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1. Executive Summary

Projected climate changes for the Pacific Northwest include increasing annual air temperature, changes in precipitation, and declining April 1 snowpack. These changes are likely to lead to a myriad of impacts including changes in the distribution of forest habitats, increased frequency and duration of fires and area burned, shifts in species distribution and abundance, and altered habitats and connectivity. The significance of these regional climate change consequences, combined with existing stressors such as land use and development, pollution, and invasive species, emphasizes the fact that existing conservation and management strategies may not be adequate to meet these challenges. This does not mean that many of the approaches we currently employ in conservation and resource management are not useful, rather that they may call for some adjustment in light of the new reality that climate change brings. Options for adapting to climate change vary depending on the unique characteristics of the systems being considered as well as the goals practitioners hope to achieve.

The climate-informed blueprints highlight some of the areas and actions likely to increase the success of conservation and management efforts in our rapidly changing climate. They are meant to inform broad, landscape-scale efforts and to give context to finer scale, on-the-ground projects.

1.1. Climate-Informed Conservation Blueprints

Collectively, the climate-informed blueprints identify areas in the Greater Puget Sound ecoregion (i.e., Washington State west of the Cascades eastern slope) that have particular ecological value – for example, focal species habitat concentration areas, biodiversity significance, or landscape integrity – and are more or less likely to undergo a shift in dominant vegetation type under modeled future climatic conditions. The spatial data layers used to develop these blueprints are briefly discussed below.

1.1.1. Projected Climate Change Layer - Predicted Future Vegetation Change

We modeled projected changes in temperature and precipitation for our study area and input this information into the MC1 dynamic vegetation model (Bachelet, Lenihan et al. 2001) developed by the Mapped Atmosphere-Plant-Soil System (MAPSS) Team at the USDA Forest Service’s Pacific Northwest Research Station. The MC1 model simulates the potential impacts of climate changes on dominant vegetation type distribution. We chose the MC1 model for this effort because it gives us information on what combined climate conditions (temperature, precipitation, humidity, freeze days, etc.) are likely to lead to major transformations in ecological systems. Rather than just looking at gradual changes in individual climate variables, MC1 allows us to look for ecological thresholds and predict when systems might experience greater levels of change – for example, what conditions may lead to shifts from one major functional type of vegetation to another (e.g., from temperate cool mixed forest to temperate warm mixed forest). This approach allowed us to assess the likelihood of shifts in dominant types of vegetation as climate change progresses.
Products of this analysis include a map of predicted future changes in dominant vegetation type. For example, the map highlights areas where the current, dominant type of vegetation is predicted to remain the same until 2085, as well as areas where the dominant type of vegetation is predicted to shift to a new type by 2085.

### 1.1.2. Blueprints

- **Biodiversity Significance**
  Blueprint maps include: (1) three tiers of biodiversity significance overlapping with projected future vegetation change areas; and (2) land ownership, high biodiversity significance areas, and projected future vegetation change areas.

  The biodiversity significance layer is based on The Nature Conservancy’s ecoregional assessments for Washington ([www.waconservation.org](http://www.waconservation.org)); an index for biodiversity significance was developed as part of these assessments. Using this index, the Washington Biodiversity Council grouped biodiversity significance into three categories – high, medium, and low. High biodiversity significance areas include significant numbers of rare species, plant communities, and/or ecosystems; high richness; and good representation of ecosystems, plant communities, and populations of species. Conversely, low biodiversity significance areas include abundant common species or habitats; possible fragmentation of ecosystems, plant communities, or populations of species; and past disturbances that have lowered richness or representation.

- **Core Landscape Integrity Areas**
  Blueprint maps include: (1) core landscape integrity areas overlapping with projected future vegetation change areas; and (2) land ownership, core landscape integrity areas, and projected future vegetation change areas.

  Our landscape integrity maps are based on the Washington Wildlife Habitat Connectivity Working Group’s (WHCWG) Connected Landscapes Project: Statewide Analysis. As part of this project, the WHCWG produced a landscape integrity map that was developed using a spatially explicit ranking of the degree of human impact on ecosystems. The resulting map shows a network of lands exhibiting relatively intact core natural areas characterized by low levels of human modification.

- **Focal Species**
  Blueprint maps include focal species habitat concentration areas overlapping with projected future vegetation change areas, and a series of similar maps including land ownership information.

  Our focal species maps are also based on the WHCWG Connected Landscapes Project: Statewide Analysis. As part of this project, the WHCWG produced a series of maps for 16 representative focal species that included important habitat patches or habitat concentration areas (HCAs). We selected five focal species from the Statewide Analysis: bighorn sheep, elk, western toad, Canada lynx, and wolverine.
Species Guilds

Products of this analysis include maps of montane or generalist species guild networks overlapping with projected future vegetation change areas; and land ownership, species guild networks, and projected future vegetation change areas.

Our species guild maps are also based on the WHCWG Connected Landscapes Project: Statewide Analysis. The WHCWG looked for common patterns among focal species by overlaying focal species linkage networks and sampling to find the level of overlap among them, which resulted in three ‘connectivity’ guilds for Washington State: (1) shrubsteppe, (2) montane, and (3) generalist. The montane species guild network includes the more mountainous and forested regions of Washington, where fragmentation from human-created barriers is less extensive and generally confined to relatively narrow areas. The generalist species guild network is comprised of relatively broad, well-connected landscapes with a few important interruptions such as heavily developed areas and busy highways. Because our study area did not encompass the shrubsteppe habitats of eastern Washington, this species guild was removed from the analysis.

1.2. Observations and Insights

- Areas predicted to retain the current, dominant vegetation type over the next 75 years occur mainly along the western slopes of the Olympic Mountains and south into the central Olympic Peninsula, north Puget Sound, and eastern Cascades.

- Along the western slopes of the Cascades and the higher elevations of the Olympic Mountains the dominant vegetation type is predicted to shift to a new type by 2080.

- Synthesis of the biodiversity significance, landscape integrity, and development risk layers with projected future vegetation change highlighted large swaths of land along the central Cascades and Olympic Peninsula that may provide the best opportunities for species and habitats under changing climate conditions.

- Areas of climatically important connectivity corridors, as determined by the WHCWG, often overlap with areas of low biodiversity significance, low landscape integrity, high future development risk, and changing dominant vegetation type. Where these corridors connect areas likely to retain the current dominant vegetation type with high biodiversity significance, high landscape integrity, and low future development risk, efforts could opt to focus on restoring or maintaining habitat connectivity so that species are able to move as climate conditions shift.

- Many ecologically important areas – for example, focal species habitat concentration areas, biodiversity significance, or landscape integrity – that overlap with areas projected to retain the current, dominant vegetation type are found on public lands.

- Recurring possible adaptation actions in this report include implementing climate-smart restoration techniques, utilizing active forest management strategies, maintaining or restoring ecosystem processes, creating or improving monitoring plans, working towards land acquisition or increased protection, and reducing non-climate stressors.
1.3. Interpreting and Using the Analysis

The mapping products, data, and report from this analysis convey a wealth of information relevant to making climate-informed conservation and management decisions in the Greater Puget Sound ecoregion, and are based on the best available information and the informed interpretation of the authors and collaborators. However, there are inherent uncertainties. We encourage users to gain an understanding of the information that each map provides, the spatial resolution at which that information is accurate, and the assumptions and known inaccuracies in the models used. Additionally, users should be aware of the methodologies and compromises inherent in the spatial data layers used as best described in the original reports of the separate studies from which data were drawn. This level of understanding will enable users to interpret the maps appropriately and make the most of each ecological component and their appropriate application. These maps are expected to serve as a foundation for identifying large landscape-scale patterns in predicted vegetation change that can then be compared to ecological spatial datasets. This information can be used to evaluate the impact that changes in the dominant type of vegetation could have on ecological components such as focal species and biodiversity, and highlights smaller-scale areas on which to target specific adaptation strategies.

The results of this analysis could be used to inform:

- The Washington State Integrated Climate Change Response Strategy, specifically the actions described by the Topic Advisory Group for Species, Habitats and Ecosystems
- Land management plan revisions and decisions for public lands in Washington State
- Decision-making by conservation organizations
- Property acquisition and conservation by federal, state, county, conservation organizations, or land trusts and conservancies
2. Introduction

The natural landscapes of the Greater Puget Sound ecoregion (Figure I-1) exist due to the regionally and locally unique combination of complex geological structure and climate. The resulting iconic ecosystems, including the Olympic Peninsula, Puget Sound, and North Cascades, have given rise to diverse plant and animal communities adapted to a multitude of specialized habitats. Washington’s diverse ecosystems, species and habitats provide a range of natural resources and services that people have come to rely on, including timber, water quality, flood and storm protection, sustained soil fertility, and cultural and recreational amenities. However, the new and variable conditions that are emerging due to rapid climate change are expected to significantly impact the natural systems that wildlife and human communities both depend on.

Projected climate changes such as increasing annual air temperature, changes in precipitation, and declining snowpack are likely to result in a myriad of impacts, including altered habitats and connectivity; shifts in species distribution, composition, and abundance; changes in the distribution of forest habitats; increased frequency and duration of fires and area burned; and altered sediment and nutrient transport to aquatic ecosystems (Climate Impacts Group 2009). Existing stressors such as pollution, habitat fragmentation and impairment, invasive species, and a growing human population further threaten ecosystems. In the face of mounting climate and land-use stressors, it is critical to develop climate change adaptation strategies that help sustain Washington’s unique ecosystems, species and habitats.

Figure I-1. The Greater Puget Sound ecoregion, which encompasses the Olympic Peninsula, Puget Trough, Mt. Rainier, and North Cascades. The eastern boundary of the ecoregion includes lower elevation habitats along the eastern slopes of the North Cascades.
The Sierra Club, arguably the oldest conservation organization in North America, sees global climate change as one of the largest threats that our natural heritage has ever faced. The Sierra Club and its partners are now actively working to support and enhance resilient habitats where plants, animals, and people are more likely to survive and thrive under new and changing conditions (http://www.sierraclub.org/habitat/). In support of Sierra Club’s efforts, climate-informed conservation “blueprints” for the Greater Puget Sound ecoregion were created to highlight and prioritize areas and actions likely to increase the success of conservation and management efforts in our rapidly changing climate. These science-based blueprints are meant to inform broad, landscape-scale efforts and to give context to finer scale, on-the-ground projects. Boxes that appear throughout the report provide helpful examples of how these blueprints can facilitate conservation and management efforts.

2.1. What is Climate Change Adaptation and Why is it Important?

Climate change adaptation refers to human efforts to reduce the negative effects of or respond to climate change. Current resource conservation and management paradigms have evolved during a time when the climate system was relatively stable and, as a result, many have yet to consider the implications of the rapidly changing climate system. The challenge of climate change is that things are unlikely to stay the same and often it is difficult to predict the change process. A few basic tenets have been developed in the adaptation world to help guide efforts to be climate savvy and were used to develop the conservation approaches suggested in this report:

• Protect adequate and appropriate space for a changing world, incorporating climatic gradients, ecosystem stability and climate refugia, habitat heterogeneity, biodiversity, and connectivity across landscapes.

• Reduce the stressors that are exacerbated by or exacerbate the effects of climate change, including development stress and habitat fragmentation, and also consider that almost all existing environmental stressors have the potential to interact with climate change in some way.

• Manage for change and uncertainty, keeping in mind that we can implement actions that allow us to adjust our course as more information is gathered or prepare for a variety of potential outcomes even when uncertainty is high or key pieces of information are missing.

• Reduce the rate and extent of local, regional, and global climate change (Hansen and Hoffman 2010).

Climate-savvy planning incorporates explicit consideration of the tenets discussed above and also considers the possibilities of unintentional maladaptation. Maladaptations are strategies that benefit one sector at the unintentional expense of others, where “costs” outweigh benefits.

2.2. What is a Climate-Informed Conservation Blueprint?

Collectively, the climate-informed blueprints identify areas in the Greater Puget Sound ecoregion (i.e., Washington State west of the Cascades eastern slope) that have particular
ecological value – for example, focal species habitat concentration areas, biodiversity significance, or landscape integrity – and are more or less likely to undergo a shift in dominant vegetation type under modeled future climatic conditions. This information can then be used to suggest priority areas and strategic conservation actions that, when combined, may provide species and ecosystems with a greater likelihood of persistence and function throughout the rapidly changing climate over the next 75 years.

2.2.1. Goals

The focus of this project is on identifying areas and related strategic conservation actions likely to increase the success of conservation and management efforts under changing climate conditions in the Greater Puget Sound ecoregion. The resulting climate-informed blueprints, like architectural blueprints, are just one of many guides that together can inform the construction of comprehensive resource management plans in the region. In other words, it would not be good conservation practice to rely solely on the findings and recommendations in this report. Conservation values, goals and opportunities all need careful consideration and an appropriate breadth and depth of information should be integrated with the information contained in this report.

Conservation planners and stakeholders have access to a growing body of resources about climate change and adaptation in the region. State and federal agencies, local universities, tribes, and a handful of conservation organizations have been adding to this collective knowledge, including the Washington Wildlife Habitat Connectivity Working Group (WHCWG 2010; WHCWG 2011); Washington State Integrated Climate Change Response Strategy (Topic Advisory Group 3 2011); North Cascadia Adaptation Partnership (http://northcascadia.org/); University of Washington Climate Impacts Group (Climate Impacts Group 2009); Olympic National Forest and Olympic National Park Climate Change Case Study (Halofsky, Peterson et al. 2011) and the Climate Change Sensitivity Database (http://courses.washington.edu/ccdb/drupal/), among others.

This analysis has a relatively coarse level of resolution that limits use to identifying patterns across the study area’s broad landscape. From this landscape-scale information, locations can begin to be targeted for on-the-ground implementation of adaptation strategies. There are many excellent regionally specific resources for additional fine-scale adaptation strategy development (see above paragraph, Appendix).

This report shares methodology and provides guidance regarding the interpretation and implementation of the blueprint maps. It provides an overview of the methods used, describes broad patterns and key insights, suggests conservation strategies or actions, and discusses important limitations associated with the maps and results.

2.2.2. Overall Approach

EcoAdapt and the Geos Institute both contributed to the Washington blueprints approach. An expert panel reviewed and commented on initial map development, the first draft of the report and final maps, and final report. Efforts were coordinated through meetings and conference calls, with most of the work being accomplished through the independent efforts of EcoAdapt and the Geos Institute. The analysis was completed by:
1. Defining the project area. The project area includes all of Washington State west of the eastern slopes of the Cascades and was defined by the Sierra Club Resilient Habitats Campaign prior to the start of this project.

2. Compiling ecological GIS layers. EcoAdapt performed a survey of existing and emerging ecological GIS datasets and selected a suite of spatial datasets including focal species habitat concentration areas and species habitat guilds, biodiversity significance, landscape integrity, and wildlife corridors likely to be important for conservation and management efforts in the project area. These spatial data were generously made available from established academic and agency research efforts in the region including the Washington Wildlife Habitat Connectivity Working Group (WHCWG 2010), The Nature Conservancy (Floberg, Goering et al. 2004; Iachetti, Floberg et al. 2006; Pryce, Iachetti et al. 2006; VanderSchaaf, Wilhere et al. 2006; Popper, Wilhere et al. 2007), and Washington Biodiversity Council (http://www.rco.wa.gov/biodiversity/index.shtml). More details on their methodologies can be found in subsequent sections.

3. Modeling vegetation change (Figure I-2). The MC1 dynamic vegetation model (Bachelet, Lenihan et al. 2001) developed by the Mapped Atmosphere-Plant-Soil System (MAPSS) Team at the USDA Forest Service’s Pacific Northwest Research Station was used to assess the relative change in dominant types of vegetation as climate change progresses. MC1 simulates the potential impacts of climate change on vegetation distribution and considers combined climate conditions to suggest potential major transformations in ecological systems – for example, what conditions may lead to shifts from one major functional type of vegetation to another (e.g., from temperate cool mixed forest to temperate warm mixed forest). For the purposes of this project we focused on areas more or less likely to undergo a shift in dominant vegetation type.

Figure I-2. Predicted likelihood of shifts in dominant vegetation type for the Greater Puget Sound ecoregion.
4. Developing climate-informed blueprints. Ecological spatial datasets such as biodiversity significance and landscape integrity were combined with the MC1 vegetation change layer to produce a suite of climate-informed maps. This analysis helped us identify where areas of current conservation importance may be undermined and areas where current conservation importance may be enhanced by more or less change in dominant vegetation type. For example, areas with high landscape integrity (i.e., areas with little to no human footprint), high biodiversity significance, and low future development risk that are predicted to retain the current, dominant type of vegetation are more likely to have greater future conservation value than areas of low landscape integrity, low biodiversity, high development risk, and the potential to undergo a major shift in dominant vegetation type (Figure I-3). Adding the MC1 climate information to ecological spatial datasets provided valuable insight into how changing conditions may impact species and ecosystems, and could be used to guide future conservation and management efforts.

5. Identifying areas and actions likely to increase the success of conservation and management efforts under changing climate conditions.

We benefited greatly from the insights of an expert panel who generously agreed to serve as peer reviewers of the methods, maps, and report. This panel included representatives from the North Pacific Landscape Conservation Cooperative, North Cascades National Park, Washington Department of Fish and Wildlife, University of Washington, National Wildlife Federation, and The Wilderness Society. The panel provided constructive feedback on the maps and this report. Several anonymous reviewers also provided important comments.

2.3. How Can Climate-Informed Conservation Blueprints be Interpreted and Used?

Using the blueprints requires thoughtful interpretation and careful evaluation of its limitations (see Box 2). We encourage users to gain an understanding of the information that each data layer provides and the spatial resolution at which that information is accurate. We urge users to read the more detailed information on the spatial data layers used, which can be found in the original reports of the separate studies from which data were drawn. This level of understanding will enable users to interpret the maps appropriately and make the most of each ecological component and their appropriate application.

The blueprints and discussion within this report provide information that can be used in a variety of ways to inform further analysis, planning, and conservation and management action. As described previously, we expect these maps to serve as a foundation for identifying large landscape-scale patterns in predicted vegetation change that can then be compared to ecological spatial datasets. This information can be used to evaluate the impact that changes in the dominant type of vegetation could have on ecological components such as focal species and biodiversity and highlight smaller-scale areas on which to target specific adaptation strategies.
Box 1. Example use: Washington State Integrated Climate Change Response Strategy for Species, Habitats and Ecosystems (TAG3)

In 2009, Washington State Legislature approved the formation of an integrated climate change response strategy to better prepare for, address, and adapt to the impacts of climate change. A Steering Committee guiding the development of the strategy formed four separate topic advisory groups (TAGs) to develop draft recommendations for different sectors. TAG3 was directed to consider impacts, vulnerabilities and draft adaptation strategies for species, habitats and ecosystems in Washington. As part of the TAG3 Interim Report, the group introduced a set of goals intended to sustain natural systems and the critical ecological services they provide under changing climate conditions.

The climate-informed conservation blueprints, when integrated with other information, could help managers to make informed decisions about where to allocate limited funds and resources in order to achieve the goals set forth by TAG3. For example, TAG3 highlighted the need to “identify and designate areas most suitable for core habitat and connectivity in light of a changing climate” (TAG3 2011). Managers could use the master blueprint (Figure I-2), which highlights areas predicted to be less likely to undergo a shift in dominant vegetation type in the next 75 years with high biodiversity significance, high landscape integrity, and low future development risk, as a starting point for landscape-level planning of designated core habitats and corridors. Once the coarse scale planning has been completed, managers can integrate more detailed, local-level information to help refine core habitat and corridor area designations. TAG3 also recommended identifying and protecting high quality habitats likely to be resistant to climate change. Because these are areas where climatic change is likely to occur more slowly or to a lesser extent than other
areas they are possible climate macrorefugia, and can help facilitate the long-term survival of species. The vegetation change map (Figure I-1) provides a coarse view of where macrorefugia are likely to exist in western Washington over the next 75 years, and again could provide a starting point for managers as they work to protect important climate resilient habitats (TAG3 2011).

2.4. Organization of This Document

This document presents the climate-informed conservation blueprints and analysis in seven sections. After the general introduction provided here in section 1, we shift to detailed presentations on each of the data layers including Vegetation Change (section 2); Biodiversity Significance (section 3); Landscape Integrity (section 4); Focal Species (section 6); Species Guilds (section 7); and the Master Map (section 5), which includes spatial datasets from sections 2, 3, and 4. Within each section, we include descriptions of the spatial data layers, key emerging patterns in the project area, and potential conservation approaches.

Box 2. Limitations to the climate-informed conservation blueprint maps

The blueprint maps, including the master, climate-informed conservation blueprint, should only be used for coarse-scale planning and with clear understanding of the 75-year timeframes discussed. Depicted edges and transitions in results, though not blurred, are imprecise and should be treated as such. Avoid zooming in on individual land parcels to guide fine scale land-use decisions, as the downscaled global climate modeling was limited to an 8 km x 8 km grid cell size. The scope of this analysis was dependent on existing, readily available and often spatially coarse data with study area-wide coverage. Areas identified by this analysis are most appropriate for guiding broad landscape-level planning and general conservation decisions.

Additionally, we urge readers to consider these results and conservation approaches as valuable additions to their decision-support toolbox. The recommendations here center on taking advantage of potential (modeled), relatively short-term future vegetation stability (that is, areas less likely to undergo a major shift in dominant vegetation type). Prudent practitioners should use multiple information sources, involve experts with local and topical knowledge, and consider appropriate timeframes when making crucial decisions. Remember models do not tell the future, rather they allow consideration of potential future conditions based on our present day understanding of how climate change will progress, how society will respond and how ecosystem processes work.

3. Predicted Future Vegetation Change

3.1. Introduction

Areas predicted to be less likely to undergo a major shift in dominant vegetation type over the next 75 years occur mainly along the western slopes of the Olympic Mountains and south into the central Olympic Peninsula, north Puget Sound, and eastern North Cascades
Conservation efforts could prioritize these areas for protection because they are less likely to undergo major habitat changes and may be possible climate macrorefugia. Conversely, the dominant type of vegetation is predicted to be more likely to undergo a shift to a new dominant vegetation type along the western slopes of the Cascades and the higher elevations of the Olympic Mountains, much of which is under federal land ownership. Practitioners could consider actions such as transplanting species to more climate-appropriate locations as well as retaining relict populations of species so that the vegetation type is available across a landscape as the species becomes established in a new area, removing invasive species and pests, or utilizing climate-smart restoration techniques, among others.

3.2. Methodology

3.2.1. Vegetation Change Analysis

Data Source: MAPSS lab at the U.S. Forest Service Pacific Northwest Research Station

In order to assess the likelihood of shifts in dominant types of vegetation as climate change progresses, we used the MC1 dynamic vegetation model (Bachelet, Lenihan et al. 2001) developed by the Mapped Atmosphere-Plant-Soil System (MAPSS) Team at the USDA Forest Service’s Pacific Northwest Research Station. MC1 simulates the potential impacts of climate change on vegetation distribution.

We used the MC1 model for this effort because it gives us information on what combined climate conditions (temperature, precipitation, humidity, freeze days, etc.) are likely to lead to major transformations in ecological systems. Rather than just looking at gradual changes in individual climate variables, MC1 allows us to look for ecological thresholds and predict when systems might experience greater levels of change – for example, what conditions may lead to shifts from one major functional type of vegetation to another (e.g., from temperate cool mixed forest to temperate warm mixed forest). MC1 provides information on when and where climate conditions are expected to support a change in the dominant type of vegetation, but due to currently established vegetation, dispersal rates, succession, and time to maturity, changes in dominant vegetation may lag behind changes in the local climate. In addition, MC1 does not take into account land use or invasive species, and tends to over estimate the positive effect of CO2 and under predict the negative effect of declining summer moisture availability. In the Pacific Northwest region, most global climate models indicate that summer precipitation will decrease which, when combined with declining soil moisture availability, has the potential to significantly impact plants in already dry locations (e.g., lower tree line or hot areas). MC1 also assumes potential vegetation; that is, it does not include what the vegetation on the ground actually is right now. This has important implications when examining the impacts of potential climatic changes on dominant vegetation type and developing adaptation strategies. For example, lowlands and prairies are heavily fragmented and already stressed, which will likely make them more vulnerable to climate change impacts than what has been predicted by the MC1 model.

The MC1 vegetation model uses output from three global climate models: Hadley (HadCM), MIROC, and CSIRO. Specific inputs to these models include such variables as greenhouse gas emissions, air and ocean currents, ice and snow cover, plant growth, particulate matter,
and many others. The MAPSS team selected HadCM, MIROC, and CSIRO from the suite of available models for three primary reasons: (1) because they perform well in the Western U.S.; (2) because they provide a range of projections, from the warmer end of the spectrum to the cooler, and also from wetter to drier; and (3) because they provide outputs, such as water vapor, that are required by the MC1 vegetation model. All three models were run at two different time steps, one around mid-century (2035-2045) and the other late-century (2075-2085), and were based on the IPCC A2 emissions scenario, which current emissions are now exceeding.

Most climate models project the future climate at global scales. Managers and decision makers however, need information about how climate change will impact the local area. The MAPSS Team adjusted global model output to local and regional scales (8km) using local data on historic temperature and precipitation patterns. This process increases the precision of the projections, but not the accuracy. Adjusting global scale models to regional (8km) scales results in greater uncertainty and variation.

The MC1 model was created to assess the potential impacts of global climate change on ecosystem structure and function at a wide range of spatial scales. It combines three modules: (1) a lifeform gradient module that looks at the composition of deciduous-evergreen tree and C3-C4 grass lifeform mixtures and classifies those lifeforms and their associated biomass using a climatologic rule base; (2) a biogeochemical module that simulates monthly carbon and nutrient dynamics including plant production, soil organic matter decomposition, and water and nutrient cycling; and (3) a fire module that mechanistically simulates the occurrence, behavior, and impacts of severe fire events. MC1 is operated in two successive modes: equilibrium and transient. The equilibrium mode runs on long-term historic mean climate data, usually representing the most recent 30 years of record (in the case of this project, 1961-1990). The transient mode operates on a monthly time step for a period of years into the future (in the case of this project, 75 years) to read the transient climatic data and produce estimates of carbon and nutrient pools for each simulated vegetation type (Bachelet, Lenihan et al. 2001).

We conducted a vegetation change analysis that involved comparing the dominant type of vegetation modeled under historical conditions (1961-1990) to those modeled under future conditions, for two future time periods (2035-45 and 2075-85). We mapped areas predicted to be less likely to undergo a shift to a new dominant vegetation type through mid- and late-century, based on agreement among all three global climate models. Areas where all three global climate models projected a shift in the dominant type of vegetation were also mapped. In areas with little agreement among models, we did not identify them as experiencing either a shift or no shift in dominant vegetation type, and instead left these as areas of uncertainty (Figure 1).

For the purposes of this project we focused on a binary more-or-less-likely to undergo a major shift in dominant vegetation type, although the MC1 model is able to predict what the dominant type of vegetation is likely to shift to – for example, from temperate woodland to temperate shrubland. For the Pacific Northwest region, the MC1 model considers twelve categories of dominant vegetation type: (1) ice; (2) tundra; (3) subalpine forest; (4) maritime evergreen needle-leaf forest; (5) temperate evergreen needle-leaf forest; (6) temperate cool mixed forest; (7) temperate warm mixed forest; (8) temperate...
evergreen needle-leaf woodland; (9) temperate shrubland; (10) C3 grassland; (11) C4 grassland; and (12) subtropical mixed forest. Because MC1 models broad-level vegetation types, in areas predicted to be less likely to undergo a shift in dominant vegetation type there could still be shifts in species composition. For example, more drought-tolerant Douglas fir could become more abundant relative to western hemlock, but this species-level information is not reflected in the MC1 output.

3.3. Results and Discussion

The vegetation change map (Figure 1) highlights three types of areas: those where the dominant type of vegetation is less likely to undergo a major shift to a new dominant type of vegetation under projected climate conditions (dark green), those where the dominant type of vegetation may already be changing due to current and future conditions (black), and those where there is model uncertainty regarding vegetation change (light green to dark grey). This section describes the key patterns and insights emerging from the analysis and important points regarding appropriate use of results.

3.3.1. Key Patterns

Areas predicted to be less likely to experience a shift in dominant vegetation type occur along the Olympic Peninsula, north Puget Sound, and eastern North Cascades. (Dark Green)

Along the Olympic Peninsula, areas predicted to retain the current, dominant type of vegetation continuously extend from the northernmost tip (Neah Bay) south past the Chehalis River. Much of this land is forested and includes heavily managed, single species plantations, although there is some developed land (urban and pasture) along Highway 12. Land ownership throughout this area includes tribal, federal, state, private, county, and city lands.

Along the eastern slopes of the North Cascades, areas projected to be less likely to experience a shift in dominant vegetation type continuously extend from the U.S.-Canada border south to Highway 12. Land cover for this area includes evergreen forest, shrub/scrub, hay or pastureland, cultivated cropland, and some urban development. Urban development areas occur mostly along interstates and state highways. Land ownership throughout this area tends to be federal, state, and private lands.

Along north Puget Sound, a significant area predicted to retain the current, dominant type of vegetation occurs from the U.S.-Canada border south to Arlington. This swath occurs along the north coast and moves inland further south; much of the I-5 corridor is included in this area. Land cover includes mixed forest, evergreen and deciduous forests, hay or pastureland, cultivated cropland, and developed urban areas (e.g., Bellingham). Land ownership is mostly private, tribal, and state lands.
Areas predicted to be more likely to undergo a shift in dominant vegetation type tend to be concentrated in Olympic National Park, the north and central North Cascades, and the northern areas of the South Cascades. (Black)

It appears that many of these areas occur in mid- to high-elevations with evergreen forest. These areas also occur at higher elevations in the northeastern and central portions of Olympic National Park, as well as the North Cascades along the U.S.-Canada border and along the western slopes of the whole Cascades range in Washington.

Areas of decreasing model certainty surround the smaller-sized areas predicted to be more likely to undergo a shift to a new dominant vegetation type. The U.S. Forest Service owns most of the lands in the North Cascades areas; both the U.S. Forest Service and National Park Service own these lands in the northern South Cascades.

3.3.2. Conservation Approaches

Areas predicted to be less likely to undergo a shift to a new dominant vegetation type

Because these areas are predicted to retain the current, dominant vegetation type, practitioners could consider prioritizing them for increased protection or preservation. In locations where increased protection may not be an option, managers could employ
strategies to restore or maintain ecosystem resilience so that these areas are better able to cope with threats when they arise. Example strategies that could be considered include maintaining or actively managing forests for heterogeneity in spatial patterns (both in terms of structure and fuels); maintaining or restoring other ecosystem processes such as natural flooding and fire regimes; utilizing climate-smart restoration activities; or supporting existing conservation and stewardship efforts, among others.

Areas predicted to be more likely to undergo a shift to a new dominant vegetation type

Depending on the conservation or management goal, a range of options could be considered for these areas. For example, rather than working to maintain all species in their present locations, managers could allow them to shift as conditions change and focus on maintaining species persistence within a larger ecoregion. Implementation of this strategy might entail transplanting species to more climate-appropriate locations or reducing disturbances to help retain relict populations of species, especially during the transition when that species is becoming established in a new area so that the vegetation type is continuously available across the landscape. Managers could also replant areas using high genetic diversity stocks optimized for a range of future climate scenarios. Other possible strategies that might help improve overall ecosystem resilience include restoring ecological function and processes such as fire or flooding regimes that slow the rate of change; reducing non-climate stressors – for example, managing development impacts or removing invasive species and pests; monitoring to detect changes to manage for a positive transition; or targeting incentives for conservation and/or climate-smart restoration of habitats.

For appropriate use of map products and recommended conservation approaches please refer to Box 2 on limitations in the Introduction.

<table>
<thead>
<tr>
<th>Box 3. Using the Vegetation Change map to facilitate restoration in the Okanogan-Wenatchee National Forest</th>
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<tbody>
<tr>
<td>The Okanogan-Wenatchee National Forest (OWNF) encompasses more than 4 million acres in Washington and stretches from the Canadian border south to the Goat Rocks Wilderness. The Cascade Crest defines the western forest boundary while the eastern edge extends into the Okanogan highlands south to the Yakima River valley. OWNF includes high, glaciated alpine peaks, numerous mountain ranges, old growth forest, and dry shrub-steppe habitats as well as a diversity of wildlife species. OWNF is managed under a multiple-use concept to provide the public with a variety of benefits however, an important emphasis of management is to maintain and enhance sustainable ecosystems for the future (<a href="http://www.fs.usda.gov/main/okawen/about-forest">http://www.fs.usda.gov/main/okawen/about-forest</a>).</td>
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<tr>
<td>In 2010, OWNF completed their restoration strategy, which identifies the need to increase landscape resilience to changing climates and disturbances through forest landscape restoration, ultimately facilitating ecosystem sustainability. However, forest managers face tremendous challenges in determining the strategic placement of restoration activities that reintroduce process such as fire while also integrating consideration of other important resource values such as wildlife habitat and preparing for likely climate change impacts.</td>
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Addressing these challenges can be facilitated by the use of spatial tools (e.g., GIS), which can be used to identify high priority, strategic restoration treatment areas including the most effective locations to restore landscape pattern, functions, and processes; reduce fire flow; restore patch sizes; and guide stand-level restoration of structure, species composition, and spatial pattern (Okanogan-Wenatchee National Forest 2010).

Across much of the OWNF, the vegetation change map shows that most areas are likely to retain the current, dominant vegetation type over the next 75 years. Depending on existing stand density, these may be key areas to reduce fire flow or guide stand-level restoration of structure and spatial pattern. For example, targeted thinning of dense, young-growth forest around existing late-successional forest and headwater streams predicted to be less likely to experience a shift in dominant vegetation type could reduce the likelihood of extreme fire events and increase the likelihood of habitat diversity and quality (Halofsky, Peterson et al. 2011). However, even though the modeling shows, for example, temperate evergreen needle-leaf forest maintaining dominance in OWNF, there could still be shifts in species composition. Thus OWNF managers might consider monitoring areas predicted to retain the current dominant vegetation type to determine if species composition is changing and whether stand-level restoration of species composition is necessary.

The vegetation change map could also be used to inform OWNF efforts to determine the amount and configuration of habitats necessary for focal wildlife species - a component of their restoration strategy. For example, OWNF managers could designate core wildlife habitat areas in places where the vegetation is predicted to be less likely to undergo a shift in dominant vegetation type in the short-term future, target restoration strategies to those areas to increase habitat quality, and design linkages between these areas to facilitate species movement through the forest (Mawdsley, O'Malley et al. 2009).

In areas predicted to undergo a shift in dominant vegetation type, OWNF managers could evaluate current activities to determine if stresses can be reduced or develop specific prescriptions for individual areas to increase habitat resilience. For example, increasing the use of prescribed fire in an area could help retain the current vegetation type (e.g., see alpine meadows example in Box 4) or replanting areas using high genetic diversity stocks that are able to cope with a range of climate conditions. Although the prescriptions for each of these areas would generally be less than 8 km in size, the vegetation change map can facilitate early planning and encourage examination of key areas.

### 4. Biodiversity Significance and Vegetation Change

#### 4.1. Introduction

Along the Olympic Peninsula and eastern North Cascades, numerous areas of high biodiversity significance overlap with areas predicted to be less likely to undergo a shift in the dominant type of vegetation through 2085 (Figures 2, 3). On the Olympic Peninsula, much of this occurs on federal, state and private lands where conservation groups could
partner with landowners to help track changes or encourage them to pilot adaptation strategies that improve overall ecosystem resilience. For example, groups could work with Olympic National Forest (ONF) and Olympic National Park (ONP) to target implementation of adaptation strategies suggested by Halofsky, Peterson et al. (2011), which include thinning to improve habitat quality and diversity, creating and protecting legacy structures such as old-growth trees, and using GIS analysis to identify gaps in desirable habitat conditions to determine where restoration treatments would be most effective (see Box 4 below).

In contrast, areas of high biodiversity that are predicted to experience a major shift in dominant vegetation type are relatively few and tend to be concentrated on federal lands along the northeastern and southeastern edges of the North Cascades. Because several of these areas occur on National Park Service lands, managers in these parks could focus on strategies for maintaining biodiversity and improving management of existing protected areas. For example, by using the high biodiversity-vegetation change map to identify high priority, strategic areas to implement climate-smart restoration techniques (e.g., see Box 3 in the Vegetation Change section). Managers could also evaluate current activities to determine if stresses can be reduced (e.g., trails and recreation use), especially in places likely to be most impacted by climate change.

### 4.2. Methodology

#### 4.2.1. Biodiversity Significance

*Data Sources: The Nature Conservancy Ecoregional Assessments and the Washington Biodiversity Council*

The maps of biodiversity significance are based on The Nature Conservancy’s ecoregional assessments for Washington ([www.waconservation.org](http://www.waconservation.org)). These assessments were developed from 1999-2004 with collaboration among the Washington Department of Fish and Wildlife, Washington State Department of Natural Resources, The Nature Conservancy, and The Nature Conservancy of Canada. Geographical information systems (GIS) analyses supplemented with expert local and regional knowledge were used to develop the assessments.1

Commonly accepted measures of biodiversity significance – richness, rarity and representation – were used in the ecoregional assessments. Richness refers to the number of target species, plant communities, or ecological systems present in a given area, and includes common species. Rarity refers to rare or imperiled species, plant communities, or ecological systems, and is characterized based on population size, geographic range and habitat specificity. Representation refers to the amount of a species, plant community, or ecological system that occurs in a given area (Washington Biodiversity Council 2007).

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1 The Nature Conservancy Ecoregional Assessments were completed between 1999 and 2004, and may no longer reflect the most recent and/or accurate assessments of biodiversity within the study area boundary. Users should consider talking with local or regional experts before making any planning or conservation decisions about a particular area.
An index for biodiversity value was developed as part of the ecoregional assessments that reflects all three measures of biodiversity significance. Using this index, the Washington Biodiversity Council grouped biodiversity significance into three categories – high, medium and low. High biodiversity significance captures 50% or more of known occurrences of each target and includes significant numbers of rare species, plant communities, and/or ecosystems; high richness; and good representation of ecosystems, plant communities, and populations of species. Low biodiversity significance captures less than 25% of each target in the analysis and includes abundant common species or habitats; possible fragmentation of ecosystems, plant communities, or populations of species; and past disturbances that have lowered richness or representation. Medium biodiversity significance captures between 25-50% of each target in the analysis (Washington Biodiversity Council 2007).

For the purposes of this project, we grouped medium and high biodiversity significance – as defined by the Washington Biodiversity Council – into one overall category of high biodiversity (see Figure 3).

4.2.2. Vegetation Change Analysis

Please read the Predicted Future Vegetation Change section for a complete description of these methods. However, the recommendations here center on taking advantage of areas predicted to be less likely to experience a shift in dominant vegetation type over the relatively short-term future (through 2085). Prudent practitioners should use multiple information sources, involve experts with local and topical knowledge, and consider appropriate timeframes when making crucial decisions.

4.3. Results and Discussion

The biodiversity significance maps (Figures 2-3) highlight two types of areas: those with high biodiversity where the current, dominant type of vegetation is likely to stay the same under projected climate conditions, and those with high biodiversity where the dominant type of vegetation may already be changing due to current and future conditions. This section describes the key patterns and insights emerging from the analysis and important points regarding appropriate use of results.

4.3.1. Key Patterns

- Larger patches of high biodiversity areas predicted to retain the current, dominant vegetation type occur along the Olympic Peninsula and eastern North Cascades.

The areas of high biodiversity that overlap with areas predicted to be less likely to experience a shift in dominant vegetation type are generally found in less developed, mid-elevation regions.

Along the Olympic Peninsula, these areas surround the western and southern edges of Olympic National Park and extend through the central portion of the peninsula and south with a strip along the Chehalis River. They tend to overlap with U.S. Forest Service and State Trust lands in the north and private lands south of Olympic National Forest. The Pacific Northwest Coast and Olympic Peninsula includes large stands of
temperate rainforest and is home to several unique species that cannot be found anywhere else in the world. More than 50% of the land is privately held – much of it by timber companies – and another 30% is federally owned (Washington Biodiversity Council 2007).

Along the eastern slopes of the North Cascades, these areas occur as smaller patches in the northern reaches and grow to larger patches moving south towards the I-90 corridor; they are peppered throughout U.S. Forest Service, private, and State Trust lands. The North Cascades include important habitats for wide-ranging carnivores such as lynx, gray wolf, grizzly bears, and wolverine. Much of the region contains large stretches of semi-natural or natural vegetation and includes several rare plants.

- Several areas of high biodiversity predicted to retain the current, dominant type of vegetation occur along north Puget Sound and the eastern Olympic Peninsula, mostly on private lands.
- Areas of high biodiversity predicted to be more likely to undergo a shift to a new dominant vegetation type are relatively few and tend to be concentrated along the northeastern and southeastern edges of the North Cascades.

In the North Cascades along the U.S.-Canada border, several of these areas occur alongside areas more likely to retain the current vegetation type, much of which overlaps with U.S. Forest Service lands.

At the southern end of the North Cascades, these areas occur on U.S. Forest Service, National Park Service, State Trust, and private lands. Large tracts of natural or semi-natural forest remain although at lower elevations, management practices have altered forest structure.

Figure 2. Low, medium, and high biodiversity significance areas and areas predicted to be more or less likely to undergo a shift in the dominant type of vegetation in the Greater Puget Sound ecoregion.
4.3.2. Conservation Approaches

- **High biodiversity areas predicted to be less likely to undergo a major shift in dominant vegetation type**

  On federal, protected lands (e.g., National Park Service) strategies could focus on maintaining biodiversity and improving management of existing protected areas to facilitate resilience. For example, consider maintaining or enhancing natural ecosystem processes such as fire or flooding regimes; using prescribed fire to reduce fuel loads and potential for catastrophic wildfires (Fischlin, Midgley et al. 2007); supporting existing restoration efforts or implementing new, climate-smart restoration techniques; or using the high biodiversity-vegetation change map to target strategic areas for restoration.

  On federal, unprotected lands, or state and private lands, actions that could be considered include increasing the amount of protected space through land acquisition, easements, and legislation; supporting existing stewardship and conservation efforts; utilizing active management techniques that promote vegetation resilience to changing climate conditions; ensuring that connectivity routes are intact by maintaining or creating migration corridors between protected areas and non-protected or mixed-use space (e.g., by removing barriers such as roads); or reducing stressors, including grazing, that might increase the likelihood of transition to new vegetation types.

- **High biodiversity areas predicted to be more likely to undergo a shift to a new dominant vegetation type**

  On federal, protected lands strategies that could be considered include creating or improving monitoring plans to track changes to identify how management strategies may possibly be modified based on new information or to provide early warning when critical ecological thresholds are nearing; restoring natural processes to build resilience; focusing on managing for function rather than species composition; managing to increase species diversity; or maintaining connectivity so species can move to new areas as vegetation changes.

  Options available on federal, unprotected lands, or state and private lands include, but are not limited to, strategies such as reducing local change in climate or related factors - for example, limiting point and non-point source pollution, removing roads or other barriers to species movement, installing snow fences that provide more snowpack for wildlife in key areas or help prevent water shortages later in the season; encouraging landowners to implement climate-smart restoration techniques to increase habitat diversity and quality; monitoring recent burns and post-fire regeneration to help determine if forage species are likely to regenerate after fire (Halofsky, Peterson et al. 2011); or engaging the public in conservation activities.
For appropriate use of map products and recommended conservation approaches please refer to the paragraph on limitations in the Introduction.

**Box 4. The Sierra Club’s Wild Olympics Campaign: Adaptation strategies for the Olympic Peninsula**

The Wild Olympics Campaign is a coalition working to protect wild forest and river watersheds on the Olympic Peninsula. As part of this campaign, the coalition has proposed National Park, Wild and Scenic River and Wilderness additions on the Olympic Peninsula, with the intent of protecting and restoring watersheds as well as preserving critical low-elevation salmon and wildlife habitats. To assess the proposed additions, the Wild Olympics Campaign boundaries were mapped onto the high biodiversity-vegetation change map (Figure 4).

*Proposed areas overlapping with high biodiversity areas predicted to retain the current, dominant type of vegetation*

Several proposed Wilderness and Wild and Scenic River additions overlap with areas of high biodiversity predicted to be less likely to undergo a shift in dominant vegetation type over the next 75 years, particularly along the western and southern edges of Olympic National Park (ONP). The proposed Wilderness additions land is entirely owned by the U.S. Forest Service; the proposed Wild and Scenic River additions land is likewise mostly under
federal ownership, although several areas are under State Trust lands. Almost all of the proposed National Park additions overlap with areas of high biodiversity predicted to retain the current, dominant vegetation type, the largest of which occur at the southwestern corner of ONP; this land is mostly U.S. Forest Service and State Trust land. Along the Olympic coast, the proposed National Park addition overlaps primarily with state and private lands.

*Proposed areas overlapping with high biodiversity areas predicted to undergo a shift to a new dominant vegetation type*

Several proposed Wilderness and Wild and Scenic River additions overlap with areas of high biodiversity predicted to be more likely to undergo a shift to a new dominant vegetation type, most of which occur in the northern and eastern parts of the Olympic Peninsula. These additions fall under federal ownership; several additions occur within ONP, which has full GAP 1 status, while several others occur within U.S. Forest Service lands.

*Possible conservation approaches*

The proposed Wilderness, Wild and Scenic River, and National Park additions along the southern and western Olympic Peninsula, particularly those that overlap with each other and with high biodiversity areas projected to retain the dominant vegetation type, appear to be good conservation investments for the Wild Olympics Campaign and may provide the group with a stronger argument when approaching federal or state governments about passing legislation for increased protection of these lands. Increased protection may help high biodiversity significance areas persist under changing climate conditions, specifically because these areas are less likely to undergo significant changes in the dominant vegetation type over the next 75 years and, if protected, are less likely to be impacted by other stressors. However, it is important to note that while the dominant vegetation type and ecosystem structure may remain relatively stable in these areas there will still likely be shifts in species composition, which could affect wildlife biodiversity.

In areas predicted to retain the current, dominant type of vegetation where high biodiversity and proposed additions overlap with private land, possible strategies include increasing the amount of protected space through land acquisition and easements, educating landowners about climate change impacts on biodiversity, or working with landowners to minimize local, non-climate impacts. Expanding areas for increased protection that have high biodiversity and are likely to retain the dominant type of vegetation in the short-term has the potential to appeal to stakeholders throughout the region, especially those who value biodiversity for cultural and recreational services. For example, hunters may possibly support the idea of protecting lands for species persistence, provided that other areas nearby remain accessible. Regardless, increasing habitat quality and connectivity for wildlife on the Olympic Peninsula will require extensive outreach to and collaboration with neighbors about where and how to establish protected area networks.

Several proposed Wilderness and Wild and Scenic River additions overlap with high biodiversity areas predicted to undergo a major shift to a new dominant vegetation type, however this does not necessarily mean these areas are poor investments. In these areas,
the Sierra Club could consider investigating non-climate stressors in order to build a conservation strategy that aims to reduce local stressors and build resilience to the predicted changes. For example in the northeast corner, proposed Wilderness and Wild and Scenic River additions occur in a large area predicted to be more likely to undergo a shift in the dominant vegetation type on U.S. Forest Service land. This corner includes productive areas where stands are more likely to positively respond to thinning through increased tree growth and vigor (Halofsky, Peterson et al. 2011), thus decreasing stand density and increasing the use of prescribed fire may help build resilience and retain wildlife.

As an alternative to establishing protected areas on the Olympic Peninsula, the Sierra Club could encourage the U.S. Forest Service to use the high biodiversity-vegetation change map for targeted implementation of adaptation strategies from the Olympic Climate Change Case Study (Halofsky, Peterson et al. 2011) to areas where treatments would be most effective. For example, Halofsky, Peterson et al. (2011) suggest that wildlife habitat quality could be increased through creation and protection of legacy structures, including old-growth trees, snags, and downed wood that provide food or prey, protection from the elements, or structures for rearing young. In ONP and Olympic National Forest (ONF), this strategy could be applied to high biodiversity areas predicted to undergo a shift to a new dominant vegetation type to provide refuge for wildlife. Thinning in existing young-growth forests may help ensure maintenance of enough forest – both late-successional and young-growth – with desired habitat characteristics to support a diversity of wildlife across the landscape (Halofsky, Peterson et al. 2011), which could be most effective in areas predicted to retain the current, dominant vegetation type. For example, in the northwestern corner of ONF – an area least connected to ONP – targeted thinning treatments could have the greatest effect on habitat quality (Halofsky, Peterson et al. 2011) and could be designed to connect these areas with ONP. Halofsky, Peterson et al. (2011) also suggest prioritizing thinning treatments around areas such as existing late-successional forest and headwater streams to increase late-successional habitat connectivity; these treatments could be targeted to areas predicted to retain the dominant vegetation type in order to increase the likelihood habitat diversity and quality is maintained over the next 75 years. Also, allowing wildfires to burn more frequently may help to maintain alpine meadows (Halofsky, Peterson et al. 2011), which appear to occur in areas predicted to be more likely to undergo a shift in dominant vegetation type.

The Forest Service could use the high biodiversity-vegetation change map to evaluate current activities in areas predicted to shift to a new dominant vegetation type to determine if stresses can be reduced, especially for species likely to be most impacted by climate change. Monitoring habitats, habitat structural components, and headwaters will also be useful for detecting changes in habitat attributes and taking management action (Halofsky, Peterson et al. 2011), and efforts could be targeted to areas predicted to experience a shift in dominant vegetation type in order to provide early warning when critical ecological thresholds are nearing.
5. Core Landscape Integrity Areas and Vegetation Change

5.1. Introduction

Core landscape integrity areas exhibit relatively intact natural areas characterized by low levels of human modification. Efforts to maintain the size and intactness of these areas could be beneficial regardless of changing climate conditions; however, it may be desirable to prioritize strategies that preserve core landscape integrity areas predicted to retain the current, dominant type of vegetation over the short-term future (e.g., see area extending from the U.S.-Canada border south to the I-90 corridor in the North Cascades, Figure 5). Conservation efforts could include advocating for legislation that increases protection of these areas or designing linkages between them to support species movements.

Several areas of landscape integrity overlap with areas predicted to experience a major shift in dominant vegetation type in Olympic National Park. Adaptive management and anticipating change, while building resilience to climate change in these areas is key. Possible options include evaluating current activities to determine if stresses can be reduced such as point and non-point source pollution, erosion, or resource uses that fragment the landscape; utilizing climate-smart habitat restoration techniques; or actively...
managing forests to prevent catastrophic wildfires and increase habitat quality and resilience.

5.2. Methodology

5.2.1. Landscape Integrity

*Data Sources: Washington Wildlife Habitat Connectivity Working Group*

The landscape integrity maps are based on the Washington Wildlife Habitat Connectivity Working Group's (WHCWG) Connected Landscapes Project: Statewide Analysis. The Connected Landscapes Project: Statewide Analysis assessed the current condition of wildlife habitat connectivity in Washington and produced a series of maps derived from two modeling approaches. The first is a focal species approach that produced linkage networks for 16 representative species (see the section on Focal Species for more details); the second is a landscape integrity approach that produced networks of lands exhibiting relatively intact core natural areas characterized by low levels of human modification.

The goal of the landscape integrity approach was to identify the best available routes for the flow of ecological processes across the landscape by connecting large, natural, and contiguous core areas. Landscape condition factors used to describe landscape integrity included land cover/land-use, housing density, freeways and major highways, secondary highways, local roads, and no roads. Core areas were identified using a series of rules including: (1) a minimum size of 10,000 acres; (2) only comprised of native land-cover types; (3) do not include freeways or highways; and (4) can include local roads, but road density must be less than 30% in the Puget Trough, less than 20% on the west coast, and less than 10% everywhere else in Washington. The local road density layer was created using a 20x20 grid cell moving window on the local roads raster layer; density values were calculated by the number of grid cells containing local roads divided by the total number of cells in the window. The final landscape integrity map was developed using a spatially explicit ranking of the degree of human impact on ecosystem integrity, their component organisms, and processes (WHCWG 2010).

The highest levels of landscape integrity in Washington were located in the Cascade and Olympic Mountains; the central and south Cascades also had significant portions of large core areas. For the purposes of this project, we focused on the highest core landscape integrity areas as identified by the WHCWG.

5.2.2. Vegetation Change Analysis

Please read the Predicted Future Vegetation Change section for a complete description of these methods. However, the recommendations here center on taking advantage of areas predicted to be less likely to experience a shift in dominant vegetation type over the relatively short-term future (through 2085). Prudent practitioners should use multiple information sources, involve experts with local and topical knowledge, and consider appropriate timeframes when making crucial decisions.

5.3. Results and Discussion
The core landscape integrity maps (Figures 5, 6) highlight two types of areas: those with high landscape integrity where the dominant type of vegetation is predicted to be less likely to undergo a shift in dominant vegetation type under projected climate conditions, and those with high landscape integrity where the dominant type of vegetation may already be changing due to current and future conditions. This section describes the key patterns and insights emerging from the analysis and important points regarding appropriate use of results.

5.3.1. Key Patterns

❖ **Areas of high core landscape integrity predicted to be *less likely* to undergo a shift in dominant vegetation type are located in the Olympic and Cascade Mountains.**

Significantly large core landscape integrity areas are centered around the Olympic Mountains – along the west side, these areas overlap with large areas predicted to retain the current, dominant vegetation type. Land ownership is mixed, but includes large pieces of federal, state, tribal, and private lands.

A significantly large core landscape integrity area extends along the North Cascades from the U.S.-Canada border to the I-90 corridor. Primarily on the eastern slope and to some degree in the center portion of the North Cascades, the core landscape integrity area overlaps with significant areas that are projected to be less likely to undergo a shift in dominant vegetation type. The majority of this land is federally owned.

❖ **Patches of high core landscape integrity areas predicted to be *more likely* to undergo a shift to a new dominant vegetation type are concentrated in Olympic National Park, distributed along the northeastern and north-central North Cascades, and scattered below the I-90 corridor.**

In Olympic National Park, core landscape integrity areas overlap with several areas predicted to be more likely to experience a shift in dominant vegetation type, and appear to occur in mid- to high-elevation areas.

In the northeastern portion of the North Cascades, several areas projected to experience a shift in dominant vegetation type occur within core landscape integrity areas – generally next to areas predicted to retain the current, dominant vegetation type. The majority of this land is federally or state owned.

Below the I-90 corridor, results are mixed – several core areas overlap with areas projected to retain the dominant vegetation type (e.g., see the southeastern corner of the study area) but several others overlap with areas predicted to undergo a shift to a new dominant vegetation type (e.g., see the northern area of the South Cascades or the area below Highway 12).
5.3.2. Conservation Approaches

- **Core landscape integrity areas: strategies for both changing and unchanging dominant vegetation type**

Core landscape integrity areas are currently valuable because they have a relatively diminished human footprint. Efforts to maintain the size and intactness of these areas could be undertaken regardless of changing climatic conditions; however, it may be desirable to prioritize strategies that maintain core landscape integrity areas that are predicted to retain the current, dominant vegetation type in the short-term future. This could include advocating for legislation that increases protection of these areas; designing linkages between core areas predicted to retain the dominant vegetation type, particularly among core areas that span altitudinal or latitudinal gradients, to support species movement; and educating the public and landowners in climate change impacts and encouraging them to implement or pilot adaptation strategies to increase overall ecosystem resilience.

In core areas predicted to be more likely to experience a shift to a new dominant vegetation type, adaptive management and anticipating change, while building resilience to climate change is key. This could include strategies such as reducing non-climate stressors (e.g., point and non-point source pollution, erosion, roads, or resource uses that fragment the landscape); utilizing climate-smart habitat restoration techniques such as planting vegetation optimized for a range of future climate scenarios or targeting restoration to strategic areas; or actively managing forests through...
thinning and prescribed burns that have the potential to increase habitat diversity and quality when appropriately applied.

For appropriate use of map products and recommended conservation approaches please refer to the paragraph on limitations in the Introduction.

![Map Image]

Figure 6. Core landscape integrity areas overlapping with areas projected to be more or less likely to experience a shift in dominant vegetation type over the next 75 years, and land ownership in the Greater Puget Sound ecoregion.

6. The Master Conservation Blueprint

6.1. Introduction

The Master Conservation Blueprint Map (Figure 7) is a good place to start when beginning to explore adaptation options in the region. It summarizes all the non-species specific metrics used in the project by combining biodiversity significance, core landscape integrity, and future development risk with predicted change in dominant vegetation type over the next 75 years. Climatically important habitat connectivity corridors, as determined by the Washington Habitat Connectivity Working Group (WHCWG 2011), are also outlined. The resulting map is a unique look at the region through both a potential conservation value lens and a future climate change lens.

Areas of high biodiversity, high landscape integrity, and low development risk overlapping with areas projected to retain dominant vegetation type are primarily distributed within
the northern Cascade Mountains and the Olympic Peninsula. Areas of low biodiversity, low landscape integrity, and high development risk overlapping with areas more likely to undergo shifts in dominant vegetation type are primarily located in lower altitude areas of the Cascade Mountains, and in and around areas of existing human development. Areas of climatically important connectivity corridors run throughout the study area often in regions of low biodiversity, low landscape integrity, high development risk and future potentially changing dominant vegetation type.

6.2. Methodology

Data Sources: Washington Biodiversity Council, Washington Wildlife Habitat Connectivity Working Group (WHCWG), and the MAPSS lab at the U.S. Forest Service Pacific Northwest Research Station

The creation of the Master Conservation Blueprint Map used predicted future vegetation change, biodiversity significance, and core landscape integrity data; each source is described in sections 2, 3, and 4 respectively. Added to these data were a future development risk layer generated by the Washington Biodiversity Council and climatically important habitat connectivity corridor information derived from the WHCWG.

The Washington Biodiversity Council used projected population density and land use from the Western Futures Growth Model to develop its future development risk map. The Washington Biodiversity Council grouped this information into three categories: low risk, medium risk, and high risk based on “land protection,” population/dwelling density in 2040, and proximity to high population/dwelling density areas in 2040 (Washington Biodiversity Council 2007). Climate-gradient corridor information was obtained from the Washington Connected Landscapes Project: Climate-Gradient Corridor Analysis (WHCWG 2011). As used here, the climate-gradient corridor data were reprocessed to adjust path width and to exclude areas of significant human development. The climate-gradient corridors were plotted independently of the other spatial data in the Master Conservation Blueprint Map.

Spatial data for each of the remaining metrics were combined with equal weighting and included three hierarchical gradations of biodiversity (section 3), eleven gradations of landscape integrity (section 4), three gradations of future development risk, and seven gradations of predicted dominant vegetation change (section 2). Areas with the highest biodiversity, highest landscape integrity, lowest future development risk and predicted to retain the current, dominant vegetation type were given a light pink color. Areas with the lowest biodiversity, lowest landscape integrity, highest future development risk and predicted to undergo a major shift in dominant vegetation type were colored light blue (Figure 7). The white hash mark areas outline climatically important connectivity corridors for the study area.

6.3. Results and Discussion

6.3.1. Key Patterns
Areas of high biodiversity, high landscape integrity, and low development risk overlapping with areas less likely to experience a shift in dominant vegetation type are primarily distributed within the northern Cascade Mountains and the Olympic Peninsula.

In the Cascade Mountains north of the I-90 corridor, these areas are concentrated at mid to high altitudes on eastern slopes; the majority of this land is federally owned. An area exists around and east of Mount Rainier, but less so on its eastern slope.

Areas exist within the Olympic Mountains region, west to the coast, and centrally south of that area to the Chehalis River. These areas are concentrated on the mountains’ western and southern slopes; much of this land is in federal, state or tribal ownership.

Areas of low biodiversity, low landscape integrity, and high development risk overlapping with areas predicted to be more likely to undergo a shift in dominant vegetation type are primarily located in lower altitude areas of the Cascade Mountains, and in and around areas of existing human development.

The largest area occurs along the western slopes of the Cascade Mountains and the Puget Sound Basin lowlands near Seattle and southward, but less so north of Seattle. The majority of this area is privately held, with the remainder in federal, state, and tribal lands. A strip also follows the I-90 corridor lowlands and is primarily composed of private land.

Areas of climatically important connectivity corridors, as determined by the WHCWG, run throughout the study area often in regions of low biodiversity, low landscape integrity, high development risk and areas more likely to undergo a shift in dominant vegetation type in the future.

These areas tend to connect areas predicted to retain the dominant vegetation type with high biodiversity, high landscape integrity, and low development risk as determined by this project.

6.3.2. Conservation Approaches

Areas less likely to experience changes in dominant vegetation type overlapping with areas of high biodiversity, high landscape integrity, and low development risk

These are the likely climate refugia within the study area, characterized by high conservation value and projected to retain the dominant vegetation type over the next 75 years. Management and conservation efforts that expand and improve protection and intactness (including buffers) and generally maintain and improve ecological function, integrity, heterogeneity, and diversity are key adaptation strategies in these areas. Connectivity to and between these areas may also facilitate movement of populations displaced by changing conditions, and maintain diversity and interchange between isolated refugia. Sections 2-4 also review conservation approaches relevant to the relationships explored here.
Adaptive management and planning in these areas are also important, so that successes and challenges are learned from and sensitive to unexpected changes. For example, some areas predicted to be less likely to undergo shifts to new dominant vegetation types may actually show significant change in species composition due to the complicated nature of ecosystems and their responses to ongoing global change. Because the predicted future vegetation change modeling only looks at changes over the next 75 years (or until 2085), managers and conservation practitioners will need to consider the timeframe limitations of these results in their longer term planning and decision-making.

- **Areas of low biodiversity, low landscape integrity, and high development risk overlapping with areas more likely to experience a shift in dominant vegetation type**

These are likely areas of lower conservation value overlapping with places of potential change in dominant vegetation type in the future. Managing for this change, as species are likely to shift, and focusing on species persistence within the larger ecoregion while working to restore ecological function and processes that can accommodate this change, are key adaptation strategies. Again, sections 2-4 review conservation approaches relevant to the relationships explored here.

For appropriate use of map products and recommended conservation approaches please refer to the paragraph on limitations in the Introduction.
Figure 7. The master climate-informed conservation blueprint for the Greater Puget Sound ecoregion. This map includes areas ranging from high biodiversity, high landscape integrity, and low development risk that are predicted to retain the dominant vegetation type, to areas with low biodiversity, low landscape integrity, and high development risk that are predicted to undergo a shift to a new dominant vegetation type.

7. Focal Species and Vegetation Change

7.1. Introduction

Wolverine, Canada lynx, and bighorn sheep habitat concentration areas (HCAs) occur throughout the North Cascades (Figures 8, 11, 12) whereas elk and western toad HCAs are more prevalent on the Olympic Peninsula (Figures 9-10). In general, the majority of these HCAs overlap with areas projected to be less likely to undergo a shift in dominant vegetation type over the next 75 years. Wolverine and Canada lynx are vulnerable to declining spring snowpack, which is predicted to decrease by almost 60% by 2080 (Climate Impacts Group 2009). Strategies that may help limit further stress to these species represent viable adaptation options, and could include actions such as maintaining existing canopy cover in areas predicted to retain current vegetation type, installing snow fences to increase snow depth, and designing corridors between HCAs more likely to retain snow depth.

In areas more likely to retain the current, dominant vegetation type, strategies that may help reduce the sensitivity of elk and bighorn sheep to climate change impacts could be considered such as maintaining or enhancing existing habitats (e.g., through the use of prescribed burns to avoid intense wildfires), removing invasive species or pests, or employing climate-smart restoration techniques. While the MC1 model does not take into account any freshwater systems, western toads do move during the year between aquatic
and terrestrial habitats and rely on connectivity between populations. Strategies that protect or limit degradation to toad HCAs overlapping with areas less likely to undergo a major shift in vegetation and enhance or maintain connectivity between these areas – as well as making sure water is available during critical life history stages – may help prevent further stress to toads as climatic changes in temperature and precipitation are likely to significantly impact this species.

7.2. Methodology

7.2.1. Focal Species

Data Sources: Washington Department of Fish and Wildlife and Washington Wildlife Habitat Connectivity Working Group

The focal species maps are based on the Washington Wildlife Habitat Connectivity Working Group’s (WHCWG) Connected Landscapes Project: Statewide Analysis. The Connected Landscapes Project: Statewide Analysis assessed the current condition of wildlife habitat connectivity in Washington and produced a series of maps including a focal species approach that produced linkage networks for 16 representative species. Focal species were selected using criteria designed to favor species that were representative of the habitat connectivity needs of many species and ecological processes at a statewide scale. Results for each focal species included maps of important habitat patches or habitat concentration areas (HCAs).

HCAs were defined as significant habitat areas that are expected or known to be important for focal species. HCAs were identified for each focal species based on habitat associations documented in the scientific literature and advice from species experts; for species with extremely broad or poorly defined populations, HCAs were defined using habitat association modeling (WHCWG 2010). For the climate-informed focal species maps, we selected five focal species from the Statewide Analysis: bighorn sheep, elk, western toad, Canada lynx, and wolverine.

- **Bighorn sheep (Ovis canadensis)**
  Most of the bighorn sheep herds were extirpated from the state by 1900 and, through considerable effort, have been reintroduced. They are now distributed across eastern Washington in 19 herds, each with limited geographic range. There are approximately 1000-1500 bighorn sheep statewide; approximately 7 HCAs were identified within the study area.

  Bighorn sheep are considered a generalist species with low physiological sensitivity to climate change, although several interacting non-climatic stressors including habitat loss or degradation, invasive or exotic species, and direct human conflict make them more sensitive to climate change impacts. Bighorn are also considered slightly sensitive to disturbance regimes such as fire that sets back forest succession, affecting foraging areas (University of Washington 2009).

- **Elk (Cervus elaphus)**
Elk are important members of the wildlife community, serving as prey for large carnivores such as cougar and wolves, and are also culturally important for hunters and Native American Tribes. Elk are common to abundant in most mountainous regions over a range of elevations and are present in many low-lying valleys, usually in winter. They can be found in coniferous swamps, clear cuts, aspen-hardwood forests, and coniferous-hardwood forests, and are known to be sensitive to development, roads and traffic, and the presence of people and domestic animals. Elk HCAs were largely identified based on vegetative cover conditions that indicated adequate forage and cover, although some areas of known elk occurrence were not included because they overlapped with areas of high human population densities; HCAs were distributed throughout the state and approximately 20 occur within the study area.

Elk are considered a generalist species that may be slightly physiologically sensitive to temperature changes resulting from climate change. They exhibit medium to high dependence on sensitive habitat types, and overall, are considered to have low sensitivity to climate change (University of Washington 2009).

- **Western toad (Anaxyrus boreas)**
  Western toads are found across much of Washington from low to high elevations, although many populations have been declining. They are pond-breeding amphibians that move during the year to access aquatic as well as terrestrial habitats, and serve as an important focal species because of their broad coverage, reliance on connectivity between populations, and their association with wetlands and aquatic systems. Toad HCAs were modeled using known and potential breeding habitats that were then linked to complementary terrestrial habitats. Ninety-four HCAs were identified within Washington – approximately 50 of which occur within the western Washington study area, with the Olympic Peninsula encompassing the densest HCA pattern and considerably fewer HCAs identified within highly developed areas.

  Overall, western toads are considered highly sensitive to climate change; they are likely to be moderately physiologically sensitive to climate changes such as temperature, precipitation, and dissolved oxygen. They also depend on sensitive habitat types including seasonal streams, wetlands and vernal pools, seeps and springs, alpine and subalpine habitats, and grasslands (University of Washington 2009).

- **Canada lynx (Lynx canadensis)**
  Canada lynx are primarily found in high elevation forests in the north-central and northeast parts of Washington. In Washington, Canada lynx are likely to be found in subalpine areas with moderate canopy cover on flat to moderate slopes. They are considered vulnerable to loss of habitat connectivity from land clearing, development, roads and traffic, and the presence of people. Eight HCAs were identified for Canada lynx within Washington, three of which are at least partially located in the study area.

  Canada lynx are considered a specialist species due to their dependence on their main prey species, snowshoe hares, although other prey can include grouse, ground squirrel, red squirrel, flying squirrel, voles, shrews, fish, beaver, mice, and porcupine (Mowat, K.G. Poole et al. 1999). Lynx depend on sensitive habitat types such as subalpine and montane habitats that include lodgepole pine, subalpine fir, Engelmann spruce, and aspen cover.
(Ruediger, J. Claar et al. 2000). They are highly sensitive to disturbance regimes such as fire severity, wind, disease, insects and pests, and human impacts such as logging, mining, agriculture, and fire suppression (Agee 1999).

Overall, lynx are considered moderately sensitive to climate change. Temperature and moisture regimes appear to limit lynx distribution via differential effects on snowfall and habitat structure (Buskirk, L. F. Ruggiero et al. 1999). Large-scale climatic regimes, such as those that increase the frequency of winter warm spells, can influence the dynamics of Canadian lynx abundance by affecting features of snow such as surface hardness, which may influence lynx interaction with the snowshoe hare. Non-climate threats including habitat loss or degradation or direct human conflict also affect the species’ sensitivity to climate change. Lynx may also be sensitive to other effects of climate change on its ecology, particularly in relationship to predator/prey dynamics, competition, and habitats (University of Washington 2009).

**Wolverine (Gulo gulo)**

In Washington, wolverine habitat is restricted to a high elevation band along the North Cascades. Wolverines tend to have large spatial requirements for their home ranges and have a remarkable capacity for long distance dispersal across forested and unforested habitat types. They tend to avoid human developments within their home ranges and appear to rely on areas with persistent spring snow cover, making them vulnerable to predicted climate changes that influence snow depth and persistence. Five HCAs were identified within Washington, two of which are located in the study area.

Wolverines are considered a specialist species because they depend on persistent spring snow cover, which is particularly important for female denning. Copeland et al. (2010) found that 98% of wolverine den sites were located within areas classified as having persistent spring snow. Overall, wolverines are considered extremely sensitive to climate change and, in particular, are physiologically sensitive to temperature changes. Temperature and precipitation changes as a result of climate change may also impact wolverine ecology through predator/prey relationships and habitat by shifting winter food supply. Direct human conflict has the potential to make the species’ more sensitive to climate change, although the extent to which winter recreation affects wolverine habitat use, distribution, dispersal, and reproductive success is unknown. Anecdotal evidence shows den abandonment in an area of high recreational activity, but there are also cases of no apparent effect (Heinemeyer, J. Squires et al. 2010).

**7.2.2. Vegetation Change Analysis**

Please read the Predicted Future Vegetation Change section for a complete description of these methods. However, the recommendations here center on taking advantage of areas predicted to be less likely to experience a shift in dominant vegetation type over the relatively short-term future (through 2085). Prudent practitioners should use multiple information sources, involve experts with local and topical knowledge, and consider appropriate timeframes when making crucial decisions.
7.3. Results and Discussion

The focal species maps (Figures 8-17) highlight areas where a particular species HCA overlaps with areas where the dominant type of vegetation is predicted to retain the dominant vegetation type under projected climate conditions and those where the dominant type of vegetation may already be changing due to current and future conditions. This section describes the key patterns and insights emerging from the analysis and important points regarding appropriate use of results.

7.3.1. Key Patterns

❖ Bighorn sheep (*Ovis canadensis*) (Figures 8, 13)

In the northern and central portions of the North Cascades, bighorn sheep HCAs overlap with areas predicted to retain the current, dominant vegetation type. In the northern portion, these places occur on state, private, and private conservation lands, and in the central portions, they occur on U.S. Forest Service, National Park Service, private, and state lands.

In the southern Cascades, bighorn sheep HCAs occur in areas where there is predicted to be a shift in the dominant type of vegetation; these areas overlap with state and private lands.

❖ Elk (*Cervus elaphus*) (Figures 9, 14)

Along the western and central portions of the Olympic Peninsula, elk HCAs overlap with areas projected to retain the current, dominant vegetation type. These elk HCAs overlap...
with several different types of land ownership including National Park Service, U.S. Forest Service, state, tribal, private, county/regional agency, and city lands. However, within the central and eastern portions of Olympic National Park, elk HCAs overlap with several areas predicted to undergo a major shift in dominant vegetation type.

In the southeastern Cascades, elk HCAs mainly overlap with areas predicted to be less likely to experience a shift in dominant vegetation type. These areas occur on U.S. Forest Service, state, and private lands. A large piece of elk HCA occurs on city land, although model projections are uncertain as to whether the dominant vegetation type will be changing in this area.

In the southwestern Cascades, elk HCAs mainly overlap with areas of predicted to undergo a shift in dominant vegetation type or areas with model uncertainty regarding vegetation change. These areas occur on National Park Service, U.S. Forest Service, state, and private lands.

![Map showing elk habitat concentration areas](image)

**Figure 9.** Elk habitat concentration areas overlapping with areas predicted to be more or less likely to undergo a shift in dominant vegetation type over the next 75 years in the Greater Puget Sound ecoregion.

- **Western toad (Anaxyrus boreas)** (Figures 10, 15)

  Along the Olympic Peninsula, western toad HCAs overlap almost entirely with areas projected to retain dominant vegetation; exceptions include patches within Olympic National Park. Land ownership where toad HCAs overlap with areas predicted to retain dominant vegetation is mixed and includes private, state, U.S. Forest Service, National Park Service, and tribal lands.

  Large portions of toad HCAs occur along the western slopes of the North Cascades, and there is uncertainty in the model projections as to whether the dominant vegetation in this region will change. In general, western toad HCAs occurring along the
northwestern and northeastern Cascades are to retain the current, dominant vegetation type; these areas occur almost entirely within U.S. Forest Service lands.

![Map of Western Toad Habitat Concentration Areas](image)

Figure 10. Western toad habitat concentration areas overlapping with areas predicted to be more or less likely to undergo a shift in dominant vegetation type over the next 75 years in the Greater Puget Sound ecoregion.

Canada lynx (*Lynx canadensis*) (Figures 11, 16)

Canada lynx HCAs overlap with several areas predicted to retain current, dominant vegetation type, particularly in the northeastern Cascades. Large areas predicted to undergo a shift in dominant vegetation type occur in the northeastern parts of lynx HCAs and are intermixed with areas predicted to retain dominant vegetation. Canada lynx HCAs are located on U.S. Forest Service and state lands; in state lands, lynx HCAs overlap with areas less likely to undergo shifts in dominant vegetation type.
Figure 11. Canada lynx habitat concentration areas overlapping with areas predicted to be more or less likely to undergo a shift in dominant vegetation type over the next 75 years in the Greater Puget Sound ecoregion.

**Wolverine** (*Gulo gulo*) (Figures 12, 17)

Areas predicted to be less likely to experience shifts in dominant vegetation type can be found throughout the wolverine HCAs, but larger areas tend to be concentrated along the central North Cascades. Areas predicted to experience shifts in dominant vegetation type are found along the fringes of wolverine HCAs, such as the northwestern, northeastern, and southern edges of the North Cascades. Wolverine HCAs are almost entirely located on U.S. Forest Service and National Park Service lands.
Figure 12. Wolverine habitat concentration areas overlapping with areas predicted to be more or less likely to undergo a shift in dominant vegetation type over the next 75 years in the Greater Puget Sound ecoregion.

### 7.3.2. Conservation Approaches

- **Bighorn sheep** (*Ovis canadensis*)

  Adaptation strategies that address interacting, non-climatic stressors including habitat loss or degradation, invasive species, and direct human conflict are likely to decrease the sensitivity of bighorn sheep to climate change impacts. Where sheep HCAs overlap with areas predicted to retain the dominant vegetation type over the next 75 years, this could include increasing the amount of protected habitat area through land acquisition, easements, and legislation in order to avoid habitat loss or degradation and limit human conflict. Alternatively, practitioners could work with landowners on strategies to maintain or enhance existing habitats or avoid habitat loss. This could include the use of prescribed burns to avoid intense wildfires, removing invasive species or pests, employing climate-smart restoration strategies, or other active management techniques. Practitioners could also work with landowners to design open, intact habitat networks that include altitudinal and/or latitudinal gradients to facilitate species movement as climate conditions change.

- **Elk** (*Cervus elaphus*)

  Because elk HCAs were largely identified based on vegetative cover conditions indicative of adequate forage and cover, focus could be placed on strategies that maintain or enhance this vegetation, particularly in areas where elk HCAs overlap with areas predicted to be less likely to undergo shifts in dominant vegetation in the short-term future. For example, forestlands could be actively managed through thinning or prescribed burns to retain appropriate vegetative structure and function. HCAs
projected to undergo shifts in dominant vegetation will not necessarily become an
unsuitable habitat type for elk because they are able to utilize a variety of land cover.
However, reducing non-climate stressors in these areas is likely to help elk manage the
change in dominant vegetation type. Possible actions could include decommissioning
roads to improve connectivity, or planning resource extractions or recreation uses
during times when elk are not present (e.g., elk move up altitudinally in the summer).

Western toad (Anaxyrus boreas)

The MC1 model does not take into account any freshwater systems, including wetlands,
thus predicted future vegetation change is unlikely to provide much insight for western
toad adaptation planning and conservation. Although western toads do not rely on
terrestrial habitats exclusively, they do move during the year between aquatic and
terrestrial habitats and rely on connectivity between populations. Managers could
consider strategies that protect or limit degradation to toad HCAs overlapping with
areas projected to retain current vegetation type and enhance or maintain connectivity
between these areas because it may help prevent further stress to toads as climatic
changes in temperature and precipitation are likely to significantly impact this species.
For example, within Olympic National Park managers could implement actions such as
removing invasive species that threaten the toads, restoring or improving natural
flooding processes, and limiting human uses when toads are migrating between
habitats. On unprotected lands, similar efforts could be implemented, as well as efforts
directed at ensuring water is available when toads need it most.

Canada lynx (Lynx canadensis)

Lynx are specialist species, tied to snow depth and snowshoe hare. While snow depth is
not necessarily associated with vegetation change, snowshoe hare are – they require
dense, brushy, usually coniferous cover that provides hiding, escape, and thermal cover
(Giusti, Schmidt et al. 1992). In Washington, dense vegetation such as early successional
forest may be fully occupied by snowshoe hares whereas in older stands with less stem
density, their abundance decreases (Koehler 1990). Where lynx HCAs overlap with
areas predicted to retain the dominant vegetation type, one potential option is to
implement actions that help maintain the existing canopy cover. This may help ensure
habitat for snowshoe hares is available even as climate conditions change – possibly
allowing lynx to remain viable in the same areas. Within these areas, snow fences could
also be installed to increase snow depth, helping lynx to retain their competitive
advantage over other predators in deep snow habitats. Lynx HCAs predicted to
experience shifts in dominant vegetation type will not necessarily change to an
unsuitable habitat type for snowshoe hares, however practitioners could consider
maintaining connectivity between areas where dominant vegetation type remains the
same and areas where it changes to let both species move if new habitat types are
unsuitable.

Wolverine (Gulo gulo)

Wolverines are able to occupy a variety of forested and unforest habitats, however
they are considered a specialist species because they rely on areas with late spring
snowmelts. Because snowpack is likely to decline in the next century, managers could consider implementing actions limiting additional stress – for example, by utilizing active forest management strategies to maintain existing canopy cover in areas predicted to be less likely to undergo shifts in dominant vegetation type – or installing snow fences to increase snowpack. Wolverines also rely on large home ranges so maintaining connectivity to areas likely to continue to accumulate snow may also be important. This could include designing wildlife corridors or limiting human uses such as recreation from snowmobiles that has the potential to impact wolverine habitat use and dispersal.

For appropriate use of map products and recommended conservation approaches please refer to the paragraph on limitations in the Introduction.

Figure 13. Bighorn sheep habitat concentration areas overlapping with areas predicted to be more or less likely to undergo a shift in dominant vegetation type over the next 75 years, and land ownership in the Greater Puget Sound ecoregion.
Figure 14. Elk habitat concentration areas overlapping with areas predicted to be more or less likely to undergo a shift in dominant vegetation type over the next 75 years, and land ownership in the Greater Puget Sound ecoregion.

Figure 15. Western toad habitat concentration areas overlapping with areas predicted to be more or less likely to undergo a shift in dominant vegetation type over the next 75 years, and land ownership in the Greater Puget Sound ecoregion.
Figure 16. Canada lynx habitat concentration areas overlapping with areas predicted to be more or less likely to undergo a shift in dominant vegetation type over the next 75 years, and land ownership in the Greater Puget Sound ecoregion.

Figure 17. Wolverine habitat concentration areas overlapping with areas predicted to be more or less likely to undergo a shift in dominant vegetation type over the next 75 years, and land ownership in the Greater Puget Sound ecoregion.
8. Species Guilds and Vegetation Change

8.1. Introduction

The montane species guild network includes the more mountainous and forested regions of Washington, where fragmentation from human-created barriers is less extensive and generally confined to relatively narrow areas. Species such as Canada lynx, wolverine, mountain goat, black bear, northern flying squirrel, and American marten were included in the montane guild. Many areas throughout the montane species network in the North Cascades exhibit potential uncertainty in terms of shifts in dominant vegetation type, and are under federal land ownership (Figure 18). One option managers for these lands could consider is modifying monitoring plans to include climate-sensitive species to provide early warning when critical thresholds may be crossed and allow for intervention.

The generalist species guild network is comprised of relatively broad, well-connected landscapes with a few important interruptions such as heavily developed areas and busy highways, and includes species such as western toad, mule deer, elk, bighorn sheep, and western gray squirrel. In the eastern North Cascades, up to all five generalist species ranges overlap with areas predicted to retain current, dominant vegetation type over the next 75 years (Figure 19). Because much of these areas occur on private and state lands, practitioners could engage landowners in discussions on climate change impacts, the likely effects on generalist species, and how these changes could impact them. This might help garner public support for adaptation actions and encourage landowners to pilot their own adaptation strategies such as planting in heterogeneous patterns to increase habitat diversity.

8.2. Methodology

8.2.1. Species Guilds

Data Sources: Washington Department of Fish & Wildlife, Washington Wildlife Habitat Connectivity Working Group

The species guild maps are based on the Washington Wildlife Habitat Connectivity Working Group’s (WHCWG) Connected Landscapes Project: Statewide Analysis. The Connected Landscapes Project: Statewide Analysis assessed the current condition of wildlife habitat connectivity in Washington and produced a series of maps derived from two modeling approaches. The first is a focal species approach that produced linkage networks for 16 representative species (see the section on Focal Species for more details); results for each focal species included maps of important habitat patches or habitat concentration areas (HCAs). HCAs are defined as significant habitat areas that are expected or known to be important for focal species. The second is a landscape integrity approach that produced networks of lands exhibiting relatively intact core natural areas characterized by low levels of human modification (see the section on Landscape Integrity for more details). Species guild maps are comprised of species habitat concentration areas (HCAs) or landscape integrity core areas, the linkage zones that connect them, and a cost-weighted distance buffer surrounding HCAs or core areas.
The WHCWG looked for common patterns among focal species by overlaying focal species linkage networks and sampling to find the level of overlap among them. A hierarchical cluster analysis was applied to overlap summaries, which resulted in three ‘connectivity’ guilds for Washington State: (1) shrubsteppe, (2) montane, and (3) generalist. The montane species guild network includes the more mountainous and forested regions of Washington, where fragmentation from human-created barriers is less extensive and generally confined to relatively narrow areas. Species included in the montane guild were Canada lynx, wolverine, mountain goat, black bear, northern flying squirrel, and American marten. The generalist species guild network is comprised of relatively broad, well-connected landscapes with a few important interruptions such as heavily developed areas and busy highways (e.g., the Chehalis River bottomlands along U.S. 12, I-90 between North Bend and Cle Elum, and the Methow River bottomlands between Winthrop and Twisp). Species included in the generalist guild were western toad, mule deer, elk, bighorn sheep, and western gray squirrel (WHCWG 2010). Because the study area for this project did not encompass the shrubsteppe habitats of eastern Washington, this species guild was removed from the analysis.

8.2.2. Vegetation Change Analysis

Please read the Predicted Future Vegetation Change section for a complete description of these methods. However, the recommendations here center on taking advantage of areas predicted to be less likely to experience a shift in dominant vegetation type over the relatively short-term future (through 2085). Prudent practitioners should use multiple information sources, involve experts with local and topical knowledge, and consider appropriate timeframes when making crucial decisions.

8.3. Results and Discussion

The species guild maps (Figures 18-19) highlight areas where a number of species ranges (either montane or generalist) overlap with places where the dominant type of vegetation is less likely to undergo shifts to a new vegetation type under projected climate conditions, and where the dominant type of vegetation may already be changing due to current and future conditions. This section describes the key patterns and insights emerging from the analysis and important points regarding appropriate use of results.

8.3.1. Key Patterns

Montane species guild

Along the Olympic Peninsula, montane species are concentrated in Olympic National Park and Olympic National Forest, with some species ranges extending to the northwest coastline. Three overlapping montane species occur within park and forest boundaries where the current, dominant vegetation type is projected to remain the same in the short-term future; these areas occur along the west side whereas areas predicted to undergo a major shift to a new dominant vegetation type occur more centrally. Montane species extend broadly across the northern Cascades and narrow moving southward, with the greatest overlap between species ranges occurring centrally where
patchy areas predicted to retain the current, dominant vegetation type exist. In the North Cascades, the most montane species overlap (i.e., 6) occurs in the north and east-central mountains. In the northeast, the dominant vegetation type includes areas predicted to be both more and less likely to undergo a shift in dominant vegetation type whereas in the east-central mountains it is primarily areas projected to retain the current, dominant vegetation type. Land ownership throughout this range is mostly federal (e.g., U.S. Forest Service, National Park Service). North and south of the I-90 corridor five species ranges overlap, but when nearing the corridor the number of species that overlap decreases to 2 or 3; shifts in dominant vegetation within this area is largely uncertain with more areas predicted to retain the current, dominant vegetation north of I-90.

Figure 18. Montane species guild overlapping with areas predicted to be more or less likely to experience a shift in dominant vegetation type over the next 75 years in the Greater Puget Sound ecoregion.

❖ Generalist species guild

Generalist species exhibit a high degree of overlap throughout the study area; at least four species ranges overlap from the Olympic Peninsula south to the Columbia River and a large portion of this range contains areas predicted to retain current, dominant vegetation type over the next 75 years. A similar trend is seen in the North Cascades where at least four species ranges overlap from the U.S.-Canada border south to Highway 12. Along the west side of the Cascades and Puget Trough, shifts in dominant vegetation are largely uncertain; along the central to east side of the Cascades, dominant vegetation type is predicted to be less likely to undergo shifts in dominant vegetation.
In the eastern Cascades, the most generalist species overlap (i.e., 5) occurs in areas predicted to retain dominant vegetation type; private and state lands make up the northeast corner while federal lands surround Lake Chelan. In the southern Cascades, the areas with the most species overlap are projected to be both more and less likely to undergo shifts in dominant vegetation type, and largely occur on state and private lands.

![Map of Greater Puget Sound ecoregion with generalist species overlap](image)

Figure 19. Generalist species guild overlapping with areas predicted to be more or less likely to undergo a shift in dominant vegetation type over the next 75 years in the Greater Puget Sound ecoregion.

### 8.3.2. Conservation Approaches

**Montane species guild**

The greatest overlap of montane species ranges primarily occurs on federal lands. In the northern Cascades where overlap occurs among six species and vegetation change ranges from maintaining current dominant vegetation type to uncertain to areas likely to undergo a shift in dominant vegetation type, strategies could focus on maintaining or enhancing existing habitats and their connectivity. For example, in areas predicted to retain the current, dominant vegetation type managers could consider employing active forest management techniques such as thinning, which may be most effective adjacent to existing late-successional forests and could help increase habitat connectivity and wildlife habitat quality (Halofsky, Peterson et al. 2011). In places where vegetation change is uncertain, managers could consider modifying monitoring plans to include climate-sensitive species to provide early warning when critical thresholds may be crossed and allow for intervention. Managers could also target restoration efforts to areas predicted to undergo a shift to a new dominant vegetation type in order to reduce the non-climate stressors likely to interact with climate change and further impact
species. This may include actions such as removing invasive species, utilizing forest management techniques such as prescribed burning to help decrease the frequency of severe fire events, or removing roads to improve connectivity and reduce erosion.

 Generalist species guild

In general, there is a large degree of generalist species overlap with areas predicted to retain the current, dominant vegetation type until 2085. Where the overlap occurs on private and state lands (e.g., see the northeast and southern Cascades or western Olympic Peninsula), one possible option could be education and outreach regarding the potential effects of climate change on generalist species and local habitats. This might help garner public support for adaptation actions by landowners such as employing heterogeneous planting patterns to maintain or enhance habitat diversity; limiting human disturbances during times when wildlife may be migrating through; or reducing fuels to decrease wildfire intensity.

In the south Puget Trough, several species ranges appear to link the Olympic Peninsula to the North Cascades. Land ownership here is mainly private, but also includes large pieces of land owned by the U.S. Department of Defense (DOD) and the U.S. Department of Energy (DOE). Because potential vegetation change in this area is largely uncertain, practitioners could consider working with DOE or DOD to maintain and connect areas of open space so that species are able to move through the mixed-use space as conditions change.

For appropriate use of map products and recommended conservation approaches please refer to the paragraph on limitations in the Introduction.
Appendix

Recommended Regional Climate Change Adaptation Resources

- University of Washington Climate Impacts Group (CIG): http://cses.washington.edu/cig/
- North Cascadia Adaptation Partnership: http://northcascadia.org/
- Washington Wildlife Habitat Connectivity Working Group: http://wawhcn.ca/
- Olympic National Forest and Olympic National Park Climate Change Case Study: http://www.fs.fed.us/pnw/pep/climatechange/peterson_ohalloran/
- Climate Change Sensitivity Database: http://courses.washington.edu/ccdb/drupal/

References


