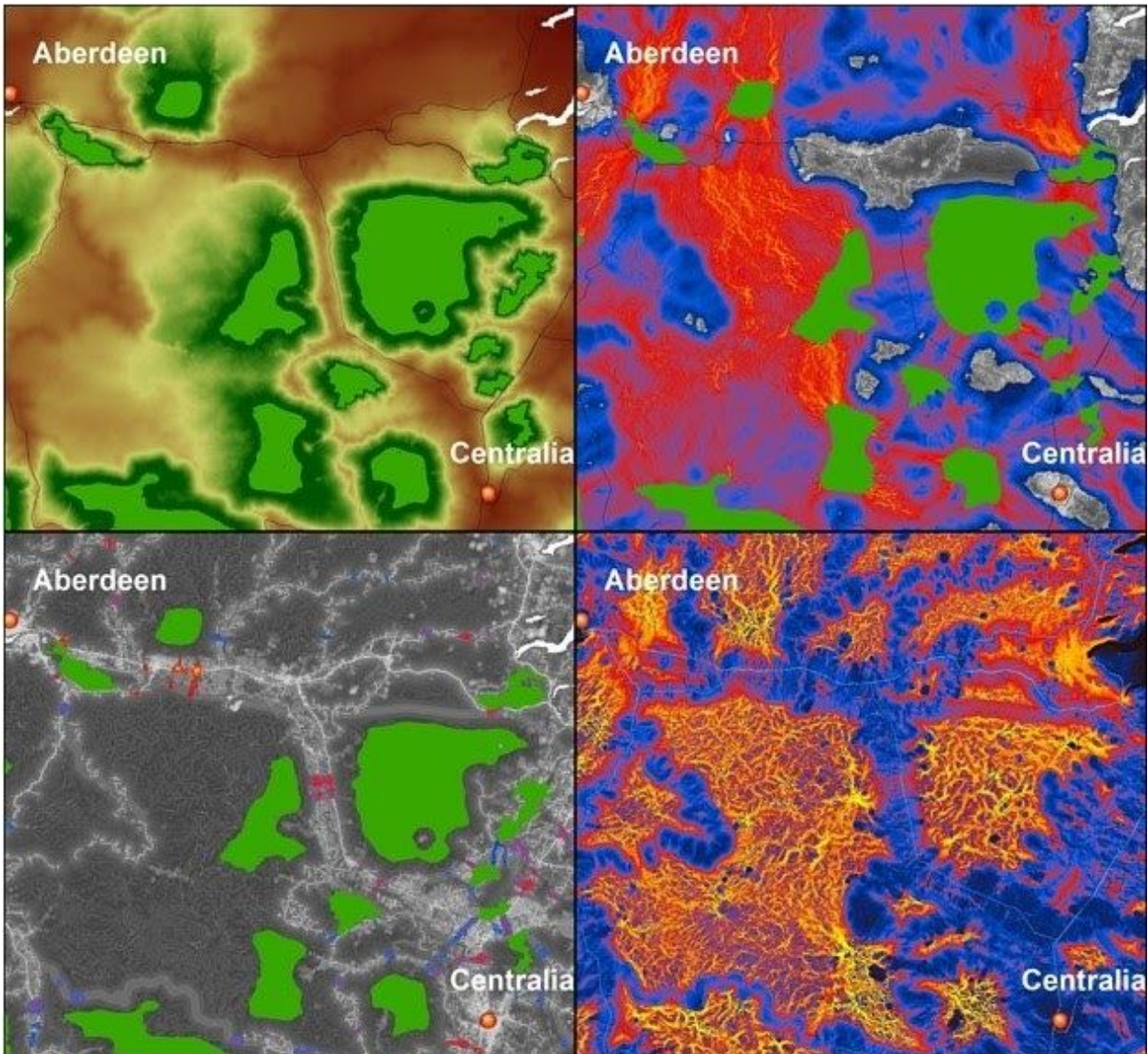


Comparing and Combining Omniscape and Linkage Mapper Connectivity Analyses in Western Washington

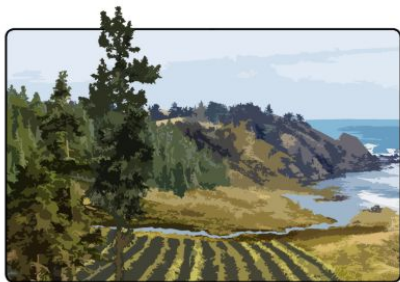
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Cascades to Coast Landscape Collaborative

designing for resiliency

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About the Cover

This is the Highway 12 portion of the study area, between Centralia and Aberdeen, where habitat connectivity is especially threatened. Maps, from left to right, top to bottom are (1) Cost-weighted distance, in green to brown, from habitat concentration areas, (2) Connectivity (red) using a weighted overlay of Linkage Pathways, Pinchpoint Mapper, and Linkage Priority, (3) Restoration Priority Areas overlaid on the Resistance Surface, and (4) Connectivity (yellow/red) using Omnidirectional CircuitScape (Omniscape).

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Executive Summary

Since 2015, the Washington Wildlife Habitat Connectivity Working Group (WWHCWG) has been planning to assess habitat connectivity across southwest and coastal Washington (i.e. western Washington). New methods and approaches in habitat connectivity analysis have evolved since that time. The goal of this analysis was to explore potential methods for assessing habitat connectivity patterns in southwest Washington: should focal species assessments for the coastal WA connectivity project use Omniscape (i.e. Omnidirectional Circuitscape) or Linkage Mapper or a combination of the two? Through this process, we developed a high quality suite of naturalness-based modeling connectivity products that can be used in real-world decision making. These are provided as interactive maps in the [Data Basin Gallery](#), with the data also being available on [Science Base](#).

To answer this, we modeled and mapped the structural connectivity of the region using the two methods, then a combination to highlight the strengths of each method. These results were presented to the WWHCWG in an in-person workshop to evaluate the results.

The decision was as follows: “Linkage Mapper will be the priority analytical tool used in modeling habitat connectivity in the coastal ecoregion. If there is a compelling need to complement Linkage Mapper using Omniscape for a particular species, USFWS can run that analysis if the resistance and habitat surfaces are finalized.”

Specifically, the focus group found that it was the novel overlay of the results from several Linkage Mapper tools into composite maps that was especially effective and useful. One such map was the Connectivity Conservation Priority (weighted overlay of Linkage Pathways, Pinchpoint Mapper, and Linkage Priority Tool) (Figure 10) and Connectivity Restoration Priorities (the previous layer overlaid with the highest priority sites identified by Barrier Mapper) (Figure 13).

Introduction

Region and Research Question

In 2010, the Washington Wildlife Habitat Connectivity Working Group (WWHCWG) statewide analysis identified a need for a closer look at this landscape extending from the Southern Cascades (from approximately Mount Rainier to the Columbia River), through southwestern Washington, and into the Olympic Peninsula (Figure 1).



Figure 1: Study Area. Boundary of the Habitat Connectivity Working Group's western Washington study area, within which the pilot analysis was run.

During meetings in 2016, 2017, and 2018, the WWHCWG group developed a plan to model the region using Linkage Mapper connectivity mapping software. In late 2018 group members from the US Forest Service and USFWS expressed a desire to explore Linkage Mapper with another approach called Omniscap. These two approaches represent “core-corridor” and “coreless” approaches, respectively. Each approach has pros and cons that represent different dimensions of habitat connectivity. It was proposed by the group that a pilot project be developed to explore both methods to help the group think through which approach to take: using one method or the other or a combination of methods to achieve a meaningful and parsimonious product.

The project partners’ driving question of the pilot project became: “should future species for the coastal WA connectivity project use Omniscap or Linkage Mapper or a combination of the two?”

Context

To best understand the research question and the decision, it is useful to consider the context. This connectivity assessment in coastal Washington builds from a set of broader mission, goals, and vision outlined by the WWHCWG and the Cascades to Coast Landscape Collaborative. In 2019, WWHCWG also created a more explicit memo of goals and end-user needs for the Coastal Washington Habitat Connectivity Modeling pilot. This included an explicit identification of end users including:

- *Local and County Governments*, to support county growth planning.
- *State and Federal Wildlife/Resource Agencies* to support land management planning (Forest Service to support Forest Plan revision, National Wildlife Refuge System for future Comprehensive Conservation Planning).
- *Transportation agencies* seeking to invest in crossing structures where they will provide the greatest long term benefits to wildlife population.
- *Land Trusts* to identify priority easements or land acquisition.
- *Working Lands Community*, which includes timber corporations, small family forest owners, ranchers, and dairy farmers, whose working lands can also provide wildlife connectivity habitat.
- *Tribes* have expressed interest in understanding the role of their lands in species conservation
- *Biodiversity advocate organizations* and individuals that interact with most, if not all, of the above organizations, and also bring an “All Lands” and “Climate-wise” perspective.

The full texts for the organizational goals and connectivity objectives are provided in the supplemental information, SI5: Goals and Objectives for the Western Washington Connectivity Assessment

Methods and Results

Data

We gathered a wealth of high quality data for this project, including roads and transportation, trails, railroad, important potential wildlife crossings under Interstate 5 (Stewart 2019), vegetation and land cover, water, transmission lines, gas and oil pipelines, housing density, building footprints, slope, climate data, historic (1981-2010), climatic moisture deficit (CMD), and an updated Protected Areas Database. These data and the process are detailed in a 15 page Supplementary Information 1: Data Inputs for the Western Washington Habitat Connectivity Assessment

Resistance Surfaces

We made three different resistance surfaces for evaluation, all at 30 m resolution. For the first, we started with a conventional methodology for creating resistance surfaces (using Gnarly Landscape Utilities), and then combined this result with nuanced layers about road impacts and building density impacts. These nuanced layers have continuous numerical values for resistance, as opposed to the conventional, small number of discrete values of Gnarly Landscape Utilities. This methodology is overviewed by the following diagram, and yields the Basic Resistance surface. We then utilized data about the location and quality of wildlife crossings under Interstate 5. This became the Standard Resistance Surface. We then incorporated protected area status. For example, those areas that were Wilderness (i.e. GAP status 1) were given a lower resistance to those areas that were private land, all else being equal. This yielded the Resistance Surface with Protected Area Benefits (Figure 2). This method is summarized in the figure below, and detailed in Supplementary Information 2: Creation of the Western Washington Resistance Surfaces Habitat Surfaces, and Habitat Concentration Areas.

Habitat Concentration Areas

To create the Habitat Concentration Areas (i.e. “cores”, Habitat Core Areas, HCAs) we did the following in a co-production process with WWHCWG. We first made a habitat surface that was essentially the inversion of the Resistance Surface with Protected Area Benefits, and a reclassification to good habitat for some of the landscape characteristics that are hard for movement, yet count as wild habitat, like steep slopes. We then used Gnarly Landscape Tools to identify the draft set of HCAs. Hence, cells that were in protected areas had a higher likelihood of becoming an HCA, all else being equal than cells outside of protected areas. We then enhanced this by using only Gap status 1 and 2 lands for the really large draft HCAs (removing area from the HCAs layer), and adding protected areas that are over 1,000 acres (adding area from the HCAs layer). More details are in Supplementary Information 2: Creation of the Western Washington Resistance Surfaces Habitat Surfaces, and Habitat Concentration Areas

Geoprocessing for the Two Models

We ran Linkage Mapper on a laptop with 32 GB of RAM and we ran Omniscape on a high-end computer with 950 GB of RAM. We ran all models at 90 m resolution. We did this instead of 30 m resolution because Omniscape and Pinchpoint mapper were both crashing with the 30 m input. This could likely be solved for Pinchpoint mapper by using a more powerful computer or by updating its code to call the

new Circuitscape code that uses Julia language. This could be solved for Omniscape by fine tuning the supercomputer settings. We decided that this was not necessary to answer the project objectives, and that doing so would detract from other project tasks, so went with 90 m.

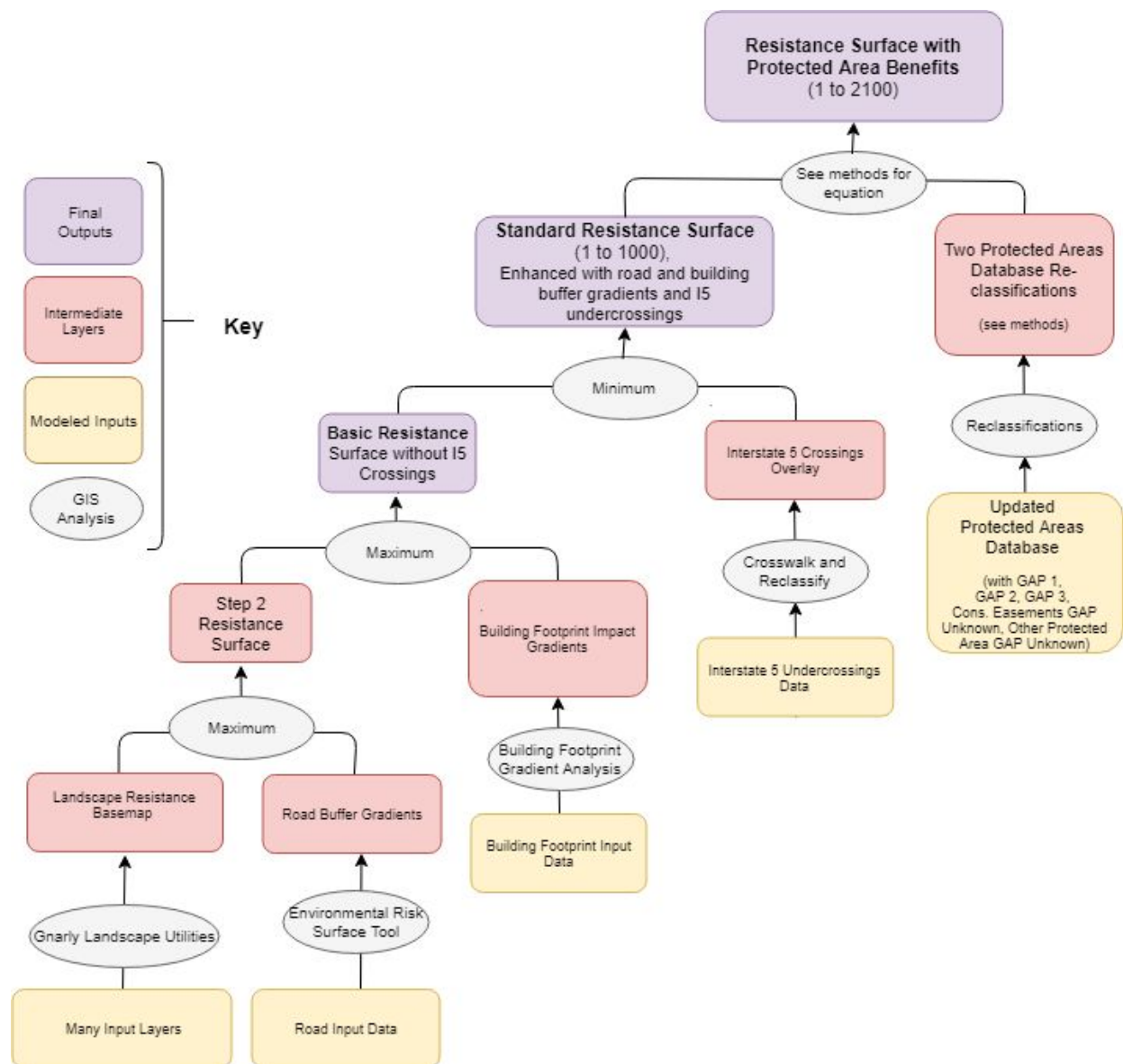


Figure 2: Resistance Surface Methodologies. Three resistance surfaces were created, above, and evaluated. The one on the top was the one chosen for the analyses.

Omniscape

One of the primary critiques of the Linkage Mapper suite of tools (and many connectivity tools), is the need to identify core areas. One of the challenges of a core area approach is that core areas are often not precisely known. Modeling using a core area approach requires either a significant amount of data to justify that an area is a “core”, or a set of assumptions based upon land cover maps that an area is a

habitat core, sometimes referred to a habitat concentration area (HCA). The Omniscape approach eliminates the need to identify core areas, and instead assumes that a species doesn't have perfect knowledge of the landscape to move towards known core areas.

The Omniscape tool is based on an omnidirectional implementation of the connectivity approach, CircuitScape. Circuitscape uses circuit theory to assess pathways across the landscape from one place to another. A benefit of Circuitscape over least-cost methods is that it can simultaneously assess all possible pathways using a resistance surface, along with core areas. Omniscape uses the Circuitscape algorithm, but instead of current flow directed from core to core (or multiple cores), flow is directed towards the center cell of a moving window. Each moving window is essentially a subsetting landscape, which are assessed for circuit flow, and then additively compiled and reconstituted to provide a measure of flow across the entire study area. Within the moving window, if a pixel is natural or semi-natural, it is considered a source of current which flows towards the center, based upon the least amount of resistance.

For more information on the OmniScape approach please see the original publication (B. H. McRae et al. 2016). For this project, we tested several different moving window sizes from 250 meters to 1250 meters. A pixel size of 90 meters was used for computational efficiency. We used the OmniScape Python script provided by TNC. We used the standard resistance surface described above, along with the habitat layer described above as the source surface.

Current Flow

The raw output of Omniscape is converted into percentiles of value called "current flow", with values of 1 to 100. For further discussion, we will refer to the 500m window size runs. Figure 3 shows Omniscape current flow outputs.

Classified Normalized Current Flow

Another important way to interpret the OmniScape outputs is to create the classified normalized current flow. We first created the Regional Flow Potential map (Supplementary Information: Geoprocessing Notes) by running Omniscape with a value of 1 for the resistance surface, and using the normal source surface, then dividing Regional Flow Potential by current flow to create the Normalized Flow Potential intermediate layer. The result is then a continuously valued surface that is then classified into different classes to yield the classified Normalized Current Flow (Figure 4). To do the classifications, we used the approach described in McRae et al. (2016), with assistance from Aaron Jones, with the standard set of five flow classes – channeled, intensified, diffuse: high, diffuse: low, and impeded. Numerical cutoffs to yield the classes were determined based upon logical distinctions between classes on the landscape and expert knowledge of the region (Figure 4).

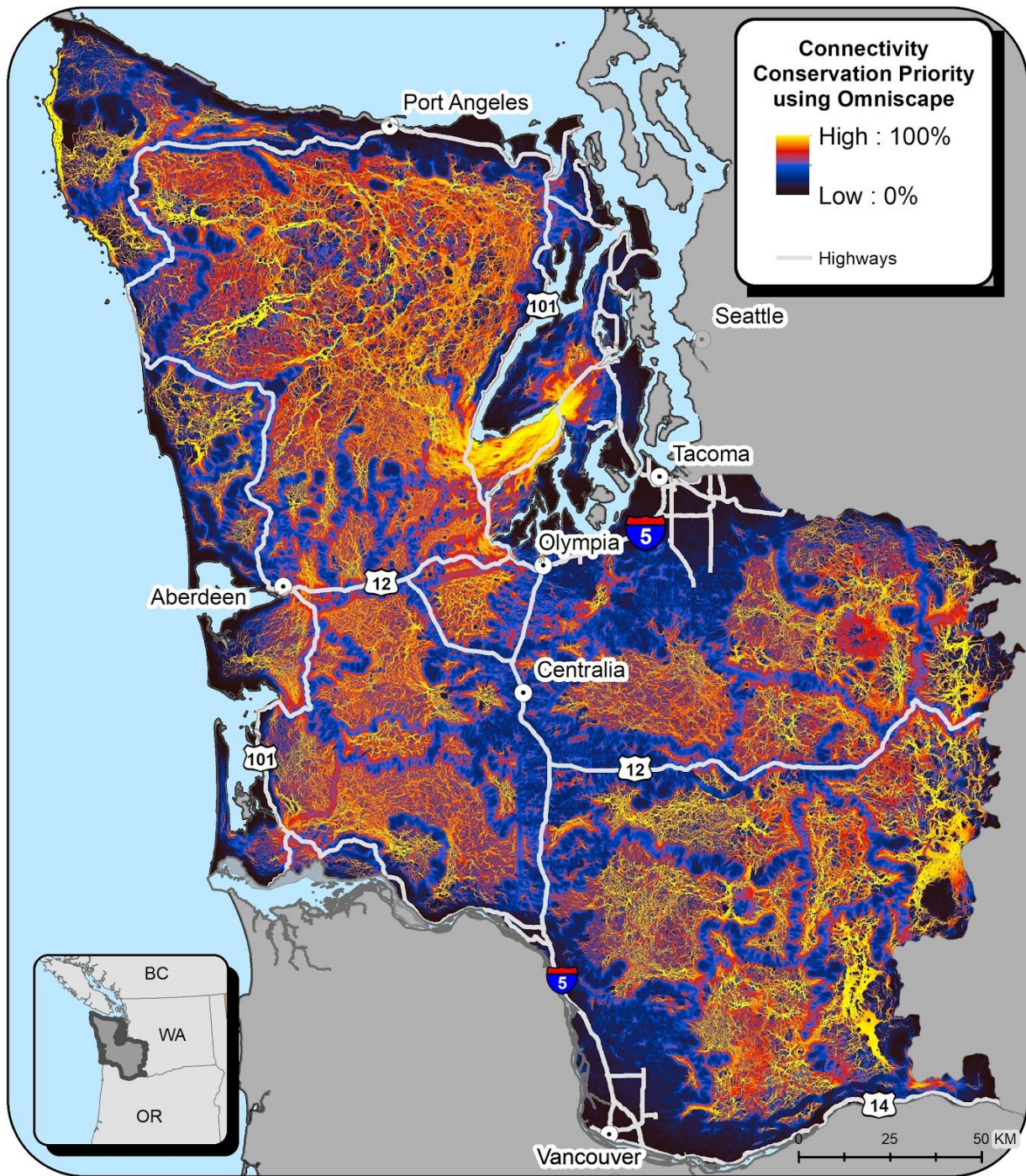


Figure 3: Connectivity Conservation Priorities Using Omniscape.

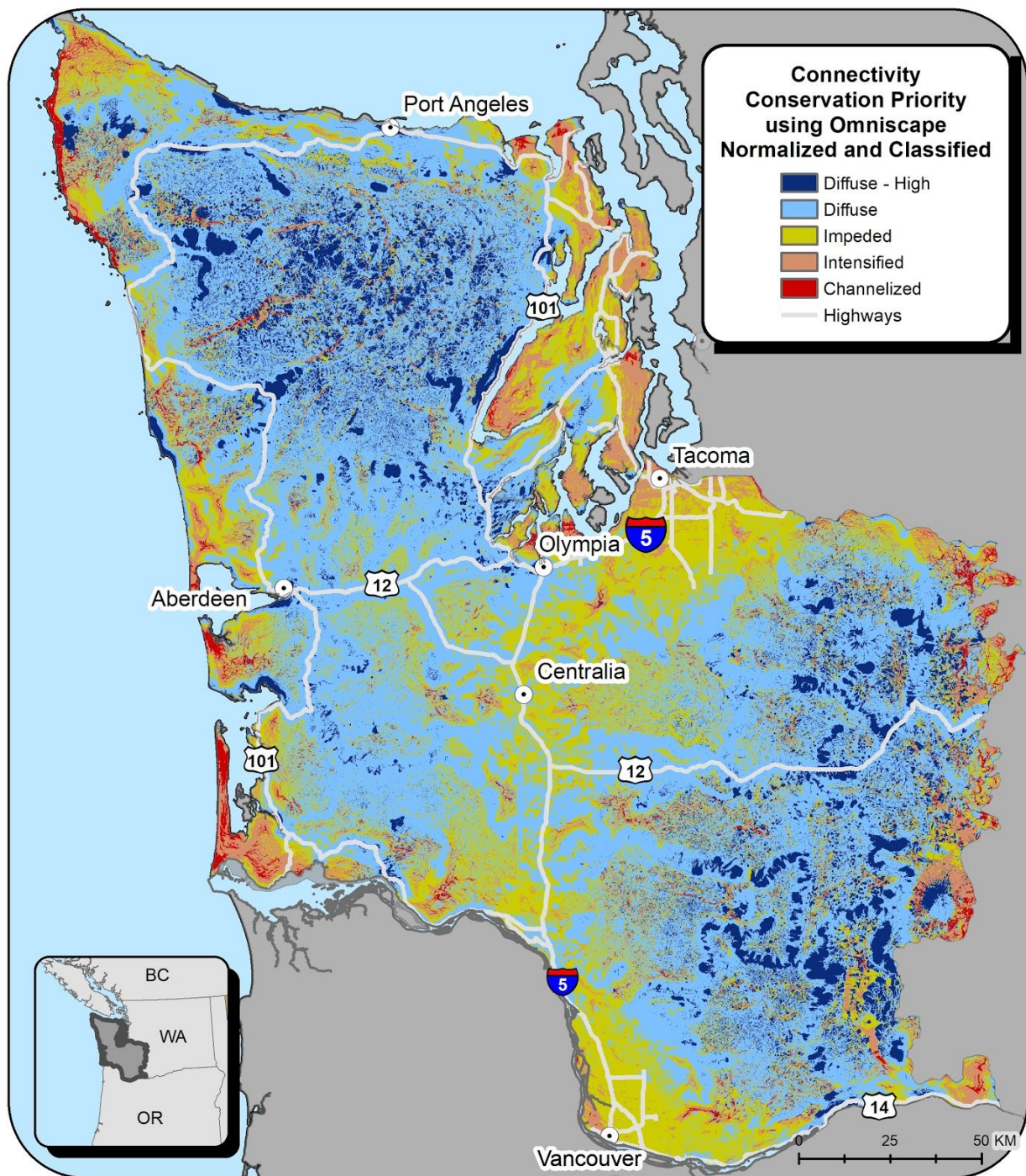


Figure 4: Connectivity Conservation Priority using Omniscape, normalized, and classified.

Linkage Mapper

Running the Three Primary Linkage Mapper Tools

The Linkage Mapper software package includes six tools. For this study we used five of these tools, producing stand-alone products which we also combined to create synthesized products. We used [Linkage Mapper v3.0.0-alpha](#) wrapped by an ArcGIS modelbuilder script to run and combine Linkage Pathways, Pinchpoint Mapper, Centrality Mapper, the Linkage Priority tool, and Barrier Mapper using the above described resistance surfaces and habitat concentration areas (HCAs) layers, and the below described methods. We used the default parameters described in the respective user guides except where otherwise noted below.

The following are the high level methods and some screengrabs of the results. Interactive maps are provided in the [Data Basin Gallery](#), and the data are also available on [Science Base](#).

The **Linkage Pathways Tool** (originally called Linkage Mapper before the rest of the tools in the toolbox were developed) maps the linkages and quantifies the value of each path within a linkage (B. H. McRae and Kavanagh 2011). We used an informal sensitivity analysis (visually evaluating mapped results using various parameter values) to establish a maximum linkage width of 800,000 cost-weighted distance units. We chose this relatively large width with the intention of using a color ramp with many colors, thereby being able to show visually where the high quality linkage locations are (corresponding to about 100,000 units in the “electric green” color in the map below) as well as the other areas that could be pathways between HCAs. This tool yielded the cost weighted distance output (Figure 5) and Linkage Pathways output (i.e. least-cost corridors), which are the standard connectivity outputs (Figure 6). It also yielded an auxiliary output that is useful for visualizing where individuals might feasibly explore for dispersal events: the cost-weighted distance layer (provided on Science Base and Data Basin).

We used **Pinchpoint Mapper**, which uses circuit theory by calling upon Circuitscape software (McRae et al. 2008), to help quantify the conservation priority of portions of a linkage that are dangerously narrow (B. H. McRae 2012c). We used the “all pairs” evaluation rather than just adjacent pairs, and transformed the result to emphasize not only the pinchpoints region-wide, but to also shed light on the pinchpoints *within* each linkage. We did this by slicing the result into ten classes, and used the Jenks natural breaks function within ArcGIS, that achieves the normalization objective (Figure 7).

We used **Centrality Mapper**, to calculate “current flow centrality” across the networks (B. H. McRae 2012b). Current flow centrality is a measure of how important a linkage is for keeping the overall network connected. This tool uses Circuit Theory and graph theory by calling upon Circuitscape algorithm from within the Linkage Mapper software.

Then, we used the **Linkage Priority Tool** that quantifies which linkages and core areas are most valuable (Gallo and Greene 2018). Core area priority value is a function of shape, mean resistance value, climate refugia, and expert opinion values, if available. Linkage priority value is a function of the

priority value of the cores being connected, and of the characteristics of each linkage. The tool provides the option to use several variables, such as permeability (i.e., the mean resistance values along the least cost path),

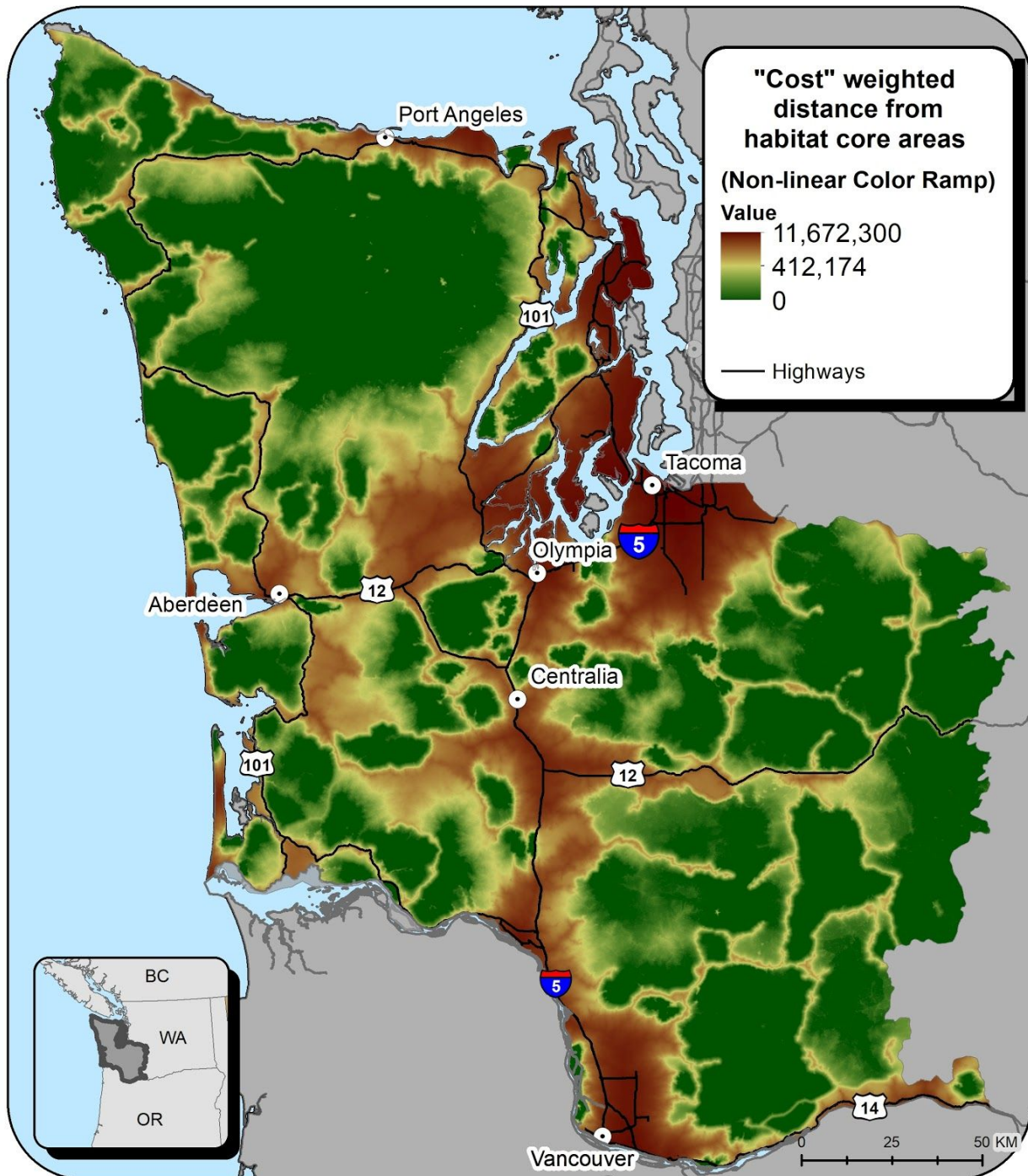


Figure 5: Cost weighted distance from habitat core areas. Note that the color ramp is

histogram equalized (non-linear).

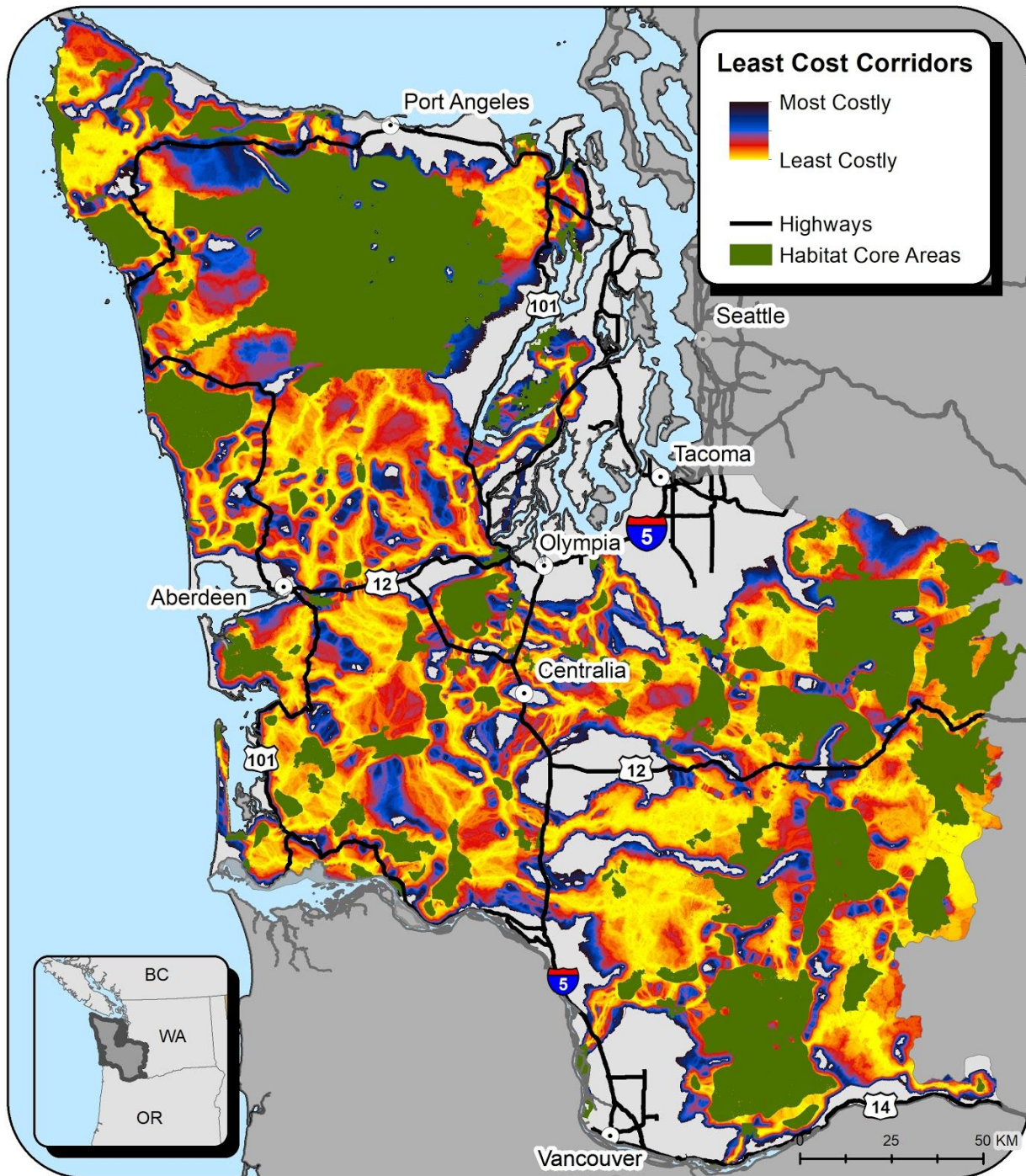


Figure 6: Least Cost Corridors. The Linkage Pathways Tool output showing least cost corridors between HCAs within the Western Washington Habitat Connectivity Modeling project boundary.

the length, the centrality, and expert opinion if available. For this study, we used several different combinations of these variables, including a run in which climate considerations were included (available upon request), and the one that the working group settled on. They felt it to be the most

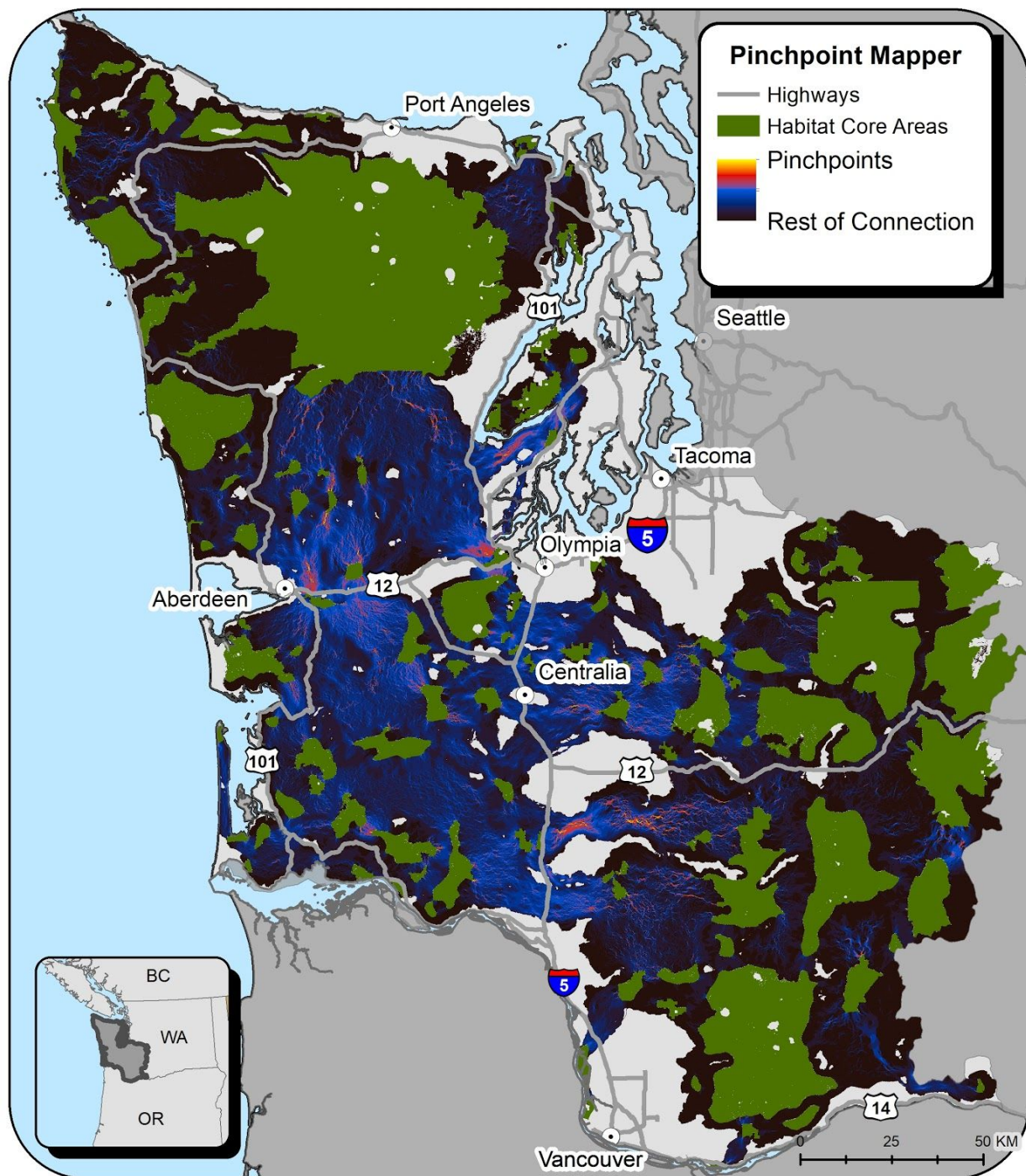


Figure 7: Pinchpoint Mapper output. Areas in yellow and red merit special evaluation for naturalness connectivity conservation.

parsimonious to include the following criteria and weights: mean permeability (0.43), proximity (shorter linkages are better than longer, all else being equal)(0.17) and the average centrality value of the two cores being connected (0.4) (Figure 8). These criteria and values were derived by an online poll with the WWHCWG. The values were the mean value of all the suggested weight values for a criterion, among all participants in the poll.

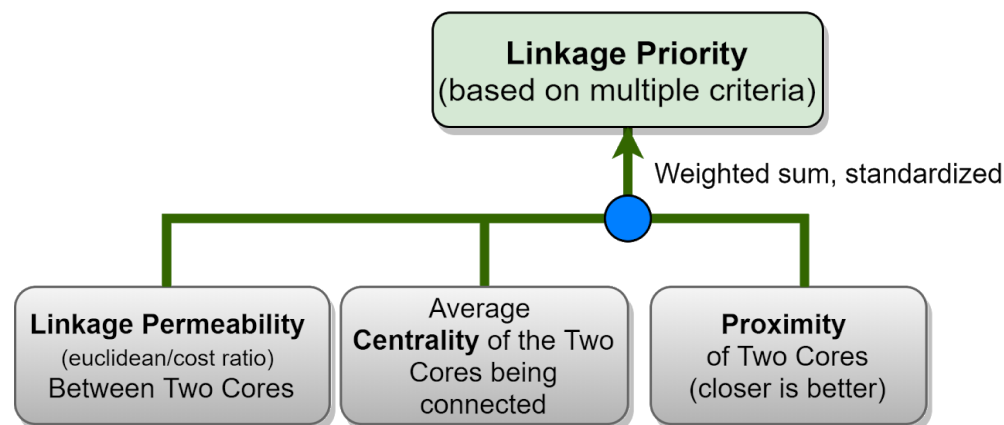


Figure 8: The three of the 12 potential criteria in the Linkage Priority Tool that were used in this analysis. They are combined in a weighted sum within the algorithm, individually for each linkage, and then combined.

Combining the Outputs to Map Conservation Priorities

Similar to what we have done in six other regions, including three in California (Gallo et al. 2019), and the Klamath Basin Region (Spencer et al. 2019), we first combined the above intermediate datasets into a single synthesis layer, called Combined Connectivity Value, using evenly weighted sums, as shown in the figure below⁴ and then mapping this with core areas overlaid (Figure 9, Figure 10).

⁴ We did this by using the default parameters in the Linkage Priority tool for combining linkage priority and linkage pathways (0.5 and 0.5 weights, yielding the “blended_priority” layer). Then we combined this product with pinchpoint mapper with weights of 0.67 and 0.33, respectively. We communicated this as combining all three layers with even weights, which is essentially the same thing and is easier for people to follow.

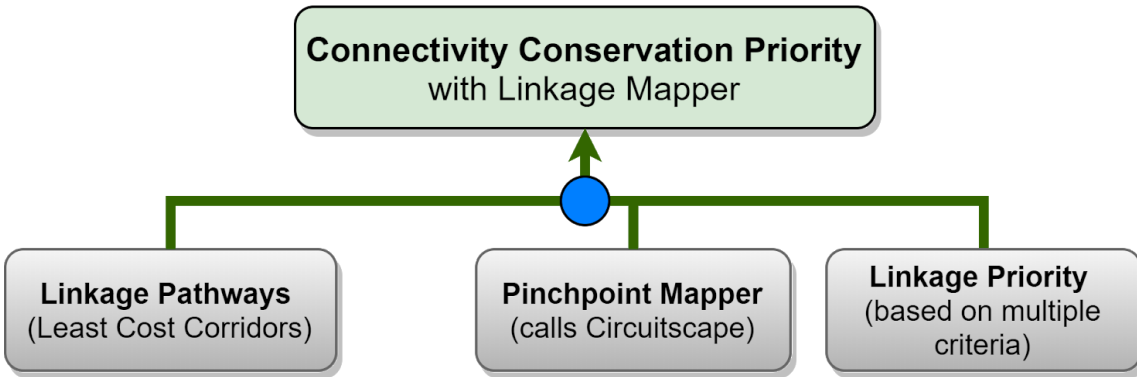


Figure 9: Logic model of the multiple criteria (map layers) combined to create Connectivity Conservation Priority with Linkage Mapper

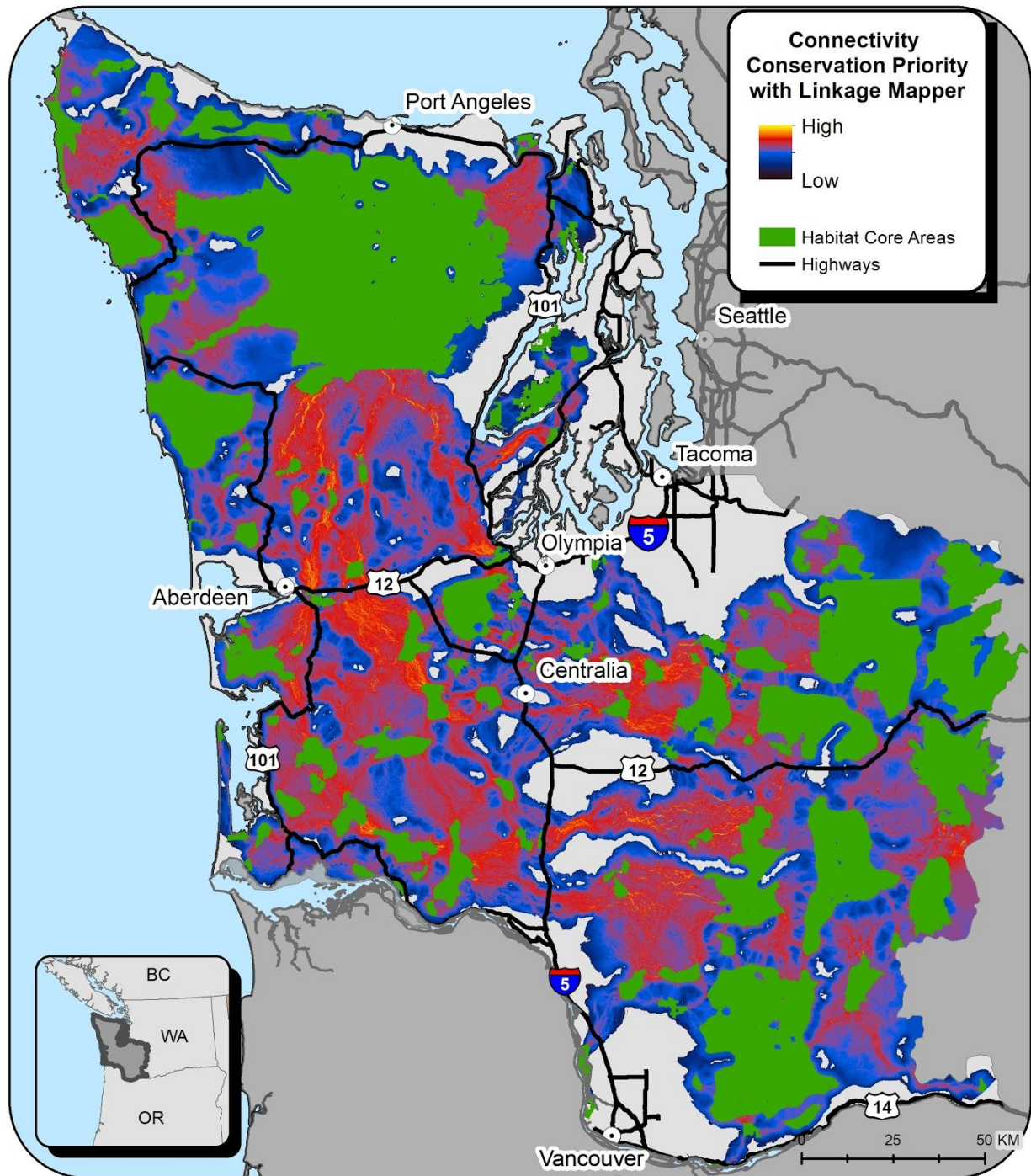


Figure 10: Combination of Linkage Pathways, Pinchpoints, and Linkage Priority

Running and Combining with Barrier Mapper for Restoration Priorities

Finally, we had the multi-tool modelbuilder script call the **Barrier Mapper** tool that quantifies the importance of “barriers” that affect the quality and/or location of the corridors (B. H. McRae 2012a). The term “barriers” is used in a general way and includes portions of a landscape that are difficult to

pass through for wildlife, but are not barriers in the formal sense of the term. In essence, they identify areas for restoration and mitigation. Much more detail is provided in a publication by McRae et al. (2012). We examined the results of five different detection radii values, and chose 180 m because it best supported an average restoration project's size and scope (Figure 11).

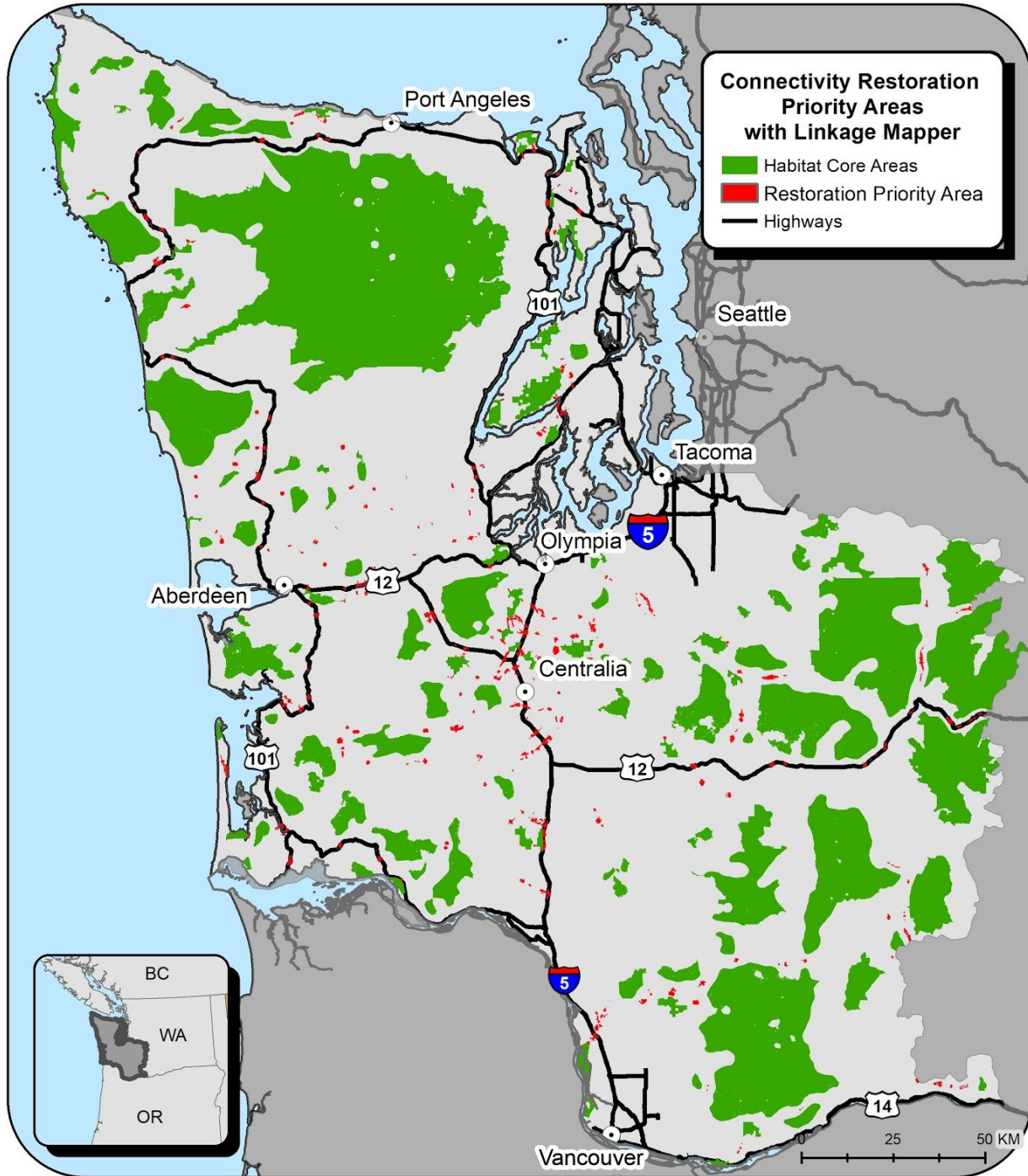


Figure 11: Connectivity Restoration Priority Areas

Due to project scope and budget, we decided against running the sixth Linkage Mapper tool: Climate Linkage Mapper. This tool would have shown how the spatial configurations of each linkage are expected to change with climate change. The other aspect of Climate Linkage mapper: prioritizing linkages based on climate gradients, is now also addressed in Linkage Priority tool.

Next we selected the highest restoration priority values from the barrier mapper output, scaled it linearly from 0-1 (with all other areas as null values), combined it in a weighted sum with the Combined Connectivity Value layer, and rescaled the output linearly to range from 0-1 (Figure 12, Figure 13)

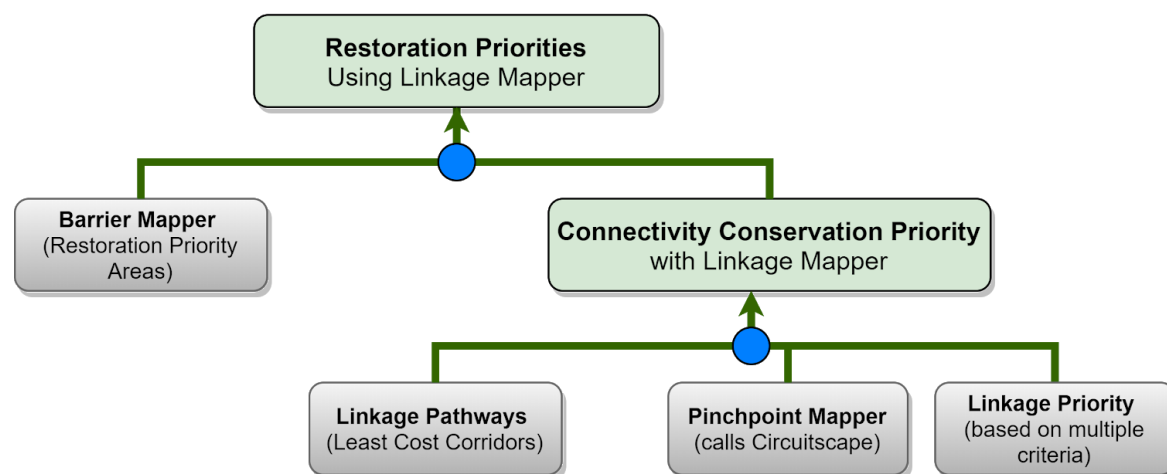


Figure 12: Logic model of multiple map layers combined to make the Restoration Priorities map.

Incorporating Threat and Climate Refugia

We also explored two other linkage priority configurations. The first addition was a criterion proxy for threat, and was that any linkage crossing highway 12 or Interstate value was valued as a 1, and all others were valued as a 0. A model was created so that this was determined and incorporated into the model automatically. Secondly, we added climate wise considerations, namely that climate refugia within a core area made it more valuable to connect to, and that linkages with high climate analog matching were also more valuable.

The WWHCWG decided that the value added was not worth the extra complexity and chose to only consider the previous, more simple combinations. These threat and climate runs became a targeted sensitivity analysis to explore how much the model changed with the extra additions. Some additional information on them is available in Supplementary Information 3: Geoprocessing Notes and Lessons Learned

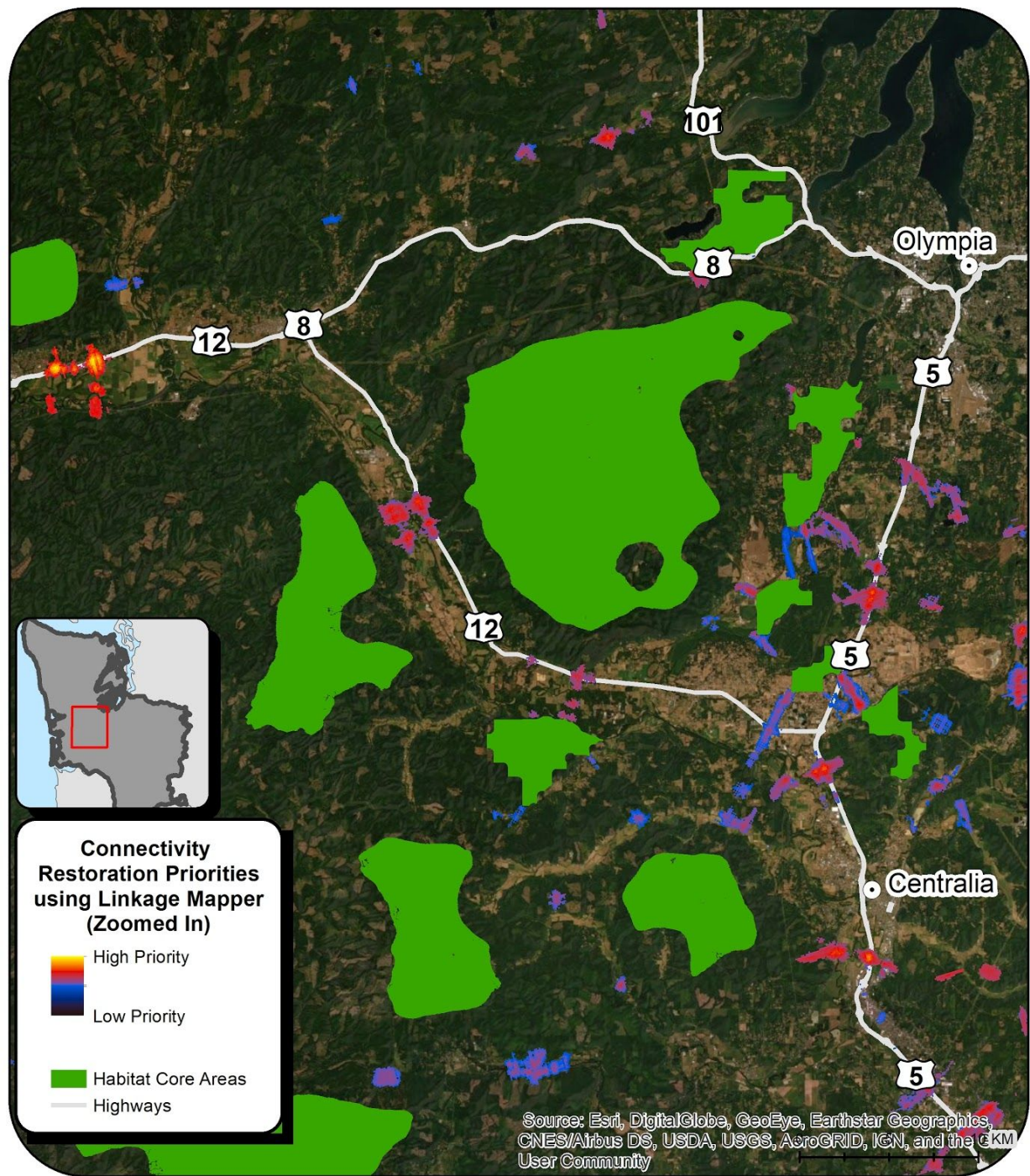


Figure 13: Connectivity Restoration Priorities. Prioritization among priority areas (barrier mapper) in a portion of the study area. The northwestern highway with the highest priority restoration areas is Highway 12 from Aberdeen to Centralia, also depicted on the report cover.

Combination of Linkage Mapper and Omniscape

We explored five ways for combining Linkage Mapper and Omniscape results. The top three are shown here, and the others are shown in [Supplementary Information 3: Geoprocessing Notes and Lessons Learned](#)

Option 1: Omniscape with Linkage Pathways and Cores

In all the diagrams below, the blue circle indicates an evenly weighted sum. Each of the inputs is normalized to range from 0-1, so they are all on the same initial numerical range. The Omniscape product was normalized linearly with the score range normalization discussed elsewhere in the Linkage Mapper documentation, such that the 100 became a 1, the 0 a 0, and all other values scaled accordingly (Figure 14).

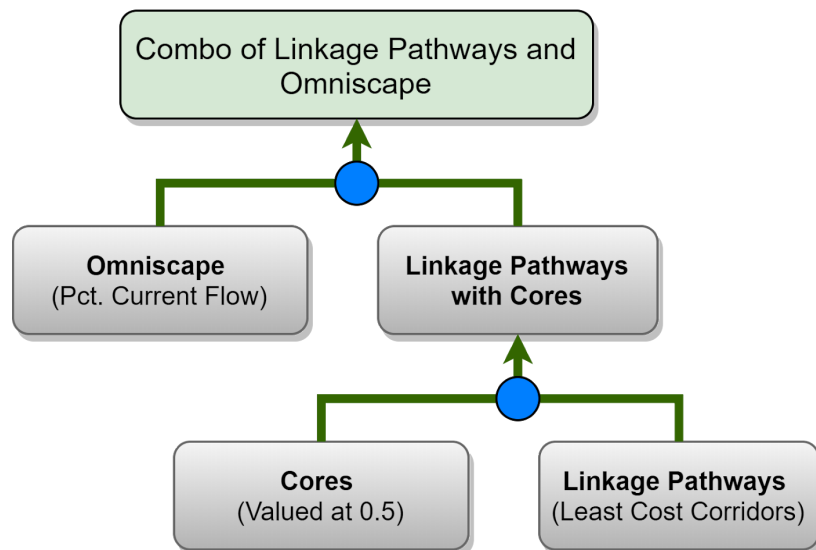


Figure 14: Logic model of the multiple criteria (map layers) combined to create the layer Connectivity Conservation Priority using combo of linkage pathways and omniscape.

We tried the above with cores valued at several levels, and found that 0.5 was the best balance, according to expert opinion (J.Gallo and T. Miewald), between giving high value to cores, but giving connectivity conservation priority to make sure the linkages get conserved (Figure 15). A value of 0.6 was not used, and would be good to examine in the future. Here is how the product (available in Science Base and Data Basin) looks:

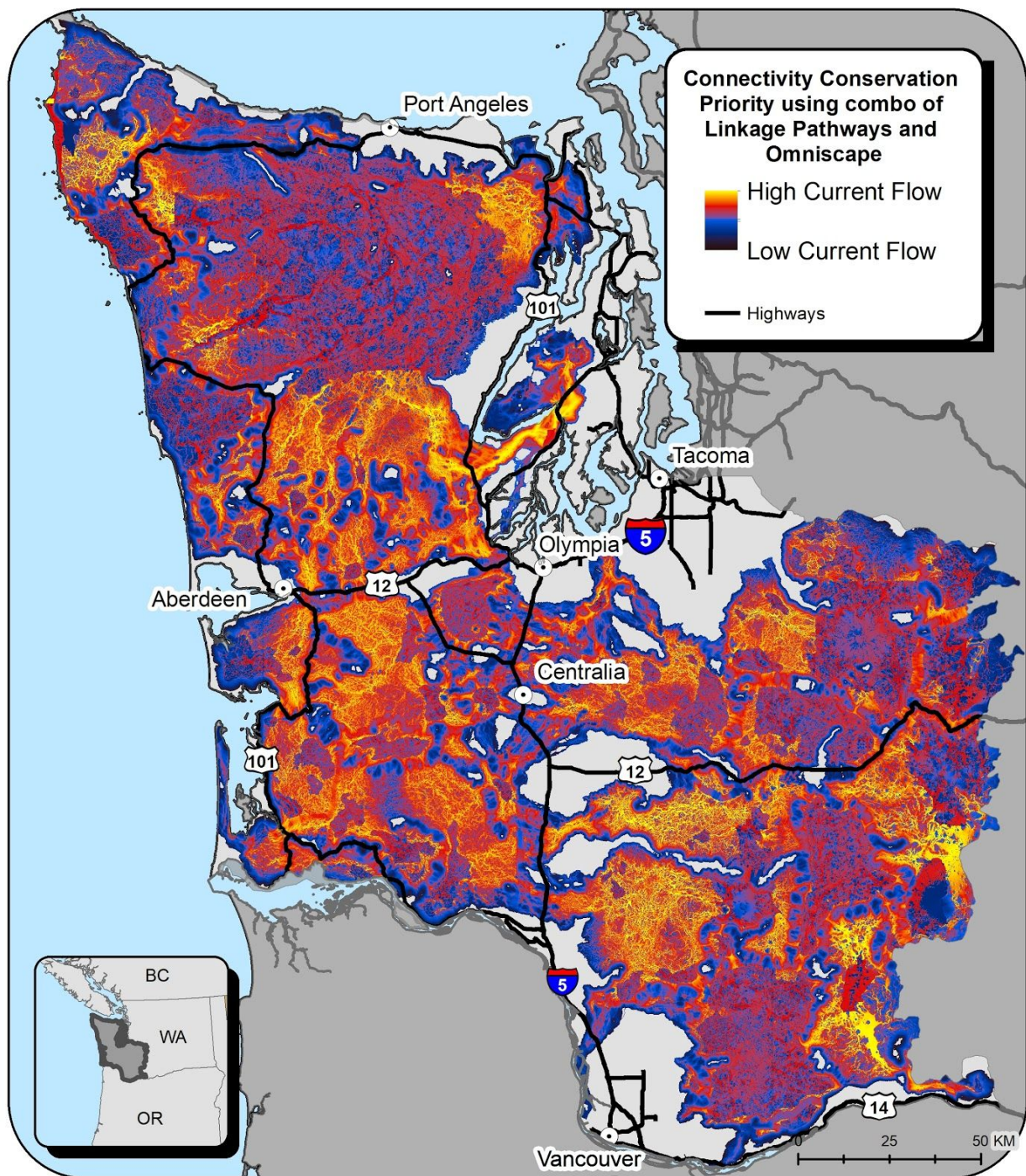


Figure 15: Combination of Linkage Pathways and Omniscape.

Option 2: Omniscape with Linkage Priority

We then added the nuance of Linkage Priority to the combination concept, thereby giving higher value to the higher priority linkages, using the following logic model and yielding the following result (Figure

16, Figure 17). Note how some of the linkages of Figure 15 that do not make as much sense ecologically as some of the others, have a lower priority value in Figure 17.

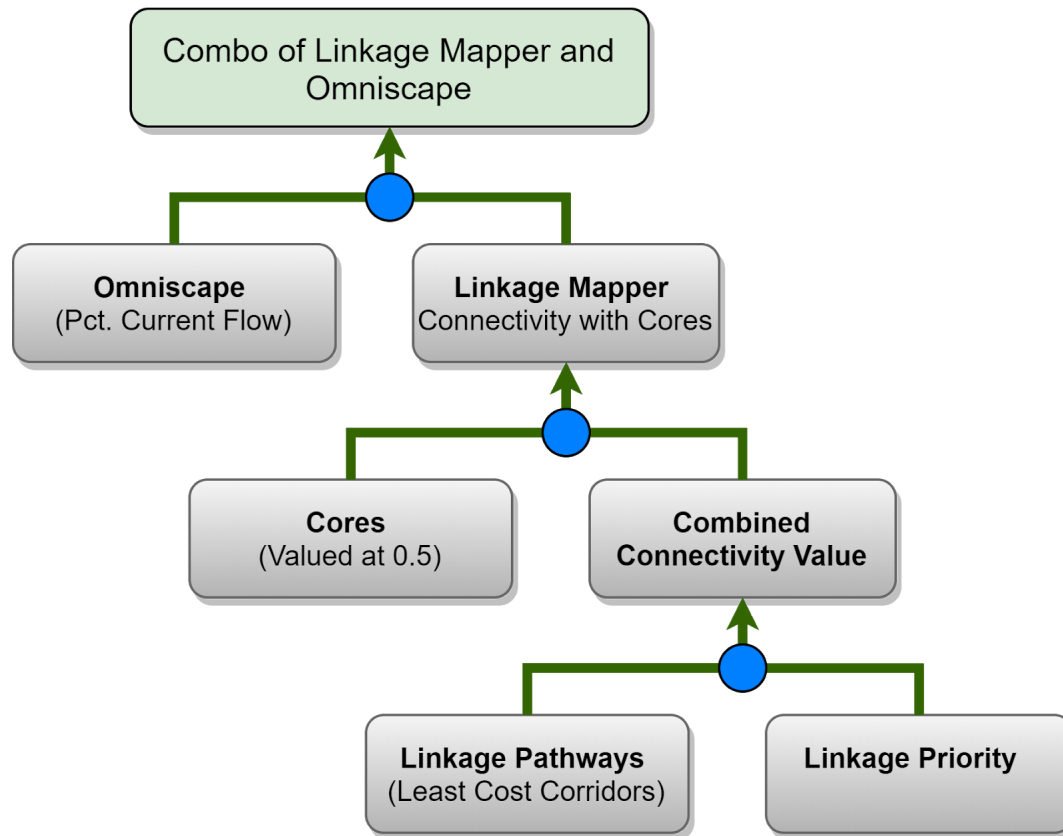


Figure 16: Logic model of the multiple criteria combined to create Connectivity Conservation Priority with two of the tools in Linkage Mapper (Linkage Pathways and Linkage Priority).

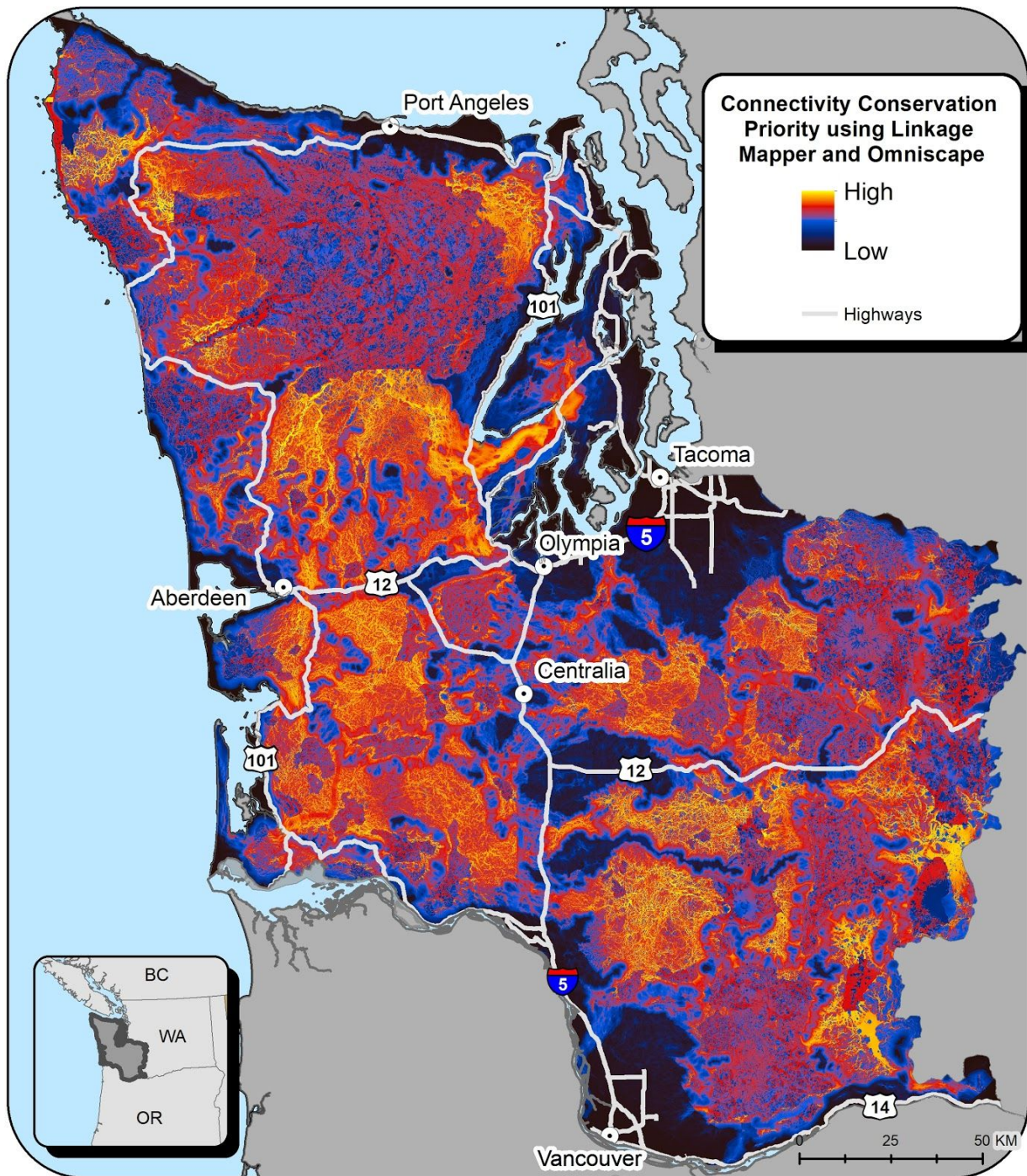


Figure 17: Combination of Linkage Mapper (Linkage Pathways and Linkage Priority) and Omniscape.

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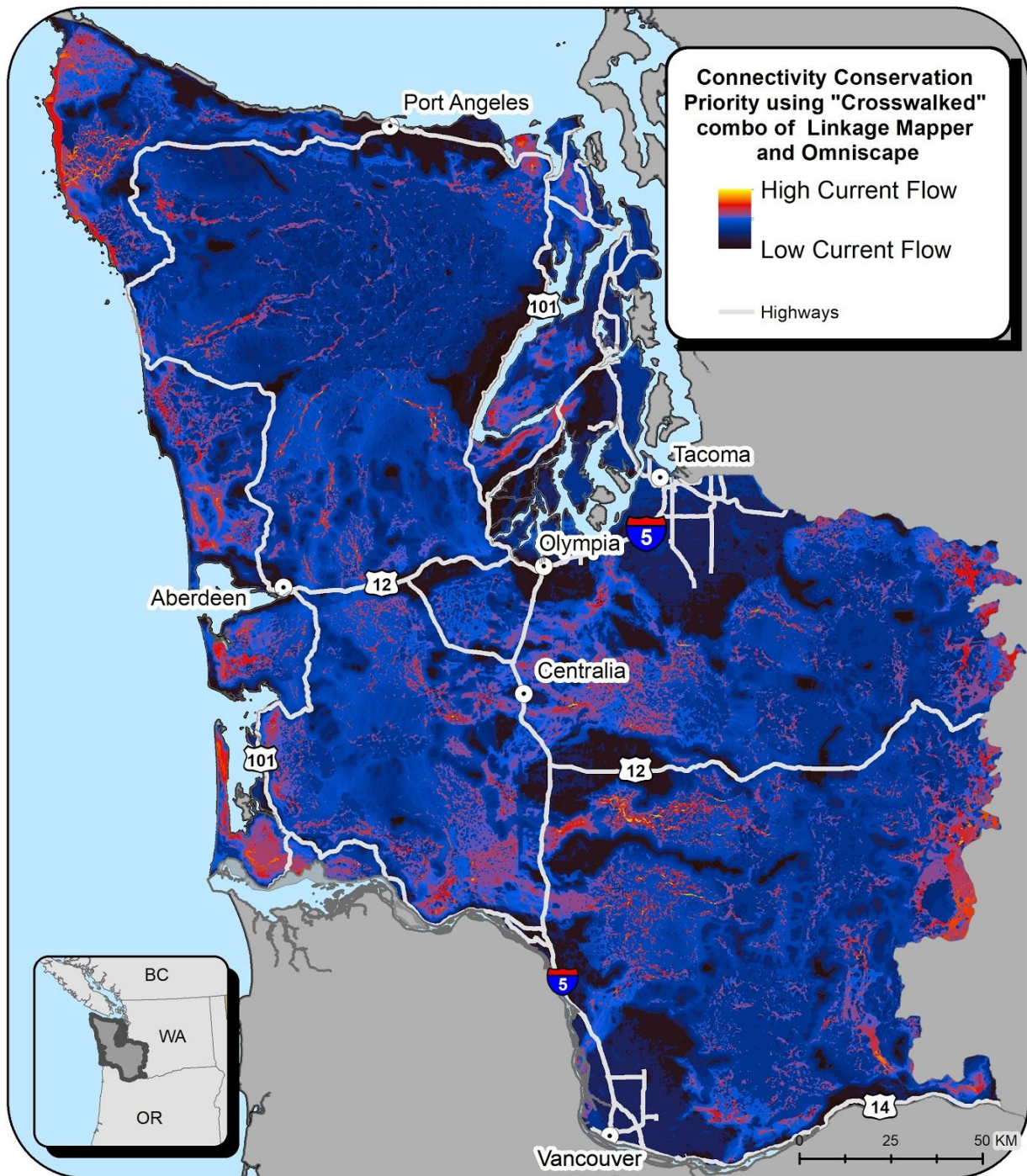


Figure 19: "Crosswalked" Combination of Linkage Mapper (Linkage Pathways and Linkage Priority) and Omniscape.

Of all these options, "Combination of Omniscape and Linkage Mapper (with Linkage Priority)" (Figure 17) was deemed the least problematic and most promising.

Evaluation

On April 18, 2019 CBI and Washington Wildlife Habitat Connectivity Working Group (WWHCWG) held a 5 hour meeting to discuss the results, with the purpose of making a decision on methods going forward. An agenda was developed with the following goals: 1) Make the decision driving this Project: Should future species for the coastal WA connectivity project use Omniscape or Linkage Mapper or a combination of the two? 2) Discuss initial mapping products and inform next steps; 3) Develop ideas and materials that can be shared with others making a similar decision, and 4) Develop approaches for species specific connectivity modeling. The full notes of that workshop are provided in the Supplementary Information 4: Coastal Washington Connectivity Review- In Person Workshop Notes

Decision

This was the conclusion of the workshop: “Linkage mapper will be the priority analytical tool used in modeling habitat connectivity in the coastal ecoregion for the reasons listed below. If there is a compelling need to complement Linkage Mapper using Omniscape for a particular species, USFWS can run that analysis if the resistance and habitat surfaces are finalized.”

This was the high level summary of the workshop that was sent out to the full WWHCWG:

“Top reasons why Linkage Mapper was chosen:

- Breadth of the Linkage Mapper outputs was felt to be more meaningful than the Omniscape outputs
- The “story” behind the science was more clear and compelling in communicating to stakeholders and decision makers.
- Linkage Mapper has the ability to more tightly quantify the geographic priorities for restoration, and for conservation.
- Linkage Mapper has been used before in the State, and the stakeholders and decision-makers are accustomed to the outputs.

These outweighed the top reasons for going with Omniscape, which were:

- No need to define core areas during the process
 - But this was discussed, and it was pointed out that defining cores is a very important step for defining hypotheses and assumptions for how species and wildlife use the landscape.
- Omniscape gives detail in the larger core areas (e.g. Olympic National Park and Forests) of the landscape that are mapped with just one color in Linkage Mapper.
 - This can be addressed by doing a multiscale linkage mapper analysis of the core itself, if such detail is needed by the end-users.
 - We also produced two prototypes for showing how the combination of the products could address this issue, (with omniscape results showing through in the cores) but it was not compelling enough to outweigh the cons (complexity, other problems outside the cores, mixing “apples and oranges” in one map).”

Discussion

One of the workshop members, Peter Singleton of the USFS, reviewed the draft of this report and commented extensively on the above section. We did not want to edit the group's findings, so have added his comments as a discussion.

"For me, it's just way easier to track the whole story using linkage mapper:

- 1) You are forced to be explicit about what you are trying to connect (cores).
- 2) You can see the broad landscape permeability patterns surrounding those cores (the CWD map).
- 3) You can identify the linkages that provide the best opportunity for connections through areas where permeability is compromised (the corridor map).
- 4) You can identify locations where restoration is likely to be most beneficial in those priority connections (Barrier & Pinchpoint Mapper).

The big challenge with Linkage Mapper is that there is no one map that tells the whole story. You have to take the time to step through the story from habitat to cores to permeability to corridors to restoration priorities. There are no short-cuts.

I would say that not defining cores for Omniscales was one of the big liabilities of that approach for us. Identifying cores is hard, and it exposes the assumptions you are making in figuring out what to connect (which can be embarrassing, but is good in the long run), but it makes interpretation of the results way more accessible.

[Regarding the final black bullet about large cores, in the "Decision"] I would argue that we don't have the resolution of landscape data to assess connectivity within those cores anyway. This is where we would need to get into a discussion of the scale and precision of our input data. I don't think that connectivity mapping within those highly permeable landscapes is meaningful because animals are likely to be moving randomly relative to the kind of spatial data that we have."

Future Work

Compared to the amount of work that has been performed to get to the chosen products (Figure 10 , Figure 13), a relatively small amount of additional work could probably double the accuracy, certainty, and usefulness of the product suite. This could be called v1.1 or v2.0 depending on how many of the below are implemented, and would be an excellent complement to the focal species analyses currently underway. A brief, bulleted list of initial potential improvements identified by WWHCWG are as follows:

- Improve the Linkage Mapper "Connectivity With Cores" product.

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- This was a suggestion made during the evaluation workshop, and implemented in a subsequent analysis elsewhere.
 - This is to combine the resistance surface with core area value in the HCAs, so there is more informative detail in the core areas.
 - This is illustrated in this map, to be made public if not public already, as part of the Pacific Fisher connectivity analysis in Oregon and California (Spencer et al. 2019).
 - Improved resistance and habitat surfaces:
 - Include riparian data
 - Could include conventional riparian data
 - and/or potential riparian, and advanced riparian data of the analysis by Meade Krosby and colleagues (2018)
 - Improved road resistance values, depending on data availability:
 - Traffic volume
 - Paved vs unpaved
 - Gated or open/closed status for forest roads
 - Transmission lines
 - Less resistance in west than in eastern WA
 - Systematize threat
 - Use a land cover change model output (many exist) to systematically identify which linkages are most threatened, instead of “if the linkage crosses I5 or Hwy 12 it is a higher priority, all else being equal.”
 - Run it at 30 m instead of 90 m
 - May be helpful to update Pinchpoint Mapper code so it calls Julia Circuitscape rather than the old Circuitscape (which was in Python, and requires more memory). That is where the first and only test of 30 m failed. It went through Linkage Mapper and linkage priority without a problem.
 - Esri Story Map
 - Communicate the big picture story of the methods and results (i.e. the resistance, the cores, and then the 6 maps) with an ESRI Story Map, that links to the data in Data Basin.
 - And/OR communicate it with Use Cases, which end up highlighting different products, like the barrier mapper output, as different scales...
 - A similar example is at <http://climateconsole.org/> under User Stories on the top right corner.
 - Use the CWD map to help define linkage priority. Apply what could be termed the goldilocks principle. But instead of "not too hot, not too cold," it is "not too much permeability everywhere around the linkage, and not too little overall."
 - Apply a more nuanced version of combining Linkage Mapper with a coreless product (Omniscape or Resistant Kernel).
 - Start with the methods of this report, but use 0.6 as a multiplier for starters, and perhaps a more nuance normalization of the core area locations in the coreless model's results.
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Supplementary Information

All located at <https://doi.org/10.6084/m9.figshare.12891695> :

SI1: [Data Inputs for the Western Washington Habitat Connectivity Assessment](#)

SI2: [Creation of the Western Washington Resistance Surfaces Habitat Surfaces, and Habitat Concentration Areas](#)

SI3: [Geoprocessing Notes and Lessons Learned](#)

SI4: [Coastal Washington Connectivity Review- In Person Workshop Notes](#)

SI5: [Goals and Objectives for the Western Washington Connectivity Assessment](#)

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