Providing a Regional Connectivity Perspective to Local Connectivity Conservation Decisions in the British Columbia–Washington Transboundary Region:

Okanagan-Kettle Subregion Connectivity Assessment

Transboundary Connectivity Group

March 2016

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Transboundary Connectivity Group

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Sinlahekin Valley, Washington. Photo by Justin Haug

Table of Contents

List of Figures

Similkameen River at Nighthawk. Photo by Justin Haug.

Executive Summary

Overview

The Okanagan-Kettle subregion straddles the Canada–USA border between the Cascade Range on the west and the Monashee Mountains and Kettle Range to the east. It has been identified as a key area for maintenance and restoration of north–south and east–west wildlife habitat connectivity. At the northern extent of the shrub-steppe communities of the Columbia Plateau Ecoregion and Great Basin, it is an important area for north–south movement of shrub-steppe habitats and species; and as the central area between two major mountain ranges, it is important for maintaining movement of large carnivores and their prey.

The analysis and connectivity maps we present in this report build on previous work by the Washington Wildlife Habitat Connectivity Working Group (see WHCWG 2010, *Washington Connected Landscapes Project: Statewide Analysis*). In this connectivity assessment of the Okanagan-Kettle subregion, we relied heavily on the WHCWG statewide analyses to establish a regional context for finer-scale analyses using both focal species and landscape integrity approaches.

The audience for this work is broad (see WHCWG 2013, *British Columbia–Washington Transboundary Habitat Connectivity Scoping Report*). The regional context—understanding how this subregion fits within the broader landscape of Washington and southern British Columbia—helps to inform managers and planners from First Nations, Tribes, provincial, state, and federal entities about key areas to focus habitat connectivity maintenance, restoration, and finer-scale planning. The analyses within the Okanagan-Kettle subregion provide more specific guidance to those involved in land management within the study area, including conservation organizations, stewardship organizations, First Nations, Tribal, provincial, municipal and state planners, and individuals and companies managing private and crown lands.

Connectivity Analysis of the Okanagan-Kettle Subregion

The goal of our analysis was to identify local Connectivity Focus Areas (CFAs) within the Okanagan-Kettle subregion that are critical to wildlife habitat connectivity at a regional scale, now and under a changing climate.

We identified Connectivity Focus Areas based on three different connectivity perspectives: (1) shrub-steppe species, whose habitat and movements generally occur in the lowest elevations of our study area; (2) montane species, whose habitat occurs in the higher elevations of our study area but is linked by movements through low-elevation areas; and (3) landscape integrity, which focuses on the most ecologically intact habitats in both high and low-elevations as well as the best places to move between them in ways that avoid human developments (areas of low ecological integrity). For each perspective, we focused on areas of interest at mid- to low-elevations. We also considered the potential impacts of future climate change to maintaining or enhancing connectivity for wildlife within the subregion. And finally, in collaboration with local stakeholders, we selected two linkage areas within the subregion where we applied our findings to help inform on-the-ground connectivity conservation planning. We also discuss the application of a Decision Support System (DSS) by a multi-partner conservation initiative underway in this subregion, to inform fine-scale linkage restoration actions and monitoring.

Interpreting the patterns in connectivity for the entire Okanagan-Kettle study area provides an overview of potential connectivity opportunities and barriers at that broad scale. In addition, we defined five fracture zones within the study area delineated primarily based on the region's major highways and associated development. These zones were created to help narrow our focus from a very large landscape to more local Connectivity Focus Areas based on the fact that the greatest barriers and future threats to connectivity are likely to occur within them.

Connectivity Focus Areas (CFAs)

Our approach to modeling Connectivity Focus Areas (CFAs) used connectivity value and development risk models (see Methods) to identify those places within the Okanagan-Kettle subregion where wildlife would likely move when migrating or making dispersal movements and that are also the most threatened by potential development. By focusing on the "intersection" of connectivity value and risk to identify key portions of the wildlife habitat network that face the greatest potential threat our analysis helps inform connectivity conservation priorities and targets in the subregion. Products of this composite analysis include maps showing Connectivity Focus Areas for each of the three connectivity perspectives (described below) as well as the convergence among the three perspectives (Fig. ES.1, see full report for maps of fracture zones).

Focal Species and Landscape Integrity Perspectives: Connectivity Value of Habitat

The Okanagan-Kettle subregion is dominated by two distinct habitats: montane forests in the higher elevations and shrub-steppe or grasslands in the lower elevations. Wildlife species associated with these habitats formed the first two perspectives—*shrub-steppe species* and *montane species*—of our analysis of habitat connectivity. These perspectives are based on the focal species guilds identified in the *Washington Connected Landscapes Project: Statewide Analysis* (WHCWG 2010). The statewide analysis found that focal wildlife species can be grouped and mapped in different connectivity guilds such as montane (including species like American black bear, Canada lynx, and wolverine) and shrub-steppe (including species like American badger, sharp-tailed grouse, and white-tailed jackrabbit). The focal species approach reflects the ways that individual species contribute to our understanding of habitat connectivity. The third connectivity perspective was based on the concept of *landscape integrity*, a modeling approach that connects the most ecologically intact areas via routes that are the least impacted by human modifications. This approach does not consider natural landscape variability (e.g., variations in elevation or slope) and species-specific habitat associations but is intended to represent the connectivity needs of species whose dispersal is primarily influenced by the relative degree of human disturbance on the landscape.

When considered together, these three perspectives offer a more comprehensive view of habitat connectivity in the Okanagan-Kettle subregion than any one alone. Our results for these analyses include maps showing the Connectivity Value of habitat for shrub-steppe species, montane species at low elevations, and landscape integrity perspectives for the subregion (Figs. ES.2, ES.3, and ES.4), and each of the five fracture zones (see full report).

Climate Change

Future climate change may profoundly affect habitat connectivity in the Okanagan-Kettle subregion; anticipating potential impacts and identifying opportunities for mitigating negative affects was a primary goal of our analysis.

We used models of projected future changes in climate to identify potential climate impacts on regional connectivity, paying special attention to impacts on low-elevation valleys. Key impacts included changes in temperature and precipitation, vegetation, and disturbance regimes. We identified a suite of actions for addressing these impacts and accounting for connectivity needs related to climate-driven shifts in species ranges. Many of these actions focused on maintaining connectivity of moist habitats in low-elevation valleys, addressing impacts related to changes in disturbance regimes, and providing opportunities for species to track shifting areas of climatic suitability (e.g., by identifying and protecting linkages—such as climate-gradient corridors—that connect warm valley floors to cooler, higher elevation locations).

Observations and Insights

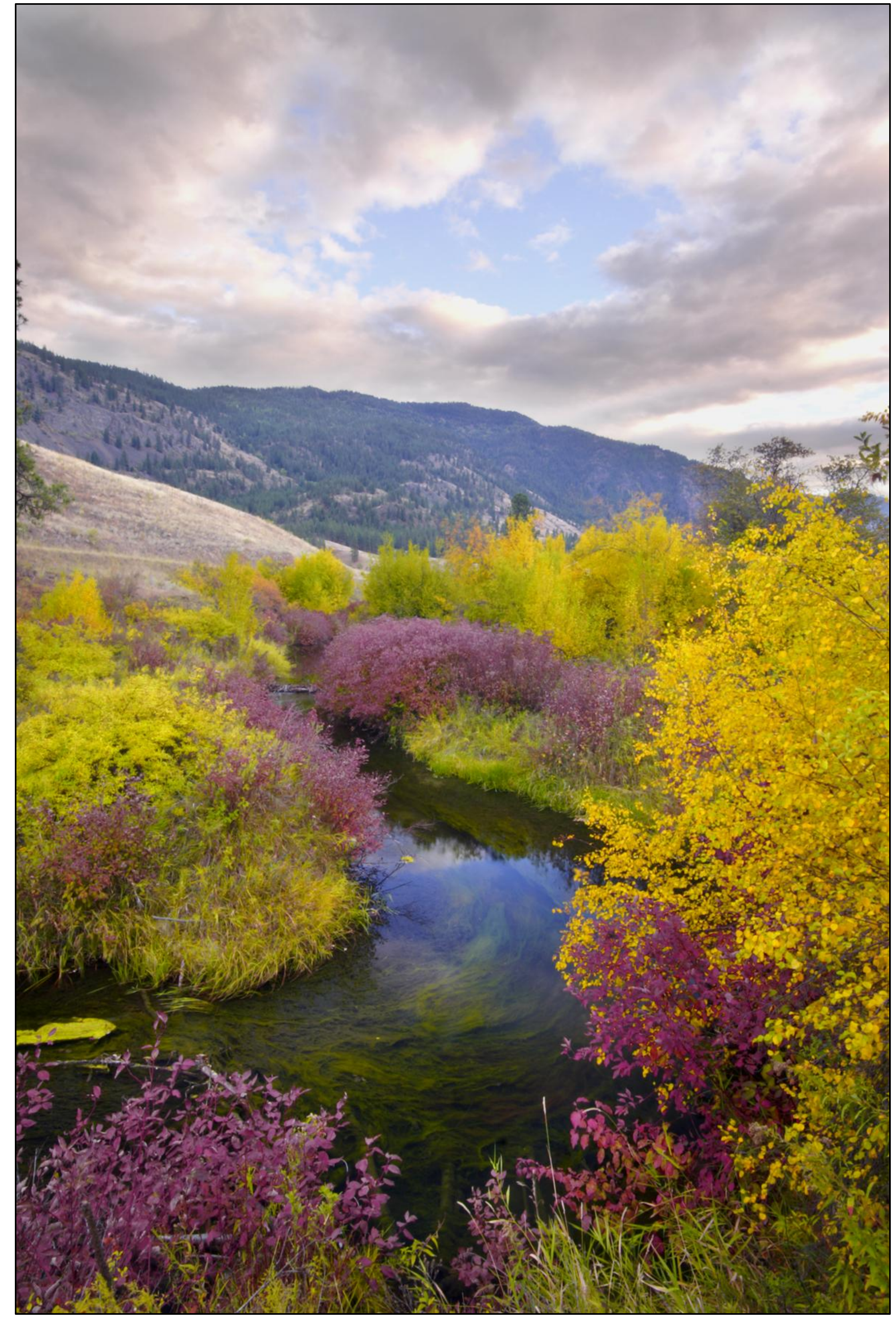
Our analysis provides valuable insights into conditions for current and future habitat connectivity in the Okanagan-Kettle subregion. We have identified both regional wildlife movement patterns and those within fracture zones as well as key areas where connectivity for all three perspectives (shrub-steppe/montane species and landscape integrity) may be most at risk. These include:

- For montane species, north–south movement corridors occur both west and east of the Okanagan Valley following largely forested, mountainous habitat. These movement corridors have a relatively low human footprint except where they cross developed side valleys of the Okanagan Valley (Fig ES.5). East–west connections linking the Cascade Range and Coast Range in the west to the subranges of the Rocky Mountains in the east are much more tenuous as they must pass through the highly modified landscape of the Okanagan Valley. In addition to the high population density and prevalence of agriculture in the lowest elevations, there are significant natural barriers to movement for montane species, including large lakes, steep slopes, and lack of forest cover.
- For shrub-steppe species, movement options through the Okanagan-Kettle subregion occur along a north–south axis in the lowest elevations of the Okanagan Valley (Fig. ES.5). Close proximity of development to these shrub-steppe habitats results in few opportunities for wildlife movements, particularly in British Columbia, where urbanization and conversion of shrub-steppe habitat to agriculture is highest. Connectivity east–west between shrub-steppe habitat in the Okanagan Valley and shrub-steppe further north near Kamloops is currently very limited (due to distance) or nonexistent as potential routes pass through mountainous forested habitat. However, if the climate in the region becomes warmer and drier, conversion of these forested barriers to shrub-steppe may make these routes more viable in the future.
- East–west trending side valleys that enter the main Okanagan Valley, such as northwest of Vernon, the Lumby Valley, east of Kelowna (following Highway [Hwy] 33), west of Peachland (following Hwy 97C), the Similkameen Valley at Keremeos, and east of Osoyoos support movement of shrub-steppe species extending out from the main Okanagan Valley, as well as north–south movements of montane species.
- Nearly half of all Connectivity Focus Areas (CFAs) where all three perspectives overlap occur between Okanagan Falls and Osoyoos, including the Okanagan Valley along Hwy 97 as well as along Hwy 3 where it loops to the west through Marron Valley, Olalla, Keremeos, and Cawston. This pattern reflects this area's importance for regional connectivity, as well as the pressure of ongoing habitat conversion to agriculture and urbanization (Fig. ES.1). Situated at the "crossroad" of four of the five fracture zones, development in this portion of the study area would impact connectivity for wildlife moving both within and across the Okanagan Valley. This area also has the largest number and extent of protected areas. Several of the CFAs identified here are near or adjacent to protected areas, and are critical to providing connectivity among these areas.
- Further development east of Osoyoos, where the boundaries of the Hwy 3 East, Hwy 97 Central, and Hwy 97 South Fracture Zones meet has the potential to sever a narrow north–south connection for shrub-steppe species moving along the east side of the Okanagan Valley (Fig. ES.2), as well as north–south movement of montane species along the eastern rim of the valley at higher elevations (Fig. ES.3).
- Areas south of Oroville near Mt Hull, and near Riverside on the US side of the Okanagan Valley are threatened by further development in the valley. They provide north–south movement for shrub-steppe species along the Okanagan Valley and offer opportunities for montane species to cross the Okanagan Valley along an east–west axis. The area near Riverside has been identified by previous analyses as key for linking forested habitat of the North Cascades eastward through the Okanagan Valley and Highlands to the Kettle Range.
- Along the narrow Similkameen Valley between Keremeos and Princeton are several bottlenecks for shrub-steppe species moving east–west between the Okanagan Valley and shrub-steppe habitats north of Princeton. The linear "stepping-stone" arrangement of the CFAs reflects the steep and rugged sides of the valley that constrain habitat connectivity and increase pressure to develop what little "flat" land occurs. Loss of one CFA may compromise the east–west connectivity function of the others. These areas also provide opportunities for north–south movements of montane species across the Similkameen Valley. North–south trending drainages may offer less steep access routes across the valley.
- The area north of Princeton may be important for maintaining east–west connectivity of higher elevation habitats as well as providing potential future access—given a changing climate—to shrub-steppe areas in the Nicola Valley and north to Merritt and beyond.

Informing Local Connectivity Conservation Decisions

The task of maintaining and restoring wildlife habitat connectivity in the Okanagan-Kettle subregion is a complex one. Community-based conservation efforts—partnerships between managers and stakeholders—are more successful with the support of local communities than without. Such efforts are based on collaboration, transparency, and accountability (Berkes 2004). We describe two place-based connectivity projects ongoing in the Okanagan-Kettle subregion where we engaged with local stakeholders to increase awareness and understanding of our connectivity maps and to gather local knowledge. These efforts included: (1) the Okanagan Futures Project, BC—a multi-stakeholder partnership whose focus is connectivity conservation planning in the Central Okanagan Regional District; and (2) Spotted Lake (Ha? Ki lil xw), BC—an area of ongoing conservation planning by the Okanagan Nation Alliance and member bands. We also include discussion of the *Working for Wildlife Initiative*—a multi-partner collaboration to conserve a critical wildlife linkage and working lands in rural north-central Washington—as an example where collaborators use a Decision Support System (DSS) to inform on-the-ground connectivity restoration actions and to monitor progress towards maintaining or restoring connectivity.

The over arching goal of our analysis is to provide information necessary to help guide conservation actions in the Okanagan-Kettle subregion that will conserve habitat connectivity both now and into the future. Critical to achieving this goal is the application of the connectivity science presented in this report to on-the-ground conservation efforts. As stated previously our intended audience is broad. Stakeholders interested in connectivity conservation differ in their familiarity with modeling approaches and products and we acknowledge that technical terms used to describe connectivity analyses may be confusing. Consequently, throughout our report we have tried to describe our results in ways easy to understand and have presented the more technical information in attached appendices. Key products of our analysis include connectivity maps for the subregion and each of the five fracture zones depicting (1) the connectivity value of habitat for shrub-steppe species, montane species, and landscape integrity perspectives, and (2) connectivity focus areas identified for shrub-steppe species, montane species, and landscape integrity. We also include a map depicting wildlife habitat linkages for the broad transboundary region. High resolution pdf versions of all map products are available from http://www.waconnected.org.



Riparian habitat in the Okanagan-Kettle subregion. Photo by Justin Haug.

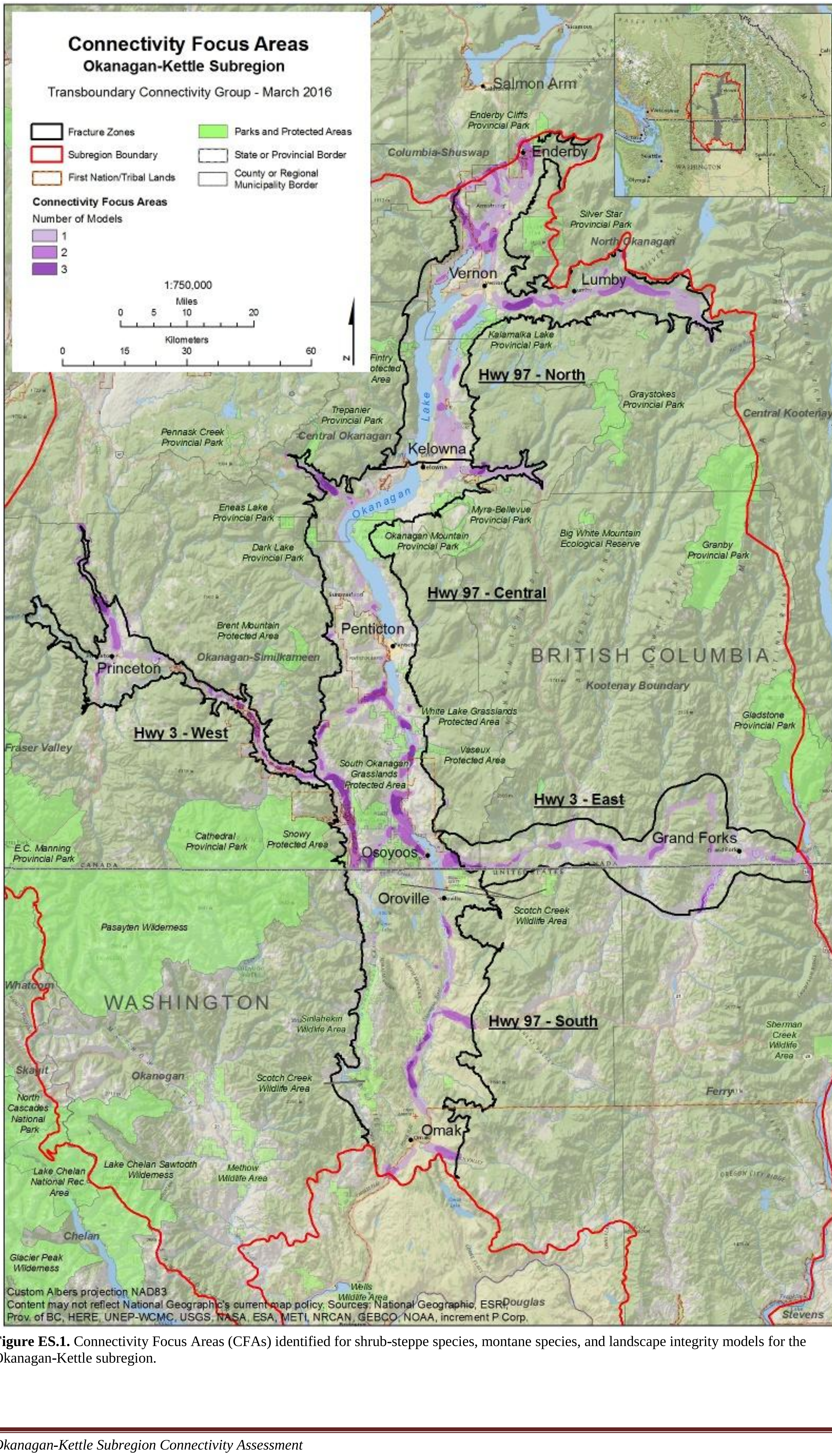


Figure ES.1. Connectivity Focus Areas (CFAs) identified for shrub-steppe species, montane species, and landscape integrity models for the Okanagan-Kettle subregion.

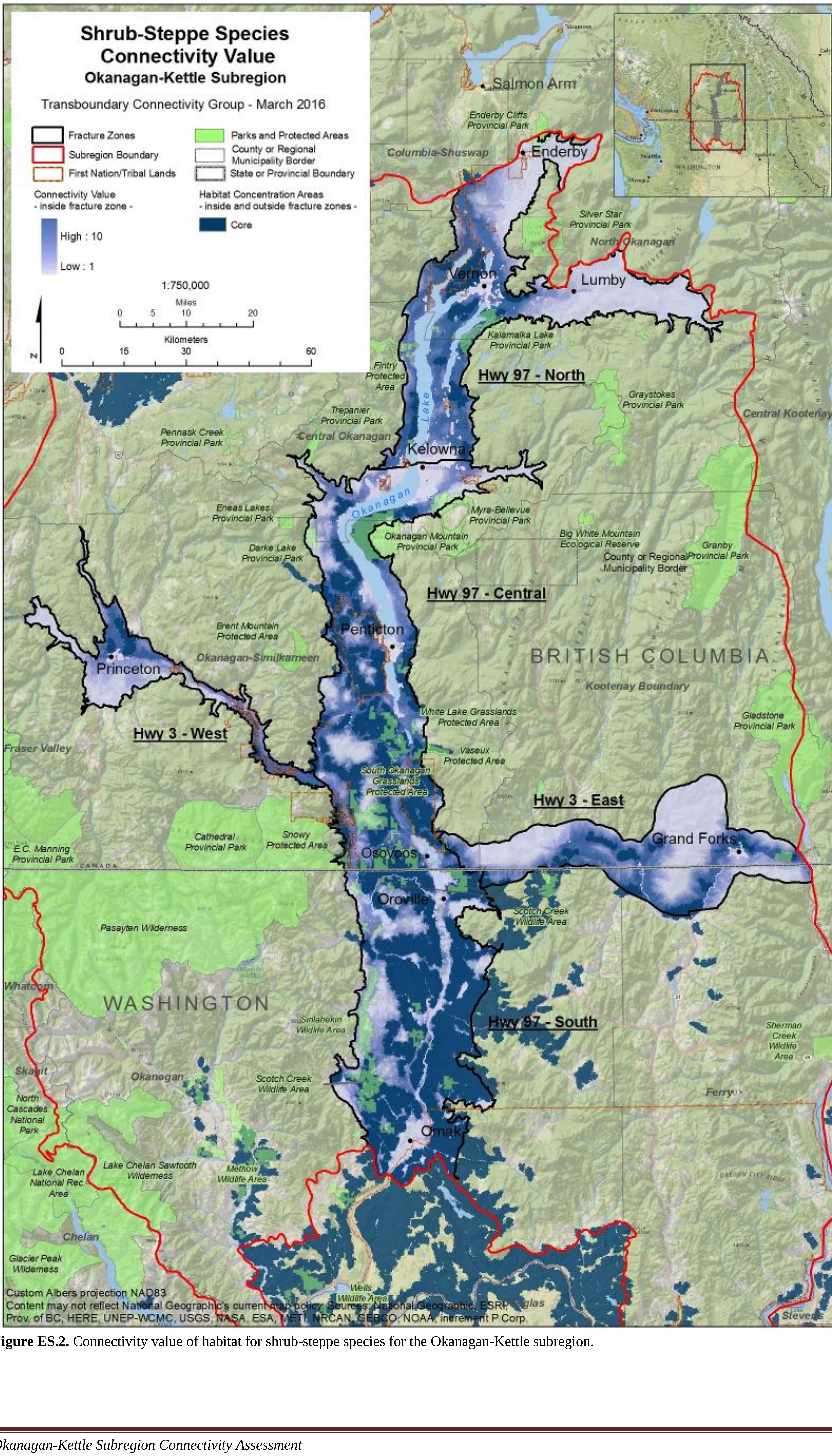


Figure ES.2. Connectivity value of habitat for shrub-steppe species for the Okanagan-Kettle subregion.

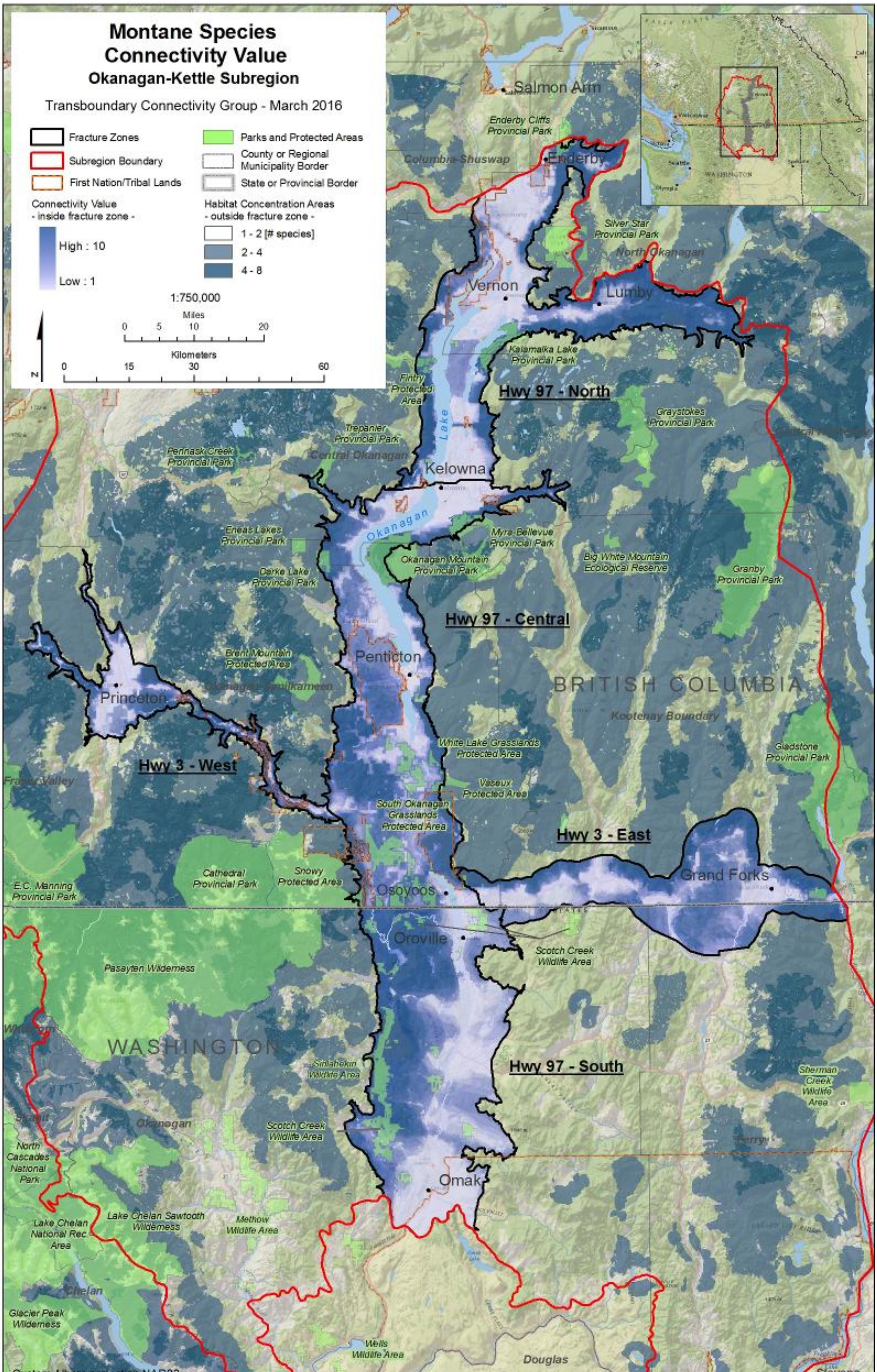


Figure ES.3. Connectivity value of habitat for montane species for the Okanagan-Kettle subregion.

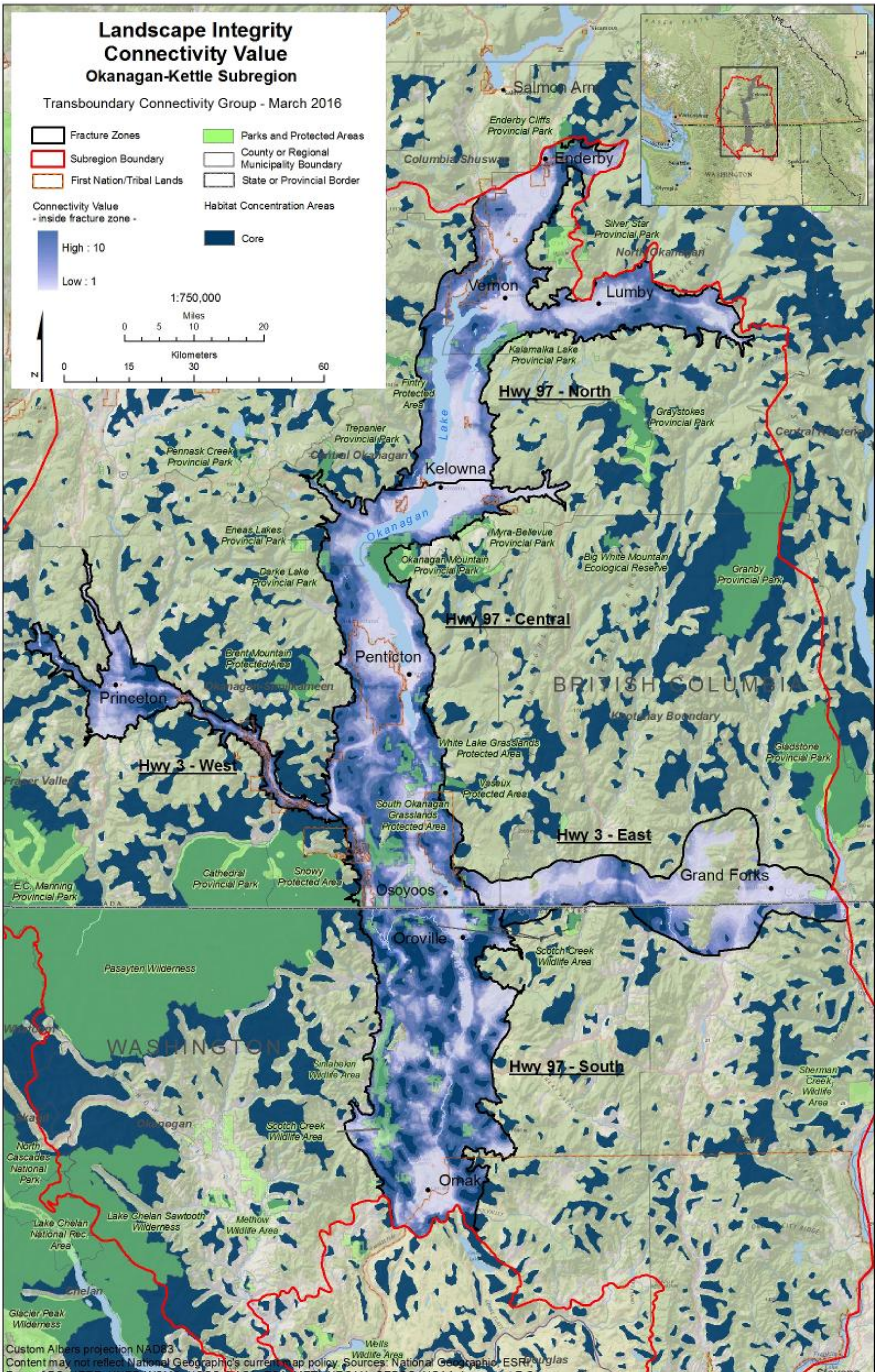


Figure ES.4. Connectivity value of habitat for landscape integrity for the Okanagan-Kettle subregion.

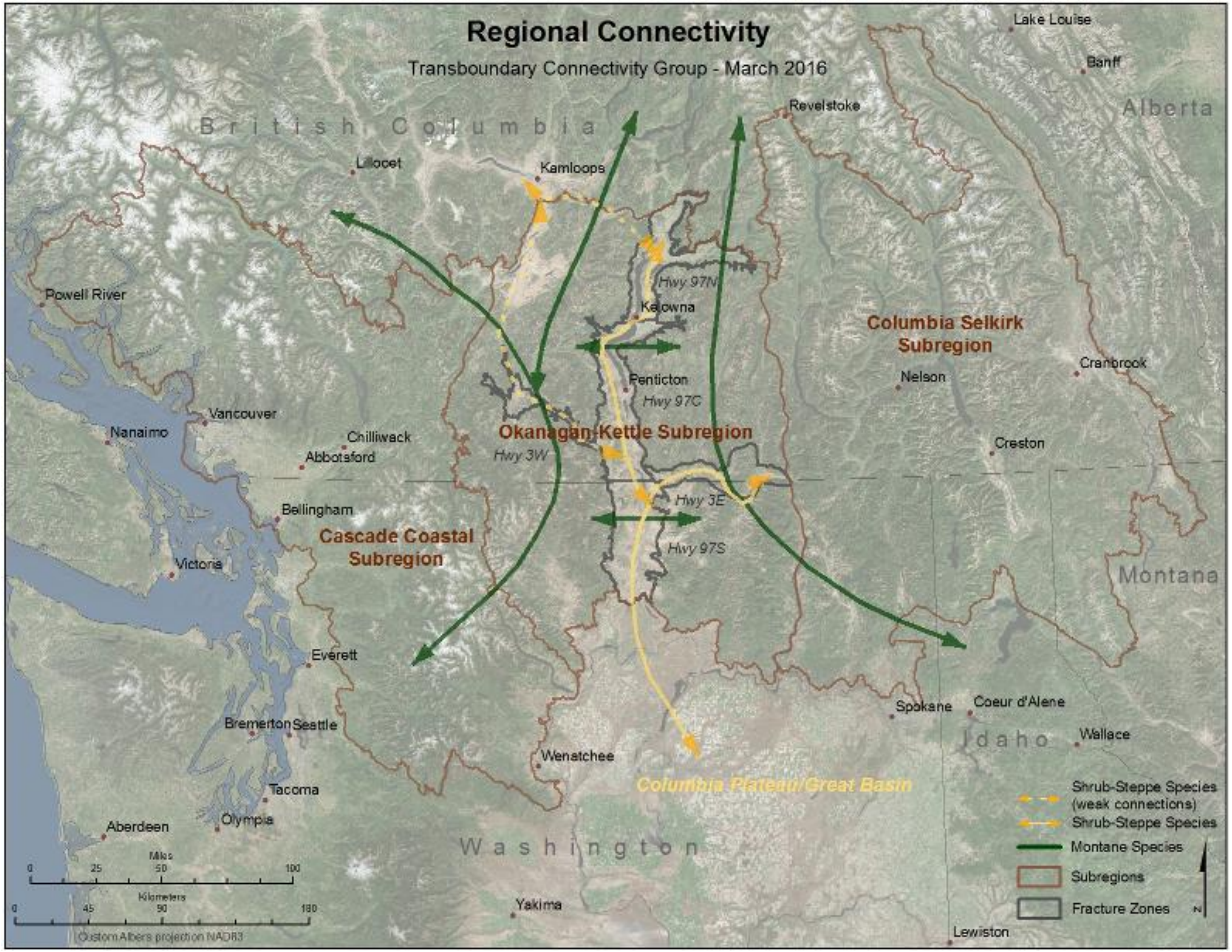


Figure ES.5. Broad-scale wildlife movement patterns for the transboundary region of British Columbia and Washington State. Green arrows show potential movement patterns for montane species (e.g., American black bear and Canada lynx). Yellow arrows show movement patterns for shrub-steppe species (e.g., American badger). Yellow arrow connecting BC and WA shows potential habitat corridor for shrub-steppe species moving between the Columbia Plateau and Great Basin regions and the Okanagan-Kettle subregion.

Introduction

Overview

The US–Canada border region of the Pacific Northwest has been recognized in a variety of conservation assessments as an area that is very important for the conservation and recovery of a wide-array of wildlife species and ecosystems, from wide-ranging carnivores (Gaines et al. 2001; Singleton et al. 2002, 2004; WHCWG 2010, 2013) to more dispersal limited species (WHCWG 2010, 2013). However the border region presents several challenges to the implementation of conservation actions, such as different political environments, technical issues that make data acquisition and compatibility difficult, and differences in the legal status of some species. Following completion of the *Washington Connected Landscapes Project: Statewide Analysis* (WHCWG 2010) the Washington Wildlife Habitat Connectivity Working Group (WHCWG) recognized that connectivity assessments of the transboundary region between Washington State and British Columbia are essential to understanding broad-scale connectivity patterns for wide-ranging species and ecological processes. Climate change and widespread loss of habitat further underscored the need for regional connectivity conservation efforts that transcended jurisdictional boundaries (WHCWG 2010). A scoping effort was subsequently initiated by the WHCWG Transboundary Subgroup to identify transboundary connectivity needs in a changing climate (WHCWG 2013). Based on review of existing connectivity analyses, and extensive outreach to stakeholders in the transboundary region, the subgroup concluded that the Okanagan-Kettle subregion presented the highest priority for focusing additional science and coordination to inform ongoing efforts to maintain a regionally connected network of habitats. Additionally, future connectivity analysis of the transboundary region would be most effective if based on a collaborative approach with local practitioners from both sides of the border (WHCWG 2010, 2013).

Maintaining and restoring ecological connectivity is a primary conservation need and the most frequently recommended climate adaptation strategy for biodiversity conservation (Heller & Zavaleta 2009). The Okanagan-Kettle subregion includes the northern-most extent of the Columbia Plateau Ecoregion (the semi-arid lands of eastern Washington) and poses a potential bottleneck to climate-driven range shifts of shrub-steppe species. It is also centrally located between the Cascade Range and the Rocky Mountains, both of which support large predators and their prey populations. Maintaining or restoring the Okanagan-Kettle's permeability to wildlife movement is thus vital for sustaining wildlife populations both today and in the future, and in promoting regional resilience to climate change.

This report presents the results from an ongoing, cross-border collaboration to assess terrestrial wildlife habitat connectivity for the Okanagan-Kettle subregion. We largely relied upon existing models (WHCWG 2010) and local knowledge to identify key areas for maintaining and enhancing wildlife movements across the subregion. In addition to identifying areas important for connectivity today, we also considered how climate change may affect regional connectivity, and which areas may be important for maintaining connectivity as climate changes.

Okanagan-Kettle Subregion Project Area

Located between the Cascade Range and the Rocky Mountains, the Okanagan-Kettle subregion has been identified by previous connectivity analyses and management plans (Gaines et al. 2001; Singleton et al., 2002, 2004; WHCWG 2010, 2013) as a priority for maintaining a connected network of habitats both north–south between British Columbia and Washington, and east–west between large blocks of relatively secure mountainous habitats. In Washington, the Okanagan-Kettle subregion includes portions of the Okanogan-Wenatchee and Colville National Forests as well as state, private, and Colville Confederated Tribal lands (Fig. 1). In British Columbia, a majority of the subregion is Crown Land, including protected areas such as Cathedral Park, Snowy and South Okanagan Grasslands Protected Areas in the southwest, Granby and Gladstone Parks in the southeast, and Okanagan Mountain Park in the centre of the region. The Okanagan-Kettle subregion lies within the territory of member bands within the Okanagan Nation Alliance.

This landscape has a long history of facilitating the movement of people and wildlife. Although natural barriers to movement such as mountains, rivers, and lakes have always existed on this landscape, more recent development associated with human activity have further restricted movement options for wildlife. A major geographic feature in the subregion is the long and narrow Okanagan (Okanogan) Valley, which lies in the rain shadow between the Cascade Range and the Columbia Mountains. Formed by glacial activity, it is characterized by low hills, and long slender lakes, especially in BC (Fig. 1). The geography of the Okanagan Valley has resulted in a concentration of development along the valley bottom that has impacted grassland habitats and associated species. In BC, more than one-third of the grasslands have been lost to development and what remains is considered endangered (Austin et al. 2008). Human activity has also impacted east–west movement for montane species that must cross the valley to access higher elevation habitats. Forest management, recreational and urban development, transportation corridors, population growth, and viticulture land use are accelerating in this area of the subregion (OCCP & SCCP 2014). Additional stressors associated with the overarching impact of future climate change highlight the need for information to help guide connectivity conservation efforts and management.

View of Osoyoos, BC showing some of the many barriers to movement wildlife encounter when crossing the Okanagan Valley. Photo by Peter Singleton.

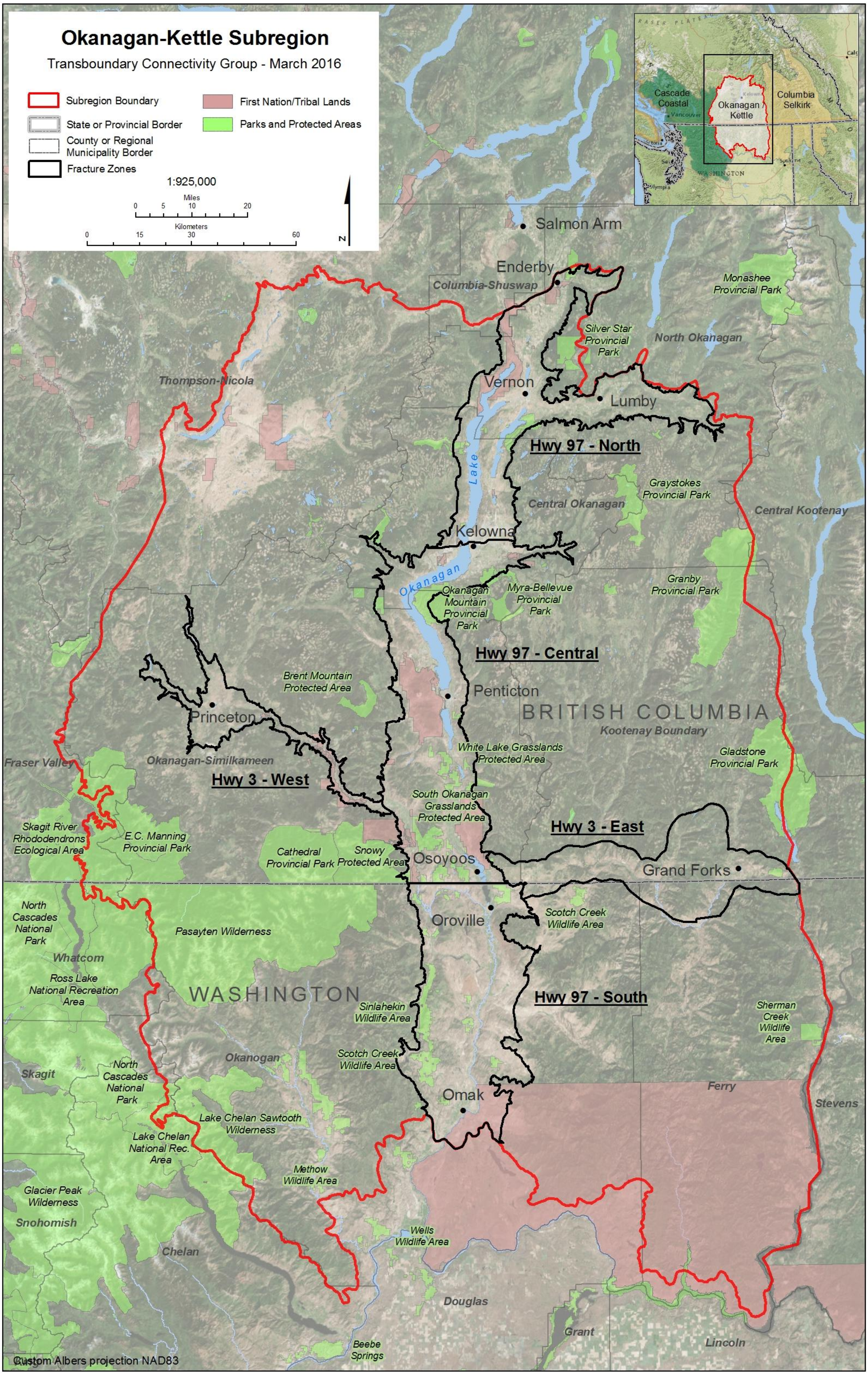


Figure 1. The Okanagan-Kettle subregion study area and fracture zones.

Goal and Objectives

The goal of our analysis was to identify local Connectivity Focus Areas (CFAs) within the Okanagan-Kettle subregion that are critical to wildlife habitat connectivity at a regional scale, now and under a changing climate.

We identified Connectivity Focus Areas based on three different connectivity perspectives: (1) shrub-steppe species, whose habitat and movements occur in the lowest elevations of the subregion; (2) montane species that move through low elevations of the subregion to access habitat at higher elevations; and (3) landscape integrity, which focuses on the most intact habitats (the best of what's left) in both high and low elevations as well as movements linking these habitats in ways that minimize contact with our human footprint. We also considered the potential impacts of future climate change to maintaining or enhancing connectivity for wildlife within the subregion. In collaboration with local stakeholders, we then selected two linkage areas where we applied our findings to help inform on-the-ground connectivity conservation efforts. We also discuss the application of a Decision Support System (DSS) through a multi-partner conservation initiative underway in this subregion that informs fine-scale linkage design and monitoring.

Interpretation

The results we present in this report are intended to help organizations and groups incorporate and prioritize connectivity into conservation efforts while meeting their particular goals and priorities. Multiple ongoing planning and conservation efforts within this subregion have the potential or are already integrating science to impact local and regional habitat connectivity including; planning initiatives of Okanagan Nation Alliance, the Okanagan Collaborative Conservation Program (OCCP), the South Okanagan Similkameen Conservation Program (SOSCP), the Okanagan Futures Project, the BC Government's exploration of additional protection measures in the South Okanagan as described in their recently released Intentions Paper[1], the Colville National Forest Plan revision (Gaines et al. 2012), and the National Fish and Wildlife Foundation *Working for Wildlife Initiative*. Our analyses complement and inform these ongoing efforts by providing a regional context to local conservation decisions, including highlighting areas that are critical to wildlife movements at the broad scale of the subregion as well as at the finer scale of the fracture zones.

The complexity of multiple analyses provides opportunities for application to varied uses, but presents challenges for full discussion and consideration within a single report. We have therefore synthesized our results to highlight areas that appear to particularly important for connectivity because they are both valuable today, and potentially at risk. This approach is intended to help prioritize areas important for the conservation of connectivity within the subregion and provide guidance for detailed linkage design. Our recommendations are not meant to be all-inclusive as we recognize that goals, priorities, and opportunities may differ among agencies and organizations.

Many of the methods, data layers, and models we use in our connectivity analyses were based on the extensive work undertaken in the *Washington Connected Landscapes Project: Statewide Analysis* (WHCWG 2010). We encourage users to refer to the WHCWG statewide analysis for a more in-depth discussion of methods and model assumptions (available from http://www.waconnected.org).

In this report we provide an overview of the findings both across the subregion, and within each of five fracture zones for the three connectivity perspectives. We provide composite analysis results that identify Connectivity Focus Areas that are key locations on the landscape where habitat connectivity for wildlife is most threatened. In addition, we discuss three collaborative efforts to conduct step-down analyses and connectivity conservation planning within the Okanagan-Kettle subregion. The operational-scale efforts include: (1) the Okanagan Futures Project in the Central Okanagan Regional District of BC; (2) Spotted Lake (Ha? Ki lil xw), BC; and (3) the *Working for Wildlife Initiative* near Riverside, WA.

This report and high resolution files of all map products are available from http://waconnected.com.

Key Terms for Understanding the Analyses

Barrier — Area where landscape features impede wildlife movement. Barriers may be partial or complete, natural (e.g., rivers, cliffs) or human-made (e.g., urban areas, highways, some types of agriculture). Partial barriers can also be quantified in terms of resistance (see below).

Connectivity — Degree to which the landscape facilitates or impedes movement among resource patches (Taylor et al. 1993).

Connectivity Focus Area — In our models, these are areas that are (1) closest to habitat concentration areas (HCAs) in cost-weighted distance and/or part of the linkages that connect HCAs, and (2) have the highest risk of being developed in the future. In other words, they are key locations on the landscape where the wildlife habitat connectivity network faces the greatest potential threat.

Connectivity Value — Refers to models that quantify proximity to the nearest HCA or proximity to the best linkages between HCAs, given the resistance to movement in the local landscape. Areas with high connectivity value are more likely to facilitate wildlife movements within the landscape surrounding HCAs or between HCAs.

Fracture Zone — A subset of the study area that bounds major barriers to connectivity, including major highways, high human population density, and conversion of native habitats to urban and agricultural uses.

Habitat Concentration Area (HCA) — Habitat areas that are expected or known to be important for focal species based on actual survey information or habitat association modeling (including landscape integrity analysis).

Landscape Integrity — A relative measure of the level of human-caused change on a landscape that combines information on land conversion, human population density, and road use and density. Areas that have low levels of human modification and are in relatively natural or semi-natural condition have high relative landscape integrity and low resistance to movement in our models.

Linkage — A connection between two HCAs that avoids barriers and high resistance where possible, while also minimizing distance traveled.

Resistance — Resistance of a raster grid cell represents its suitability for movement, with increasing values corresponding to increasing movement difficulty. It is a way to quantify the risk of mortality, behavioral avoidance, and degree of difficulty required to traverse a particular grid cell.

[1]An intentions paper, *Protected Areas Framework for British Columbia's South Okanagan* was available for comment from August 13, 2015 to October 15, 2015. The paper is no longer available.

Methods

In this section we provide a non-technical summary of our analysis approach and provide example graphics to illustrate specific concepts. More technical information about the methodology is given in Appendix A.

Connectivity Perspectives

We considered habitat connectivity within the study area from three different perspectives. The region is dominated by two distinct habitats: montane forests in the higher elevations and shrub-steppe or grasslands in the lower elevations. Wildlife species associated with these habitats formed the first two perspectives. The montane forest species connectivity assessment was a composite of 10 individual focal species models developed by the Washington Wildlife Habitat Connectivity Working Group (WHCWG 2010), using information on American black bear, bighorn sheep, mountain goat, elk, lynx, wolverine, western toad, American marten, mule deer, and northern flying squirrel. These focal species models have in common a preference for forested habitats and a tendency to avoid the more open terrain in the lowest elevations of the study area. The shrub-steppe perspective was based on models we developed to reflect the general ecological requirements of shrub-steppe and grassland animals. The shrub-steppe models reflect an avoidance of densely forested areas and a preference for low-elevation open habitats where native shrubs and grasses are common. Both the montane and shrub-steppe species models generally avoid areas of high human population density, major roads, and agricultural areas. They also tend to avoid large water bodies and steep slopes (except for mountain goats).

The third connectivity perspective was based on the concept of "landscape integrity," which seeks to connect the most ecologically intact areas via routes that are the least impacted by human modifications such as roads, housing developments, and agriculture. Importantly, natural landscape variability (e.g., variations in elevation or slope) does not influence connectivity patterns for the landscape integrity model. For example, the best route across a landscape for wildlife might move from forest to shrub-steppe and back again so long as the human disturbance is minimized. This perspective was intended to capture species that may not fit neatly into the montane or shrub-steppe habitat associations, particularly those whose dispersal is primarily constrained by the degree of human disturbance, as opposed to natural landscape variability.

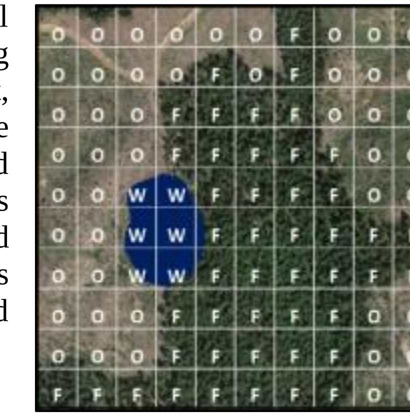
Together, these three perspectives offer a more comprehensive view of habitat connectivity in the study area than any one alone. However, depending on your interests, the individual models may be more relevant than a synthesis of all three.

Fracture Zones

The major movement barriers and the highest human disturbance within the study area occur in the lower elevation valleys, where most of the human population resides and where most of the agriculture, highway traffic, and transportation infrastructure occur. We chose to focus our analysis and interpretation on these valley fracture zones because both current and future threats to wildlife habitat connectivity are concentrated there. Specifically, we defined three fracture zones that bound the north, central, and southern portions of the Okanagan Valley and two fracture zones that bound the western and eastern approaches to the Okanagan Valley along BC Hwy 3 (Fig. 1). The emphasis on the fracture zones provided a means to narrow our focus to areas where connectivity is most threatened now and in the future.

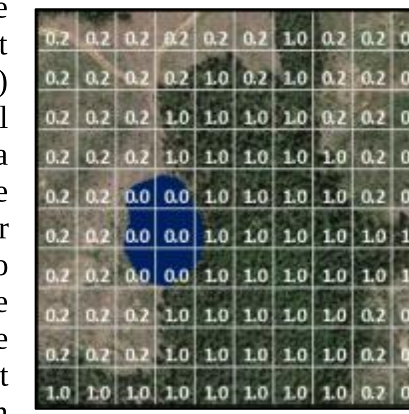
Landscape Variables

We modeled habitat connectivity within the study area based on several landscape variables that may influence wildlife movements, including roads, elevation, population density, land cover type (e.g., forest, agriculture, or urban), slope, and forest canopy cover. The landscape integrity and shrub-steppe models included additional variables described in Appendix A. All variables were represented as a grid of classified cells across the entire study area. As a simple (3-class) example of the land cover variable over a small area, the example to the right shows grid cells classified as open (O), forest (F), or water (W). The actual number of land cover classes per variable varied from 4 to 11.



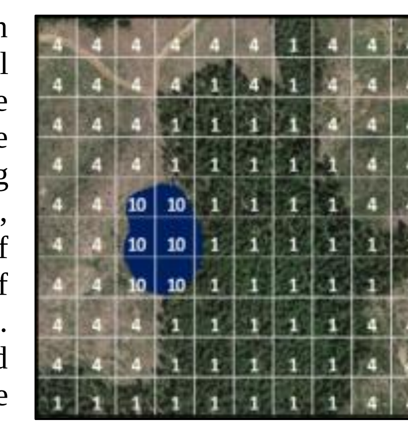
Habitat Suitability and Landscape Integrity Models

Each class of the above variables was assigned a habitat suitability value ranging from 0 to 1, with 1 being ideal habitat for the species (or the least human modification, if the perspective is based on landscape integrity) and zero being unsuitable. These values were chosen by a panel of focal species experts based on review of all available data and literature. For a forest-dwelling species, for example, forest grid cells might have a value of 1.0, while open habitats still might have some value in meeting their life-history needs and therefore have a value of 0.2, and water has no value (see example to the right). For each of the three models, we combined the various landscape variables for each grid cell into a single value based on the minimum suitability score. The results were habitat suitability and landscape integrity models for the entire study area for each of the three connectivity perspectives (the montane forest perspective was comprised of habitat models for a total of 10 species, see Appendix A).



Resistance Models

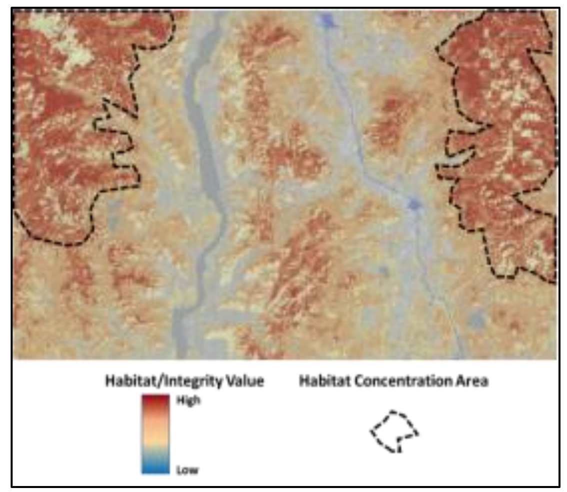
We reclassified the landscape variables to quantify the degree to which landscape features impede animal movements made during a dispersal event (based on movement ecology of the focal species). In these "resistance" models, a value of 1 is assigned to those grid cells which are the most permeable to movement (i.e., ideal dispersal habitat). Among forest-adapted species, for example, forests might have a resistance of 1, open areas might have a higher resistance of 4, and water a resistance of 10 (see example to the right). These values were chosen by a panel of focal species experts based on review of all available data and literature. Resistance values greater than 1 act as multipliers in the models, so a grid cell with a value of 10 is ten times more difficult for an animal to traverse compared to movement through ideal dispersal habitat. Summing resistances for all of the variables for each grid cell produced a single resistance model for each of the three



connectivity perspectives (the montane forest models were comprised of resistance models for a total of 10 species, see Appendix A). Resistance can be used to address a variety of factors that may influence an animal's dispersal success such as the risk of mortality (e.g., getting hit by a car while trying to cross a highway), behavioral avoidance (e.g., some species avoid crossing openings), and the degree of exertion required to traverse a grid cell (a function of distance and the resistance of the landscape features a species encounters). There may be other factors that influence species movements that may not be well accounted for in resistance models such as inter- or intra-specific competition (Spear et al. 2010).

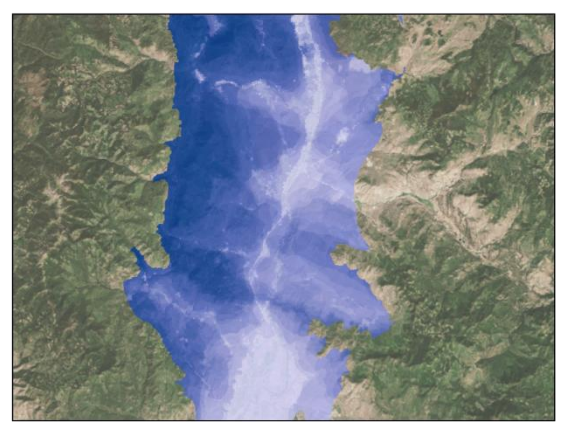
Habitat Concentration Areas (HCAs)

Habitat Concentration Areas, or HCAs, represent the largest blocks of the most suitable habitat (or high landscape integrity) that is not internally fragmented by major barriers to movement (i.e., high resistance). Animal movement within HCAs is characterized by home-range type movements, whereas movements between HCAs reflect longer distance dispersal or migration events due to the large distances involved and/or the magnitude of resistance in the intervening landscape. It is important to understand that HCAs do not capture all potential habitats within the study area (see example). They are merely the largest blocks of the most highly connected habitat. They serve as "seeds" on the landscape between which we evaluated connectivity.



Connectivity Value Models

We used the resistance models to predict areas that were either highly accessible to or from HCAs (i.e., geographically close and not separated by major barriers to movement) or were the best connections between HCAs, given the resistance in the intervening landscape. Areas close to HCAs or in the best linkages between them have the greatest "connectivity value" for wildlife. The darker blue areas in the figure to the right represent areas of high connectivity value. We only show connectivity value within fractures zones, so as to focus the attention on areas most threatened by development. For this example using a forest dwelling montane species, the lowest connectivity value areas are in the valley bottom, where the forest cover is low and the level of development and population density is high. The HCAs on the west side of the valley (not shown) are closer than the HCAs on the east side, where the forest is sparser and interrupted by open valleys. Therefore, connectivity value is generally higher on the west side, simply because it is closer to the nearest HCAs. However, notice the east-west connections across the valley, that follow the forested ribs towards the valley bottom. These are natural areas of connectivity between HCAs for montane species and therefore also have high connectivity value.

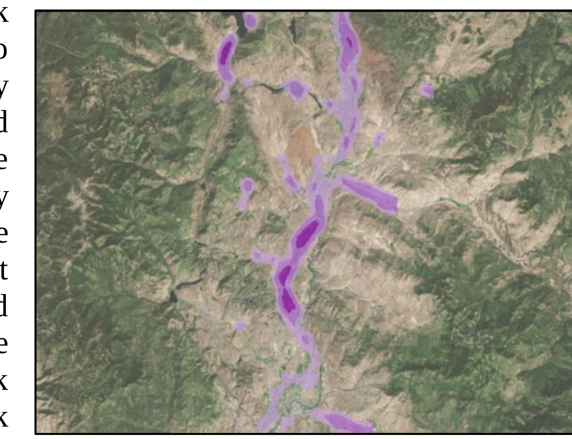


Development Risk

We produced a spatial model to identify areas on the landscape that are most at risk of projected future development. This model excluded areas that were already developed (cities, towns, industrial areas, etc.) or not developable (lakes and rivers, wetlands, and steep slopes). Areas farther than 1 km from a major road were also excluded because they were less likely to be developed. What remained were developable lands near major roads (shown in red on the example to the right). Visual inspection of recent satellite imagery reveals many areas deemed at risk were already being developed.

Connectivity Focus Areas (CFAs)

We used the connectivity value and development risk models as well as the fracture zones described above to define our ***Connectivity Focus Areas***. For each connectivity perspective in each of the 5 fracture zones, we identified areas where the models predict animals would likely move between HCAs or dispersing outwards from HCAs. By constraining our focus areas to the fracture zones, we emphasized the parts of the landscape where habitat connectivity is the most threatened. We further constrained our focus areas to places where the predicted wildlife movement areas intersected with the development risk model. Focusing on the intersection of connectivity and risk identifies key portions of the wildlife habitat network that face the greatest potential threat. We did this for each of the three connectivity perspectives and also produced a composite map showing the overlap of the three perspectives. The example above shows connectivity focus areas identified by, all three perspectives (dark purple), two of the three perspectives (medium-dark purple), and only one perspective (light purple). An overlap of three perspectives is not necessarily better than one perspective in terms of conservation connectivity planning, but it may maximize benefits where resources for conservation actions are constrained.



Results

This section presents results from the shrub-steppe, montane, and landscape integrity connectivity analyses, first at the broad scale of the Okanagan-Kettle subregion, followed by more detail at the finer scale of the fracture zones. We present connectivity value models (see Methods) that rank areas within each fracture zone on a scale of 1 to 10 (with 10 being the highest connectivity value) based on the predicted importance to wildlife movement. The Connectivity Focus Areas (CFAs) represent areas of high connectivity value that are potentially threatened by future development. We present maps of connectivity value and CFAs for each connectivity perspective, discuss observed connectivity patterns, and consider the potential impacts of climate change on future habitat connectivity.

Subregional-Scale Wildlife Movement Patterns

We observed several broad landscape-level connectivity patterns for the Okanagan-Kettle subregion. The subregion scale provides context in terms of the combined effects of the geographic and human produced barriers to movement, and is useful for consideration of larger patterns and pressures such as climate change. In the Okanagan-Kettle subregion, highway corridors and their associated development, combined with natural features of the landscape, constrain access to habitat for wildlife. Acceleration of ongoing development further compromises connectivity opportunities in many areas.

We identified six main axes of wildlife movements for the Okanagan-Kettle subregion (three for montane species and three for shrub-steppe species; see Fig. 2; see also Figs. ES.2, ES.3, and ES.4). Broad regional connectivity patterns for species whose movements are driven primarily by landscape integrity are likely to strongly resemble the montane species movements in the higher elevations and the shrub-steppe species in the lower elevations. We describe each of these axes in greater detail below.

1. Montane species moving between the Coast Range of British Columbia and the Cascade Range of Washington are highly constrained by the preponderance of human-created barriers along the Fraser River Valley. However, there are areas that are more permeable in the western portion of the Okanagan-Kettle subregion. Montane species inhabiting the interior plateau between the Coast Range and Rocky Mountains north of the study area may also connect with the Cascade Range in Washington along the highlands west of the Okanagan Valley (Fig. 2). This north–south axis is largely forested, mountainous, and has relatively few human modificaitons, except where it crosses the Hwy 3 West Fracture Zone and a small side-valley of the Okanagan extending westward from Peachland, in the Hwy 97 Central Fracture Zone.
2. Montane species moving on a north–south axis along the western sub-ranges of the Rocky Mountains may cross the highlands east of the Okanagan Valley (Fig. 2). This area is also largely forested, mountainous, and has relatively few human modifications, except where it crosses the Hwy 3 East Fracture Zone and a side-valley of the Okanagan extending eastward from Vernon past Lumby, in the Hwy 97 North Fracture Zone.
3. For montane species, east–west connections linking the Cascade Range and Coast Range in the west to the subranges of the Rocky Mountains in the east are much more tenuous as they must pass through the highly modified landscape of the Hwy 97 fracture zones. In addition to the high population density and prevalence of agriculture in the lowest elevations, these fracture zones also contain significant natural barriers to movement for montane species, including large lakes, steep slopes, and lack of forest cover. The strength of natural and man-made barriers along this east–west axis is generally greater in British Columbia than in Washington.
4. For shrub-steppe species, the primary movements through the Okanagan-Kettle subregion occur along a north–south axis in the lowest elevations of the Okanagan Valley, almost entirely within the three Hwy 97 fracture zones (Fig. 2). The close proximity of these shrub-steppe habitats to development in the valley significantly reduces opportunities for wildlife movements, particularly in British Columbia, where urbanization and conversion of shrub-steppe habitat to agriculture is highest.
5. A patchy network of shrub-steppe habitat occurs along the slopes and valleys near the Washington-British Columbia border east of the Okanagan Valley. This provides opportunities for shrub-steppe species to extend their range into pockets of suitable habitat east of the Okanagan Valley. Connectivity to this network may be reduced where the narrow linkages of shrub-steppe habitat cross the Hwy 3 East Fracture Zone.
6. A large patch of shrub-steppe habitat occurs in the vicinity of Kamloops, in the northwest portion of the Okanagan-Kettle subregion. This area appears isolated from the shrub-steppe habitat in the Okanagan Valley. However, one potential connection between the two runs along the Similkameen River towards a patch of shrub-steppe habitat near Princeton, in the Hwy 3 West Fracture Zone. From there, forests and higher elevation habitats appear to be barriers to movement for shrub-steppe species moving further north to connect to the Kamloops area. Two potential alternative shrub-steppe connections between the Okanagan Valley and the Kamloops area may occur along Shorts Creek running west from Fintry Provincial Park and along the Salmon River northwest of Vernon, along Hwy 97. As these routes ascend out of the Okanagan Valley, however, they enter more mountainous and forested habitat that is likely a significant natural movement barrier for many shrub-steppe species. At present, these three areas are not likely to offer significant levels of habitat connectivity between the Okanagan Valley and the Kamloops area. However, if the climate in the region becomes warmer and drier, conversion of these forested barriers to shrub-steppe may make these routes more viable in the future.

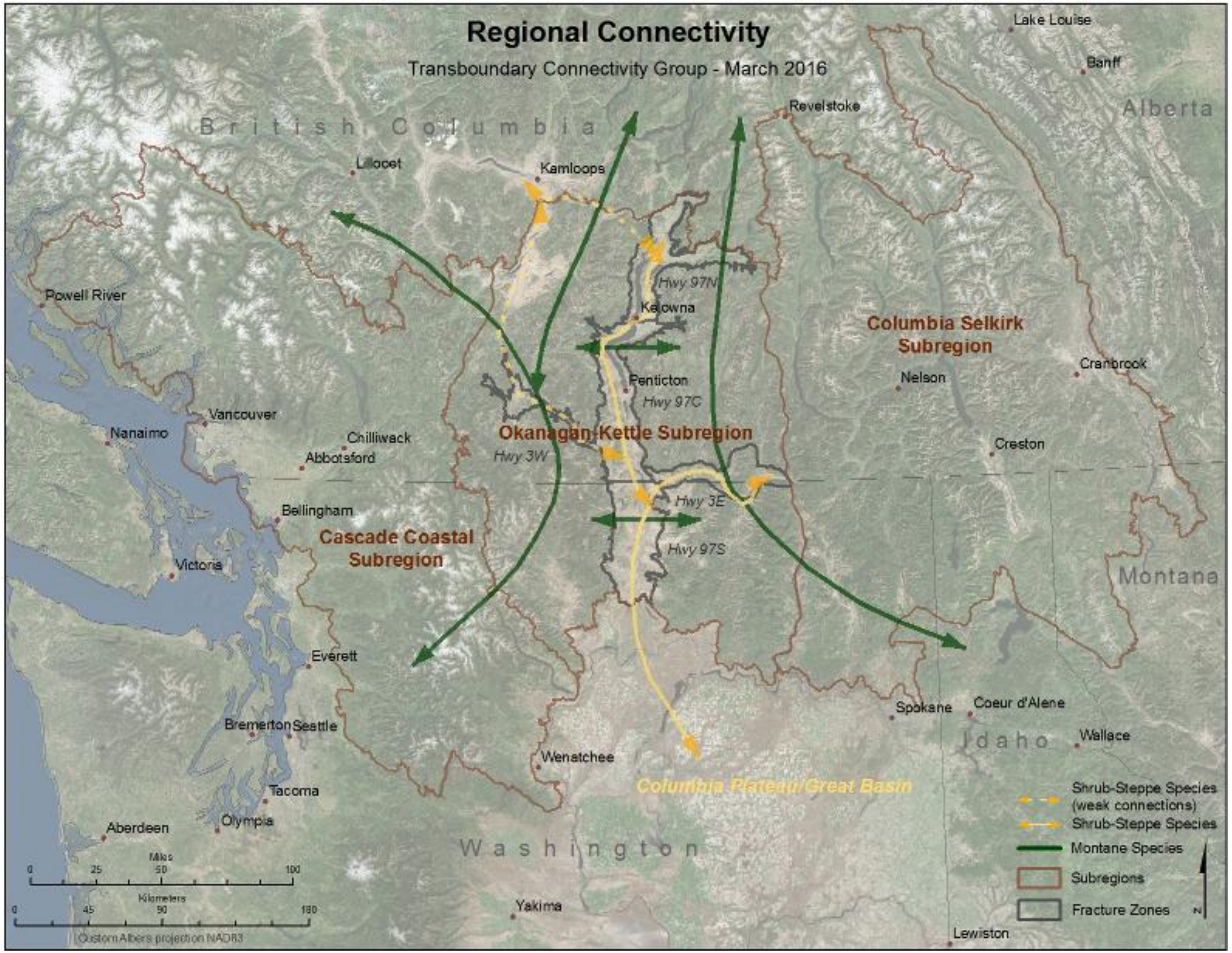


Figure 2. Broad-scale wildlife movement patterns for the transboundary region of British Columbia (BC) and Washington State (WA). Green arrows show potential movement patterns for montane species (e.g., American black bear and Canada lynx). Yellow arrows show movement patterns for shrub-steppe species (e.g., American badger). Solid yellow arrow connecting BC and WA indicates potential habitat corridor for shrub-steppe species moving between the Columbia Plateau and Great Basin regions and the Okanagan-Kettle subregion.

Fracture Zone Connectivity Focus Areas and Perspectives

Connectivity between and within fracture zones is highlighted at this scale. These results are relevant to local planning efforts where there is interest in addressing habitat connectivity with land-use planning. The results are presented by Fracture Zone, then for each Fracture Zone, details of the Connectivity Focus Areas are described, followed by a detailed description of the results for each of the three perspectives.

Hwy 97 North Fracture Zone

At the northern edge of our study area boundary, this fracture zone extends north–south roughly from Enderby to Kelowna and east–west along the Lumby Valley, BC (Fig. 1). Steep and rugged terrain is less prevalent in this portion of the study area, and relatively low-lying rounded hills bound the Okanagan Valley. The fracture zone is dominated by the city of Vernon and environs, and the agricultural and rural development along the north end of Okanagan Lake and Kalamalka Lake. Potential barriers to movement of wildlife include Hwy 97, Hwy 6, and development associated with the communities of Enderby, Armstrong, Vernon, and Kelowna. As well, Swan, Kalamalka, and Okanagan Lakes also create substantial barriers to movement for some species, especially in combination with impacts from human development. Most of the valley bottom habitat has been converted to agricultural land use, especially northwards towards Armstrong and Enderby. The corridor of the Lumby Valley is also rurally and agriculturally developed, though to a considerably lesser extent than the Okanagan Valley. In many places there are tracts of extensive residential development, such as in the vicinity of Vernon, south of Hwy 6 in the Lumby Valley, and south of Wood Lake. Although there is relatively less development along the shorelines of Kalamalka and Wood Lakes the surrounding terrain is fairly rugged. Fine-scale habitat features such as riparian "stringers" around Otter Lake, and agricultural lands south of Armstrong and east of Swan Lake, may provide movement options for some species.

CONNECTIVITY FOCUS AREAS

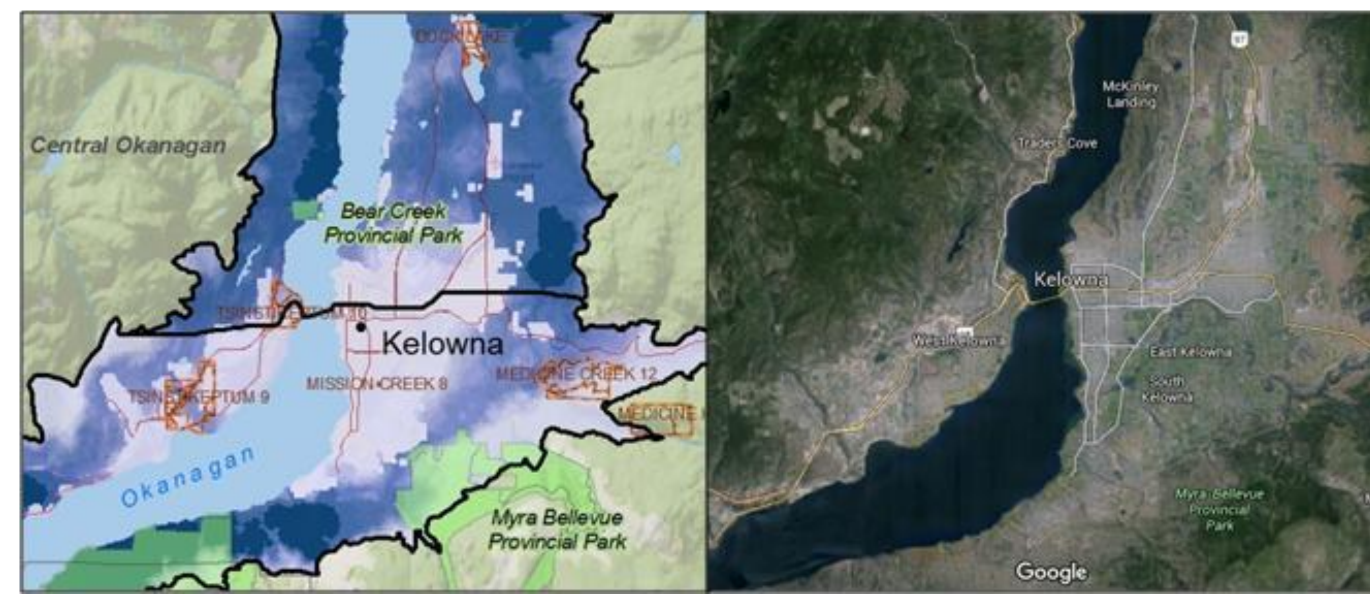
We identified several Connectivity Focus Areas (CFAs) within the fracture zone (Fig. 3). Places where all three perspectives overlap include three areas located north of Vernon near the end of Okanagan and Swan Lakes, and one at the entrance to the Lumby Valley. The areas north of Vernon are roughly located where the Okanagan Valley narrows, and may help maintain connectivity across the valley and provide an option for access to higher elevation sites under a changing climate. The area located near the entrance to the Lumby Valley, if lost, would make it more difficult to maintain north–south movement, especially for shrub-steppe species.

SHRUB-STEPPE PERSPECTIVE

A number of habitat concentration areas (HCAs) exist for shrub-steppe species within the fracture zone (Fig. 4). Due to the presence of major lakes that may create east–west movement barriers, maintaining north–south connectivity options are critical. From Vernon to Enderby most of the valley habitat has been converted to agricultural land use. There is one small HCA north of Vernon straddling the fracture zone boundary that may help provide connectivity in the future (given a changing climate) to shrub-steppe habitats in the northwest beyond our study area boundary. It may also be a future "stepping-stone" to the large HCA identified close to Merritt. However, this part of the fracture zone is near the edge of our study area boundary and we have not fully captured connectivity patterns here as we did not model HCAs further north.

A large HCA occurs west of Vernon but habitat access from this HCA is constrained by Okanagan Lake and development, both of which create sharp boundaries of resistance to movement. Two HCAs were mapped at the entrance to the Lumby Valley, but there are none in the valley itself. Ongoing development of agriculture and residential areas is a significant pressure here and maintaining functional connectivity between shrub-steppe habitats near Vernon will be difficult. The entrance to the Lumby Valley is one of the few places not intersected by a large water body and it is already heavily developed.

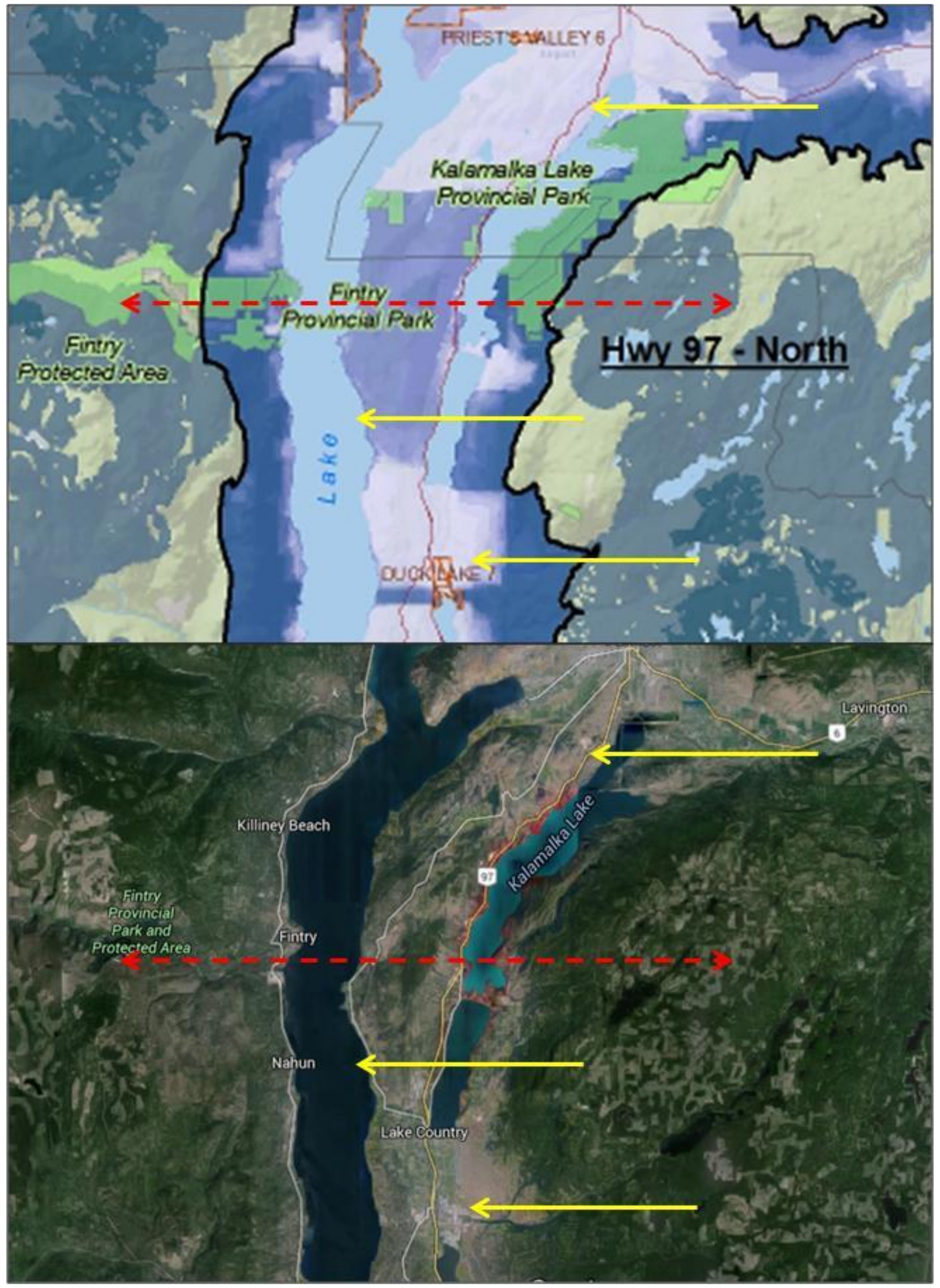
HCAs were identified along the eastern side of the Okanagan Valley and in the central part of the valley between Okanagan and Kalamalka Lakes. There is potential for movement between these HCAs, particularly along the mid-slopes of the main valley. Maintaining north–south connectivity at mid-slope is aided on the east side of the valley by Kalamalka Lake Provincial Park. Movement on the west side of the valley is more challenging as the HCAs near Vernon and those identified west of Kelowna are geographically far apart and the intervening landscape is open forest. Two HCAs were identified near Kelowna (see Close-up Example 1). One is located west of Okanagan Lake adjacent to Bear Creek Provincial Park, and the other is immediately northeast of Kelowna, near the fracture zone boundary. Development around Kelowna is a barrier to movement from these HCAs to the nearest HCAs south.



***Close-up Example 1.** (left) Close up of the shrub-steppe perspective map for the Hwy 97 North Fracture Zone (see Fig. 4) showing modeled HCAs and connectivity value of the landscape near Kelowna. (right) Aerial image of the same area showing urban development near Kelowna.*

MONTANE PERSPECTIVE

The main Okanagan Valley represents a significant barrier for east–west movement of montane species (Fig. 5). The area east of Enderby is an area within the fracture zone where there is connectivity to other subregions. Movement potential across the Lumby Valley, between HCAs to the north and south looks high, and is also an option for connectivity to areas beyond our study area boundary. This valley may be a location for pro-active conservation planning so that opportunities for connectivity are not lost. Throughout the fracture zone there are few places that stand out as potential options for east–west movement between HCAs. South of Vernon there is potential connectivity across the valley between two protected areas on either side of the fracture zone through Kalamalka Lake Park and Fintry Provincial Park (see Close-up Example 2), but both Okanagan Lake and Kalamalka Lake must be crossed. The shortest physical distance across the Okanagan Valley is just north of Vernon and Swan Lake, at the northern end of Okanagan Lake. If this area were more permeable it might provide access between HCAs to the west and those near Silver Star Provincial Park. The wide flat valley to the north of this area has few connectivity options highlighted in the model. However, finer-scale habitat features occur here that may provide important connectivity routes across the valley such as the riparian area leading to Otter Lake (see Close-up Example 3).

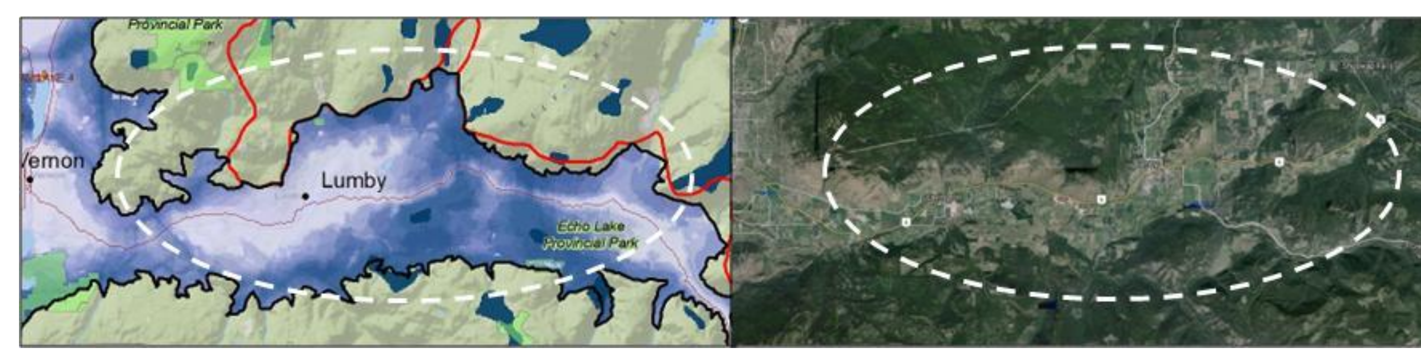


Close-up Example 2. *(top) Close-up of the montane species perspective map for the Hwy 97 North Fracture Zone (see Fig. 5) showing a potential area of connectivity between Kalamalka Lake Provincial Park and Fintry Provincial Park. (bottom) Aerial image of the same area. Yellow arrows on both panels point to resistance features that include Hwy 97, Okanagan Lake, and development near the town of Winfield. Red arrows on both panels indicate potential route for wildlife movement.*

Close-up Example 3. *Aerial view of the Hwy 97 North Fracture Zone showing area south of Armstrong and north of Otter Lake. Arrows indicate riparian habitat types that may provide connectivity options within areas that otherwise may have low permeability to movement.*

LANDSCAPE INTEGRITY PERSPECTIVE

HCAs are few, small, and far apart in this fracture zone, illustrating the extent of general habitat fragmentation (Fig. 6). The potential for east–west movement is limited in the area between Vernon and Kelowna. Similar to the montane perspective, the potential for east–west connectivity occurs between the two protected areas on either side of the fracture zone (through Kalamalka Lake Park and Fintry Provincial Park), but again, both Okanagan Lake and Kalamalka Lake must be crossed. The large HCA northwest of Vernon was also identified by the shrub-steppe model. However, this HCA is bounded to the west by Okanagan Lake and to the east by the development surrounding Vernon. There is potential for north–south movement at the eastern end of the Lumby Valley that would provide connectivity to the adjacent subregion, although Hwy 6 is an issue (see Close-up Example 4).



Close-up Example 4. *(left) Close-up of the landscape integrity perspective map for the Hwy 97 North Fracture Zone (see Fig. 6) showing connectivity value of habitat in the Lumby Valley. (right) Aerial image of the same area. Dashed ovals indicate same approximate location.*

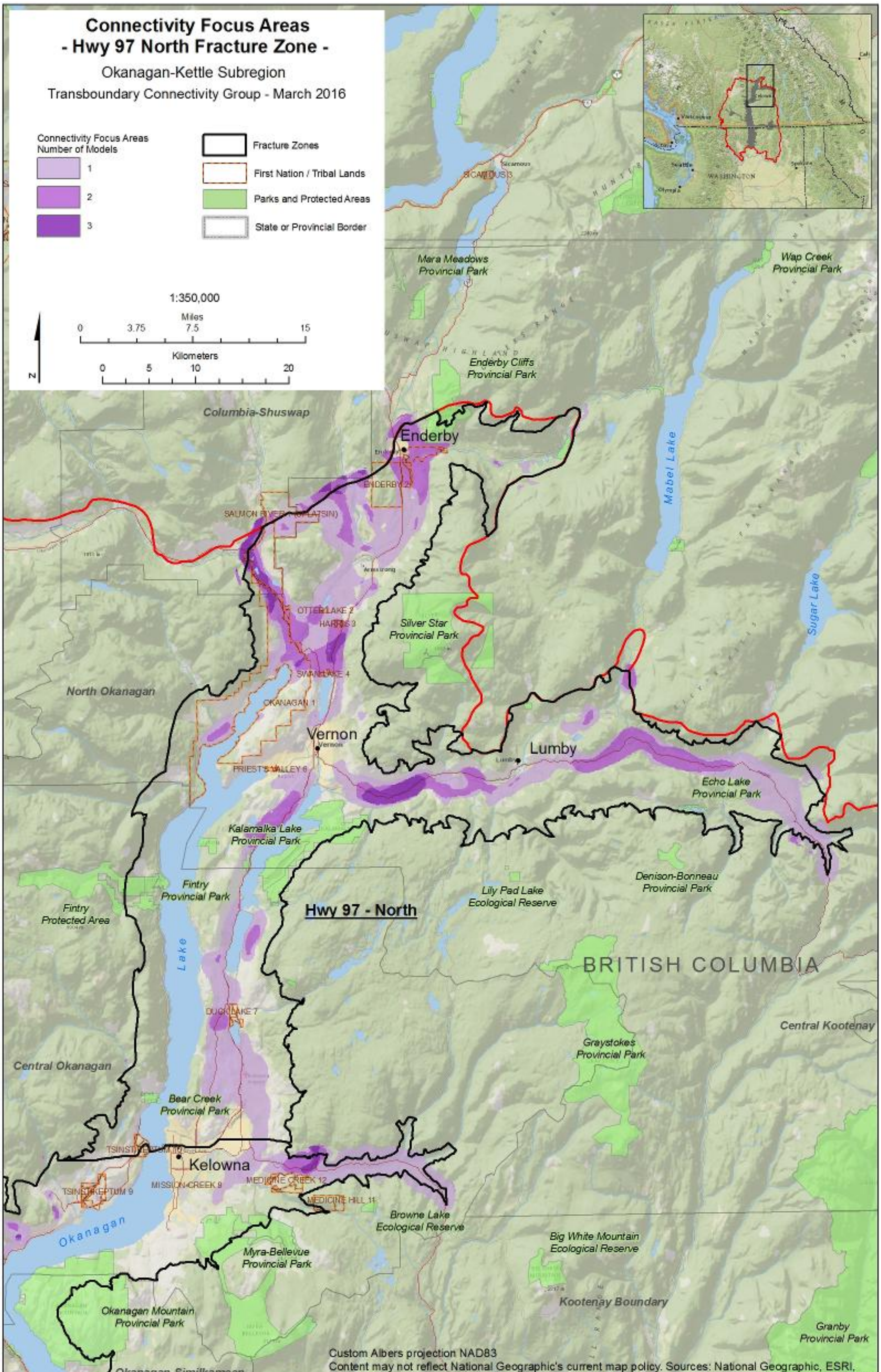


Figure 3. Connectivity Focus Areas (CFAs) identified for shrub-steppe species, montane species, and landscape integrity models for the Hwy 97 North Fracture Zone.

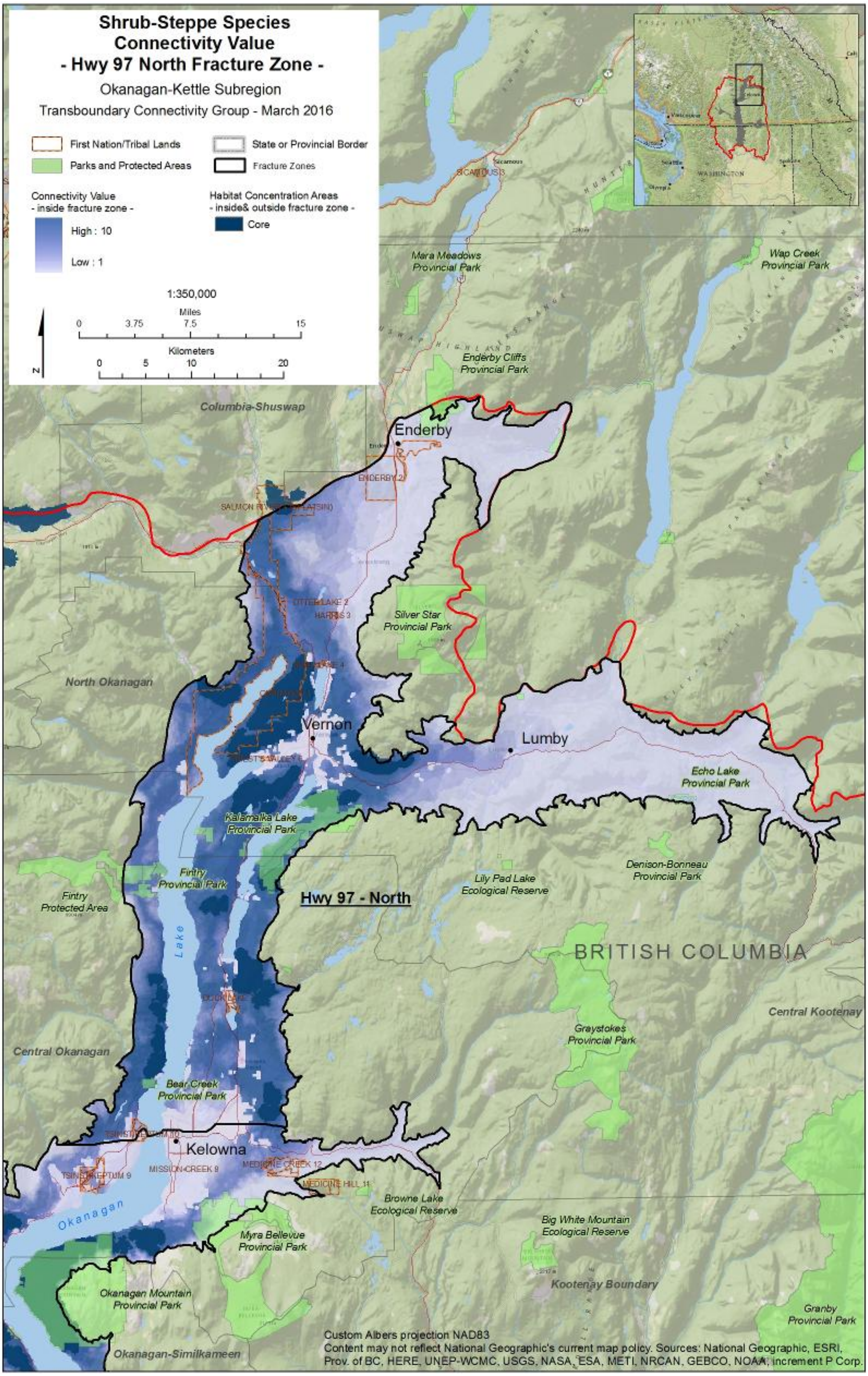


Figure 4. Connectivity value of habitat for shrub-steppe species for the Hwy 97 North Fracture Zone.

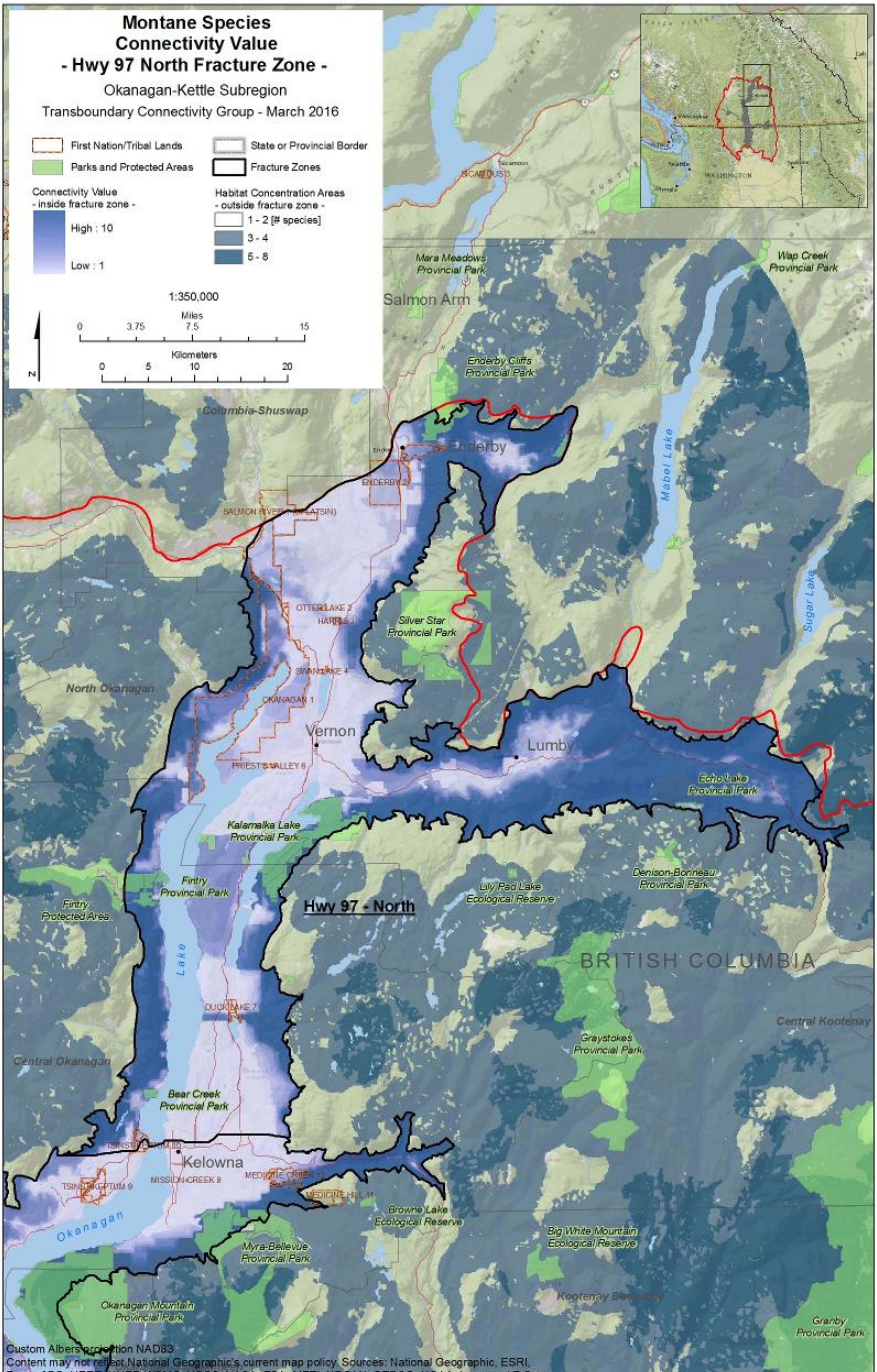


Figure 5. Connectivity value of habitat for montane species for the Hwy 97 North Fracture Zone.

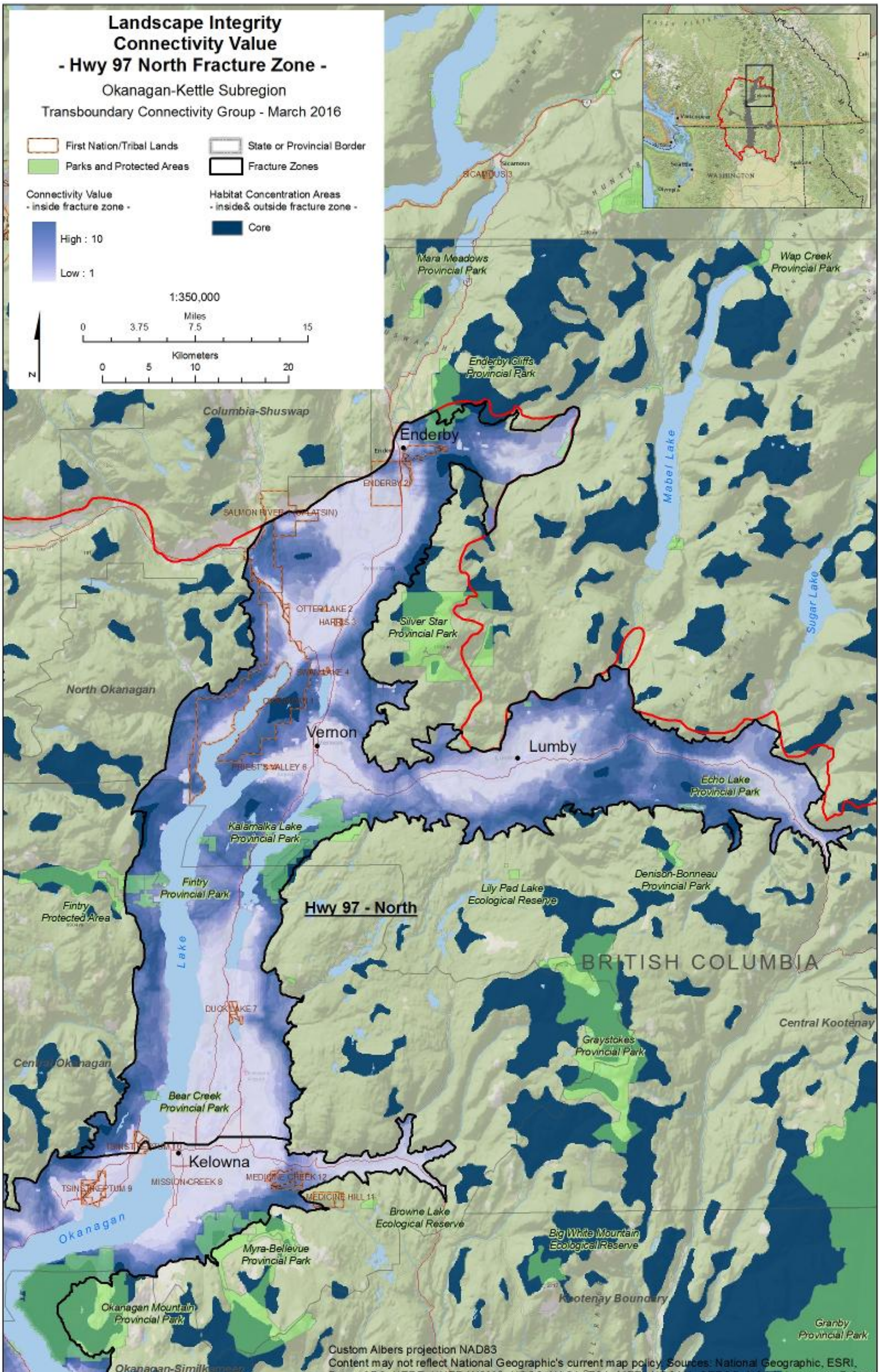
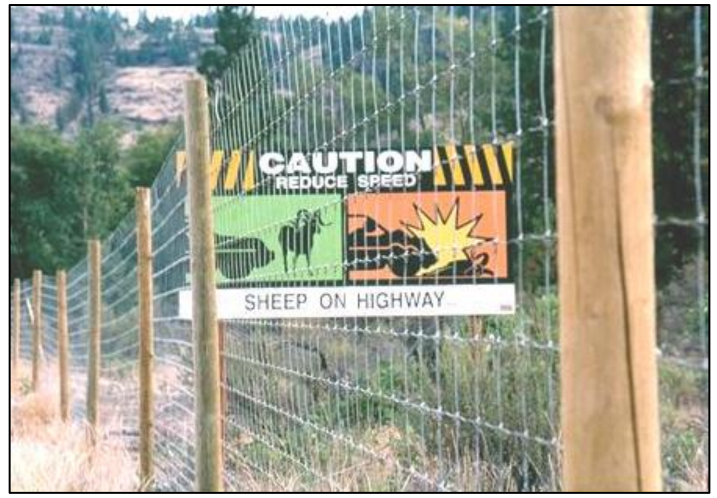


Figure 6. Connectivity value of habitat for landscape integrity for the Hwy 97 North Fracture Zone.

Hwy 97 Central Fracture Zone

This fracture zone extends from Kelowna south to Osoyoos at the Canada/US border (Fig. 1). Factors creating resistance to wildlife movement include Hwy 97, Hwy 3, development associated with the communities of Peachland, Summerland, Penticton, Okanagan Falls, Oliver, and Osoyoos, Okanagan Lake, and rugged terrain. Extensive development associated with Kelowna and Penticton creates barriers to movement. The area around Osoyoos is extensively developed as well as the area between Okanagan and Skaha Lakes. Vineyard development is rapidly occurring in many areas and much of the arable land has been converted. Wildlife fencing along portions of Hwy 97, and fencing associated with agriculture create local-scale impediments to movement of wildlife.



Wildlife fencing along Hwy 97 in BC. Photo by Peter Singleton.

CONNECTIVITY FOCUS AREAS

We identified several Connectivity Focus Areas (CFAs) within or bordering this fracture zone (Fig. 7). Many of the places we identified in the study area where CFAs for all three perspectives overlapped were located within this zone. Loss of CFAs in this part of the Okanagan Valley would impact movement potential across the Okanagan Valley, and to the four adjacent fracture zones.

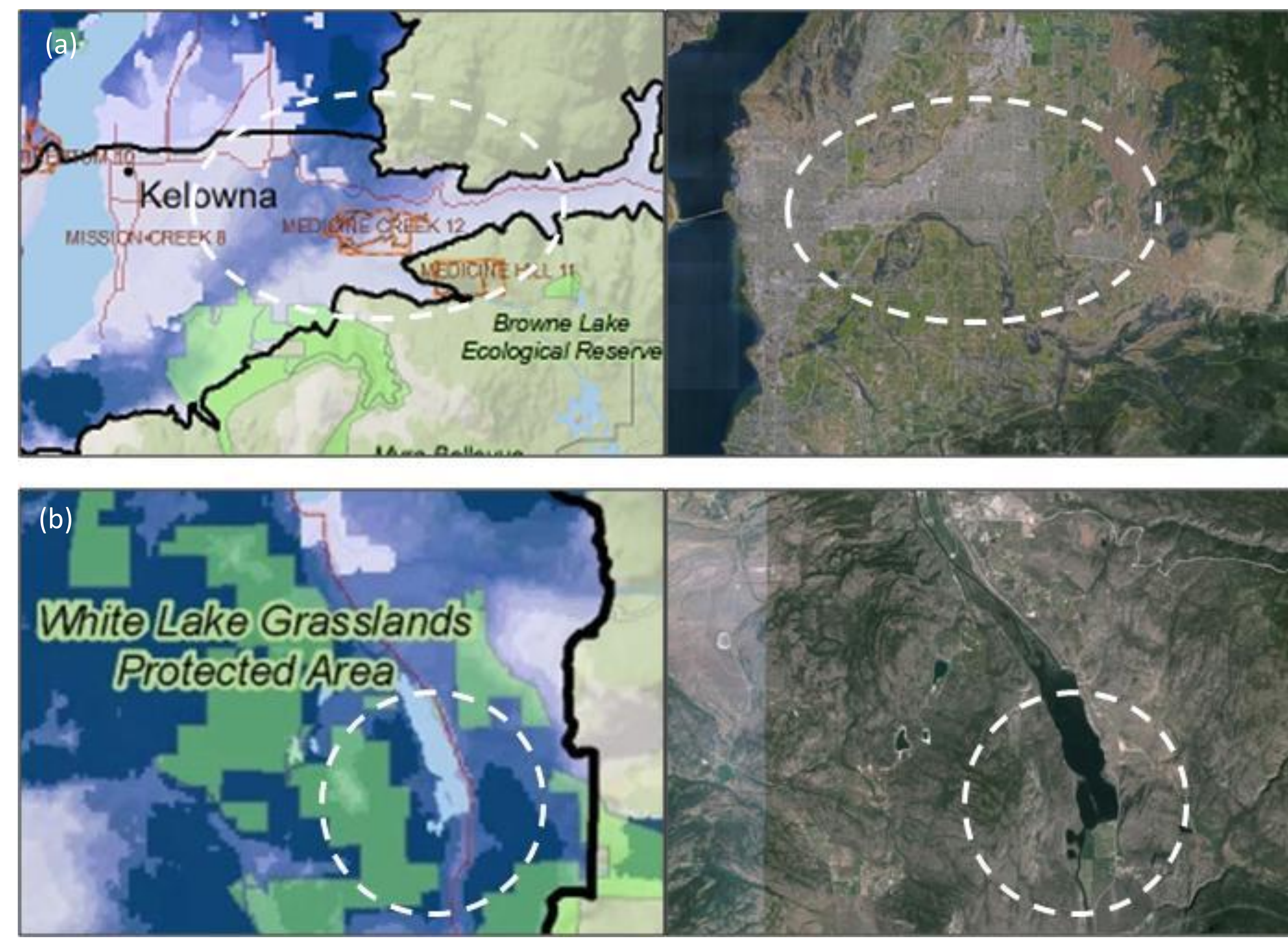
Twelve overlap areas (all three perspectives) were clustered between Penticton and Osoyoos, illustrating the ongoing expansion of development in this part of the valley. Development around Kelowna is a significant barrier to movement, and the area of overlap identified to the east is the last option for connecting to shrub-steppe HCAs to the north (see Fig. 7 and Close-up Example 5). The two areas of overlap near the side valley west of Okanagan Lake, opposite Okanagan Mountain Provincial Park, are threatened by increasing development associated with Peachland and West Kelowna. The side valleys connecting to the Okanagan Valley proper may serve as routes for species to access newly suitable habitat as the climate changes. The overlapping CFAs between Penticton and Osoyoos tend to follow the Okanagan River and the west side of the Okanagan Valley. Several are located near or adjacent to White Lake Grasslands Protected Area and the South Okanagan Grasslands Protected Area. Overlapping CFAs were also identified near the entrance to the Similkameen Valley and near Osoyoos close to the International Border.

SHRUB-STEPPE PERSPECTIVE

There are numerous habitat concentration areas (HCAs) identified for shrub-steppe species within this fracture zone (Fig. 8). The area around Kelowna acts as a barrier to movement between these HCAs and those identified in the Hwy 97 North Fracture Zone (see Close-up Example 5). Access to HCAs in the Hwy 3 West Fracture Zone is highly constrained at the fracture zone boundary by rugged terrain and development surrounding Keremeos. HCAs to the west and southeast of Osoyoos straddle the International Border and extend into the Hwy 97 South Fracture Zone, providing opportunities for north–south movement and access to HCAs in the Hwy 3 East Fracture Zone.

Movement between HCAs within the fracture zone is constrained due to significant ongoing development. There is opportunity for north–south movement in the central and western parts of the valley, and in the eastern part through the HCA near Okanagan Mountain Provincial Park. However, development forms a barrier to movement north of the park and movement south is constrained by forested habitat in addition to rugged terrain. This potentially isolates Okanagan Mountain Park, reducing its function as a connectivity pathway for shrub-steppe species.

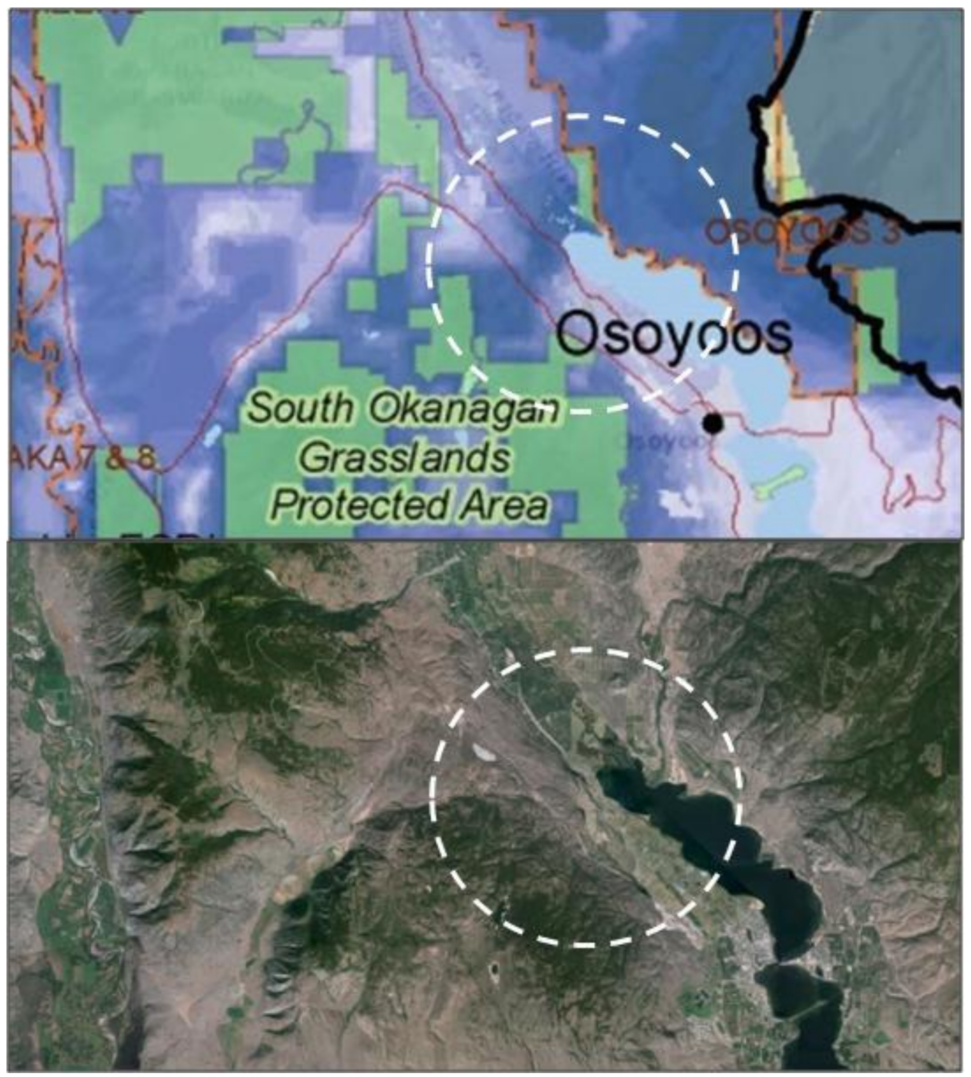
There may be a possibility of linking shrub-steppe HCAs on either side of Hwy 97 south of Vaseux Lake (see Close-up Example 5) but movement is constrained by the highway, vineyards, and steep terrain. In general, the "best" options for east–west connectivity likely exist in the southern portion of the fracture zone. Although the combined influence of roads, development, agriculture, etc., constrains habitat access between HCAs in this region, the HCAs are reasonably extensive and often overlap existing protected areas and conservation lands. For example, Osoyoos Oxbows, at the north end of Osoyoos Lake, may be a connectivity option, as well as the area south of Vaseux Lake. The area immediately northeast of Osoyoos is important for north–south connectivity, but opportunities for movement are rapidly being lost due to increasing development. North–south movement between HCAs west of Osoyoos is constrained by Hwy 3.



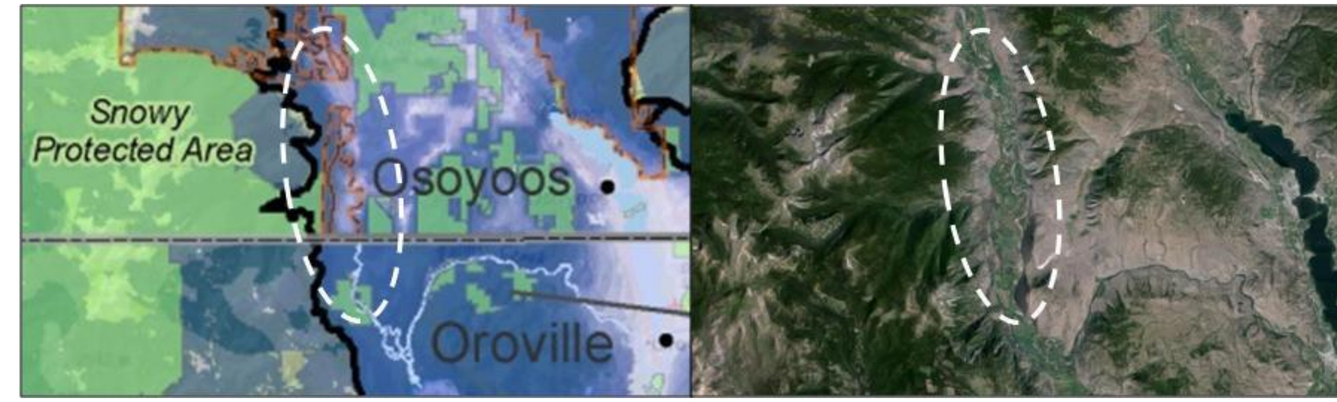
Close-up Example 5. *Close-ups of the shrub-steppe perspective map for the Hwy 97 Central Fracture Zone (see Fig. 8) and corresponding aerial images of the same areas. Dashed ovals indicate same approximate location. (a) Area east of Kelowna. (b) Area south of Vaseux Lake.*

MONTANE PERSPECTIVE

We identified many large HCAs outside the fracture zone boundary (Fig. 9). Within the main Okanagan Valley there is potential for north–south movement following higher elevation areas located above existing development. East–west movement is more challenging. North of Penticton, Okanagan Lake may be a significant barrier for species unable or reluctant to swim across. Between Penticton and Osoyoos, the areas around Skaha and Vaseux Lakes, and conservation lands associated with White Lake Grasslands Protected Area, may provide connectivity options. The Osoyoos Oxbows may also serve as an east–west linkage across wetlands and on through Haynes' Lease Ecological Reserve (see Close-up Example 6). However, there are steep slopes to the north and orchards on the east side. Habitat along the east side of the Okanagan Valley linking reserve lands is narrow and threatened by development near Osoyoos. East of Osoyoos development creates a barrier to north–south movement between this fracture zone and the Hwy 97 South Fracture Zone. The Similkameen Valley provides connectivity along the western side of the fracture zone boundary linking conservation lands north and south of the US/Canada border (see Close-up Example 7).



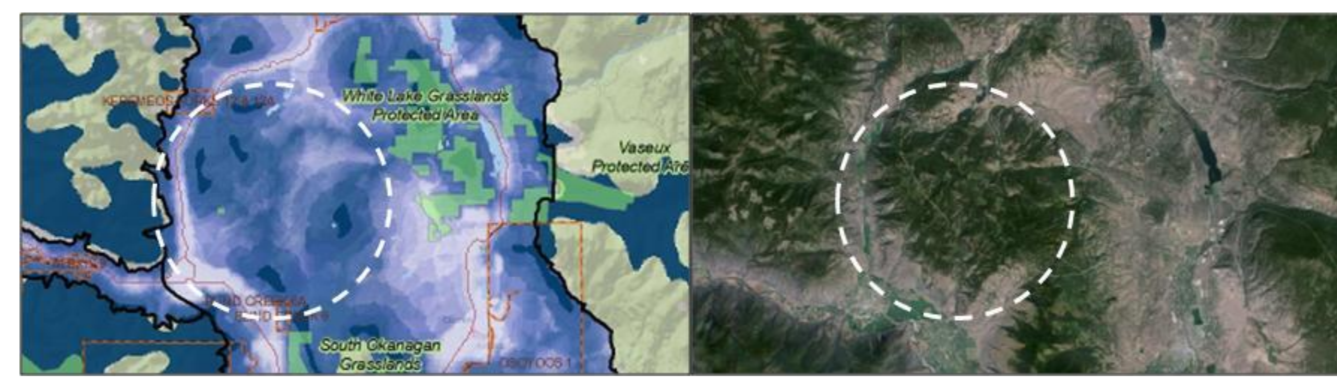
Close-up Example 6. *(top) Close-up of the montane perspective map for the Hwy 97 Central Fracture Zone (see Fig. 9), showing the Osoyoos Oxbows, north of Osoyoos Lake. (bottom) Aerial image of the same area. Dashed circles indicate approximately the same location.*



Close-up Example 7. *Close-up of the montane perspective map for the Hwy 97 Central Fracture Zone (see Fig. 9). (left) Similkameen Valley. (right) Aerial image of the same area. Dashed ovals indicate same approximate location.*

LANDSCAPE INTEGRITY PERSPECTIVE

The landscape integrity perspective highlights some of the connectivity conservation issues associated with this zone (Fig. 10). While the shrub-steppe perspective identified a fairly large number of HCAs, the landscape integrity analysis shows there are actually very few large intact patches of habitat within the fracture zone. Most landscape integrity HCAs are found outside the fracture zone. Locations where the shrub-steppe and landscape integrity HCAs align may be particularly important, suggesting the potential for functionally large habitat patches. The combined impact of highways, development, and agriculture acts to constrain movement within the valley bottom and near transportation corridors. Clusters of HCAs occur west of White Lakes Grasslands Protected Area and north of South Okanagan Grasslands Protected Area (see Close-up Example 8). Maintaining or restoring connectivity among these HCAs and nearby conservation lands should be considered.



Close-up Example 8. *(left) Close-up of the landscape integrity perspective map for the Hwy 97 Central Fracture Zone (see Fig. 10) showing a cluster of HCAs west of White Lakes Grasslands Protected Area. (right) Aerial image of the same area. Dashed ovals indicate approximately the same location.*

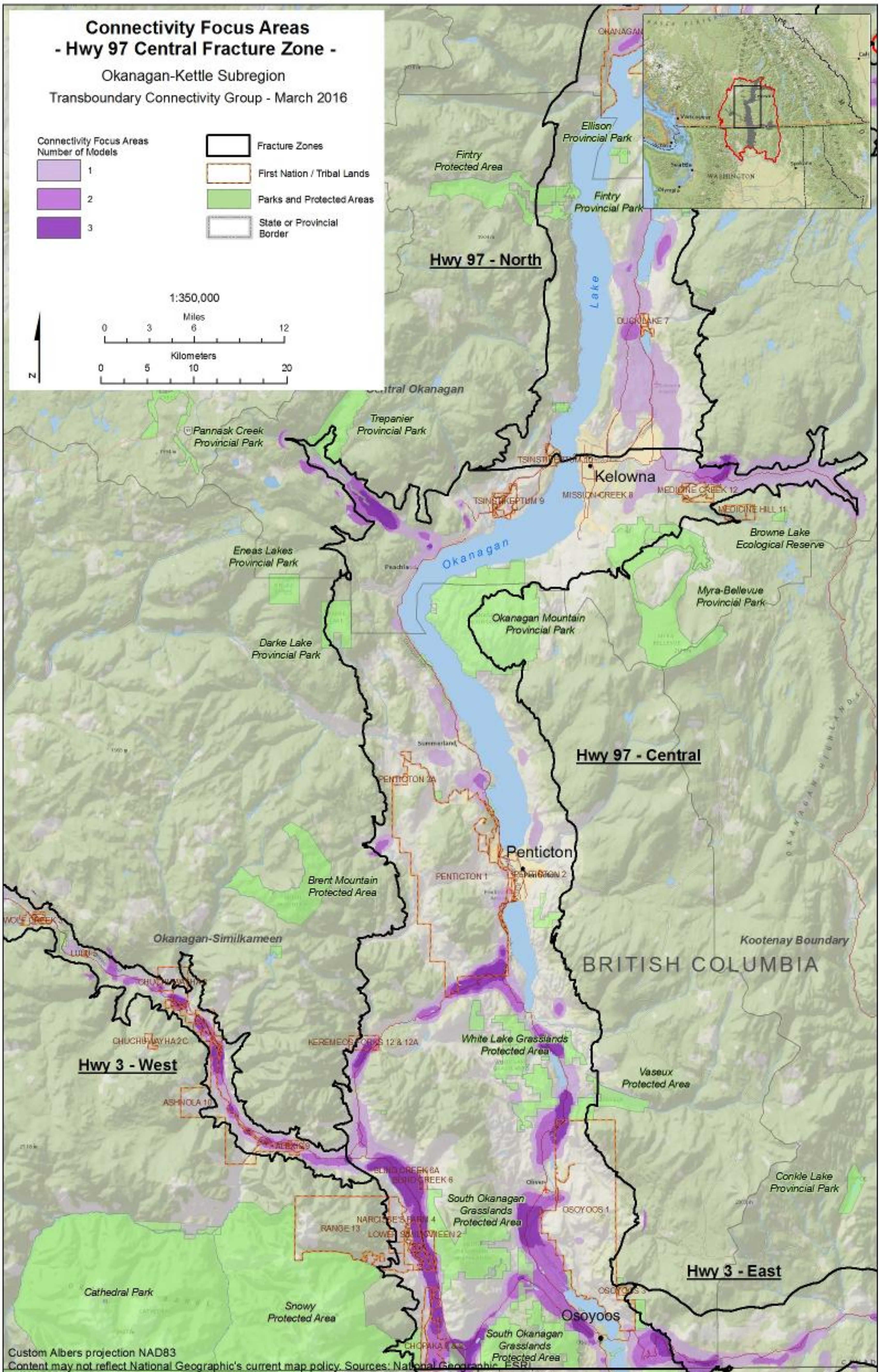


Figure 7. Connectivity Focus Areas (CFAs) identified for shrub-steppe species, montane species, and landscape integrity models for the Hwy 97 Central Fracture Zone.

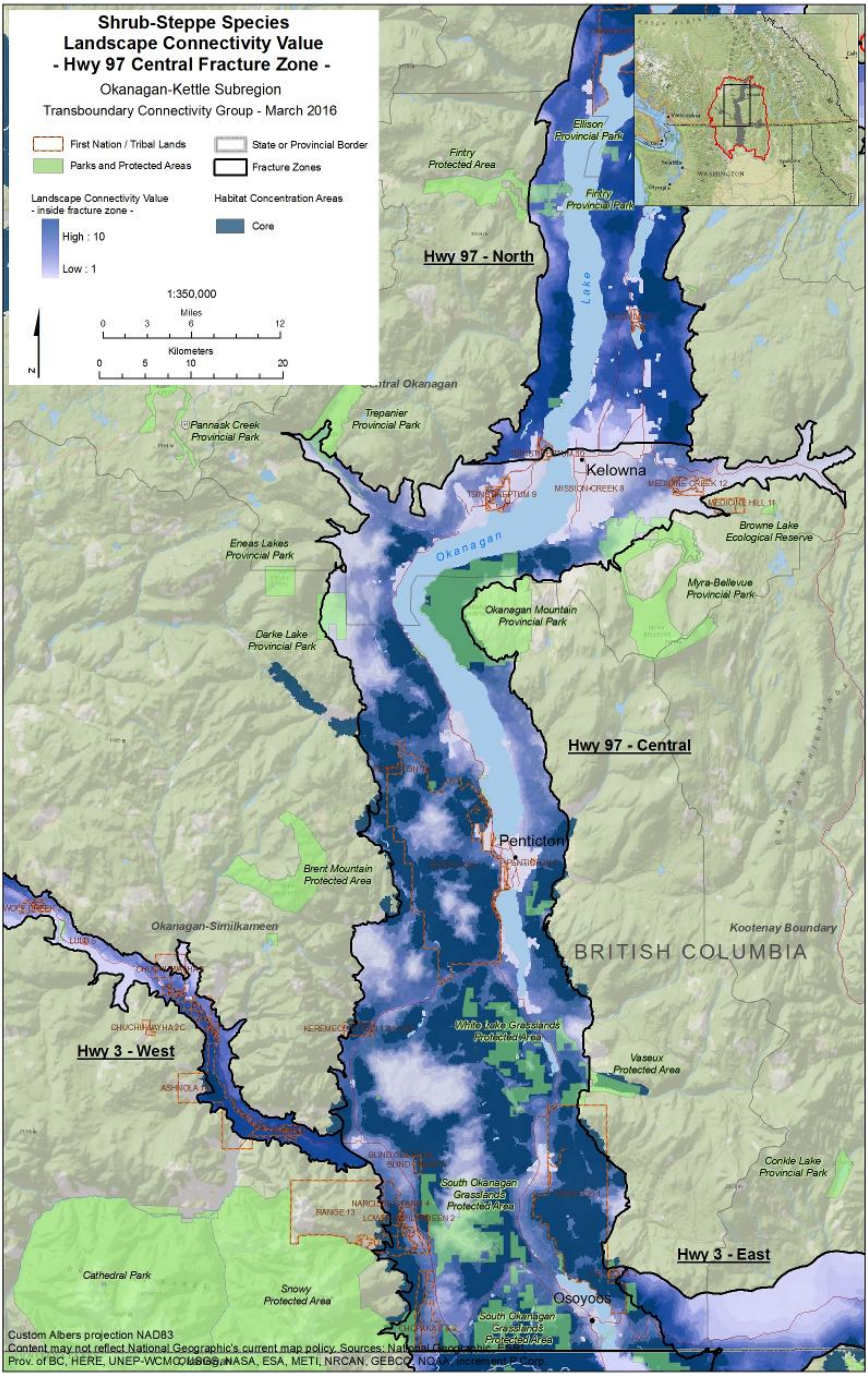


Figure 8. Connectivity value of habitat for shrub-steppe species for the Hwy 97 Central Fracture Zone.

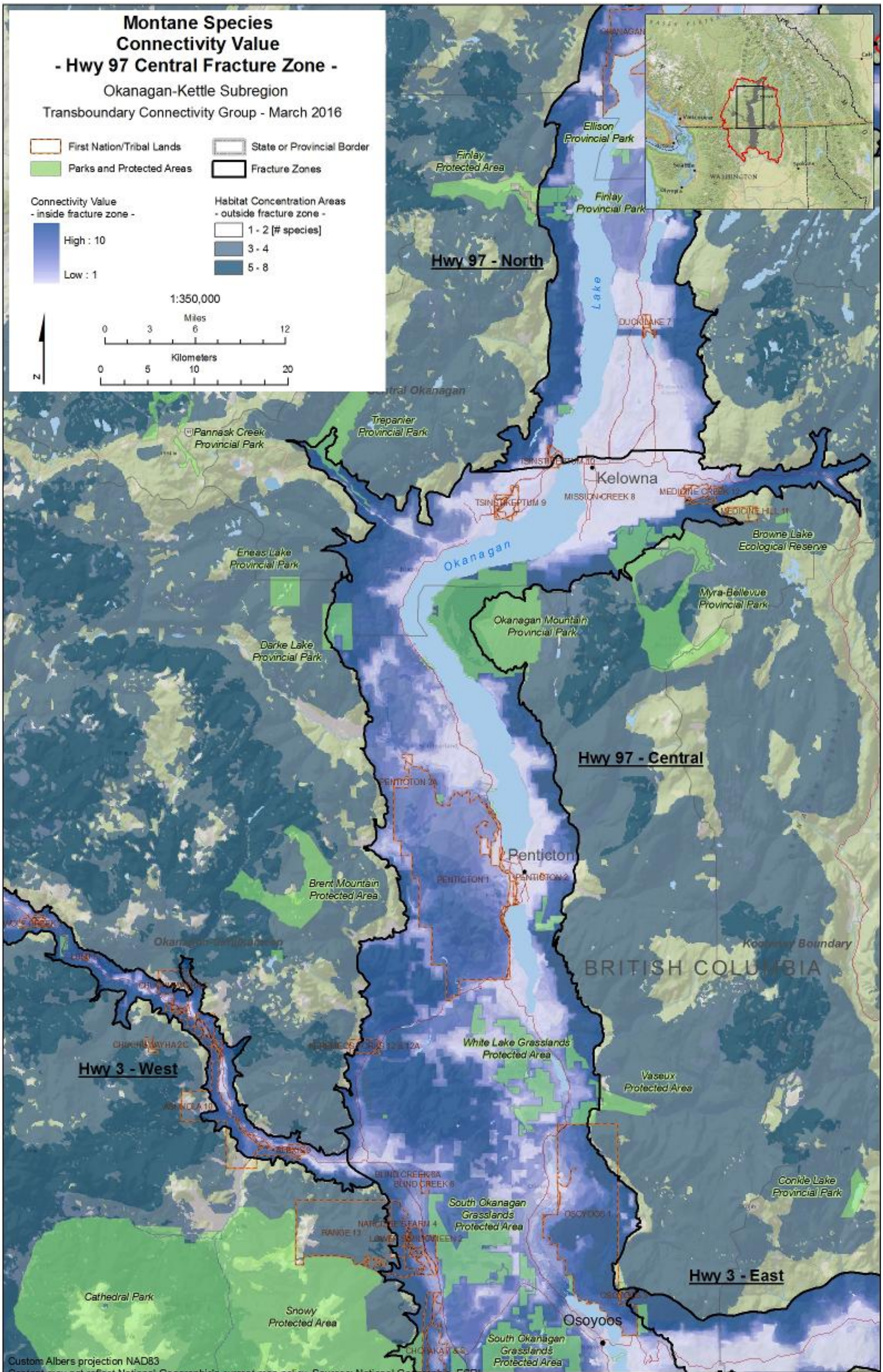


Figure 9. Connectivity value of habitat for montane species for the Hwy 97 Central Fracture Zone.

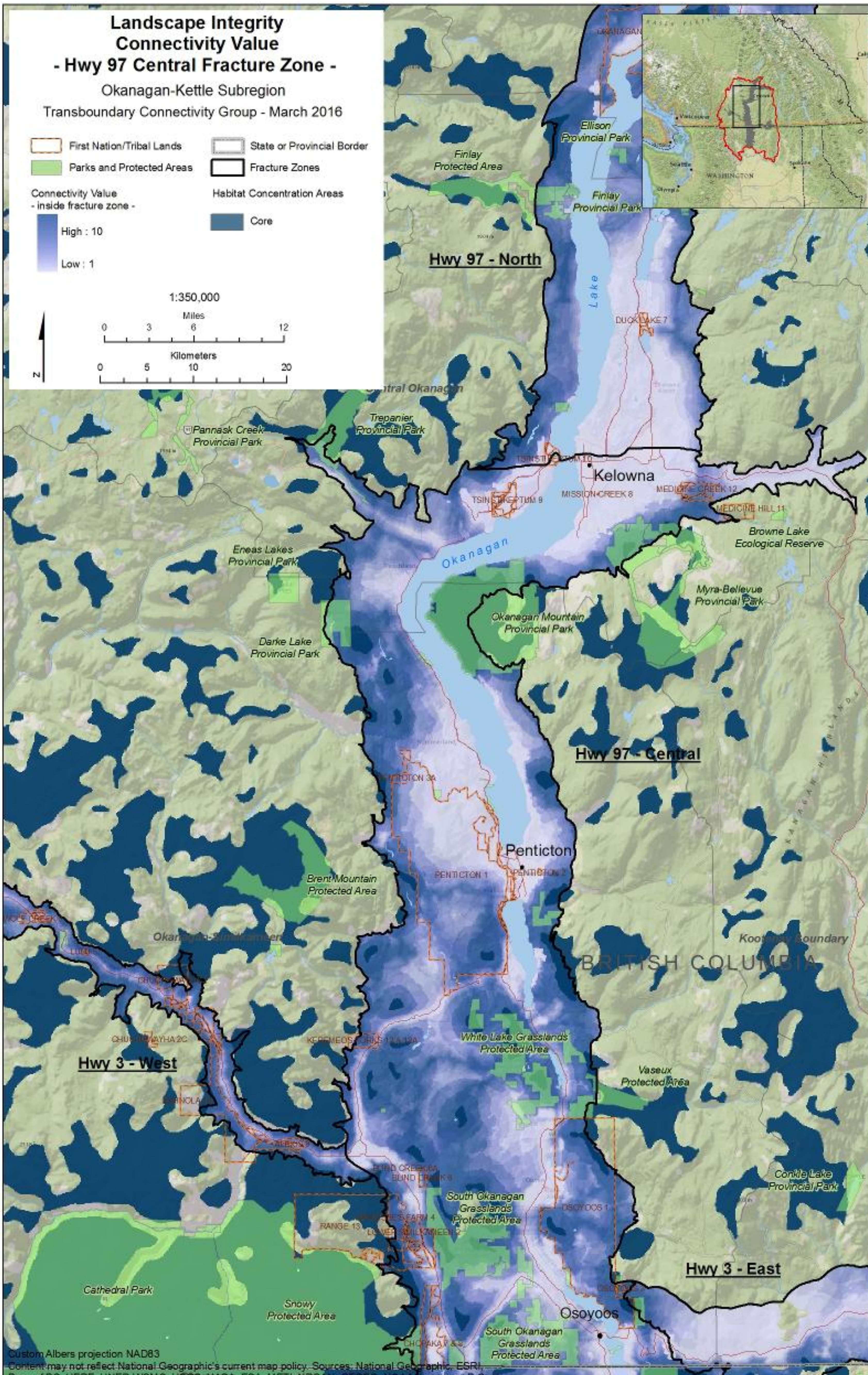


Figure 10. Connectivity value of habitat for landscape integrity for the Hwy 97 Central Fracture Zone.

Hwy 97 South Fracture Zone

This fracture zone extends from the Canada/US border south to the vicinity of the city of Omak, WA (Fig. 1). The valley is wider here and urban development less intense than on the Canadian side of the border. Features that make it more difficult for animals to move through the landscape include Hwy 97, development associated with the communities of Oroville, Tonasket, and Omak, agriculture lands, and cliffs and steep slopes. The Hwy 97 transportation corridor has been identified by other analyses as an important feature limiting wildlife movement (WHCWG 2010, 2013). To the west near Loomis, Spectacle Lake and adjacent agriculture lands create a very narrow fracture to north–south movement of montane species. The Similkameen River Valley is an option for north–south movement. Opportunities for east–west movement across the valley are constrained by Hwy 97 and associated development. The best potential for east–west connectivity is near Riverside (area north of Omak) and near Mt Hull (located south of Oroville). The Mt Hull area, while a possibility for some species, is dissected by steep terrain.

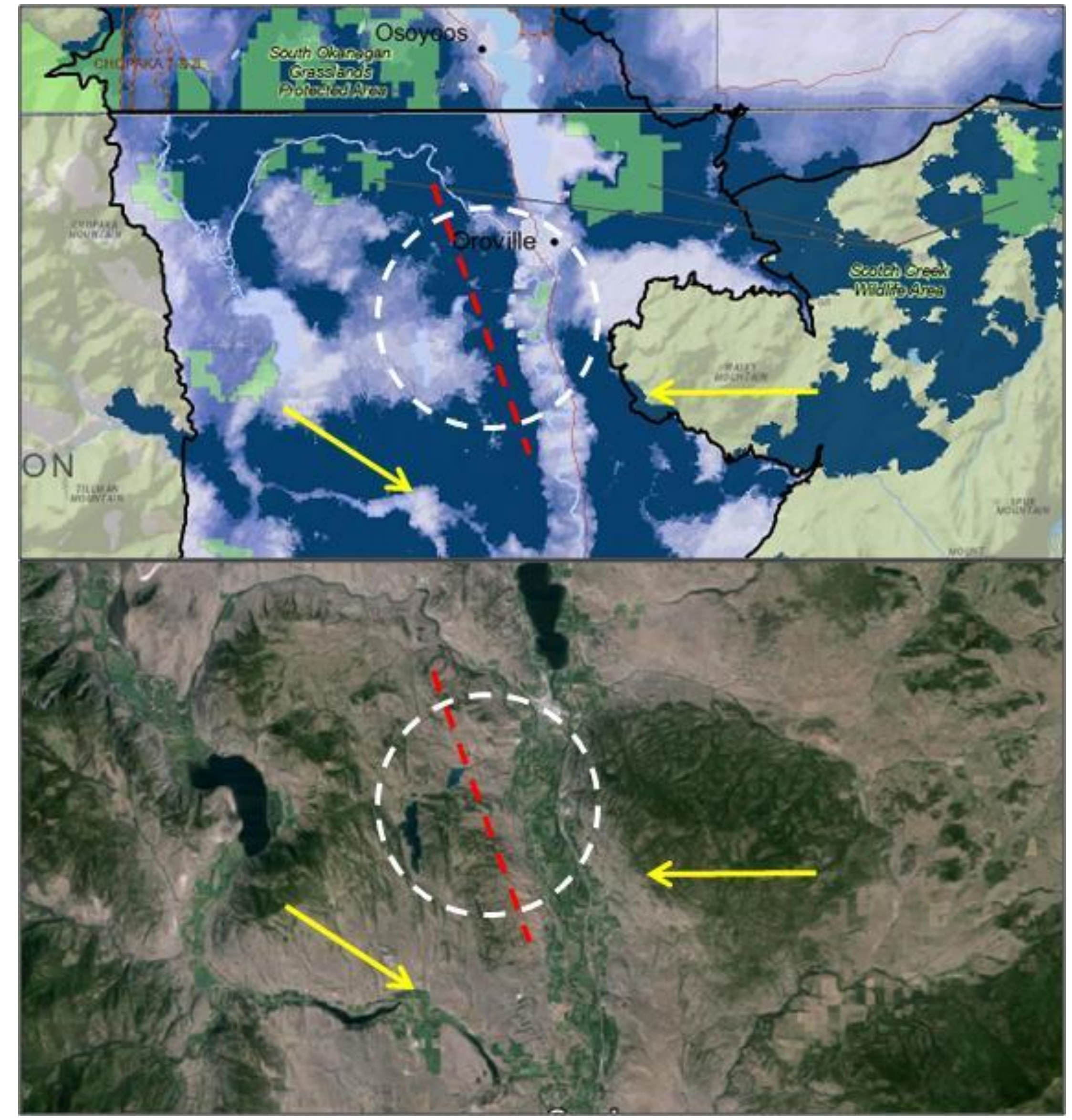
Hwy 97 south of Oroville near Mt Hull. Photo by Peter Singleton.

CONNECTIVITY FOCUS AREAS

We identified Connectivity Focus Areas located along the Hwy 97 transportation corridor and the side valleys to the east of Omak and Tonasket. Areas where the CFAs for all three perspectives overlapped were identified near Riverside and south of Oroville (Fig. 11, see also Close-up Examples 9, 10).

SHRUB-STEPPE PERSPECTIVE

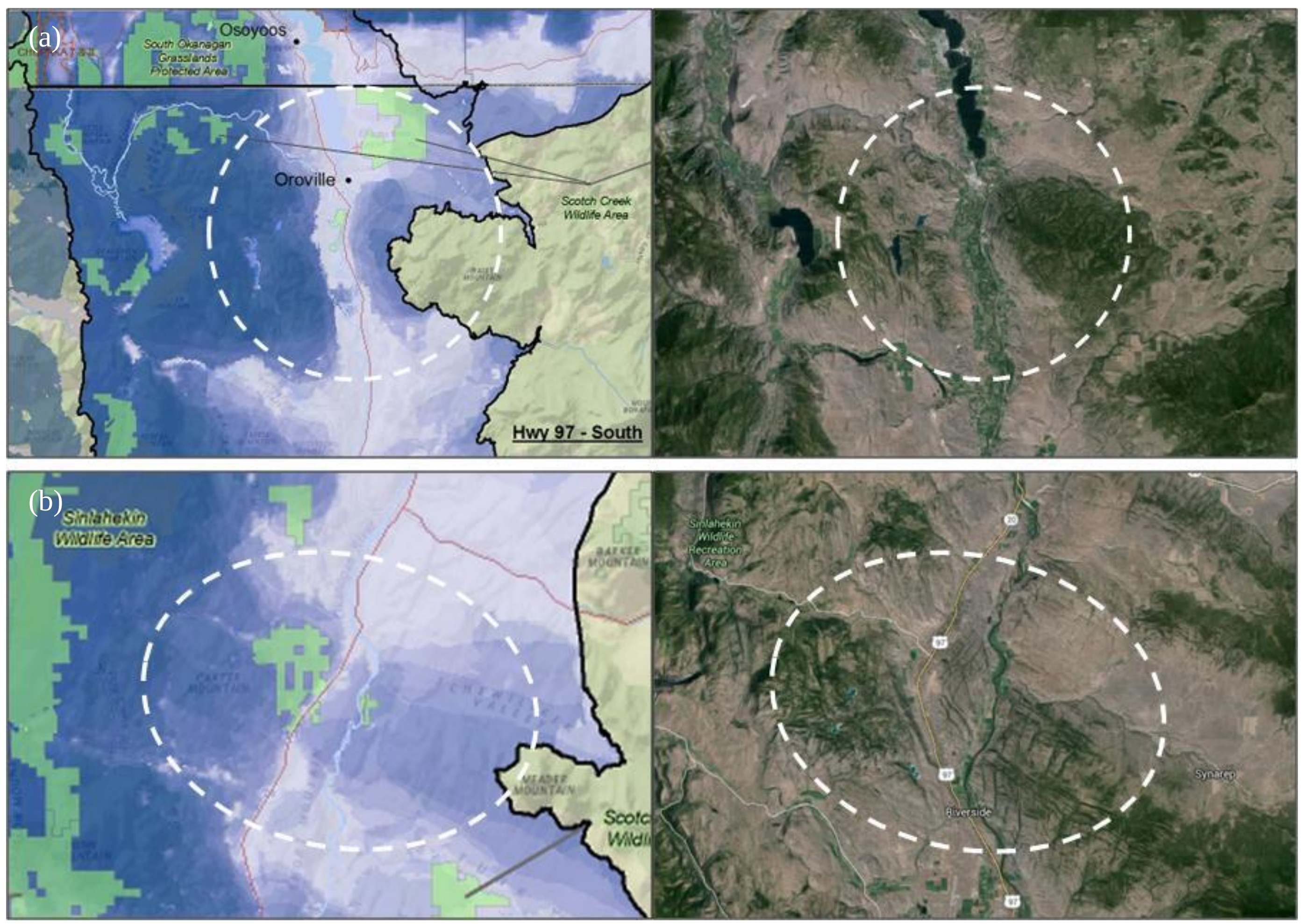
We identified several large habitat concentration areas (HCAs) within this fracture zone (Fig. 12). This is partly because there is relatively more shrub-steppe habitat found here than in other portions of the study area, and there is less urban development and fewer people. Additionally, because cattle ranching is a common land use, large tracts of shrub-steppe habitat have remained relatively intact. Although the HCAs are close together the intervening landscape is dominated by development, roads, forested habitats, and/or rugged terrain. The potential for north–south movement of shrub-steppe species is greater along the eastern side of the fracture zone, as the HCAs are more contiguous and extend south into the Columbia Plateau, and northeast following higher elevation drainages. The area south of Oroville may be an area of concern as access to HCAs in BC follows a relatively narrow portion of an HCA on the west side of the valley (see Close-up Example 9). A large HCA west of Osoyoos and Oroville straddles the International Border, facilitating north–south connectivity.



Close-up Example 9. *Close-up of the shrub-steppe perspective map for the Hwy 97 South Fracture Zone (see Fig. 12). (top) Narrowing of habitat concentration area (HCA) on the west side of the valley. (bottom) Aerial image of the area shown in top panel. Dashed circles indicate approximately the same location. Dashed red lines indicate the narrow part of the HCA. Yellow arrows indicate the sharp boundary around HCAs created by features that constrain movement.*

MONTANE PERSPECTIVE

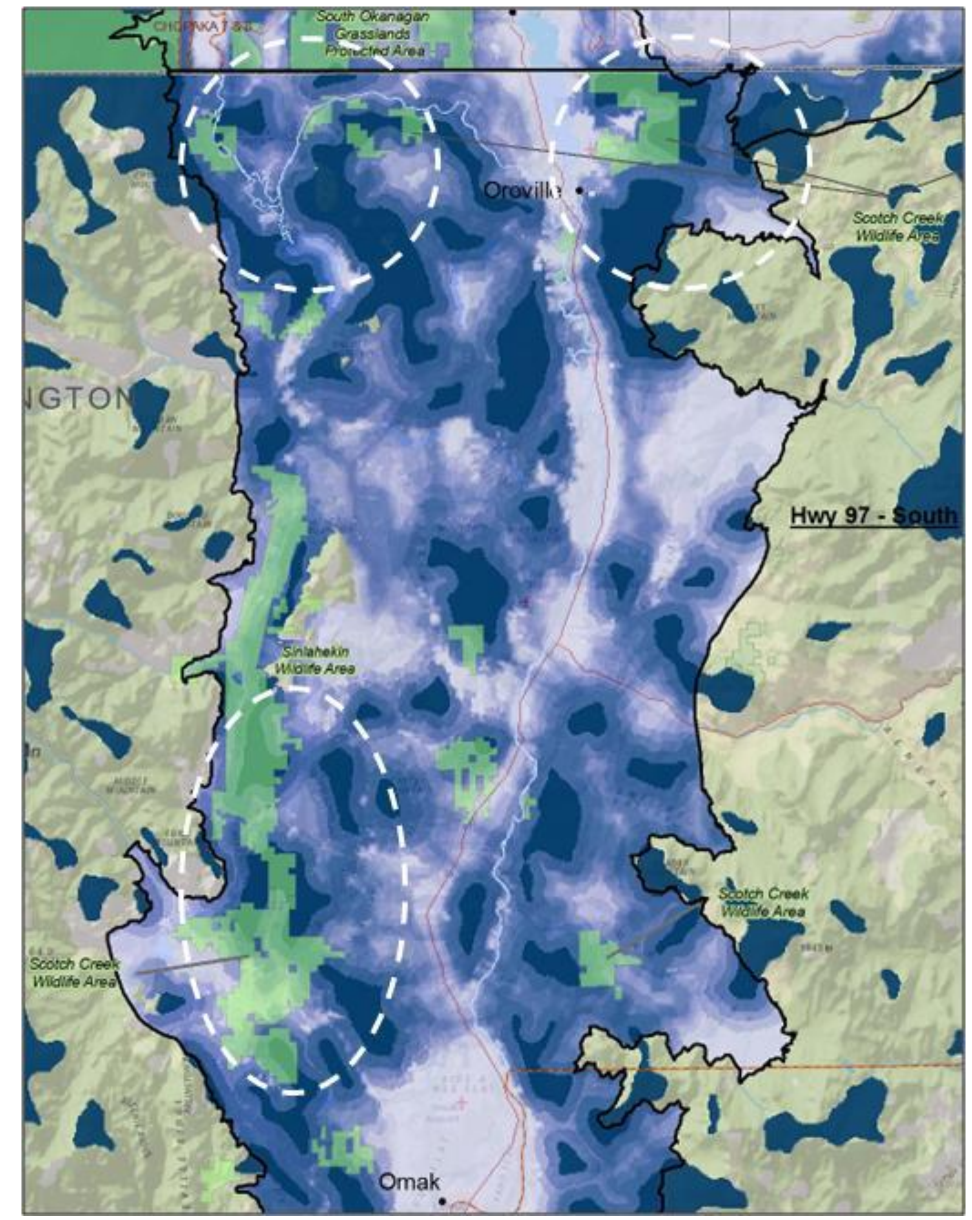
Large HCAs flank this fracture zone to the west, but are relatively far away on the eastern side of the zone (Fig. 13) and consequently the connectivity value of habitat is generally higher on the west side, simply because it is closer to the nearest HCAs. The connectivity value of the central part of the valley is low due to the presence of Hwy 97 and associated urban and agricultural development. Movement options for east–west connectivity are limited to the area immediately south of Oroville, and to the area near Riverside (see Close-up Example 10). The Riverside area (north of Omak) is the only potential option for connectivity between the Cascade Range in the US and the Kettle Range and Monashee Mountains to the east and north. In the vicinity of Loomis, the Loomis-Oroville road runs east–west along the valley. In addition to the road, barrier features include two lakes and agriculture development.



Close-up Example 10. *Close-ups of the montane perspective map for the Hwy 97 South Fracture Zone (see Fig. 13) and corresponding aerial images. Dashed ovals indicate approximately the same area for each panel. (a) The area south of Oroville, near Mt Hull. (b) The area near Riverside (north of Omak).*

LANDSCAPE INTEGRITY PERSPECTIVE

Large landscape integrity HCAs exist to the west of the fracture zone boundary, reflecting the large tracts of public lands (Fig. 14). There are several fairly large HCAs within the fracture zone, especially in the northern portion. The connectivity value of areas between HCAs is relatively low, and the Hwy 97 transportation corridor stands out as a barrier feature to east–west movement. In the northern part of the zone and in the vicinity of Omak, several of the HCAs are located near existing protected areas (see Close-up Example 11).



Close-up Example 11. *Close up of the landscape integrity perspective map for the Hwy 97 South Fracture Zone (see Fig. 14). Dashed ovals indicate areas within the fracture zone where habitat concentration areas (HCAs) occur near wildlife areas (green shaded polygons).*

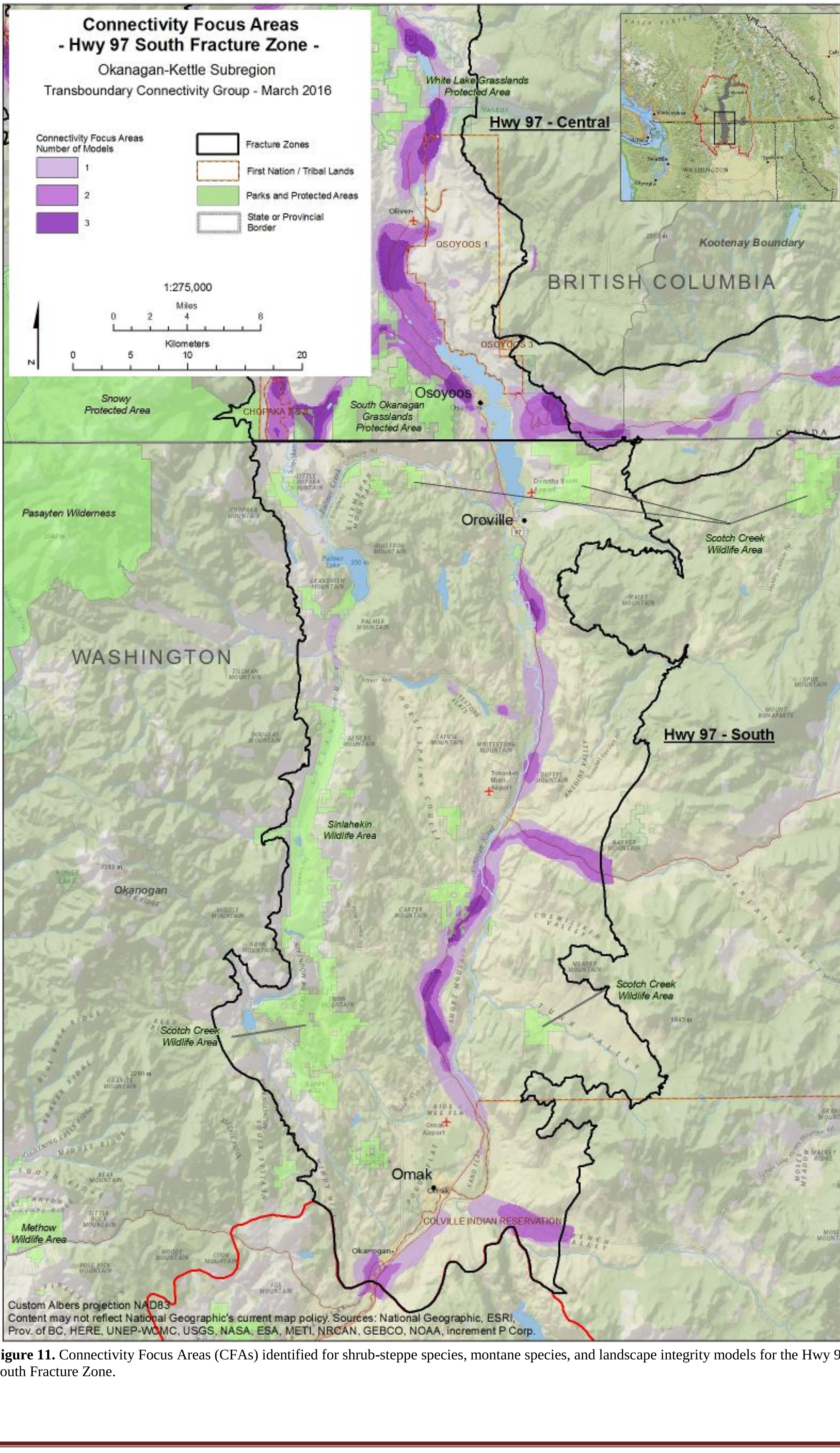


Figure 11. Connectivity Focus Areas (CFAs) identified for shrub-steppe species, montane species, and landscape integrity models for the Hwy 97 South Fracture Zone.

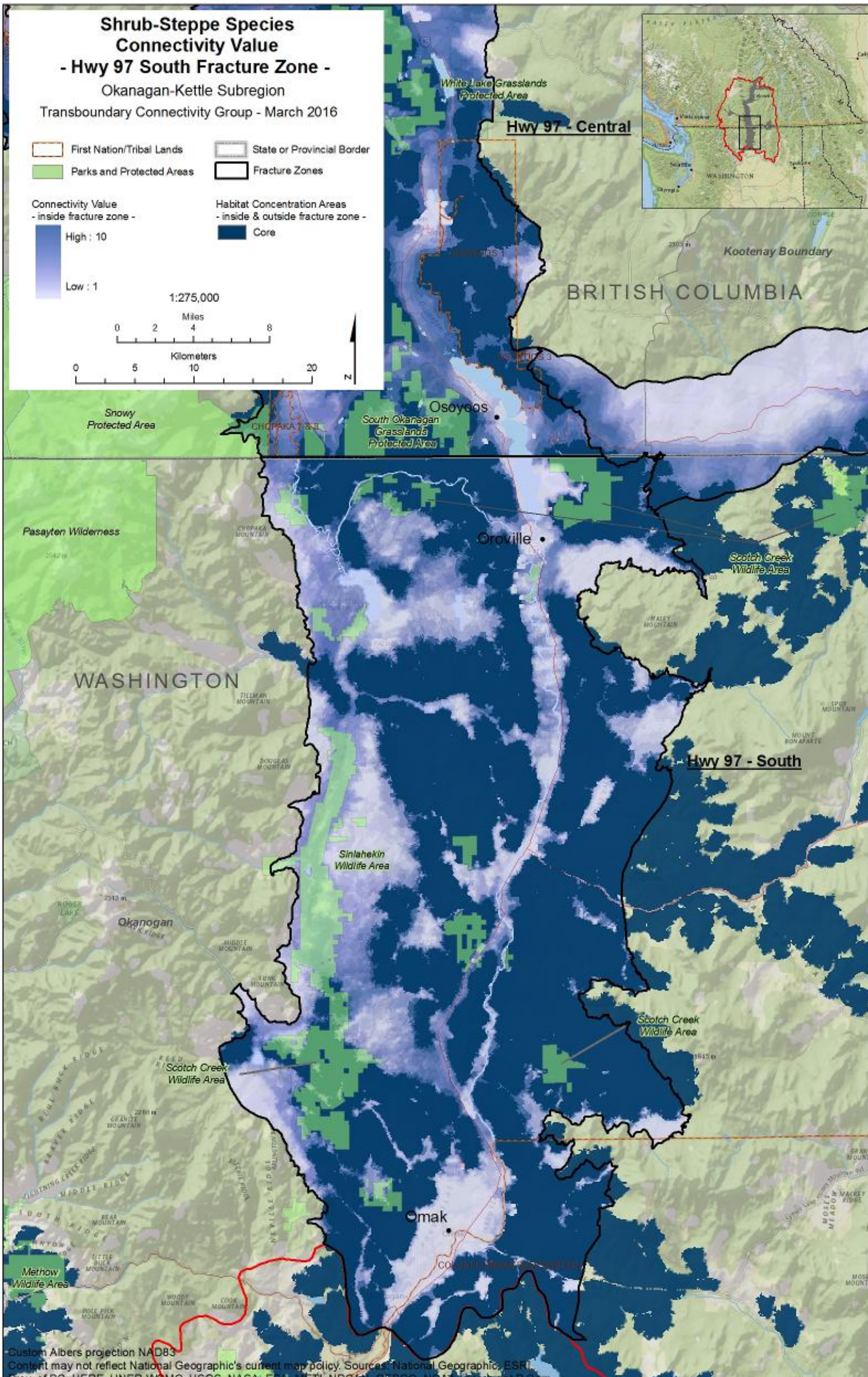


Figure 12. Connectivity value of habitat for shrub-steppe species for the Hwy 97 South Fracture Zone.

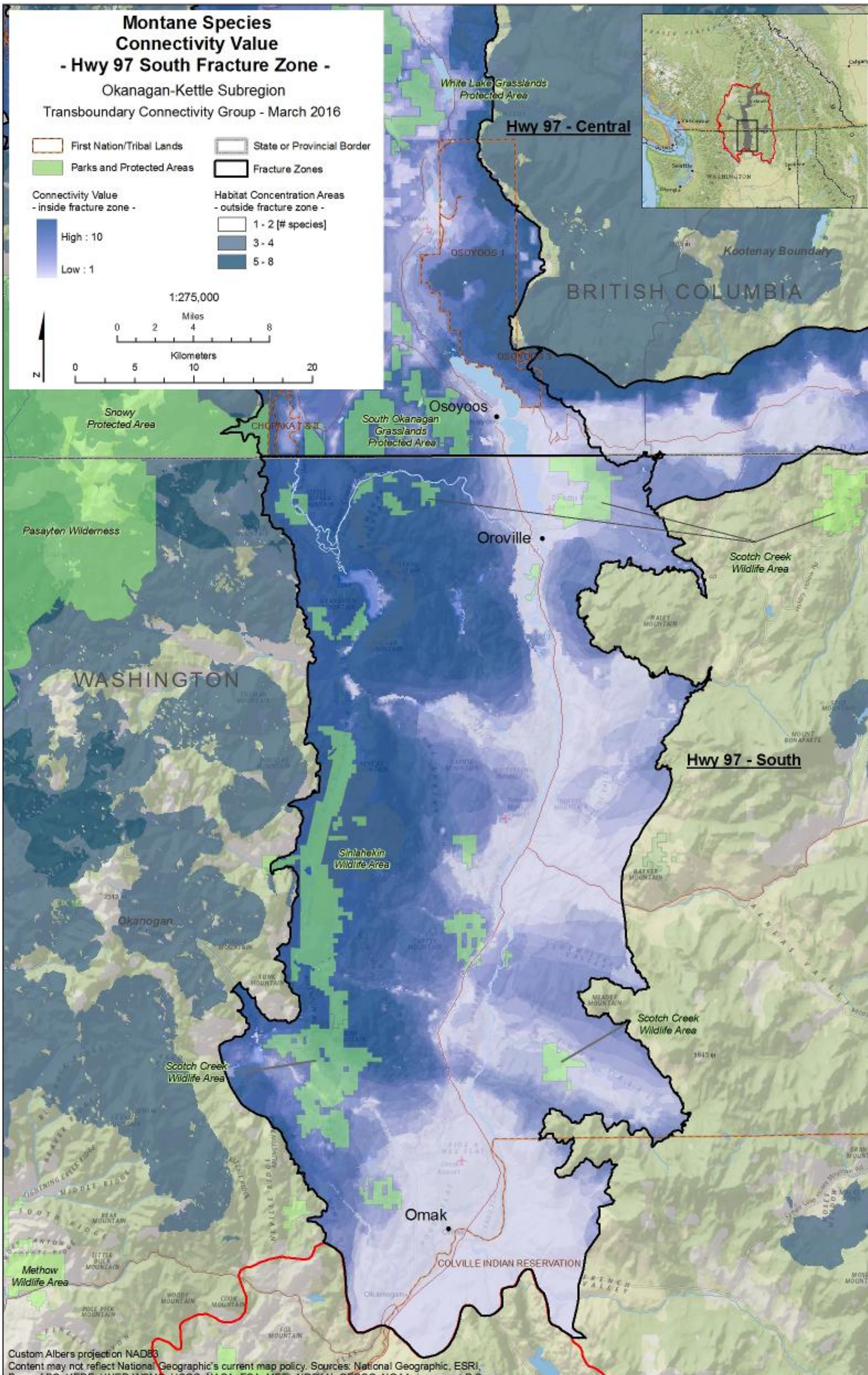


Figure 13. Connectivity value of habitat for montane species for the Hwy 97 South Fracture Zone.

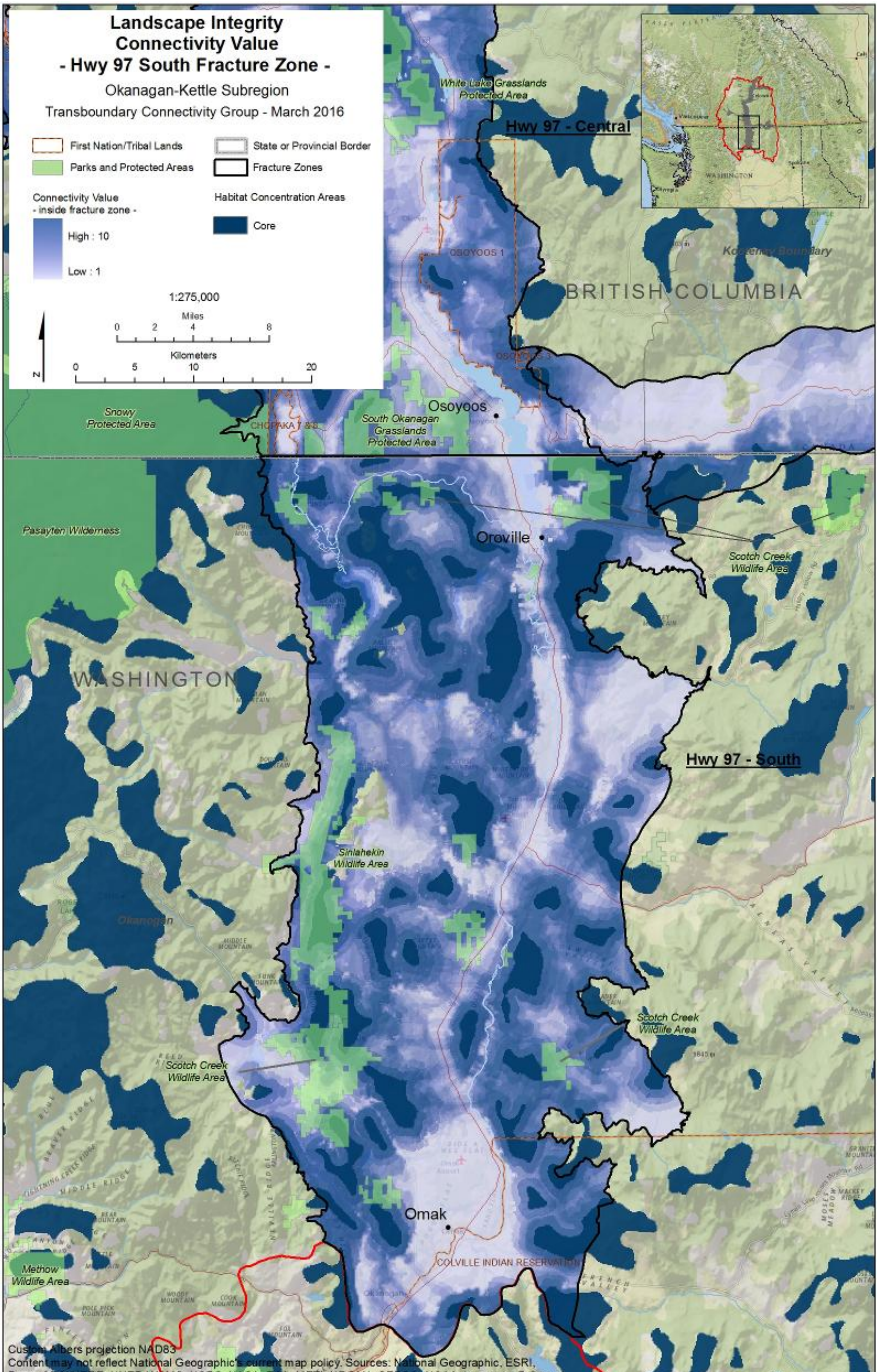


Figure 14. Connectivity value of habitat for landscape integrity for the Hwy 97 South Fracture Zone.

Hwy 3 East Fracture Zone

This fracture zone follows an east–west valley that extends from Osoyoos to Gilpin Grasslands Provincial Park, BC (Fig. 1). In general, the valley is relatively low relief and bounded by gentle hillslopes that tend to be forested on north-facing aspects, and open forest or shrub-steppe on south-facing aspects. Barrier features potentially impacting movement include Hwy 3, agriculture, rugged terrain, and residential and commercial development associated with the small towns located next to the highway. Except for Grand Forks, the region is sparsely populated. Agricultural development tends to occur along the valley in tight association with the highway, with the exception of the area around Grand Forks where much of the wide valley bottom is dominated by agriculture and other rural developments. Future pressures are likely to include increasing highway use, agricultural development, and residential development, especially close to the Okanagan Valley. In addition, climate change is expected to result in dramatic changes to the drier ecosystems here, with considerable uncertainty around future vegetation type. The prediction of warmer and drier conditions may potentially limit tree distribution further in this zone, and may result in the future expansion of shrub-steppe or other dry-adapted vegetation types.

CONNECTIVITY FOCUS AREAS

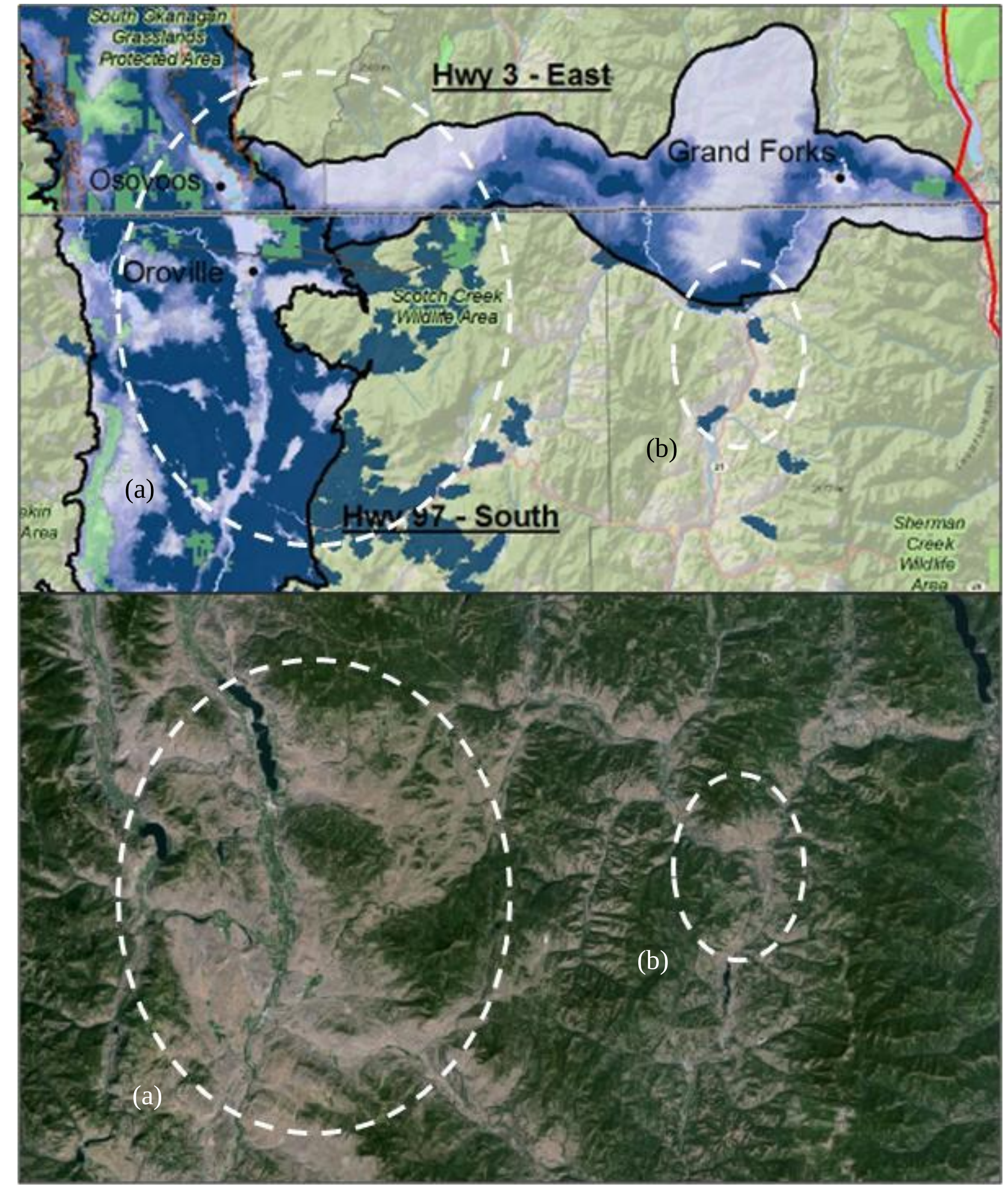
The Connectivity Focus Areas (CFAs) in this fracture zone followed the Hwy 3 transportation corridor and a portion of the Kettle River drainage system (Fig. 15). East of Osoyoos, where the boundaries of the Hwy 3 East, Hwy 97 Central, and Hwy 97 South Fracture Zones meet further development has the potential to sever a narrow north–south connection for shrub-steppe species moving along the east side of the Okanagan Valley as well as north–south movement of montane species along the eastern rim of the valley at higher elevations.

SHRUB-STEPPE PERSPECTIVE

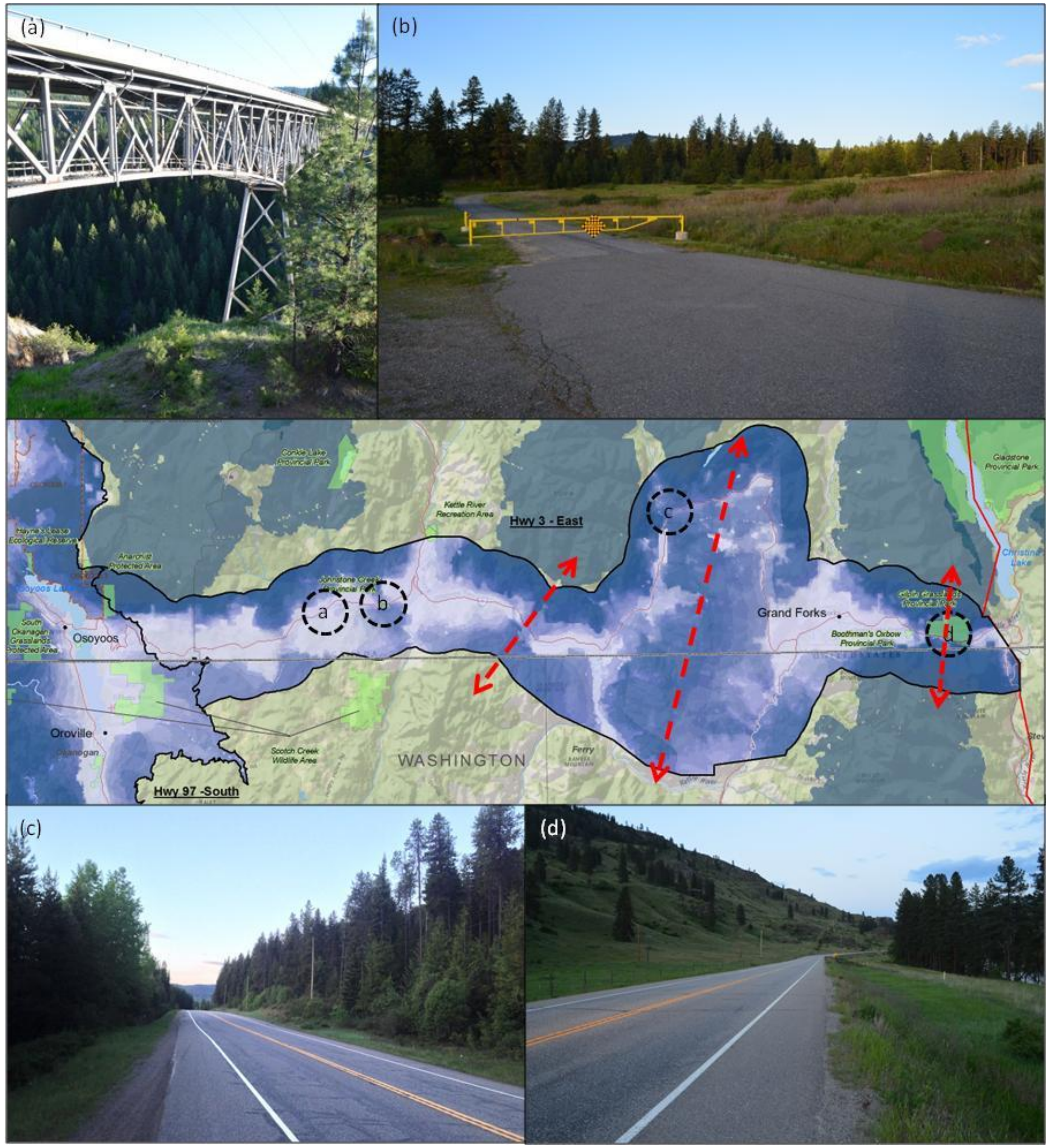
Shrub-steppe habitat tends to be patchily distributed within this fracture zone (Fig. 16). The habitat concentration area (HCA) south of Johnstone Creek Provincial Park is an extension of an HCA from the Hwy 97 South Fracture Zone, providing opportunity for movement to the main Okanagan Valley (see Close-up Example 12, circle labeled “a”). There is relatively contiguous east–west access between this HCA and the three HCAs to the north (east of Midway). Three HCAs follow the Kettle River drainage on the US side of the fracture zone. Movement north from these HCAs is constrained by rugged topography and agriculture. There is the possibility of movement south between these HCAs and five others identified outside the fracture zone boundary along US Hwy 21 (see close-up Example 12, circle labeled “b”). The HCA near Grand Forks has considerable development to the south, and movement to the HCA near Gilpin Grasslands Provincial Park is constrained by rugged terrain north of the highway and agriculture to the south.

MONTANE PERSPECTIVE

We identified several large HCAs to the north of the fracture zone and fewer to the south (Fig. 17). HCAs north and south of Gilpin Grasslands Provincial Park follow the Kettle Range. The presence of agriculture lands and development “funnels” north–south movement through the provincial park (see Close-up Example 13). Locally, game fencing along much of this stretch of highway likely impedes movement. The opportunity for movement between HCAs north and south of the fracture zone also occurs in the area west of Grand Forks.



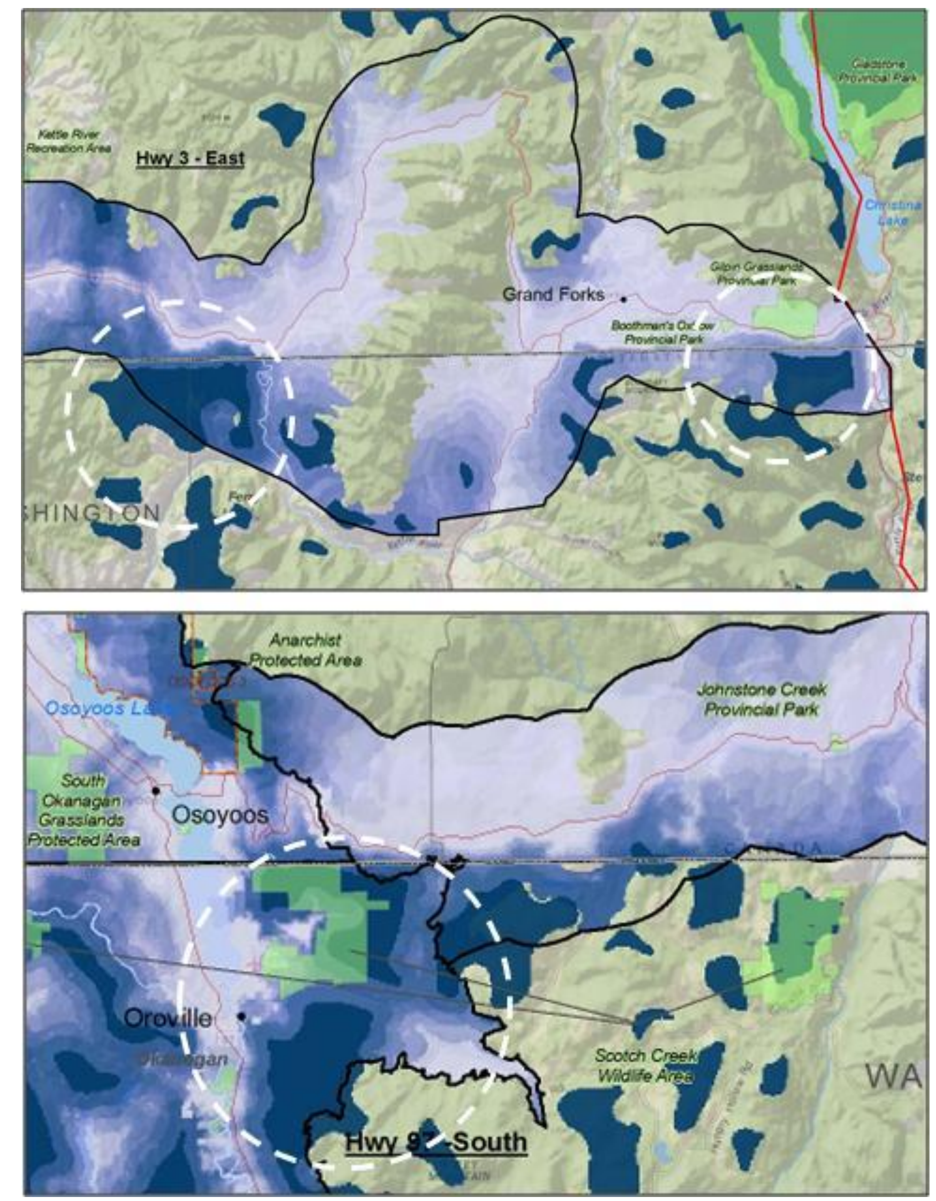
Close-up Example 12. *(top) Close-up of the shrub-steppe perspective map for the Hwy 97 South and Hwy 3 East Facture Zones (see Figs. 12 and 16). (bottom) Aerial image of the same area. Dashed circle labeled (a) shows HCAs extending from the Hwy 97 South Fracture Zone to the Hwy 3 East and Hwy 97 Central Fracture Zones. Dashed circle labeled (b) shows HCAs along the Kettle River drainage.*



Close-up Example 13. *(Center panel) Close-up of the montane perspective map for the Hwy 3 East Fracture Zone (see Fig. 17). Dashed circles labeled on the map correspond to photos. (a) Rock Creek Canyon bridge. (b) Johnstone Creek Provincial Park. (c) Forested habitat along Hwy 3 facilitating access to Monashee Mountains. (d) Gilpin Grasslands Provincial Park. Dashed red arrows indicate locations for potential north–south movement. Photos by Peter Singleton.*

LANDSCAPE INTEGRITY PERSPECTIVE

Few landscape integrity HCAs were identified within the fracture zone, and nearly all of these were on the US side of the border (Fig. 18). The large HCA near Gilpin Grasslands Provincial Park may enhance the ability of this area to support north–south movement of montane species. The large HCA midway between Osoyoos and Grand Forks (see Close-up Example 14, top panel) overlaps a potential movement pathway between shrub-steppe HCAs. The HCA at the west end of the valley near the intersection of the three fracture zones (see Close-up Example 14, bottom panel) may be important for connectivity to the Okanagan Valley. This particular area is close to other large HCAs and conservation lands on the US side of the border.



Close-up Example 14. *Close-ups of the landscape integrity perspective map for the Hwy 3 East Fracture Zone (see Fig. 18). (top) Area near Grand Forks. (bottom) Area east of Oroville. Dashed circles indicate locations of landscape integrity habitat concentration areas (HCAs).*

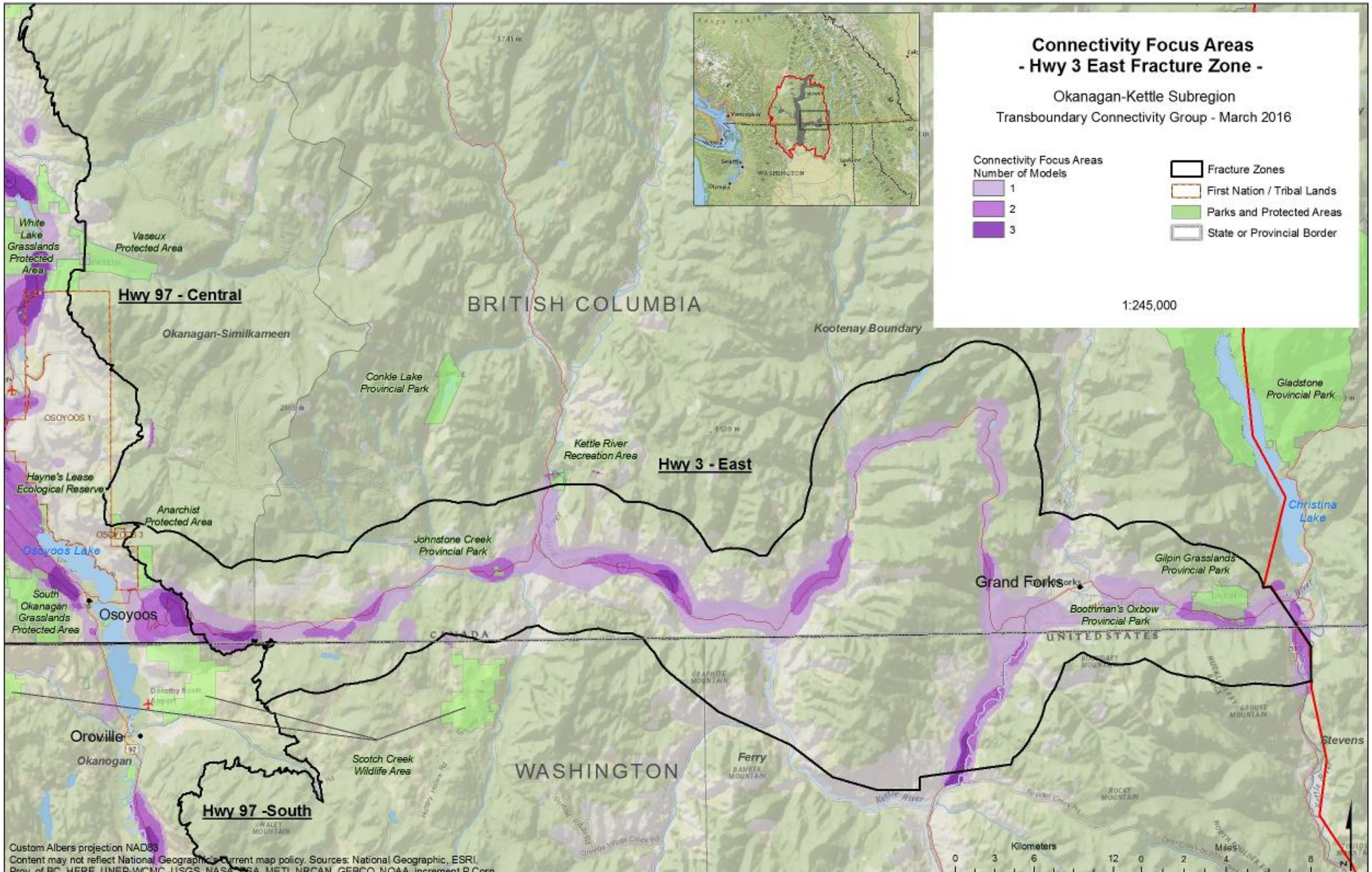


Figure 15. Connectivity Focus Areas (CFAs) identified for shrub-steppe species, montane species, and landscape integrity models for the Hwy 3 East Fracture Zone.

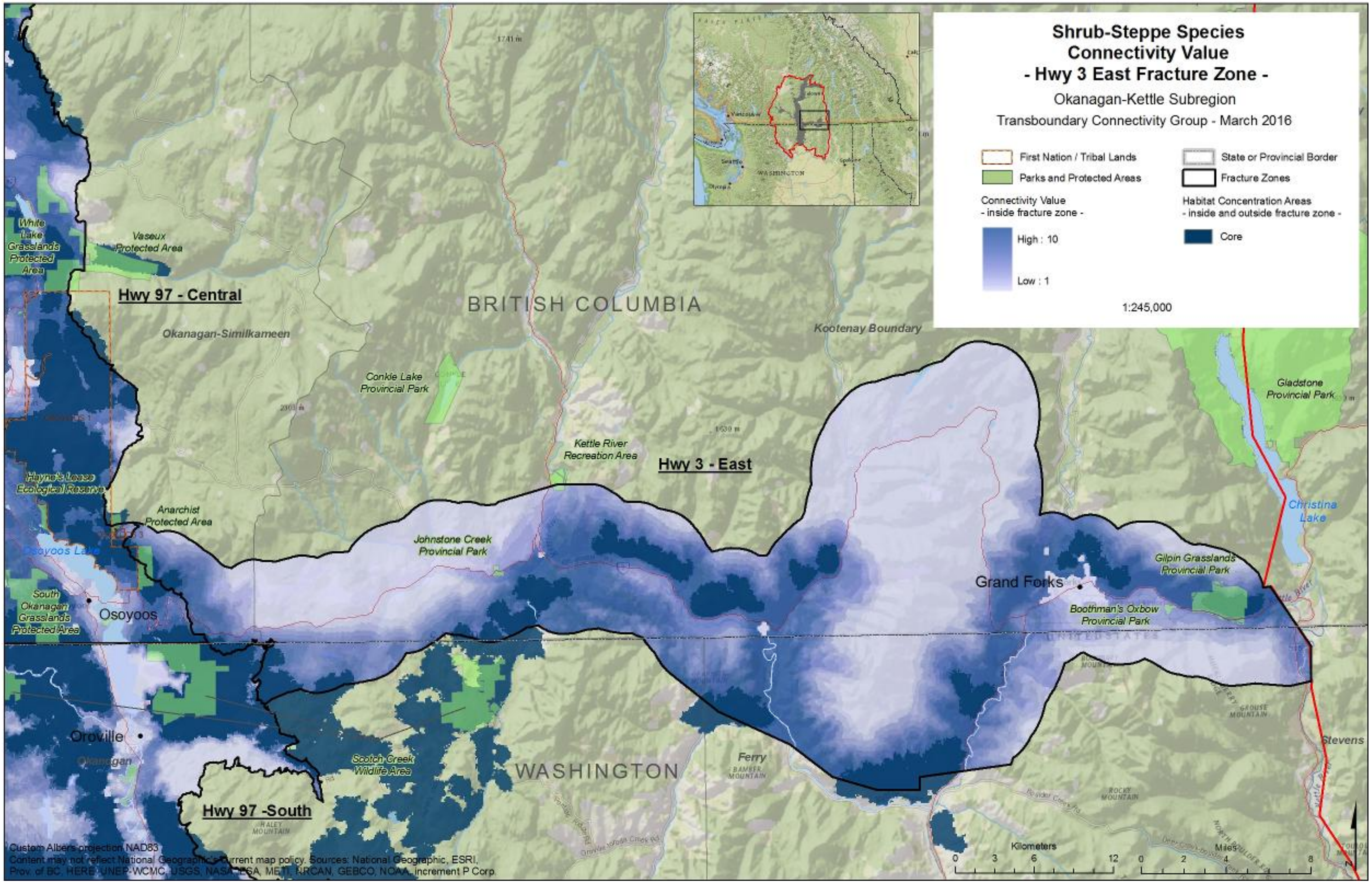


Figure 16. Connectivity value of habitat for shrub-steppe species for the Hwy 3 East Fracture Zone.

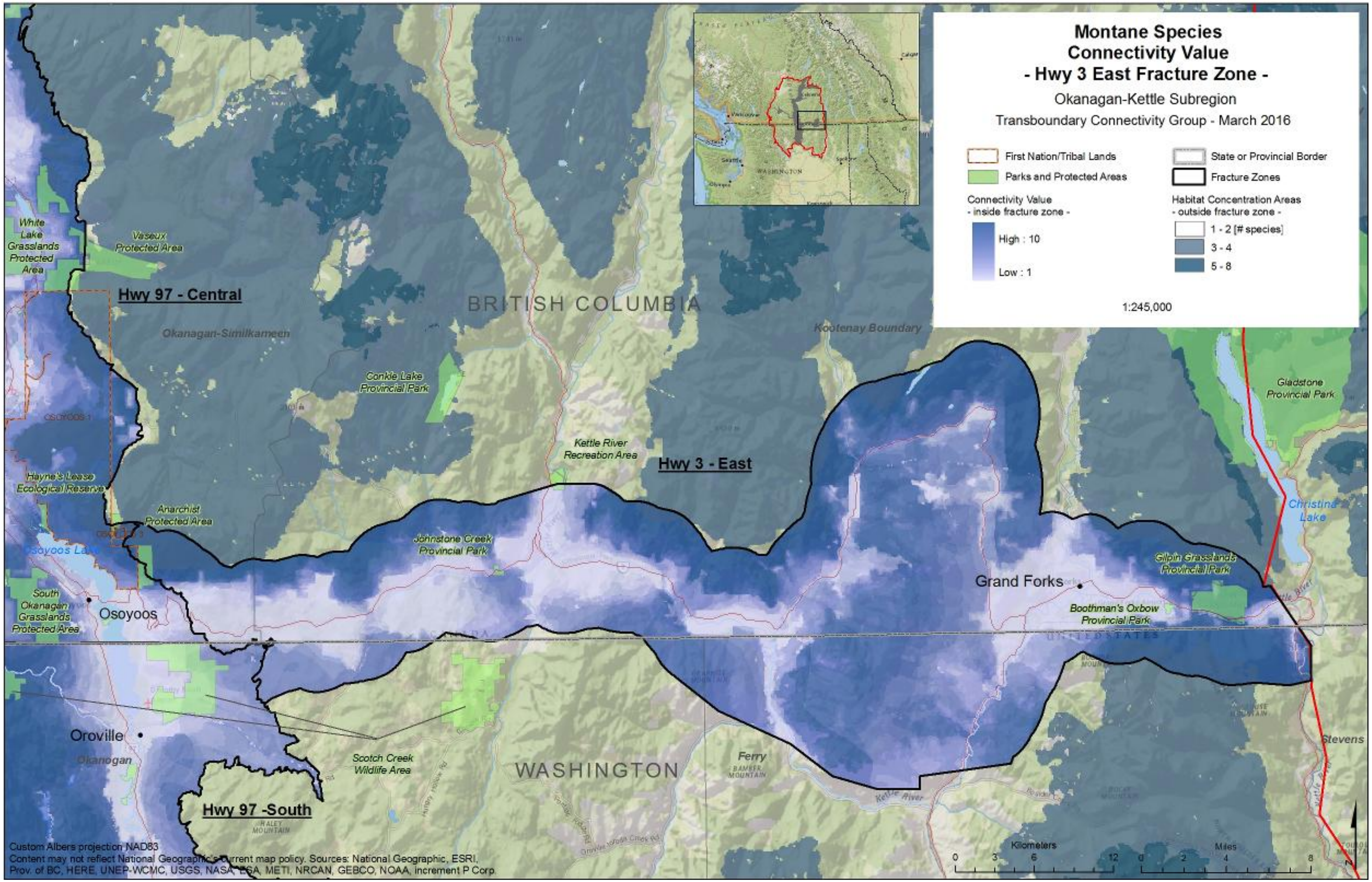


Figure 17. Connectivity value of habitat for montane species for the Hwy 3 East Fracture Zone.

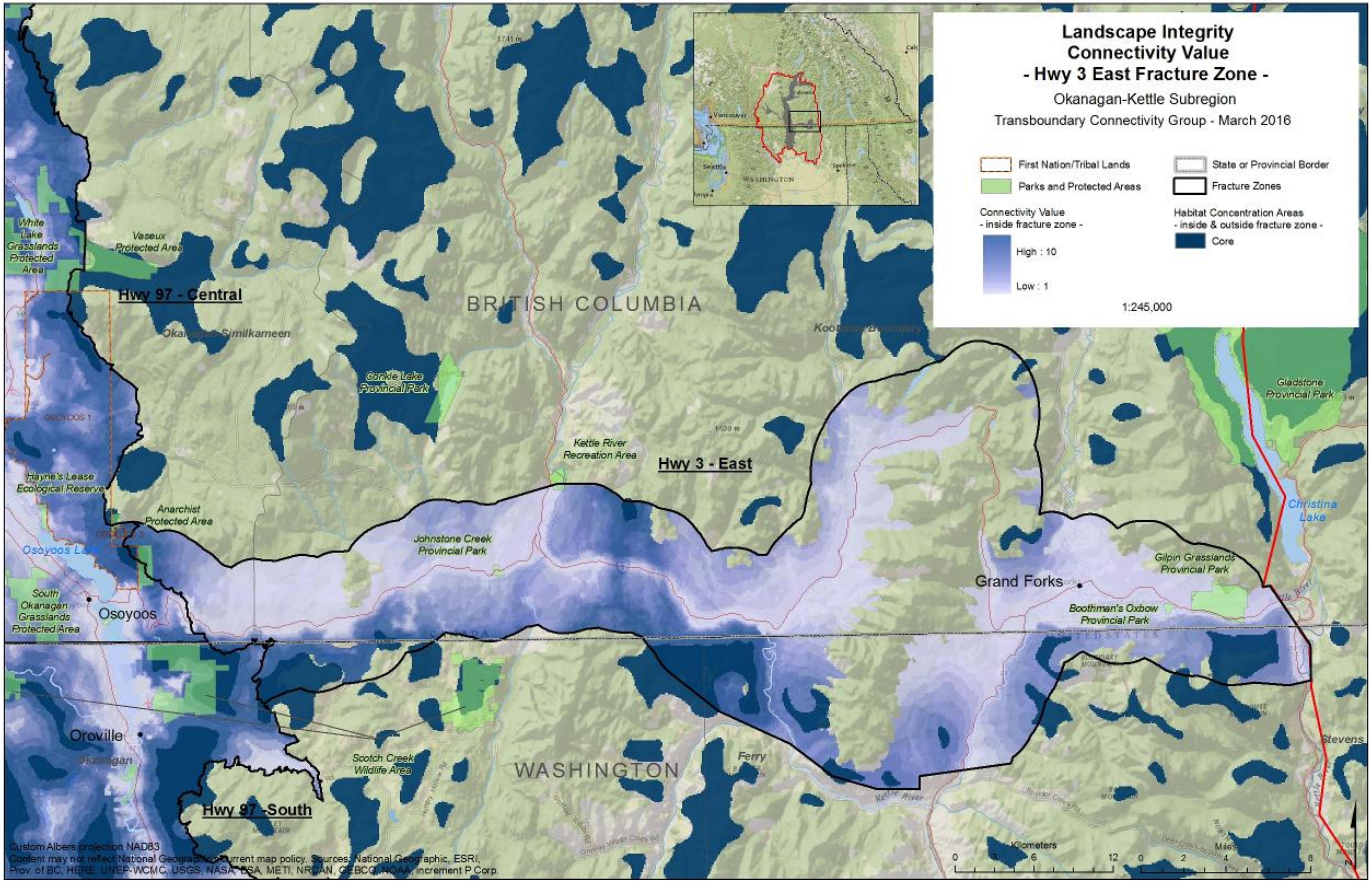


Figure 18. Connectivity value of habitat for landscape integrity for the Hwy 3 East Fracture Zone.

Hwy 3 West Fracture Zone

This fracture zone follows Hwy 3 along the Similkameen River from Keremeos west to Princeton, then continues northwards for a short distance beyond Princeton, towards Merritt, BC (Fig. 1). The narrow portion of the fracture zone reflects the rugged topography bounding the Similkameen Valley (see photo below). Existing habitat patches and riparian areas are of high value for maintaining connectivity due to the lack of options created by the narrow valley and steep-sided terrain. Significant agricultural development exists along sections of this valley and the pressure of landscape conversion is increasing. Where the fracture zone meets the Okanagan Valley, the less rugged areas are nearly all converted to residential and commercial development or agriculture. Towards Princeton, natural features of the landscape become less rugged and agricultural development is less intense.

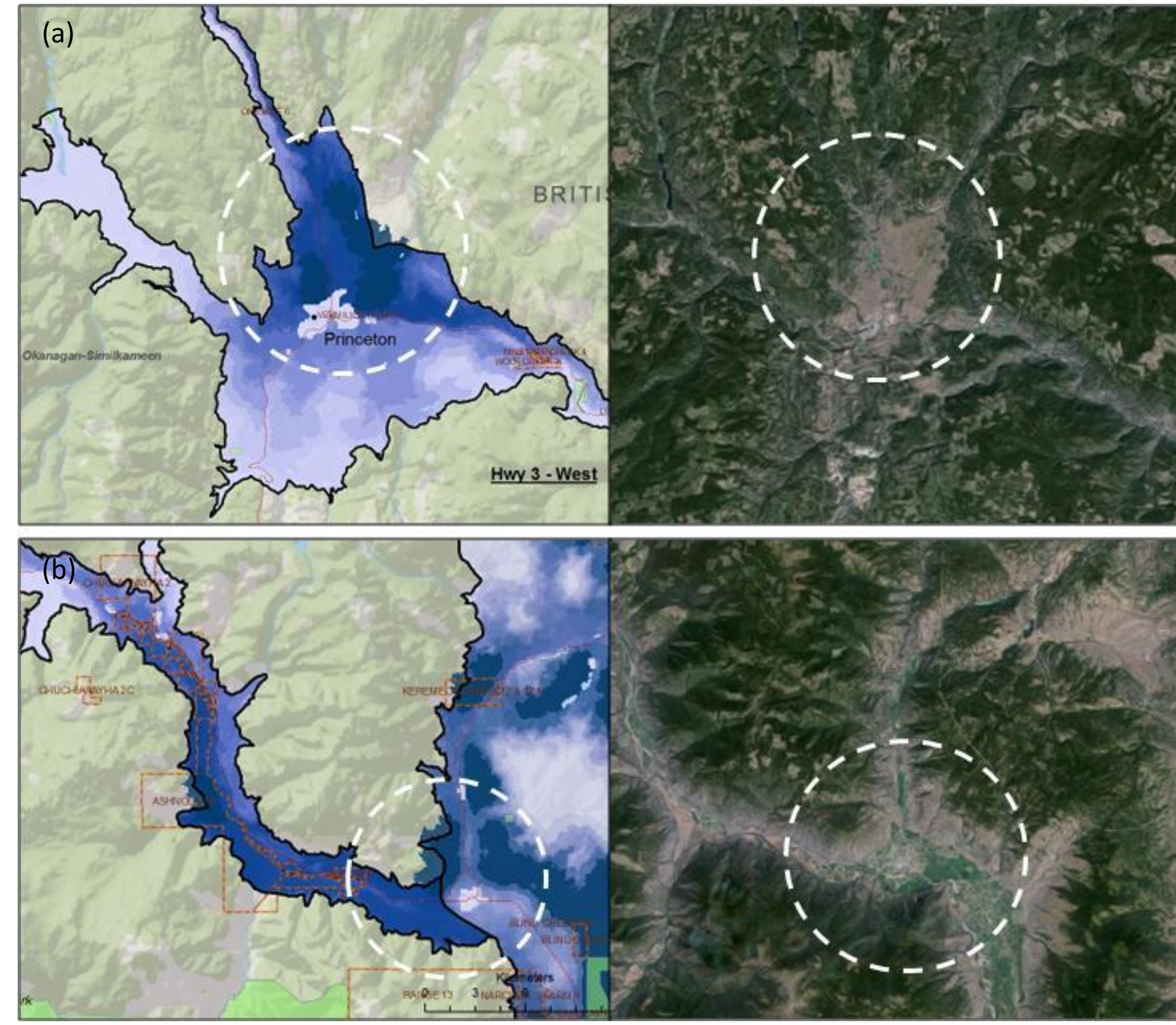
Development along the Similkameen Valley in the Hwy 3 West Fracture Zone. Photo by Peter Singleton.

CONNECTIVITY FOCUS AREAS

We identified many Connectivity Focus Areas (CFAs) along the Similkameen Valley from Keremeos to Bromley Rock Park and following Hwy 5A north of Princeton (Fig. 19). In several locations the CFAs for all three perspectives overlapped. The linear arrangement of the CFAs in the Similkameen Valley suggests that east–west connectivity would be compromised if one were lost.

SHRUB-STEPPE PERSPECTIVE

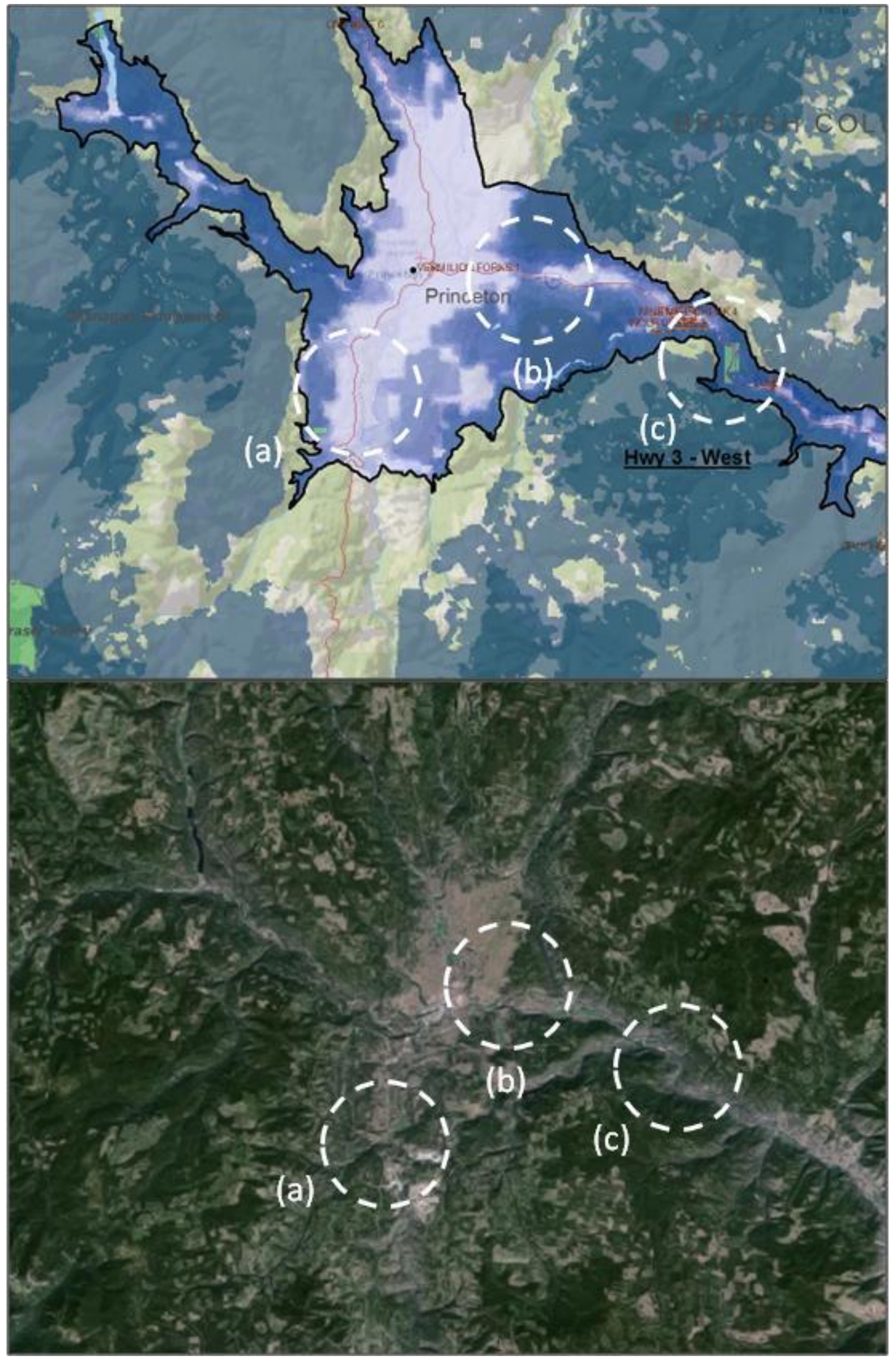
We identified two habitat concentration areas (HCAs) near Princeton and one HCA in the Similkameen Valley approximately midway between Princeton and the valley entrance near Keremeos (Fig. 20). The small shrub-steppe HCAs near Princeton are isolated from those identified in the narrow Similkameen Valley. Many of the barriers to movement between these HCAs are related to the naturally limited and patchy distribution of the shrub-steppe habitats. The area between the two HCAs near Princeton has relatively high connectivity value (see Close-up Example 15). In a changing climate they may be important "stepping-stones" for potential movement northwards towards the Merritt HCA, and shrub-steppe habitat near Kamloops and into the Thomson River drainage.



Close-up Example 15. *Close-ups of the shrub-steppe perspective map for the Hwy 3 West Fracture Zone (see Fig. 20) and corresponding aerial images. Dashed circles indicate approximately the same locations. (a) Habitat concentration areas (HCAs) near Princeton. (b) Entrance to the Similkameen Valley at Keremeos.*

MONTANE PERSPECTIVE

This fracture zone is surrounded by large HCAs for montane species (Fig. 21). Our connectivity analysis shows the impact of Hwy 3 and associated development as linear features that limit access to HCAs north and south of the Similkameen Valley. North–south drainages may create less steep movement pathways across the valley, such as around Bromley Rock Park and Shoemaker and Rattlesnake Creeks (see Close-up Example 16). Both north–south and east–west movement is constrained in the vicinity of Princeton. Maintaining the relatively high potential for movement just to the east of Princeton is important (see Close-up Example 16). The Hwy 3 (south of Princeton) and Hwy 5A (north of Princeton) transportation corridors limit east–west movement opportunities. Near Keremeos movement options are constrained by development and steep terrain.

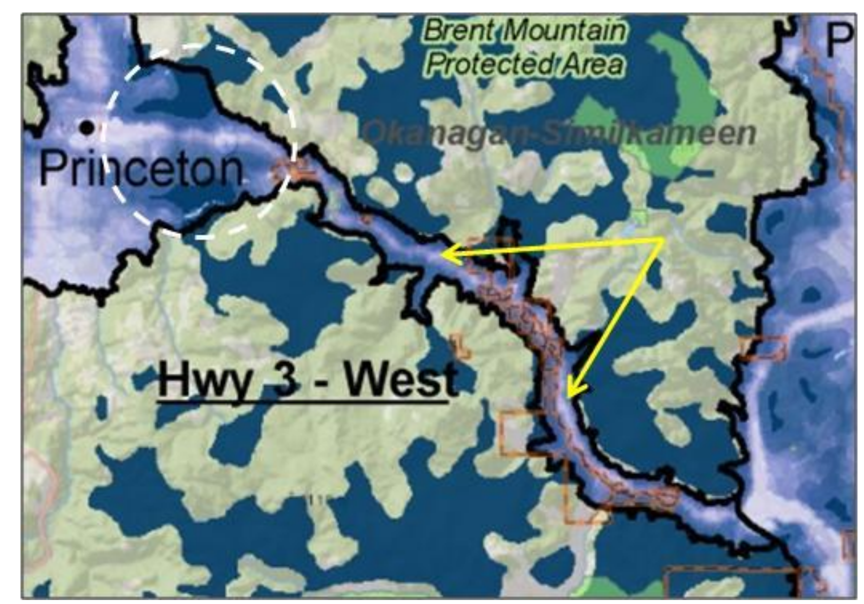


Close-up Example 16. *(top) Close-up of the montane perspective map for the Hwy 3 West Fracture Zone (see Fig. 21), and (bottom) the corresponding aerial image. Labeled circles indicate approximately the same locations. (circle labeled a) Potential area of east–west connectivity. (circle labeled b) Potential area of north–south connectivity. (circle labeled c) Vicinity of Bromley Rock Provincial Park.*

Near Bromley Rock Park along Hwy 3 in BC. Photo by Peter Singleton.

LANDSCAPE INTEGRITY PERSPECTIVE

The impact of human-caused disturbance is illustrated by the low number of landscape integrity HCAs identified within this zone (Fig. 22). We identified two HCAs east of Princeton before the narrowing of the Similkameen Valley (see Close-up Example 17). Movement between these HCAs is constrained by the highway. No HCAs were identified in the narrow portion of the fracture zone where disturbance associated with Hwy 3 creates resistance to movement across the valley.



Close-up Example 17*. Close-up of the landscape integrity perspective map for the Hwy 3 West Fracture Zone (see Fig. 22). Dashed circle indicates habitat concentration areas (HCAs) east of Princeton. Arrows indicate the Hwy 3 transportation corridor in the valley.*

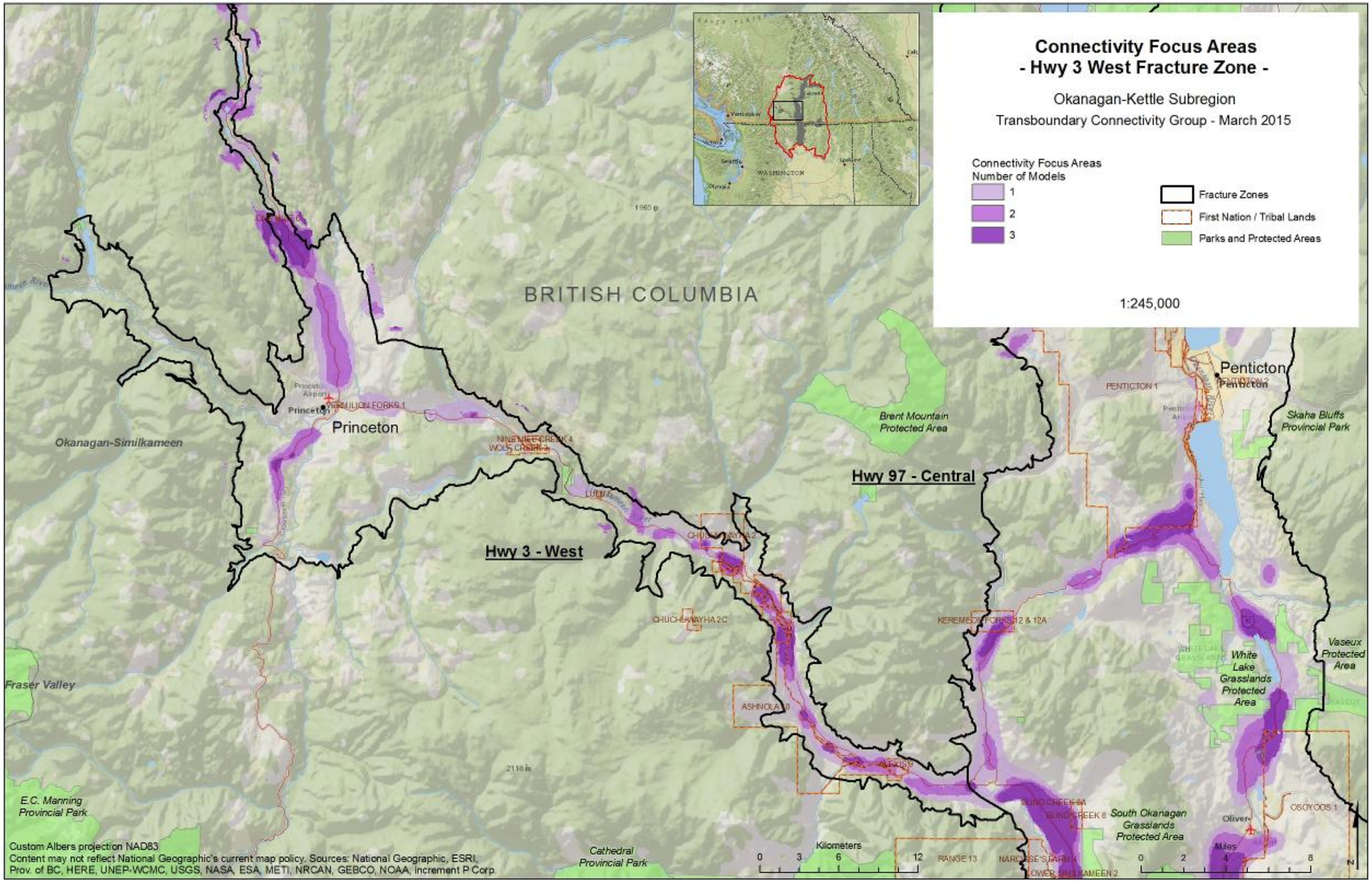


Figure 19. Connectivity Focus Areas (CFAs) identified for shrub-steppe species, montane species, and landscape integrity models for the Hwy 3 West Fracture Zone.

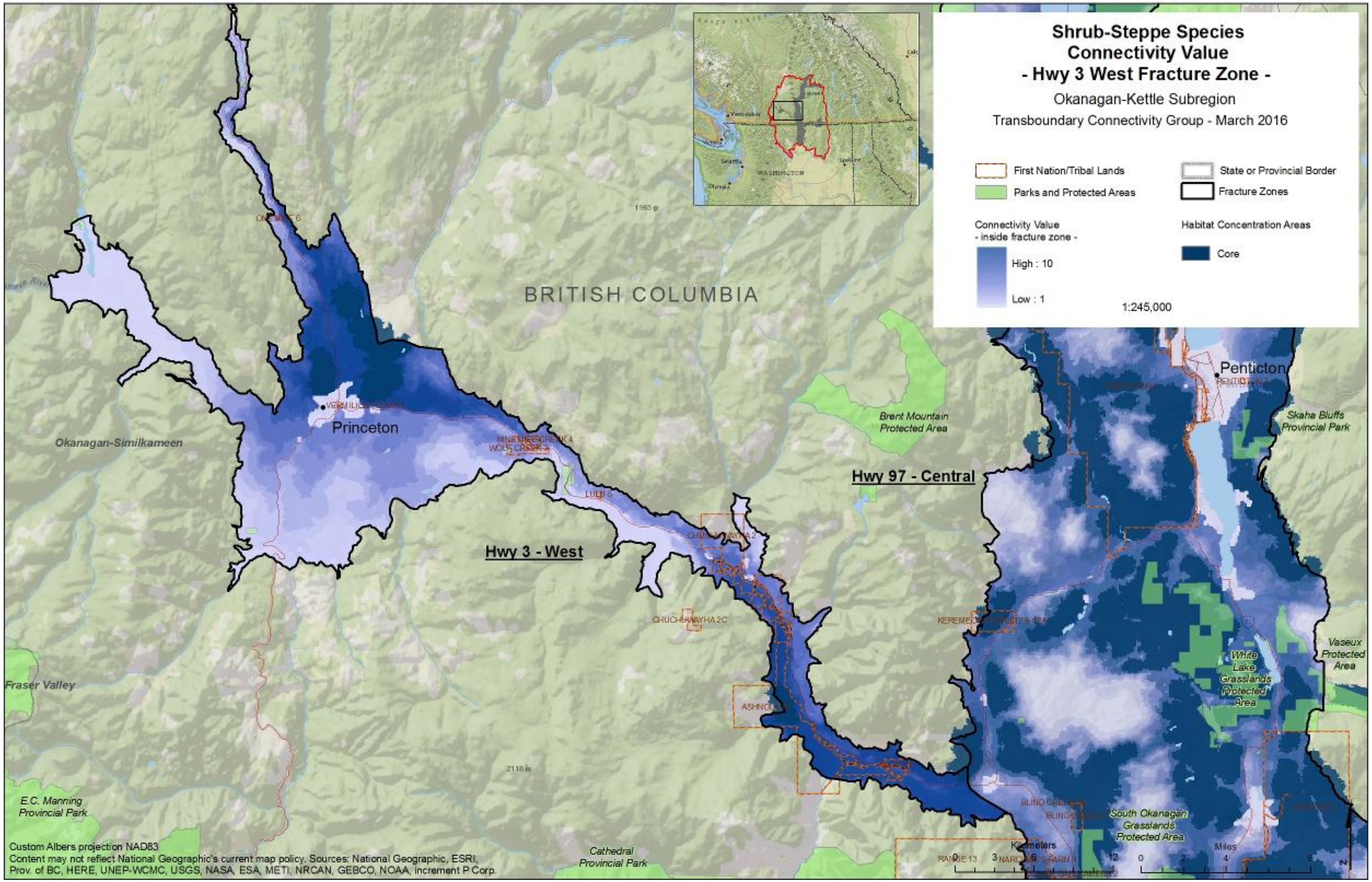


Figure 20. Connectivity value of habitat for shrub-steppe species for the Hwy 3 West Fracture Zone.

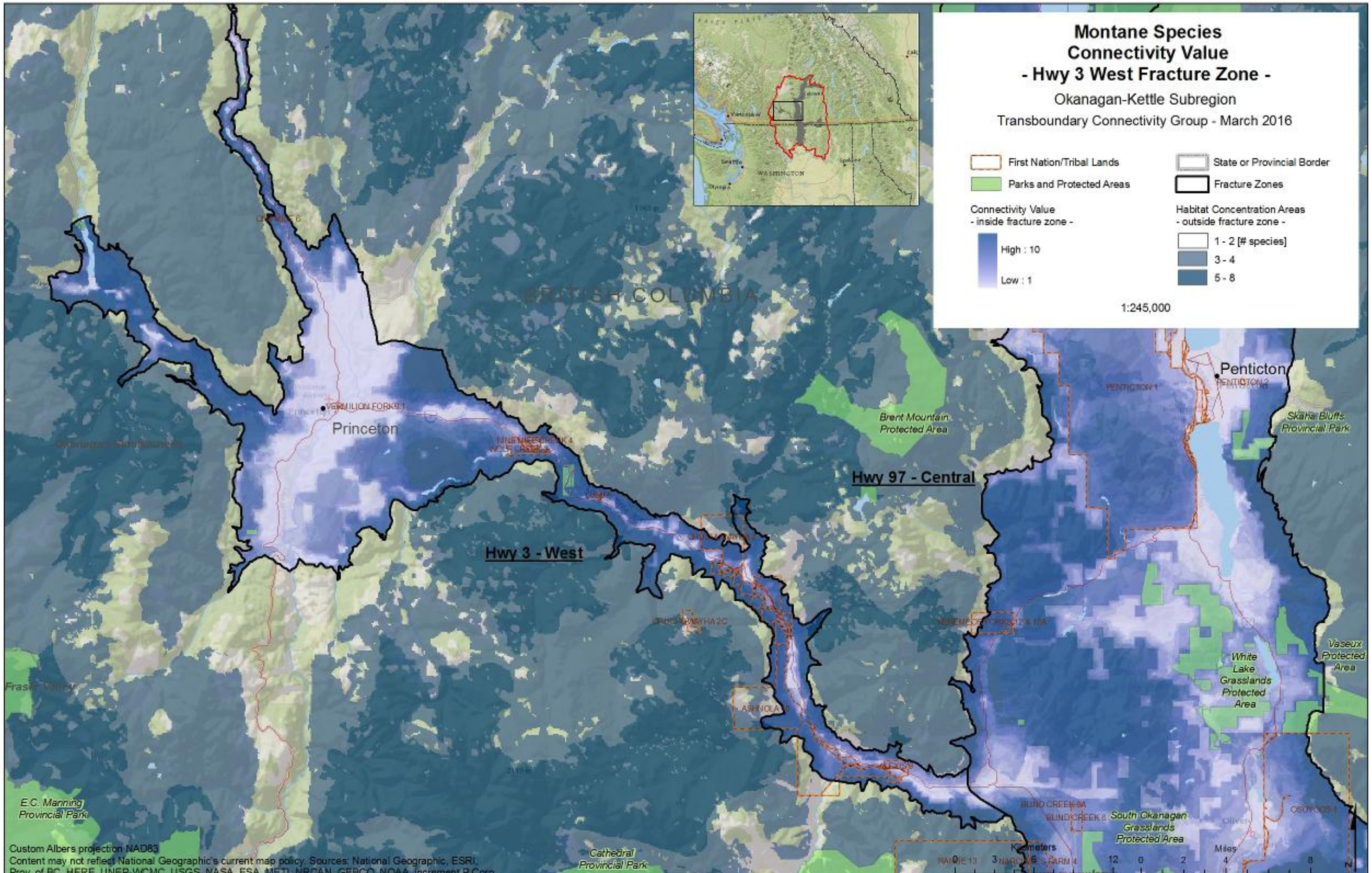


Figure 21. Connectivity value of habitat for montane species for the Hwy 3 West Fracture Zone.

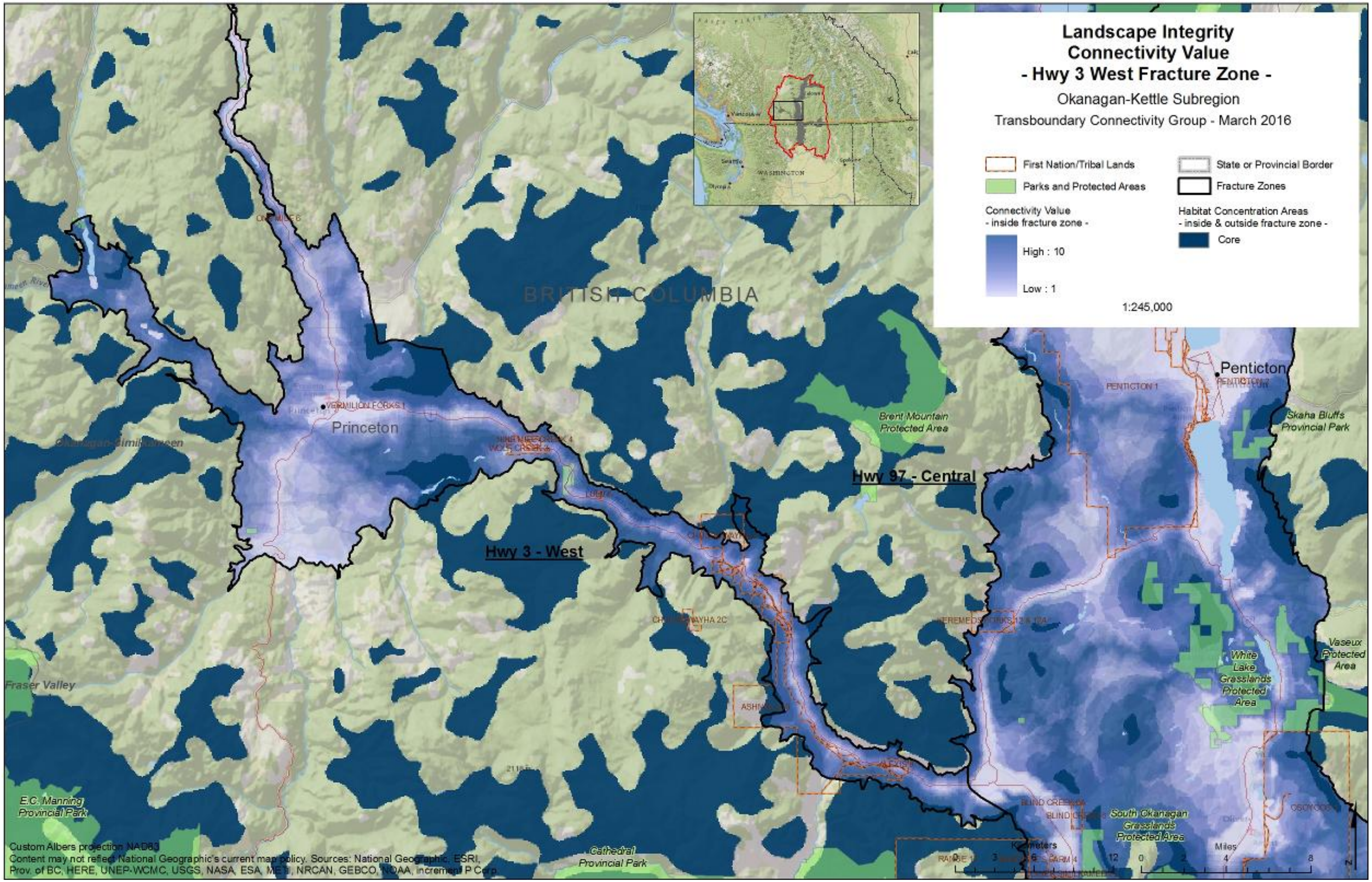


Figure 22. Connectivity value of habitat for landscape integrity for the Hwy 3 West Fracture Zone.

Climate Change

Future climate change may profoundly affect habitat connectivity in the Okanagan-Kettle subregion; anticipating potential impacts and identifying opportunities for mitigating negative affects was a primary goal of our analysis.

We used models of projected future changes in climate to identify potential climate impacts on regional connectivity, paying special attention to impacts on low-elevation valleys. Key impacts included changes in temperature and precipitation, vegetation, and disturbance regimes. Hotter and drier summers and a longer frost-free season are likely to affect connectivity of moist habitats (e.g., wetlands and riparian areas) along valley floors. Future changes in vegetation are likely to affect the distribution and quality of core habitat areas and corridors for both shrub-steppe and montane species, though there is high uncertainty around the nature of these changes, particularly for low-elevation valleys. Changes in disturbance regimes, including increased risk of pest outbreaks and wildfire, may affect habitat connectivity throughout the subregion; forested habitats and linkages may be particularly affected.

We identified a suite of actions for addressing these impacts and accounting for connectivity needs related to climate-driven shifts in species ranges. Many of these actions focused on maintaining connectivity of moist habitats in low-elevation valleys (e.g., through riparian restoration), addressing impacts related to changes in disturbance regimes (e.g., through prescribed burning), and providing opportunities for species to track shifting areas of climatic suitability (e.g., by identifying and protecting linkages—such as climate-gradient corridors—that connect warm valley floors to cooler, higher elevation locations).

Many of these impacts, actions, and priority areas for implementation are described throughout this report. A full description of climate impacts and adaptation actions identified by this analysis are described in Appendix B.

Okanagan-Kettle subregion. Photo by Justin Haug.

Operational-scale Conservation Planning

Several broad-scale assessments have identified the highways and associated development in the Okanagan Valley as significant barriers to wildlife movement. Broad-scale assessments, while providing an important regional context for connectivity, are generally too coarse in scale to provide planners with linkage-specific details needed to identify and prioritize conservation actions (WHCWG 2013). “Drilling down” to a linkage area within a fracture zone adds operational realities and local knowledge associated with the specifics of land use, ecological and human community considerations, and conservation approaches for connectivity conservation actions. Below we describe three place-based connectivity projects ongoing in the Okanagan-Kettle subregion. We held workshops with local stakeholders of two of these projects to increase awareness and understanding of our connectivity maps and to gather local knowledge to better understand the underlying landscape conditions represented in the maps. The third project, the *Working for Wildlife Initiative* in north-central Washington, highlights the use of a tailored Decision Support System (DSS) to plan fine-scale linkage design and monitor conservation investments in the subregion. Although several members of the Transboundary Connectivity Group contributed to the development of the DSS, we emphasize that development of this tool was beyond the scope of our work. Our intent here is to share a suite of approaches in the Okanagan-Kettle subregion to use connectivity science to inform fine-scale connectivity conservation actions, priorities, and outcomes. Projects included:

- ***Central Okanagan Regional District: Okanagan Futures Project, BC***—A multi-stakeholder partnership whose focus is connectivity conservation planning in the Central Okanagan Regional District, BC. Our connectivity results provide subregional context and help stakeholders prioritize connectivity linkages identified by UBC-Okanagan for the Central Okanagan (see Appendix C for workshop summary).
- ***Spotted Lake (Ha? Ki lil xw), BC***—Ha? Ki lil xw is a sacred cultural and spiritual site important to the Syilx people and is an area of ongoing priority for conservation planning by the Okanagan Nation Alliance (ONA) and member bands. The BC Government’s exploration of additional protection measures in the South Okanagan[2] recognizes that effective conservation planning and management in the South Okanagan needs to be a consultative and collaborative effort with First Nations incorporating traditional ecological knowledge. We organized a workshop with the ONA and member bands to share our connectivity results for the South Okanagan (see Appendix D for workshop summary).
- ***Working for Wildlife Initiative, WA***—An east–west linkage that runs through the Okanagan Valley just north of Riverside in the US portion of the Okanagan-Kettle subregion has been identified in multiple broad-scale assessments as a critical landscape connection between the North Cascades and the Kettle Range (Gaines et al. 2001; Singleton et al. 2002; WHCWG 2010; this report) for wide ranging species, while also containing multiple important pathways for species with smaller ranges including sharp-tailed grouse. The *Working for Wildlife Initiative* is a multi-partner collaboration whose goal is to maintain and restore landscape connectivity within this linkage area, while still preserving working lands and heritage. A key to the success of the initiative is the application of a tailored Decision Support System (DSS; based on spatial data) that collaborators use to evaluate conservation options, determine conservation priorities, and measure progress towards achieving their landscape connectivity goals (see Appendix E).

[2]An intentions paper, *Protected Areas Framework for British Columbia’s South Okanagan* was available for comment from August 13, 2015 to October 15, 2015. The paper is no longer available.

Central Okanagan Regional District, BC

In November 2015, a stakeholder workshop was held by UBC-Okanagan, the Okanagan Collaborative Conservation Program (OCCP), and the Transboundary Connectivity Group to address connectivity planning in the Regional District of the Central Okanagan (RDCO; see Appendix C for workshop summary). Approximately 40 participants attended including representatives from municipal and regional governments, provincial and federal ministries, First Nations, NGOs, private consultants, and universities. The purpose of the workshop was to (1) share information about connectivity planning tools, (2) identify important wildlife habitat corridors in the Central Okanagan, (3) prioritize corridors for protection and/or restoration, and (4) propose a strategy for on-the-ground implementation of restoration/protection of the selected corridors.

An overview of the connectivity analyses completed by UBC-Okanagan and the Transboundary Group was presented to workshop participants. Breakout groups were then formed and people were asked to examine the connectivity corridors identified within the Central Okanagan and prioritize and revise these corridors as they felt best. Many participants indicated that they needed additional information, and did not want to prioritize corridors solely within the options given (see Appendix C). Additionally, participants differed with respect to whether individual corridor areas or overall permeability of the landscape should be the focus of management. An important outcome of the workshop was the partnering of the Regional District of Central Okanagan, Okanagan Collaborative Conservation Program, and UBC-Okanagan to form a Connectivity Action Team for the Central Okanagan region.

Some of the key messages we heard from participants and lessons learned at the workshop included:

- It is important to explain—in plain language—the connectivity analysis and mapping products to practitioners and gather knowledge about local landscape conditions that may not be captured on the maps. A one-day workshop is not enough time to accomplish this. Engagement with groups interested in applying connectivity science to their decision-making process is an ongoing dialogue to help managers effectively implement connectivity products depending on their needs.
- It is important to consider current management and ecosystem context more explicitly in the mapping products. Participants commented that the detailed connectivity maps did not reflect *current* management on-the-ground and that this was a missed opportunity to anchor future connectivity corridors to existing natural areas.
- Opportunities for conservation action are increasingly limited in the Okanagan Valley making it important to conserve even those areas where the connectivity value of the habitat is relatively low.
- Building upon or creating political will for connectivity conservation actions is critical for implementation of a connectivity conservation strategy.
- It is important to build upon existing conservation capacity to implement connectivity conservation actions.

Spotted Lake (Ha? Ki lil xw), BC

In November 2015, the Okanagan Nation Alliance (ONA) held a workshop with its member communities to review our connectivity products for the Okanagan-Kettle subregion and discuss the significance of landscape connectivity and wildlife movement between the lower Similkameen Valley, Ha? Ki lil xw (Spotted Lake), and Osoyoos Lake areas (see Appendix D for workshop summary). The workshop was an important opportunity to share the wildlife habitat connectivity results with on-the-ground leaders and decision makers who could evaluate, apply, and implement these results. Four Okanagan Nation communities were represented at the workshop including the Lower Similkameen Indian Band, Upper Similkameen Indian Band, Penticton Indian Band, and the Osoyoos Indian Band as well as the Transboundary Connectivity Group.

Ha? Ki lil xw (Spotted Lake), BC. Photo by Gregory Kehm.

The purpose of the workshop was to (1) introduce our connectivity science results for the Okanagan-Kettle subregion to an Indigenous audience with perspectives and a knowledge base preceding the arrival of European settlers; (2) discuss the cultural and traditional significance of landscape connectivity and relevance of these results to the Spotted Lake landscape; and (3) engage in a technical and Elders/Knowledge Keepers discussion to identify threats and suggest actions to maintain and enhance wildlife movement through the area.

Several themes were raised throughout the day including:

- Ownership and management of the land
- Industry and business culture
- Western practices (e.g., use of road salt attracts deer and thus increases vehicle collision rates for deer)
- Aboriginal Title and Aboriginal Rights/Governance

Discussion around these themes touched on many aspects of maintaining and enhancing wildlife habitat connectivity throughout the Spotted Lake corridor, and identified a range of specific actions requiring follow-up. An important outcome of the workshop was the interest by participants to hold future community workshops in other parts of the Syilx Territory.

Working for Wildlife Initiative, WA

Several connectivity assessments have identified the east-west linkage just north of Riverside in north-central Washington as a key location for movement of wildlife between the North Cascades and the Kettle Range (see review in WHCWG 2013; this report). State, federal, Tribal, and nongovernmental groups in Washington have partnered with the National Fish and Wildlife Foundation to form the *Working for Wildlife Initiative* whose focus is maintaining and restoring habitat connectivity within this linkage while preserving working lands (NFWF 2014; see also http://nfwf.org). Early on, collaborators decided to use connectivity science as the foundation for their decision-making to guide on-the-ground implementation of conservation actions. Conservation scientists and local stakeholders worked together to develop a Decision Support System (DSS, a computer based system that uses GIS spatial information; Gaines et al. *in prep*) so that the partners could evaluate conservation options, identify priorities, and measure progress towards achieving their landscape connectivity goals (see Appendix E for full discussion of the development and application of the DSS tool). The DSS also helped collaborators allocate limited resources where they would provide the greatest benefits to maintaining or restoring habitat connectivity within the linkage. Additionally, the DSS decision-making framework helps ensure the long-term success of the initiative because it supports a co-management structure where the collaborators share responsibilities and engage in “feedback learning” that build mutual trust.

Important Areas for Connectivity in the Okanagan-Kettle Subregion

Our analysis provides valuable insights into conditions for current and future habitat connectivity in the Okanagan-Kettle subregion. Our focal species approach captures the habitat needs and movement capabilities of shrub-steppe and montane species while our landscape integrity approach reflects the needs of wildlife whose movement ability is most influenced by the human footprint. Considered together these three perspectives yield a comprehensive assessment of habitat connectivity. Below, we present some of the insights from our analysis.

Wildlife Movement Patterns

- Wildlife inhabiting the interior plateau between the Coast Range and Rocky Mountains north of the study area may connect with the Cascade Range in Washington along the highlands west of the Okanagan Valley. Wildlife moving through the western sub-ranges of the Rocky Mountains (e.g., Selkirks and Purcells) may traverse the highlands east of the Okanagan Valley. These north–south axes for movement are largely forested, mountainous, and have relatively few human modifications, except where they cross the Hwy 3 west and east fracture zones and side-valleys of the Okanagan Valley. Pro-active planning in these areas will be critically important for maintaining connectivity options into the future, especially in light of climate change projections.
- For montane species (for example American black bear, Canada lynx, and wolverine) and landscape integrity species (species whose dispersal is primarily influenced by human disturbance on the landscape), east–west connections across the Okanagan Valley linking the Cascade Range and Coast Range in the west to the mountain ranges to the east, are tenuous. Species must pass through the highly modified landscape of the three Hwy 97 fracture zones. In addition to the high population density, the prevalence of agriculture, and the high rate of current development in the lowest elevations, these fracture zones also contain significant natural barriers to movement for montane species, including large lakes, steep slopes, and lack of forest cover. Recommended actions for these areas include maintenance and restoration of connectivity where opportunities exist today so as not to foreclose future options.
- Potential movement areas for shrub-steppe species (for example, American badger, sharp-tailed grouse, and white-tailed jackrabbit) through the Okanagan-Kettle subregion occur along a north–south axis in the lowest elevations of the Okanagan Valley, almost entirely within the three Hwy 97 fracture zones. However, the close proximity of development to remaining shrub-steppe habitats in the valley significantly reduces opportunities for wildlife movements, particularly in British Columbia, where urbanization and conversion of shrub-steppe habitat to agriculture is highest. Action to maintain and restore connectivity where opportunities exist today is a vital need.
- At present, connections between shrub-steppe habitat in the Okanagan Valley and shrub-steppe habitat in the vicinity of Kamloops are not likely. However, if the climate in the region becomes warmer and drier, conversion of forested barriers to shrub-steppe may make potential routes north more viable in the future.
- Protected areas (Parks, Protected Areas, Ecological Reserves, Wildlife Management Areas, Wilderness Areas, Wildlife Areas, etc.) and other conservation lands play a significant role in the subregion both as habitat concentration areas (HCAs) and in creating the potential to maintain connectivity.
- Within the Okanagan Valley the potential for north–south movement occurs primarily along the higher elevation edges of the main valley. Encroachment of development into this area will continue to reduce connectivity options here, unless planning efforts are undertaken to maintain connectivity.
- Hwy 3 going west has important riparian and other habitats, but east–west connectivity options are limited by the physiographic features of this steep valley system. Maintaining habitat in this region will be important in the future. However, development pressures are high as vineyard and other rural developments are expanding rapidly without planning efforts to help to maintain existing movement corridors.
- Hotter and drier summers and a longer frost-free season are likely to affect connectivity of moist habitats (e.g., wetlands and riparian areas) along valley floors. Future changes in vegetation are likely to affect the distribution and quality of core habitat areas and corridors for both shrub-steppe and montane species, though there is high uncertainty around the nature of these changes, particularly for low-elevation valleys. Changes in disturbance regimes, including increased risk of pest outbreaks and wildfire, may affect habitat connectivity throughout the subregion; forested habitats and linkages may be particularly affected.

Connectivity Focus Areas Where Shrub-Steppe, Montane, and Landscape Integrity All Overlap

Places where connectivity may be at risk from multiple perspectives include, for example:

- The several east–west trending valleys that enter the main Okanagan Valley, such as northwest of Vernon, the Lumby Valley, east of Kelowna (following Hwy 33), west of Peachland (following Hwy 97C), the Similkameen Valley at Keremeos, and east of Osoyoos. These valleys are tremendously important for supporting movement of shrub-steppe species extending out from the main Okanagan Valley, as well as north–south movements of montane species. Currently, they tend to have lower development pressures than the main Okanagan Valley, but the rate of development is increasing here and urgent efforts are needed to ensure that connectivity is maintained in the future.
- The area north of Vernon may facilitate movement across the valley to higher elevation habitats and may provide connectivity to shrub-steppe communities in the northwest.
- The area between Okanagan Falls and Osoyoos, including the Okanagan Valley along Hwy 97 as well as along Hwy 3 where it loops to the west through Marron Valley, Olalla, Keremeos, and Cawston. Many of all CFAs identified in the subregion occur here, reflecting this area’s importance for regional connectivity, as well as the pressure of ongoing habitat conversion to agriculture and urbanization. Situated at the “crossroad” of four of the five fracture zones, development in this portion of the study area would impact connectivity for wildlife moving both within and across the Okanagan Valley. This area also has the largest number and extent of protected areas. Several of the CFAs identified here are near or adjacent to protected areas, and if lost would significantly reduce the ability of these conservation lands to function as habitat cores or stepping stones for movement.
- East of Osoyoos, where the boundaries of the Hwy 3 East, Hwy 97 Central, and Hwy 97 South Fracture Zones meet. Further development here has the potential to sever the remaining narrow

north–south connection for shrub-steppe species moving along the east side of the Okanagan Valley, as well as north–south movement of montane species along the eastern rim of the valley at higher elevations.

- South of Oroville near Mt Hull, and near Riverside on the US side of the Okanagan Valley. These areas are threatened by further development in the valley. They provide north–south movement for shrub-steppe species along the Okanagan and offer opportunities for montane species to cross the Okanagan along an east–west axis. The area near Riverside has been identified by previous analyses as key for linking forested habitat of the North Cascades eastward through the Okanagan Valley and Highlands to the Kettle Range.
- Along the narrow Similkameen Valley between Keremeos and Princeton we identified several bottlenecks for shrub-steppe species moving between the Okanagan and the shrub-steppe patch north of Princeton. These same areas provide opportunities for north–south movements of montane species across the Similkameen Valley. The linear "stepping-stone" arrangement of these CFAs reflects the steep and rugged sides of the valley that constrain connectivity and increase pressure to develop what little "flat" land occurs. Loss of one CFA may compromise the east–west connectivity function of the others. North–south trending drainages may offer less steep access routes across the valley.
- The area north of Princeton may be important for maintaining east–west connectivity of higher elevation habitats as well as providing potential future access to shrub-steppe areas in the Nicola Valley and north to Merritt and beyond.

Future Work and Conclusions

Development pressure—forest management, agricultural land use, recreational and urban development, and population growth—is increasing in the Okanagan-Kettle subregion, especially in BC. Many opportunities to conserve connectivity have been lost in the last 20 years and future opportunities are increasingly limited. The additional stressor associated with the overarching impact of future climate change highlights the urgency for information to guide on-the-ground connectivity conservation efforts and management. We have identified Connectivity Focus Areas (CFAs) within the Okanagan Valley fracture zones where connectivity for wildlife is most at risk. Places where CFAs for shrub-steppe species, montane species, and landscape integrity all overlap focus attention on areas that if lost may significantly impact movement of wildlife within and through the Okanagan.

Okanagan Highlands. Photo by Justin Haug.

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