# 4. ALPINE AND MEADOW ECOSYSTEMS

## ALPINE AND SUBALPINE ECOSYSTEMS, SPECIES, AND EXPECTED IMPACTS

The picturesque scenes of snow-capped volcanoes in the southern Washington Cascades are more than just a tourist attraction; they are also the home to a number of species, such as the elusive wolverine (*Gulo gulo*), Cascade red fox (*Vulpes vulpes*), and marten. From emerald, grass-covered hills, to the rocky balds where you can find roaming mountain goats (*Oreamnos americanus*) and American pika (*Ochotona princeps*), to the pointed peaks with year-round glaciers and dense winter and spring snowpacks, the subalpine and alpine regions of the Cascades play a very important role in the makeup of the larger ecosystem and contribute to the biodiversity that is essential to the survival of many species in this region.

**Features of the Alpine**

- High elevations and cold, harsh weather
- Low-lying grasses, shrubs and other uniquely-suited plants
- Rocky soil
- Presence of a distinct timberline

In the face of even mild to moderate warming, we can expect to see a recession of glaciers and the disappearance of snowpacks much earlier into the summer. Since subalpine and alpine ecosystems depend on cold winters and mild summers, they are considered one of the most threatened ecosystems in our study area. Data suggests that in regions of high altitude, the climate is changing more rapidly than elsewhere. We could easily see the

*High elevation ecosystems are considered one of the most threatened types of ecosystems in the region*
*Photo by Adam Zucker*

disappearance of several notable glaciers in this region within the next century.

The alpine region, sometimes referred to as the highlands, is associated with high elevations. The subalpine and alpine regions in the Southern Cascades have a typical elevation from about 7,000’ to 14,410’ at the peak of Mt. Rainier. Substantial snowpacks and year-round glaciers are an integral part of the alpine biome. In our study area of the Southern Cascades, glaciers cover a total of approximately 80 mi². The glaciers and snowpacks, and their associated snow-melt, are integral parts of the hydrological cycle in any alpine ecosystem. A healthy buildup of snow and ice over the winter ensures snowmelt into and through the summer months. An irregular amount of snowfall and ice build-up during the winter can lead to snowmelt in the spring and summer that is harder to anticipate, which could lead to drought or flooding. Several species, like the wolverine or cascade red fox, are dependent on the snow and ice for shelter, hunting, and food storage.

Extreme elevation, along with high latitudes, creates cold and harsh weather patterns. A high volume of winter snow, harsh winds, and cold night temperatures create the signature climate of the alpine, which is home to a unique array of plants and animals. The cold climate, rocky soil, and heavy wind make growth difficult for large trees that thrive at lower altitudes. A distinct timberline marks the transition from the conifer forest to the alpine uplands dominated by low-lying plants that hug the ground to absorb the heat and avoid the harsh winds.

As climate continues to warm, we can expect to see the timberline encroach on upland habitat. According to Gehrig-Fasel et al. (2007), current warming at higher altitudes might be responsible for the dramatic increase in the density and area


Glaciers and alpine regions in the southern Washington Cascades of tree growth rates in the timberline area (188). With climate change, we can also expect to see an earlier onset of spring and a decrease in snowpacks. Decreased snowpacks and the expected expansion of forests into higher altitudes threaten species that rely on the cold, rocky, and open terrain of the alpine region for survival. However, climate is not the only limiting factor of tree growth into alpine areas, the rocky terrain of the alpine provides little suitable soil for significant roots to take hold. According to Beniston (2003):

*"Impacts from climate change are already occuring in alpine regions"*

> "Because temperature decreases with altitude by 5-10°C/km, a first-order approximation regarding the response of vegetation to climate change is that species will migrate upwards to find climatic conditions in tomorrow's climate which are similar to today's (e.g., McArthur, 1972; Peters and Darling, 1985). According to this paradigm, the expected impacts of climate change in mountainous nature reserves would include the loss of the coolest climatic zones at the peaks of the mountains and the linear shift of all remaining vegetation belts upslope. Because mountain tops are smaller than bases, the present belts at high elevations would occupy smaller and smaller areas, and the corresponding species would have reductions in population and may thus become more vulnerable to genetic and environmental pressure (Peters and Darling, 1985; Hansen-Bristow et al., 1988; Bortenschlager, 1993)."

In the shadow of Mt. St. Helen's north facing crater, we are seeing the development of North America's newest glacier. While the forming of this glacier is an important development, this is the only glacier in the Washington cascades that is not shrinking as a result of warming temperatures.

Flowering plants in subalpine meadows have started to flower earlier in the season and this shift is expected to continue. Substantial shifts in flowering have the potential to disrupt relationships among plants, animals, fungus, bacteria, and particular species that act as pollinators, seed dispersers, herbivores, seed predators, and pathogens (189). Earlier snow melt and warmer temperatures as a result of climate change will cause subalpine meadow plant species to flower earlier and for longer periods. These expected snow and temperature patterns

Mountain Goat
*Oreamnos americanus*

Wolverine
*Gulo gulo*

American Pika
*Ochotona princeps*

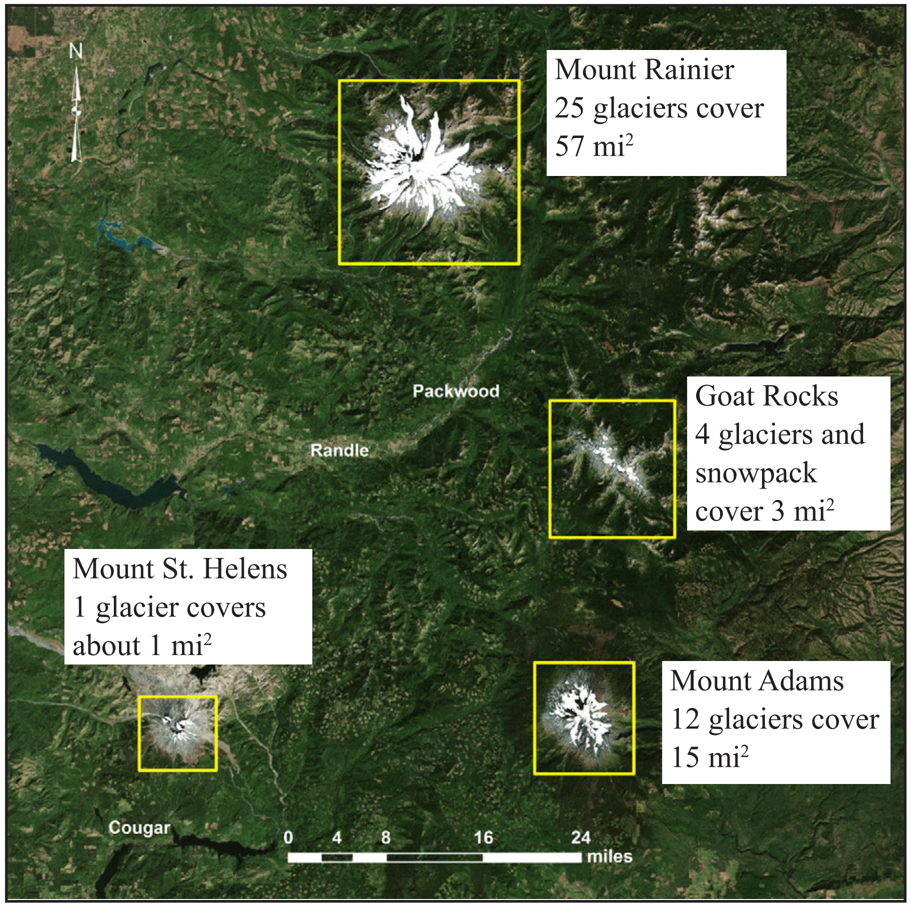
will likely lead to a loss of certain subalpine meadows from an increase tree establishment in subalpine areas and severe impacts to plant species of the subalpine region (69, 190).

Alpine and subalpine habitats in the southern Washington Cascades are naturally isolated and small in size because their occurrence is restricted to higher elevations. Large distances between habitats makes connectivity for alpine- and subalpine-dependent species difficult. If not given direct attention and managed in an adaptive and responsive manner, we could witness the loss of these specialist species and a significant decrease in rare upland plants such as Alaska cedar and limber pine. Because alpine and subalpine areas of the region are particularly sensitive and responsive to shifts in climate, they are valuable scientific indicators of change.

**Mountain goats** are found in the high elevation lands around Mount Adams, Mount St. Helens, Goat Rocks, and Mount Rainier. Their thick white coat provides both camouflage in the snow and insulation against the harsh winter elements. They are most typically found in rocky terrain where their natural ability to climb makes them difficult prey for predators such as bears, wolverines, and wolves. Mountain goats are dependent on grasses, low-growing shrubs, and mosses for sustenance. Because of their size and the typically low levels of nutrients in alpine and subalpine plants, mountain goats can also be found making pilgrimages to known mineral licks that give them the essential nutrients they need.

Mountain goat populations in the Washington Cascades have declined over the past 50 years and, while not currently an endangered species, their populations are expected to face stressors as alpine and subalpine habitats transform. They will likely suffer from a decrease in late season forage in rocky outcrops (31). An encroaching tree line and warming climate is expected to restrict their habitat and, as a result, reduce their grazing land and the amount of accessible food.


The reduction of snowpack is expected to significantly impact the **wolverine**, which relies on snow for denning and caching prey (191–193). Wolverines have specific adaptations to snow, such as enlarged feet and seasonally white fur. Although previously thought to be a habitat generalist, recent studies have found the reproductive dens of wolverines to be limited to areas that retain snow during the spring. The reasons for their general avoidance of areas without late spring snow is unknown, but it is likely to avoid summer heat, remain around suitable prey populations, and stay in areas where their food caches are kept frozen (191). In 2010, the wolverine was listed as a “Candidate” species under the Endangered Species Act. In 2014, a proposed rule to list the wolverine as “Threatened” was withdrawn by the U.S. Fish and Wildlife Service, but that decision was widely questioned and eventually disputed by a federal court. The proposed rule is currently being considered again. With shrinking habitat areas, oftentimes to narrow elevation bands, protecting wolverine habitat will require identifying habitat, mapping corridors, and enacting policies to limit influences known




Data show that glaciers on Mount Rainier, Goat Rock, and Mount Adams have all been shrinking over the last several decades and suggest that we could see the disappearance of several of these glaciers over the next century.

The **American pika** is a charismatic relative of the rabbit, adapted for rocky terrain and cold weather. American pikas are typically found living in-between the cracks and crevices of boulder fields that are at or above the subalpine tree line. As a diurnal species, they are active during the day foraging and collecting haystacks of food that can last them over the winter months. Like other native species of the upland regions that thrive in colder habitats, climate change poses a potential threat to pikas. However, there is evidence that pikas can move into and survive in lower elevations away from snow-dominated peaks (195). It is unclear whether pikas will be adaptable or dramatically impacted by climate shifts.

Well-shaded dens and thick snow packs create cooler microclimates that shelter this sensitive species from warming temperatures. Because their resting body temperature is only a few degrees below lethal body temperature, pikas can be sensitive to temperature extremes (196). Pikas seem to be most vulnerable, though, to extreme weather events (196). Climate models suggest increasing summer drought and freezing rain over the winter months. Freezing rain can incase plants necessary to the pika diet in ice and render them inedible; while drought and earlier snowmelt can reduce the snow packs that pikas sometimes depend on for both shelter, temperature regulation and food storage. Already living at elevations between 8,000-14,000 feet, many pika populations do not have the luxury of being able to extend their range upward in elevation because they already exist near the upper limits (197). In areas like the Great Basin of the Rocky Mountains researchers have found pika populations disappearing from 8 of 25 mountain locations in connection to the warming temperatures (198). How these findings in that region might overlap with our own pika populations in the southern Washington Cascades has yet to be fully understood, though, and will depend on connectivity and suitable habitat availability at lower elevations.

The **Cascade red fox**, an already rare species, could see new stressors from competition as other carnivores migrate. Habitat alterations in the uplands may also hinder population viability of **hoary marmot, marten,** and **white-tailed ptarmigan** (31).

# Mount Rainier

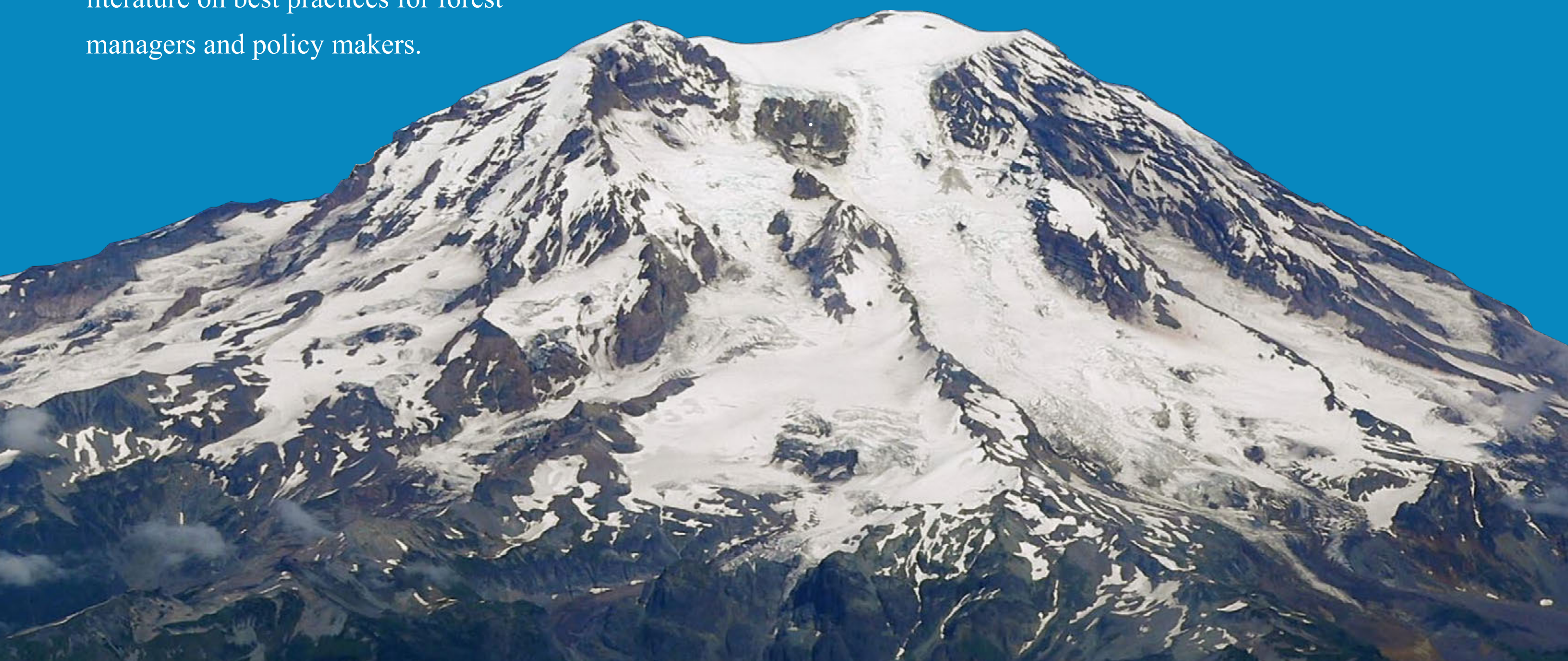
Just north of Gifford Pinchot National Forest, in the northern portion of our study area, stands the iconic white slopes of Mount Rainier. A familiar site behind the Seattle and Tacoma skyline, this volcano is one of the most photographed and recognizable geological formations in North America. Recognized early on for its magnificent landscape, legislation to establish Mount Rainier as a national park was supported by people from all walks of life. In 1899, Mount Rainier National Park became the 5th national park and established a precedent for conservation and preservation in this region.

Home to nearly 300 different vertebrate species, and countless more invertebrates, this national park contains an undeniably diverse ecosystem. The continued protection of the land and the biodiversity within it makes Mount Rainier a haven for native wildlife. In order to protect this natural habitat, 97% of the national park has been designated as protected wildlife areas. With a strong history of nature conservation, Mount Rainer, along with the Gifford Pinchot National forest, has been selected as one of the two main sites to reintroduce the fisher into the Cascades. At any given time, dozens of research, monitoring, and conservation projects are being carried out in this park to better improve understanding of the environment and contribute to the ever growing literature on best practices for forest managers and policy makers.

While the work done in this national park is an exemplar for forest managers throughout the country, there are still climate related threats that will require innovative strategies in forest management.

The approximately 92 square kilometers (57 mi$^2$) of glacier formations, make Mount Rainier the most glaciated peak in the contiguous United States. Year-round snowmelt at the peak creates six major rivers that make the lush landscape of colorful subalpine flowers and verdant riparian areas at the basin possible. Unfortunately, as discussed in the Alpine and Meadow Habitats section of this guidebook, climate change represents an especially large threat to the glaciers of these alpine regions. According to Ford (2001), “these glaciers shrank 22% by area and 25% by volume between 1913 and 1994 in conjunction with rising temperatures.”

With a range of winter and summer activities, Mount Rainier is a popular attraction for winter recreation and summer hiking and camping. In recent years, Mount Rainier has attracted nearly 2 million visitors every year. While a testament to the splendor of this national park, this high volume of visitors is a constant challenge for forest managers and stewards. As temperatures rises due to climate change, continued efforts to manage the impacts of tourism are increasingly important. The preservation of this park, and others like it, is dependent on continued research on climate change and the associated consequences.



## MEADOWS

Meadows of the southern Washington Cascades span the region and range from the low-elevation wet meadows south of the Dark Divide to the dry, alpine meadows of Mount Adams. Meadowlands house unique configurations of plants and animals that are not found in the surrounding forest landscapes.

*"Meadows filter sediment from runoff; provide breeding grounds for invertebrates, which serve as a food source for many birds, amphibians, and reptiles; and provide habitat structure for birds and small mammals, which are a prey base for raptors and other carnivores." –Ford 2001*

Meadow habitats are important pieces of the broader ecosystem puzzle and are vital components of a healthy Pacific Northwest ecosystem. Threatened and rare species, such as **pale blue-eyed grass** (*Sisyrinchium sarmentosum*) and the **mardon skipper butterfly** (*Polites mardon*) rely on meadows. As the primary breeding ground for invertebrates, the meadows in the southern Washington Cascades play a critical role in supporting continued plant biodiversity through pollinators and by providing sources of food for birds and small mammalian species. Meadows of the region support a wide array of butterflies, including skippers, checkerspots, fritillaries, sulphers, blues, and swallowtails (31). Chipping sparrow, hermit thrush, yellow-rumped warbler, and Townsend's warbler nest at the edges between meadows and conifer forests. A variety of mammals, such as bear, deer, elk, and golden-mantled ground squirrel also regularly use meadow habitat (31). Transitory species rely on connected meadow habitat to ensure genetic diversity and adequate availability of habitat in the event of a major disturbance, such as forest fires or streambank flooding.

*"Shrubs from dry meadows may move into wet meadows and displace flowering plants, which can affect elk, butterflies, and a variety of birds."*

The drier summers we can expect to see will have impacts on many of the plant species found in meadows, many of which are critical to local pollinators (81, 199). Impacts, though, will depend on topography and meadow type. The loss of critical plant species can disrupt the mating cycle of invertebrates or drive them out of the region entirely. Some of the best pollinating species, such as the mardon skipper butterfly, are limited by their non-migratory behavior. One of the concerns with non-migratory, pollinating invertebrates is that their habitats are becoming smaller and increasingly disconnected.

Mardon skipper butterflies, due to their habitat requirements and non-migratory behavior, are at risk from an increase in habitat disturbances from climate change. Photo by Tom Kogut

Warmer temperatures will likely bring threats from invasive species such as Scotch broom and vetch as well as a general loss of heterogeneity (200, 201). Already, as temperatures have increased, perennial flowering plants in some places have been replaced by low lying shrubs and sedges that are better equipped for warmer and drier weather (199). In the wetter meadows, this shift of plant life will be additionally harmful to the food stock of animal species that are not able to find the required nutrients from the sedges and shrubs. The increase in shrub-like plants and decline of floral plants has serious implications for pollinators and continued vegetative diversity (202).

*"Wet meadows are saturated with water for much of the growing season. Moist meadows may be flooded soon after snowmelt, but may not stay saturated as the water table lowers. Dry meadows may experience intermittent flooding but are well-drained and have a deeper water table than wet or moist meadows." –Southwest Washington Adaptation Partnership 2016"*

While not always the case, dry meadows tend to exist in the basin and wet tend to exist in the alpine and subalpine habitats. Climate shifts will likely favor dry meadows, which are adapted to warmer weather and seasonal drought, over wet meadows, which are dependent on consistent hydrology patterns in wet growing seasons (31). Dry meadows are expected to expand while wet meadows will shrink or transition to dry meadows. Summer droughts can threaten native plants in wet meadows that are not as effective at water storage as larger trees or shrubs. Dry meadows may, however, also respond negatively if flooding and drought shifts increase to degrees that cause significant die-off of flowering plants. Increased flooding events in dry or wet meadows may also further promote tree encroachment.

Lost Meadow in the Gifford Pinchot National Forest. Photo by Shiloh Halsey

# STRATEGIES AND RECOMMENDATIONS FOR ALPINE AND MEADOW HABITATS

## STRATEGIES AND RECOMMENDATIONS FOR ALPINE AND MEADOW HABITATS

### ALPINE and SUBALPINE HABITATS

- Because of the uncertainty in climate response, continued research on climate change and conservation practices should be expanded. The data tracked and reported by *Snotel* sites throughout the region are important for understanding the region's precipitation patterns. Efforts like these, from the U.S. Forest Service and Natural Resources Conservation Service, are important for researchers and forest managers alike in order to determine optimal restoration and conservation strategies moving forward.

- Where threatened from logging, development, or heavy recreation, protect and actively restore subalpine areas to create and maintain habitat for high elevation plants and animals. Focus areas in the southern Washington Cascades include the southern and western slopes of Mount Adams and Mount Rainier.

- Consider forest thinning strategies that limit the size and severity of uncharacteristically severe and large fires moving into subalpine areas less able to tolerate strong wildfires, such as in some subalpine areas on the west side of Mount Adams.

- Increase collaboration and project partnerships involving Mount Rainier and Okanogan-Wenatchee National Forest to support connected alpine and subalpine habitat for upland species such as wolverine, marten, and fox.

- Monitor tree mortality and current areas of alpine refugia (from a vegetative perspective) to identify where project focus should be directed, what trees should be considered for conservation and restoration, and to determine connectivity pressures.

- Monitor vegetative expanding into areas previously covered in snow.

- Monitor regrowth after disturbance.

- To mitigate a loss of biodiversity from increased disturbance regimes, coordinate citizen-agency-NGO efforts to collect cones and seedling for future population viability as new uncertainties become clearer and new restoration projects are outlined for particular areas and species.

• Advocate for less snowmobile activity near wolverine habitat to reduce negative habitat and population impacts (194).

**MEADOWS**

• In the southwestern foothills of Mount Adams, the establishment of Research Natural Areas (RNAs) or Botanic Special Areas (BSAs) would be a fitting approach to support ongoing meadow restoration efforts while also ensuring more long-term focus on impacts and improvements. Possible locations for new areas include: Lost Meadow, McClellan Meadow, and Skookum Meadow.

• Take advantage of opportunities to support the natural creation of new meadow habitat in post-fire areas and pursue designations to protect them as such. In areas where meadow patches would improve resilience for whole populations (i.e., nearby other meadows and subpopulations of meadow species), certain post-fire stands 10 to 50 acres in size can be replanted with native meadow species and then left to mature and persist with little follow-up management, aside from periodic (and only initial) pruning of encroaching conifers.

• Restoration of existing meadow habitat is also currently needed to prevent encroachment from surrounding conifer trees. The natural sway of conifer encroachment would ideally occur while other meadow patches are naturally developing, thereby creating a pulsing mosaic of meadow patches that support meadow species at the landscape scale by being less impacted by catastrophic disturbance at a local scale. Due to past forest management, fire suppression, and the patchwork of management on the landscape, this natural gain and loss has not been occurring in a manner that would support meadow species. Climate change adaptation strategies can represent an opportunity to re-establish this dynamic by offering a broader contextual blueprint that highlights the need to let fires burn, support the natural creation of meadow habitat in areas close to current meadowland, consider the role of subpopulations and genetic diversity in planning, work from natural biotic or topographic features that can shape long-term resilience and create functional diversity, and to eventually allow encroachment as part of the larger and revolving system.

• Pond and plug restoration, which is basically the building of partial dams along certain parts of a stream channel, can reroute flow and increase saturation in meadowlands (202). This technique can improve the resilience of wet meadows and help support a more diverse plant community.

# Appendix

**Mature and old-growth forest projections**

We used two data sets to examine mature forests in our study area: forest layers from Conservation Biology Institute (CBI) and a map of the old-growth structural index (OGSI) created by the USDA Forest Service.

Conservation Biology Institute forest data
Retrieved online: 2016 from www.databasin.org
Spatial layer created: 2004
Description: Satellite imagery data of forest age throughout the PNW. Mature forest classified as 50+ years, old-growth classified as 150+ years

Old-growth Structural Index
Retrieved online: 2016 from the U.S. Department of Agriculture
Spatial layer created: 2006
Description: Satellite imagery data of forest age and structure in the Pacific Northwest. Mature forest classified as 80+ years, old-growth classified as 200+ years. Further classification considered tree density, snag density, downed wood cover, and tree diameter in order to classify old-growth according the OGSI standards.

**Resistance Layer for Connectivity Analysis**

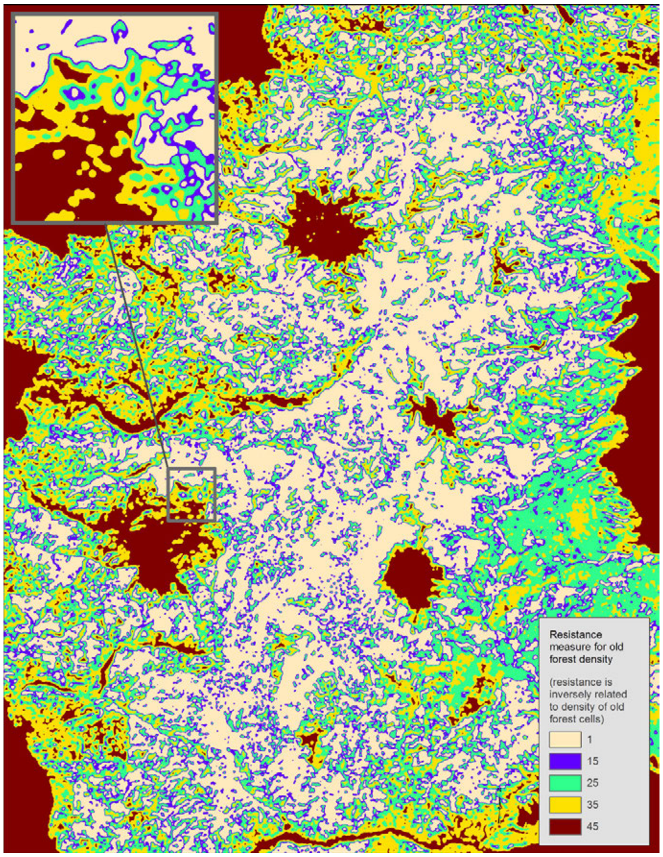
Using the mature and old-growth forest layer from Conservation Biology Institute, we ran a kernel density function measuring mature and old-growth forest density within a 1000-meter radius of each cell. The resulting layer was divided into nine classes, in order to fit the scale of the study area and the density function of the habitat core areas. The bottom four classes, the least dense areas, were reclassified (see table below) and integrated into the resistance layer with lower measures receiving higher values of resistance.

Road Density was measured by merging several different road layers through a process of joining, clipping, and buffering to avoid "double counting" road segments and to consider roads from various agencies and departments. Heavily traveled roads and highways, however, were intentionally counted twice to give them more resistance weight. The layers used in this analysis were from the Forest Service, Bureau of Land Management, and Washington Department of Transportation. We ran a kernel density analysis with a search radius of 100-meters, as this distance created a density surface that reflected biological processes for the species of focus and at the scale in which we were working. We used the top four sections in a nine-class histogram and reclassified these to reflect the resistance weights outlined below.

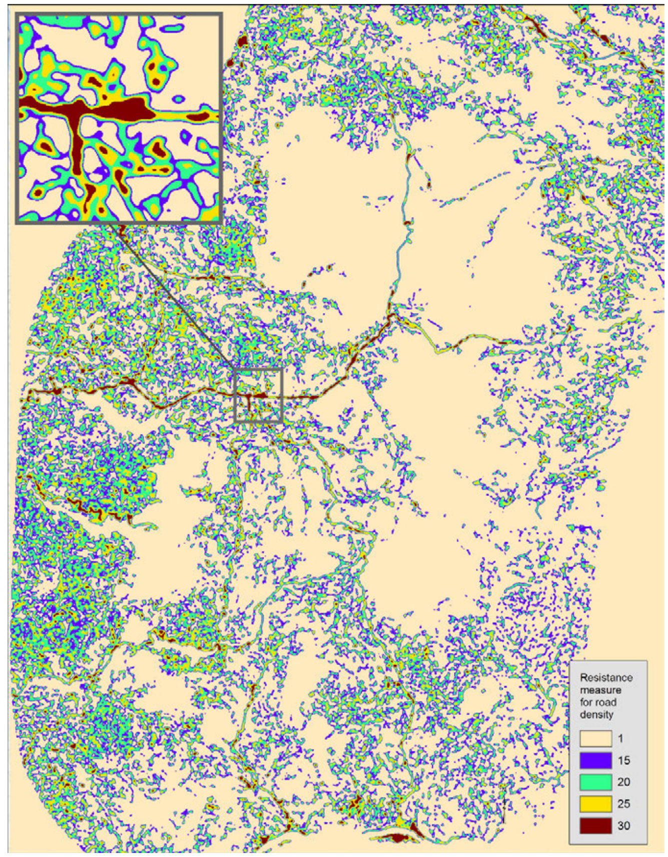
The Conversion Threat Index from Wilson et al. (2014) uses several land-use and land facet values (see page 78) to identify areas that are likely under threat from human land-use impacts, such as development and logging (203). The analysis gives increased ecological importance to areas near current "reserves," an approach that echoes the importance of expanding current reserves and "buffering" habitats against disturbance. We only considered resistance for the top two measures in this index, as the lower threat index values would have relatively little impact on connectivity.

| **Density of mature forest** | moderate | moderate-low | low | very low |
|---|---|---|---|---|
| reclass | 15 | 25 | 35 | 45 |
| **Conversion Threats Index** | 1 | 2 | 3 | 4 |
| reclass | 1 | 1 | 15 | 25 |
| **Road density** | moderate | moderate-high | high | very high |
| reclass | 15 | 20 | 25 | 30 |

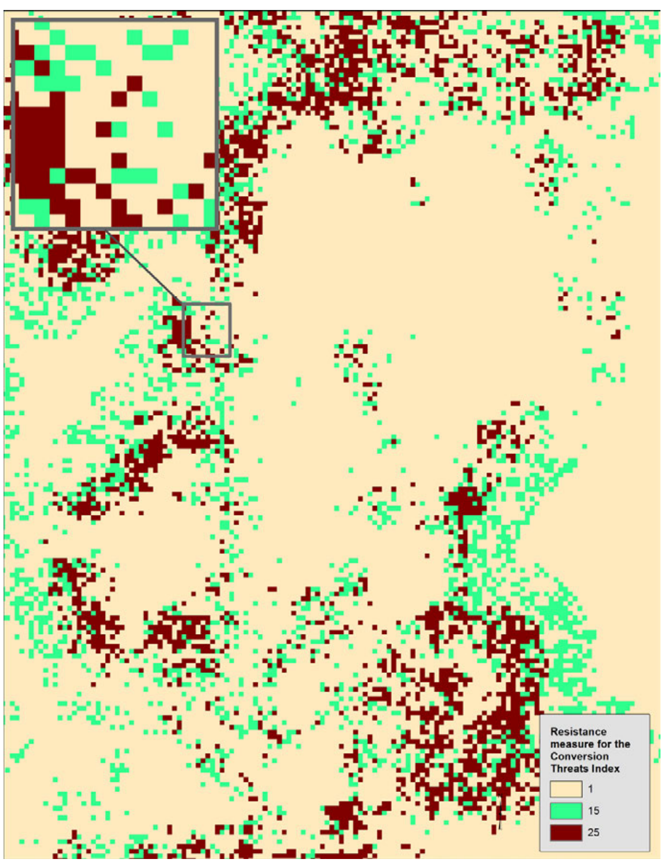
Input measures and reclassification values of the resistance layer



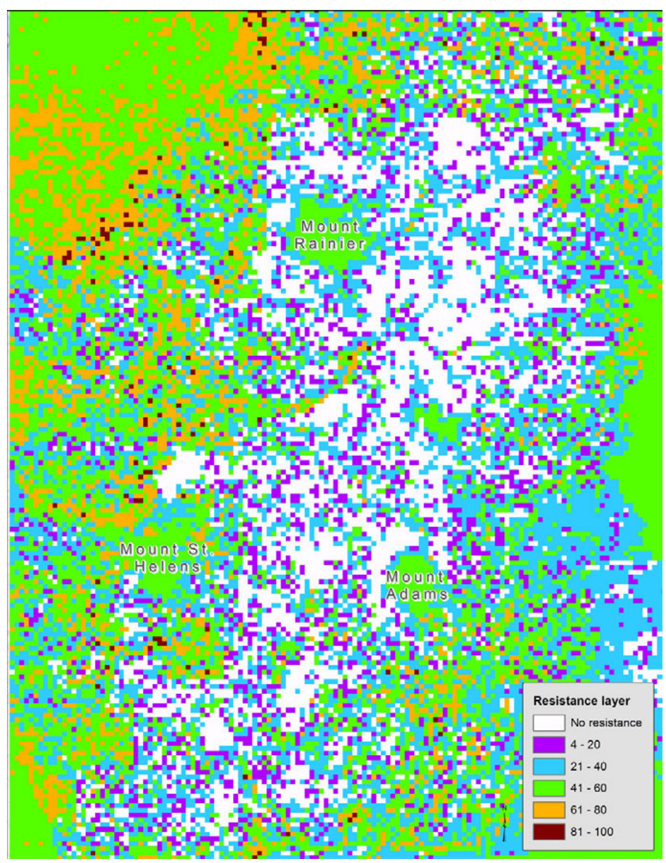

Resistance layer for old forest density




Resistance layer for road density



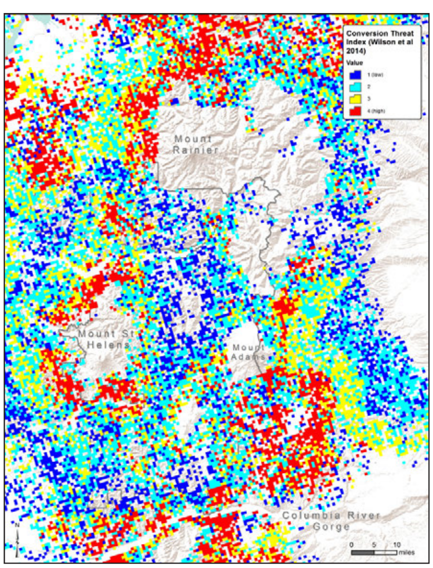

Resistance layer for the Conversion Threats Index




Final resistance layer used in the connectivity analysis

The creators of the Conversion Threats Index outline their methodology and motivation for map creation below:

> Even if species are equipped with the adaptive capacity to migrate in the face of a changing climate, they will likely encounter a human-dominated landscape as a major dispersal obstacle. Our goal was to identify, at the ecoregion-level, protected areas in close proximity to lands with a higher likelihood of future land-use conversion. Using a state-and-transition simulation model, we modeled spatially explicit (1 km2) land use from 2000 to 2100 under seven alternative land-use and emission scenarios for ecoregions in the Pacific Northwest. We analyzed scenario-based land-use conversion threats from logging, agriculture, and development near existing protected areas. A conversion threat index (CTI) was created to identify ecoregions with highest projected land-use conversion potential within closest proximity to existing protected areas. Our analysis indicated nearly 22% of land area in the Coast Range, over 16% of land area in the Puget Lowland, and nearly 11% of the Cascades had very high CTI values. Broader regional-scale land-use change is projected to impact nearly 40% of the Coast Range, 30% of the Puget Lowland, and 24% of the Cascades (i.e., two highest CTI classes). A landscape level, scenario-based approach to modeling future land use helps identify ecoregions with existing protected areas at greater risk from regional land-use threats and can help prioritize future conservation efforts.




Original Conversion Threats Index map

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