Chapter 8. Network Centrality, Pinch-Points, and Barriers and Restoration Opportunities for Least Chipmunk (*Neotamias minimus*)

Prepared by John Fleckenstein (DNR)

Modeling and GIS analysis by Brian Cosentino (WDFW), Brian Hall (WDFW), Brad McRae (TNC), Darren Kavanagh (TNC), and Andrew Shirk (UW)

This chapter is an addendum to the *Washington Connected Landscapes Project: Analysis of the Columbia Plateau Ecoregion* (2012). It includes supplemental connectivity maps for least chipmunk (*Neotamias minimus*) that can be used to help prioritize and implement conservation actions. We have also included the linkage network (Fig. 8.1) and cost-weighted distance surface (Fig. 8.2) previously modeled for least chipmunk (See Appendix A.7, WHCWG 2012, available from http://waconnected.org).

Least chipmunk, photo by Kelly McAllister

Addendum Connectivity Maps

The supplemental connectivity products developed for least chipmunk include maps of: (1) linkage network centrality (Fig. 8.3), (2) linkage pinch-points (Fig. 8.4), and (3) barriers and restoration opportunities (Fig. 8.5). 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. 8.6–8.12).

Conservation of Connectivity for Least Chipmunk

- Range and distribution of the least chipmunk are not well known. There are fewer than 25 records of the species from the last 20 years. A number of the records are outside of the mapped habitat concentration areas (HCAs).
- Home range of the least chipmunk is small enough and dispersal distance is short enough that habitat quality within the linkages must be adequate to support occupancy.
- The linkage network model is relatively conservative. A more liberal model would result in expansion of most HCAs and joining together of several. Some of these areas are indicated as unconstrained linkages connecting HCAs in the pinch-point map.
- Three unconnected clusters of HCAs are present: (1) one north of I-90 (Northern cluster), (2) one north of the Columbia River, near Lower Crab Creek (Lower Crab Creek cluster), and (3) one south and west of the Columbia River (Southern cluster). Linkages among HCAs in the Southern cluster are relatively unconstrained. The Lower Crab Creek cluster has some linkages with highly constrained pinch-points. The Northern cluster is the most fragmented, and linkages are more highly constrained than in other parts of the ecoregion.
- Barrier model results indicate least chipmunk linkages would benefit from corridor maintenance, promoting habitat improvement, and review of restoration opportunities.

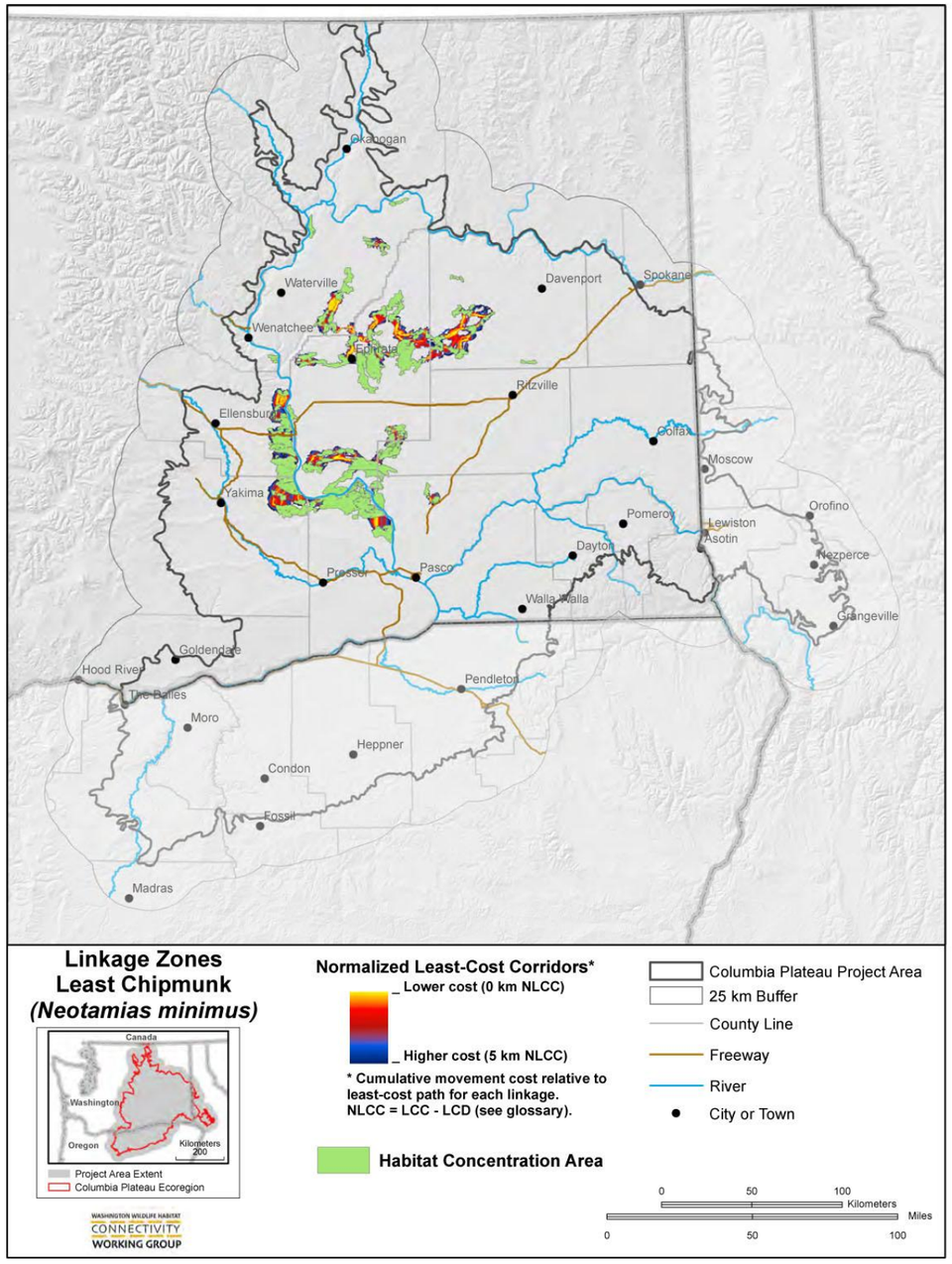

Figure 8.1. Linkage network modeled for least chipmunk in the Columbia Plateau Ecoregion (Appendix A.7, WHCWG 2012). Green polygons represent habitat concentration areas (HCAs) for least chipmunk. Linkages between HCAs are shown in bright colors; the least-cost pathways are highlighted yellow.

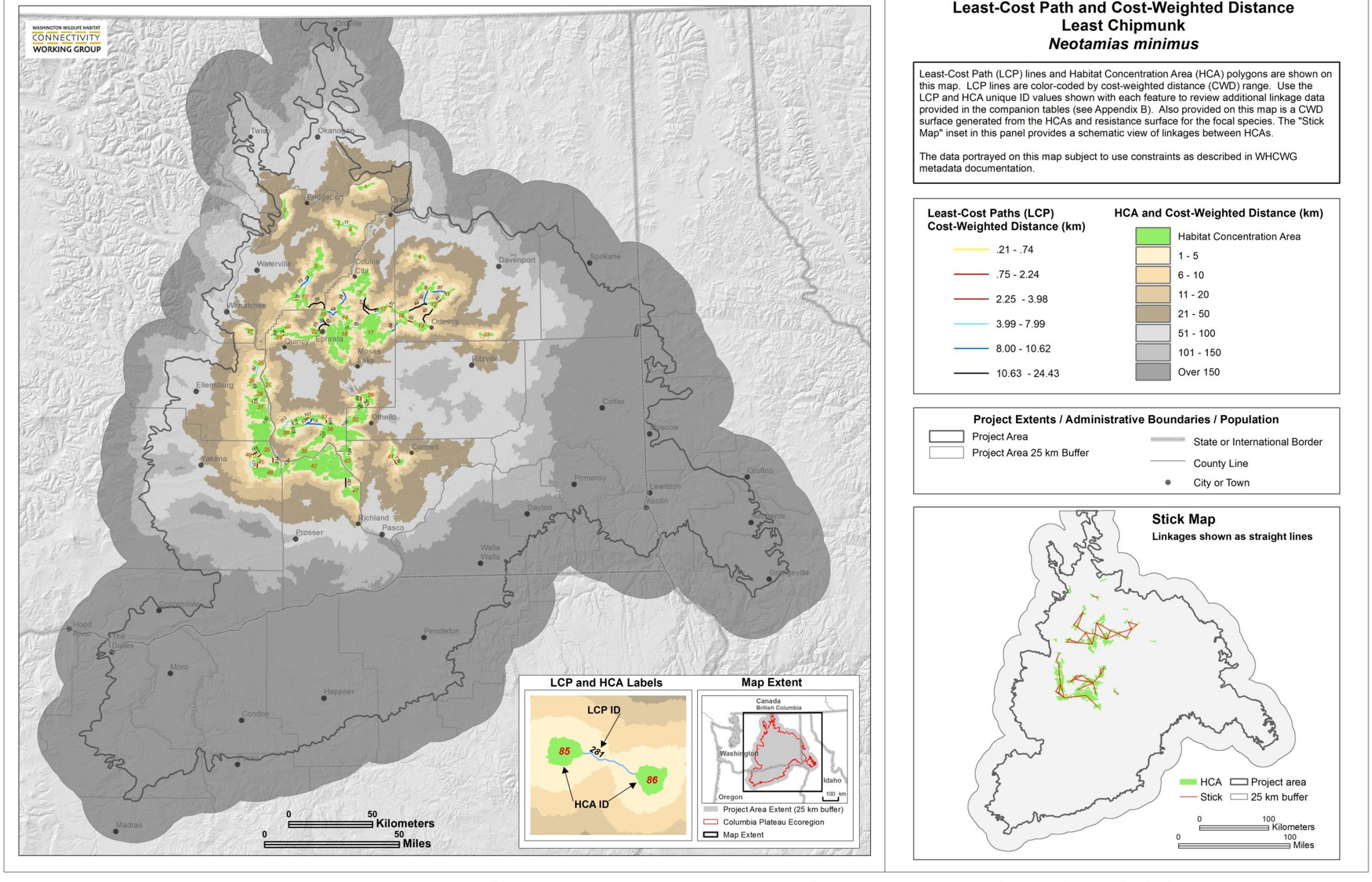

Figure 8.2. The cost-weighted distance map with numbered habitat concentration areas (HCAs) and least-cost paths for least chipmunk in the Columbia Plateau Ecoregion (Appendix A.7, WHCWG 2012).

Figure 8.3. Linkage Network Centrality for Least Chipmunk (*Neotamias minimus*).

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.

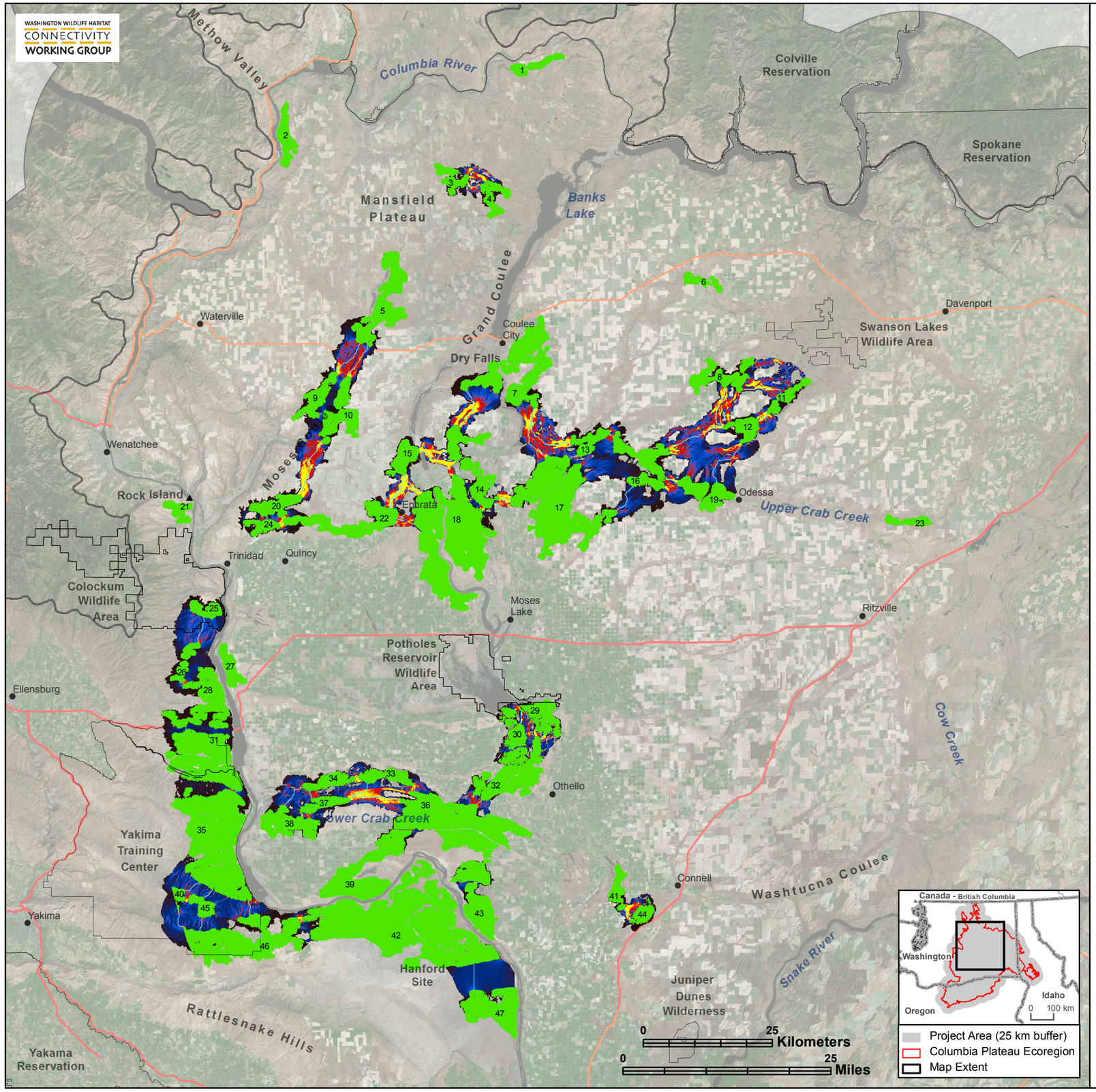

Figure 8.4. Linkage Pinch-Points for Least Chipmunk (*Neotamias minimus*).

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

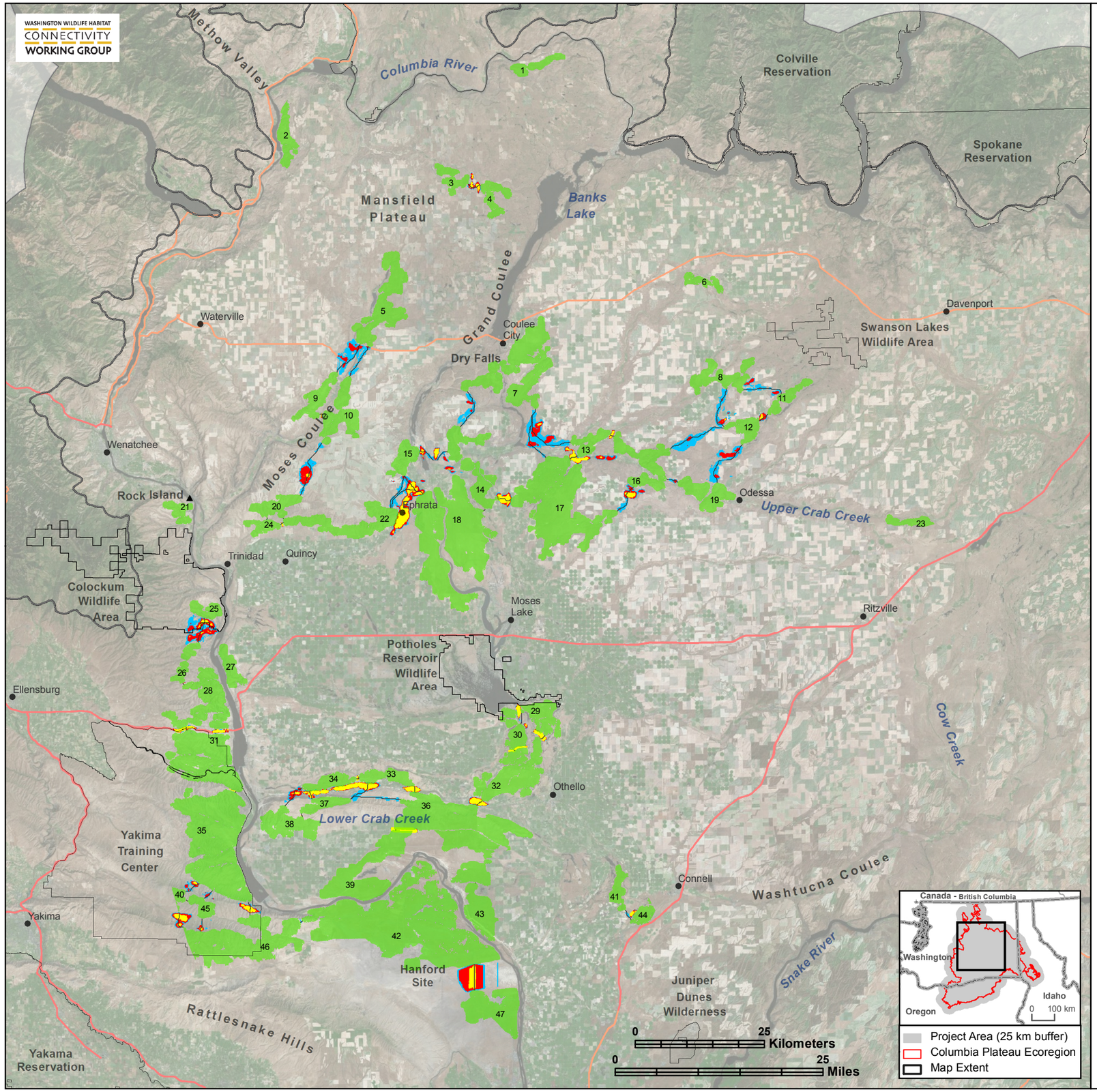

Figure 8.5. Barriers and Restoration Opportunities for Least Chipmunk (*Neotamias minimus*).

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

Example Areas of Interest for Connectivity

Linkage Network Centrality

- There are three unconnected clusters of HCAs. Each has its own pattern of centrality. The HCAs ranked Highest for centrality occur in the Northern cluster of HCAs (north of I-90, Fig. 8.6).
- Since the three least chipmunk clusters were run as part of one analysis, the Northern cluster, a large cluster, received the top centrality rankings, while the two smaller clusters did not. Careful interpretation is needed in this situation (Fig. 8.7).
- Several HCAs are isolated and not connected to the linkage network. Most of these HCAs are on the periphery of the Columbia Plateau (Fig. 8.3).

Linkage Pinch-Points

- The habitat model we used to generate HCAs was relatively conservative. These areas in some cases are indicated as unconstrained connections on the pinch-point map. A slightly more liberal habitat model resulted in significantly larger HCAs. Some of this habitat is probably of sufficient quality to support corridor-dwelling chipmunks (Fig. 8.8).
- Linkages between many of the HCAs in the Lower Crab Creek cluster have highly constrained pinch-points (Fig. 8.9).
- Some linkages, though short, are highly constrained (Fig. 8.9).

Barriers and Restoration Opportunities

- Maintenance of some corridors in the Northern cluster of HCAs may be largely a matter of maintaining and promoting improvement in habitat conditions (Fig. 8.10).
- Elsewhere, the chipmunk would benefit from improvement of linkages, for example to those connections with central HCAs. Several of these linkages cross habitat that is suitable under a more liberal habitat model, but others cross lands that are residential or agricultural where restoration would be expensive and/or difficult (Figs. 8.10, 8.11).
- Resistance of barriers is dependent on the underlying habitat and significant in assessing the cost of restoration (Fig. 8.12).
- The model identifies natural as well as human-created barriers. Sand dunes are an example of a natural barrier (Fig. 8.13).
- The Columbia River is a significant natural barrier for least chipmunk and divides the Lower Crab Creek from the Southern cluster of HCAs.

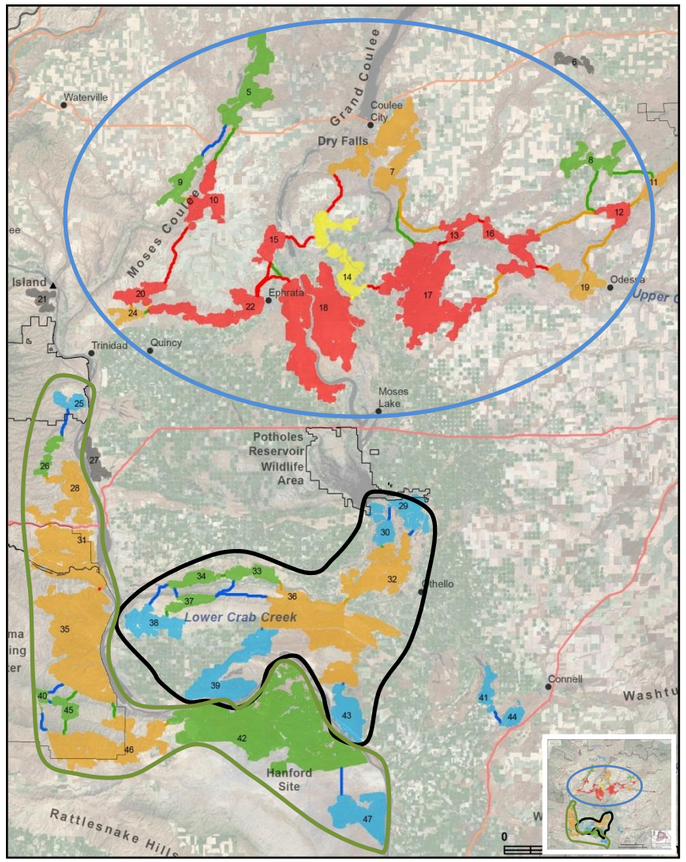

Figure 8.6. Areas of centrality for the least chipmunk.

- Centrality of the Northern cluster of HCAs (blue oval) is greatest for HCA 14; this HCA is important for maintaining connectivity of the Northern cluster.
- In the Lower Crab Creek cluster (black polygon), HCAs 36 and 32 have High centrality. This cluster is separated from the next by the largely impassable Columbia River.
- The Southern cluster (green polygon) has several High centrality HCAs arranged in a north–south orientation.
- The two southern clusters have no HCAs ranked Very High or Highest for centrality. These clusters are disconnected from the Northern cluster of HCAs and from each other. Orange colored HCAs and linkages are identified as most important for centrality within these clusters.

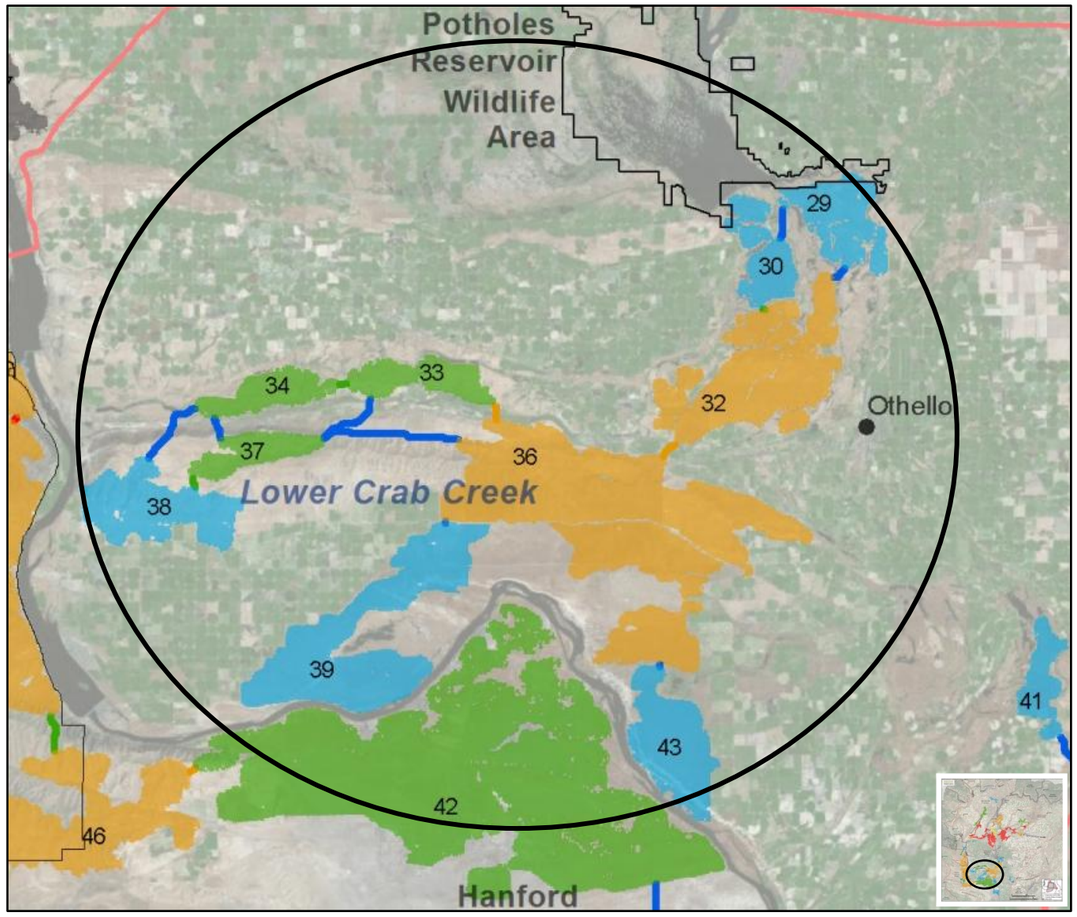

Figure 8.7. Interpreting centrality model results for isolated networks: Lower Crab Creek cluster example.

- The Lower Crab Creek cluster has no HCA with a Highest or Very High centrality rating. Because the three least chipmunk clusters were run as part of a single analysis, the Northern cluster (See Fig. 8.6), a large cluster, received the top centrality rankings, while the two smaller clusters did not.
- One modeling option would be to run centrality for isolated clusters separately. Had we done so, HCAs 32 and 36 may have ranked as Very High or Highest for centrality.
- Thus, interpretation of centrality for the HCAs and linkages in this figure should recognize orange HCAs and linkages as having the greatest relative centrality importance, while those colored green are of medium centrality, and those colored blue are of lower centrality.

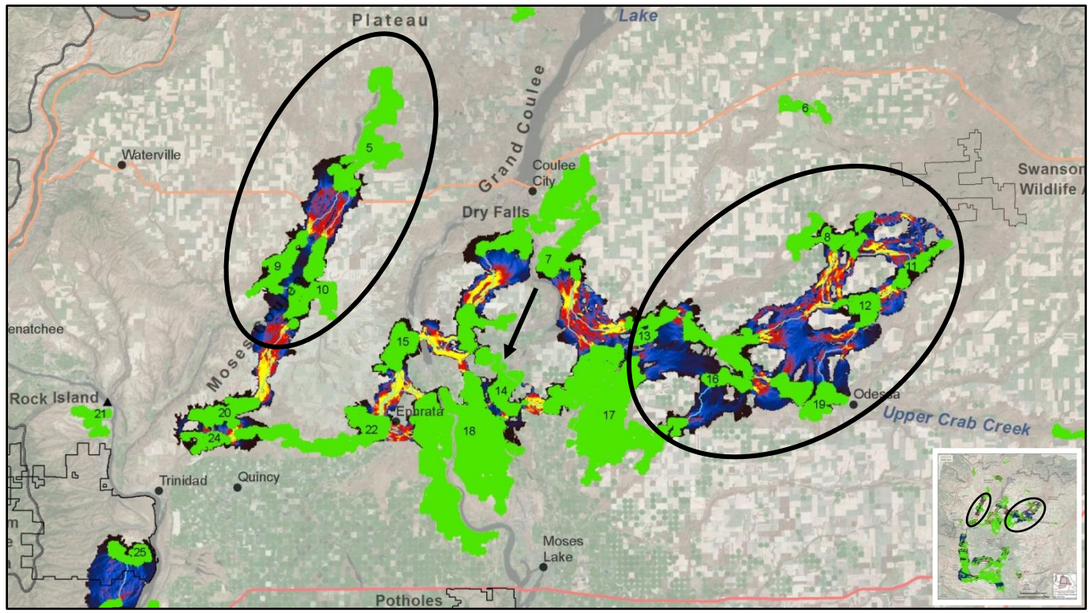

Figure 8.8. Linkage pinch-points: unconstrained and constrained linkage areas in the Northern cluster of least chipmunk HCAs.

- The conservative habitat model we used generated separate HCAs in the areas indicated by ovals. These HCAs are joined when a more liberal habitat model was applied.
- Linkages among many of these HCAs are unconstrained (i.e., dark blue areas), and may be of sufficient quality to both support resident chipmunks and to serve as linkages, (e.g., for HCAs 9–10 and HCAs 16–17). These linkages are also of low resistance as expressed by cost-weighted distance (CWD).
- The Highest centrality HCA (number 14, see arrow), has linkages to HCAs 18, 15, 7, and 17. While the linkage between HCAs 14 and 18 is largely unconstrained, the other linkages, e.g., 14 to 17 are indicated as constrained (yellow to red colors). The latter linkages are also of high resistance as expressed by CWD because they pass through agricultural or otherwise developed land.

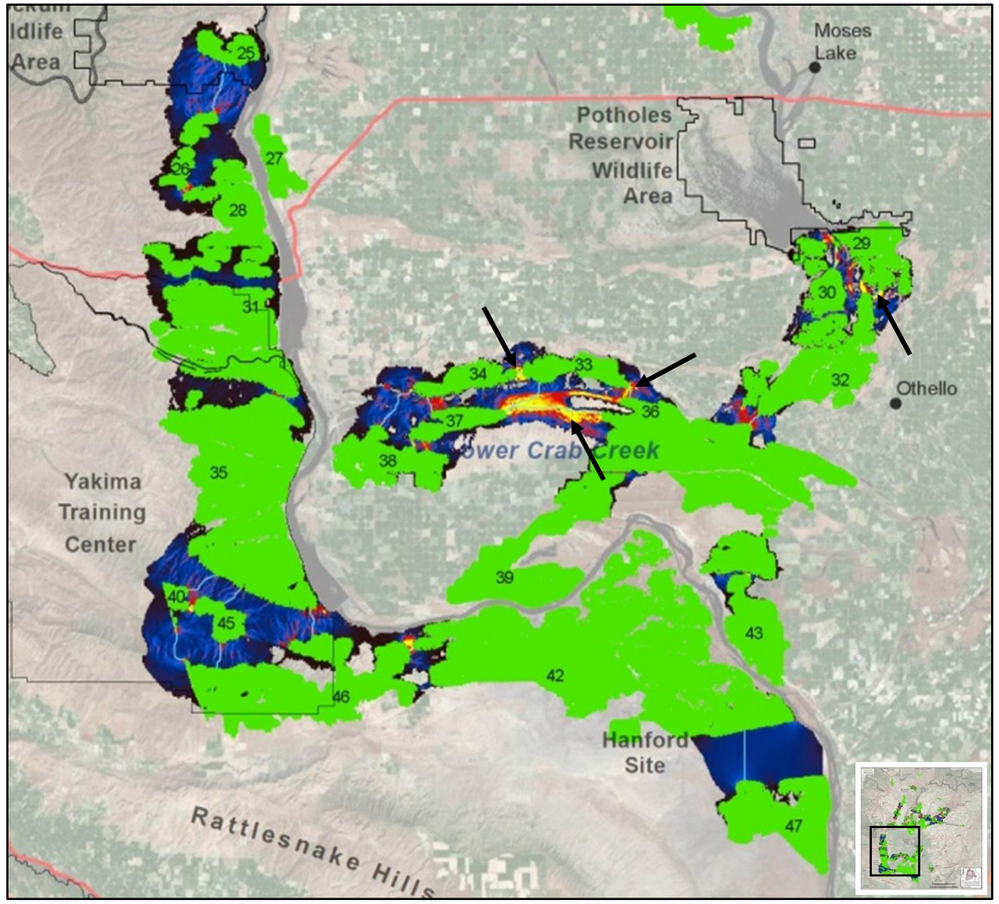

Figure 8.9. Linkage pinch-points for the two southern clusters of HCAs.

- Linkages between the HCAs in the Southern cluster (through the Yakima Training Center and Hanford Site) are relatively unconstrained, have few pinch-points, and are of low resistance.
- Movement is generally more constrained in the cluster of HCAs centered near Lower Crab Creek as many linkages have narrow pinch-points (arrows).

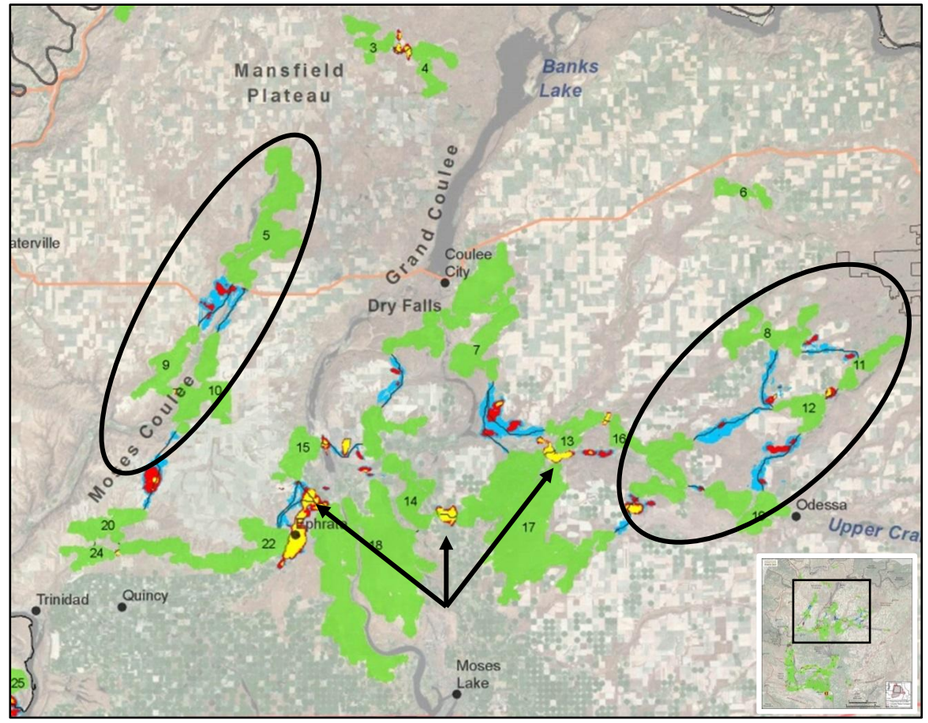

Figure 8.10. Barriers identified for linkages in the Northern cluster of HCAs.

- Under current habitat conditions, barriers among HCAs delineated by ovals have relatively low resistance as measured by CWD. Restoration would yield relatively little improvement in connectivity. Maintenance of corridors is largely a matter of maintaining and promoting some improvement in habitat conditions along these corridors.
- Arrows indicate barriers that if restored would improve connectivity for least chipmunk. These areas are important for east–west movement within the habitat cluster. They have, however, high resistance because they pass through developed land.

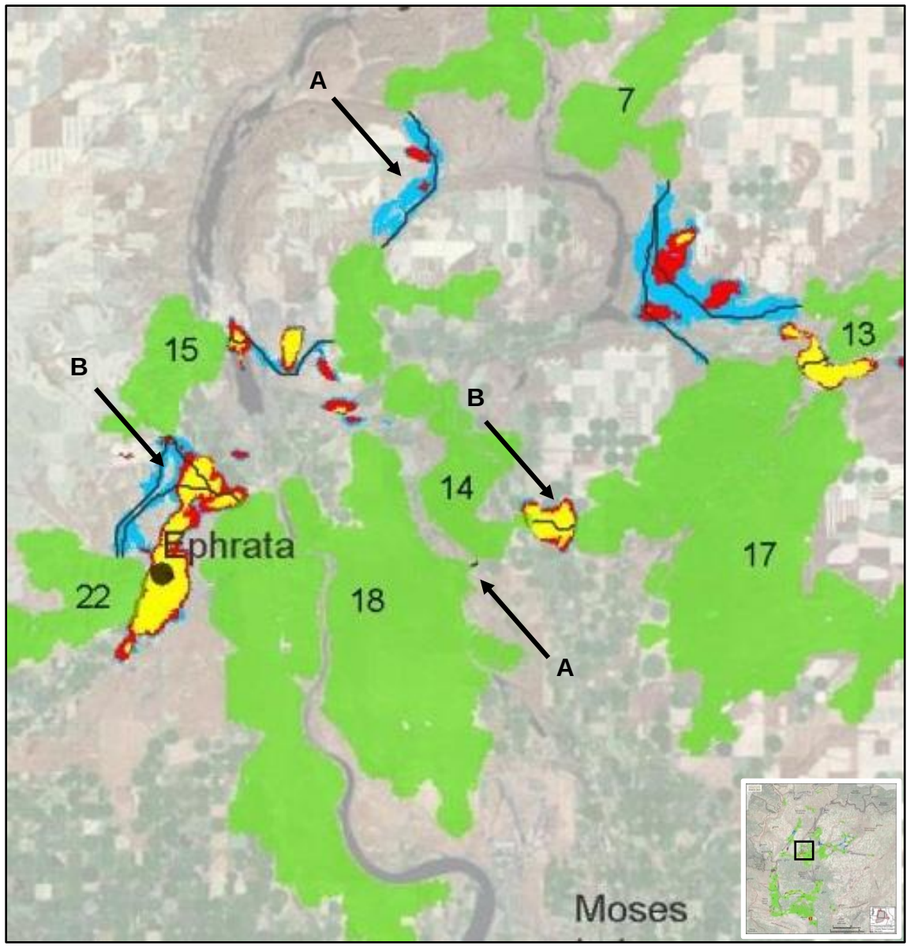

Figure 8.11. Linkage barriers and restoration opportunities in the vicinity of HCA 14; this HCA ranked Highest for centrality.

- The least chipmunk would benefit from improvement of linkages from HCA 14.
- Some of these linkages are of low resistance, e.g., linkages indicated by arrows labeled "A." They are short and cross habitat that is suitable under a more liberal habitat model.
- Other linkages cross residential or agricultural lands, e.g., linkages indicated by arrows labeled "B." Restoration would be difficult and expensive.

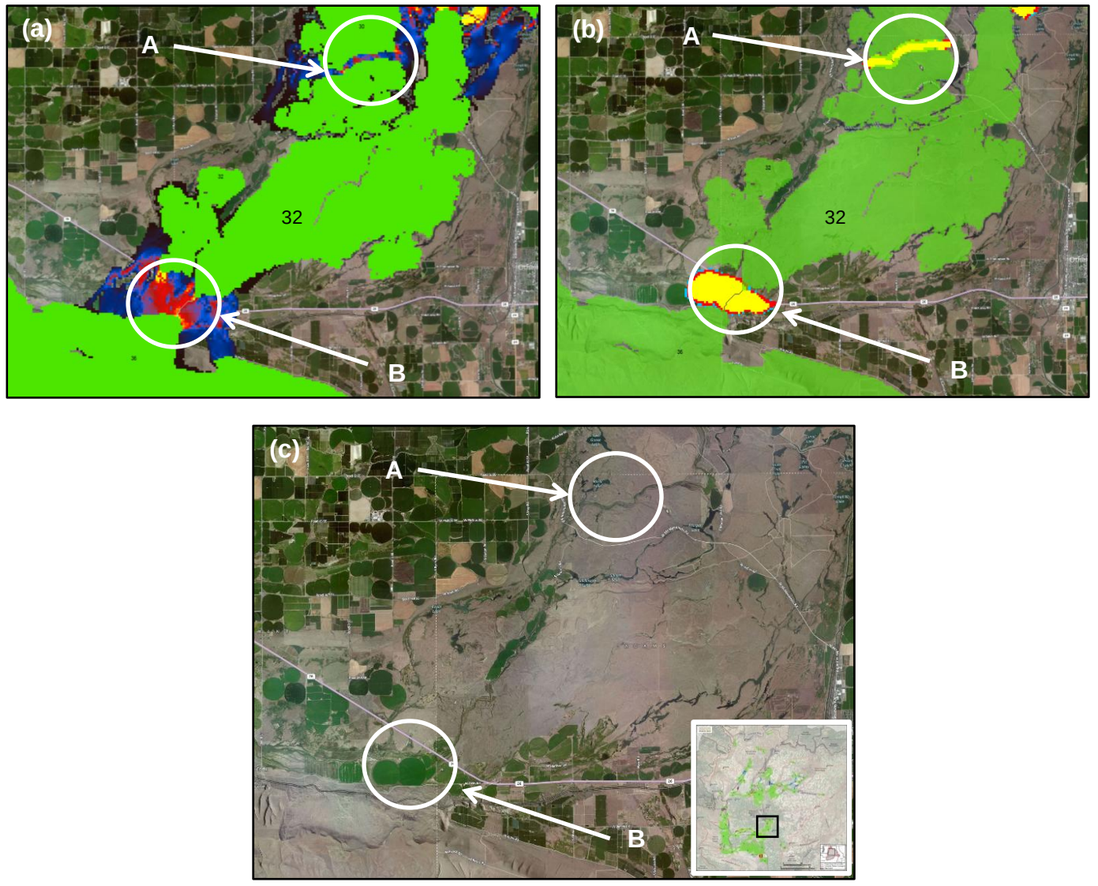

Figure 8.12. Least chipmunk maps showing two modeled barriers west of Othello, Washington. Panel "a" provides the pinch-point close-up for linkages associated with HCA 32, while panel "b" provides the barrier close-up for the same location. Panel "c" shows the underlying aerial imagery for the same area.

- Link labeled "A" is short, passes through relatively high quality habitat, and does not have pinch-points.
- Link labeled "B" is short but is more constrained and is of higher resistance as it crosses irrigated crop land and a busy highway.

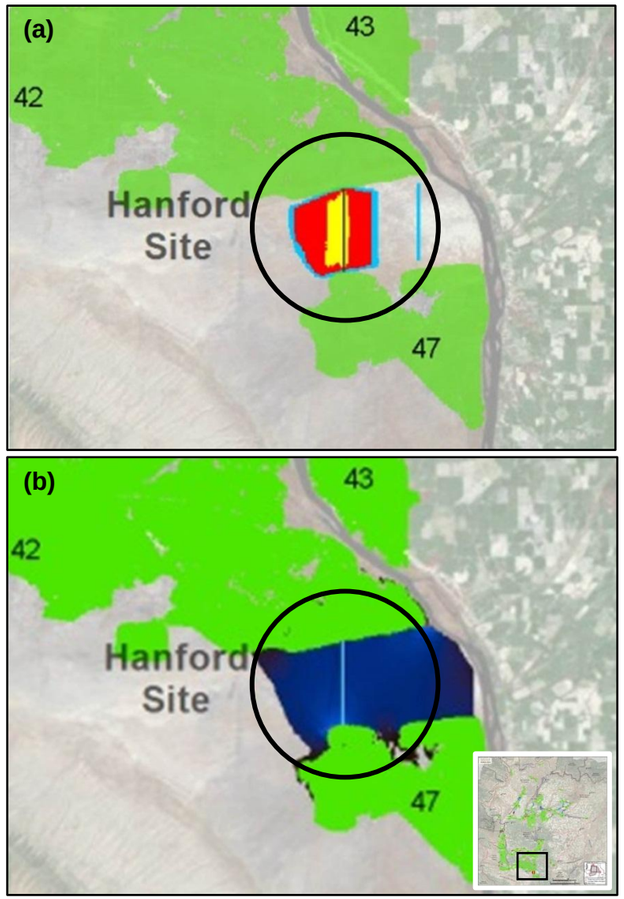

Figure 8.13. A natural barrier.

- The circles in panels “a” and “b” identify sand dunes which are unsuitable habitat and highly resistive to passage of least chipmunk.
- In panel “a” the red and yellow colors indicate that this habitat is a barrier for movement of least chipmunk.
- Panel “b” is the pinch-point map for the same location. Note that the linkage is not constrained, i.e., there is no funneling of movement between HCAs 42 and 47. This occurs because resistance to movement is relatively “uniform” along the linkage.

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