Chapter 1. Introduction

This statewide analysis provides a consistent assessment of wildlife ***habitat connectivity*** for Washington and adjacent lands. It describes current patterns of connectivity and identifies opportunities and challenges for maintaining and enhancing connectivity in the future. This assessment is meant to inform broad scale connectivity conservation and to give context for subsequent finer scale assessments.

1.1. Why is Habitat Connectivity Important?

Growing human populations and expanding infrastructure often result in the loss and fragmentation of habitat, contributing to declines in wildlife populations and loss of important ecosystem processes (Noss & Harris 1986; Kareiva & Wennergren 1995; Ricketts 2001; Moilanen et al. 2005; Hansen & DeFries 2007). Buildings, roads, dams, crops, and other features can hinder the movement of wildlife and the flow of ecological processes (Fig. 1.1). These and other stressors reduce habitat quality and contribute to increased mortality rates in wildlife populations. For instance, some animals may be unable to find mates or get to important sources of food, water, or shelter. Animals are often killed or injured while crossing roads and developed areas. Reduced immigration rates mean that fragments of habitat support fewer animals, and that local populations face higher extinction rates and reduced likelihood of recolonization following extinction (Verboom et al. 1991; Hanski 1994). Connected landscapes are especially important for wide-ranging species such as carnivores (Beier 1993), and for migratory species such as large herbivores and migratory birds (Bennett 2003). They can be critical for maintaining genetically healthy populations, because immigration helps small populations avoid inbreeding (Hanski & Gilpin 1997). In addition to these considerations, climate change may force new patterns of wildlife movements in response to changing environmental conditions and shifting habitats (Heller & Zavaleta 2009).

In Washington State, the imprint of development, transportation, and agriculture on the landscape is prevalent. Despite being the smallest western state, Washington has the second highest human population, and many wildlife habitats have been highly fragmented. Conservation and land-use planning efforts in Washington have generally focused on areas of high-quality habitat and overlooked the value of conserving portions of the intervening landscape that connect habitat patches. In this context, sustaining wildlife and natural areas, while at the same time meeting the needs of people and communities, is an increasingly difficult challenge.

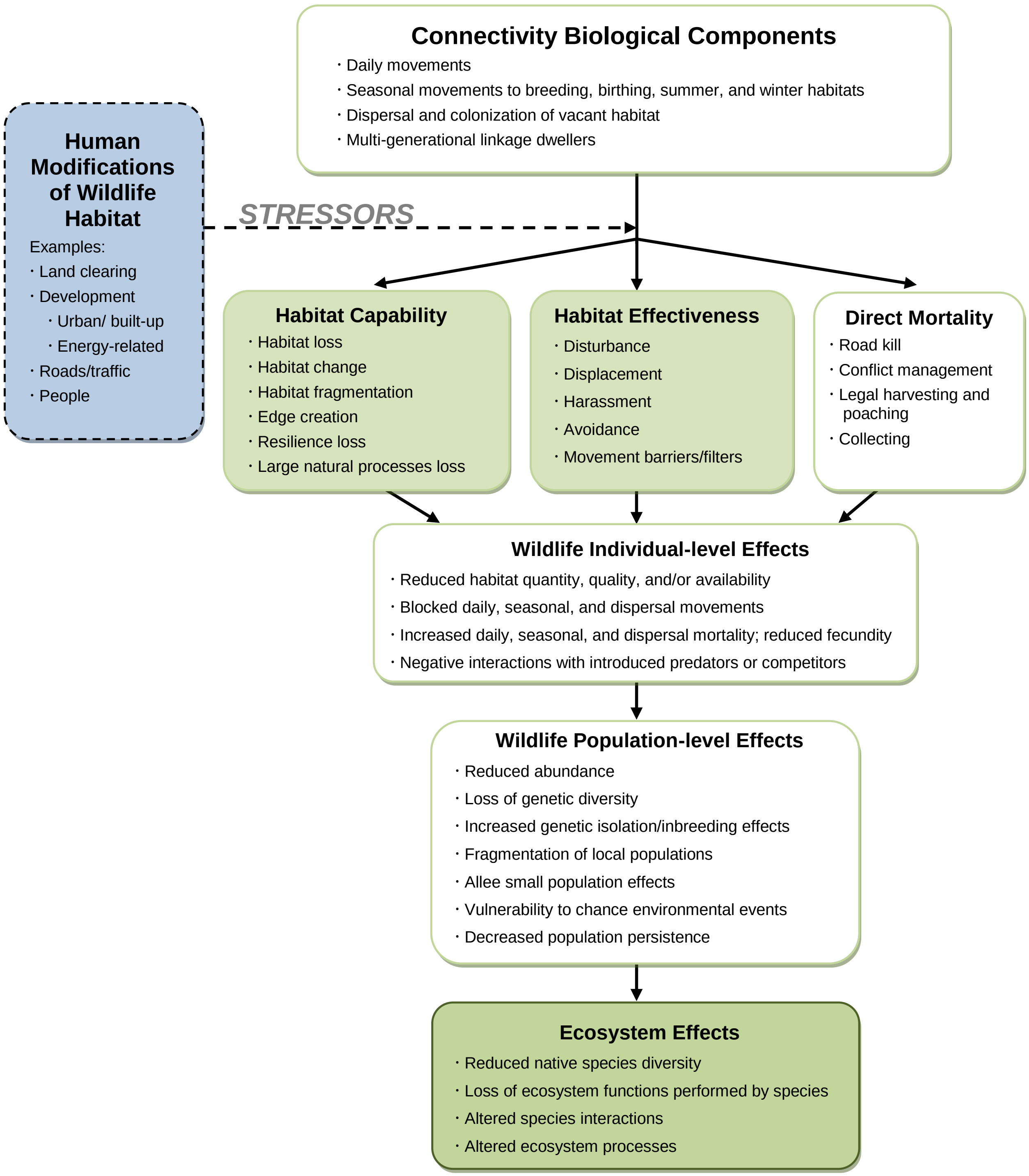

Figure 1.1. Wildlife habitat connectivity conceptual model. This model indicates ways in which human modifications of wildlife habitat interact with wildlife needs for habitat connectivity.

One way to meet this challenge is to conserve and restore conditions that sustain connected, functioning ecosystems and enable species to move. We use the term "***linkages***" to refer to potential ecological connections that may take a variety of forms, not just simple linear ***corridors*** connecting patches of habitat. A growing body of evidence indicates that enhancing habitat connectivity using such linkages can cost-effectively achieve many conservation objectives, including conserving ecosystem processes and plant and animal populations (Beier & Noss 1998; Bennett 2003; Crooks & Sanjayan 2006; Damschen et al. 2006; Haddad & Tewksbury 2006; Hilty et al. 2006; Beier et al. 2008; Gilbert-Norton et al. 2010). In some cases, the movement needs of wildlife can be served with different land cover types than those needed to sustain resident wildlife populations, creating opportunities for new strategies and new partnerships that can contribute to connectivity conservation in working landscapes.

Habitat connectivity is not a conservation panacea. Linkages are necessary for conservation, but may not be sufficient to ensure population persistence or to maintain biodiversity (Taylor et al. 2006). Compared to other conservation strategies, however, enhancing connectivity offers the distinctive benefit of creating the opportunity to build interconnected systems of habitat. Integrating conservation efforts across local, ecoregional, state, and international levels is a conspicuous advantage in view of uncertainties associated with climate change (Bennett et al. 2006; Lawler et al. 2010), and the performance of whole systems may exceed that of isolated parts (Noss & Harris 1986). Moreover, connectivity conservation is the most frequently recommended climate adaptation strategy (Heller & Zavaleta 2009), because many species will require highly permeable, well-connected landscapes to maintain movement and gene flow as vegetation patterns change, and to allow range shifts in response to shifting habitats.

Throughout the West, people treasure wildlife and natural places. These amenities inspire and nurture us, enriching our lives in subtle and profound ways. The benefits that society derives from functioning ecosystems are often referred to as "ecosystem services." Examples include air and water purification, drought and flood control, and crop pollination. In addition to these services, ecosystems also provide food, medicines, and other valuable commodities. Nature-based recreation improves mental and physical health, and provides economic value. Our ethical and philosophical traditions reflect these complex interactions, urging us to respect and enjoy nature and allow future generations the opportunity to do the same. Sustaining the capacity of ecosystems to continue providing the full array of services that support human well-being is the crux of sound ecosystem stewardship (Chapin et al. 2010). As the human population grows, developed areas expand, and climate change rearranges wildlife habitats, linkages across the landscape will become an increasingly important conservation tool that can promote human well-being, the long-term viability of species populations, and the integrity of ecological processes.

Recognizing the value of linkages as part of an integrated strategy of economic development and natural resource conservation, the Western Governors' Association launched in 2007 the Wildlife Corridors Initiative. It called for identification of "key wildlife migration corridors and crucial wildlife habitats in the West." Stewardship of these natural resources, as development continues, requires knowing where they are.

1.2. The Washington Wildlife Habitat Connectivity Working Group (WHCWG)

The Washington Wildlife Habitat Connectivity Working Group (WHCWG) is an open, science-based collaboration of land and resource management agencies, NGOs, universities, and Washington Treaty Tribes. The group is co-led by the 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 (WDNR), U.S. Forest Service (USFS), U.S. Fish and Wildlife Service (USFWS), Western Transportation Institute (WTI), the University of Washington (UW), and others.

The WHCWG was originally convened to help incorporate wildlife habitat connectivity into updates of WDFW's Wildlife Action Plan and WSDOT's transportation planning. The WHCWG subsequently took on the task of responding to the Western Governors' call for identification of key wildlife migration corridors and wildlife habitats. We work in collaboration with the Western Governors' Association Wildlife Corridors Initiative, and our analyses are part of Washington's contribution to this effort. The statewide analysis of baseline conditions presented in this document is the first science product of the WHCWG. Additional information about the WHCWG is available at http://www.waconnected.org.

The internal organization of the working group includes a "full group," with broad representation from diverse organizations as well as interested individuals, a "core team" which oversees the work of the group, and multiple subgroups that are responsible for completing specific tasks. There is considerable overlap in participation between the core group and the subgroups. The subgroups manage spatial data, select ***focal species***, lead focal species analyses, arrange for peer review, develop and implement communication strategies, conduct ***landscape integrity*** analyses, develop modeling protocols, initiate ecoregional-scale analyses and incorporate climate change modeling into our connectivity analyses. This division of responsibilities enables us to make focused progress on the variety of topics relevant to meeting our objectives, while also maintaining communication, integration, and cohesion among the subgroups.

1.2.1. Goals and Objectives of the WHCWG

The primary goal of the WHCWG is to identify opportunities and priorities for conserving and restoring habitat connectivity in and adjacent to Washington State (Fig. 1.2). We also seek to maximize the use of our analysis products through partnership and outreach.

Potential users of this document have a wide range of missions and mandates, and fulfill them by applying a correspondingly broad array of land-management approaches and tools. This analysis provides an additional set of information about how conservation actions may contribute to the maintenance and enhancement of a connected landscape. Additional guidance on how to interpret this analysis and potential uses for this information are provided in Chapter 4.

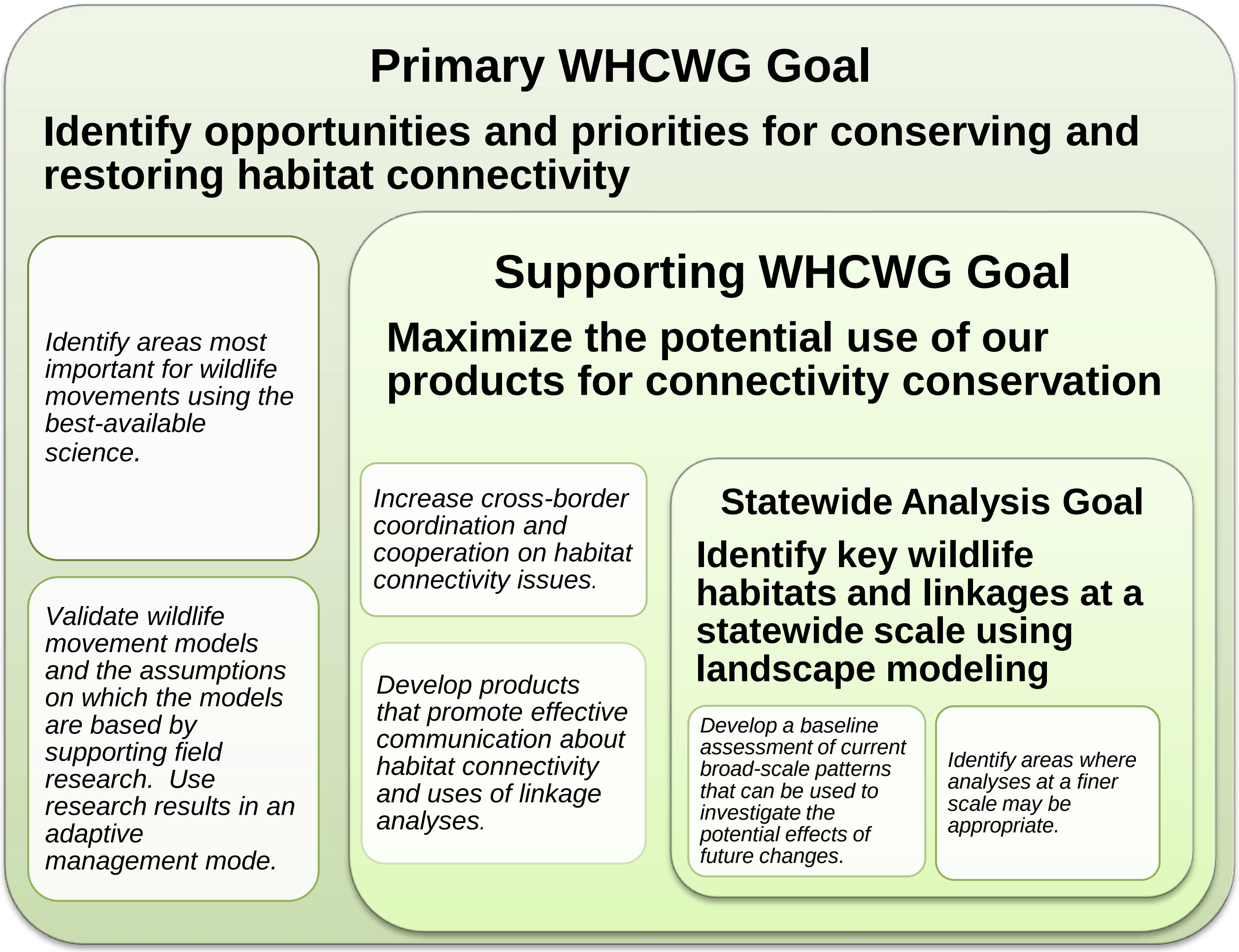

Figure 1.2. Goals and objectives of the WHCWG and for the statewide analysis.

We recognized early on that clear and transparent communications about our analysis were critical to our success. Throughout our process to date, we have worked to engage partners internal and external to our working group. Our products will be easily accessible to the public on our website, and the WHCWG is committed to supporting future connectivity analyses and implementation. We are also promoting research to validate our wildlife movement models, increasing coordination and cooperation on connectivity issues across borders, and building support for the implementation of connectivity conservation.

Partnership and collaboration have been instrumental in the completion of this statewide analysis, and will be critical to sustaining momentum to complete subsequent analyses at the ecoregional and local scales. For example, we are currently partnering with Washington's Arid Lands Initiative to complete a connectivity analysis for the Columbia Plateau ***ecoregion***, and the Hells Canyon Preservation Council is developing a similar analysis for the Blue Mountains Ecoregion. We believe ongoing partnership is essential to gathering the resources and expertise needed to conduct these complex analyses, and that building connections among people and organizations will promote conservation of habitat connectivity. Good communication also ensures that our products meet the needs of diverse potential users.

The statewide analysis is a broad scale assessment of habitat connectivity patterns. Within the scope of the Washington Connected Landscapes Project, we viewed gaining a broad perspective as a necessary first step that would enable us to see how smaller areas fit into broader regional patterns. Finer-scale analyses, at ecoregional and local scales, are needed to guide project-level connectivity conservation, but the statewide analysis provides essential context for interpreting these finer-scale assessments (Fig. 1.3).

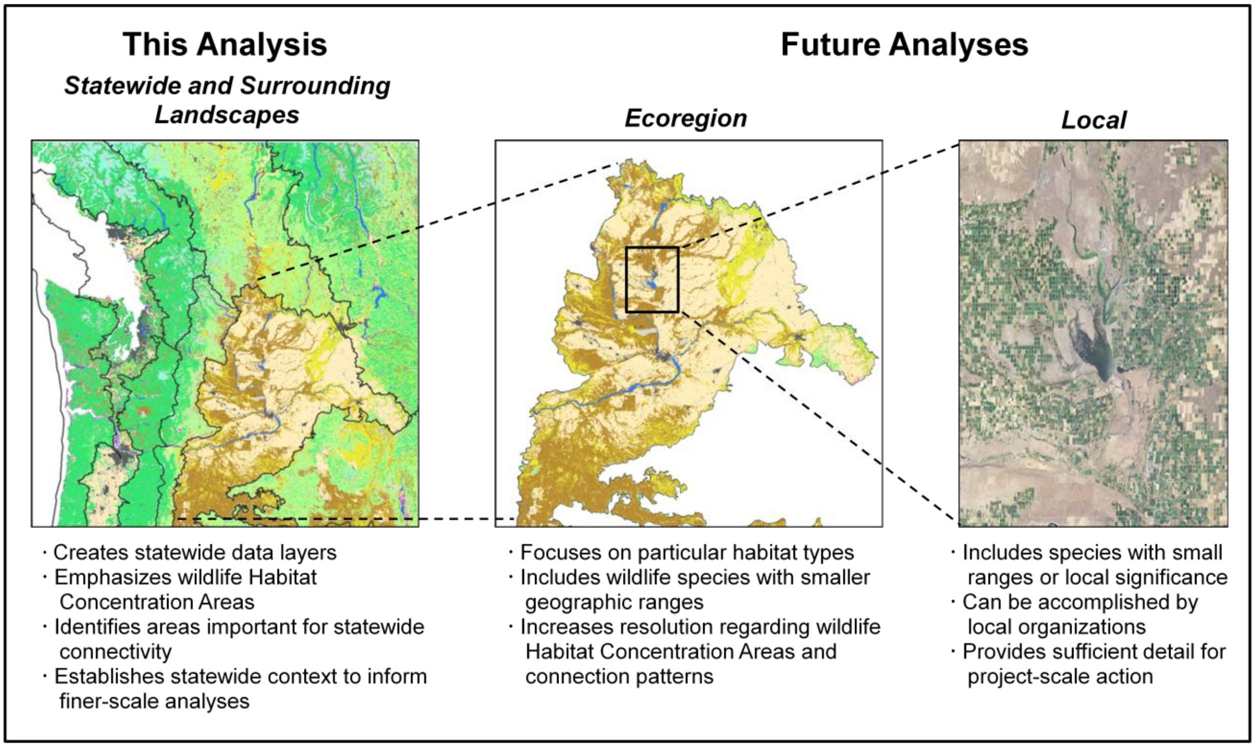

Figure 1.3. Scales of wildlife habitat connectivity analyses in Washington.

Additional analyses that are underway or envisioned for the future include analyses of connectivity across predicted future landscapes resulting from climate change and urban, residential, and energy-related development. Climate change analyses will focus on identification and prioritization of areas most likely to provide wildlife habitat and connectivity as climate changes, including the types of connectivity necessary to accommodate climate-driven shifts in species' ranges.

1.3. Goals and Objectives of the Statewide Analysis

The focus of this analysis is on identifying wildlife movement opportunities at a statewide scale. To enable us to identify transboundary movement opportunities, we extended our analysis beyond Washington to include adjacent areas of Idaho, Oregon, British Columbia and a small portion of Montana (Fig. 1.3). We refer to this geographic extent as the statewide or "statewide-plus" scale of analysis. We believe that by coordinating with partners to complete connectivity analyses that cross boundaries, we will promote the scope of connectivity necessary for wide-ranging species, for species whose populations occur near our borders, and for processes that occur over relatively longer distances and time scales, such as gene flow and movement in response to climate change.

At the statewide scale, we can identify patterns of habitat distribution that are apparent across large landscapes. This analysis has a relatively coarse level of resolution and can be thought of as a view of the land from a high-flying aircraft a perspective that allows you to see patterns across the landscape, but obscures details. We expect this analysis to inform subsequent analyses done at finer scales, such as ecoregional analyses. In particular, this statewide analysis will help to identify candidate locations for finer-scale analyses.

This analysis establishes a foundation upon which future efforts of the WHCWG and others can build. The baseline assessment of habitat connectivity presented in this document provides a framework for future scenario evaluations, planning, and conservation action. Identification of priorities is not part of this analysis, but will be considered in future work.

1.4. Statewide Connectivity Analysis Approach

All subgroups of the WHCWG contributed to the statewide analysis. We coordinated efforts through meetings and conference calls, with most of the work being accomplished through the independent efforts of subgroup members. We completed our analysis by:

1) Defining our project area to accommodate analysis of linkages across Washington's jurisdictional boundaries.

2) Compiling base GIS layers to characterize wildlife habitat and features that affect landscape ***resistance*** to animal movement, including land cover/land use, elevation, slope, housing density, roads and forest structure.

3) Using published information and expert opinion to assign resistance-to-movement values associated with each of the base GIS layers for selected focal species.

4) Applying broad-scale landscape modeling methods appropriate for the identification of habitat connectivity patterns at a statewide scale.

5) Using a two-pronged strategy to analyze statewide connectivity, including a focal species approach and an approach focused on connecting lands with relatively little human modification (high landscape integrity).

We applied this two-pronged strategy because it enabled us to gain the advantages associated with both approaches while addressing shortcomings associated with using each approach alone (See Chapters 2 and 3). The focal species approach has the advantage of being closely related to functional connectivity for particular species, but it is challenging to integrate results across focal species, modeling is labor intensive, and results may not adequately represent the connectivity needs of some non-focal species. Landscape integrity modeling is relatively efficient and can yield a unified map, but its results do not assess specific ecological functions, are difficult to validate and can be more challenging to communicate. By considering both approaches, we have an increased likelihood of representing the connectivity needs of biodiversity in our analysis area, and we provide ample opportunities for investigating the advantages and disadvantages of both.

We benefitted greatly from the insights of a panel of experts in the field of connectivity conservation who generously agreed to serve as peer reviewers of our process and products. This review panel provided extensive and constructive feedback on the study plan we developed to guide our analysis, and on this document. Although these reviewers are not members of the WHCWG, they have strongly influenced many aspects of our approach.

1.4.1. Focal Species Modeling

This approach identifies connectivity conservation opportunities based on the needs of carefully chosen focal species (See Chapter 2 and Appendix A). We selected a suite of 16 focal species using criteria designed to favor species with geographic ranges, habitat associations, and vulnerabilities to human-created barriers that made them representative of the habitat connectivity needs of many species and ecological processes at a statewide scale. We stratified our selection of species to ensure representation of major vegetation types in Washington. We intended that the linkages identified for focal species would have a high probability of meeting the needs of a substantial number of terrestrial species that are sensitive to loss of habitat connectivity. Our focal species include relatively large, area-sensitive species like American black bear, elk, and wolverine, as well as smaller, barrier-sensitive species such as Greater Sage-Grouse, and white-tailed jackrabbit, and less mobile species such as the western toad.

Our results for each focal species include maps of: (1) overall resistance to movement across the landscape; (2) important habitat patches (***habitat concentration areas*** – HCAs); (3) ***cost-weighted distance***, which depicts how resistance to movement accumulates while traversing the landscape between HCAs; and (4) modeled linkages between HCAs. For each focal species we provide a literature review containing information we used to develop our estimates of landscape resistance, and to define characteristics of HCAs (See Chapter 3 and Appendix A).

1.4.2. Landscape Integrity Modeling

The landscape integrity approach to modeling connectivity seeks to identify the best available routes for the flow of ecological processes across the landscape by connecting large, contiguous areas that retain high levels of naturalness (i.e., ***core areas*** characterized by low levels of modification by humans). Similar to the approach used in the California Essential Habitat Connectivity Project (Spencer et al. 2010), our landscape integrity modeling is intended to be broad scale and is not tailored to specific categories of species. Instead, it identifies linkages of highest landscape integrity between core areas (See Chapter 2). As a result, linkages identified by landscape integrity analysis tend to avoid urban, residential, and industrial zones, transportation infrastructure, and agricultural lands.

Products of our landscape integrity analysis include maps of landscape integrity, ***resistance surfaces*** for four levels of sensitivity to human modification, linkage maps for the four sensitivity levels, and composite landscape integrity linkages (See Chapter 3).

1.4.3. Composite Analyses

We also conducted composite analyses to find common patterns across ***linkage networks*** for both the focal species and landscape integrity analysis approaches (See Chapters 2 and 3). We looked for common patterns among focal species by overlaying focal species linkage networks, systematically sampling to find the level of overlap among them, and applying hierarchical cluster analysis to resulting overlap summaries. This process distilled linkage patterns for our 16 focal species into three "connectivity guilds:" (1) shrubsteppe associates, (2) montane associates, and (3) habitat generalists and edge-associated species. Each of these guilds shows a distinct linkage pattern within the analysis area. Comparison of linkage networks for focal species to networks for landscape integrity revealed a high level of consistency between the two approaches.

1.5. How Can the Statewide Connectivity Analysis Be Interpreted and Used?

Using this analysis effectively requires thoughtful interpretation and careful evaluation of its limitations (See Chapter 4). For instance, users must recognize how the spatial resolution of linkage maps is affected by the scale of the data used to construct the base layers that support the entire analysis. We encourage users to gain an understanding about the information that each type of map in our statewide analysis package has to offer. Although linkage maps represent the "bottom line" of connectivity analyses, resistance surfaces and cost-weighted distance maps can provide many additional insights into decisions and tradeoffs we made in the modeling process. We urge users to read the appendices, especially the species accounts, to get a deeper appreciation of underlying models. This level of understanding will enable users to interpret our products appropriately and make the most of each component of this document in their particular application.

The statewide connectivity analysis provides baseline information and consistent habitat connectivity models that can be used in a variety of ways to inform further analysis, planning, and conservation action. As described above, we expect this statewide analysis to serve as a foundation for evaluations of predicted future landscapes and smaller scale areas within our analysis boundary. We also expect that many users will incorporate connectivity into their planning and prioritization processes by combining information from this statewide analysis with other sources of information they typically consider.

1.6. Organization of This Document

This document presents the statewide wildlife habitat connectivity analysis in six chapters, a glossary of terms, and five appendices. After the general introduction we provide here in Chapter 1, we shift in Chapter 2 to a detailed presentation of methods. We include descriptions of all major steps in our analysis: defining our analysis area, developing spatial data layers, selecting focal species, building resistance surfaces for focal species and landscape integrity, delineating areas to connect, modeling linkages, and investigating correspondence among linkage networks. Chapter 3 presents our results and discussion. This chapter begins with an overview of focal species results, which introduces the ensuing summaries for each focal species. Each summary features a family of maps illustrating the steps in our process of modeling and mapping habitat linkages. Landscape integrity results and discussion follow. Chapter 3 concludes with a discussion about integrating focal species and landscape integrity networks and a summary of our key findings. Chapter 4 provides guidance to readers about how to interpret the various components of our statewide analysis, and offers suggestions about how to use the statewide analysis, illustrated with specific examples. In Chapter 5, we share some lessons learned in the process of conducting the statewide analysis. Chapter 6 presents our conclusions and looks ahead to the exciting opportunities for additional connectivity analyses that can build on the foundation presented here.

The appendices provide supporting information and many of the technical details about the statewide analysis. Appendix A includes detailed accounts for each focal species describing habitat associations, movement patterns, and other aspects of focal species biology. Appendix B contains tables compiling the parameters used in focal species and landscape integrity models of connectivity. Appendix C describes the assembly and content of our base data layers to facilitate assessment of our information base, and to explain the complexities associated with compiling spatial data layers that cover all or part of four states and cross an international border. Appendix D describes new connectivity analysis tools for GIS that we developed. The final appendix (E) provides statistics about individual linkages, such as their length and quality.