United States Department of Agriculture

Landscape Vegetation Community Types, Fire Regimes, and Associated Desired Ecological Conditions

Six Rivers Hazardous Fuels and Fire Management Project

US Forest Service (USFS) photo by Will Bojorques.

Fire plays a key functional socio-ecological role in ecosystems found on the Six Rivers National Forest[1] (SRNF or Forest), located within the North Coast Range and western Klamath Mountains of California. Driven by lightning ignitions and indigenous burning, frequent low- to moderate-severity fire was historically the most prominent intact *fire regime*[2] across this forested landscape. An intact fire regime in a frequent-fire landscape limits fuel accumulation, reduces biomass, recycles nutrients, promotes drought-tolerant, fire-adapted species, and creates structural heterogeneity providing stand- and landscape-level resilience. Historically, fires were generally patchier and burned in more complex mosaics than they currently do, with high-severity fire occurring in smaller, more complex patches and areas of *fire refugia*[3] persisting in cool drainages or in lower slope positions within the frequent-fire matrix, allowing multi-layered, diverse canopy stands to develop. Because of the current fire deficit across the landscape and the subsequent buildup of fuels, most areas are now vulnerable to the undesired effects of geographically large, high-severity fires, putting vegetation communities, cultural properties, and the human communities within and adjacent to them, at risk.

Furthermore, projected changes in temperature, precipitation, climatic water deficit, and snowpack associated with climate change all have the potential to further compromise the integrity of plant communities and their ability to recover after severe disturbances. Table 1 provides a summary of the trend direction and projected future changes for climate and climate-driven factors, extreme events, and major natural disturbance regimes for Northern California, which includes the Klamath Mountains, North Coast, and North Coast Ranges (Hilberg and Kershner 2021). Elements we considered when assessing the potential vulnerability of each plant community to these changes include elevation, aspect, slope position and

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[1] This includes the Klamath National Forest's Ukonom Ranger District, managed by the Six Rivers National Forest.

[2] *Fire regime:* role of fire in ecosystems; describe and categorize patterns of fire ignition, seasonality, frequency, type (crown, surface, or ground fire), severity, intensity, and spatial continuity (pattern and size) that occur in a particular area or ecosystem.

[3] *Fire refugia*: landscape elements that remain unburned or minimally affected by fire, thereby supporting post-fire ecosystem function, biodiversity, and resilience to disturbances.

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substrate, as well as current species composition and structure, which, in many cases, are highly departed from historic conditions due to past management actions, such as fire suppression and logging.

Table 1. Summary of trend direction and projected future changes for climate and climate-driven factors, extreme events, and major natural disturbance regimes for Northern California (Hilberg and Kershner 2021).

Variable	Trend	Projected Future Changes
Climate and Climate-Driven Factors		
Air Temperature	↑	• 2.2 to 6.1°C (4 to 11.0°F) increase in annual mean temperature by 2100.
Water Temperature	↑	• 0.4 to 0.8°C (0.8 to 1.4°F) increase in August stream temperature by the 2080s.
Precipitation	↑↓	• -23% to +38% change in mean annual precipitation by 2100. • Shorter, wetter winters and longer, drier summers likely, with higher interannual variability.
CWD & Soil Moisture	↑ ↓	• 4 to 43% increase in mean annual climatic water deficit (CWD) by 2100. • Reduced soil moisture due to enhanced evapotranspiration.
Snowpack & Snowmelt	↓ ←	• 61 to 100% decrease in April 1 snow-water equivalent (SWE) by 2100. • 5 to 15-day shift towards earlier timing of snowmelt by 2100.
Streamflow	↑↓	• General increase in wet season flows and decrease in dry season flows, with overall increase in flow variability. • 30 to 40% decline in the lowest streamflow per decade by 2100.
Coastal Fog	↓	• Weak decline in the frequency of days with coastal fog and low clouds.
Sea Level Rise	↑	• High likelihood of 0.03 to 1.24m (0.1 to 4.1 ft.) sea level rise by 2100.
Extreme Events and Natural Disaster Disturbance Regimes		
Heat Waves	↑	• Significant increase in heat-wave frequency and intensity, especially for humid nighttime events and in coastal areas.
Storms & Flooding	↑	• Increased storm intensity and duration, resulting in more frequent/intense extreme precipitation events and flooding. • 300 to 400% increase in the frequency of 200-year floods.
Drought	↑	• Drought years twice as likely to occur, with significantly increased risk of prolonged and/or severe drought.
Wildfire	↑	• 77% increase in mean annual area burned statewide, and up to 400% increase in montane forested areas of northern California. • 50% increase in the frequency of extremely large fires (>10k ha). • Significant increases in fire severity are likely due to more extreme fire behavior combined with human activity and fuel buildup.

The *Six Rivers Hazardous Fuels and Fire Management Project* (*Fire & Fuels Project*) aims to restore and sustain resilient ecosystems across a socio-ecological landscape within the context of a changing climate. Although the focus is often on conditions at a time of intact fire regimes, which included cultural burning, the interdisciplinary team (IDT) used this reference period as one of the many important pieces of information to help understand the structural and compositional characteristics of these ecosystems prior to land-use changes and altered regimes. Historical intact fire regimes prior to widespread fire suppression and prohibition of indigenous burning (Lake 2007, Lake 2013, Skinner et al. 2018, Stephens et al. 2018) provided a high level of resiliency across the landscape, which is why these regimes are looked at when developing desired ecological conditions for the future.

The IDT began by identifying vegetation types (Table 2; Figure 1) based on species composition, similarities to intact cultural fire regimes, as well as information on the natural range of variation (NRV) of structural and compositional components associated with these types. To do this, the IDT used *Biophysical Settings*[4] (BpS) and associated models developed by the *LANDFIRE Project*[5] to classify and describe desired ecological conditions (Rollins 2009). LANDFIRE BpS uses the current biophysical environment and an approximation of the historical regime to describe the vegetation that may have been present historically.

Table 2. Vegetation community types as defined by their species composition and intact fire regime.

Vegetation Types	Approx. Acres on Forest[6]	Percentage of Forest	Elevation	Biophysical Settings
Mixed evergreen	508,000	44%	1000-4000 ft	Mediterranean California Mixed Evergreen Forest – Interior/Coastal
Moist mixed conifer	232,000	20%	3800-6700 ft	Mediterranean California Mesic Mixed Conifer Forest and Woodland
Serpentine mixed conifer	142,000	12%	1200-4500+ ft	Klamath-Siskiyou Lower/Upper Montane Serpentine Mixed Conifer Woodland
Dry mixed conifer	132,000	11%	2000-5900 ft	Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland
Red fir	26,000	2%	4500-7000 ft	Mediterranean California Red Fir Forest
Montane chaparral	21,000	2%	>3000 ft	California Montane Woodland and Chaparral
Oak woodland	15,000	1%	<3600 ft	Mediterranean California Mixed Oak Woodland; California Lower Montane Blue Oak-Foothill Pine Woodland and Savanna
Pine-oak	13,000	1%	1700-3000 ft	Mediterranean California Lower Montane Black Oak-Conifer Forest and Woodland

For each primary vegetation type, a crosswalk to commonly used vegetation classifications provide additional information and helps inform more specific targets at the project level (e.g., 100 to 8,000 acres). These classifications include *existing vegetation* within CALVEG[7] (USDA 2013) and the *California Wildlife Habitat Relationships System*[8] (CWHR; Mayer and Laudenslayer 1988).Vegetation types without sufficient data about historic intact fire regimes (e.g., non-woody vegetation, riparian types) or that occupy unique habitat settings in the analysis area were considered for inclusion in a *Special Considerations* section to address some of the more unique and rare vegetation types present on the Forest that would benefit from the reintroduction of fire.

Fire behavior fuel models (RMRS-GTR-153[9] (Scott and Burgan 2005)) are also defined for each vegetation type (see *Supporting Documentation*). A vegetation type may be represented by a range of fuel models depending on stand development, species composition, and recent fire history. However, common fuel models are suggested that may be utilized for fire behavior modeling in support of prescribed fire plan

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[4] *Biophysical Settings* (BPS): the vegetation system that may have been dominant on the landscape at a time of intact fire regimes, including cultural burning. Based on the current biophysical environment and an approximation of the historic disturbance regime.

[5] *LANDFIRE Project*: a shared program between the wildland fire management programs of the US Department of Agriculture (USDA) Forest Service and US Department of the Interior (USDI), providing landscape-scale geo-spatial products to support cross-boundary planning, management, and operations.

[6] Based on LANDFIRE and rounded to the nearest 1,000 acres.

[7] *CALVEG* (Classification and Assessment with Landsat of Visible Ecological Groupings): *www.fs.usda.gov/detail/r5/landmanagement/resourcemanagement/?cid=fsbdev3_046815*

[8] *California Wildlife Habitat Relationships System* (WHR): *www.fs.usda.gov/detail/r5/landmanagement/resourcemanagement/?cid=fsbdev3_046815*

[9] *RMRS-GTR-153*: *www.fs.fed.us/rm/pubs/rmrs_gtr153.pdf*

development. Prescribed fire plan preparers assess fuel models prior to implementing projects, choosing the most appropriate model using RMRS-GTR-153 and other fuel model guides based on local conditions.

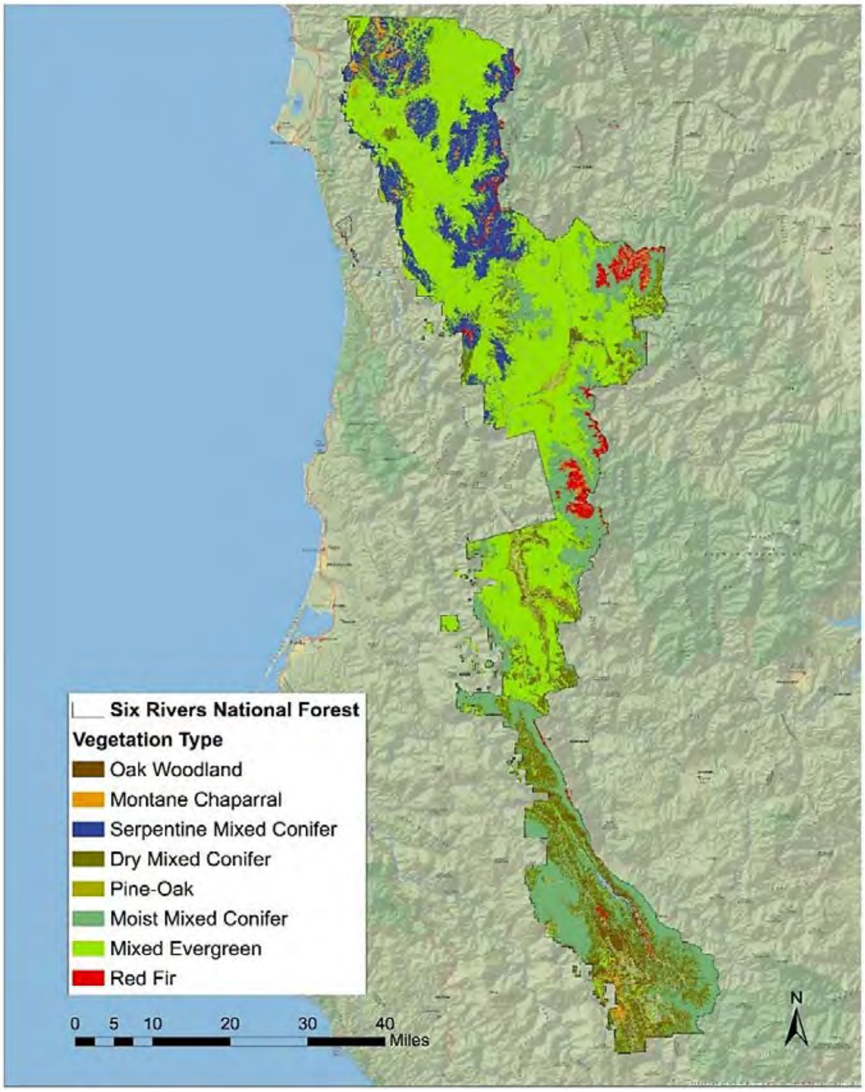

Figure 1. Map of the vegetation communities across the Six Rivers National Forest using LANDFIRE Biophysical Settings (BpS).

Fire Regime Characteristics

Fire frequency, fire severity, and fire type are important fire regime characteristics typically associated with specific vegetation types. *Fire frequency* is usually described in terms of the *fire return interval* (FRI), which is the number of years between fires. *Fire severity* is the magnitude of fire effects on a specific component of an ecosystem, and is often measured as soil burn severity, canopy cover loss, or basal area loss—as opposed to *fire intensity*, which relates to how rapidly energy is released by the fire, not the effect fire has had on an ecosystem. Fire severity, which relates well to tree mortality, is typically described as *low*, *moderate*, and *high* in forested vegetation types (Sugihara et al. 2006):

- **Low Severity:** Most of the area (>90%) burns at low severity, with minimal mortality of mature trees (although some mortality can occur) and slight impacts to understory vegetation. Less than 10 percent of area burns at moderate/high severity.
- **Moderate Severity:** Most of the area (~50 to 60%) burns at moderate severity, with lesser amounts burning at low severity (10 to 20%) and high severity (10 to 20%). Most mature trees survive while immature size classes are moderately impacted.
- **High Severity:** Fire kills most of the above-ground vegetation; however, below-ground tissues generally survive and resprout or seed.

Although fire severity in burned areas is often generalized as low, moderate, and high (Agee 1993, Sugihara et al. 2006), it is important to remember that these classifications encompass a range of overstory mortality levels. For example, *low-severity fire* does not mean that there is an absence of tree mortality; rather, low severity is commonly defined as an area resulting in less than 25 to 30 percent canopy mortality, with an average mid-point of 12.5 to 15 percent mortality of canopy trees (Agee 1993, Sugihara et al. 2006). Small pockets of tree mortality can be important for structural diversity and tree regeneration within stands, yet in low-severity fires, this mortality is very limited in extent. *High-severity fire* typically includes areas where fire-caused mortality exceeds 75 to 80 percent and patches of tree mortality tend to be large and more contiguous. *Moderate-severity* or *mixed-severity fire* simply falls somewhere in between, with a mix of low- and high-severity effects with canopy mortality potentially ranging from 25 to 75 percent with an average between 50 and 60 percent (Agee 1993, Sugihara et al. 2006).

Fire type describes the characteristics of the flaming front and includes *ground/smoldering, surface*, *passive crown, active crown,* and *independent crown fires* (Sugihara et al. 2006). *Fire regimes* generally fall into four combinations of fire types, including *surface-passive crown fire regime*, *passive-active crown fire regime, active-independent crown fire regime*, and a *multiple fire type regime* (Sugihara et al. 2006):

- **Surface-Passive Crown Fire:** Most of the area burns with surface fire, but up to 30 percent of the area may experience torching of single or small groups of trees. This fire type is typical of low- and some moderate-severity fire regimes.
- **Passive-Active Crown Fire:** Most of the burn area has surface fire supported by passive and active crown fire. Any active crown fire is dependent on surface fire. Typical of moderate- and high-severity fire regimes.
- **Active-Independent Crown Fire:** Mostly active crown fire with rare instances of independent crown fire (not dependent on surface fire). Steep topography and dense stands support this type. Typical in high-severity fire regimes.
- **Multiple Fire Type:** Both surface and crown fire are characteristic of this type, which is supported by complex topography and vegetation mosaics where fuel, topography, and weather supports a mixed-severity fire regime.

A simplified way of communicating fire regimes is by grouping vegetation types by the frequency and severity at which they are adapted to burn (Table 3). Schmidt et al. (2002) described five prominent fire regime groups (FRGs): I = 0- to 35-year frequency, low severity; II = 0- to 35-year frequency, stand replacement; III = 35- to 100-plus-year frequency, mixed severity; IV = 35- to 100-plus-year frequency, stand replacement; and V = 200-plus-year frequency, stand replacement. Of these, FRGs I and II are most common on the Forest, with FRG III also present.

Table 3. Fire regime group, historical fire frequency, fire severity, and dominant fire type by vegetation type.

Fire Regine Group	Vegetation Type	Mean Fire Return Interval	Proportion of Total fires by Severity[10]			Dominant Fire Type
			Low	Moderate	High	
FRG I (0- to 35-yr frequency, low severity)	Mixed evergreen	14	61	30	9	Surface-Passive Crown Fire
	Moist mixed conifer	15	61	33	6	
	Serpentine mixed conifer	9	82	13	5	
	Dry mixed conifer	8	71	26	3	
	Oak woodland	8	91	2	7	
	Pine-oak	10	67	27	6	
FRG II (0- to 35-yr frequency, stand replacement)	Montane chaparral	34	0	63	37	Passive-Active Crown Fire
FRG III (35- to 100-yr frequency, mixed severity)	Red fir	25[11]	43	43	14	Surface-Passive Crown Fire

Fire Return Interval Departures and Recent Fire History

Fire return interval departure (FRID) is a standard measure used by the USDA Forest Service in California to spatially map current departure from fire frequencies that were present at a time of intact fire regimes, which includes cultural burning. To determine these departures, intact fire regime frequencies were determined for major vegetation types throughout California (see Table 2 in Van de Water and Safford 2011), then using LANDFIRE Biophysical Settings (BpS) fire regime types as a framework, twenty-eight intact fire regimes groups were developed according to their relationship with fire (Van de Water and Safford 2011). These intact fire regime frequencies can then be used to compare with current frequencies (1908-present) based on CalFire's Fire Perimeters database (FRAP). FRAP provides a relatively complete record of all fires larger than 40 hectares that have occurred since 1908. After 1950, this record includes all fires over 4 hectares (*http://frap.fire.ca.gov/*; Miller et al. 2009). FRID can also be assessed for more recent fire trends using data that only includes fires since 1970. Data presented here include all fires through 2020, the most recent FRID layer available at the time.

Based on the 2020 FRID data, approximately 86 percent of the SRNF is currently experiencing a fire deficit. Fifty-seven percent (57%) of the Forest is considered to have a high positive departure, meaning these areas have missed at least three fire cycles since 1908, and 29 percent of the Forest is moderately departed, meaning FRIs are between 1.5 and 3 times the mean intact fire regimes FRIs. About 14 percent of the Forest is within the natural range of variability (NRV) for fire frequency, and less than 0.5 percent of the Forest is

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[10] Modelled proportion of all fires occurring within different severity classes under the presumed historical fire regime. Top kill within a fire perimeter for a given vegetation type: Low = <25%; Moderate = 25 to 75%; High = >75%.

[11] Fire return intervals for red fir are highly variable (Coppoletta et al. 2020). Estimates for northwestern California generally show more frequent fire than red fir forests elsewhere in California (see information for BPS model 10320: Mediterranean California Red Fir Forest), thus the modelled frequency of fire in red fir aligns more with FRG-I while the abundance of mixed severity fire makes it more appropriate to place red fir into FRG-III.

currently experiencing fire that is more frequent than we would expect historically (Figure 2a). Areas that appear to be less departed are areas where there have been multiple fires in the last 50 years (Figure 2b). In these areas, it is important to take into consideration the severity at which these more recent fires have burned to better understand the condition of the vegetation present in those areas.

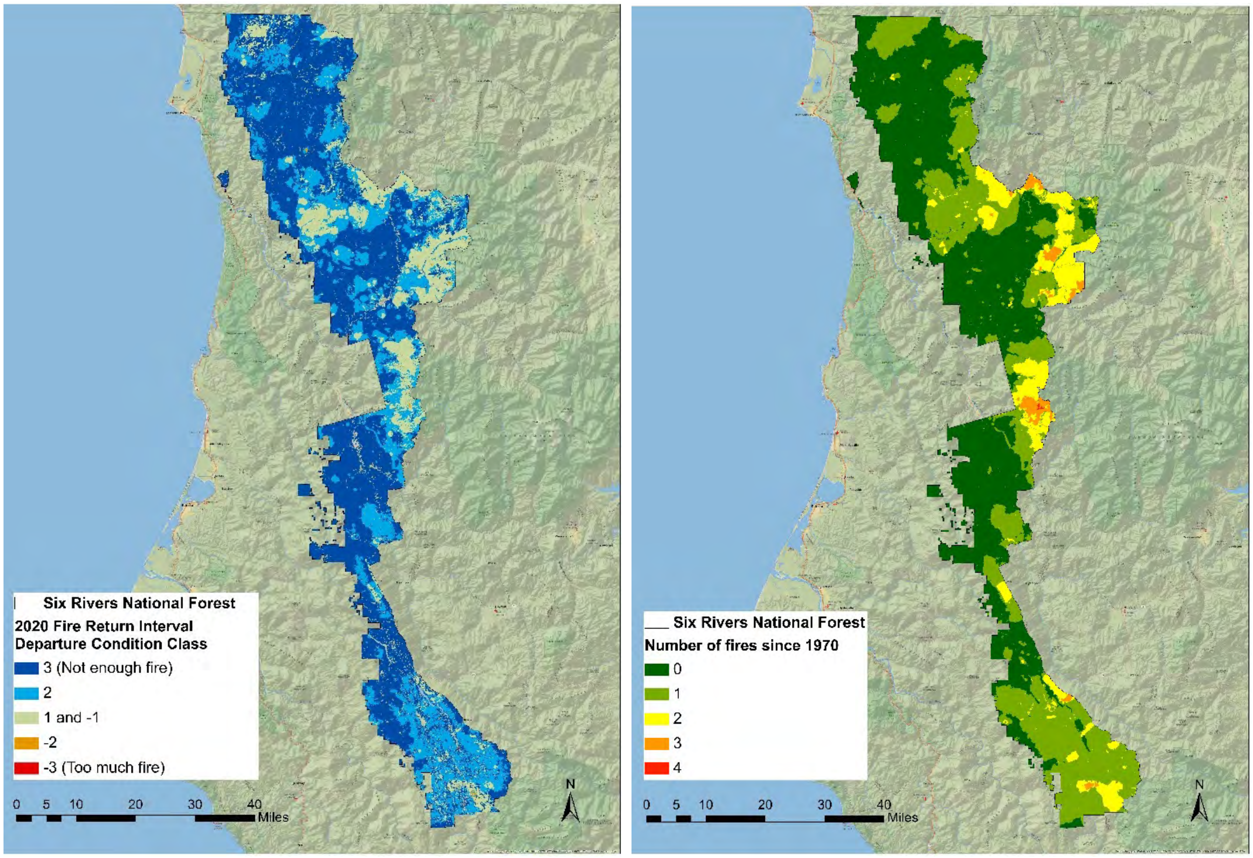

Figure 2. (a) 2020 fire return interval departure (FRID) classes across the Six Rivers National Forest since 1908. (b) Fires that occurred on the SRNF since 1970.

Vegetation types that tend to have the highest departures are those that historically had the most frequent fire and/or that occur in lower elevations where fire suppression has been the most effective. This includes oak woodland, pine-oak, mixed evergreen, and all three of the mixed conifer types. Red fir and montane chaparral have lower average departures across the landscape due largely to their longer reference fire return intervals. Although there has been some increase in fire activity on the SRNF in the last 50 years (Figure 2b), the median time since the last fire across the entire forest is 96 years. So, although there are areas where we are seeing more recent fire, most of the landscape still has not seen a fire in almost 100 years.

Fire return interval departures and recent fire activity have influenced the proportion and distribution of seral stages across the Forest. The prohibition of cultural burning and suppression of wildfire has increased stand densities and canopy cover, leading to an overabundance of closed canopy stands and more homogenous forests both structurally and compositionally. Past logging has further simplified the structure of certain areas leading ultimately to an overabundance of closed mid-seral stands. Areas that have seen more recent fire, on the other hand, are often being shifted to early seral conditions due to the high severities at which they are burning. Frequent fire historically created a complex mosaic of different seral stages on the landscape; and closed late-seral stands often persisted in areas, such as cool drainages and in lower slope positions, where fires were less frequent and more likely to be low severity when they did burn. Without the frequent-fire component reducing fuels adjacent in these areas (mid and upper slope positions), the remaining late seral stands on the Forest are at risk of loss to high-severity fire.

Climate Change Considerations

Understanding the impact that climate change may have on ecosystems present on the SRNF is critical when deciding upon management actions related to restoring active fire regimes. Based on our knowledge of the climatic conditions and disturbance regimes associated with each vegetation type described below, we can make some assumptions about potential changes in their distribution and composition across the landscape. Given that most of these ecosystems are adapted to fire and periodic drought, many can persist if they have high ecological integrity and can benefit from increases in fire rather than be degraded by those increases (which is likely to happen if fires are more severe). The first step towards increasing the ecological integrity and associated resiliency of these ecosystems that have been compromised by past management or fire suppression is to decrease structural and compositional departures and to restore active fire regimes. In stands that have missed several fire cycles and are compromised both structurally and compositionally, severe wildfire will likely reset these communities to an early seral state that could persist if stressors such as climate and recurring high-severity fire arrest the development of the site.

Places where there will likely be shifts in vegetation type due to climate are in transition zones (areas where one vegetation type transitions into a different vegetation type). For example, a lower elevation pine-oak stand may transition to an oak woodland stand due to increased climatic water deficit and the loss of the pine component. Similarly, a red fir stand immediately adjacent to a moist mixed conifer stand that is experiencing more frequent fire due to a warming climate, may start to see lower elevation conifer species enter into the stand, ultimately shifting the community from true fir to mixed conifer. No matter where on the landscape these transition zones might be, fire will likely be the greatest catalyst of change with more severe fire greatly increasing the rate of change.

In 2017, EcoAdapt completed a suite of climate change vulnerability assessments[12] that provide expert-based evaluations of the general vulnerability of each vegetation type to climate change. These assessments are based on scientific literature and outcomes from workshops that included regional experts in Northern California. Although most of the vegetation types considered in this document were included in EcoAdapt's vulnerability assessments, some types we have identified below do not have their own specific assessments but rather are included as subtypes of more prominent types (e.g., serpentine mixed conifer is included as a subtype in the *Mixed-Conifer & Ponderosa Pine* assessment). These EcoAdapt assessments evaluate the vulnerability of different vegetation types and individual species to climate change as a consideration when formulating desired conditions for a given project area and when considering the need for climate adaptation. Each assessment can be accessed via the links provided in Table 4.

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[12] Climate change vulnerability assessments: *http://ecoadapt.org/programs/adaptation-consultations/norcal/products*.

Table 4. Vegetation community types and their associated Climate Change Vulnerability Assessments developed by EcoAdapt[13].

Vegetation Types	EcoAdapt Climate Change Vulnerability Assessment Vegetation Types[12]
Mixed evergreen	Mixed-Evergreen Forest *(www.cakex.org/documents/mixed-evergreen-forests-climate-change-vulnerability-assessment-northern-california)*
Moist mixed conifer	Mixed-Conifer & Ponderosa Forest *(www.cakex.org/documents/mixed-conifer-ponderosa-forests-climate-change-vulnerability-assessment-northern-california)* Sugar Pine *(/www.cakex.org/documents/sugar-pine-climate-change-vulnerability-assessment-northern-california)*
Serpentine mixed conifer	Mixed-Conifer & Ponderosa Forests *(www.cakex.org/documents/mixed-conifer-ponderosa-forests-climate-change-vulnerability-assessment-northern-california)*
Dry mixed conifer	Mixed-Conifer & Ponderosa Forest *(www.cakex.org/documents/mixed-conifer-ponderosa-forests-climate-change-vulnerability-assessment-northern-california)* Sugar Pine *(www.cakex.org/documents/sugar-pine-climate-change-vulnerability-assessment-northern-california)*
Red fir	True Fir Forests *(www.cakex.org/documents/true-fir-forests-climate-change-vulnerability-assessment-northern-california)*
Montane chaparral	Chaparral Shrubland *(www.cakex.org/documents/chaparral-shrublands-climate-change-vulnerability-assessment-northern-california)*
Oak woodland	Oak Savanna & Open Woodland *(www.cakex.org/documents/oak-savannas-open-woodlands-climate-change-vulnerability-assessment-northern-california)* Black Oak & Tanoak Woodland *(www.cakex.org/documents/black-oak-tanoak-woodlands-climate-change-vulnerability-assessment-northern-california)*
Pine-oak	Mixed-Conifer & Ponderosa Forest *(www.cakex.org/documents/mixed-conifer-ponderosa-forests-climate-change-vulnerability-assessment-northern-california)* Black Oak & Tanoak Woodland *(/www.cakex.org/documents/black-oak-tanoak-woodlands-climate-change-vulnerability-assessment-northern-california)*

Fire Departures and Climate Change: Management Actions Needed

What does this mean in terms of the *Fire & Fuels Project* and bringing fire to long unburned stands? Any initial prescribed fire entry into stands with high FRI departures and stands that are more vulnerable to stressors associated with climate change, would be corrective or *restoration burns*, while subsequent prescribed fires in these same stands would be *maintenance burns*. Thus, treatment objectives and prescriptions may differ for each of these phases:

- **Restoration:** In highly departed stands, initial corrective restoration burns may need to occur on the higher end of the historic range in fire severity to restore stand structure and reduce the density of small subcanopy trees. For example, a yellow pine and dry mixed conifer stand that has missed four burn intervals may need to burn with closer to 30 percent canopy mortality. However, subsequent burns should be on the lower end of the severity range—closer to 5 percent canopy mortality—to maintain large, fire-resistant trees in the overstory.
- **Maintenance:** Maintenance burns will generally have minimal effects on mature overstory trees, with a focus on maintaining lower surface fuel loads and reducing ladder fuels at the low end of the range in historic fire severity. Some sites may require one or more restoration burns to transition into the maintenance phase to ensure large, fire-resistant trees are maintained.

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[13] The USDA Forest Service's Pacific Southwest Region, the USDI Bureau of Land Management (BLM)-California, and EcoAdapt partnered to conduct vulnerability assessments and climate-informed adaptation strategies for focal resources (e.g., habitats, species) of northwestern California, with a specific focus on the Six Rivers, Klamath, Shasta-Trinity, and Mendocino national forests and BLM lands in the Arcata and Redding field office areas and portions of the Ukiah field office area.

For both restoration and maintenance burns, additional considerations at the time of project and burn plan development will help inform site-specific treatment prescriptions. These may include stand age and tree size-class distributions, degree of departure from historic fire regime, recent fire history and severity of recent fires, fuel loading, and burning conditions to achieve desired fire effects.

Vegetation Community Types

Mixed-Evergreen Forest – 508,000 Acres

General Description and Current Vegetation Conditions

The most common vegetation type on the SRNF is *mixed-evergreen forest*. This vegetation type is characterized by a combination of coniferous and broadleaved trees, including Douglas-fir, canyon live oak, tanoak, Pacific madrone, California bay laurel, and tree chinquapin. Black oak is found on drier sites further inland. Sugar and ponderosa pines can also be present in this type and Port-Orford-cedar (POC; *Chamaecyparis lawsoniana*) is a common riparian associate. The structure and composition of mixed-evergreen forests is largely driven by moisture and disturbance regimes (Figure 3 and Figure 4), and typically has an abundant and diverse understory shrub layer.

Figure 3. Coastal mixed-evergreen forest with tanoak, madrone, and Douglas-fir. USFS photo.

Figure 4. Dry mixed-evergreen forest with black oak, live oak, and sugar pine. USFS photo.

Compared to historical conditions—at a time of intact fire regimes, which includes cultural burning—modern mixed-evergreen forests generally have higher tree densities, an overabundance of small-diameter trees—that act as ladder fuels—and fewer large-diameter trees, smaller and less prevalent forest gaps, and a shift toward more shade-tolerant species (McIntyre et al. 2015, Sensenig et al. 2013, Sensenig 2002). There are fewer small patches and more large landscape-level patches of early seral forest or shrubfields than there were historically, an overabundance of mid-seral forest due to fire exclusion, and an underabundance of late-seral forests due to logging. Furthermore, because of fire exclusion and the associated increases in forest densities combined with the lack of surface fuel consumption by fire over the last century, fuel loading and forest density are much higher across the landscape than they were historically.

CALVEG Types: *QB, QC, NX, QH, TX, DF, QT, TC;* ***BpS Model:*** *10431;* ***WHR Types:*** *DFR, COW. See Supporting Documentation for descriptions.*

Desired Ecological Conditions

Desired ecological conditions within mixed-evergreen forests include a complex mosaic of varying stand densities and stand structures reflective of a frequent, mixed-severity fire regime (Figure 5; Halofsky et al. 2011, Perry et al. 2011), with any variations associated with landform (aspect, elevation, slope position) and microsite conditions. Within stands—typically less than 1 acre, but up to 10 acres or more—overstory trees are arranged in clumps and as widely spaced trees with gaps in between (Larson and Churchill 2012). Canopy cover rarely drops below 40 percent and is typically as high as 60 to 100 percent depending on seral stage. Below the canopy lies a highly diverse understory.

At the landscape level, larger gaps are present—including ephemeral and more stable openings controlled by the physical environment rather than by disturbances —that vary greatly in size and shape. Generally, they average a little over an acre, although they can be much larger (Hessburg et al. 2015). These gaps are usually highly complex with a high perimeter-to-area ratio (Figure 6; Skinner 1995).

Figure 5. Fire burning in mixed-evergreen forest. USFS photo.

Figure 6. Oak woodland (foreground) and mixed-evergreen forest. USFS photo.

According to LANDFIRE’s modelled proportions given an intact disturbance regime, nearly half of all stands are expected to be in open, mid- to late-seral classes, with a little over one-third in closed, mid- to late-seral classes. Open stands (<40% canopy cover) range from hardwood dominated—especially in the mid-seral class—with conifers (mostly Douglas-fir) scattered throughout, to stands with a greater abundance of pine and Douglas-fir in the upper canopy and hardwoods, such as Pacific madrone, canyon live oak and tanoak, in the subcanopy layer. Closed stands (>40% canopy cover) are similar to their open counterparts in composition, yet hardwood cover may be higher, with late-seral stands containing large individual hardwoods. With mixed-severity fire being somewhat prevalent in this type—30 percent of all fires according to LANDFIRE—almost 20 percent of all stands are expected to be in the early-seral class. These stands include scattered Douglas-fir and pine seedlings with thickets of madrone, canyon live oak and tanoak. Shrub cover from sprouting shrubs (e.g., Oregon grape, salal) and seed banks (e.g., deerbrush) is typically high. The canopy can close quickly after fires due to resprouting hardwoods delaying the re-establishment of conifers.

The interaction between frequent, low- to moderate-severity fires with other factors—such as weather events, climatic conditions, pests, and pathogens—produces a complex structure at both the stand and landscape scales, resulting in heterogeneous, multi-aged forest conditions characterized by medium-scale canopy gaps. Late-seral forests (e.g., forests with multi-layered canopies, abundance of large-diameter trees, snags, and coarse woody debris) are more abundant at lower slope positions and on north- and east-facing slopes. While upper slope positions and south- and west-facing slopes support a more open, coarse-grained matrix of both late-successional and early seral features. This is largely driven by spatial variation in fire-severity patterns on the landscape. This forest type occurs in small- to medium-patch sizes ranging from 100 to 1,000 acres.

Fire Regime

Historically, fires in mixed-evergreen forests were frequent, burning at low to moderate severity. These were typically surface fires with areas of passive-crown fire (single- and group-tree torching). Fires were often patchy as they burned, skipping over or burning around areas due to topographic variability on the landscape and associated microclimates.

The frequency and severity at which fires burned in mixed-evergreen forests places them in FRG I (FRI from 0 to 35 years, low to moderate severity; Schmidt et al. 2002). According to LANDFIRE, the historical mean FRI for mixed-evergreen forests is 14 years with 61 percent of all fires at low severity and 30 percent at moderate severity. Fires in this type were often large—up to 150,000 acres—due to the high number of ignitions (e.g., lightning strikes, tribal burning) associated with fire events (Atzet and Wheeler 1982, Lake 2013).

Due to logging and fire exclusion, which has modified structural characteristics and fuel loading, this forest type now burns at frequencies and severities more representative of FRGs III and IV (FRI from 35 to 200 years, moderate and high severity, respectively), and are more climate limited than fuel limited (Agee 1993, Schmidt et al. 2002, Steel et al. 2015). Multiple fire intervals have been missed due to fire exclusion over the last 100-plus years (Van de Water and Safford 2011). Managed wildfire and prescribed burning, with efforts to revitalize tribal cultural burning, will help restore the active fire regime that these forests are adapted to and rely on to maintain their structural and compositional diversity (Figure 7).

Response to Fire

Mixed-evergreen forests respond to fire differently depending on pre-fire structure and composition, and fire intensity. Almost all hardwoods in mixed-evergreen forests can vigorously resprout after moderate- and high-intensity fire, while the key conifer species—Douglas-fir—relies on reseeding to regenerate. Frequent, low-severity fire promotes the persistence of large conifers in mixed-evergreen stands and can allow hardwoods to grow into the canopy as codominant or dominant trees. Patches of high-severity fire promote the dominance of resprouting hardwood species and can eliminate the presence of conifers, especially when high-severity patch size is large and when a site sees repeated high-severity fire. Mixed-severity fires typically exhibit a patchy mosaic of fire intensities and favor development of multi-aged stands of mixed-species composition.

Figure 7. Surface fire in a mixed-evergreen stand. USFS photo.

Figure 8. Applying prescribed fire in a mixed-evergreen stand. USFS photo.

Desired Outcome from Prescribed Burning

Applying low- to moderate-intensity prescribed fire in mixed-evergreen stands (Figure 8) increases compositional and structural heterogeneity by reducing dense understory vegetation, and to a lesser extent, canopy cover. Moderate-intensity fire—characterized by surface- and passive-crown fire types—promotes retention of mature trees, but mortality of subcanopy and intermediate crown classes. Upper slopes, ridgetops, and south and west facing slopes typically experience higher severities than other areas (Taylor and Skinner 1998). The density of small-diameter trees is reduced and the diversity of understory vegetation increases. Shrub cover decreases as grass and forb cover increases. In general, the reduction in ladder fuels and the increased structural heterogeneity within stands modifies future fire behavior and reduces the risk of large high-severity fires. Figure 9 shows a mixed-evergreen stand before and after prescribed fire has been applied to it.

Figure 9. Mixed-evergreen stand before (left) and after (right) prescribed fire. USFS photos.

Moist Mixed-Conifer Forest – 232,000 Acres

General Description and Current Vegetation Conditions

The second-most common vegetation type on the SRNF is *moist mixed-conifer forest*, which occurs adjacent to mixed-evergreen forests and shifts to dry mixed-conifer forests at lower elevations, on south-facing slopes and exposed ridgetops. Moist mixed-conifer forests are typically composed of diverse combinations of ponderosa pine, incense cedar, Douglas-fir, white fir (at higher elevations), and sugar pine with a notable component of hardwoods, including California black oak, Pacific madrone, golden chinquapin, tanoak, and bigleaf maple (Figure 10). Common understory species include hazelnut and dogwood, along with *Vaccinium* spp., *Gaultheria* spp., manzanita, *Ceanothus* spp., and *Ribes* spp., the latter of which are common in areas of recent fire.

Figure 10. Moist mixed-conifer forest showing recent low- to moderate- severity fire effects. USFS photo.

Figure 11. Moist mixed-conifer stand that has missed several fire cycles and has a high stand density of mostly small-diameter, shade-tolerant conifers. USFS photo.

Compared to historical conditions, modern moist mixed-conifer forests have higher stand densities, increased canopy cover, smaller average tree diameters, and greater abundance of shade-tolerant species (e.g., a shift from pine to white fir and incense cedar; Figure 11; Bohlman et al. 2021). These forests have become more homogenous across the landscape (Figure 12), with a decrease in the size of forest openings and an increase in distances between openings (Skinner 1995).

CALVEG Types: *DP, DW, MD, MK, MF, PE, WF;* ***BpS Models:*** *10280;* ***WHR Types:*** *WFR, KMC. See Supporting Documentation for descriptions.*

Desired Ecological Conditions

Desired ecological conditions at the landscape level for moist mixed-conifer forests include a complex mosaic of varying forest densities, sizes, species mix reflective of changes in landform (aspect, elevation, slope position) and microsite conditions, with fire being the primary driver of structural variability. Within individual forest stands, there is a high level of heterogeneity with variable spacing between trees and a high diversity of tree-size classes. The structural mosaic includes forest gaps, tree clumps, and widely spaced single trees at the stand level—typically less than 1 acre—however, in areas more likely to exhibit a higher percentage of moderate-severity fire, this can increase to 10 acres or more (Larson and Churchill 2012).

According to LANDFIRE's modelled proportions given an intact disturbance regime, just over half of all stands are in open, mid-to late-seral classes, with about 20 percent in closed, mid- to late-seral classes. Open stands (<40% canopy cover) develop as the primary successional pathway with frequent, low- and moderate-severity fires. These open stands are composed of ponderosa pine, Douglas-fir, and sugar pine interspersed with patches of hardwoods, and white fir in the mid-story at higher elevations. A rich herbaceous and woody understory is present with native grasses and forbs, and resprouting shrubs favored by frequent fires. The key difference between mid and late development for these open stands is that tree diameters are generally larger (>33 inches for larger conifers) in late-development stands.

Figure 12. With the exclusion of fire across the landscape, moist mixed-conifer forests have become structurally homogenous. USFS photo.

Figure 13. Dense moist mixed-conifer stand with surface fuels that indicate a departure from fire return intervals for this vegetation type. USFS photo.

Moderately closed stands (>40% canopy cover, but generally <60%) develop as alternate successional pathways in settings (e.g., lower topographic positions) and climatic periods that support longer intervals between moderate-severity fires. White fir is more abundant in the overstory of these stands, alongside ponderosa pine, Douglas-fir and sugar pine, and continues to recruit in the understory. Hardwoods may be present initially but tend to be shaded out as the canopy closes. Understory vegetation ranges from depauperate to quite dense, depending on canopy density and local site conditions. Late-development closed stands (<20% of all closed stands) have large-sized conifers (>33 inches for larger conifers) and a multi-layered, complex canopy structure. Early seral stands often occur as a result of mixed-severity fire and are present in patches ranging from 10 to 100 acres. These areas are comprised of grasses, shrubs, and shade-intolerant tree species present as seedlings, saplings and poles. Frequent, low- to moderate-severity fire in this vegetation type is largely what maintains understories of heterogeneous, patchy, and diverse native shrubs, herbs, and grass species, with tree litter and scattered downed wood at varying levels throughout.

Fire Regime

Historically, fires in moist mixed-conifer forests were frequent, burning at low to moderate severity, placing this type within FRG I (FRI from 0 to 35 years, low to moderate severity; Schmidt et al. 2002).

According to LANDFIRE, the historical mean FRI for moist mixed-conifer forests is 15 years with 61 percent of all fires at low severity and 33 percent at moderate severity. Moderate- and high-severity fire within this type typically occurs on mid- and upper-slope positions (Taylor and Skinner 1998, Taylor 2000, Bekker and Taylor 2001, Estes et al. 2017).

Due to human influences since the time of intact fire regimes, which includes cultural burning (e.g., fire exclusion, logging, grazing), these forests have largely transitioned to FRGs III and IV—infrequent (35- to 200-year FRI), moderate- to high-severity fires that now act as major disturbances to the system (Safford and Van de Water 2014, Steel et al. 2015). The primary role of fire in this forest type has changed from one of forest maintenance—relatively open-canopy, fuel-limited conditions dominated by fire-tolerant species—to one of forest transformation, where dense stands of fire-tolerant species and heavy fuel accumulations are more likely to burn at high severity, resulting in major ecosystem changes (Figure 13; Bohlman et al. 2021).

Response to Fire

Moist mixed-conifer forests are dominated by tree species specifically adapted to frequent, low- to mixed-severity fire. Hardwoods in this forest type can resprout after high-severity fire, but the dominant conifers depend on reseeding and are vulnerable to extensive high-severity fire. Frequent, low-severity fire promotes the development and persistence of large conifers and increases the diversity of understory vegetation. High-severity fire tends to favor the dominance of resprouting shrubs and hardwoods within the stand. Depending on the extent of high-severity patches, conifer regeneration can take several decades to re-establish.

Desired Outcome from Prescribed Burning

Bringing controlled low- to moderate-intensity fire into moist mixed-conifer stands helps modify future fire behavior and moves existing stands that have missed several fire cycles towards a state of higher resilience. Applying prescribed fire decreases the density of small-diameter, shade-tolerant trees in the understory and reduces shrub cover, promoting a more diverse plant community in the understory (Figure 14). Surface- and passive-crown fire behavior is required to sufficiently scorch dense stands of shade-tolerant and shade-intolerant trees in the subcanopy and intermediate crown classes (Figure 15). These fire types should have minimal impact on mature overstory trees.

Figure 14. Effects from surface- and passive-crown fire in a stand of moist mixed conifer. USFS photo.

Figure 15. Surface and passive crowning in a stand of moist mixed conifer. USFS photo.

Serpentine Mixed-Conifer Forest – 142,000 Acres

General Description and Current Vegetation Conditions

The *serpentine mixed-conifer forest* vegetation type can include a wide variety of conifer species, but some of the most common are Jeffrey pine (*Pinus jeffreyi*), Douglas-fir, and incense cedar. Port-Orford cedar can be common in riparian areas and western white pine (*Pinus monticola*) becomes common at higher elevations and as you move north. Closed-cone conifers—such as lodgepole pine (*Pinus contorta*) and knobcone pine (*Pinus attenuata*)—can also be present but are never dominant within the serpentine mixed-conifer type. Hardwoods found on serpentine include tanoak, canyon live oak, and madrone.

Vegetation composition and structure on serpentine or peridotite soils derived from ultramafic rocks are often vastly different from vegetation on non-ultramafic soils (Briles et al. 2011). Ultramafic settings are more open with rocky areas lacking any vegetative cover compared to vegetation types associated with more fertile settings (Safford and Mallek 2011). When vegetation is present, it tends to be lower in stature.

Across the SRNF, serpentine mixed-conifer forests and other ultramafic plant communities exist as islands on the landscape across elevational gradients, creating a high level of heterogeneity where different vegetation types are found intermixed with one another. Tree densities on serpentine are typically very low, often taking the form of woodlands or savannahs with perennial grasses as the primary herbaceous layer (Figure 16), but can exist with a range of conditions in the understory (Figure 17), sometimes supporting a variety of shrub species, including huckleberry oak (*Quercus vacciniifolia*), boxleaf silk tassel (*Garrya buxifolia*), Sadler's oak (*Quercus sadleriana*), greenleaf manzanita (*Arctostaphylos patula*), pinemat manzanita (*Arctostaphylos nevadensis*) and tanbark oak (*Notholithocarpus densiflorus* var. *echinoides*), or have extremely limited vegetation in the understory, such as on barrens or rock outcrops.

Figure 16. Jeffrey pine-Idaho fescue savannah on the Smith River NRA. USFS photo.

Figure 17. Rocky barren ridges, shrub patches, and scattered conifers characterize habitat types in ultramafic settings. USFS photo.

Serpentine mixed-conifer forests have not seen the same increase in stand density or shift towards shade-tolerant species as stands on non-ultramafic soils (see *Moist Mixed-Conifer Forest* and *Dry Mixed-Conifer Forest* sections). Ultramafic soils limit the establishment of species less tolerant of edaphic conditions, leading to a much slower accumulation of fuels compared to areas that are more productive

(Figure 18; Alexander et al. 2007, DeSiervo et al. 2015). However, the productivity of serpentine sites varies, and in many areas, there have still been observed increases in stand densities. One example is a Jeffrey pine savannah located in the Little Bald Hills of Redwood National Park where Sahara et al. (2015) found that tree densities increased and open grassland areas declined from 50 percent in 1942 to 10 percent in 2009, due to encroachment of woody shrubs and trees during the fire-exclusion period. These areas will likely continue to decline in the absence of fire.

Figure 18. Ultramafic landscapes have limited vegetation cover; therefore, little fuel accumulation. USFS photo.

Figure 19. The Forest Sensitive species serpentine catchfly post-prescribed burn in the Gordon Hill Project area, Smith River NRA. USFS photo.

Jeffrey pine grasslands on the SRNF support rare taxa, including the serpentine catchfly (*Silene serpentinicola)* on the Smith River National Recreation Area (Smith River NRA; Figure 19). This species' habitat niche is characterized by gravelly openings exposed to full sun or sites along the canopy margins of adjacent vegetation. The serpentine catchfly is a tap-rooted, herbaceous perennial that can re-sprout after above-ground disturbances such as fire. Sampling of an occurrence over three years prior to prescribed burning and a year after prescribed burning (2009) detected, at least in the initial stage, three times the number of plants after prescribed burning (Martorano 2019). Fire has a role in sustaining serpentine catchfly by prompting regeneration and reducing competition for light by adjacent vegetation, yet factors such as intensity and intervals between fires warrant consideration and monitoring when planning restorative and maintenance fires.

CALVEG Types: *MU;* ***BpS Models:*** *10220, 10210;* ***WHR Types:*** *JPN. See Supporting Documentation for descriptions.*

Desired Ecological Conditions

According to LANDFIRE's modelled proportions given an intact disturbance regime, over 75 percent of all stands are in open (<40% canopy cover), mid-to late-seral classes. These stands are comprised of conifers, hardwoods and shrubs, with the largest trees limited to about 30-inch dbh (diameter at breast height) due to lower site productivity (although this could be exceeded in pockets of higher productivity soil). It is most common for fuels to be limited due to either frequent fire or low productivity, although conditions would be highly variable. In some cases, ladder fuels and the subcanopy create conditions conducive to crown fire, although this is less common.

Just under 20 percent of all stands are in an early seral condition with vegetation comprised mostly of grass, shrubs, and shade-intolerant trees present as seedlings, saplings, and poles. The dominant species at this stage can be highly variable depending on site conditions. The least common stand conditions (<5% of stands) expected in serpentine mixed-conifer forests are those associated with closed (>40%), mid- to late-seral classes. These stands are typically on more productive sites or in areas with less frequent fire. Conditions in these stands may be more conducive to high-severity fire, but canopy cover above 80 percent is unlikely.

An important feature of serpentine mixed-conifer forests—and serpentine sites in general—is the high number of endemic and rare plant species that exist in forest openings. These plant communities, addressed in the *Special Considerations* section below, are a critically important component of this vegetation type. Desired ecological conditions include maintenance and promotion of these unique and rare species.

Fire Regime

There is very limited data on fire history in serpentine mixed-conifer forests due to their limited distribution, but the historical mean FRI is estimated to be 9 years according to LANDFIRE, with 82 percent of all fires at low severity and 13 percent at moderate severity. However, a critical factor in serpentine habitats is the variation in site productivity and associated composition and structure that likely led to a high level of variation in fire frequency. In some cases, fire may have been infrequent (>40-year FRI) due to a slow accumulation of fuels. The discontinuous nature of fuels on serpentine soils can also limit the spread of fire into areas that may go without fire for much longer periods of time.

Although this vegetation type overall has not responded as strongly to fire exclusion as adjacent non-serpentine mixed-conifer types have, fire frequency is still lower today than it would have been historically, and subsequently, more productive sites have seen an increase in shrubs and smaller-diameter trees (Sahara et al. 2015), which can lead to higher fire severity when these sites do burn.

Response to Fire

Like other mixed-conifer forest types, serpentine mixed-conifer forests are dominated by tree species adapted to frequent, low- to mixed-severity fire. Hardwoods in this forest type can resprout after high-severity fire, but the dominant conifers depend on reseeding and are vulnerable to extensive high-severity fire. Edaphic conditions combined with frequent, low-severity fire promote the development and persistence of open, conifer-dominated stands and increase the diversity of understory vegetation. High-severity fire tends to favor the dominance of resprouting shrubs and hardwoods present in the stand. Depending on the extent of high-severity patches, conifer regeneration can take several decades to re-establish.

Desired Outcome from Prescribed Burning

Bringing controlled low- to moderate-intensity fire into serpentine mixed-conifer stands helps modify future fire behavior, especially in more productive sites that may have a higher accumulation of fuels due to missing several fire cycles. Although the lower productivity of serpentine soils acts to limit encroachment of certain species, applying prescribed fire will help decrease the density of small-diameter trees, reduce shrub cover, and promote a more diverse plant community in the understory. Surface- and passive-crown fire may be required to sufficiently scorch dense stands of encroachment trees in the subcanopy and intermediate crown classes. However, these fire types should have minimal impact on mature overstory trees.

Dry Mixed-Conifer Forest – 132,000 Acres

General Description and Current Vegetation Conditions

Dry mixed-conifer forests are typically dominated by two or more conifer species including Douglas-fir, ponderosa pine and incense cedar—which are the most common—with black oak, live oak, and madrone common in the subcanopy. This type supports a variety of shrub species in the understory along with an herbaceous layer that ranges from patchy to continuous depending on site conditions.

Compared to historical conditions, modern dry mixed-conifer forests contain much higher tree densities with conifer regeneration dominated by shade-tolerant species. The number of small trees has increased tremendously over the last century or more, with many areas showing 2 to 5 times higher small-tree densities, making the average tree size also much smaller. In general, canopy cover has increased, and current forests have fewer gaps and larger tree clumps than they did prior to the fire-suppression era. Fine-grained heterogeneity has decreased due to increasing tree densities and infilling of gaps. Increases in large, high-severity patches of fires on the landscape have further promoted coarse-grained heterogeneity, creating a mosaic of larger, more defined patches across the landscape. Compositional changes have also occurred due to selective logging of pine species in this type (Bohlman et al. 2021).

CALVEG Types: *QK, MP, PP, PW;* ***BpS Models:*** *10270;* ***WHR Types:*** *MHW, PPN, SMC. See Supporting Documentation for descriptions.*

Desired Ecological Conditions

Desired ecological conditions for dry mixed-conifer forests include a high level of structural heterogeneity at the stand and landscape level where individual trees, small clumps, and groups of trees are interspersed with grass, herbaceous plants, and shrubs, in variable-sized openings. Open stands of predominantly pines and Douglas-fir are abundant, with hardwoods interspersed throughout.

According to LANDFIRE’s modelled proportions given an intact disturbance regime, over 70 percent of all stands are expected to be open, mid- to late-seral stands and less than 20 percent to be closed, mid- to late-seral stands. Open stands (20 to 40% canopy cover) develop as the primary successional pathway for this type and are typically dominated by pines, Douglas-fir, and varying amounts of incense cedar, with hardwood trees scattered throughout. These stands support a rich herbaceous and woody understory, with native grasses and forbs that are favored with frequent fires. Most open stands are in the late-seral class with the largest trees exceeding 33-inch dbh with light and complex surface fuels.

Closed stands (>40% canopy cover) typically develop in the absence of fire and are much less prevalent on the landscape than open stands. Although they contain largely the same tree species composition as open stands, they are much more crowded with Douglas-fir continuing to recruit into the understory. As these stands develop, they become dominated by Douglas-fir, hardwoods become shaded out, and the canopy continues to close. Given frequent fires on the landscape, closed stands are mostly found in more mesic locations or in lower slope positions. The understory can be highly variable, but ladder fuels and the subcanopy may allow for crown initiation in some stands.

Only 10 percent of all dry mixed-conifer stands are expected to be in the early seral class. These are comprised of grasses, shrubs, and young shade-intolerant tree species, with snags typically present. This seral class most commonly occurs in small patches (10 to 100 acres) resulting from mixed-severity fires.

Fire Regime

Fires in dry mixed-conifer forests were historically frequent and burned at low to moderate severity, placing them in FRG I (FRI from 0 to 35 years, burning at low to moderate severity; Schmidt et al. 2002). According to LANDFIRE, the historical mean FRI for these forests is 8 years with 71 percent of all fires at low severity and 26 percent at moderate severity. When moderate- and high-severity fire occurs in this forest type, it typically occurs on mid- and upper-slope positions (Taylor and Skinner 1998, Taylor 2000, Bekker and Taylor 2001, Estes et al. 2017).

Due to human influences since the time of intact fire regimes, which includes cultural burning, these forests have largely transitioned to FRGs III and IV—infrequent (35- to 200-year FRI), moderate- to high-severity fires that now act as major disturbances to the system (Safford and Van de Water 2014, Steel et al. 2015). Like moist mixed-conifer forests, fire's primary role in this forest type has changed from forest maintenance—relatively open-canopy, fuel-limited conditions dominated by fire-tolerant species—to forest transformation, where dense stands of fire-intolerant and fire-tolerant species and heavy fuel accumulations are more likely to burn at high severity, resulting in major ecosystem changes (Bohlman et al. 2021).

Figure 20. Burned dry mixed-conifer stand. USFS photo.

Figure 21. Applying prescribed fire to a dry, mixed-conifer forest. USFS photo.

Response to Fire

Dry mixed-conifer forests are dominated by conifers adapted to frequent, low- to moderate-severity fires (Figure 20) that promote the development and persistence of large trees and increase the diversity and abundance of understory vegetation; however, since conifers cannot resprout, they are vulnerable to extensive high-severity fire. High-severity fire tends to favor the dominance of resprouting shrubs and hardwoods present in a stand. Depending on the extent of high-severity patches, conifer regeneration can take several decades to re-establish.

Desired Outcome from Prescribed Burning

The reintroduction of low- and moderate-intensity fire into dry mixed-conifer forests helps to modify future fire behavior and moves existing stands that have missed several fire cycles towards a state of higher resilience. Prescribed fire decreases the density of small-diameter, shade-tolerant trees in the understory and reduces shrub cover, promoting a more diverse plant community in the understory (Figure 21). Surface- and passive-crown fire is required to sufficiently scorch the subcanopy and intermediate crown classes of dense conifers. Where stands are more open and less departed from historic conditions, surface fire meets stand-maintenance objectives.

Red Fir – 26,000 Acres

General Description and Current Vegetation Conditions

Red fir (*Abies magnifica* var. *magnifica* and var. *shastensis*) is the defining species for red fir forests (Figure 22), but there is a variety of common associates depending on the elevation. These include white fir, mountain hemlock and lodgepole pine, and other, less prevalent species. Shrub and herbaceous cover in the understory is highly variable and tends to have less species diversity compared to lower elevation forest types. This is primarily due to a more closed canopy and a denser litter layer that builds up during the longer fire-free periods typical of these stands.

Compared to historical conditions, modern red fir stands have higher tree densities, mainly in the smallest size classes, and higher canopy cover, mainly in the lower canopy strata. There has been an overall simplification of forest structure at both the stand and landscape scale. Many stands have shifted away from partially open canopy structure to one characterized by closed-canopy conditions (Coppoletta et al. 2021).

CALVEG Types: *RF, WF;* ***BpS Models:*** *10320;* ***WHR Types****: RFR, WFR. See Supporting Documentation for descriptions.*

Desired Ecological Conditions

Desired conditions for red fir forests include a mosaic of single trees, tree clusters, and canopy openings driven by disturbances (e.g., fire, windthrow, insect-related tree mortality) of varying intensities (Figure 23). Due to patch-regeneration characteristics, similar-sized red fir trees are found in clumps ranging from less than half an acre to several hundred acres. Stands are dominated by large trees but have patches of regeneration within forest gaps.

Figure 22. Red fir forest surrounding a grassland in the Trinity Alps Wilderness. USFS photo.

Figure 23. Disturbances, such as fire, can modify the understory of red fir stands. USFS photo.

According to LANDFIRE’s modelled proportions given an intact disturbance regime, just under half of all stands are expected to be in open, mid- and late-seral classes and nearly 40 percent in closed, mid- and late-seral classes. Open stands (<40% canopy cover) are characterized by red fir with various amounts of white fir, mountain hemlock, western white pine, and possibly other species scattered throughout.

Closed stands (>40% canopy cover) typically have the same composition as open stands, although pure red fir stands can become more prevalent. Early seral stands (~10% of all stands) often have regeneration of both red and white fir and possibly western white pine. Shrub cover can be highly variable, at times quite extensive, but is eventually shaded out by trees. Lodgepole pine and mountain hemlock can also be associated with these recently disturbed stands.

Fire Regime and Current Departure

The fire regime in red fir forests is highly variable—somewhat frequent, low- to moderate-severity fires, with occasional high-severity pockets (Skinner 2003). Red fir types are categorized as either FRG I or FRG III (FRI from 35 to 100-plus years, burning at mixed severities; Schmidt et al. 2002). According to LANDFIRE, the historical mean FRI is 25 years for red fir forests in this area, with 43 percent of all fires at low severity, 43 percent at moderate severity, and 14 percent at high severity. The higher fire frequency for Klamath Mountain red fir forests—compared to Sierra Nevada red fir forests with a mean historical FRI of 40 years (Van de Water and Safford 2011)—is likely due to their connectivity with lower elevation mixed-conifer vegetation types. Most fires in red fir move slowly through compact fuel beds, however, and are limited in extent at higher elevations by cool, moist conditions associated with heavy snowpack and natural terrain breaks (Skinner 2003, Taylor and Skinner 2003). Therefore, red fir forests at lower elevations and in transition zones with other forest types likely had higher fire frequencies than those at higher elevations, further leading to the highly variable FRIs documented for this type. Red fir forests do not appear to be as departed in their FRI as much as other vegetation types; however, departures are likely higher at lower elevation sites (Coppoletta et al. 2021). Fire sizes range from 30 to 1,800 acres with an average of approximately 400 acres (Bekker and Taylor 2001).

The FRI variations within the red fir vegetation type also prevail where these forests coincide with montane and sub-alpine settings. These settings have significant spatial and thus habitat heterogeneity so FRIs associated with relatively lower elevation red fir forests would not necessarily apply in the higher elevation landscapes. The uniqueness of montane and sub-alpine red fir forests is further discussed in the *Special Considerations* section of this document.

Response to Fire

Red fir forests are dominated by tree species susceptible to fire when young but have thick bark that protects individuals from surface fires as they mature (Figure 24). A mix of fire severities maintains a relatively open canopy and heterogeneous horizontal and vertical structure. Openings caused by higher fire severities allow patches of regenerating conifers to become established.

Figure 24. Varying red fir mortality due to fire. USFS photo.

Desired Outcome from Prescribed Burning

Prescribed fire reduces the dead and downed fuel component, reduces shrub cover and seedling densities, and raises the crown base height (ladder fuels), with the goal of reducing fire behavior in the event of a wildfire. Surface fire should be promoted with minimal impacts to overstory, mature red fir trees.

Montane Chaparral – 21,000 Acres

General Description and Current Vegetation Conditions

The *montane chaparral* vegetation type is dominated by shrub species depending on site conditions and disturbance history (Figure 25). Characteristic species include *Ceanothus* spp., *Arctostaphylos* spp., *Quercus* spp., *Ribes* spp., *Prunus* spp., and bush chinquapin (*Chrysolepis sempervirens*). Scattered trees may be present, but typically over a dense continuous shrub layer. Forbs and grasses are generally only found in small pockets interspersed between dense shrubs, becoming more abundant after disturbances.

Current conditions vary depending on recent fire history. Often these shrublands persist on the landscape indefinitely if fire returns prior to succession to conifer forest. Without fire, which is the case in many areas, the extent of montane chaparral is decreases due to the re-establishment of conifers. There may be areas, however, where this type may persist despite a lack of fire, often due to other site factors, such as the lack of conifer seed sources.

In mature stands where fire has been absent for more than a century and conifers have not been re-established, species diversity is often low, cover is high, and species that depend on fire to regenerate can begin to senesce. Alternatively, areas of frequent fire that are exposed to invasive annual grasses may be at risk for type conversion as these stands have not had adequate time to either mature enough to establish a seed bank or rebuild their stores enough to be able to resprout repeatedly.

CALVEG Types: *CC, CG, CH, CI, CL, CM, CN, CP, CQ, CS, CV, CW, CX, CY, C1, SD, WM;* ***BpS Models:*** *10980;* ***WHR Types:*** *MCH, MCP. See Supporting Documentation for descriptions.*

Desired Ecological Conditions

Desired ecological conditions in montane chaparral at the landscape scale include a mosaic of stands at varying developmental stages allowing for maximum diversity and ensuring the persistence of species that rely on fire to regenerate. Forbs and grasses are interspersed between shrub patches and are dominated by native species. Montane chaparral is considered seral to montane forested landscapes, with the extent of this type often shifting after high-severity fire, and persistence depending on time since fire and presence of montane conifers.

Figure 25. Montane chaparral intermixed with mixed-conifer forest. USFS photo.

Figure 26. Fire in chaparral-dominated landscape. USFS photo.

Given an intact fire regime, nearly half of all montane chaparral stands occur with 40 to 90 percent shrub cover with large conifers scattered throughout. Trees might include Jeffrey pine, ponderosa pine, white fir, red fir, sugar pine, Douglas-fir and incense cedar, but tree cover remains low. A third of all stands have similar shrub cover, but conifers are smaller due to more recent disturbance. The remainder of stands are early seral after large patches of stand-replacement fire. Grasses are more prevalent due to lower shrub cover (generally <70%), and tree seedlings and saplings may be present.

Fire Regime and Current Departure

Montane chaparral generally burns with a mix of moderate- and high-severity fire and is in FRG II (frequent: 0- to 35-year FRI, stand replacement severity; Schmidt et al. 2002). According to LANDFIRE, the historical mean FRI is 34 years with 63 percent of all fires at moderate severity and 37 percent at high severity. In stands where conifers are scattered throughout, fire will likely stay on the surface allowing large conifers to persist. The size of wildfires in this vegetation type is highly variable but can be quite large.

Response to Fire

Montane chaparral is composed of extremely fire-adapted species that can resprout vigorously after fire or produce fire-resistant seeds largely stimulated by fire. Semi-frequent burning that aligns with the life-history traits of many chaparral species allows this type to persist with pockets of montane conifers.

Desired Outcome from Prescribed Burning

Prescribed burning in montane chaparral creates a multi-age mosaic that increases species diversity, supports wildlife habitat, and breaks up otherwise continuous fuels on the landscape. Prescribed burning reduces densities of regenerating conifers in areas where it is desirable to maintain the dominance of this type. Passive- and active-crown fire is required to meet objectives (Figure 26).

Oak Woodland – 15,000 Acres

General Description and Current Vegetation Conditions

Oak woodlands vary in structure and composition depending on soil-moisture availability, fire frequency, and management history. Oak woodlands on the SRNF are dominated by Oregon white oak and California black oak with various broadleaf tree and shrub species and an herbaceous understory. Several other tree species may be present, including interior live oak, California buckeye, big-leaf maple, California bay, Douglas-fir, and ponderosa and gray pine. Understory vegetation includes mixed chaparral, poison oak, various shrub species, and abundant annual and perennial grasses and forbs (Figure 27).

Figure 27. Deciduous oak woodlands on ridgetops and southwest-facing slopes. USFS photo.

Figure 28. Douglas-fir encroachment in a deciduous oak woodland stand. USFS photo.

Invasive grasses and forbs are prevalent in many woodland and grassland understories and can be a challenge for fire management as these species often respond positively to disturbance (see *Invasive Plants* section under *Special Considerations* for additional information). In addition, the encroachment of coniferous species into oak woodlands (primarily Douglas-fir; Figure 28), in the absence of fire, shades and diminishes the herbaceous understory and can lead to eventual crown recession and mortality of deciduous oaks (Cocking et al. 2012, Schriver et al. 2018).

Compared to historical conditions, modern oak woodlands have experienced conifer encroachment, with many large oaks being shaded out. High-intensity fire fueled by overly dense conifer stands adjacent to oak woodlands has led to a significant shift in stand structure from one of widely spaced large individuals to multi-stemmed individuals resprouting from their root crown (Cocking et al. 2014). Modern stands have a higher proportion of annual grasses (mostly exotic) and increased shrub cover due to the lack of fire. Oak woodland canopy cover and density have increased due to ingrowth.

CALVEG Types: *CJ, PD, QG, QK;* ***BpS Models:*** *10290, 11140;* ***WHR Types:*** *BOP, MHW. See Supporting Documentation for descriptions.*

Desired Ecological Conditions

The desired ecological condition for oak woodlands is a mixture of open, savannah-like areas with large, widely spaced oaks intermixed with patches of denser oak woodland (Figure 29). Woodlands have a robust herbaceous grass layer that provides forage for various wildlife species, including deer and Roosevelt elk. Frequent, low-severity fire maintains the open stand structure, promotes regeneration, aids in nutrient cycling, and inhibits the encroachment of adjacent conifers (Figure 30). Average canopy cover is typically around 35 percent, with conifers are scattered throughout, but conifer density is kept in check by frequent fire, which also mediates woody plant development in the understory. At some sites, canopy cover increases to 70 percent or greater, forming a relatively stable hardwood forest that can support frequent surface fires fueled by grasses and litter from the hardwood overstory.

Figure 29. An open, savannah-like oak woodland. USFS photo.

Figure 30. A recently burned oak woodland. USFS photo.

Given an intact fire regime, most oak woodland stands (>75%) are open, mid- to late-seral stands dominated by oak species with an open herbaceous understory. The oldest stands have large oaks with occasional conifers, such as Douglas-fir and ponderosa pine, interspersed throughout but never dominating.

Only 10 to 15 percent of oak woodland stands are closed, with oaks still the dominant species, but with a potentially larger component of conifers in the canopy. Early seral stands are least abundant on the landscape due to the frequent, low-severity fire regime in this type, but these stands are dominated by resprouting oaks following stand-replacement fire. Early seral species of shrubs and grasses are prevalent at this stage.

Fire Regime and Current Departure

The fire regime in oak woodlands is frequent, low-severity fire. This is categorized as FRG I (FRI from 0 to 35 years, low to moderate severity; Schmidt et al. 2002). According to LANDFIRE, the historical mean FRI for oak woodlands is 8 years, with 90 percent of all fires at low severity and less than 10 percent at moderate to high severity. Historically, fire in oak woodlands has been driven by indigenous burning practices with fire frequencies likely higher than the overall average in some areas. Slow-growing oaks rely on fire to clear out competing vegetation and maintain their dominance as an important ecosystem component. Fires can occasionally be mixed severity under closed-canopy conditions or when additional species, such as conifers and shrubs, are present. Modern stands are more likely to burn at higher severities due to their current conditions.

Response to Fire

Highly adapted to fire, oak trees can withstand frequent, low-severity fire, as well as resprout when top-killed by high-severity fire. Although capable of resprouting, high-severity fire can effectively remove mature trees from a stand, greatly modifying overall structure and removing productive acorn trees (Figure 31). Given the relatively open canopy of oak woodlands, the setting is vulnerable to encroachment by invasive plant species. If present prior to fire, subsequent burning can increase the risk of spreading invasive plants without some kind of pre-treatment.

Figure 31. Areas of high-fire severity during 2020's August Complex wildfires resulted in extensive mortality of mature oak trees… yet the life of an oak can continue as seen in the photo on the right of a basal oak sprout, indicative of an oak's regenerative capacity after fire. USFS photos: left, October 2020 and right, November 2020.

Desired Outcome from Prescribed Burning

When prescribed fire is timed right, it can be highly effective at removing encroaching conifers from oak woodlands (Figure 32). It also helps ensure the persistence of large oaks on the landscape by reducing the risk of stand-replacing fire. Prescribed fire targets younger stands of encroaching conifers and achieves a minimum of 20- to 50-percent crown-volume scorch reducing the density of encroaching trees by 80 to 100 percent. Surface fires maintain oak stands and removes encroaching of Douglas-fir seedlings, while passive-crown fires reduce the density of larger conifers. Crown fires are not desirable in mature oak canopies. Sites with heavy young-conifer encroachment have minimal herbaceous understory and are a priority for treatment over woodlands with low densities of encroaching conifers. If invasive plants are present, the prescription design includes measures to limit the spread of invasive plant species, which serve as flash fuels.

Figure 32. Encroached oak woodland stand before (left) and after (right) prescribed fire. USFS photos.

Pine-Oak – 13,000 Acres

General Description and Current Vegetation Conditions

The *pine-oak* vegetation type is typically composed of scattered ponderosa pine in the overstory with one or more oaks in the subcanopy, including black oak, Oregon white oak, and canyon live oak. Douglas-fir commonly occurs in these stands as well. On most sites, oaks are quite dominant, forming a subcanopy under an open canopy of conifers. The understory in this type can range from grass-dominated with California fescue (*Festuca californica*), Idaho fescue (*F. idahoensis*) and *Melica* spp.; or shrub-dominated with manzanita (*Arctostaphylos viscida* and *A. manzanita*), deerbrush (*Ceanothus integerrimus*), buckbrush (*C. cuneatus*) and poison oak (*Toxicodendron diversilobum*), among several others.

Due to the lack of frequent fire over the last century or so, many stands where Douglas-fir is present face potential type conversion to Douglas-fir due to encroachment (Cocking et al. 2012). Fire-suppressed stands in general are denser with fewer oaks due to their shade-intolerance as adults (Long et al. 2016) with open, old-growth ponderosa pine-oak woodlands a rarity in today’s fire-suppressed landscapes. Remaining stands are at risk of top-kill by high-severity fire, which can lead to conversion to shrubby oak-dominated stands that lack the structural characteristics of mature stands as well as the pine component.

CALVEG Types: *PD, PP, QC, QG, QK;* ***BpS Model:*** *10300;* ***WHR Types:*** *MHC, MHW. See Supporting Documentation for descriptions.*

Desired Ecological Conditions

Desired ecological conditions for the pine-oak type include open stands of ponderosa pine and/or Douglas-fir interspersed within a semi-continuous subcanopy of hardwoods. According to LANDFIRE's modelled proportions given an intact disturbance regime, almost two-thirds of all stands are open (<40% canopy cover) with hardwoods dominating the subcanopy and conifers with low canopy cover interspersed in the overstory. Oak species vary depending on location and site conditions, but dbh ranges from 8 to 30 inches with the largest trees exceeding 30-inch dbh. Native bunchgrasses dominate the understory alongside shade-intolerant shrub species.

In more mesic sites, closed stands can be common (30%), but the canopy is still dominated by oak species with ponderosa pine and/or Douglas-fir. Tree diameters tend to be smaller than in open sites, but diameters of the largest trees can still exceed 30-inch dbh. Shade-tolerant shrubs and sod-forming grasses are prevalent in the understory of these more closed stands.

About 10 percent of all stands are in the early seral class. This stage is created by fire and is typically dominated by oak resprouts alongside recovering shrub species, although herbaceous cover in these stands is abundant. Conifers are present in these stands as seedlings, saplings, and poles.

Fire Regime

Fires in the pine-oak type were historically frequent and burned at low to moderate severity placing them in FRG I (FRI from 0 to 35 years, burning at low to moderate severity; Schmidt et al. 2002). According to LANDFIRE, the historical mean FRI for this type is 10 years with 67 percent of all fires at low severity, 27 percent at moderate severity, and 6 percent at high severity. Fire severity is low in open stands but can increase in stands that are denser and have a higher canopy cover (typically more mesic sites).

Cultural burning to promote large, open-canopied oaks was prevalent in this type at a time of intact fire regimes. Pine-oak woodlands are now burned less frequently, allowing conifers to become more abundant and convert many areas to conifer-dominated forests (Agee 1993, Cocking et al. 2012, Long et al. 2016), ultimately leading to higher severity fires when fire re-enters these stands, resetting them successionally.

Response to Fire

Highly adapted to fire, the pine-oak type depends on frequent, low- to moderate-severity fire to persist on the landscape. In open stands, where severity is low, frequent fire (<10 years) acts to reduce conifer establishment and development in the understory and subcanopy, reduce shrub cover, and promote herbaceous species. As fire severity increases, oaks are well positioned to maintain or re-gain stand dominance due to their ability to resprout.

Desired Outcome from Prescribed Burning

Re-introducing fire, possibly at slightly higher intensities than would have been expected historically, helps reduce the density of small-diameter, shade-tolerant conifers in the understory and subcanopy, and increases the overall integrity of pine-oak woodlands. Fire also acts to reduce shrub cover and promote herbaceous species in the understory. Both surface and passive-crown fires are required to sufficiently scorch subcanopy and intermediate crown classes of dense conifers. In some cases, high-severity fire can act to restore oak dominance in stands where conifers have become dominant and are too large to be removed by lower intensity fire (Cocking et al. 2014). Where stands are more open and less departed from historic conditions, surface fire meets stand maintenance objectives.

Special Considerations

Across the Forest, there are numerous unique habitats and plant communities requiring special considerations when examining fire regimes and fire effects. These considerations include natural fragmentation and patches of plant communities based on parent material and associated soils, extent of riparian and wetland features, topographic complexity, geologic past defining landscape features and the unique species assemblages that followed. At the landscape scale, the vegetative patterns of these unique habitats would most closely align with *patches* in the forest landscape design. In these settings, FRIs and behavior may not fit into the coarse filter of forest vegetation types discussed previously, thus warranting special considerations when developing prescriptions for restoration and maintenance. The following sections are examples of habitat settings and habitats on the SRNF that warrant special considerations—ultramafic plant communities, enriched mixed-conifer forests, riparian areas and invasive plants.

Ultramafic Plant Communities

General Description and Vegetation Characteristics

Many *ultramafic plant communities* are endemic ecosystems—geologic islands supporting a unique assemblage of species. Originating in the Earth’s mantle, ultramafic rocks find their way to the surface through various geologic processes. These processes, as well as associated weathering, can diversify ultramafic rock into rock types that vary in chemistry and texture. The primary ultramafic rocks on the Forest include serpentinite and peridotite, the former being most common. The ecosystems arising from ultramafic soils have been influenced by extreme abiotic factors relating to the soil/substrate (edaphic conditions), including areas of shallow soils, macronutrient deficiency, and high micronutrient or heavy metal concentration (e.g., magnesium and iron; Alexander et al. 2007). Low-soil fertility leads to a low rate of plant growth and landscape heterogeneity, with large extents of bare ground or barrens and outcrops lacking any vegetative cover compared to vegetation types associated with more fertile settings (Harrison and Safford 2008, Safford and Mallek 2011). On the Forest, these ultramafic habitats exist as islands in sharp contrast to the “sea” of more productive vegetation types like Douglas-fir-mixed evergreen and moist mixed-conifer forests (Harrison and Safford 2008).

Ultramafic plant communities on the Forest include the North Fork Smith watershed and other watersheds on the Smith River NRA—the largest ultramafic expanse on the SRNF—the Bluff Creek Watershed on the Orleans Ranger District (RD), in upper reaches of the East Fork Willow Creek on the Lower Trinity RD, and the Lassics region of the upper Van Duzen River and eastern Eel River watersheds on the Mad River RD (Figure 33).

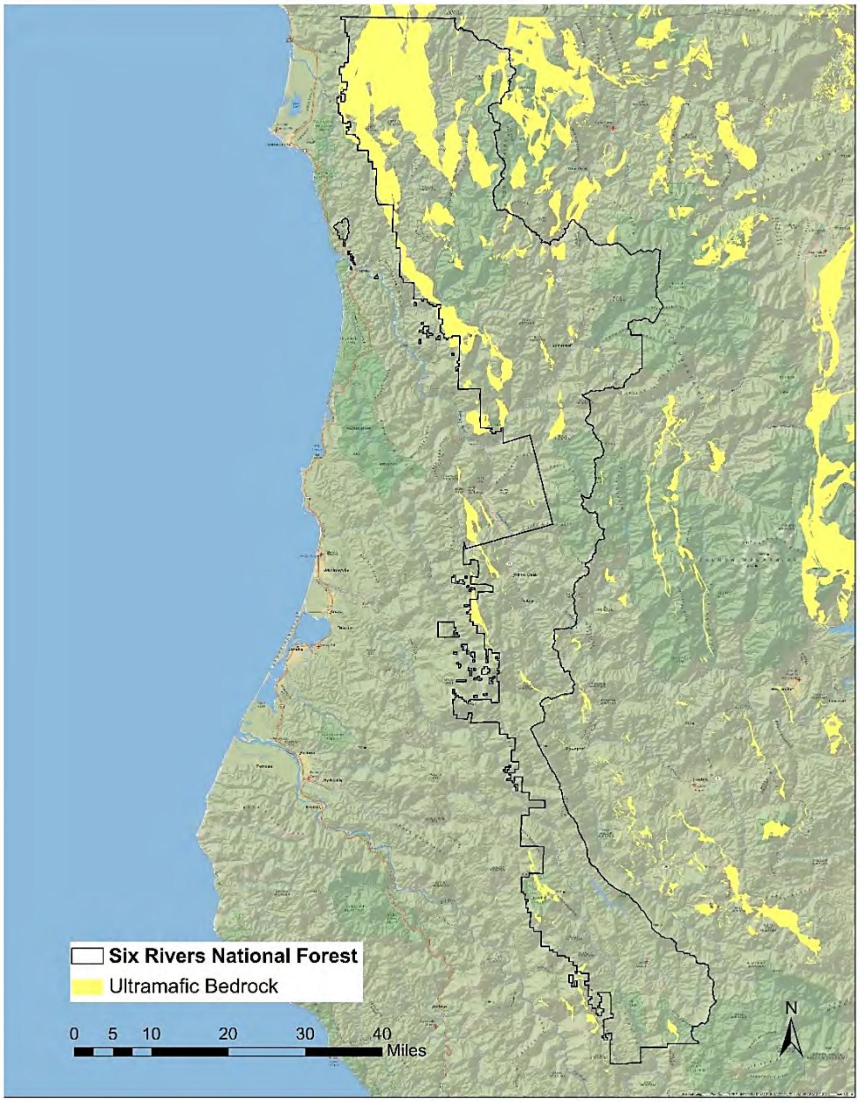

Figure 33. Map of ultramafic bedrock underlying the Six Rivers National Forest and adjacent areas.

Endemism and Rarity

Species associated with ultramafic soils are highly adapted to limited resources. This adaptive ability to soils that are nutrient poor with high metal content and habitat settings of the geographic context and spatial complexity of ultramafic habitats, have resulted in an array of species that are restricted to or *endemic* to ultramafic settings soils (Harrison and Safford 2004, Safford and Miller 2020). As an example, approximately 60 plant species are restricted to the ultramafic areas of the Klamath-Siskiyou bioregion—more species than any other ultramafic area in California (Safford and Miller 2020).

An example of a very narrow endemic on the Forest is the Lassics lupine (*Lupinus constancei*). Lassics lupine occurs primarily in exposed, ultramafic barrens only in the Lassics Region on the Mad River RD (Figure 34). The species consists of two sub-populations—one at the base of Red Lassic Peak and the other about 0.7 miles away on Mt. Lassic, between 5,200 and 5,700 feet in elevation. Combined, the occupied habitat covers 3 to 5 acres. Over two decades of monitoring, the population has ranged from 350 plants to 1,233 plants. Pressures on the species include small mammal herbivory, chaparral vegetation growing into the barren habitat and reduced snowpack that provides the primary moisture for the growing season. In April 2018, the Lassics lupine was listed as *endangered* under the California Endangered Species Act and is under review for federal listing (Hoover 2020).

Figure 35. The narrow endemic Lassics lupine. USFS photo.

Figure 34. L.E. Horton Research Natural Area, a Darlingtonia wetland. USFS photo.

While low vegetative cover, rock outcrops, barrens, and bare ground characterize much of the habitat that support endemic and rare plant species of ultramafics, so to do high water table or spring-fed settings in the form of Darlingtonia wetlands (Figure 35). Located on the Smith River NRA, Darlingtonia (*Darlingtonia californica*), commonly called California pitcher plant, an insectivorous plant, is a rare species restricted to southwestern Oregon and northern California—the latter including the Smith River NRA. Darlingtonia is a dominant plant cover of ultramafic wetlands—wetlands fed by a source of perennial water during the summertime when upland vegetation is subject to a prolonged dry period (Jules et. al. 2011). Two other endemic and rare plant species that occupy Darlingtonia wetlands on the Smith River NRA are western bog violet (*Viola primulifolia* ssp. *occidentalis*) and Waldo gentian (*Gentiana setigera*).

Fire Regime Heterogeneity and Climate Influences

The edaphic conditions of ultramafic settings limit plant growth, stem density and woody fuels accumulations—factors that influence fire and its behavior. Given the vegetative structure of ultramafic habitats, these habitats may be less departed, fire return-wise, than non-ultramafic areas (DeSiervo et al. 2015). Relative to climatic influences, a paleo-ecological study of the early and middle Holocene period (approximately 11,600 years before present) reveals that the vegetation composition and structure on non-ultramafic substrates changed more significantly than on ultramafic substrates indicating that species on ultramafic substrates have been less impacted by changes in climate, allowing these systems to persist over the long term (Briles et. al. 2011). This study of potential climate refugia for vegetation associated with ultramafic substrates primarily addressed woody species—trees and shrubs. A much more recent investigation of the herbaceous layer response to climatic warming yielded different results. In 2007, plots established in the 1950s in the ultramafic habitat of the Klamath-Siskiyou region were resampled. The results indicated that the herbaceous communities had declined in cover and species composition and shifted to one resembling a south-facing slope, raising concern for the regional extinction of species endemic to particular niches within ultramafic substrates (Damschen et al. 2010).

Historic FRIs applied to Jeffrey pine in the yellow-pine forest type do not readily crosswalk to Jeffrey pine plant communities growing on ultramafic soils, likewise for chaparral and closed-cone conifer forests on ultramafic soils that are grouped with like vegetation types associated with non-ultramafic soils (Table 2). With reduced growth and accumulation of fuels, as well as their influence on vegetative continuity, structure and spatial heterogeneity, ultramafic soils could not support the high fire frequencies aligned with Jeffrey pine or chaparral in other settings (Safford and Van De Water 2014). This variation—vegetative continuity, structure, spatial heterogeneity within ultramafic areas—influences fire frequency and intensity across such landscapes. As an example, LANDFIRE estimates the FRI for ultramafic areas at 9 years compared to historic FRIs estimated at more than 40 years in another study (see *Serpentine Mixed Conifer Forest* section; Van de Water and Safford 2011).

It is very likely that this variation in FRI estimates is due to the variables associated with fire history studies in serpentine habitats across the landscape (e.g., patch size, proximity to the coast such as the North Fork Smith area of the SRNF versus inland within the Sierra Nevada Mountains). This variation is best described as *The Serpentine "Context": All Serpentine is not Equal* (Safford and Mallek 2011).

Role of Fire and Fire Effects

Recognition of FRI departures associated with ecologically unique habitats like ultramafics, nested within more productive vegetation types, is important for guiding ecologically based fire management. Fire certainly has a role in these communities. Research on historic stand structure in Jeffrey pine savannahs suggests some open savannah areas have been encroached by trees and will continue to decline without fire as a disturbance process (Sahara et al. 2015). Following are examples of ultramafic plant communities and rare species that have been studied relative to fire effects including the pre- and post-fire monitoring of species composition, the number of individuals and reproductive capacity.

For the ***Lassics lupine***, recent monitoring indicates that given its primary occupancy of barren settings and the open spacing between plants, fire does not directly affect plants growing in barrens (Figure 36), rather it appears to have positive indirect effects. Prior to the 2015 Lassics Fire, the population of Lassics lupine was at its lowest point; however, since the fire, there has been an increase in Lassics lupine seed germination and a rate of growth likely associated with either heat or smoke-related cues (Carothers 2019, Lopez 2019). Prior to the 2015 wildfire, there were only four fires recorded near the Lassics peaks that were larger than one acre—all from lightning strikes in August 1953 (Carothers 2017). In addition to the role fire appears to play in the germination rate of the Lassics lupine, fire also sets back the succession of forest and chaparral vegetation into the barren habitat preferred by the Lassics lupine. While there are cumulative factors affecting the population viability of the Lassics lupine, such as the extent of available soil moisture through the growing season based on snowpack and summer temperatures (USFWS 2012), the intervals between fires also appear to be putting a strain on the viability of this species.

Figure 36. Patchy vegetation adjacent to barrens with Lassics lupine. Burned chaparral from 2015's Lassics Fire on west slope (left). Photo courtesy of Dr. Dan Barton.

Figure 37. Darlingtonia plants resprouting after a wildfire. Photo courtesy of Dr. Erik Jules.

In ***Darlingtonia wetlands***, growth habit and hydrologic conditions play a significant role in the effects of fire on these communities. Many species associated with these wetlands have an extensive underground rhizome network that facilitates a response to fire. This growth habitat coupled with the moisture conditions indicate that these wetlands are generally resilient to fire. In addition, two pre- and post-fire studies of Darlingtonia wetlands on the Smith River NRA and the Rogue-Siskiyou National Forest in southwest Oregon were undertaken after the 2002 Biscuit Fire. The rare western bog violet and Waldo gentian appeared stable two years post-fire (Kramer and Frost 2005), likewise, the overall species assemblage sampled more than four years after the fire shows no significant difference in abundance before or after fire (Jules et al. 2011; Figure 37). While Darlingtonia wetlands exhibit resiliency to fire, the maintenance of hydrologic conditions in the setting where these wetlands occur is essential and thus a concern with climatic shifts of decreased rainfall affecting the groundwater recharge that sustains these wetlands (Sims et al. 2020).

Opposite-leaved lewisia (*Lewisia oppositifolia*) is a Forest Sensitive plant species associated with ultramafic Jeffrey pine or western white pine woodlands, as well as Idaho fescue (*Festuca idahoensis*) grasslands on the Smith River NRA. The species is a tap-rooted perennial that appears to reproduce entirely by seed. During extended drought periods, the species can remain dormant for several growing seasons. Specific habitat settings for opposite-leaved lewisia include water-holding depressions within pebble plains or bare patches in grasslands (Figure 38).

Figure 39. Opposite-leaved lewisia in the spring, Smith River NRA. USFS photo.

Figure 38. Patchy burn pattern, Coon Mountain prescribed burn, Smith River NRA. USFS photo.

Opposite-leaved lewisia was monitored for three years prior to prescribed burning at Coon Mountain on the Smith River NRA, and two years post-prescribed burn. The post-prescribed burn monitoring indicated that the spring 2008 prescribed burn appeared to avoid the settings occupied by the lewisia; therefore, the results relative to plant counts were not notably distinct from those associated with pre-burning (Figure 39). Burning in the spring, coupled with the habitat moisture at that time, resulted in no direct effect to the species. The Coon Mountain Fire—part of the 2015 Gasquet Complex of wildfires—burned through much of the same areas that were subject to prescribed burning in 2008. Post-wildfire sampling of the opposite-leaved lewisia indicated a decline in the species (Carothers 2016). It is recognized that other factors, besides the wildfire, may have contributed to the decline. Was it low background levels of soil moisture or accumulation of needle litter where the plants were located that may have influenced localized burn intensity? Had some of the individuals been dormant when monitoring occurred? Was the burn interval of seven years between the prescribed fire and wildfire too narrow for this habitat and the species it supports? While prescribed fire has notable benefits to some rare species in ultramafic areas, lessons learned from monitoring a species like the opposite-leaved lewisia for restorative and maintenance burning include 1) consideration of the rare species ecology with the burn season and burn interval to best sustain the population and 2) the need for longer post-burn monitoring than just a single year to better incorporate seasonal variations in plant physiology and habitat conditions.

Klamath Mountains: Enriched Mixed-Conifer Forest

General Description and Vegetation Characteristics

Enriched mixed-conifer forests are associated with the upper montane and sub-alpine elevation zone of the Klamath Mountains. Many conifer species in the Klamath Mountains exist as isolated stands characteristic of refugia (Sawyer and Thornburgh 1977). While there are similarities to red fir forests with a mosaic of single trees, tree clusters and canopy openings driven by disturbance of varying intensities, in enriched mixed-conifer forests there is not one, single forest type; rather, it is an agglomeration of different species that can exist in close proximity due to abrupt changes between mesic, hydric and xeric habitats, and the great range in elevation over short distances (Figure 40; USDA 2014).

Figure 40. Heterogeneity of habitat settings associated with the enriched mixed-conifer forest of the Klamath-Siskiyou Mountains with Brewer spruce in the foreground (left); and closeup of Brewer spruce (right). Photos courtesy of Dr. Erik Jules.

Due to its geologic history, parent material diversity, landscape position, and topographic variation, the higher elevation zones of the Klamath Mountains contain an array of habitats that support a unique blend of species converging from the north and the south. The landscape heterogeneity of this region provided refuge for species during glacial times. An example of a relict species at the edge of its range—finding *refuge* in the Klamath region—is Alaska yellow cedar (*Callitropsis nootkatensis*). This species ranges from southeastern Alaska to the Klamath Mountains and reaches its southern extent on the western edge of the Forest in the Bear Basin Butte Botanical Area and the adjacent Siskiyou Wilderness on the Klamath National Forest.

Another conifer species of the upper montane zone in the botanical area is Brewer spruce (*Picea breweriana*), a Klamath-area endemic, ranging from southwest Oregon to northwest California (Thornburgh 1990). Brewer spruce occupy shallow soils derived from sedimentary, granitic serpentine and metavolcanic rocks in a variety of topographic settings, existing as small stands or individual trees in late-successional, mixed-conifer forests (Cope 1992, Thornburgh 1990).

Other species within enriched mixed-mixed conifer forests include mountain hemlock (*Tsuga mertensiana*) and Shasta red fir (*Abies magnifica* var. *shastensis*). In all, there are 14 conifer species within Bear Basin Butte Botanical Area—some species are near or at the limit of their range growing as dominant species of small stands, within stands as a codominant species or like mountain hemlock, growing as patches or individual trees in stand *niches* that provide for lingering snowpack (USDA 1998).

Habitat Heterogeneity, Disturbance Scale and Current Risks

Small-scale disturbance in the form of an individual tree or group mortality event serves the regeneration and development requirements of certain species in enriched mixed-conifer forests. Stand structure heterogeneity, such as canopy gaps, can provide openings preferred for colonization, seed germination, and early stem development; diffused light conditions for tree growth of shade-tolerant species; and partially shaded conditions that help extend the longevity of snowpack and thus retention of soil moisture well into the summer. Spatial and temporal variation in disturbance creates habitat heterogeneity that contributes to species diversity (Odion et al. 2004).

Spatial variation in soil productivity, as well as vegetation patterns, steep gradients, and abrupt changes in aspect across the landscape play a significant role in connectivity, fuel accumulation and thus fire behavior and intensity (Skinner et al. 2006, Taylor and Skinner 1998, USDA 2014). Fires, driven largely by lightning ignitions, were historically very patchy and generally small due to limited fuel availability (Skinner et al. 2006). It is this landscape variability that can limit the ability to predict the fire regime of a forest patch when fire from adjacent vegetation may be the source of fire in the forest patch (Taylor and Skinner 1998).

Habitat characteristics can restrict the likelihood, frequency, and intensity of fires for species in fire-limiting habitats. For example, in some areas of the Klamath-Siskiyou region, red fir-dominated forests in montane settings that burn infrequently or at low intensity, serve as refugia for endemic or relict conifers that are fire sensitive, such as Brewer spruce (Sawyer and Thornburgh 1977). Both Brewer spruce and Alaska yellow cedar can also occupy rocky and shallow soils where vegetative fuels for a fire would be limited (Figure 41); likewise, mountain hemlock, a fire-intolerant species, occupies cool, north-facing slopes where snow accumulation is heavy and moisture retention is relatively high (Tesky 1992, USDA 1998). Corresponding to the fire-limiting habitats of certain species in the enriched mixed-conifer forest are the lack of fire-adapted traits. For example, Brewer spruce is thin barked and shallow rooted with drooping branches making it sensitive to fire (Thornburgh 1990, Cope 1992).

Figure 41. Patch of Alaska yellow cedars growing downslope of a boulder area indicative of its habitat setting. Photo courtesy of Julie Evens.

Climate change has created situations where extreme fire weather is more prevalent, and areas that would have historically been missed by fire due to local micro-climate conditions, substrate differences and discontinuous fuels, are now more vulnerable to burning during a wildfire (Sawyer and Thornburgh 1977). Concerns related to the extent of climatic shifts are increasing as drought conditions have led to increased tree mortality in the Klamath enriched mixed-conifer forest beyond background levels, such as increased mortality of Shasta red fir in the subalpine zone due to fir engraver beetle (*Scolytus ventralis*).

This native beetle infests trees that are recently dead or stressed, resulting in outbreaks where host trees are abundant. Stand density, perhaps increased due to fire suppression, has influenced the spread of the infestation (DeSiervo et al. 2018).

Drought conditions, fire suppression and related cumulative effects (e.g., mortality due to insect infestation) are all factors putting enriched mixed-conifer forests of the Klamath Mountains at risk. An increase in large fires will essentially remove fine-scale mosaics of differently aged stands, especially if the fires are severe (Kauffman et al. 2007). The early-seral vegetation that follows severe fires may self-perpetuate if the FRI is not long enough for conifer trees to establish and mature (Odion et al. 2010). This shift would reduce the species diversity and array of seral stages within the Klamath Mountains, and risk extinction of endemics, such as Brewer spruce (Thornburgh 1990).

The enriched mixed-conifer forest of the upper montane and sub-alpine Klamath-Siskiyou region warrants a closer look relative to the application of established fire regimes. Red fir is the most similar vegetation community with a historical mean FRI of 25 years of primarily low to moderate severities (LANDFIRE). While fire regimes for the red fir community can serve as a general guide, this vegetation community type does not account for the spatial heterogeneity of upper montane and sub-alpine reaches of the Klamath Mountains. Related is the fact that historic fire regimes may not apply to current conditions based upon variables such as fire history and past land management in adjacent forest (e.g., logging nearby montane forests). Furthermore, the regimes would also not factor in the current status of at-risk species like Brewer spruce, the impact of invasive plant species, compromised watershed function and a changing climate (Frost 2001).

Riparian Areas

Wildfire Regime Variability

Stream channels and riparian zones vary across the landscape and often differ from adjacent slopes or ridges in terms of topography, microclimate, moisture dynamics and vegetation; therefore, disturbance regimes such as wildfire, would differ accordingly (Moore and Richardson 2012). Elements of disturbance regime variability between riparian and adjacent habitat settings include spatial distribution, frequency, and severity. The influence of these elements within riparian areas are further affected by the watershed position and stream size.

The heterogeneous elements of riparian systems lead to heterogeneity in fire behavior ranging from surface fires and unburned patches to crown fires (Pettit and Naiman 2007). Proximity to water and vegetative shading and/or density results in relatively high humidity and surface moisture conditions that can preclude frequent fire entry into riparian zones compared to upland slopes (Agee 1988, Pettit and Naiman 2007). Yet the extent of fire as a disturbance agent is also affected by location within a given watershed, the extent of woody material accumulation in the riparian zone between fires, and baseline conditions relative to land-use history—influencing fire's potential continuity between riparian areas to adjacent slopes (Everett et al 2003) and resulting in fires burning in riparian areas with comparable frequency to adjacent uplands (Dwire and Kauffman 2003).

For the most part, riparian systems on the SRNF differ from adjacent upland slopes given the steep slopes, deeply incised streams and riparian vegetation that characterizes most of this landscape. In the Klamath Mountains, median FRIs were up to twice as long in riparian areas as in upland forest sites with departures related to intermittent streams in the upper watershed (Skinner 2003). Yet situations exist, like in certain watersheds on the Mad River RD, the southernmost district on the Forest, where there is little difference in the microclimate and vegetation between the riparian area and the adjacent slopes—if fire enters the area, the draw serves as a chimney, spreading fire up the channel and burning more intensely within the riparian area than adjacent slopes (Dresser 2021).

Wildfire Effects

Wildfires are an integral component of long-term forest and stream ecosystem dynamics (Bisson et al. 2003) with direct benefits to stream habitat and biota, including most life stages of spring Chinook salmon (Flitcroft et al. 2016). As an example, heterogeneity in riparian vegetation structure whether by windthrow or fire-created gaps, yields canopy openings that result in light availability to the stream that can positively influence primary production, nutrient cycling, and food-web dynamics (Warren et al. 2017). While influenced by spatial variability and other factors, in general, immediate wildfire effects on riparian areas include relatively short-lived pulses of nutrients and sediment, as well as increases in instream woody debris (Bisson et al. 2003, Pettit and Naiman 2007). The erosional processes that accompany wildfires are important for recruiting large wood and coarse sediment that form essential habitats for many aquatic organisms (Benda et al. 2004). From the pulse of immediate wildfire effects in riparian areas, the legacy of canopy openings and instream wood deposition creating instream diversity and nutrient contributions will be passed downstream and can last for decades (Pettit and Naiman 2007, Scherer 2008). Yet with continued fire exclusion from these systems in the context of climate change, aquatic and riparian ecosystems have been altered in ways not fully recognized (Spies et al. 2018).

Management Implications

The *Biological Assessment (BA) for the Thinning and Fuels Reduction Program* (USDA 2019) documents potential environmental impacts to streams resulting from thinning and fuels reduction in riparian areas. The BA, with the incorporation of scientific studies and literature review, also documents the role of these activities to improve ecological conditions in riparian areas that have been compromised by past-management activities, including wildfire suppression. Where baseline conditions have been compromised by past management or non-native and invasive species, it is recognized that thinning, founded in ecologically- and place-based objectives, is necessary as an initial step before fuels management activities, such as prescribed fire or wildland fire use, can be applied and play a role in restoring riparian habitat quality and resiliency.

The BA references the *Aquatic Conservation Strategy (ACS) of the Northwest Forest Plan* (USDA/USDI 1994) and its role in improving ecological conditions of watersheds across the planning area. Since the ACS, the *Synthesis of Science to Inform Land Management within the Northwest Forest Plan Area* (Spies et al. 2018) was released. Based on monitoring and incorporation of updated literature, the synthesis determined that active management may be needed to address the lack of natural disturbance—primarily wildfire—and climate change. Where forest structure is homogenous due to past management practices, thinning creates variable riparian vegetation conditions (Spies et al. 2018), emulates small-scale disturbances, and increases light availability with minimal effects on water temperature (Zwieniecki and Newton 1999, Kreutzweiser et al. 2009). Beyond any initial thinning, these partial openings and resultant ecological benefits can be sustained by natural disturbance agents as overstory tree mortality, windfall, localized slope instability and fire.

One caveat to thinning or burning to restore the role of natural disturbance agents is the occurrence of invasive species within or proximal to the riparian area. Given the shade conditions typical of riparian areas, many invasive species are precluded from establishment as many invasive grasses and herb species are shade intolerant. Exceptions that are present on the SRNF include English ivy (*Ilex hedera*) and Himalayan blackberry (*Rubus armeniacus*). Given its vine habitat and ability to climb tree trunks and cover areas of the canopy, English ivy influences fire behavior and poses a threat in riparian forests (Anzinger and Radosevich 2008). Likewise, Himalayan blackberry, with its dense growth and extensive stems/canes, serves as a surface and ladder fuel to carry any fire that reaches the riparian area beyond where it would naturally burn, including the canopy. Invasive species are also changing successional pathways in riparian areas at a watershed scale, including the displacement or elimination of “signature” native riparian species, such as salmon berry (*Rubus spectabilis*) and thimble berry (*Rubus parviflorus*). Research in riparian reaches of western Oregon found that the constancy of Himalayan blackberry was higher (89%) than the native salmonberry (36%) or thimbleberry (43%; Fierke and Kauffman 2006).

Restoration needs to start with an assessment of current conditions versus desired future conditions to determine if the latter has ecological basis (Spies et al. 2018). Relative to fire as a restoration tool in riparian zones, it will be important to understand differences in the ecological effects of riparian fire for different stream orders and elevational gradients under different climatic regimes (Pettit and Naiman 2007).

Invasive Plants

Native vegetative communities—the habitat they support for a variety of species, the ecological processes therein, and the culturally significant offerings—have been compromised by land-use practices and landscape events that have fostered inroads for *invasive species*. Invasive species fall into various forms—from plants to pathogens—but invasive plants readily respond to landscape manipulations or changes, such as logging, livestock grazing and fire (prescribed or wild).

The goal of the project is to restore native vegetative communities—species assemblages, structures and processes—in keeping with landscape-scale fire regimes that incorporate historic fire frequency. This is in line with invasive species management direction: “to conserve native species, their habitats and ecosystems” by including design measures that reduce the risk of introduction, establishment and spread of invasive species (USDA 2011[14], USDA 2013).

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[14] Executive Order (EO) 13751 (USDA 2016) amended the language of EO 13112 (USDA 1999) cited in Forest Service Manual 2900 (USDA 2011) as follows: “refrain from authorizing, funding, or implementing actions that are likely to cause or promote the introduction, establishment or spread of invasive species… unless… the agency has determined and make public its

Invasive species are those that are transported—intentionally or accidentally—from the geographic area where they evolved to a new range where they spread and persist due to the species' *plasticity* to exist over a range of environments (Rejmanek 1999) and other attributes, such as dispersal capacity and positive response to disturbance. While not exclusively human-driven, introductions have been ongoing for centuries and continue due to expanding transportation and commerce (Mack et al. 2000).

The establishment of invasive plants in some geographic areas of the Forest, the threat of spread into previously native vegetative communities and the invasive-favoring conditions following fire and canopy openings, create a challenge to project thinning and burning to restore *functioning* native vegetative communities that rely on inter-relationships between vegetative species, not just one element of the community. Due to their high dispersal capacity and positive response to both increased light availability and post-burn nutrient pulses, invasive plants are poised to take advantage of this situation (Keeley 2006; Martinson et. al. 2008). Climate change exacerbates all the above as decreased summer precipitation and weather pattern changes coupled with a baseline of high fuel loading due to decades of fire exclusion are contributing to wildfire size and frequency (Reilly et al. 2020).

The following section provides some information about the ecology of invasive plant species that contribute to the concern for their introduction and spread. The section also addresses specifics about a suite of invasive plant species that occur on the SRNF and the Ukonom RD. This information is intended to help frontload those characteristics of a species that would trigger the need for project design features in the application of the proposed action or if deemed a priority, active restoration to reduce or eradicate the invasive plant occurrence.

Characteristics of Invasive Species and Ecosystem Influence

An overarching characteristic of invasive plants is the capacity to persist and spread due to their genetic *plasticit*y or ability to maintain a relatively constant fitness over a range of environments (Rejmanek 1999), as well as their reproductive capacity compared to most native species. This capacity includes relatively high seed production, high germination rate, short juvenile period and a relatively quick shift to the reproductive stage, long fruiting period, long-distance dispersal capacity and seed-banking potential for some species, resulting in consistent reproduction and thus rapid population growth (Davis and Sheley 2007, Rejmanek and Richardson 1996).

Once established, invasive plant species can influence ecosystem function above and below ground. An example of an above-ground influence are the negative effects on pollinator dynamics. Studies have indicated that the presence of invasive plants intermixed with native species have broken the link between pollinator visits to the native species, reducing the fruiting of native plants (Kaiser-Bunbury et al. 2017). Below ground, mycorrhizal fungi colonize the root system of plants and facilitate the absorption of important nutrients and water for the plant. Once established, invasive plant species with quick and early germination rates, and deep and widespread root systems can out-compete native species for access to the

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determination that the benefits of such actions clearly outweigh the potential harm caused by invasive species; and that all feasible and prudent measures to minimize risk of harm will be taken in conjunction with the actions."

mycorrhizal fungi and in so doing, select for the community of fungi that serves the invasive plant species over the native species (Hawkes et al. 2006).

Constant fitness of invasive species also relates to the competitive ability of some invasive plants to readily access resources. In grasslands, for example, perennial invasive plant species tend to have deep taproots that extract moisture from the soil profile allowing them to grow later in the summer than native bunchgrasses and forbs (DiTomaso 2000). Release from the checks and balances of native herbivores or pathogens in their native habitat also gives invasive plant species an advantage in their introduced range (Blumenthal 2005).

Invasive plant species also influence ecosystem dynamics by altering fire disturbance regimes. Invasive plants can survive after a fire via their seed banks or if seeds from a nearby unburned area are dispersed seed into the burned area after fire. The seed bank, seed dispersal capacity and quick growth to the reproductive stage, puts invasive plants in the lead to take advantage of resources that are more abundant and available after fire at the expense of native species (Zouhar et al. 2008). Once established, the presence of certain invasive plants can alter FRIs and influence fire spread. Cheatgrass, with its extensive cover of mat-forming litter, serves as a fuel that increases the risk of recurring fires. Invasive shrub species, such as Scotch broom (*Cystisus scoparius*), alters fire behavior by increasing its potential to spread. With its long-lived seed bank and seed-projectile capabilities from the pod, Scotch broom is favored by fire, which stimulates the germination of the seed already present in the soil or dispersed into the burn area. Once mature, Scotch broom can displace existing vegetation and form dense stands, subsequently serving as a fuel layer to carry fire into landscape settings that would otherwise not have burned (Anzinger and Radosevich 2008).

Following are attributes of some invasive plant species documented within the geographic area of the *Fire & Fuels Project*. The attributes provided display some differences in respective invasive capacity, responses to disturbance, and preferred habitat settings.

Cheatgrass (*Bromus tectorum*) is documented on the SRNF’s Orleans/Ukonom RD. The following information is drawn primarily from a synthesis of literature—*Element Stewardship Abstracts* (Carpenter and Murray 1999). Some invasive attributes of cheatgrass include:

- Fibrous root system (down to around 11 inches) that develops and continues to grow over the winter, and the ability to draw down soil moisture and nutrients to low levels; therefore, denying other species of these resources.
- Fibrous root system allows cheatgrass to access underground mycorrhizal fungi more readily than many native grasses. This leads to a homogenizing of the fungal community to species of fungi utilized by invasive plants over those used by native species (Hawkes et al. 2006).
- Produces many seeds that are dispersed short distances by wind and further if seeds attach to fur, feathers, or clothing. Germination is typically staggered from August until May.
- Plants mature early and then dry out. This complete summer drying combined with its fine structure creates a mat of litter that carries fire. This sets the stage for recurring fire, thus shortening the FRI, which reduces the ability for perennial grasses or shrubs to re-establish.

- Early fall rains are important for germination and the subsequent fall growth of cheatgrass.
- It is not able to establish in mature forest habitats in part due to the plants photosynthetic rate that shaded settings do not offer. Preferred habitat is disturbed shrublands and grasslands, in particular those that have been overgrazed, eroded and along road edges.

Medusahead (*Taeniatherum caput-medusae*) is a grass species that is currently distributed in the grasslands and some oak woodlands of the Mad River RD—the district that supports the most grassland/oak woodland habitat on the Forest. This species was also recently documented on the Ukonom RD in association with road edges dissecting grassland habitat. Attributes of medusahead include:

- It is considered a winter annual grass with seeds that are initially dormant but are stimulated to germinate after a cold period and continue to grow under a layer of snow (Burritt 2019). Seed production can be abundant and dispersal distance is about 6 feet from the parent plant unless seeds are picked up by animals or humans. The seed viability in the soil begins to wane after two years (Innes 2019). It matures later in the season than other annual invasive species like cheatgrass (Maurer et al. 1988).
- It has no forage value for wildlife due to its high silica content, which reduces its palatability and digestibility. Furthermore, its growth habit competes with shrubs, forbs and perennial grasses, plant groups that have forage value.
- Its silica content also slows the breakdown of the plant resulting in litter accumulation. In areas of high medusahead cover, the plant material forms a dense thatch layer. This layer reduces the amount of light reaching the soil surface and ties up soil nutrients, thus inhibiting germination of other plant species. This thatch layer can control the relative humidity near the ground, which aids in perpetuating germination of medusahead seed. Medusahead thatch is highly flammable, serving as a fuel for spreading fire (Burritt 2019; Innes 2019).
- Its preferred habitat is grassland. Akin to many invasive plant species, habitats with canopy shade can preclude such establishment. Studies of medusahead in grasslands versus oak woodlands found that medusahead in oak woodlands grew at lower densities and had less reproductive production compared to plants growing in grasslands (Gornish et al. 2015).

Himalayan blackberry occurs in various settings across the SRNF. Unlike many of the invasive plant species in this geographic area, this species is a perennial shrub that is evergreen in habit, thriving in both shady riparian settings and high light settings, often those that have been previously disturbed. Attributes of Himalayan blackberry include:

- Reproduces by seed but also clonally through the growth of stems that can set root if in contact with the soil, forming impenetrable thickets. Stems, also called canes, can grow to lengths up to 21 feet in one season. Seed production, germination, and fruiting is limited without full sunlight (Hoshovsky 1989).
- Supported by a root crown, an established shrub can be up to 8 inches in diameter from which lateral roots grow reaching depths of 35 inches. Root fragments can also result in establishment of new plants (Soll 2004).

- Tolerant of a wide range of habitat settings and soil conditions. Once introduced, stands can occur in nearly closed canopies and open habitats, and on shallow to steep slopes. Tolerant of soils with low-water content and nutrient availability, giving this species competitive advantage especially to post-anthropogenic disturbance, which makes space, light, and soil resources available (Caplan and Yeakley 2006).
- Tolerant of shade and closed-canopy conditions, which is a departure from most other invasive plant species. Given this tolerance and ability to grow clonally, blackberry can dominate riparian areas displacing native species that contribute to riparian ecological function, such as streambank stability and contribution of woody debris to the stream channels (Bennett 2007).
- Readily invades various habitats—riparian, forest edges, oak woodlands, road edges and other open areas—within all forest types. Once established, blackberry thickets can alter migration and movement of large mammals from grassland or meadow openings to forest, will out-compete the diversity of native shrubs and forbs providing food sources to various animal species, and prevent establishment of shade-intolerant trees, such as Douglas fir, and white and black oak (Soll 2004).

Characteristics of Habitat Invasibility

Habitats most vulnerable to invasive plant introductions are those that have little to no overstory canopy cover, such as grasslands, some oak woodlands, and chaparral vegetation existing as scattered patches. These open habitats facilitate dispersal of invasive plant seeds by wind. The availability of resources—light, nutrients, and water—is an overriding theme to habitat invasibility (Blumenthal 2005, Zouhar et al. 2008) with very few invasive plant species established in intact, late-successional habitats where resources are fully utilized by existing native vegetation (Anzinger and Radosevich 2008, Rejmanek 1999).

Regardless of the existing habitat, invasive plants are considered disturbance-followers. In most cases, the canopy opening, the reduction in native plant competition, and the disturbance's alterations to the soil all contribute to habitat invasibility. Adaptive characteristics of invasive plant species enable their ability to readily take advantage of various agents of disturbance, for example, seeds of the invasive yellow starthistle (*Centaurea solstitialis*) can survive fire, grow to a reproductive stage and spread (Figure 42). Invasive plant abundance can be notable in disturbed areas along corridors subject to repeat disturbance, including river bars, trails, powerlines and in particular roads, as vehicles and heavy equipment are key vectors of invasive plant introduction and long-distance dispersal (Figure 43; Trombulak and Frissell 2000, Zouhar et al. 2008, Keeley 2001). Forested landscapes of the Klamath Mountains have been affected by expansion of invasive grass species, likely associated with roads, into once old-growth mixed-conifer/hardwood forests following short-interval, high-severity wildfires (Reilly et al. 2020). With the climatic conditions favoring more frequent and severe wildfire conditions, forest habitats are vulnerable to loss and more receptive to invasives.

Figure 42. The invasive yellow starthistle within a burned landscape. USFS photo.

Figure 43. Invasive meadow knapweed along a road and in a powerline corridor—likely introduced via equipment operating in the area. USFS photo.

Management Approach, Perspective, Strategy

Stewardship actions proposed to alter the distribution and amount of live and dead fuels in preparation for subsequent prescribed or natural fires come with trade-offs relative to sustaining native plant communities. Active management offers opportunities for restoration and maintenance of native plant communities, but it must be recognized that there has been a fundamental change to baseline conditions of the current landscapes with regards to the abundance of aggressive invasive plant species (Keeley 2006). The composition, structure, and dynamics of vegetation types of intact cultural fire regimes will affect invasive and native species' responses to thinning or fire and "cannot simply be undone by reintroduction of historic fire regimes" (Anzinger and Radosevich 2008). Historic fire regimes should not serve as the only guide to fire's use in the future as invasive plant species may have altered the competitive environments for native species; therefore, the fire response would not reflect that of historic fire regimes (Agee 1996). With this baseline perspective in place and understanding of vegetative changes that encourage invasive plant spread, active management—thinning small trees and understory vegetation, and prescribed burning—can improve conditions for ecosystem revival and resilience to changing conditions.

If invasive plants are present in the habitat area planned for activities or nearby, it is likely that canopy openings, use of heavy equipment, and removal of native understory vegetation will increase the risk of spreading invasive plant species. An assessment of local conditions and the potential for sustainable positive or negative results is needed to determine the type of approach to be taken—*mitigation measures* that avoid the risk of spread (e.g., maintenance of a vegetative buffer, burn pile locations) or *restorative measures* that integrates actions to sustain the native species components of the plant community.

The decision framework for active management aimed at restoration needs to:

- Communicate across resource areas and partners. Integrate the knowledge of ecology of native and invasive plant species—the regeneration strategies, phenology, and site requirements of all species in the planning area—into integrated management techniques and monitoring to best ensure management objectives are met (Figure 44; Smith et al. 2008, Zouhar et al. 2008).

Figure 44. Repeated manual treatment of French broom species by the Northwest Youth Corps and prescribed burning in the Mvs-yee-se′-ne oak woodlands on the Smith River NRA. This project integrates botany, archaeology, and fuels in collaboration with the Tolowa Dee-Ni′ Nation and Elk Valley Rancheria. USFS photo.

- Consider local conditions when prioritizing areas for restoration including:
    - Habitat characteristics—its potential to resist or be vulnerable to plant invasion, keeping in mind the dynamics associated with climate change (e.g., fire frequency) that will influence which vegetative communities may become vulnerable in the future (e.g., old-growth forests).
    - Extent of invasive plant species near the project area compared to native species.
    - Extent of invasive species at a larger scale, beyond the project area—is it a discrete occurrence or widespread in the watershed?
    - Presence and potential ecological impacts of a particular invasive species on the existing plant community.
    - Setting—the importance of the area for cultural purposes or other resource values (e.g., proximal to wilderness).
    - Evaluation of whether the extent to which the proposed action or cultural practice will alter conditions conducive to the introduction or spread of invasive plant species.
- Evaluate the practicality and sustainability of implementing and monitoring the restoration actions:
    - If deemed necessary for restoration, is there a long-term commitment of funding for integrated treatments that span several years? This would take into consideration support of staffing to manage and monitor the integrated treatment and adapt as needed.

- Invasive species dependent, the timing and season of restoration involving fire may not benefit native plant species (Anzinger and Radosevich 2008, DiTomaso et al. 2006) or be prudent due to the fire season variables.
- Limitations (e.g., funding, timing, data gaps) may prioritize efforts that are “channeled, toward projects that address the most damaging invasive plants with the greatest likelihood of success” (DiTomaso et al 2006).

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Supporting Documentation

CALVEG Types

Table 5. CALVEG (Classification and Assessment with Landsat of Visible Ecological Groupings) types. Descriptions and spatial data can be found at: *www.fs.usda.gov/detail/r5/landmanagement/resourcemanagement/?cid=stelprdb5347192*.

CALVEG Code	CALVEG – Regional Dominance	CALVEG Code	CALVEG – Regional Dominance
BX	Great Basin – Mixed Chaparral Transition	DP	Douglas-Fir – Ponderosa Pine
C1	Ultramafic Mixed Shrub	DW	Douglas-Fir – White Fir
CA	Chamise	MD	Incense Cedar
CC	Ceanothus Mixed Chaparral	MF	Mixed Conifer – Fir
CK	Coyote Brush	MK	Klamath Mixed Conifer
CL	Wedgeleaf Ceanothus	MU	Ultramafic Mixed Conifer
CQ	Lower Montane Mixed Chaparral	PE	Sugar Pine
CS	Scrub Oak	WF	White Fir
CW	Whiteleaf Manzanita	CG	Greenleaf Manzanita
KP	Knobcone Pine	CH	Huckleberry Oak
SC	Blueblossom Ceanothus	CI	Deerbrush
SD	Manzanita Chaparral	CM	Upper Montane Mixed Shrub
WM	Birchleaf Mountain Mahogany	CN	Pinemat Manzanita
MP	Mixed Conifer – Pine	CP	Bush Chinquapin
PW	Ponderosa Pine - White Fir	CV	Snowbrush
DF	Pacific Douglas-Fir	CX	Upper Montane Mixed Chaparral
NX	Interior Mixed Hardwood	CY	Mountain Whitethorn
QB	California Bay	CJ	Brewer Oak
QC	Canyon Live Oak	PD	Gray Pine
QH	Madrone	QG	Oregon White Oak
QM	Bigleaf Maple	RF	Red Fir
QT	Tanoak (Madrone)	JP	Jeffrey Pine
TC	Tree Chinquapin	PP	Ponderosa Pine
TX	Montane Mixed Hardwood	QK	Black Oak

Biophysical Setting (BpS) Models

Table 6. Biophysical setting models (BpS). Descriptions and spatial data can be found at *www.landfire.gov/vegetation.php*.

BpS Model Code	BpS Model Name
310430	Mediterranean California Mixed Evergreen Forest
310280	Mediterranean California Mesic Mixed Conifer Forest and Woodland
310220	Klamath-Siskiyou Upper Montane Serpentine Mixed Conifer Woodland
311050	Northern and Central California Dry-Mesic Chaparral
311700	Klamath-Siskiyou Xeromorphic Serpentine Savanna and Chaparral
310990	California Xeric Serpentine Chaparral
310970	California Mesic Chaparral
310300	Mediterranean California Lower Montane Black Oak-Conifer Forest and Woodland
310270	Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland
310210	Klamath-Siskiyou Lower Montane Serpentine Mixed Conifer Woodland
311140	California Lower Montane Blue Oak-Foothill Pine Woodland and Savanna
310290	Mediterranean California Mixed Oak Woodland
310080	North Pacific Oak Woodland

Wildlife Habitat Relationship Types

Table 7. Wildlife habitat relationship (WHR) types present on the Six Rivers National Forest. Descriptions and spatial data can be found at *https://wildlife.ca.gov/Data/CWHR/Wildlife-Habitats*. Additional WHR types throughout the Pacific Southwest Region can be found at *www.fs.usda.gov/detailfull/r5/landmanagement/gis/?cid=fsbdev3_048103&width=full*.

WHR Type	Description	WHR Type	Description
DFR	Douglas-Fir	CSC	Coastal Scrub
COW	Coastal Oak Woodland	MHW	Montane Hardwood
PGS	Perennial Grassland	JPN	Jeffrey Pine
WFR	White Fir	PPN	Ponderosa Pine
KMC	Klamath Mixed Conifer	SMC	Sierran Mixed Conifer
MCH	Mixed Chaparral	AGS	Annual Grassland
CRC	Chamise-Redshank Chaparral	BOP	Blue Oak-Foothill Pine
CPC	Closed-Cone Pine Cypress		

Fuel Model Descriptions

Table 8. Common fuel models for each vegetation type.

Vegetation Type	Fuel Behavior Fuels Models[16]
Mixed evergreen	TU1, TU5, TU2, TL2, TL3, TL4, TL6
Moist mixed conifer	TL2, TL8, TL3, TL4, TL7, TU1, TU2, TU5
Serpentine mixed conifer	TL8, TU1, TL3, TL4, TL6, TL5
Dry mixed conifer	TL8, TU1, TL3, TL4, TL6, TL5
Red fir	TL3, TL4, TL5, TL7
Montane chaparral	TL8, SH2, SH5, SH7, GS2, GS3
Oak woodland	TL2, TL6, TL9, GR1, GR2, GR4, TU1
Pine-oak	TL8, TU1, TL3, TL4, TL6, TL5

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[16] This list of fuels models is not all inclusive but includes representative fuels models for each PFR Group/Vegetation type. Fuel model selection should be assessed at the burn plan development stage, as some PFR groups may be represented by a number of different fuel models depending on overstory tree composition, understory shrub development, stand development stage, and recent fire history. See RMRS-GTR-153: *Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model* (Scott and Burgan 2005).