3. FOREST ECOSYSTEMS AND CONNECTIVITY

FOREST ECOSYSTEMS, SPECIES, AND EXPECTED IMPACTS


American marten
Martes americana

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.


Northern spotted owl
Strix occidentalis caurina

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.


Northern flying squirrel
Glaucomys sabrinus

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 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

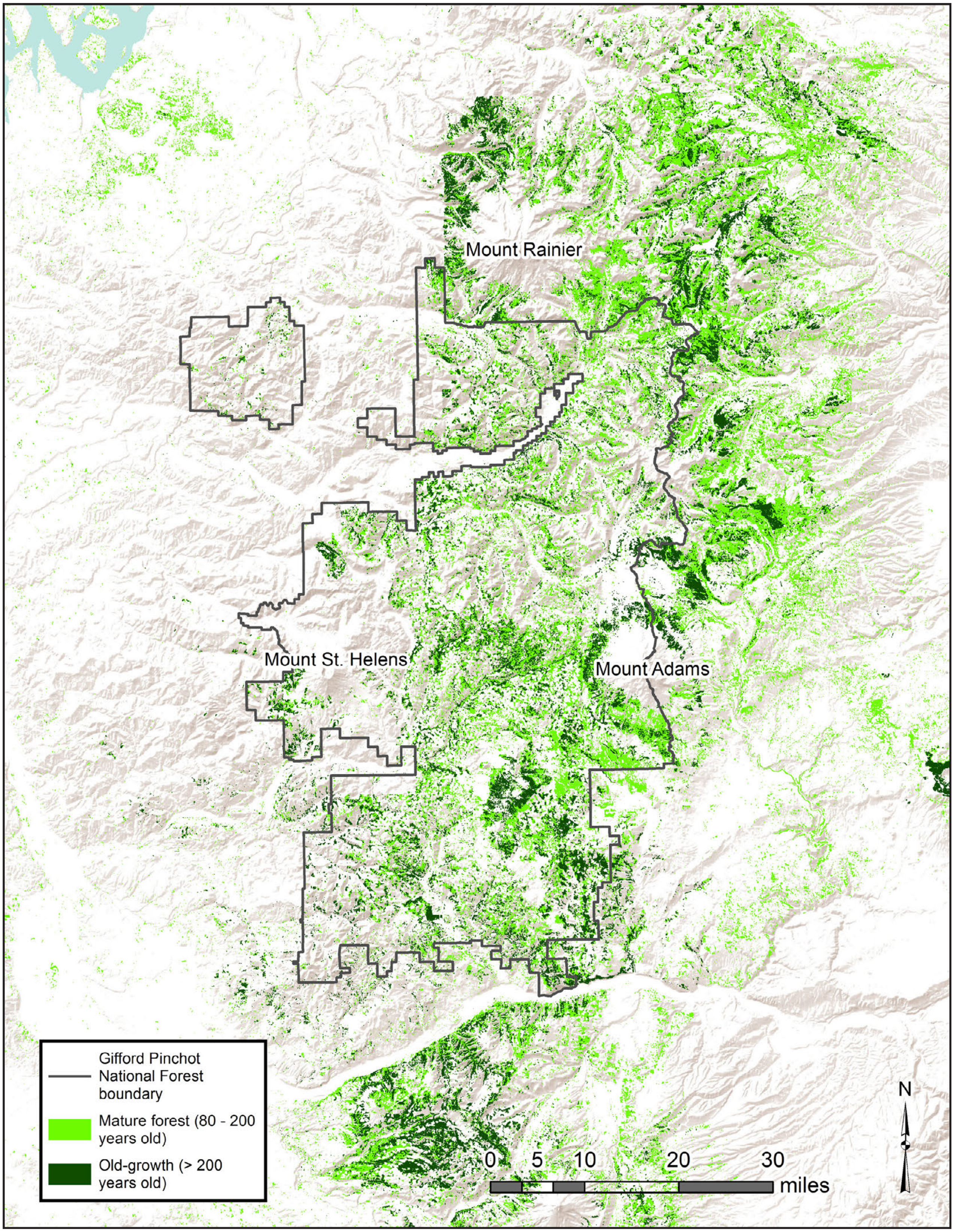
Decades of clear-cutting on federal lands drove the northern spotted owl and other old-growth dependent species to the brink of extinction. In an attempt to balance conservation concerns with the economic needs of timber-dependent communities, a team of specialists drafted the Northwest Forest Plan (NWFP). 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.

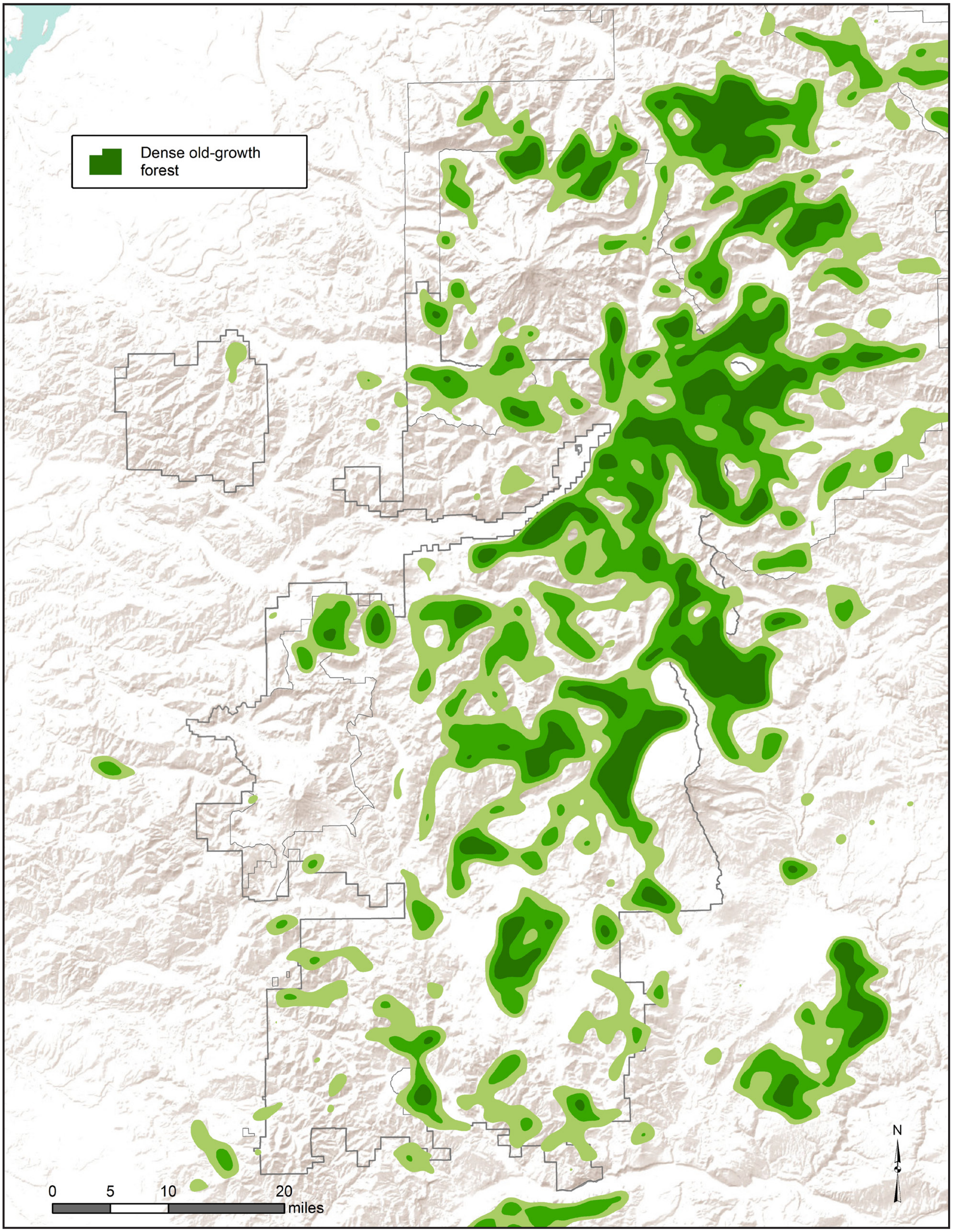
- **Late Successional Reserves** (LSR) were set aside by the NWFP to protect current, and develop future, old-growth habitat. Forests in LSR greater than 80 years old are protected from logging unless it will benefit the creation of old-growth conditions. Timber harvest may occur in LSR forest younger 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."

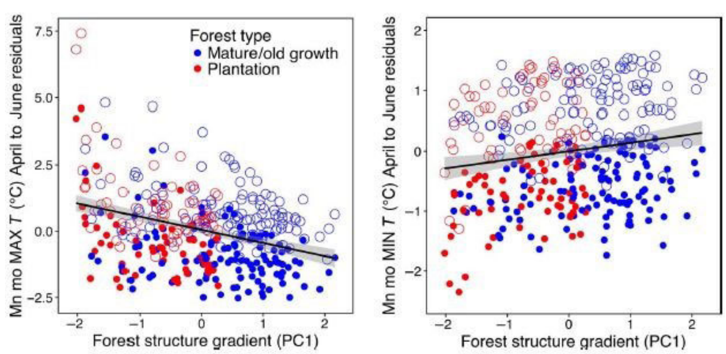
Biodiversity is one of the main features of old forests that provide long-term protection in the face of disturbance and climate impacts. Biodiversity represents a "library of possibilities" for local ecosystems and enables landscapes to have inherent resilience in the face of threats (66). Old forests 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:

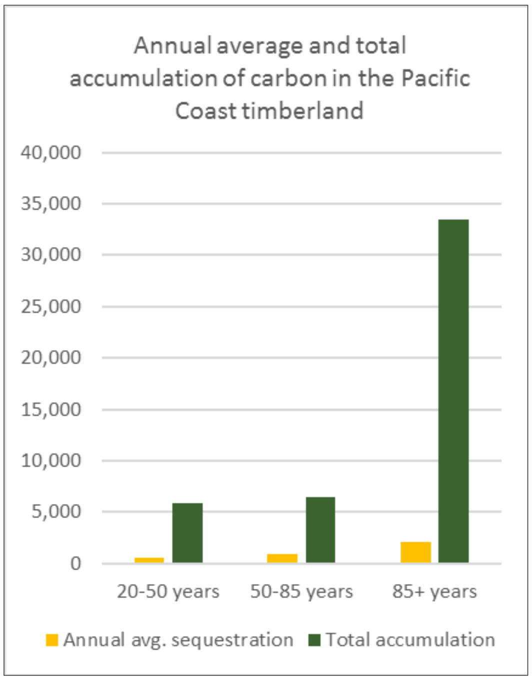
> Vegetation characteristics associated with older forest stands appeared to confer a strong, thermally insulating effect. Older forests with tall canopies, high biomass, and vertical complexity provided cooler microclimates compared with simplified stands. This resulted in differences as large as 2.5°C 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.

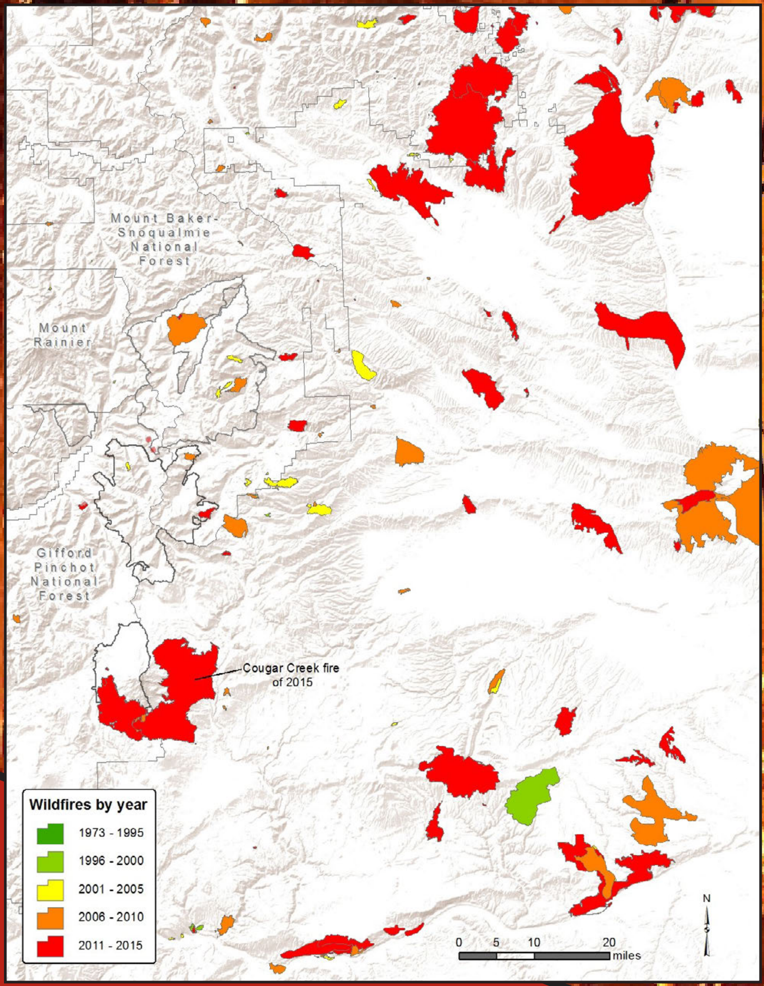
Climate models project that by the end of the century, temperature in the region will increase will roughly 0.5° to 8°C (1° to 15°F) above 20th century averages (11, 80). Models also suggest that summers will be drier, which is likely to adversely affect a wide array of forest species (81–83).

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.

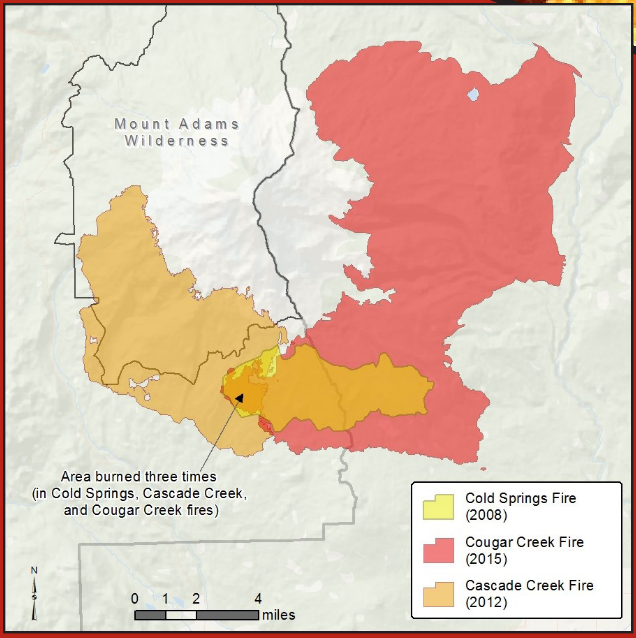
Research also shows potential **shifting forest growth behavior** in response to a changing climate (82). Forest "zones" are expected to move upward in elevation, potentially causing important species relationships to decouple and creating ripple effects through the ecosystem. Shifts will likely make 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).

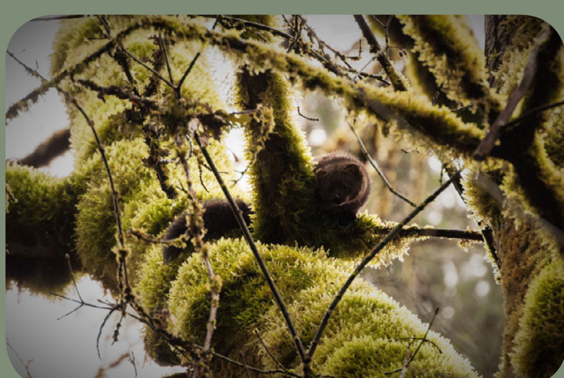


Photo by Michael Sulis

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).

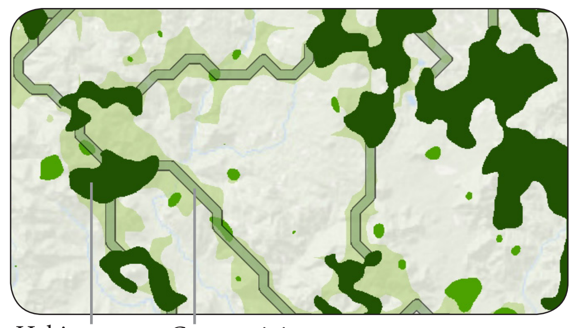
Paleoecological records suggests that Douglas-fir, red alder (*Alnus rubra*), and lodgepole pine (*Pinus contorta*) will be relatively resilient to the effects of climate change (31). Similarly, Oregon white oak

(*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.

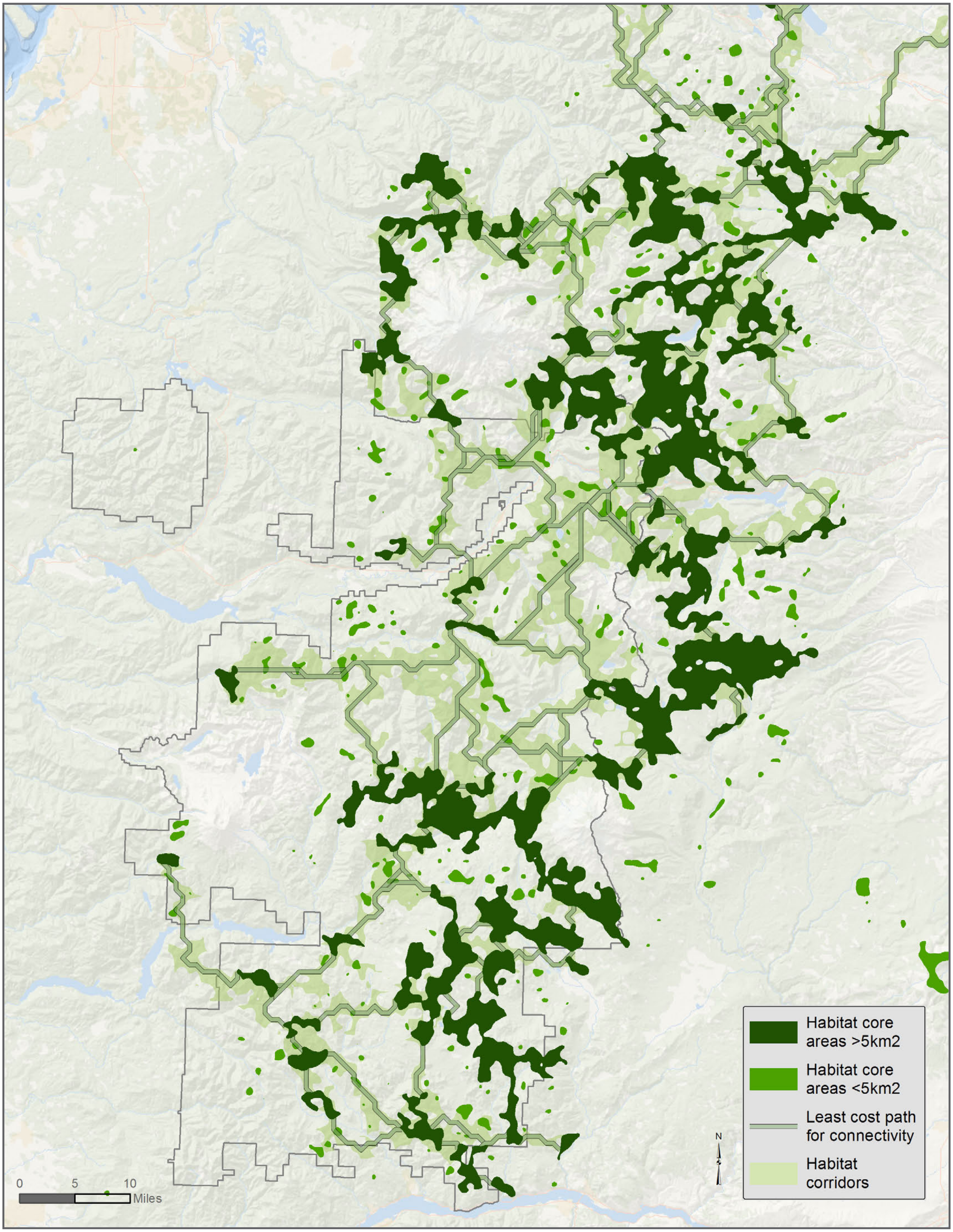
To give context for some of the details and parameters of the connectivity analysis, we will outline some general habitat features for the species of focus. **Fishers** require certain habitat features often found in mature and old-growth forests, such as wide trees and dense canopy cover. These components 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). 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).

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

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.

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



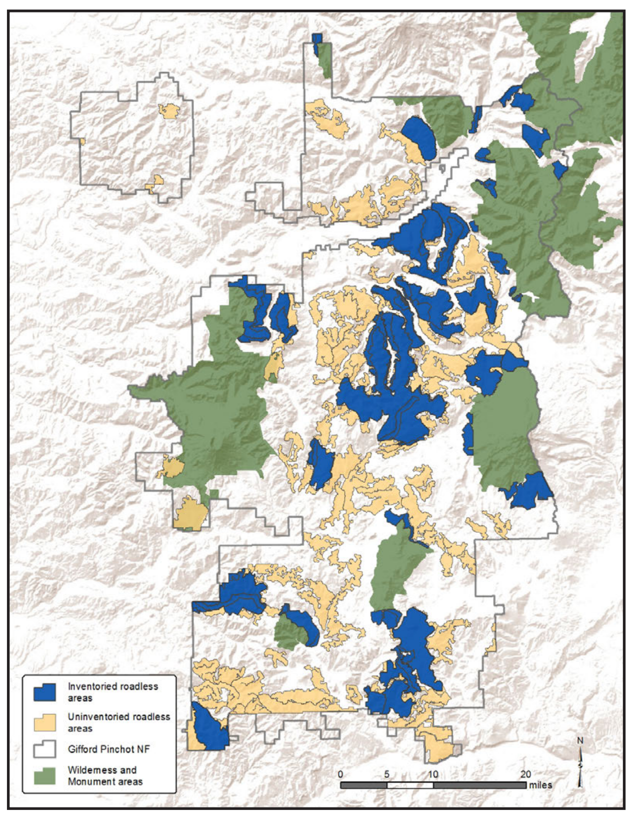
Functional connectivity for species residing in mature forest habitat

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).



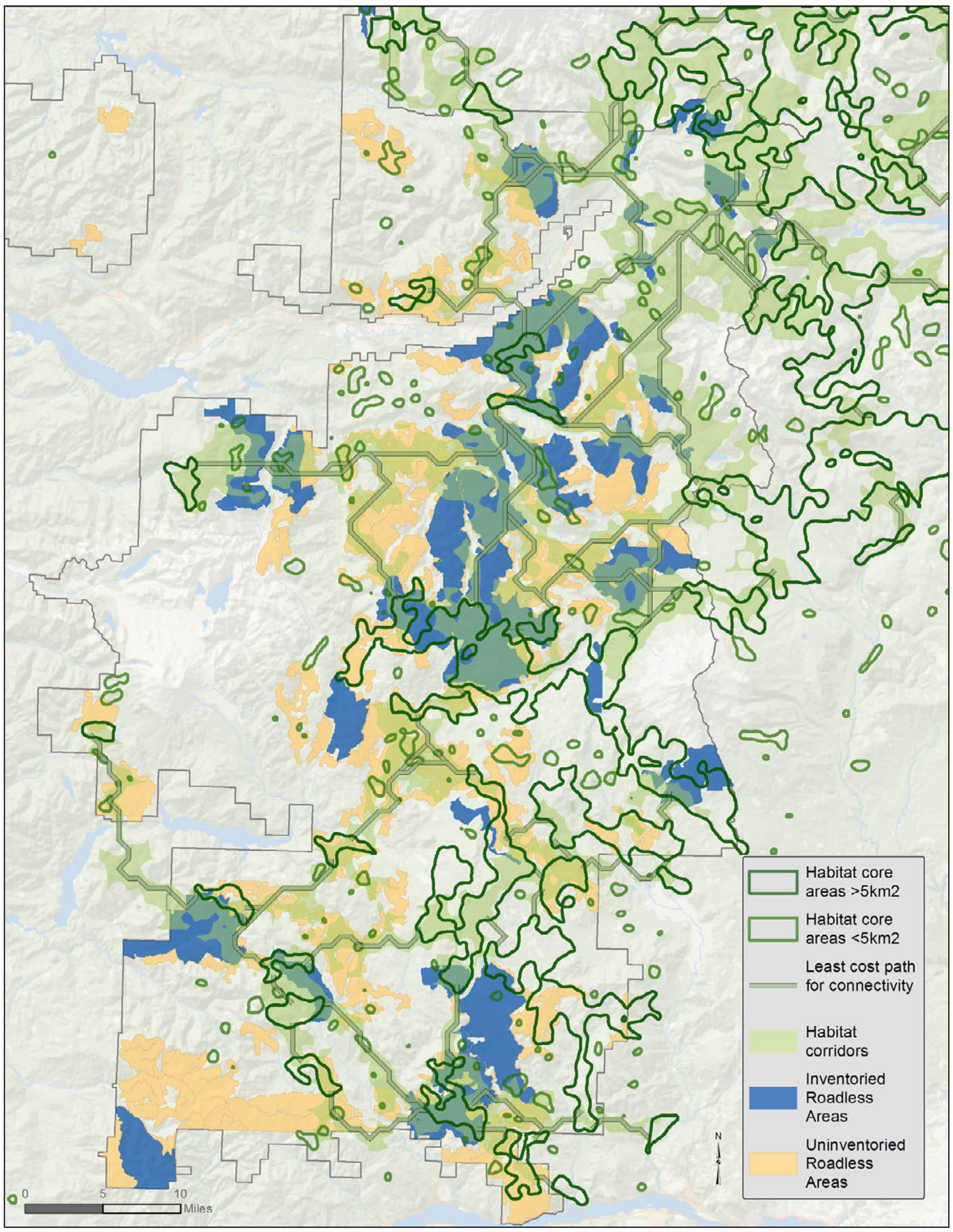
Inventoried and Uninventoried Roadless Areas

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.

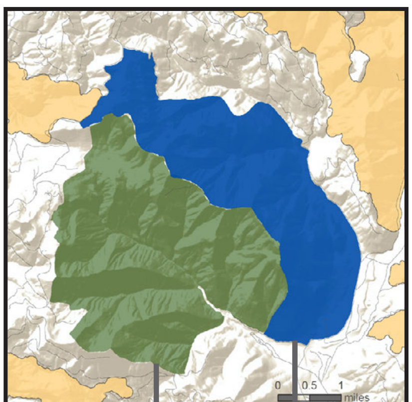
Mount Rainier National Park. Photo by Robert Scheller

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.

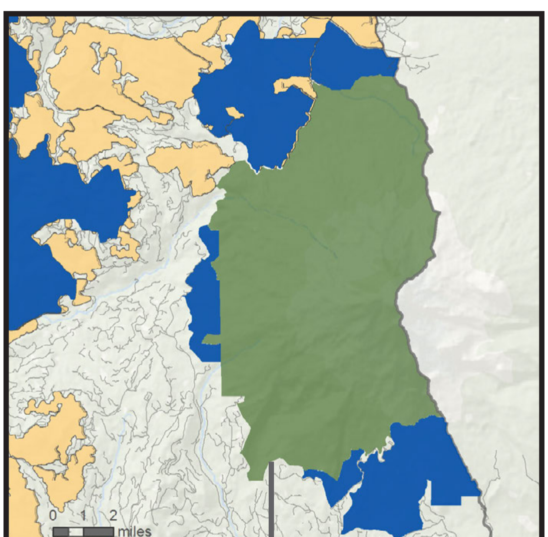
In the following pages, we will outline specific strategies and recommendations for building resilience to climate change.

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

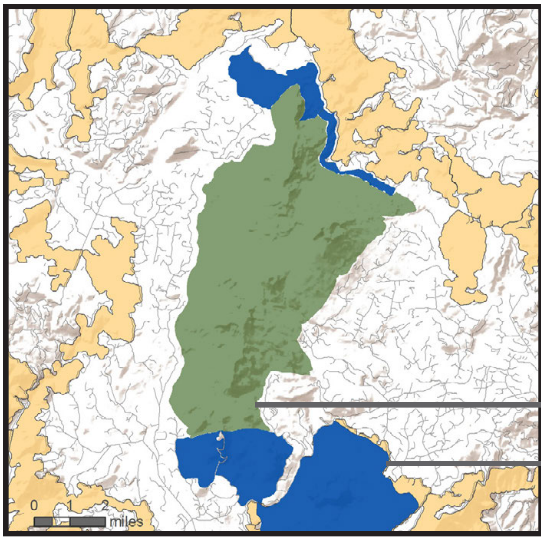
• **Strategically expand current Wilderness and protected areas:** Despite the variety of possible approaches for mitigating impacts of climate change, there is one theme that runs throughout: protect land rapidly to help buffer biodiversity against climate change (1). Climate change demands the expansion 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.



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.



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.

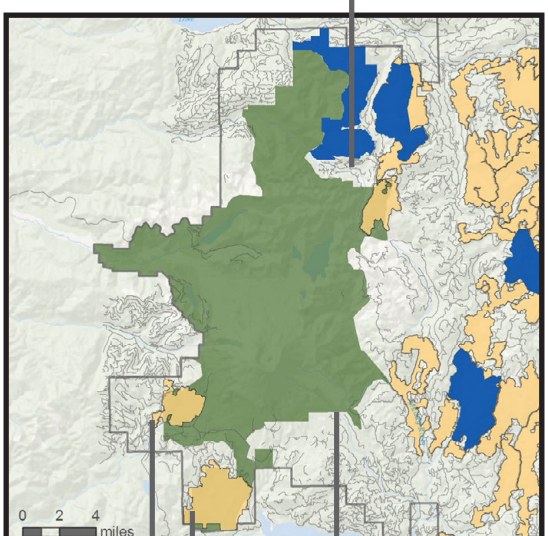


o **Indian Heaven Wilderness Addition:** Potential Wilderness expansion areas bordering the south end of the Wilderness are currently in Matrix, while expansion areas in the north are mostly administratively withdrawn as not currently eligible for timber harvest. The Indian Heaven Wilderness is a forested 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

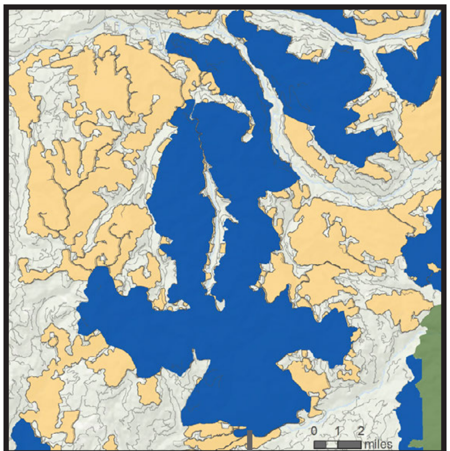


Not currently IRA, but recommended for reserve expansion out from Mount St. Helens National Volcanic Monument

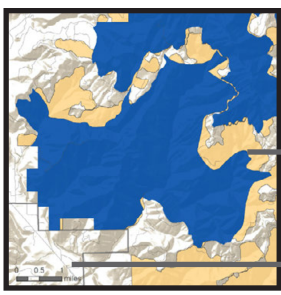
Mount St. Helens National Volcanic Monument, established 1982

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.

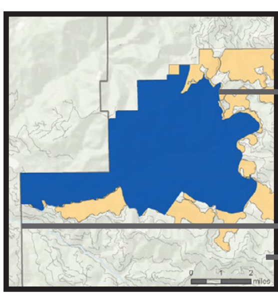
• **Designate new Wilderness areas:** On the previous page, we discussed additions to current reserves. In this section, we will identify new Wilderness areas and outline reasons and recommendations for seeing these areas formally protected as Wilderness. Similar to the expansions of current reserves, 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.



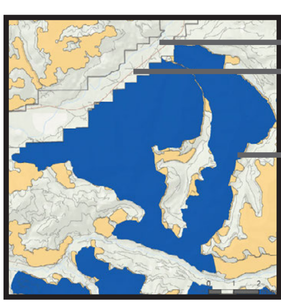
o **Dark Divide -** This iconic roadless area is drenched with more lore and wonder than any other part of the Cascades. This area is thought to be home to Bigfoot, and it was once considered the likely site of the missing fugitive, D.B. Cooper, who parachuted from a plane in 1971 with bags of stolen 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.

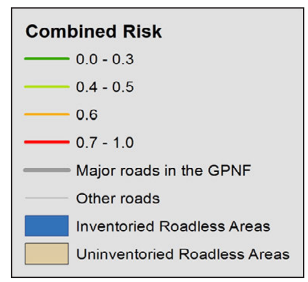
All three approaches used the RoadRight analysis to identify priority roads (134). RoadRight measures the impact that roads are having on terrestrial and aquatic systems by considering aspects such as stream crossings, soil stability, topography, high sedimentation potential, surrounding habitat designations, 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)"

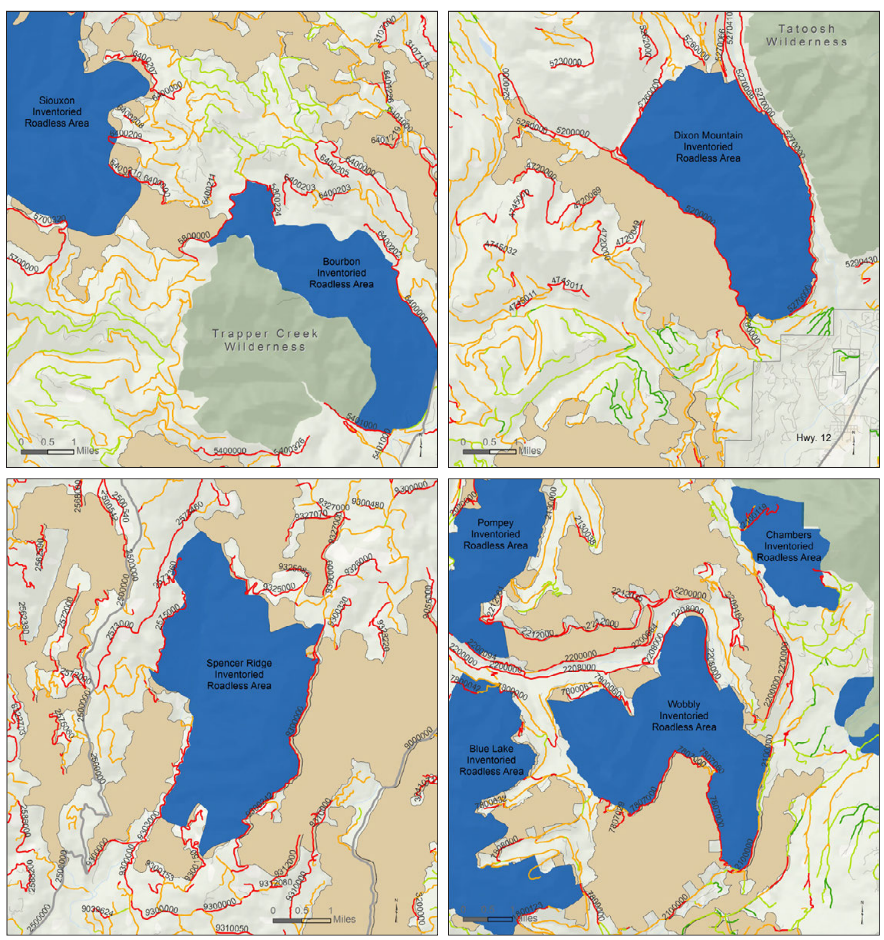
We don't expect all the identified roads to be closed or decommissioned, but by prioritizing and mapping the roads and the different aspects of impact, managers and organizations can more easily identify suitable opportunities when local or regional projects are planned. The RoadRight analysis was designed 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).



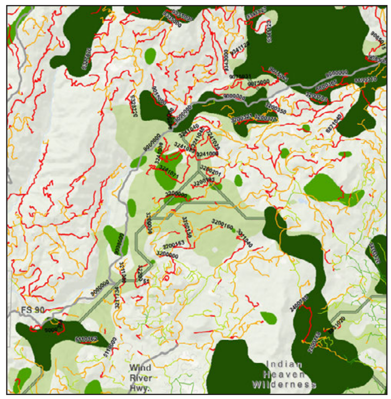
priority roads identified in pages xx to xx, we will increase the roadless nature of habitat areas and corridors while also improving the upkeep of surrounding forest roads needed for recreation and management needs.

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.

3.



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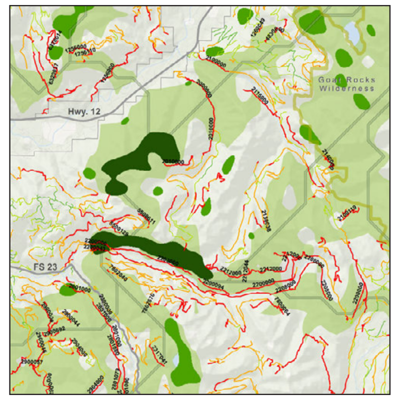

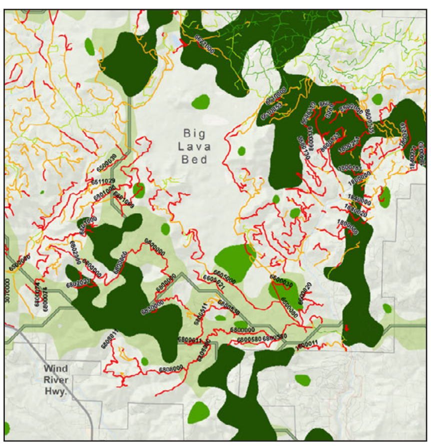

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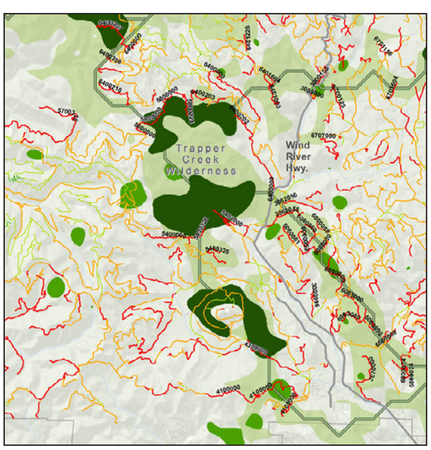

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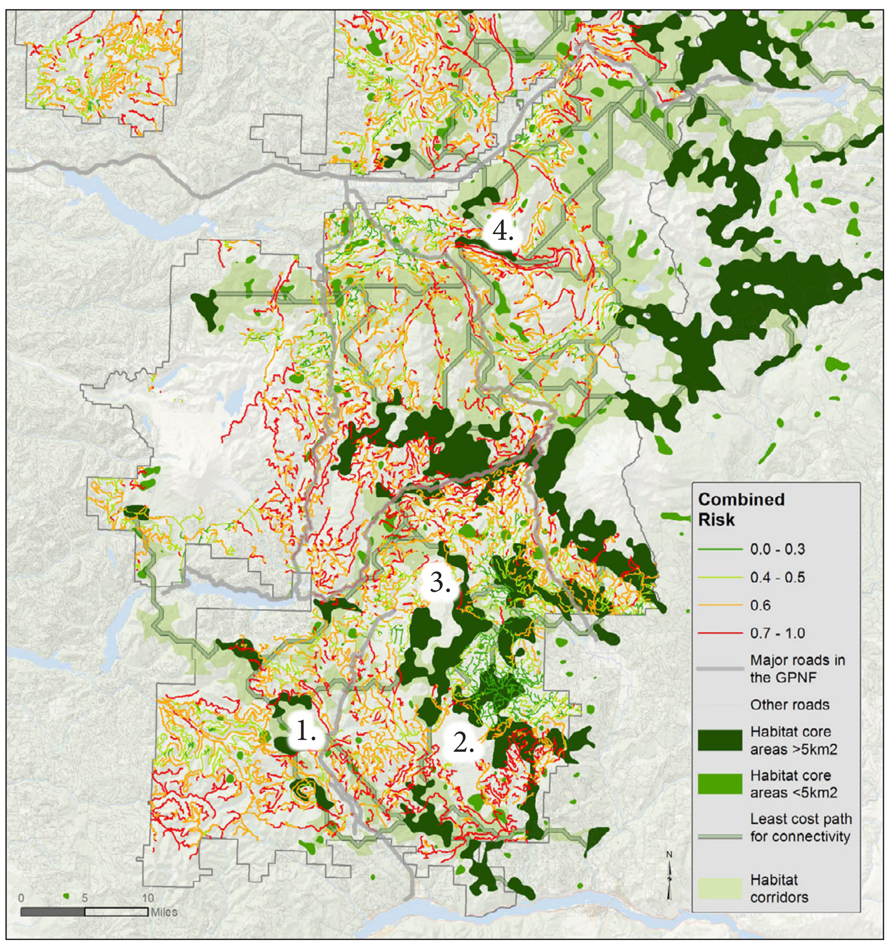
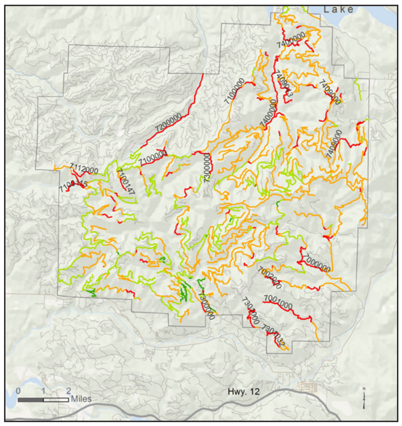


example of a successful road-crossing project. Implemented in 2016, with an expected completion in 2019, this project created a much needed passage route for wildlife in the Cascades. Similar efforts can be carried out along other corridor areas of I-90 and in regions east of our focus areas where I-84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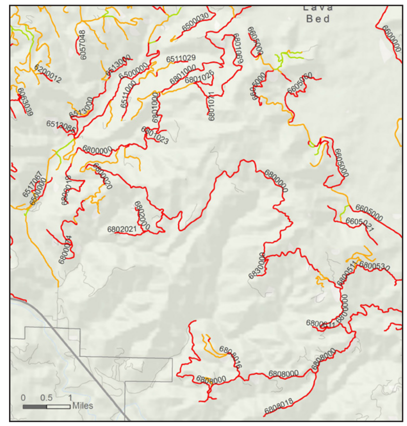

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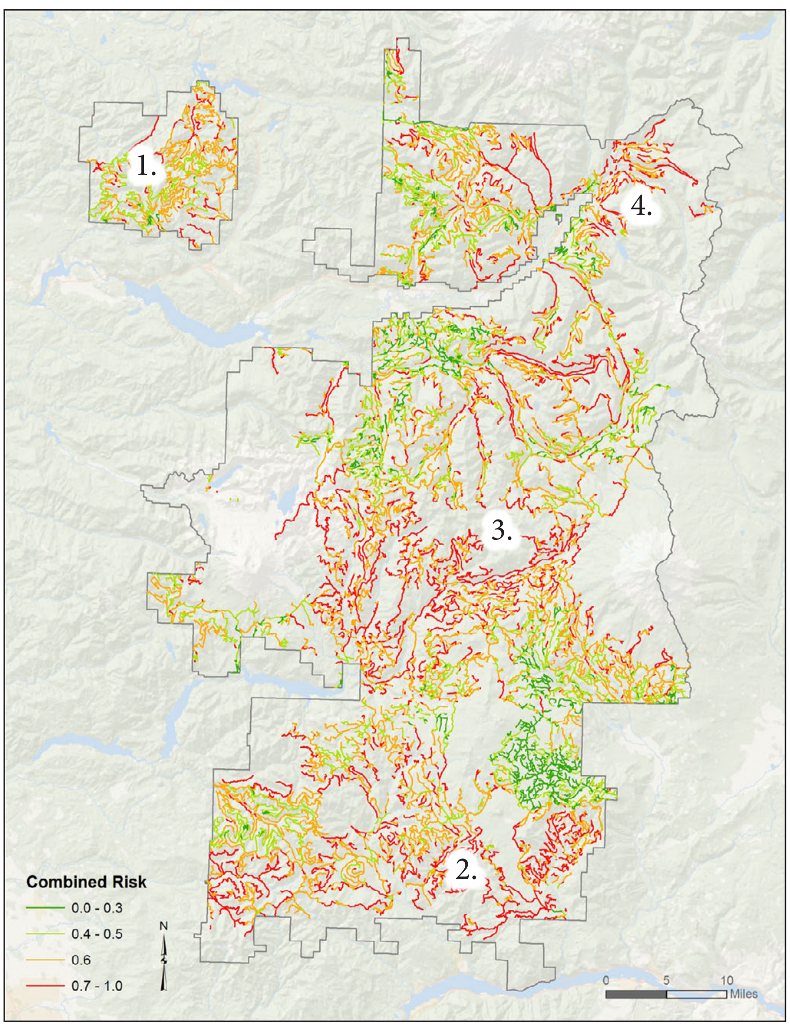

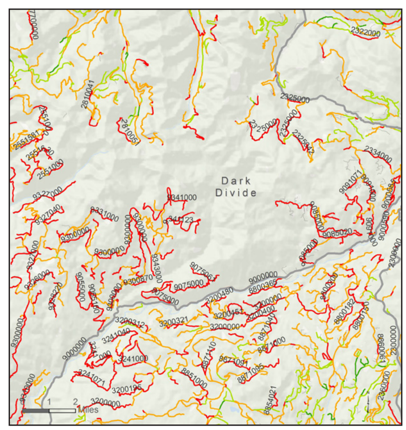

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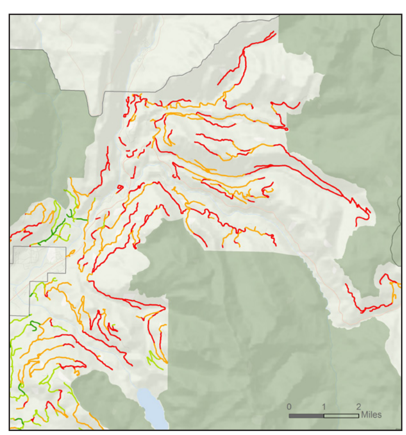


4.

• **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.

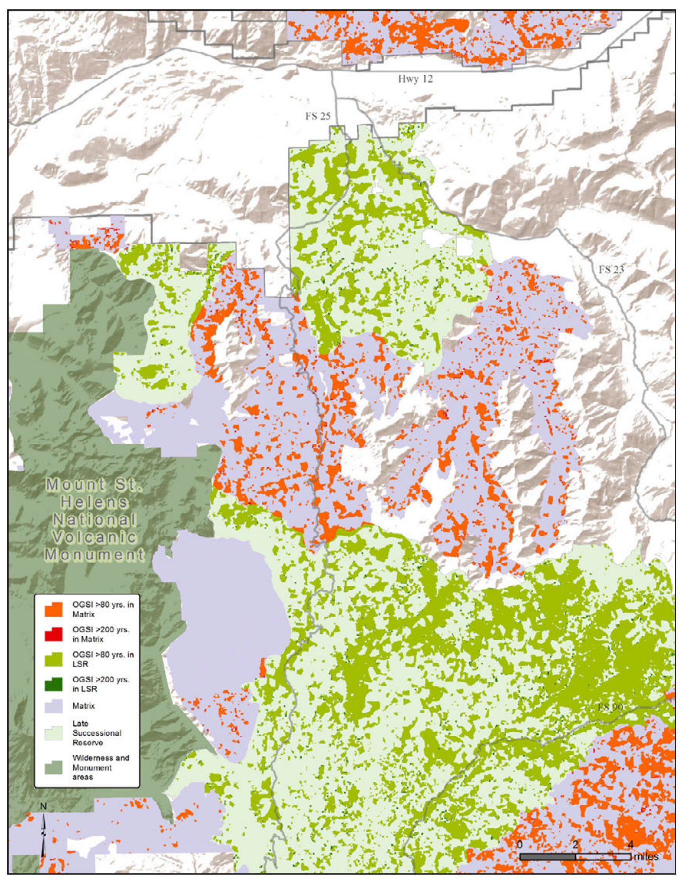
o **Climate Resilience Areas (CRAs)**
This is not currently a type of designation. We are proposing the creation of a new designation tailored for climate mitigation planning, where adaptive management and climate research are paramount. These areas should be created to specifically study climate impacts 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.

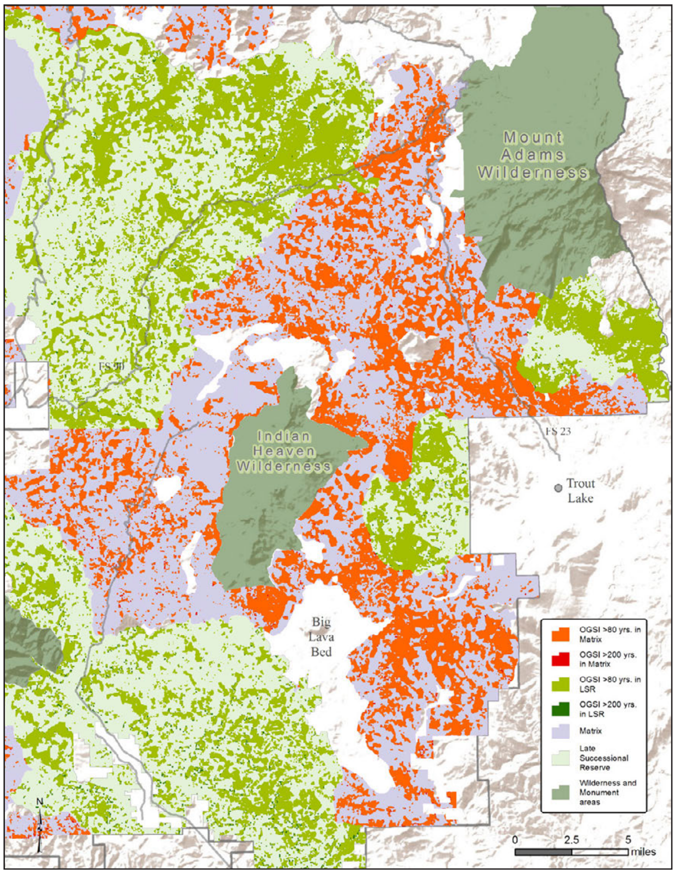
To ensure that future old-growth habitat is abundant and protected and to support carbon sequestration, we must increase protections for forest stands over 80 years old, especially those that are in Matrix and are therefore most threatened (mapped below). With new climate realities, it is important that 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.

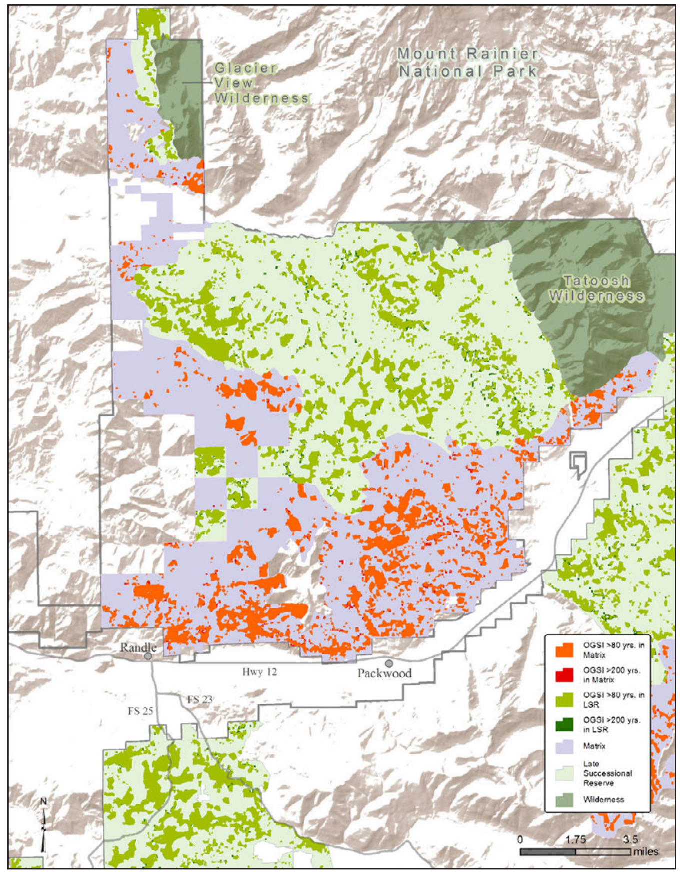
To protect and improve forest habitat during logging, important steps include: (1) protecting snags and nest trees; (2) leaving downed wood; (3) outlining plans to protect soils during management; and (4) preserving or improving all forest stands over 80 years old.



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.

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 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

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.