
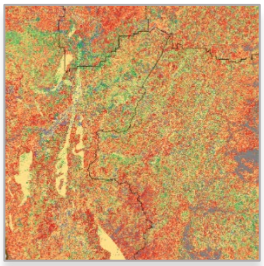
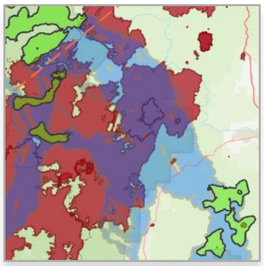

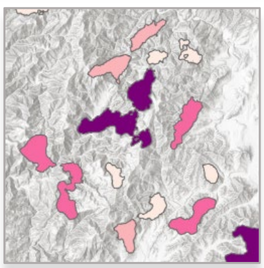

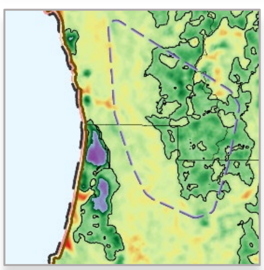
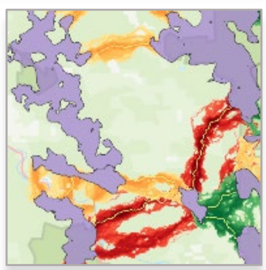
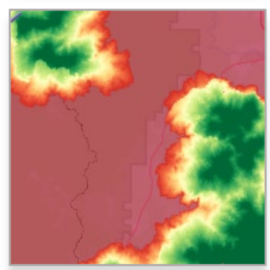
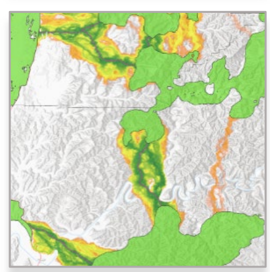

# Executive Report:

## A Landscape Connectivity Analysis for the Coastal Marten (*Martes caurina humboldtensis*)

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This "executive report" is a shorter version of the full report on the methods and findings of our project modeling habitat connectivity for the coastal marten. The intention is to provide a short summary of key findings for readers less interested in the details of the project, as well as a relatively small-sized file that will be easier to share via e-mail. It consists of the executive summary of the full report, along with the figures and tables that are referenced within it. Figure and table numbers match those in the full report and thus are not consecutive.



## Suggested Citation

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## Document Availability

This report and associated spatial data are available online at:

https://www.fws.gov/arcata/shc/marten

## Cover

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# Executive Summary

The coastal marten (also known as Humboldt marten) is a medium-sized carnivore that is endemic to northwestern California and western Oregon. In 2018, it was proposed for listing as threatened under the Federal Endangered Species Act and was listed as endangered under the California Endangered Species Act. The species primarily inhabits mature coastal forests in this region, but can also be found in dune forest habitat and certain areas with dense shrub cover on serpentine soils. Coastal marten populations declined from a combination of heavy trapping pressure in the late 19th and early 20th Centuries and the loss and fragmentation of mature forests. It is currently known to exist in four isolated populations, two in California and two in Oregon. A conservation strategy document for the species was recently produced by the Humboldt Marten Conservation Working Group that incorporated a landscape-scale habitat model. However, this model had limitations in terms of its ability to assess habitat connectivity at scales that would facilitate conservation planning efforts. It was also based on locations of the remnant marten populations at high elevations and therefore did not depict suitable habitat in lower elevation coastal areas where the species is known to occur. Therefore, we developed a landscape-scale habitat connectivity model for the coastal marten across the extent of its historical range, with the goals of better understanding the distribution of habitat, the likely degree of isolation of the existing populations, and the potential for the species to recolonize areas of suitable but unoccupied habitat. We hope that this model would be able to inform ongoing Species Status Assessment (SSA) and Endangered Species Act listing processes, as well as ongoing conservation planning efforts related to the coastal marten.

We developed our coastal marten connectivity model using a spatial analysis tool called Linkage Mapper, along with information about the species' biology to assess its ability to move through or occupy habitat. We first identified "habitat cores", which are relatively large patches (>1500ha) that are likely to contain sufficient high quality habitat to support long-term occupancy by coastal martens, and thus represent important areas for the species' conservation. They are not intended to represent all potentially suitable habitat on the landscape. These habitat cores are then connected via "least-cost corridors", which are estimated to be the easiest routes for dispersing martens to move through based on land cover types and the presence of features such as rivers and roads. The habitat cores were primarily identified using an old-growth structure index (OGSI), a fine-scaled spatial data layer that has been developed by researchers with the U.S. Forest Service and Oregon State University as a means of evaluating the effectiveness of the Northwest Forest Plan. We also incorporated data on the location of serpentine soils that likely support habitat suitable for coastal martens. The corridors were mapped by dividing the landscape into a raster (gridded) surface with 30m X 30m cells, and assigning each cell a "resistance value" based on land cover type, with higher values indicating the cover type as more difficult or hazardous for martens to move through. Based on a set of guiding assumptions about marten biology and habitat use, we assigned higher resistance values to younger forests, non-forested areas, and large roads and rivers, and lower resistance values to areas with mature forest or suitable serpentine habitat. The least-cost corridors were mapped onto swaths of land that collectively had the lowest resistance between habitat cores. Corridor width varied considerably depending local conditions.

Using our input parameters, our model identified 51 habitat cores linked by 97 least-cost corridors (Fig. 10). Habitat cores ranged in size from 1,624 – 178,091ha, with the total area of all habitat cores being 788,290ha (3,043.6 miles$^2$). Over 82% of this area was on lands managed by the U.S. Forest Service. Only 29% of the total area of the habitat cores was on lands managed with the strictest protections for biodiversity (USGS GAP status categories 1 and 2). There are several possible ways of assessing the degree of isolation of habitat cores or populations from one another. We used a metric called "cost-weighted distance", which takes the resistance values within the least cost corridor into account so that the difficulty of the terrain and barriers crossed was factored in as well as the physical distance. This cost-weighted distance was then normalized for comparison

to km. We used a standard of ≤15 cost-weighted km for a corridor to be considered "well connected" (based on published marten dispersal distances), with corridors ≤45 cost-weighted km considered "moderately connected" and longer corridors "poorly connected". Based on this standard, 36.1% of the corridors were considered well connected, 28.9% moderately connected, and 35% poorly connected. The more traditional method of assessing connectivity by the Euclidean ("as-the-crow-flies") distance between habitat cores without taking the nature of the intervening landscape into account would have classified 64.9% of the corridors as well connected (Table 4).

The two Oregon populations were indicated to be poorly connected to one another, and to the populations in California no matter what metric was applied. The two California populations were mapped as connected by a large habitat core rather than a corridor (although the intervening area is not known to be currently occupied). We also ran a separate Linkage Mapper trial that treated the known population boundaries as habitat cores, and this classified these two populations as moderately connected by cost-weighted distance and well connected by Euclidean distance (Fig. 12). We identified five "habitat core clusters" that could be linked by least-cost corridors of ≤45 cost-weighted km (Figs. 13 and 14). Three of these were in Oregon, two of which included extant coastal marten populations. Another cluster included most of the habitat cores in California along with some adjacent ones in Oregon, and the fifth cluster linked two relatively small, isolated, unoccupied cores in California. Habitat cores within the same cluster can be considered "functionally connected" for coastal martens to some degree, with long-term potential for dispersal, gene flow, and recolonization between them.

We also ran Linkage Mapper trials on two landscape scenarios that we developed to illustrate ways in which this model might be used as a conservation planning tool. The first trial explored how timber harvest might affect habitat connectivity, using an example from the area between the Six Rivers National Forest and Prairie Creek Redwoods State Park. Timber harvests here since 2012 (subsequent to the collection of the data used to produce the OGSI) shifted the least-cost path somewhat and increased the cost-weighted distance between two habitat cores (Fig. 15). The second trial identified a discrete area of the landscape in the Rogue River-Siskiyou National Forest where a modest improvement in habitat quality (for example, through allowing the forest to mature) had the potential to significantly improve connectivity between the habitat core clusters in Oregon and California (Fig. 16). Linkage Mapper's output includes several metrics that can be used to assess the connectivity value of individual linkages between habitat cores. These metrics can then be used to help evaluate the potential impacts of changes on the landscape, including comparing among alternative proposed management actions.

There are some important caveats in considering the results of our habitat connectivity analyses. First, there are a number of aspects of coastal marten dispersal behavior that are not well understood; in particular how dispersing animals respond when encountering sub-optimal habitat, non-habitat, and barriers such as rivers and roads. There is also more to be learned about what constitutes high and low quality habitat for the species, and how this might vary over the breadth of its range. We incorporated a number of simplifying assumptions into our model to account for data gaps. Second, the OGSI and most other habitat data we used were based on surveys and analyses conducted in 2012 and therefore do not reflect changes from more recent disturbance events such as timber harvest and fires. They also have a modest rate of misclassification errors, and while the data are very useful for describing patterns of forest structure at the landscape scale, the potential for such errors to give an inaccurate view of forest structure increases at finer scales. Third, it needs to be understood that the habitat cores do not represent all coastal marten habitat on the landscape, nor should all of the area within these cores be considered suitable habitat for the species. The final set of habitat cores we used in the model had a minimum size of 1500ha, but many smaller areas of "habitat core" could be identified using a smaller minimum size threshold; indeed, many of these smaller cores form important anchors of the corridors identified in the model.

Given that the SSA identified small and isolated populations as one of the major threats to the coastal marten, maintaining habitat connectivity between populations where it exists and improving it where it is poor should be high conservation priorities. Connectivity between existing populations and large patches of suitable but unoccupied habitat will be important in allowing the species to expand its distribution and increase its numbers. The clearest examples of such areas identified by our model include (1) a set of habitat cores in and around the Siuslaw National Forest to the east of the Central Coastal Oregon population, and (2) a number of habitat cores adjacent to the two California populations that are primarily located on the Six Rivers National Forest and Redwood State and National Parks. If translocations are considered as a conservation tool for the coastal marten, the chances of successfully establishing and maintaining new populations using this method will be higher if they can have a degree of connectivity to one or more established populations. Therefore, patterns of landscape connectivity should be taken into account in selecting potential release sites.

There are several areas of research that could provide important new data to improve our understanding of habitat connectivity for coastal martens. These include: (1) additional surveys aimed at better understanding the current distribution of the coastal marten (especially in California), (2) habitat use studies of radio-collared animals that could improve our understanding of preferred habitat types and dispersal behavior, and (3) analyses of genetic structure among and within coastal marten populations that could provide insights into gene flow patterns over time.

**Table 4.** Percentages of habitat core pair linkages classified as "well", "moderately", or "poorly connected" based on three distance metrics. Euclidean distance and least-cost path length are measured in km, while cost-weighted distance is measured in "cost-weighted units" normalized to km.

| | Euclidean distance | Least-cost path length | Cost-weighted distance |
|---|---|---|---|
| **Well connected (0-15km)** | 64.9% | 54.7% | 36.1% |
| **Moderately connected (15-45km)** | 21.7% | 27.8% | 28.9% |
| **Poorly connected (>45km)** | 13.4% | 17.5% | 35.0% |

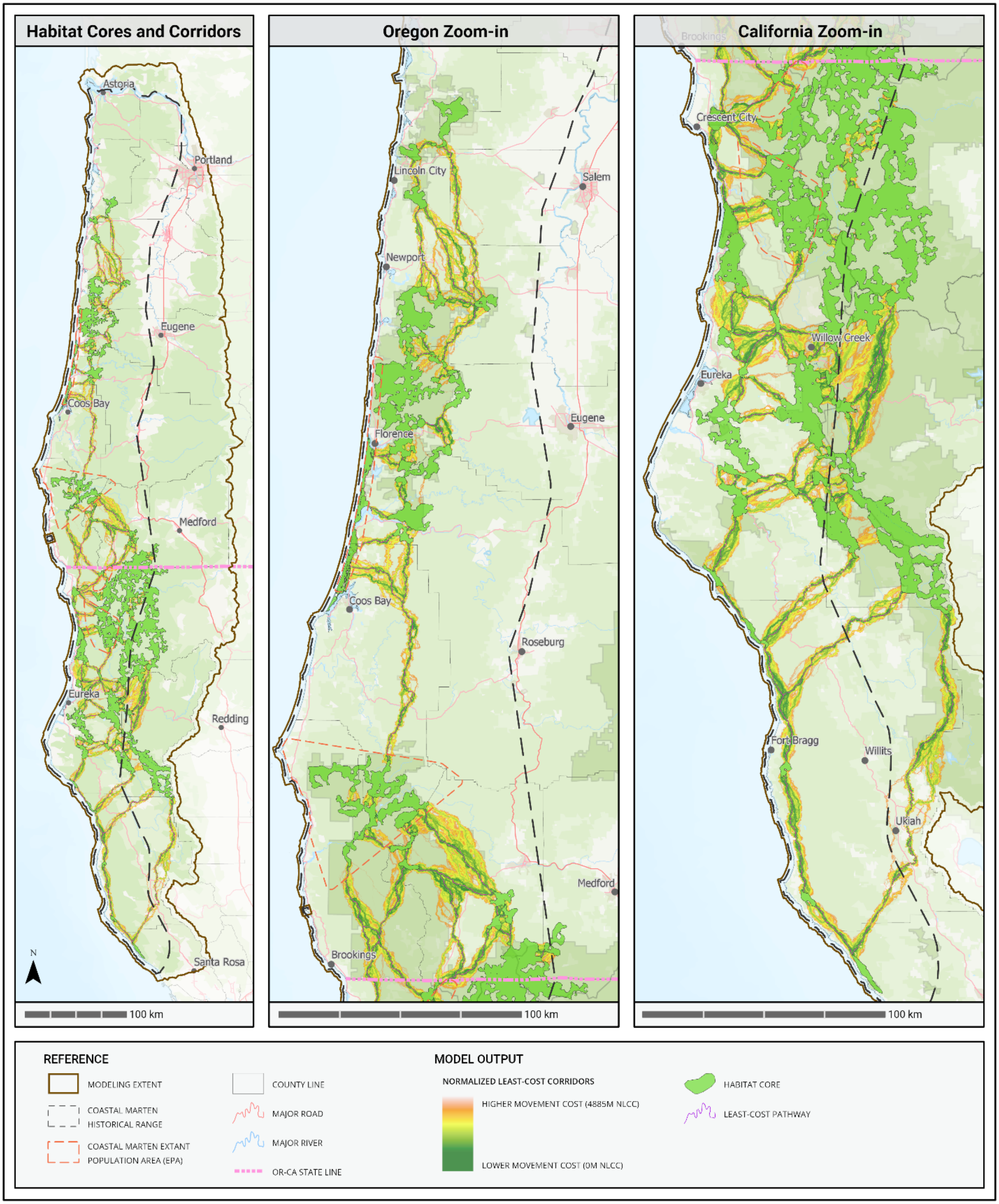



**Figure 10.** Modeled habitat cores and least-cost corridors for the coastal marten. Some corridors are likely too long or cross too much poor quality habitat to be viable.

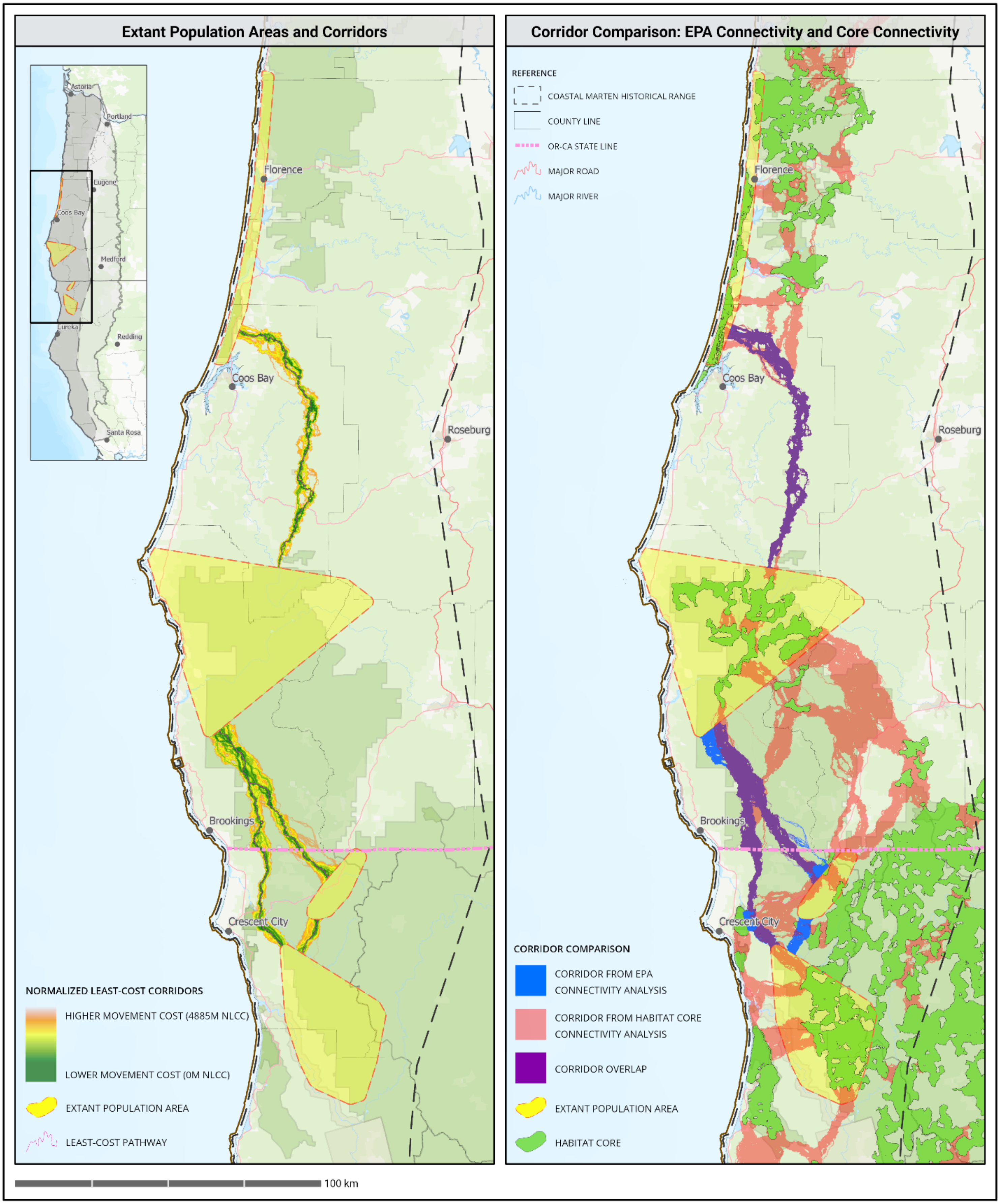



**Figure 12.** Results of the secondary model treating the four known existing coastal marten populations as habitat cores. Least-cost corridors largely overlapped those derived from the primary model results shown in Fig. 10, except for a novel corridor linking the Oregon-California Border and Northern Coastal California populations.

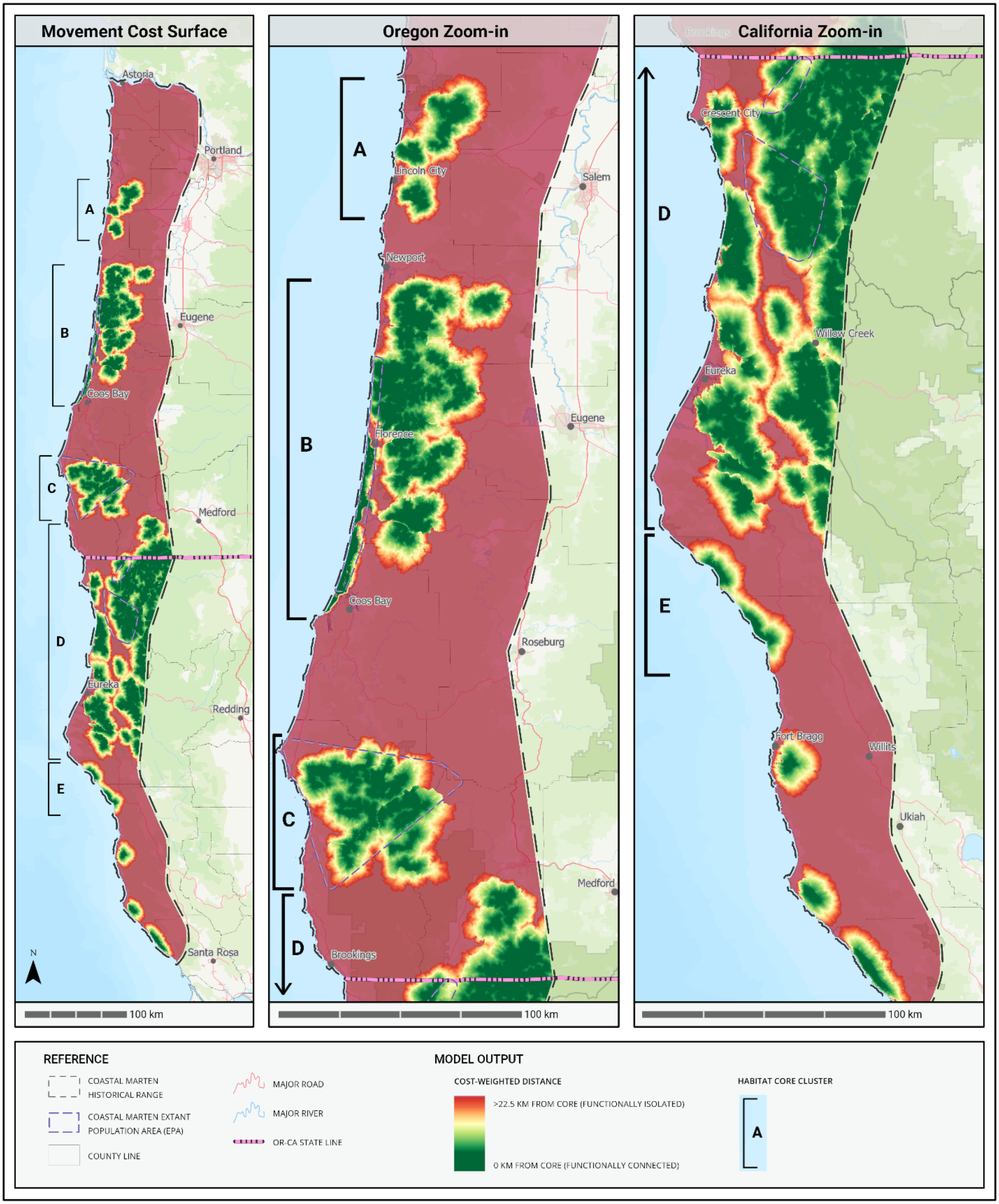



**Figure 13.** Clustering of coastal marten habitat cores connected by ≤45 cost-weighted km. The habitat core clusters supporting the two extant populations in Oregon appear to be functionally isolated, while the two California populations occur in the same cluster.

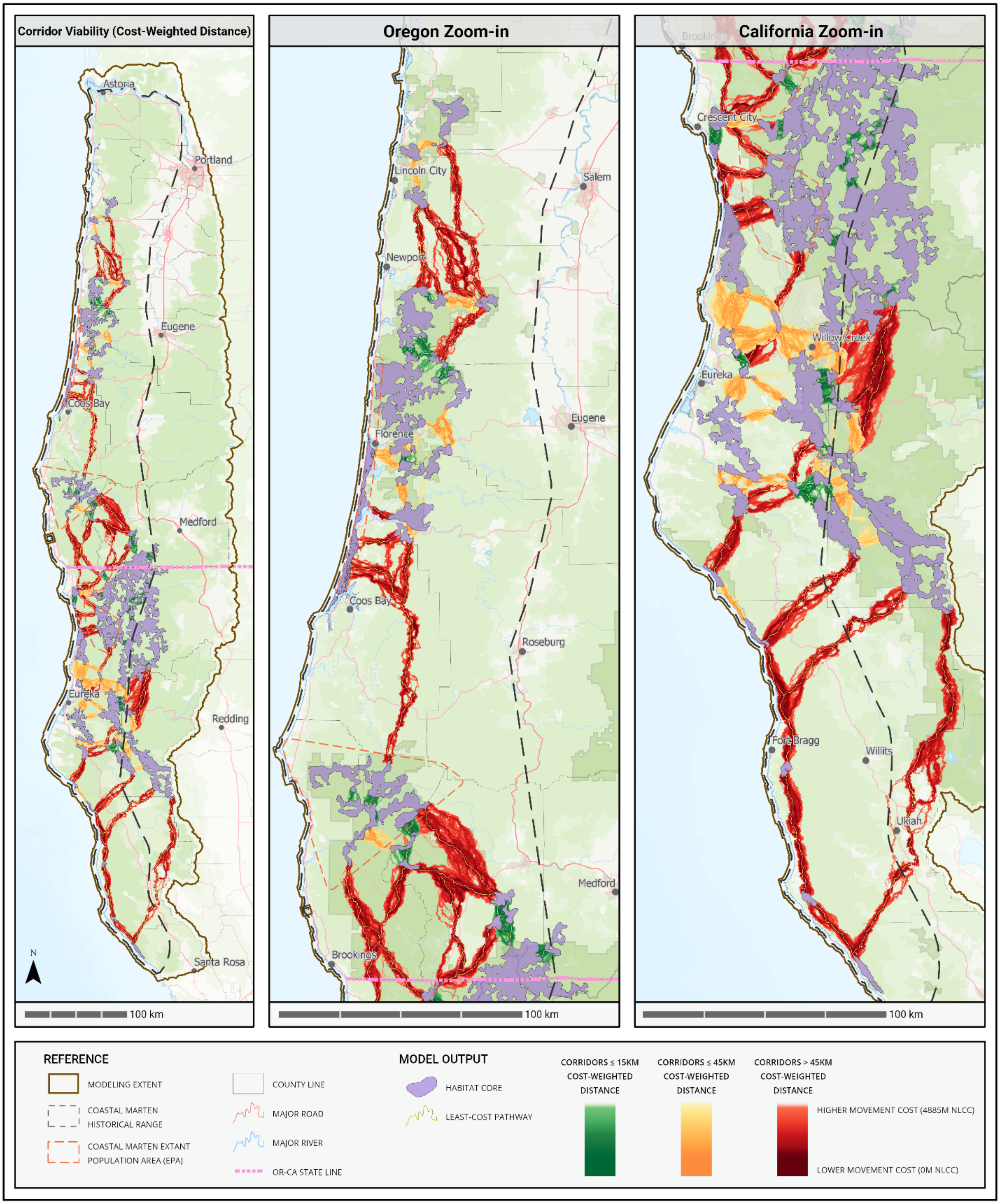
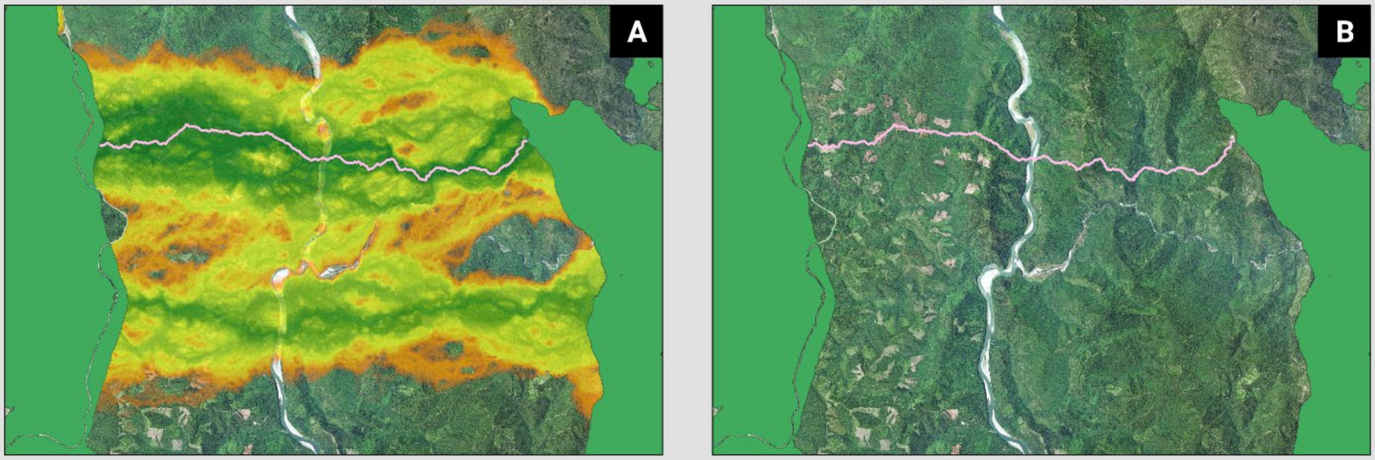
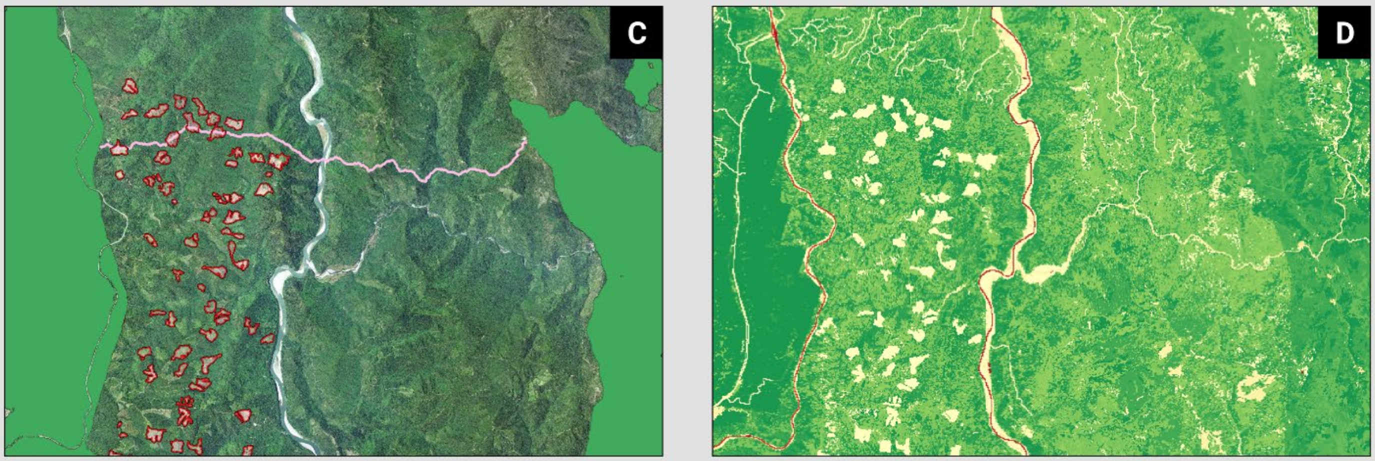


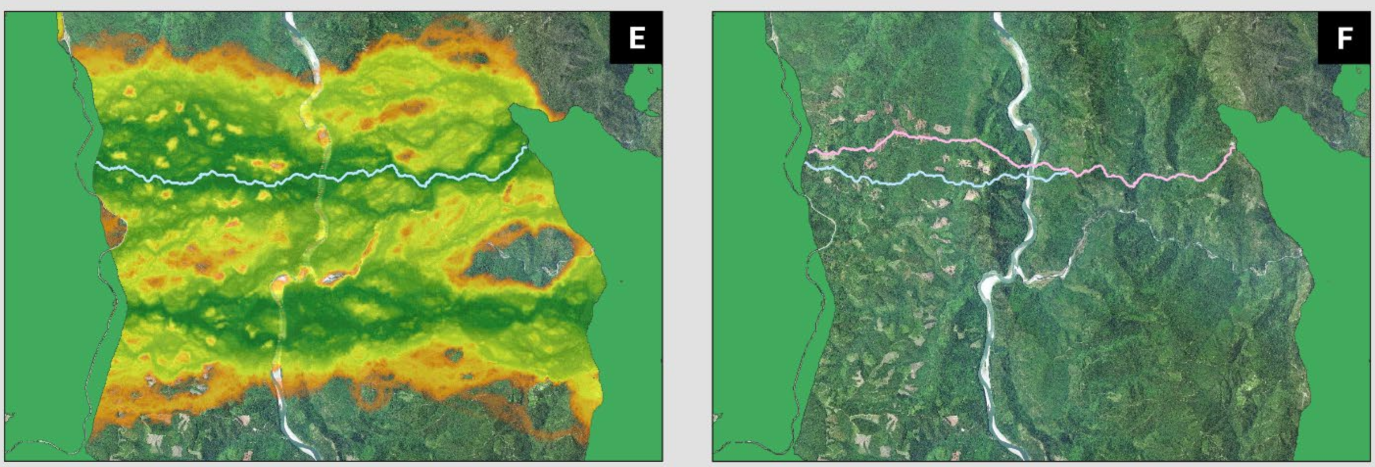

**Figure 14.** Coastal marten least-cost corridors classified as well connected (≤15km), moderately connected (≤45km), or poorly connected (>45km) based on cost-weighted km. The habitat cores within the clusters depicted in Fig. 13 can all be linked by either a well or moderately connected corridor (i.e. green or orange, respectively).




The primary coastal marten connectivity model identified a least-cost corridor (pink line) linking two habitat cores (in green) with considerable conservation significance (A); the Northern Coastal California population occupies the eastern core, and Slauson et al. (2019a) identified the western core (Redwood State and National Parks) as a potential Population Reestablishment Area. However, examination of aerial imagery showed that several patches of mature forest traversed by the least-cost path have been harvested since the data used to derive the old-growth structure index (OGSI) were produced in 2012 (B).

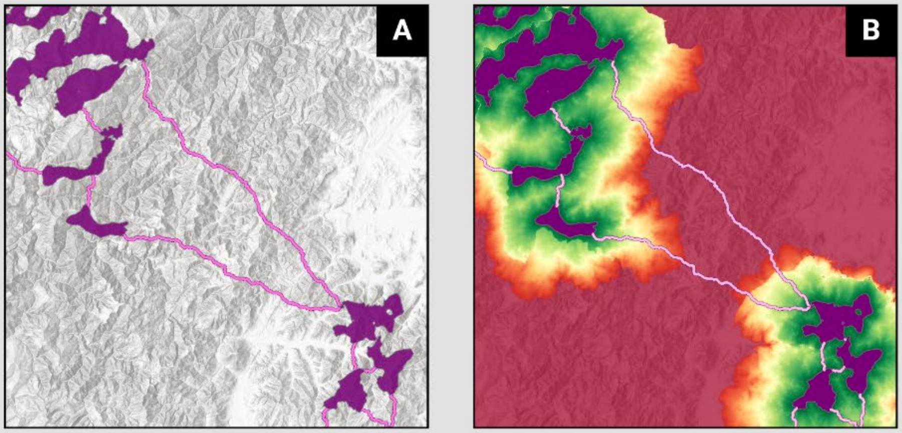



We used Google Earth Engine to delineate areas where timber had been harvested on this part of the landscape between 2013-2018 (in red) (C), and then created an updated resistance surface where all of the pixels in these harvest areas were assigned to the highest OGSI-based resistance category (10/pixel) (D). See Fig. 4, Part 2 for map legend.

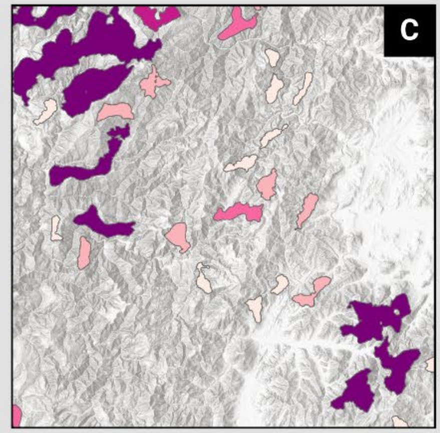



We reran Linkage Mapper using the updated resistance surface (E). The least-cost path shifted slightly to the south (F), and the least-cost corridor became somewhat more diffuse as the amount of pixels with higher OGSI values has declined, although the general "parallel" corridor structure still exists. The post-harvest least-cost path was 1.58% longer than in the main model, and the cost-weighted distance was 3.67% longer. Note that this methodology could also be applied to examining the effects of proposed harvests or other habitat alterations.

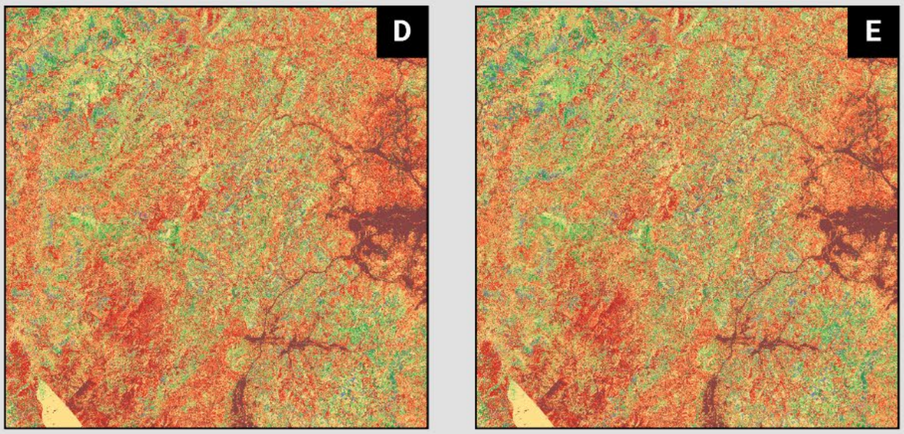
**Figure 15.** Development and outcome of the timber harvest scenario. After an examination of the landscape revealed significant changes since the GNN data were collected in 2012, we modified the primary model to explore the potential effects of recent timber harvests on habitat connectivity for coastal marten. A similar methodology could also be used to estimate the potential impact of proposed timber harvests.



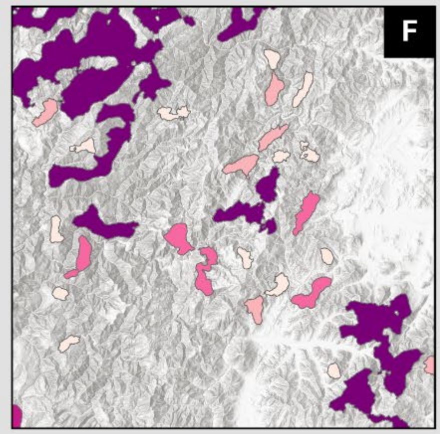

**Identify Functional Isolation:** While the results of our primary model run identified a least-cost path in this part of the landscape as the best quality linkage between Oregon and California (A), analysis of the cost-weighted distance indicated that these habitat cores (shown in purple) were poorly connected (B). See Figs. 8 and 11 for map legends. Least-cost corridor delineation has been omitted here for clarity.



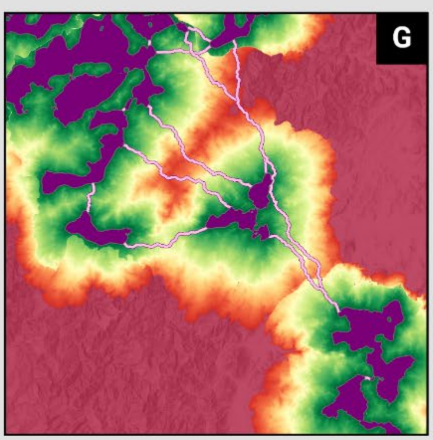

**Identify Smaller Habitat Cores:** Cores that are too small to be included in our final model but large enough to include one female home range (i.e. 300-1499ha; shown in shades of pink) can identify areas where new full-sized cores might form with small improvements in habitat values.



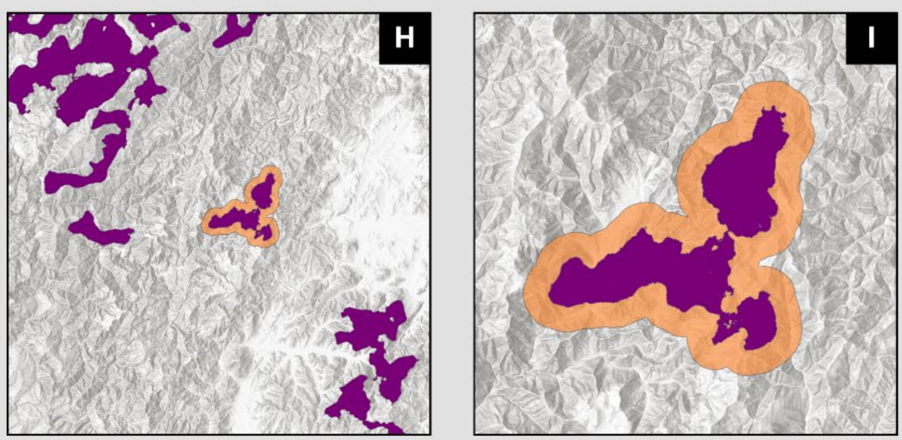

**Increase Habitat Value by 1:** The habitat cores in our primary model were derived from a surface with pixel values ranging from 0-100 (D). These pixel values were mostly based on the old-growth structure index (OGSI), a model of forest maturity incorporating data on tree size diversity and the abundance of large trees, snags, and downed wood. By growing all non-zero values on the habitat surface by 1.0, we simulated a modest amount of forest growth (E). See Fig. 5 for map legend. While this modest increase is barely discernable by visual inspection, it can have a noticeable impact on moving window averages in Core Mapper.




**Rerun Core Mapper:** In this example, running Core Mapper on the revised habitat surface showed that even the slight increase in pixel values (1.0 each) was sufficient for a new habitat core meeting our 1500ha minimum size threshold to form from the nucleus of two smaller "mini-cores".




**Verify Functional Connectivity:** We then combined this new habitat core with those used in the primary model and re-ran them in Linkage Mapper with the original resistance surface. Functional habitat connectivity for coastal martens improved greatly (see text for details).




**Delineate Target for Restoration:** This scenario revealed that modest changes in habitat quality on a relatively small portion of the landscape (7268.3ha) could yield significant improvements in connectivity for the coastal marten (H). This area encompasses the new habitat core (2861.9ha) plus a buffer the radius of the moving window we used in Core Mapper (977m) (I). This methodology appears to be a relatively simple and efficient way to identify and prioritize areas where management could be targeted to improve connectivity.

**Figure 16.** Development and output of the habitat restoration scenario. This secondary model explored a method for identifying discrete areas on the landscape where modest improvements to habitat quality might result in significant gains in habitat connectivity for coastal martens.