Chapter 12. Network Centrality, Pinch-Points, and Barriers and Restoration Opportunities for Tiger Salamander (*Ambystoma tigrinum*)

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This chapter is an addendum to the *Washington Connected Landscapes Project: Analysis of the Columbia Plateau Ecoregion* (2012). It includes supplemental connectivity maps for tiger salamander (*Ambystoma tigrinum*) that can be used to help prioritize and implement conservation actions. We have also included the linkage network (Fig. 12.1) and cost-weighted distance surface (Fig. 12.2) previously modeled for tiger salamander (See Appendix A.11, WHCWG 2012, available from http://waconnected.org).

Tiger salamander, photo by William P. Leonard

Addendum Connectivity Maps

The supplemental connectivity products developed for tiger salamander include maps of (1) linkage network centrality (Fig. 12.3), (2) linkage pinch-points (Fig. 12.4), and (3) barriers and restoration opportunities (Fig. 12.5). There are numerous potential applications of these maps for informing connectivity conservation. We highlight examples on the landscape where conservation efforts for connectivity may be needed (Figs. 12.6–12.13).

Conservation of Connectivity for Tiger Salamander

- Tiger salamanders likely exist in distinct subpopulations, represented by clusters of habitat, each with their own centrality considerations.
- Each distinct habitat cluster deserves its own set of conservation priorities.
- The most extensively distributed and well-connected habitat cluster has a roughly north-south axis and greatest centrality within the Columbia Basin Irrigation Project, between Banks Lake and Moses Lake.
- Important elements of tiger salamander habitat networks correspond with the Braided Scabland Swath and Lower Crab Creek Linkage Zone. Both areas are identified as important to a suite of focal species.
- Barriers are associated with natural features and human-created features like rocky slopes and ridges, large lakes and rivers, and highways or agricultural areas. Culverts under roads and undisturbed corridors through agricultural lands could mitigate the barrier effects of these features.

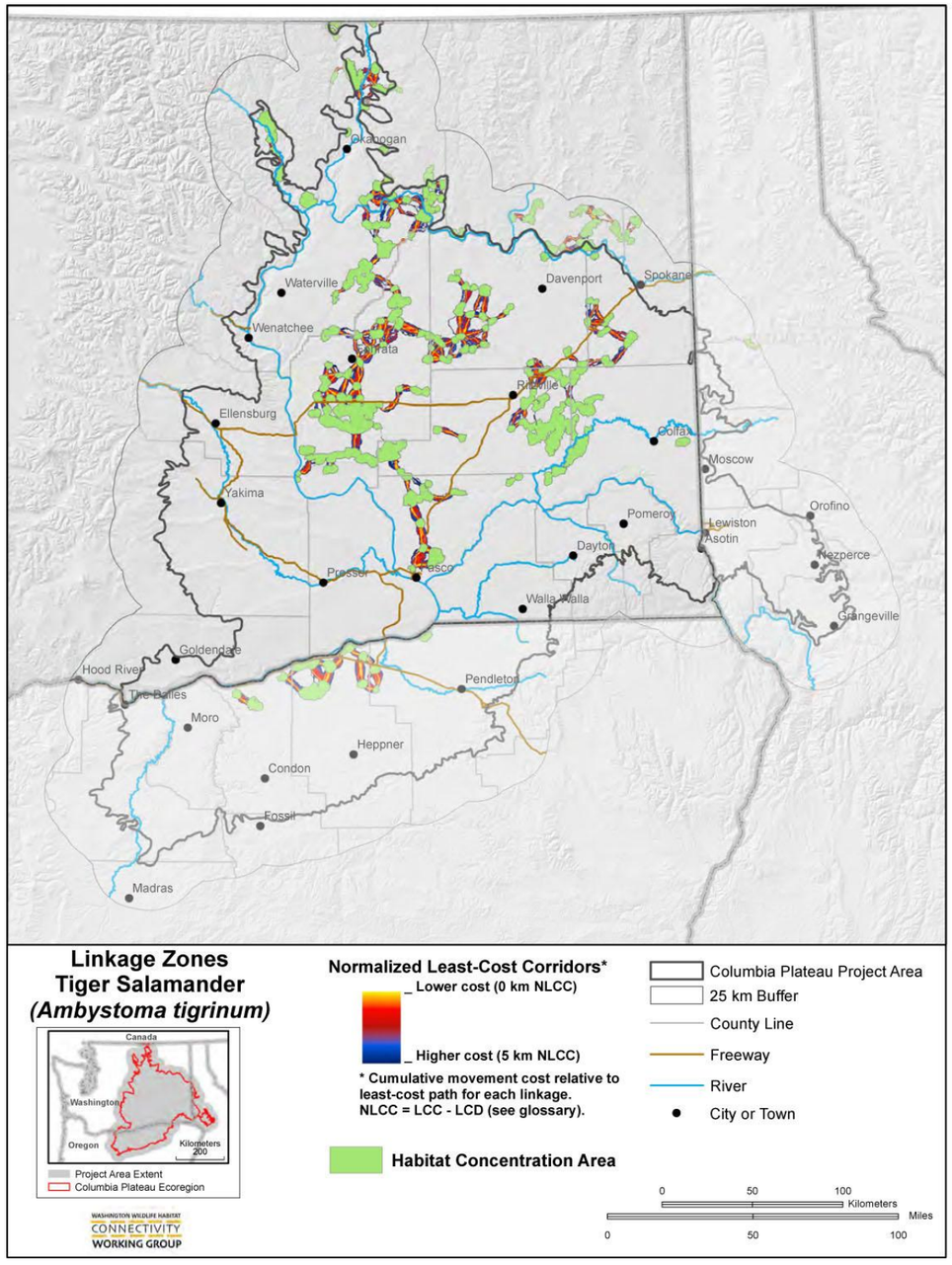


Figure 12.1. Linkage network modeled for tiger salamander in the Columbia Plateau Ecoregion (Appendix A.11, WHCWG 2012). Green polygons represent habitat concentration areas (HCAs) for tiger salamander. Linkages between HCAs are shown in bright colors; the least-cost pathways are highlighted yellow.

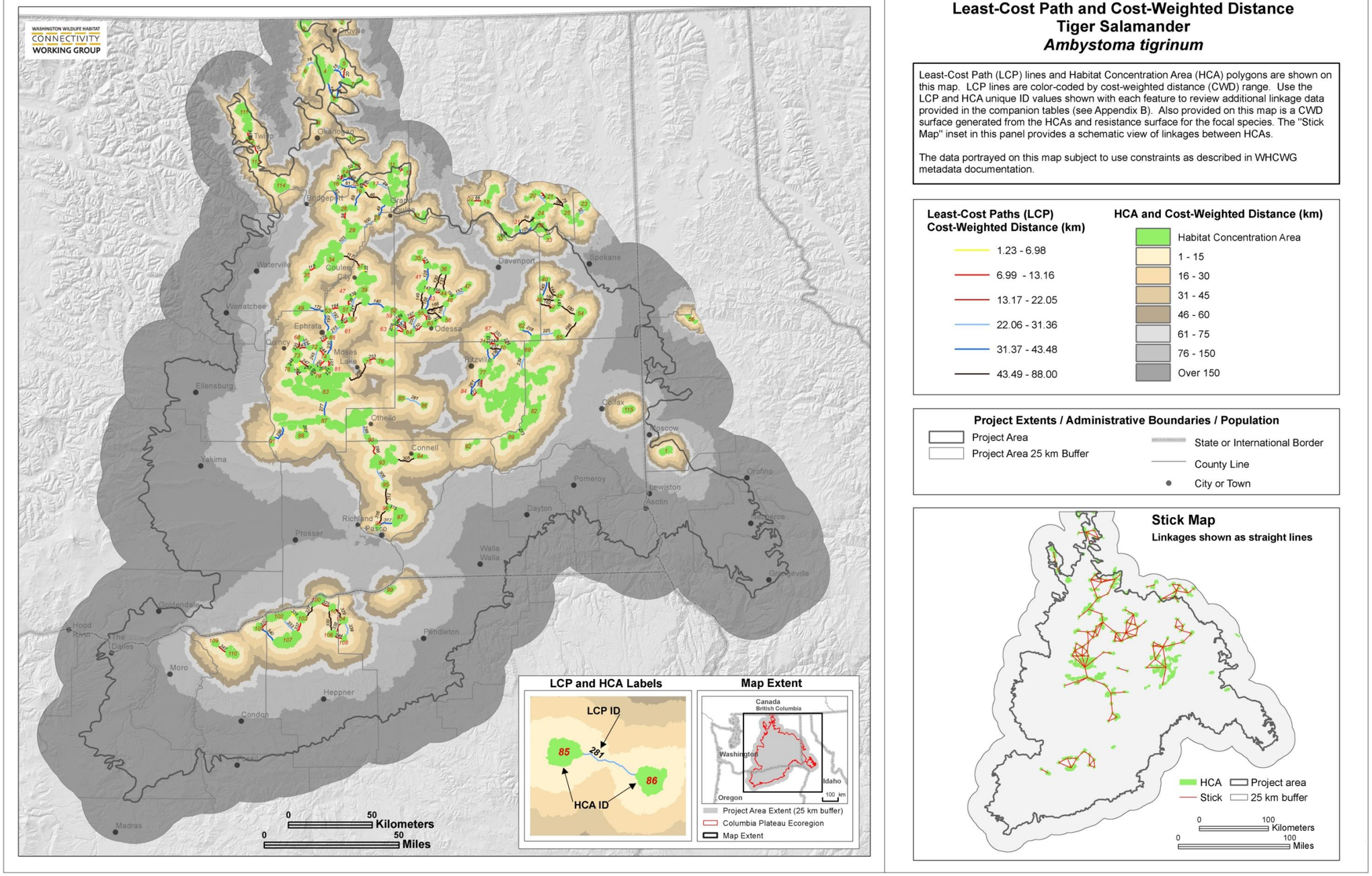


Figure 12.2. The cost-weighted distance map with numbered habitat concentration areas (HCAs) and least-cost paths for tiger salamander in the Columbia Plateau Ecoregion (Appendix A.11, WHCWG 2012).

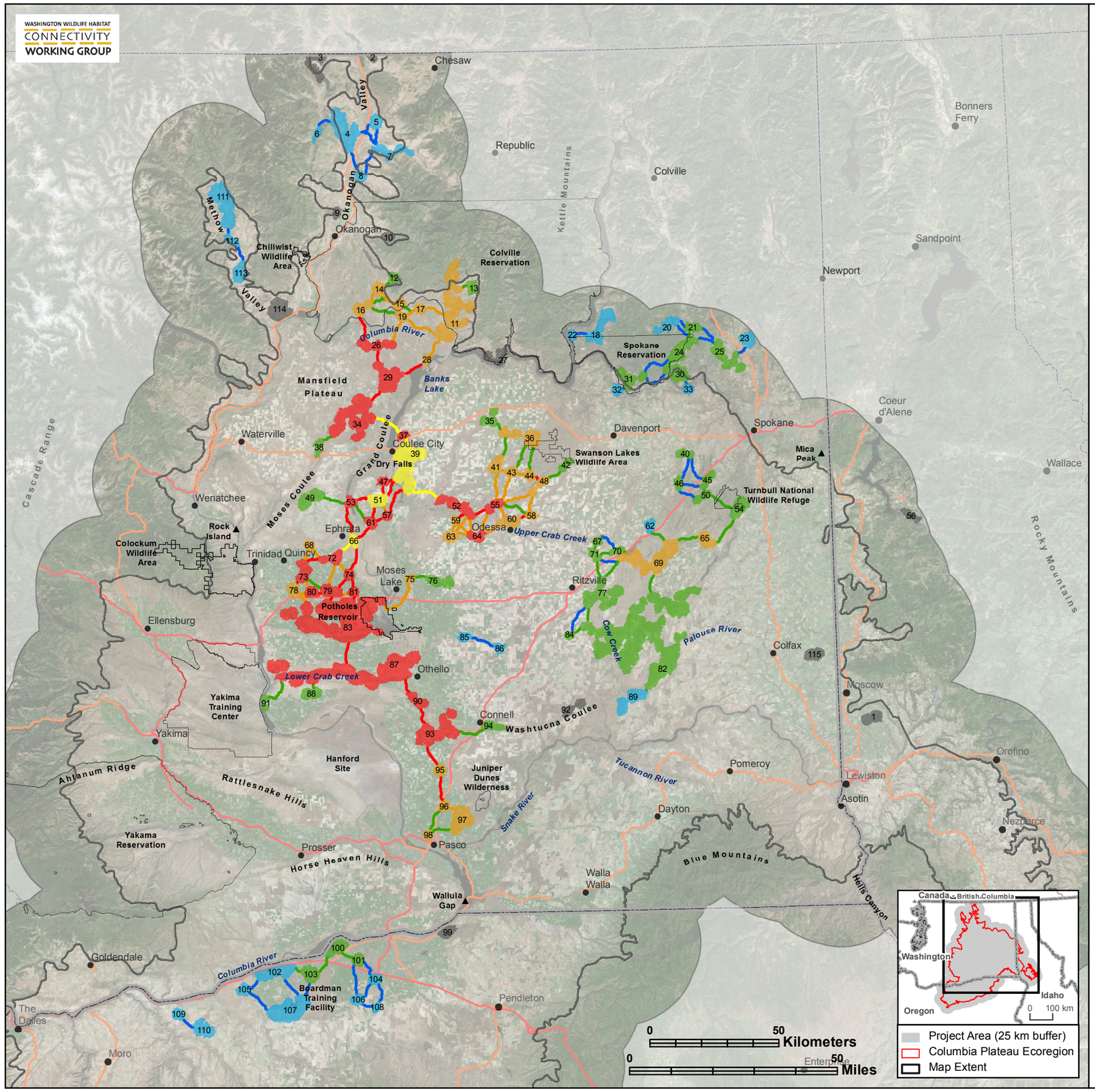


Figure 12.3. Linkage Network Centrality for Tiger Salamander (*Ambystoma tigrinum*).

WHAT IS CENTRALITY?

Centrality is a measure of how important a habitat area or linkage is for keeping the overall connectivity network connected. For our analyses, we calculated current flow centrality using the Linkage Mapper Toolbox (see more at http://www.circuitscape.org /linkagemapper).

WHY IS CENTRALITY IMPORTANT?

The connectivity network is comprised of habitat concentration areas (HCAs) and linkages for movement of wildlife between them. Linkages or HCAs with high centrality are expected to be the "gatekeepers" for connectivity. For example, if a linkage with high centrality is severed, a wildlife species may risk having its population separated into sub-populations.

HOW IS CENTRALITY DEPICTED ON THE MAP?

- Centrality results are depicted based on four quartiles (four equal parts). However, the top quartile includes areas shown in yellow (the top 10% of this quartile), and red (the remaining 90%).
- Linkages and HCAs shown in orange also have relatively high network centrality, while those colored blue and green tend to be on the periphery of the network.

TYPES OF QUESTIONS AND DECISIONS THIS MAP HELPS INFORM

- Where are important areas on the landscape for maintaining connectedness?
- Where should further disturbance to connectivity be avoided?
- Which HCAs might be important for species recovery efforts (e.g., sites for translocations and augmentations of populations)?

Notes: This map depicts modeled HCAs and linkages (see more at http://waconnected.org). While we've used the best available data layers, field review is necessary to ensure the HCAs and linkages are viable. We included areas in Oregon and Idaho to help understand transboundary connectivity; however, our products may be less accurate in these adjoining areas.

Habitat Concentration Area (HCA) Centrality*

- Highest
- Very High
- High
- Medium
- Low
- Not Connected

*Habitat Concentration Area (HCA) polygon labels on the map indicate HCA ID number.

Least-Cost Path (LCP) Centrality

- Highest
- Very High
- High
- Medium
- Low

Boundaries and Population Centers

- Columbia Plateau Project Area
- Columbia Plateau Project Area 25 km Buffer
- State or Provincial Border
- Freeway
- Major Highway
- City or Town
- Important Site

The data portrayed on this map are subject to use constraints as described in WHCWG metadata documentation.

Figure 12.4. Linkage Pinch-Points for Tiger Salamander (*Ambystoma tigrinum*).

WHAT ARE PINCH-POINTS?

Pinch-points are "bottlenecks" where wildlife movement is funneled within linkages. Pinch-point modeling methods are based on electrical circuit theory. Locations where current is very strong are constrictions within linkages and represent areas most vulnerable to being severed (see more at http://www.circuitscape.org /linkagemapper). Pinch-points can be the result of both natural and human-made landscape features.

WHY ARE PINCH-POINTS IMPORTANT?

Pinch-points are a conservation priority as they are locations where loss of a small area could disproportionately compromise connectivity due to a lack of alternative movement routes. Loss of these areas may sever migration routes, or impact other critical movement needs.

HOW ARE PINCH-POINTS DEPICTED ON THE MAP?

- Habitat concentration areas (HCAs) are indicated in green, while the linkages are depicted in a yellow to blue color ramp.
- Reds and yellows indicate moderate to highly constrained areas for movement within linkages.
- Blue areas are not necessarily "better" areas of the linkages but rather places where resistance is similar across broad swaths of the landscape.

TYPES OF QUESTIONS AND DECISIONS THIS MAP HELPS INFORM

- Where along linkages is potential movement highly or moderately constrained?
- Are there areas where alternative movement routes may not be available?

To determine the relative importance of pinch-points in different linkages, users should consider the pinch-point map in conjunction with other measures, such as centrality.

Notes: This map depicts modeled HCAs and linkages (see more at http://waconnected.org). While we've used the best available data layers, field review is necessary to ensure the HCAs and linkages are viable. We included areas in Oregon and Idaho to help understand transboundary connectivity; however, our products may be less accurate in these adjoining areas.

Linkage Pinch-Points

Current Flow

- Highly Constrained
- Unconstrained

Habitat Concentration Area (HCA)*

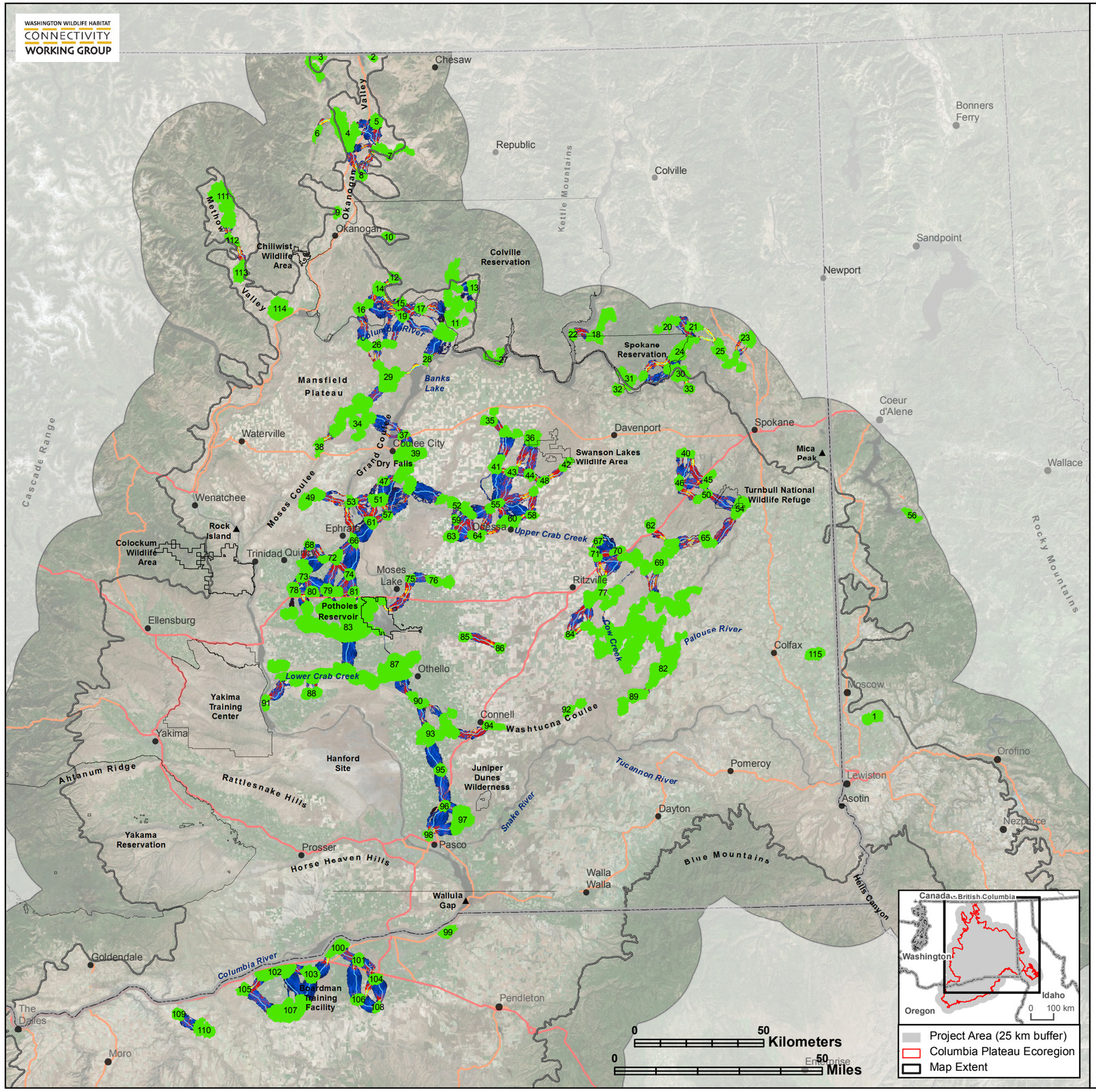
Least-Cost Path (LCP)

*Habitat Concentration Area (HCA) polygon labels on the map indicate HCA ID number.

Boundaries and Population Centers

- Columbia Plateau Project Area
- Columbia Plateau Project Area 25 km Buffer
- State or Provincial Border
- Freeway
- Major Highway
- City or Town
- Important Site

The data portrayed on this map are subject to use constraints as described in WHCWG metadata documentation.



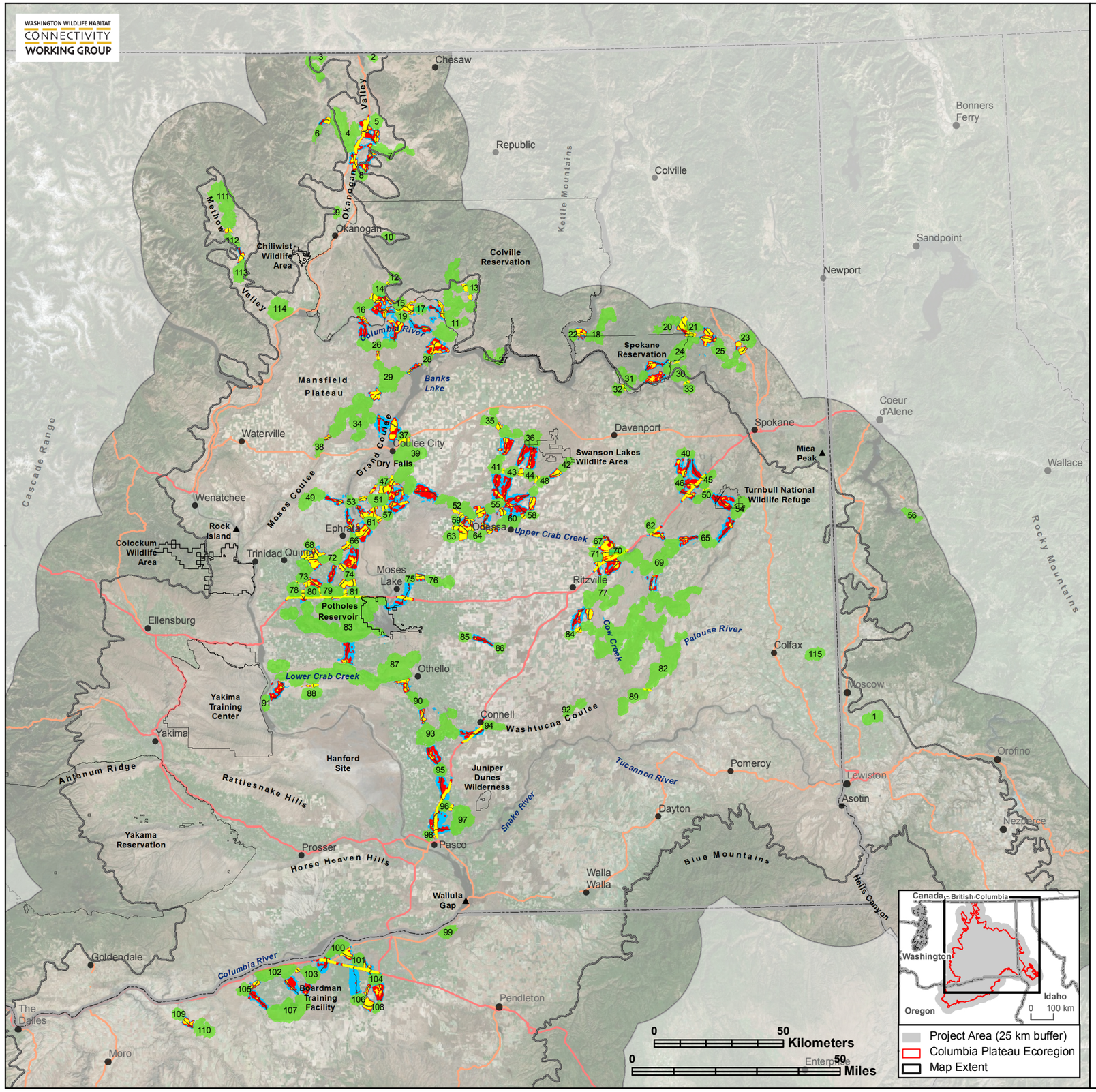


Figure 12.5. Barriers and Restoration Opportunities for Tiger Salamander (*Ambystoma tigrinum*).

WHAT ARE BARRIERS?

Barriers are areas where landscape features impede wildlife movement between habitat concentration areas (HCAs). Least-cost modeling methods (see more at http://www.circuitscape.org/linkagemapper) identify and rank barriers by their impact and quantify the extent to which restoration may improve connectivity. Barriers may be partial or complete, and they may be natural (e.g., rivers, cliffs) or human-made (e.g., urban areas, highways, some types of agriculture). Not all barriers are restorable.

HOW ARE BARRIERS AND RESTORATION OPPORTUNITIES DEPICTED?

- The Barrier Impact/Restoration Improvement Score reflects the percent reduction in corridor resistance per hectare restored. The scores are shown as three equal proportions, indicated in the colors of yellow, red, and blue.
- Barriers highlighted yellow or red are places that, if restored or enhanced, may yield the greatest improvement in potential movement between HCAs.
- Areas highlighted blue may yield moderate improvement in potential movement if restored.
- Barriers identified outside linkage pathways have the potential to produce new, alternative corridors for movement between HCAs if restored.

TYPES OF QUESTIONS AND DECISIONS THIS MAP HELPS INFORM

- Where in a linkage will restoration efforts have the greatest effect on connectivity?
- Where can alternate linkage pathways be created through restoration of key areas or removal of key barriers?

Since **all types** of barriers to movement are identified on this map users must further evaluate the feasibility of each restoration opportunity.

Notes: This map depicts modeled HCAs and linkages (see more at http://waconnected.org). While we've used the best available data layers, field review is necessary to ensure the HCAs and linkages are viable. We included areas in Oregon and Idaho to help understand transboundary connectivity; however, our products may be less accurate in these adjoining areas.

Barrier Impact / Restoration Improvement Score

- Highest
- High
- Moderate

HCAs and LCPs

- Habitat Concentration Area (HCA)*
- Least-Cost Path (LCP)

*Habitat Concentration Area (HCA) polygon labels on the map indicate HCA ID number.

Boundaries and Population Centers

- Columbia Plateau Project Area
- Columbia Plateau Project Area 25 km Buffer
- State or Provincial Border
- Freeway
- Major Highway
- City or Town
- Important Site

The data portrayed on this map are subject to use constraints as described in WHCWG metadata documentation.

Example Areas of Interest for Connectivity

Linkage Network Centrality

- The HCAs and linkages ranked Highest for centrality are mostly within the Columbia Basin Irrigation Project area. (Fig. 12.6). A Highest centrality linkage across Banks Lake is also identified as a strong barrier.
- One cluster of tiger salamander HCAs corresponds to the Braided Scablands Swath, an area identified as valuable for connectivity of multiple focal species (Fig. 12.7).

Linkage Pinch-Points

- Pinch-points, like the one at the south end of Moses Lake (Fig. 12.8), illustrate the model's emphasis on terrestrial dispersal routes for tiger salamanders.
- Pinch-points can reflect natural constraints associated with drainages, soils and topography (Fig. 12.9). Successful exchange of individuals among populations separated by these features can be enhanced by the presence of multiple movement corridors that facilitate continued movement by rare dispersers that traverse the natural impediment.

Barriers and Restoration Opportunities

- We identified I-90 as a significant barrier that bisects tiger salamander range in an area important for network centrality (Fig. 12.10). Additional culverts or other safe crossing opportunities could improve connectivity in this important area.
- The Columbia River and infrastructure that parallels the river create a significant impediment to dispersal among tiger salamander populations. In some places, like the Methow Valley, populations may be relatively isolated from the core of the species' Washington range (Fig. 12.11). In several cases, we identified the Columbia River as a significant barrier between individual HCAs (Fig. 12.12). Considerable uncertainty surrounds the degree to which a wide, deep-water habitat with numerous salamander predators impedes salamander movement. Genetic research could help determine the relative permeability of this natural barrier.
- Within the Scablands Swath, strong impediments to tiger salamander movements include highways, I-90 being one of the most important due to its structure and the volume of traffic it carries (Fig. 12.13). Culverts that pass water as well as dry culverts may reduce the barrier effect of roads to salamanders. Again, landscape genetic analyses could shed light on whether highways are separating salamander populations and limiting gene flow.

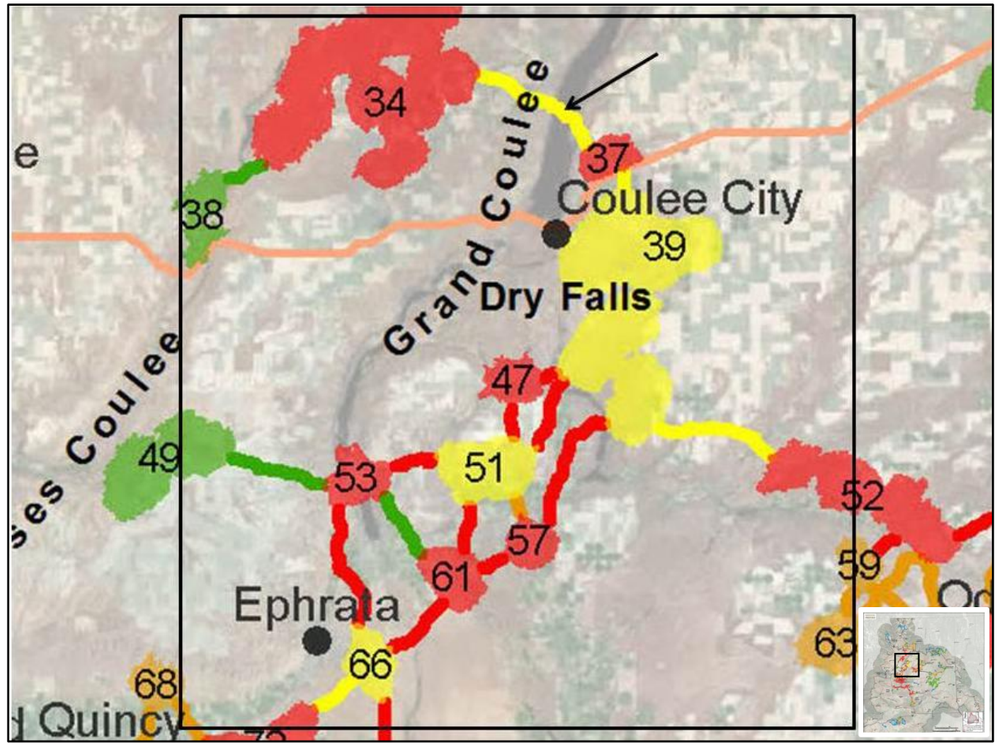


Figure 12.6. High centrality HCAs and linkages within the Columbia Basin Irrigation Project area.

- The HCAs and linkages ranked Very High to Highest for centrality are mostly within the Columbia Basin Irrigation Project area. Distribution of irrigation water here has increased surface water over a broad area, potentially increasing breeding habitat for tiger salamanders, and possibly providing stepping stones that increase the potential for successful dispersal between relatively distant HCAs.
- One linkage ranked Highest for centrality crosses Banks Lake (arrow), a landscape feature identified as a strong barrier. A longer but potentially better linkage, which wasn't identified in the modeling because its length exceeded the maximum length allowed, crosses south of Dry Falls dam in an area with numerous small ponds that likely provide breeding habitat for tiger salamanders. Maintenance or restoration of stepping-stone habitat along this longer linkage could play an important role in maintaining connectivity among tiger salamander populations.

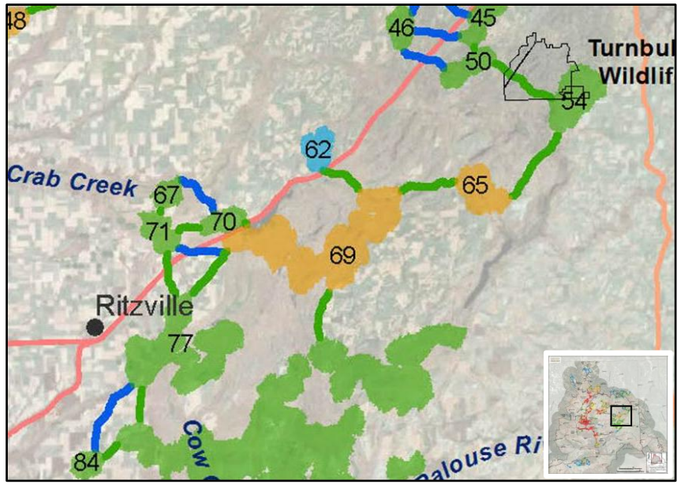


Figure 12.7. Tiger salamander HCAs corresponding to the Braided Scablands Swath.

- One cluster of tiger salamander HCAs corresponds to the Braided Scablands Swath, an area we identified as valuable for multiple focal species. An area east of Sprague Lake (tan HCAs) was identified for its centrality to this habitat network. This area has retained many important characteristics for tiger salamanders that resulted from the Missoula floods, including many ponds and small lakes.

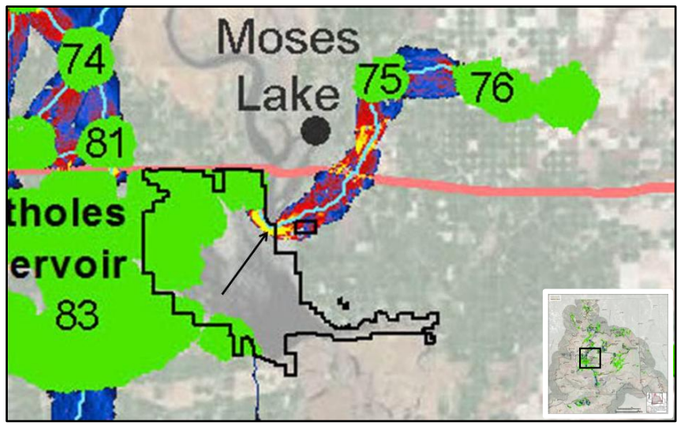


Figure 12.8. Linkage pinch-point for tiger salamander near Potholes Reservoir.

- Pinch-points, like this one (arrow) at the south end of Moses Lake, illustrate the model's emphasis on terrestrial dispersal routes for tiger salamanders. If robust fish populations in Moses Lake and Potholes reservoir prevent aquatic dispersal of tiger salamanders, then this terrestrial pinch-point would be an essential linkage for tiger salamanders in HCAs 75 and 76.

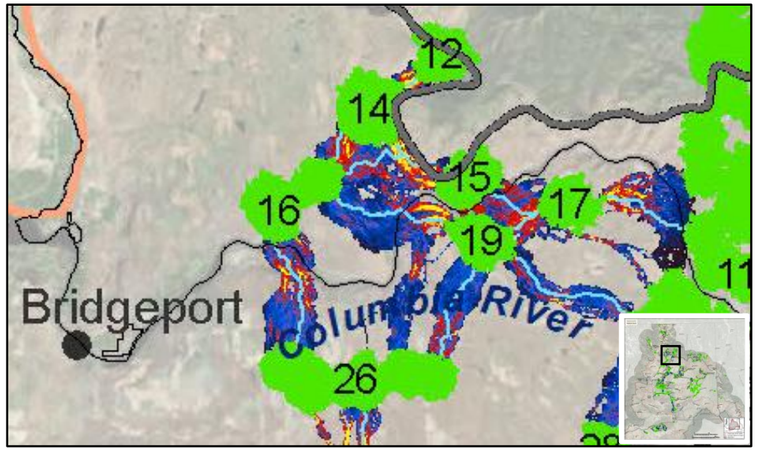


Figure 12.9. Linkage pinch-points for tiger salamander created by natural landscape features.

- Pinch-points, like these on the Colville Reservation, can reflect natural constraints associated with major rivers, soils, and topography. Successful dispersal across these natural impediments is likely infrequent. Preserving multiple corridors that can support salamander movements near these features may increase the likelihood that rare dispersers reach another population and contribute to gene flow.

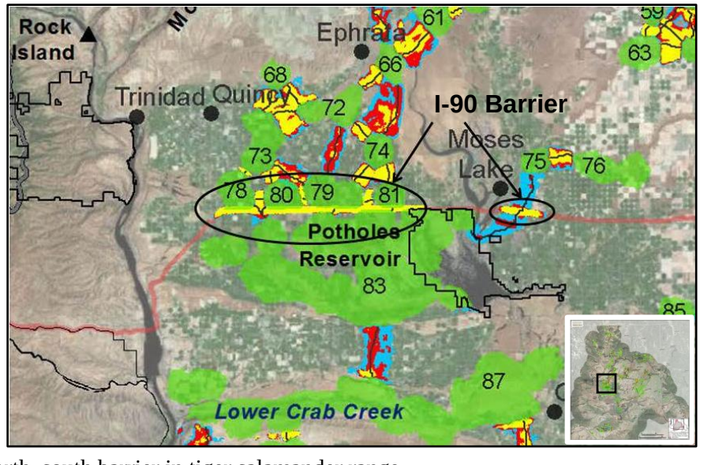


Figure 12.10. I-90 north–south barrier in tiger salamander range.

- I-90 bisects tiger salamander range in an area important for network centrality (see Fig. 12.6). The interstate was identified as a significant barrier (ovals). Some permeability may have been missed where culverts provide aquatic connections to get salamanders past the highway. Additional culverts could improve connectivity in this important area.

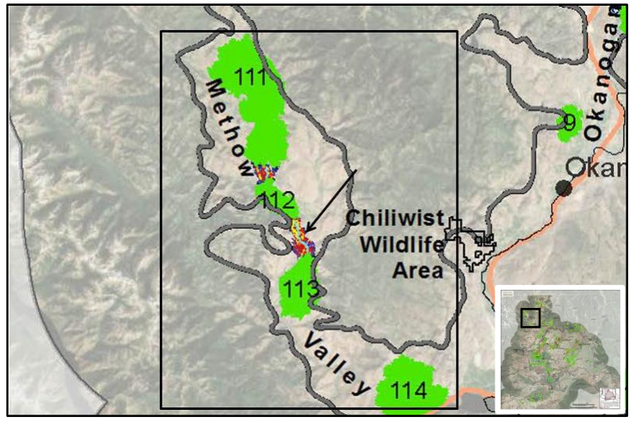


Figure 12.11. Identified barriers for tiger salamanders in the Methow Valley.

- The Columbia River has been identified as a significant barrier separating tiger salamanders in places like the Methow Valley (rectangle) from populations in the core of the species' Washington range. Dry conditions inhibit connectivity within the Methow Valley, though permeability could be improved by creating one or more movement corridors to get salamanders past development and State Route 153 between HCAs 112 and 113 (arrow) in the Methow River valley bottom.

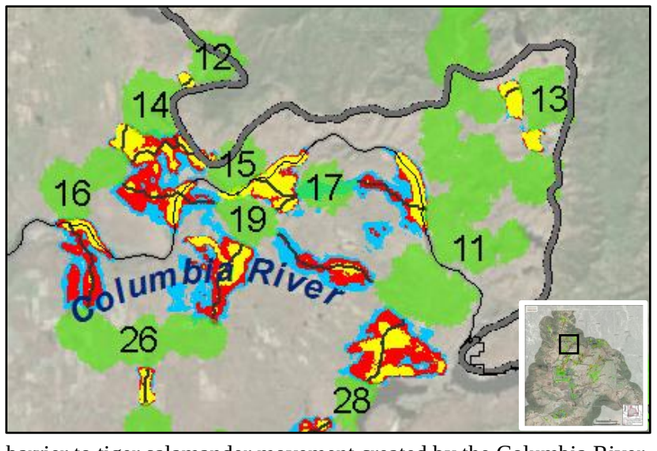


Figure 12.12. A natural barrier to tiger salamander movement created by the Columbia River.

- The Columbia River was identified as a significant barrier between HCAs 16 and 26; 15 and 19; 16 and 19; 15 and 17; and 17 and 11 as well as other locations. It is not entirely clear that a wide deep-water habitat with numerous salamander predators is a complete barrier to movements. Some research, perhaps genetics investigations, might help describe the strength of this barrier. Habitat conducive to movement of salamanders that is located adjacent to such natural impediments may increase the likelihood of successful crossings of these features.

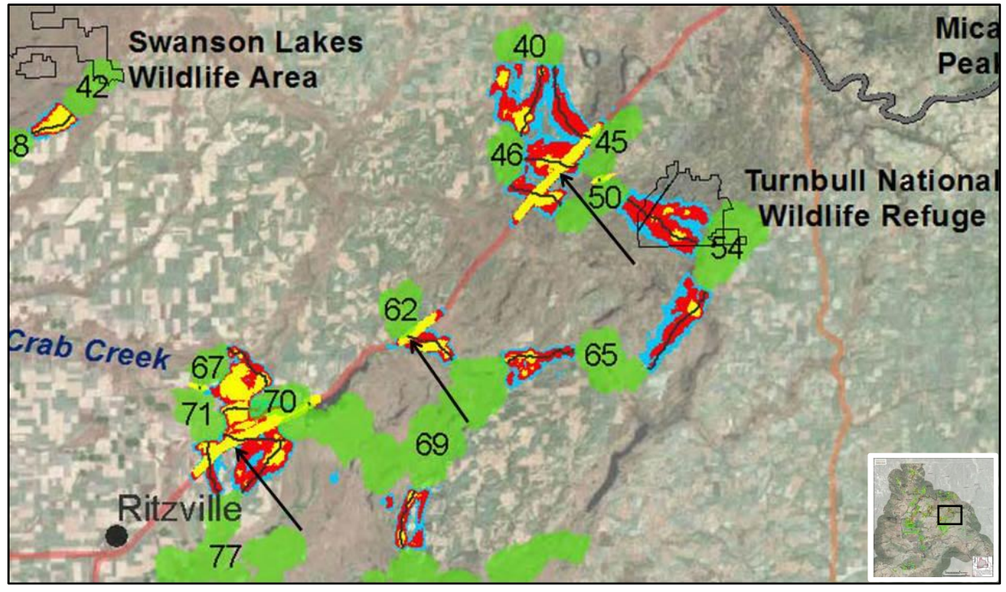


Figure 12.13. Barrier to tiger salamander movement created by I-90.

- Within the Scablands Swath, barriers to tiger salamander movements include highways. I-90 (arrows) is one of the most important highway features due to its structure and the volume of traffic it carries. Culverts that pass water as well as dry culverts reduce the barrier effect of roads to salamanders. However, our spatial data layers did not include these features. Areas indicated by arrows are places that warrant local-scale evaluation to better assess the permeability of the I-90 barrier. Research and genetic evaluation could be used to evaluate the efficacy of existing culvert pathways.

Acknowledgements

Brian Hall and Brian Cosentino have provided tremendous support for map production and facilitation of work sessions where biologists discuss interpretations of the maps. Thanks also to Steve Spear (Orianne Society) for providing input. As with virtually all of the Working Group's efforts to get high quality products done on time, Joanne Schuett-Hames (WDFW) and Leslie Robb (Independent Researcher) deserve our most sincere gratitude.