and around the Olympic National Park (Figure 10). There are also medium sized core areas along the Peninsula's coastal area, as well as all along the western slopes of the Cascades. Between the Cascades and the Olympic Peninsula, there are a number of smaller, scattered core areas, mainly west of the I-5 corridor (Figure 10).

The analysis highlights some noticeable fracture zones separating core areas. These fracture zones are consistent with the fracture zones identified in the connectivity analyses for some of the focal species. The largest and most noticeable fracture zone is a wide swath along the I-5 corridor, characterized by significant development from Olympia to Vancouver. The development on the northern end, around Olympia and across most of the Kitsap Peninsula, with the exception of some habitat areas on the western side, characterizes areas with significant human impact, and therefore lacking in naturalness characteristics. A second significant fracture zone extends along US 12 and SR 8 west of the I-5 corridor, and notably includes the private forested lands north of these two highways, widening the fracture zone as far west as Elma. To the east of the I-5 corridor, US 12 still poses significant resistance to movement, yet the fracture zone is noticeably narrower. A similar, narrow fracture zone can also be seen along US 101 between Aberdeen and Raymond (Figure 10).

The landscape integrity connectivity analysis highlights a multitude of linkages that can provide connections from large to medium to small core areas north and south along the Cascades Range, and from the Olympics south to the Willapa Hills and beyond, on both sides of the I-5 fracture zone (Figure 10). These linkages tend to converge as they cross the US 12 fracture zone, concentrating between Satsop and Aberdeen. On the east side of I-5, however, multiple linkages cross US 12, suggesting greater permeability, which is consistent with the narrower and less noticeable fracture zone (Figure 10).

Four main areas appear to provide opportunities for connectivity between landscape integrity core areas on either side of the I-5 fracture zone (for the restoration priority values for each of these crossings, see Figure 13 in Gallo et al. 2019). The widest and most distributed include multiple linkages across the I-5 fracture zone between Olympia and Centralia, concentrating along Scatter Creek (Figure 10). Moving southward along the fracture zone, there is another area of greater permeability that could provide connectivity opportunities, between Toledo and Castle Rock, north of the Toutle River, followed by another one between Castle Rock and Kelso. The fourth linkage area is narrower, and could potentially connect—if permeable enough—core areas in the southern Cascades to those along the Columbia River via lands along Cedar Creek (Figure 10).

Key Findings – Synthesis Across Focal Species and Landscape Integrity

Key areas permeable to wildlife movement emerge when the linkage networks of all five focal species and landscape integrity are viewed together (Figure 11). Similarly, this composite view of habitat connectivity across the Cascades to Coast region also highlights critical linkages across highways and developed areas, where attention is needed if the few remaining opportunities for maintaining and restoring connectivity are to persist.

Overall, 88 percent of the Cascades to Coast region is part of at least one linkage network, and 77 percent is part of two or more networks. However, nowhere do the six networks all overlap, since the western gray squirrel and mountain beaver occur in different parts of the region, with the squirrel network centered in and around JBLM, and the mountain beaver forming a broad U-shape from the western Olympic Peninsula, sweeping south and then east along the Toutle watershed, and then north along a mid-elevation swath of the Cascades (Figure 11). In addition, the nature of the American beaver linkage network, with such a strong relationship to riparian and aquatic habitats, drives that the main areas where five linkage networks overlap mainly follow that spatial pattern of long, narrow areas along draws, creeks and rivers (Figure 11).

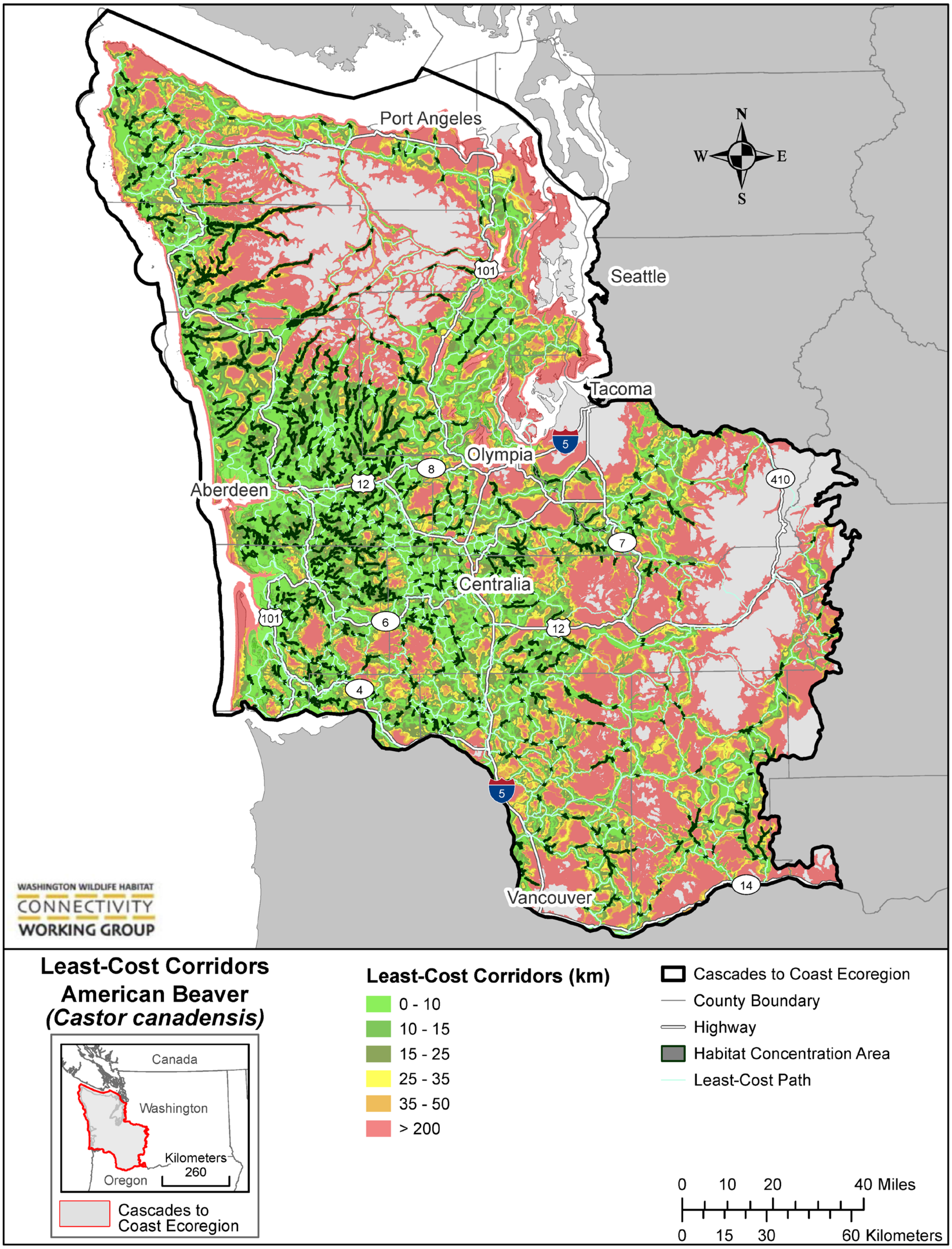

Figure 9. *American beaver habitat connectivity model, including Habitat Concentration Areas, least-cost paths and least-cost corridors.*

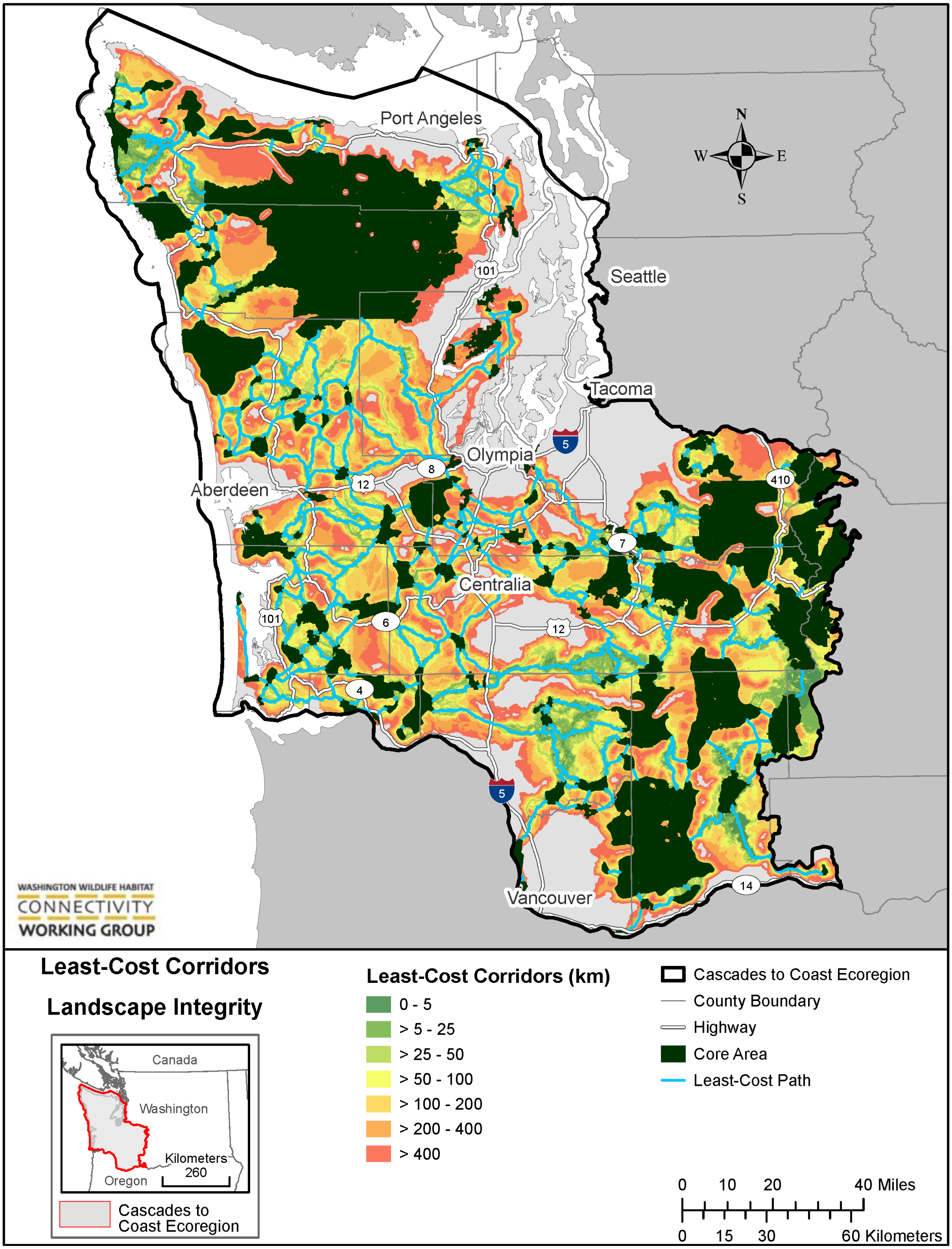

Figure 10. *Landscape integrity connectivity model, including core areas, least-cost paths and least-cost corridors.*

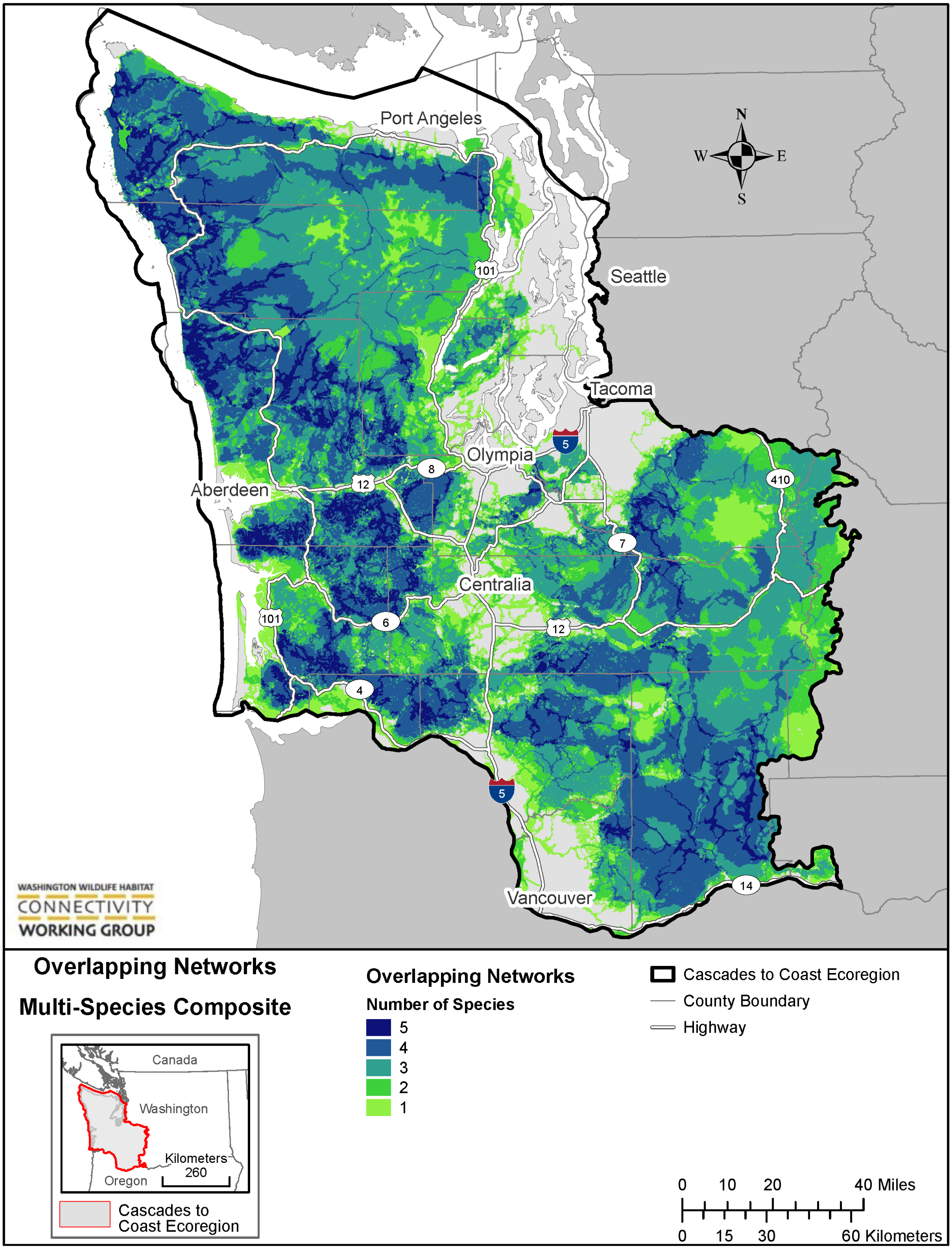

Figure 11. *Composite of the five focal species' and landscape integrity's linkage networks.*

Three main, broad-scale patterns in habitat connectivity arise from the overlap between the linkage networks. The first pattern is the convergence of networks in areas of broad permeability for multiple species and landscape integrity along the western Olympic Peninsula, south to the Willapa Hills, and the mid-elevation portions of the Cascade Range, particularly arching south and west of Mount Saint Helens and Mount Rainier (Figure 11). Areas to the northeast of these peaks exemplify the second broad-scale pattern, where rugged topography and high elevations become natural barriers for some species, a pattern that is also observed in the eastern Olympic Peninsula (Figure 11). The barriers that highways and associated human development pose to most species' movement, as well as to the integrity of the landscape, drive the third distinct pattern across the Cascades to Coast region: there is a broad swath with little to no habitat connectivity along the I-5 corridor and around the cities of Olympia, Puyallup and Tacoma (including around JBLM), and narrower but still significant resistance to wildlife movement across US 12, both east and west of I-5, and SR 8 towards Olympia (Figure 11).

The most significant fracture zone is clearly associated with the urban areas along Puget Sound, merging into a wide swath of developed and converted lands along I-5. However, the connectivity analyses for multiple species and landscape integrity highlight a few areas that still remain as the best opportunities for maintaining connectivity across this fracture zone. The broadest of those linkage zones, which would appear to serve the needs of multiple species, is along the Toutle River, between Kelso and river's crossing under I-5 (Figure 11). This broad zone includes some linkages with the potential to provide connectivity for three or four species, interspersed with areas that would only allow for movement of some of the focal species studied. Further north there are multiple narrow linkages that are mostly part of only one species' network (mostly American beaver, whose linkages follow rivers and creeks flowing under the highway), yet only three additional, relatively narrow areas can be considered linkage zones that could provide for connectivity of multiple species: one between Olympia and Grand Mound along Scatter Creek, and two between Grand Mound and Chehalis (Figure 11).

The nature of the fracture zones along US 12 is somewhat different to that of the I-5 corridor, and also varies between the lands to the east and west of I-5. To the east of I-5, the linkage networks of our focal species and landscape integrity cover most of the landscape, except for particular places in close proximity to the highway. There are multiple linkages across the highway and associated development, and most of them are part of two to three linkage networks, and even four linkage networks just west of Randle (Figure 11). On the west side of I-5, linkages across US 12 and SR 8 are also abundant and fairly wide, but most of them belong to only two (and in many cases just one) linkage networks (Figure 11). The one exception is the linkage around McCleary, where multiple linkage networks overlap as they cross SR 8 between the Capitol State Forest and the southern foothills of the Olympics (Figure 11).

The area around the lower Nisqually River is an area that has unique characteristics that add value to the regional connected landscape, though it may not emerge as a priority for the whole region. Habitat and linkages in the Lower Nisqually are immersed in a matrix of developed lands, and are surrounded and fractured by highways with high traffic volume. However, these lands—part of which are in Joint Base Lewis-McChord—contain the last remaining inhabited Habitat Concentration Areas for western gray squirrel, a focal species representing the habitat and

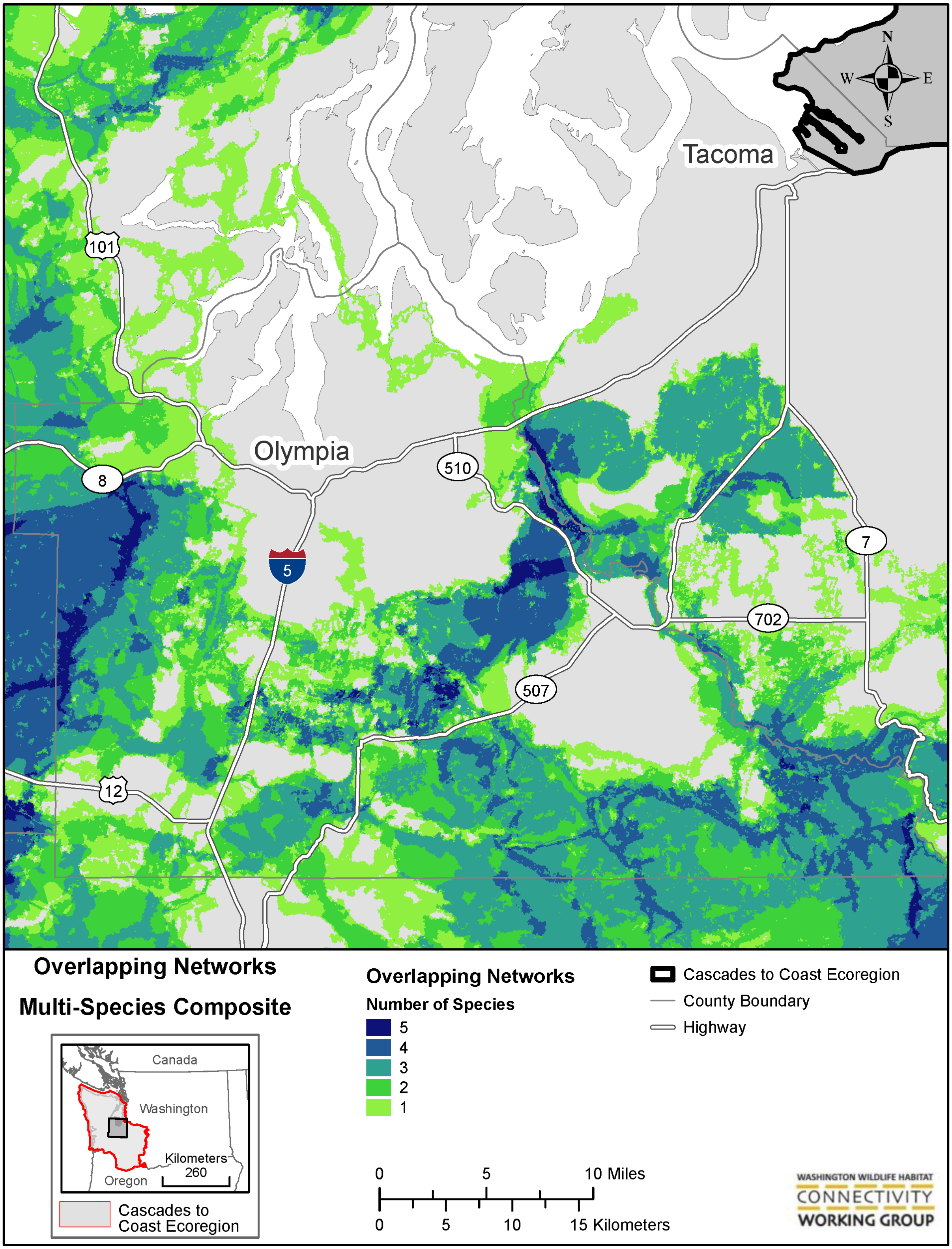

Figure 12. Composite of the five focal species' and landscape integrity's linkage networks in the vicinity of Joint Base Lewis-McChord. The composite is the same as shown in Figure 11, and the inset map shows the relation between the scope of Figure 11 (red boundary) and this Figure (black box).

connectivity needs of species associated with pine-oak woodlands. The western gray squirrel linkage network for the most part overlaps with the networks of at least two other species (cougar and Pacific fisher), and the portion of this network that connects to the linkages around Scatter Creek is actually part of the network for four focal species and landscape integrity (Figure 12). Ensuring that these linkages persist in the future provides an additional redundant path in this north-central portion of the region, which is highly threatened by further development (with the possible exception of JBLM itself).

Opportunities for Maintaining and Restoring Habitat Connectivity

The linkage zones highlighted by combining the linkage networks for landscape integrity and the five focal species (Figure 11) provide a broad overview of where the best remaining opportunities for maintaining connectivity across fracture zones are. Yet this composite map does not provide much detail, and does not distinguish between linkages that are currently functional for multiple species—and therefore need to be conserved—and those that may still have potential to connect habitat patches, but may either only be functional for a few, wide-ranging species, or may require restoration to live up to their connectivity potential.

The connectivity analysis provides additional information that can help prioritize linkages for conservation or for restoration. The team focused on linkages across the main fracture zones associated with major highways (Figure 4 in Chapter 2), and prioritized linkages across them, first for each species individually (as well as for landscape integrity), and then overlaying those priority linkages to identify linkages that are priorities for multiple species and landscape integrity. The level of threat posed by the major highways themselves was also considered. The team used annual average daily traffic (AADT) volume data, and their trends over time, to further inform the identification of priority linkages, in particular distinguishing linkages that can be considered opportunities for maintaining habitat connectivity from those that are likely to require restoration.

The areas where priority linkages for two or more species overlap and that have relatively low traffic volumes (AADT of up to 5,000 vehicles per day) are concentrated along SR 101, US 12 east of I-5, and other highways within the broadly permeable areas along the western Olympic Peninsula, south to the Willapa Hills, and the mid-elevation portions of the Cascade Range, in this case also extending north along SR 410 (yellow areas in Figure 13). The combined characteristics of relatively high permeability for multiple species and relatively low threat, as reflected in the traffic volumes, emphasize the importance of prioritizing efforts to conserve the existing permeability along these linkages, to maintain their connectivity value. Highways with higher AADT are usually located in or near more developed urban or suburban landscapes and have more development pressures than lower AADT highways.

At the opposite end of the spectrum are areas where two or more priority linkages overlap, yet face a high level of threat, as quantified via traffic volumes (volumes greater than 10,000 vehicles per day; red areas in Figure 13). These include six locations across I-5 (including one as it runs east-west just south of Puget Sound), and another three across US 12 west and SR 8. Particularly along I-5, the high traffic volume coincides with greater development along both sides of the highway. Their centrality highlights the key role these linkages play in maintaining connectivity from the

Cascades to the Coast. Yet these linkages are generally long and have low permeability, which makes them urgent opportunities for restoring connectivity across major fracture zones, given continued development pressures.

There are a handful of additional linkage zones important for two or more species that have intermediate traffic volumes (between 5,000 and 10,000 vehicles per day; orange areas in Figure 13). The threat from traffic is not as high, and they vary in terms of the extent of development and permeability to movement of the lands on either side of the highway. These areas are also connectivity priorities. However, additional assessment in the field is likely needed for each of these connectivity priority areas to determine if each specific linkage currently provides functional connectivity across a fracture zone—and therefore should be maintained—or whether additional actions are needed to restore connectivity along that potential linkage as it crosses that fracture zone.

Overall, this analysis highlights that opportunities do exist for maintaining and restoring connectivity for habitat throughout the Cascades to Coast region. However, for some fracture zones, particularly the one associated with the I-5 corridor, those opportunities are few and far between, and most will likely require restoration to be fully functional for a wide range of species. This analysis therefore highlights the urgent need for further attention at these six critical linkage zones across I-5. The need for improving permeability to movement in these key locations is an opportunity for taking advantage of the multiple values of riverine corridors, the value that working forests can provide in maintaining permeability, and the opportunity to build partnerships and explore a wide array of actions that can support animal movement between habitat concentration areas across the Cascades to Coast region (see examples in Section B).

A Vision for a Connected Cascades to Coast Region

The results of the Cascades to Coast connectivity analysis highlighted a series of connected arcs and key linkage zones—broad areas that contain multiple core areas and linkages within them—that together (a) can provide north-south habitat connectivity for a wide array of species both along the west side of the Olympics continuing down to the Willapa Hills in the southwest, and along the mid-elevation of the Cascades; and (b) highlight key opportunities for habitat connectivity between these connected arcs. We have identified four main connected arcs, two connectivity zones that include many, redundant north-south linkages across relatively narrow fracture zones, and three east-west linkage zones—narrower, longer and more discrete zones across more significant fracture zones—that together provide a vision for a connected Cascades to Coast region in Washington (Figure 14).

Connected arcs

The connected arcs that form part of our vision for a connected Cascades to Coast region are broad and long swaths of lands where the linkage networks of multiple species and landscape integrity overlap, highlighting the overall permeability of the current landscape, the habitat connectivity these lands currently provide, and their potential for maintaining connectivity in the future. The four connected arcs (dashed white arrows in Figure 14) are:

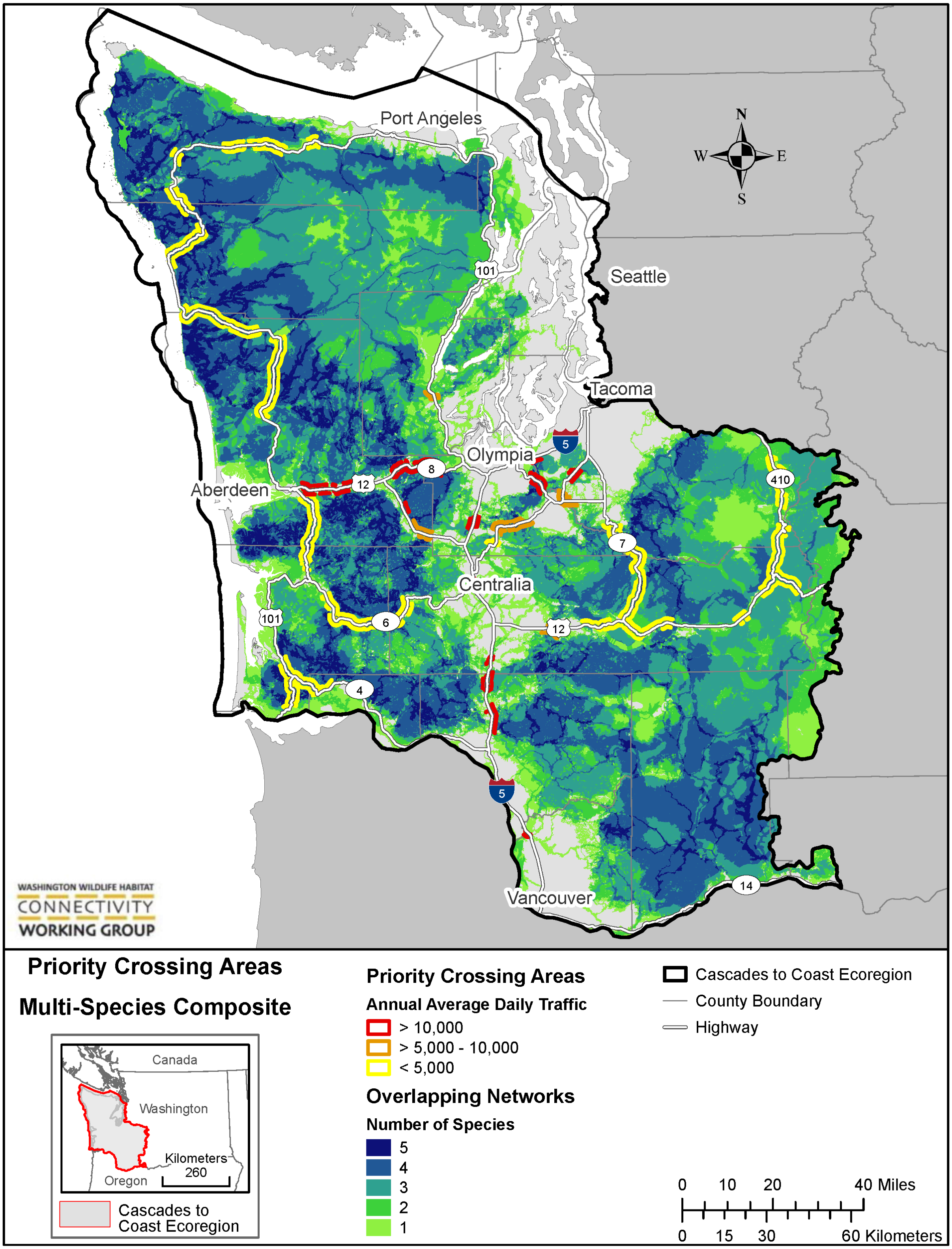

Figure 13. *Priority crossing areas across major fracture zones in the Cascades to Coast region. Crossing areas highlighted in red, orange and yellow reflect areas where there are overlaps between priority linkages for two or more linkage networks, and the colors reflect the threat posed by varying traffic volumes.*

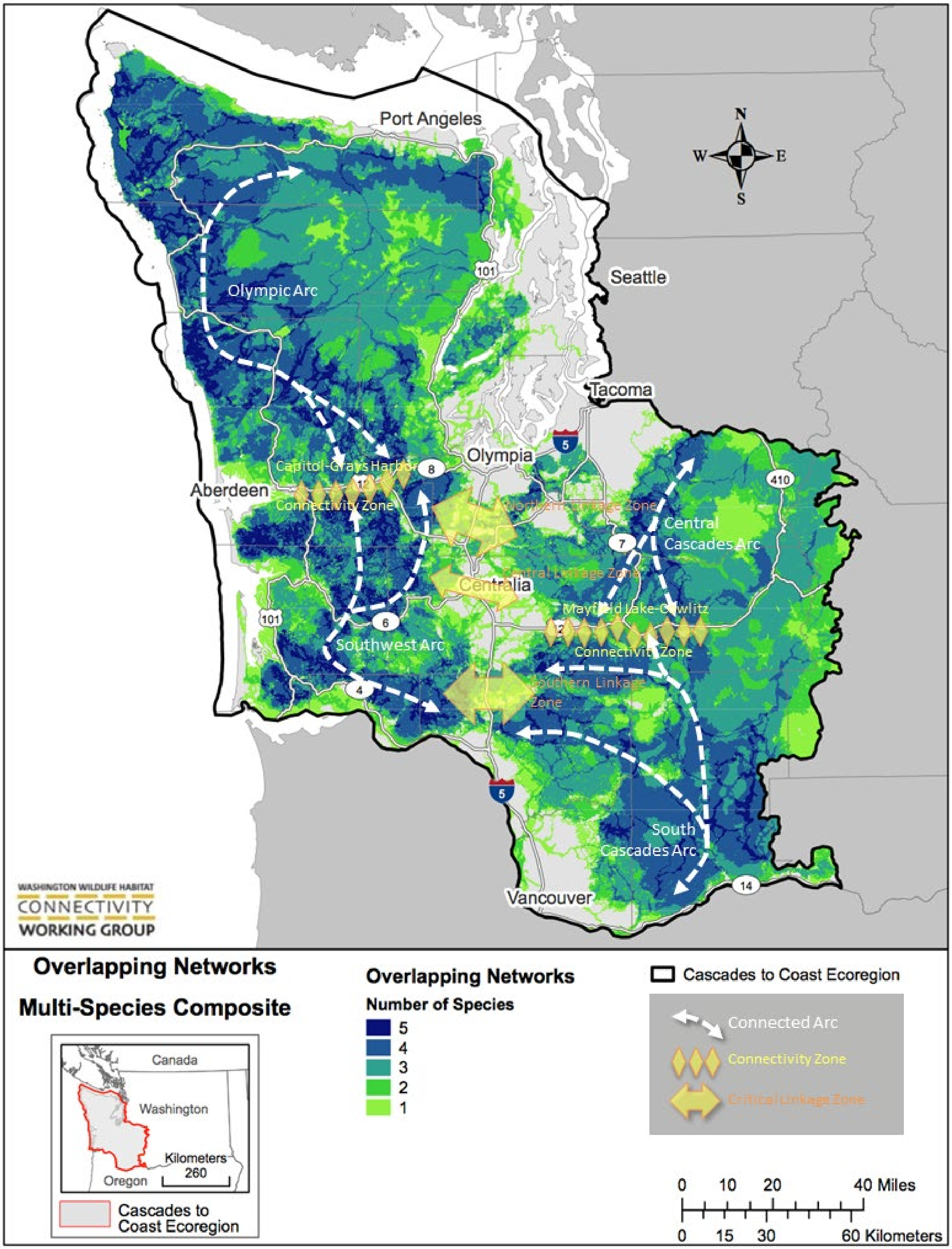

__Figure 14.__ A vision for a connected Cascades to Coast region.

The Olympic Arc: This arc curves at mid-elevations along the western slopes of the Olympic Mountains through a combination of public (National Park, National Forest and Washington Department of Natural Resources), Tribal (Quinault Indian Reservation) and private lands. The arc then continues east and south through a broad swath of mostly private working forestlands from the southern foothills of the Olympics towards US 12 west and SR 8 (Figure 14).

The Southwest Arc: From south to north, this arc roughly follows a string of large yet separate Washington Department of Natural Resources parcels from the Cowlitz-Wahkiahum County line, northwest towards the Willapa Hills, where it curves northeast all the way to the Capitol State Forest. In addition to this main arc, the private forestlands in northern Pacific County and southern Grays Harbor County contribute another branch to this arc, providing habitat connections for multiple species up to US 12 west (Figure 14).

The South Cascades Arc: Similar to the Southwest Arc, the South Cascades Arc also follows large parcels of public lands (Washington Department of Natural Resources and National Forest) as it heads east from I-5 in two main swaths, following the North Fork of the Toutle River and the Lewis River, respectively. Once in the mid-elevation area of the Cascade Range it arcs south, and extends all the way to the Columbia River throughout Skamania County (Figure 14).

The Central Cascades Arc: As described earlier, the linkage networks for multiple species overlap at mid-elevations on the slope of Cascades, circling to the west of Mount Rainier National Park, including a mix of state, federal and private working forestlands mostly to the west of the large block of Gifford-Pinchot National Forest lands (Figure 14).

Key connectivity and linkage zones

The key areas that cross important fracture zones in the region, connecting the four connected arcs, can be grouped in two types, with very distinct characteristics. One type, which we call *connectivity zones*, are characterized by many short, redundant linkages spread out along the majority of the fracture zone, and occur where the fracture zone is relatively narrow, with high permeability lands on both sides. These connectivity zones bridge across major portions of US 12 west (including part of SR 8) and US 12 east (string of yellow diamonds in Figure 14). *Linkage zones*, on the other hand, are also areas that cross major fracture zones, but are characterized by a few, long and mostly narrow linkages, which may require enhancement to provide functional connectivity for many species. There are three main linkage zones, all of them bridging across the much wider and less permeable I-5 fracture zone (yellow double-headed arrows in Figure 14).

Connectivity Zones

The Capitol-Grays Harbor Connectivity Zone: US 12 west and SR 8 are the central linear feature of the fracture zone between the southern ends of the Olympic Arc and the northern ends of the Southwest Arc (Figure 15A). Between Capitol State Forest and Grays Harbor, much of the land in close proximity to the highway on either side is permeable to movement, and there are at least six locations where linkages cross the fracture zone, most of them being part of multiple linkage networks.

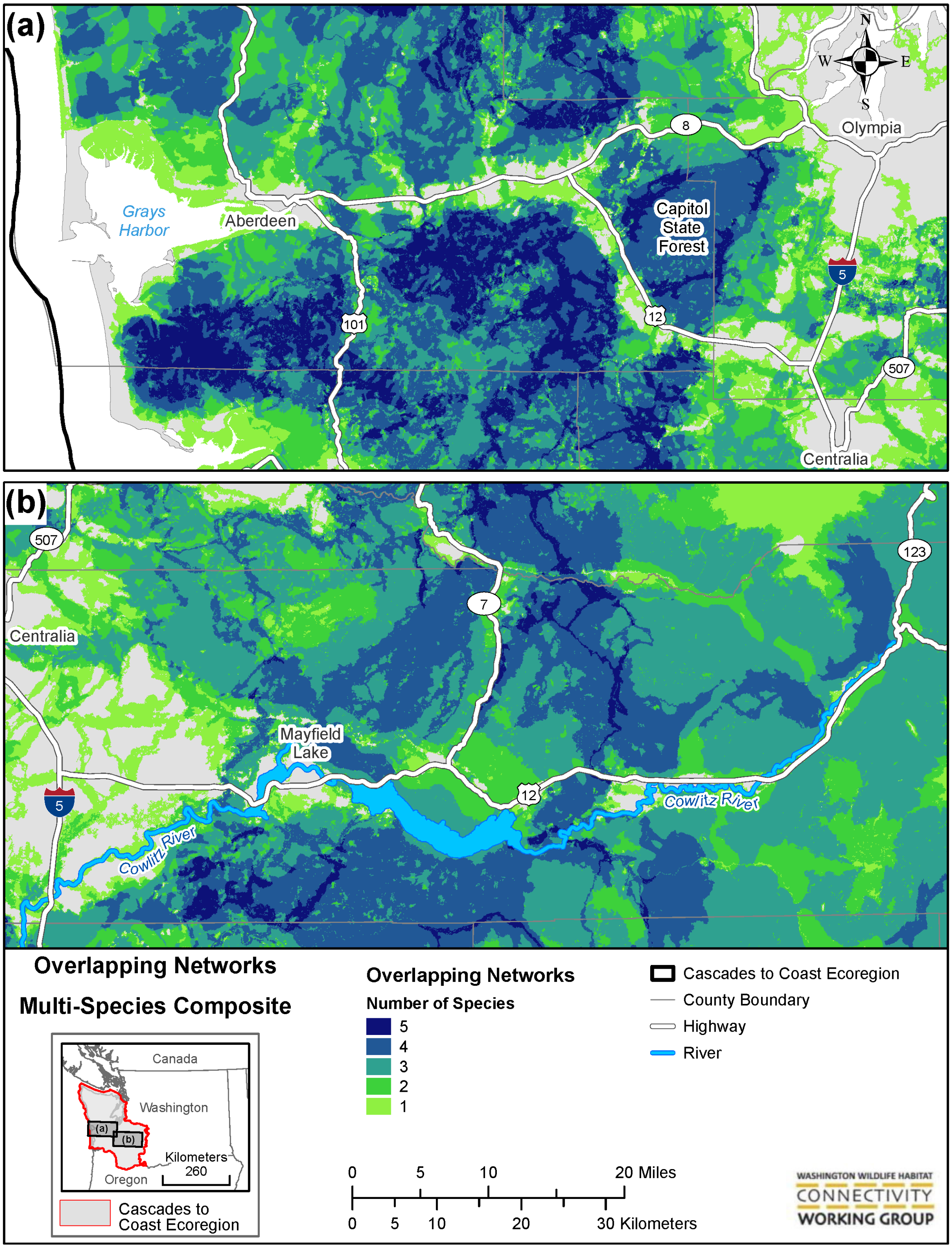

Figure 15. *The two main connectivity zones in the Cascades to Coast region.* ***(a)*** *Composite of the five focal species' and landscape integrity's linkage networks in the Capitol-Grays Harbor Connectivity Zone.* ***(b)*** *Composite of the five focal species' and landscape integrity's linkage networks in the Mayfield Lake-Cowlitz Connectivity Zone. The composite is the same as shown in Figure 11, and the inset map shows the relation between the scope of Figure 11 (red boundary) and this Figure (black boxes).*

Mayfield Lake-Cowlitz Connectivity Zone: Similar to the Capitol-Grays Harbor Connectivity Zone, a long stretch of US 12 east, especially east of Mayfield Lake, has important connectivity lands in close proximity on either side of the highway, and broad areas where the linkage networks of multiple species cross US 12 (Figure 15B). The importance of this area for providing redundant linkages across the US 12 east fracture zone, and therefore connecting the Central and South Cascades Arcs, highlights the need for maintaining connectivity in this zone.

Linkage zones across the I-5 corridor

Northern Linkage Zone: Scatter and Beaver Creeks. This linkage zone includes multiple places across the I-5 fracture zone south of Olympia, and including locations south of Grand Mound (Figure 16A). Linkages across the fracture zone are fairly distinct, occurring within a matrix of developed lands on either side of the highway. Though the linkages in this zone are fairly long and narrow, they are to some extent braided and interconnected, and appear to provide connectivity for multiple species. In addition, the northern portion of this linkage zone becomes a fairly robust connection to the unique area around the Lower Nisqually River described earlier.

Central Linkage Zone: Newaukum River and Salzer Creek. This linkage zone across the I-5 fracture zone is likely the most tenuous of the three linkage zones. The linkages that cross I-5 and the associated development between Salzer Creek to the north and the Newaukum River to the south are mostly long and very narrow, and most are not part of more than two or three species' linkage networks (Figure 16B). However, given the length of the I-5 corridor and the limited opportunities for maintaining and restoring connectivity from the Cascades to the Coast, this linkage zone becomes an opportunity that deserves some serious attention and investment, providing some redundancy should fire or other disturbances temporarily or permanently impact the Northern or Southern Linkage Zones. This redundancy enhances its natural value as a place where additional connectivity across this central portion of the I-5 fracture zone is possible. However, investments in improving this linkage zone for wildlife movement are likely needed to fully maintain functional connectivity.

Southern Linkage Zone: Toutle and Cowlitz Rivers. This linkage zone across the I-5 fracture zone appears to be the most robust of the three, where shorter, wider linkages overlap across multiple species and bridge across a relatively wide portion of the fracture zone, connecting to both branches of the South Cascades Arc (Figure 16C). This is a key linkage zone that, if maintained and enhanced, transforms the connectedness of the landscape from two mainly north-south swaths of connected lands to a broad U-shape that also provides connectivity across the I-5 corridor, connecting the Cascades to the Coast.

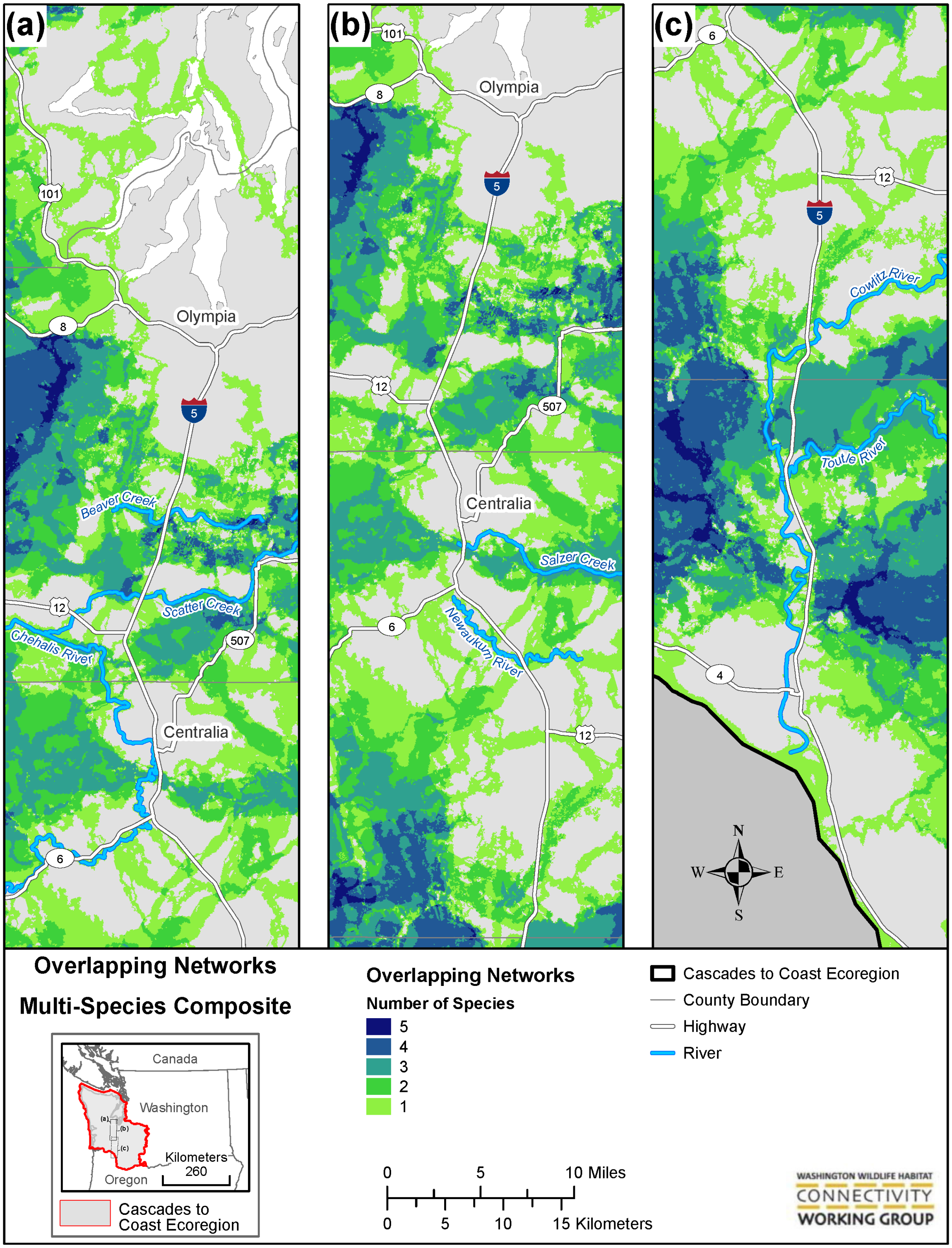

Figure 16. *The three main linkages zones across the I-5 corridor in the Cascades to Coast region.* ***(a)*** *Composite of the five focal species' and landscape integrity's linkage networks in the Northern Linkage Zone.* ***(b)*** *Composite of the five focal species' and landscape integrity's linkage networks in the Central Linkage Zone.* ***(c)*** *Composite of the five focal species' and landscape integrity's linkage networks in the Southern Linkage Zone. The composite is the same as shown in Figure 11, and the inset map shows the relation between the scope of Figure 11 (red boundary) and this Figure (black boxes).*

Chapter 4. Future Work and Conclusions

Future Work

The *Cascades to Coast Analysis*, like the WHCWG's previous analyses (WHCWG 2010, 2012, TCG 2016) provide a foundational assessment of connectivity in the region that can provide a springboard for future work. Three types of work have and will continue to be informed by these connectivity models: (a) efforts to validate the models using observational field data, (b) analyses that help connect the results of this connectivity analysis with additional specific questions particular decision-makers might have, and (c) efforts to maintain and enhance connectivity across the Cascades to Coast region. We describe one example of each of these types of work.

Linkage model validation

Panthera plans to collaborate with a graduate student at the University of Montana to integrate data on cougar movements collected using GPS collars on cougars into a connectivity model. A comparison of the findings of our cougar model and the new one using GPS data will inform the validity of our expert- and literature-driven modeling decisions, helping us understand how cougars respond to different landscape features as they move. This comparison can also provide insights into the extent to which the invasiveness and cost of capturing and collaring cougars is required for providing useful information on key areas to maintain and restore connectivity for this species.

Future modeling analyses

A current college student recently used the American beaver connectivity model, in combination with other existing datasets (U.S. Geological Survey's hydrography and protected areas data, Washington Department of Natural Resources' hydrography data, WSDOT's city points data, and others) to locate key headwaters where climate refugia might overlap with habitat core areas and linkages identified in the *Cascades to Coast Analysis*. This analysis complements the results provided in this report, and can help nonprofits and others integrate climate change considerations as they prioritize watersheds for restoration and conservation action.

Implementation

The Washington Department of Fish and Wildlife is exploring ways to make connectivity information easily accessible and useable for county planners to integrate into their land use planning processes. Recent efforts focus on products of the *Connectivity Analysis of the Columbia Plateau Ecoregion* (WHCWG 2012). However, due to the similarity in approaches used and WDFW's statewide mandate, that effort would set the stage for similarly integrating the *Cascades to Coast Analysis* into their Priority Habitat and Species database (see Case Study 3 in Section C).

Conclusions

Our knowledge continues to advance regarding what makes a landscape functionally connected for all species of interest, and how to apply this knowledge to maintaining and improving habitat landscapes. This *Cascades to Coast Analysis* first and foremost achieved its goal to use science-based methods to identify connected habitat networks that highlight the most important areas for conserving and restoring conditions that promote desirable wildlife movements for the broadest possible range of native species across this landscape. In addition, this analysis, and the resulting insights obtained from the synthesis of the information captured in the individual linkage networks, both highlights the complexity involved in understanding habitat connectivity, and portrays the range of opportunities for maintaining and enhancing connectivity from the Cascades to the Coast in southwestern Washington State.

The vision for a connected Cascades to Coast region (Figure 14) emphasizes large swaths of the region where conditions are conducive to wildlife movement, such as the mid-elevation connected arcs along the western slopes of the Olympic and Cascade Mountains, as well as in the southwestern portion of this region. These are areas that may not provide contiguous core habitat for wildlife species, but that are permeable to their movement, and a focus on maintaining connectivity will be instrumental to their continued permeability in the future, in light of development pressures in the region, and the enhanced need for wildlife to move in response to changing habitat conditions and a changing climate.

This analysis has also highlighted where there are opportunities for enhancing or restoring connectivity and, in particular, made some key distinctions between linkage zones across the I-5 highway and developed corridor, and broader connectivity zones across US 12. The linkage zones across I-5 emphasize a small number of distinct corridors with potential to provide connectivity for a wide array of species, given that they are confined by mostly impermeable lands on either side. On the other hand, the connectivity zones across US 12 emphasize broad areas where opportunities exist for enhancing permeability across long segments of this highway in benefit of multiple species. If permeability on both sides of the highway is maintained along the whole length of these connectivity zones, and if multiple, redundant wildlife crossing opportunities are maintained or developed across the highway itself, these areas offer opportunities not only for enhancing connectivity across fracture zones, but also opportunities for enhancing connectivity in ways that are robust and resilient to continued change in conditions across the landscape, whether due to forest management practices or longer-term changes driven by climate change. The convergence in importance of these connectivity zones for multiple species with different habitat and movement needs, combined with the redundancy provided by efforts to enhance connectivity across long highway segments, helps address the uncertainties inherent in modeling efforts such as this one, where data inputs are never perfect, and the potential for change in the future is not always predictable.

The *Cascades to Coast Analysis* is part of a multi-scale connectivity framework posed by the Washington Habitat Connectivity Working Group when they carried out the *Statewide Connectivity Analysis* (WHCWG 2010). This framework posed three important scales at which to view connectivity needs, which could inform different actions to maintain and enhance connectivity across Washington State. The statewide analysis of the *Washington Connected*

Landscapes Project represented “a vital, collaborative effort to describe current connectivity conditions, identify crucial wildlife habitats and habitat linkages, and set the stage for finer-scale analyses” (WHCWG 2010). As was concluded in the *Connectivity Analysis of the Columbia Plateau Ecoregion* (WHCWG 2012), the first ecoregional-scale analysis, we expect this *Cascades to Coast Analysis* to also “support the development and implementation of innovative strategies and efficient and effective efforts to help fulfill the vision” of a connected Cascades to Coast region.

In addition to the overarching vision described above, the *Cascades to Coast Analysis* also provides insights into a unique area within the region, the lower Nisqually-Deschutes landscape around Joint Base Lewis-McChord. Given the characteristics of development, land ownership and management objectives in this particular part of the landscape, it will be critical to combine the results and interpretation of these ecoregional-scale analyses with field assessments of these areas to inform actions to enhance connectivity for wildlife. These ecoregional-scale results, meanwhile, provide important insights related to the contributions that this area makes to the overall opportunities for connections from the Cascades—particularly the central Cascades—through the Capitol State Forest and northwest to the Olympic Arc around the Olympic Mountains.

The goal of the *Cascades to Coast Analysis* was to identify the most important areas for maintaining and enhancing wildlife habitat connectivity across the region. This work provides foundational understanding of where these opportunities occur across the landscape, as well as key characteristics and conditions that can guide practitioners in how to go about maintaining and enhancing connectivity in support of robust and resilient populations of wildlife that can persist and adapt to future changes to come across the Cascades to Coast region.

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Washington Connected Landscapes Project: Cascades to Coast Analysis

SECTION B

Case Studies: Using the Connectivity Models

Case Study 1 – Avoiding Collisions and Facilitating Movement

Major highways and the associated developed corridors that accompany them are major impediments for wildlife movement, even for large, highly mobile species like the cougar, which can be considered an umbrella species representing the connectivity needs of other, high-mobility species. But how can a connectivity model help facilitate cougar movements? And are there additional benefits to our communities in doing so?

The Washington Department of Transportation (WSDOT) is interested in keeping drivers safe by helping avoid vehicle-wildlife collisions, and is interested in reducing and mitigating the impact highways have on wildlife movement and mortality. These interests align with the efforts of the Olympic Cougar Project (OCP), which is looking to ensure cougars can move across the Cascades to Coast region, to take advantage of all existing habitat, and facilitate genetic transfer. The Olympic Cougar Project is a collaborative effort co-led by the Lower Elwha Klallam Tribe and Panthera, an international non-governmental organization focused on conservation of large wildcats, and includes several other tribal members, including the Skokomish Indian Tribe, Makah Tribe, Port Gamble S'Klallam Tribe, Jamestown S'Klallam Tribe, and the Quinault Indian Nation. The results of the cougar habitat connectivity model became the basis for an extensive effort to determine where cougars are crossing highways—particularly Interstate 5—in the Cascades to Coast region.

OCP has invested in wildlife monitoring cameras, which were strategically deployed at places that local knowledge and best available science—including the *Cascades to Coast Connectivity Analysis*—suggest had high likelihood of being crossing points for cougars. Between when cameras were deployed, starting in August 2021, and now (July 2022), cougars have been captured on camera close to at least six potential crossings. Sometimes the same cougar was caught on multiple cameras, or the sightings were paired with GPS collar locations, allowing those studying the images to conclude where and how the cougars crossed the highways, and even (in some cases) how long they were on the other side before coming back.

OCP and WSDOT are gathering an array of data that helps identify the best locations for investments of crossing structures or other strategies to facilitate cougar movement across highways while avoiding vehicle-wildlife collisions. The *Cascades to Coast Connectivity Analysis*, particularly the cougar model, was a foundational piece of information that helped these partners target feasible locations, narrowing the scope of places they monitor to obtain the information they need to make serious, long-term investment decisions. And in the process, they are also learning about many other critters—black bear, bobcat, black-tailed deer, spotted skunks, striped skunks, coyotes, otters, flying squirrels, mink, saw whet owls, beavers, snowshoe hares, raccoons, porcupines—that use these same linkages to move around. This information, in turn, helps ensure that future WSDOT investments in crossing structures facilitate movement of a wide array of wildlife species in the Cascades to Coast region.

Case Study 2 – Wildlife Movement across Private Lands

The Cascades to Coast region has some areas that are highly developed, and the population in these counties continues to grow. However, even across the major fracture zones along I-5 and US 12 there are managed forests, agricultural lands and native habitats that provide opportunities for wildlife movement across these fracture zones. Yet these lands are under significant pressure from the continued development being experienced in these counties. So how can individual landowners who value their lands' open space, productive capacity and purpose maintain these values, in the face of this developmental pressure? Here are two examples of the opportunities that are available for private landowners when their lands are part of an important connectivity or linkage zone.

Northern Linkage Zone Example. The non-profit organization Conservation Northwest (CNW) has partnered with an interested landowner with over 100 acres in a modeled linkage zone across I-5 to monitor wildlife movement across this property. Through this monitoring they found the farm to be a major destination point for a diverse suite of species, including black bear, black-tailed deer, elk, bobcat, cougar, coyote, raccoon, rabbit, and numerous bird species. WSDOT similarly has invested in camera monitoring in the area, documenting cougar (west of the highway), bobcat (east of the highway), and many other common species on both sides of the highway. The abundance and diversity of wildlife documents around this linkage zone was greater than at many remote locations monitored by CNW's Community Wildlife Monitoring Program. Based on these data, CNW is advocating for the creation of a wildlife crossing over or under I-5 in this area.

In parallel, the landowner is working with the Natural Resource Conservation Service to explore opportunities for obtaining funding and implementing conservation programs on their land, such as replacing fencing with strategically placed, movement-friendly hedgerows; developing a connectivity-friendly forestry plan; and designing agricultural fields to work in conjunction with the natural corridors they intersect, increasing the opportunities to both use land for agriculture while also allowing species to move through the landscape.

Capitol-Grays Harbor Connectivity Zone Example. Another landowner has land close to where the Satsop River flows under US 12, creating an underpass for a variety of wildlife. The Satsop crossing is modeled as an important linkage for American beaver; however, it is outside other species' linkages. In collaboration with CNW, significant investments have been made in restoring the riparian vegetation along this crossing, potentially re-connecting permeable terrestrial lands on both sides of the highway, thereby broadening the linkage and increasing opportunity for a wider suite of wildlife to move freely. The fact that this area was identified as a priority for enhancing connectivity across the US 12 fracture zone supported their efforts to obtain funding for weed control and riparian vegetation restoration projects the landowner was interested in implementing. Funding was obtained through generous grants from the Leah Foundation and Tulalip Cares, and the restoration efforts were possible thanks to hundreds of volunteer hours and donations from Conservation Northwest members.

These examples highlight how landowners interested in maintaining their lands under their traditional and valued land uses in the face of continued development pressure can leverage or get recognition for their lands' connectivity value. This recognition can help them access existing, voluntary programs and funding that allows them to achieve their own goals in a complex context.

Case Study 3 – Land Use Planning that Minimizes Impacts on Wildlife

In Washington State, the Growth Management Act (GMA; RCW 36.70A) planning policy (WAC 365-190-130) specifically states that counties and cities should create systems of "fish and wildlife habitat with connections between larger habitat blocks and open spaces." The GMA also explicitly requires the adoption of land use plans and regulations that maintain populations of fish and wildlife and avoid the creation of isolated subpopulations. There are many opportunities to use data from the Cascades to Coast connectivity analysis to help counties and cities create and implement policies to help protect and maintain connected landscapes.

Since the inception of GMA, the Washington Department of Fish and Wildlife (WDFW) has helped counties and cities identify, designate, and protect important fish and wildlife habitat in their GMA plans and regulations. This assistance is typically provided by WDFW through its Priority Habitat and Species Program (PHS). Local governments regularly use PHS in their GMA planning and the state Supreme Court has affirmed that PHS is a source of "best available science," as required by the GMA (RCW 36.70A.172).

These PHS resources include a list of species and habitats that jurisdictions should use to identify what to protect in their local development regulations. The PHS program also provides maps of known and expected locations of priority species and habitats. These maps are typically used by local jurisdictions to flag and designate areas for protection. PHS also provides written guidance that cities and counties should use to help protect and conserve critical fish and wildlife habitat conservation areas. Regional Habitat Biologists with WDFW are available to assist local governments in applying PHS guidance to a specific project or when they are updating their GMA regulations.

One of the priority habitat types in PHS is a "Biodiversity Area and Corridor." This habitat type is designed to identify places that are either high in biodiversity or important as ecological connections between large contiguous blocks of wildlife habitat. Currently, WDFW is exploring how to effectively use spatial data from connectivity models such as those developed in the *Analysis of the Columbia Plateau Ecoregion* (WHCWG 2012) and this *Cascades to Coast Analysis* in their widely used PHS online spatial tool called PHS on the Web. Getting this type of information in PHS on the Web puts it directly into the hands of local planners and decision-makers and encourages them to use it to guide local plans, regulations, and land use decisions.

Cities and counties across Washington are scheduled to update their GMA plans and regulations between 2024 and 2027 (see https://www.commerce.wa.gov/serving-communities/growth-management/periodic-update/). WDFW wants to help counties and cities update their plans and regulations in ways that help maintain critical linkages for wildlife habitat connectivity. To do this, WDFW is looking for ways to use data from the *Washington Connected Landscapes Project*, including the *Cascades to Coast Analysis,* to improve the spatial connectivity data in PHS on the Web. WDFW also plans on developing a PHS guidance publication to help local jurisdictions maintain wildlife habitat connectivity through GMA planning.

Case Study 4 – Facilitating Landscape-Level Collaborations to Enhance Connectivity Conservation in Southwestern Washington

Over the course of the last year, representatives from numerous agencies and organizations—Conservation Northwest, Washington State Department of Fish and Wildlife, U.S. Fish and Wildlife Service, the Cascades to Coast Landscape Collaborative, Defenders of Wildlife, the Wildlands Network, Lewis County Conservation District and the National Wildlife Federation—have been meeting to discuss potential challenges and tangible opportunities for on-the-ground work to conserve connectivity in southwestern Washington State. Through these discussions, this coalition has determined that a regional, bi-annual summit could help these diverse entities collectively leverage their work in the region, while also identifying where stakeholders and interested parties can come together to address and advance connectivity conservation in the region.

This coalition has found that an opportunity for shared goals exists around landscape-scale connectivity conservation, where different interests, including land management and use, conservation, infrastructure, adaptation to climate change and ecological resilience coalesce. By bringing people together to discuss maps and models (such as those from the *Cascades to Coast Analysis)*, engage with research around connectivity, and listen and discuss connectivity conservation opportunities, the coalition hopes to catalyze a series of collaborations and partnerships that will coordinate collective actions that advance the community and ecological needs at the local, state and federal level. As development in southwestern Washington continues and as climate change impacts increase, the need for resilient landscapes is more important and urgent than ever. A foundational block of landscape resilience is habitat connectivity, which allows wildlife and other species to move in response to changing climate conditions.

The first regional, bi-annual connectivity summit is scheduled for July 20-22, 2022. It will focus on "connected landscapes and grassroots solutions." The event will foster efforts to identify where different stakeholders' values align and where they can come together to meet the challenges posed by "climate change, development, landscape fragmentation, economic pressures, and shifting public values." By connecting the people, projects, and policies that can facilitate a landscape-level connected blueprint for a functional landscape, this inaugural summit will kick off conversations and collaborations that can "ensure a resilient landscape for our future, one that benefits species, systems, economies, and our communities."

Washington Connected
Landscapes Project:
Cascades to Coast Analysis

SECTION C

Focal Species' Accounts

(TO BE ADDED SOON)