Conserving Cascadia

A Management Plan for Coexistence

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Executive Summary

This report aims to inform the conservation and land-use policies that govern the Cascadia bioregion. Adopting a multi-level management approach that accounts for both landscape-scale and species-specific conservation needs, we address ecological concerns across the bioregion. Our objective is to create management recommendations that preserve current biodiversity patterns and prepare the region's ecology for future climate conditions. In this report, we examine current and future conservation needs in an effort to protect the region's wildlife through minimization of human-induced impacts and coexistence on the landscape.

We consider a suite of diverse species with overlapping habitats in Cascadia: the Canada Lynx, Elk, Gray Wolf, Greater Sage-Grouse, Grizzly Bear, North American Beaver, Silver Haired Bat, and Snowshoe Hare. We conduct species distribution modeling and connectivity mapping to better understand the presence and movement of these species on the landscape. We generate additional distribution modeling informed by estimates of future climatic conditions and various regional biophysical attributes to predict the potential habitat changes that each species will experience under a changing climate. We utilize connectivity mapping to identify corridors of species movement between current population hubs within the region, with respect to various biophysical boundaries. The combination of current landscape connectivity estimates and future species habitat predictions is further used to develop Priority Landscape Areas that are important to the conservation of our eight focal species in the bioregion.

Prioritization of the landscape allows for the demarcation of regions whose protection is necessary or helpful to meet conservation objectives throughout the bioregion. We then use our bioregional modeling outcomes to design a management plan tailored to the U.S. portion of Cascadia, in the Pacific Northwest. To minimize current and future human-induced impacts on wildlife, we spatially weigh future and current conflicting uses of the land with our priority recommendations. Specifically, we consider potential wind development, forest fragmentation, federal grazing allotments, and oil and gas plays and basins in the region to determine ongoing and potential threats to wildlife populations.

The management recommendations we set forth aim to secure and protect future climate refugia and land parcels essential to landscape connectivity for our eight focal species. We present recommendations on:

- Public land management and prioritization, particularly in Washington's Cascade Range and in Central Idaho
- Private land conservation priorities for maintaining connectivity between high-value priority areas in Washington
- Compromise regions for competing land use development in lower-ranked priority landscapes
- Special habitat protections for the Canada Lynx to account for absence from our aggregate modeling approach

Introduction

An entirely species-driven conservation approach has proven insufficient for the holistic management of landscapes that serve multiple land-uses. Our research considers the interaction of multiple species in an interconnected food web, as well as the anthropogenic land-uses that compete for allocation of resources in the Cascadia bioregion. We first consider the population viability of eight terrestrial species (Canada Lynx, Elk, Gray Wolf, Greater Sage-Grouse, Grizzly Bear, North American Beaver, Silver Haired Bat, and Snowshoe Hare) and map their habitat ranges under current and future climatic and land-use conditions using known occurrence data. We model landscape connectivity for each of the species, incorporating their habitat needs and movement restrictions in a circuit-theoretic connectivity model. We focus on the impact of current and future land-use allocations on the connectivity dynamics and priority habitat areas for the chosen species. With the objective of protecting current biodiversity patterns and identifying future climate refugia in light of a changing climate, we combine our connectivity analyses and future habitats to create a landscape prioritization map that addresses the conservation needs of the species. We contrast our conservation landscape prioritization against current and future competing land-uses, specifically wind development, forest fragmentation, federal grazing allotments, and oil and gas plays and basins, to inform landscape-level management recommendations that lessen human-caused strain on the species. Our management plan identifies critical, desirable, and advantageous areas for both conservation and competing land uses to better enable policy makers to balance development and conservation objectives in Cascadia.

Study Scope

Recognizing that political, economic and ecological contexts are significantly different across the U.S. and Canadian border, our management recommendations utilize information from our bioregional modeling process to inform a regional management plan for the continental U.S. portion of this region only. Our hope is that this focused plan might inform a comprehensive management scheme for the transboundary bioregion in future partnership with Canadian and Alaskan conservation entities.

Study Site

Cascadia is a transboundary bioregion that contains the Alaskan Peninsula, much of British Columbia, all of Washington and Idaho, most of Oregon, and small portions of Montana and Northern California. It is dominated by several mountain ranges, including the Coast Range, Cascade Range, Olympic Mountains, Columbia Mountains, and the Rocky Mountains. Within its 600,000 square miles, the region contains many terrestrial landscapes, including bunchgrass prairie, oak woodlands and savannahs, old growth conifer forests, riparian woodlands, fresh and tidewater wetlands, shrub steppe, taiga, rainforest, and tundra (Cascadia Institute 2015).

The region is home to approximately 17 million people (as of 2010) who predominantly live in dense clusters within metropolitan areas. Over 80 percent of that population lives on less than 10 percent of the region's land, with half the population in the cities of Seattle, Portland, and Vancouver, BC (Cascadia Institute 2015).

Human use of the of the landscape is diverse. Abundant forests in the region cover most of the Alaskan Peninsula, over 60 percent of British Columbia (Council of Forest Industries), one half of Washington (Washington Forest Protection Association) and Oregon (Oregon Forest Resources Institute 2010), and over 40 percent of Idaho (Our Public Lands). This resource has supplied a historically robust timber industry, although management for broader values and uses has caused industry declines in recent decades.

Much of this forested land (and other biomes) is federally-managed, particularly in the U.S. portion of our bioregion, including most of the Alaskan Peninsula, over 30 percent of the landmass of Washington state, 50 percent of Oregon and Washington (Pentland 2011), and over 90 percent of British Columbia (British Columbia Ministry of Water, Land, and Air Protection 2010). Cascadia contains six U.S. National Parks, over forty U.S. National Forests, and eleven Canadian Parks, all of which are

Figure 1: Cascadia bioregion

Large portions of Cascadia experience a mild climate, allowing for a highly diversified agricultural economy and long growing season (Washington Agriculture in the Classroom 2014). For instance, about 24 percent of Washington, Oregon and Idaho are devoted to agriculture, producing crops that range from orchard fruits, to grains, dairy, livestock, hay, and Christmas trees (Timmons 2014). Seafood industries are also prevalent within coastal communities throughout Cascadia.

The region produces much of its own energy from predominantly renewable sources. In the U.S. Pacific Northwest, major sources include hydroelectric, natural gas, biomass, and wind (U.S Energy Information Administration). In British Columbia, primary sources are natural gas, crude oil, hydropower, biomass and coal, with hydropower generation accounting for about 90 percent of total electricity used in the province (Energy BC).

Species of Interest

This report focuses on eight species that together represent a range of biodiversity and conservation concerns in Cascadia. They include ecosystem engineers, predator and prey species essential to their broader food webs, and species that are threatened, endangered, or of conservation concern within Cascadia. Most have direct trophic connections to other focal species in our study, with the exception of the Greater Sage-Grouse, which has a highly specialized habitat and is included because of its significant conservation interest in the American West.

The **North American Beaver** is a keystone species, promoting biodiversity through essential ecosystem engineering of riverine systems. Despite past threats to their viability, the are now abundant throughout their range, and are considered essential partners in maintaining the climate-resiliency of ecosystems.

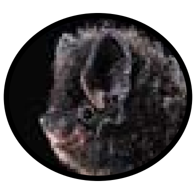
The **Canada Lynx** is listed as Threatened in the U.S., "Not at Risk" in Canada, and an IUCN species of Least Concern, indicating that it is most threatened within the southern reaches of its continental U.S. range. It is highly specialized, with Snowshoe Hare constituting 97% of its diet and a need for the deep snows of northern, boreal forests as habitat.

Elk (Roosevelt and Rocky Mountain) have overcome a history of over-hunting and are now abundant throughout western North America. Their browsing can cause notable impacts to forest structure and composition within their habitats. The species is highly valued for hunting by humans, and can pose management challenges related to conflicts with human uses (primarily road accidents, and agricultural and livestock operations).

The **Gray Wolf** is an IUCN species of Least Concern, Not at Risk in Canada, and has been de-listed within the U.S. (although certain populations still have localized protection). It is considered a keystone predator, and while very adaptive, is sensitive to habitat fragmentation and experiences high human-use conflicts (primarily with agricultural production).

The **Greater Sage-Grouse** was recently de-listed as a candidate species in the U.S, but is listed as Endangered in Canada and Near Threatened by the IUCN. They are highly dependent on sagebrush ecosystems and face habitat degradation challenges from human and energy development and agricultural practices.

The **Grizzly Bear** is a keystone species, and is listed as Endangered in the continental U.S., of Special Concern in Canada, and of Least Concern by the IUCN. Habitat fragmentation in the continental U.S. has created isolated population patches, including in northern Washington state and eastern Idaho and western Montana (within the Greater Yellowstone Ecosystem).



Silver-Haired Bats are abundant within their range, and provide essential ecosystem services by consuming a large quantity of insects. They require structurally diverse forests and old growth structure to roost, and can be threatened by forest management practices, pesticide use, and wind energy development.

The **Snowshoe Hare** is an essential prey species for many predators of conservation interest, including lynx, wolves, foxes and raptors. Their habitat requirements - forests with dense conifer understories - make them sensitive to forestry practices that remove this essential vegetation.

Mapping Priority Landscapes

Rationale

In keeping with the Yale Framework Matrix for climate change adaptation, this management plan is motivated by two primary land use planning objectives: the protection of current patterns of biodiversity where they exist, and the identification and management of future areas that will provide space for species expected to be displaced by climate change (Schmitz et al. 2015). The creation of a management plan that implements these objectives is achieved through a multi-step modeling process. We first consider the aggregate needs of our eight focal species by assessing their current patterns of occurrence across Cascadia, as well as the relationship of those patterns to habitat features and climatic conditions. We then use that information to model predicted areas where suitable habitat will be lost and gained under future climate scenarios of varying greenhouse gas emission intensities. We conduct circuit theory connectivity mapping to ascertain which portions of the landscape may be essential for movement as species adapt their ranges in response to changing climate conditions. Finally, we narrow our focus to the socio-political contexts of the U.S. Pacific Northwest, in an attempt to consider how human uses may conflict with conservation in areas identified as essential to our species. Through this process, we are able to make informed predictions about our eight species' habitat and climate needs, propose the prioritization of landscapes for conservation, and consider land use planning compromises that allow future development to coexist with species conservation efforts.

Modeling Approach and Methodology

In order to identify priority landscapes for conservation, we use the following five-step modeling approach:

1. Create current species distribution models using climatic and biophysical landscape features as predictors of species occurrence.
2. Model future species habitat distributions in response to varying levels of greenhouse gas emissions and temporal scales.
3. Estimate each species' capacity to move across the landscape in response to various biophysical and environmental features.
4. Identify and aggregate the most critical areas from the previous 3 steps into a final layer of priority lands across all species and the landscape.
5. Compare the presence of and potential for various land use conflicts with prioritized lands to provide management recommendations that pragmatically meet both conservation and social goals.

We create Species Distribution Models (SDMs) using current and future climatic data and biophysical features of the landscape. To do so, we employ the maximum entropy method (Maxent). We first use an iterative regression approach to determine the most statistically significant climatic predictors of species occurrence. These predictors are then employed to model species ranges with and without incorporating landscape and species-specific enduring features. Specific biophysical features of the landscape are also considered depending on the natural history of every species. Similar processes and predictors are then used to model the future habitat distributions of our species of concern in response to various greenhouse gas emission scenarios.

We present two maps for both current and future climate-based SDMs: one depicting aggregate species habitat distribution across the landscape on an overall priority scale of 1 to 10 (10 being the highest overall priority and 1 being the lowest), and a second showing the three highest priority habitat areas distilled from the aggregate map. Landscape connectivity predictions for each species, created using Circuitscape software, are also been aggregated and mapped on a scale of 1 to 10 (10 being the highest overall connectivity) across the landscape. This aggregate map is similarly distilled into a projection of the three highest priority connectivity areas across all species.

Our objective is to provide management recommendations that preserve current biodiversity hotspots, while also identifying and preparing for the provision of future habitats due to changes in climate. To this end, we then combine high priority future habitats with high priority connectivity areas to generate a final output of land within the bioregion that is key to the viability of our focal species. This map allows us to account for the space needed by every species for movement from current habitats to possible future habitats. This landscape-level prioritization map is presented in 3 categories, each of which is briefly defined, as follows:

- **Advantageous for conservation goals:** this land is beneficial, but not critical, to the preservation of aggregated species habitat and connectivity
- **Desirable for conservation goals:** this land is necessary to achieve long-term aggregated habitat and connectivity conservation goals
- **Critical for conservation goals:** this land is indispensable for species' current and future viability

Species Distribution Analyses

For each species of interest, we model habitat distributions under current and future climate scenarios, with and without accounting for various landscape-level enduring biophysical features. These habitat distributions of individual species are then combined to present aggregated maps of priority land for each species with respect to various combinations of predictive variables. Finally, future habitat distributions are analyzed in relation to baseline current distributions for each species to provide an estimate of the potential habitat lost or gained within the Cascadia bioregion by each species over time.

Current habitat distributions incorporating climatic variables alone, and in conjunction with various species-specific enduring features layers, can both be found as Appendix E. Future habitat distributions incorporating species-relevant climatic variables can be found as Appendix G. See Appendix C for a list of climatic layers selected for use in distribution modeling for each species, per multiple linear regressions conducted to determine the most significant predictors of species occurrence.

Current Species Habitat Distributions

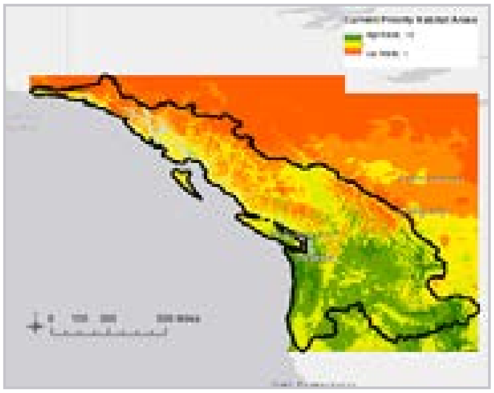


Figure 2: Aggregated Current Priority Habitat Areas based on individual species distribution models

Figure 3: Three Highest Priority categories of the Aggregated Current Priority Habitat Areas

As seen in Figure 2, there is a clear vertical transition in overall current habitat suitability from the south to the north for our species of interest within Cascadia. Current species distributions are clustered in the southern regions of the project area, with the highest aggregated priority habitat generally shifting to mid-quality habitat at the Canadian border. As one moves further northward into Canada, habitat becomes decreasingly suitable for a majority of the species considered. Figure 3 shows the most suitable aggregated habitat broken into three priority levels. The most suitable land areas fall generally in the southern reaches of the bioregion.

Future Species Habitat Distributions

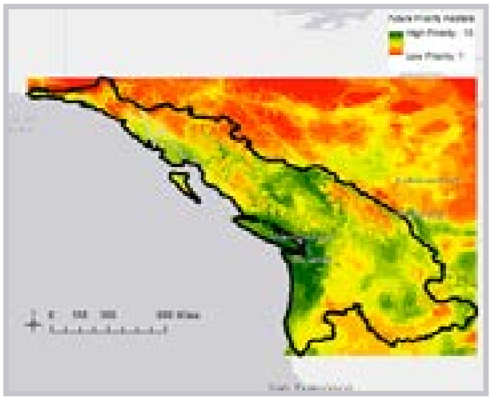


Figure 4: Aggregated Future (2050) Priority Habitat Areas based on individual species distribution models

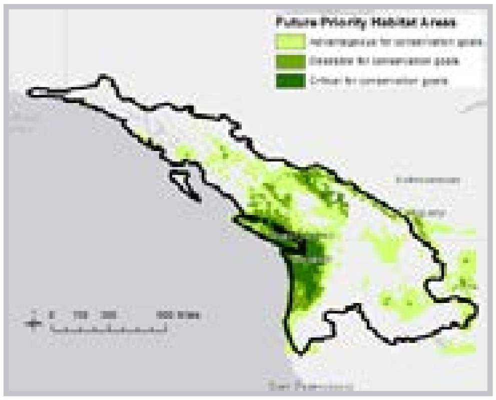


Figure 5: Three Highest Priority categories of the Aggregated Future Priority Habitat Areas

When compared to current species habitat distributions as shown in Figure 4, a northward trend of species habitat distribution in response to climate change is seen over the next three decades. Areas in Canada become more crucial for conservation, as a greater number of species come to inhabit the region. The southwest of the Cascadia region continues to remain crucial climate refugia for focal species,, with only slight northward movement of prime habitat.. Figure 5 presents the three most suitable classes of aggregated habitat from Figure 4, classified into three priority levels, with the most suitable land areas falling generally in the southwestern corner of the Cascadia bioregion.

Habitat Lost and Gained Over Time

For a better understanding of the changes in key habitat areas for each species as a result of climate variability over time, we model the difference between current and future habitat distributions (Appendix H).

North American Beaver

There is a clear northward trend in movement of suitable beaver habitat in response to heavy greenhouse gas emissions over time. Large patches of habitat are lost in the southern regions of Cascadia, while future suitable habitat is gained and retained primarily along the northern coast.

Canada Lynx

A northeastern shift out of the bioregion is evident for the Canada Lynx in response to high greenhouse gas emissions over time. The Lynx loses its core habitat in the northeastern parts of Cascadia, and suitable habitat shifts almost entirely out of the United States and into British Columbia.

Elk

The Elk performs favorably under higher levels of greenhouse gas emissions over time. The species not only retains the majority of its key habitat within Cascadia, but also gains additional suitable habitat along the coast, and to the north of its current key habitat.

Gray Wolf

The Gray Wolf also fares well under heavy rates of greenhouse gas emissions over time. The species retains the majority of its southern habitat within the project area, while also gaining significant area along the northern part of the Cascadia coast.

Greater Sage-Grouse

The Greater Sage-Grouse loses a significant amount of key habitat within our project area under the modeled climate conditions. Within Cascadia, the species range contracts heavily and moves northward. (Outside of our project area, the habitat range similarly contracts into northern pockets of the Great Basin sagebrush steppe). Only small, fragmented refugia of key Sage-Grouse habitat remain in the bioregion.

Grizzly Bear

Under high levels of greenhouse gas emissions, the Grizzly Bear loses a significant portion of its southern range in Cascadia. However, the species does gain strips of land along the eastern boundary of the bioregion in the northern Rocky Mountains.

Silver-Haired Bat

Key habitat for the Silver-Haired Bat contracts from both the northern and southern extents of its range within Cascadia into a large coastal pocket. The species does gain some riparian habitat in the southeastern region of the project area.

Snowshoe Hare

Snowshoe Hare habitat conditions follow a predictable, northward-moving trend under high levels of greenhouse gas emission over time. The species gains some northern and eastern key habitat within the bioregion at the expense of its southern coastal range.

Connectivity Analysis

An understanding of landscape connectivity is imperative for meeting the long-term conservation needs of species populations. A connected landscape allows for the flow of both individuals and genes to and from source and sink populations of a given species. Uninhibited species movement is also essential to allowing the future habitat range of a species to shift as it adapts to changing climate conditions.

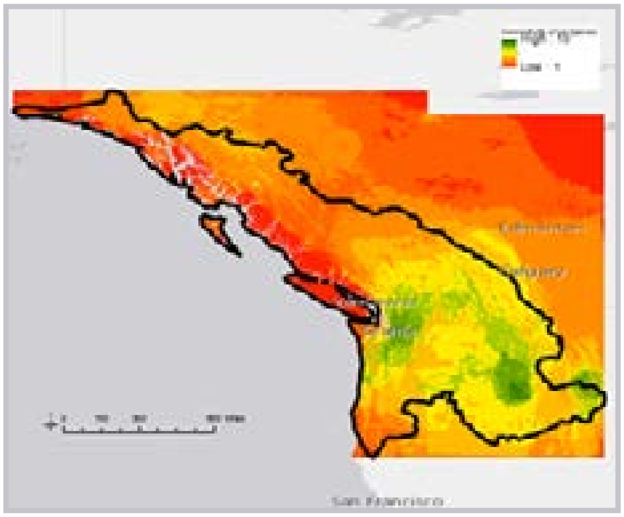


Figure 6: Aggregated connectivity map of all species

Figure 7: Three highest priority categories of the aggregated connectivity map

Figure 6 presents the aggregate of connectivity maps for all eight focal species. Little connectivity is observed across the northern segments of the bioregion. However, higher connectivity is apparent in the southern regions of the project area. Figure 7 depicts the regions of highest priority for landscape connectivity. The three highest classes of priority as per the aggregate of the species connectivity maps (Figure 6) are presented in Figure 7.

Priority Conservation Areas

Using the methods and results described above, we were able to identify key land areas that serve both the current connectivity and potential future habitats required by a majority of our species. We now combine the results of both our future species distribution modeling and connectivity analyses to generate an output that identifies land parcels that meet both the characteristics of climate refugia and low-resistance landscapes for species movement. This approach ensures that species ranges will be able to effectively expand and contract to priority habitat areas under various future climate scenarios.

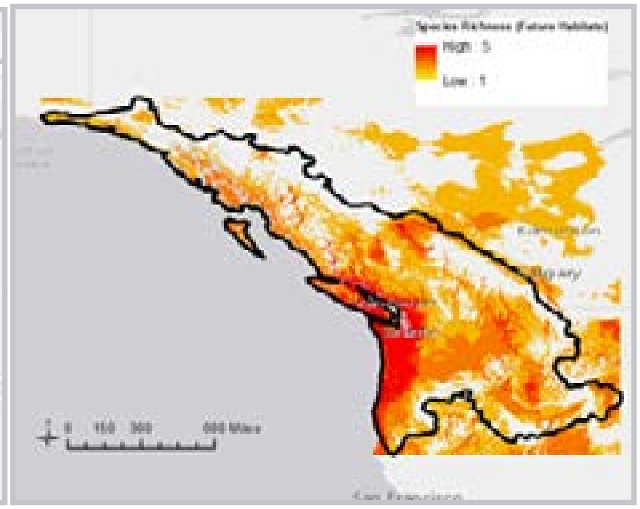


Figure 8: Landscape Prioritization representing the sum of all future high priority habitats (Fig. 5) and current connectivity high priority areas (Fig 7)

Figure 9: Species Richness of the Cascadia bioregion based on the summation of eight individual species distribution models based on future climate predictions

Figure 8 presents landscape prioritization for Cascadia as a combination of high priority current connectivity landscapes and high priority future habitat areas. Priority conservation areas occur primarily in the mid- to southern-segments of the bioregion, which include areas in and around the cities of Vancouver and Seattle.

Figure 9 presents an alternate method of identifying priority landscapes which we considered in this study: an approach based on species richness. This approach values habitat on the basis of the number of species present upon it. The individual species future habitat distribution maps are combined to present the richness of the landscape.

As several of our eight focal species, including the Canada Lynx and Greater Sage-Grouse, have distinct, highly specialized habitat needs, we found that a species richness map was less useful in identifying priority landscapes for their range of requirements. Figure 8 takes into consideration the aggregate of all the species distributions and connectivity areas allowing for equal weighting of all the species as well as equal consideration of priority habitats and connectivity corridors, which are essential for the species movement. In the case of a species richness approach to landscape prioritization, areas with fewer than three to four species using the landscape would most likely not be considered as priority landscapes for conservation, thus favoring only a few select species. Connectivity corridors are disregarded by the species richness map which are crucial for the movement of species from the current habitats to future climate refugia with a changing climate. For this reason, we refer to the map of aggregate current connectivity and future habitat areas in the design of our management proposals.

Competing Land Uses

Wind Energy Potential

New state policies that encourage the expansion of renewable energy have caused an influx of wind farm developments in the Pacific Northwest in recent decades. While these developments have largely been limited to private lands, opportunities have increased since a 2009 White House Executive Order directing federal agencies to implement renewable energy projects on federal lands (Council on Environmental Quality 2009). The Bureau of Land Management has an active national wind energy program, and the U.S. Forest Service has published agency directives on wind energy projects (although none have yet been approved). Wind farms have a wide footprint, requiring turbine installation, transmission facilities, roads, and other infrastructure that present considerable conservation management challenges. Impacts to wildlife include habitat loss, modification and fragmentation, fire hazards, collision mortalities, and impacted hydrology. Landscapes of greatest interest to wind generation include uplands, grasslands, and offshore coastal areas. (Mockrin 2012)

In mapping the overlap between our priority conservation areas and future wind development potential, there are several portions of priority habitat with high potential for wind energy development, primarily a strip along the Cascade Range and clusters in central and eastern Idaho.

Developing wind energy in these areas could have significant implications for various species of concern. In North America, around 80 percent of bat fatalities at wind energy facilities are of migratory, tree-roosting species, including the Silver-Haired Bat (Baerwald 2014). Within Cascadia, the bat lives primarily along the coast, as well as riparian zones that stretch to the eastern boundaries of Washington and Oregon (Appendix D/ E).

Additionally, these pockets become increasingly critical habitat refugia under various future climate scenarios (Appendix G). With greater wind energy development in our priority habitat and along bat migratory routes, the likelihood of bat fatalities rises dramatically, and the viability of the species declines as a result (Baerwald 2014).

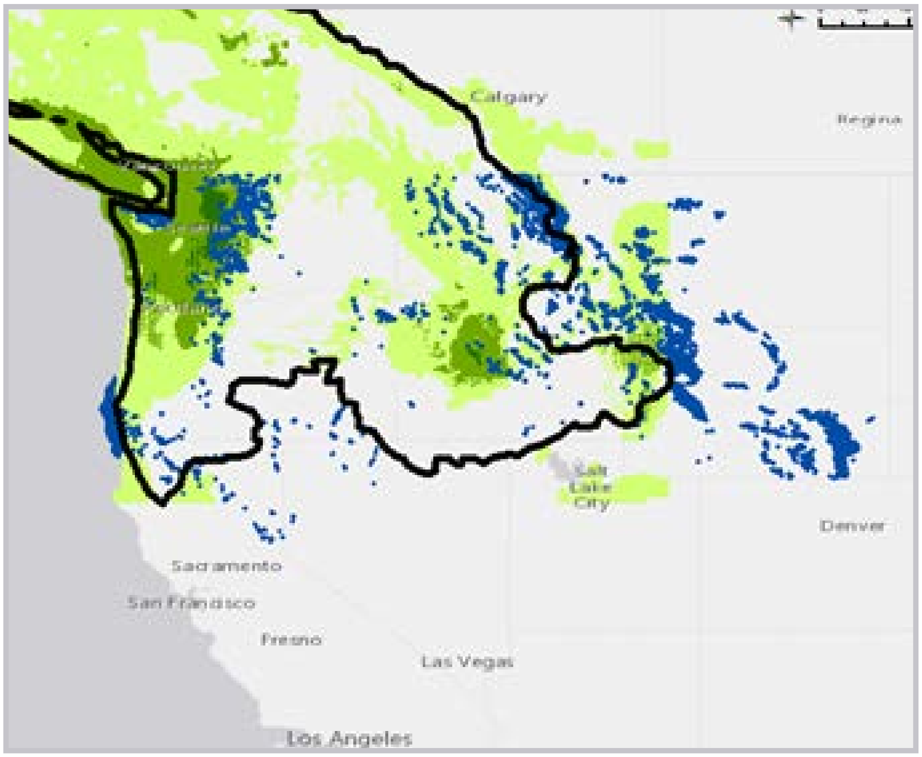


Figure 10: Wind Energy development potential in and around the Cascadia bioregion contrasted against the landscape prioritization map

Forest Practices and Fragmentation

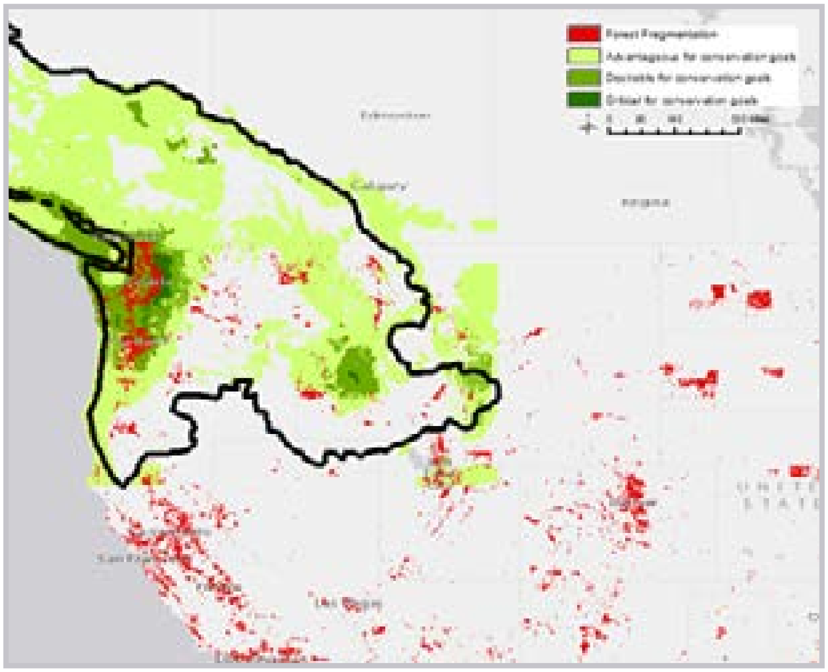


Figure 11: Forest Fragmentation in the Cascadia bioregion contrasted against the landscape prioritization map

Approximately half of the Pacific Northwest land base is forested, with wetter temperate forests west of the Cascades and drier forests to the East. Timber-dependent industries were largely responsible for supporting rural economies through wood products and pulp and paper production. However, the advent of new environmental regulations and biological studies dating back to the 1970's has resulted in new species protections, new public land planning standards, and a renewed emphasis on managing for multiple uses and biodiversity. As a result, forest-based economies in the Pacific Northwest have declined significantly, and federal land management agencies experience continued pressure to increase timber contracts and support other rural, forest-based job opportunities (Cashore 1999).

The region's history of forestry and timber practices has caused significant declines in the abundance of old growth forests and mixed-successional forests containing dead snags and coarse woody debris. Past intensive timber production has resulted in forest simplification, and habitat fragmentation has been caused by road construction and land-use conversion, leaving patchy, isolated forest stands and a reduction in interior habitats (Swanson 2005).

Many of our species of interest require large connected tracts of land to serve as home ranges and migratory habitat. As an example, the Grizzly Bear requires a home range between 50 to 500 square miles per individual, and its movement is highly sensitive to forest fragmentation and road development. The Elk, Gray Wolf, and Canada Lynx are all similarly threatened by forest fragmentation and human development (Appendix D).

The results of our forest fragmentation analysis are meaningful when considering the aggregated priority habitats of our species of interest. The highest rates of forest fragmentation caused by human development occur around heavily populated regions along the coast. However, despite human presence, these regions remain the most suitable habitat for many species of concern, and the importance of these areas as future habitat refugia increases under various climate change scenarios. As population densities increase along the coast and the land surrounding areas of high population density becomes more heavily fragmented, species will become decreasingly viable in the bioregion and less connected across the landscape as a whole.

Grazing

Federal grazing allotments are prevalent throughout eastern Oregon and southern Idaho. They are present but less dominant within western Montana and northern California, and have a small presence in eastern Washington. Grazing is a highly contentious public land use: critics claim the practice destroys vegetation, contaminates waterways, damages soil, and is generally incompatible with maintaining biodiversity; proponents argue that ranching permittees are stewardship partners who maintain important habitat and open spaces for wildlife and other uses. The tension between these positions has resulted in a decline in the prevalence of public land grazing over time (Bureau of Land Management 2016). Similar to impacts on forestry practices, federal managers now place greater emphasis on balancing many competing land uses under their multiple-use mandates. For that reason, permits for grazing allotments are increasingly being considered for non-renewal, permanent retirement, or creation of "grass banks" in order to address the values of varied constituencies (Western Governors Association 2014).

When existing grazing allotments are compared to the locations of our priority conservation areas, the greatest overlaps are visible in eastern, southern and central Idaho. In this area, allotments fall within an important section of desirable priority landscape, as well as large portions of a surrounding advantageous landscape that follows the spine of the Rocky Mountains. This habitat is especially critical to the Greater Sage-Grouse, which is adapted to and dependent on sagebrush that is only found in shrubland/steppe ecosystems. Additionally, a 2012 federal evaluation of rangeland health reveals that most grazing allotments in this region do not meet "land health status" requirements (PEER 2012).

Land managers and grazing permit holders are already constrained and guided by state and federal management plans designed to restore Greater Sage-Grouse habitats and prevent the eventual listing of this species. In support of this goal, federal, state and local entities are deploying a suite of new resources to implement conservation practices on the ground.

This is cause for optimism that grazing impacts to our priority habitats are already being addressed. However, because grazing leases will continue to experience scrutiny in favor of alternate uses, the map above (Figure 12) provides insights as to which leases could be selectively and strategically phased out to achieve conservation objectives, particularly leases within habitat that is desirable for conservation goals (the highest level impacted).

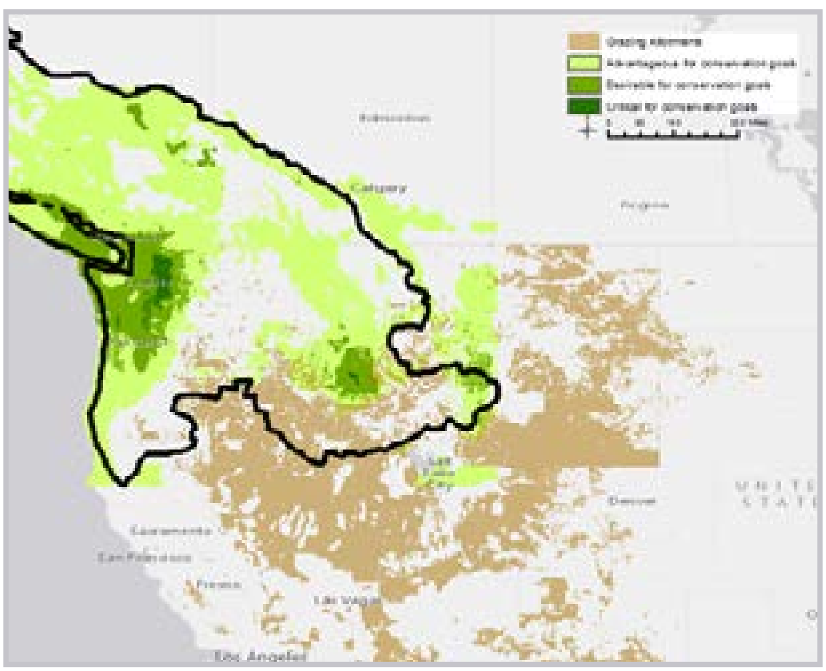


Figure 12: Grazing allotments in the Cascadia bioregion contrasted against the landscape prioritization map

Oil and Gas (Plays and Basins)

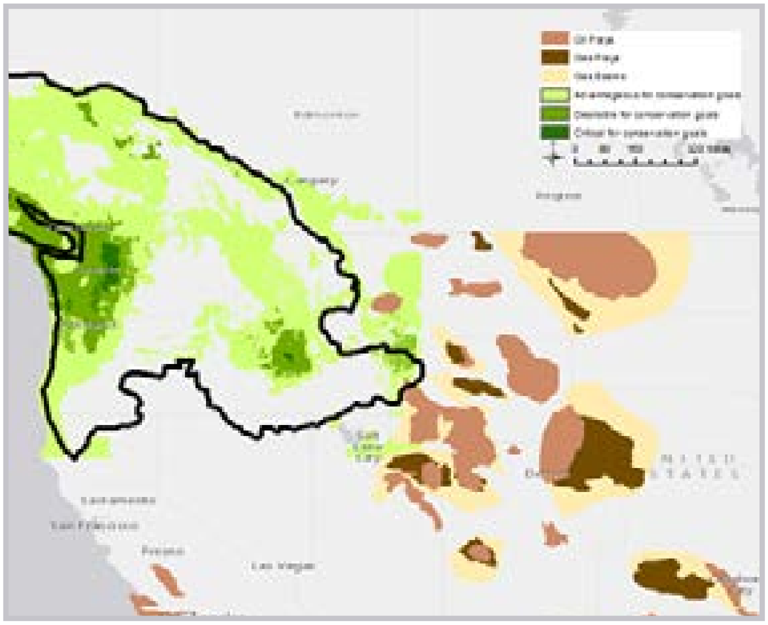


Figure 13: Oil and Gas Plays in the Cascadia bioregion contrasted against the landscape prioritization map

Domestic oil and gas production continues to play an important role in the midwestern United States and the Pacific Northwest (Bureau of Land Management 2016). Historically, drilling for oil and gas has caused significant surface disturbance throughout the western U.S. and has degraded and fractured large regions of habitat critical to the viability of various species (Wilbert et al. 2008).

Several species of concern depend upon continuous, undisturbed landscapes in order to maintain viable populations. Thus, further encroachment of oil and gas production into the Pacific Northwest would have considerable implications for the future biodiversity and ecological well-being of the region. In particular, the greater sage-grouse has faced continuous habitat destruction as a result of expanding human development and energy infrastructure in the west. Because the species is so dependent upon large, conterminous patches of sagebrush steppe, infiltration by oil and gas projects on the landscape significantly decreases the viability of bird populations, as well as the connectivity of the source and sink populations that remain (Braun et al. 2002).

We considered the potential risk for encroachment of oil and gas into our bioregion by examining the presence of current oil and gas basins and plays (Figure 13). We found very little presence of oil and gas reserves in our bioregion, suggesting little threat of land degradation as a result of future oil and gas expansion. However, the heavy presence of oil and gas wells to the immediate southeast of the bioregion does have important implications for the population dynamics of various species within our project area.

As an example, the range and priority habitat of the greater sage-grouse extends only slightly into the southeastern regions of the Cascadia bioregion, with sink populations existing within its boundaries. Continued obstruction and land degradation caused by oil and gas development in the Great Plains has the potential to inhibit movement from source populations to our bioregion, and severely decrease the viability of sage-grouse source populations. With decreased connectivity between populations as a result of increased development, the flow of individuals and genes into Cascadia would likely drop, greatly influencing the viability of the sink populations within our area of interest. A similar dilemma exists when accounting for grizzly bear populations that exist to the southeast of this region, particularly those in the Bitterroot and Yellowstone populations. These bear populations could be significantly harmed by increased development throughout the midwest as a result of their high sensitivity to land fragmentation and road infrastructure, large home ranges, and reliance on large, conterminous patches of undisturbed mosaic landscape.

Management Proposals

Current Political Boundaries

Our three Priority Conservation Areas are foundational to the design of management proposals for the U.S. Pacific Northwest portion of our bioregion. Three levels - *critical*, *desirable*, and *advantageous* - represent a scale of habitat priorities that provide necessary biophysical and climatic features for our eight focal species, as well as connectivity corridors that facilitate movement as species shift their ranges in response to climate change. However, additional analyses are important to place these landscape priorities into a regional context.

Figure 14 overlays the boundaries of **U.S. federal lands** with our Priority Conservation Areas. Much of our priority areas are already under the management of federal agencies, visible along the Cascade Range in western Washington, and in central Idaho.

It's important to note that in Washington, a portion of this federal overlap includes the North Cascades National Park and Olympic National Park. Because these lands experience a high degree of protection from human development, they offer the most secure sources of habitat and climate refugia over time. However, surrounding both Parks and in central Idaho, much of our federal overlap is with land managed by the U.S. Forest Service or the Bureau of Land Management. These are subject to a higher degree of multiple and impactful uses, including recreation, grazing, timber harvests, and energy development. Here, land management that prioritizes habitat conservation and limits disruptive human uses will be vital to protecting biodiversity.

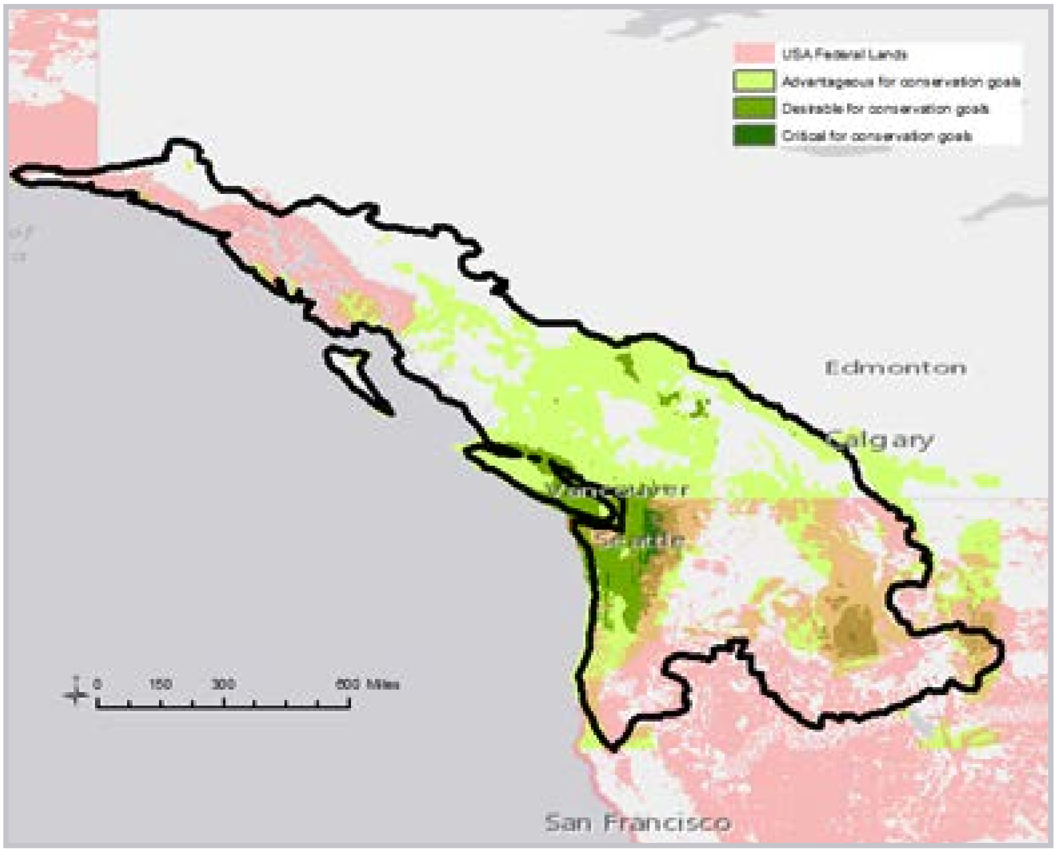


Figure 14: US Federal Lands as compared to the Cascadia bioregion landscape prioritization map

Private lands along Washington's coast are perhaps the most vulnerable within our study area. These lands are almost entirely *desirable* priority conservation areas, offering a high degree of favorable habitat. However, this coastal stretch is also home to major human developments, including the cities of Bellingham, Seattle, Tacoma and Olympia. To maintain the value of habitat in this region, a section of private land located south of Olympia may be a high-impact area to conserve. Seen in Figure 15, it separates two islands of federal land that receive primarily *critical* and *desirable* prioritizations in our analysis. Improving and maintaining connectivity between these priority landscapes may be essential to protecting species viability under future climate conditions.

Figure 15: Federal lands in Washington. From: http://www.wilsoncreek.org

Species-Specific Concerns

Our priority area selections account for an averaged, aggregate utility of the land across all eight of our focal species. This holistic management approach allows us to consider the ecological needs of the landscape as a whole, while not focusing on the wellbeing of certain species at the expense of others. Our priority selections account for an averaged, aggregate utility of the land across all eight of our focal species. This holistic management approach allows us to consider the ecological needs of the landscape as a whole, while not focusing on the wellbeing of certain species at the expense of others.

However, we also consider the effectiveness of our overall recommendations on a species-specific basis to determine whether all species of concern are served by our proposals.

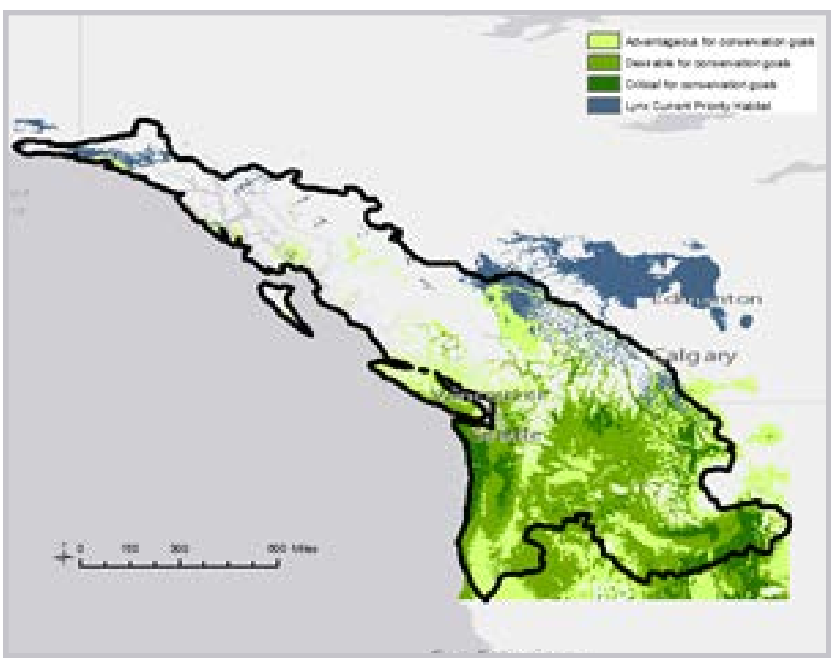


Figure 16: Canada Lynx current priority habitat contrasted against Current Priority Habitats as presented in three categories

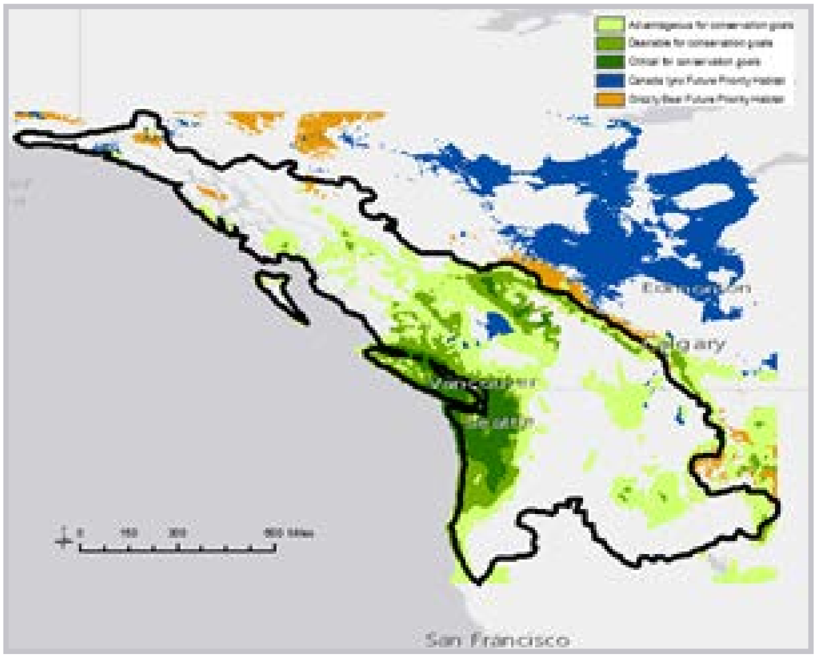


Figure 17: Canada Lynx and Grizzly Bear Future Priority Habitats contrasted against Future Priority Habitats as presented in three categories

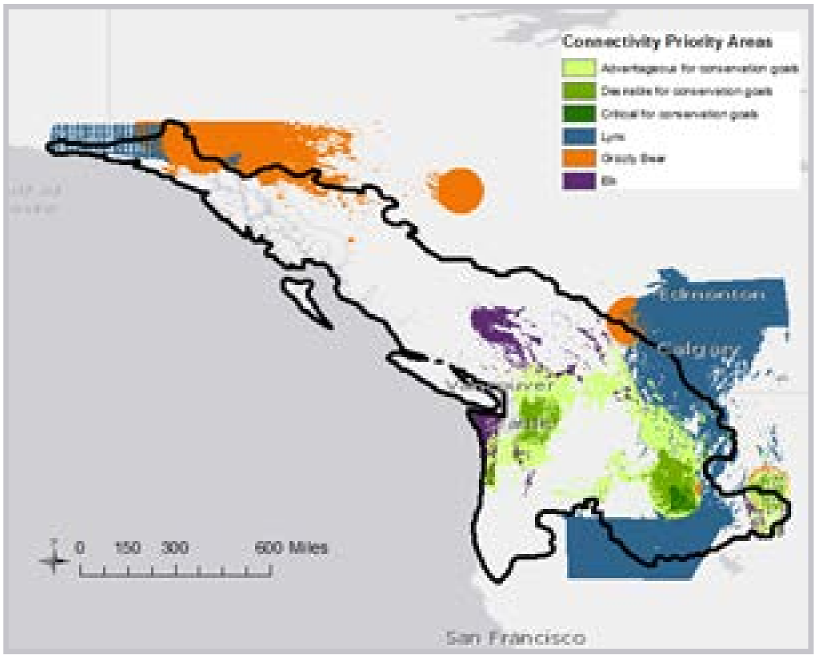


Figure 18: Canada Lynx, Grizzly Bear and Elk connectivity priority areas contrasted against the Aggregate high priority connectivity areas

A review of Figure 2, an aggregate of current habitats for our focal species, makes clear that not all favorable habitat for individual species is represented. For example, Figure 16 contrasts the priority habitat of the Canada Lynx with our aggregated priority habitat areas. Current Lynx priority habitat, while accounted for in our landscape-level priority recommendations, lies almost exclusively outside of our Priority Conservation Areas. Similarly, Figure 17 contrasts aggregated future priority lands with the habitats of species whose future ranges are not well represented by our management recommendations. The future priority habitats of the Lynx and Grizzly Bear are further north of the aggregated priority habitat. Finally, Figure 18 presents the aggregated connectivity priority areas against the connectivity priority areas of select species- the Canada Lynx, Grizzly Bear and Elk. As can be seen the lands most essential for movement of these three species is largely unrepresented in our prioritization recommendations. This has significant implications at the species-level when consideration the adoption of our management plan.

These findings demonstrate the need for species-specific accommodations when using our priority landscapes to design a management plan. Specifically, the habitat needs of the Canada Lynx, and connectivity corridors for the Lynx, Grizzly Bear and Elk should receive additional conservation consideration.

Competing Uses

Existing and future competing land uses will pose challenges for landscape conservation and require compromises that allow human development and viable wildlife populations to coexist.

Wind energy potential along Washington's Cascade Range overlaps with both *critical* and *desirable* habitat. However, the presence of the North Cascades National Park provides a degree of protection to the region. Parks land is not available to wind development, and in addition, the agency actively works to avoid cross-boundary impacts to Park features (including wildlife and habitat) through coordination "...with other federal and state energy and environmental protection agencies, local zoning boards, and research institutions" (National Parks Service 2016). Within Idaho and western Montana, there is an abundance of high wind potential areas that overlap with our lowest level of priority landscapes (*advantageous*). In these less critical areas, compromises with energy developers may be considered in order to protect more valuable and essential habitat within *critical* and *desirable* landscapes.

Forest Fragmentation due to timber harvest practices correlate with many of the same essential habitats along the Cascade Range in Washington. Future timber practices should consider the ecological damages of tree removal on local species, and seek to retain legacy trees and snags for old-growth dependent species like the Silver-Haired Bat (Hayes and Wiles 2013), and mosaiced landscapes critical to Grizzly Bear and Elk (Montana Fish, Wildlife, and Parks 2006). There is great potential for federal land managers implement and enforce standards of ecological forestry on lands under their management.

Federal grazing allotments overlap with our priority landscapes in central Idaho, but existing and ongoing Greater Sage-Grouse restoration efforts are also focused in this region and are likely to promote the conservation of this landscape in a manner that is complementary to our management goals. Additional gains could be made by identifying opportunities to phase out federal grazing permits that fall within habitat that is considered *desirable* for the conservation and viability of our focal species.

Oil and gas plays and basins fall almost exclusively outside of our region's boundaries, which means that future development poses no strong threat of direct impacts within our study area. Only indirect conflicts between species viability and oil and gas development exist. The proximity of plays and basins immediately outside of the bioregion has strong implications for the connectivity of source and sink populations within and outside of its boundaries. While oil- and gas-specific management recommendations are not appropriate within the bioregion, this stresses the need for transboundary conservation solutions that meet the needs of whole, dynamic wildlife populations.

To view competing land uses holistically, we aggregated areas with current and future potential development using a presence/absence averaged scale (Figure 19). This map represents the highest priority lands for competing uses overall, and gives priority to areas where the highest total number of conflicting land uses has the potential to occur. Individual competing use maps are useful for narrowing in on each use.

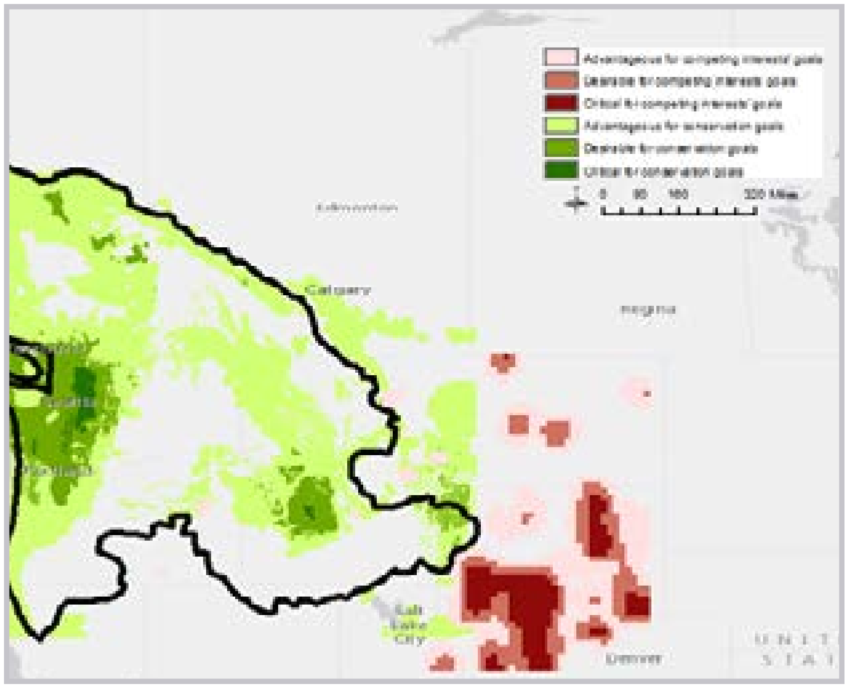


Figure 19: Conflicting land uses in and around the Cascadia bioregion presented in three categories of priority

Summary Narrative

The objective of our management plan is to provide recommendations that preserve current biodiversity patterns and prepare the region's ecology for future climate conditions. We are motivated by two primary land-use planning goals within the Yale Framework Matrix: the protection of current patterns of biodiversity where they exist, and the identification and management of future areas that will provide space for species expected to be displaced by climate change (Schmitz et al. 2015). Using a five-step spatial and statistical modeling approach, we have identified three levels of favorable habitat that represent key land in need of protection to ensure current and future species viability and climate change adaptation. With priority conservation lands determined, we then narrowed our focus to the socio-political contexts of the U.S. Pacific Northwest and examined current and future development and competing land-use threats to our conservation objectives. This process provided us the capacity to predict the habitat and climate needs of our eight focal species, prioritize landscapes for conservation, and balance human social and economic goals with species conservation efforts.

Federal Lands: We recommend a federal policy that manages both *critical* and *desirable* areas (our two highest priority conservation areas) for the primary benefit of species' current and future habitat requirements. Because small pockets of *critical* habitat are encircled and connected to one another by larger areas of *desirable* habitat, inclusion of both categories is essential to meeting our stated management objectives. On National Park lands, which are largely protected from development, these objectives are already central to their current management priorities. For the U.S. Forest Service and the Bureau of Land Management, two agencies that must weigh statutory multiple-use requirements and a varied constituency of users, this may require garnering public and political support, and developing new management plans. Forest fragmentation and federal grazing allotments are specific practices called out in our study as impacting high-value habitat for our eight focal species. Higher forestry practice standards, and the strategic retirement of grazing permits in central Idaho, will contribute to maintaining valuable habitat and connectivity on federal lands in our priority areas while still allowing for the continuation of these uses - whether in less impactful ways, or on alternate sites.

Private Lands: A region of private land south of Olympia, Washington provides important connectivity between Priority Conservation Areas under federal management in the Olympic Peninsula and along the Cascade Range. Should this private land experience an expansion of development over time, which is likely given its proximity to urban centers, connectivity between these islands of public land would easily be threatened. Efforts to conserve and protect habitat, and facilitate movement in this region should be aggressively pursued, through mechanisms such as land easements and wildlife corridors.

Compromise Zones: Figure 19 demonstrates that the highest-value lands for overall competing land uses (wind energy, forest practices, federal grazing allotments, oil and gas) fall mostly outside of our Priority Conservation Areas. However, when viewed individually, there are areas of overlap with most competing uses and our conservation areas (excluding oil and gas). This plan would propose that competing uses be phased out, or severely limited, in both *critical* and *desirable* areas. This would most heavily impact forestry practices and wind energy potential that is notably strong along the Cascade Range in Washington (see Figure 10 and Figure 11). To a lesser degree, this would also require the retirement of a small amount of federal grazing leases in central Idaho (Figure 12). However, our management plan proposes that our third level of priority conservation (*advantageous*) be considered "compromise zones." While these lands are beneficial to our species conservation objectives, they are less essential than *critical* and *desirable* areas, and offer continued or expanded human development for wind energy, federal grazing, and forestry.

Supplemental Conservation for the Canada Lynx: In verifying the soundness of our modeling outcomes, we found that most *critical* portions of the Canada Lynx habitat and connectivity corridors lie outside the Priority Landscape Areas we identified (Figure 16, 17 and 18). Sink populations of the Lynx do exist within some parts of priority areas in Washington, and they are provided protection through the North Cascades National Park and the protected national forests around it. However, for the population viability in the United States, the source population of the Lynx east of Cascadia, primarily lying in Canada, must be protected. Connectivity corridors leading from the source population in Canada to habitats in our bioregion should be strengthened through a reduction in forest fragmentation in parts of British Columbia that border Washington and Montana. National parks on the border of Canada and the United States, namely, the North Cascades National Park in Washington, should strengthen connectivity corridors to Canada. There is need for more collaboration between the Canada and the United States given the unique case of the lynx source-sink population dynamics.

Appendix A:

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Appendix B:

Detailed Methods

Detailed Methods

For every species chosen, occurrence data was derived from Global Biodiversity Information Facility (GBIF). GBIF data is primarily sourced from direct human observation or compiled from peer-reviewed literature. Species occurrence data were compiled and cleaned. A sample project area of the Cascadia bioregion was created in ArcGIS. This project area was used as the spatial bounds for all raster layers subsequently considered in this analysis. Current and future climate data was obtained from WorldClim. Current climatic data is of a 10 arc-minute resolution. Future climate GIS data was obtained from the Hadley Global Environment Model 2 - Earth System (HadGEM2-ES), using the 'bioclimatic' data under the Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathways (RCPs) of 2.6, 4.5, 6 and 8.5 for 2050 and 2070. Enduring features considered for species include elevation, land cover, water bodies and the presence of sage brush. These variables have been considered to identify the unique ecosystems that each species requires within the Cascadia bioregion, which is imperative to meet the objective of preserving the current patterns of biodiversity as per the Yale Framework matrix.

Species Distribution Modeling:
A subset of the occurrence data derived from GBIF was selected and presence and pseudo-absence data points were created to produce a linear regression model that assumes climate data layers as potential predictors of species occurrence. GLM linear regression was then run a second time to determine only the most statistically significant climatic layers that serve as predictors of occurrence data for each species. Finally, the occurrence data subset was fit to a maxent model based on climate predictors and displayed in ArcGIS (Appendix E and Appendix G). For each species, occurrence data was resampled and converted to a spatial object employing the same resolution and extent as the project area layer.

The following table presents the Bioclim layers identified through General Linear Modeling (GLM) and used to run a species distribution model for each of our eight species under the current climatic models. The significance level of 0.01 was used to select the Bioclim layers.

Species	Bioclim Layer
Canada Lynx	5
Elk	3, 4, 8, 10, 11, 12, 13, 14, 16, 18, 19
Gray Wolf	1, 10
Greater Sage-Grouse	2
Grizzly Bear	4, 10, 11
North American Beaver	12
Silver Haired Bat	11, 19
Snowshoe Hare	1, 5, 10

Detailed Methods

A similar process was used to generate a second model that considered only enduring features within the Cascadia bioregion as potential predictors of the distribution of each species. The enduring feature layers were reprojected using a common coordinate system, and were given a consistent extent to allow for comparison of the rasters. Enduring features files were then stacked and cropped to the project area. Linear regression and advanced spatial modeling were again performed, using both climatic variables and enduring features layers as predictors of the geographical locations of a subset of occurrence data (Appendix C).

Projected climate data from four IPCC RCPs were collected for both 2050 and 2070 under the Hadley Global Environment Model 2 - Earth System (HadGEM2-ES) climate model. The RCPs represent four possible climate futures deemed possible depending on the levels of greenhouse gas emissions in the near future. Nineteen distinct layers were collected for each RCP2.6, RCP4.5, RCP6, and RCP8.5 for both 2050 and 2070. The RCPs represent four possible climate futures deemed possible depending on the levels of greenhouse gas emissions in the near future. For the purpose of a comparison to current SDMs, the report has focused on RCP 8.5 for 2050. The RCP 8.5 assumes the 'business-as-usual' scenario and accounts for no climate change mitigation action before 2100 (Liddicoat et al. 2013). Of the nineteen distinct 'bioclim' layers, only the previously determined statistically significant climate variables were used to create SDMs for individual species (Appendix B). Spatial modeling was again used to generate 8 distribution models (Appendix G) representing potential habitat ranges for that species under varying climate conditions in the years 2050 and 2070. These distributions provide an estimate of species presence in the bioregion

For a better understanding of the changes in habitat each species will face with a changing climate, 'habitat change' maps were created. The current high priority habitats were assigned values of 2's and 0's to indicate the priority habitat area of species in question and the lack of it. The future high priority areas were reclassified to 1's and 0's to indicate the availability of priority habitat and the lack of it respectively. An 'addition' function of the tool Raster Calculator in ArcGIS produced a layer of 0's, 1's, 2's and 3's which represent no presence of species, habitat gained, habitat lost and habitat that remains unchanged respectively.

Species Connectivity Mapping:

Connectivity maps were made with the Circuitscape software using specific physiological attributes of the landscape for every species and species occurrence data. Physiological attributes include the elevation, land cover, presence of water bodies and sagebrush cover. Depending on the species, each of these attributes were considered as 'resistances' to their movement. The resistances have been classified on the basis of the study of each species natural history. Next, 'focal nodes' were created for each of the 8 species. The focal nodes represent the areas of high species population density. Each species had an average of 3 focal nodes which were created as polygon shapefiles in Arc GIS. The focal nodes and resistance layers were used to generate connectivity maps in Circuitscape.

Detailed Methods

Connectivity maps of all 8 species were then reclassified in ArcGIS on a 1 - 10 scale, with high values allocated to those regions with highest species connectivity. Reclassified connectivity layers for each species were then combined and averaged to provide an aggregated calculation of current species priority areas across the landscape (Figure_X). This aggregated connectivity layer was reclassified to generate a new layer which consisted of only the top 3 classes of priority (8, 9 and 10) presenting the connectivity high priority habitat across the bioregion, distributed across 3 categories of priority: advantageous for conservation goals, desirable for conservation goals, and critical for conservation goals.

Landscape Prioritization:

The landscape prioritization map (Figure X) has been created using the 'addition' function of Raster Calculator in ArcGIS, the three high priority classes of the connectivity map and the future priority habitats are combined to present the final map of landscape prioritization. The raster calculator result, which was indicated on a scale of 0 to 6 was then reclassified into 3 categories keeping it consistent with other maps used in the report. Classes 1 and 2 were classified as advantageous for conservation goals, 3 and 4 as desirable for conservation goals and classes 5 and 6 as critical to conservation goals.

Appendix C:

Data Sources

Data Sources

Species Occurrence Data:

Species occurrence data was obtained from Global Biodiversity Information Facility (GBIF).

GIS Data Sources:

Layers	Source
Future and current climate	WorldClim
Landcover	National Center for Earth Resources Observation and Science, U.S. Geological Survey
USA Federal Lands	National Atlas of the United States, via USGS
Water bodies (lakes and rivers)	Natural Earth Data
Sage Brush	United States Geological Survey, SAGEMAP
Wind Potential	National Renewable Energy Laboratory
Oil and Gas Plays	U.S. Energy Information Administration
Grazing Allotments	Department of Interior - Bureau of Land Management, GeoCommunicator
Forest Fragmentation	United States Geological Survey, SAGEMAP

Climate Data

Below are the layers that were used as predictors for the species distribution models:

Bioclim Layers	Layer Variable
1	Annual Mean Temperature
2	Mean Diurnal Range (Mean of monthly (max temp - min temp))
3	Isothermality (BIO2/BIO7) (* 100)
4	Temperature Seasonality (standard deviation *100)
5	Max Temperature of Warmest Month
6	Min Temperature of Coldest Month
7	Temperature Annual Range (BIO5-BIO6)
8	Mean Temperature of Wettest Quarter
9	Mean Temperature of Driest Quarter
10	Mean Temperature of Warmest Quarter
11	Mean Temperature of Coldest Quarter
12	Annual Precipitation
13	Precipitation of Wettest Month
14	Precipitation of Driest Month
15	Precipitation Seasonality (Coefficient of Variation)
16	Precipitation of Wettest Quarter
17	Precipitation of Driest Quarter
18	Precipitation of Warmest Quarter
19	Precipitation of Coldest Quarter

Appendix D:

Natural History Profiles

Species Profile

North American Beaver

Castor Canadensis

Distribution and Abundance

Although once nearly extirpated from North America, the Beaver is now considered abundant and exists within most of the temperate Northern Hemisphere.

Diet and Foraging Behavior

Beavers are vegetarians and seek habitat that offers a variety of woody trees and shrubs. They will also consume tender vegetation such as grasses, leaves, and agricultural crops (National Trappers Association). They are 'central place foragers,' making short-distance foraging trips to feed and protect young kits in the den, and long-distance trips for adult self-feeding. Beavers are generally inactive during winter months, protected in their lodges and under ice from extreme temperatures (Baker 2003).

Habitat and Movement Requirements

Beaver are highly adaptable across climates and biomes, but require semi-aquatic habitats and prefer stable water levels, low valley grades, specific rock types (glacial till, schist or granite), bifurcated stream channels, and a diversity of riparian vegetation and woody biomass for their diets and dam construction (Payne 1989).

Their movement across landscapes requires healthy aquatic habitats, a high percentage of forest cover, a 15 percent or less stream gradient, and ample food species. Human activity that is found to negatively impact beaver dispersal includes grazing, railways, the presence and density of roads, and land clearings (Leary 2012).

Viability

Beavers have long lifespans and survive up to 24 years in the wild. Survival rates are also high, with young beavers being the most vulnerable to predation.

Beaver fecundity is most heavily influenced by the quality and abundance of available habitat, which provides ample food for reproductive females and prevents saturation of habitat by overly dense populations (Payne 1989).

Conservation Status

The Beaver is no longer threatened but remains a keystone species of conservation interest. As ecosystem engineers, they provide a host of ecosystem benefits such as improved aquatic habitat, regulated stream hydrology, habitat complexity, recharged groundwater and the creation of wetlands (Pollock et al. 2015).

Species Profile

Canada Lynx

Lynx Canadensis

Distribution and Abundance

Lynx populations in the contiguous United States are considered metapopulations, which are thought to emanate from the population in the core habitat of the northern boreal forests of central Canada (USFWS). The boreal forests of Canada and Alaska are the primary habitat of lynx in North America and habitat suitability decreases with decreasing latitude (Koehler and Aubrey 1994). It now covers the states with most of the boreal forests of North America. Its range extends from Alaska to Newfoundland, including the lower 48 states in northern New England, the Western Great Lakes region, the Pacific Northwest, and the Rocky Montana, Wyoming) (Meaney and Beauvais 2004).

Diet and Foraging Behavior

Close to 60 to 97 percent of the lynx's diet is made up of the snowshoe hare and it is estimated that the average consumption rate is one hare every 1 to 2 days (Koehler and Aubrey 1994). The hare population often peaks in cycles of ten years and thus the lynx population is similarly affected in certain sections of its geographic range where the cycle is most pronounced (Stenseth et al. 1997). With respect to foraging activities, the movement patterns of the lynx are influenced by its strategies to pursue snowshoe hare, and thus the lynx's habitat choices respond to those of the hare (Fuller and Harrison 2010). Daily movement distances vary, often depending on the hare density (Ruediger et al. 2000) with daily movements ranging from 2.7 to 5.4 kms (Meaney and Beauvais 2004).

Habitat and Movement Requirements

Lynx generally prefer habitats above the elevation of 1220 meters (Stinson 2001), which often have cool and moist coniferous forests with cold, snowy winters (Mckelvey et al. 1999). Lynx tend to use early successional forests, which tend to have a high number of their primary prey, the hare, for foraging purposes and late successional forests for denning and to provide adequate cover and more heat for kittens (Koehler and Brittell 1990). Typically, lynx do not use clearings wider than 300 feet, they do however make use of silviculturally thinned forest stands with 180 trees/ acre with no shrubs (Koehler 1990). A complex mosaic of different age classes of forests provide fitting habitat for the lynx. Lynx, especially in the northern segments of their range, the lynx may make long-distance movements during periods of prey scarcity; recorded distances have been up to 1,000 km (Poole 1997). The southern segment of the lynx range is more fragmented in terms of forested landscapes and the lynx must move between islands of forests (USDI 2005).

Viability

Due to the low population density in the ecoregion, the lynx are vulnerable to habitat exploitation and other human disturbances (Koehler and Brittell 1990). Habitat fragmentation may also have influence on the lynx population dynamics given the very specific needs with relation to prey and use of different aged forest stands and cleared forests (Koehler and Aubrey 1994). Moreover, due to the booms and crashes in snowshoe hare populations, especially at higher elevations, lynx are more sensitive to habitat fragmentation in the northern latitudes than the southern latitudes where snowshoe hare populations are less susceptible to such peaks and troughs (Koehler and Aubrey 1994).

Conservation Status

The lynx has been given the conservation status of 'least concern' by the IUCN.
In the United States, the USFWS has given it the status of 'threatened' in the chosen ecoregion of the Northern Cascades in the state of Washington. It holds the 'S1' status by IRMA, and is considered critically imperiled. It is thus given 'management priority' within the national park (IRMA).

Species Profile

Elk

Cervus Canadensis

Distribution and Abundance

There are two elk populations within Cascadia, separated by the Cascade Mountains. The coastline range of the Roosevelt Elk runs between northern California and southern British Columbia, while the Rocky Mountain Elk range spans from the American Southwest into the middle of British Columbia.

Diet and Foraging Behavior

Elk are ruminants, and eat grasses, lush forbs, shrubs, tree vegetation and bark.

Habitat and Movement Requirements

Elk require mosaic landscapes: dense woodland cover is essential for protection from weather and predators, and open areas provide forage for grazing. While seasonal migration patterns are less pronounced for the Roosevelt Elk due to the temperate climate within their range, Rocky Mountain Elk are known for long migrations to seek summer range (higher altitudes), transition range, and winter range (protected valleys and wooded areas). Elk also move in response to predators and human disturbance, and avoiding roads and developments.

Viability

While elk usually segregate by sex for most of the year, mature bulls begin to gather harems of cows during late summer months for mating. Calving rates are low - mature cows (2+ years) typically birth one calf a year, and reproductive fitness is highly sensitive to nutrition, physical condition, and age (Oregon Elk Management Plan 2003). Elk typically live 10-20 years.

Conservation Status

Elk are considered abundant and are a popular trophy species for hunters. Management plans seek to control herd size, reduce over-browsing of vegetation that supports biodiversity, mitigate conflict with human uses (including ranching, road-accidents, and agriculture), and prevent disease transmission.

Species Profile

Gray Wolf

Canis lupus

Distribution and Abundance

Wolves were historically prevalent throughout North America, but today are reduced to Canada, Alaska, the Great Lakes, Northern Rockies, and the Pacific Northwest. They are able to travel extreme distances, have large ranges, and are adapted to varied habitat conditions.

Diet and Foraging Behavior

As opportunists, wolves are adapted to hunt large ungulates like elk and deer, as well as small prey species like rabbits and beavers. Additionally, they scavenge dead animals and consume vegetation.

Habitat and Movement Requirements

Wolves are habitat generalists, but must have sufficient access to prey, areas for denning and taking shelter, and protection from human disturbance and harassment. They are generally found near populations of ungulates, with forest cover, low human density, and low road density.

Viability

Breeding typically occurs in February between the dominant mature male and female in a pack. Whelping occurs in April, producing a range of 1-9 pups. Pup survival varies due to factors such as disease, predation and nutrition. Wolves live an average of seven years.

Conservation Status

The Gray Wolf is an IUCN species of Least Concern, Not at Risk in Canada, and has been de-listed within the U.S. (certain populations still have localized protection). It is considered a keystone predator, and while very adaptive, is sensitive to habitat fragmentation and experiences high human-use conflicts (primarily with agricultural production).(including ranching, road-accidents, and agriculture), and prevent disease transmission.

Species Profile

Greater Sage-Grouse

Centrocercus urophasianus

Distribution and Abundance

The greater sage-grouse is both native and restrained to the North American sagebrush (Artemesia spp.) steppe, which currently exists in the Northwestern United States and the Alberta and Saskatchewan provinces of Canada (U.S. Fish and Wildlife Service 2014). As a sagebrush obligate, the sage-grouse requires an extensive, interconnected expanse of sagebrush of varying densities and heights, with a collection of native understory grasses and forbs for insect habitat and food supply (U.S. Fish and Wildlife Service 2014). Most of the sagebrush biome exists between the Sierra Nevada, Cascade, and Rocky Mountain ranges, but the plant species also extends east into the northern Great Plains of Wyoming and south-central Montana (Miller and Eddleman 2001).

Diet and Foraging Behavior

The greater sage-grouse is an omnivorous species, eating both plants and insects throughout its lifespan. The bird's diet consists primarily of high-protein insects within the first month of life, with a gradual shift to a wider variety of invertebrates, including ants and beetles, early in life. As the sage-grouse ages, its diet becomes increasingly plant-based (Macias 2011). Adult sage-grouse eat primarily a diet of various forbs during the summer and early fall. In winter, however, more than 99% of the species' diet consists exclusively of sagebrush leaves and buds (Macias 2011, Rosales 2006).

Habitat and Movement Requirements

Soils, topography, and climate vary widely across the bird's range, allowing the sage-grouse to move from valley floors to higher elevations, and from semi-arid uplands to wet meadows (Miller and Eddleman 2001). Additionally, the species is known to exist between elevations ranging from 4,000 to over 9,000 feet (U.S. Fish and Wildlife Service 2014). Sage-grouse have distinct habitat requirements throughout the year, categorized into breeding, late brood-rearing, and wintering periods. An ability to move effectively between these habitats is critical for annual sage-grouse fecundity and survivorship.

Viability

Because the sage-grouse has such an obligatory relationship with sagebrush habitat, the recent upward trends in both conversion and degradation of this habitat have significant negative effects on the survivorship and reproductive capacity of the sage-grouse throughout its range. The western United States has faced recent, significant development and agricultural pressures. As a result, sage-grouse populations throughout the country are following a trajectory of decreased growth and population decline (Johnson and Braun 1999, Braun et al. 1977).

Conservation Status

Following extensive landscape-scale conservation efforts from both the U.S. Fish and Wildlife Service and the Bureau of Land Management, protection of the greater sage-grouse under the Endangered Species Act was deemed unwarranted in 2015. However, the species currently occupies only 56% of its historic range (U.S. Fish and Wildlife Service 2013). Sagebrush habitat has become increasingly degraded and fragmented with increased human use, particularly for agriculture, infrastructure development, and energy resources. Very little sagebrush habitat is currently undisturbed and approximately 50 percent to 60 percent has either been altered or lost completely to land conversion.

Species Profile

Grizzly Bear

Ursus arctos horribilis

Distribution and Abundance

Like many large carnivores throughout the United States, the grizzly bear is sparsely distributed across large areas throughout its range (Kendall et al 2009). In North America, the species once existed as far south as northern Mexico and east to the Great Plains. However, today there are only an estimated 750 to 1000 individuals persisting in the continental United States, and an additional 25,000 in British Columbia and Canada. The natural abundance of the grizzly bear depends heavily upon the relative abundances of their prey species and the productivity of the landscape. Because of high population densities throughout the Pacific Northwest, as well as intensive agriculture and livestock grazing, the species has largely been forced out of the Cascadia bioregion and into more northern parts of their North American range.

Diet and Foraging Behavior

Although grizzly bears have been historically classified as carnivores and their digestive tract is more specialized for meat consumption, the species' diet is comprised of a wide variety of foods and the bear consumes primarily plant material (British Columbia Ministry of Water, Land and Air Protection 2002). Grizzly bears feed opportunistically and will prey or scavenge on almost any available food (U.S. Fish and Wildlife Service 2007). The grizzly bear relies on water bodies, specifically wetlands and estuaries, for food forage.

Habitat and Movement Requirements

Movement of the grizzly bear is primarily driven by the species' search for food, as the bear will generally move where it can best meet its food requirements and survive. The grizzly bear generally requires large spatial areas for omnivorous foraging, winter denning, and security cover. Land fragmentation greatly disturbs grizzly bear habitat suitability and movement, as the species generally requires large, conterminous tracts of land without road presence (U.S. Fish and Wildlife Service 2007). Forest cover is also a critical component of grizzly bear habitat, as bedding usually occurs close to trees. However, the species typically prefers a mosaiced landscape that includes forested land among various other types of cover.

Viability

Habitat availability is widely regarded as the limiting factor of grizzly bear viability in the northwestern United States (Boyce et al. 2001). However, a significant amount of grizzly bear mortality still occurs from hunting, poaching, and highway or railway accidents (Boyce et al 2001). Additionally, heavy fragmentation of the northwestern landscape continues to threaten grizzly bear conservation, as a disjointed landscape prevents connectivity and gene flow across subpopulations of the sparsely dispersed species.

Conservation Status

The U.S. Fish and Wildlife Service listed the five remaining grizzly bear populations in the United States as threatened in 1975 (Kendall et al. 2009). Of those five populations, only two were thought to support populations over 50 individuals as of 2009, both of which existed in northwestern Montana (Kendall et al. 2009). Recovery plans were created and approved for the species by the U.S. Fish and Wildlife Service in both 1982 and 1993 (Boyce et al. 2001). As human development continues into grizzly bear habitat, it will continue to be fragmented and degraded, causing a host of conservation challenges.

Species Profile

Silver-Haired Bat

Lasionycteris noctivagans

Distribution and Abundance

Silver-Haired Bats are common throughout forested and montane habitats in North America. Their abundance is not well understood, but they are believed to be found in population pockets throughout their range.

Diet and Foraging Behavior

Bats prey on various soft and hard-bodied insects, including moths, flies, beetles, leafhoppers, and true bugs. They typically forage in and over riparian zones, openings, streams, ponds, and along forest margins, flying in slow, short glides (Harris 2005).

Habitat and Movement Requirements

Cover is essential for these solitary, nocturnal bats; they prefer older, structurally diverse forests with a high snag density for roosting, and riparian areas for foraging. They roost most commonly in snags and live trees, including ponderosa pine, Douglas-fir, lodgepole pine, western white pine, western larch, western redcedar, grand fir, aspen, and black cottonwoods (Hayes and Wiles 2005). They may also roost in buildings, within caves, and under tree bark.

Although little is known about their migratory habits, they move north in spring, and south toward milder climates in the autumn and winter, towards the lower third of the U.S. and Mexico. Their movements are largely associated with incoming cold fronts, and they hibernate over winter in protected roosting habitat.

Viability

After mating in autumn, female Silver-Haired Bats will store sperm over winter, ovulate in spring, and after a 50-60 day gestation period, produce one to two young (Harris 2005). Females form nursery colonies in the summer where they raise their young, containing anywhere from six to 22 individuals and roosting 13-39 feet above the ground near water. Silver-Haired Bats are believed to live up to 12 years. (TX Parks and Wildlife)

Conservation Status

The Silver-Haired Bat population is an IUCN species of Least Concern, and their population in North America is considered stable. However, they face increasing risks from wind farm development, and forest management practices that reduce forest complexity and remove critical roosting sites.

Species Profile

Snowshoe Hare

Lepus americanus

Distribution and Abundance

The snowshoe hare is associated with the northern boreal forests of North America (Nagorsen 1984. With the most extensive distribution of any North American species, it is distributed as far north as the tree line (Nagorsen 1984). Southern limits of the geographic range of the snowshoe hare are the Sierra Nevada, the southern Rocky Mountains, the Great Lakes region, and the Appalachian Mountains of the United States (Nagorsen 1984).

Diet and Foraging Behavior

The snowshoe hare usually forages at dusk and dawn and remains inactive during daylight hours (USDI 2013). They usually prefer herbaceous food, like leafy greens and deciduous shrubs, during spring and woody browse, which is comprised of branches, twigs and evergreen needles during winter (USDI 2013).

Habitat and Movement Requirements

Across northern boreal forests in Canada, habitats which are cold and dry with a moderately deep level of snow (100- 127m) are preferred by the snowshoe hare (USDI 2013). In northern boreal forests, the snowshoe hare are most abundantly found in early seral stands with dense, multi-layered under- and mid-stories (Meaney and Beauvais 2004). In the north west of United States, Engelmann spruce (Picea engelmannii), subalpine fir (Abies lasiocarpa), mixed spruce-fir, mixed aspen and spruce-fir, and mixed lodgepole and spruce-fir and lodgepole pine are preferred cover types (USDI 2013).

Hares are non-migratory and usually occupy one area for an entire year (USDI 2013). Seasonal movements between summer and winter for foraging purposes take place (USDI 2013). Home ranges usually cover 5–10 ha (12–25 ac) (USDI 2013). Movement of the Snowshoe Hare, in form of dispersal from home range, may be influenced by overcrowding, competition for mates and food resources, or vulnerability to predation (USDI 2013).

Viability

Cyclic fluctuations of snowshoe hares have persisted for at least 200 years in North America's boreal forests (Keith and Winberg 1978). These fluctuations in populations are more severe in the northern parts of the snowshoe hare's geographic range and are thought to be generated by the interaction between the hare, their winter food supply and predation (USDI 2013). Juvenile survival is one of the most significant factors influencing population stability in both the northern and southern reaches of the snowshoe hare's geographic range (USDI 2013).

Conservation Status

The snowshoe hare has been given the status of 'least concern' by the IUCN Red List of Threatened Species (IUCN 2016). Populations of the snowshoe hare are considered healthy overall, however this is a concern regarding its population in south- eastern USA (IUCN 2016). The hare holds no special status as per the US Federal List of Endangered Species(USFWS 2016).

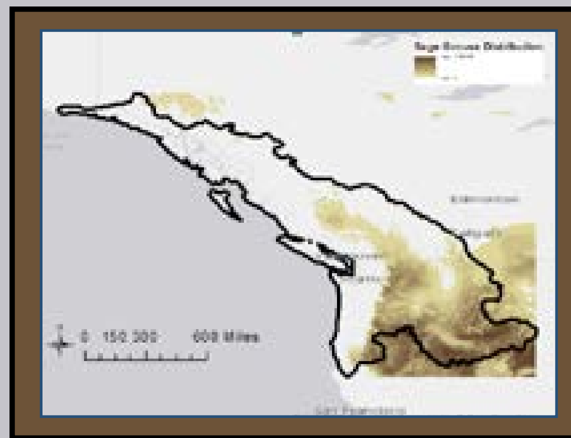
Appendix E:

Current Species Distribution models

Current Species Habitat Distributions

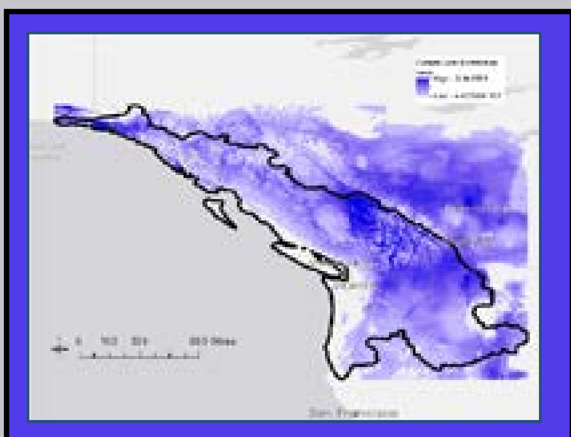
Including only climatic variables

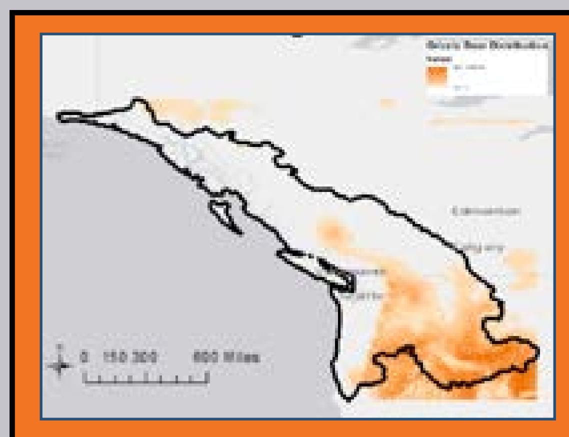
North American Beaver



Greater Sage-Grouse

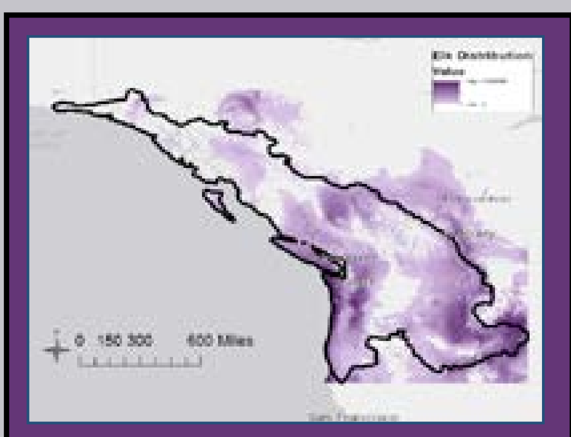
Canada Lynx

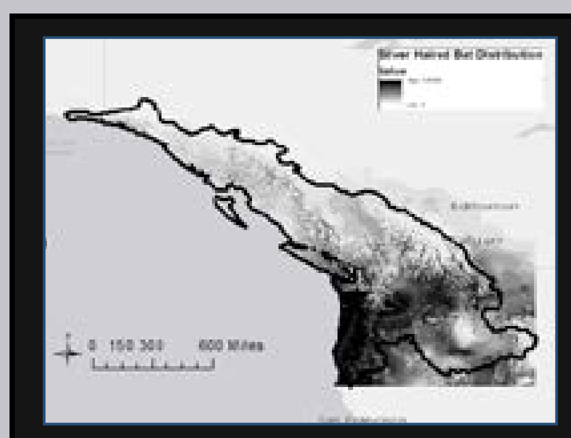




Grizzly Bear

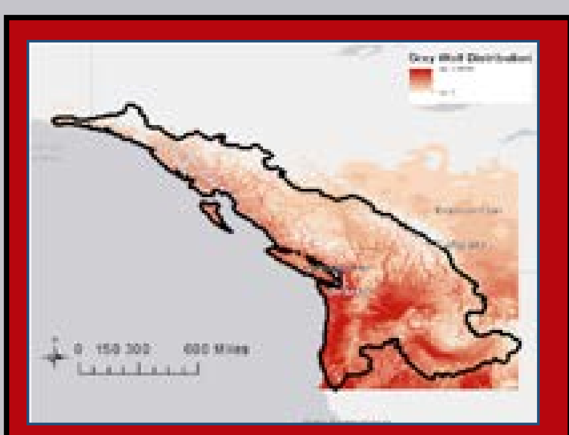
Elk

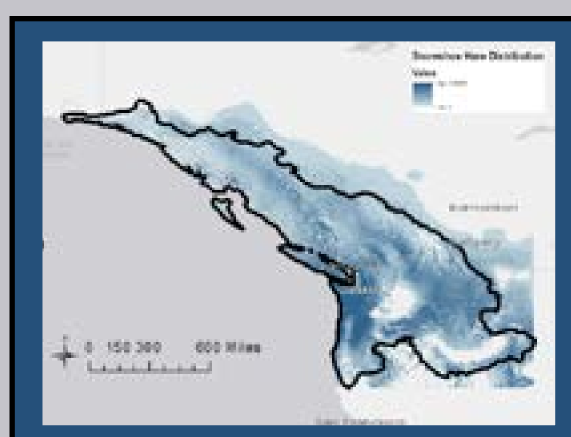




Silver-Haired Bat

Gray Wolf





Snowshoe Hare

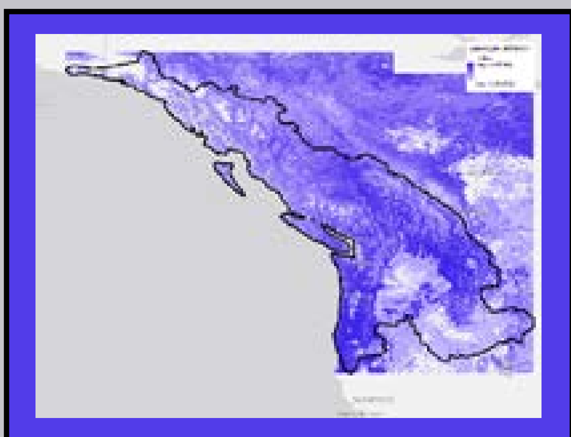
Current Species Habitat Distributions

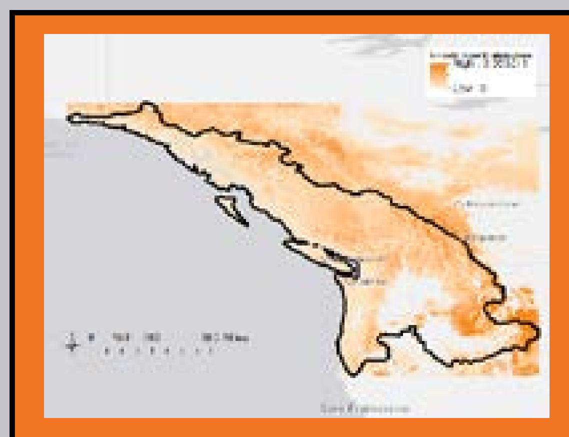
Including climatic variables and enduring features

North American Beaver

Greater Sage-Grouse

Canada Lynx



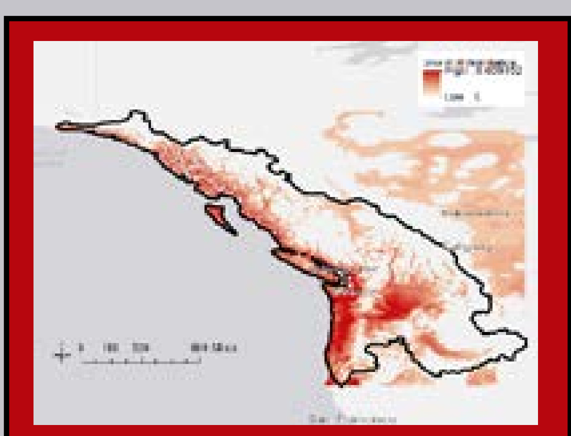


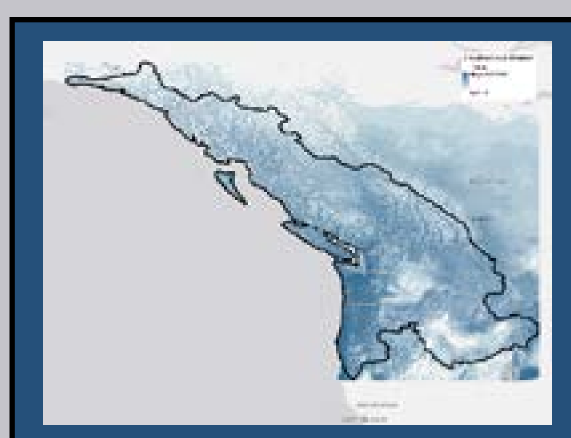
Grizzly Bear

Elk

Silver-Haired Bat

Gray Wolf





Snowshoe Hare

Appendix F:

Current Habitat Priority areas

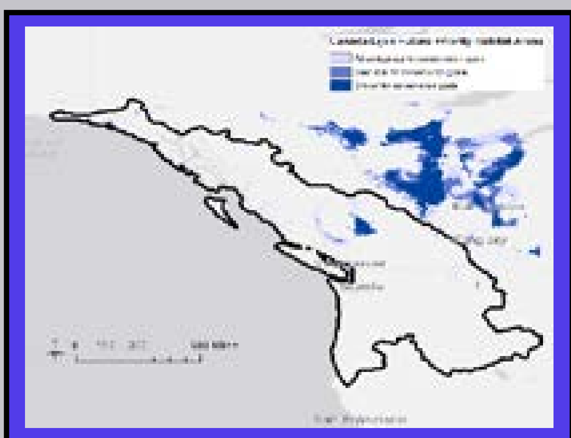
Current Species Habitat Priority Areas

Including climatic variables and enduring features

North American Beaver

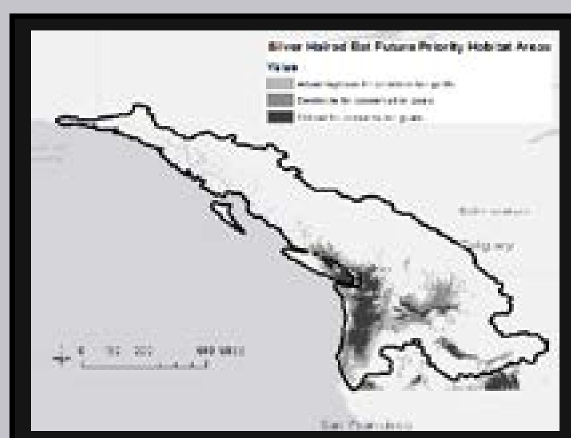
Greater Sage-Grouse

Canada Lynx



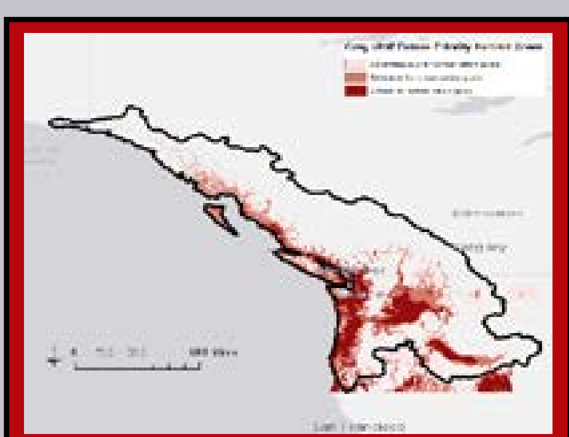
Grizzly Bear

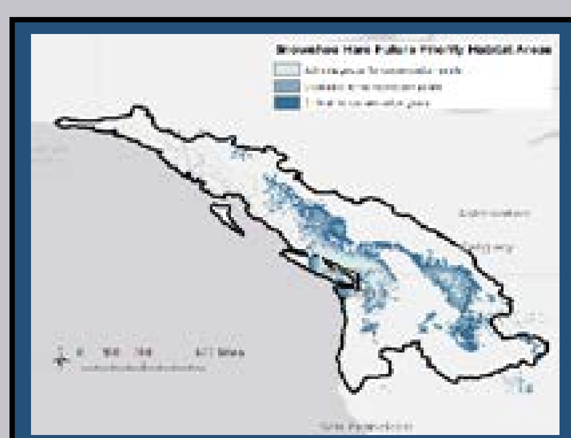
Elk



Silver-Haired Bat

Gray Wolf





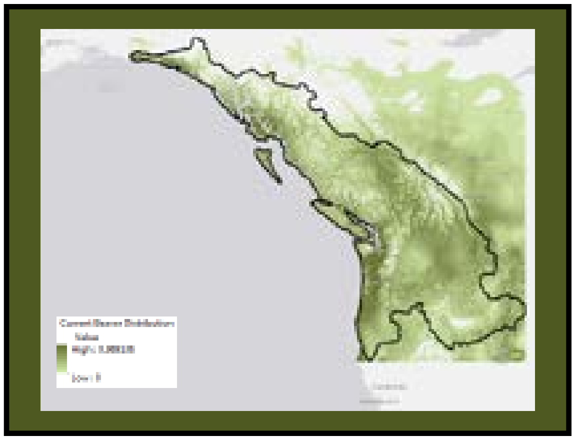
Snowshoe Hare

Appendix G:

Future Species Distribution models

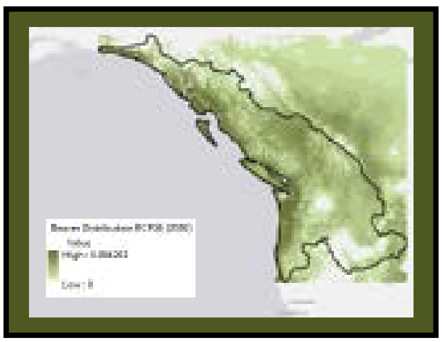
Future Species Habitat Distributions

North American Beaver



2050

2070



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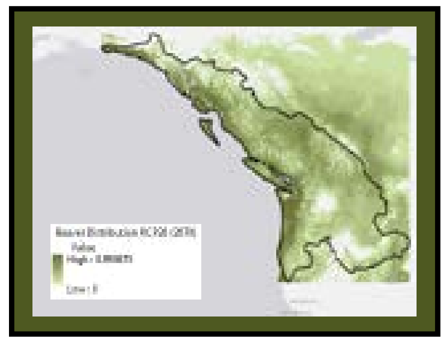

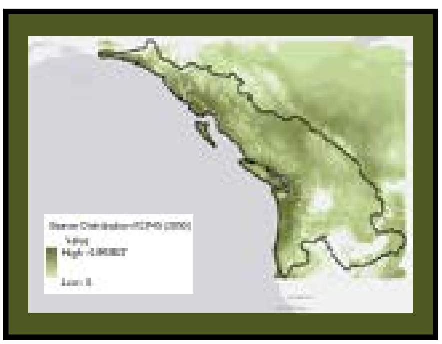

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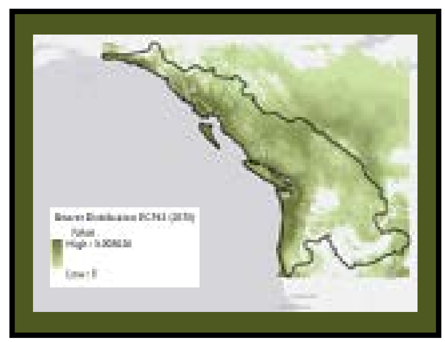
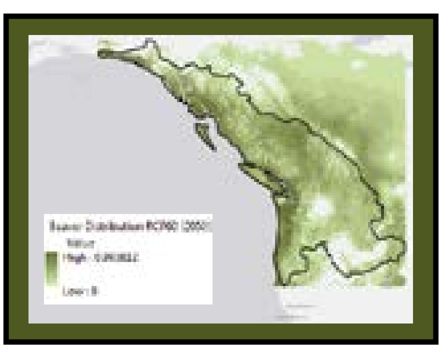
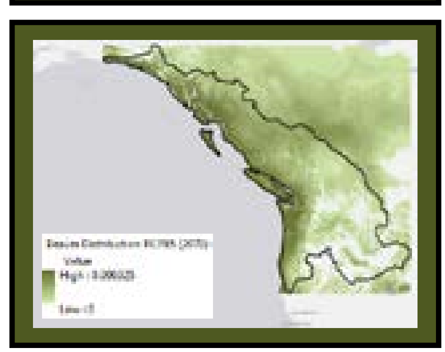




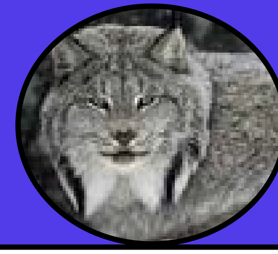
RCP 60

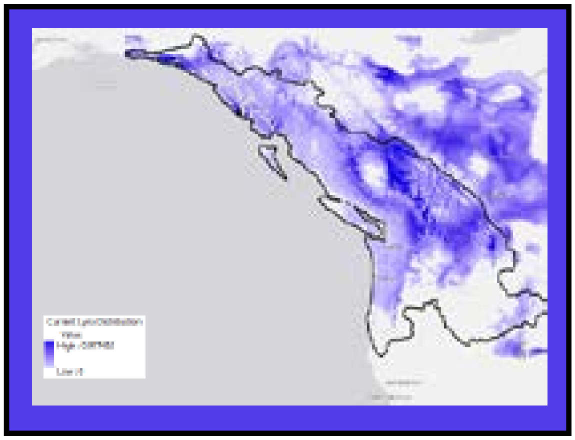
RCP 85



Future Species Habitat Distributions

Canada Lynx





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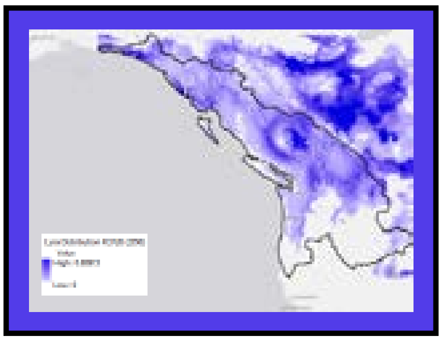
2070



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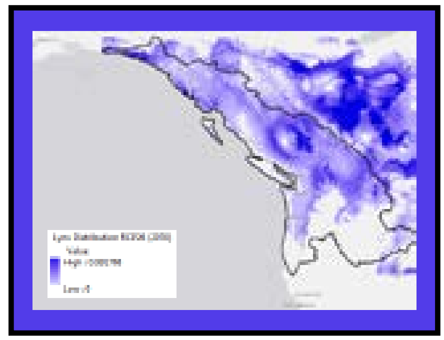

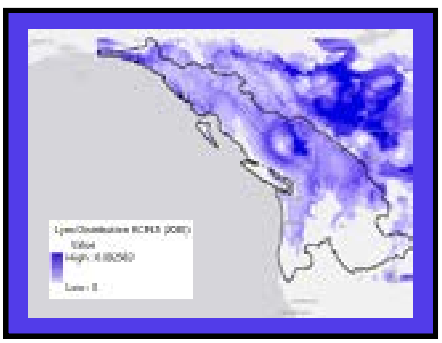

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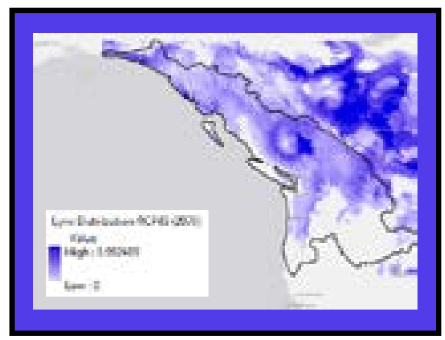

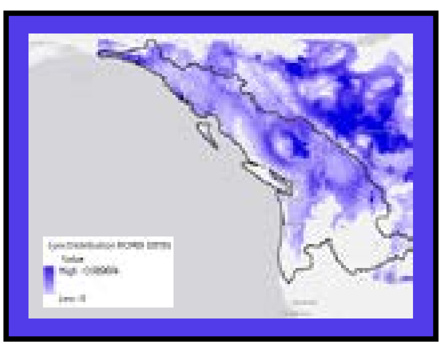

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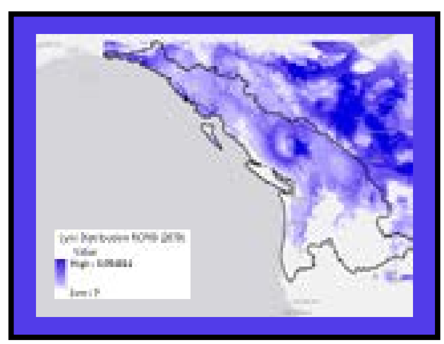

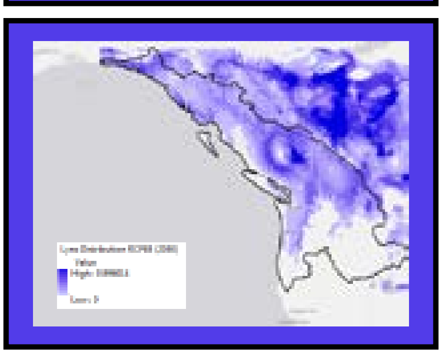

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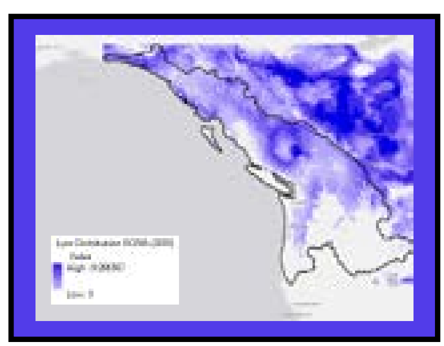
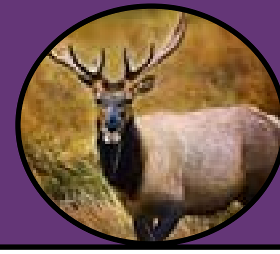
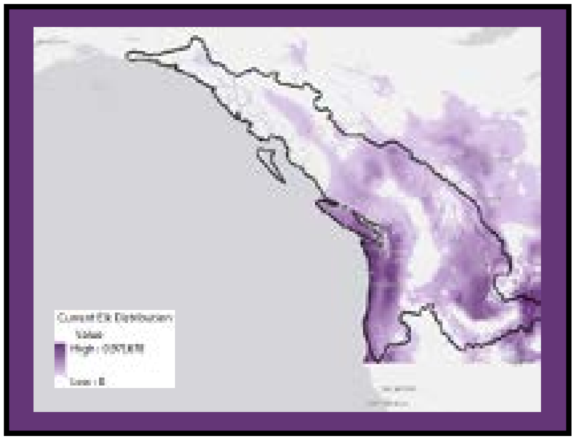


Future Species Habitat Distributions

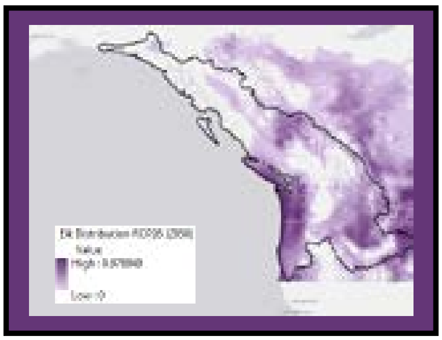
Elk (Roosevelt and Rocky Mountain)

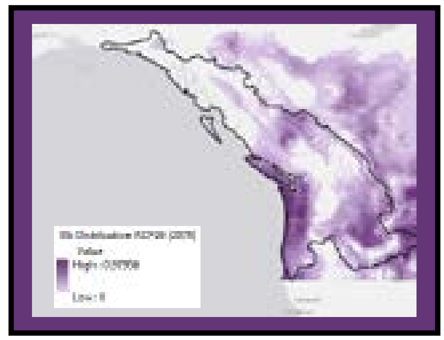




2050 | **2070**

RCP 26





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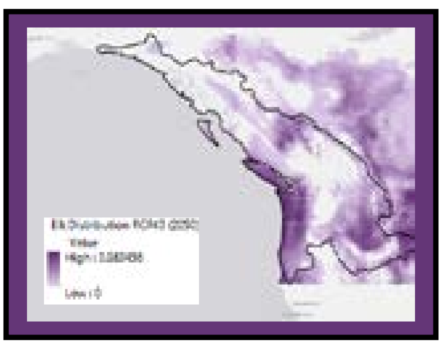

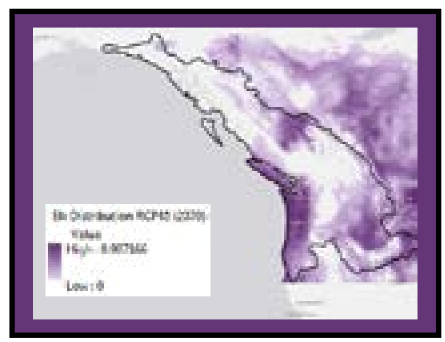

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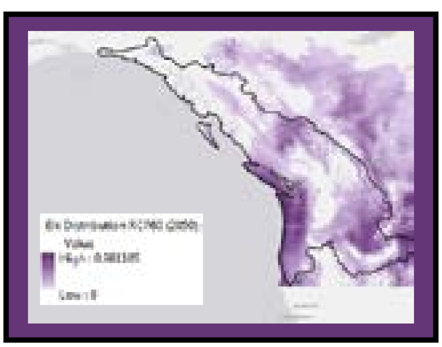

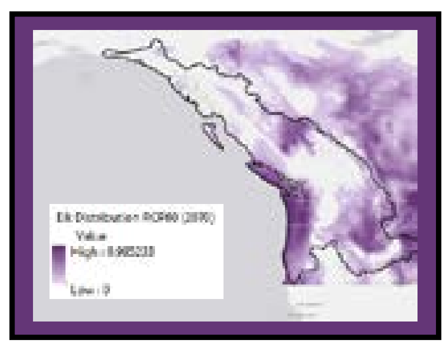

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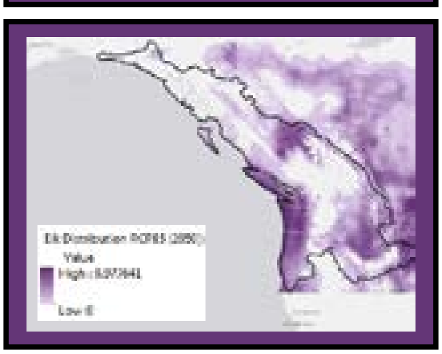
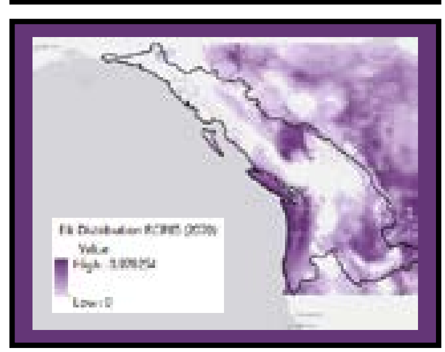
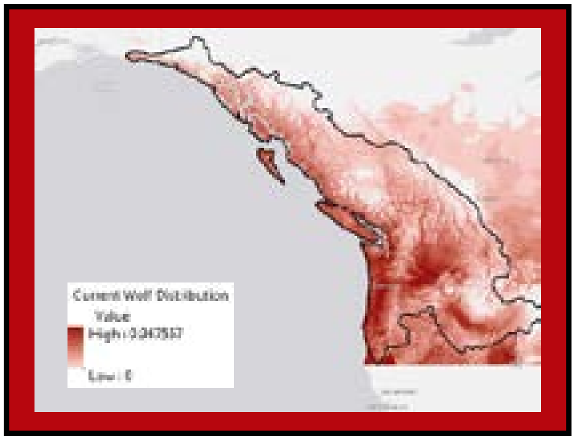
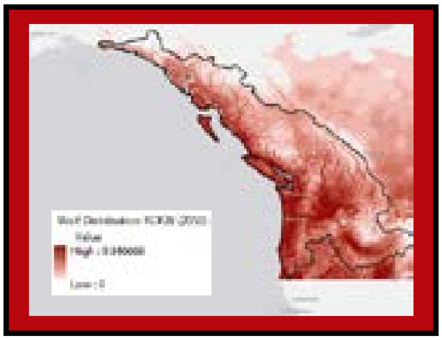
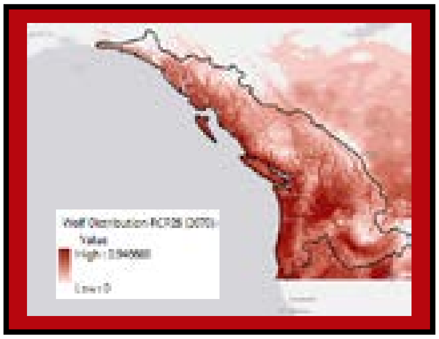
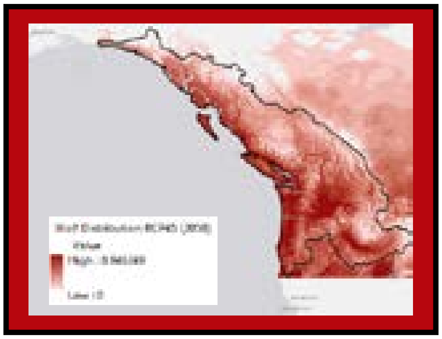
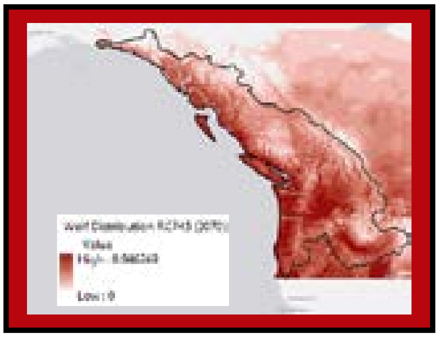
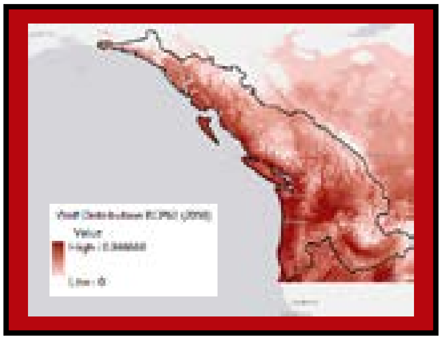
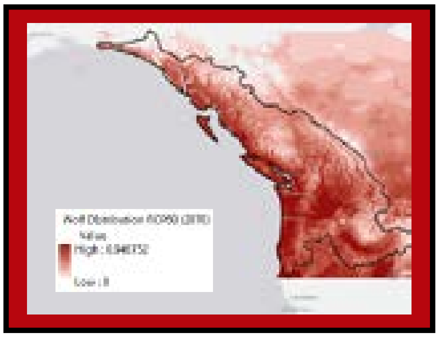
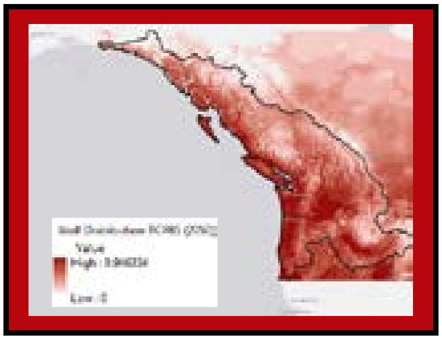
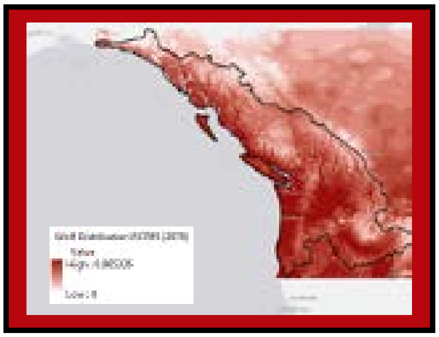




Future Species Habitat Distributions

Gray Wolf



2050		2070
	RCP 26	
	RCP 45	
	RCP 60	
	RCP 85	

Future Species Habitat Distributions

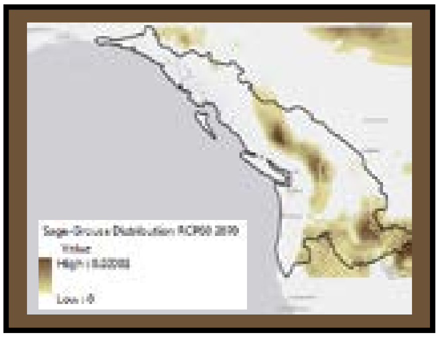
Greater Sage-Grouse

2050 | **2070**

RCP 26

RCP 45

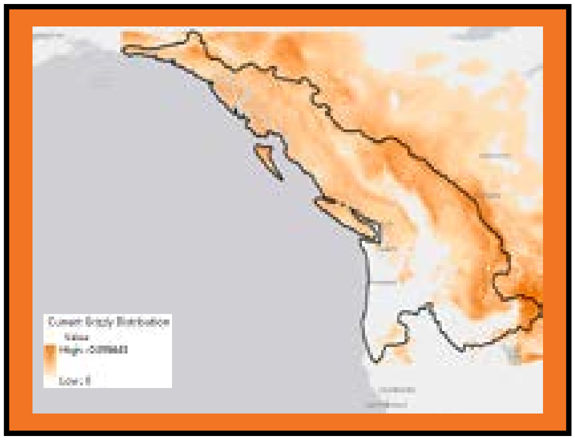
RCP 60



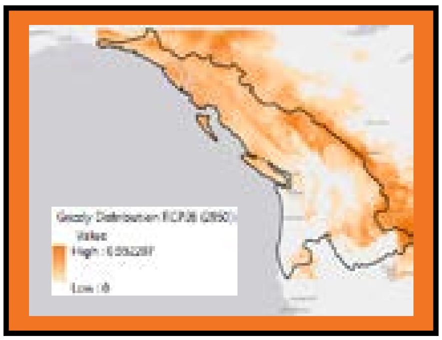
RCP 85

Future Species Habitat Distributions

Grizzly Bear



2050 | **2070**



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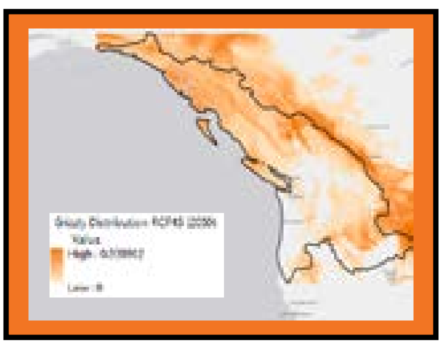

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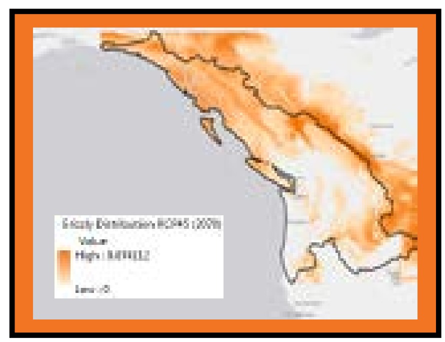

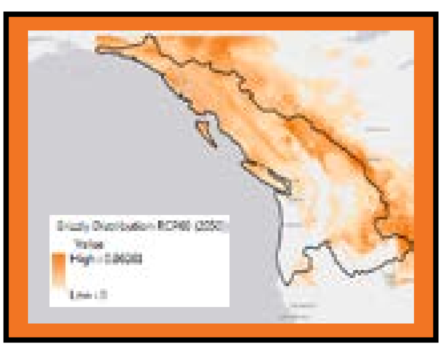

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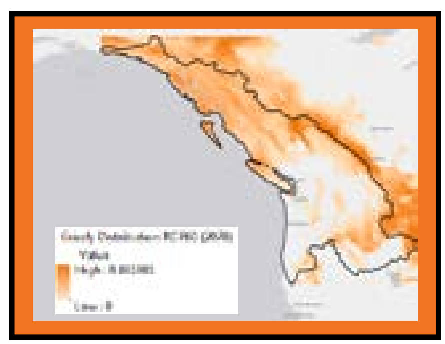
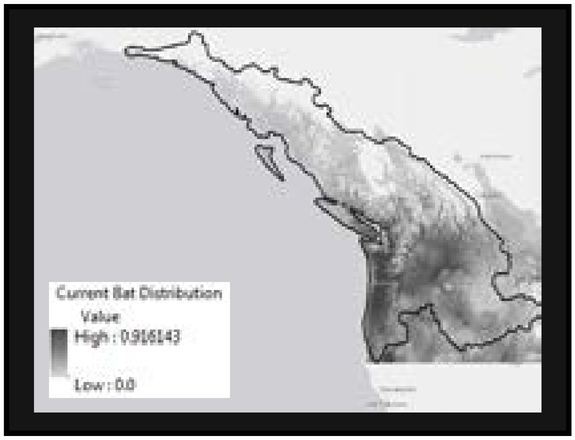


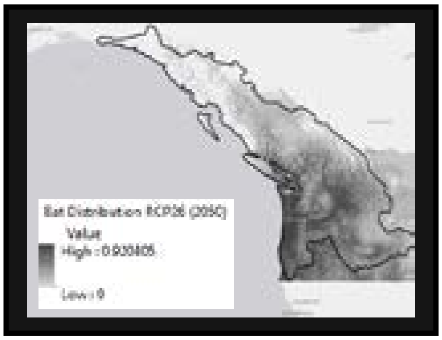
RCP 85

Future Species Habitat Distributions

Silver-Haired Bat



2050 | **2070**



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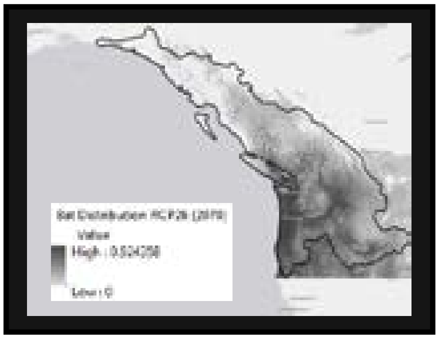

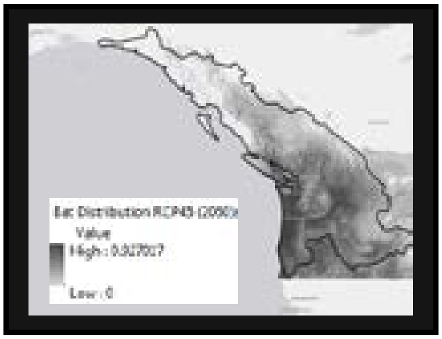

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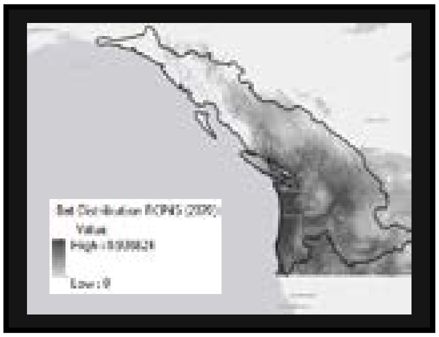

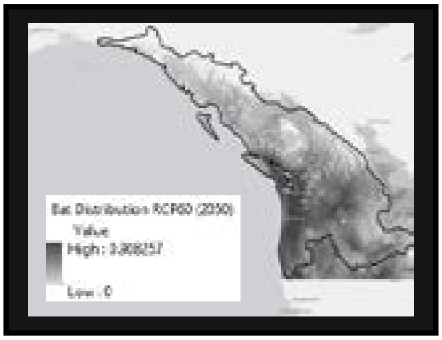

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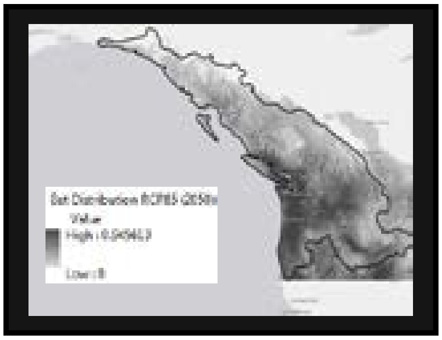
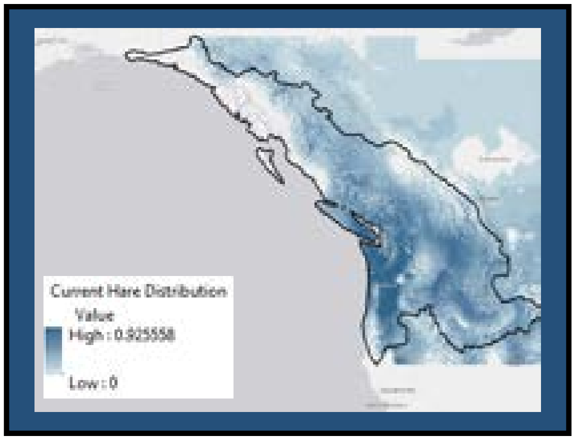


RCP 85

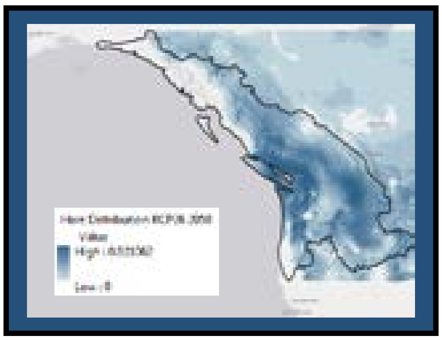
Future Species Habitat Distributions

Snowshoe Hare



2050

2070



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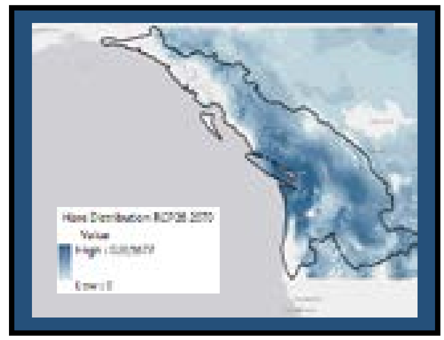

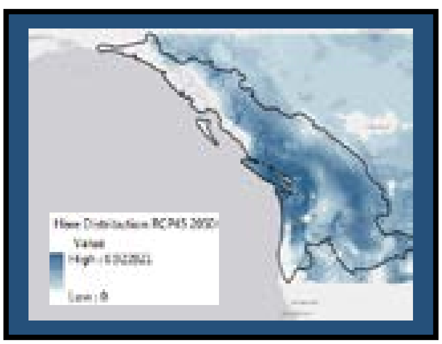

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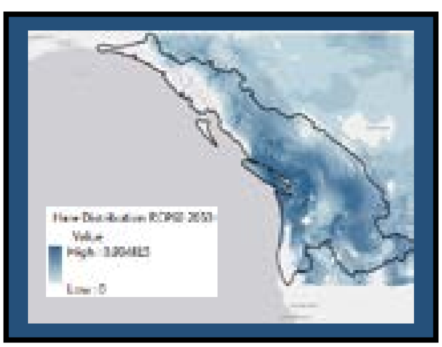

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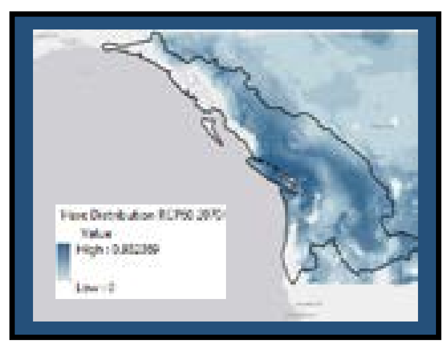

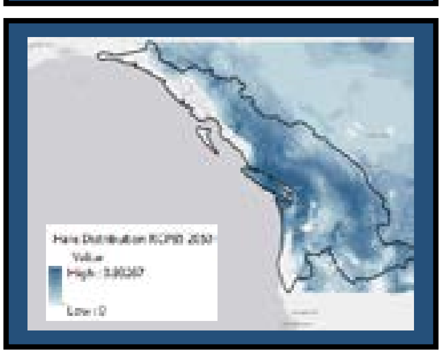

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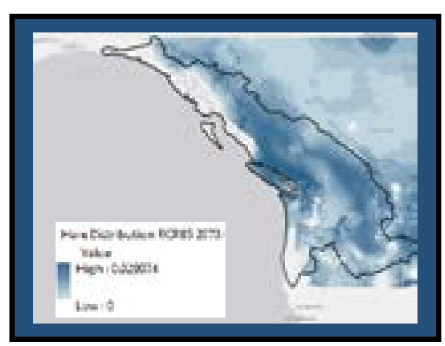


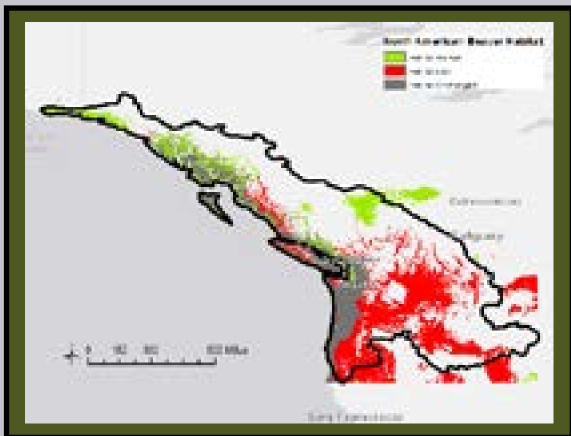
Appendix H:

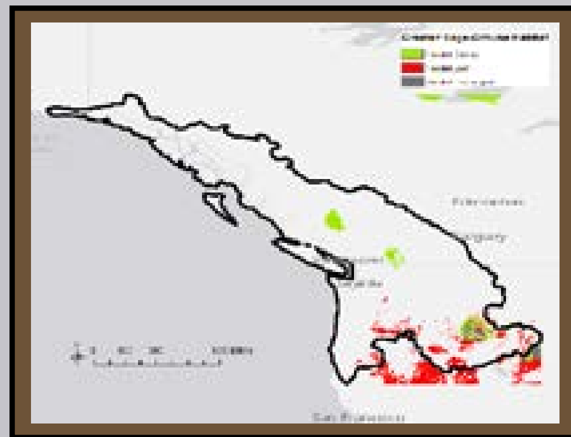
Habitat Lost and Gained

Habitat Lost and Gained

A comparison of current and future (RCP85 2050) SDMs

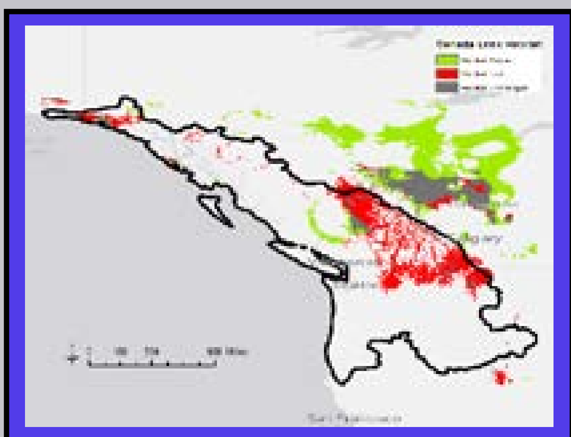
North American Beaver

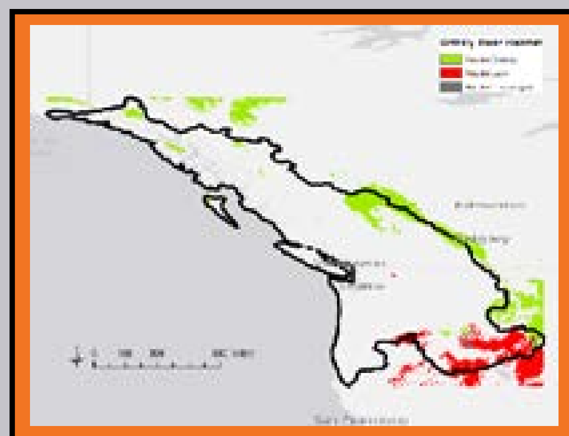




Greater Sage-Grouse

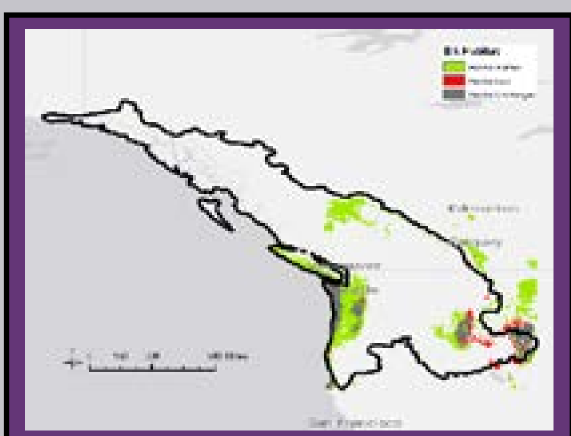
Canada Lynx

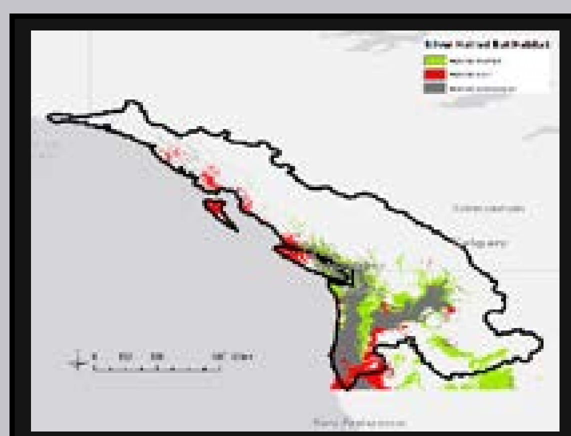




Grizzly Bear

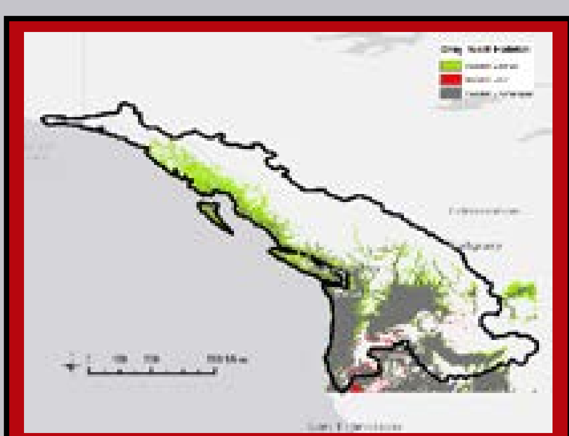
Elk

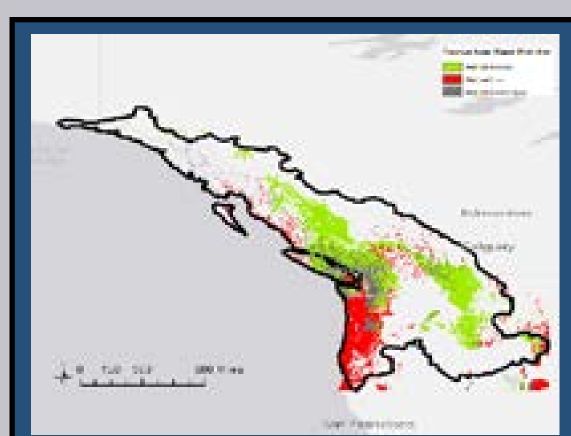




Silver-Haired Bat

Gray Wolf





Snowshoe Hare

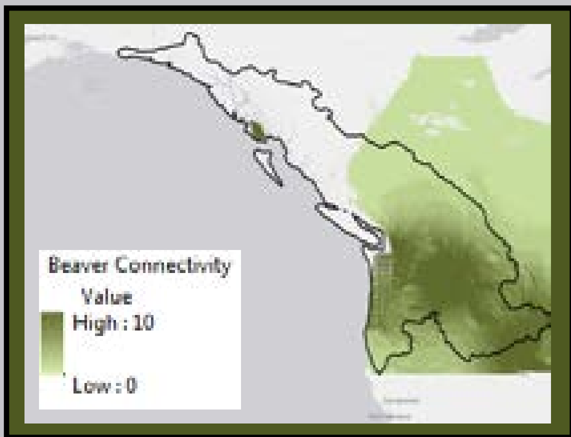
Appendix I:

Landscape Connectivity models

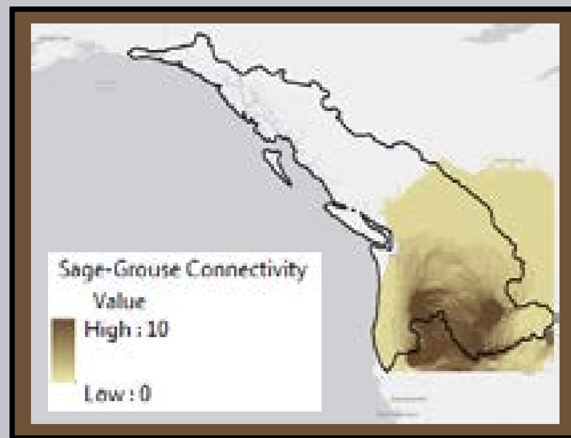
Landscape Connectivity

Including climatic, land cover, and species-specific variables

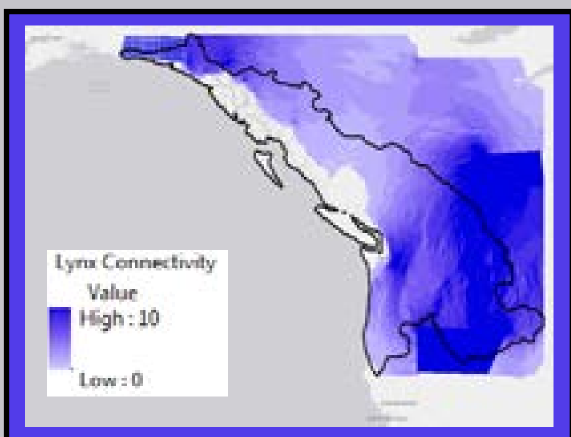
North American Beaver



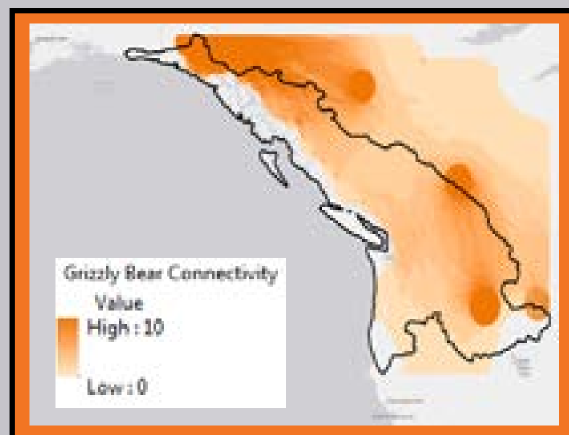
Greater Sage-Grouse



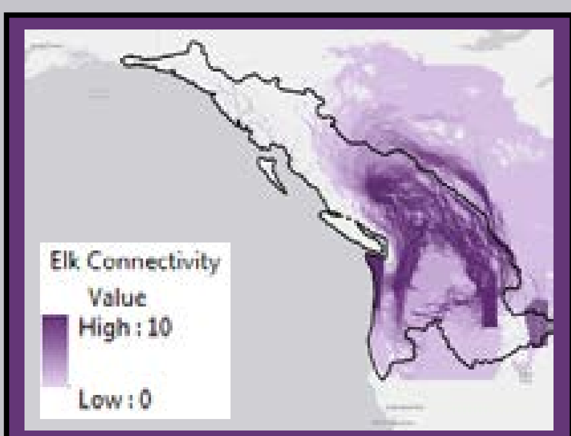
Canada Lynx



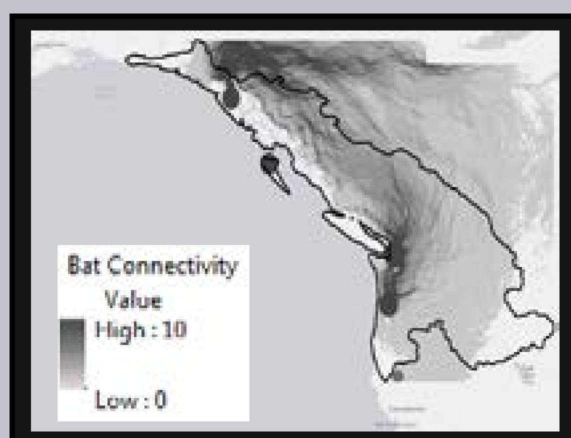
Grizzly Bear



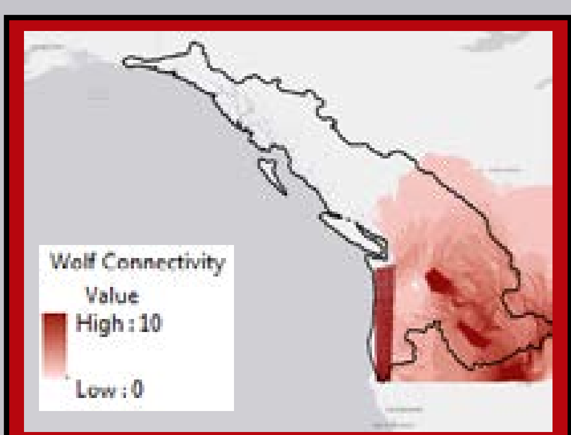
Elk



Silver-Haired Bat



Gray Wolf



Snowshoe Hare