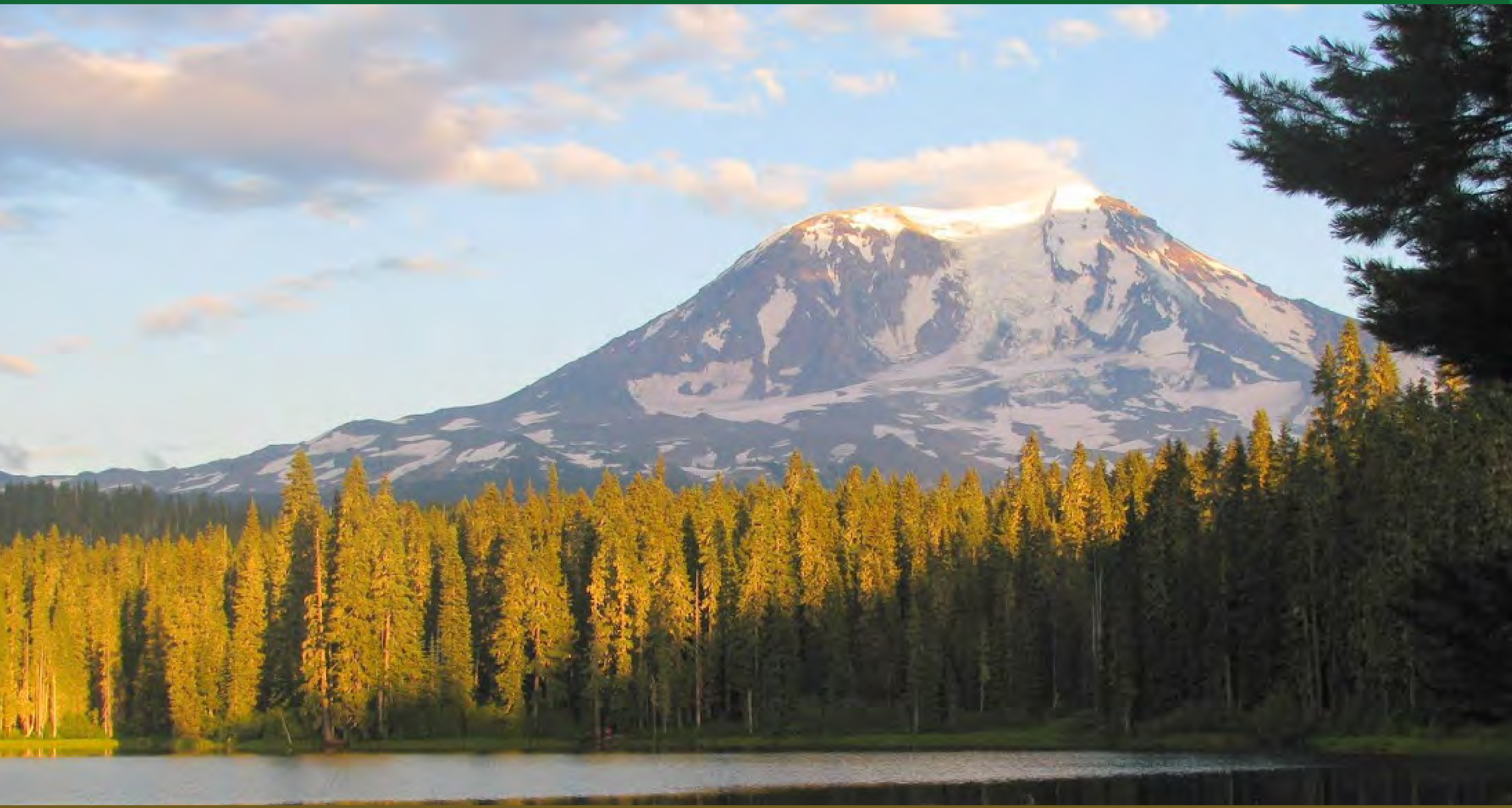
The Wildlife and Climate Resilience Guidebook

A Conservation Plan for the Southern Washington Cascades



Cascade Forest Conservancy

The Wildlife and Climate Resilience Guidebook: A Conservation Plan for the Southern Washington Cascades

Prepared by the Cascade Forest Conservancy

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1. INTRODUCTION

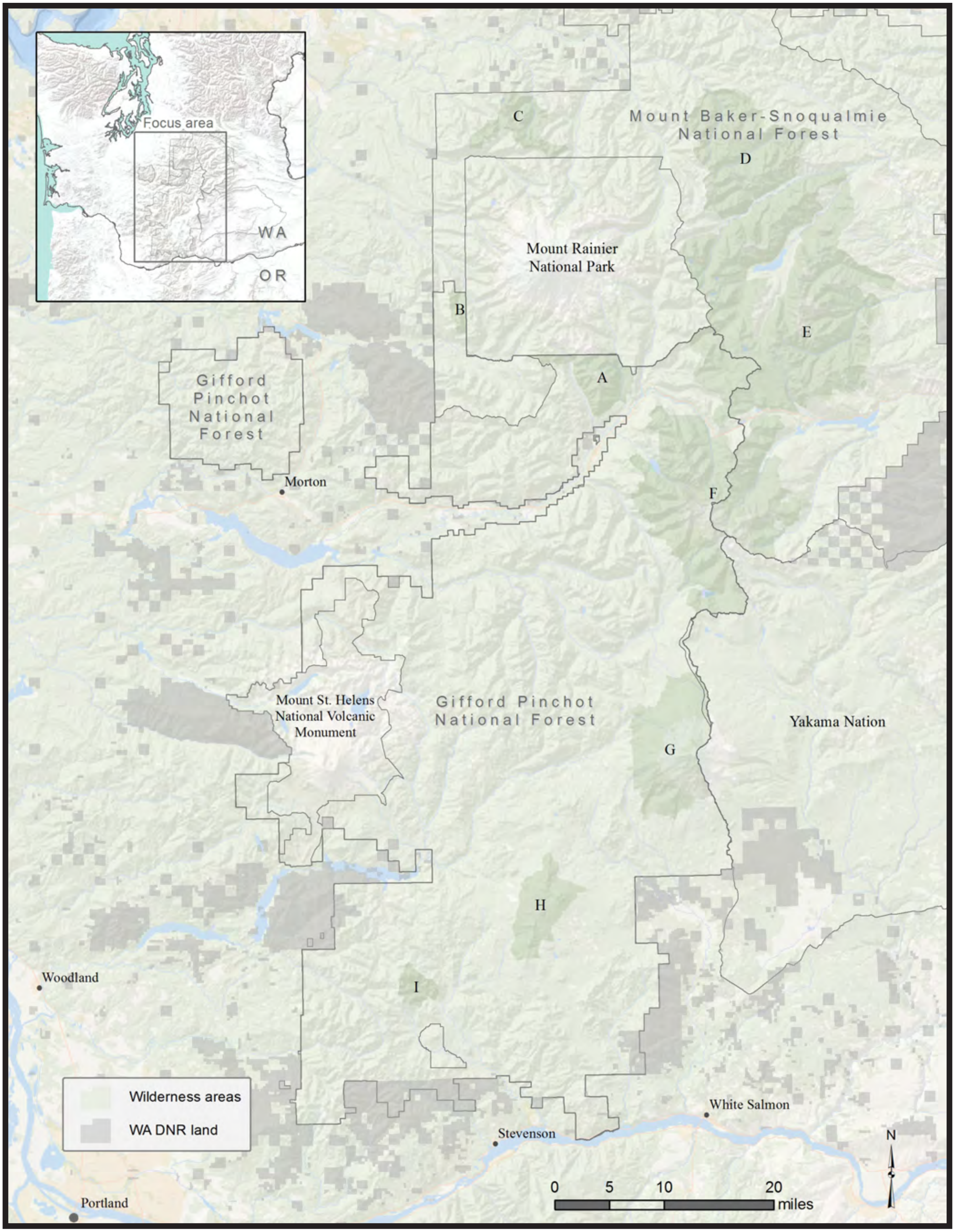
THE SOUTHERN WASHINGTON CASCADES

The southern Washington Cascades lie at the center of the Pacific Northwest and encompass Mount Adams, Mount St. Helens, Mount Rainier, and the lands between. Bordered on the south by the mighty Columbia River, this diverse and magnificent landscape is home to a wide array of ecosystems and wildlife as well as many threatened and rare species. The streams and rivers of this region are critical habitat for threatened salmon, steelhead, and bull trout. The forests are home to many iconic species including northern spotted owls, fishers, mountain lions, and bears. The alpine meadows sustain a striking diversity of plants and animals, and the alpine systems tower above and throughout the region.

We call this region the heart of the Cascades not only because of its placement within the broader biome, but also because this area serves as a vital transition zone and a stronghold of critical habitat. The Gifford Pinchot National Forest is the centerpiece of this landscape and is integral to the continued health and resilience of the region.

This guidebook will investigate climate projections and conservation opportunities throughout the southern Washington Cascades, although a large part of our focus, and especially that of our management discussions, will be on the Gifford Pinchot National Forest. We also address the surrounding and interconnected state, private, park, and tribal lands that constitute the southern Washington Cascades.

We have been working in the southern Washington Cascades for over thirty years. Our connection with this landscape extends back to 1985 when forest advocates banded together under the name Gifford Pinchot Task Force to stop the logging of old growth forests; we continue to advocate for protecting this important habitat. More recently we expanded our focus to include collaboration, restoration, citizen science, and youth and community involvement. We firmly believe that strong partnerships and community collaboration are keys to effective conservation.



The southern Washington Cascades with land designations outlined in gray and Wilderness Areas labeled as follows: A – Tatoosh, B – Glacier View, C – Clearwater, D – Norse Peak, E – William O. Douglas, F – Goat Rocks, G – Mount Adams, H – Indian Heaven, I – Trapper Creek.

WHAT TO EXPECT IN THE GUIDEBOOK

This guidebook outlines a series of strategies for NGOs, state and federal agencies, and citizen volunteers for tackling the impacts that climate change is expected to have on the ecosystems and communities of the southern Washington Cascades. We identify vulnerable habitats and species, in addition to highlighting naturally resilient parts of the ecosystem. As climate change impacts our natural resources over the coming decades, agencies and conservation groups must consider how current and near-future actions will affect the long-term health of our forests, waterways, and wildlife. We consulted and summarized the relevant science and research to identify focus areas for restoration and conservation and to create specific recommendations that can improve the resilience of ecosystems in our region. We also identify surveying and monitoring needs that can improve our understanding of climate impacts. And, we highlight the role of partnerships and the value of building communities for conservation.

Long-term planning and new policies are necessary to address climate adaptation regionally. The 2012 Planning Rule of the U.S. Forest Service requires managers to integrate long-term or regional climate goals into forest management projects and decisions. Heller and Zavaleta (2009) highlight important tools that can be deployed for climate change adaption, including reserve selection, ecosystem management, and land-use zoning schemes (1). Adaptation to climate change also requires an expanded spatial and temporal perspective, something district managers should consider in concert with managers of nearby areas. Evaluating and adapting current conservation plans may often be the best plan of action for climate change. Due to the cross-boundary nature of climate change shifts and the need for long-term commitments, strong partnerships and communication of knowledge are central components to making lasting and meaningful improvements with these plans (2).

The Cascade Forest Conservancy is uniquely positioned to provide the guidance contained herein. We have a long history of working with local communities on restoration and conservation, and we can address climate change effectively at the local scale. A local blueprint of strategies will offer benefits in the short-term and the long-term, benefits that extend outward to all groups working to build resilience in the southern Washington Cascades. The inherent uncertainties of climate change require us to be nimble and adaptive to new developments and projections. We expect new research will uncover new opportunities for climate adaptation and therefore we expect our understanding of conservation and restoration approaches to be further refined as our projects are implemented and tested throughout the region. This guidebook will be updated as our knowledge grows.

"Managers should plan to implement a broad range of short-term and long-term measures, from precautionary to somewhat risky."

In the strategies and recommendations sections of this guidebook, many of the plans outlined are site-specific, such as implementing prescribed

WHAT YOU'LL FIND IN THIS GUIDEBOOK

A detailed description of the ecosystems and wildlife of the southern Washington Cascades

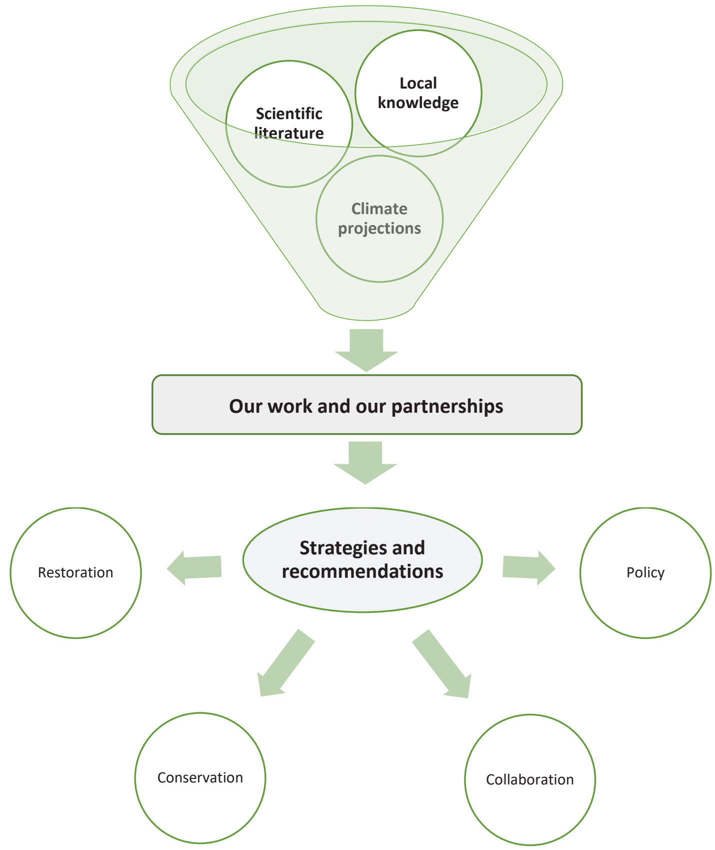
A review and synthesis of climate change research and what it means for the region burning in the mixed conifer forests of Mounts Adams or side-channel restoration in the tributaries of Trout Creek. Others are focused more directly on process, such as highlighting the need to reconnect floodplains for aquatic connectivity or the value of Research Natural Areas for expedited reserve designation.

"Due to the cross-boundary nature of climate impacts, strong partnerships are central to mitigation and adaptation efforts."

Heller and Zavaleta (2009) highlight the need to implement a broad range of short-term and long-term measures, from precautionary actions to innovative and somewhat risky actions. Monitoring is an essential step that must occur in conjunction with and after climate adaptive actions. Dunwiddie et al. (2009) recommends that those involved with climate change planning or restoration "document practices and results to permit continued assessment of success, reformulation of hypotheses, and further refinement of strategies"(3).

Resilience
The ability to survive a given change

Resilience at a regional scale
The capacity of an ecosystem to maintain function and biodiversity despite pressures brought on by climate change



Original maps and analysis completed by the Cascade Forest Conservancy

Policy recommendations and management strategies to build resilience

A description of ways in which you can get involved to help future conservation efforts

BACKGROUND INFORMATION

To create this guidebook, we reviewed and incorporated a broad set of information from various sources. Working from the scientific literature and climate models, consulting with local ecologists and climate scientists, and employing a wide array of ArcGIS tools and datasets, we summarized the large amount of information and results into a format that is applicable for planning on-the-ground projects and designing policy recommendations for the region.

The spatial layers from DataBasin (databasin.org), and in particular, those created by Conservation Biology Institute (consbio.org), were invaluable for designing and carrying out our forest ecosystem and connectivity analyses. The maps and spatial analysis tools published by the Washington Wildlife Habitat Connectivity Working Group (waconnected.org) formed the foundation of our connectivity analysis. The GIS data layers supplied by the U.S. Forest Service were valuable for many parts of the guidebook, from forest ecosystems to alpine habitats to aquatics. Maps and documents from the Lower Columbia Fish Recovery Board helped in identifying site-specific aquatic restoration needs. They maintain a comprehensive list of past, current, and planned projects, some of which are located in or near the project areas identified in this guidebook (lowercolumbiasalmonrecovery.org).

We were fortunate to receive valuable input from partners, including other conservation organizations, researchers from local universities, local stakeholders, and Forest Service specialists. Input from Forest Service specialists was essential for our fine-scale investigations and for outlining conservation and restoration strategies. These specialists work on-the-ground in these areas and have in-depth knowledge of local processes and place-based strategies. The work of the Southwest Washington Adaptation Partnership (adaptationpartners.org/swap) was also an integral part of our efforts to bring large-scale climate information into a context that is applicable at the scale of our focus area.

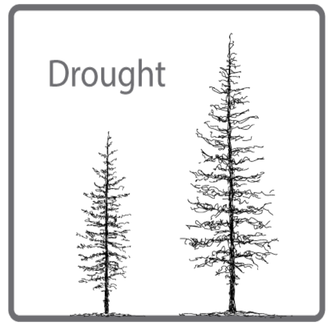
Chipping sparrow at Mount St. Helens. Photo by Michael Sulis

“The paleoecological record suggests that organisms can respond in three ways to climate changes (Davis et al. 2005). First, they may persist in suitable microsites or other refugia in otherwise unsuitable habitat (“persistence”). Second, they may adapt through either behavioral changes or selection of genotypes better adapted to novel conditions (“adaptation”). Third, they may shift to a new site by migrating or otherwise altering their range (“dispersal”). Our assumption is that developing more effective methods for enhancing these responses is an important strategy for managers seeking to counteract the stresses that climatic changes may impart to many species.” (Dunwiddie et al. 2009)

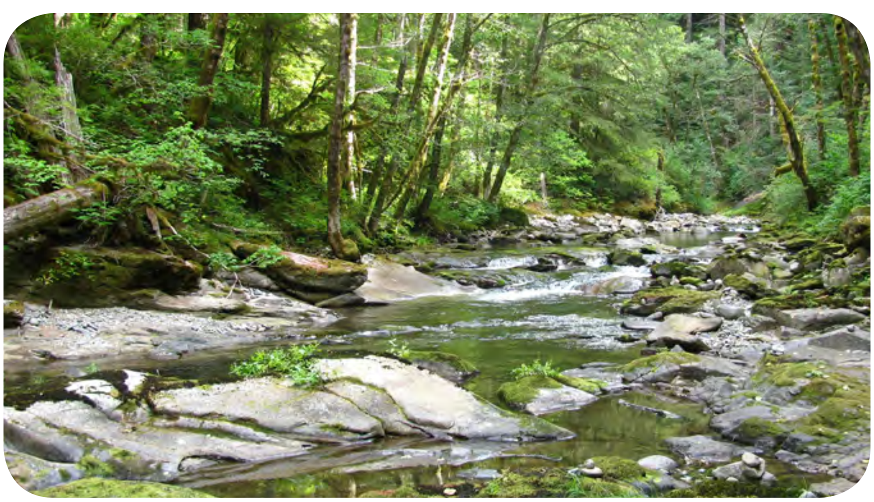
AN OVERVIEW OF WHAT TO EXPECT WITH CLIMATE CHANGE IN THE SOUTHERN WASHINGTON CASCADES

Projections of future shifts indicate that the southern Washington Cascades will experience changes in weather patterns, temperature, and rainfall, as well as resulting shifts in habitat locations, disturbance regimes, snow cover, and water availability. Climatic zones will, in general, shift to higher elevations and latitudes, but other and more varied shifts are expected as well (4, 5). Climate change is expected to cause more weather extremes and generally higher temperatures in both warm and cool seasons (6, 7). Extreme droughts and flooding are expected to occur with greater frequency and magnitude (8–10). By the later decades of this century, temperatures for the Columbia River basin are expected to rise anywhere from roughly 0.5° to 8°C (1° to 15°F) above 20th century averages (7, 11).

Many of the climate impacts on **terrestrial ecosystems** will be due to the alteration of seasonal patterns (12–14). Although projections of precipitation are more varied and uncertain than projected shifts in temperature and snow, precipitation is expected to decline in the summer and increase during fall and winter (6, 15). An increase in the variability of winter precipitation will be a significant factor in habitat availability and hydrologic shifts. A significant decrease in snowpack is expected, and peak runoff from snowmelt will likely occur three to four weeks earlier than current averages (10, 16). More winter precipitation is expected to fall as rain, rather than snow, and habitats near the tree line are expected to move upward (10, 17, 18). A longer growing season in high elevation habitats may occur due to lower snowpacks (6, 16).



During recent decades, there has been an increase in the size and severity of fires and insect outbreaks throughout the western United States; further increases, up to 2- to 4-fold, are expected in the coming century (19–22). Drier summers and drought are expected to exacerbate this further, and plant mortality from disease is expected to increase accordingly.



Temperature increases of 0.5° to 8°C are expected to impact all ecosystems in the region

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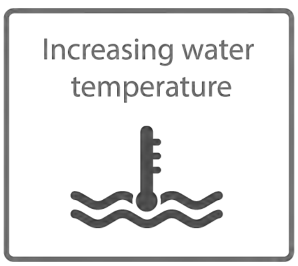
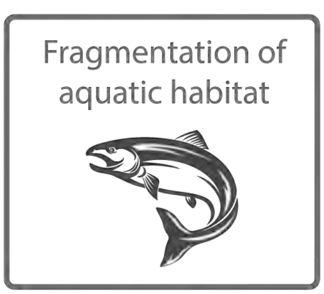
As the climate changes, we can expect to see more erratic patterns of low and high streamflow events.

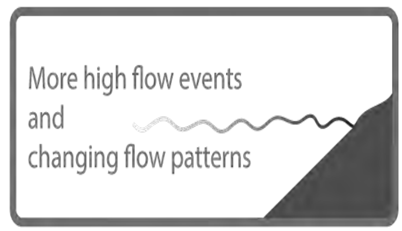
For **aquatic environments,** warming waters are expected to significantly threaten a variety of species, especially fish. Decreases in streamflow in spring and summer will be pronounced in many areas, and an increase in high flow events and the alteration of hydrologic regimes will often compound the aforementioned effects (15, 23).



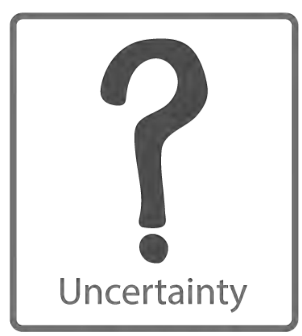
Snowmelt dominated watersheds are expected to shift to mixed rain-snow, which will likely increase winter flows and reduce late summer flows (6, 24–26). Similarly, mixed rain-snow watersheds are expected to become mostly rain-dominated, which will mean less snow and more rain during winter months (7, 10). Rain dominated watersheds may experience an increase in winter precipitation and higher winter streamflows (10). The shift from snowfall to rainfall will be most pronounced in mid-elevation areas (15).



Species distributions shifts, such as upward or poleward movement and phenological or life history changes have already been observed in the region and scientists expect these alterations to continue and increase (5, 27). Parmeson (2006) has documented current shifts in annual life-history events, such as earlier flowering of plants, egg laying and migratory patterns of birds, and mating of amphibians.



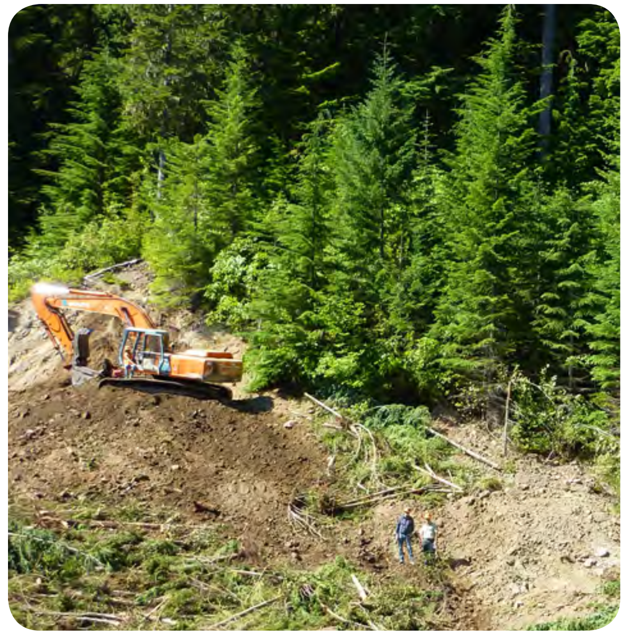
It is critical to keep in mind that these expected shifts in wildlife habitat will depend on the scale of investigation. Many of the projections that have been discussed in the scientific literature have concentrated on regional effects. We investigate how these broad shifts will be affecting the wildlife at localized scales and what practical actions can be taken to mitigate the worst climate effects while preserving regional biodiversity.



RESILIENT COMMUNITIES

In addition to the ecological impacts, climate change is expected to negatively affect local communities and infrastructure. Wildfires can reduce air quality or burn structures at the forest-residential interface, loss of snow can impact recreation tourism, drier summers can affect agriculture, warming waters can degrade fishing opportunities, and high flow events can wash out roads, reduce water quality, or flood croplands. There are, however, ways to mitigate and decrease the likelihood of some of these costly events. And through these mitigation efforts, there are economic opportunities for local communities in the form of restoration work and other jobs in the forest.

Forests and rivers benefit local communities in many different ways, such as supplying drinking water, clean air, recreation opportunities, harvest opportunities for forest products, and various economic opportunities through maintenance, restoration, harvesting, and tourism. The forests of the southern Washington Cascades also offer future economic opportunities through carbon sequestration in future carbon markets.



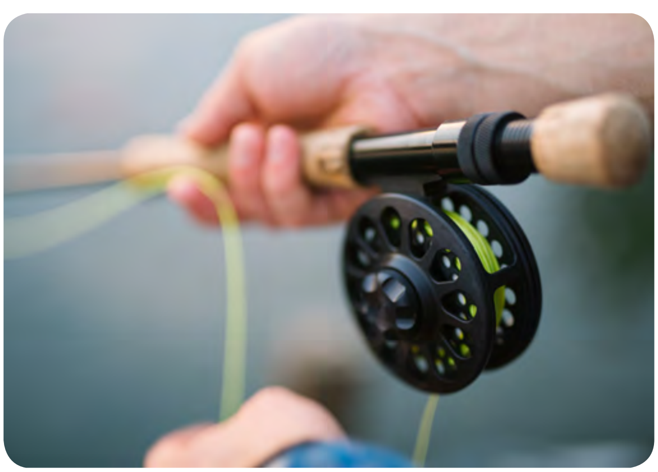
Road decommissioning in the national forest

Forest jobs are an integral part of the heritage of many communities that live within and around the forests of the Pacific Northwest. With the potential for significant job creation, resilience-building projects in the southern Washington Cascades should be prioritized for local community members, businesses, and contractors. Potential employment includes

Collaborative field trip to review a prescribed burning project stewardship contracting, road maintenance and decommissioning, forest and river restoration, preparation steps for prescribed burning, and planting of diverse tree species in anticipation of climate change. Moreover, employment associated with the U.S. Forest Service and Bureau of Land Management contributes significantly to local economies (28).

"Forest jobs are an integral part of the heritage of many communities that live within and around the forests of the Pacific Northwest."

Collaboratives can help bridge the gap between local communities, stakeholders, and forest managers. Resilience-building projects for local workers can be designed by collaborative members and financially supported as retained receipts projects (see page 58). Restoration plans can also be integrated into timber management proposals and supported through the Knutson-Vandenberg program (K-V funds, see page 58). Also, county or city groups can partner with non-profits to obtain funds for restoration projects through grants and infrastructure-related programs, such as hydroelectric mitigation and drinking water improvement programs.



Fly fishing is a popular recreation activity in the southern Washington Cascades

Recreation and tourism also offer economic opportunity. If the groundwork is laid to support the influx of forest visitors that will likely result from population growth, local communities will reap the benefits of this market. In the 20-year report of the Northwest Forest Plan, visitor spending was found to be the largest source of economic activity associated with Bureau of Land Management and Forest Service lands in the region (28). Similar studies have found spending per visitor to range from $24 to $261 per day for visitors to state parks and natural areas, and the average local spending for mountain bikers to be $385 per trip (29, 30). Recreation dollars particularly boost economies associated with hotels, motels, cabins, campgrounds, breweries, coffee shops, gift shops, restaurants, guiding services, and firewood cutting.

"Climate change has the potential to significantly impact infrastructure and drinking water. Climate adaptation and restoration work offers opportunities to build resilience and bring jobs to local communities."

Citizen engagement is another important element in building resilient communities. Stewardship requires both a passion for protecting the area's natural resources and the opportunity to get involved in the on-the-ground work. Throughout this guidebook, we will outline citizen engagement opportunities so that local community members can support climate resilience directly and actively. Whether these efforts are aimed at protecting drinking water or improving forest health in the face of threats, the work of community members is an essential piece in ensuring a robust and resilient forest ecosystem.

2. AQUATIC ECOSYSTEMS

Higher water temperatures

- Impacts to fish phenology, survival, productivity, and habitat, particularly salmon, steelhead, and bull trout
- Thermal barriers preventing migration and genetic interchange for aquatic species
- Altered structure and abundance of aquatic invertebrates, plants, microbes, and nutrients

Altered streamflow patterns and timing

- Impacts to life stages of salmonids, including eggs, juveniles, and adults
- Decoupling of seasonal interactions

AQUATIC ECOSYSTEMS, SPECIES, AND EXPECTED IMPACTS

Aquatic systems in the southern Washington Cascades are expected to be affected by climate change in several ways. Increasing air temperatures, changing soil moisture contents, and shifts to riparian vegetation are predicted to warm waters and impact aquatic and riparian habitat for an array of fish, amphibians, and terrestrial species (6, 24). In addition, many aquatic and riparian species are already relying on fragmented and degraded habitat. Some aquatic species are already living close to the upper range of their thermal tolerance and therefore even small shifts in temperature can have dramatic effects on populations (15). Increases in water temperature can cause salmonids to become more susceptible to disease, which can affect population viability and can increase predation. The increase in water temperature also causes a decrease in dissolved oxygen, which can impede survival for various aquatic species (6).

Altered streamflow patterns are also expected to degrade aquatic ecosystem function and decrease the quantity and quality of spawning habitat (9). Increased precipitation falling in the form of rain rather than snow in the winter and spring months is expected to result in higher peak flows during these months and in lower base flows in the summer months. These shifts can cause an increase in sediment introduction, scouring of stream substrates and salmonid redds, and downcutting of the stream channels, thereby disconnecting them from their floodplains and fish refugial areas. In addition to negatively affecting salmonid redds, these shifts would also lead to higher levels of mortality for newly-emerged fry, particularly for winter and spring spawning species, as well as parr and adults (7). Lower streamflows during the summer months are expected to decrease habitat and population connectivity, increase water temperatures, and create thermal barriers for fish.

Bull trout - one of the many aquatic species threatened by the changing water cycle and warming water temperatures. Photo by USFWS

Aquatic systems are in a particularly precarious position due to the multiple stressors created by shifting water temperatures, altered flow patterns, and the inability of many aquatic species to move and adjust to new habitat (10). The main concerns relate to the cumulative effects of these anticipated stressors, the already degraded condition of many aquatic habitats, and the variability of habitat and species responses.

Due to natural temperature mitigation from snowmelt and colder groundwater sources, streams and lakes that are currently fed all, or mostly, by these sources appear to be less sensitive to warming. However, even in these systems, the shift to decreased snowpacks, peak flows, nd earlier spring thaws is expected to affect the survival and timing of migration, spawning, incubation, and rearing of salmonids throughout the year. These shifts will also affect other aquatic species that have adapted to certain temperature and flow regimes. Climate-related changes in the marine environment are already resulting in negative effects to anadromous salmonids, thereby also affecting the freshwater aquatic and riparian ecosystems where they spawn and rear. Some of the primary changes in the marine environment that are affecting salmonids are (1) ocean temperature, current, and upwelling patterns; (2) persistent and large dead/anoxic zones; (3) abundance and distribution of forage fish, invertebrates, jellyfish, and planktons; and (4) ocean acidification that is impacting the

Increased frequency of high flow events

- Scouring of spawning substrate and eggs, affecting winter and spring spawning salmonids
- Reduced overwinter fish survival, especially juveniles Road failures
- Increase in sediment delivery

Low summer flows

- Habitat and population fragmentation
- Reduction in available habitat
- Drought impacts in surrounding floodplains
- Exacerbated instream and riparian microclimate warming

growth and survival of important salmonid food sources, such as krill and amphipods.

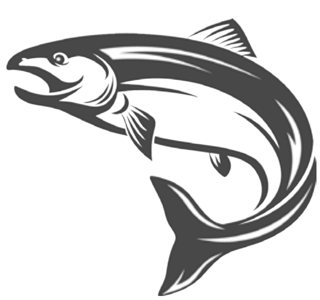
In many instances, as water temperatures rise, suitable stream habitat will shift upstream or, in the case of lakes and reservoirs, will shift to lower strata (6). Isaak and Rieman (2012) estimated that stream temperature gradients in the Pacific Northwest may shift upstream 5-143 km (3-89 miles) by 2050. Complicating this wide-ranging dynamic is the expectation that altered hydrologic regimes, changing channel structure, and culverts can impede access to new habitat areas.

In the Gifford Pinchot National Forest, a decrease in mean summer stream flow is expected to impact many stream reaches, with significant shifts in the streams listed below (31). Many of these streams are highlighted as project area priorities on pages xx and xx where restoration and conservation priorities are outlined.

CISPUS AREA	Big Creek	Cabin Creek
Pumice Creek	Little Creek	Woods Creek
Squaw Creek	Wakepish Creek	Ferrous Creek
Fourmile Creek	Hemlock Creek	Lower reaches and tributaries of Quartz Creek

LEWIS RIVER, MUDDY RIVER, AND PINE CREEK AREAS	Upper reaches and tributaries of Clearwater Creek	Upper reaches and tributaries of Elk Creek
Wright Creek	Tillicum / Lower Tillicum Creek	Copper Creek
Chickoon Creek	Strawberry Creek	(An increase in Pepper Creek)

WIND RIVER AND EAST FORK LEWIS RIVER AREAS	Big Hollow Creek	Panther Creek	Cedar Creek
Trout Creek	Dry Creek	Green Fork	
East Fork Trout Creek	Oldman Creek	McKinley Creek	



An increase in temperature is also expected to impact many streams, with significant shifts in the streams listed below.

CISPUS RIVER AREA	The confluences of Cispus River with Quartz Creek, Woods Creek, Iron Creek, and Greenhorn Creek	Yellowjacket Creek

LEWIS RIVER, MUDDY RIVER, AND PINE CREEK AREAS	Smith Creek	Pine Creek
Clear Creek	Clearwater Creek	Rush Creek
Muddy River	Lewis River	

WIND RIVER AND EAST FORK LEWIS RIVER AREAS	Brush Creek	Trapper Creek	Anaconda Creek
Wind River	Layout Creek	Big Hollow Creek	Snass Creek
Little Wind River	East Fork Trout Creek	Panther Creek	Side Creek

Salmonids will be particularly sensitive to shifts resulting from climate change, and it has the potential to affect all their life stages (23). Dalton et al. (2013) highlights how evolutionary challenges relate to the current threats to salmon:

> "As different salmon species and populations within species evolved over time, they acquired diverse spawning and migratory behaviors to take advantage of variations in temperatures, streamflow, ocean conditions, and other habitat features (Mantua et al. 2010); these characteristics now shape their vulnerability to climate change. For example, steelhead (*Oncorhynchus mykiss*), "stream-type" chinook salmon (*O. tshawytscha*), sockeye salmon (*O. nerka*), and coho salmon (*O. kisutch*) are particularly sensitive to changes in stream conditions as young fish remain in freshwater habitats for a year or more after hatching before migrating to the sea. The adults then return in the spring and summer, often taking several months to migrate upstream to high-elevation headwater streams to spawn (Mantua et al. 2010). For these populations, higher stream temperatures and altered streamflows due to climate change are likely to be significant limiting factors."

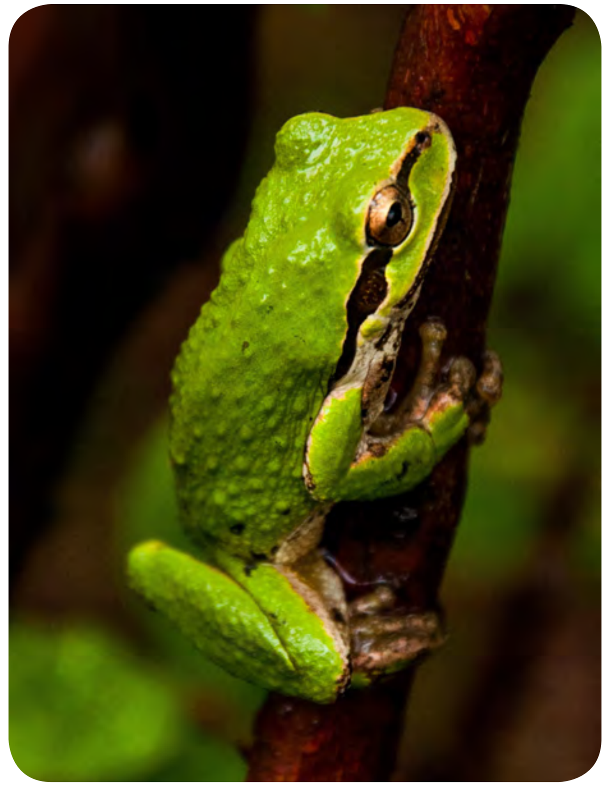
As noted in the previous pages, the impacts to spawning, rearing, and adult survival of salmon is a significant concern for the region. Conservation and restoration efforts to increase the species resilience is one of the primary objectives we considered when identifying and prioritizing aquatic projects.

Crozier and Zabel (2006) found that Chinook salmon in the Snake River of Idaho that inhabited wider and warmer streams were more sensitive to higher summer temperatures than those inhabiting narrower and cooler streams. However, they found that the salmon in these narrow and cool streams were more sensitive to reduced fall streamflows than their wide stream brethren.

Similar to **cutthroat trout** (*Oncorhynchus clarkii*), **steelhead** and other **rainbow trout** (*Oncorhynchus mykiss*) will likely be more sensitive to the changes in hydrology than the warming of waters. An increase in high flow events can disrupt spawning and rearing habitat, causing eggs to wash away or downcutting of stream beds, which can further alter healthy flow dynamics. Low summer flows can impact survival by causing stranding and heat mortality. Low flows can also negatively impact foraging and genetic diversity.

"Steelhead will be most sensitive to the changes in hydrology, while salmon and bull trout will be impacted by both temperature increases and hydrologic shifts."

Bull trout (*Salvelinus confluentus*) are expected to be heavily impacted by climate change, particularly due to warmer water temperatures. Bull trout are sensitive to temperature shifts and rely on cool water for spawning. Without proper mitigation, bull trout habitat is expected to shrink and thermal bottlenecks will make access to upstream habitat limited. Bull trout are relatively rare, but there are populations currently found in several streams in the region, including Pine Creek, Rush Creek, Cougar Creek, Lewis River, North Fork Tieton River, Klickitat River, Bumping River, Rattlesnake Creek, and there are likely still remnant populations in stream reaches located in the foothills on the north side of Mount Rainier. Spawning areas are, however, more limited and will be greatly affected by warming waters. Fortunately, restoration efforts can be implemented to mitigate some of the more extreme impacts. Efforts to support and expand bull trout habitat (mainly through planting for shade) are outlined in the subsequent section of the guidebook.



Pacific tree frog. Photo by Michael Sulis

Amphibian species that may be affected by shifts to riparian systems, such as impacts from fragmentation, drying, and altered flow regimes, are: Cascades frog, chorus frog, garter snake, long-toed salamander, northwestern salamander, Van Dyke's salamander, Larch Mountain salamander, and western toad. As ectotherms, amphibians are especially susceptible to the environment and more at risk in changing air and water temperatures. Toxic contaminants from pesticides, herbicides or fungicides can further impact amphibians by killing them directly or affecting their behavior and reducing their growth rates (32). Considering the potential cumulative impacts to amphibians in shifting riparian systems, it is important to reduce this added impact by reducing the use of damaging aquatic chemicals on state and federal lands. In addition, it will be important to work with private land owners to ensure cross-boundary collaboration that supports broad ecosystem health. Road washouts from high flow events can quickly destroy potentially critical patches of habitat for Van Dyke's salamanders (*Plethodon vandykei)* and other amphibians that reside near waterfalls and in high gradient systems. Ephemeral ponds at higher elevations, which support various amphibian populations, may disappear as a result of lower snowpacks.

The Southwest Washington Adaptation Partners identified **bird species** that are expected to be particularly vulnerable to climate impacts in riparian systems: hairy woodpecker, red-breasted sapsucker, American dipper, harlequin duck, wood duck, and hooded merganser. Other birds impacted by climate change are discussed in the Forest Ecosystems chapter.

"Van Dyke's salamanders and other amphibians that reside near waterfalls and other high gradient systems will be sensitive to high flow events from climate change."

STRATEGIES AND RECOMMENDATIONS FOR AQUATIC ECOSYSTEMS

The threats to aquatic ecosystems are significant, but there are attainable strategies that can be implemented to lessen and even counteract many of the negative impacts (15, 24, 25, 33–38).

"Reducing fragmentation and removing barriers can provide flexibility for fish populations to shift as climate pressures increase and new habitat areas are required"

In this section, we will outline recommendations for protecting and restoring aquatic habitat and building resilience to climate change effects. Ultimately, the best approach will be a mix of different strategies, plans that take local and fine-scale issues into consideration while maintaining focus on the broader, regional context. In addition to input from local biologists and hydrologists, the work of Johnson (2004), Battin et al. (2007), Beechie et al. (2012), and Dalton et al. (2013) was instrumental in helping us outline these restoration and conservation strategies.

• **Floodplain and side-channel reconnection** can can reduce the negative consequences of high peak flows by dissipating streamflows through more natural and varied routes, storing flood water, and increasing the availability of refugia. This work can also mitigate temperature increases by increasing the length of hyporheic flow paths beneath the floodplain, which can cool water during the summer (15). Examples of this type of project include the creation of side channels and sloughs, removal of levees/dikes, and re-meandering of dredged or straightened channels.

STRATEGIES AND RECOMMENDATIONS

- Floodplain and side-channel reconnection
- Road reduction
- Dam removal and stream crossing structure upgrades
- Expansion of Wild and Scenic River designations
- Management and expansion of riparian buffers to restore natural function
- Reintroduction of beavers
- Reduction in grazing and restoration of areas currently impacted by grazing
- Planting of trees
- Control of invasive plants
- Addition of large wood
- Restoration of incised channels
- Increase in surveys and monitoring with improved data sharing

Logging and stream "cleanout" activities of the 1970s and 1980s, which disrupted natural flows and depleted the amount of large wood in and around streams, caused the mainstems of many of the streams to downcut and become disconnected from the side-channels. The building of roads exacerbated and expanded this problem.

Floodplain and side-channel reconnection projects are often large-scale and accompanied by significant initial hurdles, but when organizations and agencies are working from a similar blueprint and a common strategy, new opportunities can more easily develop and benefits are more encompassing than when independent actors are working disparately. Additionally, stream channel projects benefit local communities by decreasing road maintenance costs, improving fish habitat and water quality, and oftentimes hiring local contractors for the work.

Floodplain and side-channel reconnection in the southern Washington Cascades can help re-establish natural flow regimes that were altered by logging, roads, and a general loss in large instream wood structures (focus areas are outlined below and on the maps on pages 26 and 27).

o In **Trout Creek** and its tributaries (Compass, Crater, Layout, East Fork, Planting, and Martha Creeks), the disconnection of mainstems from historic side-channels poses a significant risk to fish survival due to expected increases in high streamflow events. Loss of channel complexity, as well as high and low flow refugia, are primary limiting factors for Lower Columbia River steelhead trout. These fish are currently listed as "Threatened" under the Endangered Species Act (ESA) so the need to increase their resilience to expected changes is imperative. Side-channel restoration along these stream reaches will expand future rearing habitat and will increase the availability of spawning habitat and adult steelhead "holding" habitat that will be critical during summer low flow and winter/spring high flow periods. The site-specific restoration areas along Trout Creek and its tributaries are areas where historic side-channels existed, as evident from the presence of river gravel, old scour, and deposition features.

o **Wind River** is also at risk from past timber harvest activities and will require restoration to build sufficient climate resilience. Climate impacts include habitat fragmentation, instream and riparian habitat degradation, and reduced productivity and distribution of fish and other aquatic species. Currently, side-channel and other refugial habitat is scarce throughout the Wind River watershed. An increase in side-channel habitat here will increase the amount of important refugia for both juvenile and adult steelhead during high and low flow events. Spawning gravels and over-summer pools are also scarce so side-channel restoration efforts along Wind River should be tailored to address these aspects as well.

o The coho and winter steelhead that reside in **Little Wind River** will benefit from floodplain and side-channel reconnection. The initial stretches of this river are the priority areas for restoration.

o In the **North Fork of the Cispus River**, past management has affected channel complexity and the amount of large wood structures in the waterway. With expected warming due to climate change, nine miles of anadromous fish distribution, and Clean Water Act 303D listing in the lower reaches for temperature, this river is a priority focus area for floodplain reconnection.

o The ESA-listed fish in the **Cowlitz River** are currently persisting in degraded habitat and will be further impacted as climate change alters habitat function. Side-channel and floodplain reconnection will improve future resilience. Establishing agreements with local landowners to comprehensively improve fish habitat and water quality is an integral part of the restoration strategy of the Cowlitz River.

o The multitude of fish species in the upper reaches of **Lewis River** are at risk from warming waters and changes to streamflow. Side-channel restoration is one of the primary methods for improving habitat for aquatic and riparian species here. Although not currently a spawning area for bull trout, these fish do occur in the Lewis River and will benefit from these restoration actions.

o Side-channel restoration and floodplain reconnection along **Greenhorn Creek** and its tributaries would benefit anadromous and resident fish that depend on this waterway and are at-risk from low summer flows and impacts from high flow events due to loss of channel complexity. Populations of coho, spring Chinook, and winter steelhead currently reside here.

Recently decommissioned forest road

• The **reduction of road density** significantly improves aquatic and terrestrial systems, decreases stressors to wildlife, and also brings jobs to local communities (39–49). The maps on pages 52 to 54 highlight the specific roads we have identified for closing or decommissioning due to ecological risk, including aquatic impact factors such as the number of stream crossings, particular topographic qualities, and erosion potential. As a general rule, we believe that reducing the amount of road miles should be one of the restoration activities associated with each timber harvest project. This could be cost- and time-effective because the NEPA, ESA, and Heritage Resource consultation for both timber harvest and road projects could be combined into one effort. Also, it is a time when road work would be occurring concurrently with other actions, thereby lessening the span of impact from active management. Road closures and decommissionings should also be considered for stand-alone management projects.

"The reduction of unneeded forest roads can improve aquatic ecosystems, decrease stressors to wildlife, reduce the impacts of invasive species, and bring jobs to local communities"

• **Dam removal** can dramatically change river flows and riparian areas in a short period of time. By removing barriers that once prevented native salmon and steelhead from reaching miles of habitat, dam removal efforts have helped to restore native fish populations and improved future resilience. The Condit Dam on the White Salmon River prevented fish passage from 1913 until it was breached in October 2011. Dam removal was completed in December 2012, and anadromous fish species have successfully recolonized the historically accessible tributaries and mainstem reaches upriver from the former dam site (33). Removal of the Hemlock Dam on Trout Creek in 2009 has had similar success by allowing ESA-listed steelhead trout and other species unimpeded access to 15 miles of stream habitat, with additional miles being added as side-channel reconnection projects are implemented.

Future opportunities to improve connectivity through dam removal should focus on restoring aquatic habitat connectivity. Even if certain dams provide some level of fish passage, they should be considered for removal where feasible in order

The Condit Dam on the White Salmon River prevented the passage of fish and other aquatic wildlife since it was constructed in 1913. Since its removal in December of 2012, native fish species have recolonized upstream of where the dam once stood. Photos by Ben Knight

to improve fish population viability, enhance water quality, and restore streamflow, large wood cycles, and sediment routing regimes. Dams that degrade water quality and impact sensitive species through abnormally high or low temperatures should also be top considerations for removal. Throughout southern Washington, dams still exist that negatively impact fish populations and fish habitat, including on the Columbia, Nisqually, Cowlitz, Cispus, and Lewis Rivers. All of the dams on these rivers are located outside of federal lands. There are also dams located on smaller streams, many of which are no longer serving any purpose, yet are fragmenting fish populations and disrupting natural stream processes. Feasible means to amend this issue vary widely with land designation and current political environments. Some of these dams are listed in the National Inventory of Dams prepared by the U.S. Army Corps of Engineers. The Colvin Dam, located on Colvin Creek and affecting fish habitat along the North Fork of the Lewis River, has been proposed for removal by the Cowlitz Tribe. We support the removal of this dam to benefit the health and resilience of Chinook, Coho, Chum salmon and winter Steelhead. Other existing dams should be prioritized for removal based on their impacts to fish habitat and life cycles, continued utility, and potential long-term, ecosystem benefits resulting from their removal.

• **Expansion of Wild and Scenic River designations** should include the Green River, Cispus River, Wind River, Lewis River, and East Fork Lewis River. These rivers, as well as some of their tributaries, have been evaluated by the Gifford Pinchot National Forest and found to be eligible for inclusion in the National Wild and Scenic River System. These proposed Wild and Scenic Rivers are often already managed to maintain their outstanding recreational, fisheries, historical, cultural, geological, and scenic values. However, we believe it is important to permanently protect these values from harmful management and development activities via their Congressional designation as Wild and Scenic Rivers, especially where these rivers run through non-federal land ownerships. This permanent protection would also contribute to their long-term resilience in the face of increasing climate change-related stressors. This legislative step also prohibits dams and other federally-assisted projects that would impair the river's free-flowing character, water quality, or outstanding values. Wild and Scenic River designation further protects the river and riparian areas from degradation by establishing a protected corridor extending ¼ mile from the ordinary high water mark on both sides of the river. Also, the acreage of the Congressionally-designated corridor can be reallocated to protect connected waterways. For example, corridor acreage within already highly protected areas, such as wilderness areas, may more effectively restore connectivity of riparian areas if it is allocated elsewhere. These particular rivers are noted for designation because they have outstanding values that are threatened by current and recent projects. Once a river is designated, the resulting management plan for the river would exclude uses that are inconsistent with the maintenance of the river's outstanding and remarkable values.

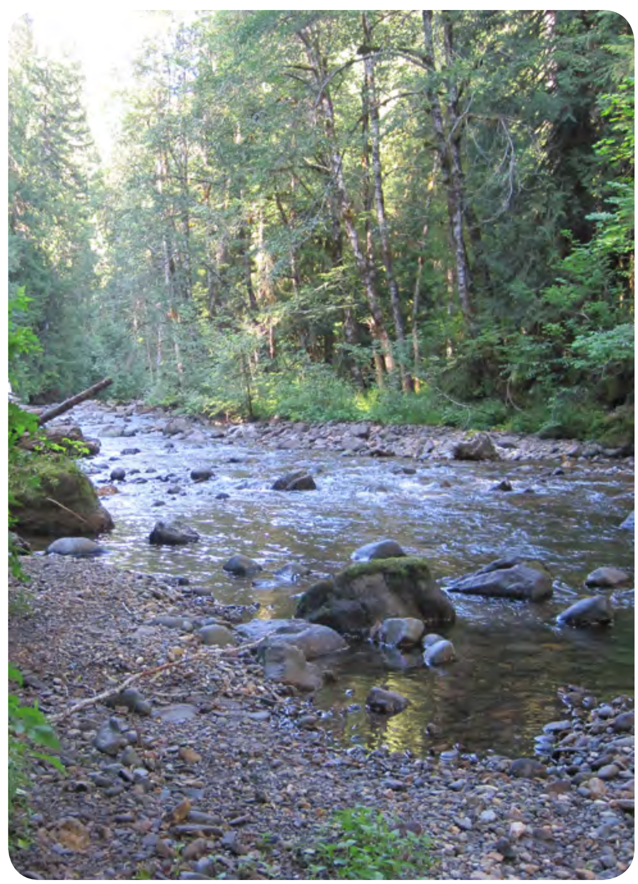
"Riparian no-cut buffers help protect streambank stability, water quality, stream temperatures, soil moisture, downed wood, and large instream wood sources"

While organizations can work to promote Wild and Scenic River designation, community support is vital because only Congress can make these designations. Citizens should write or call their representatives to express support for this type of watershed protection.

• **The preservation and broadening of riparian buffers** on federal, state, and private lands is a needed step to ensure that riparian functions and values are protected (50–52). Riparian buffers are areas along streams that are designated as off-limits to commercial timber harvest and heavy equipment incursions in order to protect streambank stability, water quality, stream temperatures, soil moisture, downed wood, and large instream wood sources. Much of the focus of these buffers has been on protecting species listed as Sensitive, Threatened, or Endangered. Now that the Forest Service's 2012 Planning Rule highlights the need to consider climate change in forest management planning, we hope to see the size of buffers increase in some areas and to specifically consider climate change aspects, such as microclimate impacts (53).

Laws governing federal, state, and private forest lands in southern Washington require varying levels of protection for riparian areas.

On federal lands, the Northwest Forest Plan designated Riparian Reserves for the protection of land bordering lakes, streams, rivers, and wetlands. The Aquatic Conservation Strategy (ACS) of the Northwest Forest Plan is designed to prevent further degradation of watershed condition and protect high-quality fish habitat and populations. Within the Riparian Reserves, a no-cut buffer is established and is intended to eliminate commercial harvest within its borders. The size of the riparian no-cut buffer is based on the type of waterbody and whether it is fish-bearing. We believe that attainment of the ACS Objectives demands a precautionary approach to forest management within Riparian Reserves, and harvest within the reserves should



Quartz Creek in the Gifford Pinchot National Forest only occur when necessary for riparian health. This is a high standard of proof, and considering recent justifications for logging in Riparian Reserves, conservation groups and citizens should be diligent with oversight to keep the microclimate of these areas undisturbed and maintain suitable levels of large trees for instream wood. Since riparian thinning can easily cause significant negative impacts to aquatic species, it should be limited to areas where the benefit is clear and significant and where the management efforts are supported by a broad set of research (35, 52, 54, 55).

On state and private lands, riparian buffers are broken down into three Riparian Management Zones (RMZs) – the Core Zone, Inner Zone, and Outer Zone. The Core Zone excludes all timber harvest and extends 30-50 feet from the ordinary high water mark, depending on the type of stream. The Inner Zone allows some harvest, if harvest allows for adequate shade and meets the desired future condition. Harvest in the Outer Zone requires leaving 20 conifer trees at least 12” dbh per acre (WAC 222-30-040). Changing state laws to eliminate harvest from the RMZ, especially the Core and Inner Zones, will be most beneficial to riparian ecosystems.

To further protect riparian areas, alternative ways to retain riparian areas on private forest lands under the Forest Practices Rules should be pursued. For example, on private forest lands there is a small forest landowner riparian easement program offering small landowners money in exchange for retention of their forested lands. This program is intended to prevent the reduction of habitat available for the restoration of salmon and other aquatic resources (WAC 222-21-005). Riparian areas on other private lands may also be protected through conservation easements, or encouraging the landowner to develop a management plan in cooperation with the Washington Department of Natural Resources, other agencies, and impacted tribes (WAC 222-23-010).

• **Surveying** stream culverts and erosion on forest roads is important for prioritizing where restoration efforts should be focused (35, 39). Obtaining up-to-date information is essential for maintaining suitable aquatic habitat connectivity and lessening negative impacts from high flow events. Each year, and increasingly likely with climate change, forest roads are failing and causing harm to aquatic habitat and hindering access for forest users (56). Many of these failures can be mitigated by maintaining current condition data on culverts and erosion. Current data on fish presence is also very beneficial for biologists and planners to help identify current distribution, conservation needs, and priority restoration areas. Through partnerships between state agencies, federal agencies, local organizations, and the public, forest resource specialists can help prioritize focus areas for monitoring.

Severe erosion found on a citizen science road survey

• The **reintroduction of beavers** (*Castor canadensis*), as well as increasing the abundance and distribution of beavers in watersheds where they are already present, can have a multitude of positive impacts on riparian and aquatic ecosystems. These include decreased water temperatures and peak flows, increased streamflow retention, improved access to floodplain habitat, and increased abundance and biodiversity of aquatic- and riparian-dependent flora and fauna (57, 58). With relatively little expense or controversy, beaver reintroduction can be a holistic way to improve aquatic resilience while also re-establishing an important piece of the trophic cascades. Due to trapping, grazing (which depletes the natural stock of hardwoods), and loss of channel complexity due to logging and other management activities, beaver populations have decreased in many parts of the southern Washington Cascades. New regulations on body-gripping traps, set in place in 2000 by the Washington State Legislature, have significantly reduced beaver trapping. Livestock grazing has been reduced in many areas and with new climate pressures suggesting a need to reduce this influence even further, we hope to see grazing continue to be focused away from sensitive and valuable stream systems. The simplification of stream systems will be addressed through restoration projects, which can often be coupled with beaver reintroduction efforts. Moreover, reintroduction, if not carried out in conjunction with side-channel improvements, should be focused on areas where reduced channel complexity will not be a limiting factor for new beaver populations.

Our recommendation is to coordinate ahead of time with state and county agencies, as well as companies that work with wildlife on private land, to set up agreements for the transfer of beavers that have been trapped as "nuisance" animals (likely found chewing on trees that the state, county, or landowner wished to keep in place). These animals would be kept in holding ponds to acclimate and then transferred to appropriate reintroduction locations on state and federal lands. The site-specific locations along the priority creeks outlined below will be identified by the presence of suitable forage for beavers, site-specific restoration values, and the existence of past lodges or dams. Priority beaver reintroduction locations in the southern Washington Cascades were identified with the help of local wildlife and aquatic specialists and include:

o Hampton Creek
o Woods Creek
o Big Creek
o Bee Tree Ponds
o Lone Butte

A map of these areas can be found on pages 26 and 27. Some of these areas are completely lacking in extant beaver populations while others have small populations that need to be enhanced.

"Beavers can have a multitude of positive impacts on riparian systems"

• **Planting** native trees for shade and bank stability can help decrease stream temperatures, improve biodiversity, and reduce erosion and sedimentation by strengthening bank stability, increasing riparian shade, enhancing nutrient delivery, and decreasing the spread of non-native plants (26, 35, 59, 60). Planting and seeding in strategic locations will enhance both short-term and long-term ecosystem health for riparian areas and the species that depend on these areas. This work is best focused along waterways that are not only degraded but also at risk and important for overall ecosystem integrity in the face of a shifting climate. The priority tree species are cottonwood, willow, cedar, and Douglas-fir. In the southern Washington Cascades, areas in need of planting are shown on pages 26 and 27, and they include Rush Creek, Pine Creek, Yellowjacket Creek, Cispus River, North Fork of the Cispus River, Cowlitz River, Wind River, Little Wind River, Trout Creek, Panther Creek, and Muddy River.

o **Rush Creek and Pine Creek** are the two main spawning streams for ESA-listed Columbia River bull trout on in the southern Washington Cascades. These two creeks, which are in close proximity to each other also provide habitat for coho, Chinook, steelhead, cutthroat, and rainbow trout. Expanding the "reach" of bull trout habitat along these creeks is critical to ensuring the species' long-term viability as waters warm and current habitat becomes less suitable. Local fish biologists have identified riparian planting as a priority to mitigate stream temperature increases. Since some reaches of Pine Creek extend into private property, we also suggest working with the local landowners to set up coordinated restoration strategies and agreements. Non-profit organizations are in a good place to be able to bridge these gaps, and we plan to work in this realm accordingly.

"Planting cottonwood, willow, cedar, and Douglas-fir trees in riparian areas can improve resilience in aquatic ecosystems"

o Cottonwood and aspen trees are needed along **Yellowjacket Creek** to increase shade, enhance bank stability, and sustain future beaver populations. These efforts will support spring Chinook, fall chinook, coho, winter steelhead, and overall aquatic resilience.

o In addition to channel configuration needs in the **Cispus River** and **North Fork of the Cispus River**, riparian planting will significantly build the resilient capacity of this critically important area. Currently home to steelhead, Chinook, and coho, the Cispus waterways have suffered from past sediment deposition and logging, and they are currently impacted by heavy recreation on their shores. Due to expected warming along the Cispus River, planting will be an important mitigation measure that should be enacted soon.

o **Cowlitz River** is one of the Gifford Pinchot National Forest's largest rivers and is home to Chinook, coho, steelhead, and an array of riparian species that rely on this large, winding waterway. Riparian planting along the river will benefit many different aquatic and riparian species. Much of this river flows through private land, so cross-boundary efforts will be needed to effectively improve long-term resilience.

o Invasive reed canary grass has become a problem along the **Muddy River** and is expected to become an even larger issue as climate change further threatens bank stability and impacts native riparian plant communities. Native riparian plants are intrinsically tied to the health of fish and aquatic invertebrates they protect, yet they are severely threatened by the likely increase in the spread of invasive plants due to changing weather patterns, which can sometimes introduce an added stressor for native plant populations. One of the main ways to wipe out reed canary grass is to crop it low and plant trees that will shade it out (61). This has the added benefit of decreasing stream temperatures, which is expected in this area, according to models (31).

o Planting and seeding along **Wind River** will be an important restoration step for improving climate resilience for salmon and steelhead in the region. These efforts should be focused on areas that were heavily logged in the past, are infested with weeds (especially reed canary grass), have low tree species diversity, have high solar impact, and have low levels of instream wood.

o Planting efforts along **Little Wind River** should be coupled with floodplain or side-channel reconnection to improve habitat resilience for coho and winter steelhead.

o Planting along **Panther Creek** should be focused between Jimmy Creek and Cedar Creek to support bank stability and to decrease stream temperatures for an array of aquatic species and for the ESA-listed fish downstream in Wind River.

o **Trout Creek** and many of its tributaries contain fish populations that will be impacted by climate change, especially ESA-listed Lower Columbia River steelhead trout. These impacts include higher stream temperatures for longer periods of the year and altered peak and base flows (higher flows in late fall-spring and lower flows in summer-early fall). This creek, its tributaries, and downstream rivers will benefit greatly from riparian planting of conifers and hardwoods. In addition to a fine-scale focus on areas impacted by past management and invasive species, this work should also be carried out at the old Hemlock Dam site (where the vegetation has not recovered).

• **Removing and controlling invasive plants** can help mitigate temperature increases by decreasing competition and supporting native trees and shrubs (51). Controlling invasive plants also supports biodiversity since non-native plants will often take over large areas and displace different species that would normally comingle. Care should be exercised to make sure that invasive control efforts do not bring unintended impacts such as negative impacts on water quality from herbicides or sediment delivery from active management. Approaches such as early-detection rapid-response, similar to what is currently underway along hiking trails, could aid in the early adoption of mitigation measures in riparian areas, which could then be enacted through small-scale, manual treatment efforts. If invasive plant populations in certain areas are too large to control with manual treatment, aquatically-appropriate herbicides should be used to ensure that efforts are not causing more harm than good. As outlined in the planting section above, invasives treatment should be focused along **Trout Creek and its tributaries, Wind River,** and **Muddy River**, and should be coupled with riparian planting to improve the long-term benefit.

Reed canary grass (*Phalaris arundinacea*) - an invasive plant in riparian areas. Photo by Roger Banner

• **Eliminating mining** along most waterways, especially those important to fish, will improve the habitat viability of fish populations by minimizing harmful mining pollution, sedimentation, and physical impacts, enhancing their ability to survive the stressors from climate change.

o Hard rock mining threatens water quality and fish habitat through acid mine drainage, increased copper levels, and sedimentation commonly associated with hard rock mines. Salmonids are particularly sensitive to copper, and it is toxic to them even at low concentrations. Additionally, hard rock mines often require large tailings ponds to contain mining waste, and failure of tailings ponds can be catastrophic to the watershed. Hard rock mining proposals within the Gifford Pinchot National Forest have historically been located along the Green River, a Wild Steelhead Gene Bank and proposed Wild and Scenic River. The Green River provides important habitat for native steelhead, which needs increased protection to counteract the expected decreases in steelhead habitat due to climate change.

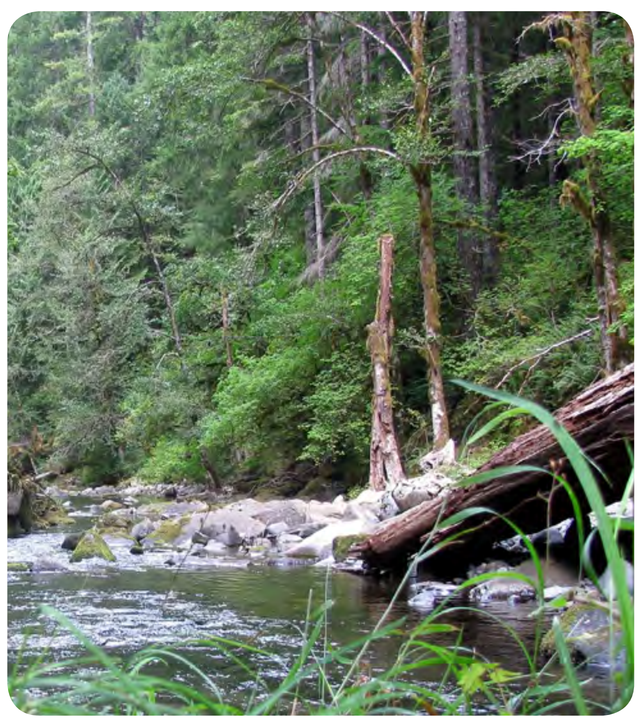
o Suction dredge mining is a process where miners use a motorized suction pump and hose to vacuum the sediments on the river bottom in search of gold. The sediment is then released in a plume that flows downstream, along with toxic heavy metals that were previously settled in the river bottom. In addition to polluting the water column, suction dredge mining destroys redds and degrades spawning substrate and water quality, thereby reducing quality spawning areas and harming salmonid eggs and alevins that rely on clean and appropriately-sized substrate for incubation and rearing. As warming waters reduce suitable habitat for salmonids, it is essential that suction dredge mining be eliminated or significantly reduced in waterways important for their life cycles.

• **A reduction in livestock grazing** near riparian areas will directly reduce sediment delivery to streams and will aid in the restoration of vegetation, which traps sediment and increases stream shade. In the southern Washington Cascades, the amount of private grazing on public land has decreased in the past decade, but impactful grazing allotments still remain in sensitive ecological areas.

The number of grazing allotments in the GPNF has decreased from four to one in the last ten years. The remaining allotment, encompassing approximately 30,000 acres, is located on the south side of Mount Adams and intersects 132 linear miles of streams, all of which flow south and into the White Salmon and Columbia Rivers. While the current primary focus of management concerning this allotment is the effect on local wildlife and terrestrial vegetation (aspens and shrubs), the effects on aquatic systems are significant and will likely increase as climate change brings new and different pressures. In lieu of removing this allotment from our public land, there are steps that can be taken to minimize the negative effects on the local aquatic environment and downstream communities. These steps include (1) maintaining proper fencing and adjusting (and enforcing) appropriate timing of grazing activities, such as limiting grazing during important times of perennial growth; (2) adjusting boundaries to avoid important riparian areas, such as shrinking the western portion of the allotment to avoid the Riparian Reserve of the White Salmon River and/or Cascade Creek; (3) constructing and maintaining plentiful, alternative water sources for the cattle in the form of troughs and guzzlers; and (4) reducing the size of the allotment where it intersects perennially flowing streams such as Gotchen Creek and Morrison Creek. The grazing allotment currently encompasses the following waterways: Buck Creek, Cascade Creek, Crofton Creek, Gotchen Creek, Hole in the Ground Creek, Morrison Creek, Salt Creek, Shorthorn Creek, Wicky Creek, and the White Salmon River.

•**The addition of large wood structures** can provide benefits to aquatic systems and fish populations (57). This approach can be quite effective in adding valuable habitat features to aquatic environments (15). These types of habitat features are expected to be increasingly needed as aquatic climate refugia. Unfortunately, though, they are expected to become less abundant due to lower summer flows and disrupted channel configuration through high flow events. Due to logging, which removed most large trees in riparian areas, there is a shortage of large wood structures in some creeks and rivers of the region. In the southern Washington Cascades, there are several priority areas for large wood addition, including **Cispus River, North Fork of the Cispus River, Trout Creek and its tributaries,** and **Wind River and its tributaries**. Wood addition projects in these waterways should occur both during and independent of timber harvest projects, taking care to

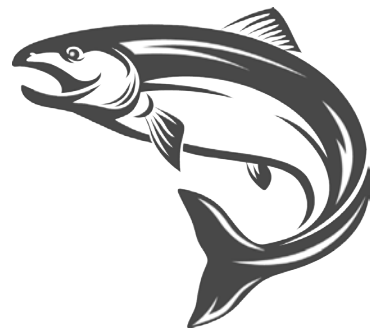
"Instream wood structures provide habitat areas and refugia for aquatic species."

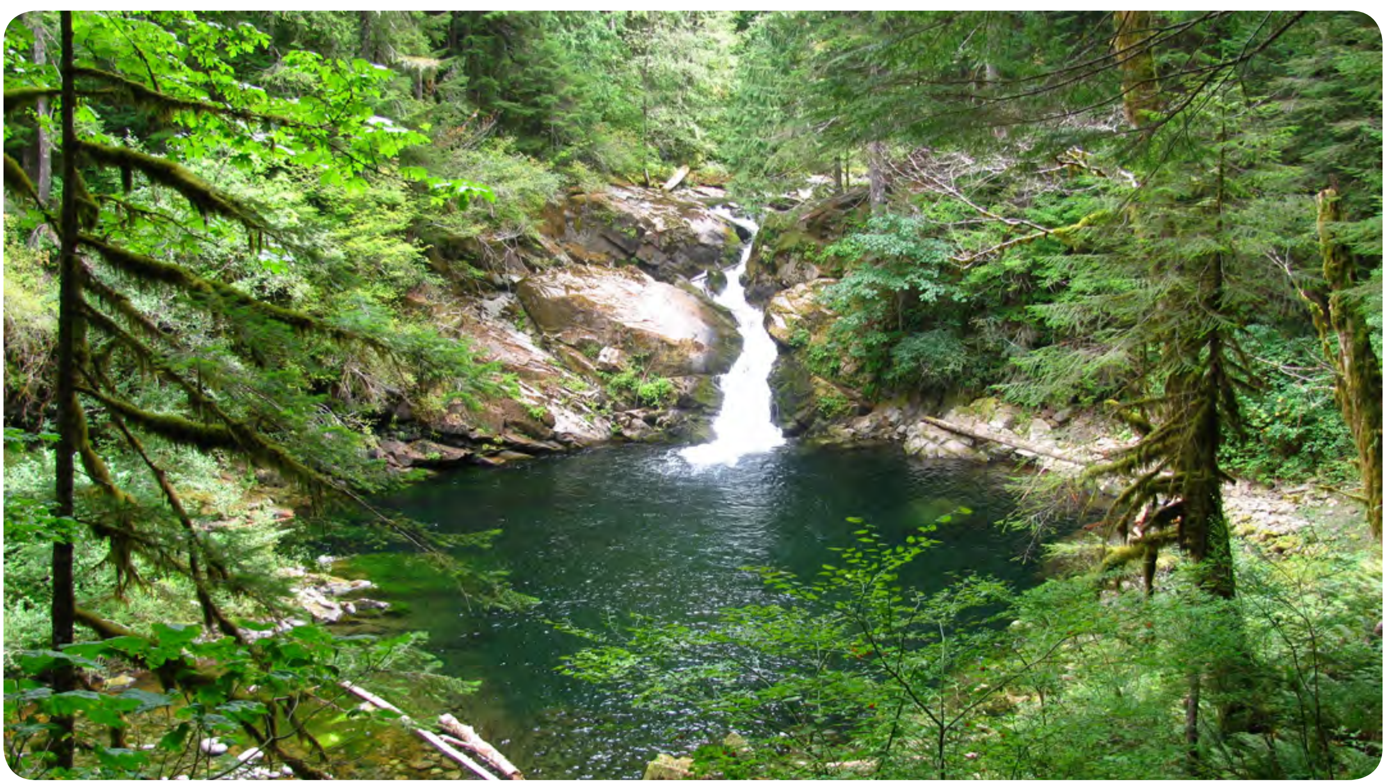


minimize harm to the existing riparian environment. Trout Creek, in particular, needs more deep pools for spawning and rearing habitat for steelhead. And, Lower Trout Creek and Wind River mainstems need large wood in the main channel and in its re-opened/reconnected relict side-channels that are currently being restored with a multi-year Lower Trout Creek Habitat Enhancement Project.

Conservation groups and restoration planners should establish community partnerships ahead of time to use fallen timber from surrounding lands. Agreements put in place with power companies, reservoirs, state lands, and private land owners can benefit both parties by increasing project efficiency, decreasing costs, and helping landowners in the removal of fallen large trees.

- **Other aquatic restoration improvements** include (1) reducing water withdrawals along different ownership classes; (2) supplementing depleted streams with fish carcasses or analogues for seasonal nutrient additions; (3) restoring incised channels; (4) increasing flood storage allocations and connected reductions in hydropower production that would help in the maintenance of instream flows for salmon and steelhead; and (5) infrastructure and human-use shifts such as upgrading to more efficient water application systems and changing to crops that require less water, which can mitigate the negative effects of a reduced supply (6, 15, 35, 62, 63).





PRIORITY AREAS FOR AQUATIC RESTORATION

Part I: North

Cispus River
- Side-channel restoration to re-establish sinuosity and improve resilience
- Planting to reduce temperature impacts
- Addition of large wood to increase habitat pools
- Expand Wild and Scenic River designation efforts to decrease impacts from logging

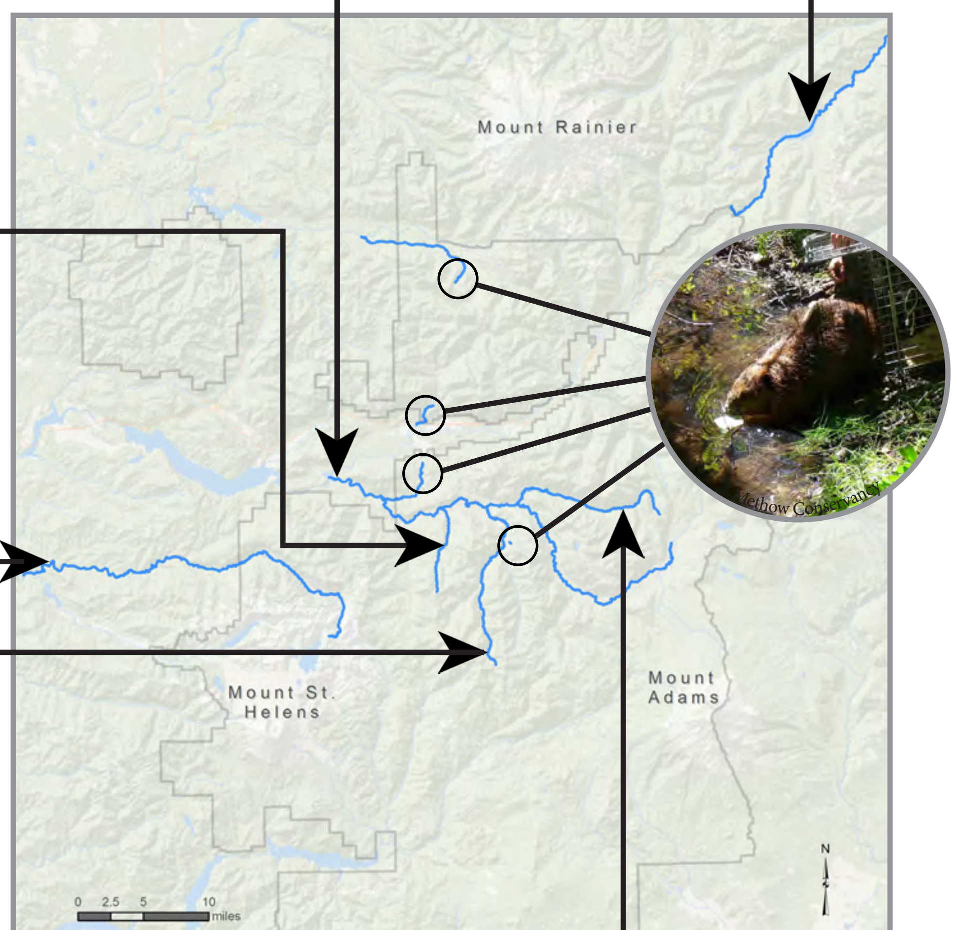
Bumping River
- Planting for shade to support existing bull trout habitat
- Side-channel restoration to improve aquatic resilience

Greenhorn Creek
- Side-channel restoration and floodplain reconnection to enhance channel complexity and reduce impacts from high flow events

Green River
- Eliminate mining to support fish habitat, water quality, and the role of the Green River as a Wild Steelhead Gene Bank.
- Wild and Scenic River designation

Yellowjacket Creek
- Planting cottonwood and apsen to decrease temperature impacts for anadromous fish

North Fork of the Cispus River
- Addition of large wood to increase habitat features for fish
- Planting conifers and hardwoods to mitigate temperature increases



PRIORITY AREAS FOR AQUATIC RESTORATION

Part II: South

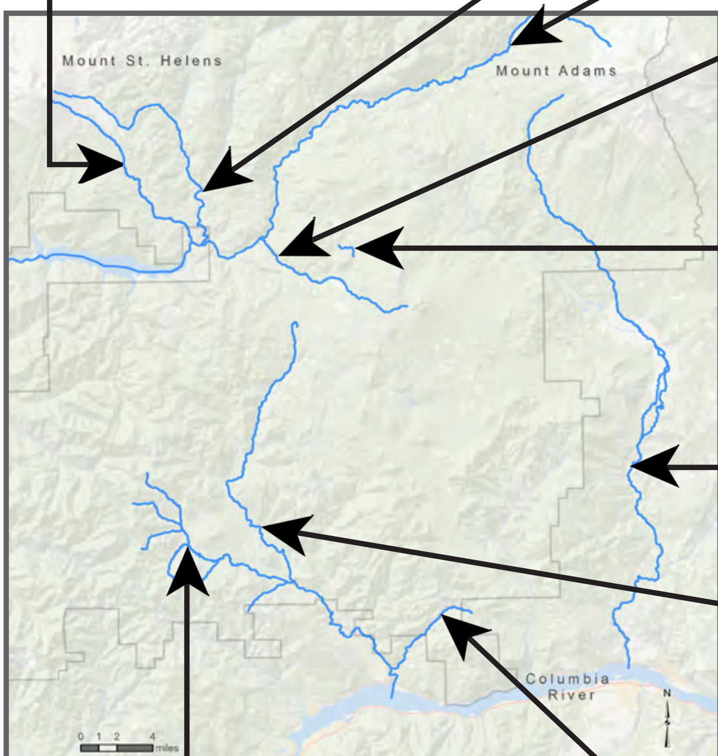
Pine Creek
- Planting for shade and erosion control to support existing bull trout habitat and improve water quality
- Work with private land owners of private in-holdings to expand restoration outside the GPNF

Muddy River
- Invasives control to decrease spread of reed canary grass
- Planting to shade out invasives and maintain bank stability

Lewis River
- Floodplain and side-channel reconnection to improve habitat for salmon, steelhead, and bull trout

Rush Creek
- Planting for shade to expand suitable bull trout habitat upstream

Lone Butte
- Beaver reintroduction to improve wetland and riparian habitat



White Salmon River
- Promote continued expansion of Wild and Scenic River designation
- Reduce grazing impacts by adjusting seasonal schedules and ensuring proper fencing

Wind River
- Side-channel restoration to increase channel complexity, decrease temperature impacts, and mitigate impacts from high flow events
- Planting for shade
- Large wood addition and beaver reintroduction to create more pools and habitat features

Trout Creek
- Side-channel restoration to improve steelhead habitat and resilience
- Planting for shade
- Invasives control to mitigate future impacts from reed canary grass
- Large wood addition to increase habitat features
- Beaver reintroduction to enhance riparian health

Little Wind River
- Planting for shade to mitigate expected instream warming
- Large wood addition to increase habitat features

3. FOREST ECOSYSTEMS AND CONNECTIVITY

FOREST ECOSYSTEMS, SPECIES, AND EXPECTED IMPACTS

From the towering Douglas-fir forests where spotted owls and eagles soar through the canopy, to the dry, mixed conifer forests where great ponderosa pines dominate the ridgelines, the southern Washington Cascades are host to a diverse array of plants and wildlife. The value of rich biodiversity in these landscapes cannot be overstated, and this understanding sits at the heart of all our conservation and restoration strategies. As the realities of climate change begin to challenge these forest ecosystems, it is imperative that we employ management practices and apply policies that target the preservation of biodiversity and the building of resilience, enabling these forests to weather the upcoming changes.

WHAT IS OLD-GROWTH?

Forest ecosystems represent the centerpiece of our conservation work, and old-growth conifer forests are the hallmark of Pacific Northwest forests. Iconic for the giant evergreens that dominate the landscape, these forests are characterized by wide and tall trees, multi-layered canopies rich with biodiversity, and decaying logs of fallen giants that feed new life. As a climate refuge for a vast number of species dependent on old forests and the microclimates they create, it is important that we focus our efforts on stemming the fragmentation of these areas and the stressors created by climatic change. In recent years, many old-growth stands throughout the Pacific Northwest have benefitted from protective forest management practices that have slowed harvesting and the destruction of these habitats (64). This more nuanced management of old-growth has resulted in a decrease in the loss of old-growth habitat, however, there is still much work to be done in protecting mature forests that will be the old-growth of the near future, ensuring connectivity, and restoring degraded forest stands.

Finding a universal old-growth definition is no simple matter; some definitions are nearly identical while others vary widely. Old-growth is generally identified by age and a collection of attributes

American marten
Martes americana

Northern spotted owl
Strix occidentalis caurina

Northern flying squirrel
Glaucomys sabrinus

such as large living and dead trees, vertical and horizontal diversity, and coarse woody debris on the forest floor.

"Old-growth forests are biodiverse habitats that are characterized by large trees, often greater than 150 years in age; multi-tiered canopies; and snags and downed woody debris that invertebrates and small mammals can live in."

Old-growth is oftentimes recognizable by the sheer size of the trees. A few of the more common giants that can make up old-growth in the region are western hemlock (*Tsuga heterophylla*), Douglas-fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), and ponderosa pine (*Pinus ponderosa*). It is not uncommon to find old-growth stands with trees well over 200 years old and reaching sizes greater than 150 feet in height and 8 feet in diameter. In thin patches of sunlight, and growing beneath the shadow of the large old trees, are more shade tolerant trees and plants that create the different levels of an old-growth system. Rich with life, the canopies represent distinct ecosystems, harboring up to 1,500 invertebrate species (65). As centuries pass, natural and anthropogenic disturbances will kill some of the ancient trees. Even in death, the trees perform very important ecological roles by providing shelter and nutrients for other plants and animals. Taller snags, sometimes called "the standing dead," are preferred nesting sites for many small mammal and bird species in the forest, and when snags fall they can benefit streams, reduce erosion, and provide homes for various terrestrial and aquatic species.

Fisher
Pekania pennanti

Western gray squirrel
Sciurus griseus

WHERE ARE THE OLD FORESTS OF THE SOUTHERN WASHINGTON CASCADES?

As we began our examination of the threats and dynamics of old forests in our region, we looked at two different datasets on forest age and structure in the Pacific Northwest. The first is a spatial layer called the Old Growth Structural Index (OGSI), which classifies forests based on the following functional components: density of trees, density of snags, the amount of down wood cover, tree diameter, and age (64). The other dataset is from Conservation Biology Institute (CBI), and it uses different age class divisions and concentrates solely on age. We considered both of these datasets in our efforts to prioritize conservation work, to identify where old-growth forests occur, and to determine what areas have the potential to be old-growth in the near future.

Marbeled murrelet
Brachyramphus marmoratus

In our efforts to identify areas of old-growth habitat with related functional components, we used the OGSI spatial layer. Under the OGSI classification, stands that are 80-200 years and have suitable levels of mature forest features are considered mature, and those that are >200 years and have old-growth characteristics are considered old-growth (see map on page 31).

We used the 80 year+ representation from OGSI to look at areas that are currently functional as mature forests. Later on in this guidebook, we identified where these areas overlapped potential areas of logging or development, and we also used the OGSI layer to investigate "functional connectivity" between dense patches of mature forest by running a connectivity analysis (page 41).

Since the OGSI layer omits old forest stands that are yet to be fully considered old-growth under that classification (i.e., they are still in the process of acquiring sufficient levels of snags, down wood, and other old forest attributes), we used CBI layer to help us identify the current locations of mature forests that can be protected or restored to become old-growth in the future. The spatial data provided by CBI identify mature forest as stands over 50 years old and old-growth as stands over 150 years. We used the old-growth classification of the CBI layer to visualize where the densest aggregations of these old forests remain in the region (page 32).

In the Strategies and Recommendations section of this guidebook, we will explore how management in and around these areas can be oriented to promote long-term ecosystem health.

WHAT IS THE ROLE OF OLD-GROWTH FORESTS IN BUILDING CLIMATE RESILIENCE?

The result of centuries of growth and accumulated biodiversity, these ecosystems are critical in buffering the negative effects of climate change. Old forests serve as **climate refugia** for many

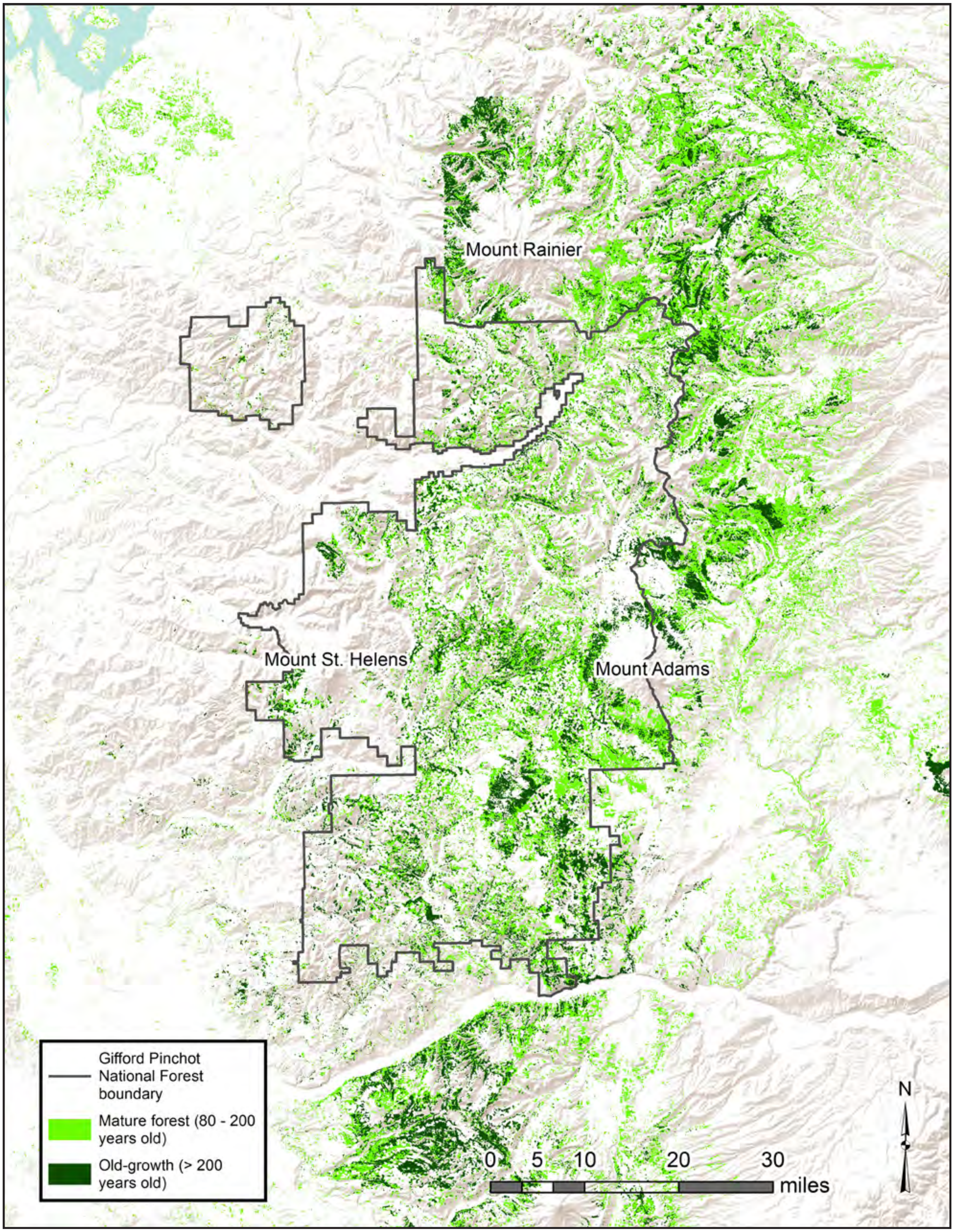
Decades of clear-cutting on federal lands drove the northern spotted owl and other old-growth dependent species to the brink of extinction. In an attempt to balance conservation concerns with the economic needs of timber-dependent communities, a team of specialists drafted the Northwest Forest Plan (NWFP). Since 1994, the NWFP has directed management of Forest Service and Bureau of Land Management lands throughout the range of the spotted owl, west of the Cascades from Washington to northern California. The NWFP created land designations on federal lands throughout the region, and provided management direction based on those designations.

- **Matrix** is land designated for multiple use, including timber harvest. Mature and old-growth forest within this land designation have few protections from logging.

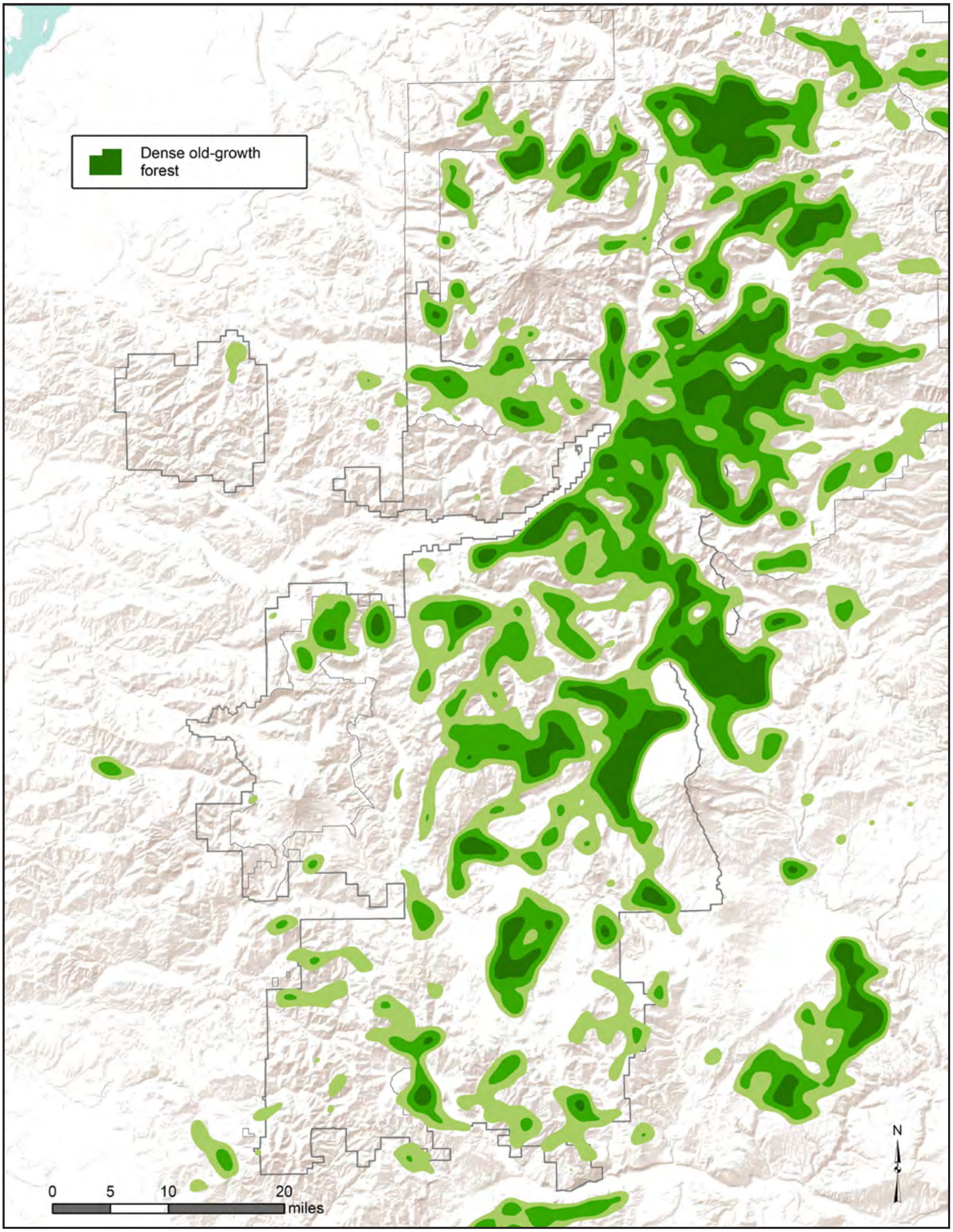
- **Late Successional Reserves** (LSR) were set aside by the NWFP to protect current, and develop future, old-growth habitat. Forests in LSR greater than 80 years old are protected from logging unless it will benefit the creation of old-growth conditions. Timber harvest may occur in LSR forest younger than 80 years as long as it encourages, or does not inhibit, the creation of old-growth conditions.

- **Adaptive Management Areas** (AMA) are intended to be areas where experimental land management strategies may be tested. AMAs are exempt from many NWFP rules, though, so logging of old forest stands within these areas can occur.

- **Riparian Reserves** are located along waterways and wetlands to protect riparian habitat from logging impacts. Harvest within these areas should only occur when necessary for the health of the riparian area.



Cell-based map of mature and old-growth forest using the Old-Growth Structural Index



Dense areas of old-growth forest >150 years old species and can withstand stressors that may threaten other ecosystem types. There are, however, significant threats to these areas, and the threats are most severe if the functional components of old forest habitat are not protected or properly restored. Before we look into the threats that face these forests, we'll examine their features that offer protection and provide resilience.

"Our definition of old forests includes all mature and old-growth forest areas."

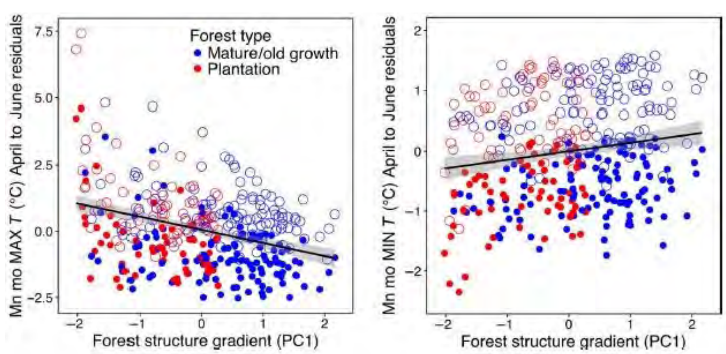
Biodiversity is one of the main features of old forests that provide long-term protection in the face of disturbance and climate impacts. Biodiversity represents a "library of possibilities" for local ecosystems and enables landscapes to have inherent resilience in the face of threats (66). Old forests are relatively resilient to disturbance, and with climate change being a force that will likely bring severe stresses and cause pockets of mortality from drought impacts, wildfires, or population shifts, these forest areas are more important than ever as habitat refugia and species "banks" (1, 67–69). Recently logged or otherwise disturbed forests that are still in a state of recovery are not yet able to mitigate the magnitude of impacts that old forests can. Some of our focus will be on protecting and improving mature forests since they represent our future old-growth, and they are important to the resilience of the southern Washington Cascades. The region will need more areas that function similar to old-growth forests in order to weather the impacts of climate change.

"Older forest stands confer a strong, thermally insulating effect. With tall canopies, high biomass, and vertical complexity, older forests provided cooler microclimates compared with simplified stands. Frey et al. (2016) observed differences as large as 2.5°C between plantation sites and old-growth sites, a temperature range equivalent to predicted global temperature increases over the next 50 years."

The regulation of microclimate is a unique trait of large old-growth stands that adds a dynamic defense to climate change. Research has demonstrated the ability of old-growth to minimize temperature variation compared to clearcut or heavily thinned forests (70). Frey et al. (2016) explain the effectiveness of old-growth in microclimate regulation in comparison to simplified plantation stands:

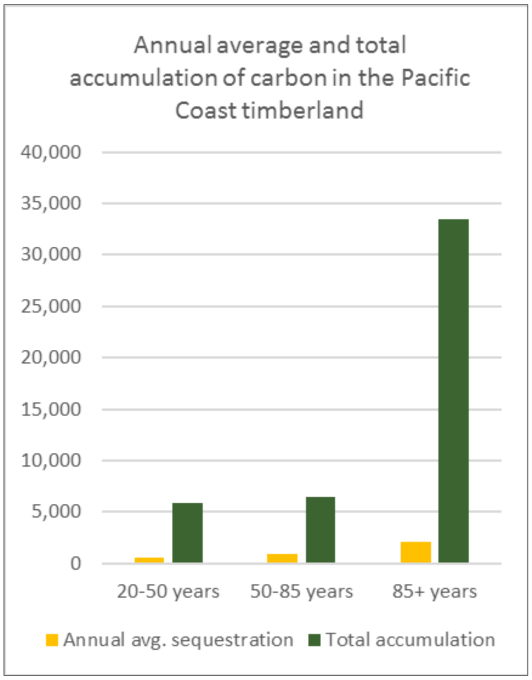
> Vegetation characteristics associated with older forest stands appeared to confer a strong, thermally insulating effect. Older forests with tall canopies, high biomass, and vertical complexity provided cooler microclimates compared with simplified stands. This resulted in differences as large as 2.5°C between plantation sites and old-growth sites, a temperature range equivalent to predicted global temperature increases over the next 50 years. (p. 6)

The passage above is further explained in the figure below, which illustrates the greater extremes in temperature between structurally simple forest stands in comparison to old-growth.



Differences in microclimate conditions across a gradient in forest structure (after accounting for the effects of elevation). Closed circles represent 2012 and open circles represent 2013. Maximum monthly temperatures (A) decreased by 2.5°C (95% confidence interval, 1.7° to 3.2°C) and observed minimum temperatures (B) increased by 0.7°C (0.3° to 1.1°C) across the observed structure gradient from plantation to old-growth forest. Reprinted from "Spatial models reveal the microclimatic buffering capacity of old-growth forests" Copyright 2016 by Science Advances.

In another investigation, Chen et al. (1993) found a significant difference between daily temperature change in the clearcut to that inside the forest. "Under unstable weather conditions (e.g., during the change from hot, sunny to windy, cloudy weather), change in air temperature was as high as 25-28°C (77-82°F) in the clearcut and at the edge, but considerably smaller (15-17°C, 59-67°F) inside the forest" (71). The tall canopy of old forests also serves a very important secondary function with its ability to collect a significant percentage of the forests water through fog and cloud drip on high branches and leaves (65). This helps mediate changes in moisture as well as temperature.



Annual average and total accumulation of carbon in Pacific Coast timberland. Copyright 1992 USDA FS.

The ability of old forests to mitigate increasingly unstable weather conditions makes old-growth patches and corridors important for specialist species to persist amidst shifts within and around current habitat. Restoration and protection of large habitat areas and corridors for connectivity will help populations endure changes in overall landscape health as well as the deleterious shifts within old forest habitat patches.

There is a growing body of literature that suggests that mature and old-growth forests are uniquely valuable as natural **carbon banks** (72–75). Mature conifer forests account for some of the highest annual carbon storage in North America, and the Gifford Pinchot National Forest is ranked fourth in the nation for carbon storage (76, 77).

"The Gifford Pinchot National Forest is ranked #4 in the nation for carbon storage"

Forests store carbon by pulling the most prominent greenhouse gas, CO2, from the atmosphere through the process of photosynthesis and then converting it into glucose, which is used for growth and other functions. Photosynthesis allows these old-growth forests to act as such effective carbon banks. The sheer size of the trees in old-growth forests make them particularly good at carbon sequestration (72). Forests in the Pacific Northwest store more carbon than most other forest systems (74, 78). Data from the Intergovernmental Panel on Climate Change shows that forests like those in the Cascades sequester an average of 68 tons of carbon per acre every year in their soil and plant life (73). The carbon is stored in the soil, leaves, bark, and organic debris. To prevent misconceptions, it is important to understand that carbon sequestration is stored in the complex forest system rather than the individual trees. Soil and downed logs themselves account the majority of the carbon stored in old-growth forests – which makes understanding the forest as a system, rather than a collection of trees, all the more important.

Clearcutting and heavy thinning not only prevents the continued sequestration of carbon, but acts to release much of the stored carbon back into the atmosphere (66, 79). Most commercial timber managers cut stands before their carbon storage is maximized (75). Forest management plans on most privately owned lands call for thinning and clearcutting practices that are particularly detrimental to the biomass stocks responsible for continued carbon storage (74). For this reason, it should be a priority to support the development of carbon trading systems, similar to the Cap-and-Trade Program of the California Air Resources Board, while continuing to develop the carbon storage stocks on state, federal, and private land through preservation and restoration of mature forest stands. This is not only important for local forest health and connectivity, but also has far reaching global implications for the continued climate crisis.

"There is a growing body of literature that suggests that mature and old-growth forests are uniquely valuable as natural carbon banks."

Quote box: Continued development of the carbon storage stock on state, federal, and private land through preservation and restoration of mature forest stands is not only important for local forest health, but has far reaching global implications.

"Most commercial timber managers cut stands before their carbon storage is maximized".

Representing havens of biodiversity, being nature's most effective carbon banks, and acting as regulators of water and microclimate, old-growth stands in the southern Washington Cascades are one of our best tools for building climate resilience on a landscape scale. Current and future old-growth forests can help mitigate many of the common stressors associated with climate change.

"Continued development of the carbon storage stock on state, federal, and private land through preservation and restoration of mature forest stands is not only important for local forest health, but has far reaching global implications."

HOW WILL OLD-GROWTH FORESTS SURVIVE THE IMPACTS OF CLIMATE CHANGE?

Despite the natural resilience of old-growth forests in the Pacific Northwest, they are not impervious to threats. In addition to continued development and logging in mature forests, climate impacts from drought, insects, fire, and fragmentation are significant current and future threats.

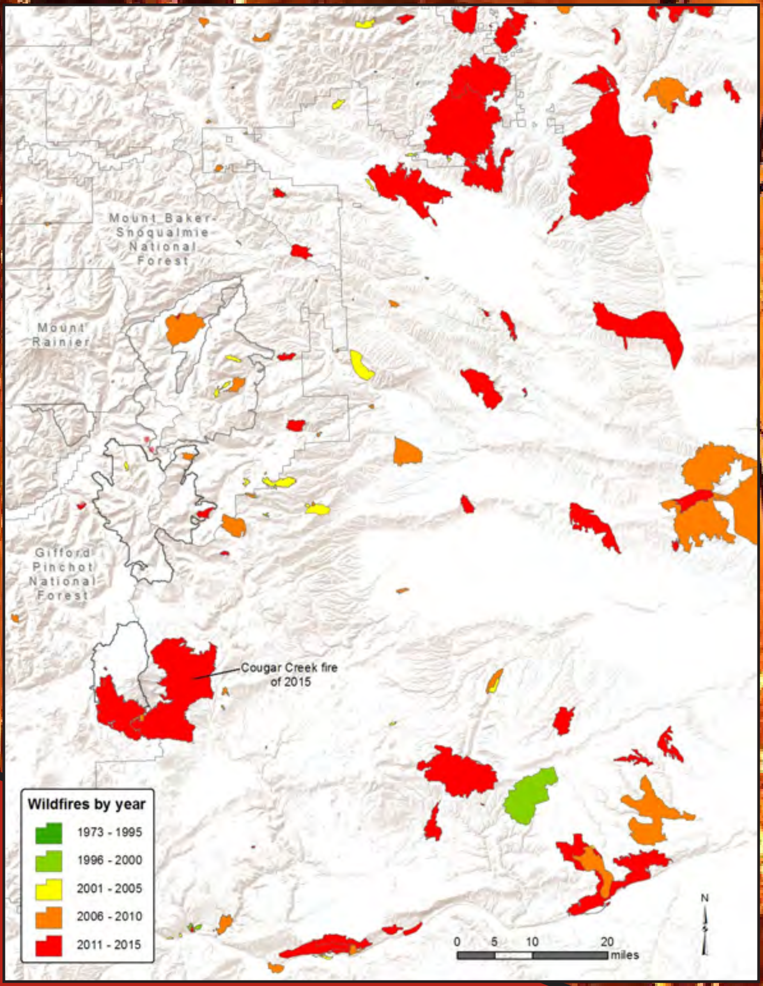
Climate models project that by the end of the century, temperature in the region will increase will roughly 0.5° to 8°C (1° to 15°F) above 20th century averages (11, 80). Models also suggest that summers will be drier, which is likely to adversely affect a wide array of forest species (81–83).

Summer **drought** and **heat related mortality** of conifer trees in North America have spiked drastically since the 1980s and 1990s (68). Warmer and drier summer months will also bring higher rates of wildfire, insect, and disease mortality that will further put forests and species at risk. These concerns are especially relevant for the more vulnerable new-growth and second-growth that have yet to acquire the stability and biodiversity that comes from decades of maturity.

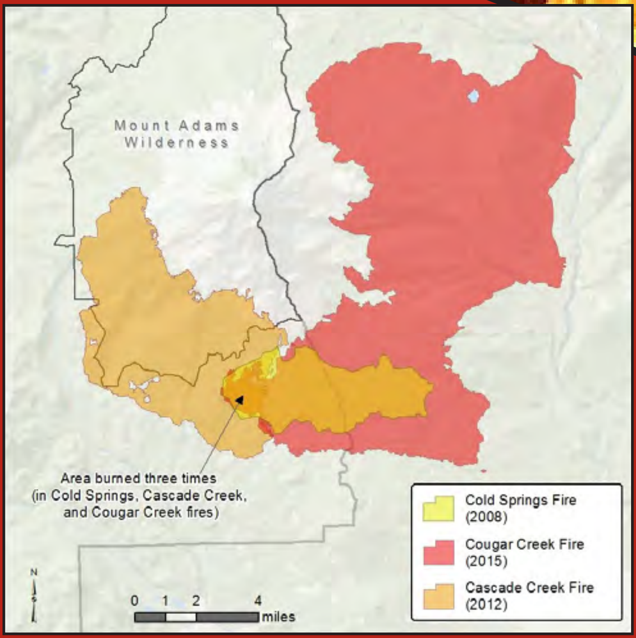
Research also shows potential **shifting forest growth behavior** in response to a changing climate (82). Forest "zones" are expected to move upward in elevation, potentially causing important species relationships to decouple and creating ripple effects through the ecosystem. Shifts will likely make native forest species more susceptible to displacement, oftentimes by invasive or other plant species that are less likely to be suitable as wildlife habitat (84, 85). Some forest plant species will be unable to move and adapt fast enough to avoid local extirpation.

Slight to moderate warming may actually increase the ability for some land areas to store carbon through increased growth and geographic expansion (i.e., new carbon sinks in the Pacific Northwest). Forest communities could expand into current rangelands, thereby absorbing more CO2 and becoming a net carbon sink. However, there is likely a warming threshold above which they will start to decline due to drought stress and increased disturbance. Further, these areas are often places where past and expected management is focused on short-term economic benefit over the long-term health of ecosystems and considerations of the carbon equation.

FIRE IN THE SOUTHERN WASHINGTON CASCADES



WILDFIRES have shaped the southern Washington Cascades ecosystem. They have helped create the diverse habitat mosaics that we see today, which add to the health and resilience of Pacific Northwest ecosystems. The famous Yacolt Burn of 1902 was the largest wildfire in the history of Washington state and burned 500,000 acres in the southern part of the Gifford Pinchot National Forest and along the Columbia River Gorge. This high-severity fire dramatically altered the landscape of the region. The Cispus Fire of 1918 burned almost a third of the Randle Ranger District, which encompassed the northern part of the National Forest (the district boundaries have since changed and its name is now the Cowlitz Valley Ranger District). Many other smaller fires swept through the area during the next several decades. The results of these events can still be seen. The map to the right shows the most recent fires in the Washington Cascades and eastward, ranging from 1970 to 2015.



The forests around Mount Adams have been altered dramatically over the last decade through wildfires. Some of these impacts are natural, and others are a result of past management and current climatic conditions.

As we can see in the lower map, some areas of the three most recent fires have re-burned three to four times, an uncommon occurrence in unmanaged stands, a disturbance that can cause harm to soil and recovering native plants. These areas will need monitoring and may need restoration to assist with recovery. Most post-fire areas can normally recover naturally, but when the pre-fire conditions lead to more catastrophic impacts, such as sterilized soils or exhausted seed sources, active post-fire planting and seeding may be warranted.

An **increase in wildfire spread and severity** is a concern for forests in the region (86). Fires have been a natural part of the Pacific Northwest system for centuries, though. They not only help create habitat for species that depend on post-fire landscapes, but they are also a driver in creating the diversity that supports resilience and long-term forest health. Fire is essential to the existence of some species, through seed dispersal and germination as well as habitat and forage development. While fire is an important and natural part of forest ecosystems, many of the region's landscapes are presently ill-equipped to withstand severe fire impacts without management actions to improve resilience. These actions include active restoration, updated wildfire response policies, and stronger protection measures for areas nearby fire-risk zones. The areas of greatest concern for stand-replacing fires are the old-growth forests in the western part of the region and the mixed conifer forests near Mount Adams (31).

"Due to the current decrease in contiguous old-growth habitat, stand-replacing fires can cause the disappearance of key species or communities"

When fire regimes are outside their natural range of variability (in terms of distribution and severity), they can interfere with achieving the goal of ecosystem resilience. Due to the small amount of contiguous old-growth forest that remains, stand-replacing fires can have significant impacts on key species or communities. Unlike in the dry, mixed conifer forests where thinning may decrease the risk of severe ecosystem disturbance, forest thinning efforts in the western part of the Cascades will not help in improving ecosystem resilience, except in young plantations (87, 88). The amount of thinning that would be needed to measurably decrease fire intensity and spread in west side, moist forests is so great that the direct and immediate negative impacts from logging would far outweigh any risk-reduction benefits. Conservation focus in these forests is best geared toward the protection of connected and contiguous mature forest patches, thinning of young plantations, and restoration in the form of planting, seeding, felling trees in mid-age stands for downed wood, and girdling trees to create snags and more abundant future habitat. On page 46, we explore these and other strategies and recommendations for forest ecosystems. And, on page 64, we examine what can be done to improve climate resilience in the mixed conifer forest at the crest of the Cascades.

Changes in climate can also directly and indirectly cause an **increase in the presence and impact of insects and disease**, likely most pronounced in higher elevations (18, 22, 89). The direct cause is the expected climatic shifts that will create more suitable conditions for insects that attack trees. The indirect causes are from an increase in tree competition that enables insects to more effectively spread and kill trees, as well as climate impacts that hinder insect competitors (82, 90). Insect outbreaks and disease can, however, benefit forest ecosystems by culling the weaker trees and thinning the canopy and reducing tree density. This creates a mosaic of varying age classes and allows older and stronger trees to grow faster (without introducing the negative impacts of heavy machinery and other tools of active management). However, while disease and insect associated die-off in forests might be part of the natural process, like fire, the expected increase in temperature will increase the rate at which forest cover is destroyed.

Natural thinning through disease in a mixed conifer forest near Mount Adams.

The fisher (*Pekania pennanti*) is a medium-sized member of the mustelid family whose historic range in the Pacific Northwest once extended through most of the Cascade and Coast Ranges, including the Olympic Peninsula (169–172). Fishers were extirpated from Washington in the middle part of the 1900s because of trapping and habitat fragmentation, and only a few populations remained in other parts of the western United States (171, 173). Trapping of fishers in Washington was prohibited in 1933, but populations had already dropped significantly; comprehensive multi-agency surveys in the latter part of the century showed no fishers in the Washington Cascades (174, 175). Recent reintroduction efforts have brought fishers back to parts of their historic range, though, including the southern Washington Cascades.

Fisher reintroduction in the Gifford Pinchot National Forest. Photo by Michael Sulis

Fishers are dietary generalists, which enables them to shift their diets depending on location, season, and prey abundance. When it comes to habitat, however, fishers require certain conditions (176–179). Fishers use large diameter trees for denning and resting, so old-growth forest stands are particularly important for maintaining healthy populations (119, 172, 174). Dense canopy cover is also needed and ensures the availability of adequate resting sites, habitat for prey species, and refuge from predators (100, 119, 180, 181). A dense canopy also decreases snow depth on the ground, which is important for fishers because they do not have the subnivean capabilities of their marten and wolverine relatives (175, 182, 183). Fishers prefer low- and mid-elevation forests and they tend to avoid high elevations due to deep snow, lower abundance of prey, dispersed tree cover, lack of large trees, and a lower abundance of snags and downed wood (103, 172, 183, 184).

Photo by Michael Sulis

Fishers, like many old forest species, will be impacted by habitat loss and fragmentation from an increase in disturbances as a result of climate change (185, 186). The distribution of quality habitat patches and the ability for fishers to travel to and among these areas will be primary factors in fisher survival (187). The intrinsic uncertainty of climate-induced ecosystem shifts underscores the importance of a healthy distribution of potential habitat areas across a wide variety of different landscapes. Large and/or sufficiently connected populations will be more resilient to the pressures from climate change, as local habitat shifts or disturbances can greatly affect small or isolated populations. Isolated fisher populations are at significant risk due to both catastrophic local impacts and gradual extirpation from genetic isolation. Protecting quality fisher habitat, maintaining suitable connectivity, and monitoring population shifts will be critical for ensuring that fishers are able to persist in the face of climate change.

Severe impacts from disease and insects would also diminish the overall resilience of landscapes, landscapes that could previously survive cycles of disturbance due to higher levels of biodiversity, connectivity, and the existence of a suitable forest mosaic.

Logging and **land development** remain as threats to forest ecosystems. Though logging has declined since the implementation of the Northwest Forest Plan in 1994, a policy intended to protect old-growth forest habitat for the northern spotted owl, it still remains one of the primary factors affecting habitat abundance and fragmentation, accounting for 17-20% of forest loss each year (64). Old-growth forests form a shrinking network broken up by roads and pockmarked by logging sites. In addition to logging, continued road and land development will threaten important forest connectivity and habitat for sensitive and threatened species. Reducing these impacts, which compound the effects of climate change, will make efforts to build resilient forests significantly more effective and meaningful.

"Plants and animals of the region will respond to climate change in a variety of ways and over varying temporal stages. Direct impacts brought on by increasing temperatures and changing weather patterns will be most readily apparent."

The **plants** and **animals** of the southern Washington Cascades will respond to climate change in a variety of ways and over varying temporal stages. Direct impacts, such as those brought on by increasing temperatures and changing weather patterns, will sometimes be more readily apparent than the more indirect impacts, which could occur through shifts of prey, predators, competitors, symbiosis, or disturbance regimes.
Most of the climate impacts to species of forest landscapes are intricately tied to and explained through the ecosystem threats outlined above. Some individual species responses do warrant particular attention, though.

Birds of the southern Washington Cascades inhabit many different types of ecosystems, from old-growth to post-fire areas, with each type of ecosystem serving as habitat for different species and in different ways. As such, the impacts to birds will vary greatly with the various responses of habitat types to climate change. For instance, we could expect the black-backed woodpecker, a fan of post-fire habitats, to respond positively to the likely increases in wildfires. Marbled murrelets, though, are at risk from changes in old forest habitat and oceanic environments.

An icon of wildlife conservation in the Pacific Northwest, the **northern spotted owl** (*Strix occidentalis caurina*) has been at the center of conservation for two decades. The fate of the northern spotted owl aligns strongly with the future of old-growth forests, and the threats outlined above will mirror the changes we can expect to see for populations of northern spotted owl. Climate change, however, may directly disrupt the mating seasons and affect the distributions of northern spotted owl prey, which could negatively influence owl populations (91). Carroll (2010) found winter precipitation to be an important variable for predicting northern spotted owl abundance and distribution; changes in this cycle can potentially impact the population viability of the species (92). Patterns observed during a 15-year study of northern spotted owls suggest that an increase in summer droughts would negatively impact annual survival, recruitment, and population growth (93). Moreover, this threat exists is in combination with a potential increase in local disturbances from wildfires (94). Northern spotted owls tend to not mate if conditions are unfavorable, however, this tendency may shift as stressful climatic conditions become more common. This remains a source of significant uncertainty, as do the future cumulative impacts of logging and barred owls, which can displace northern spotted owls.

Northern goshawks (*Accipiter gentilis*) also nest in dense patches of old forest, and similar to northern spotted owls, have strong site fidelity (95, 96). Their risks will revolve around impacts to old forest patches and shifting distributions of prey (96). With home ranges averaging around 16 km^2, the availability of connectivity corridors and contiguous suitable habitat will be key components in determining their resilience in the face of climate change. **Bald eagles** (*Haliaeetus leucocephalus*), with a diet dependent on healthy fish populations, will be affected by aquatic shifts in the upper reaches of riparian corridors (97). According to the Aububon Society's climate model, bald eagles may have as little as 26% of their current summer range remaining by 2080 (climate.audubon.org/all-species). Preferring old Douglas-fir forests with large horizontal nesting features, **marbled murrelets** (*Brachyramphus marmoratus*) will be impacted if their current habitat areas are degraded by drought or wildfire. Connectivity initiatives and restoration efforts in the heavily-roaded northwest section of the Gifford Pinchot National Forest can help mitigate some of these losses to habitat for marbled murrelets.

"Resilience is the capacity of ecosystems to persist and to absorb change and disturbance, while maintaining key relationships among important system variables or populations. The loss of resilience thereby would increase the necessity and the urgency of organisms to either adapt or disperse to avoid extirpation or extinction." –Dunwiddie et al. 2009

Most wide-ranging mammals of the region, such as **deer, elk,** and **bear**, are not expected to be particularly sensitive to climate impacts. With increases in disturbance events such as wildfire, insect outbreaks, and die-off from drought, there may actually be an increase in available habitat and forage. If droughts become severe, however, these species will be affected. **Wolves** (*Canis lupus*) are not expected to be habitat-limited by climate change because most of their diet includes species, such as ungulates, that are not likely to be impacted by climate change. **Coyotes** (*Canis latrans*) are opportunistic mesocarnivores with flexible habitat needs, and if old-forest specialists are pushed out of reserves due to disturbances or vegetative shifts, coyotes may replace these previous inhabitants. Coyotes are one of the most adaptable mammals in the forest and are expected to have little problem adjusting to the impacts of climate change. They may even expand in their range. Competition with bobcats, wolves, and fishers will be important regulators on the widespread expansion of coyotes. Although having distinct habitat niches in forest ecosystems, **bobcats** (*Lynx rufus*) can adapt to less-than-ideal conditions and will also likely prove to be similarly adaptable to most climate impacts. Their role as a competitor to coyotes is invaluable. If wolves return to the region in healthy numbers, they will further help improve the balance of carnivores in these forest ecosystems. In addition, wolves can help to support the health of riparian areas due to the influence of their predation on herbivores (98, 99).

Trees are generally the most obvious component of the forest ecosystem, and changes in their health and distribution will be particularly noticeable. Regional climate models suggest that Pacific silver fir (*Abies amabilis*), subalpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmannii*), and noble fir (*Abies procera*) will decline in abundance in the region due to warming patterns (31). Ponderosa pine, a species that occurs on the eastern side of the southern Washington Cascades, will likely be impacted by a trilogy of threats: increases in the scale and severity of wildfire, insect infestations, and drought. Aspen (*Populus tremuloides*), also most commonly found in the eastern reaches of our study area, is sensitive to temperature increases and decreases in moisture availability; it is therefore expected to be sensitive to climate change. Whitebark pine (*Pinus albicaulis*) is expected to be impacted by the upward movement of vegetation zones, which would decrease the amount of available habitat. Dry summers can also increase drought stress for whitebark pine and increase their susceptibility to pests (31).

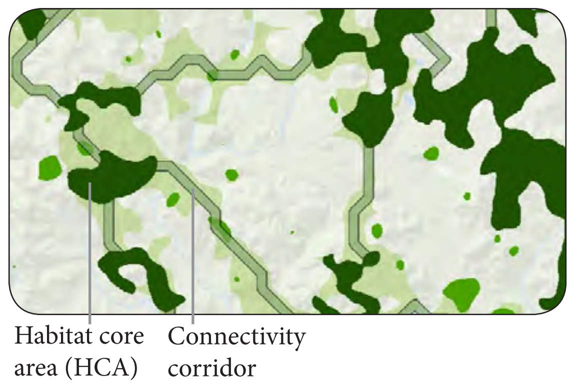
Paleoecological records suggests that Douglas-fir, red alder (*Alnus rubra*), and lodgepole pine (*Pinus contorta*) will be relatively resilient to the effects of climate change (31). Similarly, Oregon white oak

(*Quercus garryana*), western white pine (*Pinus monticola*), and giant chinquapin (*Chrysolepis chrysophylla*) may expand into new ranges. Oregon white oak and giant chinquapin may fill in spaces created by drought or fires, or they may prove to be more robust to warmer temperatures than the trees that currently dominate areas where oak and chinquapin exist. Western white pine may move into current subalpine parkland areas and other upward / northward shifts. Hemlock and subalpine fir populations may move to higher elevations, but their overall region-wide viability is uncertain (31). While there may be suitable locations and favorable seasonal patterns to support these shifts, changes may produce complex and deleterious interactions. This is because the shifts will not happen evenly throughout the region or in predictable patterns, so new and varied landscape patterns may arise and present new challenges yet unknown. Maintaining updated information and enacting adaptive management, as outlined in the strategies and recommendations sections of this guidebook, will be key components of a thorough conservation strategy for the region's more sensitive plant species.

"Connectivity facilitates the movement of species and populations throughout the landscape."

CONNECTIVITY

Connectivity is a key component to consider when developing strategies and opportunities to conserve species. Connectivity represents the critical arteries sustaining the ecosystem. Robust connectivity throughout the landscape enables wildlife populations to be more resilient to climate impacts by allowing movement to alternate habitat areas and decreasing the degree to which disturbance in a particular habitat patch affects the overall viability of the population. The movement of forest types as a result of climate change, oftentimes to higher elevations and northward, will force population shifts and species migrations. These distribution changes will be exacerbated and sometimes caused by the decoupling of species relationships and local-scale disturbances. Impacts to habitat patches from wildfire or drought can cause populations to become extirpated if suitable habitat is not located nearby or connected by corridors of viable dispersal habitat. We must provide room to allow species and population movements to occur and not be hindered by geospatial bottlenecks. A landscape perspective of connectivity that anticipates and adapts with these shifts will enhance conservation efforts and help mitigate the pressures of habitat loss and shifting distributions.



Analysis Of Connectivity Of Old Forest Habitat

We designed a region-wide connectivity analysis to assist in conservation planning and to help prioritize resilience-building efforts for species that live in old forest habitats. This analysis identified core habitat areas and potential connectivity corridors. The analysis parameters we set are broad enough to encompass habitat needs of a suite of species yet focused enough to be effective for the individual conservation needs of each. The suite of species we considered for this connectivity analysis included: fisher, northern spotted owl, marten, northern flying squirrel, and pileated woodpecker. While the particular habitat needs and preferences of each species varies, there are commonalities and it is in this area of common ground where we focused our analysis.

To give context for some of the details and parameters of the connectivity analysis, we will outline some general habitat features for the species of focus. **Fishers** require certain habitat features often found in mature and old-growth forests, such as wide trees and dense canopy cover. These components are critical for denning and resting. The home range of a female fisher is around 9.8 km^2 (3.8 mi.^{2}), while the home range size of a male can be significantly larger and sometimes double that of the females in a region (100–102). Fisher home ranges, while generally centered on old-growth forests, sometimes extend into lower quality areas that have fewer denning and resting features. Dispersal distances of young fishers and males searching for new habitat vary depending on habitat quality but average around 6 to 10 km (3.7 to 6.2 mi.) (101, 103, 104) . A general home range for a pair of **northern spotted owls** ranges between 12 and 20 km^2 (4.6 to 7.7 mi.^{2}), most of which is in older forest habitat (105–111). Northern spotted owls generally migrate to new territories that are within approximately 15 to 25 km (9.3 to 16 mi.) (107, 111, 112). The average home range of a **marten** (*Martes americana*) in comparable landscapes is 2.3 km^2 (0.9 mi.^{2}), yet depending on habitat features and elevation, this number can vary quite widely (102, 113). Affected by logging and sensitive to impacts from genetic isolation and inbreeding depression, martens require strong connectivity (114–117). Average dispersal is around 3.8 km (2.4 mi.), and like the fisher, the distribution of resting sites determines successful dispersal for marten (115, 118–120). The home range of a **northern flying squirrel** (*Glaucomys sabrinus*) spans from 0.12 to 0.4 km^2 (0.05 to 0.15 mi.^{2}) (121, 122). Flying squirrels are most often found in old forest stands with trees >74 cm (29 in.) DBH and they are significantly affected by logging around their habitat areas (123–125). They require mature forest stands for travel corridors (126, 127).

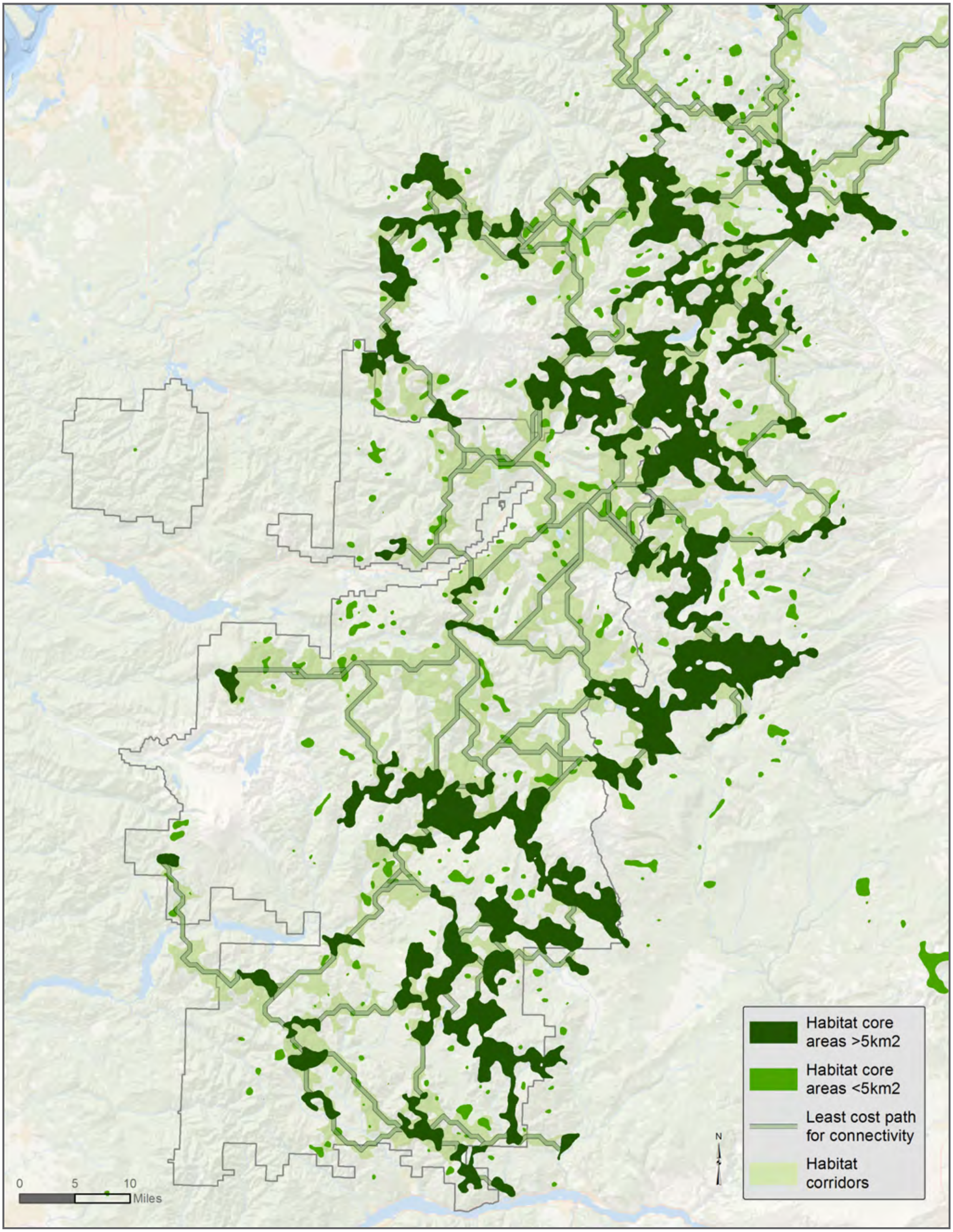
"This analysis considers habitat requirements, identifies core habitat areas, and highlights potential connectivity corridors throughout the region."

"Improving connectivity for old forest specialists will also enhance the future resilience of other plants, insects, and wildlife that benefit from mature forest habitat"

Northern flying squirrels are essential prey for many mesocarnviores, such as marten and fisher (126). **Pileated woodpeckers** (*Hylatomus pileatus*) of the Pacific Northwest also prefer these older forest habitats, particularly areas with an average DBH >73 cm (28.7 in.) (128, 129). The home range of a pair can vary widely, from 0.71 km^2 up to 20 km^2 (0.27 to 7.7 mi.^{2}) (130, 131).

The first step in the connectivity analysis was to identify **current areas of suitable habitat**. Using the OGSI layer of mature forest habitat, we ran a density function in ArcGIS to locate dense aggregations of forest stands that were 80 years of age or older and which contained structural components associated with healthy old-growth forests (see explanation for OGSI spatial layers on page 30). For the density function, each cell was set to measure density of similar habitat within a 1,000-meter radius. This distance and measure of habitat aligns with home ranges and habitat requirements of the species of focus. These dense mature forest areas represent relatively contiguous areas of old forest habitat, refugia areas that are not only relatively resilient but which can provide valuable support for populations of plants and animals that depend on older forest habitat.

In order to focus on the habitat patches that were of sufficient size for these species, we removed from the connectivity analysis all habitat core areas (HCAs) that were under 5 km^2 (1.9 mi.^{2}). These patches were, however, visualized in our final map to help identify conservation needs and locate opportunities to support future habitat areas. Of our species of focus, fishers would prefer the larger HCAs, as these areas would encompass several male and female home ranges, which are generally connected and overlapping. Marten prefer mid and high elevation habitats, which was not a variable modeled in this analysis. However, many of the



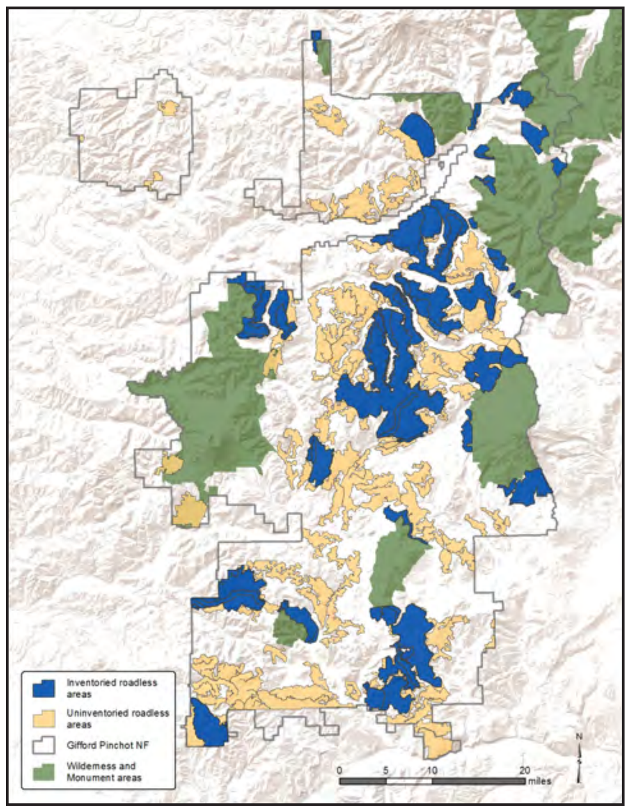
Functional connectivity for species residing in mature forest habitat

HCAs identified in this work were located in zones suitable for marten. The home range size and spatial arrangement of marten home ranges aligns with this connectivity approach. Northern flying squirrel and pileated woodpecker populations will function at much smaller scales than we have focused on, but the habitat parameters and measures we outlined should do well to maintain connectivity of their habitat as well.

The next step in the analysis was to identify **connectivity corridors** between these habitat areas. In addition to using HCAs, the connectivity analysis process calls for the input of a resistance layer to determine where species movements would be limited, such as crossing agriculture land, traversing a mountain top, or moving through areas with low forest cover. Our resistance layer included (1) density of mature forest (inversely), (2) road density, and (3) a Conversion Threats Index measure. For more information on these variables and the parameters we set for them, refer to the Appendix. For the mature forest density measure in the resistance layer, we chose to use the spatial layer created by the Conservation Biology Institute that identifies forest areas over 50 years of age and which does not require other forest components as part of the measure of maturity. This approach allowed us to include areas that would be potential routes of connectivity in the future or that could be modified or managed to function as dispersal habitat.

The dispersal distances of the focal species considered here vary and the spatial and temporal uses of this network will also vary. Fishers, northern spotted owls, and martens can follow these routes and function as groups of connected metapopulations. Flying squirrels and pileated woodpeckers, on the other hand, disperse at much smaller distances so their connectivity needs will be most applicable through the smaller connections in the analysis. Looking at connectivity at a generational scale, though, all of these species will benefit from these networks and improved connectivity.

With the base connectivity layers in place, we then ran the region-wide connectivity analysis using a linkage mapper tool created by the Washington Connectivity Working Group. This tool uses network analysis processes and identifies the "least cost paths" for connectivity, i.e., areas where movements or dispersal are least obstructed. The output of this connectivity analysis is shown on page 43. Mapping these patterns is an important step in understanding the need for and placement of habitat corridors and the areas where efforts are needed to protect, sustain, and improve connectivity. Although not explicitly modeled, this connectivity analysis should also provide connectivity for plants, insects, and other wildlife that depend on mature forest habitat. Moreover, the species we focused on often serve as dispersers of seeds and can therefore support plant populations and improve resilience through their distribution (132).



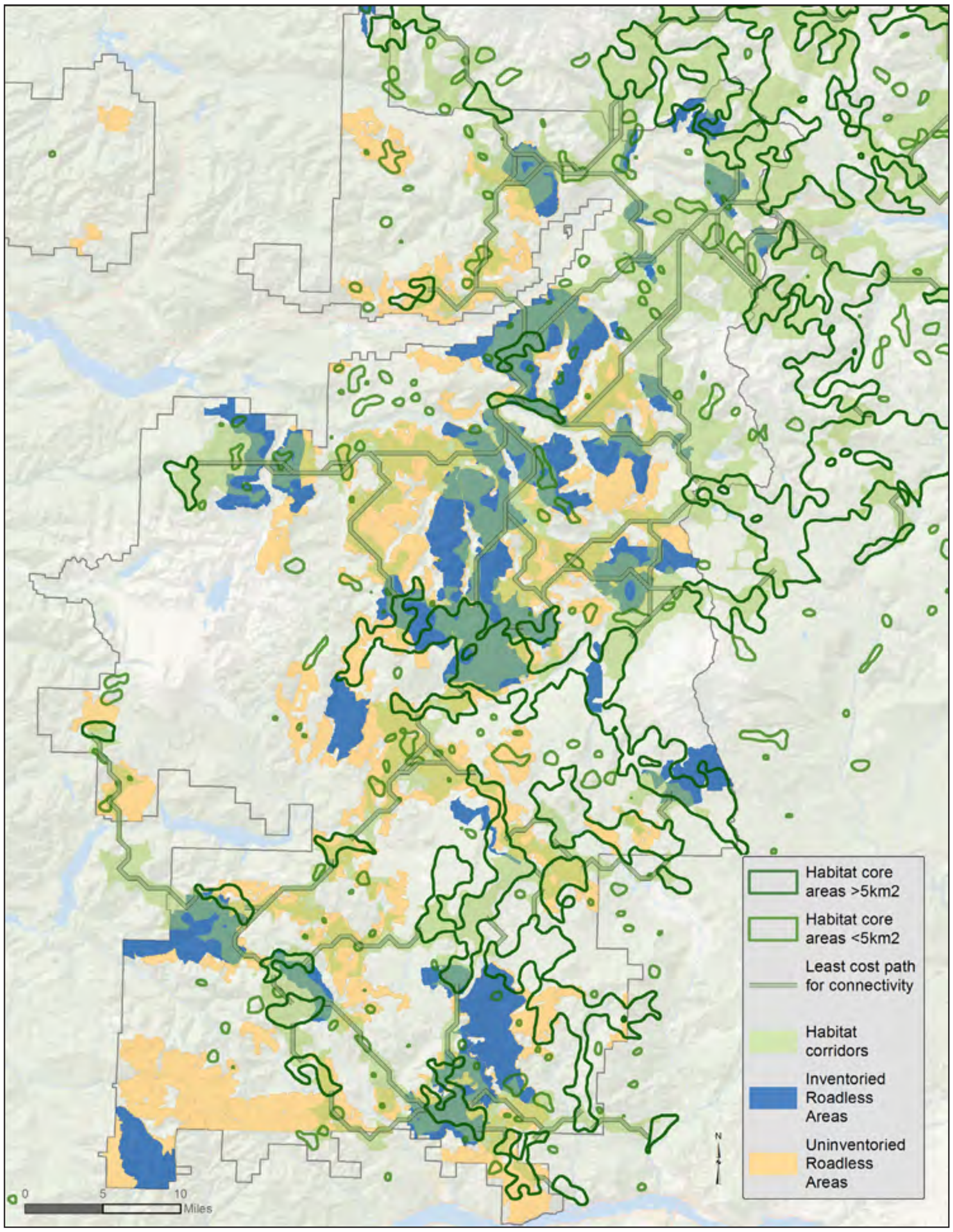
Inventoried and Uninventoried Roadless Areas

We also mapped the current location of roadless areas in the southern Washington Cascades to begin to examine potential land designation improvements and to explore where connectivity is negatively affected by road densities or positively affected by roadless areas.

There are two main types of roadless areas. **Inventoried Roadless Areas (IRAs)** are federally designated areas identified and mapped in accordance with the Roadless Area Conservation Final Rule, commonly referred to as the "2001 Roadless Rule." These undeveloped areas, usually greater than 5,000 acres, meet the minimum criteria for Wilderness consideration under the Wilderness Act and were inventoried during the Roadless Area Review and Evaluation (RARE) or other similar Forest Service assessments in the early 2000s. IRAs carry strong protections due to the value they offer in terms of habitat, recreation, and biodiversity.

During the RARE classification processes when IRAs were designated, **uninventoried roadless areas** were mapped to identify areas that were predominantly roadless, yet not formally designated. Remnant Maintenance Level 1 roads (roads that are closed yet still on the system for potential future use) remain in some of these areas. These remnant roads, as well as the roads that lie between two potentially conjoining roadless areas, are top priorities for road reduction.

To more fully understand where roadless areas exist in relation to habitat core areas and connectivity corridors, we have overlaid the connectivity layers and the roadless maps. This step helps us understand where we may want to focus our climate mitigation efforts with regard to strengthening roadless values and decreasing fragmentation. Below, we'll explore how this ties in with strategies and recommendations for conservation.



Old forest habitat corridors overlaid with the roadless areas map

STRATEGIES AND RECOMMENDATIONS FOR FOREST ECOSYSTEMS AND CONNECTIVITY

Strategies and recommendations for forest ecosystems and habitat connectivity encompass a broad set of approaches that includes restoration projects, new frameworks for conservation, citizen involvement, partnerships, and protection of key areas through land and river designations.

The two central concepts in this section are that resilient and sufficiently large habitat areas are needed to ensure lasting biodiversity and healthy wildlife populations, and connectivity between these areas is needed to support regional populations and long-term ecosystem stability in the face of a changing climate.

"Contiguous and resilient habitat areas are needed to ensure lasting biodiversity and healthy wildlife populations. Connectivity between these areas is needed to support long-term ecosystem stability."

We suggest working on several levels to increase the climate resilience of forest ecosystems. Many of the on-the-ground efforts will be planned and carried out at the district and national forest levels, so much of our focus will be there. However, it is also important to have strong policy at the regional and national levels, as the local forest offices implement their projects based on these policies. We suggest working with regional offices of the Forest Service to encourage the implementation of the climate-focused policies described below. It will also be important to enhance partnerships with planners and landowners working in the connected state, private, and tribal lands that are part of the entwined checkerboard of impact throughout the region. There are areas where significant

STRATEGIES AND RECOMMENDATIONS

- Expand and create new Wilderness areas
- Designate Research Natural Areas, Botanical Special Areas, and conservation easements
- Upgrade Inventoried Roadless Areas and expand other roadless areas
- Protect and improve corridors and core habitat areas during timber projects
- Actively restore forests
- Close and decommission roads
- Work with forest plan revisions
- Survey and monitor management activities, habitats, and species
- Identify economic opportunities for carbon sequestration
- Work with state and private land holders

enhancements or protections in these lands will dramatically improve the connectivity or habitat viability of surrounding national forest land.

"Public involvement and strong partnerships will be integral to climate change adaptation efforts."

Public involvement will be critical. We encourage citizens to call, write, or meet with their congressional representatives and Forest Service officials to advocate for the protection of special natural areas and support carbon sequestration. Legislative or administrative protection of an area is more likely if that protection is strongly supported by the public. Additionally, forest plan revisions or other forest planning processes represent opportunities for citizens to advance the concepts of resilience-building and climate impact mitigation.

Mount Rainier National Park. Photo by Robert Scheller

Strong partnerships will be integral to climate change mitigation plans, and oftentimes, the most effective strategies and projects will encompass broad landscapes and span different fields of study. They will require groups working in concert at different scales. This underscores the importance of a detailed blueprint, and our hope is that these recommendations serve as foundations for short-term and long-term resilience-building projects in the region.

In the following pages, we will outline specific strategies and recommendations for building resilience to climate change.

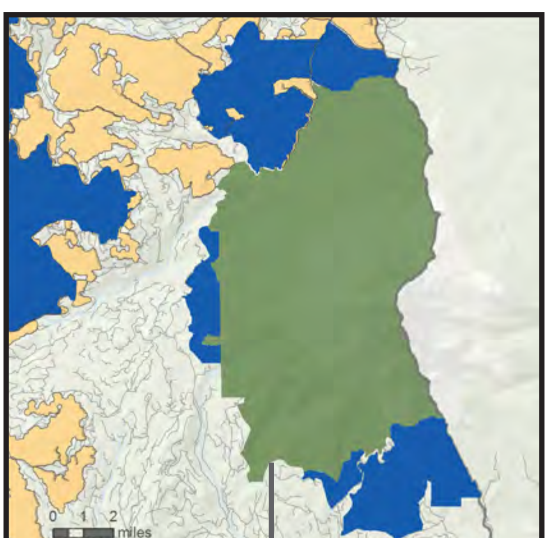
Citizen science projects can offer benefits to forest ecoystems and provide opportunities for local community members to be involved in meaningful stewardship activities

• **Strategically expand current Wilderness and protected areas:** Despite the variety of possible approaches for mitigating impacts of climate change, there is one theme that runs throughout: protect land rapidly to help buffer biodiversity against climate change (1). Climate change demands the expansion of reserves and protected areas in order for current habitat to persist as functional habitat in a changing landscape (1, 2). Connectivity between these areas is also critical. With shifting populations and patterns, it is important to remove dispersal barriers, such as large swaths of unsuitable habitat, and to ensure that current or future reserves are located relatively nearby one another to increase likelihood and success of migration and population shifts (1). To locate areas for Wilderness expansion, we identified important reserves by considering future wildlife corridors and habitat needs, prioritizing areas already designed as roadless. Inventoried Roadless Areas have already been federally designated for meeting the minimum criteria for Wilderness consideration under the Wilderness Act and therefore present fewer roadblocks for expanding protection.

Trapper Creek Wilderness

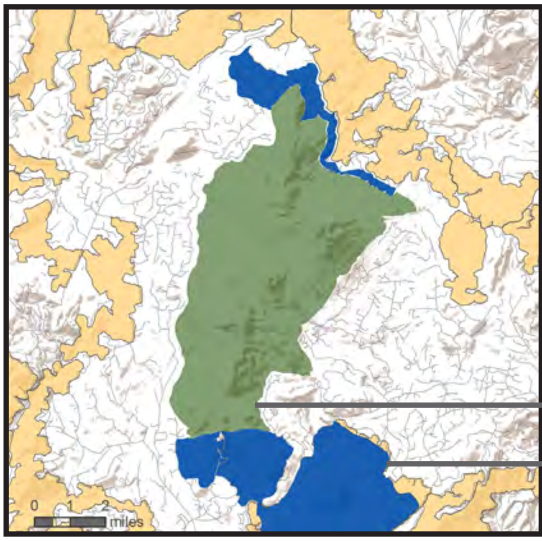
Bourbon Creek Addition

o **Trapper Creek Wilderness Addition:** The "Bourbon Creek" addition on the north side of Trapper Creek contains healthy stands of old-growth forest and is currently roadless. It is listed as "late-successional reserve" (LSR), so logging impacts are reduced but not limited. There is significant public support for this small wilderness addition. The expansion would provide important enlargement of contiguous habitat in the southern part of the Gifford Pinchot National Forest and an additional buffer of climate protection amidst the surrounding mix of Matrix land, forest edges, and roads. Also, there are a lack of Wilderness areas within the GPNF that are easily accessible from population centers. This Wilderness area is a popular location for day-use recreation, and expansion will enhance those opportunities. Wildlife camera surveys have shown this area to be well-used by a diverse set of animals, and considering the nearby pressures of development, logging, and habitat shifts, there is good reason to formally establish protection for this area by adding it to Trapper Creek Wilderness.



Mount Adams Wilderness

o **Mount Adams Wilderness Addition:** There are three small Wilderness additions that would make up this expansion. Much of this land is currently managed as LSR and Adaptive Management Areas (AMAs), areas which are set aside for experimental timber harvest. The Mount Adams landscape is a unique area in the region and is the primary habitat for many forest species that reside in the mid- to high-elevation forests near the ecotone boundary with the eastern Cascades. Considering the loss of upper elevation tree density from recent fires, a case can be made for expanding the area protected around here and ensuring that sufficient mid- to high-elevation habitat is maintained. In addition, some areas should be actively restored to improve ecological function and return degraded stands back to their historically resilient state. While plans are being developed to further designate this area, efforts should be focused on restoration and ensuring increased habitat protections during timber and management projects.

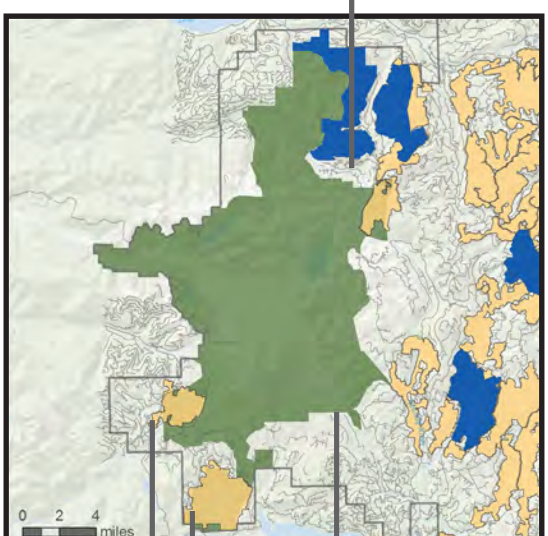


o **Indian Heaven Wilderness Addition:** Potential Wilderness expansion areas bordering the south end of the Wilderness are currently in Matrix, while expansion areas in the north are mostly administratively withdrawn as not currently eligible for timber harvest. The Indian Heaven Wilderness is a forested plateau containing many small lakes, ponds, and marshes, and is abundant in edible berries. Expansions of this Wilderness area should focus on protecting areas containing these features important for wildlife, cultural, and ecological purposes.

Indian Heaven Wilderness

Big Lava Bed - an Inventoried Roadless Area, but not recommended for inclusion in Wilder-

Green River Valley - recommended for Monument inclusion or alternative reserve protection to support recreation, protect old-growth, and reduce mining threats



Not currently IRA, but recommended for reserve expansion out from Mount St. Helens National Volcanic Monument

Mount St. Helens National Volcanic Monument, established 1982

o **Mount St. Helens National Volcanic Monument Additions:** Part of the Tumwater IRA is in LSR designation, while the other sections are Matrix. The Strawberry IRA, to the east, is largely in Matrix. The Green River Valley, home to remaining stand of old-growth and a river identified as a Wild Steelhead Gene Bank, lies in Matrix land between these IRAs and the Monument. These sections of the forest, as a whole, have immense ecological value and are also important for recreational needs. These areas are priority recommendations for reserve expansion. Also, the uninventoried roadless areas on southwest part of the Monument, while not currently IRAs, are considered as important additions to the Monument. Adding these areas to the Monument or including sections as a connected Research Natural Area (RNA) or Botanical Special Area (BSA) would benefit the fragile and important ecosystem of the Mount St. Helens area. The Green River valley and neighboring Ryan Lake were originally considered for inclusion in the Monument at the time of designation; this area is a prime candidate for inclusion in the Monument as it was within the blast zone and is already managed by the Monument.

• **Designate new Wilderness areas:** On the previous page, we discussed additions to current reserves. In this section, we will identify new Wilderness areas and outline reasons and recommendations for seeing these areas formally protected as Wilderness. Similar to the expansions of current reserves, designating these particular areas as Wilderness is both relatively feasible and valuable for long-term resilience, due to their current designation as roadless and their value in habitat and connectivity.

o **Dark Divide -** This iconic roadless area is drenched with more lore and wonder than any other part of the Cascades. This area is thought to be home to Bigfoot, and it was once considered the likely site of the missing fugitive, D.B. Cooper, who parachuted from a plane in 1971 with bags of stolen money and the makings of a legendary story. Although highly important as a habitat reserve for its contiguous old-growth forest stands, the Dark Divide has become filled with the loud and damaging footprint of off-road vehicles. Hiking and camping has decreased due to this, and along with, terrestrial and aquatic habitat quality. The Dark Divide has come close to formal Wilderness designation on several occasions, but the has yet to gain that level of protection. In looking to our forest maps and connectivity analyses, we can see the value of formally protecting this area.

o **Bear Creek -** The Bear Creek area is not only an accessible potential Wilderness Area near the Columbia River and the towns of Carson and Willard, it also contains tracts of oak woodland, a unique and threatened ecosystem of the region. The Bear Creek area was identified as a valuable habitat core area in our connectivity analysis.

o **Siouxon Creek** - Many great fires swept through the Siouxon area in the early part of the 1900s, including the famous Yacolt Burn of 1902. The results of these fires can still be seen today. In fact, the post-fire habitat that is closely intermingled with patches of old-growth, is one of the reasons this area is a prime candidate for preservation and study. In addition, this site is an important connectivity corridor and a popular recreation area that would benefit from formal Wilderness designation.

o **Pompey** - As noted previously, recreation and close public access are two of the primary objectives in the delineation of Wilderness. The Pompey Roadless Area sits between, and within minutes of, the towns of Randle and Packwood, WA. This area is also a connectivity corridor and an area of dense patches old-growth habitat.

• **Decrease road densities in habitat areas**: Roads can impact forest ecosystems in a variety of ways, from habitat fragmentation to the introduction of invasive species (39–43, 46, 133). Failing roads, eroding surfaces, and plugged culverts also impact aquatic ecosystems in many ways. In addition to their ecological costs, roads carry significant maintenance costs and can impact water quality for downstream communities. Road repair needs and water quality impacts are expected to increase with climate change. Most of the forest roads in the region were built when timber harvest was unsustainably rampant, yet the total amount of roads has not decreased to match current usage. A reduction of road miles improves ecological health and increases the degree of attention that can be paid to the roads that are needed. These efforts should be coupled with planting of native species along the former road to enhance revegetation. Road closing and decommissioning can be an important economic driver (47–49). Road projects can and should be prioritized for contractors in local communities that surround national forest lands.

"In addition to their ecological costs, roads carry significant maintenance costs and can impact water quality for downstream communities. Road decommissioning projects should be prioritized for contractors in local communities"

In this section, we will be taking three approaches for identifying roads for removal and prioritizing areas to decrease road densities. The cumulative impacts associated with climate change and roads is a threat to habitats and to the resilience of communities and ecosystems.

I. The first approach (Part I on page 52) is centered on identifying areas that have currently been designated as "uninventoried roadless areas" in order to reduce both the amount of remnant roads that remain within these areas and the roads separating two adjacent roadless areas.

II. The second approach (Part II on page 53) is identifying where areas of high road density intersect wildlife corridors.

III. The third approach (Part III on page 54) is a measure of general impact, unrelated to the frameworks identified for the other two approaches.

All three approaches used the RoadRight analysis to identify priority roads (134). RoadRight measures the impact that roads are having on terrestrial and aquatic systems by considering aspects such as stream crossings, soil stability, topography, high sedimentation potential, surrounding habitat designations, and isolation values. High rankings of "combined risk" translate to high impact or high risk. While not necessarily being roads that affect roadless areas (as with Part I) or intersect corridors (as with Part II), the roads identified through the third approach will be roads that top the scales of risk for current impact and are therefore priorities for removal.

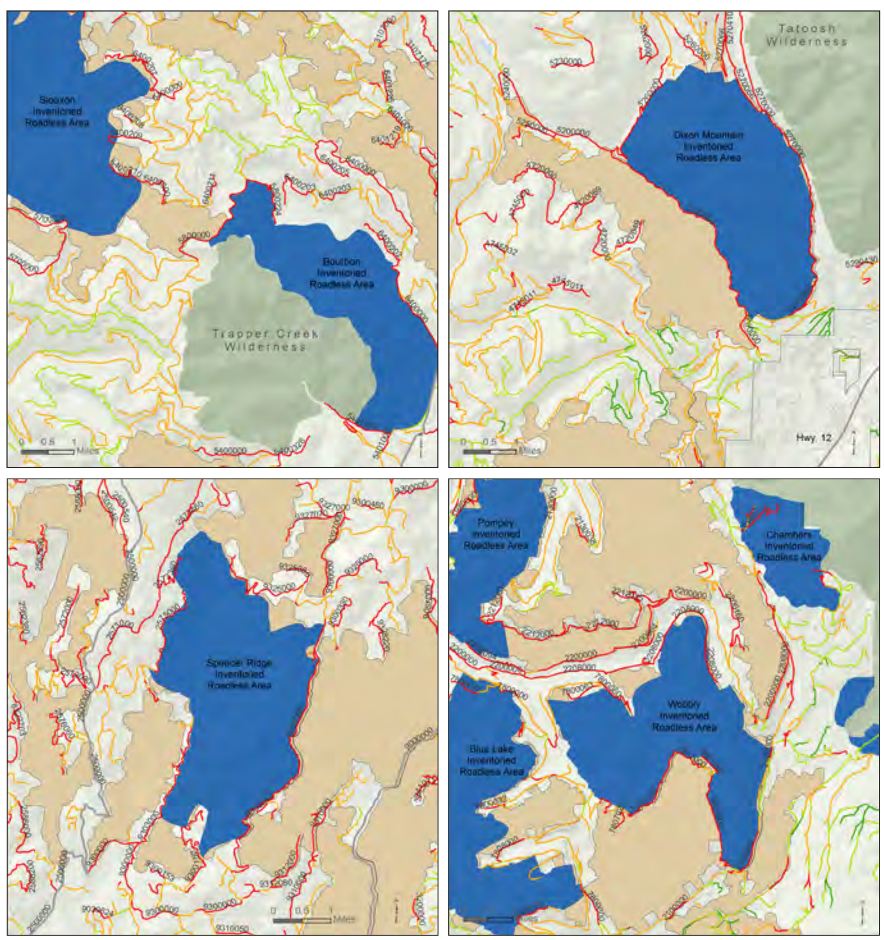
"There are currently over 4,000 miles of road in the Gifford Pinchot National Forest (enough to go to Texas and halfway back)"

We don't expect all the identified roads to be closed or decommissioned, but by prioritizing and mapping the roads and the different aspects of impact, managers and organizations can more easily identify suitable opportunities when local or regional projects are planned. The RoadRight analysis was designed to ignore roads that are needed for access. There will likely be, however, roads identified as high priority for removal that should remain on the road network due to their importance for local communities or for particular access needs. These qualities are best highlighted at the project scale, as are site-specific road measures identified in Road Maintenance and Abandonment Plans (135).

There are various ways to right-size the road system. Although an initial hurdle, moving ML 1 roads to a decommissioned state will have lasting benefit in increasing the longevity of protection and potential for designation, possibly representing areas of future wilderness expansion. ML 1 roads are technically closed but still on the system and available for potential future use. Decommissioned roads are closed and removed from the system. Culvert removal is part of conversion to either designation. However, decommissioning steps entail more regrading and naturalization. The ML 2 roads are currently open; those found to be high priority for closure in this analysis can either be moved stepwise to ML 1 or decommissioned. By concentrating on the high

Part I: High risk roads in or dividing areas that are predominantly roadless

Uninventoried roadless areas do not have the same direct Wilderness potential or protection as Inventoried Roadless Areas (IRAs), but these areas do carry varied levels of heightened protection and can also be designated as "Potential Wilderness Areas" during forest plan revisions. Some remnant Maintenance Level 1 (ML 1) roads are found within uninventoried roadless areas, but many of these are in a state of disrepair (possibly with plugged culverts). We prioritized these remaining roads for closure to improve the roadless nature of the area, to increase the amount of connected land where aquatic impacts from roads is absent, and to increase the future opportunities for heightened protection. In addition to identifying these remnant roads, we also prioritized roads that were dividing two roadless areas that would otherwise be joined to create a larger and more contiguous roadless expanse. Creating large expanses of uninventoried roadless areas could change how these areas are considered in a NEPA analysis (the National Environmental Policy Act outlines process steps for projects on Forest Service land). For instance, in a case involving logging in two uninventoried roadless areas adjacent to an IRA, the Ninth Circuit held that the U.S. Forest Service was required to analyze the roadless and Wilderness characteristics of the uninventoried roadless areas in a NEPA analysis if the area is contiguous with an IRA, if it is greater than 5,000 acres, or "is of sufficient size to make practicable its preservation and use in an unimpaired condition" (529 F.3d 1219).



priority roads identified in pages xx to xx, we will increase the roadless nature of habitat areas and corridors while also improving the upkeep of surrounding forest roads needed for recreation and management needs.

In addition to improving roadless areas, it is important to also create safe passage across large highways that remain as obstructions to connectivity. The wildlife crossing over I-90, just east of Snoqualmie Pass, is a local case study and

Part II: High risk roads and high road densities impacting wildlife corridors

The density of roads influences habitat connectivity for both aquatic and terrestrial species, and is a critical consideration in the context of changing plant and animal distributions. Suitable habitat connectivity increases ecosystem and species resilience in the face of climate shifts and local disturbances such as wildfires. By identifying areas where roads are likely to be affecting connectivity, we can improve the resilience of migrating populations, wide-ranging mammal species, and overall ecosystem function.

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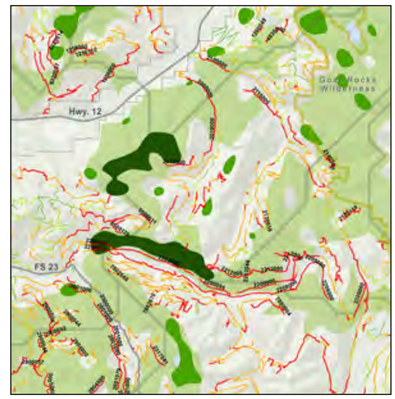

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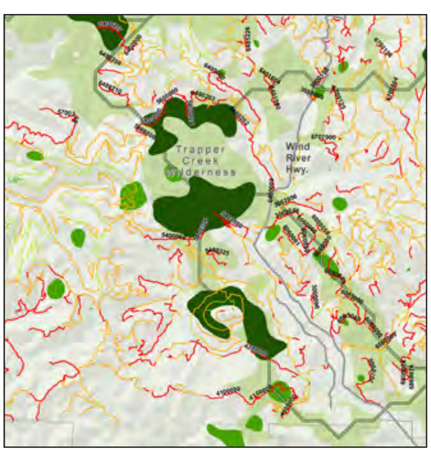
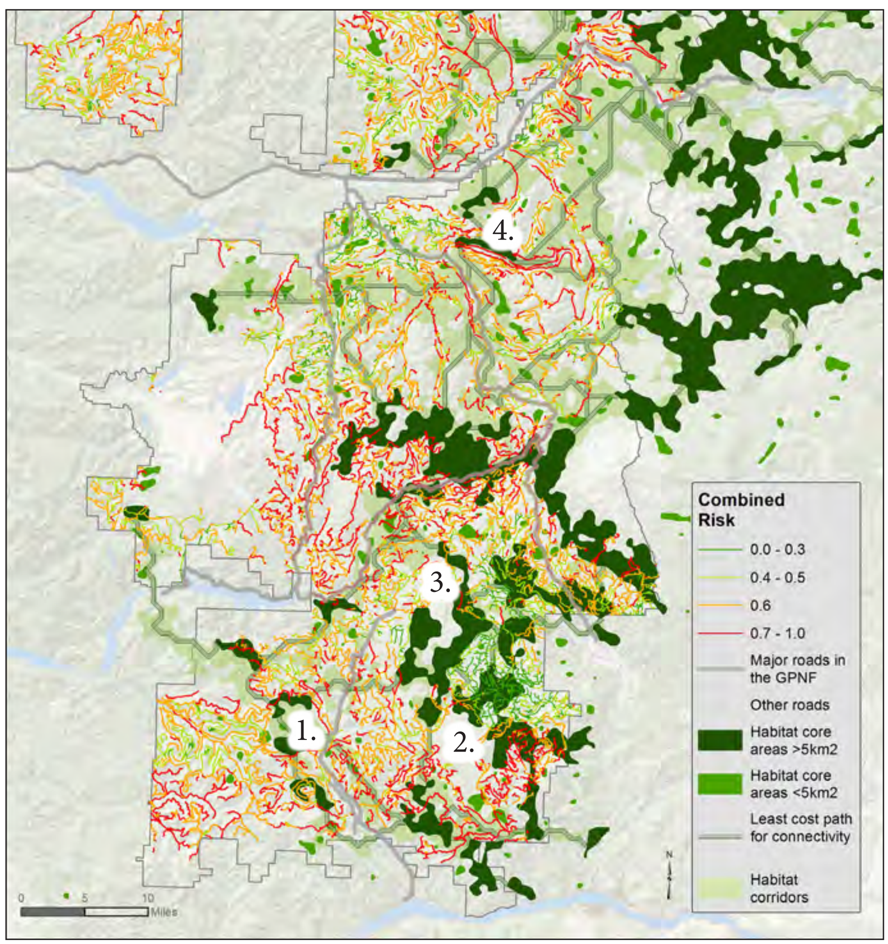
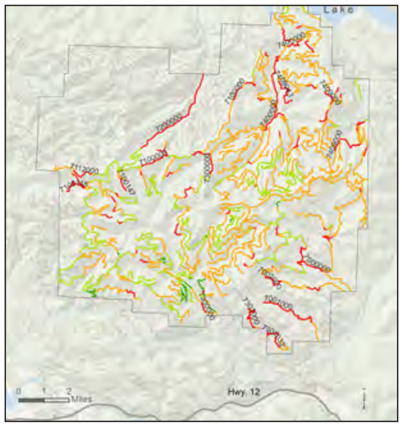




example of a successful road-crossing project. Implemented in 2016, with an expected completion in 2019, this project created a much needed passage route for wildlife in the Cascades. Similar efforts can be carried out along other corridor areas of I-90 and in regions east of our focus areas where I-84 splits from the Columbia River.

Part III: Overall priority high risk roads

Part III highlights areas where a particularly large amount of high impact roads are located, as identified through the RoadRight analysis.



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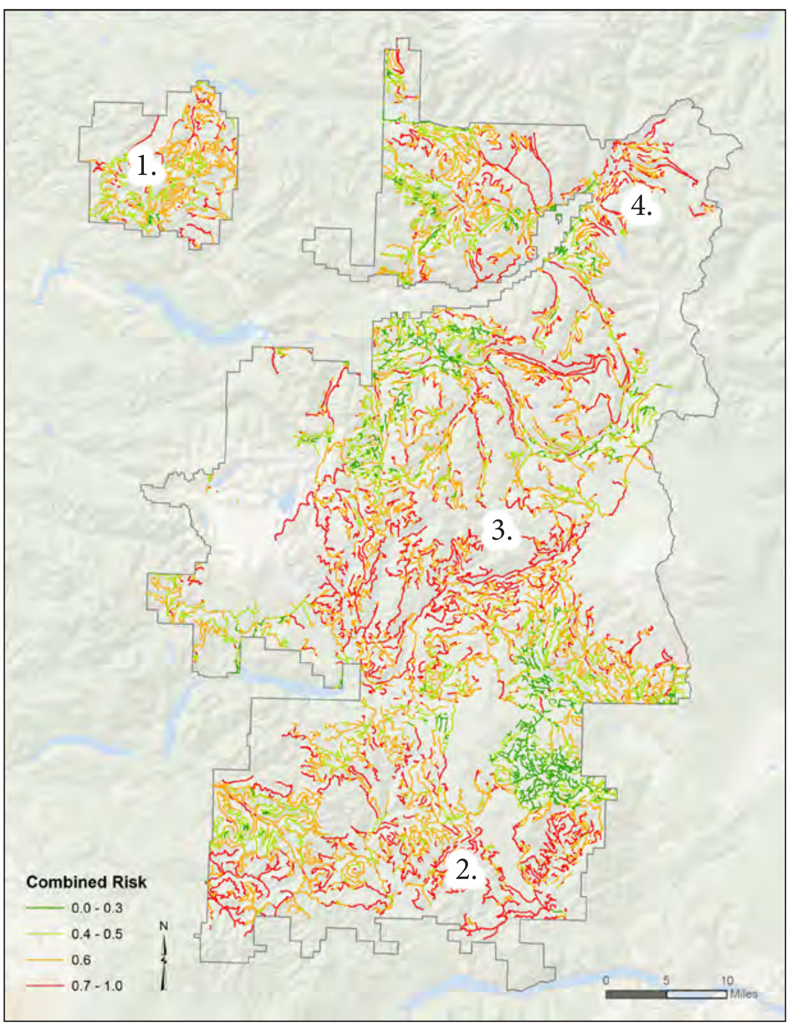

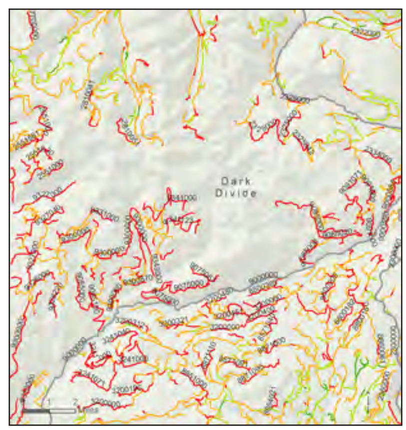

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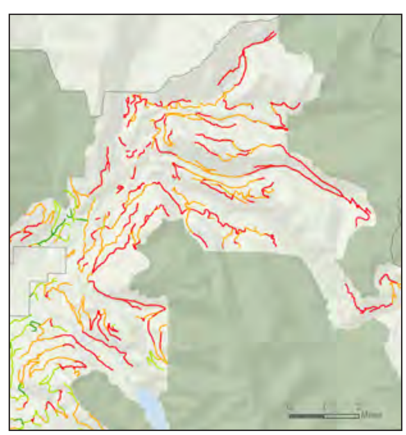


4.

• **Promote and support other reserve designations to further protect habitat**. The Forest Service can designate “special areas” to protect and/or study sensitive species and habitats. These administrative land designation steps are often much simpler and quicker than those to designate Wilderness. Expanding reserves and preserving current habitat is a critical step in protecting species in the face of climate change.

o **Research Natural Areas (RNAs)**
This approach is promising for its relative simplicity. It is suitable to resilience-building needs because the rules that surround management of these areas are determined by the original reason for its designation. In other words, if an area was designated because it has been found to be a valuable habitat stronghold, management of it would be focused on upholding that trait. This would enable managers to deal with uncertainty and more easily allow adaptive management or restoration that is supported by observed shifts or current literature. The Forest Service outlines a similar case for these areas, noting that “[o]ne of the goals of the program is to preserve a wide spectrum of pristine areas. We want to preserve and maintain genetic diversity. Within these areas we want to protect against serious environmental disruptions. The natural areas serve as a reference for the study of succession.”

o **Botanical Special Areas (BSAs)**
Botanical Special Areas can be designated to secure important plant communities. Designation for these areas is similar to that for RNAs, yet focused on preserving certain botanical species or communities. Management of these areas comes with a distinct set of rules; these rules and their flexibility vary with the type of special area.

“[A] special area can be designated by the Regional Forester if less than 100,000 acres, and by the Secretary of Agriculture if greater than that. Local examples of administratively designated special areas range from the one-acre proposed Columbia Mountain Lookout archaeological special interest area on Colville National Forest to the 48,000-acre Teanaway recreational special interest area on the Okanogan-Wenatchee National Forest” (136). The designation of areas less than 160 acres may be delegated to Forest Supervisors (36 CFR 294.1b).

One of our top priorities for BSA designation is a 170-acre ancient forest remnant located near Lost Creek in the Little White Salmon drainage, just north of the Columbia River Gorge Scenic Area boundary. This area contains the largest known trees in the Columbia Gorge. It is home to western redcedars over 9 feet in diameter, Douglas-firs up to 8.5 feet, and massive western hemlocks towering over the hillsides. On the forest floor is a rich mix of botanical diversity and numerous streams. The area was threatened by a timber sale about 20 years ago, but local citizens and stewards appealed and stopped the sale. The area still remains at risk from logging and should be set aside as a habitat reserve and Botanical Special Area for its rare ecological integrity.

Cedars in Lost Creek. Photo by Darryl Lloyd

o **Conservation Easements**
On private land, new conservation easements should be considered, with a focus on promoting broad climate mitigation measures and cross-boundary protection of reserves. Future partnerships in the area, with Columbia Land Trust and The Nature Conservancy, will be integral to this strategy. We recommend using the connectivity analysis of this guidebook to help identify priority areas for conservation easements.

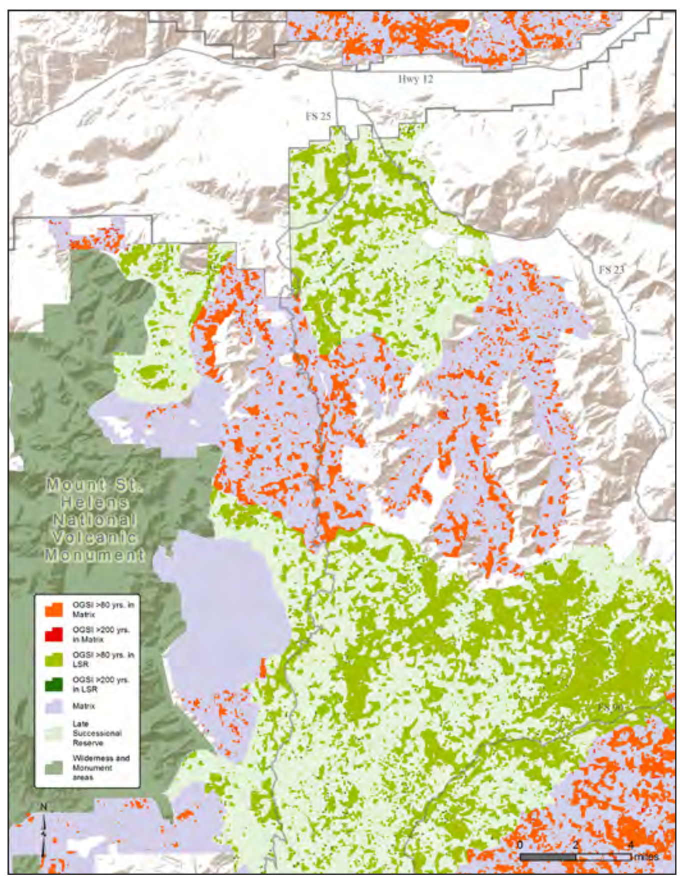
o **Climate Resilience Areas (CRAs)**
This is not currently a type of designation. We are proposing the creation of a new designation tailored for climate mitigation planning, where adaptive management and climate research are paramount. These areas should be created to specifically study climate impacts and species responses. We feel that the magnitude of climate change mandates a new designation that is focused on building climate resilience and mitigating the more serious negative impacts locally and beyond.

• **Protect and improve forest habitats during logging**. The cumulative impacts of climate change and continued logging is a pressing concern. An improvement in forest management is needed, one that employs a more holistic, landscape-scale perspective and outlines potential climate impacts in planning. As habitat pressures increase, migration patterns change, and plant and animal distributions shift, it is necessary to identify and provide suitable wildlife habitat and corridors.

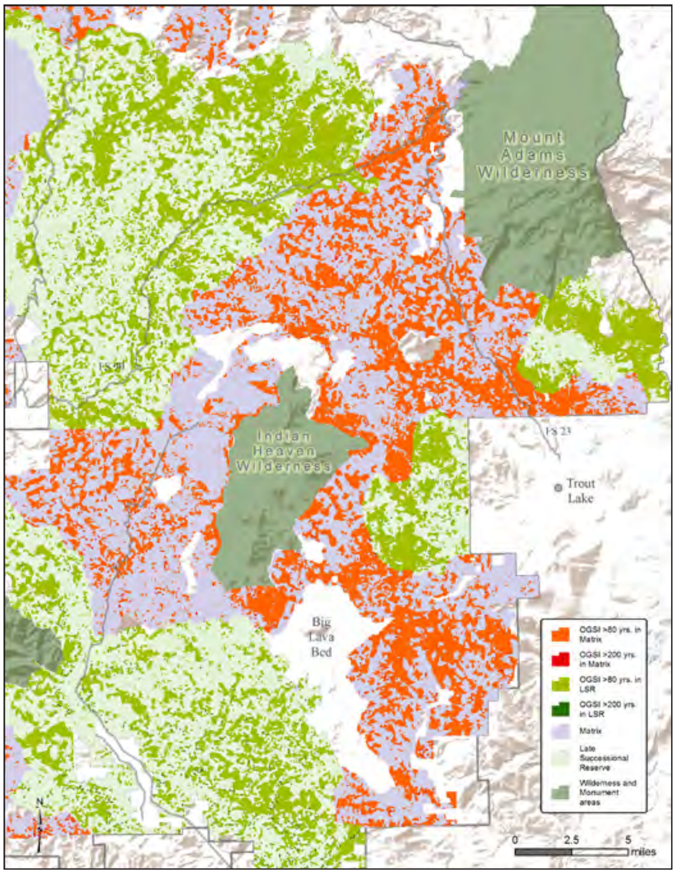
The cumulative impacts of climate change and logging is a pressing concern in certain areas. A landscape-scale perspective to timber harvest, which outlines potential climate impacts in planning, will help mitigate the increases in significant cumulative impacts. As habitat pressures increase and plant and animal distributions shift, it is necessary to identify potential threats and restoration opportunities.

To ensure that future old-growth habitat is abundant and protected and to support carbon sequestration, we must increase protections for forest stands over 80 years old, especially those that are in Matrix and are therefore most threatened (mapped below). With new climate realities, it is important that we soften the land-use practices occurring in Matrix land (137–139). The interconnected nature of mature forest lands is an integral piece of forest management.

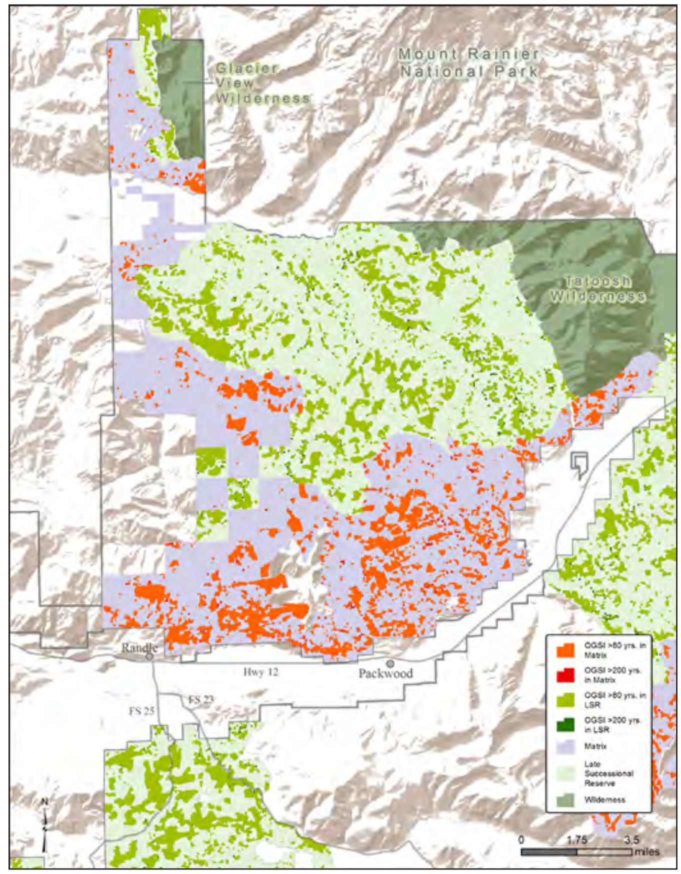
To protect and improve forest habitat during logging, important steps include: (1) protecting snags and nest trees; (2) leaving downed wood; (3) outlining plans to protect soils during management; and (4) preserving or improving all forest stands over 80 years old.



o As seen in the map above, the forest areas east of Mount St. Helens contain a large amount of high quality forest habitat, yet are threatened by their location within Matrix designation. With a large number of streams, tracts of old silver fir, and a scattering of northern spotted owl nest sites, this area is one where careful management will be of utmost importance for the resilience and long-term health of the species and habitats within.



o While timber harvest persists as an economic driver in many parts of the region, timber management projects here in the Mount Adams and Wind River area should also focus intensively on long-term impacts and consider the role that these forests can play in future carbon markets. Restoration in these areas is also important and should be carried out during timber management projects; these jobs should be prioritized for local communities. New levels of protection should be written into long-term plans, such as identifying possible Research Natural Areas, reducing the road network, and avoiding management units in habitat core areas or along wildlife corridors. The streams of the Wind River watershed are critical habitat for steelhead and salmon, and water quality issues in this area impact the downstream communities of Carson and Stevenson, WA. Microclimate impacts should be decreased by ensuring there are sufficiently large riparian buffers to prevent logging near streams.



o The mature forest stands in this part of the forest, which lies south of Mount Rainier and north of Randle and Packwood, are home to northern spotted owls, martens, and other old forest species. Management plans in these forests should outline distinct protections for these species and should work to expand future habitat, as climate impacts threaten to damage many parts of their current range.

"Forest restoration efforts should be integrated into timber harvest proposals and also carried out as stand-alone efforts using timber receipts."

• **Restoration to enhance the resilience of forests:** Many of the forest stands that currently have trees in the range of 50 to 100 years of age lack structural diversity and biodiversity. Many of these stands are just now reaching certain levels of maturity or developing old-growth characteristics after clearcutting or wildfires in the early 20th century. By creating snags and downed wood, and increasing biodiversity where necessary, we can increase the structural diversity, habitat value,


Girdled grand fir trees

and resilience of these areas. We should focus some of these efforts in areas that are along old forest habitat corridors. The efforts outlined below should be proposed during the planning stages and carried out as part of timber management projects. They can also be carried out as retained receipts projects or through Knutson-Vandenberg (K-V) Program funding. Retained receipts are funds from completed timber harvests that are designated for restoration work, such as improving wildlife and fish habitat, improving forest health and native vegetation, reducing sediment deliver to waterways, and controlling invasive species. K-V funds are also obtained through timber harvest projects, yet these funds are limited to projects within the sale area and generally include reforestation and similar forest enhancements. Restoration project focus areas include:

o Girdle trees during timber harvest activities to create snags for wildlife habitat

o Integrate resilience-focused planting and seeding as part of timber harvest activities and as stand-alone restoration projects. Consider native plant species that will likely be most robust to climate change. Plant genotypes that are more resistant to catastrophic impacts or diseases, such as whitebark pine genotypes that are more resistant to white pine blister rust. Consult with local botanists to identify genetically-adapted species from suitable seed zones, and use the climate-smart seedlot selection tool (https://seedlotselectiontool.org/sst/), which was created by Oregon State University, the U.S. Forest Service, and Conservation Biology Institute.

o When planting after management, maintain a relatively low to mid-density of trees to support healthy regrowth that requires fewer future thinning efforts.

o Highlight the ecological and economic advantages of restoration for collaboratives in the region so awareness of long-term benefit is more clear to a broader set of stakeholders.

o Adjust pre-commercial thinning techniques to maintain the most resilient trees for expected future conditions, keeping in mind that this might differ from past objectives of particular stands. And, during commercial thinning projects, ensure that efforts are focused on maintaining or increasing biodiversity to help stands become more resilient to the effects of climate change.

o Carry out forest restoration in the mixed conifer forests along the Cascade crest using a mosaic approach balancing historic conditions with future resilience needs. Make sure that restoration projects are fine-tuned and do not disrupt potential current nest sites or habitat strongholds of sensitive species such as the northern spotted owl. Effective restoration of mixed conifer forests should consider patterns and processes at multiple scales and strive to protect and enhance the system's evolutionary capacity to respond to disturbance (140).

• **Shift the management of and approach to wildfires and other disturbances**

o Embrace the beneficial aspects of wildfires (as well as tree disease and insect outbreaks) and anticipate the natural intensity of these forces as well as the expected increases in spread or severity (141–145).

o Allow fires to burn naturally in suitable areas, yet away from homes and structures.

o Pursue prescribed burning in forests that would benefit from introduced fire, such as in the mixed conifer forests (89, 146–148).

o Ensure that the preliminary step of preparing land for burning (by raking and removing uncharacteristically high fuel loads of needles and downed wood) is carried out and incorporated into restoration plans. These preparation steps and the subsequent prescribed burning efforts should be carried out as part of timber harvest projects as well as retained receipts projects using timber harvest funds.

o Forge new partnerships to ensure that the preliminary steps can more easily be carried out so that agency planners can more realistically carry out large-scale prescribed burning projects. Work with state lands and other organizations who have a history of prescribed burning, such as the Nature Conservancy, to implement more local projects. Work with stakeholders to promote awareness on the need for prescribed burning and identify incentives.

o Ensure that monitoring is part of post-burn plans, and that it is also carried out after wildfires to increase our understanding of cause, effect, and recovery. This monitoring will also help us identify site-specific conditions that create fire refugia.

o Consider historic levels of insect disturbance and allow similar degrees of impact as part of the complex mosaic of natural forest landscapes. Ensure that managers or citizen science groups are monitoring the spread and severity. Avoid planning forest management activities using unsupported correlations of insect outbreaks and wildfire potential (145, 149).

Citizen science survey of forest health and disturbance risk

• **Work with forest plan revisions** to implement strategies to increase land protection and connectivity.

o Under the National Forest Management Act, the Forest Service is required to create and regularly update Forest Plans for each National Forest. The Gifford Pinchot National Forest Plan was written in 1990, and amended by the Northwest Forest Plan in 1994. Revisions to the Gifford Pinchot National Forest Plan will likely occur as part of a revision process for Forest Plans throughout the region of the Northwest Forest Plan. Whether these Forest Plans are revised simultaneously, or at different times, it is essential that each Forest Plan maintain or strengthen the land and watershed protections within the Northwest Forest Plan. Losing these important protections in any Forest Plan in the Northwest threatens habitat and connectivity within the region.

o Forest Plan revisions are also an important opportunity for implementing new strategies for land protection and habitat connectivity. During the revision process, the Forest Service will be identifying areas suitable for Wilderness, Wild and Scenic Rivers, and other protective land designations. Forest Plan revisions are high- profile projects that typically have multiple opportunities for public engagement through listening sessions with the Forest Service and public comment periods. The revision process is a fantastic opportunity for members of the public to advocate for land management that aligns with expected climate impacts.

Public meeting concerning the 20-year monitoring report of the Northwest Forest Plan

• **Surveys and monitoring:** Support and carry out surveys to obtain up-to-date information on the health of forest areas or species. Efforts should also focus on surveying for risks and potential areas of future climate impact. Monitoring during and after conservation and restoration projects will improve future work. Many climate shifts are just beginning or about to begin, and therefore, baseline surveys are critical at this time.

o Ongoing monitoring of the Late Successional Reserve Assessment with citizen volunteers

o Monitoring pests at ecotone boundaries; capturing current baseline data and carrying out regular follow-up surveys will ensure more rapid response

Population Growth and Forest Conservation: A Match for the Masses

Population growth in the Pacific Northwest, forest recreation, and climate resilience are in one sense opposing in their roles and needs. Yet, they represent a potentially valuable and complementary combination.

Photo by Darryl Lloyd

As people move into the region, access to areas of quiet recreation and isolation becomes more difficult, especially with the current amount of designated reserves and the multitude of intersecting forest roads. Expanding Wilderness and roadless areas supports forest recreation by creating more opportunities for quiet recreation and isolation from the hustle and bustle while at the same time filling the need for mitigating the negative impacts of climate change. So, as climate needs increase and they begin to parallel the planning needs for recreation managers, the objectives of these perspectives start to align more than might be obvious on first glance.

o DNA can play an important role in conservation planning to support population health and counteract impacts from genetic isolation. Capturing or using previously obtained DNA information is relatively cheap and is useful for large-scale monitoring and can help managers mitigate population threats (150–153).

o Citizen volunteers can improve ecosystems in their area by monitoring timber projects to make sure standards and forest recommendations are being followed (www.cascadeforest.org/get-involved).

Rufous hummingbird at Mount St. Helens. Photo by Michael Sulis

o Monitor pests at ecotone boundaries, capturing current baseline data, and carrying out regular follow-up surveys will ensure more rapid response when insect disturbances expand beyond historic concentrations

o Monitor grand fir encroachment in the dry, mixed conifer forests and identify areas of high grand-fir density that put the surrounding landscape at-risk from drought, wildfire, or insects

o Carry out ponderosa pine surveys to identify at-risk stands and to prioritize restoration by measuring tree size, crown ratios, density of ladder fuels, and levels of competition from surrounding vegetation

o Capture baseline vegetation data to inform future management and conservation needs using shareable and public programs such as *LeafSnap*

o Begin dialogue with universities and native plant organizations to promote surveys and studies in new Botanical Special Areas and future Climate Resilience Areas

o Continue assessments of restoration methods, update as uncertainty is addressed, adaptively manage

o Monitor post-fire effects (from prescribed burning and wildfires) through citizen science research projects

o Birds can be important indicators of environmental change, and are relatively easy to detect and monitor. Impacts to bird species in forest ecosystems may be quite severe but there remains great uncertainty in projections for most species. Citizen science can play an important role in the arena and can serve as the “eyes on the ground,” ensuring that researchers and planners are working with the most up-to-date and thorough information possible. The Audubon Society and the local chapters that make up their team are critical resources for local needs and opportunities for community involvement. Current local efforts can be found through these centers: Willapa Hills Audubon Society, Black Hills Audubon Society, Tahoma Audubon Society, Vancouver Audubon Society, Rainier Audubon Society, Kittitas Audubon, and Audubon Washington. We also recommend that conservation organizations and citizen groups take note of bird observations in their forests and record them on the e-bird platform (www.ebird.org). This resource is used by a broad array of scientists and organizations to inform conservation work and update projects. Up-to-date information, especially in less frequented forest areas, is critical.

• **Identify carbon sequestration solutions** to promote preservation of mature and old-growth forests. Although more local management of land (private, county, and state) has generally resulted in relatively larger areas of tree loss and ground disruption, there are likely areas in these regions that can now be protected for purposes of carbon sequestration, for future systems that might monetize carbon emissions and trade credits for carbon sequestration. In other words, looking beyond timber production and harvest as a measure of economic opportunity.

Using forest **biomass** for the production of energy, such as has been proposed in the region, should not be viewed as a carbon-neutral approach for obtaining fossil fuels. Small-scale biomass facilities associated with timber mills are likely to be low-impact sources of local energy. However, large-scale biomass energy facilities would produce large amounts of carbon emissions while increasing demand for timber harvest on public lands.

• **Work with state and private land holders** to improve integrated conservation strategies for broader ecosystem planning.

o Increase communication between state agencies, tribes, and federal agencies (including other federal agencies, such as National Parks, U.S. Fish and Wildlife, National Marine Fisheries Service, and the Army Corps of Engineers). Stronger, cross-boundary partnerships will enhance the efficacy of climate projects.

Northern pygmy owl. Photo by Andy Chilton

THE MIXED CONIFER FORESTS on the south side of Mount Adams are a unique forest landscape, home to a variety of plant and animal communities not found elsewhere in the region.

This area is vulnerable to climate change and the resulting impacts of drought, wildfire, insect outbreaks, disease, and shifting plant communities (89, 140, 154, 155). Restoration is needed, but impacts from logging threaten to exacerbate climate impacts and disrupt sensitive and intact habitat areas that are increasingly important as habitat refugia in the face of climate change and wildfires (88, 156–162).

Euro-American settlement originally brought impacts in the form of widespread and repeated timber harvest, development of road and railroad networks, fire prevention and suppression, and sheep and cattle grazing. Intensive logging began here in 1942, and the construction of rail lines enabled the cutting of most of the ponderosa pine in the area. The combination of timber harvest and fire exclusion has led to denser mixed conifer forests with a greater number of small, fire-intolerant trees and fewer large, fire-tolerant trees than were historically present (163, 164). Finally, sheep grazing became common practice in the early 20th century among the middle and upper elevation forests on the south side of Mt. Adams, and cattle were introduced into the area later in the 20th century. Grazing affected forest composition, riparian systems, and disturbance regimes by influencing the quantity and type of vegetation and fuels present (163, 165–167). An active cattle grazing allotment still exists in the Mount Adams area.

Historically, these forests went through regular cycles of low- to mixed-severity wildfire about every 10 to 20 years (88). More frequent, low-severity fires on drier sites favored open canopy forests dominated by early-seral, long-lived, and fire-tolerant species like ponderosa pine, western larch, and Douglas-fir. Grand fir was likely rare or uncommon as a forest overstory species in these forests because thin-barked seedlings and saplings would have been killed by frequent fire (168). With grand fir starting to dominate the overstory and understory, old ponderosa pines, Douglas-firs, and the overall health of large tracts of the landscape are at risk. Higher tree densities increase competition for available water and nutrients, and drought-stressed trees may be more susceptible to some insects and pathogens (140). The connected overstory canopy and thicker understory can carry fire across the landscape and become ladder fuels that bring fire up into the canopy where it can kill the older pine and Douglas fir trees. Without the ladder fuels and heightened competition, these trees would normally be resistant to fire due to their thick bark and high limbs. Throughout previous fire cycles, fire would sweep through and wipe out the competing shrubs and young grand fir trees, leaving the older trees intact and creating a landscape mosaic, a resilient system that can withstand local disturbance.

Today's mixed conifer forests near Mount Adams need restoration and long-term planning to build resilience back into the system, often to a state analogous to their historic conditions (34, 79). The benefits of restoration can, however, be outweighed by the direct and immediate negative impacts of logging in and around habitat areas and sensitive vegetation (88). Logging in owl circles, for instance, has the potential to improve overall ecosystem resilience, but it directly impacts habitat in the short-term and possibly long-term as well. Considering the site fidelity of northern spotted owls, the loss of owl habitat from climate change, and impacts from barred owls and logging projects in other parts of the forest, efforts should be tailored to protect habitat around current or recently inhabited nest areas (owl circles). Other direct and immediate impacts include soil compaction, degradation of the understory plant communities, and introduction of invasive plants. Further, the logging of large grand fir and Douglas-fir trees, whether they are historically situated or not, can remove currently occupied habitat features or den trees for species such as martens or flying squirrels.

Despite the potential impacts of thinning in these forests, we still recommend restoration to promote long-term ecosystem health. It is important, though, to fully consider current habitat use and immediate impacts and to shift plans accordingly in order to create a restoration plan that offers more benefit than harm. Below we will outline restoration strategies to build resilience in the mixed conifer forests of Mount Adams.

Reducing grand fir densities will build resilience and enable the landscape, as a whole, to be able to weather the likely increase in disturbance and stressors of drought and competition. These efforts should be focused in areas with lower historic grand fir densities. Leaving some dense aggregations of grand fir is important, however, since areas with certain topographic qualities did and should have relatively dense stands. These areas include valley bottoms, east slopes, and north slopes (83).

Prescribed burning will help these areas become more resilient to climate impacts and more in-line with their historic conditions. Prescribed burning, if effective, can clear out the understory and remove the smaller trees currently competing for water and nutrients, increasing insect risks, and serving as ladder fuels. High densities of these smaller trees would have historically been present in small patches, not in a widespread fashion as it is currently.

Careful preparation for prescribed burning is a necessary step for burning efforts in this particular forest due to the current fuel loads from needles and downed wood, which have piled up higher than usual due to fire suppression. These efforts, mechanical raking and clearing, should be carried out careful so as to not nullify the benefit by causing damage to soils and standing trees.

Surveys are essential for prioritizing restoration focus areas, such as identifying the locations of large ponderosa pines and Douglas-firs or identifying current mosaic patterns and enhancing the patterning of management. **Monitoring** is also important for identifying best practices and determining where follow-up efforts are needed and where negative impact from management actions may have been greater than expected.

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 mi^2. 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

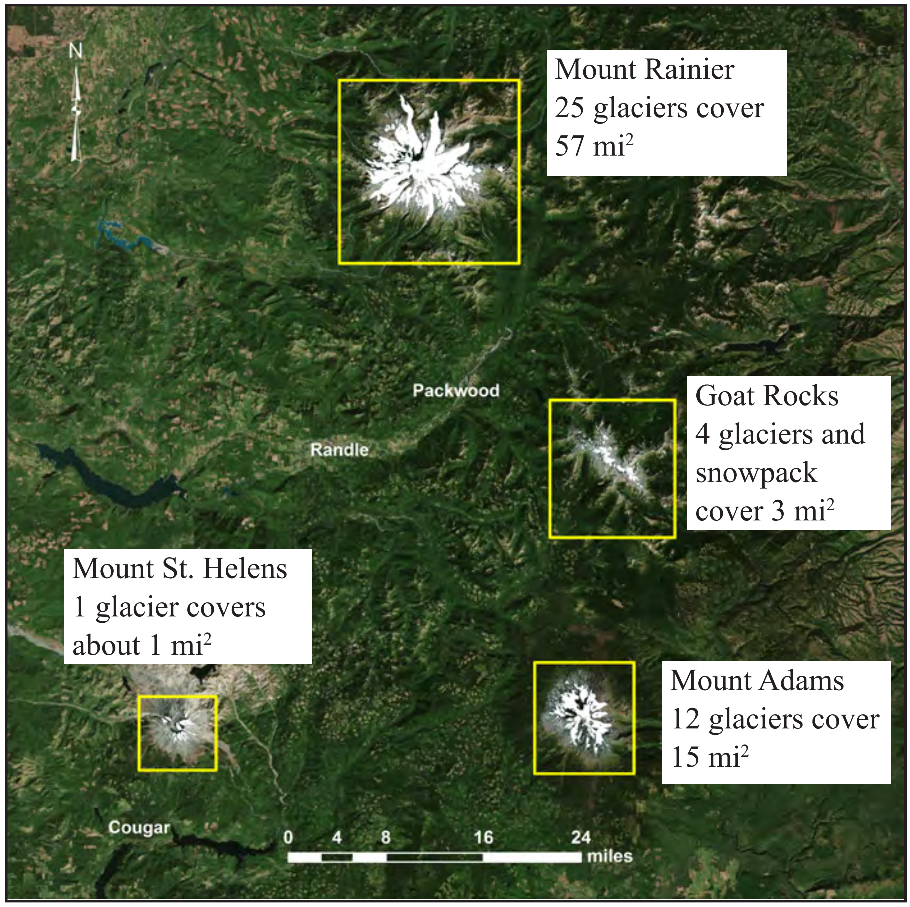
will likely lead to a loss of certain subalpine meadows from an increase tree establishment in subalpine areas and severe impacts to plant species of the subalpine region (69, 190).

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

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.



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.

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

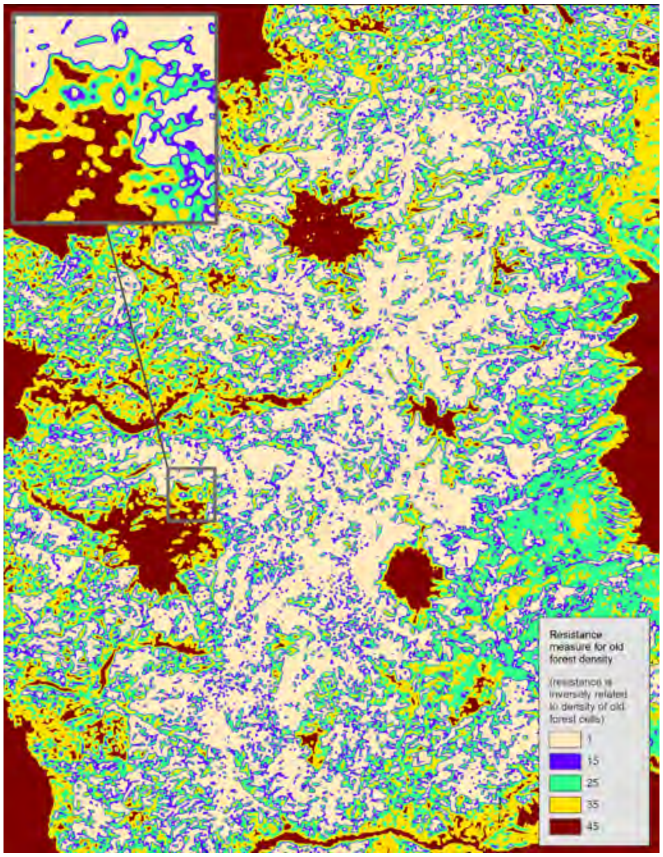
Using the mature and old-growth forest layer from Conservation Biology Institute, we ran a kernel density function measuring mature and old-growth forest density within a 1000-meter radius of each cell. The resulting layer was divided into nine classes, in order to fit the scale of the study area and 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.

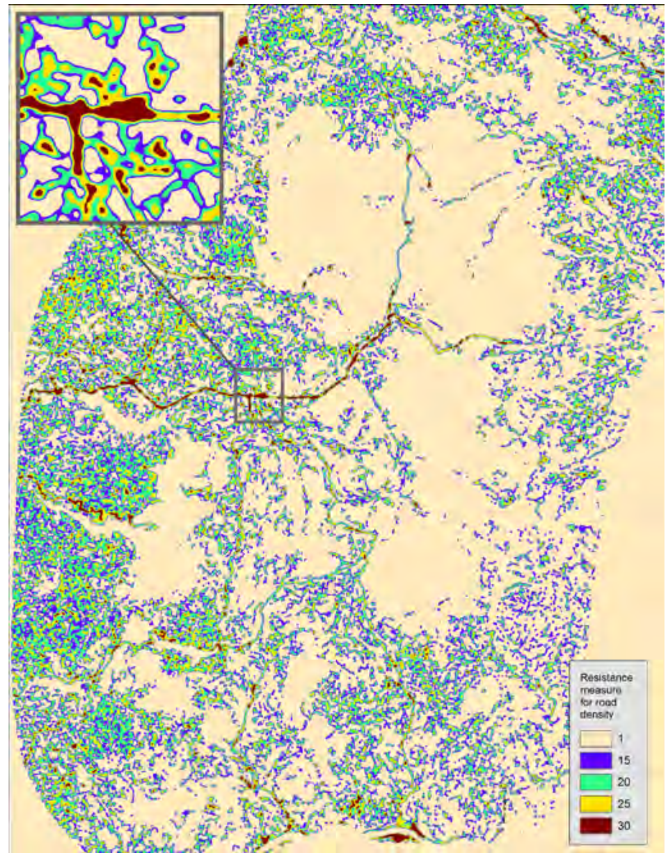
The Conversion Threat Index from Wilson et al. (2014) uses several land-use and land facet values (see page 78) to identify areas that are likely under threat from human land-use impacts, such as development and logging (203). The analysis gives increased ecological importance to areas near current "reserves," 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

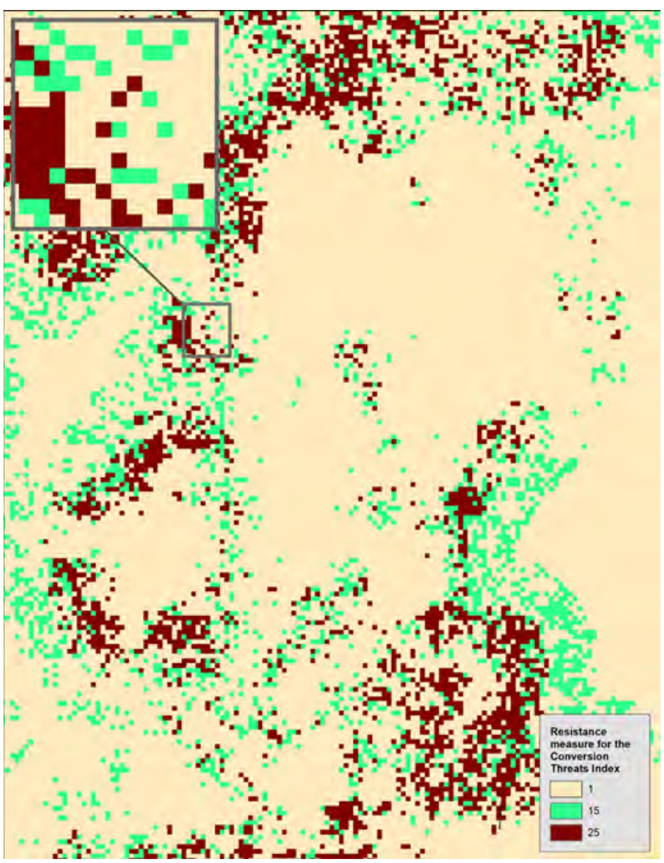
Input measures and reclassification values of the resistance layer



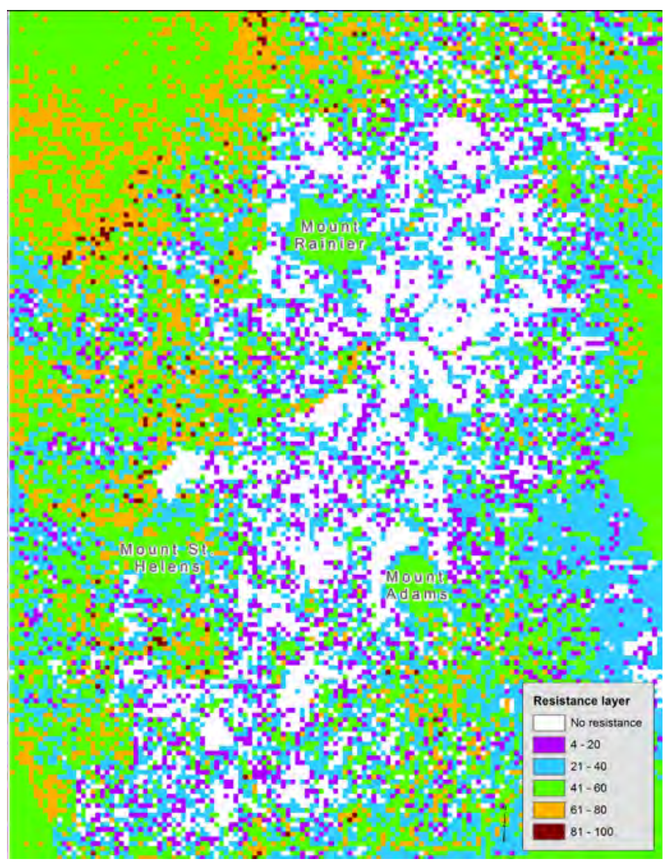
Resistance layer for old forest density



Resistance layer for road density



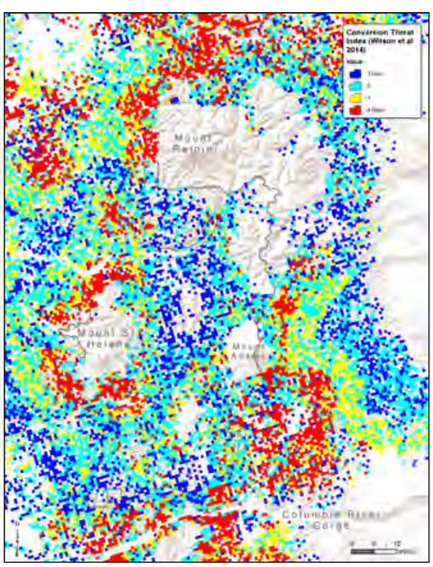
Resistance layer for the Conversion Threats Index



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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