Project Title: ***The Washington Connected Landscapes Project, Part I: Supporting Connectivity Conservation Now and Under Future Climates***

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Partners: The Washington Wildlife Habitat Connectivity Working Group (WHCWG) is a science-based collaboration of land and resource management agencies, NGOs, universities, and Washington Treaty Tribes. The group is co-led by Washington State Departments of Fish and Wildlife (WDFW) and Transportation (WSDOT), with active participation from member organizations including The Nature Conservancy (TNC), Conservation Northwest (CNW), Washington Department of Natural Resources, U.S. Forest Service (USFS), U.S. Fish and Wildlife Service, Western Transportation Institute, and University of Washington (UW).

Project Summary: We are requesting funding to support 9 months of a multi-year project, which will identify essential habitats and habitat linkages required to connect these habitats under both existing conditions and future climate change scenarios. Specifically, this project will:

- Conduct comprehensive habitat connectivity analyses for Washington, including lands in adjacent states and provinces (Fig.1 in Appendix).
- Incorporate climate change into connectivity analyses, such that essential habitats and linkages are likely to be resilient to climate change, while providing for the movement of species and systems in response to climate change.
- Develop and release innovative methods and GIS tools to support land managers' efforts to plan for connectivity conservation and "climate-smart" connectivity.

This proposal represents Part I of a two-part project. Part II (submitted concurrently) focuses on model validation, describing an exceptional opportunity to test and refine our habitat connectivity models using field and genetic data.

Need: The Washington Connected Landscapes Project will provide a framework to address the interacting impacts of habitat fragmentation and climate change on ecological systems and wildlife species within the Great Northern Landscape Conservation Cooperative (GNLCC) boundary.

Managing for well-connected landscapes is a key strategy to enhance resilience and ensure the long-term viability of plant and animal populations. However, conservation planning efforts have rarely included connectivity for ecological processes such as dispersal, migration, and gene flow. Connectivity conservation is particularly important in the face of climate change, because many species will require highly permeable, well-connected landscapes not only to maintain dispersal and gene flow as vegetation patterns change dramatically, but also to allow range shifts. Indeed, maintaining connectivity is the single most frequently cited climate adaptation strategy; yet rigorous examples of connectivity conservation plans designed to promote climate change adaptation are lacking. The proposed project will develop the science products necessary to support efforts to conserve connectivity now and under future climates.

There is also a need to test assumptions of emerging tools to support connectivity conservation and climate adaptation. For example, efforts to plan for connectivity conservation at large scales and for multiple species concurrently are leading to the development of new approaches that focus on connecting areas of high ecological integrity, regardless of the particular vegetation or animal communities that are currently present. Because they require fewer data and resources than species-based approaches, such integrity-based methods are gaining favor (e.g., the soon-to-be released California Essential Habitat Connectivity Project). Although promising, the ability of these methods to identify connectivity needs for biodiversity conservation has not been rigorously evaluated. The products of the proposed project will provide the foundation for such an evaluation.

The need for connectivity conservation planning, including consideration of climate change, has been identified by multiple management and planning entities within the GNLCC and beyond. The Western Governors' Association's Wildlife Corridors Initiative is an example of this at the multi-state scale. WDFW's Comprehensive Wildlife Conservation Strategy (2005) identified habitat conversion, fragmentation, and degradation as the most serious statewide threats to Washington's native fish and wildlife resources, and since then habitat connectivity and climate change have been elevated to among the top planning priorities for WDFW. At a somewhat finer scale, Washington's Arid Lands Initiative (ALI) is developing a coordinated strategy for the conservation of the Columbia Plateau, in pursuit of its vision of conserving and restoring "a viable, *well connected* system of eastern Washington's arid lands."

As part of Washington's contribution to the Western Governors' Association's Wildlife Corridors Initiative and WDFW's investment in connectivity and climate change planning, the WHCWG is advancing multi-state connectivity conservation through analyses and communications. Our goal is to produce detailed landscape connectivity maps and reports that can be used by multiple entities to 1) conserve or enhance connectivity, and 2) plan for climate change adaptation. This goal includes both statewide and ecoregional level products (Fig.1 in Appendix). The WHCWG is coordinating closely with the ALI on the Columbia Plateau ecoregional connectivity analysis, so that these science products have direct management application for the ALI partner organizations.

Objectives: This proposal directly supports three LCC objectives and functions: 1) *Decision support tools/systems or science applications for focused resource conservation*, 2) *testing assumptions of model predictions*, and 3) *inventory of resource conditions or trends*. Final products include analysis and decision support tools for connectivity conservation and climate adaptation, rigorous tests of emerging strategies for connectivity conservation and climate adaptation planning, and connectivity analyses that will describe resource conditions in Washington and adjacent landscapes under both current conditions and future climate scenarios. Specific project objectives are:

Objective #1. *Complete statewide and ecoregional connectivity analyses and publish results.* The statewide analysis of essential habitat and linkage areas across Washington and into neighboring landscapes will inform priorities for habitat conservation, create exportable methods and examples, and create an analytical framework for habitat connectivity that integrates across the Great Northern and Northern Pacific LCCs.

A more detailed analysis of the Columbia Plateau Ecoregion, which will explicitly incorporate climate change, will inform the Arid Lands Initiative's shared priorities - including the identification of restoration opportunities - and will be the test case for the development of methods and tools for future analyses in the seven remaining ecoregions intersecting Washington. The Columbia Plateau was selected for this first ecoregional-scale assessment specifically to support climate adaptation. Several climate models suggest that the Columbia Plateau ecoregion in Washington is likely to be a stronghold of shrub-steppe ecosystems under climate change. However, much of this habitat type has been converted, highlighting the need to understand interactions between connectivity and climate change impacts.

Objective #2. *Identify linkages most likely to sustain connectivity and facilitate species movements under climate change.* We will produce a comprehensive analysis of essential habitat and linkage areas that are most likely to 1) continue to provide functional connectivity under climate change, and 2) accommodate climate-driven shifts in species ranges. Our analytical framework will minimize the uncertainty associated with predicting future species' movements in response to climate change by using a diverse suite of modeling approaches, prioritizing results that show agreement over a wide range of approaches, scenarios of future climate and species responses. As part of a pilot program funded by the Western Governor's Association, we will coordinate the extension of this analysis framework across the Northwest, including Washington, Idaho, and Oregon.

Objective #3. *Develop and share methods, protocols and spatial analysis tools for connectivity prioritization*. We are aware of no other effort developing connectivity plans at this scale with the breadth of species and level of detail proposed here (see Tasks 1.1 and 1.2 for details). This has presented opportunities to apply new and innovative connectivity modeling methods (e.g., hybrid models combining least-cost and circuit theory approaches, and novel algorithms to identify areas where restoration could most optimally enhance connectivity; Fig. 2 in Appendix). The success of this project depends on efficient and repeatable linkage modeling between large numbers of essential habitat areas across large regions. While existing tools (e.g., Corridor Designer, Funconn, and Circuitscape) provide valuable foundations, none meet the criteria necessary to achieve our objective of mapping linkages for large numbers of focal species and areas of high ecological integrity. We will therefore develop new GIS decision support tools to automate linkage modeling and overcome limitations of existing tools. These will accelerate our capacity to analyze current conditions, conduct sensitivity analyses, and analyze connectivity needs under future climate scenarios.

Methods: The tasks detailed in this section will allow us to fulfill Objectives 1 through 3 by September 2012, supported by the federal FY 2010 LCC funding requested here, significant in-kind support from WHCWG partners, and additional funding to be requested from the GNLCC in FY 2011 and FY 2012 (estimated in the budget).

Objective #1. Complete statewide and ecoregional connectivity analyses.

Task 1.1: *Complete a broad-scale wildlife habitat connectivity analysis across Washington State and adjacent landscapes in Idaho, Oregon, and British Columbia*. We are using spatially explicit habitat and connectivity models to map essential habitats and linkages for 1) 16 focal species, and 2) intact areas of high ecological integrity and biodiversity value. Parallel products based on focal species and ecological integrity will provide the groundwork for testing the effectiveness of integrity-based analyses for capturing the connectivity needs of broad suites of species. Key Cooperators: All WHCWG Partners.

Task 1.2: *Conduct a fine-scale connectivity analysis for the Columbia Plateau Ecoregion.* We will refine our statewide methods to conduct a more detailed analysis of the Columbia Plateau Ecoregion, with increased local participation, higher resolution data sources, and inclusion of features impossible to consider at a statewide scale. This analysis will include focal species and integrity-based approaches, and will incorporate climate-smart connectivity methods described below. Key cooperators: All WHCWG partners and the Arid Lands Initiative.

Task 1.3: *Develop and share documents and web-based products.* High-quality maps and documents that clearly communicate our results are essential to the impact of our work. Results will be presented directly to a wide range of groups, including scientists, groups interested in applying these methods in other areas, and entities such as the Arid Lands Initiative who will use these results to inform their resource conservation and management efforts. We will also make our documents and data available on the web. Key cooperators: CNW, WDFW, WSDOT, TNC.

Objective #2. Incorporate climate change into connectivity analyses.

Task 2.1: *Identify areas most likely to continue providing habitat and connectivity as climates change*. Downscaled climate projections will be obtained and analyzed in combination with statewide essential habitat and linkage areas to prioritize those areas most likely to contribute to resilience to climate change. We will concurrently incorporate this approach into the Columbia Plateau connectivity analysis, so the end product is "climate-smart." These Phase I analyses will include models of current and future climate, but not models of future species distributions. Key cooperators: UW, WDFW, USFS, TNC.

Task 2.2: *Identify connectivity areas most likely to facilitate species movements in response to climate change*. As projections of future species distributions become available (expected in spring 2011 from a current collaboration between UW, USGS, and TNC), they will be incorporated into the statewide "climate-smart" connectivity analysis. These Phase II analyses will identify which linkages are most likely to contribute to species' abilities to move in response to changing climates. Key cooperators: UW, WDFW, USFS, TNC.

Objective #3. Develop and share methods, protocols, and spatial analysis tools.

Task 3.1: *Present and publish new connectivity analysis methods for broad-scale and fine-scale analyses.* Innovative connectivity modeling methods under development include hybrid models combining least-cost and circuit theory approaches, which can be used to quantify redundancy and identify "choke points" in least-cost corridor designs, and novel algorithms based on circuit theory to identify areas where restoration could most greatly enhance connectivity (Figs 2C and D in Appendix). We will test and publish the new methods, and release an updated version of Circuitscape software (www.circuitscape.org) incorporating the new algorithms. Key cooperators: TNC, WDFW.

Task 3.2: *Develop, test, and publish spatial analysis tools to automate connectivity modeling*. We will create open-source ArcGIS toolboxes written in Python to 1) identify essential habitat areas; 2) build networks of essential habitat areas; and 3) map, characterize, and prioritize important linkages between core areas (Figs. 2 and 3 in Appendix). These tools will be more flexible than previous ones, allowing a wide range of choices for modeling steps and user review and editing of products at multiple stages. They will also take advantage of newly available network algorithms to accelerate processing, cutting processing times from weeks to hours and facilitating iterative analyses and updates. We will release fully documented ArcGIS toolboxes that can be applied to other ecoregions in the GNLCC and beyond. Key cooperators: TNC, WDFW, UW.

Task 3.3: *Disseminate protocols for climate-smart connectivity planning across state borders, and integrate into a decision support tool.* The analytical framework we are developing for climate-smart connectivity planning, like much climate change adaptation science, requires trying and testing. It is therefore critical to obtain peer-review, and disseminate our methods and results so that a wide array of scientists and managers can test them through further research and on-the-ground implementation, monitoring and adaptive management. We will present an overview of our analytical framework and Phase I and Phase II results at scientific conferences, and publish the results in peer-reviewed journals. Key cooperators: UW, WDFW, WSDOT, USFS, TNC.

Deliverables:

Task #	Description	Due Date
Objective #1. Complete statewide and ecoregional connectivity analyses.		
Task 1.1	Summary report of statewide analysis, including high quality map products.	OCT 2010
Task 1.2	Summary report of Columbia Plateau ecoregional analysis, including high quality map products.	OCT 2011
Task 1.3	Reports and searchable map layers for statewide and ecoregional analyses on web. Minimum of 6 presentations to diverse stakeholder groups	FEB 2011- JUL 2012
Objective #2. Incorporate climate change into connectivity analyses.		
Task 2.1	Updated statewide connectivity products identifying priority connectivity areas in light of climate change. “Climate-smart” Columbia Plateau connectivity analysis, and associated decision support framework Reports and searchable map layers for “climate-smart” analyses on web	MAY 2011 OCT 2011 JUL 2011 – JUL 2012
Task 2.2	Updated statewide connectivity products identifying priority connectivity areas for species shifts in response to climate change. Adaptive management protocols to inform future “climate-smart” connectivity planning	JUL 2012 JUL 2012
Objective #3. Develop and share methods, protocols, and spatial analysis tools.		
Task 3.1	Spatial analysis decision support tools: At least 4 conference and workshop presentations, and at least 4 publications in peer-reviewed journals	2010-2012
Task 3.2	First release of spatial analysis toolset with user guide to implement our analysis methods in other regions (ongoing releases and support anticipated)	NOV 2010
Task 3.3	Climate-smart tools and protocols: At least 4 conference and workshop presentations, and at least 4 publications in peer-reviewed journals	2010-2012

Schedule:

Washington Connected Landscapes Project **Part I:** ***DRAFT***	FY2010	FY2011				FY2012			
	2010	2011				2012			
	Jul-Sep[a]	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep
Objective #1. Complete statewide and ecoregional connectivity analyses.									
Task 1.1. Statewide analysis									
GIS linkage modeling	Light blue								
Task 1.2. Columbia Plateau ecoregional analysis									
GIS layer acquisition/development									
Focal species selection	Light blue								
Focal species and ecological integrity work sessions, resistance model development & review	Light blue	Light blue	Light blue						
GIS linkage modeling & review			Light blue	Light blue	Light blue				
Task 1.3. Develop and share documents and web-based products									
Summary documents and maps released on web for statewide and Columbia Plateau analyses		Dark blue				Dark blue			
Searchable web-based maps released for statewide and Columbia Plateau assessments			Light blue	Dark blue			Light blue	Dark blue	
Presentations and workshops for stakeholder groups within project area			Light blue	Light blue	Dark blue		Light blue	Light blue	Dark blue
Objective #2. Incorporate climate change into connectivity analyses.									
Task 2.1. Connectivity areas resilient to climate change (statewide and ecoregional scale)									
GIS layer acquisition/development	Light blue								
Climate downscaling (CIG)	Light blue	Light blue							
GIS modeling (Statewide Phase I)	Light blue	Light blue	Light blue						
GIS modeling (CP Ecoregional Phase I)		Light blue	Light blue	Light blue					
Final report (Statewide Phase I)				Dark blue					
Disseminate Statewide Phase I results (conference presentations, journal article)					Dark blue				
Final report (CP Ecoregional Phase I)						Dark blue			
Task 2.2. Connectivity areas for species range shifts									
GIS modeling (Statewide Phase II)					Light blue	Light blue	Light blue		
Final report (Statewide Phase II)								Dark blue	
Disseminate Statewide Phase II results (conference presentations, journal article)								Light blue	Dark blue
Objective #3. Develop and share methods, protocols, and spatial analysis tools.									
Task 3.1. Present and publish new connectivity methods									
Present connectivity methods at national conferences and publish in peer-reviewed journals	Light blue	Light blue	Light blue	Dark blue					
Update Circuitscape software to include barrier detection and hybrid least-cost methods		Dark blue							
Task 3.2. Develop and share spatial analysis tools									
Spatial analysis tools: Python programming, ArcGIS integration, web release with user guide	Light blue	Dark blue							
Present ArcGIS toolboxes a national conferences, ongoing support and enhancement			Light blue	Light blue	Light blue	Light blue	Light blue	Light blue	Light blue
Task 3.3. Develop and share climate-smart connectivity framework									
Present literature review and overview of WA framework at conferences	Light blue								
Coordination with transboundary partners (ID/OR/BC)	Light blue	Light blue	Light blue	Light blue					
Analytical framework for transboundary connectivity and climate change analysis		Light blue	Light blue	Dark blue					
Transboundary Decision Support Tool development (WA/ID/OR)					Light blue	Light blue	Light blue		
Transboundary Decision Support Tool delivery								Dark blue	
Present and publish climate-smart methods, decision support tools, and protocols				Light blue	Light blue	Light blue	Light blue	Light blue	Dark blue

Bright green: time interval covered by this funding request
Gray green: time interval indicated in budget as estimated future costs
Light blue: interim processes and products
Dark blue: final products

[a] Tasks may be initiated sooner if funding is available earlier.

Appendix: Washington Connected Landscapes Project - Study area and examples of draft analysis products.

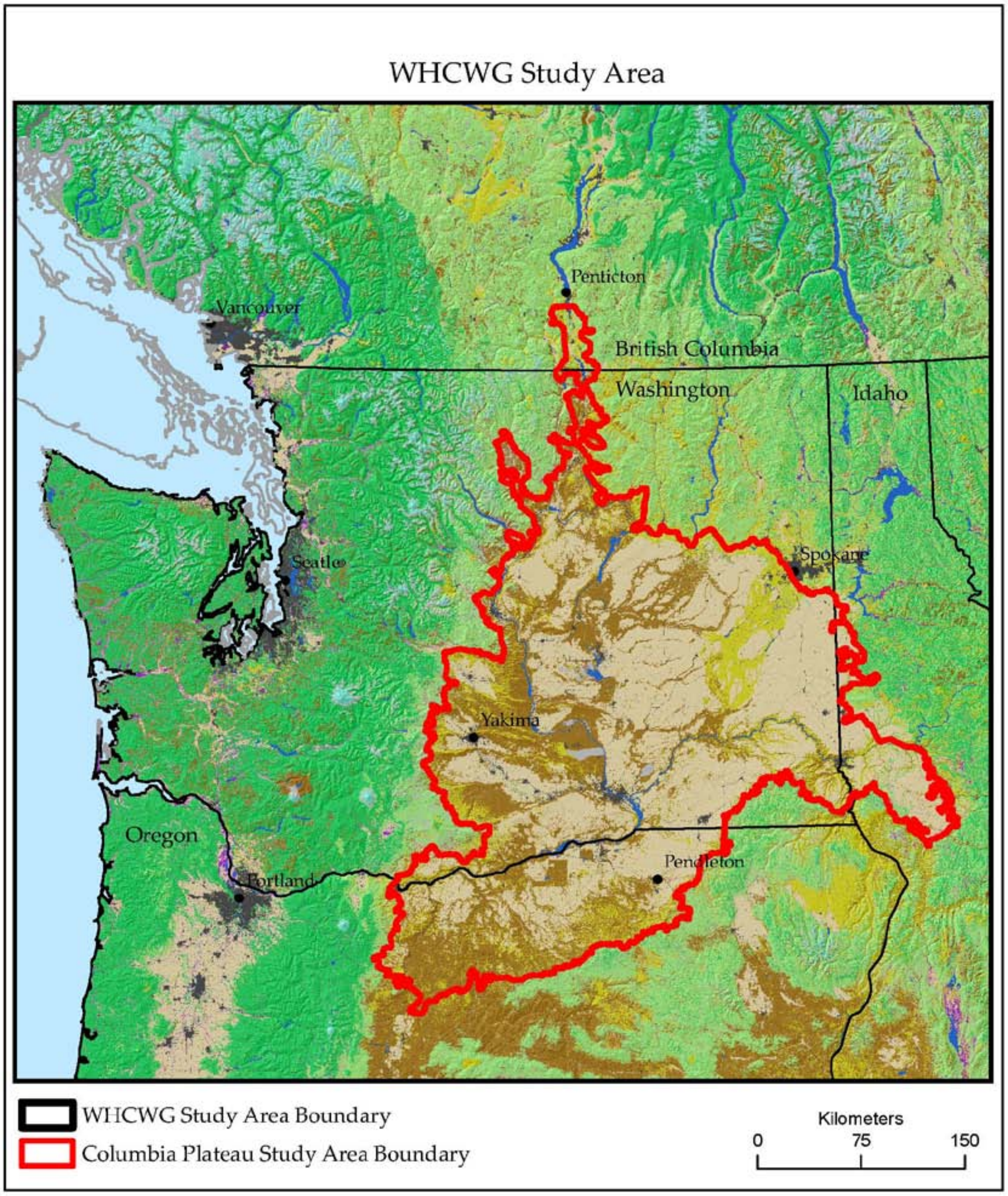

Figure 1. Project areas for statewide and Columbia Plateau Ecoregional connectivity analyses.

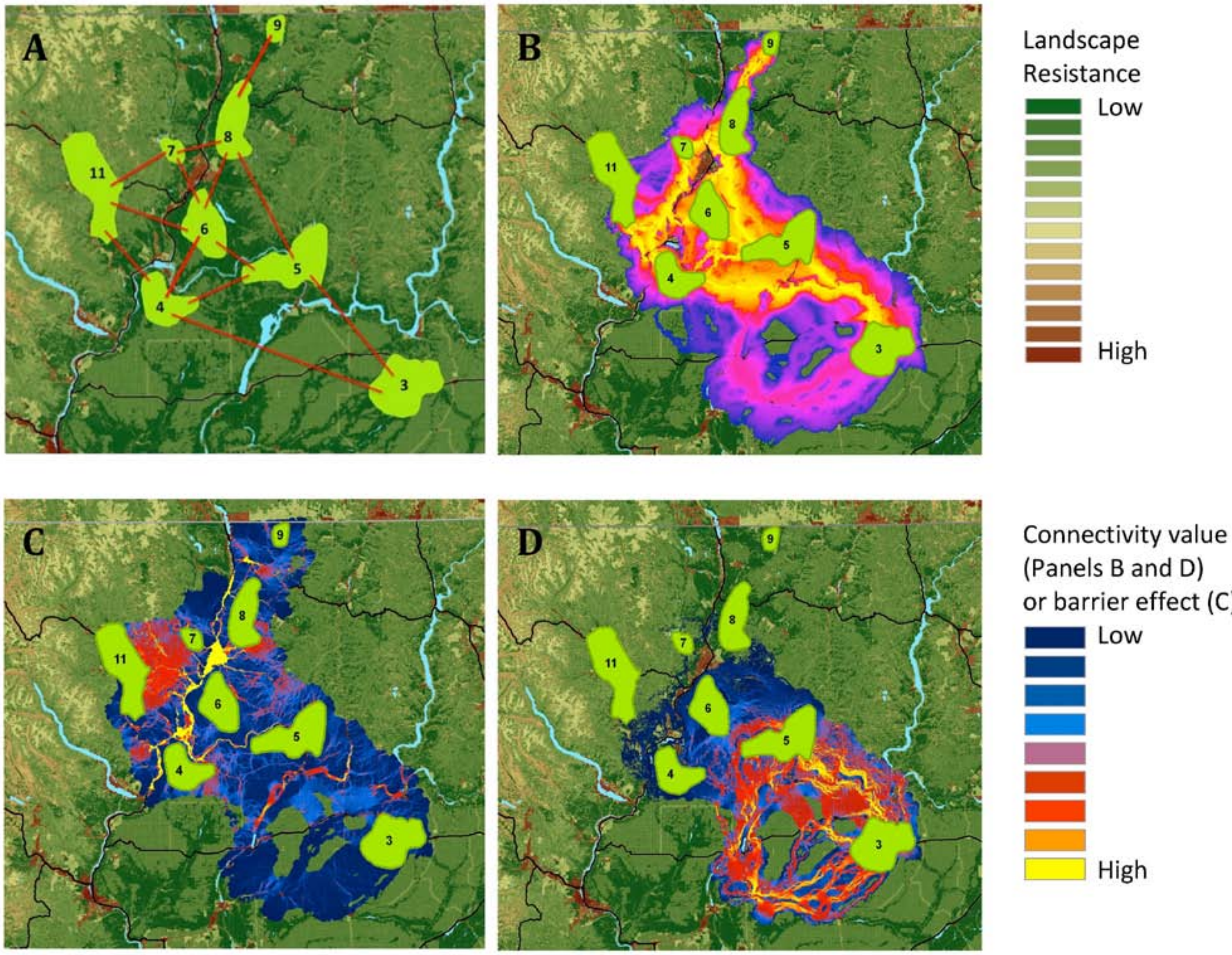

Figure 2. Draft connectivity analysis methods applied to Columbian sharp-tailed grouse. A) Draft core habitat areas for a portion of the species' range (green polygons), and landscape network identifying linkages to be mapped (red lines). One of the ArcGIS toolboxes we will develop will automatically delineate core areas based on distribution of suitable habitat and presence of dispersal barriers within candidate habitat patches. A second toolbox will create the landscape network, based on user-specified criteria for deciding which core habitat areas to connect. **B)** Synthetic map showing locations of important movement corridors. Warmer colors show areas closer to least-cost route between any pair of core areas directly connected by the landscape network. These were created manually in ArcGIS using least-cost corridor algorithms; we have identified programming tasks needed to fully automate the modeling workflow for release as an ArcGIS toolbox. **C)** Synthetic map showing most important barriers in study area, derived from new application of circuit theory. These can be used to identify restoration opportunities, or core areas that are too isolated for connectivity to be restored (e.g., core area #11, which has lost its grouse population). **D)** Map showing redundancy in linkages between two core areas using least-cost/circuit theory hybrid. Important "choke points," where connectivity can most easily be lost, are shown in yellow. These techniques will be applied for fine-scale linkage design, and can help distinguish between scenarios in which movement routes must pass through bottlenecks *vs.* those where alternative movement options exist, maximizing the ability to design cost-effective connectivity conservation plans.

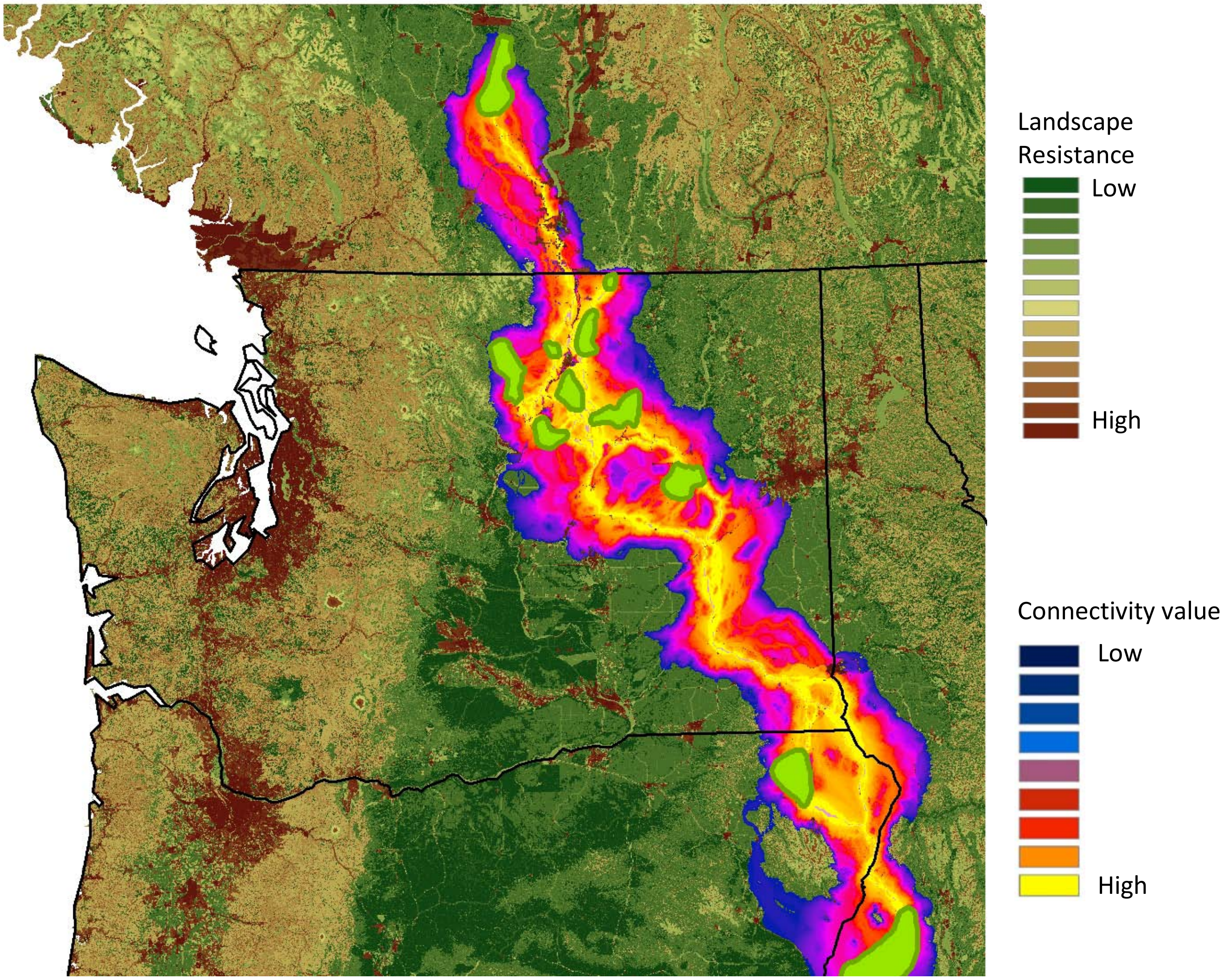

Figure 3. Application of draft corridor analysis methods to full project area for Columbian sharp-tailed grouse. Other focal species and ecological integrity analyses will involve connecting far larger numbers of core areas, requiring automation.