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Post-fire Restoration Strategy for the 2021 Windy Fire, KNP Complex, and French Fire

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Summary

- We developed a post-fire restoration strategy based on the post-fire restoration framework (Meyer et al. 2021) for forest landscapes affected by the 2021 Windy Fire, KNP Complex, and French Fire on the Sequoia National Forest (including the Giant Sequoia National Monument) and Sequoia-Kings Canyon National Parks, which burned approximately 214,190 ac (86,680 ha).
- Over a large geographic area in the southern Sierra Nevada, we evaluated fire effects and restoration opportunities for two key resources: (1) all giant sequoia groves in the Giant Sequoia National Monument and Sequoia-Kings Canyon National Parks, and (2) fisher habitat, including habitat connectivity, from the Middle Fork of the Kings River to the southern Greenhorn Mountains on the Sequoia National Forest, Giant Sequoia National Monument, and Sequoia-Kings Canyon National Parks. Primary stressors of these resources include altered fire regimes, insects, drought, and climate change.
- We based our spatial assessment of post-fire ecological condition of sequoia groves and fisher habitat in the analysis area primarily on vegetation type, vegetation burn severity (total amount and size of high severity patches), and fire return interval departure. Additional variables analyzed included predicted post-fire natural conifer regeneration, mechanical (or other) treatment accessibility, pre-fire stand densities, climatic water deficit, and California spotted owl protected activity centers. We evaluated fisher habitat using a combination of modeled reproductive habitat, habitat connectivity, and pre-fire forest vegetation including conifer and hardwood forest types.
- Out of 15 wildfires that burned in the analysis area between 2010 to 2021, 12 wildfires managed under full suppression objectives (including the 2021 Windy Fire, KNP Complex, and French Fire) produced negative fire effects predominantly outside the natural range of variation (NRV), whereas five wildfires managed for multiple objectives (including resource objectives) resulted in consistently beneficial fire effects within NRV. About 44% of the 1.51 million acre analysis area has been burned in wildfires over roughly the past decade.
- Within our study area of the southern Sierra Nevada, about 83% of the total area of sequoia groves (20,805 ac; 70 groves total) burned from 2010 to 2021. Over 77% of this

total burned area experienced low to moderate severity fire that is generally considered beneficial in groves, with some exceptions related to the mortality of large sequoias.

- All sequoia groves that burned primarily at low severity in the past 10 to 20 years in wildfires managed for resource objectives (Cunningham, Wishon) and prescribed fires (Giant Forest, Grant, Atwell) subsequently burned at low to moderate severity in large and severe wildfires between 2015 and 2021. Additionally, several sequoia groves burned in resource objective wildfires, including the Monarch grove (burned in 2010 Sheep Complex), Burro Creek and Silver Creek groves (burned in the 2018 Alder Fire), and Middle Tule and Maggie Mountain groves (burned in the 2016 Hidden Fire) experienced limited incursion by subsequent large and severe wildfires such as the 2015 Rough Fire and 2020 Castle Fire. This supports a growing body of evidence that managed wildfires regulate the effects of subsequent wildfires across Sierra Nevada forest landscapes.
- About 33% (420 ac) of the cumulative sequoia grove area burned in the Windy Fire and 11% (763 ac) of grove area burned in the KNP Complex burned at high severity. These values were substantially lower than the percentage of forest vegetation that burned at high severity in the Windy Fire (46%) and the KNP Complex (32%), suggesting lower severity fire effects within groves relative to the surrounding forest matrix.
- Approximately 57% (702 ac) and 22% (986 ac) of total sequoia grove area burned in the Windy Fire and KNP Complex, respectively, were predicted to experience natural conifer regeneration failure under a drier scenario anticipated with climate change. Under a mean precipitation scenario, 12% (144 ac) and 9% (398 ac) of sequoia groves in the Windy Fire and KNP Complex, respectively, are expected to experience conifer regeneration failure. These model predictions are for non-serotinous mixed conifer species that excludes giant sequoia, a semi-serotinous conifer.
- About 95% of the area (203,293 ac) that burned in 2021 wildfires occurred in fisher habitat, and 40% of this area (81,923 ac) burned at high severity. The 2021 wildfires resulted in partial (*Habitat Core* area 3) to near complete (*Habitat Core* area 2) degradation of fisher habitat connectivity in the study area (based on habitat core areas described in the 2016 Fisher Conservation Strategy).

- Across 100 Potential Operational Delineations (PODs) analyzed in the study area, 71% burned outside NRV and 29% burned within NRV. 65 percent of PODs burned outside NRV in the Windy Fire, KNP Complex, French Fire, and Castle Fire.
- The restoration portfolio focused primarily on two potential forest restoration actions: (1) prescribed burning and mechanical thinning to reduce fuels loads and restore forest structure, composition, and function; and (2) reforestation and post-fire fuels reduction to reduce fuel loads and restore forest cover. These actions in combination with other recommended efforts (e.g., post-fire vegetation and wildlife monitoring) support forest restoration goals in the analysis area.
- Priority areas for the application of prescribed fire and other fuel reduction actions (e.g., mechanical thinning) to restore desired conditions over the next decade or longer included sequoia groves and fisher habitat that burned primarily at low to moderate severity, are relatively accessible, contained high pre-fire surface and ladder fuels, and are highly departed from their natural fire return interval; these live forests are generally still at risk of loss in future uncharacteristically large and severe wildfires. Priority areas are presented for both the more focused (Windy Fire, KNP Complex, French Fire) and broader (2015-2021 fires) assessment areas.
- Priority areas for reforestation and associated post-fire fuels reduction activities over the next few years include sequoia groves that burned at high severity and fisher habitat that burned outside the natural range of variation for high severity patch size. This is particularly the case in deforested but accessible areas that are unlikely to support post-fire natural conifer regeneration based on model predictions and field surveys, relatively less vulnerable to climate change, and supportive of fisher habitat connectivity where currently disrupted from fire-driven forest loss.

Background

Application of the Post-fire Restoration Framework

The-post-fire restoration framework (PSW-GTR-270, Meyer et al. 2021) provides a science-based approach to planning restoration projects in severely burned landscapes on national forests in California. It is rooted in several guiding restoration principles designed to enhance or recover ecological integrity and sustainability in landscapes with altered fire regimes. The framework uses a five-step process to spatially assess landscape condition and divide the landscape into areas where fire: (1) improved or maintained ecological conditions, (2) degraded ecological conditions and restoration actions may restore these conditions, and (3) degraded ecological conditions but restoration actions are infeasible or undesirable, resulting in the reevaluation of desired conditions. The framework's post-fire flow chart (Figure 1) identifies restoration opportunities for these three areas in the affected landscape and facilitates the development of a "restoration portfolio" that includes a suite of potential management actions designed to maintain, restore, or reevaluate desired ecological conditions. More information about the post-fire restoration framework is provided in Meyer et al. (2021).

Giant Sequoia Groves and Fisher Habitat of the Southern Sierra Nevada

The Sierra Nevada ecoregion contains an extraordinary range of habitat types, supporting many unique and endemic species (Mayer and Laudenslayer 1988). Two of these species, giant sequoia (*Sequoiadendron giganteum*) and the federally-endangered southern Sierra Nevada distinct population segment of fisher (*Pekania pennanti*) are largely endemic to the west slope of the southern Sierra Nevada (Stephenson 1996, Spencer et al. 2016), where the structure and composition of coniferous forests changed dramatically in the mid-19th century (Stephens et al. 2015, Safford and Stevens 2017). Fire exclusion and historical logging have been primary drivers in altering composition and structure in most Sierra Nevada yellow pine and mixed conifer forests (Safford and Stevens 2017), including giant sequoia groves (Stephenson 1996, York et al. 2013). Changes have included loss of fire-tolerant/shade-intolerant species (e.g., pines, giant sequoia), reduced structural heterogeneity, increased canopy cover and tree densities (especially in the smallest size classes), elevated woody fuel loads, and reduced habitat quality and diversity and increased forest fragmentation (Knapp 2015, Knapp et al. 2013, North et al. 2009, North 2012, Steel et al. 2018). Prior to Euro-American colonization, Sierra Nevada mixed conifer forests experienced frequent (burning every 11 to 16 years, on average), low to moderate severity (mostly surface) fires, but today these fires are relatively rare (Safford and Stevens 2017). However, in the past seven fire seasons these ecosystems in the southern Sierra Nevada have experienced repeated uncharacteristically large and severe wildfires that have dramatically altered the forest landscape. These severe wildfires are the result of a combination of interacting stressors, including long-term fire exclusion, drought- and insect-related tree mortality, and climate change, leading to widespread habitat fragmentation and potentially long-term forest loss

(Kolb et al. 2016, Westerling et al. 2006, Stephens et al. 2018). Recent forest restoration treatment rates in the region are not at the spatial scale necessary to address the wildfire issue (North et al. 2012), although coordinated prescribed fire and mechanical treatments may facilitate more beneficial fire within Sierra Nevada forest landscapes (North et al. 2021).

Mature mixed hardwood-conifer and conifer-dominated forest in the southern Sierra Nevada provide habitat for many species that rely on features of older forests such as multi-layered canopy, large diameter trees, and tree cavities; these mature forests also provide critical structures for fishers (endangered in the southern Sierra Nevada) to use during annual reproduction as well as daily resting bouts (Zielinski et al. 2014, Spencer et al. 2016, Green et al. 2019). In this region, tree species that provide the most consistent source of cavity microsites for denning female fishers include California black oak (*Quercus kelloggii*), white fir (*Abies concolor*), and incense cedar (*Calocedrus decurrens*); however, for daily resting, male and female fishers commonly use ponderosa pine (*Pinus ponderosa*), sugar pine (*P. lambertiana*), and canyon live oak (*Q. chrysolepus*) in addition to California black oak, white fir, and incense cedar (Green et al. 2019). The primary difference between structures used for denning and those used for resting is that reproductive females only use cavities in boles of live trees, snags, or logs when rearing young, but resting fishers (male and female) use a wide variety of microsites (e.g., broken tops, large limbs, branch clusters, cavities) throughout the year (Green et al 2019). While tree species used by fishers differ by elevation, habitat type, and local availability, many structures used for denning and resting in the southern Sierra Nevada and elsewhere are large in diameter, old, and have some amount of decay (e.g., Green et al. 2019, Weir et al. 2012, Zielinski et al. 2004). Thus, these structures are not easily replaced once removed from the landscape.

Fishers are a species with clear ties to large trees and patches of older forests, but they can benefit from habitat heterogeneity and variation in stand structure, patterns that would have existed historically in the southern Sierra Nevada (Sauder and Rachlow 2015, Safford and Stevens 2017). This is a key concept in finding a balance between retaining fisher habitat, reducing fuels to decrease risk of catastrophic fire, and finding restoration options that also benefit other key resources (e.g., sequoia groves). In addition to “old forest refugia” that provide rest and den structures, fishers need habitat that support a diverse diet, facilitate safe daily movements, and allow for more extensive travel during dispersal events within or between subpopulations. In the southern Sierra Nevada, fishers have a diverse diet that includes higher calorie mammalian prey such as Douglas, Humboldt's flying, and western gray squirrels, but they also consume birds, berries, lizards, snakes, insects, and even fungi (Zielinski et al. 1999, Smith et al. 2022, Pilgrim et al., in prep). Accordingly, heterogeneous habitat configurations are likely to provide suitable foraging habitat. Fishers also utilize areas with vegetative cover that facilitate safe travel on a daily basis and during infrequent (but important) dispersal events; the tendency of fishers to avoid more open areas is thought to be at least in part to reduce risk of predation by larger mammalian carnivores (e.g., mountain lions, bobcats), the primary source of fisher mortality in this region (Green, unpublished data, Wengert et al. 2014, Gabriel et al. 2015, Sweitzer et al. 2016). Maintaining or restoring connectivity of live forest and other vegetation on the landscape between patches of older forest (including "local linkages" in areas with reduced cover and "population linkages" between subpopulations at natural landscape constrictions) is critical for fishers in the southern Sierra Nevada (Spencer et al. 2016). Planning for a more heterogeneous landscape where fuels are strategically reduced but habitat connectivity is promoted can contribute to long-term resilience of mixed-conifer forest habitat. Reducing the risk of severe, large-scale disturbances that could eliminate remaining suitable old forest refugia of value for denning and resting for fishers would likely also benefit other old forest species such as the California spotted owl (*Strix occidentalis occidentalis*) (North et al. 2017).

Ecological restoration in fire-excluded giant sequoia groves and fisher habitat is based primarily on reductions of forest density and fuels where they exceed desired conditions and are at risk to future large and severe wildfires. This is accomplished using fire or silvicultural treatments to reestablish stand structure, composition, and function that is more likely to be resilient to future conditions (Stephenson 1999). Reforestation may also help reestablish forest cover in larger high severity patches where conifer seed sources are lacking and tree recruitment is constrained. These restoration approaches are especially critical for restoring and protecting giant sequoia groves and fisher habitat from further loss in the southern Sierra Nevada.

Windy Fire, KNP Complex, French Fire, and Other Recent Wildfires

The Windy Fire (97,573 ac; started September 9, 2021), KNP Complex (89,315 ac; September 9), and French Fire (27,302 ac; August 18) burned a total of 214,190 ac (86,680 ha) primarily on federal lands in the southern Sierra Nevada of California (Figure 2). Nearly all of the Windy Fire burned on the Giant Sequoia National Monument (67%), Sequoia National Forest (13% of fire area), and Tule River Indian Reservation (19%). The KNP Complex burned primarily in Sequoia-Kings Canyon National Parks (88%) and the Giant Sequoia National Monument (9%), with the remainder (~3%) on California state and private lands. Most of the French Fire burned on the Sequoia National Forest (81%), with the remainder on state, private, and other federal lands. Vegetation in this burned landscape was primarily a combination of ponderosa pine forest, oak woodlands, and mixed chaparral below 4500 feet elevation, and mixed-conifer forests interspersed with montane chaparral at higher elevations (4500-7500 feet). In the Giant Sequoia National Monument and Sequoia-Kings Canyon National Parks, about 96% of the area burned in the Windy Fire and KNP Complex consisted of conifer and hardwood forests. Nine giant sequoia groves totaling approximately 1284 ac (520 ha) in the Giant Sequoia National Monument burned in the Windy Fire[2], and 16 giant sequoia groves, primarily in Sequoia-Kings Canyon National Parks, totaling approximately 4386 ac (1775 ha) burned in the KNP Complex. Fire behavior during these wildfires was quite variable (Figure 3). No sequoia groves burned in the 2021 French Fire, which was located outside the historical geographic range of giant sequoia. Collectively, these fires and other recent wildfires (e.g., 2020 Castle Fire) killed many large and old sequoias in the Giant Sequoia National Monument and Sequoia-Kings Canyon National Parks, with the greatest impacts to large sequoias (by proportional area) in the Belknap Complex, Board Camp, Deer Creek, Freeman Creek and Homer's Nose sequoia groves (Stephenson and Brigham 2020, Shive et al. 2021). In comparison, the greatest impacts to large sequoias by total area burned occurred in the Freeman Creek and Redwood Mountain groves (Stephenson and Brigham 2020, Shive et al. 2021). Additionally, these 2021 fires burned notable parts of fisher habitat designated in the 2016 southern Sierra Nevada fisher conservation strategy (Spencer et al. 2016), including *Core Area* number 2 (located in the Greenhorn Mountains primarily on the Giant Sequoia National Monument and Sequoia National Forest), *Core Area* number 3 (centered on Sequoia-Kings National Parks), *Population Linkage* B (located in Bear Creek of the Tule River Watershed), and *Population Linkage* C (located in the Middle Fork of the Kings River Canyon) (Figure 2). Land management agencies and stakeholders were concerned with the potential long-term impacts of the Windy Fire, KNP Complex, and French Fire to giant sequoia

[2] Parker Peak and North Cold Spring sequoia groves in the Tule River Indian Reservation were also burned in the 2021 Windy Fire but not included in the analysis due to the lack of available spatial (i.e., grove perimeter) data.

groves, fisher habitat (including habitat connectivity), and other key resources (coniferous forests) (see below).

In the last decade (2010-2021), the landscape containing and surrounding the 2021 Windy Fire, KNP Complex, and French Fire (hereafter referred to as the ‘analysis area’) has experienced numerous wildfires with variable fire effects (Figure 4) totaling 667,043 burned acres. Most notably, the 2020 Castle Fire burned 170,648 ac (69,059 ha) including 20 sequoia groves and grove complexes in the analysis area. However, prior to the 2015 Rough Fire most of these wildfires were relatively small and much of the landscape had not burned for over a century (i.e., most of the landscape was moderately to highly departed from the historical fire return interval). A number of previous wildfires were primarily managed for resource objectives and produced stand-replacing patches that were relatively small and within the natural range of variation (NRV) and desired conditions (Table 1; generally less than 10 ac (4 ha) and not exceeding 100 to 250 ac (~40 to 100 ha)), especially for the 2010 Sheep, 2016 Hidden, 2016 Meadow, 2017 Lion, and 2018 Alder fires, which were primarily managed for resource objectives (Meyer 2015).

Assessment of Giant Sequoia Groves and Fisher Habitat at Different Spatial Scales

We conducted our assessment of sequoia groves and fisher habitat separately, while integrating both resources together in each assessment. First, we used the post-fire framework to analyze fire effects to sequoia groves across the entire analysis area (step 3, question A in Figure 1), using NRV and desired conditions as benchmarks for assessing whether fire effects to sequoia groves or forest vegetation were generally considered beneficial/neutral or negative (Table 1). Next, we considered the effect of interacting stressors (step 3, question B) on sequoia groves and the feasibility of management actions (step 3, question C) to integrate restoration opportunities into a sequoia grove restoration portfolio at relatively smaller spatial scales: sequoia groves range widely in size from 0.3 ac to 3,220 ac (0.1 to 1,303 ha) with a median grove size of 61 ac (25 ha). For the integration step (step 4), we included the consideration of fisher habitat connectivity and California spotted owl habitat (protected activity centers). We conducted this assessment at the grove scale to provide land management agencies with a finer-scale, spatially explicit analysis of post-fire grove condition and restoration opportunities for sequoia groves in the entire assessment area.

In a separate analysis, we followed a similar process to evaluate fisher habitat and habitat connectivity in the assessment area. In contrast to sequoia groves which occur in discrete and more easily identifiable locations on the landscape, fishers have historically occurred over a broad portion of the southern Sierra Nevada landscape, individual animals are difficult to locate and move around extensively, and suitable habitat is often identified through predictive models. However, we know enough about fisher habitat requirements and home range size in the southern Sierra Nevada to develop alternative strategies to reduce fuels, restore heterogeneity, and maintain habitat at appropriate spatial scales. For example, HUC watersheds (Hydrologic Unit Code, with HUC 14 being a particularly relevant size) appear to be useful potential surrogates for female fisher home range placement on the landscape (Green et al. in prep). However, we used Potential Operational Delineations (PODs) as units of analysis in our assessment to evaluate restoration opportunities for fisher. Although POD boundaries are often based on artificial features such as roads and managed fuel breaks, POD delineations overlap extensively with that of watersheds (i.e. Hydrological Units) as perimeters often overlap ridgelines and centers represent bottoms of drainages. These units not only useful for fire planning (e.g., establishing larger units for planning prescribed fire), but also have ecological value useful in land management. Using PODs as our assessment unit also allows for integration of other key ecological resources (e.g., sequoia groves, California spotted owl protected area centers (PACs) for different management activities (e.g., prescribed fire, reforestation) within a management-defined operational boundary relevant to fire behavior.

In our analysis of PODs, we extended Step 3 of the post-fire framework to first include prioritization of PODs by ecological resource value and risk (see below). With increasingly larger fires and extensive areas in need of fuels reduction to limit wildfire risk to fisher habitat, the use of PODs (or HUC 14s) can focus efforts where vegetation treatments can meet multiple resource objectives at broader spatial scales. We conducted this assessment at the POD scale to provide land management agencies with a spatially explicit analysis of post-fire condition and prioritized restoration opportunities across using PODs in the Windy Fire, KNP Complex, and French Fire and other recent wildfires (e.g., 2020 Castle Fire).

Sequoia National Forest and Sequoia-Kings Canyon National Parks Leadership Intent

Leadership of the Sequoia National Forest (SQF), which includes the Giant Sequoia National Monument (GSNM), and Sequoia-Kings Canyon National Parks (SEKI) recommended that spatial assessment of the 2021 Windy Fire, KNP Complex, and French Fire include the following considerations:

- Focal resources should include giant sequoia groves and habitat for the federally endangered Southern Sierra Nevada Distinct Population Segment (DPS) of fisher (*Pekania pennanti*), both of which are unique and highly valued natural resources of SQF and SEKI.
- Place the 2021 wildfires within the larger context of previous large wildfires, drought, and bark beetle outbreaks which have affected much of the SQF and SEKI over the past decade. This will provide a better understanding of the cumulative impacts of these stressors to focal resources.
- Evaluate opportunities for prescribed burning and identify locations that could benefit from this treatment, especially in those areas that did not burn at high severity.
- Examine opportunities for reforestation and identify locations that are likely to support natural conifer regeneration or would benefit from active planting to restore coniferous forest cover, particularly in severely burned mixed conifer and yellow pine forests.
- Evaluate fire impacts in a holistic fashion and consider additional restoration opportunities that may support desired vegetation, fuels, and habitat conditions in SQF and SEKI.

In addition to this report, initial assessments of fire effects from the Windy Fire, KNP Complex, and French Fire are covered in three separate BAER reports, a post-fire assessment of large giant sequoias (Stephenson and Brigham 2020, Shive et al. 2021), and a rapid post fire recovery assessment (USDA Forest Service 2022). The last of these reports addressed a broader array of concerns, including emergency response and public safety, infrastructure, recreation, watershed, wildlife habitat, vegetation, and other resources, particularly on the SQF.

Post-fire Restoration Framework

Step 1: Identify Priority Resources, Desired Conditions, and Restoration Goals

Although the Windy Fire, KNP Complex, and French Fire cover a large landscape composed of many vegetation types, we focused our analysis primarily on giant sequoia groves and conifer and hardwood forest types (primary habitat for fisher) based on input from SQF and SEKI leadership (see above).We reviewed and summarized desired conditions and restoration strategies for these key resources based on information provided in land management and resource planning documents (Spencer et al. 2016; USDA Forest Service 2012, 2019) (Table 2, Table 3, Table 4, Table 5). Based on these sources, we developed two restoration goals and associated analysis areas: (1) maintain and restore giant sequoia grove forest ecosystem integrity and resilience, including forest vegetation surrounding grove boundaries (i.e., grove buffers) where appropriate; and (2) maintain and restore sufficient suitable fisher habitat and connectivity (Table 2). Hereafter, we refer to the ‘analysis area’ as encompassing both focal resources, which is effectively based on the larger fisher habitat analysis area.

Step 2: Gather and Review Relevant Spatial Data

We greatly expanded the analysis area perimeter beyond areas burned in the Windy Fire, KNP Complex, and French Fire to encompass predicted fisher habitat around and between these fire footprints. Specifically, we centered on the polygons for *Core Areas* 2 and 3 (plus small portions of 1 and 4) identified in the Southern Sierra Nevada fisher conservation strategy (Spencer et al. 2016) and all HUC12 watersheds that intersected fire footprints in these core areas (Figure 2). This expanded analysis area also covered all giant sequoia groves within the Giant Sequoia National Monument and Sequoia-Kings Canyon National Parks (including mapped groves with other land ownerships), which includes approximately 96% of the total grove area in the Sierra Nevada. We identified ecological condition of vegetation prior to the fire using existing pre-fire vegetation type (classified into broad forest vegetation types; see Meyer et al. 2021) and partitioned the analysis area using potential wildland fire operational delineation (POD) boundaries for the consideration of forest restoration treatment units (particularly for prescribed burning). We focused our analysis on giant sequoia groves and fisher habitat using several existing spatial data layers including boundaries of existing sequoia groves and California spotted owl PACs (Table 6). We used datasets at various stages in this assessment to identify potential fisher habitat, including: (1) pre-drought fisher foraging model (max sum sensitivity/specificity threshold) as a very general representation of areas fishers might use (Spencer et al. 2015), (2) post-drought fisher reproductive habitat (using the ≥ 10% threshold) to represent a more narrow band of critical habitat that can support reproductive females and young (Thompson et al. 2021), (3) combined hardwood + conifer forest ("forest vegetation") with large trees (>40 inch dbh) as a proxy for fisher habitat based on presence of mature forest with potential den and rest structures as documented in Green et al. 2019 (F3 data, USFS R5 Remote Sensing Lab), and (4) changes in habitat connectivity pre and post fire (Table 6, Appendix A. Creation of a habitat connectivity layer for fisher). These datasets represent the best available information for fisher habitat, and we endeavored to use each as appropriate in data analyses and maps (See Appendix F for an overview map comparing the extent of these datasets).

We assessed post-fire ecological condition to determine the extent to which wildfire effects represented a departure from NRV and desired conditions (as defined in Table 1) in both individual fires and within PODS impacted by fire. This was evaluated using fire severity data (the four-class percent change in basal area as represented by the RAVG data) (Table 6) analyzed with four metrics: (1) high severity proportion (i.e., amount of high severity fire effects), (2) high severity patch size (including proportional area located in a large high severity patch), (3) Fire Severity Index (FSI; a composite measure of all fire effects within a wildfire that ranges from 0, or unburned, to 4, equal to high severity; fires with low to moderate severity fire effects generally range from 1, or unchanged, to 2.5, representing mostly low to moderate severity fire effects), and (4) Fire Return Interval Departure (FRID) condition class. Burned areas dominated by conifer or hardwood forest were classed as burning at less than stand-replacing severity (i.e., unchanged, low, or moderate fire severity; 0-75% change) or high severity (>75% change). We considered high severity patches dominated by forest vegetation in four patch size classes: 1) patches less than 4 ha (10 ac) in size, 2) patches between 4 ha (10 ac) and 40 ha (100 ac) 3) patches between 40 ha and 100 ha (250 ac) and 4) patches that exceeded 100 ha (250 ac) in size. Size classes 3 and 4 were considered to be moderately and extremely departed, respectively, from desired conditions and NRV (Tables 1 and 2) (Estes et al. 2021).

Step 3a: Use the Post-fire Flow Chart to Identify Restoration Opportunities for Sequoia Groves

Where did fire improve or maintain ecological conditions (or degrade conditions) and are fire effects within desired conditions or NRV? (Question A in Fig. 1)

Fire Effects in the Larger Analysis Area (1.51 million acres)

We evaluated fire severity and fire regime patterns for all 2015-2021 wildfires in our analysis area, with a focus on the 2021 Windy Fire, KNP Complex, and French Fire (Table 7, Figure 6), and compared these fire patterns with NRV and desired conditions (Table 1). All analyzed wildfires managed with full suppression objectives burned outside NRV, whereas wildfires managed for multiple (including natural resource) objectives produced fire effects within NRV (Table 7). The largest wildfires tended to produce the greatest number and total area of large (>100 to 250 ac) high severity patches (Table 7, Figure 4), many of these exceeding NRV (Figure 7). The Windy Fire, KNP Complex, and French Fire each produced more than 10,000 to 45,000 acres of high severity patches, with of most these patches exceeding 250 acres (NRV) and a number of these occurring in sequoia groves and fisher habitat (Table 7, Figure 8, Figure 9, Figure 10). The high severity patch size distributions of these fires and the 2020 Castle Fire were atypical of NRV and desired conditions (Appendix B. Fire severity, POSCRPT, and tree density analyses and maps, Figure 36).

The analysis area was also evaluated for departure from the historical fire return interval (FRID). About 44% of the 1.51 million acre study area has burned in wildfires over roughly the past decade. The 2016 Meadow Fire, a wildfire managed partially for resource objectives, burned the Cunningham Grove at low to moderate severity prior to the 2021 Windy Fire. This resulted in subsequent beneficial fire effects to the Cunningham Grove during the Windy Fire (Table 8). However, the majority of the analysis area including nearly all sequoia groves are still considered moderately departed following the Windy Fire, with substantially fewer fires occurring in the prior 50 years (1970-2020) than would have occurred historically (pre-1850).

Fire Effects in Giant Sequoia Groves

From 2010 to 2021, about 83% of the total area occupied by sequoia groves (20,805 ac) and 83% of sequoia groves (70 total) burned in the study area. About 33% (420 ac) of the total sequoia grove area burned in the Windy Fire and 11% (763 ac) of total grove area burned in the

KNP Complex burned at high severity. These values were substantially lower than the percentage of forest vegetation that burned at high severity in the Windy Fire (46%) and the KNP Complex (32%), suggesting lower severity fire effects within groves relative to the surrounding forest vegetation. Approximately 77% of the total burned area in sequoia groves (16,050 ac) experienced low to moderate severity fire effects that are generally considered beneficial to groves (see Appendix G: Photos of post-fire grove conditions in the Giant Sequoia National Monument following the 2021 Windy Fire.). This includes several groves (Cunningham, Wishon, Giant Forest, Grant, Atwell) that previously burned at low to moderate severity in wildfires managed for multiple objectives (2016 Meadow Fire for Cunningham; 2018 Alder Fire for Wishon) or prescribed fires (Giant Forest, Grant, Atwell), that subsequently burned again at low to moderate severity (high severity patches <1 ac) in subsequent large and severe wildfires (includes 2021 Windy Fire for Cunningham, 2020 Castle Fire for Wishon and Giant Forest, 2015 Rough Fire for Grant, 2021 KNP Complex for Atwell). Moreover, several sequoia groves that burned in resource objective wildfires (i.e., primarily for resource benefits), including the Monarch grove (burned in 2010 Sheep Complex), Burro Creek and Silver Creek groves (burned in the 2018 Alder Fire), and Middle Tule and Maggie Mountain groves (burned in the 2016 Hidden Fire) experienced limited incursion by subsequent large and severe wildfires such as the 2015 Rough Fire and 2020 Castle Fire. This supports a growing body of evidence that managed wildfires and prescribed fires regulate the effects of subsequent wildfires across Sierra Nevada forest landscapes (Collins et al. 2009, van Wagtendonk et al. 2012, Harris and Taylor 2017, Povak et al. 2020).

It is noteworthy, however, that Stephenson and Brigham (2020), Shive et al. (2021), and Shive et al. (2022) estimated 14% and 24% mortality in large (>120 cm or >48 inch dbh) sequoias following low to moderate severity fire effects, respectively, following recent wildfires in sequoia groves. Consequently, despite the many ecosystem benefits of low to moderate severity fire in recent wildfires, they may still lead to some undesirable outcomes in groves (i.e., loss of large iconic sequoias is considered a significant natural resource impact).

Fire effects (i.e., vegetation burn severity) from the Windy Fire and KNP Complex were highly variable among sequoia groves, ranging from predominantly low to moderate severity (e.g., Cunningham grove) to complete stand-replacement (e.g., Starvation Creek grove). Six of nine sequoia groves (67%) burned in the Windy Fire exhibited fire effects outside NRV (see

Table 1 for a description of NRV and desired conditions), and only 2 of 9 (22%) exhibited fire effects clearly within desired conditions (Table 8). In comparison, 3 of 15 sequoia groves (80%) that burned in the KNP Complex exhibited fire effects outside NRV and desired conditions, although grove size varied substantially in this fire perimeter (Table 9). Of the total grove area burned in the Windy Fire, 33% burned at high severity and 7.5% occurred in large high severity patches exceeding 250 acres. Of total grove area burned in the KNP Complex, 10.5% burned at high severity and 7.3% occurred in large high severity patches exceeding 250 acres; 95% of this large high severity area in the KNP Complex occurred in the Redwood Mountain grove. Fire effects to vegetation in the 2020 Castle Fire (Table 10) and previous wildfires (2015-2019) (Table 11) were also variable in the analysis area.

A total of 67 acres of sequoia groves burned in the Windy Fire experienced high soil burn severity (a measure of fire effects to soils rather than aboveground vegetation), especially in the Starvation Creek grove where 63% of the grove area was characterized by high soil burn severity. A total of 351 acres of sequoia groves burned in the KNP Complex experienced high soil burn severity, especially in Redwood Mountain grove.

Where do other factors threaten ecological resilience and sustainability? (Question B in Fig. 1)

Additional interacting stressors affecting the resilience and sustainability of sequoia groves in the analysis area include drought, insect outbreaks, excessive post-fire fuels, and climate change. Since most of these stressors are driven to a great extent by a combination of water availability and evaporative demand, we used climatic water deficit (CWD; an indicator of vegetation moisture stress) as our primary variable for evaluating the impacts of these stressors to sequoia groves (CWD was also highly correlated with projected future climate exposure in sequoia groves within our analysis area but had incomplete coverage). These additional stressors are described below and evaluated in the prioritization of groves for the maintenance of desired conditions (Restoration Opportunity 1), restoration of desired conditions (Restoration Opportunity 2), and reevaluation of desired conditions (Restoration Opportunity 3).

We used current (1980-2010) CWD to identify giant sequoia groves and fisher habitat that were likely to experience lower or higher levels of moisture stress currently and over the next two decades (Table 6); projected future (2010-2039) CWD was highly correlated with current CWD and was not considered separately. Areas of greater future CWD that were also extremely departed from NRV for fire severity may not be feasible sites for traditional management approaches and might require the reevaluation of desired conditions. Within sequoia groves, many areas were characterized by relatively high projected future CWD (CWD classes based on pre-defined thresholds), suggesting that these groves may be at risk of relatively high levels of moisture stress presently and in the coming decades. We also evaluated climate exposure for sequoia groves based on Thorne et al. (2016) but did not use this dataset in final evaluations, because it lacked complete coverage for sequoia groves and was highly correlated with CWD in our analysis area; climate exposure was heavily influenced by CWD and other water balance metrics (e.g., actual evapotranspiration) in predictive models for giant sequoia and mixed conifer species.

We evaluated post-fire fuels using F3-derived estimates of pre-fire small to medium diameter (1–20 and 5–20 inch dbh) tree densities across our analysis area (Table 6). We assumed that pre-fire tree densities were generally indicative of relative post-fire tree densities and ladder fuels within stands that did not burn at stand-replacing (i.e., high) severity, especially within the unchanged and low fire severity classes, the latter where tree densities generally decrease by 25% during a prescribed fire (North et al. 2007). However, we recognize that using F3 pre-fire data for approximating post-fire ladder fuels are inexact and potentially erroneous due to inaccuracies in the F3 dataset. Nevertheless, these spatial data may provide a relative estimate of ladder fuels condition within recently burned sequoia groves and fisher habitat in our analysis area. Post-fire vegetation and fuels inventory and monitoring efforts will be required to field validate F3-based estimates of post-fire tree densities and other stand conditions.

Where are management approaches feasible for the restoration of desired conditions given current and anticipated future conditions? (Question C in Fig. 1)

We evaluated the feasibility and desirability of restoration actions in the Windy Fire (Giant Sequoia National Monument) with the mechanical treatment opportunities data layer that captures topographic and road proximity constraints (North et al. 2015, Table 6). Opportunities for the application of prescribed fire and mechanical-based fuels reduction as a pre-treatment are generally more limited outside more accessible locations, such as steep slopes and areas far from accessible roads that can serve as critical anchor and control points. In the KNP Complex, we used a similar approach to the mechanical treatment opportunities data layer but based access on proximity to roads (1,000 feet from a road). Additionally, we used the mechanical treatment opportunities layer to evaluate reforestation constraints in the Windy Fire, based on the assumption that mechanical pre-treatment (i.e., salvage harvest) may be required in some sites to provide a safe and effective environment for planting sequoias and other conifers in the Giant Sequoia National Monument.

Coniferous forests that burned outside NRV, particularly large high-severity patches, may be at elevated risk of conifer regeneration failure primarily due to the lack of nearby seed sources (Welch et al. 2016). Areas that were outside of NRV (for fire severity or high severity patch size) identified in the previous step made up a significant part of the Windy Fire, KNP Complex, and French Fire (Figure 8, Figure 9, Figure 10). Using POSCRPT (Post-fire Spatial Conifer Regeneration Prediction Tool), developed by Shive et al. (2018) and refined by Stewart et al. (2020) (Table 6), we identified areas in the Windy Fire, KNP Complex, and French Fire at risk of conifer regeneration failure at five years post-fire (Figure 17, Figure 18, Figure 19).

The POSCRPT 40 to 60 percent regeneration probability class supports a median of 166 seedlings per ha (Shive et al. 2018), which is within NRV but below the Region 5 stocking standard. The median seedling density found in the POSCRPT's 60-80% regeneration probability class is 333 seedlings/ha (134/ac), which is 67% of the current stocking rate in Region 5 and also within NRV. Both of these regeneration probability classes may indicate sufficient natural conifer regeneration, although the former class (40-60% probability) likely provides a more realistic estimate that is closer to NRV and the future range of variation (including potential vegetation shifts that include more hardwoods) that we used as our post-fire regeneration threshold of concern (i.e., areas at risk of natural conifer regeneration failure; <40% probability). The latter value (60-80% probability) likely provides a more conservative estimate that attempts to restore higher conifer densities consistent with the Region 5 stocking standard by accounting for higher rates of seedling mortality associated with climate change. We evaluated natural conifer regeneration of all main mixed conifer species (e.g., Jeffrey pine, white fir), because POSCRPT does not currently predict post-fire regeneration for giant sequoia (i.e., POSCRPT results do not predict post-fire regeneration for giant sequoia in any of our outputs and results). To address the range of anticipated future conditions on potential natural conifer regeneration, we used both the average and low (i.e., below average) scenarios for precipitation and seed availability in our POSCRPT runs for the Windy Fire, KNP Complex, and French Fire. Approximately 57% (702 ac) and 22% (986 ac) of total sequoia grove areas burned in the Windy Fire and KNP Complex, respectively, are predicted to experience natural conifer regeneration failure (for non-serotinous conifers excluding giant sequoia) under a drier scenario anticipated with climate change. Under a mean precipitation scenario, 12% (144 ac) and 9% (398 ac) of sequoia groves in the Windy Fire and KNP Complex, respectively, are expected to experience conifer regeneration failure. Sequoia groves with the highest levels of conifer regeneration failure are summarized in Appendix B. Fire severity, POSCRPT, and tree density analyses and maps. Post-fire conifer regeneration predictions specific to giant sequoia are not currently available. However, recent studies and monitoring suggest giant sequoia exhibit generally similar patterns to non-serotinous conifer species in the Sierra Nevada with the lowest densities of sequoia regeneration evident in large high severity patches (Bernal et al. 2022) and higher densities in moderate severity patches and relatively small (≤4 ha) high-severity patches (Meyer and Safford 2011).

Step 3b: Use the Post-fire Flow Chart to Identify Restoration Opportunities for Fisher Habitat with Potential Operational Delineations (PODs)

Where did fire improve or maintain ecological conditions (or degrade conditions) and are fire effects within desired conditions or NRV? (Question A in Fig. 1)

Fire Effects in Potential Operational Delineations (PODs)

Using a similar approach described for assessing NRV in individual fires across the study area, we evaluated fire severity and fire regime patterns for all PODs in our analysis area impacted by 2015-2021 wildfires and compared these fire patterns with NRV and desired conditions (Table 12). Of the 138 PODs that experienced wildfires between 2015-2021, just over half of these (N=72) experienced fire effects outside of NRV (Figure 14). PODs that were classified as having fire effects outside of NRV tended to be in the center of the larger fires, while PODs on the periphery of these fires experienced fire effects within NRV. Collectively, these fires burned 220,454 acres of conifer/hardwood habitat types (32% of which burned in 2021), resulting in high severity fire effects to 46,949 acres of conifer/hardwood habitat types with >40 inch trees (36% burned in 2021) and 86,681 acres of reproductive habitat (>10% threshold – medium/high; Thompson et al. 2021) for southern Sierra Nevada fishers (55% burned in 2021) (Table 13). Fire burning at high severity can have long-term consequences for the persistence of fishers on the landscape by eliminating habitat and structures for breeding, cover to avoid predators, and places to forage. High severity fire can also further fragment suitable habitat by creating barriers for safe movement and dispersal (Figure 16). These fires also impacted linkages at population and local spatial scales; the combined effects of the 2021 Windy Fire, 2021 KNP Complex, 2021 French Fire, and 2020 Castle Fire reduced habitat connectivity across 52,488 acres (Table 13). Additional impacts to fisher habitat and habitat connectivity have resulted from large stand-replacing fire patches from other recent wildfires, particularly the 2015 Rough Fire and 2016 Cedar Fire (Figure 16).

Where do other factors threaten ecological resilience and sustainability? (Question B in Fig. 1)

We considered all PODs that experienced fire effects outside of NRV and those PODs that burned within NRV, but that were at high risk of future high severity fire, to require additional management consideration to increase the resilience and sustainability of fisher population. To determine PODs most in need of management to reduce fuels, we first classified each ecological resource (fisher habitat, sequoia groves and California spotted owl PACs) within each POD as Low, Moderate, and High based on the remaining unburned habitat (fishers—composite score) or their total area (sequoia groves, PACs) within a POD (Table 30 in Appendix C. Classification criteria used to evaluate and prioritize PODs in need of fuel reduction and reforestation treatments). To identify PODs most in need of active reforestation, we followed a similar process but used separate criteria for evaluation of priority resource needs within PODs (Table 31 in Appendix C. Classification criteria used to evaluate and prioritize PODs in need of fuel reduction and reforestation treatments). Potential for shorter-term success of reforestation-efforts were characterized by the risk of regeneration failure and longer-term by climatic water deficit. Ecological restoration need was classified as Low, Moderate, and High based on the amount of burned habitat (fishers—composite score) or their total area (sequoia groves, PACs) within a POD. This process was completed for the Windy Fire (Table 15), KNP Complex (Table 16), French Fire (Table 17), and Castle Fire (Table 18).

Steps 4 and 5. Restoration Portfolio for Sequoia Groves

Restoration Opportunity Ia: Prescribed fire and other fuels reduction activities to promote desired conditions over the next decade

In sequoia groves that burned primarily at low to moderate severity, the promotion of desired forest conditions could be achieved through: (1) maintenance of fire using prescribed burning in areas that burned at low to moderate severity to reestablish natural fire regimes, (2) application of fuel breaks, variable-density thinning, or other mechanical treatments in strategic locations (e.g., surrounding grove administrative and natural boundaries) to break up the continuity of post-fire fuels, and (3) the reintroduction of fire in unburned (i.e., fire excluded) giant sequoia groves with the full suite of restoration approaches (e.g., prescribed fire, mechanical thinning) within the analysis area to reduce fuel loading and reestablish a key ecological process. Priority areas for this restoration opportunity can be refined based on spatial fire behavior modeling and other decision-support tools, field validation, and expert opinion. Restoration opportunities at the POD scale for fisher habitat and sequoia groves are summarized in the following section (Steps 4 and 5. Restoration Portfolio for Fisher Habitat Using Operational Delineations).

Maintenance of fire with prescribed burning

Sequoia groves that burned primarily at low severity and are moderately departed from their historical fire return interval (i.e., moderate FRID departure; burning less frequently over the past 50 to 100 years compared to the historical fire frequency) may still be outside NRV and desired conditions with respect to vegetation structure (e.g., fuel loading) and composition (e.g., relative density of shade-tolerant conifers). For instance, sequoia groves that burned at low severity may continue to be characterized by homogenous forest structure and elevated fuels and tree densities susceptible to future severe wildfires, bark beetle outbreaks, drought, and other stressors (Figure 20, top panel). In such cases, prescribed fires and wildfires managed for resource objectives, applied in the near-term (next 5 to 10 years) or long-term (>10 years), could restore stand structure, reduce fuel loads, and increase the resilience of sequoia ecosystems, particularly in areas where mechanical treatments are limited due to access (North et al. 2015). In recently burned (and unburned) stands, mechanical thinning prior to prescribed burning may be necessary to reduce hazardous fuels and more quickly restore forest structure and composition, especially in areas with high fuel loading (Stephens et al. 2009) and areas that experience delayed post-fire tree mortality associated with bark beetles that can result in increased fire severity (Stephens et al. 2018, Wayman and Safford 2021). Prescribed burning could be applied either in the short-term (i.e., next decade) or the long-term (10+ years) depending on the post-fire fuels and stand structural conditions within and adjacent to a sequoia grove (Table 14). Such information could be obtained from post-fire vegetation and fuels monitoring data.

We identified sequoia groves that burned within NRV, resulting in beneficial fire effects that promoted desired conditions (Restoration Opportunity 1, Table 14). These areas and others that have experienced long-term fire exclusion would be targeted for prescribed fire, alone or in combination with mechanical thinning, to help achieve the primary restoration goals, desired conditions, and restoration strategies for sequoia groves (Table 2, Table 3, Table 4, Table 5). Based on our prioritization assessment[3], priority groves included those that burned at primarily at low to moderate severity (or fire excluded), are relatively accessible to mechanical equipment and prescribed fire crews, contain elevated fuel loads and stand densities, are critical areas of habitat for fisher (especially linkage areas for habitat connectivity) and California spotted owl, and are relatively more susceptible to moisture stress. Priority sequoia groves targeted for prescribed fire and other fuels reduction activities are shown in Table 14, Figure 23, and Figure 24 for the Windy Fire and in Table 21 for the KNP Complex. In the entire analysis area, high priority groves for prescribed fire and other fuel reduction activities are listed in Table 23. Priority areas for prescribed fire and other fuel reduction treatments in sequoia groves are shown in Figure 25 (Windy Fire), Figure 27 (KNP Complex), and Figure 29 (French Fire).

Fuel breaks, variable-density thinning, and other strategically placed mechanical treatments

The maintenance or creation of strategic fuel breaks and forest restoration treatments (e.g., variable-density thinning) adjacent to sequoia groves can reduce the spread and impact of uncharacteristically severe wildfires and promote the broader-scale use of prescribed fire across the forest landscape (North et al. 2021; Appendix D. Pyrosilviculture approach to restoring forest landscapes in the Giant Sequoia National Monument). These strategic fuel breaks and other forest thinning treatments could be particularly effective for groves that are: (1) recently treated using prescribed burning and/or mechanical thinning to restore grove structural conditions (especially reduced fuel loading), and (2) surrounded by access roads on at least two sides or in areas where mechanical accessibility exists within approximately 1,000 feet of a grove boundary. Following the application of restoration treatments within groves (a necessary first step), forest thinning treatments could be applied immediately adjacent to the administrative boundaries of groves in the Giant Sequoia National Monument, that typically include a 300- to 500-foot buffer

[3] Prioritization of sequoia groves for prescribed burning was based primarily on identifying the total number of grove acres that burned at low to moderate severity (or fire excluded) and were relatively accessible for fuel reduction actions (mechanical treatment scenario D). These areas were then scored higher if they contained areas of higher: (1) climatic water deficit, (2) FRID condition class (increased departure), (3) pre-fire fuels, and (4) overlap with fisher habitat and California spotted owl protected activity centers. In particular, essential areas of habitat connectivity for fisher were given high priority.

around actual grove boundaries. Or treatments could be applied within natural grove boundaries where they may more effectively achieve forest restoration objectives (e.g., increase in forest heterogeneity and resilience through variable density thinning followed by prescribed fire; North et al. 2009, North 2012) in addition to strategic fuel reduction objectives designed to control uncharacteristic wildfire spread and increase the "pace and scale" of prescribed fire and managed wildfire (North et al. 2021). Sequoia groves that meet these criteria include Long Meadow, Packsaddle, Redhill, and Deer Creek, although only a small portion of Deer Creek burned at low to moderate severity where these forest restoration approaches would be effective (see Restoration Opportunity II: Reforestation and post-fire fuels reduction to restore desired conditions in areas where management actions are feasible) (Table 14, Table 23).

Restoration of fire-excluded sequoia groves with the full suite of restoration approaches

In the analysis area, there are 14 sequoia groves that have not burned in the past decade and have experienced over a century of fire exclusion (Figure 20, bottom panel). Although some exceptions exist (e.g., all three BLM Case Mountain groves partially burned in the 1980s), nearly all of these areas have some degree of excessive tree densities and other fuels that creates an elevated risk of uncharacteristically large and severe wildfires and insect outbreaks (Figure 39, Figure 40, Figure 41, Figure 42). These areas could be prioritized for restoration using prescribed burning and mechanical thinning, with the latter treatment designed to prepare stands for safe and effective prescribed fire entry and to achieve more precise restoration objectives (e.g., decrease in medium diameter trees to increase stand resilience and health). The unburned Bearskin, Landslide, Indian Basin, and Big Stump groves that are relatively accessible are considered high priorities for mechanical and prescribed fire treatment (Table 23).

Restoration Opportunity Ib: Prescribed fire and managed wildfire to maintain desired conditions in twice burned groves in the long-term (≥ 10 years)

Sequoia groves that burned primarily at low to moderate severity twice in the past 50 to 100 years are within NRV with respect to fire regime and, oftentimes, forest structural characteristics (Figure 21, top panel). As shown in step 3 of this process, many of these twice burned groves and other repeatedly burned forested areas were the result of earlier prescribed burns and managed wildfires, which resulted in beneficial fire effects within NRV (e.g., Table 7). In the near future (next five years), these areas, particularly sequoia groves, could be targeted for post-fire ecological monitoring surveys to evaluate whether forest structure and composition is within NRV and desired conditions (Table 14, Table 23), such that a future wildfire would result in minimal impacts to forest ecosystem function and integrity. Priority sequoia groves that continue to exceed NRV with respect to forest structural characteristics, despite recent beneficial fire effects, could be targeted for wildland fire treatment within the next decade (North et al. 2012). In contrast, other forested areas that meet desired conditions could be the focus of planned wildland fire treatments over the long-term (>10 years) after monitoring and assessing post-fire vegetation change and fuel deposition rates in these areas.

Restoration Opportunity II: Reforestation and post-fire fuels reduction to restore desired conditions in areas where management actions are feasible

In the Windy Fire, KNP Complex, and French Fire, high severity burned sequoia groves may be noticeably departed from NRV or desired conditions. These areas represent restoration opportunities to restore giant sequoias and essential forest cover through reforestation efforts where natural conifer regeneration, as predicted for non-serotinous conifer species, is unlikely to occur (Figure 17, Figure 18, Figure 19). In the Giant Sequoia National Monument, associated site preparation and fuel reduction (e.g., salvage) actions may be needed to reduce competing vegetation, create a safe planting environment for reforestation crews, and diminish the potential for high severity reburns (Table 14, Figure 21). In the Windy Fire, priority areas for reforestation activities[4] in sequoia groves are listed in Table 20 and shown in Figure 23 and Figure 24. In the KNP Complex, priority areas for reforestation activities in sequoia groves are listed in Table 22. In the larger analysis area, high priority sequoia groves for reforestation activities are summarized in Table 23 and shown in Figure 25 (Windy Fire), Figure 27 (KNP Complex), and Figure 29 (French Fire). Within sequoia groves that burned in the 2020 Castle Fire, potential priority areas for reforestation based on POSCRPT predictions and accessibility considerations are summarized in Appendix B. Fire severity, POSCRPT, and tree density analyses and maps.

Climate-smart reforestation actions would greatly increase the long-term success and restorative value of planted seedlings. Several best practices for reforestation when considering

[4] Prioritization of sequoia groves for reforestation was based primarily on identifying the total number of grove acres that had a low (<40%) probability of natural conifer regeneration (from POSCPRT) and were relatively accessible for reforestation actions (mechanical treatment scenario D in GSNM; distance to road for SEKI). These areas were then scored higher if they contained: (1) a greater acreage of high soil burn severity, and (2) overlap with areas of critical fisher habitat connectivity.

changes in climate and fire regimes are summarized in North et al. (2019) and presented online (https://climate-wise.shinyapps.io/reforest_toolkit/). Several of these best practices include: (1) using topographic and microsite variation to vary seedling densities based on site productivity and available soil moisture; (2) creating a heterogeneous spatial arrangement to emulate a pattern of individual scattered trees, clumps of trees, and openings (ICO) that are more likely to be resilient to interacting stressors; (3) applying prescribed burning in young stands to reduce fuel loads and increase their resilience; (4) promoting mixed-species stands dominated by drought and fire-resistant trees such as pines and hardwoods, particularly in drier areas (e.g. southwest-facing slopes), and (5) considering current and future site suitability and avoiding planting conifers in marginal areas near the edge of its distribution (e.g., lowest elevation sites). For a graphic example of climate-smart reforestation, see Appendix E. Climate-smart reforestation example from North et al. (2019).

The regeneration and recruitment of relatively shade-intolerant tree species (e.g., giant sequoia, sugar and Jeffrey pines, black oak) would restore several desired conditions using restoration strategies specific to sequoia groves (Table 2, Table 4, Table 5), particularly within high severity patches where natural seed sources are limited (i.e., generally exceeding 50 to 200 m from a green seed tree; Collins and Roller 2014, Welch et al. 2016, Shive et al. 2018). Additional science publications (e.g., North et al. 2019) and decision support tools (e.g., USDA 2022) can provide science-based guidance for reforestation activities to restore desired conditions in sequoia groves and other mixed conifer forests. Associated post-fire regeneration monitoring of giant groves (e.g., Bernal et al. 2022) could guide reforestation efforts by identifying target areas that contain insufficient regeneration of sequoias and other conifers. Moreover, monitoring data could be used to assess the accuracy of post-fire conifer regeneration prediction models (e.g., POSCRPT, used in this assessment) for predicting post-fire regeneration in giant sequoia and other mixed conifer species, which would guide future reforestation efforts in sequoia groves. Notably, post-fire conifer regeneration prediction models like POSCRPT that is based on non-serotinous conifers species currently lack information for giant sequoia, a semi-serotinous species, and post-fire monitoring data would help address this information gap.

Restoration Opportunity III: Reevaluate desired conditions in severely burned sequoia groves and fisher habitat that experienced dramatic forest loss

Some severely burned sequoia groves where fire effects are greatly outside NRV (i.e., sequoia grove burned area exceeding 50% high severity or within large high severity patches) and are inaccessible may be unsuitable for the attainment of desired conditions in the near future (Table 14). This is particularly the case in remote forest stands of high moisture stress (e.g., high climatic water deficit, south-facing slopes at lower elevations) with elevated levels of pre-fire drought-induced tree mortality. In these areas, management actions may not be feasible for the restoration of current desired conditions in the foreseeable future (e.g., reestablishment of large sequoias in high severity patches), and a new set of desired conditions may be better aligned with likely future conditions (Figure 25, Figure 27, Figure 29). For example, semi-accessible sequoia groves burned primarily at stand-replacement severity could be reforested at lower densities and in new spatial arrangements to reestablish a new cohort of sequoias that could be resilient to future warmer and drier conditions. Alternatively, assisted migration approaches could be considered and planned to establish young stands of sequoias in new locations at higher elevation or other climate refugia based on desired outcomes, feasibility, and climate envelope model predictions. In severely burned coniferous forest that is relatively inaccessible, vegetation could transition to a new ecosystem type with minimal management intervention, such as broadleaf woodland or chaparral that support similar, reduced, or new ecosystem services (Millar and Stephenson 2015). Even in accessible locations (e.g., strategic fuel breaks and other treatment areas), conifer forests transitioning to hardwood forests could be facilitated through vegetation management techniques (including cultural burning) that promote resilient species such as black oaks (Long et al. 2017).

Forest management efforts could also focus on a subset of more feasible desired conditions for sequoia groves and other coniferous forests to achieve some long-term restoration goals. In areas of the Windy Fire and KNP Complex that burned within NRV, this may include maintaining or establishing many fine-grained and irregularly shaped forest canopy openings (especially in drier topographic positions and low productivity sites) within approximately 10% of the forest landscape to promote early successional habitat. In severely burned areas of the Windy Fire and KNP Complex, this may also include providing some patches of moderate to dense tree or shrub cover to support forest habitat connectivity for forest-dependent species.

Additional desired conditions for sequoia groves could be developed based on climate adaptation recommendations and approaches (e.g., North et al. 2019, Swanston et al. 2020).

Additional Potential Management Actions and Decision-Support Tools Relevant to Multiple Restoration Opportunities

Management actions to restore desired conditions in sequoia groves and surrounding conifer forests encompass a wide range of treatment recommendations and other activities besides prescribed burning and mechanical thinning. Recommendations for fisher habitat are addressed in the following section. Additional post-fire restoration actions may include watershed restoration, control and eradication of non-native invasive plants, promotion of black oaks and other plant species of tribal importance through cultural burning and other traditional practices, habitat improvements that create denning and nesting structures for fisher and spotted owl, meadow and riparian restoration, and other management approaches (e.g., restoration approaches that promote biodiversity or additional species of conservation concern).

Several decision support tools (DSTs) are available or in development that can help with prioritizing areas for restoration. As mentioned earlier, reforestation DSTs are provided on the USDA California Climate Hub's website (USDA 2022). Forest restoration treatment DSTs includes Conservation Biology Institute's EEMS-based modeling system and associated project specifically designed to prioritize fisher habitat within the analysis area. This DST is currently being refined to address major changes to the landscape resulting from recent wildfires. Additional DSTs that could assist in planning forest restoration treatments in the analysis area include the ACCEL and PROMOTe tools project by the USFS (Pacific Southwest Research Station and Region 5 Remote Sensing Lab), Vibrant Planet's LandTender web-based platform, and other DSTs. In addition to DSTs, upcoming land management workshops and symposia (e.g., Southern Sierra reforestation and climate change workshop) could help inform future reforestation and other land management efforts in the analysis area.

Steps 4 and 5. Restoration Portfolio for Fisher Habitat Using Operational Delineations

Management actions to ensure the persistence of fisher habitat and other key resources require management to retain the remaining unburned habitat and restore desired conditions in areas that burned with high severity effects. Approximately 578,520 acres within the study area that did not burn at high severity area and may need fuel reduction and forest restoration treatments (e.g., reduce densities of small and medium trees and surface fuel loads), of which only 127,598 acres (22%) are accessible via mechanical equipment. Within areas that burned at high severity across the study area from 2015-2021, 84,390 acres are estimated to experience conifer regeneration failure under a mean precipitation scenario, and only 28,772 acres (34%) are mechanically accessible. Collectively the acreage that is most in need of management to address key ecological resources is often not accessible and will require innovation in management practices, such as prescribed burning or seeding of more easily established species. Below is a restoration portfolio for the 2021 fires that is also summarized in Table 14. Post-fire restoration considerations specific to fisher habitat across multiple scales are presented in appendix F (Appendix F. Restoration opportunities for fisher in a post-fire landscape). Additional restoration considerations in fisher habitat are provided in appendices D and E (Appendix D. Pyrosilviculture approach to restoring forest landscapes in the Giant Sequoia National Monument; Appendix E. Climate-smart reforestation example from North et al. (2019)). Spatially explicit actions for the 2021 Windy Fire, 2021 KNP Complex, 2021 French Fire and the 2020 Castle Fire are presented in Figure 26, Figure 28, Figure 30, and Figure 31, respectively.

Restoration Opportunities I and IIa: Prescribed fire and other fuels reduction activities to maintain and promote desired conditions over the next decade

Although most of the PODs in the analysis area burned outside of NRV, PODs burning within NRV and with moderate to low fuel loads are likely to be more resilient to high intensity fires in the short-term. These areas could be monitored to evaluate whether current conditions are similar to desired conditions (Restoration opportunity I; Table 14).

Prescribed fire and other fuel reduction actions (e.g., mechanical thinning) could be applied in portions of priority PODs to reduce the risk of uncharacteristically large and severe wildfires and other stressors to fisher habitat and other key resources. Prioritized PODs and associated acreages for fuels reduction treatments in each POD are shown and summarized for the Windy Fire (Table 24, Figure 26), KNP Complex (Table 25, Figure 28), French Fire (Table 26, Figure 30), and Castle Fire (Table 27, Figure 31). PODs that are of high ecological value could be prioritized according to risk. Ideally, the proportion of a POD (or alternatively HUC14) considered for fuels reduction treatments could be limited in certain areas or fuel reduction activities could be alternated between adjacent units in a given year to balance the need for implementing treatments and limiting impacts to fishers currently living in the area. By retaining sufficiently large undisturbed live forest patches within individual PODs (or HUC 14s) or across adjacent units, fishers could presumably find sufficient suitable habitat to survive and reproduce (even if some are temporarily displaced or impacted), while fuels reduction projects are planned and implemented.

Restoration Opportunity IIb: Reforestation to restore desired conditions in areas where management actions are feasible

Areas within each POD that are most in need of active reforestation are presented for the Windy Fire (Table 24), KNP Complex (Table 25), French Fire (Table 26), and Castle Fire (Table 27); see associated figures noted above. PODs of high ecological value could be prioritized for reforestation particularly where natural conifer regeneration is most limited (e.g., large high-severity patches). Reforestation actions may also require additional forest management treatments to decrease competition from shrubs and reduce post-fire fuels.

Restoration Opportunity III: Reevaluate desired conditions in severely burned PODS that experienced dramatic forest loss

Given the increasing size and severity of recent wildfires and area in need of management, areas predicted to have limited natural post-fire conifer regeneration and high-water stress may need to be reevaluated for future desired conditions (Table 14). Although these areas were dominated by conifers in the past, future climatic conditions and forest management constraints (e.g., accessibility) may prevent many of these areas from being successfully reforested with conifers even with significant long-term investment. Many of these areas will transition to hardwood forests with some minor component of conifers that may still benefit fisher by providing suitable resting, denning, and foraging habitat.

Additional Potential Management Actions and Decision-Support Tools Relevant to Multiple Restoration Opportunities

See Additional Potential Management Actions and Decision-Support Tools Relevant to Multiple Restoration Opportunities above for a discussion of these topics.

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Tables

Table 1. Fire severity metrics and their desired conditions for wildfires that burned giant sequoia groves and fisher habitat in the analysis area, including the Giant Sequoia National Monument, Sequoia National Forest, and Sequoia-Kings Canyon National Parks in California. Desired conditions are based on supporting documents for the revised Sequoia Forest Plan, Giant Sequoia Monument Plan, Southern Sierra fisher conservation strategy, and other sources.

Fire severity metric	Desired Condition (% of burned landscape)[a]
High severity proportion[b]	<10% in sequoia groves (100%) <15% in coniferous and hardwood forest vegetation (100%)
High severity patch frequency attributed to very large and extremely large patches[c]	Very large patches (100-250 ac) are rare (<1%) Extremely large patches (>250 ac) are absent (0%)
High severity patch frequency attributed to small and medium patches[c]	Small patches (≤1 ac) are frequent (>60%) Medium patches (2-10 ac) are infrequent (<30-35%) Large patches (10-100 ac) are uncommon (<5-10%)
High severity patch frequency within sequoia groves or fisher habitat (%)	<5% occurs in large patches (10-50 ac) 0% occurs in very large and extremely large patches (>50 ac)
Fire severity index[d]	≤2.0 within sequoia groves and fisher habitat (primarily low to moderate severity fire effects) (100%) ≤2.25 within other coniferous and hardwood forests (100%)
Fire Return Interval Departure condition class (CC)	Either CC 1 (low departure) or CC 2 (moderate departure)

[a] Desired conditions for fire severity indicators in sequoia groves and fisher habitat are assumed to be on the lower end of NRV to minimize impacts to this key resource.

[b] Proportion of each wildfire that burned at high severity (>75% basal area reduction)

[c] High severity patch frequency refers to the frequency of occurrence of all high severity patches within a fire (see Figure 36).

[d] Fire severity index (FSI) is a composite measure of all fire effects within a wildfire that ranges from 0 (unburned) to 4 (high severity). Fires with low to moderate severity fire effects generally range from 1 (unchanged) to 2.5 (low to moderate).

Table 2. Desired conditions for giant sequoia groves, fisher habitat, and conifer forests in the post-fire analysis area (Giant Sequoia National Monument and Sequoia-Kings Canyon National Parks).

Ecosystem Component	Giant sequoia groves	Fisher
Vegetation Structure and Composition	Groves are resilient to climate change and other stressors. Forest composition is patchy, consisting of a variable mixture of conifer and hardwood trees as well as shrubs. Spatial distribution of vegetation is variable and heterogeneous. Most forest stands are characterized by low tree densities and fuel loads, with frequent and variable canopy openings especially in drier topographic positions.	Old forest structure (large trees and snags, spatial heterogeneity, canopy cover) provides foraging, resting, and denning habitat.
Fire Regimes	Groves are within the natural range of variation for mixed-conifer forests, with fires typically burning at low to moderate severity with some high-severity patches interspersed.	There is a low risk of high severity fire to fisher habitat.
Objects of Interest and Key Habitat Elements	Large sequoias and other objects of interest are protected from the undesirable impacts of wildfires and other stressors.	Large live and dead trees are common and well-distributed across the landscape, especially large pines, black oaks, sequoias, and trees containing cavities and deformities.
Regeneration and Connectivity	Periodic flushes in oak, pine, and sequoia regeneration replace mortality in older trees.	Habitat linkage areas maintain connectivity between habitat core areas, including patches of moderate to dense tree canopy cover where conditions permit or shrub cover where tree cover is lacking.

Table 3. Primary restoration goals and their associated analysis areas.

Primary Restoration Goals	**Analysis Area**
Maintain or restore giant sequoia grove ecosystem integrity, diversity, and resilience, including forest vegetation surrounding grove boundaries	All giant sequoia groves, recently burned (2015-2021) and fire excluded, within the Giant Sequoia National Monument and Sequoia-Kings Canyon National Parks.
Maintain sufficient habitat suitability and connectivity for fisher	Fisher habitat *Core Areas* 2 and 3 (from 2016 Conservation Strategy) and all HUC12 watersheds that intersected recent wildfires that burned in these core areas.

Table 4. Ecological restoration strategies for giant sequoia groves and fisher habitat in the Giant Sequoia National Monument Plan.

Ecological Restoration Strategy:
1. Emphasize the protection of large giant sequoias and other trees (especially black oaks, pines, incense cedar, and red fir) from severe wildfires and other stressors.
2. Restore essential ecological processes and patterns (e.g., natural fire regimes, structural heterogeneity) to reduce impacts of current stressors.
3. Provide additional protection to named giant sequoias from wildfires, and other stressors. Protect these trees by removing surface and ladder fuels that could promote undesirable fire effects and behavior (e.g., crown fire).
4. Improve stand resilience and health by varying spacing of trees both inside and outside of giant sequoia groves and fisher habitat.
5. Where not meeting desired conditions, reduce ladder fuels, shrubs, and downed woody material.
6. Promote heterogeneity in plantations and young stands by encouraging more diversity in species composition and age. Reduce stand density in young stands and encourage shade-intolerant species such as giant sequoia, pines, and oaks.
7. Encourage natural regeneration of tree species, including giant sequoia. In areas where natural regeneration is not likely, use planting as determined in site-specific project analysis.
8. Improve the potential for forest ecosystems to return to desired conditions following natural disturbances, such as the use of prescribed fire, managed wildfire, or mechanical treatments to reduce ladder fuels or tree densities.

Table 5. Ecological restoration strategies for giant sequoia groves and fisher habitat in Sequoia-Kings Canyon National Parks and Giant Sequoia National Monument.

Ecological Restoration Strategy:
1. Protect sequoia groves and core fisher habitat features within NRV and those areas recovering from 2020 and 2021 fires from re-burns. Create and maintain fuel breaks, reduce ladder fuels, shrubs, and downed woody material.
2. Adopt a multi-agency, landscape partnership to coordinate resources and activities. Refer to issues and outcomes of the George Wright Society Fire 24/7/365 workshop of Spring 2021.
3a. Restore ecological process: Frequent, low severity fire regime through combinations of mechanical and fire treatments in unburned buffer areas and across the multi-burn landscape.
3b. Restore landscape patterns: Structural heterogeneity by way of managing for multiple seral stages, Individual-Clump-Open (ICO) patterns, and variable tree spacing. Create larger heterogeneous patterns following POD-based assessments in this report.
4. Develop regional partnerships for revegetation of large, burned patches. Coordinate seed sourcing, collections, increase, and storage. Create central repositories for revegetation best practices and test new techniques. Encourage natural regeneration of tree species, including giant sequoia. In areas where natural regeneration is not likely, use planting as determined in site-specific project analysis.
5. Promote heterogeneity in young stands by encouraging more diversity in species composition and age. Reduce stand density in young stands and encourage shade-intolerant species such as giant sequoia, pines, and oaks. Facilitate species shifts along climate gradients.
6. Maintain sufficient large diameter snags, large live trees with hollows, and create fisher habitat features with large woody debris on the ground.
7. Monitor fisher use and potential adaptations to modified landscapes.
8. Prioritize areas for maximum fire suppression as burned areas recover. (For fisher, consider incorporating information on known recent occurrence to facilitate population persistence.)

Table 6. Resources and spatial datasets used in the post-fire assessment. Several spatial data sources (e.g., natural conifer regeneration, fire severity) would benefit from field validation and verification.

Resources	**Spatial Data**	**Explanation**
Giant sequoia groves (actual grove boundaries)	Giant sequoia management areas (R. Hart, USFS R5 Remote Sensing Lab)	The sustainability of giant sequoia groves is essential in the Giant Sequoia National Monument and Sequoia & Kings Canyon National Parks
Fisher foraging habitat (boundaries)	Fisher foraging habitat model, pre-drought (max sensitivity/specificity; Spencer et al. 2015)	Maintenance and restoration of habitat that supports a varied but calorie sufficient diet is critical to persistence of fishers in the southern Sierra Nevada
Fisher reproductive habitat (boundaries)	Fisher reproductive habitat model, post-drought (Thompson et al. 2021)	Maintenance and restoration of fisher reproductive habitat is critical to the persistence of the fisher population in the southern Sierra Nevada
Fuel loading	F3-derived estimates of pre-fire small to medium diameter (1–20 and 5–20 inch dbh) tree densities (30-m pixel) (USFS R5 Remote Sensing Lab)	High densities of small to medium diameter trees can increase the potential for high intensity fire
Large trees (<40 inch dbh)	F3-derived estimates of pre-fire large diameter (>40 inch dbh) tree densities (30-m pixel) (USFS R5 Remote Sensing Lab)	Large trees are used as structures for breeding for both fisher and CA spotted owls
Watersheds	Watershed (HUC12) (USGS National Hydrography Dataset)	Watershed boundaries can help delineate landscape-scale units important to watershed processes (e.g., runoff)
Pre-fire coniferous and hardwood forest vegetation	EVeg (see Estes et al. 2021)	Conifer and hardwood forests provide numerous ecosystem services including carbon sequestration, soil stabilization, and biodiversity.
Post-fire natural conifer regeneration probability	POSCRPT - Shive et al. (2018); Stewart et al. (2020) Field assessment –Welch et al. (2016)	Natural conifer regeneration is essential for reestablishment and resilience of conifer forest vegetation following fire.
Fire	Vegetation burn severity (RAVG) (30-m pixel)	Fire severity based on RAVG data displays the magnitude of fire effects to vegetation in four categories of percent change in basal area
Climate change	Climatic Water Deficit (CWD) from BCM – current	CWD and climate exposure estimates long-term vulnerability of vegetation to climate change

Resources	Spatial Data	Explanation
	and projected for 2010-2030 (270-m pixel)	
Fireshed boundaries for prescribed burning planning and wildfire management operations	Potential wildland fire Operational Delineations (PODs) (Thompson et al. 2016)	Potential wildland fire Operational Delineations, or "PODs", are used to spatially plan strategic responses to fires (prescribed fire, wildfire) based upon potential control locations.
Mechanical treatments opportunities	North et al. 2015	Dataset identifies areas on the landscape that are accessible for mechanical treatments
Soil burn severity	Burned Area Reflectance Classification (BARC)	Soil burn severity may refine priority areas for reforestation by identifying areas in need of reestablishing soil productivity (e.g., high soil burn severity)
Roads	USFS roads	Access roads surrounding GSNM sequoia groves help identify areas for potential strategic fuel breaks.
PatchMorph tool for burn severity analysis	Stevens et al. 2021 in Meyer et al. 2021	Tool delineates contiguous high severity patches and calculates patch size in forest vegetation.
Circuitscape tool	McRae et al. 2021	Tool predicts habitat connectivity iteratively using an all-directional moving window.
California spotted owl Protected Activity Center (PAC)	USFS R5	California spotted owl PACs represent the best available 300 acres of nesting, roosting, and foraging habitat

Table 7. Percent of burned area attributed to high severity fire and large high severity patches within wildfires that burned in the analysis area (2015-2021; ≥1,000 ac). Focal wildfires in our analysis area are highlighted in gold. Wildfires are ordered by year of incident. All fire severity measures are estimated for forest vegetation (conifer and hardwood) only (i.e., excludes non-forest vegetation such as chaparral).

Fire Name (Year)[a]	High Severity (%)	High Severity in Patches 100-250 ac (%)	High Severity in Patches >250 ac (%)	Mean (and Maximum) High Severity Patch Size (ac)[b]	Fire Severity Index	Fire Effects within NRV
Sheep (2010)[c]	3	0	0	2 (48)	1.8	**Yes**
Cabin (2015)	11	0	10	95 (677)	1.8	No
Rough (2015)	16	4	15	6 (1942)	2.1	No
Jacobson (2016)	20	12	0	55 (192)	2.0	No
Cedar (2016)	57	3	40	221 (9567)	3.1	No
Hidden (2016)	6	0	0	8 (15)	1.8	**Yes**
Meadow (2017)	11	2	0	30 (103)	1.6	**Yes**
Lion (2017)	12	0	0	14 (88)	2.1	**Yes**
Schaeffer (2017)	36	0	7	24 (347)	2.6	No
Pier (2017)	21	3	3	34 (822)	2.0	No
Alder (2018)	4	0	0	17 (17)	1.3	**Yes**
Eden (2018)	3	0	0	2 (11)	2.1	Yes
Castle (2020)	40	3	20	98 (6635)	2.8	No
Windy (2021)	46	2	30	156 (6212)	2.9	No
KNP Complex (2021)	32	2	11	51 (2488)	2.5	No
French (2021)	43	4	19	76 (2642)	2.9	No
Walkers (2021)	26	1	0	40 (556)	2.5	No

[a] Fires in bold were managed for multiple objectives including resource objectives and typically contain high severity patches that do not exceed 100 to 250 acres in size (i.e., fire effects are within NRV and desired conditions). All other wildfires were managed with full suppression objectives.

[b] Mean NRV high severity patch size is 0.1 to 17 acres.

[c] Sheep Complex (2010) is also included in this table, because it is the only other large (≥1,000 ac) wildfire that burned a giant sequoia grove in the analysis area within the past 50 years.

Table 8. Fire effects in giant sequoia groves burned in the 2021 Windy Fire. Groves are listed by latitude from north to south. Analysis area for the Black Mountain, Redhill, Peyrone, and South Peyrone groves includes shared grove boundaries within the Giant Sequoia National Monument and Tule River Indian Reservation.

Sequoia Grove	Grove Size (ac)	% Low Severity[a]	% High Severity	% High Severity in Large Patch[b]	Fire Severity Index	FRID Cond. Class[c]	Fire Effects within NRV[d]
Black Mountain[e]	222	97	1	75	1.2	2.1	Yes
Redhill	456	37	41	0.4	3.0	2.0	No
Peyrone	230	70	13	0	2.1	2.0	Marginal[f]
South Peyrone	33	29	39	13	3.1	2.0	No
Long Meadow	214	50	33	14	2.6	1.9	No
Cunningham[g]	10	88	0	N/A	1.7	0.9	Yes
Starvation Creek	25	0	97	100	4.0	2.0	No
Packsaddle	175	49	33	4	2.7	2.0	No
Deer Creek	35	8	81	79	3.7	2.0	No

[a] Includes both unchanged and low fire severity classes (i.e., <25% basal area mortality)

[b] Large high severity patches exceed 250 acres in size. In Redhill Grove, 20% of high severity patch area is attributed to a moderately large patch 100-250 acres in size.

[c] Fire Return Interval Departure (FRID) condition class, including the 2021 Windy Fire. Condition classes 1 and 2 represent low and moderate departure, respectively, of the current fire return interval (1970-2021) from the historical fire return interval.

[d] NRV and desired conditions for fire effects in sequoia groves are described in Table 1.

[e] Only includes the small portion of the Black Mountain grove in the Giant Sequoia National Monument that burned in the 2021 Windy Fire. All other groves shown were 100% burned in the 2021 Windy Fire.

[f] Marginally within NRV for coniferous forests but exceeding desired conditions for sequoia groves.

[g] Cunningham Grove burned primarily at low severity in the 2016 Meadow Fire, a wildfire managed for resource objectives.

Table 9. Fire effects in giant sequoia groves burned in the 2021 KNP Complex[a]. In this and following tables, groves are listed from north to south. Analysis area for the Redwood Mountain grove includes both grove boundaries in the Sequoia National Park, Giant Sequoia National Monument, and state ownership. See Table 8 for fire metric descriptions.

Sequoia Grove[b]	Grove Size (ac)	% Low Severity	% High Severity	% High Severity in Large Patch	Fire Severity Index	FRID Cond. Class	Fire Effects within NRV
Redwood Mountain	2604	15	26	19	2.1	1.9	No
Big Springs	2	100	0	0	1.3	2.0	Yes
Lost	35	100	0	0	1.1	1.8	Yes
Muir	245	91	4	0	1.4	1.8	Yes
Pine Ridge	43	98	0.5	0	1.2	2.1	Yes
Skagway	61	94	3	0	1.3	1.9	Yes
Suwanee	68	20	52	37	3.3	2.1	No
Giant Forest	2106	97	1	<0.1	1.2	1.4	Yes
Castle Creek	218	79	6	0.6	1.8	1.3	Yes
Douglass	1	100	0	0	1.2	2.2	Yes
Oriole Lake	43	99	0.6	0	1.2	2.0	Yes
Squirrel Creek	7	90	3	0	1.5	2.0	Yes
Atwell	922	87	7	0	1.5	1.0	Yes
Redwood Creek	46	89	5	0	1.5	2.0	Yes
New Oriole Lake	15	66	22	0	2.2	1.1	No

[a] All groves burned in the 2021 KNP Complex were more or less 100% burned except for Atwell (42% burned), Giant Forest (24% burned), and Lost (84% burned).

[b] Excludes East Fork grove because only 1% of the grove area burned in the KNP Complex.

Table 10. Fire effects in giant sequoia groves burned in the 2020 Castle Fire, including groves located in Sequoia National Park (Homers Nose to Dillonwood) and the Giant Sequoia National Monument (Dillonwood to Carr Wilson). Several groves have multiple land ownerships (e.g., Mountain Home, Alder Creek). See Table 8 for fire metric descriptions.

Sequoia Grove	Grove Size (ac)	% Low Severity	% High Severity	% High Severity in Large Patch	Fire Severity Index	FRID Cond. Class	Fire Effects within NRV
Homers Nose	130	23	58	47	3.4	2.0	No
Board Camp	48	4	91	88	3.8	2.0	No
Cedar Flat	15	94	2	0	1.7	1.8	Yes
South Fork	239	93	2	0	1.5	1.7	Yes
Clough Cave	1.4	100	0	0	0.8	2.3	Yes
Putman-Francis	0.3	100	0	0	2.2	2.0	Yes
Forgotten	2	60	20	0	2.7	2.2	No
Garfield	1233	90	6	0.2	1.6	1.7	Yes
Devil's Canyon	9	100	0	0	1.0	1.8	Yes
Dennison	13	98	0	0	1.6	2.1	Yes
Dillonwood	1036	75	15	8	2.0	2.0	Marginal
Dillonwood West	4	10	70	0	3.7	2.1	No
Dillonwood South	4	52	9	0	2.9	2.2	No
Upper Tule	6	100	0	0	1.2	2.0	Yes
Middle Tule	478	90	4	0	1.3	2.0	Yes
Mountain Home	3220	65	24	12	2.2	1.9	No
Wishon[a]	15	100	0	0	1.1	1.1	Yes
Alder Creek	563	62	30	25	2.2	1.9	No
Freeman Creek	1413	26	63	55	3.3	2.0	No
Belknap Camp	99	55	33	28	2.5	2.0	No
Wheel Meadow	575	8	79	65	3.7	2.0	No
McIntyre	279	26	45	19	3.1	2.0	No
Carr Wilson	13	57	27	0	2.4	1.9	No

[a] All groves burned in the 2020 Castle Fire were more or less 100% burned except for Clough Cave (78% burned) and Middle Tule (51% burned in 2020 Castle Fire and 33% burned in 2016 Hidden Fire).

[b] Most of the Wishon grove burned at low severity in the 2018 Alder Fire prior to burning the Castle Fire (Table 11).

Table 11. Fire effects in giant sequoia groves burned in the 2015 Rough Fire, 2010 Sheep Fire, 2018 Alder Fire, and 2017 Pier Fire, and FRID condition class of groves located in the Giant Sequoia National Monument, Sequoia National Park, and Bureau of Land Management lands. See Table 8 for fire metric descriptions. Groves listed approximately from north to south.

Sequoia Grove	Grove Size (ac)	% Low Severity	% High Severity	% High Severity in Large Patch[a]	Fire Severity Index	FRID Cond. Class	Fire Effects within NRV
Rough Fire (2015)							
Cabin Creek	150	89	4	0	1.6	2.0	Yes
Converse Saddle	23	91	3	0	1.6	1.9	Yes
Converse Mountain	33	3	90	89	3.9	1.8	No
Verplank	26	58	35	27	2.4	2.0	No
Converse Basin	1544	86	8	0.6	1.6	1.9	Yes
Hoist Ridge	50	55	32	19	2.6	1.5	No
Lockwood	66	65	24	5 (11)	2.1	1.9	No
Evans	958	84	8	0	1.7	1.9	Yes
Agnew	10	73	9	0	2.1	2.0	Marginal
Deer Meadow	62	95	1	0	1.5	2.0	Yes
Cherry Gap	64	68	10	0.6	2.2	1.9	Marginal
Kennedy	181	85	5	0	1.6	2.0	Yes
Little Boulder	76	98	0.6	0	1.2	2.0	Yes
Boulder Creek	25	96	4	0	1.4	2.0	Yes
Abbot	8	94	3	0	1.6	2.0	Yes
Grant	167	81	8	0.7	1.7	1.3	Yes
Sheep Complex (2010)							
Monarch	7	90	0	0	2.0	2.1	Yes
Unburned (Giant Sequoia National Monument, Hume Lake Ranger District)							
Indian Basin[b]	212	—	—	—	—	2.7	—
Landslide		—	—	—	—	2.9	—
Bearskin	70	—	—	—	—	3.0	—
Sequoia Creek	16	—	—	—	—	3.0	—
Unburned (Sequoia National Park)							
Big Stump[c]	283	—	—	—	—	2.8	—

Sequoia Grove	Grove Size (ac)	% Low Severity	% High Severity	% High Severity in Large Patch[a]	Fire Severity Index	FRID Cond. Class	Fire Effects within NRV
Granite Creek	1.5	—	—	—	—	3.2	—
Redwood Meadow	171	—	—	—	—	2.6	—
Little Redwood Meadow	26	—	—	—	—	3.1	—
Horse Creek	48	—	—	—	—	3.0	—
Cahoon	14	—	—	—	—	3.1	—
Coffeepot Canyon	6	—	—	—	—	2.7	—
Surprise	22	—	—	—	—	3.1	—
Eden Fire (2018)							
Eden Creek[d]	437	98	0	0	2.0	2.1	Yes
Unburned (BLM Case Mountain groves)[e]							
Nutmeg	66	—	—	—	—	1.7	—
Case Mountain	42	—	—	—	—	2.2	—
Salt Creek Ridge	93	—	—	—	—	1.9	—
Alder Fire (2018)							
Maggie Mountain	27	100	0	0	1.2	1.8	Yes
Silver Creek	61	97	1	0	1.2	2	Yes
Burro Creek	113	99	0	0	1.1	1.9	Yes
Wishon	15	100	0	0	1.1	1.1	Yes
Pier Fire (2017)							
Black Mountain[f]	1956	80	9	0.4	1.8	2.1	Marginal
Meadow Fire (2016)							
Cunningham[g]	10	98	0	0	1.8	0.9	Yes

[a] Percent grove area burned in high severity patches 100-250 ac in size is provided in parentheses.

[b] Less than 1 acre of the Indian Basin grove burned in the 2015 Rough Fire.

[c] Located in SEKI and GSNM.

[d] 76% of the Eden Creek grove burned in the 2018 Eden Fire.

[e] BLM Case Mountain groves were mostly burned in the 1987 Case Fire.

[f] Most (88%) of the Black Mountain grove burned in the 2017 Pier Fire, 11% of the grove burned in the 2021 Windy Fire (11%), and only 12 acres (<1%) has not experienced fire in over 50 years.

[g] Also burned in the 2021 Windy Fire (Table 8).

Table 12. Fire metrics pertaining to Potential Operational Delineations (PODs) following large wildfires (>1,000 ac) that burned in the analysis area. PODs are ordered based on overlap with the 2021 Windy Fire, 2021 KNP Complex, 2021 French Fire, and 2020 Castle Fire.

POD ID	POD Size (ac)	Acres Burned (% POD)	Acres Low Severity (% POD)	Acres High Severity (% POD)	Acres (%) Large High Severity Patches[a]	Fire Severity Index	FRID Cond. Class	Fire Effects within NRV
Windy Fire (2021)								
64	21,120	14,721 (70%)	2,255 (11%)	10,814 (51%)	7,622 (36%)	2.5	1.6	No
67	6,264	5,731 (91%)	1,246 (20%)	3,338 (53%)	2121 (34%)	3.0	2.6	No
71	9,023	5,549 (62%)	1,496 (17%)	2,992 (33%)	682 (8%)	2.0	2.0	No
72	7,667	6,493 (85%)	1,047 (14%)	4,602 (60%)	4,112 (54%)	3.0	2.7	No
74	9,683	5,368 (55%)	2,210 (23%)	1,970 (20%)	981 (10%)	1.6	2.4	No
75	6,465	6,465 (100%)	1,358 (21%)	4,308 (67%)	3,160 (49%)	3.4	2.5	No
79	8,870	8,811 (99%)	1,942 (22%)	5,624 (63%)	3,979 (45%)	3.3	2.3	No
82	12,964	12,341 (95%)	6,064 (47%)	4,119 (32%)	2,186 (17%)	2.5	2.5	No
83	39,158	14,408 (37%)	11,018 (28%)	1,912 (5%)	351 (1%)	0.7	2.3	Yes
480[b]	8,923	8,025 (90%)	2,191 (25%)	4,108 (46%)	1,882 (21%)	2.8	2.5	No
482	5,358	2,074 (39%)	595 (11%)	1,186 (22%)	323 (6%)	1.2	2.1	No
483	8,868	8,271 (93%)	1,824 (21%)	5,093 (57%)	2,886 (33%)	3.1	2.4	No
484	5,696	3,143 (55%)	208 (4%)	2,768 (49%)	2,390 (42%)	2.1	2.5	No
485	2,514	2,515 (100%)	843 (34%)	1,332 (53%)	911 (36%)	3.0	3.0	No
486	4,375	4,366 (100%)	1,215 (28%)	2,457 (56%)	1,547 (35%)	3.2	2.2	No
489	5,673	1,331 (23%)	851 (15%)	271 (5%)	178 (3%)	0.5	2.4	Yes
490	3,964	2,009 (51%)	1,547 (39%)	246 (6%)	8 (0%)	1.0	2.8	Yes
493	7,055	5,454 (77%)	3,542 (50%)	826 (12%)	45 (1%)	1.7	2.6	Yes
494	5,255	4,984 (95%)	2,311 (44%)	1,523 (29%)	392 (7%)	2.5	2.4	No
KNP Complex (2021)								
118	24,272	2,375 (10%)	1,361 (6%)	633 (3%)	60 (0%)	0.2	2.1	Yes
129	17,991	3,188 (18%)	2,630 (15%)	260 (1%)	0 (0%)	0.3	1.9	Yes
136	14,119	13,655 (97%)	6,805 (48%)	4,867 (34%)	1,937 (14%)	2.5	2.8	No
508	4,657	4,616 (99%)	2,159 (46%)	1,641 (35%)	75 (2%)	2.7	2.1	No
509	2,570	2,330 (91%)	1,500 (58%)	611 (24%)	410 (16%)	1.9	2.9	No
511	8,600	2,807 (33%)	2,506 (29%)	200 (2%)	0 (0%)	0.5	2.6	Yes

POD ID	POD Size (ac)	Acres Burned (% POD)	Acres Low Severity (% POD)	Acres High Severity (% POD)	Acres (%) Large High Severity Patches[a]	Fire Severity Index	FRID Cond. Class	Fire Effects within NRV
512	5,859	5,845 (100%)	1,003 (17%)	4,017 (69%)	2,231 (38%)	3.4	2.5	No
664	30,053	17,115 (57%)	11,038 (37%)	3,909 (13%)	481 (2%)	1.3	2.1	Yes
665	20,950	6,341 (30%)	3,558 (17%)	1,692 (8%)	231 (1%)	0.7	2.0	Yes
666	12,247	12,163 (99%)	6,732 (55%)	3,885 (32%)	311 (3%)	2.5	2.0	No
734	19,146	1,111 (6%)	405 (2%)	562 (3%)	0 (0%)	0.2	2.3	Yes
735	15,076	10,856 (72%)	5,082 (34%)	4,358 (29%)	2,488 (17%)	1.9	2.5	No
736	19,302	6,151 (32%)	1,911 (10%)	3,315 (17%)	971 (5%)	1.0	2.0	No
French Fire (2021)								
52	7,325	7,090 (97%)	1,194 (16%)	4,967 (68%)	1,878 (26%)	3.4	2.3	No
54	20,542	7,417 (36%)	2,195 (11%)	4,220 (21%)	1,108 (5%)	1.1	2.0	No
56	13,116	2,141 (16%)	1,013 (8%)	870 (7%)	561 (4%)	0.5	2.5	Yes
460	2,757	1,128 (41%)	531 (19%)	350 (13%)	0 (0%)	1.1	2.0	Yes
461	4,804	3,180 (66%)	2,168 (45%)	392 (8%)	114 (2%)	1.4	2.0	Yes
462	4,380	2,971 (68%)	134 (3%)	2,604 (59%)	30 (1%)	2.6	1.3	No
464	10,476	9,239 (88%)	3,773 (36%)	4,053 (39%)	2,657 (25%)	2.5	2.3	No
Castle Fire (2020)								
88	19,045	5,864 (31%)	1,843 (10%)	3,169 (17%)	309 (2%)	1.0	2.1	No
91	11,856	11,859 (100%)	2,039 (17%)	7,898 (67%)	5,271 (44%)	3.5	2.0	No
94	14,686	13,892 (95%)	7,395 (50%)	4,591 (31%)	2,315 (16%)	2.4	2.1	No
96	13,713	13,304 (97%)	3,425 (25%)	7,533 (55%)	691 (5%)	3.1	1.4	No
101	30,528	30,096 (99%)	9,834 (32%)	13,924 (46%)	7,586 (25%)	3.0	1.9	No
103	7,769	1,813 (23%)	666 (9%)	825 (11%)	72 (1%)	0.7	1.2	Yes
104	9,317	3,947 (42%)	2,404 (26%)	1,220 (13%)	911 (10%)	1.0	1.6	No
106	10,114	9,968 (99%)	5,552 (55%)	3,418 (34%)	2,514 (25%)	2.4	2.0	No
107	14,070	13,721 (98%)	7,735 (55%)	3,611 (26%)	950 (7%)	2.4	2.0	No
108	11,567	7,871 (68%)	4,242 (37%)	2,408 (21%)	876 (8%)	1.7	1.4	No
109	19,335	9,490 (49%)	5,912 (31%)	2,303 (12%)	879 (5%)	1.1	1.6	Yes
110	12,033	1,655 (14%)	1,292 (11%)	182 (2%)	101 (1%)	0.3	2.2	Yes
517	9,362	3,497 (37%)	2,146 (23%)	619 (7%)	0 (0%)	0.9	1.7	Yes
518	8,139	1,474 (18%)	1,085 (13%)	159 (2%)	0 (0%)	0.4	1.3	Yes

POD ID	POD Size (ac)	Acres Burned (% POD)	Acres Low Severity (% POD)	Acres High Severity (% POD)	Acres (%) Large High Severity Patches[a]	Fire Severity Index	FRID Cond. Class	Fire Effects within NRV
519	10,320	5,870 (57%)	1,597 (15%)	3,378 (33%)	38 (0%)	1.8	1.1	No
521	9,069	8,683 (96%)	2,982 (33%)	4,576 (50%)	254 (3%)	2.9	1.3	No
523	4,254	2,587 (61%)	716 (17%)	1,386 (33%)	0 (0%)	1.9	2.0	No
524	2,650	2,637 (99%)	644 (24%)	1341 (51%)	446 (17%)	3.2	2.0	No
528	7,829	4,739 (61%)	4,020 (51%)	323 (4%)	0 (0%)	1.0	2.0	Yes
530	8,041	7,992 (99%)	4,611 (57%)	2,424 (30%)	600 (7%)	2.4	1.8	No
531	3,483	3,096 (89%)	1,485 (43%)	1,144 (33%)	713 (20%)	2.4	2.0	No
533	4,920	3,685 (75%)	2,463 (50%)	760 (15%)	458 (9%)	1.6	2.1	No
534	5,516	4,939 (90%)	2,801 (51%)	1,353 (25%)	615 (11%)	2.2	2.1	No
535	8,067	7,958 (99%)	1,526 (19%)	5,540 (69%)	4,532 (56%)	3.4	2.0	No
538	10,276	8,710 (85%)	5,321 (52%)	1,941 (19%)	491 (5%)	1.9	1.8	No
539	6,302	6,101 (97%)	3,738 (59%)	1,634 (26%)	166 (3%)	2.2	1.9	No
1118	6,227	3,847 (62%)	512 (8%)	3,059 (49%)	537 (9%)	2.2	1.1	No
1119	3,945	3,493 (89%)	2,035 (52%)	775 (20%)	0 (0%)	2.2	1.4	No
PODs outside the Windy Fire, KNP Complex, French Fire, and Castle Fire								
60	11,768	1,567 (13%)	1,220 (10%)	135 (1%)	0 (0%)	0.3	2.6	Yes
90	9,886	9,268 (94%)	5,811 (59%)	2,418 (24%)	186 (2%)	2.0	2.0	No
111	12,869	10,092 (78%)	8,065 (63%)	705 (5%)	0 (0%)	1.4	1.3	Yes
147	11,150	1,016 (9%)	602 (5%)	178 (2%)	2 (0%)	0.2	2.7	Yes
150	19,189	19,177 (100%)	3,788 (20%)	11,621 (61%)	6,253 (33%)	3.4	2.0	No
154	6,321	3,895 (62%)	1,380 (22%)	2,120 (34%)	736 (12%)	1.8	1.5	No
155	23,309	8,576 (37%)	3,714 (16%)	3,326 (14%)	375 (2%)	1.0	1.7	Yes
156	9,082	9,012 (99%)	1,243 (14%)	5,957 (66%)	1,212 (13%)	3.5	2.0	No
159	15,726	13,954 (89%)	3,875 (25%)	8,261 (53%)	3,252 (21%)	2.8	2.0	No
160	20,797	15,448 (74%)	8,507 (41%)	4,712 (23%)	744 (4%)	1.8	1.8	No
161	4,997	3,666 (73%)	1,984 (40%)	980 (20%)	259 (5%)	1.9	2.0	No
172	10,553	4,287 (41%)	3,328 (32%)	464 (4%)	6 (0%)	0.8	2.5	Yes
384	2,605	1,491 (57%)	359 (14%)	817 (31%)	207 (8%)	1.9	2.4	No
385	2,154	2,046 (95%)	981 (46%)	487 (23%)	0 (0%)	2.5	2.0	No
386	5,104	5,106 (100%)	1,302 (26%)	2,577 (51%)	450 (9%)	3.2	2.0	No

POD ID	POD Size (ac)	Acres Burned (% POD)	Acres Low Severity (% POD)	Acres High Severity (% POD)	Acres (%) Large High Severity Patches[a]	Fire Severity Index	FRID Cond. Class	Fire Effects within NRV
396	6,586	2,202 (33%)	1,325 (20%)	560 (9%)	177 (3%)	0.8	2.6	Yes
397	5,518	5,454 (99%)	1,202 (22%)	3,209 (58%)	1,754 (32%)	3.3	2.0	No
399	12,535	12,539 (100%)	6,817 (54%)	3,694 (29%)	724 (6%)	2.5	2.0	No
400	15,874	5,284 (33%)	4807 (30%)	167 (1%)	0 (0%)	0.5	1.5	Yes
424	6,807	4,364 (64%)	825 (12%)	2,996 (44%)	1,084 (16%)	2.2	2.6	No
426	2,991	2,783 (93%)	996 (33%)	1,583 (53%)	1,423 (48%)	2.8	2.1	No
428	2,189	2,180 (100%)	787 (36%)	973 (44%)	0 (0%)	2.9	1.8	No
459	2,515	1,244 (49%)	138 (5%)	844 (34%)	0 (0%)	1.7	1.7	No
466	7,186	6,298 (88%)	3,041 (42%)	2,456 (34%)	1,606 (22%)	2.4	2.1	No
481	3,258	1,263 (39%)	817 (25%)	225 (7%)	0 (0%)	0.8	1.9	Yes
520	7,394	2,176 (29%)	998 (13%)	925 (13%)	0 (0%)	0.8	2.1	Yes
525	13,516	2,571 (19%)	1,690 (13%)	515 (4%)	0 (0%)	0.4	1.2	Yes
526	10,763	7,423 (69%)	3,949 (37%)	2,254 (21%)	556 (5%)	1.8	1.6	No
536	2,401	2,403 (100%)	1,102 (46%)	1,104 (46%)	615 (26%)	2.7	2.0	No
537	3,181	3,181 (100%)	1,563 (49%)	1,262 (40%)	0 (0%)	2.6	2.0	No
540	17,736	1,5887 (90%)	10,650 (60%)	3,032 (17%)	204 (1%)	1.9	2.0	No
541	6,766	6,615 (98%)	2,565 (38%)	3,150 (47%)	188 (3%)	2.8	1.9	No

[a] Area of conifer hardwood habitat that burned in high severity patches >250 ac in size

[b] Burned in the Windy Fire and the Castle Fire

Table 13. Impact of the 2021 wildfires on fisher habitat, including conifer/hardwood forest habitat that burned at high severity (>75% basal area loss), including habitat containing large trees that are typically used for denning, medium-high quality reproductive habitat, and connectivity. Total loss of habitat in the larger study area is also provided including fires that burned between 2015-2020.

Fire	Habitat Burned (ac)	Habitat Burned at High Severity (ac)	>40 inch trees that Burned at High Severity (ac)	Reproductive Habitat that Burned at High Severity (ac)	Degradation of Connectivity[a] (ac)
Windy	93,254	43,861	12,977	27,922	23,616
KNP Complex	86,642	27,421	3,725	13,959	25,115
French	20,932	9,179	389	6,018	3,717
Total 2021 fires:	179,896	71,282	17,091	47,899	52,488
Entire Study Area	442,417	220,454	46,949	86,681	—[b]

[a] Details of connectivity layer are described in text. Estimates of degradation are only provided post-2018.

[b] This metric could be calculated across the entire analysis area as some fires burned prior to 2018.

Table 14. Restoration portfolio for giant sequoia groves and fisher habitat in the analysis area[a].

Target Areas	**Management Actions**[b]
Restoration Opportunity 1: Maintain and Promote Desired Conditions	
Priority sequoia groves and fisher habitat that either burned within NRV and where natural regeneration is likely adequate in high severity patches or are fire-excluded (>50 to 100 years since last fire)	• Use prescribed fire or managed wildfire consistent with the historical fire return interval to maintain desired fuels loads within the next 5 to 10 years based on Rx fire prioritization analysis. • Maintain long-term (≥10 years) beneficial fire effects in groves burned twice in the past 25 years or within NRV for fuel loading. • Use mechanical thinning where appropriate to reduce stand densities and facilitate safe and effective prescribed fire entry. • Monitor areas of post-fire vegetation recovery in sequoia groves and other forested areas, particularly survivorship of large sequoias, regeneration, and fuel loading (1-5 years). • Conduct field evaluation of vegetation and soil conditions to fine tune site prescriptions. • Maintain or install fuel breaks surrounding sequoia groves in strategic locations where current fuel loading in above desired conditions. • As feasible, retain and promote individual large diameter structures (live trees, snags, logs) with potential cavities or other microsites for fishers (e.g., California black oak, incense cedar, white fir, pine sp.). • Prioritize suppression preparedness and response in and around these target areas until a second round of prescribed fire has been implemented or desired fuels conditions are achieved. • Develop coordinated reforestation infrastructure (e.g., cone collections, seed storage and greenhouse facilities, planting equipment and staffing) among agencies for giant sequoia.
Restoration Opportunity 2: Take Management Actions to Restore Desired Conditions	
Sequoia groves and surrounding mixed-conifer forest that burned primarily at low to moderate severity but with fire effects outside of NRV and are accessible	• Conduct climate-smart reforestation and fuels reduction activities to avoid high severity reburns and restore sequoia and other desirable conifer cover in high severity patches. • Monitor high severity burn patches for post-fire sequoia and other conifer regeneration. Evaluate effectiveness of post-fire natural conifer regeneration prediction tools (e.g., POSTCRPT) for giant sequoia and other species. • Monitor post-fire vegetation change in sequoia groves burned at high severity (1-5 years).
Key linkage areas for fisher habitat connectivity that burned at high severity and have low probability of natural conifer regeneration and are accessible	• Conduct fuels reduction and reforestation activities where appropriate to restore conifer cover in priority fisher connectivity areas in high severity patches; promote shrub patches for near-term connectivity. • Retain important fisher habitat elements including large snags and hardwoods and coarse woody debris where feasible and desirable. • Consider promoting California black oak regeneration by retaining black oak resprouts and seedlings during reforestation efforts.

Target Areas	**Management Actions**[b]
	• Monitor fisher use of fuel breaks, severely burned habitat, and remaining isolated green patches to evaluate potential adaptation to novel forest conditions.
Restoration Opportunity 3: Reevaluate Desired Conditions Considering Interacting Stressors	
Sequoia groves that burned at ≥50% high severity or fisher habitat within large high severity patches that have low probability of natural conifer regeneration and are inaccessible	• Conduct reforestation and fuels reduction activities to restore sequoia and other desirable conifer cover in severely burned groves. • Consider assisted migration of sequoias into higher elevation or climate refugia areas. • Monitor severely burned stands at high risk of type conversion. • Encourage hardwood cover in severely burned areas where desirable. • Identify potential replacement species and assemblage types under multiple climate scenarios or reference conditions (NRV, FRV) and assess for compatibility with fisher habitat requirements. • Direct change towards appropriate species assemblages with an emphasis on Southern Sierra Nevada hardwood species.

[a] This portfolio is based on the primary management goals, approaches, and opportunities summarized in Tables 3, 4, & 5 and spatially represented in Figure 25 for the Windy Fire, Figure 27 for the KNP Complex, and Figure 29 for the French Fire.

[b] All management actions are considered moderately to highly feasible, especially in accessible areas.

Table 15. Fire effects of the 2021 Windy Fire to PODs in the analysis area and the acres of priority ecological resources impacted.

POD	Acres Burned	% Low Severity	% High Severity	% High Severity in Large Patch	Fire Severity Index	FRID Cond. Class	Grove Area (ac)	Fisher Habitat (ac)	PAC Area (ac)	Fire Effects within NRV
64	1110	1	4	2	0.2	1.6	0	15462	1646	Yes
67	5728	20	53	34	3.0	2.6	35	6013	1310	No
71	5538	16	33	8	2.0	2.0	0	5481	334	No
72	6480	13	60	54	3.0	2.7	25	7231	2154	No
74	5362	23	20	10	1.6	2.4	0	8156	915	No
75	6465	21	67	49	3.4	2.5	175	6452	431	No
79	8810	22	63	45	3.3	2.3	192	8766	1395	No
82	12321	47	32	17	2.5	2.5	772	12681	703	No
83	6428	13	2	1	0.3	2.3	16	22822	4	Yes
480	3972	13	24	13	1.4	2.5	0	8420	362	No
482	2063	11	22	6	1.2	2.1	0	1237	0	No
483	8267	21	57	33	3.1	2.4	18	7542	481	No
484	3137	4	49	42	2.1	2.5	0	3785	415	No
485	2515	34	53	36	3.0	3.0	15	2511	0	No
486	4366	28	56	35	3.2	2.2	0	4321	909	No
489	1329	15	5	3	0.5	2.4	0	3693	0	Yes
490	1677	31	6	0	0.8	2.8	0	3921	572	Yes
493	5442	50	12	1	1.7	2.6	0	6620	0	Yes
494	4199	36	25	7	2.2	2.4	499	4958	2	No

Table 16. Fire effects of the 2021 KNP Complex to PODs in the analysis area and the acres of priority ecological resources impacted.

POD	Acres Burned (ac)	% Low Severity	% High Severity	% High Severity in Large Patch	Fire Severity Index	FRID Cond. Class	Grove Area (ac)	Fisher Habitat (ac)	CSO PAC (ac)	Fire Effects within NRV
118	2152	5	2	0.3	0.2	1.9	130	17632	0	Yes
129	3101	14	1	<0.01	0.3	2.1	1713	12665	0	Yes
136	13651	48	34	13.7	2.5	2.2	0	14047	13	No
508	4615	46	35	1.6	2.7	1.6	0	4440	0	No
509	2327	58	24	16.0	1.9	2.1	1	2567	0	No
511	2795	29	2	0.0	0.5	2.9	1	8596	0	Yes
512	5845	17	69	38.1	3.4	2.6	63	5401	451	No
664	16907	36	13	1.6	1.2	2.1	1	28758	0	Yes
665	6245	17	8	1.1	0.7	2.1	873	20016	0	Yes
666	12161	55	32	2.5	2.5	2.0	701	11633	0	No
734	1106	2	3	<0.01	0.2	2.0	1	4351	0	Yes
735	10843	34	29	16.5	1.9	2.3	0	14856	0	No
736	6145	10	17	5.0	1.0	2.5	10	11118	0	No

Table 17. Fire effects of the 2021 French Fire to PODs in the analysis area and the acres of priority ecological resources impacted.

POD	Acres Burned (ac)	% Low Severity	% High Severity	% High Severity in Large Patch	Fire Severity Index	FRID Cond. Class	Grove Area (ac)	Fisher Habitat (ac)	CSO PAC (ac)	Fire Effects within NRV
52	7087	16	68	26	3.4	2.3	0	5565	744	No
54	5989	9	17	4	0.9	2.0	0	6116	466	No
56	2064	7	7	4	0.4	2.5	0	6601	0	Yes
460	1126	19	13	0	1.1	2.0	0	2746	113	Yes
461	3174	45	8	2	1.4	2.0	0	3666	0	Yes
462	2968	3	59	1	2.6	1.3	0	618	0	No
464	4064	24	15	6	1.2	2.3	0	9523	1605	No

Table 18. Fire effects of the 2020 Castle Fire to PODs in the analysis area and the acres of priority ecological resources impacted.

POD	Acres burned	% Low Severity	%High Severity	% High Severity in Large Patch	Fire Severity Index	FRID Cond. Class	Grove Area (ac)	Fisher Habitat (ac)	CSO PAC (ac)	Fire Effects within NRV
88	4108	7	12	0	0.7	2.1	0	10906	564	Yes
91	11859	17	67	44	3.5	2.0	1412	11204	617	No
94	7287	18	24	16	1.5	2.1	2390	14573	2400	No
96	12911	24	53	5	3.0	1.4	0	7653	0	No
101	23883	22	41	25	2.5	1.9	0	29803	3	No
103	1803	8	11	1	0.7	1.2	0	4248	0	Yes
104	1324	8	5	3	0.4	1.6	0	8904	0	Yes
106	6963	28	32	25	1.9	2.0	783	10040	594	No
107	13716	55	26	7	2.4	2.0	1177	13406	944	No
108	6143	28	17	8	1.4	1.4	0	9587	0	No
109	9436	30	12	5	1.1	1.6	1545	17230	0	Yes
110	1630	11	2	1	0.3	2.2	0	8619	0	Yes
480	4207	13	23	8	1.5	2.5	0	8420	362	No
517	3485	23	7	0	0.9	1.7	0	5930	0	Yes
518	1464	13	2	0	0.4	1.3	0	4214	0	Yes
519	5770	15	32	0	1.8	1.1	0	5874	245	No
521	1092	3	7	0	0.4	1.3	0	4196	328	Yes
523	2294	15	29	0	1.7	2.0	0	2628	0	No
524	2636	24	51	17	3.2	2.0	1	2420	2	No
528	4731	51	4	0	1.0	2.0	13	6617	0	Yes
530	4872	34	20	7	1.5	1.8	0	8030	0	No
531	3092	43	33	20	2.4	2.0	0	3296	0	No
533	3679	50	15	9	1.6	2.1	449	3834	310	No
534	4935	51	25	11	2.2	2.1	2067	5349	280	No
535	7781	17	68	56	3.4	2.0	0	8035	826	No
538	6170	32	17	5	1.5	1.8	1046	9568	303	No
539	4384	40	20	3	1.7	1.9	138	5563	0	No
1118	3719	7	48	9	2.2	1.1	0	1762	0	No
1119	3483	51	20	0	2.2	1.4	0	2941	0	No

Table 19. Priority areas for *prescribed burning and other fuel reduction actions* in giant sequoia groves burned in the 2021 Windy Fire. Prescribed burn treatment rank is based on variables presented in this table and Table 8.

Sequoia Grove[a]	Mechanically Accessible and Low to Moderate Severity, ac (%)[b]	Climatic Water Deficit (mm)	Pre-fire Stand Density, (trees/ac)[c]	Post-fire Fisher Connectivity Increase[d]	California Spotted Owl PAC Overlap (%)	Rx Burn Treatment Priority[e]
Black Mountain	71 (32)	280	263 (118)	Moderate	2	Moderate
Redhill	144 (32)*	401	269 (119)	High	0	High
Peyrone	53 (19)	419	249 (103)	Low	31	High
South Peyrone	0 (0)	446	248 (112)	Moderate	66	Low
Long Meadow	37 (17)*	561	280 (101)	Moderate	61	High
Cunningham[f]	7 (73)	598	310 (117)	Low	0	Low
Starvation Creek	0 (0)	567	229 (110)	Low	89	Low
Packsaddle	12 (7)*	576	189 (96)	High	91	High
Deer Creek	4 (12)*	603	196 (88)	Low	100	Low

[a] Sequoia groves in *italics* burned outside NRV and desired conditions listed in Table 1. Priority groves for the maintenance or creation of nearby fuel breaks are underlined.

[b] Acres that burned at low to moderate severity (or unchanged) and are mechanically accessible. Values with an asterisk indicate groves where strategic fuel breaks could be feasibly applied surrounding grove boundaries.

[c] Includes trees 1-20” dbh and 5-20” dbh (latter in parentheses). In mixed conifer forests, NRV is approximately 66 ± 48 trees/acre (for stems ≥1” dbh) and 47 ± 28 trees/acre (for stems ≥4” dbh). Low severity burned areas may experience ~25% reduction in stem densities (≥1” dbh), resulting in post-fire stand densities above NRV in groves burned in the Windy Fire. Examples of histograms of pre-fire stand densities are shown in Figure 37. Stand density value for Black Mountain grove is based on USFS common stand exam data collected in 1999.

[d] Fisher habitat connectivity increase ratings per grove are based on Circuitscape analysis results where: (1) high = >20 ac of fisher habitat connectivity increase, (2) moderate = 5-20 ac, and (3) low <5 ac.

[e] Prescribed fire treatment priorities are based on groves that burned within NRV and desired conditions and have relatively higher: (1) mechanical accessibility, (2) moisture stress (high climatic water deficit), (3) FRID condition class (i.e., higher departure), (4) pre-fire fuels, and (5) overlap with fisher and California spotted owl habitat.

[f] Cunningham Grove was completely burned at low to moderate severity (mostly low) in the 2016 Meadow Fire (managed wildfire) and may potentially benefit from prescribed burning in the long-term (>10 years).

Table 20. Priority areas for *reforestation and post-fire fuels reduction* in giant sequoia groves burned in the 2021 Windy Fire.

Sequoia Grove[a]	Post-fire Fisher Connectivity Decrease[b]	Predicted Natural Conifer Regeneration Failure, ac (%)[b]		Regeneration Failure Overlap with Mechanical Access for low scenario (ac)	Reforestation Treatment Priority[c]
		Low Scenario[b]	Mean Scenario[b]		
Black Mountain	Moderate	1 (2)	0 (0)	0	Low
Redhill	High	249 (54)	27 (6)	161	High
Peyrone	High	94 (34)	9 (3)	52	High
South Peyrone	Low	24 (73)	0 (0)	0	Low
Long Meadow	Moderate	180 (84)	56 (26)	67	High
Cunningham[d]	Low	1 (11)	0 (0)	<1	Low
Starvation Creek	Low	24 (97)	20 (78)	3	Moderate
Packsaddle	High	94 (53)	16 (9)	5	High
Deer Creek	Moderate	33 (97)	2 (5)	23	High

[a] Sequoia groves in italics burned outside most or all of NRV and desired conditions listed in Table 1.

[b] Fisher habitat connectivity decrease ratings per grove are based on Circuitscape analysis results where: (1) high = >30 ac of fisher habitat connectivity decrease, (2) moderate = 15-30 ac, and (3) low <15 ac.

[c] Based on POSCRPT low precipitation and seed availability scenario with <0.4 probability of natural conifer regeneration (all mixed conifer species).

[c] Reforestation treatment priorities are based on groves that have a greater number of acres of potential conifer regeneration failure that is mechanically accessible (and generally burned more severely than the NRV and desired conditions) and larger decline in post-fire fisher habitat connectivity.

[d] Cunningham Grove was completely burned at low to moderate severity (mostly low) in the 2016 Meadow Fire (managed wildfire) and is highly unlikely to require any reforestation action (not applicable).

Table 21. Priority areas for *prescribed burning and other fuel reduction actions* in giant sequoia groves burned in the 2021 KNP Complex prescribed burn treatment rank is based on variables presented in this table and Table 9.

Sequoia Grove[a]	Mechanically Accessible & Low-mod Severity, ac (%)[b]	Climatic Water Deficit (mm)	Pre-fire Stand Density, (trees/ac)[c]	Post-fire Fisher Connectivity Increase[d]	Rx Burn Treatment Priority[e]
Redwood Mountain	321 (12)	484	247 (54)	High	High
Big Springs	0 (0)	613	1014 (95)	Low	Low
Lost	34 (97)	478	1587 (49)	Low	Moderate
Muir	0 (0)	422	1813 (52)	Moderate	Low
Pine Ridge	0 (0)	607	907 (62)	Very Low	Low
Skagway	0 (0)	488	571 (31)	Very Low	Low
Suwanee	0 (0)	486	1742 (59)	Moderate	Low
Giant Forest	947 (45)	369	959 (46)	High	High
Castle Creek	0 (0)	366	223 (78)	High	Low
Douglass	0 (0)	278	147 (75)	Very Low	Low
Oriole Lake	0 (0)	267	145 (72)	Very Low	Low
Squirrel Creek	3 (45)	387	232 (101)	Very Low	Moderate
Atwell	209 (23)	232	164 (78)	Low	Moderate
Redwood Creek	8 (18)	366	169 (83)	Moderate	Moderate
New Oriole Lake	0 (0)	461	203 (65)	Very Low	Low

[a] Sequoia groves in *italics* burned outside NRV and desired conditions listed in Table 1.

[b] Acres that burned at low to moderate severity (or unchanged) and are mechanically accessible.

[c] Includes trees 1-20” dbh and 5-20” dbh (latter in parentheses). Values >500 trees per acre likely represent overestimates of tree density from the F3 model. In mixed conifer forests, NRV is approximately 66 ± 48 trees/acre (for stems ≥1” dbh) and 47 ± 28 trees/acre (for stems ≥4” dbh). Low severity burned areas may experience ~25% reduction in stem densities (≥1” dbh), resulting in post-fire stand densities above NRV in groves burned in the KNP Complex. Examples of histograms of pre-fire stand densities are shown in Figure 37.

[d] Fisher habitat connectivity increase ratings per grove are based on Circuitscape analysis results where: (1) high = >20 ac habitat connectivity increase, (2) moderate = 5-20 ac, (3) low 1-5 ac, and (4) very low = <1 ac.

[e] Prescribed fire treatment priorities are based on groves that burned within NRV and desired conditions and have relatively higher: (1) road accessibility, (2) moisture stress (high climatic water deficit), (3) FRID condition class (i.e., higher departure), (4) pre-fire fuels, and (5) increase in post-fire fisher habitat connectivity.

Table 22. Priority areas for *reforestation* in giant sequoia groves burned in the 2021 KNP Complex.

Sequoia Grove[a]	Post-fire Fisher Connectivity Decrease[b]	Predicted Natural Conifer Regeneration Failure, ac (%)[c]	Regeneration Failure Overlap with Mechanical Access (ac)	Reforestation Treatment Priority[d]
Redwood Mountain	High	362 (14)	50 (2)	High
Big Springs	Low	0 (0)	0 (0)	Low
Lost	Low	0 (0)	0 (0)	Low
Muir	Moderate	4 (2)	0 (0)	Moderate
Pine Ridge	Low	0 (0)	0 (0)	Low
Skagway	Low	0.9 (1.5)	0 (0)	Low
Suwanee	Moderate	7 (10)	0 (0)	Moderate
Giant Forest	Low	1 (<0.1)	0.7 (<0.1)	Low
Castle Creek	Low	2 (1)	0 (0)	Low
Douglass	Low	0 (0)	0 (0)	Low
Oriole Lake	Low	0 (0)	0 (0)	Low
Squirrel Creek	Low	0 (0)	0 (0)	Low
Atwell	Low	19 (2)	5 (0.5)	Moderate
Redwood Creek	Low	2 (4)	2 (3)	Moderate
New Oriole Lake	Moderate	0.2 (1.5)	0 (0)	Low

[a] Sequoia groves in italics burned outside most or all of NRV and desired conditions listed in Table 1.

[b] Fisher habitat connectivity decrease ratings per grove are based on Circuitscape analysis results where: (1) high = >30 ac of fisher habitat connectivity decrease, (2) moderate = 5-30 ac, and (3) low <5 ac.

[c] Based on POSCRPT mean precipitation and seed availability scenario with <0.4 probability of natural conifer regeneration (all mixed conifer species). Under the low scenario, regeneration failure values increase substantially in most sequoia groves, especially Redwood Mountain (710 ac; 27%) and Atwell (130 ac; 14%).

[d] Reforestation treatment priorities are based on groves that have a greater number of acres of potential conifer regeneration failure that is mechanically accessible (and generally burned more severely than the NRV and desired conditions) and a larger decline in post-fire fisher habitat connectivity.

Table 23. High priority sequoia groves for treatment according to each restoration opportunity within the Windy Fire, KNP Complex, and other groves (recently burned and fire excluded) in the analysis area[a].

<table>
<tr><th>Windy Fire</th><th>KNP Complex</th><th>Other Fires and Fire Excluded Groves</th></tr>
<tr><td colspan="3">Restoration Opportunity 1a: Promote beneficial fire effects in accessible groves with prescribed fire and targeted mechanical treatments[b], where applicable, in groves burned at low to moderate severity or fire-excluded groves (right column) (timing: within 5 to 10 years)</td></tr>
<tr><td>• <u>Long Meadow</u>
• <u>Redhill</u>
• Peyrone
• <u>Packsaddle</u></td><td>• Redwood Mountain
• Giant Forest
• Atwell
• Lost
• Redwood Creek
• Squirrel Creek</td><td>• <u>Bearskin</u>
• <u>Landslide</u>
• <u>Indian Basin</u>
• <u>Big Stump</u>
• Redwood Meadow and Little Redwood Meadow[c]</td></tr>
<tr><td colspan="3">Restoration Opportunity 1b: Maintain beneficial fire effects in groves burned twice recently (past 25 years) at low to moderate severity (or fire excluded) with prescribed fire or managed wildfire[d] (timing: within 20 to 25 years but generally after10 years)</td></tr>
<tr><td>• Cunningham Grove</td><td>• Giant Forest
• Atwell</td><td>• Wishon (Castle Fire)
• Grant (Rough Fire)</td></tr>
<tr><td colspan="3">Restoration Opportunity 2: Restore desired conditions with targeted reforestation and post-fire fuels reduction treatments in groves burned at high severity (<50%) in smaller patches (<250 ac) that are accessible (timing: within 1 to 2 years)</td></tr>
<tr><td>• Long Meadow
• Redhill
• Packsaddle
• Peyrone
• Deer Creek</td><td>• Redwood Mountain (accessible areas)</td><td>• Alder Creek (Castle Fire)
• Mountain Home (Castle Fire)
• Belknap Camp (Castle Fire)
• Black Mountain (Pier Fire)</td></tr>
<tr><td colspan="3">Restoration Opportunity 3: Reevaluate desired conditions and restore key ecosystem function with reforestation and in groves burned at high severity (>50%) generally in large patches (>250 ac)[e] (timing: within 1 to 2 years)</td></tr>
<tr><td>• Starvation Creek
• Deer Creek</td><td>• Redwood Mountain (inaccessible areas such as steep slopes)</td><td>• Board Camp (SEKI)
• Homers Nose (SEKI)
• Dillonwood West (GSNM)
• Freeman Creek (GSNM)
• Wheel Meadow (GSNM)</td></tr>
</table>

[a] Each restoration opportunity also includes ecological monitoring to evaluate ecological trajectories.

[b] Groves underlined may also benefit from the maintenance or creation of nearby strategic fuel breaks.

[c] Redwood Meadow and Little Redwood Meadow groves are accessible by trail only.

[d] Includes accessible and inaccessible groves. Most recent wildfire is listed, but includes the 2017 Meadow Fire (Cunningham), 2018 Alder Fire (Wishon), and prescribed fires (Giant Forest, Grant Grove).

[e] Includes groves burned in the 2020 Castle Fire in Sequoia-Kings Canyon National Parks (SEKI) and the Giant Sequoia National Monument (GSNM).

Table 24. Potential Operational Delineations (PODs) in the 2021 Windy Fire where active reforestation and fuels reduction are in greatest need to restore desired conditions for fishers and other ecological resources (e.g., sequoia groves) (highest priority highlighted in gold).

Reforestation						Acres		Fuel Reduction			Acres	
POD ID	NRV	Fisher Priority	Ecological Priority	Risk of Regen Failure	Climatic Risk	Access	Limited Access	Fisher Priority	Ecological Priority	Risk of Future Loss	Access	Limited Access
64	No	Moderate	Moderate	High	High	432	34	Moderate	Moderate	Moderate	257	6
67	No	High	Moderate	High	Moderate	408	1771	Moderate	Moderate	Moderate	794	1351
71	No	Moderate	Moderate	Moderate	High	526	883	Moderate	Moderate	Moderate	562	1659
72	No	High	Moderate	High	Moderate	1310	2187	Low	Moderate	Moderate	517	1220
74	No	Moderate	Moderate	Moderate	High	269	978	High	Moderate	High	212	3034
75	No	High	High	High	High	2286	725	High	High	Moderate	1110	853
79	No	High	High	High	Low	2589	1914	Moderate	High	Moderate	955	2093
82	No	Moderate	High	Moderate	Low	515	1719	High	High	Moderate	1159	6757
83	No	Low	Low	Low	High	4	323	Moderate	Low	High	0	5412
94	Yes	Low	Moderate	Low	Moderate	0	4	High	Moderate	Moderate	129	764
471	No	Low	Low	Moderate	High	17	44	Moderate	Low	Moderate	34	189
480	No	Moderate	Low	High	High	1130	588	Moderate	Low	Moderate	1200	350
481	Yes	Low	Low	Low	Low	0	0	High	Low	Moderate	29	138
482	No	Low	Low	Moderate	High	58	360	Low	Low	Moderate	43	160
483	No	High	Moderate	High	High	1983	1036	High	Moderate	Moderate	1256	933
484	No	Moderate	Moderate	High	High	1010	752	Moderate	Moderate	Moderate	34	117
485	No	High	Moderate	High	Moderate	922	138	High	Moderate	Moderate	942	168
486	No	Moderate	Moderate	High	Moderate	1135	464	Moderate	Moderate	Moderate	1210	600
487	Yes	Low	Low	Low	High	60	10	High	Low	Moderate	484	207
489	No	Low	Low	Moderate	High	0	224	Low	Low	High	0	1030
490	Yes	Low	Moderate	Low	Moderate	42	76	Low	Moderate	Moderate	993	365
493	No	Low	Low	Low	Moderate	29	341	High	Low	High	247	4228
494	No	Moderate	Moderate	Moderate	Moderate	26	613	Moderate	Moderate	High	64	2561
Total Acreage						**14,752**	**15,186**	**Total Acreage**			**12,232**	**34,195**

Table 25. Potential Operational Delineations (PODs) in the 2021 KNP Complex where active reforestation and post-fire fuels reduction are in greatest need to restore desired conditions for fishers and other ecological resources (e.g., sequoia groves) (highest priority highlighted in gold).

Reforestation						Acres		Fuel Reduction			Acres	
POD ID	NRV	Fisher Priority	Ecological Priority	Risk of Regen Failure	Climatic Risk	Access	Limited Access	Fisher Priority	Ecological Priority	Risk of Future Loss	Access	Limited Access
118	No	Moderate	High	Moderate	Low	125	188	High	High	Moderate	391	872
129	Yes	Low	Low	Low	Low	2	37	High	Moderate	Moderate	212	2264
134	Yes	Low	Low	Low	Low	23	19	Moderate	Moderate	Moderate	514	311
136	No	Moderate	Moderate	Moderate	Low	52	2901	High	High	Moderate	668	7975
137	No	Moderate	Moderate	Low	High	7	5	Low	Low	Moderate	7	167
147	Yes	Low	Low	Low	Low	0	0	Moderate	Moderate	Moderate	151	42
506	No	Low	Low	Moderate	High	22	10	High	Moderate	High	114	20
508	No	Moderate	Moderate	Low	Moderate	0	137	Moderate	Moderate	Moderate	0	2826
509	No	Moderate	High	Moderate	Moderate	364	95	High	High	Moderate	708	990
511	Yes	Low	Moderate	Low	Low	47	92	High	High	Moderate	863	1658
512	No	High	High	High	Moderate	1303	1071	Low	Moderate	Moderate	965	753
663	Yes	Low	Low	Low	Low	0	0	High	Moderate	Moderate	0	238
664	No	Moderate	Moderate	Low	Low	10	751	High	High	Moderate	1010	10228
665	No	Moderate	Moderate	Low	Moderate	91	211	High	High	Moderate	753	3433
666	No	Moderate	Moderate	Low	Moderate	58	546	Moderate	Moderate	Moderate	563	7587
734	No	Low	Low	Low	High	0	6	Low	Low	High	19	304
735	No	Moderate	Moderate	Moderate	Low	485	1710	Moderate	Moderate	Moderate	2129	4047
736	No	Moderate	Moderate	Low	High	5	24	Moderate	Moderate	Moderate	127	1710
Total Acreage						**2,595**	**7,803**	**Total Acreage**			**9,192**	**4,5425**

Table 26. Potential Operational Delineations (PODs) in the 2021 French Fire where active reforestation and fuels reduction are in greatest need to restore desired conditions for fishers and other ecological resources (e.g., sequoia groves) (highest priority highlighted in gold).

Reforestation						Acres		Fuel Reduction			Acres	
POD ID	NRV	Fisher Priority	Ecological Priority	Risk of Regen Failure	Climatic Risk	Access	Limited Access	Fisher Priority	Ecological Priority	Risk of Future Loss	Access	Limited Access
52	No	Moderate	Moderate	High	High	1217	1115	Low	Moderate	High	743	1024
54	No	Moderate	Moderate	Moderate	High	503	519	Moderate	Moderate	High	1160	1147
56	No	Moderate	Low	Moderate	High	387	152	Moderate	Low	High	277	863
460	No	Moderate	Low	Moderate	High	237	56	Moderate	Low	High	564	180
461	Yes	Low	Low	Low	High	157	68	Moderate	Low	High	903	1578
462	No	Low	Low	Low	High	0	43	Low	Low	Moderate	0	90
464	No	Moderate	Moderate	Moderate	High	608	297	High	Moderate	High	941	2198
Total Acreage						**3110**	**2250**	**Total Acreage**			**4,587**	**7,079**

Table 27. Potential Operational Delineations (PODs) in the 2020 Castle Fire where active reforestation and post-fire fuels reduction are in greatest need to restore desired conditions for fishers and other ecological resources (e.g., sequoia groves) (highest priority highlighted in gold).

Reforestation						Acres		Fuel Reduction			Acres	
POD ID	NRV	Fisher Priority	Ecological Priority	Risk of Regen Failure	Climatic Risk	Access	Limited Access	Fisher Priority	Ecological Priority	Risk of Future Loss	Access	Limited Access
86	No	Moderate	Low	High	High	28	65	Low	Low	Moderate	19	49
88	No	Low	Low	Moderate	Low	136	703	Low	Low	Low	348	342
91	No	High	High	High	High	2567	3575	Moderate	High	High	1337	1891
94	No	High	High	Moderate	Moderate	404	1158	Moderate	High	High	749	2491
96	No	Low	Low	Moderate	High	0	2700	Low	Low	Moderate	0	2900
101	No	Moderate	Low	High	Moderate	974	6796	Moderate	Low	Moderate	957	8677
103	No	Low	Low	Moderate	Low	0	340	Low	Low	Low	0	249
104	No	Low	Low	Moderate	Low	0	159	High	Moderate	Moderate	0	441
106	No	High	High	Moderate	Low	182	1576	Moderate	High	Moderate	122	3122
107	No	Moderate	High	Moderate	Moderate	6	1463	High	High	High	33	9136
108	No	Low	Low	Moderate	Low	0	1442	Moderate	Low	Moderate	0	3011
109	No	Moderate	Moderate	Moderate	Low	0	1570	High	Moderate	Moderate	0	6750
110	No	Low	Low	Low	High	20	70	Moderate	Low	High	264	639
111	Yes	Low	Low	Low	Low	0	1	Moderate	Low	Moderate	0	237
113	Yes	Low	Low	Low	Low	0	4	Moderate	Low	Moderate	0	390
116	Yes	Low	Low	Low	Low	0	7	Moderate	Low	Moderate	0	100
480	No	Moderate	Moderate	High	High	799	813	Moderate	Moderate	High	1261	657
481	No	Low	Low	Low	Low	20	65	High	Moderate	Moderate	499	129
517	No	Low	Low	Low	Low	0	275	Moderate	Low	Moderate	0	2045
518	Yes	Low	Low	Low	Low	0	129	Moderate	Low	Moderate	0	418
519	No	Low	Low	Moderate	Moderate	13	790	Low	Low	Moderate	18	1235
521	No	Low	Low	Moderate	Moderate	0	120	Low	Low	Moderate	0	127
523	No	Low	Low	Moderate	High	0	266	Low	Low	Moderate	0	511
524	No	Moderate	Moderate	Moderate	High	465	188	Moderate	Moderate	High	630	504

528	Yes	Low	Low	Low	Moderate	0	38
530	No	Moderate	Low	Moderate	Low	0	782
531	No	Moderate	Low	Moderate	Moderate	3	578
533	No	Moderate	High	Moderate	High	39	343
534	No	Moderate	High	Moderate	Moderate	163	476
535	No	High	Moderate	High	Low	2488	1475
537	No	Moderate	Moderate	Low	Moderate	0	0
538	No	Low	Moderate	Moderate	Low	0	931
539	No	Moderate	Moderate	Low	High	9	237
1117	Yes	Low	Low	Low	Low	0	2
1118	No	Low	Low	Moderate	Low	0	828
1119	No	Low	Low	Low	Moderate	0	301
Total Acreage						**8,314**	**30,264**

Moderate	Moderate	High	106	3862
High	Moderate	Moderate	4	1909
Moderate	Low	High	150	1698
Moderate	High	High	296	2226
High	High	High	716	2731
Moderate	Moderate	Moderate	1448	512
High	Moderate	High	104	29
High	High	Moderate	1	3094
High	Moderate	High	292	2242
Moderate	Low	Moderate	0	36
Low	Low	Low	0	236
Moderate	Low	Moderate	0	1095
Total Acreage			**9,354**	**65,722**

Figures

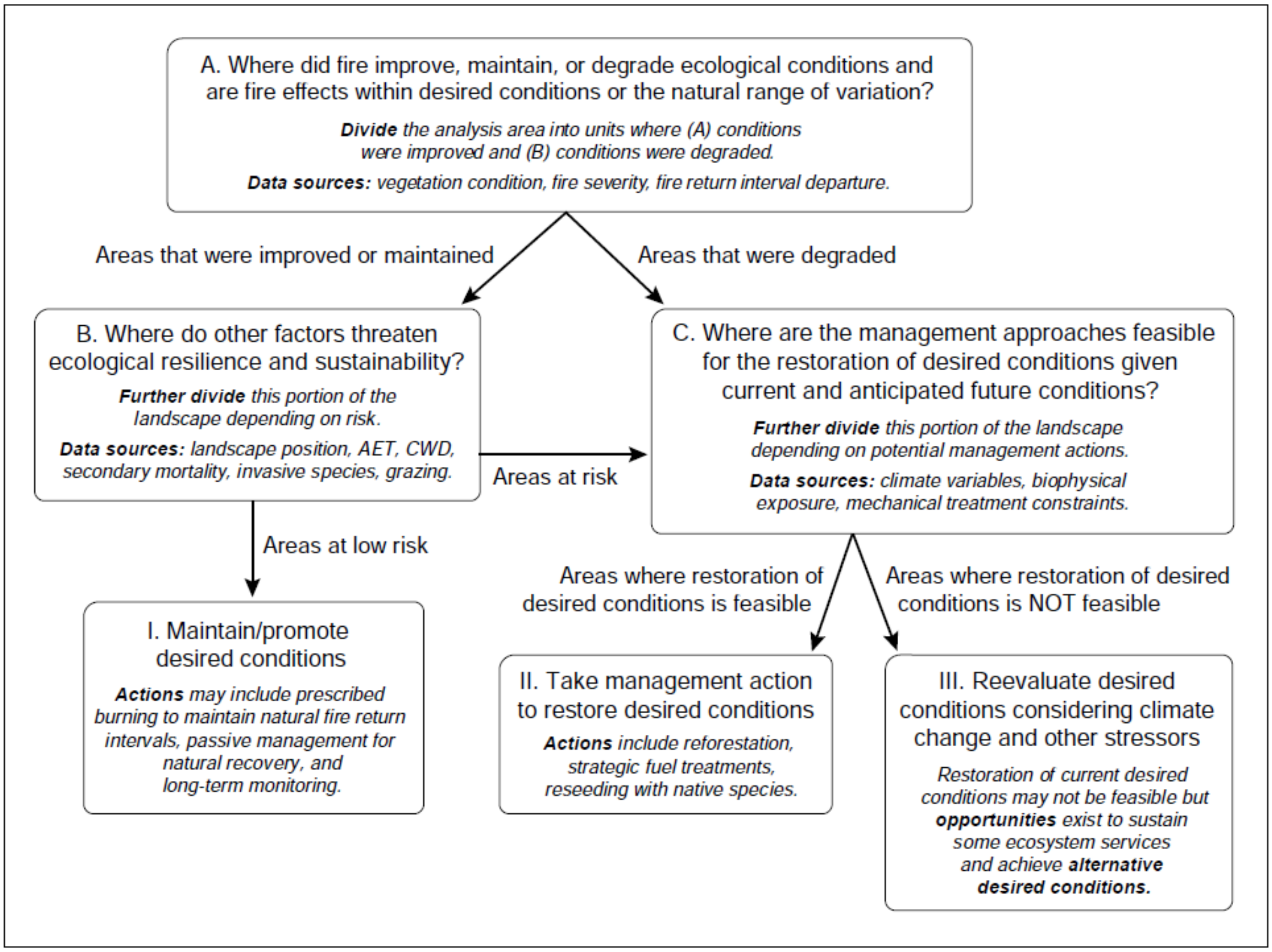

Figure 1. Post-fire flow chart from Meyer et al. (2021) asks three questions (A, B, and C) for the identification of management responses or “restoration opportunities” (1, 2, and 3) that support overarching restoration goals in different portions of the affected landscape.

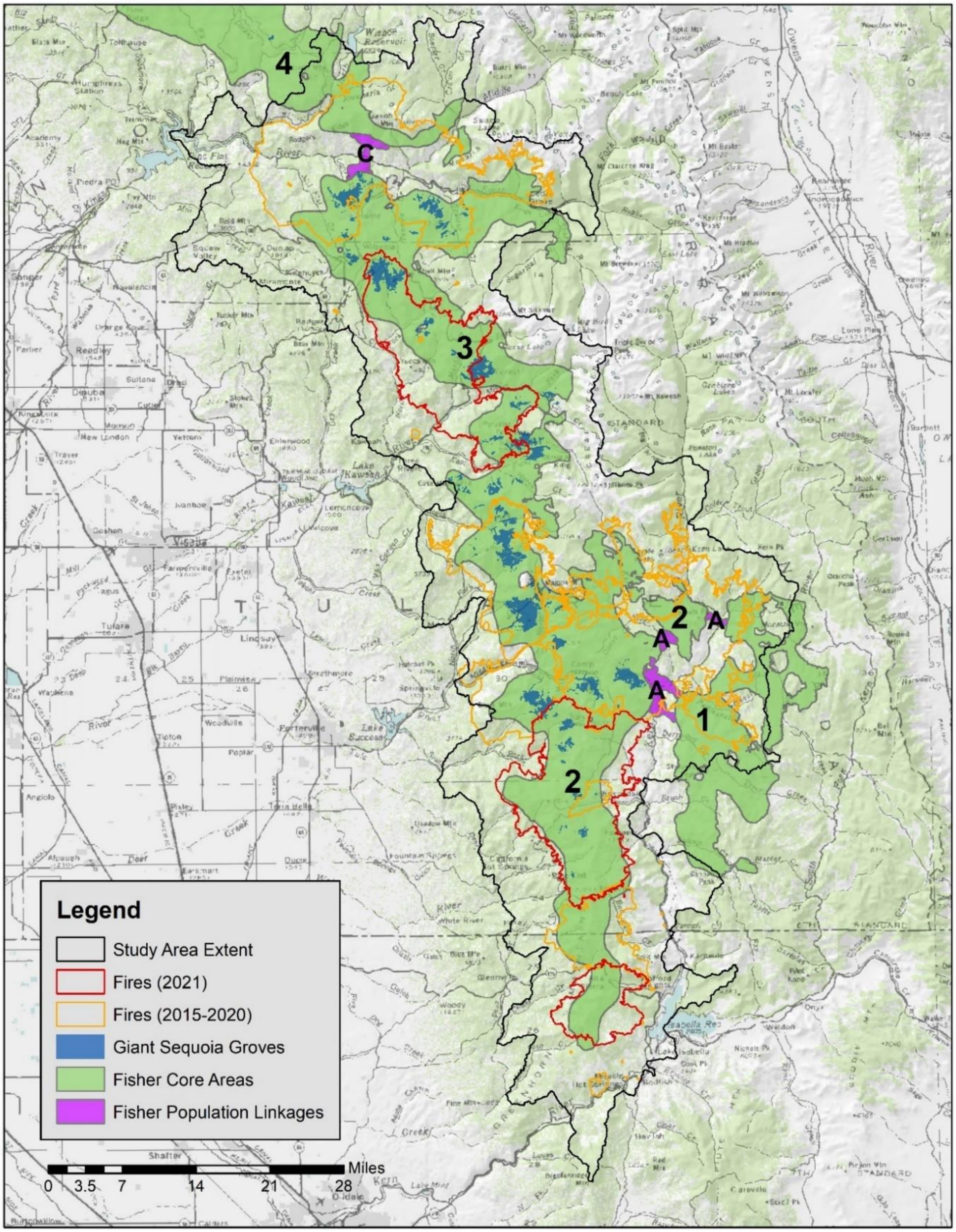

Figure 2. Analysis area showing the spatial extent of recent wildfires, giant sequoia groves, and fisher habitat represented by Core Areas and Population Linkages identified in the Southern Sierra Nevada fisher conservation strategy; Spencer et al. 2016. Note the modeled Fisher Core areas are from the 2016 strategy (based on 2012 imagery) do not reflect current landscape conditions but serve as a reference.

Figure 3. Variation in fire behavior in giant sequoia groves burned in the Windy Fire and KNP Complex.

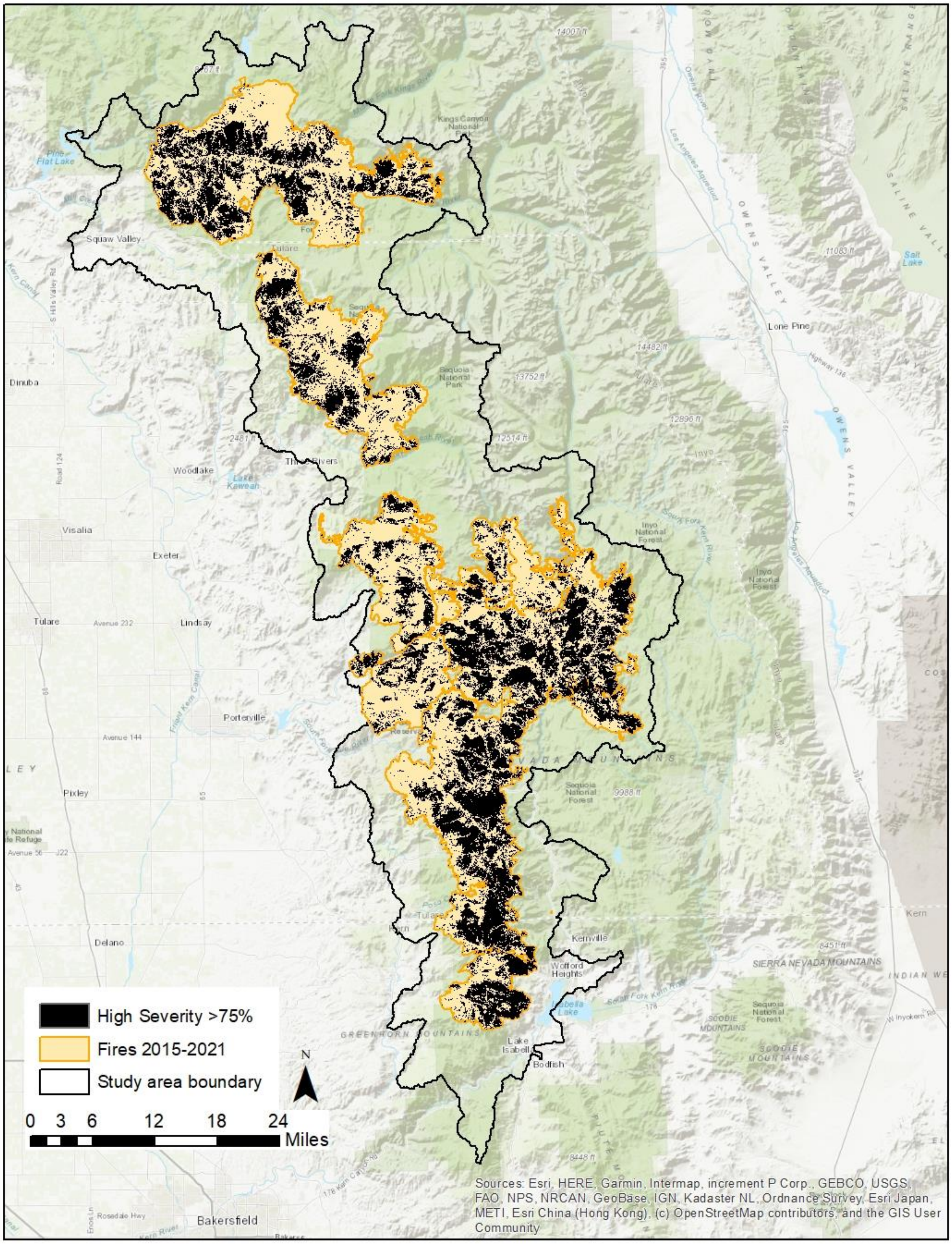

Figure 4. Fire perimeters and high severity (>75% basal area loss; all vegetation types) patches following wildfires that occurred between 2015 and 2021, as classified by RAVG vegetation burn severity data.

Figure 5. Fire severity proportions of forest area within wildfires (≥1,000 ac) that burned in the analysis area between 2015 and 2021. The threshold value for high severity fire based on NRV and desired conditions is 15% (red line).

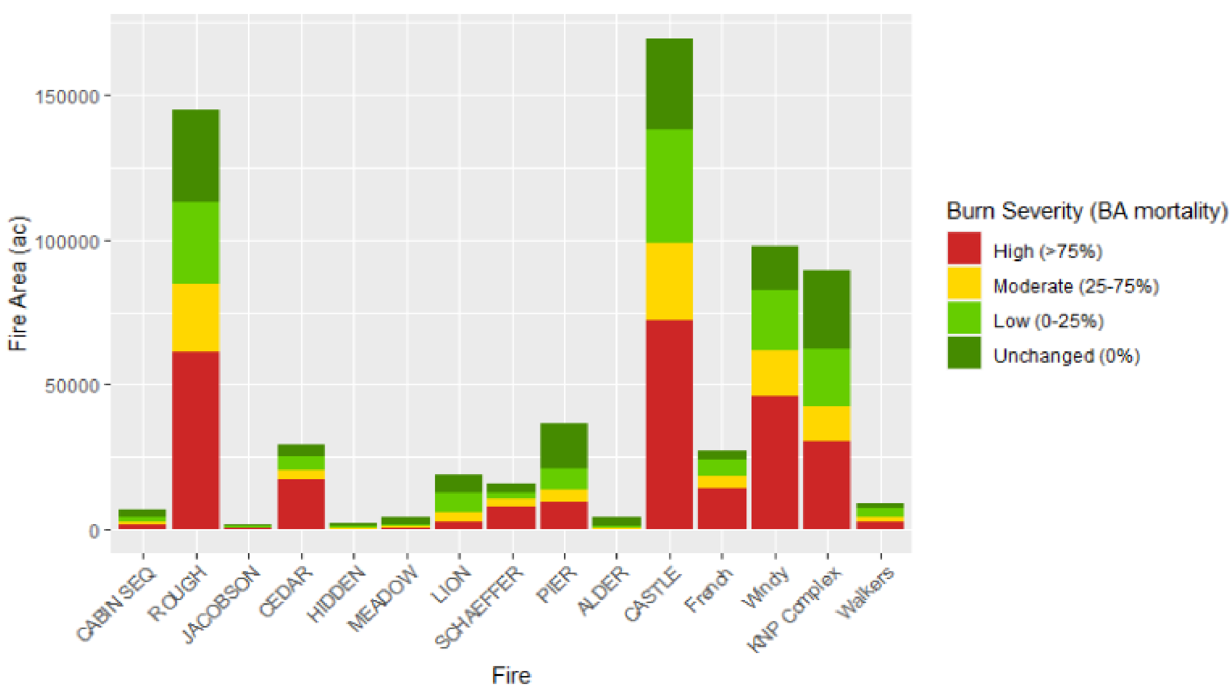

Figure 6. Fire severity area (acres) of wildfires (≥1,000 ac; includes forest and non-forest vegetation) that burned in the analysis area between 2015-2021.

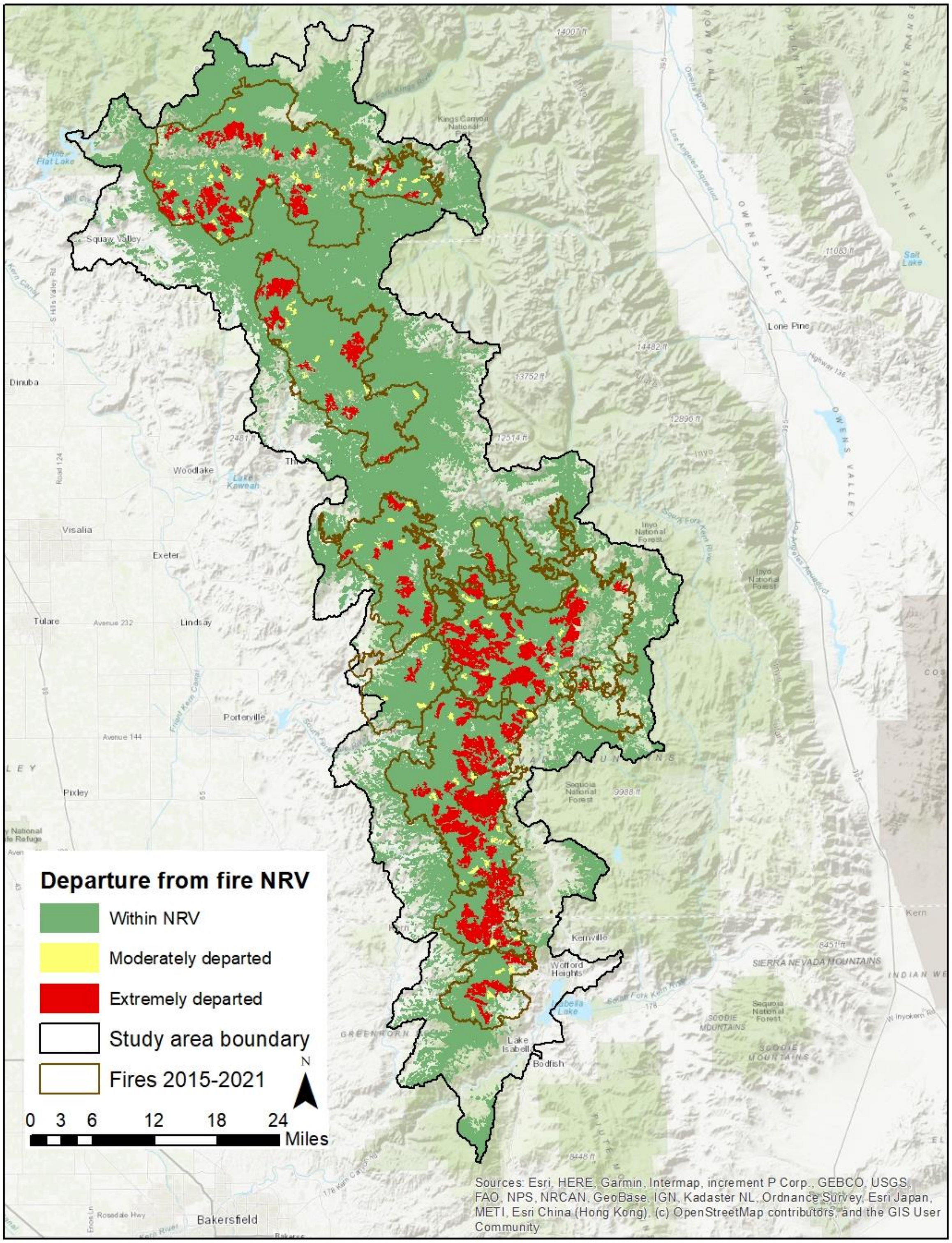

Figure 7. Forest vegetation in the analysis area that burned within NRV (primarily low to moderate fire severity; maintain/restore desired conditions) or were moderately to extremely departed from NRV (high severity patches >100 or 250 acres, respectively; take management actions to restore desired conditions or reevaluate desired conditions).

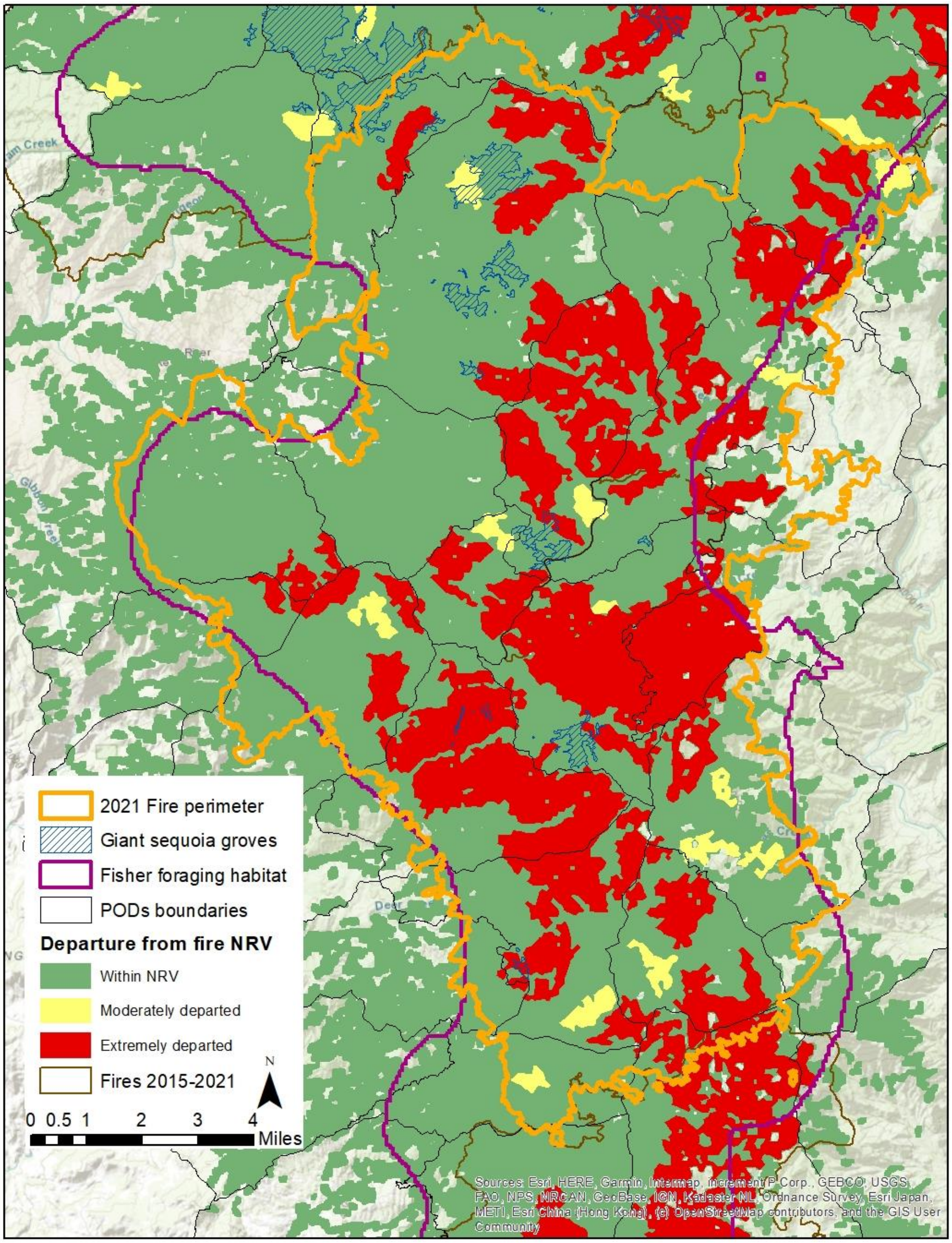

Figure 8. Forest vegetation in the 2021 Windy Fire (Giant Sequoia National Monument) that burned within NRV or were moderately to extremely departed from NRV (high severity patches >100 or 250 acres, respectively). Giant sequoia grove boundaries (blue cross-hatched), fisher foraging habitat (purple outlines), POD boundaries (black lines), and forest vegetation (green areas) are also shown.

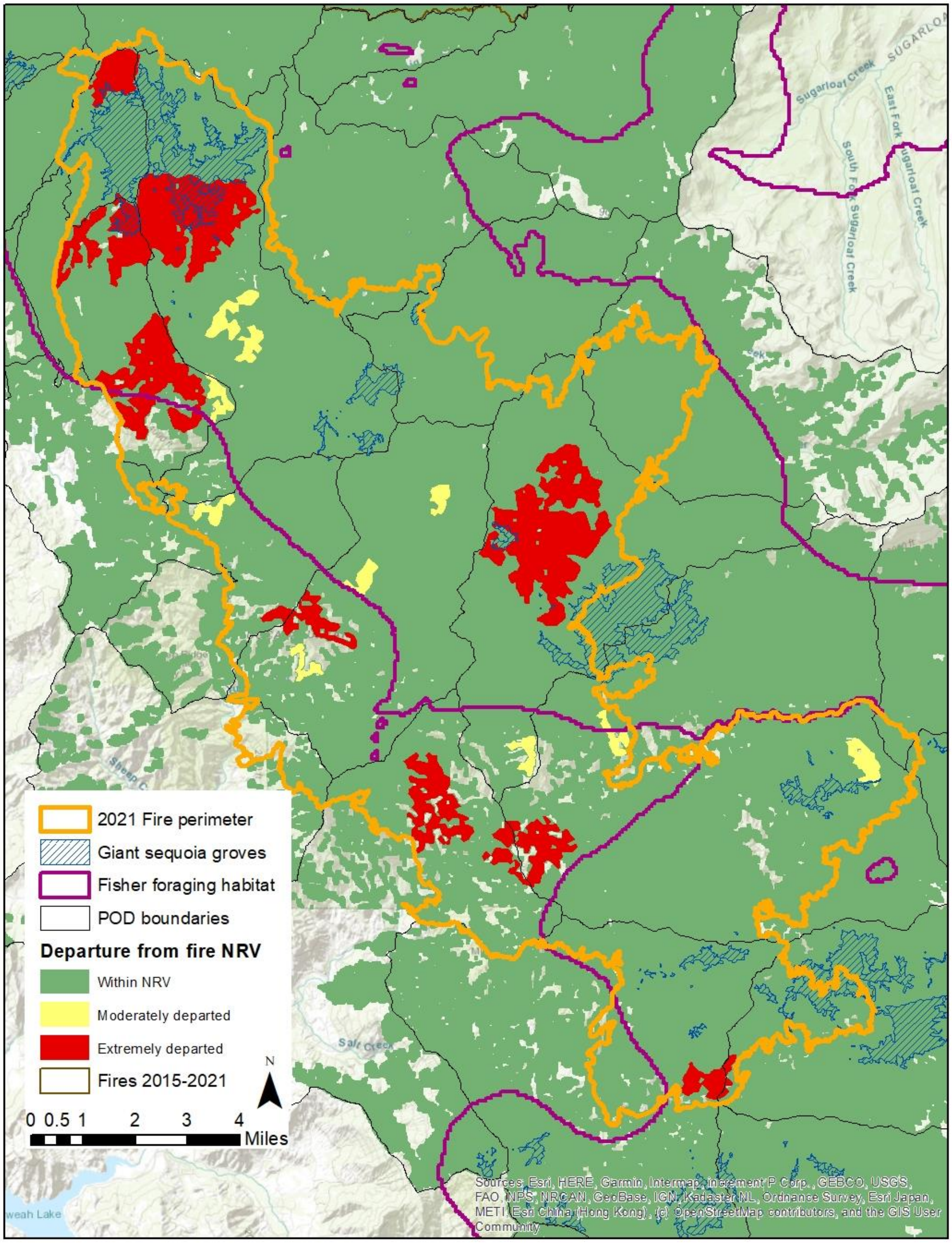

Figure 9. Forest vegetation in the 2021 KNP Complex (Sequoia-Kings Canyon National Parks) that burned within NRV or were moderately to extremely departed from NRV (high severity patches >100 or 250 acres, respectively). Giant sequoia grove boundaries (blue cross-hashed), fisher foraging habitat (purple outline), POD boundaries (black lines), and forest vegetation (green areas) are also shown.

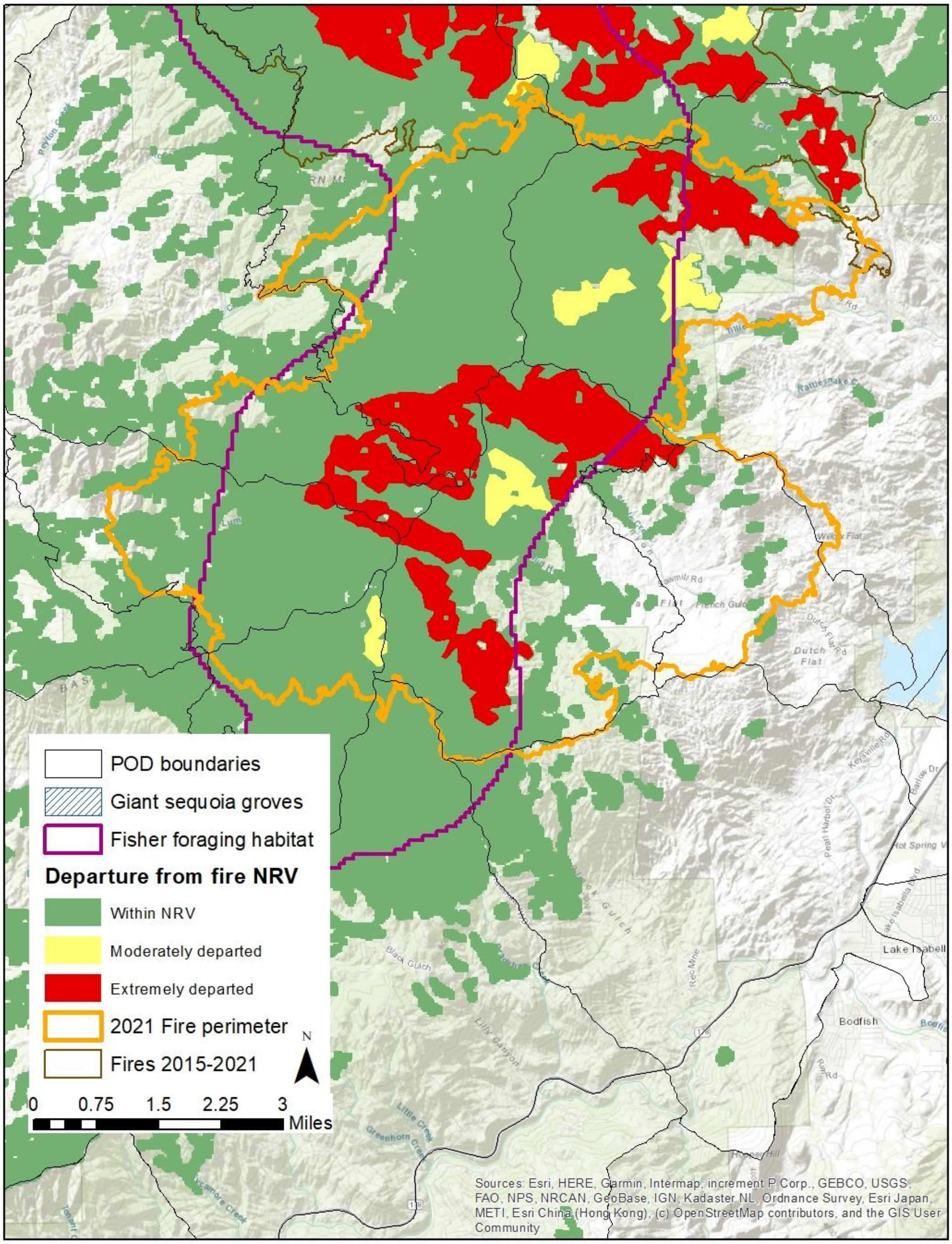

Figure 10. Forest vegetation in the 2021 French Fire (Sequoia National Forest) that burned within NRV or were moderately to extremely departed from NRV (high severity patches >100 or 250 acres, respectively). Fisher foraging habitat (purple outline), POD boundaries (black lines), and forest vegetation (green areas) are also shown.

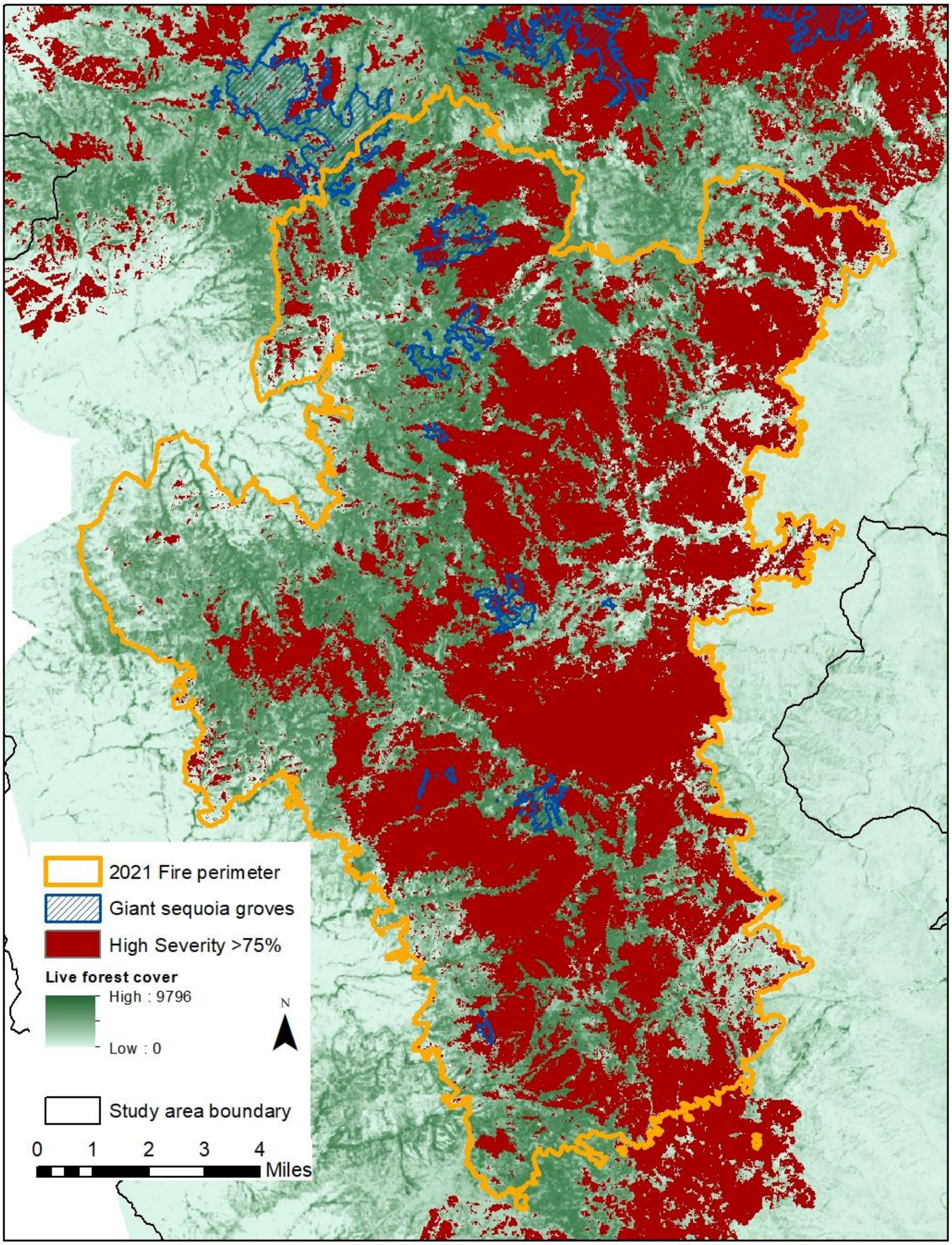

Figure 11. Patches of high severity fire (in all vegetation types) and remaining live forest cover providing habitat connectivity for fisher in the 2021 Windy Fire. Connectivity is particularly limited by several pinch points centered on sequoia groves such as Packsaddle and Long Meadow groves located in the central portion of the fire.

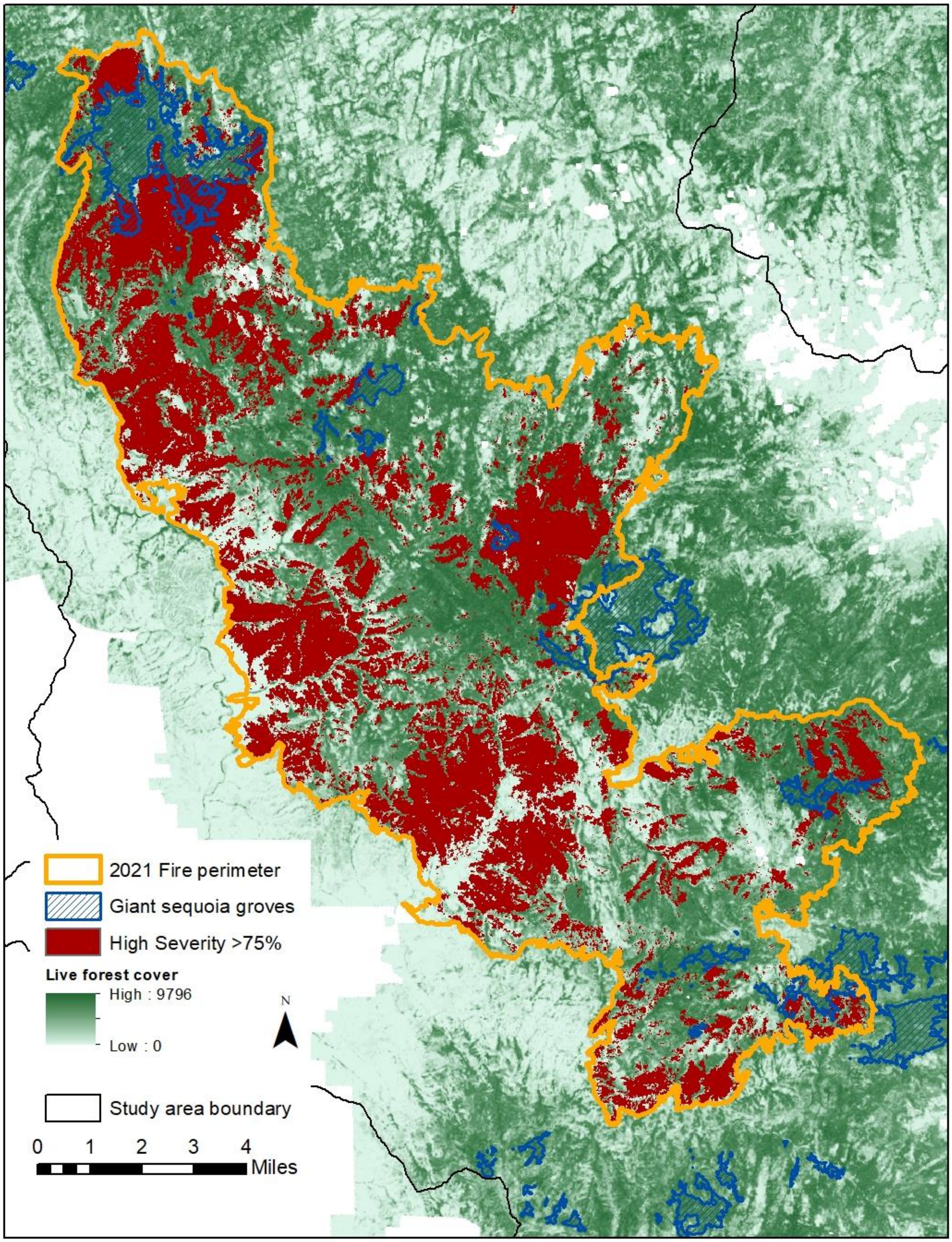

Figure 12. Patches of high severity fire (in all vegetation types) and remaining live forest cover providing habitat connectivity for fisher in the 2021 KNP Complex. Connectivity is particularly limited by several pinch points in various locations of the fire such as near Redwood Mountain grove at the top of the map.

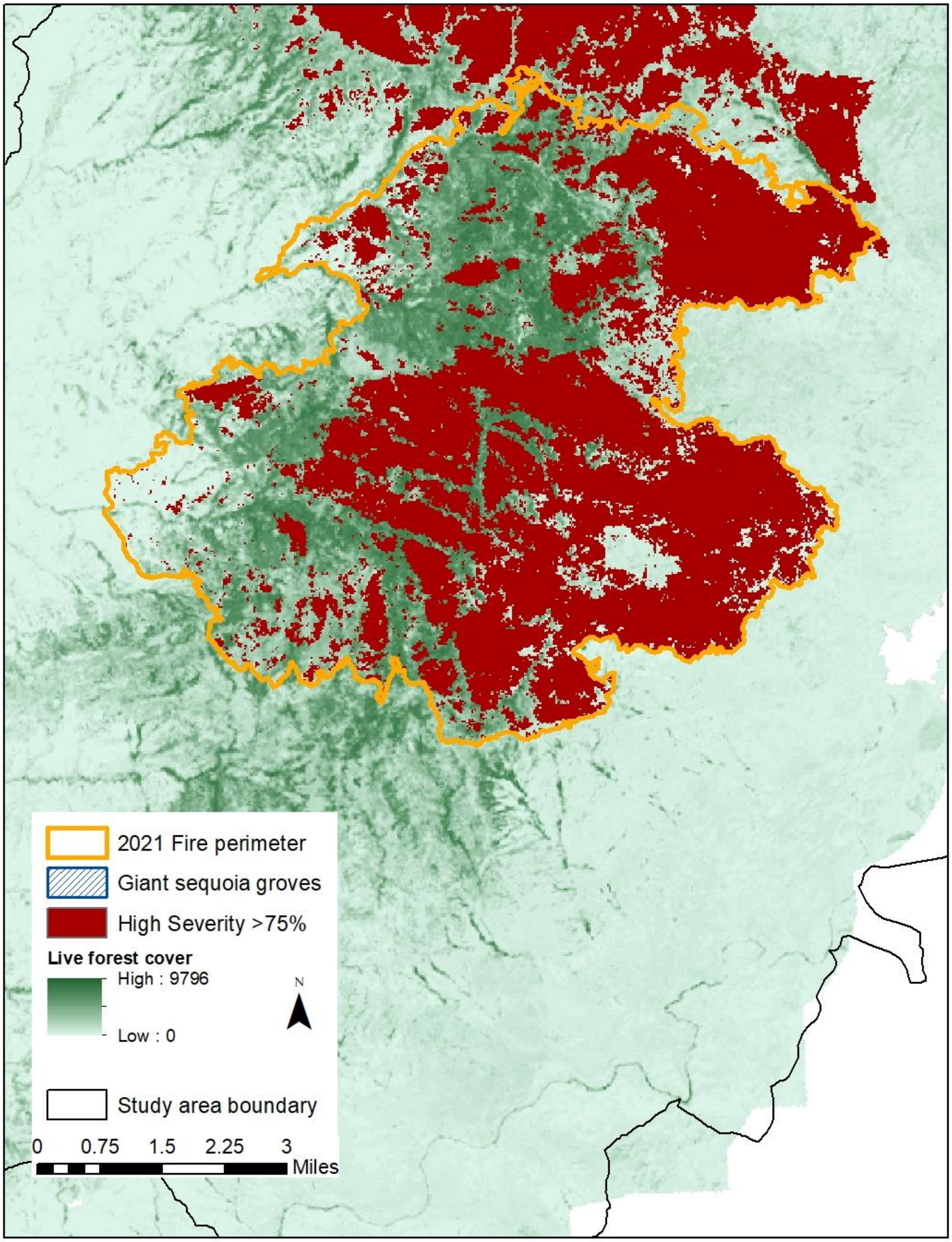

Figure 13. Patches of high severity fire (in all vegetation types) and remaining live forest cover providing habitat connectivity for fisher in the 2021 French Fire. Connectivity is particularly limited by several pinch points throughout the fire and previous fires (i.e., 2016 Cedar Fire to the north).

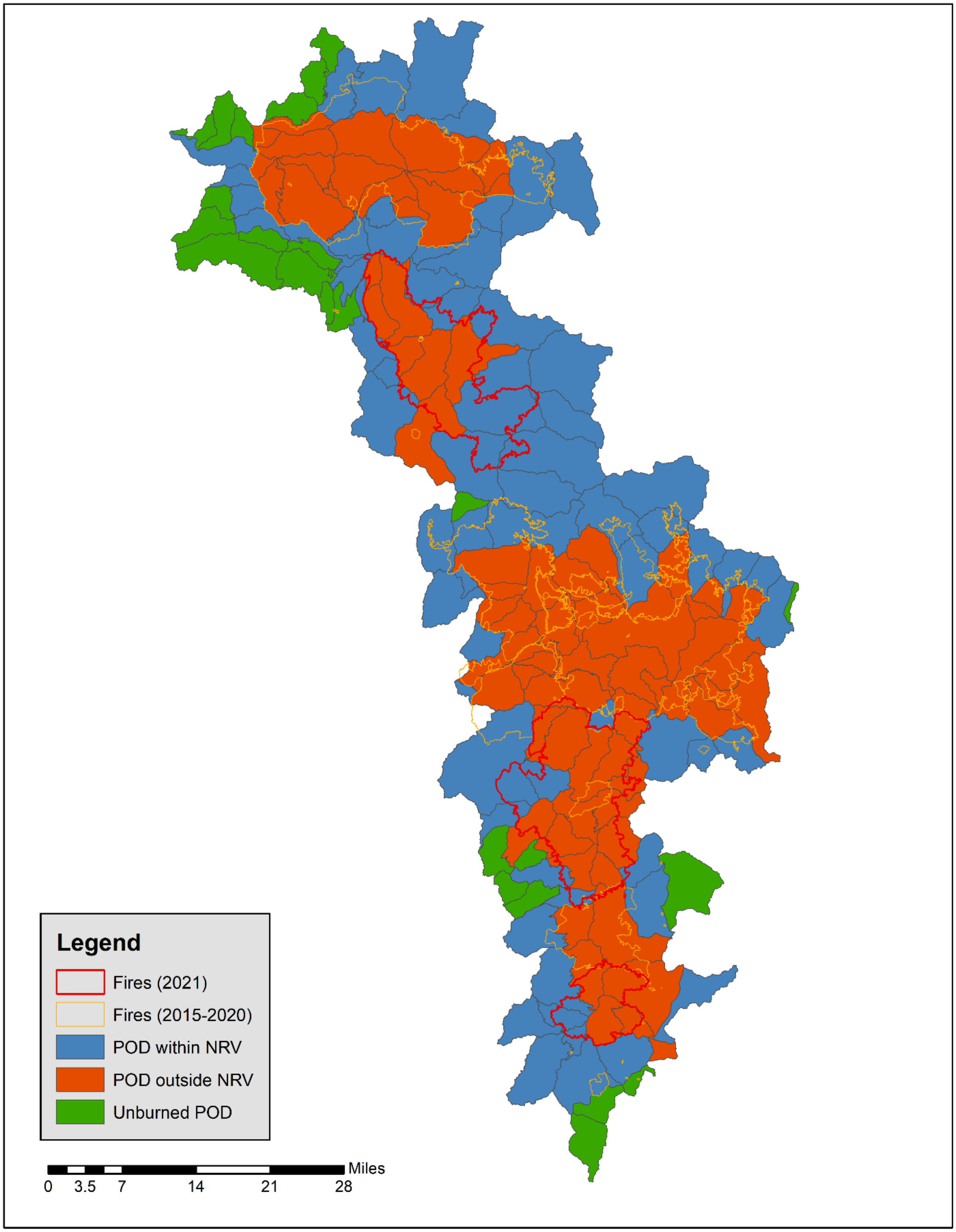

Figure 14. Potential operational delineations (PODs) that experienced fire effects within NRV, outside NRV, or unburned in recent wildfires.

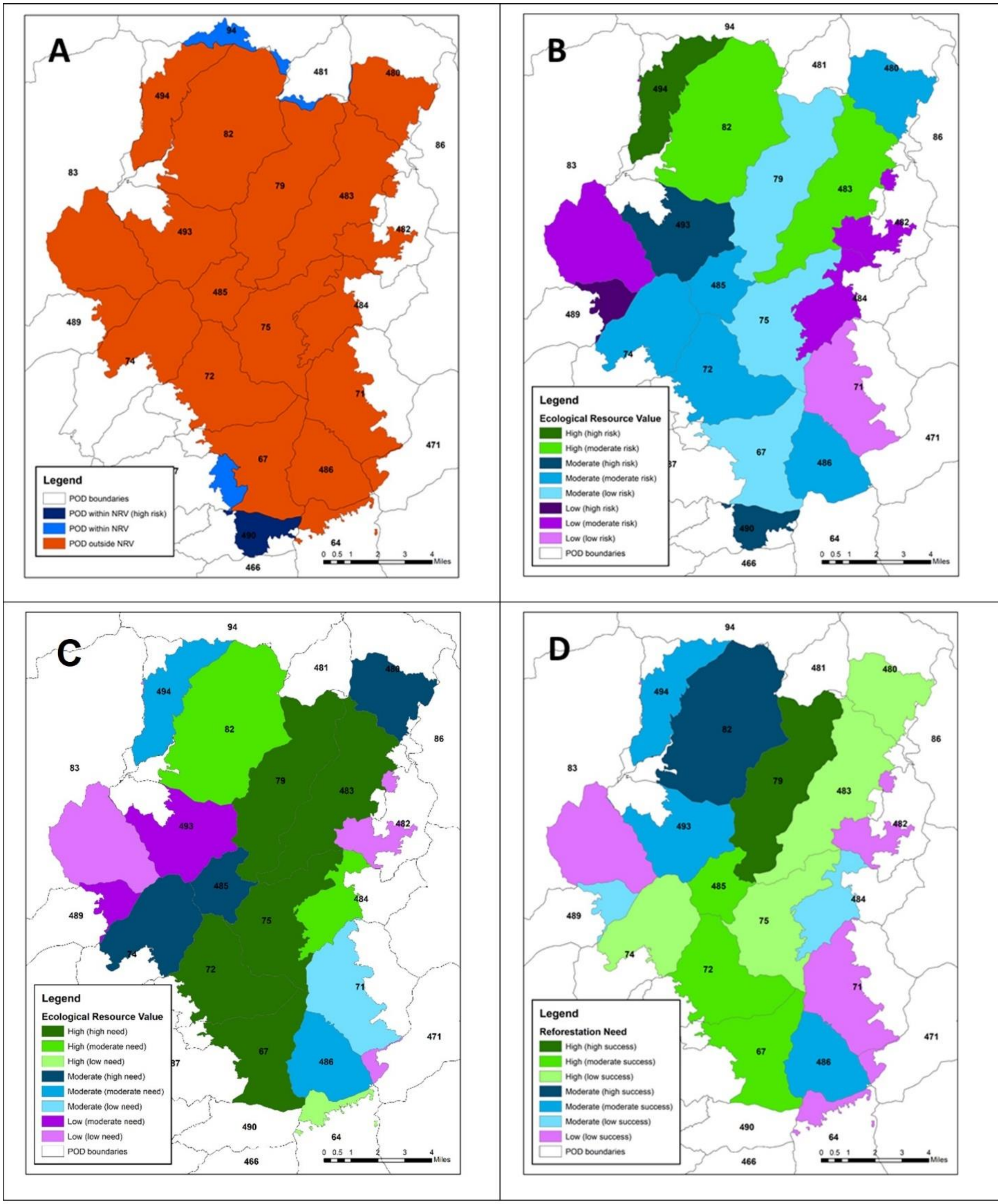

Figure 15. Extended step 3 of the post-fire framework for the 2021 Windy Fire. (A) Potential Operational Delineations (PODs) that experienced fire effects outside of NRV or within NRV but at high risk, (B) PODs of high ecological resource value and of future risk, (C) PODs of high ecological resource value in need of reforestation, and (D) PODs with a high probability of success of needed reforestation.

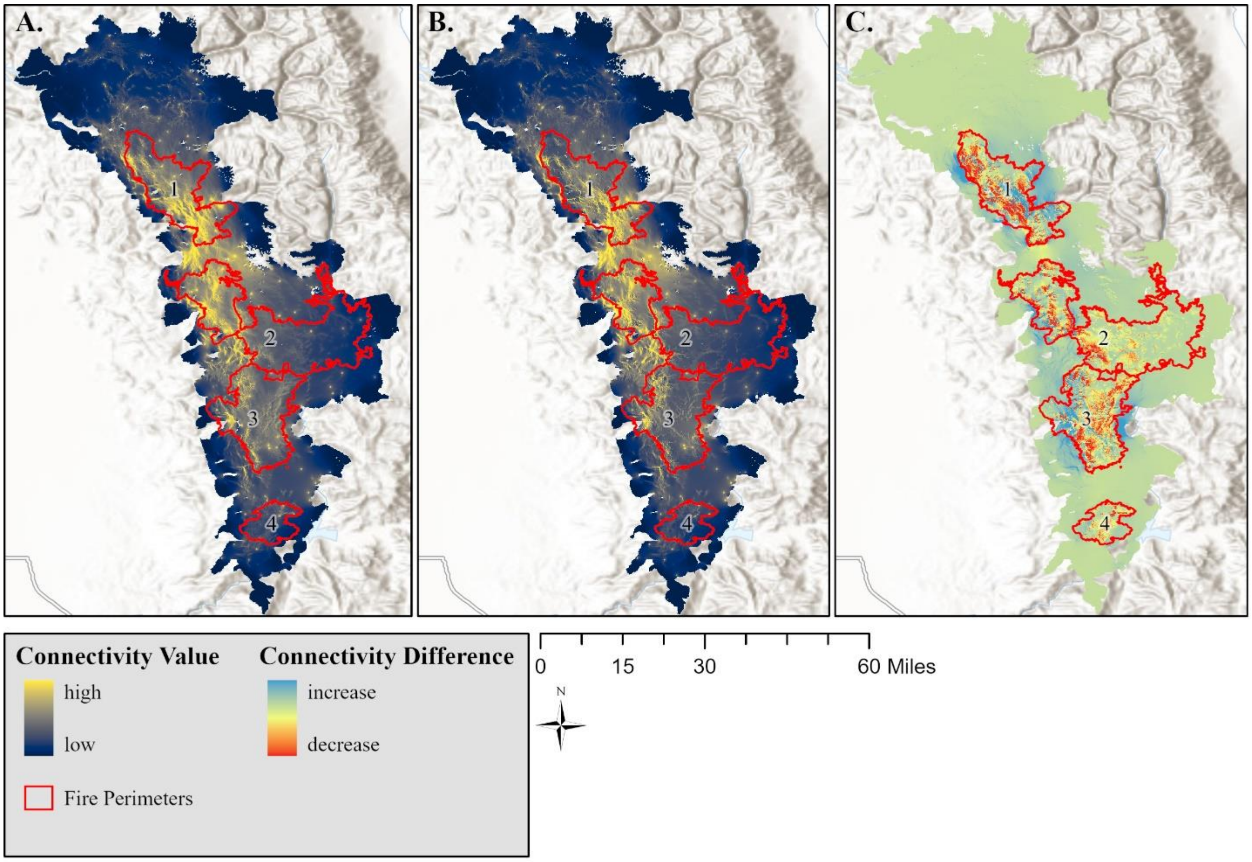

Figure 16. Pre-fire connectivity values (A) for fishers prior to fires burning in or after 2018, and after the 2021 wildfires (B). The difference between these layers highlights areas of increased and decreased connectivity value (C). Wildfires are indicated as follows: (1) 2021 KNP Complex, (2) 2020 Castle Fire, (3) 2021 Windy Fire, and (4) 2021 French Fire.

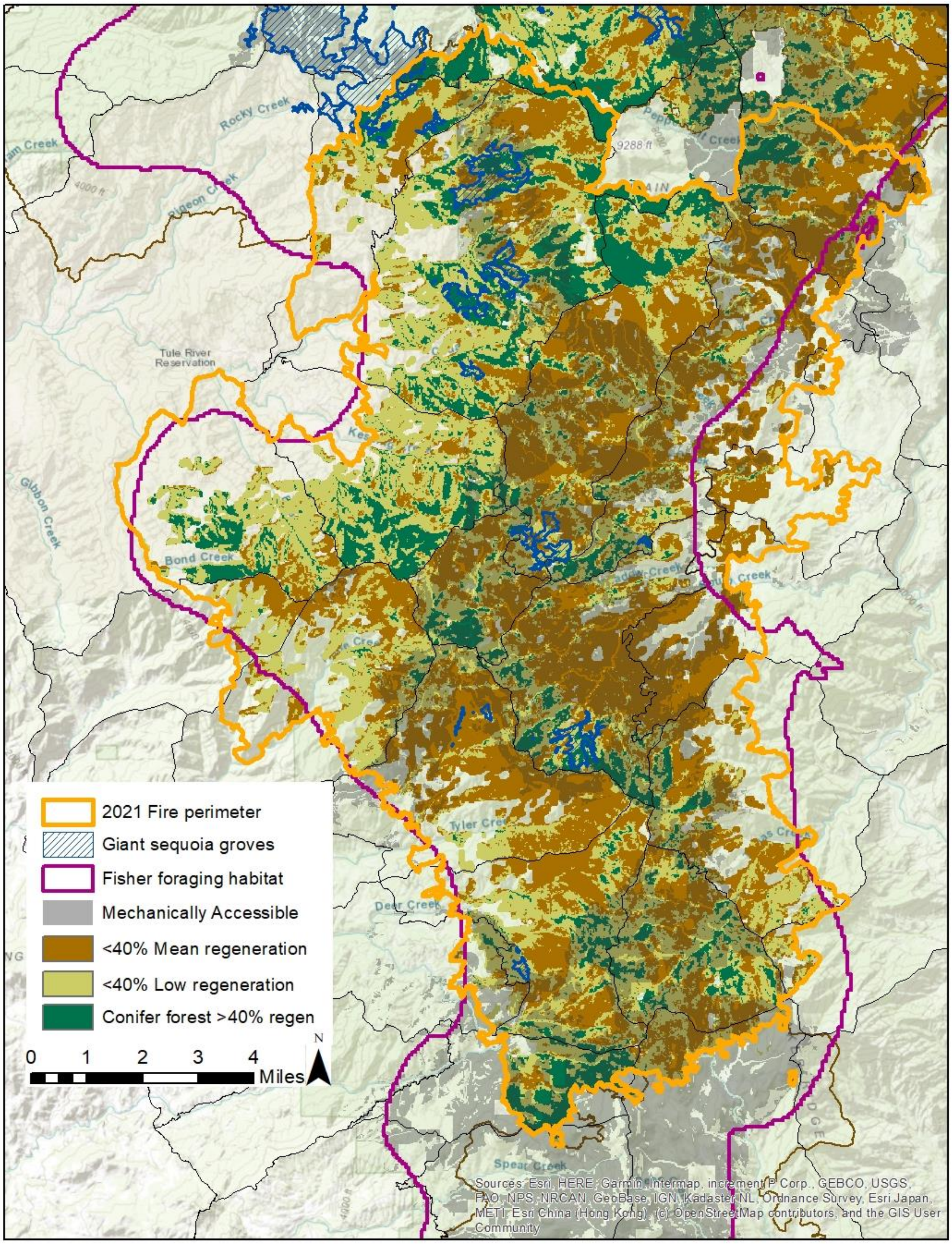

Figure 17. Potential post-fire conifer regeneration for the 2021 Windy Fire (based on POSCRPT model). Darker and warmer colors indicate areas of greater potential conifer regeneration failure and type conversion to non-forest vegetation (e.g., chaparral) under a mean (brown) or low (yellow) precipitation and seed availability scenario. Areas without pre-fire forest vegetation are not shown.

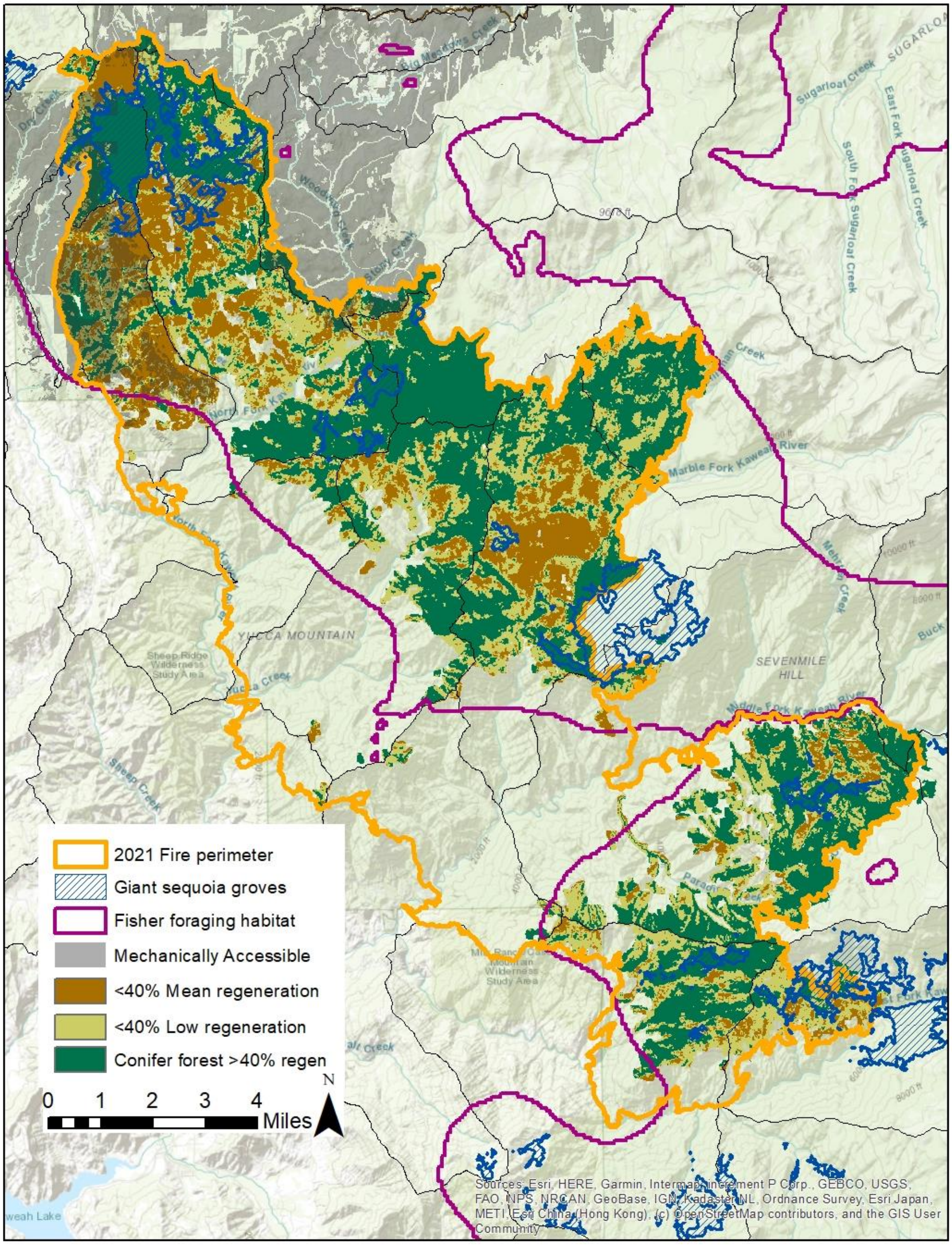

Figure 18. Potential post-fire conifer regeneration for the 2021 KNP Complex (based on POSCRPT model). See Figure 17 for a description of each regeneration scenario. Main areas of conifer regeneration failure are predicted for south of Redwood Mountain grove and northeast of Giant Forest grove.

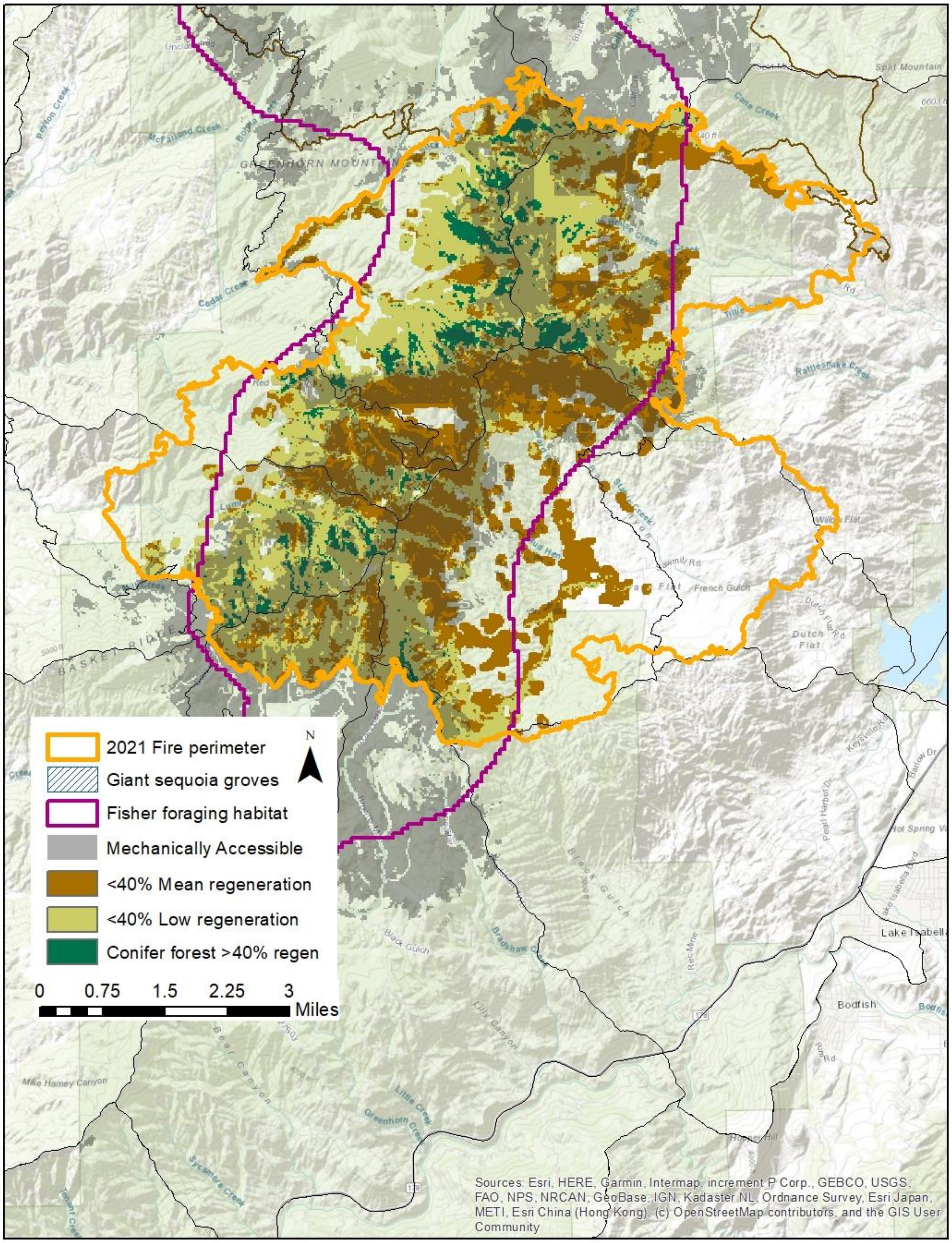

Figure 19. Potential post-fire conifer regeneration for the 2021 French Fire (based on POSCRPT model). See Figure 17 for a description of each regeneration scenario.

Figure 20. Elevated stand densities and surface fuels in a sequoia grove that burned at low severity after a recent wildfire (top) and in a fire-excluded grove that has not experienced fire in over a century (bottom).

Figure 21. Post-fire conditions in giant sequoia groves burned twice in the past 50 years at low to moderate severity (top) and recently once at high severity (bottom).

Figure 22. Sequoia grove that burned in a large high severity patch, where desired conditions (e.g., presence of large sequoias) are unlikely to be restored in the foreseeable future. Post-fire management actions may restore a more limited set of ecosystem desired conditions (e.g., ample sequoia regeneration).

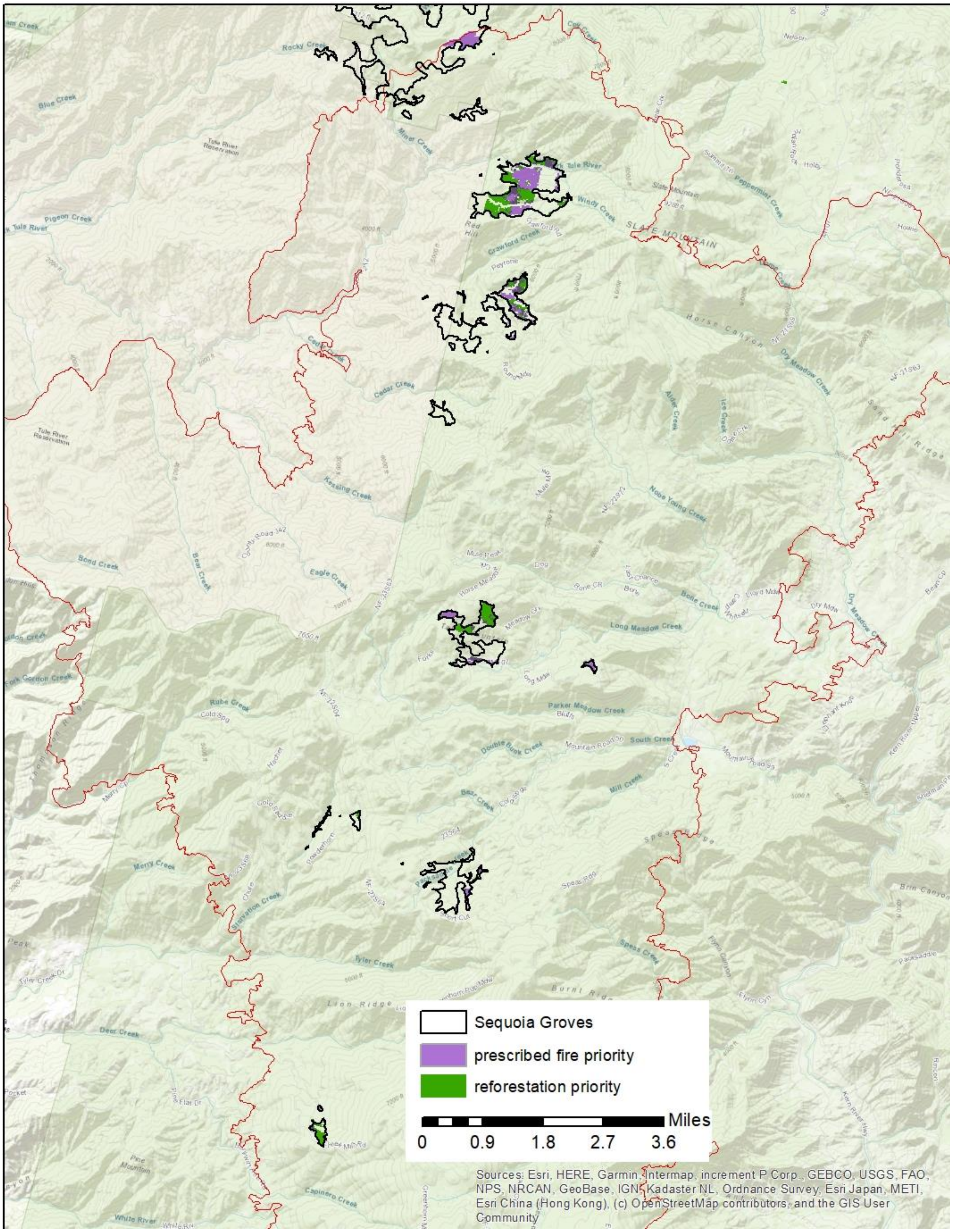

Figure 23. Priority areas for prescribed fire (restoration opportunity 1) and reforestation (restoration opportunities 2 and 3) in giant sequoia groves within the Windy Fire area.

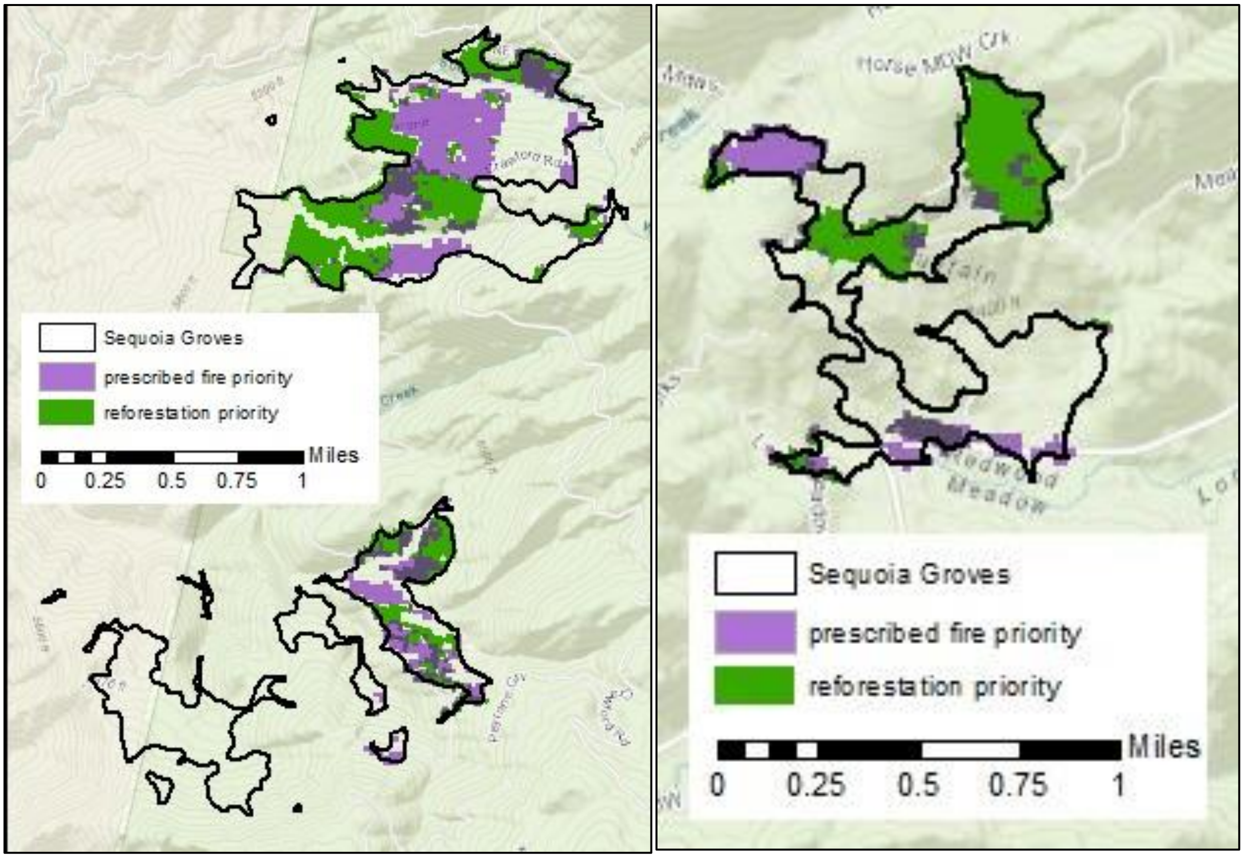

Figure 24. Priority areas for prescribed fire and reforestation in the Redill and Peyrone groves (left panel) and Long Meadow grove (right panel) burned in the 2021 Windy Fire.

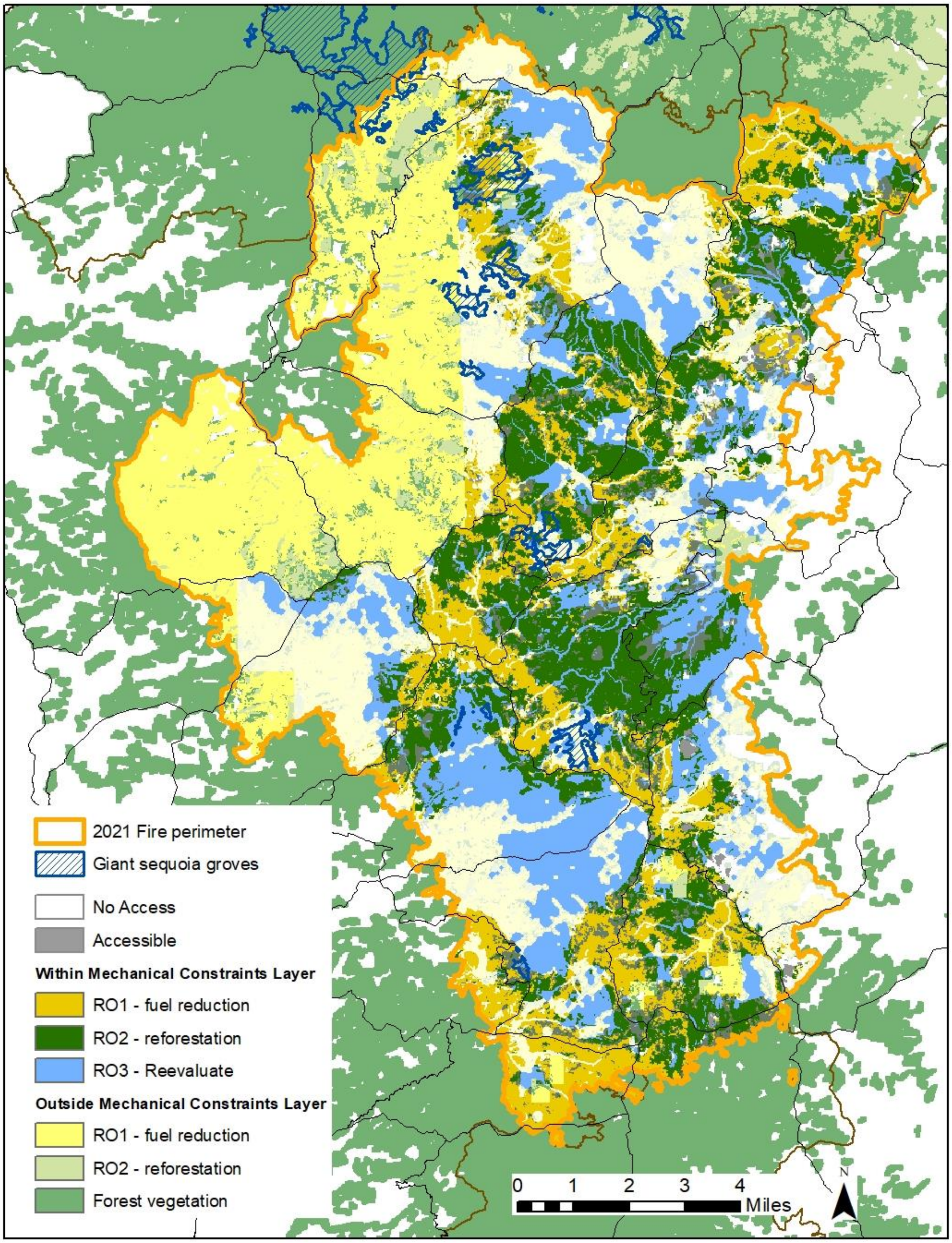

Figure 25. Restoration portfolio for the 2021 Windy Fire area includes forested areas: (1) burned at low to moderate severity that is mechanically accessible (orange; RO1: fuel reduction) (2) burned at higher severity with low probability of natural conifer regeneration and mechanically accessible (dark green; RO2: reforestation), and (3) burned at high severity and not accessible (light blue; RO3: reevaluate desired conditions). Areas outside the GSNM and inside the Windy Fire (mostly in the Tule River Indiana Reservation) are shown in pastel yellow (potential fuel reduction) or light green (potential reforestation).

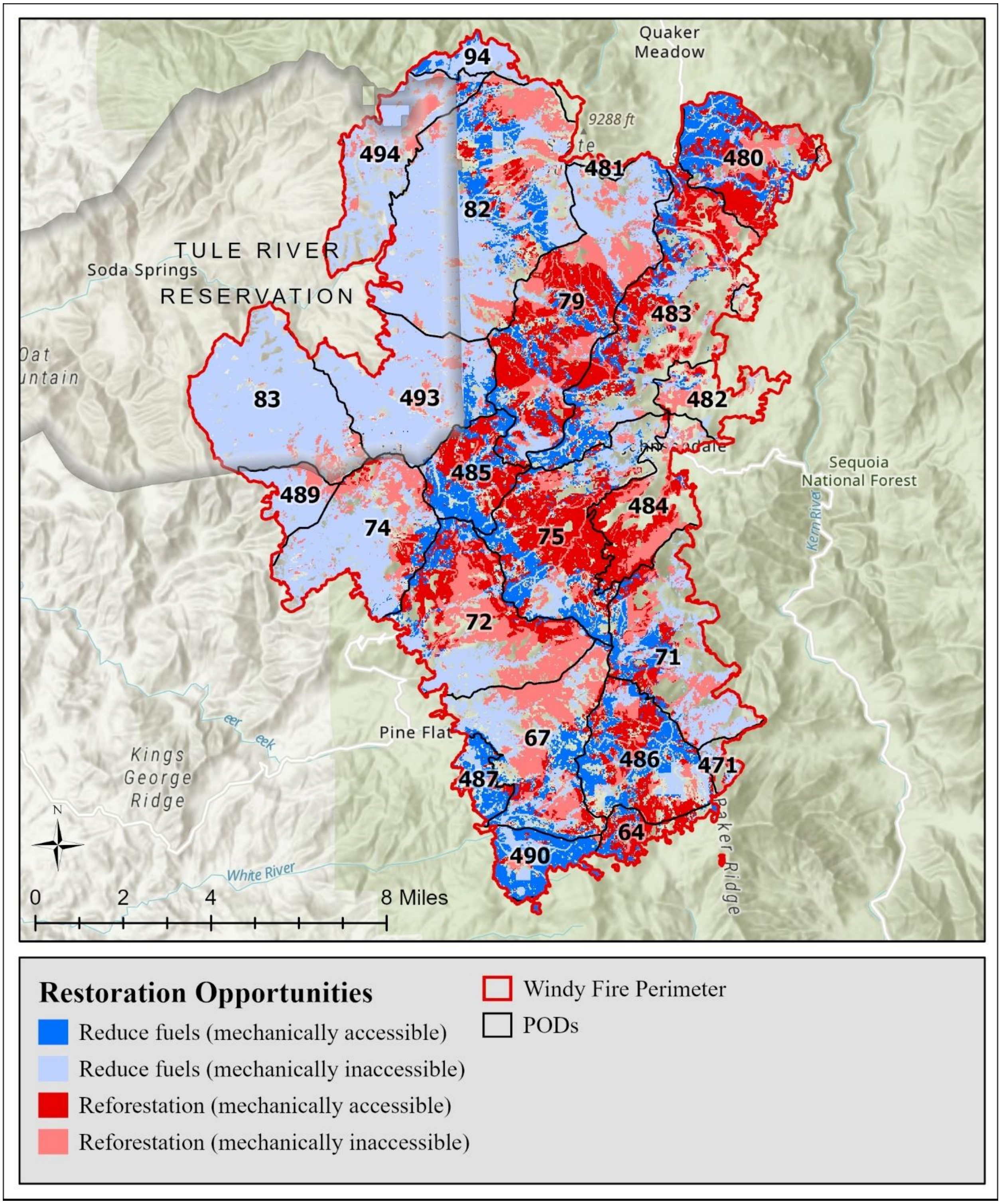

Figure 26. Restoration portfolio showing priority PODs for fuel reduction (blue) and reforestation (red) activities in the 2021 Windy Fire. Darker colors indicate areas that are mechanically accessible.

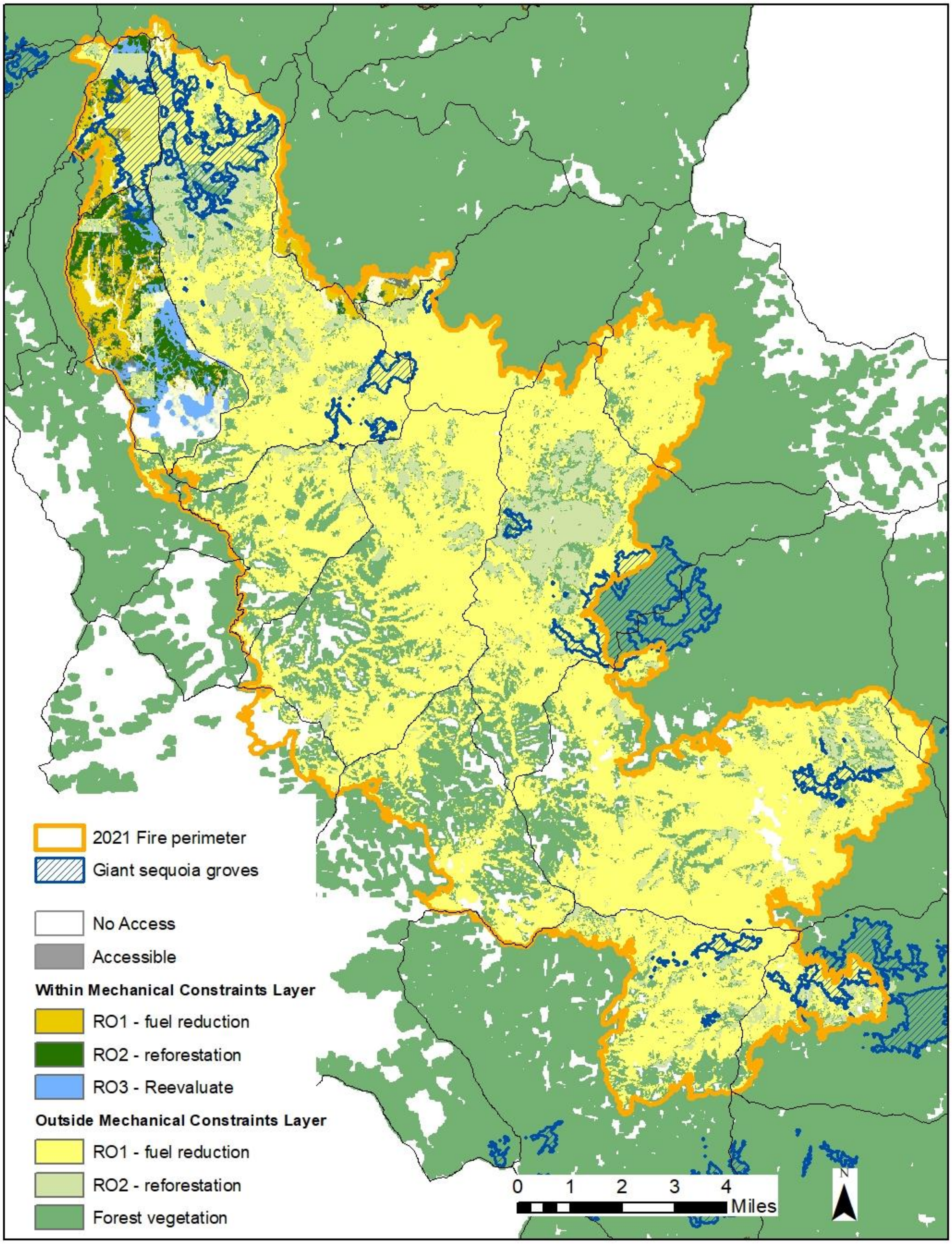

Figure 27. Restoration portfolio for the 2021 KNP Complex area. See Figure 25 for a description of color-coded areas.

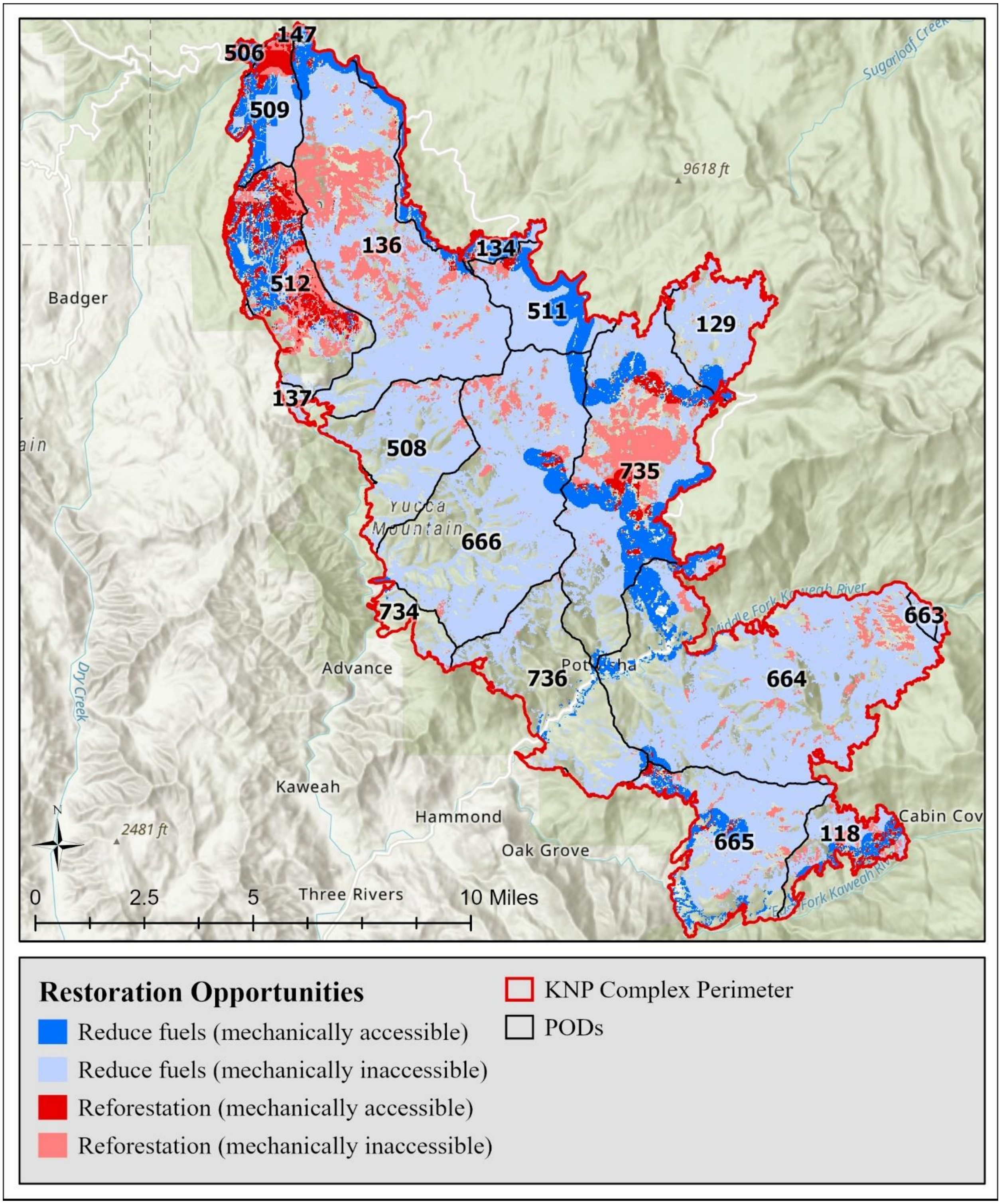

Figure 28. Restoration portfolio showing priority PODs for fuel reduction (blue) and reforestation (red) activities in the 2021 KNP Complex. Darker colors indicate areas that are mechanically accessible.

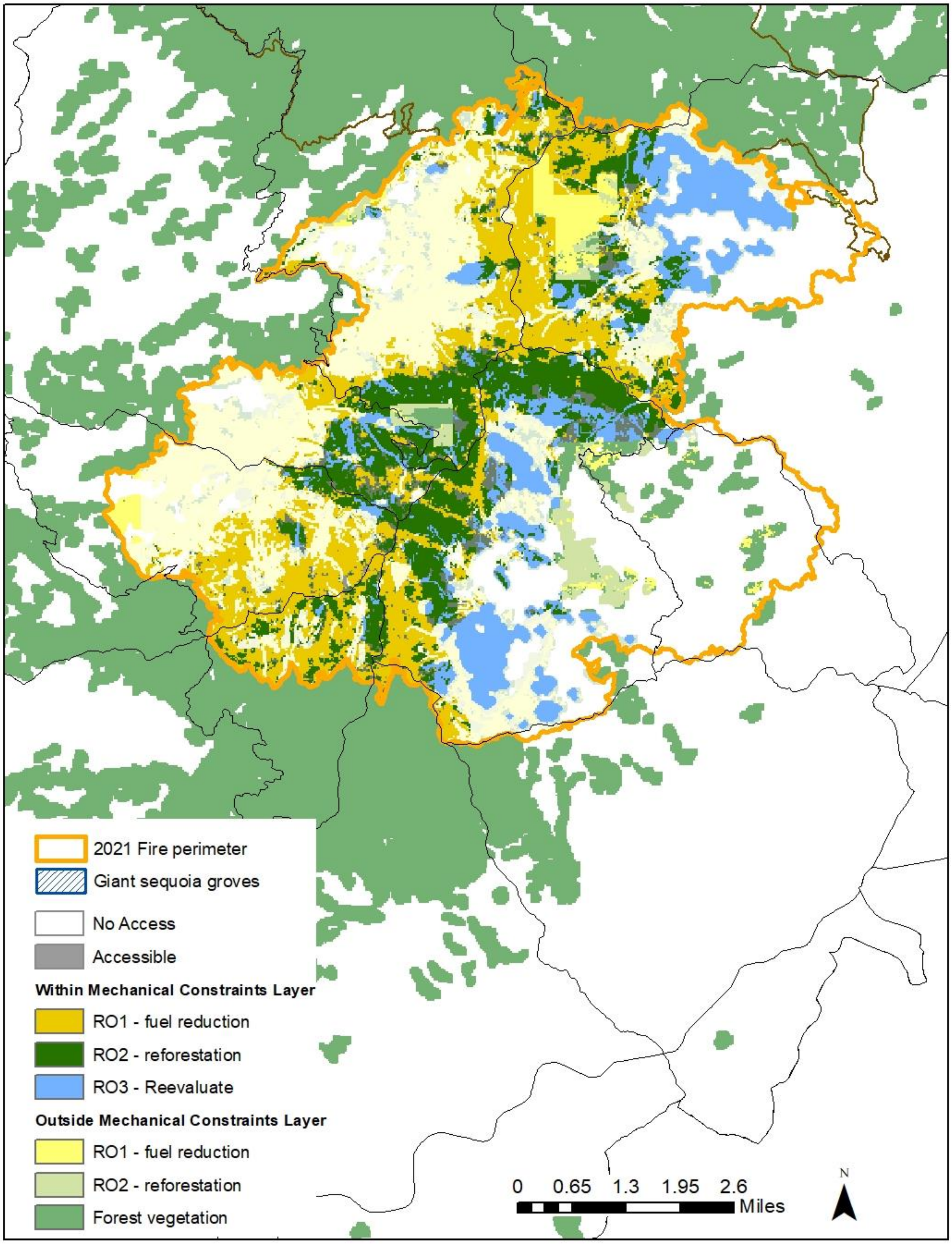

Figure 29. Restoration portfolio for the 2021 French Fire area. See Figure 25 for a description of color-coded areas.

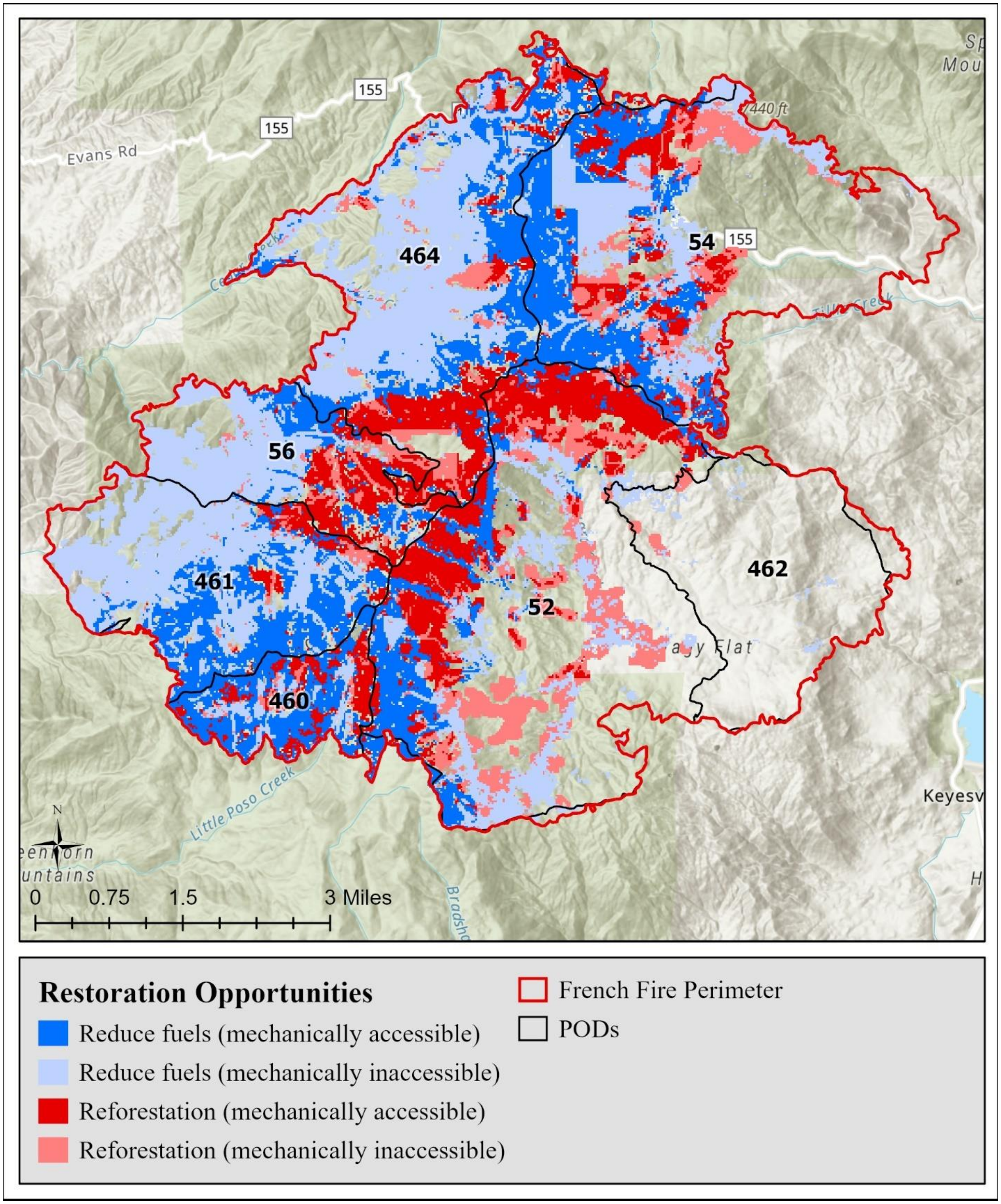

Figure 30. Restoration portfolio showing priority PODs for fuel reduction (blue) and reforestation (red) activities in the 2021 French Fire. Darker colors indicate areas that are mechanically accessible.

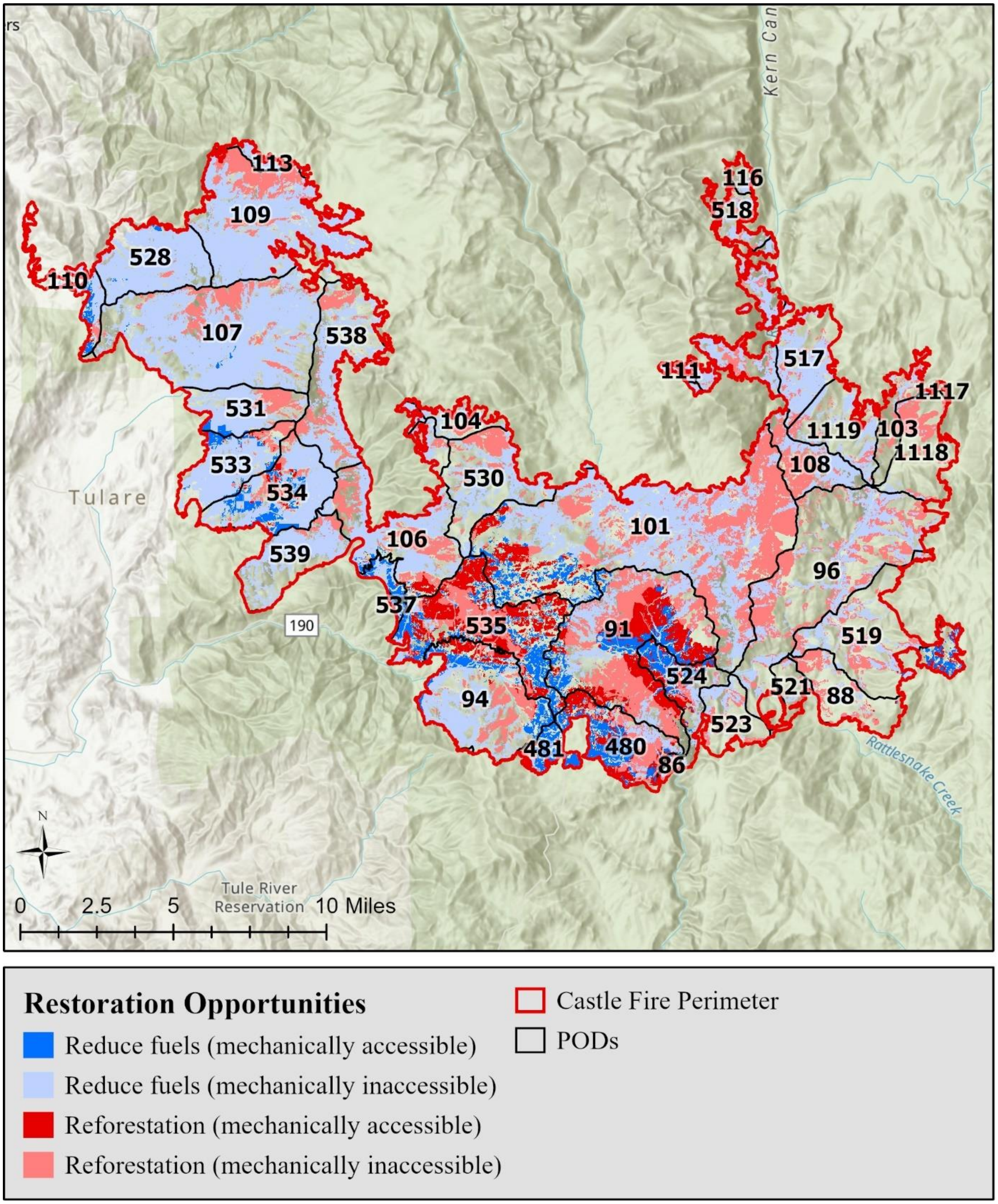

Figure 31. Restoration portfolio showing priority PODs for fuel reduction (blue) and reforestation (red) activities in the 2020 Castle Fire. Darker colors indicate areas that are mechanically accessible.

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Appendices

Appendix A. Creation of a habitat connectivity layer for fisher

To create the habitat connectivity layer, we extended a model developed in the Kings River Fisher Project (KRFP) study area, directly north and adjacent to our area of interest for this project, to represent the potential connectivity of fisher habitat (Green et al. in prep). First, we applied beta coefficients from the KRFP resource selection analysis to the same spatial covariates within our area of interest to derive a map of fisher habitat suitability for 2018. Covariates included fractional cover of live forest cover, tree mortality, bare ground, and shrub, distance to dense forest patches (>60% cover), distance to roads, distance to streams (perennial and intermittent), and elevation. Land cover variables represented 2018 conditions. All covariates were 30-m pixel resolution raster grids. We transformed the derived suitability layer into a resistance surface using a c8 negative exponential transformation to create a representation of how permeable the landscape may be to fisher movement (Keeley et al. 2016, Zeller et al. 2018). This creates a surface where 0 is fully permeable and 100 is fully resistant. Finally, potential connectivity was derived using a pair-wise approach in Circuitscape software (McRae and Shah 2009). This created a 30-m resolution spatial dataset on pre-fire connectivity for areas that burned in or after 2018. To characterize postfire connectivity within these areas, we set resistance values to 95 where high severity fire occurred, based on RAVG data. We selected a resistance value of 95 after investigating values within high severity fire perimeters that occurred before 2018 (i.e., these resistances were captured in the suitability model itself). Previous field studies also indicated that patches of high severity fire could impact fisher habitat connectivity in the southern Sierra Nevada (Thompson et al. 2021). We ran this new resistance layer through Circuitscape to generate a post-fire view of potential landscape connectivity. To highlight areas that decreased or increased in relative connectivity value for fishers, we differenced the two Circuitscape raster grids such that negative numbers in the output indicate where connectivity value declined and positive numbers are indicative of areas that increased in importance given the surrounding degradation (i.e., post-fire – pre-fire, Figure 32, Figure 33, Figure 34, Figure 35). We used this difference layer to generate a binary dataset representing increases and decreases in connectivity value, which was used to calculate the areas of each within PODs and grove boundaries. The analysis area included mid-elevation conifer (e.g., mixed conifer and yellow pine) and hardwood (e.g., mixed pine-hardwood, hardwood) forests which encompass approximately 1,010,171 (408,976 ha) in the analysis area.

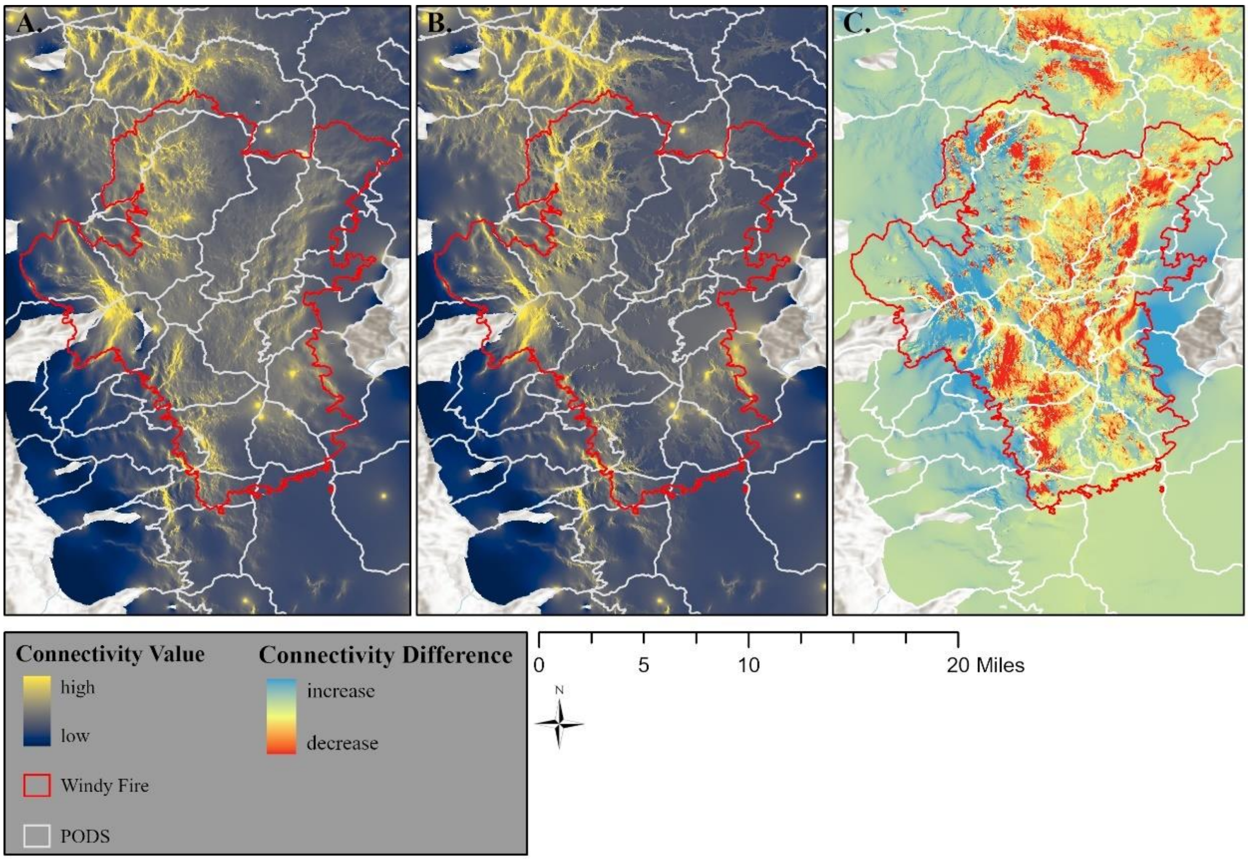


Figure 32. Fisher habitat connectivity value before (A) and after (B) the 2021 Windy Fire. The difference between postfire and pre-fire values (C) highlights areas of increased and decreased relative connectivity. Potential Operational Delineations (PODs) are shown in grey.

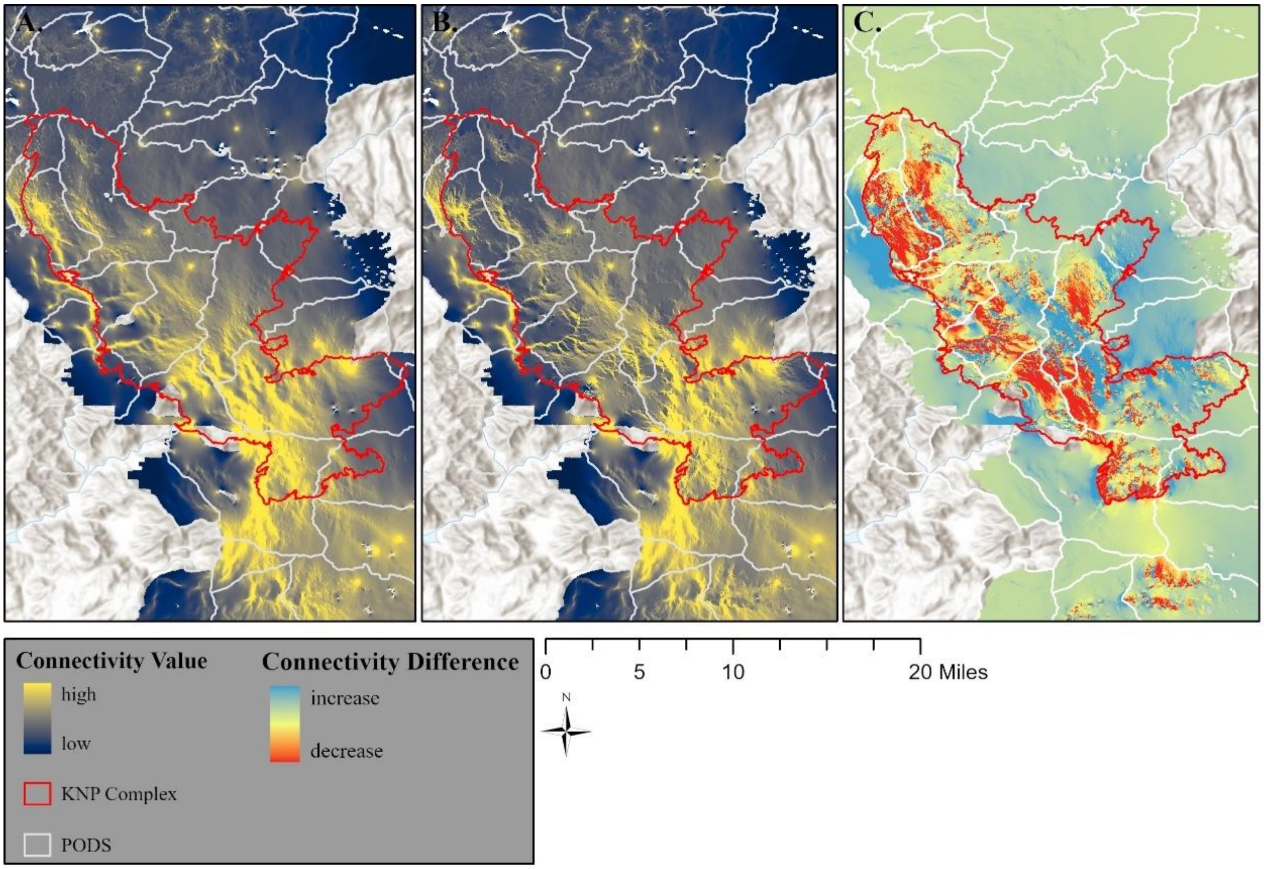


Figure 33. Fisher habitat connectivity value before (A) and after (B) the 2021 KNP Complex. The difference between postfire and pre-fire values (C) highlights areas of increased and decreased relative connectivity. Potential Operational Delineations (PODs) are shown in grey.

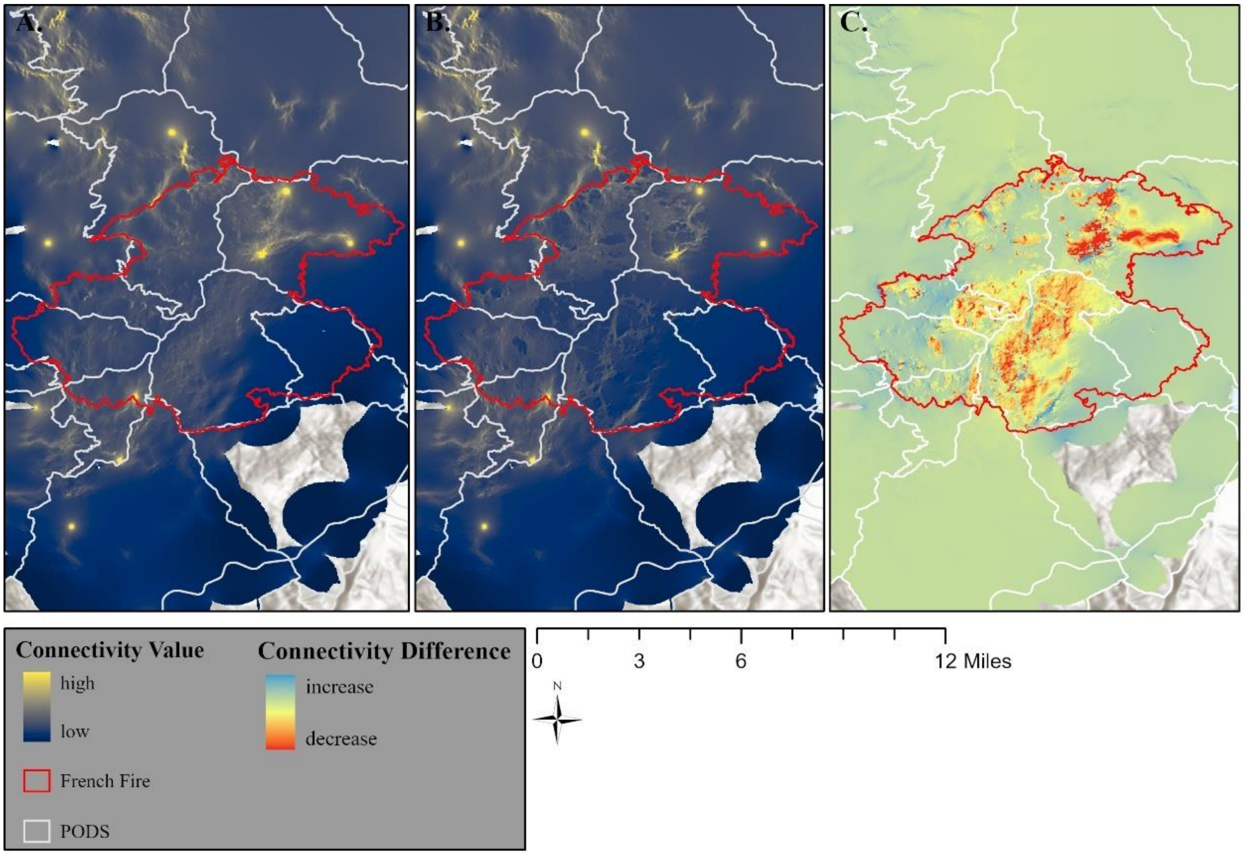


Figure 34. Fisher habitat connectivity value before (A) and after (B) the 2021 French Fire. The difference between postfire and pre-fire values (C) highlights areas of increased and decreased relative connectivity. Potential Operational Delineations (PODs) are shown in grey.

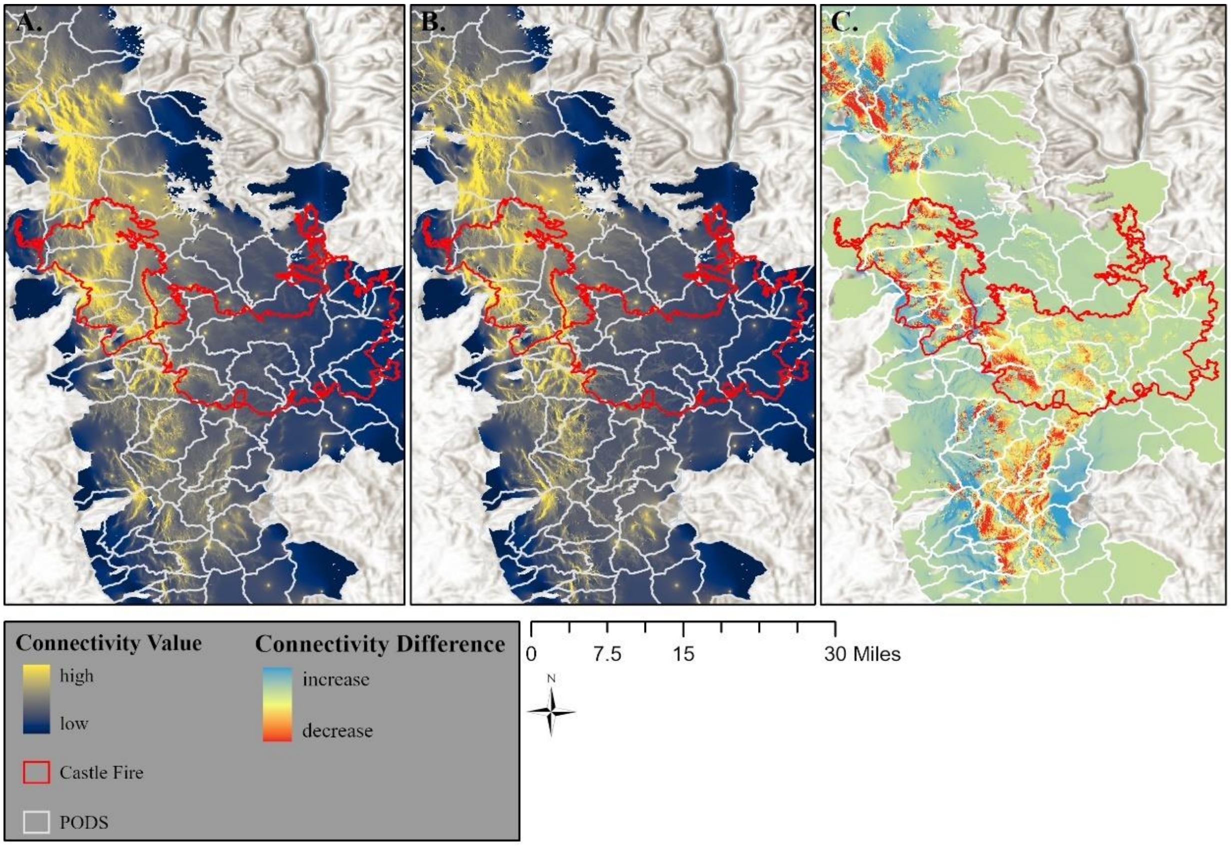


Figure 35. Fisher habitat connectivity value before (A) and after (B) the 2020 Castle Fire. The difference between postfire and pre-fire values (C) highlights areas of increased and decreased relative connectivity. Potential Operational Delineations (PODs) are shown in grey.

Appendix B. Fire severity, POSCRPT, and tree density analyses and maps

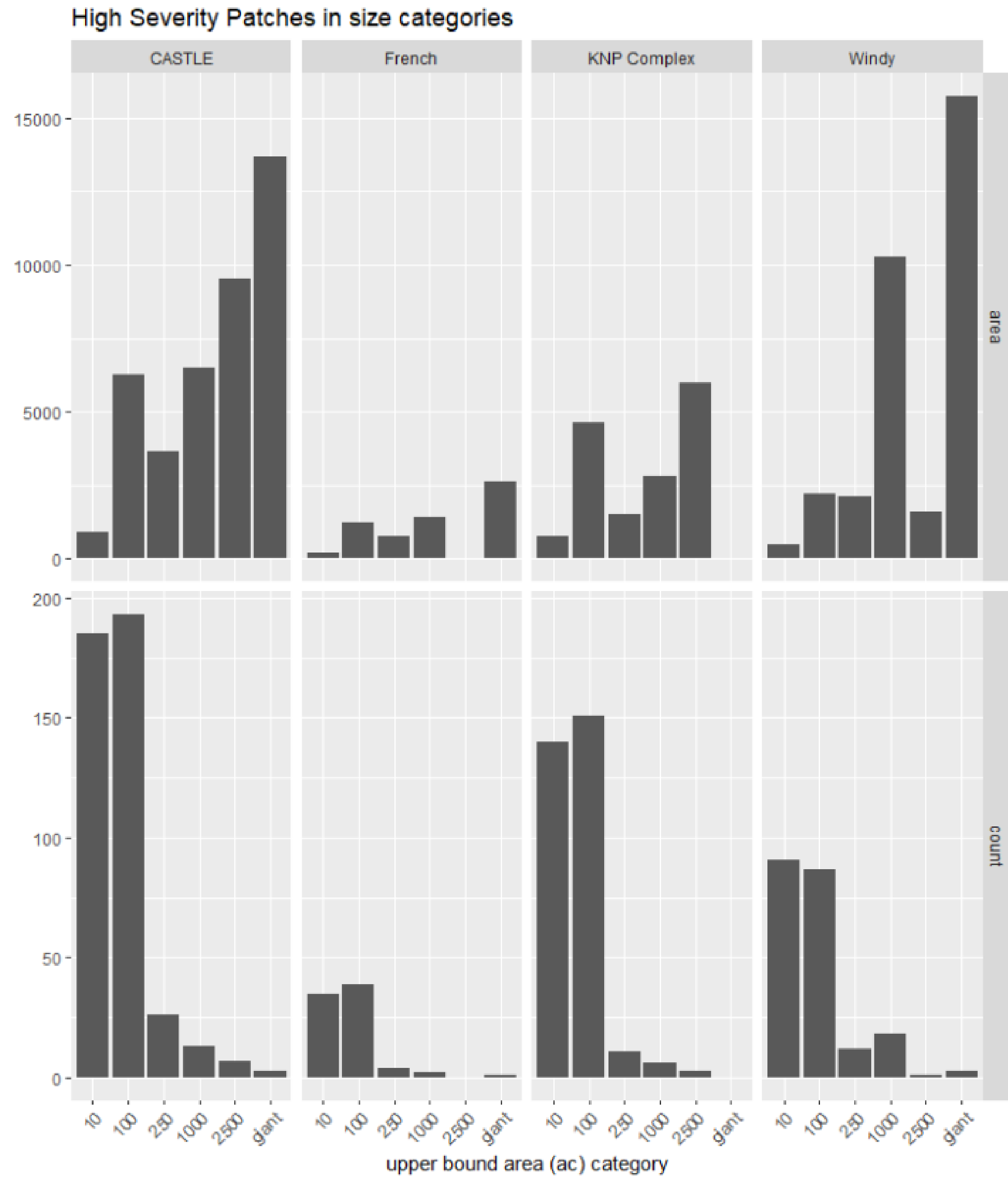


Figure 36. High severity patch size distribution based on patch area (upper panel) and patch count (lower panel) for 2020-2021 wildfires in the study area. In the upper panel, desired conditions and NRV would exhibit a relatively flat distribution (i.e., <50% of patch area attributed to large patches >100 to 250 ac).

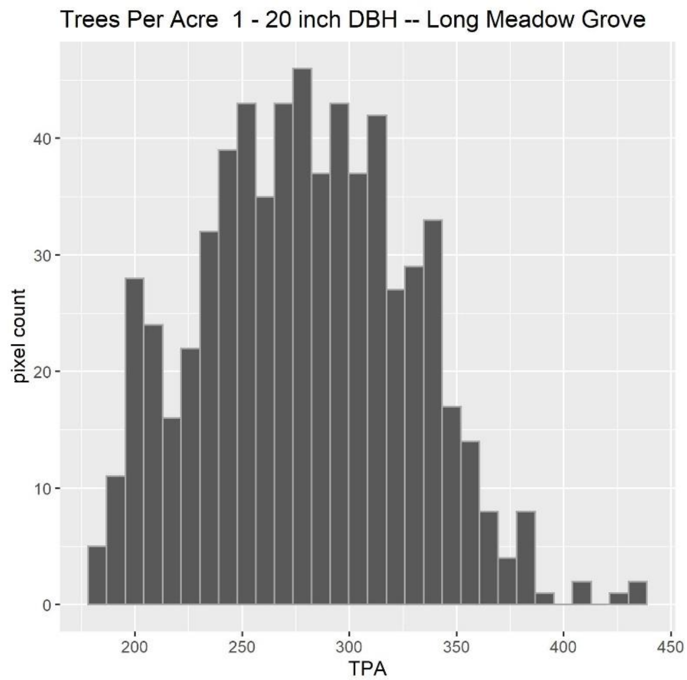
Table 28. Number of high severity patches by patch size class for wildfires in the analysis area. Focal wildfires that burned in 2021 are highlighted. Under NRV and desired conditions, high severity patch sizes rarely exceed 50 to 100 ac and patches >250 ac do not occur (Table 1).

FIRE NAME	1-10	10-100	100-250	250-1000	1000-2500	2500+
CABIN SEQ	4	1	0	0	0	0
ROUGH	48	22	4	1	0	0
JACOBSON	2	1	1	0	0	0
CEDAR	31	25	4	2	1	1
HIDDEN	2	1	0	0	0	0
MEADOW	3	3	1	0	0	0
LION	23	20	0	0	0	0
SCHAEFFER	30	16	0	2	0	0
PIER	46	26	4	1	0	0
ALDER	0	1	0	0	0	0
CASTLE	185	193	26	13	7	3
French	35	39	4	2	0	1
Windy	91	87	12	18	1	3
KNP Complex	140	151	11	6	3	0
Walkers	23	22	1	0	0	0

Table 29. Predicted natural conifer regeneration failure[a] in giant sequoia groves burned in the 2020 Castle Fire, including groves in SEKI (Homers Nose to Dillonwood) and GSNM (Dillonwood to Carr Wilson).

Sequoia Grove	**Low Scenario**		**Mean Scenario**	
	Potential Natural Conifer Regeneration Failure, ac (%)	Regeneration Failure Overlap with Access (ac)	Potential Natural Conifer Regeneration Failure, ac (%)	Regeneration Failure Overlap with Access (ac)
Homers Nose	113 (87)	0 (0)	51 (39)	0 (0)
Board Camp	46 (96)	0 (0)	30 (62)	0 (0)
Cedar Flat	8 (52)	0 (0)	0.4 (3)	0 (0)
South Fork	19 (8)	0 (0)	1 (0.5)	0 (0)
Clough Cave	0 (0)	0 (0)	0 (0)	0 (0)
Putman-Francis	0 (0)	0 (0)	0 (0)	0 (0)
Forgotten	0.4 (22)	0 (0)	0 (0)	0 (0)
Garfield	173 (14)	0 (0)	39 (3)	0 (0)
Devil's Canyon	0 (0)	0 (0)	0 (0)	0 (0)
Dennison	0 (0)	0 (0)	0 (0)	0 (0)
Dillonwood	357 (34)	0 (0)	94 (9)	0 (0)
Dillonwood West	4 (100)	0 (0)	1.3 (34)	0 (0)
Dillonwood South	1.8 (43)	0 (0)	0 (0)	0 (0)
Upper Tule	0.7 (10)	0 (0)	0 (0)	0 (0)
Middle Tule	116 (24)	0 (0)	7 (1.4)	0 (0)
Mountain Home	1307 (41)	173 (5)	346 (11)	64 (2)
Wishon[a]	6 (42)	0 (0)	0 (0)	0 (0)
Alder Creek	179 (31)	42 (8)	19 (3)	0.2 (0.04)
Freeman Creek	1172 (83)	277 (20)	676 (48)	173 (12)
Belknap Camp	49 (50)	33 (34)	8 (8)	6 (6)
Wheel Meadow	510 (89)	77 (13)	164 (29)	5 (1)
McIntyre	128 (46)	9 (3)	7 (3)	0 (0)
Carr Wilson	5 (37)	0 (0)	1 (9)	0 (0)

[a] Based on POSCRPT <0.4 probability of natural conifer regeneration (all mixed conifer species). Groves with higher regeneration failure values under both scenarios are highlighted as potential priorities for reforestation.



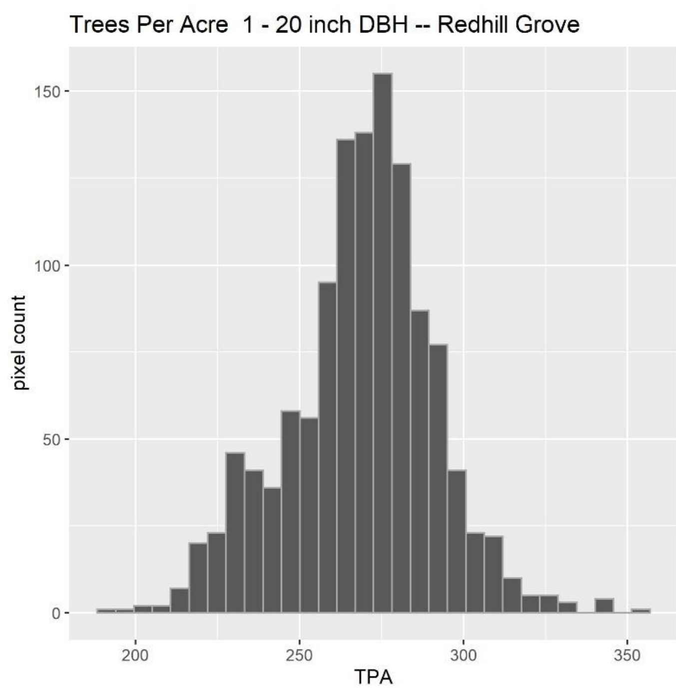


Figure 37. F3-derived estimates of tree densities (1-20 inches dbh) in the Long Meadow (top) and Redhill (bottom) giant sequoia groves on the Giant Sequoia National Monument. Based on NRV, tree densities within groves are 66 ± 48 trees/acre (i.e., values above 114 to 162 trees per acre are generally considered elevated).

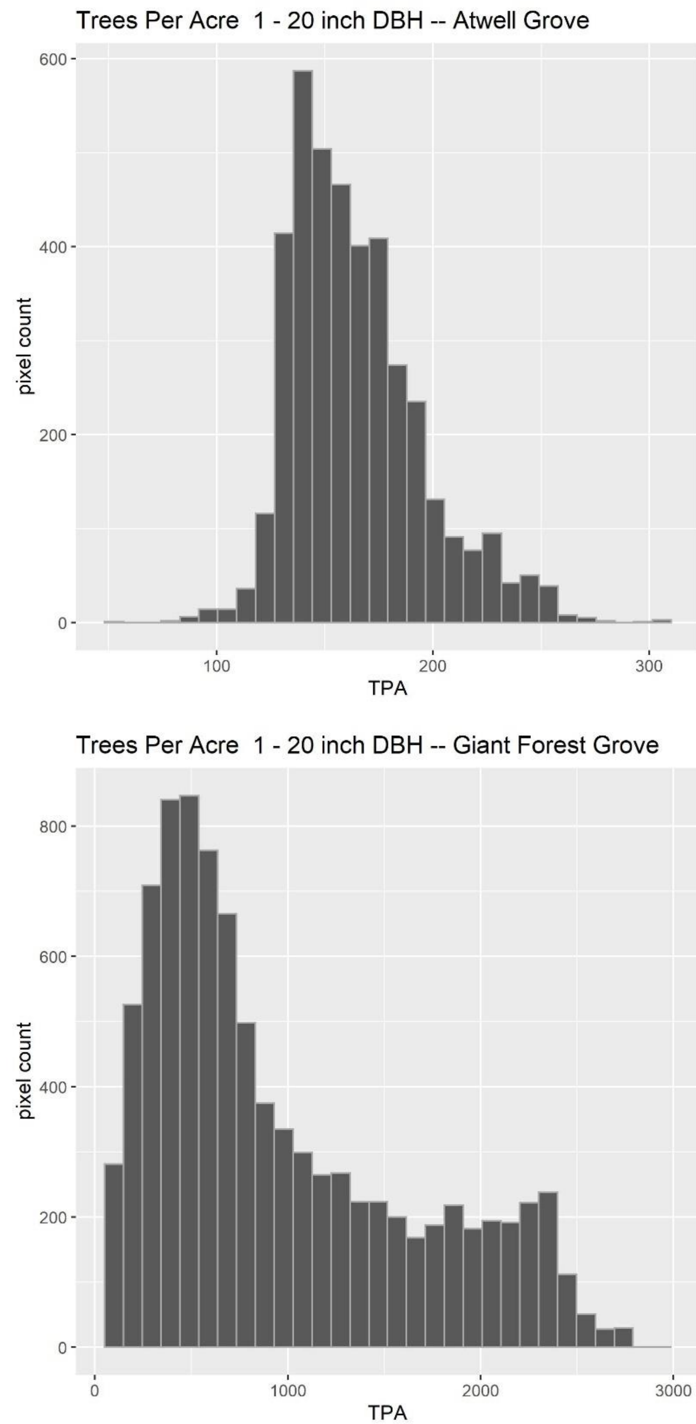


Figure 38. F3-derived estimates of tree densities (1-20 inches dbh) in the Atwell (top) and Giant Forest (bottom) sequoia groves in Sequoia-Kings Canyon National Parks. Based on NRV, tree densities within groves are 66 ± 48 trees/acre (i.e., values above 114 to 162 trees per acre are generally considered elevated). F3 estimates of tree densities exceeding 500 trees per acre (bottom panel) are likely overinflated due to data inaccuracies.

Many

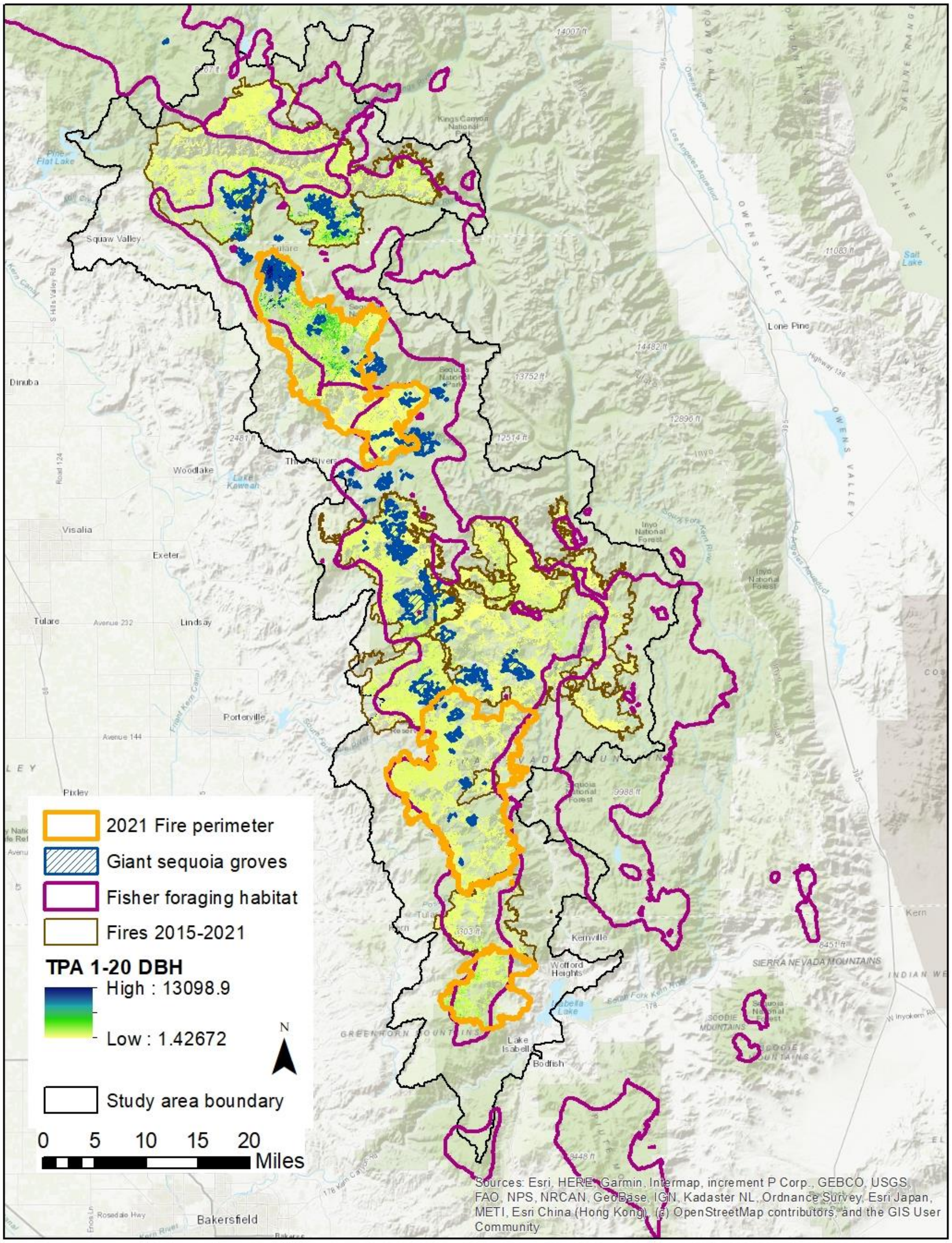


Figure 39. Tree density estimates based on F3 in forest vegetation across the study area, including within sequoia groves and fisher habitat.

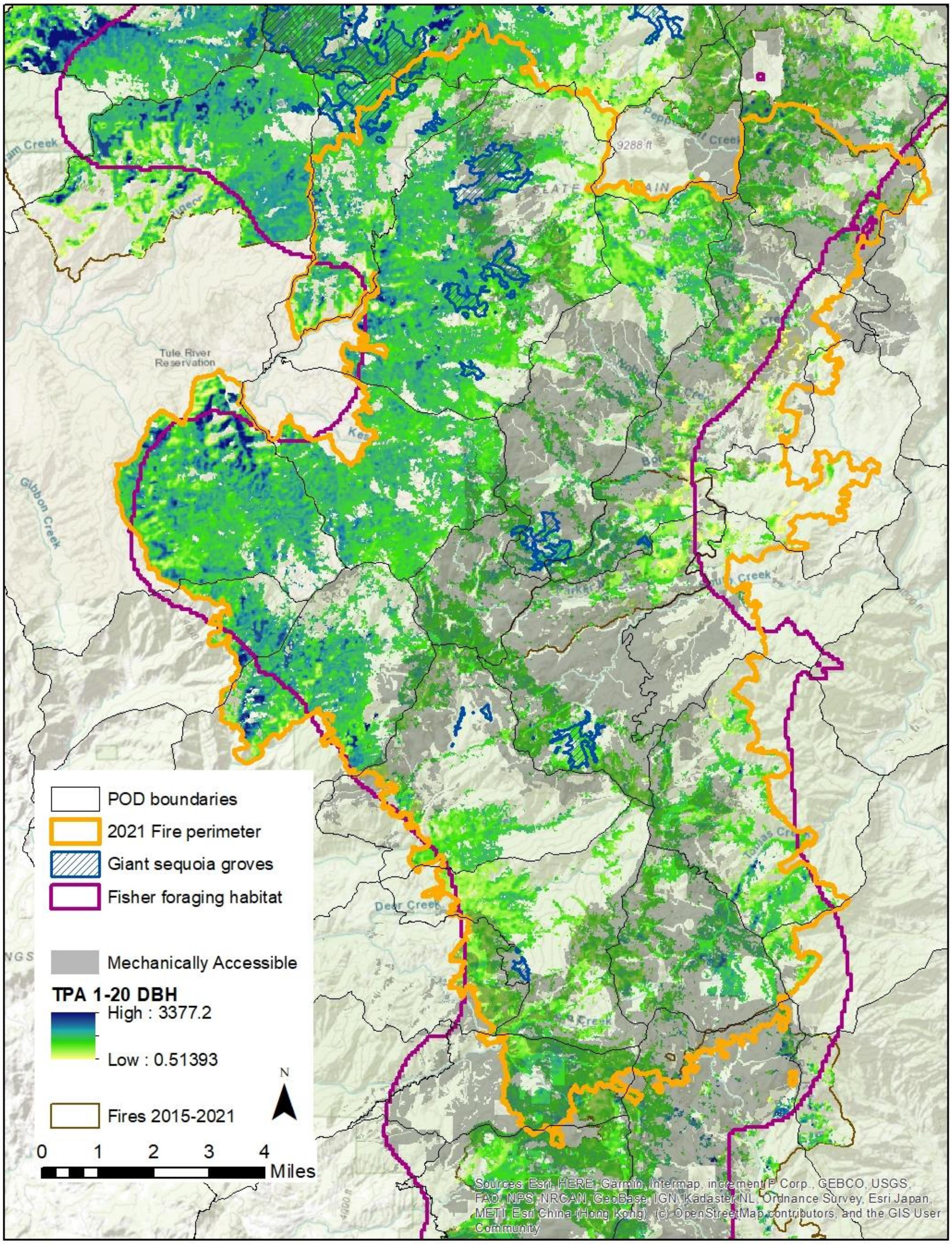


Figure 40. Tree density estimates based on F3 within the 2021 Windy Fire. Most tree densities shown in this map (green to blue color) exceed the NRV at approximately 66 ± 48 trees/acre (stems ≥1 inch dbh).

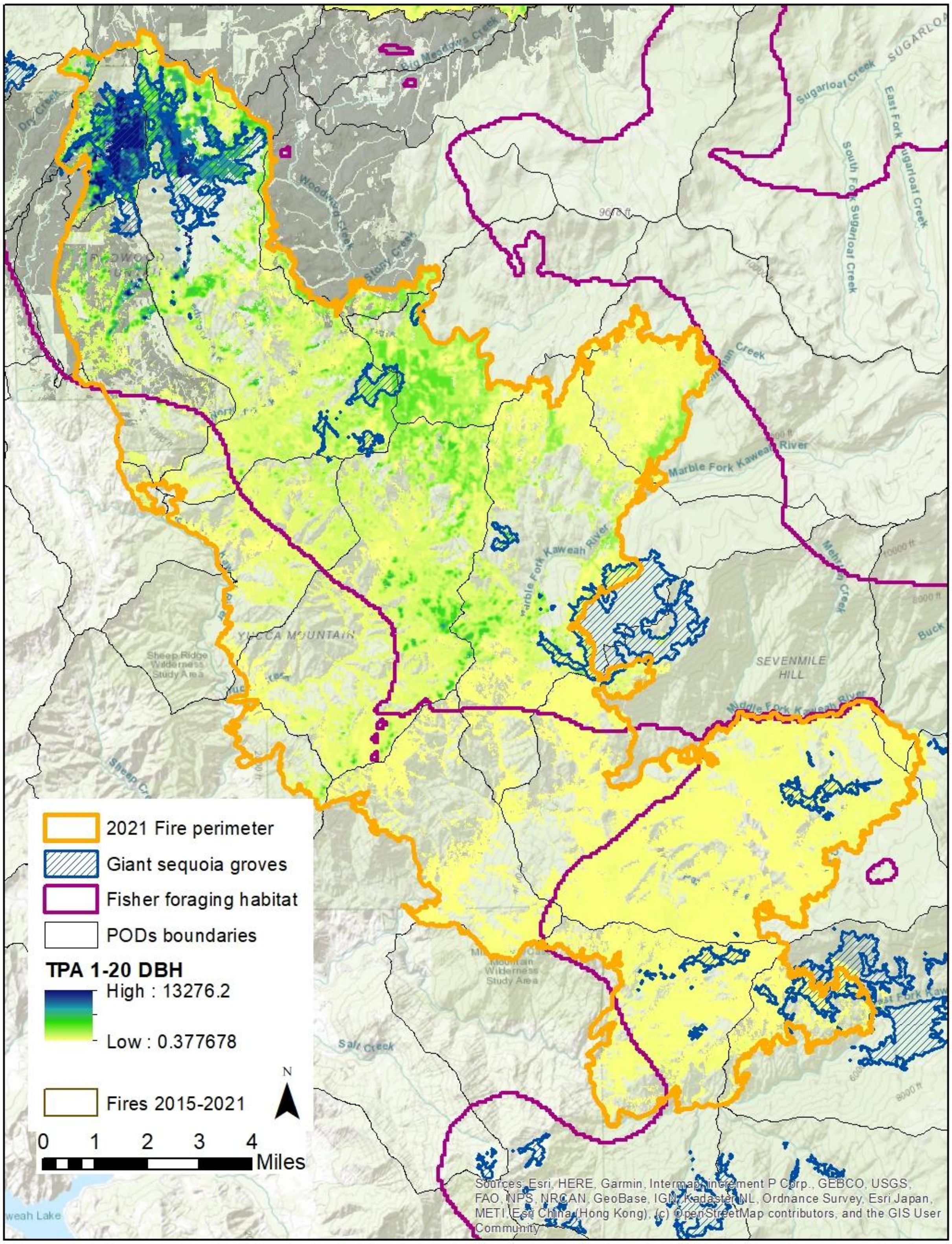


Figure 41. Tree densities in the KNP Complex.

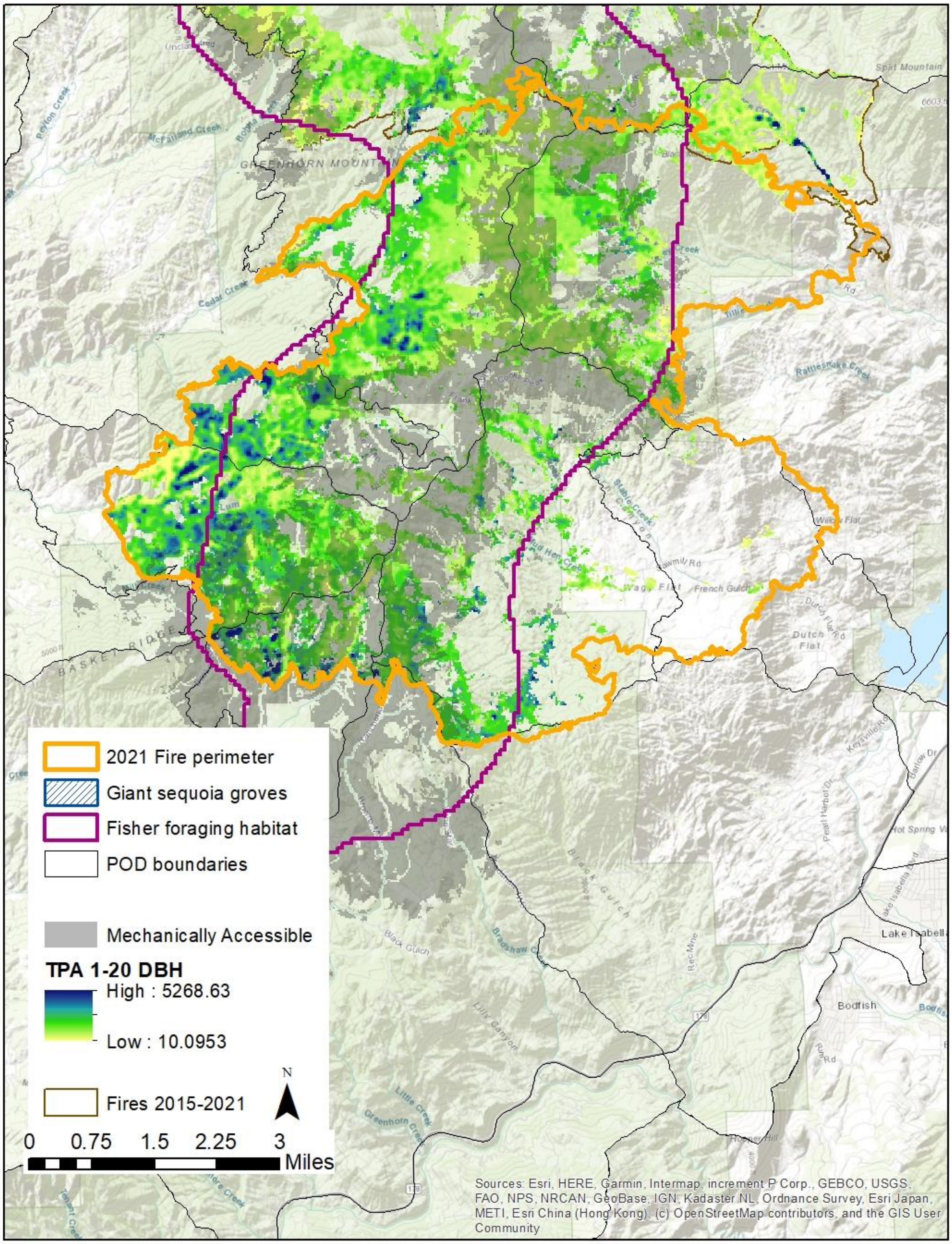


Figure 42. Tree density estimates based on F3 within the 2021 French Fire. Most tree densities shown in this map (green to blue color) exceed the NRV at approximately 66 ± 48 trees/acre (stems ≥1 inch dbh).

Appendix C. Classification criteria used to evaluate and prioritize PODs in need of fuel reduction and reforestation treatments

Table 30. Classification criteria used to evaluate and prioritize PODS in need of fuel reduction treatments to reduce the potential risk of further loss of ecological resources.

Ecological Resources	Factor	Classification Criteria for POD	Criteria
1. Fisher habitat (composite score)	Potential habitat	Low (<40%)	Habitat classified pre-fire as hardwood, conifer, or mixed hardwood/conifer habitats
		Moderate (40 - ≤60%)	
		High (>60%)	
	Reproductive habitat	Low (<10%)	Areas defined as having medium to high reproductive value for fishers (Spencer 2016)
		Moderate (≥10 – <25%)	
		High (≥ 25%)	
	Large trees (>40 in)	Low (<10%)	Percent of forested habitat with ≥2 trees per acre (F3-derived estimate) as a proxy for denning structures
		Moderate (10 - <30%)	
		High (≥ 30%)	
Sequoia groves		Low (0%)	We used the sequoia groves layer to designate potential areas that could support sequoias long-term
		Moderate (<5%)	
		High (≥5%)	
California spotted owl PACs		Low (<1%)	We used the Protected Activity Centers for California spotted owls to designate potential areas that could support owls long-term
		Moderate (<5%)	
		High (≥ 5%)	
2. Risk of future forest loss (composite rank)	Potential moisture stress to forest vegetation	Low (<650 mm))	We used climatic water deficit (CWD) as an indicator of forest drought stress
		Moderate (≥650 - <750 mm)	
		High (≥750 mm)	
	Small and medium diameter ladder fuels	Low (<150 tpa))	F3-derived density estimates of pre-fire small and medium diameter (1–20 in dbh) trees
		Moderate (≥150 - <250 tpa)	
		High (≥250 tpa)	
	Medium diameter ladder fuels[a]	Low (<50 tpa)	F3-derived density estimates of pre-fire medium diameter (5–20 inch dbh) trees
		Moderate (≥50 - <100 tpa)	
		High (≥100 tpa)	

[a]These factors were double-weighted when evaluating composite ranks

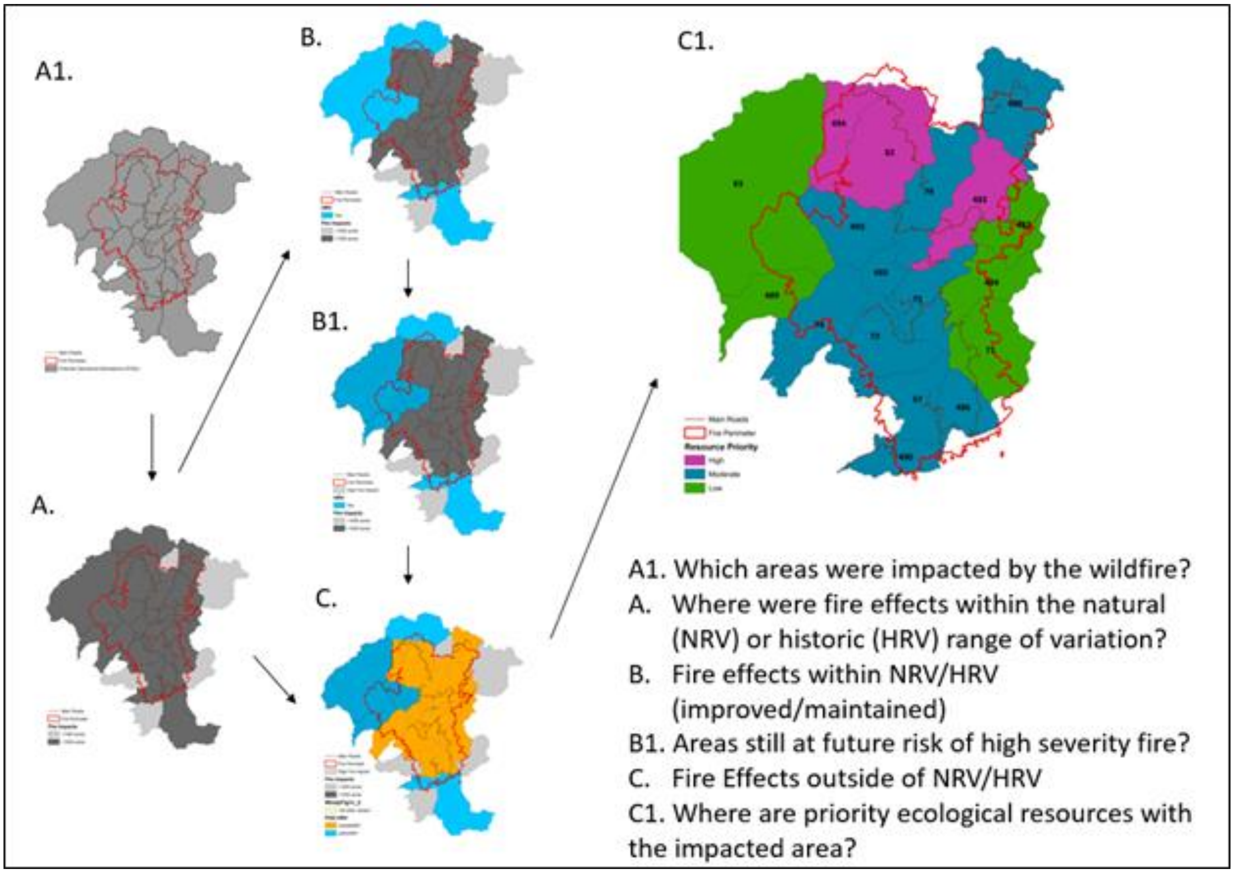


Figure 43. Diagram illustrating the process for identifying and prioritizing fuel reduction and forest restoration treatment opportunities in the 2021 Windy Fire.

Table 31. Classification criteria used to evaluate and prioritize PODS in need of active reforestation to achieve desired for ecological resources.

Ecological Resources	Factor	Classification Criteria for POD	Criteria
1. Fisher habitat (composite score)	Loss of habitat	Low (<20%)	Habitat classified pre-fire as hardwood, conifer, or mixed hardwood/conifer habitats that burned at high severity
		Moderate (20-40%)	
		High (>40%)	
	Loss of Reproductive habitat	Low (<20%)	Areas defined as having medium to high reproductive value for fishers (Spencer 2016) that burned at high severity
		Moderate (20–39%)	
		High (≥ 40%)	
	Loss of connectivity	Low (<10%)	Areas in which connectivity decreased
		Moderate (10-29%)	
		High (≥ 30%)	
Sequoia Groves		Low (0%)	We used the sequoia groves layer to designate potential areas that could support sequoias long-term
		Moderate (0.1-4%)	
		High (≥5%)	
California spotted owl PACs		Low (<1%)	We used the Protected Activity Centers for California spotted owls to designate potential areas that could support owls long-term
		Moderate (1-4%)	
		High (≥ 5%)	
2. Risk of natural conifer regeneration failure		Low (<10% of POD)	POSCRPT output in which risk of conifer regeneration failure at five years post-fire was <40%
		Moderate (10-29% of POD)	
		High (≥ 30% of POD)	
3. Climatic risk of conifer forest loss in the long-term (CWD)		Low (<650 mm)	Higher levels of CWD indicate higher drought stress and decreased probability of conifer forest over the longer-term
		Moderate (650-749 mm)	
		High (≥750 mm)	

Appendix D. Pyrosilviculture approach to restoring forest landscapes in the Giant Sequoia National Monument and other lands (where appropriate)

A pyrosilviculture approach to forest restoration as described in North et al. (2021) could be readily applied to the restoration of sequoia groves and fisher habitat in the Giant Sequoia National Monument, and some general concepts could also be applied to other land ownerships. This approach uses a combination of strategic mechanical thinning (e.g., strategic fuel breaks, variable density thinning), prescribed burning, and use of areas burned at low to moderate severity in wildfires to plan and implement prescribed fire at larger spatial scales. Forest thinning would be applied in "anchor," "ecosystem asset," and "revenue" focused treatments shown in Figure 44 and

Figure 45 below.

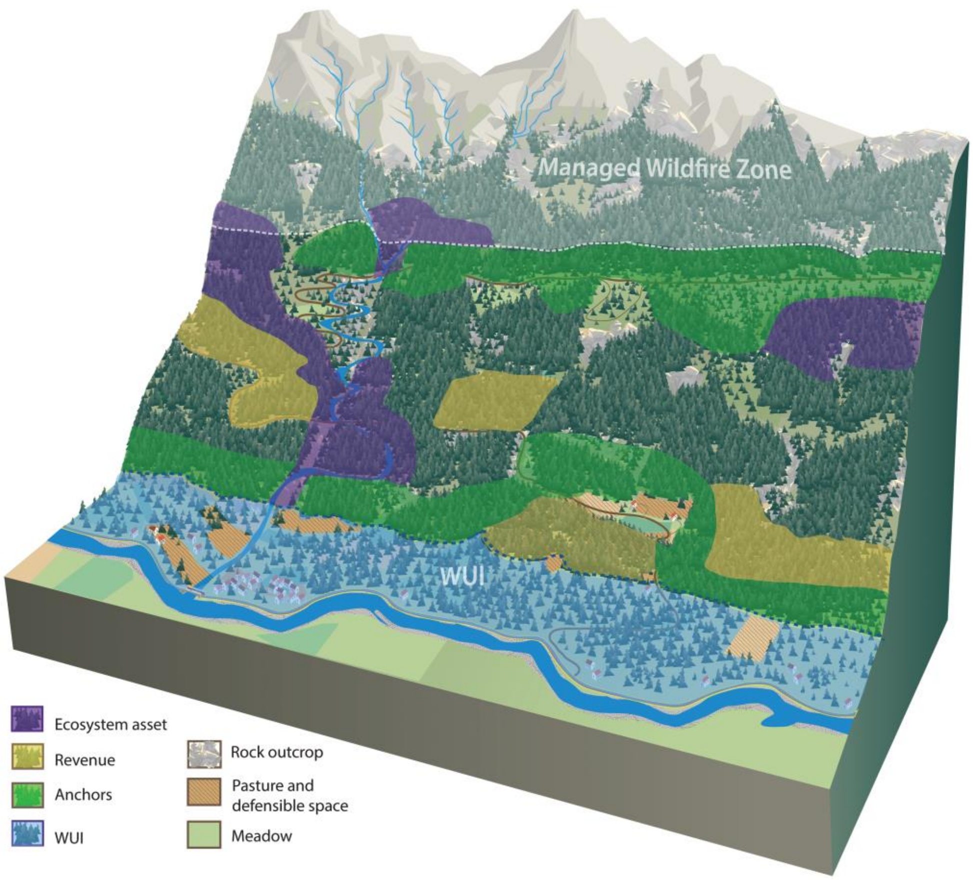


Figure 44. Schematic from North et al. (2021) of how anchors, ecosystem assets, and revenue thinning treatments might be placed in a landscape. Anchors back to roads or strategic fuel breaks and are ignition locations for expanding prescribed fire between anchors. Managers have the option of letting prescribed fire continue up through or managed wildfire burn down through the upper string of anchors under favorable conditions. Ecosystem assets (e.g., burned giant sequoia groves) are located where fuel reduction is needed to maintain particular ecological values, and revenue thinning treatments (e.g., mixed conifer forest matrix, some fire-excluded sequoia groves) are in locations where larger shade-tolerant fire-sensitive species can be removed to restore resilience and provide sawlog revenue.

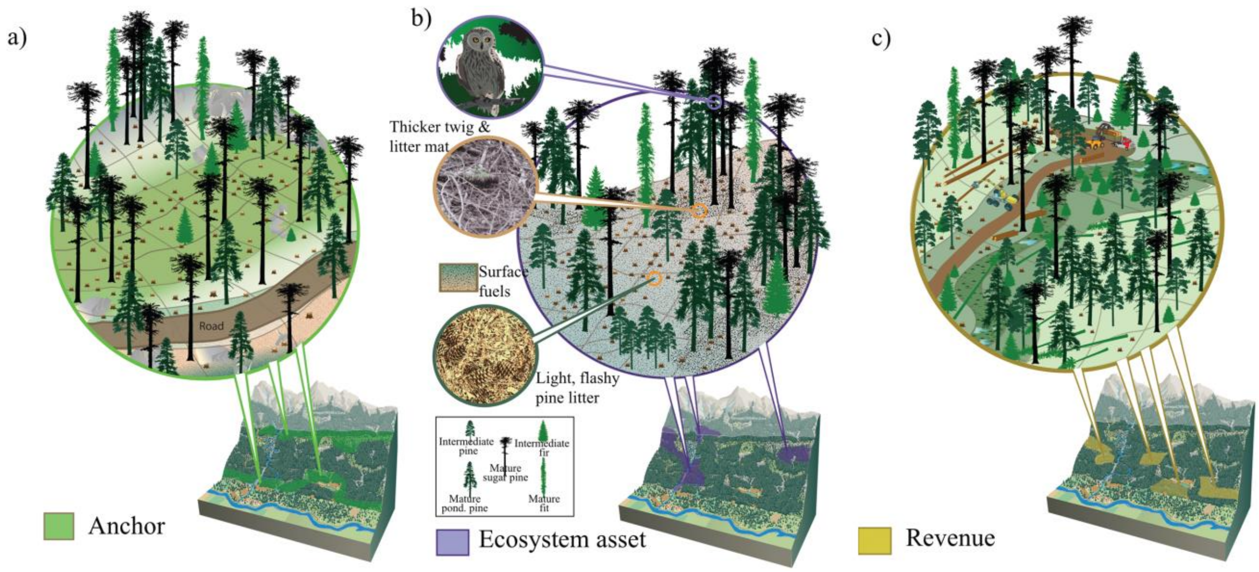


Figure 45. Stand-level schematics from North et al. (2021) of the three thinning treatments: (a) an anchor, or strategic fuel treatment near a road to serve as a "backstop" to fire (requires heavy fuels reduction leaving only large spatially separated pines possibly bordering sequoia grove actual or administrative boundaries) grading into a more mixed-species forest with a fire resistant spatial pattern (i.e., individual trees, clumps of trees and openings [ICO]) where the fire leaves the anchor; (b) an ecosystem asset (e.g., burned sequoia groves) where most thinned trees are ladder-fuel size (includes small and medium-diameter trees), an ICO pattern is created, and pine litter is dispersed in openings to facilitate fire spread; and (c) a revenue thinning (e.g., mixed conifer forest matrix, some fire excluded groves with elevated stand densities) where intermediate and larger fire-sensitive white fir and incense cedar are removed for sawlog processing.

Appendix E. Climate-smart reforestation example from North et al. (2019)

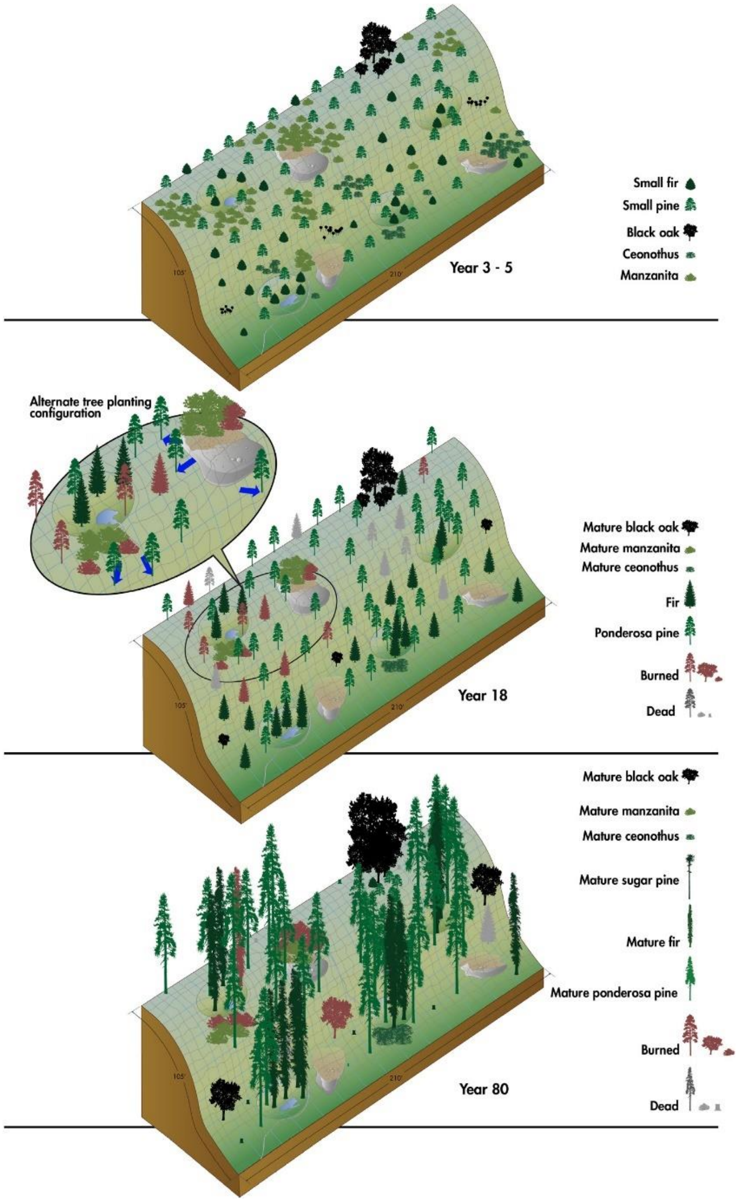


Figure 46. Schematic of the initial planting and stand development for a dissected, more fire and drought prone 0.2 ha (0.5 ac, 105 by 210 ft) slope of mixed-conifer forest where favorable cluster microsites are more easily identified. (A) Initial planting schematic (usually within 1–5 years following disturbance). First more mesic microsites (concavities in the figure) are identified and planted with clusters of trees and then the remaining area is planted with individual trees on a regularly spaced grid (here 4.6 m or 15′ by 15′). In this example only 60 of 115 (i.e., if fully planted on a 4.6 m spacing) potential trees are regularly planted, and 22 are planted in four clusters at mesic microsites. (B) After the first burn (15 years after planting). In this hypothetical example, of the 82 original conifers, eight have died over the last period and nine were killed by the prescribed fire, reducing live tree density to 65 on the 0.2 ha (0.5 ac). The prescribed fire, designed to maintain tree and shrub separation, has also killed some shrubs. (C) After 77 years of growth. Fire has been applied every 15 years to reduce fuels and shrub cover. In this example, 22 more trees have been killed by drought and prescribed fire, leaving a mature forest density of 40 conifer and three oak live trees (212 tree/ha or 86 trees/ac), within the estimated historical mixed conifer density range of 59–329 tree/ha (24–133 trees/ac) (Safford and Stevens 2017). Figure and caption from North et al. (2019).

Appendix F. Restoration opportunities for fisher in a post-fire landscape

Considerations to retain old forest and promote growth of trees in burned areas

Purpose: In this report, we outlined steps to assess post-fire landscapes, consider available restoration opportunities, and prioritize areas for restoration actions based on occurrence of key resources and/or continued risk of loss to catastrophic fire. We suggested that land managers first identify priority areas at the spatial scale of the POD, small watershed (HUC 14), or other locally relevant unit, then use this appendix to consider restoration opportunities and strategies within the unit(s) that could benefit fisher. Much thought, discussion, and review of recently collected data from fishers near fire footprints have contributed to this appendix, some suggestions are based on years of data while others are based on limited recent observations; as such, these guidelines would benefit from re-evaluation after monitoring the response of vegetation and wildlife in restored portions of fire footprints and other forest habitat.

Background: The fisher is a forest-dwelling carnivore of conservation concern in western North America, with particular importance to forest management in the southern Sierra Nevada (SSN) where the distinct population segment was federally listed as endangered in 2020. Fishers are associated with features of old forests (e.g., large diameter trees, decay, dense canopy cover), require large areas of land relative to their body size, and have a relatively low reproductive rates (i.e., on average females may have 1-2 kits per year after reaching adulthood). While we have learned much about their ecology, behavior, and habitat needs in this region over the last decade to help facilitate conservation – they are challenging species to study and keep track of, particularly during the reproductive period. As the SSN landscape continues to change due to altered climatic conditions, extensive conifer mortality, and large high intensity fires, we want to highlight fisher habitat needs to consider in post-fire landscape planning. We have framed this appendix around three spatial scales that are relevant to fishers and restoration. We mention timing and temporal scales because these are important to think through to try and minimize impacts to fishers living in this altered landscape as management actions occur.

Spatial Scales: We identified three primary spatial scales with particular relevance to fisher habitat use and restoration opportunities in a post-fire landscape (e.g., fuels reduction, planting). These are:

1. *Fine-scale* – Denning and Resting habitat → Microsites and Structures
2. *Moderate-scale* – Travel and Foraging habitat → Linkages and Foraging Patches
3. *Broad-scale* – Den Cluster and Home Range Core habitat → Old Forest Refugia

Timing & Temporal Scales: When possible, consider the annual reproductive cycle of fisher as well as short- and long-term impacts (and benefits) of forest management activities when planning projects.

1. *Denning season and fisher development (see other resources for more details)* – In the SSN, female fishers only give birth once a year between about 15 March – 10 April. Mating also occurs within 1-2 weeks after females give birth – making early spring a sensitive time of year. Kits have limited mobility from March until about mid-June, when they begin to climb outside the den cavity. By late June / early July they start to follow their mother through the forest instead of being carried. From mid-July through mid-September, kits become increasingly agile but still

travel with their mother as they learn navigate the forest, find safe rest sites, and hunt for food. Kits do not appear to become independent until October. Management activities are often restricted during the LOP (March 1 – June 30) because females are either about to give birth or are caring for fully dependent young. During summer and early fall, kits are increasingly mobile with a greater capacity to avoid or escape danger, but may still be at risk from some activities.

2. *Short-term vs Long-term – Impacts vs Benefits of Fuels Reduction* - Management activities such as prescribed fire or mechanical thinning often have trade-offs between short-term negative impacts and long-term benefits to wildlife. Historically, fires in the SSN would have occurred in summer and fall after denning, but due to current climate and fuels conditions, these seasons may be riskier for burning. On the other hand, prescribed fires during the spring may negatively impact reproductive female fishers through direct harm, loss of kits, loss of den structures, or reduction in prey base. Pros and cons should be considered for individual areas, and as feasible attempts made to minimize impacts and maximize benefits to fishers and other key resources.
3. *Near-term vs Future – Planning for Forest Cover now and later* – In post-fire landscapes, fishers are likely to use a variety of features that can provide concealment for movement – including fast-growing vegetation (naturally regenerating or planted), logs, rock outcrops, topographic features such as ravines, and remaining pockets of live vegetation. Fishers will likely benefit from efforts to “stitch together” or add stepping-stones of cover through planting and mechanical work to create travel corridors in areas where they are limited. Experimenting with artificial cavities (den or rest boxes) in areas with cover, but limited safe microsites, could be considered. Future plans could include planting native species that are likely to be successful under a changing climate (e.g., California black oak) and retaining a subset of large structures (e.g., logs, small log piles) where few to no large live trees are present to contribute to future coarse woody debris.
4. *Rotate impacts and fuel reduction* – One option for implementing management actions with short-term negative impacts but long-term benefits (e.g., prescribed burning, thinning) to fishers in the SSN is to rotate where projects occur on the landscape each year such that only a few individual fishers might be negatively impacted, but not the whole local population, with the objective that at least some females have the chance to reproduce under relatively stable conditions. If using the POD or small watershed approach, conducting activities in a portion of a unit (e.g., half) or in non-adjacent units each year might be a reasonable goal to disperse impacts yet still reduce fuels and fire risk. Considering the juxtaposition of new projects relative to recent disturbance (e.g., high intensity wildfire, other recent prescribed fire) can also help avoid cumulative impacts.

Additional considerations: While evaluating important issues for fisher at different spatial and temporal scales, take time to consider other factors or resources to layer into management plans to meet multiple objectives when feasible and try to limit conflicts in managing different resources. Areas with potential shared management and conservation objectives with fisher needs include:

- Other old forest wildlife – such as California spotted owl, Sierra marten, Humboldt flying squirrel, woodpeckers (especially pileated), various songbirds, and terrestrial salamanders
- Giant sequoia groves, other old forest habitat (e.g., mixed-conifer, montane-hardwood, red fir)
- Streams and stream corridors – maintain function, integrity, and associated flora and fauna
- Restoration actions – tree planting – consider oaks as well as conifers, clumps, and nurse logs
- Restoration actions – decrease fuels, reduce fire risk, and reintroduce fire as a natural process

Fine Spatial Scale: Denning and Resting habitat → Microsites & Structure

Fishers tend to use structures with microsites where they can stay hidden and secure (e.g., large diameter live trees, snags, and logs with cavities or platforms, rocky outcrops, burrows). These microsites and structures appear to provide physical protection from predators or competitors, but can also offer thermal protection from hot or cold temperatures. Female fishers rely exclusively on trees (live or dead) with cavities in the bole to house kits during the den season. As females cannot make their own cavities – they rely on natural processes of decay, fungi, and pileated woodpeckers for their creation. Male and female fishers use a greater variety of microsites and structures as refuges for resting throughout the year.

Primary Considerations at the fine spatial scale

- Retain existing large structures (live trees, snags, logs)
  - with cavity microsites in the bole
  - with platform or chamber microsites
- Grow structures that could develop into suitable large den and rest structures
- Add artificial structures with secure microsites that can support denning or resting
  - Den or rest boxes that could be attached to trees (*see previous designs*)
  - Small strategic piles with interstitial spaces

Options / Ideas for Restoration and Fuels Reduction Plans

Retain remaining live forest through fuels reduction:

1. Large old live trees, snags, and logs - Conserve these important habitat elements on the landscape for fishers and other old forest wildlife by reducing fuels and lowering risk of loss in high intensity wildfires through implementation of prescribed fire and other mechanical tools.
2. Minimize loss of old live structures – In areas with high fuel loads, consider minimizing concentration of fuels at the base of high-quality live trees through raking or other means prior to prescribed burns.
3. Retain clumps of trees and incomplete burns – In areas where suitable live forest is limited, yet fuel reduction is desired to lower risk of loss to catastrophic fire, consider actively aiming for a more patchy / incomplete burn where clumps of live trees (+ snags / logs) and other shrubs are left largely intact to allow for near-term use by fishers and prey species.

Restore habitat in burned areas:

1. Large old structures - Where feasible, leave a subset of individual large trees or logs to provide future structure in areas where burned trees might be removed due to safety reasons or fire risk. If trees cannot be safely let standing, consider strategically leaving a subset of large logs (especially ones with hollows) or small piles (2-3 large logs) in an arrangement that works well for fire personnel, benefits fishers and prey, and can help facilitate growth of tree seedlings.
2. Tree species - California black oaks, white fir, and incense cedar appear to provide the greatest source of suitable cavities for denning and resting, while canyon live oaks, ponderosa pine, and sugar pine have demonstrated considerable use during resting. Thus planting or monitoring to ensure that natural regeneration of these species is of value.
3. California black oak resprouts – Although oaks often resprout after fire, there is some concern that stump sprouts may not lead to the large single stem trees that tend to develop cavities

suitable for denning and resting. In high intensity burns, options such as seed collection and dispersal as well as monitoring and potential trimming of sprout clusters should be considered.

4. Clumps – When planting trees, consider incorporating a "clumpy" design that creates heterogeneity of value to fishers, increase success of seedling growth, and generate a more fire resilient landscape.
5. Den / Rest Boxes – In areas where some cover remains after a fire, butstructures with suitable microsites were lost (particularly cavities), consider deploying and monitoring some artificial boxes to encourage near-term use of the area. On the Kings River Fisher Project, several styles of boxes were used when preparing orphaned kits for release and other efforts have been attempted in British Columbia and Wisconsin. These boxes must be large, durable, and attached in some fashion to trees or logs.

Photos of fisher artificial den and rest box designs to consider. 1. An example of a female fisher using an artificial cavity as a reproductive den from a fisher study in British Columbia (davis-2016-fisher-den-box-with-drawings.pdf (bcfisherhabitat.ca)). 2. An example of an orphaned juvenile fisher using an artificial rest box in a soft release pen from Kings River Fisher Project (PSW, Green et al., unpub. data).

Reference Info - Characteristics of Microsites & Structures used as Fisher Den & Rest Sites in the SSN

- **MICROSITE**: A fine scale feature within a structure where a fisher physically rests or hides kits. These fall into 4 general categories: **cavities, platforms, chambers,** and **interstitial spaces**. Females always use cavities in boles of trees or logs for denning, but males and females can also use cavities throughout the year for resting. Common access routes are via broken limb, woodpecker hole, crack/split in bole, broken trunk, or basal hollow. Platforms are semi-protected spaces on large limbs, broken trunks, branch clusters, or stick nests. Chambers are secure spaces underground. Interstitial spaces are in rock or log piles.
- **STRUCTURE**: A habitat element that contains a fine scale feature used by a fisher for denning or resting. These fall into 6 general categories: **live tree, snag, log, burrow, rock pile, or log pile**.
- **TREE SPECIES, DBH, and COMMON FEATURES**: Table 1 lists tree species commonly used for resting and denning on the KRFP. Note this list reflects local availability (i.e., other species may be used in SSN). Most den/rest trees are large in diameter, but small trees occasionally have suitable microsites (note the range). Table 2 lists features that may help identify potential den/rest trees; cavities are not always obvious.

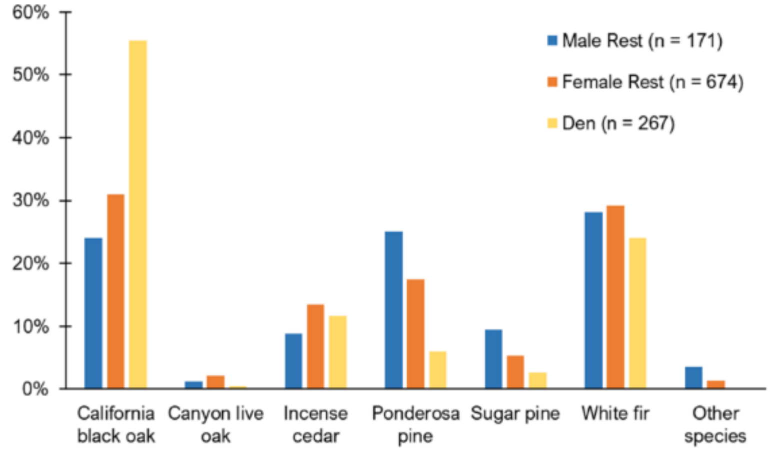
Table 1. DBH measurements for tree species used as den or rest sites by fishers on the Sierra NF (species used but not included due to small sample size; big leaf maple, white alder, Douglas fir, giant sequoia, Jeffrey pine, red fir).

Feature	Description and Relevance for Fisher
Basal hollow	Potential access point to cavity in bole of tree; often reflect presence of a hollow in the trunk.
Branch cluster	Unique growth, clump, or cluster on large limb can form a rest platform (common in conifers)
Broken top	Trunk of tree has snapped off, leaving a partially flat hidden platform (especially in conifers)
Broken trunk	Trunk has broken and allowed access to a protected interior hollow bole (common in oaks)
Dead top or section	May indicate cavities in live portion of tree (common in conifers with woodpecker activity)
Hollow in log	Entrance to hollow can be through root wad, side of trunk (e.g., broken limb), or broken top
Large broken limb	Scars from large broken limbs are often entrance points to cavities (hardwoods & conifers)
Large limb	Large limbs (≥ 12 cm diam.) provide platforms, especially if with unique flat / cupped shapes
Split / Crack in bole	Long vertical openings provide access to cavity in tree bole; often partly healed / not obvious
"Stick nest"	An actual large old nest or a clump of sticks & leaves, often in tree fork or base of large limb
Woodpecker hole	Openings created by pileated woodpeckers (≥ 11 x 7 cm) provide cavity access for females

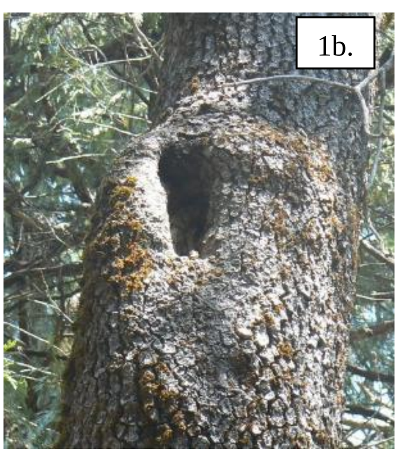
Table 2. Features often associated with microsites and structures used by fishers for denning or resting activities.

Tree Species	Den Structures dbh (in)		Rest Structures dbh (in)	
	Mean ± SD (range)	*n*	Mean ± SD (range)	*n*
Live Hardwood				
California black oak	29.9 ± 7.3 (15.8 – 53.0)	138	31.0 ± 7.7 (13.9 – 64.2)	168
Canyon live oak	38.6 (0)	1	22.9 ± 9.8 (9.9 – 38.2)	7
Live Conifer				
Incense cedar	49.0 ± 8.5 (34.7 – 60.4)	19	45.8 ± 15.7 (16.5 – 80.4)	37
Ponderosa pine	46.3 ± 9.3 (29.5 – 55.1)	7	34.8 ± 12.2 (14.4 – 72.7)	90
Sugar pine	48.5 ± 5.4 (42.3 – 52.6)	3	41.0 ± 13.6 (20.5 – 61.1)	22
White fir	41.6 ± 9.3 (26.6 – 63.0)	34	35.7 ± 11.4 (7.1 – 72.7)	86
Hardwood Snag or Log				
California black oak	27.3 ± 5.0 (22.8 – 39.8)	12	29.2 ± 8.6 (17.1 – 53.6)	24
Conifer Snag or Log				
Incense cedar	40.5 ± 9.1 (28.8 – 58.5)	16	38.6 ± 13.2 (11.6 – 78.4)	39
Ponderosa pine	38.0 ± 11.4 (18.4 – 51.0)	9	39.2 ± 10.4 (18.7 – 57.1)	25
Sugar pine	54.5 ± 8.9 (28.4 – 66.9)	4	51.4 ± 11.0 (35.1 – 70.9)	13
White fir	40.7 ± 11.2 (21.1 – 59.3)	32	41.4 ± 11.9 (21.7 – 67.6)	105

Hardwoods In the SSN, California black oaks plays a key role in providing suitable cavities for reproductive females during denning and provide cavities and platforms for resting males and females throughout the year. In the Sierra NF, black oaks comprised over half of all den trees located and a high proportion of rest locations. Females need cavities with relatively small openings for denning, but a wide variety of sizes are used for resting. Other available hardwoods may also be used (e.g., live oaks, big leaf maple, red alder), but do not appear to provide many cavities.

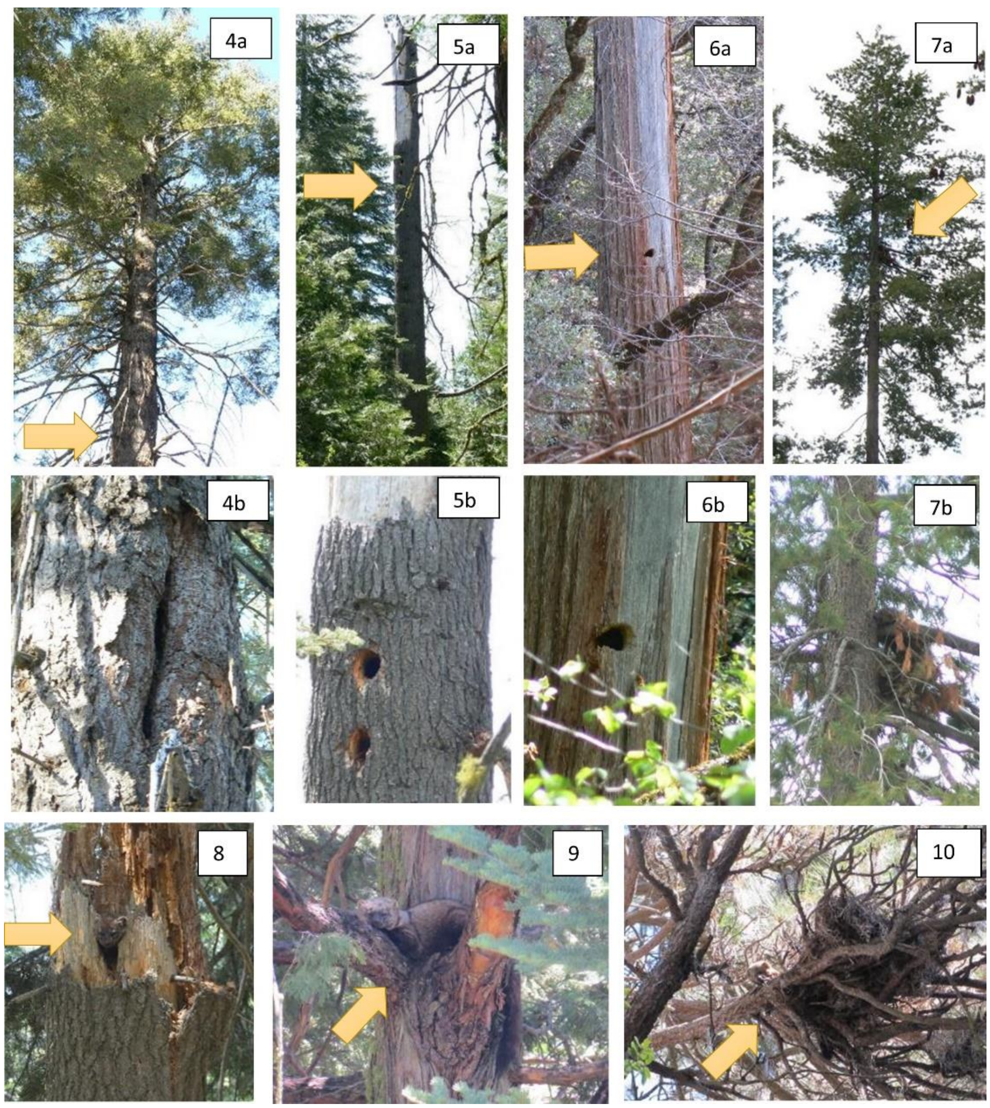


Hardwood photos: All trees shown were used as reproductive dens by female fishers. Photo 1 a-b shows a natal den with a basal hollow and a small cavity entrance formed by a broken limb. Photo 2 a-b shows a maternal den with a broken trunk that allowed access to a deep cavity in the trunk. Photo 3 a-b is of a late maternal den where a low vertical split allowed access for the female and her semi-mobile kits that were just learning to climb.



<u>Conifers</u> In the SSN, white fir and incense cedar are commonly used by reproductive females for dens, and are also used regularly for resting. Ponderosa pine and sugar pine can be used as dens, but are more commonly used for resting. Entrances to cavities in live trees and snags may be created by broken limbs, woodpecker holes, or broken trunks. Platforms for resting include large limbs, broken tops, branch clusters and stick nests.

Conifer photos: Photo 4 a-b shows a live white fir with a crack in the side that provided an entrance to a maternal den cavity. Photo 5 a-b shows a white fir snag used as a maternal den where a pileated woodpecker hole provided an entrance. Photo 6 a-b is of a live incense cedar used as a natal den with a woodpecker hole in the dead section of the tree. Photo 7 a-b is of a live sugar pine with a "stick nest" near the bole used for resting. Photo 8 is of a male resting in the broken top of a white fir snag. Photo 9 is a male resting on large limbs in a live incense cedar. And photo 10 shows a male in a live ponderosa pine resting on a branch cluster – a unique cup-shaped branch growth.



Medium Spatial Scale: Travel and Foraging habitat → Linkages & Foraging Patches

While we still have more to learn about habitat that supports fisher movement and foraging, recent data from scat surveys and GPS collars from the SSN suggest some recognizable patterns. First, fishers appear to be closely tied to cover (of some sort) in their daily movements within home ranges and in longer (infrequent) dispersal events. Second, fishers tend to travel along riparian areas, streams, and ravines, and have been documented crossing roads near drainages and vegetated "pinch points" where exposure is minimized. Third, although fishers spend a considerable amount of time in forests with dense cover (or at least a network of cover), they have been documented venturing into natural narrow linear segments of vegetation where the surrounding habitat is uncharacteristically open; examples include lower elevation vegetation sandwiched between granite outcrops, high elevation forested stringers (narrow stream corridors), and segments of low to moderate severity fire. Last, while there are exceptions, fishers tend to avoid large natural and human-created openings (e.g., open rock, patches of high severity fire, clear-cuts).

It is important to remember that fishers would have navigated a more heterogenous landscape with frequent fire disturbance in this region historically. Presumably, the close association between fishers and overhead cover is tied to minimizing risk of predation by larger carnivores (e.g., mountain lions, bobcats) – the primary source of mortality in this region. But fisher patterns of movement are also influenced by availability of prey and other food and the presence of other fishers and competitors. Regardless of why fishers prefer to move in cover, fishers are mobile animals with some capacity to navigate around openings if routes with cover are available. Maintaining connectivity within live forest where it still occurs seems critical in the SSN, and reconnecting live cover where connectivity or individual linkages of live forest have been lost could facilitate fisher movement for multiple purposes (e.g., travel within home range, predator avoidance, foraging, mating, territory marking) and allow for more dispersal options.

Primary Considerations at moderate spatial scales

- Maintain a connected network of live cover (forest, shrub) within potential fisher habitat
- Restore connections that may have been lost during high intensity fires
- Consider in planning: size, arrangement, composition, and location of linkage habitat
- Focus on stream corridors as areas of both natural travel for fishers and regeneration for plants
- Understand that fishers generally avoid open areas (open granite, high intensity fire patches)
- As characterization of foraging habitat continues, consider where diet items occur, including:
    - Squirrels, other small mammals, birds, reptiles, insects, fruit, fungi

Options / Ideas for Restoration and Fuels Reduction Plans

Retain remaining live forest through fuels reduction:

1. Stream corridors – Maintaining some vegetative cover along waterways is generally desirable for multiple objectives and feasible during implementation of prescribed fires due to higher moisture. Thus, plan to maintain linkages of live cover for fishers along streams during fuel reduction.
2. Other Linkages – In landscapes with extensive live forest cover, fishers generally have many options for traveling in cover – so identifying a particular area of linkage habitat may not really be needed (as demonstrated by the connectivity modeling in the main report). However, in areas where high intensity fire, natural openings (rock, meadow), or other human activities constrict

options to move in cover to few choices – then having a plan to maintain those linkages during prescribed fire or thinning is much more critical. The fisher connectivity models generated for this report highlight specific areas of importance pre- and post-fire. Where linkages area particularly rare or isolated, more conservative steps (e.g., pre-fire mechanical treatment, burn during less risky conditions) should be considered to maintain integrity of cover.

3. Composition, size, and arrangement – Fishers commonly use CWHR categories Montane Hardwood, Montane Hardwood-Conifer, Sierran Mixed Conifer, and White Fir forest in larger tree size classes (4, 5, and 6). While moderate to dense multi-layered canopy cover has generally been considered higher quality for fishers (>40%), any forest cover (or forest-shrub combination) is likely to be used compared to completely open areas. The size of a linkage (width, length) may be less critical than how many other options are available nearby; if connectivity is limited in an area, retaining a larger width during treatments is likely preferred. We do not yet have specific guidance on width / length of vegetated linkages to maintain – but even relatively narrow corridors could be of value at key pinch points along roads or major fuel breaks (e.g., 25-50 m width might be best, but even 5-10 m might be used if available). Land managers should work with what is available to maintain periodic connections between larger patches of high-quality live forest; these could include a combination of large or small live trees (oaks, conifers), shrubs, logs (especially on uphill slope), small log piles, or rocks and could be strategically located to facilitate fisher movement (e.g., at drainages, saddles on ridges) but also be designed with low fire risk in mind.

Restore habitat in burned areas:

1. Stream corridors – Restoring vegetation to support fisher movement and foraging opportunities along streams will likely only be needed in areas of high intensity fire – particularly very large patches. At a minimum, these areas should be monitored to see if native trees, fruiting shrubs, riparian vegetation (e.g., willow) are coming back and where feasible enhance recovery of vegetation through planting on the slopes adjacent to streams.
2. Recreating Linkages – In addition to facilitation recovery of vegetation along streams, managers should identify other areas where planting and other mechanical treatment (e.g., leaving strategic logs, log piles) could recreate previously important linkages or simply improve connectivity for terrestrial species like fisher between larger patches of live forest. Reviewing the results of the connectivity model, fire intensity maps, and field visits can help identify specific areas to target for restoration. Also, building off of any remaining pockets of live vegetation may improve success of restoration and increase cover for wildlife more quickly.
3. Stepping-stones of vegetation (arrangement, size) – As the recent fire footprints are so large and restoration efforts will be limited, aiming for a “stepping-stone” approach to planting and recreating cover may be a good option to maximize efforts, recreate linkages more quickly, and set up a more fire resilient landscape. Working with available options on the landscape, managers could leave a combination of snags/logs/small log piles as well as plant trees (and possibly shrubs if they are not regenerating naturally) in strategically placed clumps to ultimately reconnect larger live patches of forest. The composition of the “stepping-stones” could include a combination of species to maximize chances of some trees surviving under future conditions (e.g., include oaks, pines, cedars, firs) and the size could be variable – with even small patches (e.g., 10-25 m square) likely having value for fishers and prey species.

4. Foraging habitat – As linkages are being encouraged or recreated with restoration efforts, it is worth considering what additions might be incorporated to also improve foraging opportunities. Defining foraging habitat itself is still challenging, but we do have recent information on fisher diet. Fishers rely heavily on mammalian prey for calories such as western gray squirrels, Douglas squirrels, and Humboldt's flying squirrels in addition to other smaller species like chipmunks, pocket gophers, and mice. But they also eat songbirds and quail, lizards, snakes, and insects. Recent studies post-tree mortality also highlight the consumption of fruit (*Ribes* sp.) and fungi. So, any restoration planning that could consider this diverse diet may improve success.

Broad Spatial Scale: Den Cluster and Home Range Core habitat → Old Forest Refugia

At the level of the POD or small watershed (e.g., HUC 14), maintaining areas of older forest ("old forest refugia") that are proportional in size to the needs of reproductive female fishers is one strategy to maintain self-sustaining local populations of fisher in the SSN. A den cluster is a term for the group of den trees used by a female fisher in a single reproductive season; as such, the average area of land encompassed by a den cluster represents an important spatial scale to consider in planning. Other slightly larger relevant patches include home range estimates of male and female fishers, with an emphasis on females due to their critical role in reproduction. As home range sizes of fishers are large and some portions are used more than others, 30 to 50% core areas may also represent an appropriate target size for old forest patches. Primary considerations in restoration planning are to find ways to retain existing old forest refugia through fuels treatment and/or plant appropriate tree species (and potentially add den boxes) in arrangements and composition that mimic known den cluster and core areas sizes.

Primary Considerations at broad spatial scales

- Retain patches of old forest refugia comparable in size / composition to den clusters
- Retain patches of old forest refugia comparable in size / composition to female HR core areas
- Consider the size of male and female 95% home ranges in planning, but focus on maintaining 30 to 50% home range core size areas with a network of connectivity (live vegetation / forest)
- Consider the spatial arrangement of old forest refugia relative to proposed treatments, recent fire footprints (particularly high intensity fire), and other available suitable habitat

Options / Ideas for Restoration and Fuels Reduction Plans

Retain remaining live forest through fuels reduction:

1. Plan around key areas of old forest – Use available spatial data to identify moderate to large older forest stands and consider options to leave some den cluster (92 ha) or female core area-sized patches (60 ha or 130 ha) relatively undisturbed while portions of surrounding landscape are treated with prescribed fire and/or mechanical thinning. In future years, the treatments areas might be reversed to improve resiliency of these old forest refugia.
2. Maintain diverse, multi-layered forest patches – As climate, bark beetles, and fire continue to alter forests in the SSN, consider that maintaining a forest with diverse species composition (hardwoods and conifers), mixed age groups, and multi-tiered canopy generally provide suitable habitat for fishers, but also help ensure that some trees will survive the next disturbance event.
3. Spatial arrangement – When planning to maintain areas of old forest refugia, consider also where linkages already occur or might be recreated. Additionally, consider juxtaposition to open areas

(e.g., high intensity fire footprints) and potential hazards (e.g., busy highways) when planning treatments – especially if prescribed burns need to occur prior to or near the end of den season.

Restore habitat in burned areas:

1. Where to focus efforts - At this broader spatial scale, it may be challenging to decide where to focus restoration efforts in large fire footprints with extensive areas of high intensity burn. Perhaps the best suggestions are to focus efforts in areas where potential benefits to fishers overlap with other objectives (e.g., restoration of sequoia groves, habitat for California spotted owls, hydrologic function of particular streams) and areas where restoration efforts are likely to be most successful (e.g., use PostScript model, enlarge remaining patches and edges of live forest). Another option is to focus on areas that were high quality habitat prior to the fire, and determine whether restorations might be of value in the long-term based on juxtaposition of other usable fisher reproductive habitat.
2. Species to plant – In addition to planting native conifer species that would have occurred prior to fires (e.g., ponderosa pine, sugar pine, white fir, incense cedar, giant sequoia), consider also projected conditions under a changing climate and how that might influence choices for planting. While California black oaks and canyon live oaks are often not targeted for planting because they resprout and may be hard to grow in a greenhouse – these species are drought tolerant with many benefits for fishers and other wildlife. At a minimum, consider spreading seeds in large patches of high intensity fire where natural regeneration might be limited unless encouraged.
3. Arrangement and size – As in the linkage section, consider planting and leaving other old structure cover (e.g., patches of snags, logs, small log piles) in clumps or clusters to create a more heterogenous landscape that may better reflect past conditions, be more resilient in future conditions, and still be of use to fishers and other wildlife species. Also, by focusing on a restoring vegetative cover in a clustered pattern may be an efficient way to spread resources across the burned landscape and restore cover more quickly. Size of clumps could vary somewhat based on site conditions and availability of seedlings to plant, but should be monitored to assess whether there is an ideal size to maximize efficiency and success of planting.

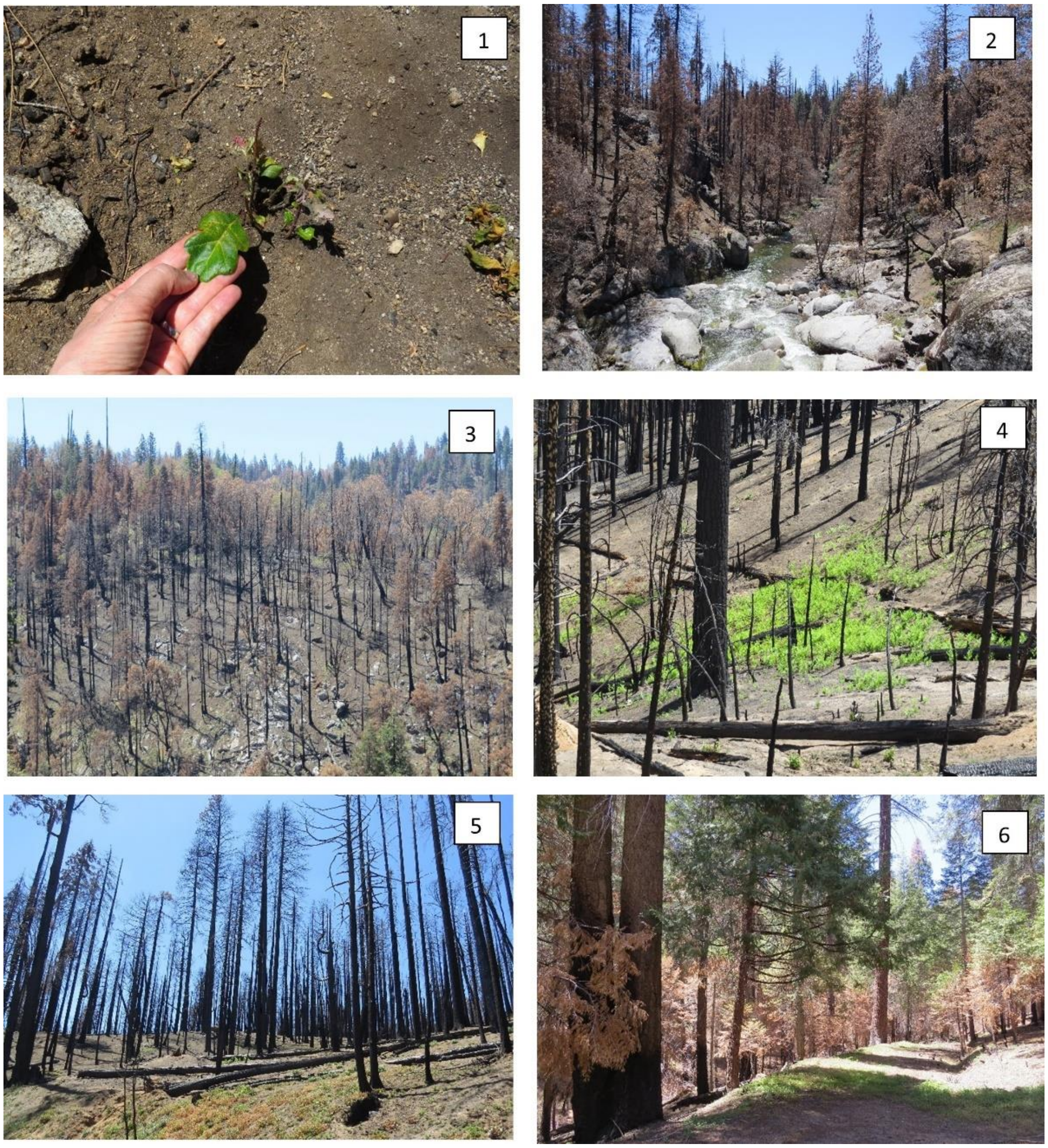
Reference data from KRFP Final report (Green et al. 2021, and manuscripts in preparation)

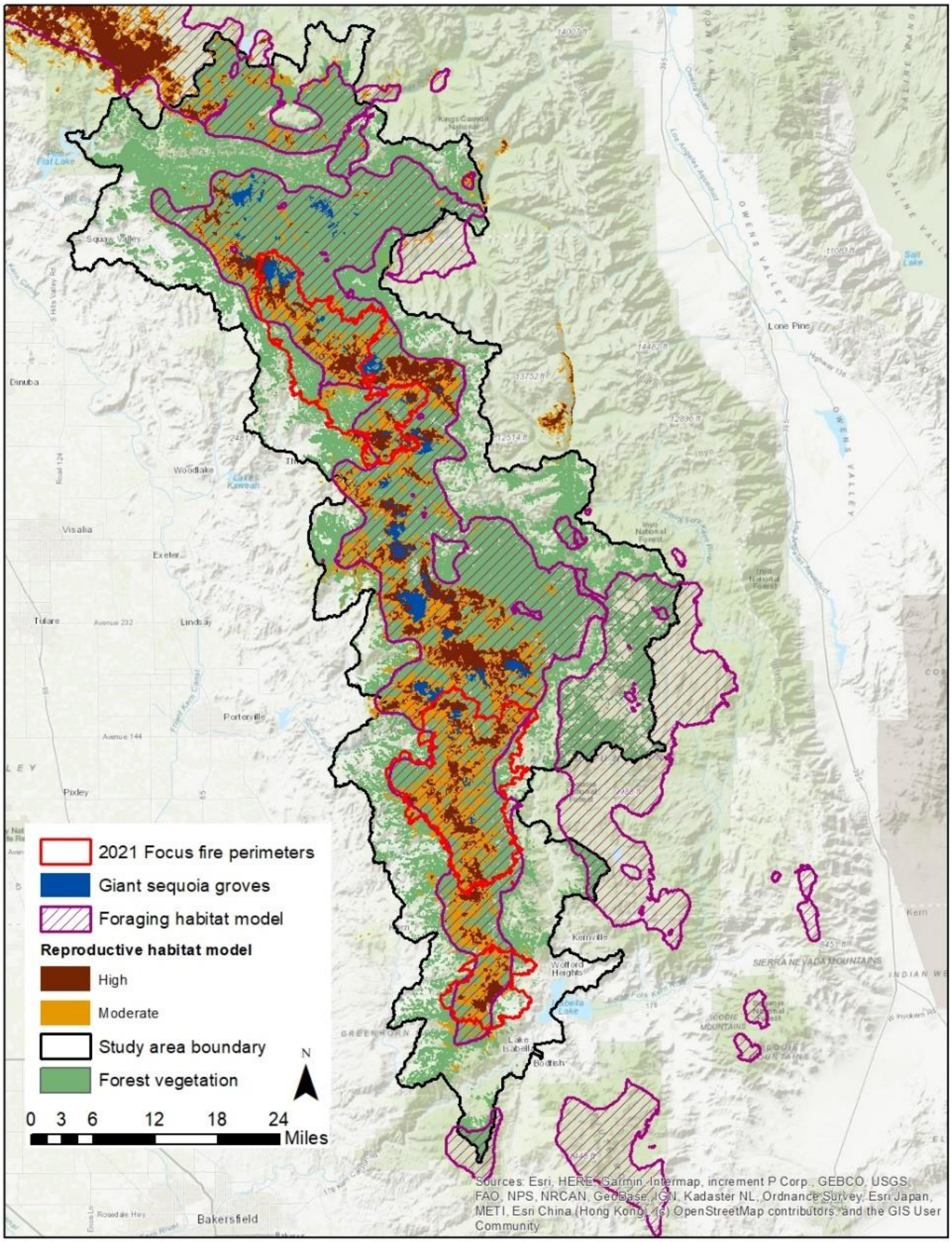
- Mean number of dens per year / female ("den cluster) = 3.6 dens
- Mean distance moved between dens in a cluster = 345 m
- Mean den cluster area (MCP + 250 m buffer) = 92 ha

Mean home range estimates from the Sierra NF during the recent period of tree mortality (calculated by M. Martin using data from all years of KRFP data)

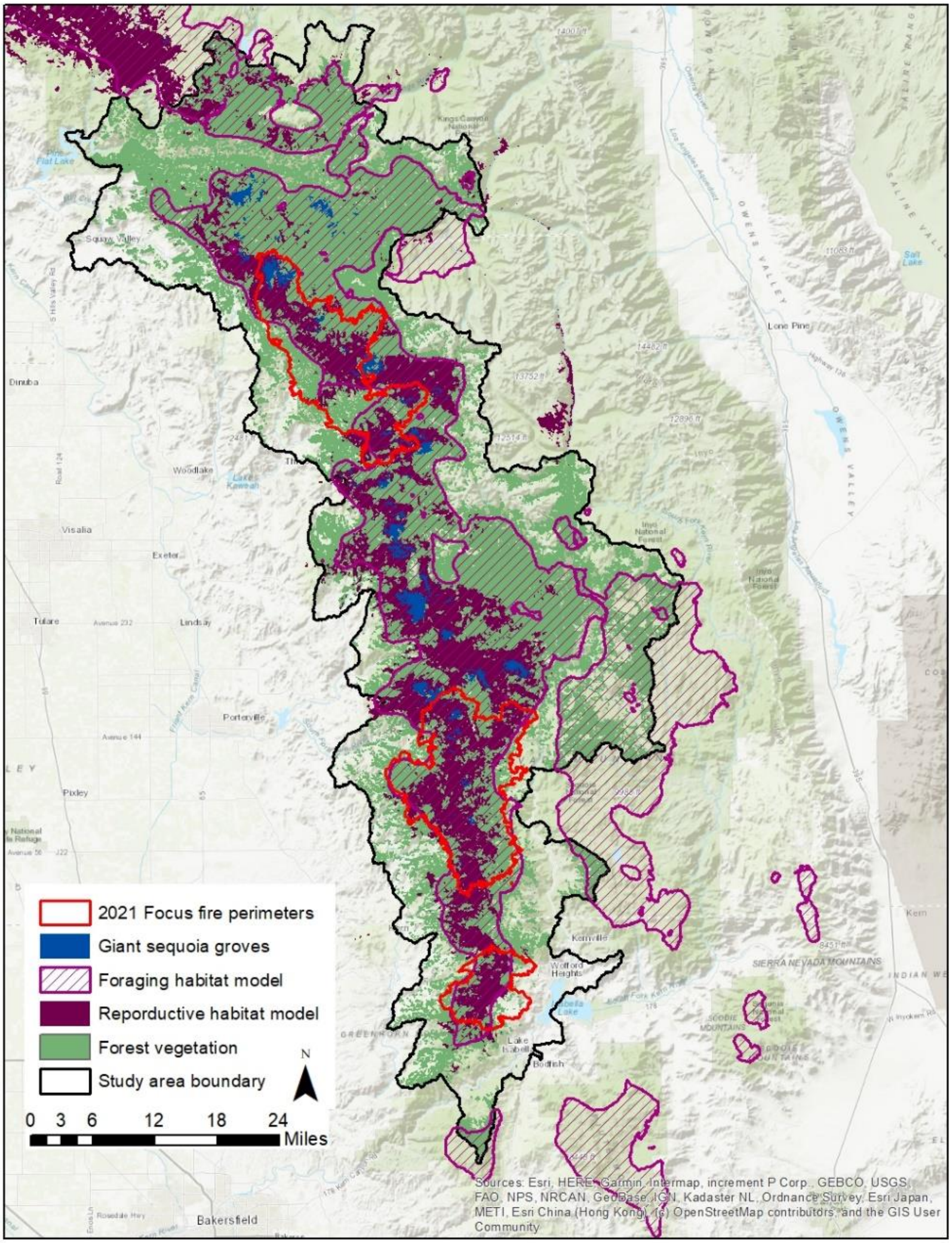
Group	30% HR Core	50% HR Core	95% HR Core
Female fisher	60 ha	130 ha	670 ha
Male fisher	190 ha	530 ha	2320 ha

Photos from KNP Complex in what was predicted to be high quality fisher habitat prior to the KNP Fire (Colony Mill Road, taken spring 2022). 1. California black oak seedling in high intensity burn area near Marble Fork of the Kaweah River. 2. High intensity burn along stream corridor. 3. Large patch of high intensity bun on a hillside with live forest in background. 4. High intensity burn area where plants (bracken fern, fruiting shrubs) are starting to grow. 5. High intensity burn area with little regrowth so far. 6. Low to moderate severity burn patch – live forest linkage.





Fisher Habitat Overview Map 1. For general reference, this map includes the pre-drought fisher foraging model (Spencer et al. 2015), the post-drought fisher reproductive model showing moderate and high classifications (Thompson et al. 2021), forest vegetation masks smoothed with a 5x5 pixel moving window (CWHR categories: MHW, MHC, MRI, PPN, RFR, SMC, WFR), Giant sequoia groves, the focal 2021 fire footprints (Windy, KNP, French), and our study area boundary.



Fisher Habitat Overview Map 2. For general reference, this map includes the pre-drought fisher foraging model (Spencer et al. 2015), the post-drought fisher reproductive model with merged moderate and high categories (Thompson et al. 2021), forest vegetation masks smoothed with a 5x5 pixel moving window (CWHR categories: MHW, MHC, MRI, PPN, RFR, SMC, WFR), Giant sequoia groves, the focal 2021 fire footprints (Windy, KNP, French), and our study area boundary.

Appendix G: Photos of post-fire grove conditions in the Giant Sequoia National Monument following the 2021 Windy Fire.

Figure 47. Low to moderate severity fire effects following the 2021 Windy Fire and 2016 Meadow Fire in the Cunningham Grove, Giant Sequoia National Monument. Note the relatively open stand conditions.

Figure 48. Low (top panel) and moderate (bottom) severity fire effects following the 2021 Windy Fire and 2016 Meadow Fire in the Cunningham Grove, Giant Sequoia National Monument.

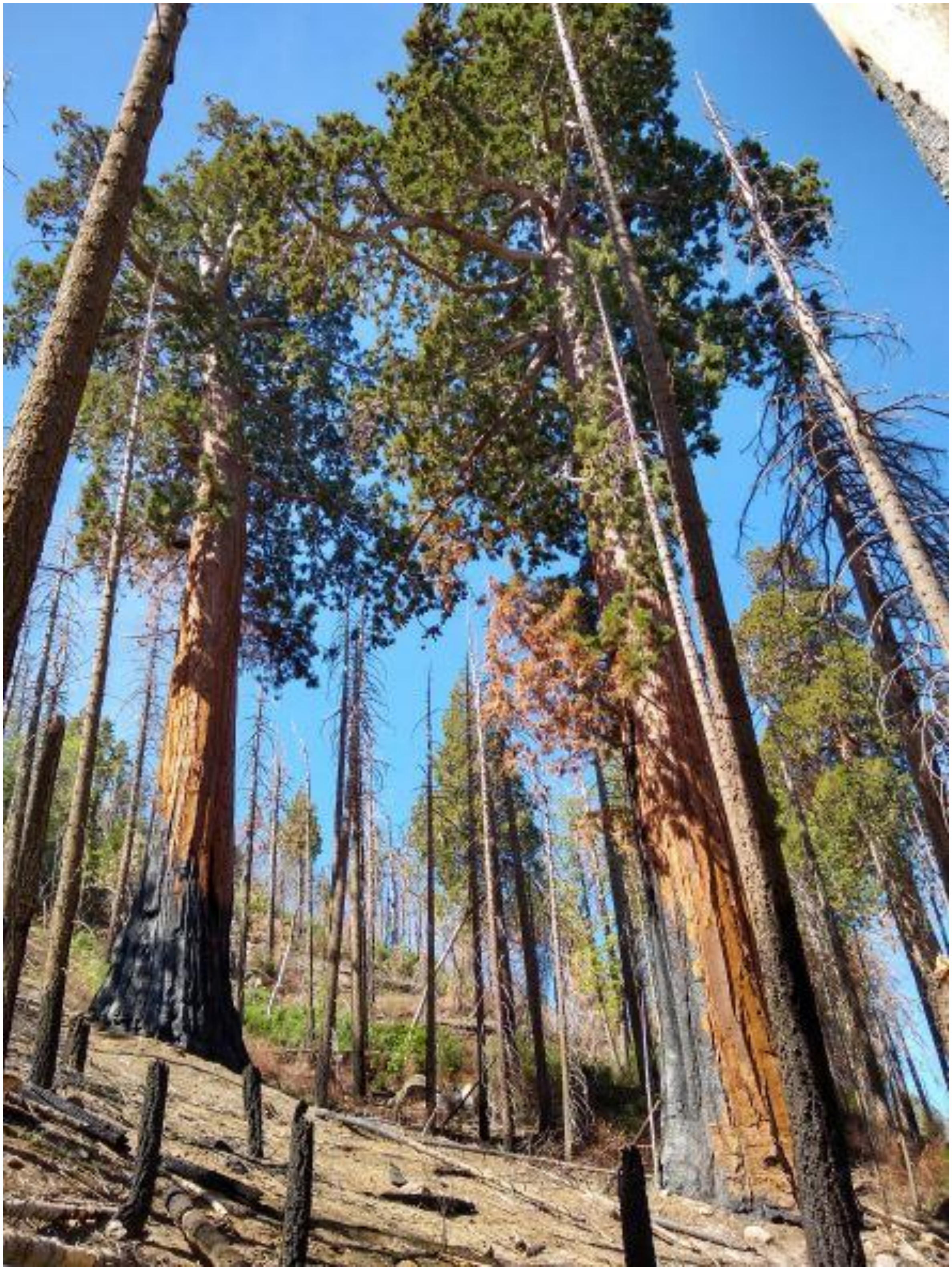


Figure 49. Consumption of ladder fuels in the Cunningham Grove following the 2021 Windy Fire and 2016 Meadow Fire, Giant Sequoia National Monument.

Figure 50. Low severity fire effects in the Long Meadow Grove following the 2021 Windy Fire, Giant Sequoia National Monument. Note that crown scorch is concentrated in the smaller-diameter ladder fuels.

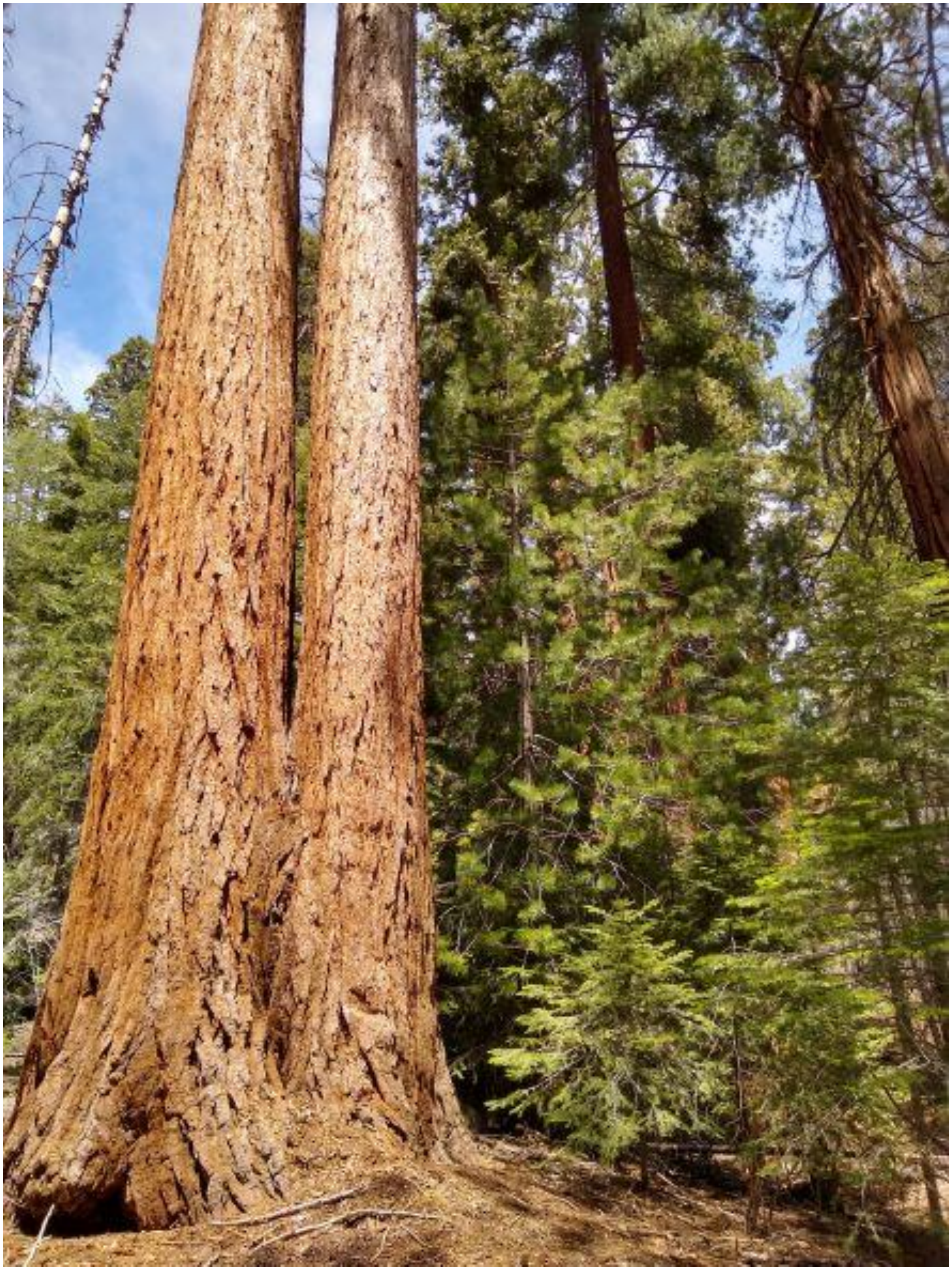


Figure 51. Residual ladder fuels following the 2021 Windy Fire in the Long Meadow Grove, Giant Sequoia National Monument.

Figure 52. Low severity fire effects in the Long Meadow grove, resulting in the consumption of surface and small-diameter ladder fuels, Giant Sequoia National Monument.

Figure 53. Residual ladder fuels in the Long Meadow Grove following the 2021 Windy Fire, Giant Sequoia National Monument.

Glossary (excerpted from PSW-GTR-270)

Active restoration or management—Direct interventions to achieve desired outcomes (including restoration), which may include harvesting and planting of vegetation and the intentional use of fire, among other activities.

Adaptive capacity—The ability of ecosystems and social systems to respond, cope, or adapt to disturbances and stressors, including environmental change, to maintain options for future generations.

Adaptive management—A structured, cyclical process for planning and decision-making in the face of uncertainty and changing conditions with feedback from monitoring, which includes using the planning process to actively test assumptions, track relevant conditions over time, and measure management effectiveness. Additionally, adaptive management includes iterative decision-making through which results are evaluated and actions are adjusted based upon what has been learned.

Biodiversity—In general, the variety of life forms and their processes and ecological functions, at all levels of biological organization from genes to populations, species, assemblages, communities, and ecosystems.

Climate adaptation—Management actions to reduce vulnerabilities to climate change and related disturbances.

Climate change—Changes in average weather conditions (including temperature, precipitation, and risk of certain types of severe weather events) that persist over multiple decades or longer, and that result from both natural factors and human activities such as increased emissions of greenhouse gases (U.S. Global Change Research Program 2017).

Climatic water deficit (CWD) —Annual evaporative demand that exceeds available water, summed annually. It is calculated based on potential evapotranspiration minus actual evapotranspiration. CWD measures when plants have insufficient water to support photosynthesis and is a measure of plant drought stress.

Community (plant and animal)—A naturally occurring assemblage of plant and animal species living within a defined area or habitat.

Composition—The biological elements within the various levels of biological organization, from genes and species to communities and ecosystems.

Connectivity (of habitats) —Environmental conditions that exist at several spatial and temporal scales that provide landscape linkages that permit: (a) the exchange of flow, sediments, and nutrients; (b) genetic interchange of genes among individuals between populations; and (c) the long distance range shifts of species, such as in response to climate change.

Desired conditions—A description of specific social, economic, and/or ecological characteristics toward which management of the land and resources are directed.

Disturbance regime—A description of the characteristic types of disturbance on a given landscape; the frequency, severity, and size distribution of these characteristic disturbance types and their interactions.

Disturbance—Any relatively discrete event in time that disrupts ecosystem, watershed, community, or species population structure and/or function and changes resources, substrate availability, or the physical environment.

Ecological conditions—The biological and physical environment that can affect the diversity of plant and animal communities, the persistence of native species, invasibility, and the productive capacity of ecological systems. Ecological conditions include habitat and other influences on species and the environment. Examples of ecological conditions include the abundance and distribution of aquatic and terrestrial habitats, connectivity, roads and other structural developments, human uses, and occurrence of other species.

Ecological integrity—The quality or condition of an ecosystem when its dominant ecological characteristics (for example, composition, structure, function, connectivity, and species composition and diversity) occur within the natural range of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human influence.

Ecological restoration—"The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (SER 2004). Ecological restoration focuses on reestablishing the composition, structure, pattern, and ecological processes necessary to facilitate terrestrial and aquatic ecosystems sustainability, resilience, and health under current and future conditions (36 CFR 219.19).

Ecosystem—A spatially explicit, relatively homogeneous unit of the earth that includes all interacting organisms and elements of the abiotic environment within its boundaries.

Ecosystem services—Benefits people obtain from ecosystems, including provisioning services (e.g., clean air, fresh water, food, wood products), regulating services (e.g., carbon storage, water filtration and storage; regulation of disturbances and diseases), supporting services (e.g., pollination, seed dispersal, soil formation, and nutrient cycling), and cultural services (e.g., spiritual, recreational, and aesthetic experiences. Some references distinguish "ecosystem goods" from services, while others categorize "goods" under "provisioning services".

Endangered species—Any species or subspecies that the Secretary of the Interior or the Secretary of Commerce has deemed in danger of extinction throughout all or a significant portion of its range.

Endemic—Native and restricted to a specific, geographical area.

Exposure—The sum of climate and climate-related changes that may negatively or positively affect an ecosystem, population, or other resource.

Fire-dependent vegetation types—A vegetative community that evolved with fire as a necessary contributor to vitality and renewal of habitat for its member species.

Fire exclusion—Curtailment of wildland fire because of deliberate suppression of ignitions, as well as unintentional effects of human activities such as intensive grazing that removes grasses and other fuels that carry fire.

Fire intensity—The amount of energy or heat released during a fire.

Fire regime—A characterization of long-term patterns of fire in a given ecosystem over a specified and relatively long period of time, based upon multiple attributes including frequency, severity, extent, spatial complexity, and seasonality of fire occurrence.

Fire return interval—The amount of time between successive fire events in a given area.

Fire return interval departure—Comparison between pre-Euro-American settlement and contemporary fire return intervals.

Fire risk—The likelihood of a negative outcome and the severity of subsequent negative consequences resulting from fire.

Fire severity—The magnitude of the effects of fire on ecosystem components including vegetation or soils.

Fire suppression—The act of extinguishing wildfires by humans.

Fuels (wildland)—Combustible material in wildland areas including live and dead plant biomass such as trees, shrub, grass, leaves, litter, snags, and logs.

Fuels management—Manipulation of wildland fuels through mechanical, chemical, biological, or manual means, or by fire, in support of land management objectives to control or mitigate the effects of future wildland fire.

Function (ecological) —Ecological processes, such as energy flow; nutrient cycling and retention; soil development and retention; predation and herbivory; and natural disturbances such as wind, fire, and floods that sustain composition and structure.

Future range of variation (FRV)—The natural fluctuation of pattern components of healthy ecosystems that might occur in the future, primarily affected by climate change, human infrastructure, invasive species, and other anticipated stressors.

Goals (in land management plans)—Broad statements of intent, other than desired conditions, that do not include expected completion dates.

Guideline—A constraint on project and activity decision-making that allows for departure from its terms, so long as the purpose of the guideline is met. Guidelines are established to help achieve or maintain a desired condition or conditions, to avoid or mitigate undesirable effects, or to meet applicable legal requirements.

Habitat—An area with the environmental conditions and resources that are necessary for occupancy by a species and for individuals of that species to survive and reproduce.

Habitat fragmentation—Discontinuity in the spatial distribution of resources and conditions present in an area at a given scale that affects occupancy, reproduction, and survival in a particular species.

Heterogeneity (forest)—Diversity, often applied to variation in forest structure within stands in horizontal (e.g., single trees, clumps of trees, and gaps of no trees) and vertical (e.g., vegetation at different heights from the forest floor to the top of the forest canopy) dimensions, or across large landscapes (North et al. 2009).

High severity burn patch—A contiguous area of high severity or stand-replacing fire.

Historical range of variation (HRV)—Past fluctuation or range of ecosystem conditions over a specified area and period of time.

Invasive species—Any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to a particular ecosystem, and whose deliberate, accidental, or self-introduction is likely to cause economic or environmental harm or harm to human health.

Land and Resource Management Plan (Forest Service)—A document or set of documents that provide management direction for National Forest administrative unit.

Landscape—A defined area irrespective of ownership or other artificial boundaries, encompassing a mixture of terrestrial and aquatic ecosystems, landforms, and plant communities, repeated in similar form throughout such a defined area.

Late seral forest—A forest distinguished by old trees (generally >150 to 200 years) and related structural attributes that often (but not always) include large trees, relatively high biomass of dead wood (i.e. snags, downed coarse wood), multiple canopy layers, distinctive species composition and functions, and vertical and horizontal diversity in the tree canopy. In dry, fire-frequent forests, old growth is characterized by large, old fire-resistant trees and relatively open stands without canopy layering.

LiDAR–Remote sensing survey method that uses pulsed laser light to measure the height and coverage of terrain and vegetation.

Mixed chaparral—Shrubland vegetation type confined to Mediterranean climate zone in California that occurs in the lower elevation foothill zone generally below 1520 m.

Montane chaparral—Shrubland vegetation type confined to Mediterranean climate zone in California that generally occurs with the montane or upper montane zones.

Monitoring—A systematic process of collecting information to track implementation (implementation monitoring), to evaluate effects of actions or changes in conditions or relationships (effectiveness monitoring), or to test underlying assumptions (validation monitoring).

Native species—A species historically or currently present in a particular ecosystem as a result of natural migratory or evolutionary processes and not as a result of an accidental or deliberate introduction or invasion into that ecosystem.

Natural range of variation (NRV)—Spatial and temporal variation in ecosystem characteristics under historical disturbance regimes during a reference period or from a reference location.

Objective (in land management plans)—Concise, measurable, and time-specific statement of a desired rate of progress toward a desired condition.

Patch—A relatively small area with similar environmental conditions, such as vegetative structure and composition. Sometimes used interchangeably with vegetation or forest stand.

Potential wildland fire Operational Delineation unit (POD)—Spatial representation of an area that summarizes wildfire risk in a meaningful operational fire management context. Potential operational delineations can follow fine-scale features such as ridgetops, water bodies, roads, barren areas, elevation changes or major fuel changes.

Prescribed fire—A wildland fire originating from a planned ignition to meet specific objectives identified in a written, approved, prescribed fire plan for which NEPA requirements (where applicable) have been met prior to ignition (synonymous with controlled burn).

Reburn—Fire that burns an area where fuels (such as scorched needles, twigs, branches, and tree boles that fall to the surface) are primarily derived from a previous burn. Reburns may result in reduced ecosystem integrity when they facilitate fire regime transitions outside the natural range of variation, such as fire burning too frequently or severely.

Recovery, ecosystem—The reestablishment of essential ecosystem structure, composition, and function that supports long-term ecological integrity, health, and sustainability. Recovered ecosystems contain sufficient biotic and abiotic resources to continue successional development without assistance, are functionally self-sustaining, exhibit resilience to anticipated environmental stressors and perturbations, and interact with adjoining connected ecosystems (SER 2004; see "ecological restoration").

Refugia—An area that remains less altered by climatic and environmental change (including disturbances such as wind and fire) affecting surrounding regions and that therefore forms a haven for relict fauna and flora.

Resilience—The capacity of an ecosystem to absorb disturbance and reorganize (or return to its previous organization) so as to retain essentially the same function, structure, identity, and feedbacks. Definitions emphasize the capacity of a system or its constituent entities to respond or regrow after mortality induced by a disturbance event, although broad definitions of resilience may also encompass "resistance" (see below), under which such mortality may be averted.

Resistance—The capacity of an ecosystem or an entity to withstand a disturbance event without much change or alteration in essential characteristics.

Restoration, ecological—see "ecological restoration"

Restoration, functional—Restoration of dynamic abiotic and biotic processes in degraded ecosystems, without necessarily a focus on structural condition and composition.

Restoration strategy—A strategic vision that describes broad ecological restoration approaches that support ecosystem management goals and objectives within a specific landscape of interest.

Riparian areas—Three-dimensional ecotones [the transition zone between two adjoining communities] of interaction that include terrestrial and aquatic ecosystems that extend down into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain to the water, laterally into the terrestrial ecosystem, and along the water course at variable widths (36 CFR 219.19).

Scale—In ecological terms, the extent and resolution in spatial and temporal terms of a phenomenon or analysis, which differs from the definition in cartography regarding the ratio of map distance to earth surface distance.

Serotinous— An ecological adaptation in some plants in which seed release occurs in response to an environmental trigger such as heat or smoke from a fire.

Shrubland—An area (generally large and persistent) dominated by shrubs.

Soil burn severity—The effect of fire on ground surface characteristics, including organic matter loss, reduced infiltration, char accumulation, and altered soil structure.

Species of conservation concern—A species, other than federally recognized threatened, endangered, proposed, or candidate species, that is known to occur in the plan area and for which the Regional Forester has determined that the best available scientific information indicates substantial concern about the species' capability to persist over the long-term in the plan area.

Stand—A land management unit consisting of a contiguous group of trees sufficiently uniform in age-class distribution, composition and structure, and growing on a site of sufficiently uniform quality, to be a distinguishable unit.

Stand-replacing fire— High severity fire, where fire kills more than 75% of the dominant vegetation (see "vegetation burn severity").

Stressors—Factors that may directly or indirectly degrade or impair ecosystem composition, structure or ecological process in a manner that may impair its ecological integrity, such as an invasive species, loss of connectivity, or the disruption of a natural disturbance regime (36 CFR 219.19).

Structure (ecosystem)—The organization and physical arrangement of biological elements such as snags and down woody debris, vertical and horizontal distribution of vegetation, stream habitat complexity, landscape pattern, and connectivity.

Sustainability—The capability to meet the needs of the present generation without compromising the ability of future generations to meet their needs. Sustainability is sometimes defined in terms of three dimensions: ecological (capability to maintain ecological integrity), economic (capability to produce and benefit from goods and services), and social (capability to support networks of relationships, traditions, culture, and activities that connect people to the land and to one another in vibrant communities). (36 CFR 219.19)

Sustainability (ecological)—The capability of ecosystems to maintain ecological integrity (36 CFR 219.19).

Succession—Non-seasonal and directional change in species composition and structure in an ecological community over time.

Uncertainty—Amount or degree of confidence as a result of imperfect or incomplete information.

Vegetation burn severity—The magnitude of the effect of fire on vegetation (see "fire severity"), often classified as: (1) low severity, with <25% mortality of the dominant vegetation (e.g., trees, shrubs); (2) moderate severity, with 25-75% mortality of the dominant vegetation; and (3) high severity, with >75% mortality of the dominant vegetation (also referred to as "stand-replacing fire").

Vegetation type—A general term for a combination or community of plants (including grasses, forbs, shrubs, or trees), typically applied to existing vegetation rather than potential vegetation.

Vulnerability—The degree to which a system is susceptible to, or unable to cope with, change.

Watershed—A region or land area drained by a single stream, river, or drainage network; a drainage basin.

Watershed restoration—Restoration activities that focus on restoring the key ecological processes required to create and maintain favorable environmental conditions for aquatic and riparian-dependent organisms.

Wilderness—Any area of land designated by Congress as part of the National Wilderness Preservation System that was established in the Wilderness Act of 1964 (16 U.S.C. 1131–1136).

Wildlife—Undomesticated animal species including amphibians, reptiles, birds, mammals, fish and invertebrates or even all biota that live wild in an area without being introduced by humans.

Wildfire—Unplanned ignition of a wildland fire (such as a fire caused by lightning, volcanoes, unauthorized and accidental human-caused fires) and escaped prescribed fires.