Regional Prioritization of Forest Restoration

across California's Sierra Nevada

The Nature Conservancy

CONTENTS

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To see the report online please visit: scienceforconservation.org/products/sierra-blueprint.

COVER: A National Forest Service crew burns a pile of thinned trees to restore the forest and reduce fire risk above Lake Tahoe. The water hose helps tokeep the burn under control.

INTRODUCTION

Forests and meadows of the Sierra Nevada, Cascades, and Modoc Plateau of California are vital parts of California's natural heritage and economy. These lands, hereafter referred to as the Sierra Nevada, support over 400 species of wildlife along with almost half of California's plant diversity - 3,500 species.[1] The Sierra Nevada provides approximately 30-60% of the water supply for 39 million people in California and has some of the world's highest density of carbon storage in its forests. [2] This region also provides the scenic beauty and opportunities that drive a recreational economy estimated to be worth $3-5 billion annually.[3]

California spotted owl is one of the five sensitive species dependent on large trees that we included in this assessment. © Photo by USFS Region 5

The Sierra Nevada's forests have been transformed since European settlement by logging, fire exclusion, livestock grazing, road building, mining and urban and exurban development. These activities altered the vegetation structure and composition. Most old-growth forests have been lost, and biologically rich riparian forests, streams, and meadows are degraded in many parts of the range.[1,4,5] What remains are uncharacteristically young, dense forests with increased overall tree density, canopy cover, and structural homogeneity. [6–8] These forest conditions, combined with ongoing fire suppression, have disrupted natural fire regimes that are important for maintaining the diversity of these systems [9,10] and created higher fuel loads that promote more extreme fire behavior. Most of the Sierra Nevada now experiences less fire on an annual basis than is needed to maintain forest health and reduce the risk of "megafires."[11,12] Today, megafires are more frequent and tend to burn larger areas of forest at high-severity than was historically the case.[13–16]

These changes in forest structure, fire behavior, riparian corridors, and meadows have negative consequences for the biodiversity and ecological resilience of the Sierra Nevada. [17] Younger, denser forests, in lower elevations where fire used to play a more prominent ecological role, are more susceptible to drought and insect outbreaks.[18–20] Over 100 million trees have died since 2010, a period of prolonged drought in California.[21] Many species associated with older forests—like California spotted owl *(Strix occidentalis occidentalis*) and Pacific fisher (*Martes pennanti*)—are at risk due to habitat loss[22,23] and are threatened by increasing high-severity fire behavior.[24–26]

People also suffer consequences from these altered forest dynamics. Extreme fire events can cause heavy erosion that reduces water quality and clogs or degrades reservoirs and hydropower facilities downstream. [27,28] Large, uncharacteristically intense wildfires contribute more air pollution and carbon dioxide than managed wildfires or prescribed fires and often occur during periods of already low air quality, creating severe health effects for vulnerable communities.[29] Further, large-scale, high-severity fires can destroy homes, infrastructure, and timber.

The cost to taxpayers of fighting wildfires is also increasing. From 1995 to 2015, the U.S. Forest Service (USFS) expenditures for fire suppression and management increased from 16% to more than 50% of its annual budget; these costs are projected to reach $1.8 billion by 2025.[30] Most of this money is spent on fighting the relatively few, but unusually large and destructive wildfires. The 2013 Rim Fire in the central Sierra Nevada burned nearly 257,000 acres at a cost of more than $127 million to fight the fire, with the loss of an estimated $1 billion in ecosystem service value.[31] As a result, the USFS's budget available for funding forest restoration, thinning and prescribed fire is declining.

Large-scale, proactive restoration is needed to restore the health and resilience of the region's forests and meadows and to avoid long-term adverse impacts to both people and nature. Unfortunately, the current pace and scale of ecologically based forest management is insufficient to address the problem; at current rates, millions of acres of forest will remain at risk of extreme wildfires.[32–34] To avoid the worst effects of increasing fire severity and to restore forests back to a condition that can safely accept more fire, significantly more investment is needed in proactive, ecologically based restoration, such as strategic thinning and prescribed fire. And, given limited resources, these restoration efforts must be strategically targeted to maximize the return on any investment.

To help achieve this goal, we conducted a systematic regional-scale assessment to identify watersheds for forest restoration activities that would offer the greatest risk reduction to biodiversity and human infrastructure. Also, in order to assess how much fuels reduction has already occurred in recent years and how accessible watersheds are for proactive restoration, we compiled information on fuels reduction efforts since 2010, wildfire burnt areas since 2006, and operable areas for restoration This analysis can inform efforts to achieve greater return on restoration investment in the region over the next 10-20 years, and accelerate restoration of this vulnerable ecosystem.

A thinned area of Stanislaus National Forest illustrates the openness characteristic of a healthy forest condition © David Edelson/The Nature Conservancy

METHODS

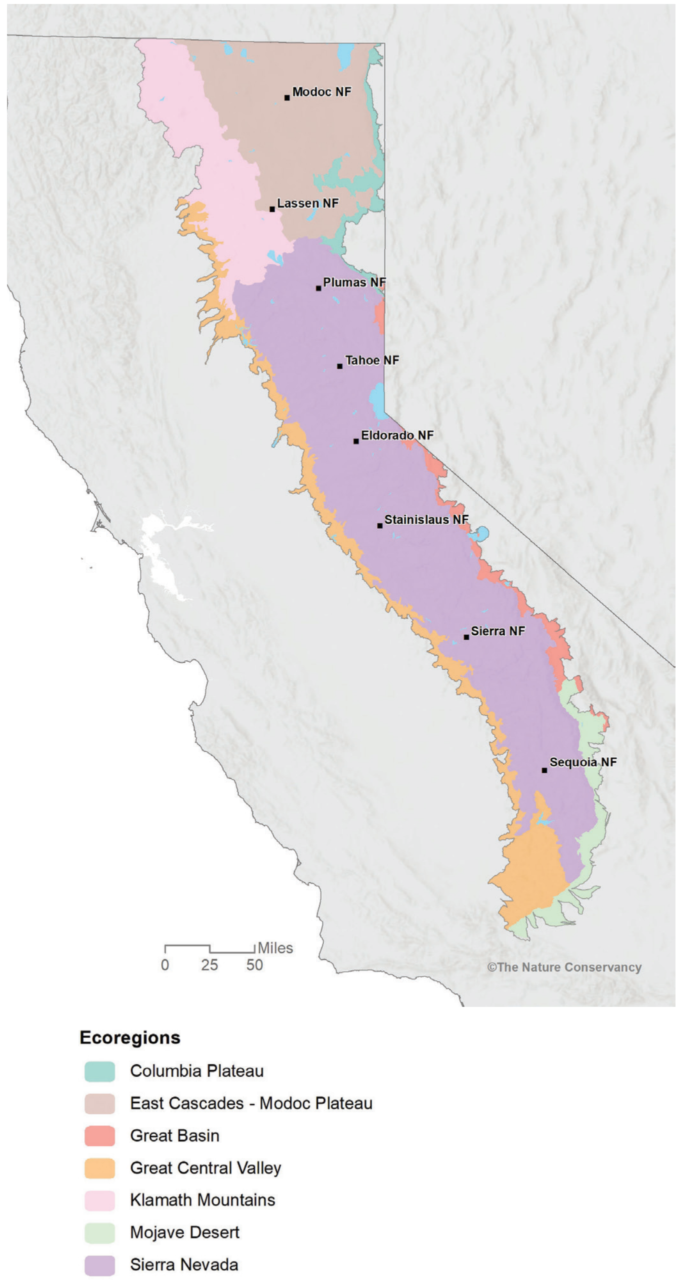
Study Area

The assessment's study area encompasses seven ecoregions, two mountain ranges, and a plateau. The ecoregions we used are based on *Global Ecoregions, Major Habitat Types, and Biogeographical Realms* developed by The Nature Conservancy in 2009.[i] The study area includes all 12-digit hydrologic unit code (USGS HUC-12) watersheds (Seaber et al. 1987) that intersect the California portion of Bailey's (1994) *Sierran Steppe-Mixed Forest-Coniferous Forest-Alpine Meadow Province* (Figure 1). The resulting 1,149 HUC-12 watersheds range in size from 10,000 to 100,000 acres. The area experiences a Mediterranean-type climate with precipitation in the winter, mostly as snow, and hot and dry summers. The Sierra Nevada is mountainous with vegetation following elevational bands from woodlands and shrublands to evergreen forests. The total study area is 25,280,050 acres (39,500 square miles), including 11 National Forests, other public lands, and interspersed private lands. To ensure watersheds were compared consistently across the Sierra Nevada, we used region-wide, publicly available datasets that provide data for all watersheds.

Watershed Prioritization

We prioritized watersheds based on biodiversity value, ecological departure of forests from historic fire regimes, and fire risk to infrastructure. These three factors are useful for prioritization because they: 1) account for the risk of high-severity wildfires to a broad suite of biodiversity, 2) provide a measure of need for restoration based on interruption of fire as a critical natural process, and 3) account for the risk of catastrophic fire to people. We identified those watersheds where biodiversity values were high to very high, fire frequency was lower than pre-settlement averages, and fire risk to infrastructure was moderate to high. Combined, these factors point to watersheds where there is a need to reduce wildfire risk for both biodiversity and human infrastructure through ecologically based mechanical thinning and reintroduction of fire as a natural process.

FIGURE 1. Study area boundary encompassing seven different ecoregions.



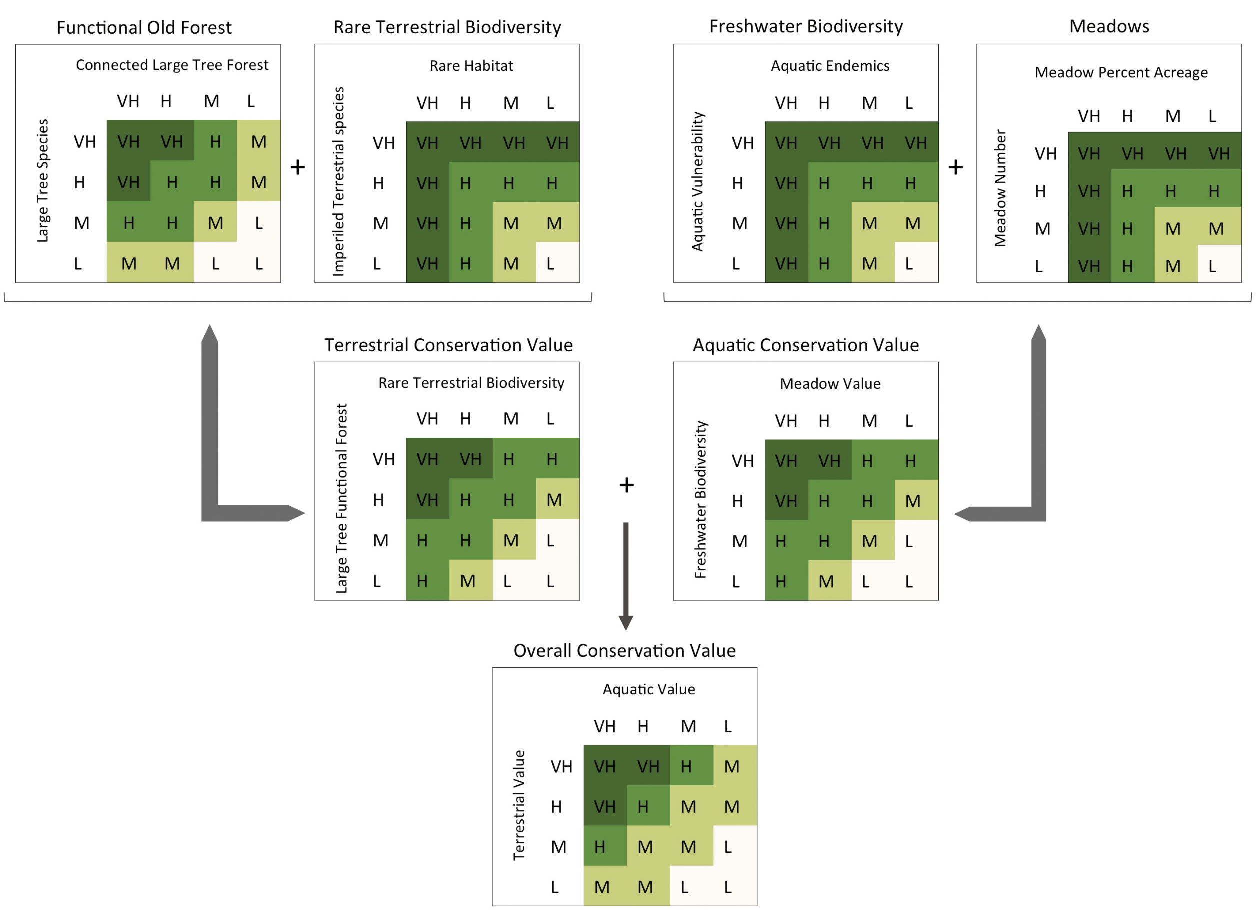
Biodiversity Value

To estimate biodiversity value, we assembled nine sets of publicly available spatial datasets for terrestrial and aquatic biodiversity and calculated the habitat area or number of species within each watershed. Using these data, we created a relative index of biodiversity, from low to very high, for each attribute and rolled these into a composite index of overall biodiversity value (Figure 2). The data and rules used to combine data to derive a composite index of biodiversity value are described below (Table 1).

We evaluated terrestrial biodiversity by combining five metrics: (a1) connected large-tree forests plus (a2) remnant patches of large trees, (b) number of large-tree associated wildlife species present, (c) the number of rare terrestrial wildlife species present, and (d) the area of rare terrestrial habitat types. Connected large-tree forests were defined and mapped as those areas where a connected network of medium sized trees (>20 inches diameter at breast height, dbh) and remnant patches of large trees (>30 inches, dbh) persist. We assessed the presence of large tree-associated wildlife—Pacific marten (*Martes caurina*), Pacific fisher, wolverine (*Gulo gulo*), Sierra Nevada red fox (*Vulpes vulpes necator*) and California spotted owl—based on records since 1980 from the California Natural Diversity Database (CNDDB)[35], California Department of Fish and Wildlife Spotted Owl database[36], and an unpublished USFS wildlife observation database. Wolverine and Sierra Nevada red fox are more habitat generalist species, but they are associated with large-tree forests, so they were included in the large-tree associated wildlife attribute.

We used CNDDB and the unpublished USFS plant and wildlife observation databases to determine how many other rare terrestrial plant and wildlife species are present in each watershed. These included any species or subspecies, other than the large-tree associated wildlife mentioned above, with an imperilment status of G1, G2, or G3 based

FIGURE 2. Biodiversity value indices used to score watersheds according to their specific and overall levels of biodiversity.



on NatureServe's rankings of imperilment[ii]. Finally, we defined rare terrestrial habitat types as those vegetation classes that represent less than 1% of the total study area, a relative measure of rarity. To map rare habitat types across the study area, we used a combination of three data sources: USFS eVEG 2015[iii], USGS maps of serpentine soils and the USFWS National Wetland Inventory.[iv]

We assessed the importance of watersheds for aquatic biodiversity based on four metrics: (e) number of aquatic endemic species present, (f) number of vulnerable aquatic species present, (g) total area of montane meadows, and (h) number of montane meadows. The number of vulnerable and endemic aquatic species were assessed using the California Freshwater Species Database v2.[v] The California Freshwater Species Database records the presence or absence of 3,906 vascular plants, macroinvertebrates, and vertebrates across all HUC12 watersheds in California.[37] Vulnerable species are those formally listed by state or federal agencies as endangered or threatened, being reviewed for listing, or considered as species of special concern. It also includes species listed as vulnerable or imperiled by other organizations, such as NatureServe. Endemic species are those known to be restricted to California based on available data sources. We used the University of California Davis Meadow GIS dataset[vi] to calculate the area and number of meadows occurring in each watershed.

Fire Frequency

We used estimates of change in fire frequency developed by Safford and Van de Water[12] as an index of the degree to which forested areas have diverged in terms of this key ecological process. This is a useful measure of ecological change for prioritizing areas for restoration, fuels reduction, and fire management given that fire is an important, natural disturbance that maintains the structure and function of many of the forests across the Sierra Nevada. The Fire Return Interval Departure Index quantifies the change in current fire

TABLE 1. Biodiversity attributes included in the overall biodiversity index and thresholds used to classify watershed value for each attribute.

Biodiversity Attributes	Categories (% watersheds in each category)			
	Low	Medium	High	Very High
a1. Connected Large Tree forest (LTF) a2. Remnant Patches of Large Trees	<30% LTF or any remnant patch (24)	>30 LTF or any remnant patch (44)	>50% LTF or >10% remnant patch(19)	>85% LTF or >20% remnant patch (13)
b. Large-tree Associated Wildlife (#)	0-1 (42)	2 (28)	3 (18)	4-5 (12)
c. Rare Terrestrial Species (#)	0-1 (41)	2-3 (28)	4-6 (17)	>=7 (15)
d. Rare Terrestrial Habitat (acres)	<1,136 (25)	1,137 - 2,494 (25)	2,495 – 5,115 (25)	>5,115 (25)
e. Aquatic Endemic Species (#)	0 – 2 (29)	3 – 7 (24)	8 – 13 (26)	>13 (22)
f. Aquatic Vulnerable Species (#)	0 – 8 (26)	9 – 14 (26)	15 – 22 (25)	>22 (23)
g. Meadow Area (acres)	0 (41)	0 – 0.23 (19)	0.24 – 1.16 (20)	>1.16 (20)
h. Meadows (#)	0 (41)	1 – 6 (22)	7 – 25 (19)	>25 (18)

Looking downstream past two reservoirs on the Tahoe National Forest. © Brie Coleman, Placer County Water Agency

frequencies from prior to Euro-American settlement. Safford and Van De Water[12] calculated mean, minimum, median, and maximum percent fire return interval departure (PFRID) for each of 28 Pre-settlement Fire Regime vegetation groups based on the USFS's CALVEG classification. Each PFRID estimate was further categorized into condition classes of low (0% to +/-33%), moderate (- 33% to - 67% or +33% to +67%), and high departure (-67% to -100% or +67% to +100%), where positive departure classes indicate fire return intervals that are longer than the historic average.[38–40]

We combined mean and max PFRID to create an index. Mean PFRID is a measure of departure from average pre-settlement fire return intervals and is the most widely used by the USFS to assess departure.[39] Maximum PFRID is a more conservative measure of departure that indicates substantial change only if fire frequencies are longer or shorter than ever recorded for pre-settlement forests.[12] We classified areas as burning less or more frequently than historically by combining the moderate and high condition classes for both mean and max PFRID, and excluding locations where either or both PFRID estimates were classified as low departure. Watersheds were classified as burning too little (or too much) based on the dominant combined condition class across the watershed.

Fire Risk to Infrastructure

To classify relative risk to infrastructure from fire across watersheds in the Sierra Nevada, we used the Fire Risk Index (FRI) developed by the Sanborn Map Company.[41] This index is a measure of the potential risk from fire to a variety of resources. It includes parameters that estimate fire probability, potential fire behavior, amount of human infrastructure at risk, and difficulty of suppressing fires, resulting in an index that combines the probability of an acre burning with the expected effects if a fire occurs. The infrastructure values included and their relative importance weighting are: Infrastructure Assets (schools, airports, hospitals, roads, and railroads), 46.2%; Wildland Development Areas, 44.7%; Drinking Water Importance Areas, 1.0%; Forest Assets (sensitive, resilient, and adaptive tree species), 3.6%; and Riparian Assets (riparian corridors), 4.5%. We grouped FRI values into six bins of relative risk and calculated the cumulative area-weighted mean of this relative risk score for each watershed. Based on the cumulative score, we categorized each watershed as low, moderate, and high risk (scores from the FRI of -3.13 to -51.38, -51.4 to -572.61, and -572.6 to -1,299.99, respectively). Moderate- and high-risk watersheds represent those in the top 20% of relative risk across the western United States.

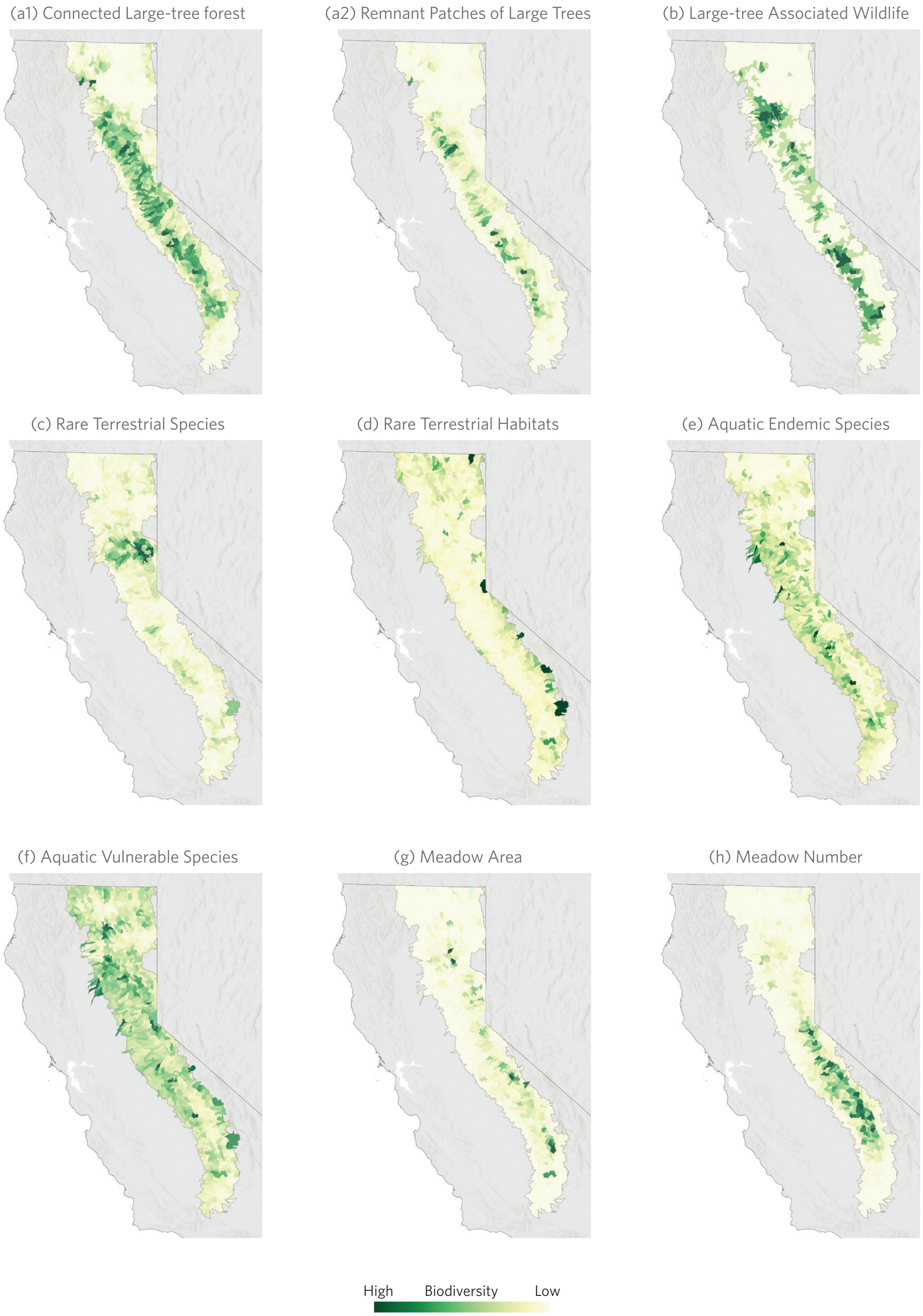
Forest Restoration Feasibility

Some of the forest areas across the region have already been managed through logging, thinning, prescribed fire, or have recently burned in wildfires. These areas, broadly, may represent a lower priority for near-term restoration investments as there are likely to be lower fuel loads. To address this, we used USFS data on fuels management activities using the Forest Service Activity Tracking System (FACTS)[42] and maps of recent wildfires from the Wildland Fire Leadership Council[43] to calculate what percent of the priority and all-other watersheds have had any fuels reduction since 2010 or wildfire since 2006. Our summary of recent fuels management is only an assessment of USFS lands, due to limited availability of data for other land ownerships. Given that the USFS manages the majority of the forest within our priority watersheds, we assume that this assessment is useful approximation of land in need of near term restoration. In locations where more than one activity occurred, the activity with the largest area was used to calculate total area treated. Areas where mechanical treatments only, fire only, and mechanical treatments plus fire occurred were calculated separately. We only included activities from the FACTS database recorded as "Completed."

We selected the time periods since treatment or fire based on the length of time over which fire hazard benefits can be expected to persist without further intervention. Fire by itself or mechanical treatments plus fire have the most lasting effects.[44] North et al. [33] proposed that forests accumulate uncharacteristically high fuel loads if fire or treatments do not occur within twice the historic fire return interval (HFRI). The average HFRI for low- to mid-elevation, pine-dominated forests is ~8 years and the average HFRI for all of North's "Active Management" forest types is ~12.5 years. Therefore, we assumed areas that have not had fuel reduction within these timeframes are priorities for treatment.

Limited access to forests can limit restoration options and increase costs. We calculated the total area of accessible forest by watershed for the study area. In 2014, North et al.[32] developed alternative criteria and scenarios to map forested areas that are accessible or "operable" for mechanical fuels management. We replicated North et al.'s operational constraints scenarios for all public and private lands across our study area using CalFire's Fire and Resource Assessment Program vegetation data.[45] For this assessment, we used Scenario D, which assumes an area is operable for forest fuels management if it has greater than 10% forest cover, is outside designated wilderness and roadless areas, and has slopes less than 35% within 2,000 feet of an existing road, or 35-50% slope within 1,000 feet of an existing road.[32]

FIGURE 3. Biodiversity data layers included in the assessment of biodiversity value for watersheds. Scores of low to very high biodiversity were normalized by maximum value observed within the study area.



RESULTS AND DISCUSSION

Biodiversity, Fire Frequency, and Fire Risk to Infrastructure

The spatial distribution of different biodiversity attributes varies substantially. Connected large-tree forest (Figure 3, a1) and remnant patches of large trees (Figure 3, a2) span watersheds across the Sierra Nevada with only a small gap in remnant patches in the center of the ecoregion. Large-tree associated species are concentrated in the area south of Lassen National Forest, as well as in the watersheds around Yosemite National Park, and Sierra and Sequoia National Forests. Other rare terrestrial species are concentrated in watersheds to the north, northwest, and within Tahoe National Forest. In contrast, concentrations of rare terrestrial habitats are found mostly on the eastern slope of the Sierra Nevada in the Great Basin and Mojave Desert ecoregions. Aquatic endemic and vulnerable species are found throughout the region, especially vulnerable species, with high concentrations particularly in the watersheds west of Lassen National Forest in the Feather River, Mill, Deer, Battle, and Butte Creek watersheds. Large meadows are concentrated mostly in watersheds in the southeastern Sierra Nevada and overall there are more meadows in watersheds of the southern Sierra Nevada ecoregion.

Given the very widespread distribution of some aspects of biodiversity and varying distribution of others, watersheds with an overall biodiversity value of high and very high span large areas of the entire Sierra Nevada (Figure 4a; 578 watersheds, 50% of the total). There are fewer in the northern portion, including the Cascades and Modoc Plateau ecoregions, and in the farthest south portion of the region, including the Great Central Valley and Mojave Desert ecoregions (Figure 4a). We identified 835 watersheds (73%) that are highly departed from their historic fire frequency and are burning too infrequently (Figure 4b). This pattern is dominant across most of the northern half of the study area, and the west side of the study area. The only exceptions are watersheds in the southeastern portion of the Sierra Nevada and Mojave Desert ecoregion where there is low to no departure from historical fire patterns, and in a few watersheds that have recently burned. There are 321 watersheds (28% of the total) where there is a moderate to high risk of fire to human infrastructure, and the risk is concentrated along the western foothills of the Sierra Nevada in the central and northern watersheds near Tahoe National Forest and Plumas National Forest (Figure 4c).

FIGURE 4. Three watershed attributes used to identify priority watersheds: biodiversity value (a), Fire Return Interval Departure (b), and Fire Risk Index-FRI (c) across the study area.

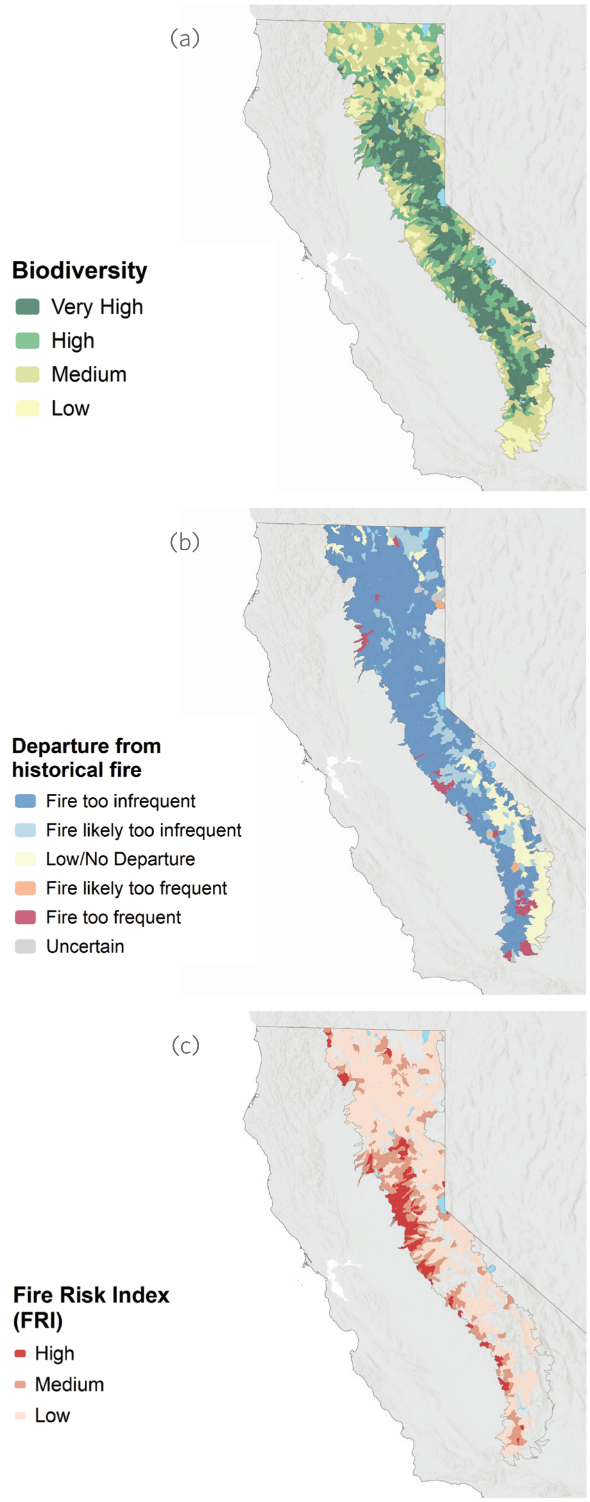
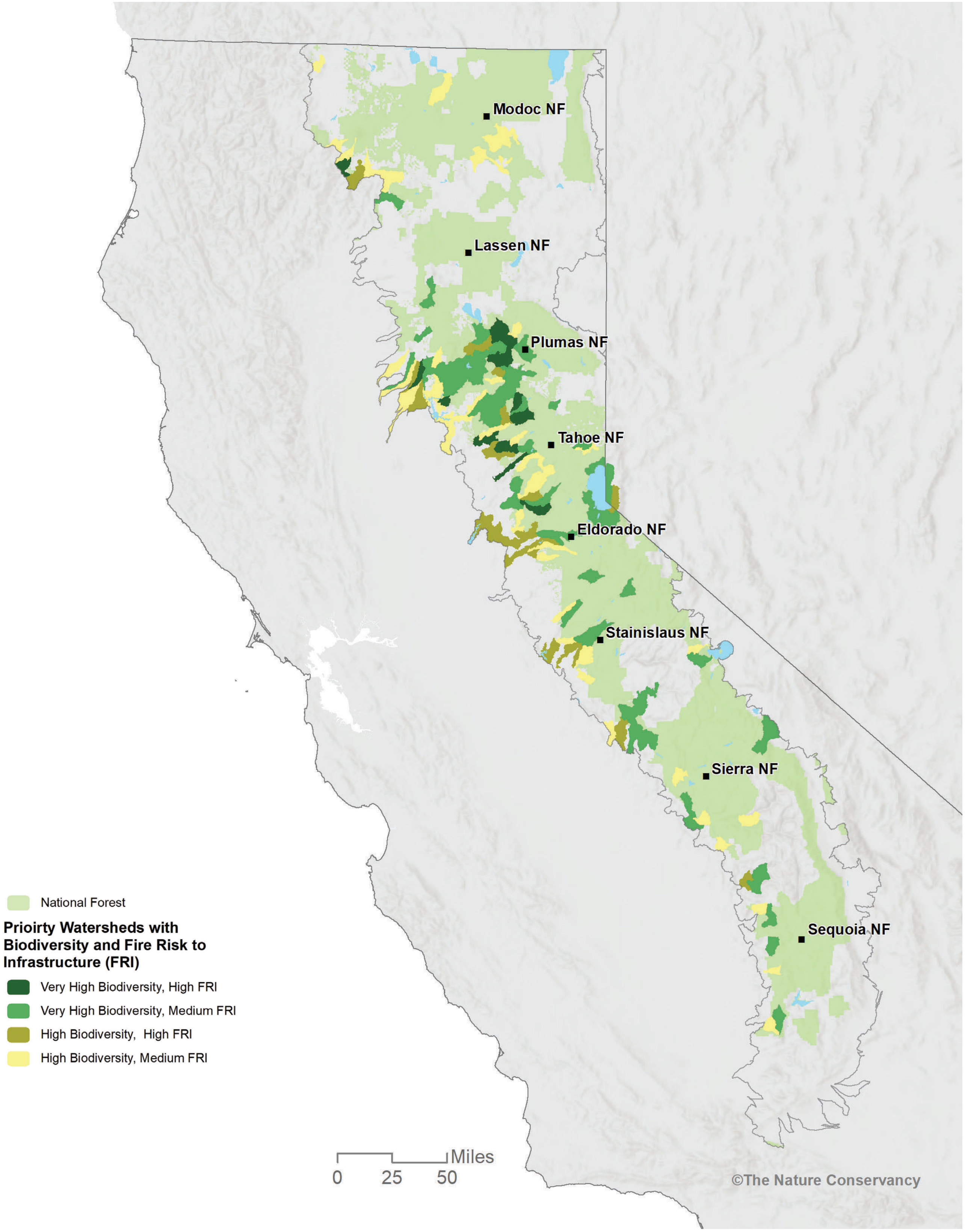


FIGURE 5. Priority watersheds (n =146) based on fire return interval (PFRID) too infrequent, biodiversity value, and fire risk to infrastructure (FRI), within US Forest Service boundaries.



A marten glances back at the camera trap placed to monitorfor this rare species and other wildlife. © Photo by USFS Region 5

Priority Watersheds for Forest Restoration

We identified 146 priority watersheds, 13% of the total, based on biodiversity, fire frequency departure, and fire risk to infrastructure (Figure 5). These priority watersheds total ~3.5 million acres, including 1.9 million acres of conifer forest. They are primarily concentrated along the west slope of the northern Sierra Nevada and scattered across a few watersheds in the southern Sierra Nevada. The priority watersheds are strongly influenced by the Fire Risk Index data and about 40% of the total Wildland Urban Interface of the region occurs within these priority watersheds. In terms of total area of priority watershed, the top five national forests (NF) are Plumas NF, Tahoe NF, Sierra NF, Eldorado NF, and Stanislaus NF (Figure 6). However, Lake Tahoe Basin Management Unit (LTBMU), Plumas NF, Tahoe NF, Eldorado NF, and Shasta-Trinity NF are the forests with the greatest percentages of their lands in priority watersheds (Figure 6).

FIGURE 6. Total acres of forest within the outer boundaries of national forests across the Sierra Nevada study area and level of operability for productive conifer forests. All but two national forests have over 50% of the productive conifer forest within their outer boundary accessible for proactive management.

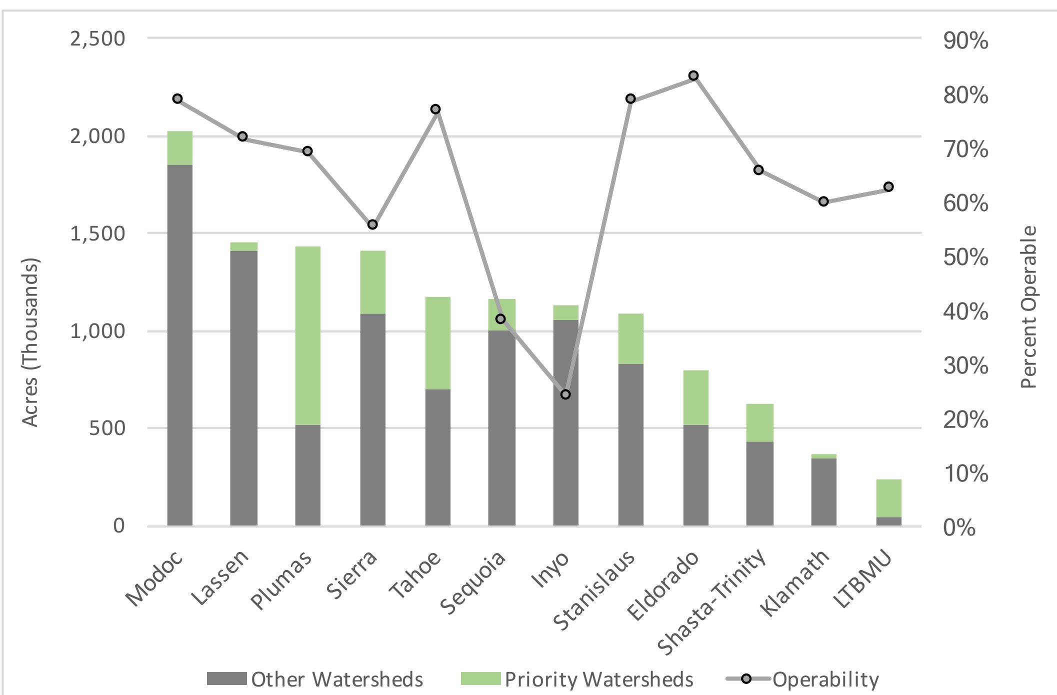


TABLE 2. Biodiversity within priority watersheds and relative to all watersheds. Percentages over 100% reflect an increase in the average number of species in priority watersheds relative to all watersheds combined (e.g. there are almost 2x as many imperiled terrestrial species records in priority watersheds on average relative to all watersheds).

Terrestrial and Aquatic Biodiversity	Total in priority watersheds	% difference between priority and all other watersheds
a2. Remnant patches of large trees (acres)	124,983	208%
b. Large Tree Associated Wildlife (# records)	225	149%
c. Rare Terrestrial Species (# records)	935	187%
d. Rare Terrestrial Habitat (acres)	643,008	105%
e. Aquatic Endemic Species (#)	2124	183%
f. Aquatic Vulnerable Species (#)	3470	153%
g. Meadow Area (acres)	14,410	60%
h. Meadows (#)	1,415	64%

TABLE 3. USFS treated and operable areas with percentages of conifer forest on USFS land in parentheses. The total burned area is divided by the total watershed area.

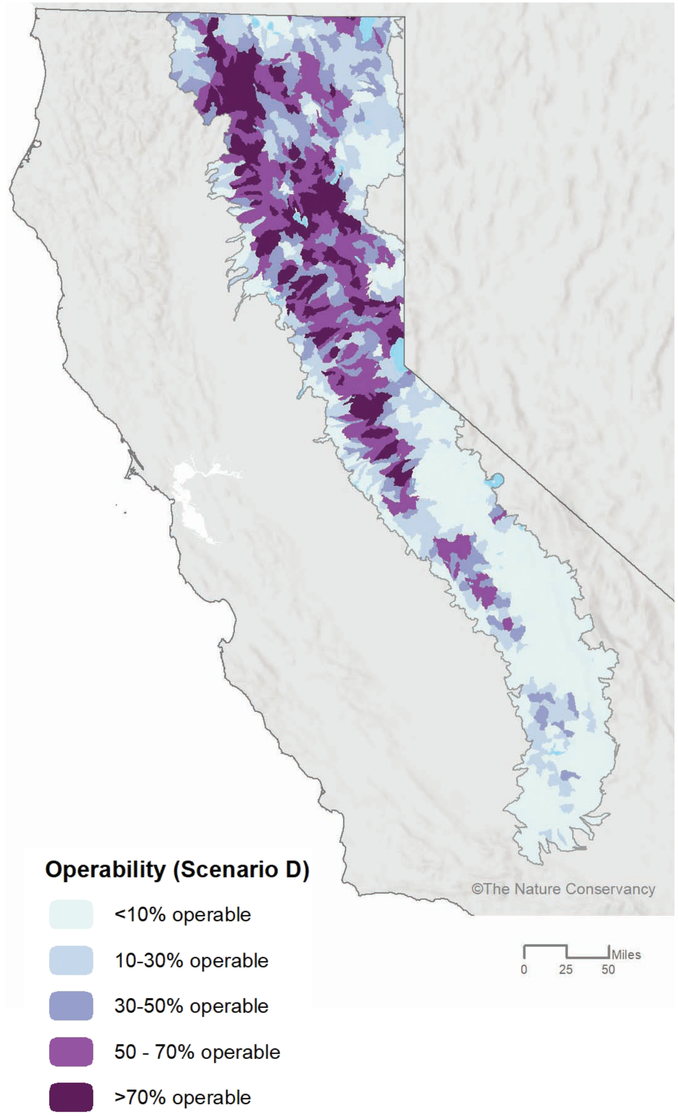
Forest Restoration Feasibility Criteria	Priority Watersheds (acres)	All Other Watersheds (acres)
USFS Land Treated	83,006 (7%)	253,736 (5%)
USFS Burned Area	128,386 (4%)	870,923 (7%)
Total Burned Area	187,298 (5%)	1,433,436 (7%)
USFS Operable Forest Area	1,316,073	6,126,332

The priority watersheds support a significant amount of biodiversity, with over 1.5 times as many large-tree associated wildlife records, rare terrestrial species records, aquatic endemic species, and aquatic vulnerable species on average compared to all watersheds in the Sierra Nevada (Table 2). Meadows are underrepresented in priority watersheds relative to the region overall; priority watersheds include about 8% of the total meadow area and total number of meadows across the study area. This is likely because meadows are concentrated at higher elevations, where risk factors for human infrastructure tend to be lower, and fire return interval departure is lower.

Feasibility of Restoration

The USFS is the dominant landowner in the Sierra Nevada, managing ~12 million acres, 51% of the Sierra Nevada, and 52% of the total forested area. In priority watersheds, 54% of the forested land (62% of conifer forest) is under USFS ownership. Other federal and state agencies manage 8% of the forests across the priority watersheds and the rest are private timberlands (38%). A total of 337,000 acres have received treatment since 2010 on USFS lands, which is 6% of the total conifer forest cover on USFS lands (most or all mechanical fuels treatments occur within conifer-dominated forests). This represents about 48,000 acres/year. In priority watersheds, 83,000 acres have been treated, which represents 7% of conifer forests on USFS lands in priority watersheds (Table 3). The total area burned in addition to treated USFS lands is 6% of the watershed area overall since 2006, and 5.3% across priority watersheds. This is logical given that priority watersheds have more infrastructure at risk, so there is greater percentage treatment and less burned area compared to the rest of the region. Based on these estimates, approximately 10 million acres of USFS lands have had no fuels reduction during the last 10 years, 2.9 million acres within priority watersheds. Not all of these lands are fire-prone and -dependent conifer forest, but conifer forests represent about 52% of USFS lands.

FIGURE 7. Percent operability for forest restoration with priority watersheds indicated.



Approximately 7.4 million acres of conifer forest are operable across the study area, with 1.3 million acres operable for restoration within the priority watersheds (Table 3). The operability varies among watersheds (Figure 7), but, over 25% of the priority watersheds are at least 50% accessible, encompassing over 900,000 acres of forest. Operability for forest restoration is concentrated in the central and northern Sierra, where the road network is expansive. For the national forests specifically, over 3 million acres of conifer forest are operable (50%) for strategic mechanical thinning and use of prescribed fire, with all but two of the national forests having greater than 40% operability (Figure 6).

Conclusions

Transitioning Sierra forests into a more resilient condition will require that the pace and scale of restoration increase dramatically. Given current funding and capacity constraints, we need to prioritize where we restore forests to get the biggest bang for the buck. Focused investments will help ensure we are successful at meaningfully increasing forest resilience and reducing the risks of high-severity fire. Investments need to be prioritized at both the regional and local scale. This assessment can play an important role by helping to strategically prioritize restoration at the regional scale, including through the USFS forest plan revision process. Emerging landscape restoration efforts, such as the Tahoe-Central Sierra Initiative, can also use this assessment for planning and build on it by integrating other relevant stakeholder data, and possible climate change drivers.

The watersheds used in this assessment should be an effective scale at which to prioritize work given that they are commensurate with the scale at which action needs to be taken (across tens of thousands of acres). These watersheds also have familiar biophysical boundaries that are relevant to many plant and animal species, as well as to natural ecological processes like hydrology and fire behavior.

There are many socioecological factors that need to be considered in selecting priority areas for restoration. This assessment addresses three important factors: biodiversity value, potential risk to human infrastructure, and the degree of departure from historic fire regimes. As a result, the prioritized watersheds from this analysis represent logical landscapes where investments in restoration should yield significant benefits for both people and nature. However, more thorough planning for specific resources and local stakeholder values will need to be included in detailed, local project planning.

There are large areas within the priority watersheds that have neither been treated nor burned by wildfires in recent years. These watersheds are primarily dominated by relatively dry and mesic, low-elevation and mid-montane forests that historically experienced frequent fires of mostly low to moderate severity.[46] This fire regime served an important ecological role in structuring the forest and reducing fuels accumulation. Because of this, reintroduction of mixed severity fire should be a key objective in many parts of the priority watersheds. However, given the history of fire suppression along with the high biodiversity values and concentration of human infrastructure in these watersheds, reintroducing fire under current conditions could have negative consequences for both people and nature. Protecting biodiversity values in these watersheds will require careful planning and implementation of mechanical fuels management to minimize impacts to species and habitats that can be adversely affected, at least in the short term. This makes these watersheds challenging, but important places to focus investments in strategic, ecologically-based forest thinning that can then be combined with controlled burning and managed wildfires in appropriate areas. This will ultimately enable fire to once again play an essential role in creating the mosaic of natural habitats important for biodiversity and forest health, while moderating the risk of wildfires to human infrastructure.[47,48,49]

Most of the watersheds in the northern Sierra, and especially the priority watersheds in this assessment, are highly accessible for fuels management through thinning and prescribed fire based on road access, slope, and other factors. For this reason, it is logistically feasible to implement restoration at a much greater pace and scale if the other barriers to large-scale restoration (e.g., funding and infrastructure to process wood) can be addressed. By investing in restoration at scale in these watersheds based on their value for protecting both biodiversity and human well-being, the benefits of those investments will be high and, once restored, they will serve as important anchors from which to promote healthier, more resilient forests throughout the Sierra.

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Back cover: Remnant patch of old-growth forest in Onion Creek Experimental Forest. © Jordan Plotsky

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