Washington Connected Landscapes Project: Climate-Gradient Corridors Report

WASHINGTON WILDLIFE HABITAT CONNECTIVITY WORKING GROUP

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Mission Statement of the

Washington Wildlife Habitat Connectivity Working Group

Promoting the long-term viability of wildlife populations in Washington State through a science-based, collaborative approach that identifies opportunities and priorities to conserve and restore habitat connectivity.

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Document and Data Layers Availability

This document and companion files, including a full technical report and data layers, are available online at http://www.waconnected.org

Washington Connected Landscapes Project: Climate-Gradient Corridors Report

This report is intended to guide the interpretation and use of the climate-gradient corridor analyses and maps described in Nuñez (2011). It has been prepared by the ***Washington Wildlife Habitat Connectivity Working Group (WHCWG) Climate Change Subgroup:*** Meade Krosby, lead (University of Washington); Joshua Lawler (University of Washington); Brad McRae (The Nature Conservancy); Tristan Nuñez (University of Washington); John Pierce (Washington Department of Fish and Wildlife); Peter Singleton (US Forest Service – Pacific Northwest Research Station); and Joshua Tewksbury (University of Washington), with additional input from the full WHCWG. For complete information on the membership and activities of the WHCWG, see WHCWG (2010) or visit http://www.waconnected.org

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Introduction

In 2010, the Washington Wildlife Habitat Connectivity Working Group (WHCWG) released a report assessing habitat connectivity patterns for wildlife across Washington State (WHCWG 2010). The WHCWG Climate-Gradient Corridors Report adds a climate change lens to this assessment, by identifying corridors intended to improve the ability of wildlife and their habitats to respond to future changes in climate.

A key means by which wildlife respond to climate change is to adjust their geographic ranges to remain in areas with suitable climate and habitat characteristics. For example, as the climate has warmed over the past century, the ranges of diverse species have begun moving upward in both elevation (~6.1 m/decade) and latitude (~6.1 km/decade) (Parmesan & Yohe 2003). These kinds of shifts will become even more critical over the coming century as climate change becomes more severe. And yet, species attempting to track suitable climates will increasingly encounter barriers as they move through fragmented landscapes. Increasing ecological connectivity – the degree to which a landscape facilitates the movement of the organisms within it – has therefore become the most frequently recommended strategy for reducing the negative effects of climate change on biodiversity (Heller & Zavaleta 2009).

This report aims to provide guidance regarding the interpretation and implementation of maps identifying corridors intended to facilitate climate-driven range shifts through fragmented landscapes. It provides a brief overview of the methods used to identify these corridors (for more detailed methodology please refer to Nuñez 2011), describes broad scale patterns and insights revealed by the analysis, discusses important caveats and limitations associated with the results, and suggests how these map products might be appropriately implemented and improved upon by future analysis.

Climate-Gradient Corridor Approach

The climate-gradient corridor analysis aims to facilitate climate-driven range shifts by identifying corridors that fall along the climatic gradients (e.g., temperature) species are likely to follow as they track changing climates. The primary rationale for the approach is that if species need to adjust their ranges to track their current climates as temperatures warm, and if climatic gradients are conserved (e.g., as temperatures increase, higher elevations will still be relatively cooler than lower elevations even if both are eventually warmer), then species can be expected to move from what are today warmer climates to nearby areas with cooler current climates (Fig. 1). Furthermore, species that will be sensitive to climate change will likely avoid moving through areas that are much cooler or much warmer than the climates they currently inhabit (Fig. 2). For example, an alpine species is not likely to move across a hot valley bottom to get to the next higher meadow and a lowland species is not likely to cross a cold mountain range to get to a slightly cooler valley.

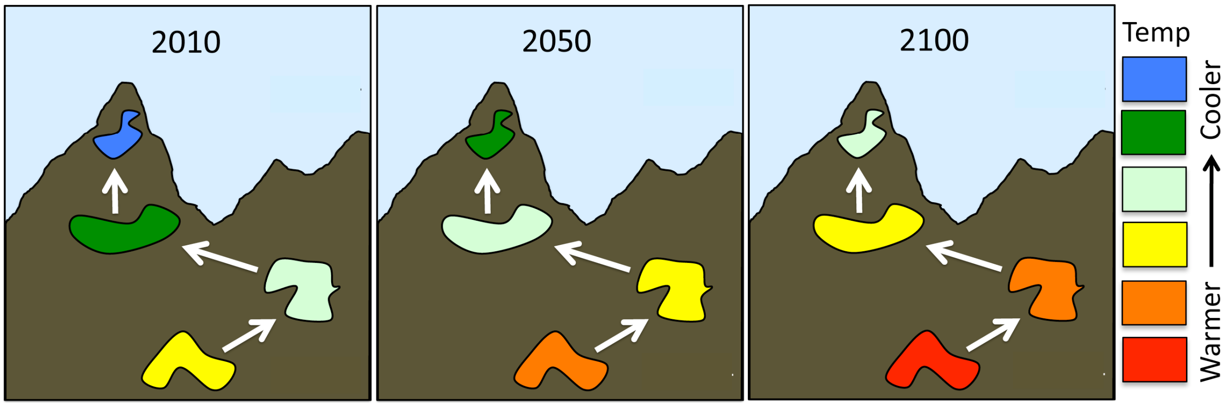

Figure 1. ***Pathways through a Changing Climate.*** As the climate warms, corridors (arrows) between relatively warmer and cooler core areas offer wildlife opportunities to track their suitable climates across the landscape. Essentially, they promote a species' ability to "run to stand still," that is, to move to new areas on the landscape in order to experience little to no change in climate.

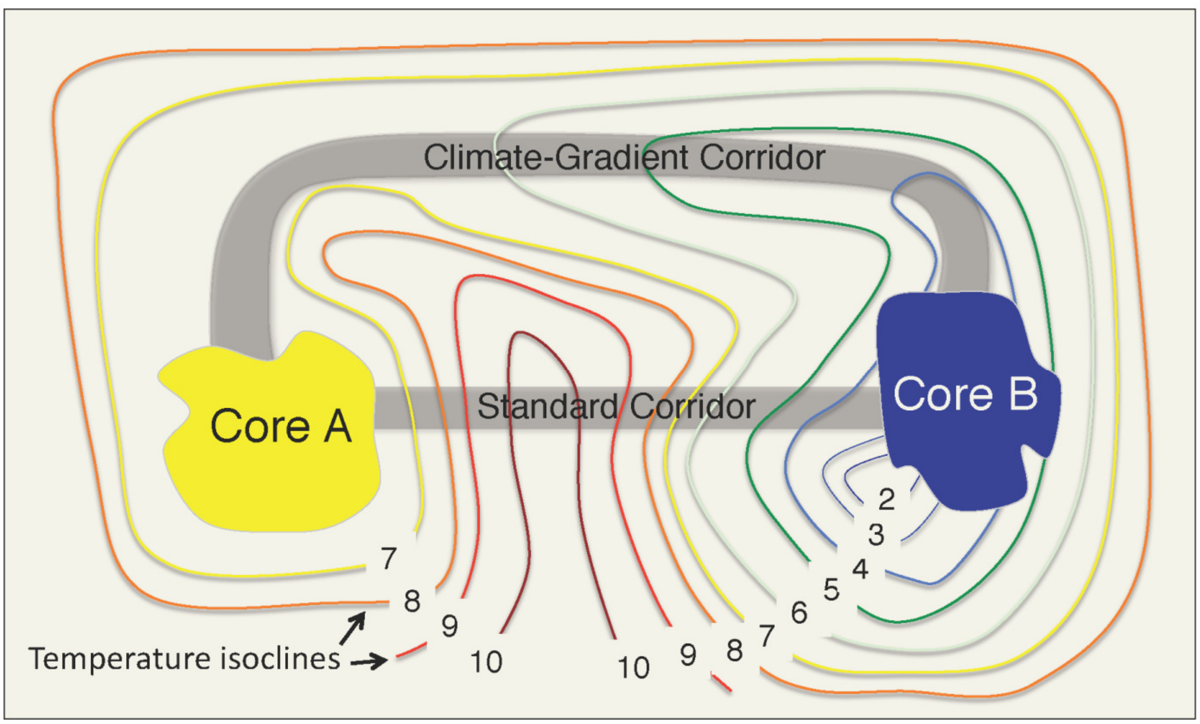

Figure 2. ***Climate-Gradient Corridors.*** While a standard corridor seeks to minimize geographic distance and barriers between two core areas, a climate-gradient corridor also seeks to minimize changes in climate (e.g., temperature) encountered between core areas. In this example, this results in the climate-gradient corridor being geographically longer, yet prevents it from crossing through the hot area between the warmer (A) and cooler (B) core areas.

Key Assumptions

The climate-gradient corridor approach is based on several simplifying assumptions:

- ***Species ranges will move to track suitable climates.*** In particular, species ranges will tend to move down temperature gradients (i.e., upward in elevation or latitude) as the climate warms. This is well-documented in paleoecological studies and in observations of species responses to recent climate change.

- ***Climatic gradients between core areas will remain largely constant.*** We base this assumption on evidence that temperature and moisture gradients at scales between several kilometers and several hundred kilometers are driven largely by enduring physiographic features, particularly topography (Daly 2006). Because topography itself is unchanging, we assume that the shape of climate gradients will not change substantially at these scales.

- ***Species range shifts will be more likely to occur through natural areas.*** We assume that species range shifts, being ultimately facilitated by the dispersal movements of individuals, will be more likely to occur through areas with fewer anthropogenic barriers to movement (e.g., roads, urban areas).

Key Limitations

The climate-gradient corridor approach has several important limitations:

- This approach models corridors between designated core areas, rather than modeling connectivity across all portions of the study area. Thus, the locations of corridors in this analysis will be strongly influenced by the locations of the core areas that they connect.

- This approach models corridors based on the assumption that species' distributions are primarily determined by climate, whereas the distributions and movements of some species under climate change will be more strongly influenced by other factors, such as interactions with other species or changes in environmental variables other than climate.

- Due to the mountainous nature of the region, elevation will often have a stronger influence on the locations of corridors than latitude (as a 3 ºC increase in temperature can be met by moving upward in elevation <500 m, versus a poleward shift of almost 400 km). This has two important implications:

    ◊ Climate-gradient corridor networks will often terminate at high-elevation core areas. This may ultimately result in climatic dead-ends for some high-elevation species, as cooler climates eventually disappear off the tops of mountains altogether. Such species may require alternative management approaches such as assisted migration to habitats at higher latitudes.

    ◊ Environmental variables other than climate (e.g., solar radiation, soils, slope steepness) may also change rapidly with elevation. Thus, this analysis may be most appropriate for species with relatively strong sensitivities to climate but relatively low sensitivities to other environmental variables that vary with elevation.

Methods

Climate-gradient corridors were identified using cost-distance modeling to map corridors with 1) the most unidirectional rate of change in temperature and 2) the highest landscape integrity (lowest human impact) between core areas. Details of the methods are presented in Nuñez (2011). The basic modeling steps were:

1) Core Area Selection

The core areas linked together in our analysis were the Landscape Integrity core areas previously identified in the WHCWG (2010) statewide analysis. These core areas are large, contiguous areas of land with a high degree of naturalness relative to the rest of the study area.

2) Linkage Rules

We identified pairs of core areas that, if connected, would allow species to move from warmer to nearby cooler areas. We therefore connected core areas based on:

- Their temperatures, connecting core areas if they differed in their coldest mean annual temperatures by at least 1 °C. If the climate is warming, the temperature of the coldest places within a core area indicates its capacity to continue to provide thermally suitable habitat as the climate changes.

- Their distances from one another, connecting core areas if they were ≤50 km apart (in order to avoid unrealistically long linkages).

3) Linkage Modeling

We combined *Linkage Mapper*, a corridor-mapping tool for ArcGIS, with algorithms in GRASS GIS to model least-cost corridors between core areas. This was done in two ways:

- Temperature-Only Corridors: Modeling corridors that found the routes of most unidirectional change in temperature between core areas.

- Temperature-Plus-Landscape Integrity Corridors: Modeling corridors that found the routes of most constant change in temperature between core areas (as above), but also avoiding areas of low landscape integrity (e.g., roads, agricultural areas, urban areas).

Results and Discussion

The climate-gradient corridor analysis resulted in two networks of landscape integrity core areas connected by corridors falling along Washington's major temperature gradients: a temperature-only corridor network (Fig. 3), and a temperature-plus-landscape integrity corridor network (Fig. 4). This section describes the key patterns and insights emerging from the analysis, major gaps and opportunities for future analysis, and important points regarding appropriate use of results.

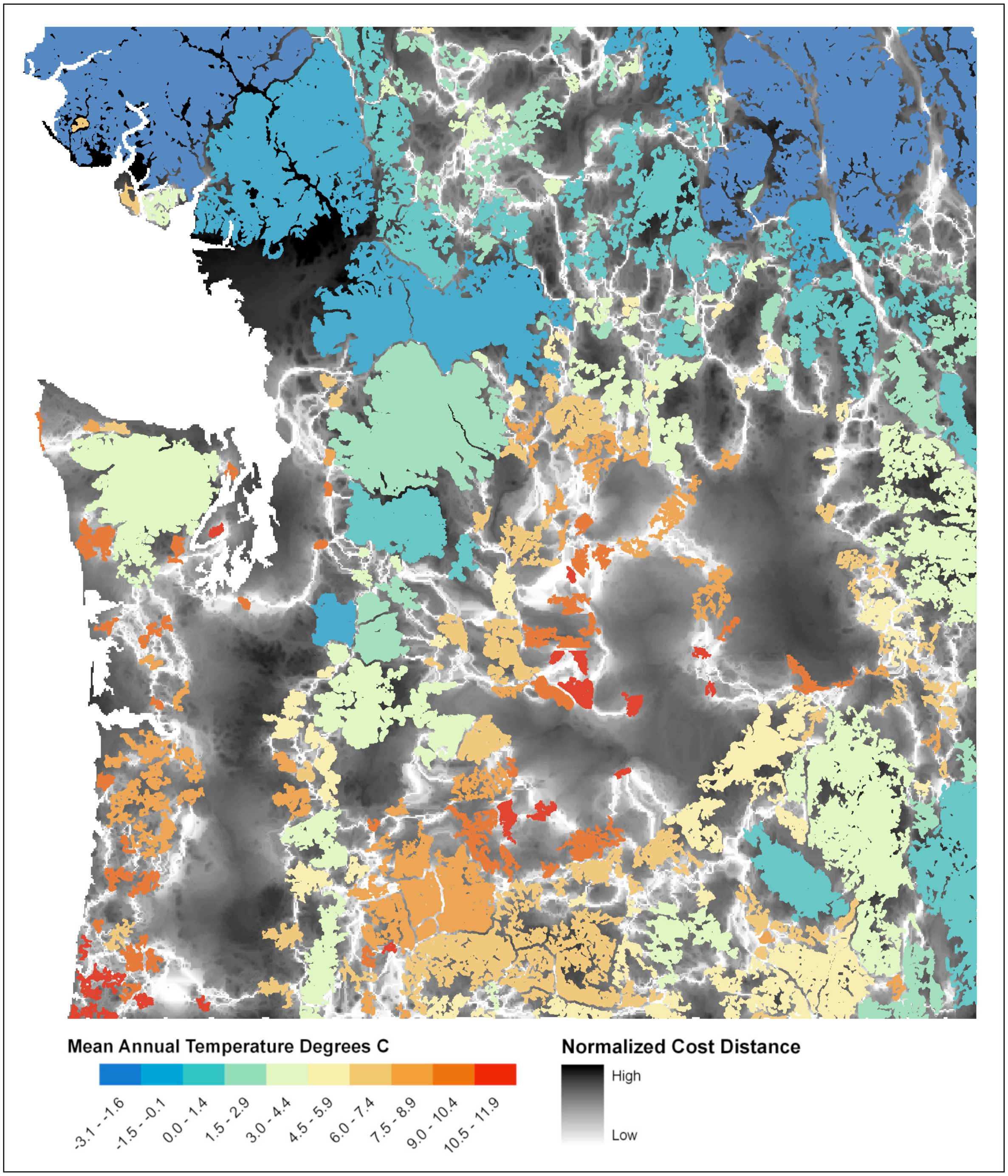

Figure 3. ***Temperature-Only Corridor Network.*** Corridors (glowing white areas above, with resistance to movement increasing as white fades to black) connect core areas of high landscape integrity (polygons above, shaded to reflect mean annual temperatures) that differ in temperature by >1 ºC. The corridors thus allow for movement between relatively warmer and cooler core areas, while minimizing major changes in temperature along the way (e.g., crossing over cold peaks or dipping into warm valleys).

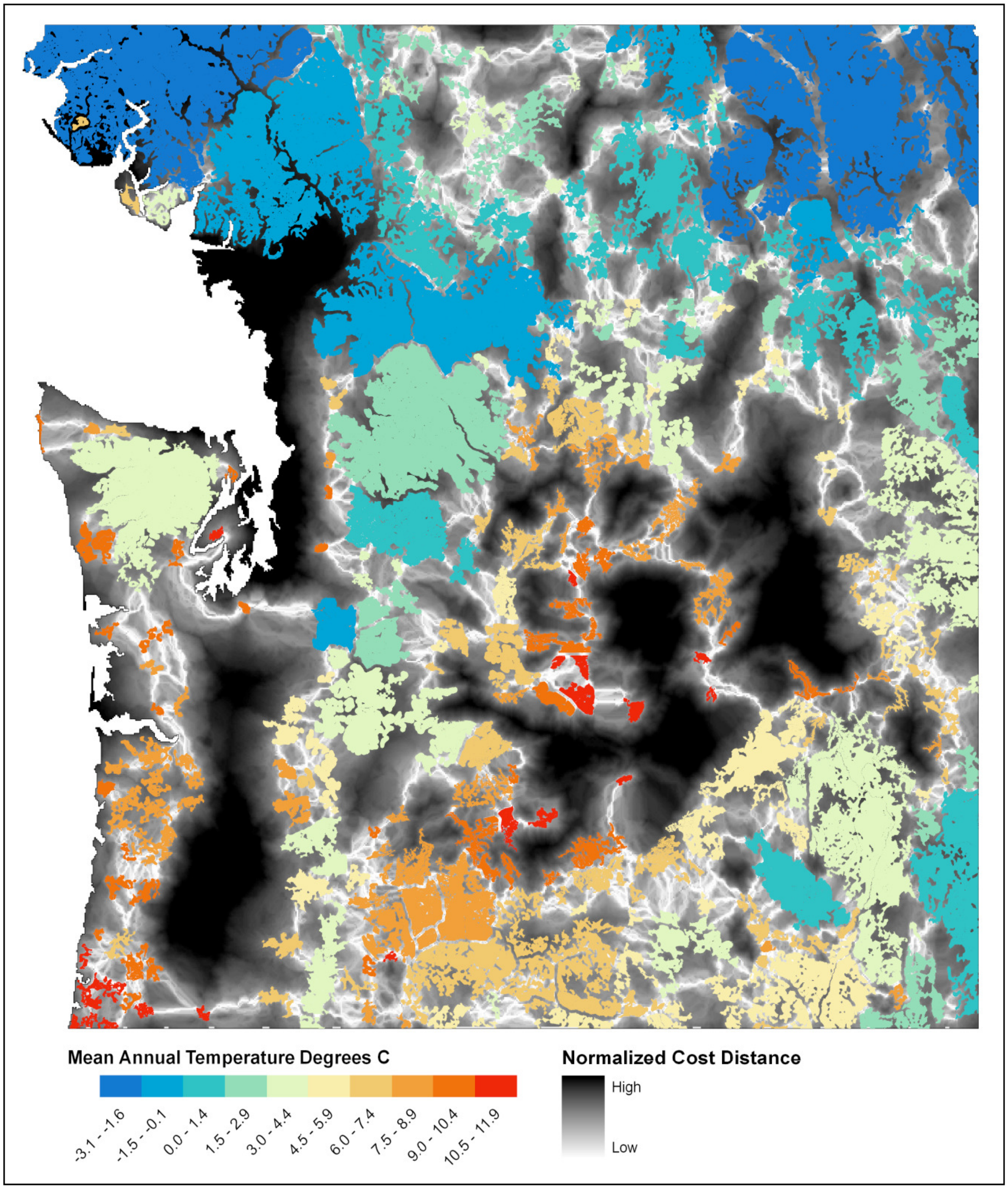

Figure 4. ***Temperature-Plus-Landscape Integrity Corridor Network.*** In addition to minimizing changes in temperature along routes between warmer and cooler core areas, this corridor network also avoids areas of low landscape integrity (e.g., roads, agricultural areas, urban areas).

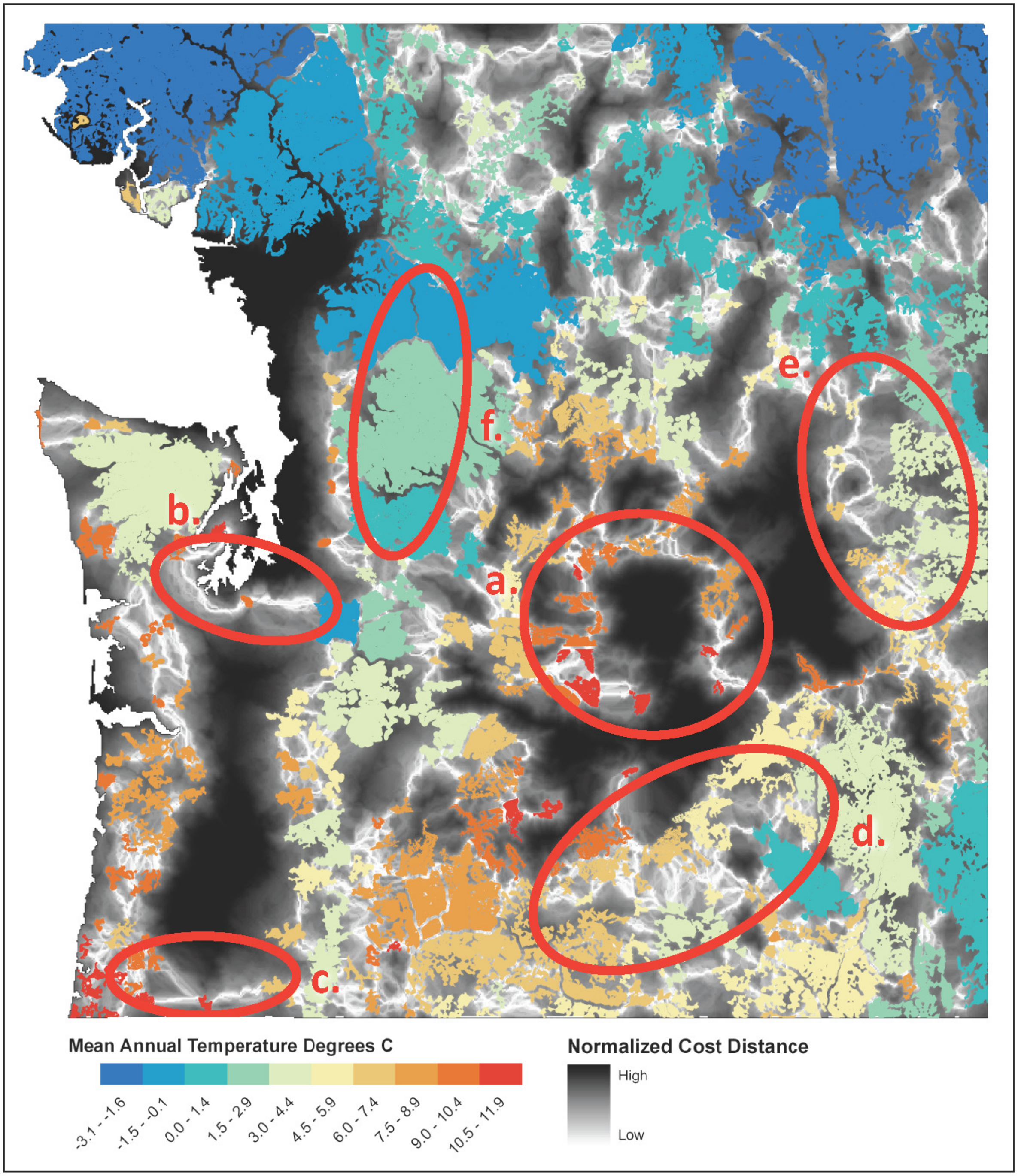

Figure 5. ***Climate-Gradient Corridor Networks: Key Patterns and Insights.*** Labeled, circled areas correspond to examples of key patterns described in the text below.

Key Emerging Patterns and Insights

- ***The warmest core areas act as sources, rather than dead-ends or stepping-stones, for climate-driven movement.*** The warmest core areas – generally found in highly developed, lower elevation regions with relatively few core areas – can be misinterpreted to represent dead-ends or stepping-stones to movement through these areas. In fact, these warmest cores act as sources for movement out of these areas. For example:

  ◊ The warmest core areas in the center of the Columbia Plateau are linked in stepwise fashion to ever-cooler core areas (Fig. 5, circled area "a"). These warmest cores are thus sources for movement out of the Columbia Plateau toward cooler areas west into the Cascade Mountains, south into the Blue Mountains, or north and east into the Rocky Mountains.

  ◊ The two sets of long corridors that run through the Puget Trough (Fig. 5, circled area "b") and Willamette Valley (Fig. 5, circled area "c") appear to offer connectivity between the Cascades and the Coast Ranges. However, these corridors in fact promote movement out of two core areas, *either* east up into the Cascades or west up into the Olympics or Coast Range.

These patterns also suggest the following:

- ***Climate-gradient corridors between warmer and cooler core areas are not predominantly oriented South-to-North.*** As noted earlier, temperature gradients at the regional scale of this analysis will tend to be more heavily influenced by changes in elevation than changes in latitude. This will tend to result in corridors that link lower to higher elevation areas, regardless of direction, as shown in the previous two examples and further illustrated by the following examples:

  ◊ Core areas in the foothills of mountain ranges connect to core areas that include colder regions toward the centers of these ranges, as seen in the North-to-South corridors leading up into the Blue Mountains (Fig. 5, circled area "d") and West-to-East corridors leading up into the Rockies (Fig. 5 circled area "e").

This also leads to the following important point:

  ◊ The corridor network through the Cascades (Fig. 5, circled area "f") may appear to offer continuous South-to-North climate connectivity, yet closer inspection shows that corridors networks in the Cascades often terminate at local temperature minima within the range (i.e., core areas that include cold peaks), and thus are as likely to link warmer to cooler cores in a North-to-South as South-to-North direction. At a continental scale, however, the Cascades likely do in fact act as an important South-to-North corridor for wildlife movement.

- ***The large variation in core size and density across the landscape in turn influences regional patterns of corridor placement and density.*** For example:

  ◊ Mountainous areas such as the Cascades (Fig. 5, circled area "f") have relatively large and densely distributed core areas due to the relatively low human impact at higher elevations. These areas are often fragmented only by major roads. As a result, our modeling approach resulted in many short, redundant corridors between these closely-spaced cores.

  ◊ Highly developed, lowland areas such as the Columbia Plateau (Fig. 5, circled area "a"), Puget Trough (Fig. 5, circled area "b"), and Willamette Valley (Fig. 5, circled area "c") have relatively fewer, smaller core areas. In these regions, individual corridors may represent the only available routes for species within cores to move with climate change.

- ***For temperature-only corridors, steepness of climate gradients will limit corridor width and placement.*** Because higher elevation areas tend to have steeper climate gradients and more complex topographies, routes between warmer and cooler cores in these areas will generally be more likely to encounter large changes in temperature. As the climate-gradient corridor model minimizes changes in temperature encountered between cores, higher elevation areas with steeper climate gradients will tend to have narrower corridors. For example:

  ◊ Higher elevation areas such as the Cascades (Fig. 6a, circled area "a") tend to have narrower temperature-only corridors than lower elevation areas such as the Columbia Plateau (Fig. 6a, circled area "b").

  These wider temperature-only corridors in lowland areas often pass directly through urban or agricultural regions. Yet, in reality, land use patterns will likely restrict the most direct movement of organisms along temperature gradients, depending on species-specific dispersal abilities and sensitivity to land use and climate change. This is reflected in the following pattern:

- ***For temperature-plus-landscape integrity corridors, land-use intensity is the primary driver of corridor width and placement in highly developed, lower elevation areas.*** Places with relatively shallow climate gradients tend to have much heavier land-use intensity, so that land-use in these areas tends to be the primary driver of corridor width and placement. Places with relatively steep climate gradients tend to have much lower land-use intensity, so that climate remains the primary driver of corridor location in these areas. For example:

  ◊ Land use has a stronger influence on corridor placement in highly developed areas such as the Columbia Plateau (Fig. 6b, circled area "b") than in less developed areas such as the Cascades (Fig. 6b, circled area "a").

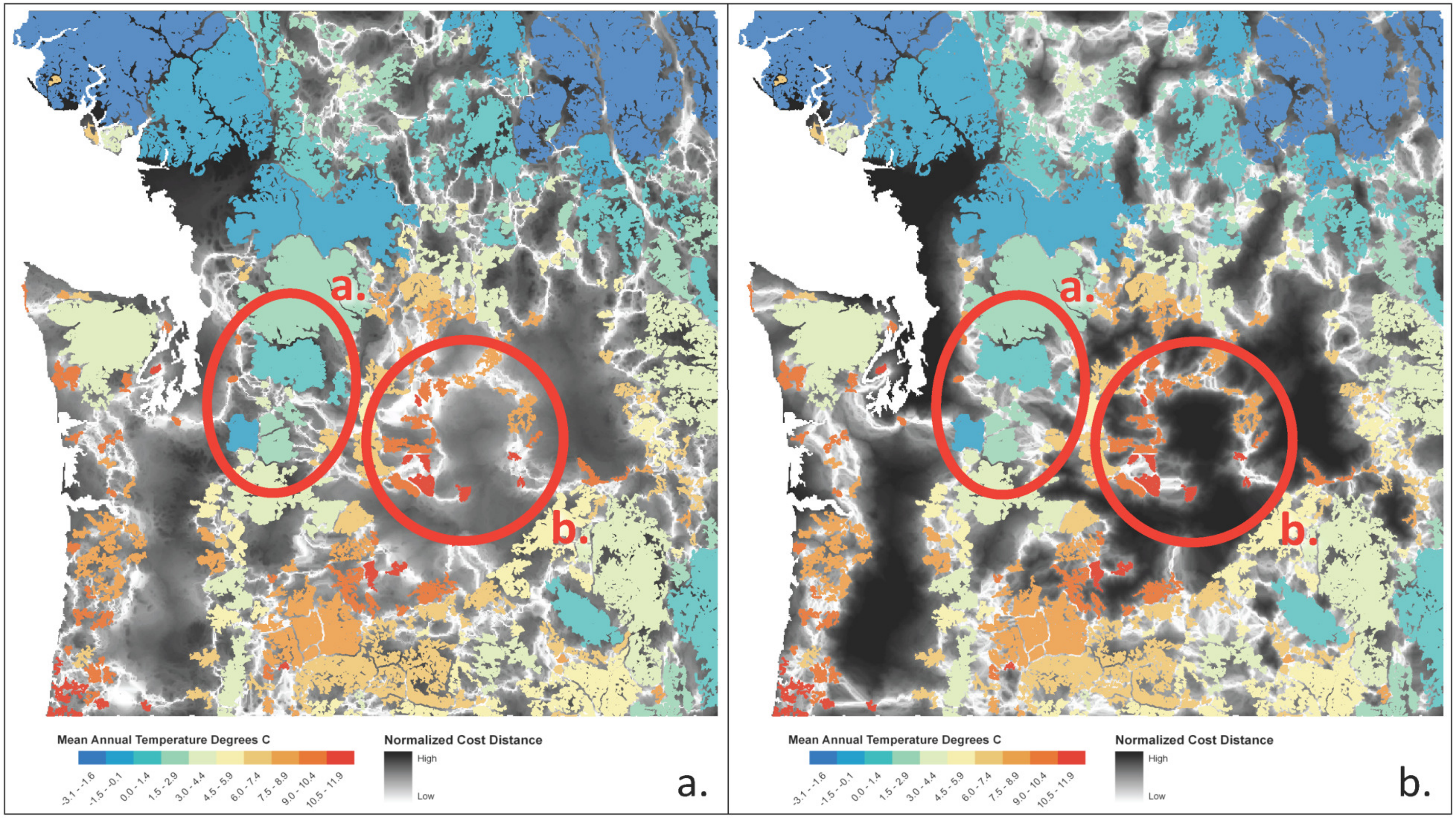

Figure 6. ***a) Temperature-Only and b) Temperature-Plus-Landscape Integrity Corridor Networks.*** The temperature-only corridor network (Fig. 6a) seeks to find routes of most unidirectional change in temperature between warmer and cooler core areas, while the temperature-plus-landscape integrity corridor network (Fig. 6b) also seeks to avoid areas of low landscape integrity (e.g., roads, agricultural areas, urban areas). Labeled, circled areas correspond to examples of key patterns described in the text above.

Major Gaps and Opportunities for Future Analysis

- ***Addressing the influence of core area size and density.*** Large core areas in fact feature a wide range of climatic variation (Fig. 7); connecting smaller areas of more uniform climatic conditions would increase the accuracy of the model in identifying corridors that provide for movement along unidirectional climatic gradients. For example:

    ◊ Breaking cores into smaller (e.g., ~10,000 acre) patches of more uniform climatic conditions would tend to identify corridors that encompass more direct, unidirectional climatic gradients.

- ***Scaling down to finer scales.*** Re-running the models using finer scale underlying data, or parameters that allow for finer scale analyses, may lead to improved results. For example, conducting these analyses at finer scales may lead to:

    ◊ The identification of additional core areas in regions that currently have few cores (e.g., the Puget Trough or Columbia Plateau), in turn leading to the identification of more climate-gradient corridors in such areas.

    ◊ More accurate and precise corridor locations, due to the higher-quality data available at finer scales (e.g., land use).

- ***Prioritizing individual corridors.*** Currently, this analysis provides little guidance regarding the relative importance of any particular corridor in the network. Possible approaches for prioritization include conducting analyses to identify:

    ◊ Areas where loss of landscape integrity would most compromise movement across the landscape. This could be achieved using tools such as Circuitscape that aim to detect "pinch points" in corridors or to identify core areas and corridors whose loss would lead to a dramatic reduction in overall network connectivity.

    ◊ Climate-gradient corridors that overlap with areas identified as important in other planning analyses. This could include composite analyses that overlay climate-gradient corridors with Landscape Integrity corridors identified by WHCWG (2010), with species distribution data (to indicate landscape integrity core areas with high diversity value), or with land ownership to help guide management or acquisition decisions.

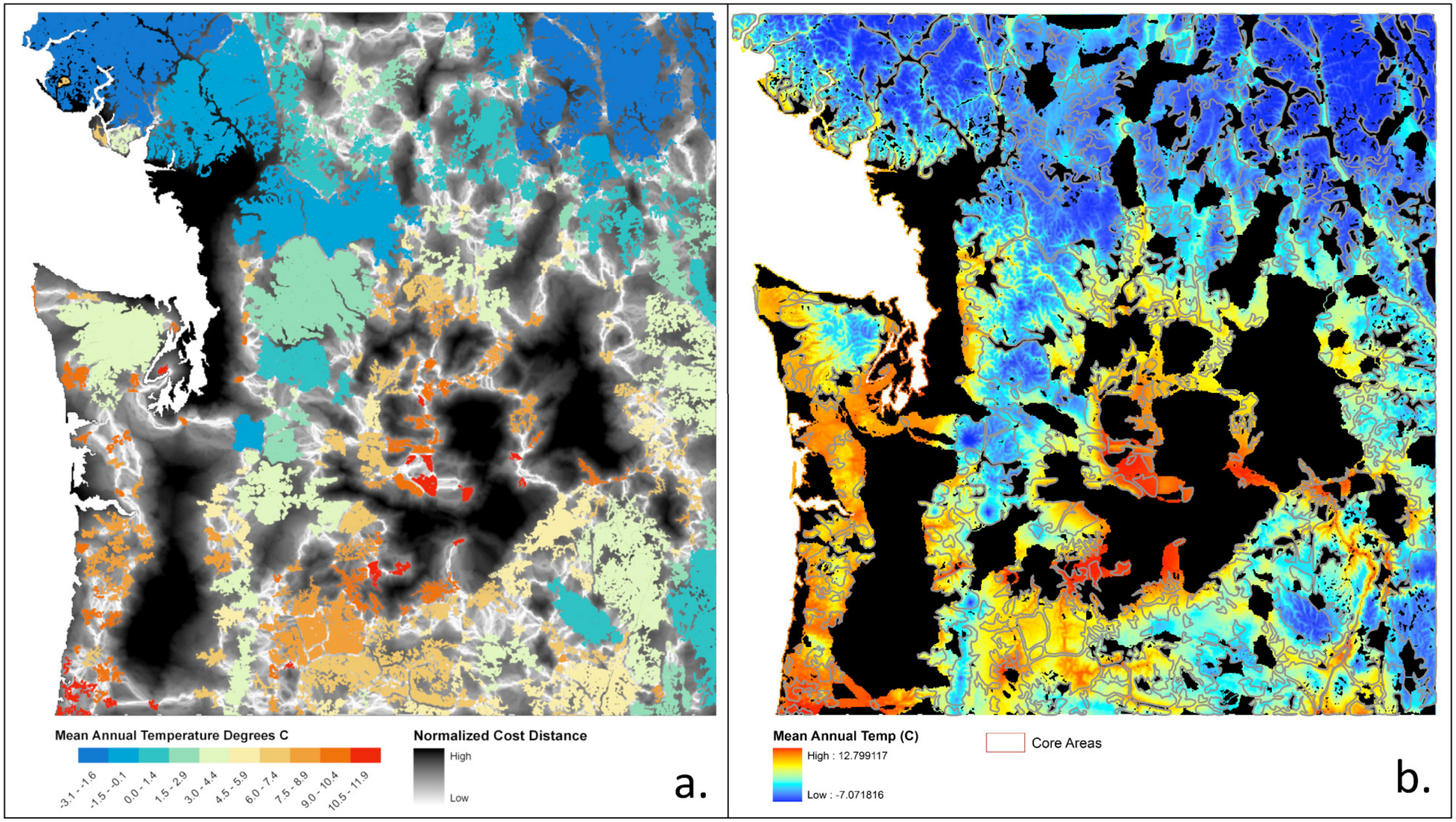

Figure 7. ***Temperature Variation within the Climate-Gradient Corridor Network.*** Figure 7b shows the wide range of temperatures present within the core areas and corridors of the climate-gradient corridor networks (Figure 7a provided for comparison).

Appropriate Use of Climate-Gradient Corridor Map Products

Users should be aware of the following key points regarding appropriate use of the climate-gradient corridor analysis:

- ***Corridors identified by this analysis should be used only for coarse-scale, landscape-level planning.*** The assumption of ongoing climate-gradient stability is most robust at scales above several kilometers and below several hundred kilometers. Thus, climate-gradient corridors identified by this analysis are most appropriate for guiding landscape-level planning decisions over large areas. Zooming in on individual corridors to guide local scale (<5 km) land-use decisions (e.g., parcel acquisition or management) would violate the underlying assumptions of the model. Instead, the climate-gradient corridor network would be best used to inform large-scale initiatives aimed at improving the ability of wildlife and their habitats to move with climatic change.

- ***Climate-gradient corridors should not be overlaid with species habitat layers to identify species-specific climate-gradient corridors.*** As habitat distributions are expected to shift in the future, it would be inappropriate to use individual species distribution maps as sources or destinations for species-specific climate-gradient corridors. Species distribution maps may, however, be used to prioritize climate-gradient corridors (e.g., by identifying and prioritizing corridors leading to landscape integrity core areas featuring relatively high levels of species diversity).

Conclusions and Future Work

This novel analysis has provided a series of maps identifying corridors intended to improve species' capacities to shift their ranges in order to respond to changes in climate. It has been completed as part of a larger suite of climate analyses planned for completion and release by the WHCWG over the next year. This includes additional climate-related analyses at the statewide scale, as well as finer scale, ecoregional analysis, beginning with the Columbia Plateau. In the coming year, the WHCWG will also be releasing additional interpretation products that will further synthesize the results of the climate-gradient corridor analysis with other statewide connectivity mapping products. Together, these maps and interpretation tools aim to inform regional wildlife management and land-use planning decisions around the movement needs of wildlife and the habitats they rely on, now and into the future.

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