National Park Service
U.S. Department of the Interior

Sequoia and Kings Canyon National Parks
Interior Regions 8, 9, 10 and 12

Re-establish Tree Seedlings in Severely Burned Giant Sequoia Groves and Adjacent Fisher Habitat

Environmental Assessment

Revised and Reissued October 2023

As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

ON THE COVER

Photo showing giant sequoias killed by high severity fire in Board Camp Grove in the southern part of Sequoia National Park.

[National Park Service Photo]

Purpose of Reissuing a Revised EA

The NPS released the *Re-establish Tree Seedlings in Severely Burned Giant Sequoia Groves and Adjacent Fisher Habitat Environmental Assessment* on July 7, 2023, for a 30-day public review period. During this time, the NPS received roughly 1,900 pieces of correspondence, most of which expressed either support or opposition to the proposal but some of which raised concerns that were substantive in nature. In reviewing and responding to public and agency comments, the NPS typically releases an errata documenting any changes in text if determining a Finding of No Significant Impact (FONSI). However, given the considerable public interest in this project, the NPS determined that reissuing a revised EA, with all errata directly incorporated, would better allow the public to see where changes were made and the nature of those changes. In developing this revised EA, the NPS also took the opportunity to provide further clarifications as well as make minor grammatical corrections. Under NPS policy, public review is not required or typically associated with the release of a revised EA.

The following is a summary of revisions made in the revised EA:

- Additional information provided on sequoia ecology and results of recent studies (page 3).
- Additional detail on NPS' rationale for including Invasive Species and Soil Pathogens as an issue considered but dismissed (page 11).
- Additional detail and clarifications on NPS' rationale for considering but dismissing Understory Vegetation as an issue considered but dismissed (page 16).
- Additional detail on tiering actions to this EA (page 18).
- Additional detail and clarifications on mortality and regeneration assessments—including the threshold below which the NPS would consider regeneration insufficient (pages 19 and 21).
- Clarifications on limited tree removal under Alternative 2 and 3 (page 34).
- Dismissal of similar alternatives, and clarifications for other alternatives incorporated under Alternatives Considered but Dismissed (pages 36 and 38).
- Additional detail provided in Affected Environment for Sequoia Grove Recovery and Resilience, Fisher Habitat, and Wilderness Character (beginning on pages 45, 56, 57 and 61).
- Minor modifying language added to effects to Sequoia Grove Recovery under Alternatives 1 and 2 (pages 49 and 52).
- Additional detail added, as well as clarifying reorganization of, cumulative effects analysis for Sequoia Grove Recovery and Resilience, Fisher Habitat, and Wilderness Character (pages 52, 54, 61, 66, and 69).
- Additional clarifying language made to effects section in Wilderness Character (beginning on page 67).
- Results of Endangered Species Consultation incorporated into Chapter 4 (page 72).
- Details of best management practices that would be implemented incorporated into Appendix A.
- The addition of an Appendix F to provide more detail on planting plans that would be tiered to this EA.

Table of Contents

List of Appendices

List of Tables

List of Figures

Chapter 1: Purpose and Need

Introduction

The National Park Service (NPS) is proposing to replant giant sequoia *(Sequoiadendron giganteum*) and other mixed conifer seedlings in up to six giant sequoia groves: Redwood Mountain, Suwanee, New Oriole Lake, Dillonwood[1], Board Camp, and Homers Nose, and in an endangered fisher (*Pekania pennanti*) habitat corridor severely impacted by recent wildfires in Sequoia and Kings Canyon National Parks (parks). Regeneration is not anticipated to be sufficient to largely restore the pre-fire natural composition of forest cover in areas where planting is being considered, and the NPS anticipates that in portions of these forests where this is the case, these areas may instead type-convert to high severity, frequent fire shrub communities without action.

Purpose and Need

The purpose of the proposed action is to promote post-fire recovery of giant sequoia groves and proposed fisher critical habitat impacted by high severity fire[2] in areas where these forests are otherwise unlikely to recover. The NPS believes action is needed at this time to:

1) Reduce the potential for an unacceptable loss of giant sequoias—a fundamental resource that these parks were established to protect—in the limited number of groves where they naturally occur;
2) Restore proposed critical habitat for an endangered species; and
3) Avoid type conversion of these forests to high severity, frequent fire shrub communities, thereby protecting, in part, the surrounding forests from more frequent, high severity fire.

The goal of the proposed action is to direct the trajectory of severely burned areas toward forest recovery—as would have likely occurred naturally had unnaturally high fuel loading (a result of over 100 years of active fire exclusion exacerbated by more recent effects of climate change driven hotter drought) not led to severe fire effects across large, contiguous acres of sequoia groves and other mixed conifer forests during recent wildfires.[3]

Giant sequoia (sequoia) is a fundamental resource for which Sequoia and Kings Canyon National Parks were established and is an attribute of the natural quality of the wilderness character of the Sequoia-Kings Canyon and John Krebs wildernesses (NPS 2014). As a dominant feature of two of America's first national parks, the sequoia also serves as an iconic symbol of the NPS; their

---

[1] The boundary between Garfield and Dillonwood groves has historically been inconsistently defined and was mapped in a manner that did not consider ecological conditions—e.g. slope and aspect, relationship to landscape topography, etc. For the purposes of this Environmental Assessment, the portions of the Garfield grove occurring in the same drainage as Dillonwood, and therefore sharing the same ecological conditions as Dillonwood, are considered part of the Dillonwood grove.

[2] High severity fire: Fire that results in 75-100 percent tree mortality.

[3] In recent years, wildfires, including the Castel Fire and KNP Complex Fire which affected these groves, have burned large contiguous areas of mixed conifer forests at high severity, a previously uncommon occurrence in these forest types. Evidence indicates that these more recent fires, where large areas have burned at high severity, are driven by the synergistic effects of fire suppression combined with changes in fuel loading and fire behavior that have been caused by climate change-driven hotter droughts (Hagmann et al. 2021).

silhouette is prominently featured on the NPS logo, and their cones adorn uniform hatbands and belts. And yet, despite its prominent status in the history of the NPS, the giant sequoia is found in only one other national park and exists in only a narrow band of the earth's topography—roughly 39% of its total acreage on the planet is confined to Sequoia and Kings Canyon National Parks. See additional background in Giant Sequoia Ecology and Appendix B:
Relevant Law, Policy, and Management Guidance.

In 2020 and 2021, the Castle (one of the fires of the SQF Complex) and KNP Complex (KNP) wildfires together burned 27 NPS-managed sequoia groves, six of which experienced contiguous areas of high severity fire effects where mortality of large sequoias occurred at a scope and scale previously unprecedented in sequoia groves (Stephenson and Brigham 2021). Post-fire assessments by the NPS and partner agencies have determined that low seedling regeneration and lack of adequate seed source near these contiguous high-severity patches within these six groves could leave these areas vulnerable to long-term conversion from forest to fire-initiated shrub-dominated communities (Coop et al. 2020; Meyer et al. 2022; Guiterman et al. 2022). As described below, field surveys evaluating the levels of natural regeneration and adult tree mortality in these areas have either been completed or are underway to inform final determinations as to whether and to what extent action is needed. See additional background in Recent Fire Effects and additional discussion in Appendix D: Minimum Requirement Analysis.

Action is also anticipated to be necessary at this time to maintain (or restore) connectivity within proposed critical habitat for the southern Sierra Nevada distinct population segment (DPS) of fisher (*Pekania pennanti*), a federally endangered forest-dependent species increasingly threatened by wildfire driven habitat loss, which was listed as endangered by the United States Fish and Wildlife Service (USFWS) in 2020 (USFWS 2020). During the Castle and KNP wildfires, approximately 12,400 acres of proposed critical habitat for fisher within the parks burned at high severity. Post-fire modeling and assessments determined that roughly 1,725 acres of Fisher Core Habitat Area 3 south of Redwood Mountain Grove, like the sequoia groves, is highly vulnerable to long-term conversion from forest to fire-initiated shrub-dominated communities (Postfire Spatial Conifer Reforestation Planning Tool (PostSCRPT) Modeling; Stewart et al. 2021). Of that area, 485 acres were identified as a high value habitat corridor and is therefore a high priority for restoration (Meyer et al. 2022). See additional background in Recent Fire Effects and additional context in Appendix B: Relevant Law, Policy, and Management Guidance.

Notably, the anticipated need for action also comes with some level of urgency in order to increase the likelihood of success and avoid potentially more intensive action across the proposed planting areas. Acting now and within the next few years, when these areas are at their closest to post-fire conditions, enables planted seedlings to compete with surrounding shrubs as they regenerate within proposed planting areas and more closely mimics what re-establishment would have occurred naturally had it not been for the impacts of fuel loading and resulting high severity fire. Additionally, conversion to fire-initiated shrub communities, if not halted by timely intervention, is likely to exacerbate a high severity fire cycle and increase the likelihood of degradation that could occur should high severity fire spread from these new shrub communities to other areas, including remnant portions of affected groves (Coop et al. 2020; Coppoletta et al. 2016). Once shrub communities become dominant, this degradation would likely be self-perpetuating and irreversible without substantial intervention (e.g. mastication, herbicide). See additional discussion in Appendix C: Evaluating Ecological Intervention Proposals in Wilderness.

Background

Giant Sequoia Ecology

Giant sequoia are impressive trees native to the Southern Sierra Nevada of California; their immense size and age have inspired generations of visitors and conservationists. Individual giant sequoia trees are known to grow over 30 feet (ft, ') in diameter (dbh) and can live over 3,000 years (Weatherspoon 1986). Though remarkable in their size and age, sequoias have a very limited distribution. In fact, the species is currently restricted to 80 groves and grove complexes, covering approximately 26,000 acres (ac). Nearly half of these, 37 groves covering 10,000 acres, occur within the boundaries of Sequoia and Kings Canyon National Parks (NPS analysis based on Hart 2021). The iconic nature of sequoias, combined with their limited distribution, makes any acreage loss within these limited number of groves very concerning to grove managers and, arguably, the public at large.

Sequoias are highly resilient to environmental stressors, and any given large sequoia (defined here as equal to or greater than 4' dbh) is likely to have survived through several periods of long-term drought and insect outbreaks over the course of its centuries-long life. As well, tree-ring analyses documenting several thousands of years of spatial patterns of both giant sequoias and past wildfires show that large areas of mature giant sequoias were not killed in wildfires prior to suppression of both traditional cultural burning practices and lightning caused fires (Swetnam et al. 2009). Almost all large sequoias bear the evidence of fire in the form of a characteristic fire scar—known as a "cat face"—running up their thick barked trunk, just one piece of evidence that these trees evolved with frequent fire and have adaptations that have allowed them to survive many fires over the course of their long lives.

In addition to large sequoias having survived centuries of fire, it is also well known that regeneration of sequoia seedlings relies on the conditions created by frequent fire that result in overall low to moderate[4] severity fire effects with small canopy gaps (mostly 0.25 - 1 acre in size) created by very small patches of high-severity fire (Stephenson 1994; York et al. 2011). Within these canopy gaps, competition for light and moisture is reduced, and bare mineral soil is exposed, creating ideal conditions for sequoia seedlings.

Sequoia groves produce hundreds of thousands of seeds per acre, and after fire, large numbers of these are released to fall to the forest floor, 90% of which falls within only 164 feet of the parent tree (A. Das personal communication January 2023[5]; Clark et al. 2021). Despite this initial abundance, sequoia seeds dry out quickly and often fail to germinate, and first year seedlings tend to die at high rates (Harvey et al. 1980). Similarly, studies indicate that sequoias do not successfully regenerate in significant numbers more than two to three years post-fire because conditions favoring sequoia germination and seedling survivorship rapidly disappear (Harvey et al. 1980). Due to their high mortality rate and low regeneration rate (if not complete absences of regeneration) more than three years post-fire, very high numbers of seedlings are needed immediately post-fire to ensure enough survive to maturity to create a stable population. In a recent analysis of post-fire sequoia regeneration across 26 different fires spanning a 48-year period in Sequoia and Kings

---

[4] Low severity fire: 0-24 percent tree mortality due to fire. Moderate severity fire: 25-75 percent tree mortality due to fire.

[5] Actual seed dispersal kernel, which was generated by Clark for use in Clark et al. 2021, was provided by Jim Clark to Adrian Das who then provided information to NPS (A. Das personal communication January 2023).

Canyon National Parks, Stephenson et al. 2023 (in preparation[6]) found that the mean sequoia seedling density in the first-year post-fire was 62,031 per acre (152,278 seedlings/hectare), and in the second year after fire, the mean density was 14,112 seedlings per acre (34,870 seedlings/hectare), with the first year Bayesian estimated mean of 70,312 seedlings per acre (173,742 seedlings/hectare) and 16,011 seedlings per acre 95% CI 5,739-73,254 (39,562 seedlings/hectare) during the second summer after fire. A lifetable analysis of giant sequoia by York et al. (2013) indicates that post-fire densities are representative of the numbers needed to create a stable population as only a handful of these seedlings survive to become the majestic trees that we see today.

There is little consistency in the literature regarding the age at which sequoias produce viable seed; findings vary widely (Hartesveldt et al 1975). Although cones with fertile seeds have been observed on sequoias as young as ten years old, other studies have shown that sequoias have large cone crops associated with reproductive maturity at around 150-200 years (Hartesveldt et al 1975) and Harvey et al. (1980) suggest that trees of approximately 400 years old and older produce large number of cones and represent the significant reproductive individuals of the population. Based on review of literature and observations in the field, the NPS estimates that planted sequoias could begin to reach maturity and produce cones with viable seed within decades (Hartesveldt et al 1975; Harvey et al 1980).

Recent Fire Effects in Sequoia Groves

Due to the apparent resiliency of sequoia trees, and despite extensive study of the species, mortality of even small numbers of large sequoias from fire has rarely been documented (Hartesveldt and Harvey 1967; Weatherspoon 1986) until recently (Shive et al. 2021; Stephenson and Brigham 2021). Save the Redwoods League, the United States Forest Service (USFS), and other partners documented the first large groupings of large sequoias killed by high-severity fire in 2015, followed by additional losses in 2017 (NPS 2015a; Shive et al. 2021). The number of documented cases increased dramatically as a result of the 2020 Castle and 2021 KNP wildfires which burned through a total of 27 of the groves within the parks. As well, the NPS estimates that 21 additional groves burned outside the parks in the Castle Fire and the 2021 Windy Fire.

While fire effects in many of the groves that burned at lower severity during the Castle and KNP wildfires appear to be beneficial (removing fuels without killing large sequoias and opening small areas for sequoia regeneration), contiguous high severity patches greater than 2.5 acres were documented in six of the 27 groves that burned in recent wildfire within the parks. As previously mentioned, this scale of high-severity fire in sequoia groves—and the scale of loss of individual sequoias—is unprecedented. In all, these fires (including the Windy Fire), resulted in the mortality of an estimated 9,760 to 14,237 large giant sequoias, accounting for 13-19% of the range wide total population of large giant sequoia trees (NPS 2020; Stephenson and Brigham 2021; Shive et al. 2021).

Factors driven by climate change, including extended periods of hotter droughts and less snowfall have contributed to fuel accumulations from the die-off of millions of trees in the Sierra Nevada (Diffenbaugh et al. 2015; Griffin and Anchukautus 2014). These factors likely contributed to certain sequoia groves burning at high severity during the Castle and KNP wildfires. However, while all 27 groves that burned during these fires were subjected to these same climate-driven factors, not all experienced high-severity fire effects. In fact, groves with recent natural or prescribed fire and thus

[6] This paper has undergone USGS peer review and is available to the public on a preprint server.

less fuel accumulation experienced largely beneficial effects from recent wildfire, while the groves with a history of fire exclusion were vulnerable to high-severity fire. Other important factors contributing to severe fire effects were weather, steep topography, and fire spread patterns (Shive et al. 2021; York et al. 2013; NPS 2020; NPS 2021). However, the key difference in pre-fire fuel conditions has led fire ecologists and sequoia experts to conclude that, were it not for high pre-fire fuel loading in the groves where severe fire effects were documented, more sequoias would have survived (Caprio unpublished data n.d.).

Within months of the 2020 Castle Fire, the NPS and its partners finalized a preliminary Burned Area Emergency Response (BAER) assessment (NPS 2020), indicating that high burn severity and sequoia mortality in the Board Camp, Homers Nose, and Dillonwood Groves may lead to regeneration failure (NPS 2020). Similarly, the BAER assessment for the KNP Fire, which was completed November 5, 2021, found that three additional groves (Redwood Mountain, Suwanee, and New Oriole Lake) and one modeled habitat corridor for fisher (within proposed critical habitat) had burned at high severity (NPS 2021; Meyer et al. 2022). Like those that burned during the Castle Fire, these areas had also suffered extensive sequoia and mixed conifer mortality, and data indicated they were likewise vulnerable to regeneration failure (NPS 2021).

Beginning in fall of 2021, one-year post-Castle Fire, the NPS began to build upon these initial assessments by quantifying the remaining number of living giant sequoias and estimating the number and spatial variability of sequoia seedling regeneration within the vulnerable groves. Initial findings from these assessments, which are described further below, suggested that not only was there a need to survey seedlings in a statistically rigorous sample, but also that the measured densities needed to be evaluated against previous observations from fires that, unlike the Castle and KNP wildfires, burned within the range of natural variation for fire severity patch size. The United States Geological Survey (USGS) conducted just such an analysis in 2022 and 2023 (Stephenson et al. 2023 in preparation).

As of May 2023, field assessments as described above have been completed in two of the six groves considered for action within this plan, and surveys are underway in another two groves (see). Through these assessments, the NPS and its partners found large contiguous areas with few to no living giant sequoias (the largest patch in Board Camp is 26.6 acres and the largest in Redwood Mountain is 270.6 acres). In addition, the USGS and NPS found that the mean density of first- or second-year giant sequoia seedling regeneration within the areas considered for replanting are far lower than densities observed following other wildfires or prescribed fires (Soderberg et al. 2023 in review;[7] Stephenson et al. 2023 in preparation). As described above in Giant Sequoia Ecology, giant sequoias produce tens of thousands of seedlings after a fire, and only a handful of these achieve large sizes over 4’ in diameter. While seedling density in these six groves and adjacent fisher habitat varies (Soderberg et al. 2023 in review), it is nowhere near the documented mean of 62,031 sequoia seedlings per acre the first year after fire and Bayesian estimated mean of 16,011 95% credible interval (CI) 5739-73,254 (14,112 sample mean) of sequoia seedlings per acre the second year after fire measured in typical post-fire plots (Stephenson et al. 2023 in preparation). In fact, the NPS and partners completed field surveys of sequoia seedlings in 2022 of Redwood Mountain Grove (high severity fire effects areas only), Board Camp Grove (sampled entire grove),

[7] This paper has undergone USGS peer review and is available to the public on a preprint server.

New Oriole Lake Grove (sampled the entire grove), and Suwanee Grove (sampled the entire grove) and found the following densities of sequoia seedlings:[8]

- Board Camp Grove: Bayesian estimated mean of 651 seedlings/acre 95% CI 708-1,906; <0.1% probability of the estimated mean being equal to the second-year seedling densities after fire;
- Redwood Mountain Grove (only high severity area of the grove): Bayesian estimated mean of 4,266 seedlings/acre 95% CI 3000-6345; 1.1% probability of being equal to the second year seedling densities after fire;
- Suwanee Grove: Bayesian estimated mean of 4,763 seedlings/acre 95% CI 3,030-8,094; 2.4% probability of meeting the second-year seedling density after fire;
- New Oriole Lake Grove: Bayesian estimated mean of 6,875 seedlings/acre 95% CI 3,883-14,238; 11.2% probability of meeting the second-year seedling density after fire (Soderberg et al 2023 in review).

Based on the above findings, the NPS' primary concern is that current sequoia seedling densities in patches of these groves may be insufficient in both quantity and distribution to re-establish and generate a stable sequoia population (Soderberg et al. 2023 in review; Stephenson et al. 2023 in preparation) (see Sequoia Grove Post-Fire Conditions for more information). Seedlings that are present in the proposed action areas are also largely restricted to small patches in drainages or other protected microsites. Additionally, areas of this size contain large patches that are beyond the distance that the majority of sequoia seeds disperse (A. Das personal communication January 2023; Clark et al. 2021). In high severity patches, this combination of factors (potentially insufficient natural seedling densities and lack of living sequoias), combined with previous studies (e.g. Harvey et al. 1980) that demonstrate a high mortality rate of post-fire germinated sequoia seedlings and low (though not zero) seedling regeneration at more than three years post-fire, indicate that these areas are highly vulnerable to conversion from forest to fire-initiated shrub-dominated communities in the long term (Coop et al. 2020).

Fire Effects in Fisher Habitat

The BAER assessments completed post-Castle and KNP wildfires identified post-fire threats to the fisher and actions that may be necessary to prevent further degradation to the species' habitat. These reports concluded that over 5,000 thousand acres of mixed-conifer fisher habitat was either too far from the edge of intact forest or to have burned at such high severity that regeneration failure was likely (NPS 2020; NPS 2021).

Since these reports were finalized, the NPS has updated fisher habitat modeling data and currently estimates that over 12,000 acres of modeled fisher habitat within the parks burned at high severity in recent wildfires (see Table 1: Grove and Area Acreage of Areas Where Planting Would Be Considered Under Alternatives 2 and 3). This loss of forested area is particularly concerning as some of the primary causes of endangerment—noted at the time of fisher listing—included "loss and fragmentation of habitat resulting from high-severity wildfire and wildfire suppression (i.e., loss of

[8] For Board Camp, New Oriole Lake, and Suwanee, seedlings were measured throughout the entire grove, not just the high severity target planting areas. For Redwood Mountain, only the high severity target planting area was measured (Soderberg et al 2023 in review).

snags and other large habitat structures on which the species relies), climate change, and tree mortality from drought, disease, and insect infestations" (USFWS 2020).

In 2022, the NPS worked with cooperators to use the framework for prioritization of reforestation, developed by Meyer et al. (2021), to further refine target areas for restoration which was used to update the restoration specification outlined in the KNP BAER plan (Meyer et al. 2021; NPS 2021). This effort in turn led to the NPS to target the area proposed for replanting under this proposal as the highest priority for restoration (see Chapter 3: Affected Environment and Environmental Consequences for more information).

Re-planting Proposal Development

Given the extent of impacts described above, the NPS began considering whether replanting impacted areas would be necessary to achieve recovery of affected groves and fisher habitat. As part of this consideration, the NPS applied the minimum requirement concept to initially evaluate whether action may be necessary within affected wilderness, which represents a large percentage of the proposed action area. The NPS typically refers to this initial evaluation as Step 1 of a minimum requirement analysis (MRA).

The minimum requirement concept includes evaluating such factors as: 1) the situation that may prompt administrative action in wilderness, 2) whether or not action could be taken outside of wilderness to address the situation, 3) whether requirements of federal legislation require the NPS to act, and 4) whether action is necessary to preserve one or more qualities of wilderness character. In further support of the minimum requirement concept, the NPS also considered factors identified within Reference Manual 41: Wilderness Stewardship, *Guidelines for Evaluating Ecological Intervention Proposals in National Park Service Wilderness*. These guidelines outline suggested factors to consider when deciding whether or not to take ecological intervention action within wilderness when there is a potential conflict between protecting the untrammeled quality (not intervening) and avoiding degradation of the natural quality (protecting/restoring natural resources) of wilderness character.

Through the initial evaluation, the NPS preliminarily determined that action was necessary in wilderness to address the situation described above (and further supported by the works cited) for the reasons stated below. These reasons below provide additional context to the purpose and need for action and are further supported by additional information outlined in Appendices C and D.

- Although the large sequoias lost to the Castle and KNP wildfires—some of which had lived up to 3,000 years—are irreplaceable in their mature stature within our lifetimes, the NPS has a fundamental responsibility under the Organic Act of 1916, the 1978 Amendment to the NPS Organic Act, and Sequoia National Park and Kings Canyon National Parks' enabling legislation to protect the species from population loss (26 Stat. 478, 26 Stat. 650 and 54 Stat. 41, see also Appendix B: Relevant Law, Policy, and Management Guidance).
- In accordance with the Endangered Species Act, the NPS shall "utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species listed pursuant to section 4 of this Act." Given the 2020 listing of the Southern Sierra Nevada Distinct Population Segment of Fisher, the proposed listing of Critical Habitat for the species, the susceptibility of the species and its habitat to impacts from high severity fire, the impacts to fisher and extensive loss of fisher habitat from recent fire, and specifically the threat of long-term loss of a key modeled

habitat corridor for this species, the NPS has responsibility under the Endangered Species Act to protect the fisher from a loss of connectivity within proposed critical habitat.

- The potential loss of portions of six sequoia groves, a species specifically identified as an attribute of the natural quality of wilderness character of the Sequoia-Kings Canyon Wilderness and the John Krebs Wilderness, and the loss of habitat connectivity for the endangered Southern Sierra Nevada DPS of Fisher (as described above) pose an equivalent threat to the natural quality of wilderness as they do to the parks—as designated by Congress—and more fundamentally, to the species at risk.
- Acting entirely outside of wilderness would not address the lack of seedling regeneration in affected areas. The six groves where action is proposed have existed in their general size and configuration for thousands of years; replanting seedlings in a different location does not restore these groves to their former grandeur. Should conversion of these areas occur, it would diminish the range-wide distribution of an iconic species the NPS is obligated to protect (NPS Organic Act: 39 Stat. 535; Coop et al. 2020; Guiterman et al. 2022). Likewise, the fisher habitat where action is proposed serves as a key habitat corridor between otherwise disjointed and fragmented surrounding habitat (Meyer et al. 2022). Restoring forest in areas outside of wilderness would not create habitat corridors where the corridor is needed.

Due to the number of areas where action is being considered, and the high level of public interest in this proposal due to the wilderness designation of most of these areas, the NPS has prepared this Environmental Assessment (EA) and refined analyses concerning proposed actions within wilderness to facilitate National Environmental Policy Act (NEPA) and Wilderness Act review and decision-making processes, and to ensure agency action conforms with all other federal resource protection laws.

Issues

Issues Selected for Detailed Analysis

The following issues are carried forward for further analysis in Chapter 3 for one or more of the following reasons identified in the NPS NEPA Handbook (NPS 2015b):

- the environmental impacts associated with the issue are central to the proposal or of critical importance;
- a detailed analysis of environmental impacts related to the issue is necessary to make a reasoned choice between alternatives; or
- the environmental impacts associated with the issue are a big point of contention among the public or other agencies.

Sequoia Grove Recovery and Resilience

As outlined above, giant sequoia is an iconic species symbolizing the NPS and a fundamental resource for which these parks were established and which the NPS is legally obligated to protect. Sequoia groves suffered extensive losses to high-severity fire during the Castle and KNP wildfires, and some severely burned areas are unlikely to recover on their own. Planting sequoia and other mixed conifers would beneficially affect sequoias by directing the trajectory of these areas toward forest recovery—as they would have done naturally had unnaturally high fuel loading due to active fire suppression not led to severe fire effects in these six groves. The NPS anticipates that replanting tree seedlings would not only increase the likelihood that forests are restored to their pre-fire composition in the long term but would also reduce the potential for high severity fire cycles to impact remaining sequoias adjacent to severely burned patches of affected groves. Although beneficial impacts are anticipated for this iconic species, the proposed alternatives may vary in their impacts to genetic composition of individual sequoia groves and future climate change resiliency. Finally, in planting seedlings in areas that recently burned at high severity, the NPS would modify the fuels within these groves which may influence future fire behavior in the area. Given these impacts, and the centrality of this issue to the purpose and need for the project proposal, the NPS has carried this issue forward for further analysis in the EA.

Fisher Habitat Connectivity

The Southern Sierra Nevada Distinct Population Segment (DPS) of fisher is federally listed as endangered, and the species is increasingly threatened by wildfire-driven habitat loss (USFWS 2020). Like sequoia, fishers suffered extensive habitat alteration during the Castle and KNP wildfires; including extensive loss of large diameter trees to high-severity fire and reduction of canopy cover within the modeled corridor of proposed critical habitat where replanting is proposed (Meyer et al. 2022; USFWS 2022). Re-establishing conifer seedlings in this area would benefit fisher by promoting post-fire recovery of tree cover in this key habitat corridor. Fishers tend to avoid open areas, stick to areas with cover while traveling or foraging, and rely on patches of older forest to meet resting and denning needs (Purcell et al. 2009; Thompson et al. 2021; Green unpublished data 2023); thus, restoration of this specific area is expected to improve suitability for fisher movement and increase connectivity between remaining live older forest by speeding up the return of tree cover. Increased tree cover in this burned corridor can also facilitate future dispersal and associated gene flow vital to the conservation of this species. Given these potential impacts and the nexus of this issue to the purpose for taking action, the NPS has carried this issue forward for further analysis in the EA.

Wilderness

Approximately 840,000 acres of Sequoia and Kings Canyon National Parks are designated or managed as wilderness, and this proposed action, if approved, would occur across up to roughly 1,130 acres of designated or recommended wilderness. (Consistent with NPS Management Policies (2006), all designated and recommended wilderness are managed for wilderness preservation, and so, for the purposes of this EA, areas that are designated wilderness or recommended wilderness will be referred to jointly as wilderness.) For any proposed action within wilderness, the NPS must consider and analyze the proposal through the lens of preserving wilderness character. This includes an understanding of purposes for which these wildernesses were designated, the legal mandate to preserve the qualities of wilderness character, the importance of both un-manipulated and naturally functioning ecosystems, and the unique role that wilderness contributes to visitor experiences and societal ideals. As well, the NPS must ensure that both the proposed action and the methods and tools used to achieve the action are the minimum required to manage the area as wilderness. Replanting these areas would have both short-term impacts and long-term benefits to several qualities of wilderness character. Given the above, and the proposal to take action in wilderness, this issue is carried forward for additional analysis in the EA.

Issues Considered but Dismissed

The following issues were identified but dismissed from further analysis for the following reasons identified within the NPS NEPA Handbook (NPS 2015b):

- The environmental impacts associated with the issue are not central to the proposal or of critical importance;

- A detailed analysis of environmental impacts related to the issue is not necessary to make a reasoned choice between alternatives;
- The environmental impacts associated with the issue are not a big point of contention among the public or other agencies; or
- There are no potentially significant impacts to resources associated with the issue.

Cultural Resources

Not all historic properties have been identified to date, and should historic properties be present within these groves and fisher habitat, ground disturbance associated with planting activities, as proposed within the action alternatives, could have long-term direct and indirect impacts on cultural resources. These potential impacts would be from planting seedlings and from tree growth within or directly outside site boundaries. However, these impacts can be minimized, if not eliminated, through avoidance and using an avoidance buffer outside the site.

Given the ability to refine an area's specific planting plan to avoid action within historic properties (if present), the NPS does not anticipate adverse effects to historic properties in the action area. Because mitigations would be implemented to reduce the risk of adversely affecting cultural resources, this issue was dismissed from further analysis in the EA.

Environmental Justice

Executive Order 12898 requires federal agencies to identify and address disproportionately high and adverse human health or environmental effects of their programs on minorities and low-income populations or communities.

Communities bordering the parks include those of low income, communities where English-speaking skills are limited, those where a high number of residents have less than a high school degree, and those where access to internet services may be limited (EPA 2022). These communities may be disadvantaged in their potential to be exposed to environmental contaminants and their ability to access resources or obtain information that may affect their health.

None of the alternatives would have direct or indirect effects outside park boundaries in that none of the alternatives or their components would modify existing environmental conditions; limit access to resources in identified affected communities; result in bodily impairment, infirmity, illness, or death; result in air, noise, and water pollution and/or soil contamination; and/or disproportionally limit these communities from accessing the parks. Thus, disadvantaged populations would not be disproportionately affected; environmental justice was therefore dismissed from further analysis.

Indian Trust Resources

Indian Trust Resources are lands or interests in lands, minerals, natural resources, or other physical assets held in Trust by the federal government for beneficial owners and natural resources in which Indian Tribes have federally protected or reserved interests (e.g., water, fish, wildlife, vegetation). Executive Order 13175 requires early consultation if a proposal is to have substantial direct effect on Indian Trust Resources. As there are no Indian Trust Resources within the project areas, this issue is dismissed from further consideration in this EA. Chapter 4 includes information on tribal consultation completed for this proposed action, to date.

Invasive Species and Soil Pathogens

Some commentors expressed concern that planting seedlings would introduce invasive species or soil pathogens to the project area. Planting seedlings and workers traveling off-trail through forested areas have the potential to disturb soil and result in the importation of contaminated fill, providing an opportunity for invasive species to be introduced to the parks or become established and spread. Invasive plant seeds and propagules can also be introduced to the parks and transferred between project areas on project equipment, tools, and clothing.

There is also a history of inadvertent pest introduction from nursery materials (e.g. the pathogens that caused white pine blister rust and chestnut blight) (Parke & Grünwald, 2012). As a result, the nursery industry, generally, and the reforestation and restoration sector of the nursery industry in the western United States, specifically, have identified a series of best management practices (BMPs) and systems approaches for managing risk of new introductions during replantings (Frankel et al. 2020, Parke & Grünwald, 2012). These systems are designed to prevent introduction and reduce the incidence of plant pathogens within the nursery or from incidental introduction to wildlands (James 2005, Frankel et al. 2020). The systems approach to pest management identifies five main contamination hazards: incoming plants, potting media, water, pots, and ground that are managed through standard BMPs and have been shown to eliminate detections of *Phytophthera spp.* after their implementation (Frankel et al. 2020).

Seedlings used in this project would be sourced from reforestation nurseries who would follow identified best management practices (BMPs) typically employed by these nurseries, as outlined in Appendix A, as well as conduct pest/pathogen/weed surveillance and management practices. Implementing standard BMPs would result in the project having a low risk for soil pathogens or invasive plant propagules being introduced via seedling sources. The application of mitigation measures including equipment and clothing inspections would further prevent the potential for invasive species introduction to be introduced via other mechanisms outlined above, or to persist in the environment.

Because there are no potentially significant impacts to resources associated with the issue and mitigations would be implemented to further reduce the risk of invasive species or soil pathogen introductions factors, this issue was dismissed from further analysis in the EA.

Soils and Soil Erosion

Commentors during public scoping suggested that the NPS should include an analysis of soils and/or soil erosion in the EA. Actions that disturb soil, including digging and foot traffic, can contribute to soil erosion, while restoring vegetative cover and roots serve to protect and stabilize soils. Currently, most of the action areas have severely burned soils with high erosion potential due to loss of vegetative cover (NPS 2020, NPS 2021). The NPS' BAER plans for the Castle and KNP wildfires used Burned Area Reflectance Classification (BARC) images from USGS to gauge burn patterns and locations for evaluating soil burn severity (SBS). Sequoia groves impacted by the Castle and KNP wildfires experienced a range from low to high SBS (NPS 2020; NPS 2021).

To evaluate soil erosion potential, the BAER plans used the Watershed Erosion Prediction Project (WEPP) Cloud, post-fire erosion prediction (PEP) to evaluate soil erosion and sediment potential specifically for giant sequoia groves. The reports concluded that sequoia groves located below hillslopes with moderate to high burn severity were likely to experience destabilization of living and dead trees due to erosion, loss of soil productivity, and loss of seed banks and indicated that the effects of erosion would be exacerbated on slopes steeper than 60% (NPS 2020; NPS 2021).

Specifically, the model predicted that Redwood Mountain, Homer's Nose, Dillonwood, and Board Camp Groves would likely experience the greatest post-fire erosion impacts. The potential for erosion impacts to standing live and dead sequoia trees and the seed bank was high in the Homer's Nose Grove (due to erosion rates exceeding 40 tons/acre annually) and moderate to high in the Dillonwood and Board Camp Groves. The model also indicated that Oriole Lake and Garfield Grove would have less post-fire erosion (NPS 2021). The NPS anticipates that the atmospheric rivers occurring during the winter of 2022-2023 has contributed to erosion in the proposed project areas where post-fire erosion was anticipated but has not visually assessed grove conditions post-winter.

While actions that disturb soil can further contribute to erosion, this project would not contribute to extensive soil disturbance beyond that already occurring in the system post fire. Further, restoring forest cover is expected to benefit soils by stabilizing them against further erosion in the long term. NPS crews would minimize their contribution to soil erosion in these areas to the maximum extent feasible by limiting the hole sizes to the minimum needed to plant seedlings, avoiding sensitive areas, and avoiding creation of social trails. Because the proposed action would not result in significant impacts to soils, and because a detailed analysis of environmental impacts related to this issue is not necessary to make a reasoned choice between alternatives, the NPS dismissed soils and soil erosion from further analysis.

Wildlife Disturbance and General Wildlife Habitat

General

Many commentors during public scoping were interested in how the project would affect wildlife. Tree planting crews, or mule pack trains delivering supplies, could trample delicate herpetofauna (i.e., salamanders, toads, frogs) causing injury or mortality to herpetofauna, though would have no impact to such fauna on a population level. As well, the presence of work crews—working and in some cases camping—for up to two weeks at a time in each of the seven planting areas (over the course of five to six years), may startle or temporarily displace other wildlife (black bear, mule deer, various small mammals, reptile, and bird species) from these areas if they were present.

For areas where seedlings need to be transported via helicopter, wildlife would be additionally impacted by removal of several snags per landing site, which otherwise provide some habitat to birds and small mammals, and the noise associated with chainsaw or explosive use (if needed to create a helicopter sling load landing zone) and helicopter use.

The degree of disturbance related to the removal of snags would vary in both intensity and duration depending upon the tool selected (chainsaws or explosive) and timing of removal. For example, chainsaws would be expected to produce intermittent sound of up to 110 decibels (dB) for up to 2-3 hours at each location if as many as 10 snags required felling. This sound may travel up to two miles depending on topography and vegetation. The sound from explosives, on the other hand, would range from 170 -180 dB or greater and would last only seconds. While chainsaws would create increased decibel levels for a longer time, explosive use is likely to have a greater startling effect for animals in the immediate vicinity (within 0.25 miles), and the sound would travel much further from the action area—potentially a distance of 2-10 miles depending on topography and vegetation and the quantity and type of explosives used (A. Fiorino personal communication March 2023) (see Table 3. Total Proposed Helicopter Support In Wilderness Over a Period of Roughly Five Years for information on where tree felling may be considered).

Though tree felling can remove fisher denning habitat, it is unlikely that fisher would den in areas where tree felling would occur due to diminished habitat value in these areas (see Fisher Habitat

Connectivity for more information) nor would felling of some trees result in limited snag habitat for other species given the context of these areas within an area with extensive tree mortality. Further, the NPS would avoid removing trees with den qualities. If removal of den quality trees cannot be avoided due to access limitations or safety concerns, they would not be removed during the Limited Operating Period (LOP) (March 1 – June 30) to avoid direct impacts to a fisher and her kits, should they be present despite surrounding poor habitat quality. All snag removal, and associated tool use, would most likely occur only in the first year of implementation in a planting area.

When used, helicopters would travel at a speed of roughly 75 miles per hour and produce decibel levels of roughly 85-90 dB when taking off, flying in-route, or approaching sling-load sites at areas where helicopters are being considered, totaling approximately 16 hours of flight time over the course of five to six years (L. Perez personal communication March 2023; U.S. Dept of Transportation 1979) (see Table 3. Total Proposed Helicopter Support In Wilderness Over a Period of Roughly Five Years). For comparison, continuous noise levels produced by vehicles traveling a well-traveled highway typically range from 70-80 dB roughly 50 feet from the source while equipment such as dump trucks produce 76-86 dB (Department of Transportation 2017). Due to the speed at which the aircraft would travel, wildlife present along the flight path for each flight would experience these high decibel sounds for a period of seconds as a helicopter approached and prior to the sound dissipating as the helicopter continued.

As sling loads would be delivered, 85-90 dB of noise would be continuous near the sites for roughly five minutes for each landing, amounting to 20-40 minutes, total, over the course of five to six years each of the proposed planting locations (see Table 3. Total Proposed Helicopter Support In Wilderness Over a Period of Roughly Five Years). This level of sound disturbance, as well as rotor-wash (wind) from the hovering aircraft would disturb both non-sensitive and sensitive species should they be present in the area and may cause temporary displacement to particularly sensitive species, or at the very least cause a disruption to foraging or cause animals to hide. As snags, if present, would be felled in preparation for initial sling-load delivery, potential disturbance from both tree felling and sling-load delivery would be separated in time such that any wildlife present may experience noise disturbance on two separate days, or multiple times over the course of one day in the first year of implementation in a planting area.

While disturbances from human presence may occur, due to the current conditions of the affected environment in the action area (severely burned with little vegetation), the NPS expects wildlife use within large patches of high severity burn—by many species—will be limited during the timeframe of the planned activities (Fontaine and Kennedy 2012; Eyes et al. 2017; Jones et al. 2020); though wildlife use is expected to increase as the understory vegetation begins to recover and leaf litter begins to develop. As of this writing (almost two years post-KNP Fire and almost three years post-Castle Fire), the NPS anticipates that—to the extent that some vegetative recovery has occurred—some birds and small mammals may be using some of the proposed planting areas. Notably, such use would be highly variable based on local site conditions. Regardless, for many species, the remaining live forest habitat adjacent to the proposed action areas offer habitat where wildlife can move to (if needed) to avoid human presence while continuing daily foraging or resting activities.

Due to the transitory nature of helicopters flying along a flight path, the NPS anticipates there would be no direct wildlife impacts (startling response or avoidance behavior) from this component of the action. While higher intensity actions (chainsaws, helicopters, or explosives) would disturb wildlife if present, these actions are of short duration (1-2 hours total at each site in the case of chainsaws, 10 seconds in the case of explosives, 5 minutes at a time in the case of sling load delivery). Therefore, wildlife would be expected to recover—continue foraging or other activities—

relatively soon after the chainsaw or explosive use ceases or the helicopter moves away, and no long-term impacts to wildlife (especially any sensitive species in the area) are expected. Additionally, flights would not occur within one mile of known locations (or regular use areas) of Sierra Nevada bighorn sheep herds (*Ovis candensis sierra;* federally listed as endangered), and the proposed action areas are outside of bighorn sheep habitat such that no impacts to these species would be anticipated.

The NPS would also protect wildlife and comply with the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act, by implementing relevant U.S. Fish and Wildlife Service Nationwide conservation measures and additional NPS-developed measures. These measures include but are not limited to: cutting trees, if necessary, outside the core bird nesting period of February 1 to August 1 for migratory and resident species, conducting pre-clearance bird nesting surveys for tree felling if this activity needs to be conducted during the core bird nesting season to avoid impacts to any active nests (including owls or eagle), and completing the project in an expedient manner to avoid continued disturbance as the forest understory vegetation recovers from fire and birds and mammals return (see Appendix A: Mitigations). Further, though the NPS is estimating, for the purposes of analysis, that up to roughly 10 large snags per landing site (and roughly 40 smaller snags in camping areas) may need to be felled, the NPS would actively seek naturally clear areas for sling-load delivery and camping areas, to minimize the number of trees felled and the associated level of noise disturbance such that this action and its associated impacts may not occur or at least would be minimized from the impacts outlined above.

Though it is possible that individual herpetofauna may be inadvertently trampled and killed by foot traffic through the area, any individual loss would not have a population level effect on these faunae and the NPS would avoid trampling to the extent feasible (see Appendix A: Mitigations). All other short-term, direct impacts associated with project implementation are expected to be limited to those temporary impacts described above, and the NPS would implement mitigations to further minimize, if not avoid, impacts. In the long term (a period of 10-50 years and beyond), re-establishment of forest cover would improve habitat suitability in the proposed action area for wildlife that prefer sequoia and mixed conifer forest (as opposed to shrub-dominated areas), such as fisher (as further described in Chapter 3), pileated and white-headed woodpecker, tree squirrels (e.g., Douglas squirrel, Humboldt's flying squirrel), Sierra marten, western spotted skunk, and other forest dependent species. As described previously, these impacts to habitat are analyzed further in this EA as part of habitat connectivity for the endangered fisher but would have similar impacts to other forest dependent wildlife within or near the project areas.

Though temporary disturbance to wildlife would occur under the action alternatives, there are no potentially significant impacts to resources associated with general wildlife beyond those related to habitat connectivity, which is being analyzed as a separate issue, associated specifically with the fisher. Therefore, further detailed analysis of environmental impacts related to general wildlife is not necessary to make a reasoned choice between alternatives, and this topic is dismissed from further analysis in this EA.

California Spotted Owl

California spotted owl (*Strix occidentalis occidentalis*) is a California Department of Fish and Wildlife Species of Special Concern, and the Sierra Nevada distinct population segment (DPS) of the species is currently proposed for federal listing as threatened under the Endangered Species Act. The species relies on medium to large diameter trees for nesting and roosting.

The NPS does not anticipate that the activity of planting of trees, the presence of work crews planting or camping in these areas, and/or the use of mules in severely burned areas would disturb owls, have a direct effect on individual owl nests, influence survival, or alter prey availability in active territories. Further, 85-90 dB noise from helicopters traveling over areas where owls are present is unlikely to result in an alert response for owls (Jones et al. 2020; Tempel et al. 2016; Pater et al. 1995). Similar to other wildlife mentioned above, owls, if present, may also experience such noise disturbance for roughly 20-40 minutes over the course of five to six years in areas where sling-loads are delivered, and either up to 110 dB sound intermittently for roughly two hours over the course of one to two days if trees were felled using chainsaws or up to 180 dB sound for five to ten seconds over the course of one day were trees to be felled using explosives. If owls were resting within 350 feet of such activities, these disturbances may cause them to “flush” (be startled into taking off and leaving the immediate area in a state of heightened stress) (Jones et al. 2020; Tempel et al. 2016; Pater et al. 1995). As snags would be felled in preparation for sling-load delivery in some locations, potential disturbance from these two actions would be separated in time such that any owls that were present may experience noise disturbance on two separate days or multiple times over the course of one day (see Table 3. Total Proposed Helicopter Support In Wilderness Over a Period of Roughly Five Years for more information on proposed helicopter use).

This said, as with other wildlife, the NPS does not expect spotted owls to be utilizing or nesting in areas where either tree planting or sling-load delivery would occur until vegetation—particularly the overstory canopy—begins to recover; a period of five to ten years (Jones et al. 2020; Tempel et al. 2016). Even were owls to be present during project activities, the NPS would avoid impacts to nesting owls by either conducting higher-disturbance activities (sling-load delivery or chainsaw use) entirely outside the owl nesting LOP (April 1-August 15) or not conducting these activities within the standard 0.25 miles nesting buffer (where nests are documented). As well, helicopters, explosives, or chainsaw use would be of limited duration and occur in areas where owls are unlikely to be present (Jones et al. 2020; Tempel et al. 2016). For these reasons, this component of project implementation would also not be expected to impact nesting owls. Disruption to owl resting activities, if any were present in or near the action area, would be intermittent and of short duration.

Should the California Spotted Owl be listed under the Endangered Species Act and the NPS determine that any components of the proposed action may affect the species, the NPS would initiate Section 7 consultation with the U.S. Fish and Wildlife Service in accordance with the Endangered Species Act as necessary to identify conservation measures to further minimize, if not avoid, impacts to the species and ensure such actions do not jeopardize the existence of the species, which is not anticipated given the above.

Though temporary impacts to wildlife would occur under the action alternatives, taking action would be largely beneficial for spotted owl in the long term as the NPS anticipates that forest cover would be largely restored across planting areas under the action alternatives. As described previously, these impacts to habitat are analyzed further in this EA as part of habitat connectivity for the endangered fisher who are more limited than owls in their ability to cross unforested patches.

Because none of the alternatives would result in potentially significant short- or long-term negative impacts to spotted owl, and a detailed analysis of impacts to spotted owl is not necessary to make a reasoned choice between alternatives, spotted owl as a standalone topic was dismissed from further analysis in this EA.

Understory Vegetation—Including Special Status Plants or Shrub Communities

Special Status Species

Besides giant sequoias, there is one other special status plant, California pinefoot (*Pityopus californicus*), documented to occur in the proposed conifer replanting area in Redwood Mountain, and there are other plants on the parks special status plant list that are known to occur near the other proposed replanting areas and/or have the potential to occur in replanting areas. If present, special status plants could be damaged by planting activities or trampling by individual teams of up to 15 individuals traveling to, walking through, or camping near the action area over a period of one to two weeks. If planting activities occur outside the blooming season for an annual species, which would limit the ability to detect the presence of a special status species, there is a potential that the planting activity, including the planted seedling itself, would inhibit or prevent establishment of annual species.

While individual special status plants that have or have not been documented may occur within the planting areas, along trail-less travel routes, and in camping areas, and could be trod upon, plants are evolved to withstand occasional disturbances such as trees falling, wildlife trampling, and wildfire and crews will be trained to avoid trampling vegetation. Though first- or second-year sequoia seedlings may have delicate root systems, and therefore be more susceptible than older seedlings which would be expected to be more robust, the limited number likely to both be trampled and fail to recover would be unlikely to affect overall sequoia regeneration given both high natural seedling mortality rates and that planting will not occur until the end of the 2nd growing season post-fire or later. By this time, new seedlings are unlikely to be germinating at significant rates (Harvey et al. 1980). Further, those that have survived would be of sufficient size as to either be more visible, or durable enough to withstand inadvertent trampling.

Though some trampling of vegetation generally would be expected due to the nature of the work, planting sequoia and other mixed conifers in areas that are unlikely to recover on their own would be expected to better enable forest recovery. Were forest recovery to be successful, it would provide a greater benefit to special status plants that may have survived high severity fire by providing suitable habitat in the future once forests are re-established. Finally, mitigations outlined in Appendix A:Mitigations, including minimum impact requirements, would be implemented to prevent trampling and social trailing impacts in the planting areas, along travel routes, or in selected camping areas.

Finally, this project is not anticipated to impede natural sequoia regeneration via competition between natural regeneration and planted seedlings for two key reasons. First, the action alternatives do not propose to plant seedlings in areas with adequate sequoia regeneration post fire as described under Alternative 2. Second, the NPS would plant species based on species assemblages in the planting areas, which means there would not be a disproportionately high level of non-sequoia species unduly competing with sequoia seedlings.

Due to anticipated low likelihood of current occurrence combined with minimal disturbance (potentially being trod upon once) and application of mitigations to further reduce potential impacts, the NPS does not expect that implementing either of the action alternatives would result in loss of special status or rare plant populations been present prior to the fires (and may either still occur in the area or in the immediate vicinity) and further that these species would benefit from forest recovery as they are adapted to forested habitat.

Common Species

Other common plant species, e.g. ceanothus species and other perennial shrub species, that exist in the action area are resistant to disturbance, including trampling at the levels expected for this project, or are so common that even were individuals lost, it would not effect the population as a whole. That said, were the NPS to implement one of the action alternatives, and if, as expected, tree seedlings that are planted become successfully established, shrub communities that would otherwise become increasingly established in burned areas would be crowded out over an estimated period of 50-100 years as the forest canopy recovers and competition with trees for light and water increase. However, this process would have also occurred naturally in these areas had they not burned at such high severity and led to the likelihood of conversion from forest to shrub-dominated plant communities.

Conclusion

Due to a combination of low probability of occurrence for special status plants, their reproductive life history strategy making their populations resilient to limited trampling generally, as well as mitigations that limit trampling to the maximum extent feasible, the proposed action would not be expected to result in potentially significant impacts to understory special status plants such as sequoia, other rare plants, or other understory vegetation. Given the above, and because consideration of this issue, beyond sequoia grove resilience more broadly which is further considered elsewhere, is not necessary to make a reasoned choice between alternatives, the NPS dismissed this issue as a stand-alone topic from further analysis in the EA.

Chapter 2: Alternatives

This chapter describes a no action alternative and two action alternative(s), as well as a brief description of alternatives considered but dismissed from further analysis.

Alternative 1: No Action

Under Alternative 1, the NPS would not consider replanting any severely burned sequoia groves or adjacent proposed fisher critical habitat. Rather, the NPS would continue to monitor species succession within former sequoia grove footprints within Redwood Mountain, Suwanee, New Oriole Lake, Dillonwood[9], Board Camp, and Homers Nose Groves as well as plant distributions in the proposed fisher critical habitat adjacent to Redwood Mountain Grove. For the purposes of analysis, this EA assumes that monitoring would involve development of monitoring plots which may include installation of 600 small plot markers, such as rebar, as well as 60 other installations, such as temperature and moisture probes, to characterize and understand microclimatic factors. The NPS also assumes these markers would remain for at least 30-40 years to track conditions. Previously collected seed would remain in the seed bank for research and potential planting in the future, and seedlings that have been germinated would be transferred to partner organizations or agencies for their use.

Under Alternative 1, the NPS anticipates that sequoia and other conifer seedlings would be more likely to remain either absent or at densities below that needed to support forest recovery in affected areas than the action alternatives outlined below. As such, these areas are more likely to convert to fire-initiated shrub-dominated communities for decades, if not centuries to come. Loss of forest cover would lead to diminished natural quality of wilderness character in the long term. In addition, because fisher habitat connectivity between remaining green forest patches would not be restored, fisher genetic exchange would be diminished as well as that of other forest dependent wildlife. Fire frequency and severity would also likely increase as the vegetation converts to shrub-dominated communities without tree cover. These factors are further analyzed in Chapter 3.

Alternative 2: Replant Seedlings Grown from Seed Collected from the Local Genetic Community and Other Source Populations (Preferred Alternative)

Alternative 2 outlines a framework for how the NPS would determine the appropriate post-fire response (i.e., monitoring or planting and monitoring) within six sequoia groves and an adjacent fisher habitat corridor within Sequoia and Kings Canyon National Parks to best meet the purpose and need for action. For each potential action area where the framework indicates there is a high potential for natural recovery, the NPS would take no further action other than monitoring. However, for each potential action area where the framework indicates there is a low potential for natural recovery, the NPS would develop site specific documentation tiered to this EA in order to

---

[9] The boundary between Garfield and Dillonwood groves has historically been inconsistently defined and was mapped in a manner that did not consider ecological conditions—e.g. slope and aspect, relationship to landscape topography, etc. For the purposes of this Environmental Assessment, the portions of the Garfield grove occuring in the same drainage as Dillonwood, and therefore sharing the same ecological conditions as Dillonwood, are considered part of the Dillonwood grove.

move forward with implementation of planting/restoration. While details outlined in this alternative are provided to assist the NPS in planning and to analyze the full extent of impacts, the NPS would anticipate were planting implemented across all potential action areas, this site specific documentation would include additional compliance and consultations. Thus, a decision to adopt the framework and methodology outlined below would not, in and of itself, be a final decision to take action.

Under Alternative 2, the NPS would implement a framework to determine whether or not to plant giant sequoia (*Sequoiadendron giganteum*) and other mixed conifer seedlings in up to six giant sequoia groves in Sequoia and Kings Canyon National Parks: Redwood Mountain, Suwanee, New Oriole Lake, Dillonwood[10], Board Camp, and Homers Nose where these forests may be otherwise unlikely to naturally recover following the impacts of high severity fire. The NPS would also utilize this framework to determine whether or not to plant other conifer seedlings in the mixed conifer forest immediately south of the Redwood Mountain Grove where seed sources were also lost and where natural conifer regeneration is lower than what is estimated as necessary to re-establish this important fisher habitat corridor. See Table 1: Grove and Area Acreage of Areas Where Planting Would Be Considered Under Alternatives 2 and 3 for action area information, like acreages, etc. See Figures 1-6 on pages 23-28 for maps of all potential planting areas.

In areas where planting is ultimately determined necessary, the NPS would also add genetic diversity to replanted giant sequoia groves by sourcing cones/seed from not only within the groves where planting is proposed but also from arid groves and groves with known higher levels of genetic diversity within the seed zone. This approach is based on current sequoia-specific research and general understandings of adaptation in trees to increase the likelihood of project success in a changing climate while also preserving local genetic stock containing any local adaptation and long-term genetic diversity of the species (see Appendix E). Assisted gene flow, as this climate adaptation tool is called, is a common practice in forestry and has been implemented across Canada and the United States with conifer species (Ying & Yanchuk 2006, Gray and Hamman 2011, Handler et al.2018). Under this alternative, the NPS would limit introduction of seedlings from outside the local genetic community (collected from seed zone 534, 540, and 550 respectively) to 20% of all seedlings replanted as this is the quantity of nonlocal genotypes (the genetic constitution of an individual organism) that can be introduced into a population without negatively impacting the genetic structure of the local population (Appendix E; Aitken and Whitlock 2013).

Considering the purpose and need for action outlined in Chapter 1, the goal of this proposed action is to direct the trajectory of severely burned areas toward forest recovery, or in other words, plant sequoia and mixed conifer seedlings at sufficient densities to increase the likelihood that forests are restored to their pre-fire composition in the long term, avoid type conversion of these forests to shrub-dominated communities, and reduce the potential for high severity fire cycles to impact remaining sequoias adjacent to severely burned patches of affected groves. With this in mind, in areas where 1) there are large contiguous patches of high severity fire effects, 2) where the area is more than typical seed dispersal distances from a live, reproductive sequoia, 3) where the estimated mean density of natural regeneration does not have a 90% probability of aligning

[10] The boundary between Garfield and Dillonwood groves has historically been inconsistently defined and was mapped in a manner that did not consider ecological conditions—e.g. slope and aspect, relationship to landscape topography, etc. For the purposes of this Environmental Assessment, the portions of the Garfield grove occuring in the same drainage as Dillonwood, and therefore sharing the same ecological conditions as Dillonwood, are considered part of the Dillonwood grove.

with post-fire reference densities (consistent with a stable, self-sustaining sequoia grove) and 4) where climate assessments indicate the area is likely to support a forest into the future, the NPS would plant 100 to 400 total seedlings per acre. These densities would be refined within site specific planting plans as planting densities would be generally based on USFS technical guidance and may be reduced or increased in areas depending on likelihood of reburning within a decade (indicating an increase in planting density was necessary), current and future drought stress (indicating a reduced planting density was necessary), and other site-specific factors such as slope, aspect, etc. The mix of species and their proportions of the total planted would depend on site characteristics, forest community structure before wildfire, and the availability of seed for each species (see further discussion on planting plans in Appendix F). Additionally, the NPS would not plant additional trees in sub-areas of the potential action areas where there may be high levels of natural regeneration, as evaluated in the field by an agency restoration ecologist. (Although natural regeneration levels may not meet the threshold for planting, there are likely patches of dense, healthy sequoia seedlings that would be avoided during planting activities.)

Pre-Planting Site Assessments and Decision Tree

Based on post-fire assessments completed to date, the NPS has preliminarily determined that, in order to address the purpose and need for action, intervention may be necessary on up to roughly 1,200 acres of formerly forested areas across Redwood Mountain Grove, Suwanee Grove, New Oriole Lake Grove, Dillonwood Grove, Board Camp Grove, Homers Nose Grove, and the proposed critical habitat corridor in Fisher Core Habitat Area 3, south of Redwood Mountain Grove. However, the NPS would apply the results from additional site-specific analyses that have been, and would continue to be, completed through a decision-making framework to determine if planting is necessary and, if so, the extent to which it is warranted in each proposed location. This decision-making framework, or decision tree, is described below, and is outlined in Figure 7 on page 26. If action is determined necessary through this decision tree, the NPS would further refine planting locations through site-specific planting plans that would align the final scope of action with site-specific needs of each location.

By implementing this decision-making framework, the NPS would only plant in areas where data show insufficient natural regeneration for sequoia mixed conifer forest to successfully re-establish without supplemental planting and where analyses indicate the site can support forest cover in the future. In other words, action would not occur in areas that show regeneration is sufficient to support forest recovery or where analyses indicate the site may not support forest cover in the future.

This decision tree would incorporate: (1) analysis of remote sensing data to identify areas of concern based on post-fire conditions; (2) current conditions as measured in the field; (3) comparison of measured natural seedling densities to thresholds of natural seedling levels required to reestablish monarch sequoias within the groves (based on previous datasets) or other conifers in the fisher habitat corridor (based on the Postfire Spatial Conifer Regeneration Prediction Tool (PostSCRPT, Stewart et al. 2021)); and (4) climate change vulnerability given site conditions such as elevation and slope. These components are described further below.

Identifying Patches of High Severity Fire (Completed)

The first step in the decision tree is to identify contiguous patches of high severity fire effects. This began with an assessment of fire effects on forested habitats immediately post Castle and KNP wildfires using the Rapid Assessment of Vegetation Condition after Wildfire, Standardized Composite Burn Index (RAVG 4 category CBI product). This remote sensing tool rapidly identified areas where sequoia and mixed conifer mortality was so high and so widespread that successful tree cover reestablishment was unlikely. The NPS used maps derived from these data to identify the seven proposed re-planting areas being considered for action under this alternative; all of the areas considered for planting meet this first criteria in that all have large contiguous areas of high severity fire effect (NPS Castle BAER Report 2020, NPS KNP Complex BAER Report 2021, Meyer et al. 2021).

Mortality and Regeneration Assessments (Ongoing)

For those areas with large contiguous patches of high severity fire effects, the second step in the decision tree is to identify contiguous areas without living reproductive trees and survey natural regeneration to determine whether or not seedlings are present at sufficient densities and distribution to continue stable/self-sustaining forest/grove into the future. Due to the unprecedented loss of sequoias to these high severity fires and the overall complexity of forest regeneration, the precise number of natural sequoia seedling regeneration necessary to ensure sequoia grove recovery is unknown. With this in mind, the NPS applied seedling reference densities from Stephenson et al. 2023 (in preparation) and considered the level of acceptable risk that sequoias would not recover to a self-sustaining population absent intervention (C. Brigham, personal communications, August 2023). The NPS has set the threshold sequoia seedling density below which regeneration would be considered "insufficient" at a 90% probability of the Bayesian estimated mean for the project area being equal to the Bayesian estimated mean of 16,011 seedlings per acre reference density (14,112 sampled mean) two years post fire found by Stephenson et al. 2023 (in preparation) for project areas sampled two years after fire by NPS and partners using a rigorous peer-reviewed sampling design. While the framework also serves as a decision support tool in the proposed critical habitat corridor for fisher, the NPS has not set thresholds for seedling densities as it has for sequoias, rather, recovery potential is based on a post-fire forest recovery model (POSTSCRPT) combined with plot data collected to verify model outputs outlined below.

To understand mortality and natural regeneration levels, field crews from NPS and partner agencies (USGS, UC Davis, and USFS) began implementing a rigorous sampling protocol to assess seedling density and tree mortality in target areas. Only RAVG areas identified as high severity were assessed in this step or if the groves were sufficiently small, the entire grove area was sampled (e.g., Board Camp, Homers Nose, Suwanee, and New Oriole Lake Groves). These evaluations include field data which documents survival of reproductive trees, natural regeneration, and the potential for measured reproduction to be sufficient to reestablish large sequoias or mixed conifer forests (in the case of fisher habitat) at densities similar to pre-fire conditions.

As of September 2023, field assessments have been completed for five of the six groves (Redwood Mountain (years 1 & 2 post-fire), Suwanee (years 1 & 2 post-fire), New Oriole Lake,(years 1 & 2 post-fire)Board Camp (year 2 post-fire), and Dillonwood (years 2 & 3 post-fire). The NPS intends to complete surveys in the fisher corridor immediately to the south of Redwood Mountain Grove (year 2 post-fire, year 1 post fire were completed in 2022) and Homers Nose (year 3 post-fire) in fall 2023 and complete quality control and analysis of all data no later than the winter of 2023-2024. In areas where full site assessments and analysis have been completed—Redwood Mountain Grove, Board Camp Grove, and the 485-acre proposed critical habitat corridor in Fisher Core Habitat Area 3, south of Redwood Mountain Grove—survey data, as applied through the decision tree, indicate action may be necessary to reduce the potential for loss of a self-sustaining sequoia forest in these areas (e.g., measured seedlings densities are likely not adequate to establish a stable age structure of giant sequoias in these areas). portions of these sequoia groves and mixed conifer forests to convert to shrub dominated landscapes.

TABLE 1: GROVE AND AREA ACREAGE OF AREAS WHERE PLANTING WOULD BE CONSIDERED UNDER ALTERNATIVES 2 AND 3

Grove/Area Name	Total Grove/Area Acres	Total Wilderness Acres[11] within Grove/Area	Total Acres Burned at High Severity	Total Acres Considered for Planting	Total Wilderness Acres Considered for Planting
Dillonwood[12]	1,160	125	102	86	52
Homer's Nose	119	119	55	52	52
Board Camp	48	48	38	38	38
New Oriole Lake	15	15	3	3	3
Suwanee	69	69	27	26	26
Redwood Mountain	2,074	1,883	516	493	475
Total Acres within Sequoia Groves	3,485	2,259	741	698	646
Fisher Proposed Critical Habitat	72,219	65,003	12,411	485	485
Total Acres	75,704	67,262	13,152	1,183	1,131

[11] For the purposes of calculating total wilderness acreage the NPS did not differentiate between designated and recommended wilderness as both are managed as wilderness regardless of final designation in accordance with NPS 2006 Management Policies.

[12] The boundary between Garfield and Dillonwood groves has historically been inconsistently defined and was mapped in a manner that did not consider ecological conditions—e.g. slope and aspect, relationship to landscape topography, etc. Therefore, for the purposes of this EA, the portions of the Garfield grove occuring in the same watershed as Dillonwood, and therefore sharing the same ecological conditions as Dillonwood, are considered the Dillonwood Grove.

FIGURE 1. AREAS PROPOSED FOR RE-ESTABLISHING SEQUOIA AND OTHER CONIFER SEEDLINGS IN REDWOOD MOUNTAIN GROVE

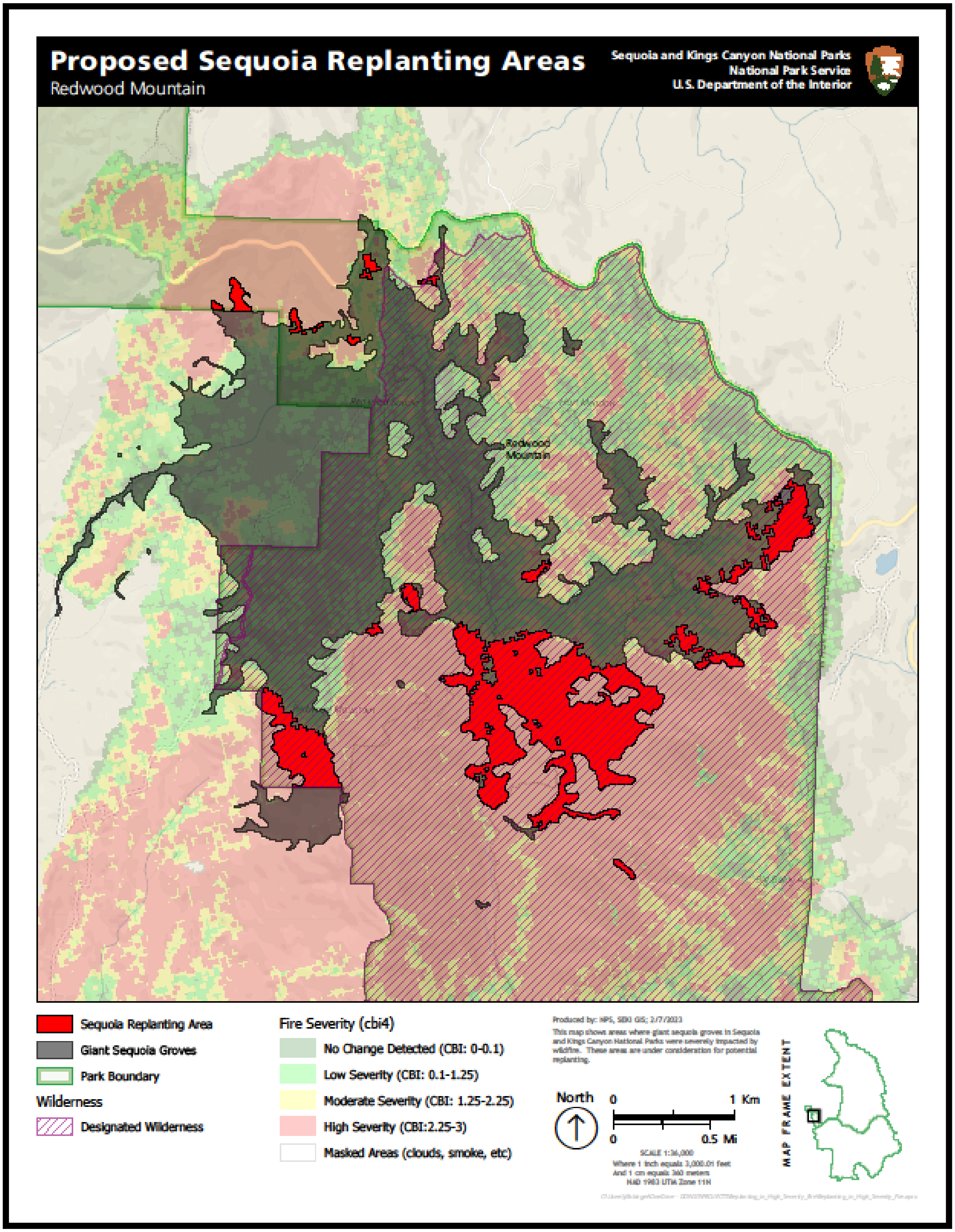


FIGURE 2. AREAS PROPOSED FOR RE-ESTABLISHING SEQUOIA AND OTHER CONIFER SEEDLINGS IN SUWANEE GROVE

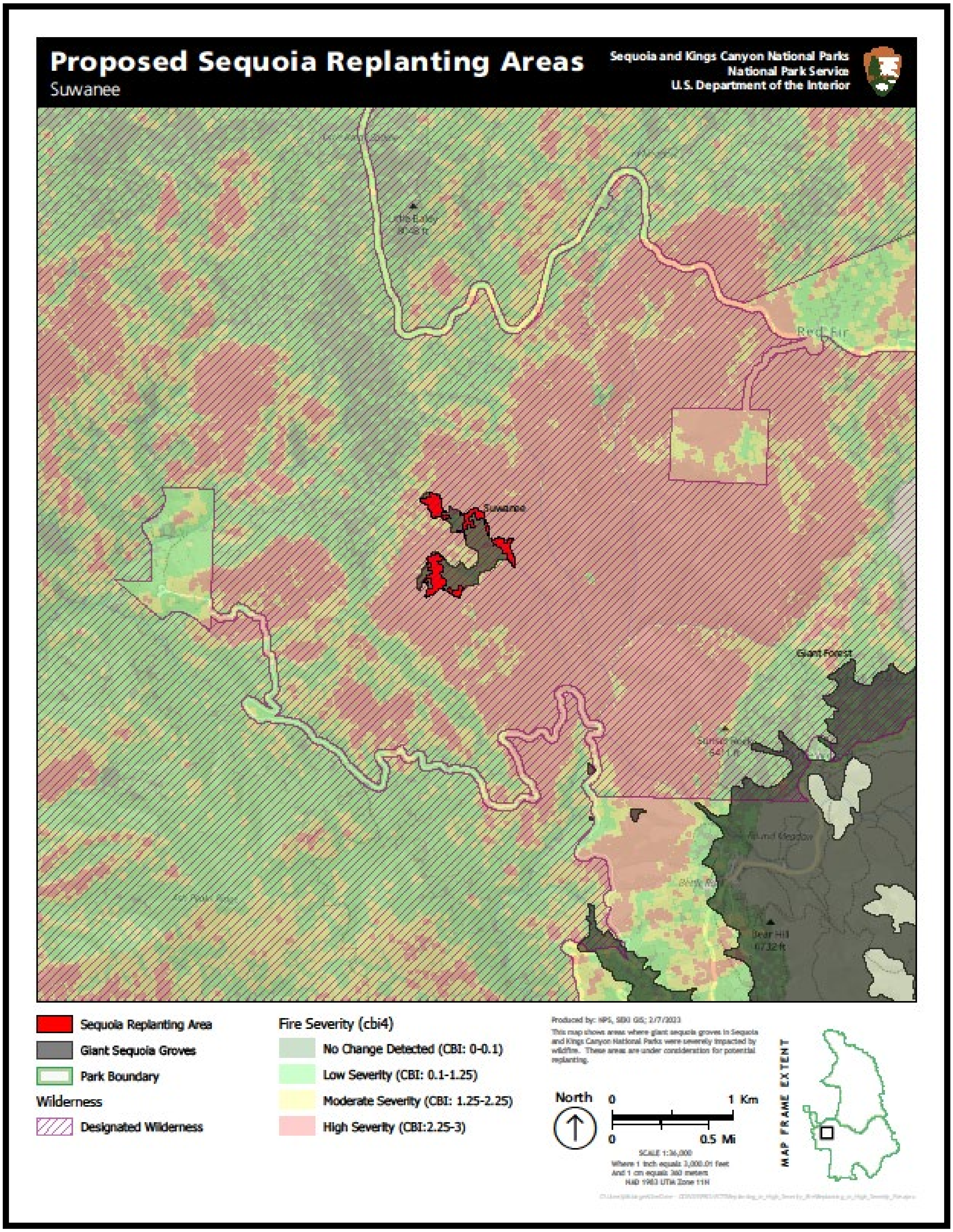


FIGURE 3. AREAS PROPOSED FOR RE-ESTABLISHING SEQUOIA AND OTHER CONIFER SEEDLINGS IN NEW ORIOLE LAKE GROVE

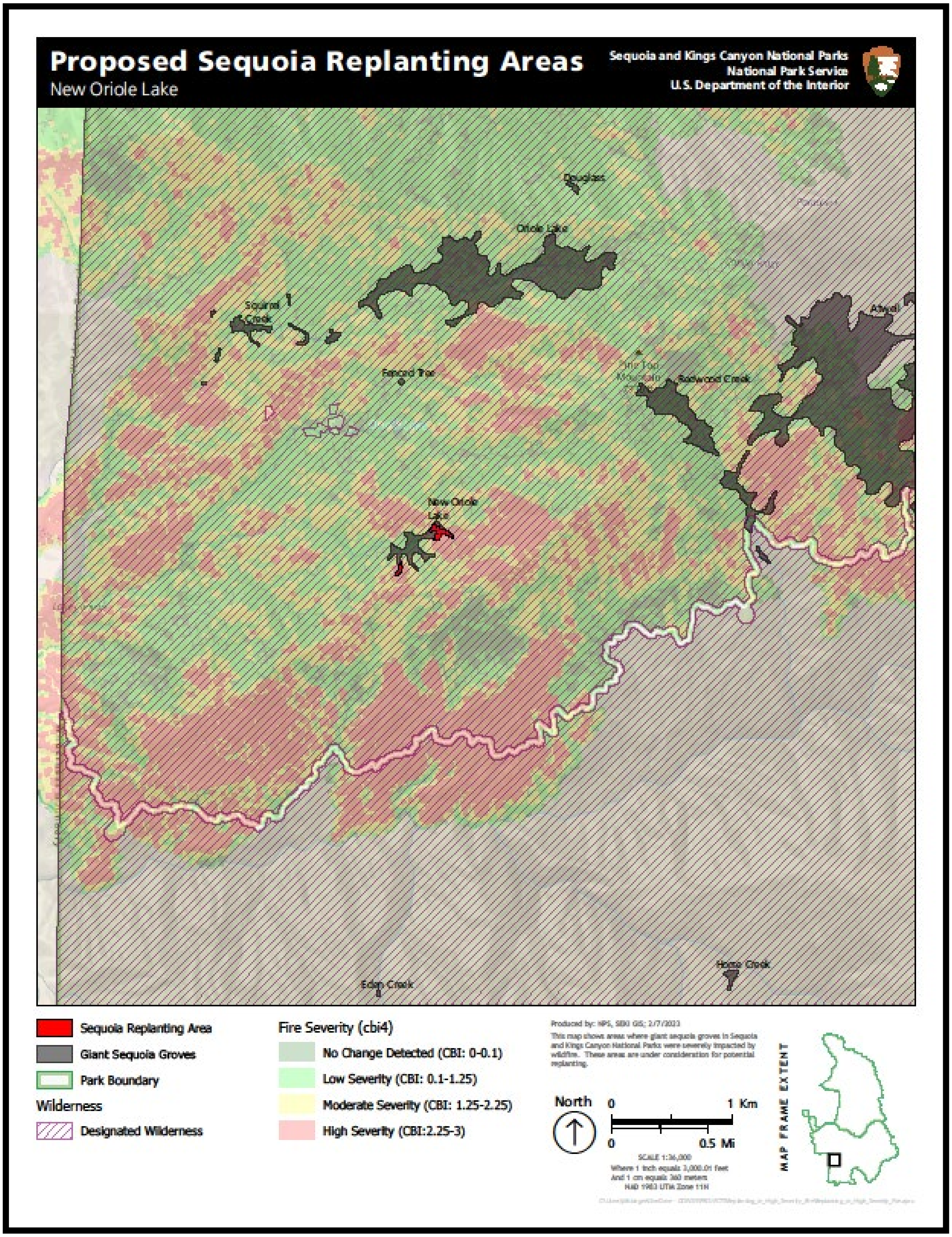


FIGURE 4. AREAS PROPOSED FOR RE-ESTABLISHING SEQUOIA AND OTHER CONIFER SEEDLINGS IN DILLONWOOD GROVE

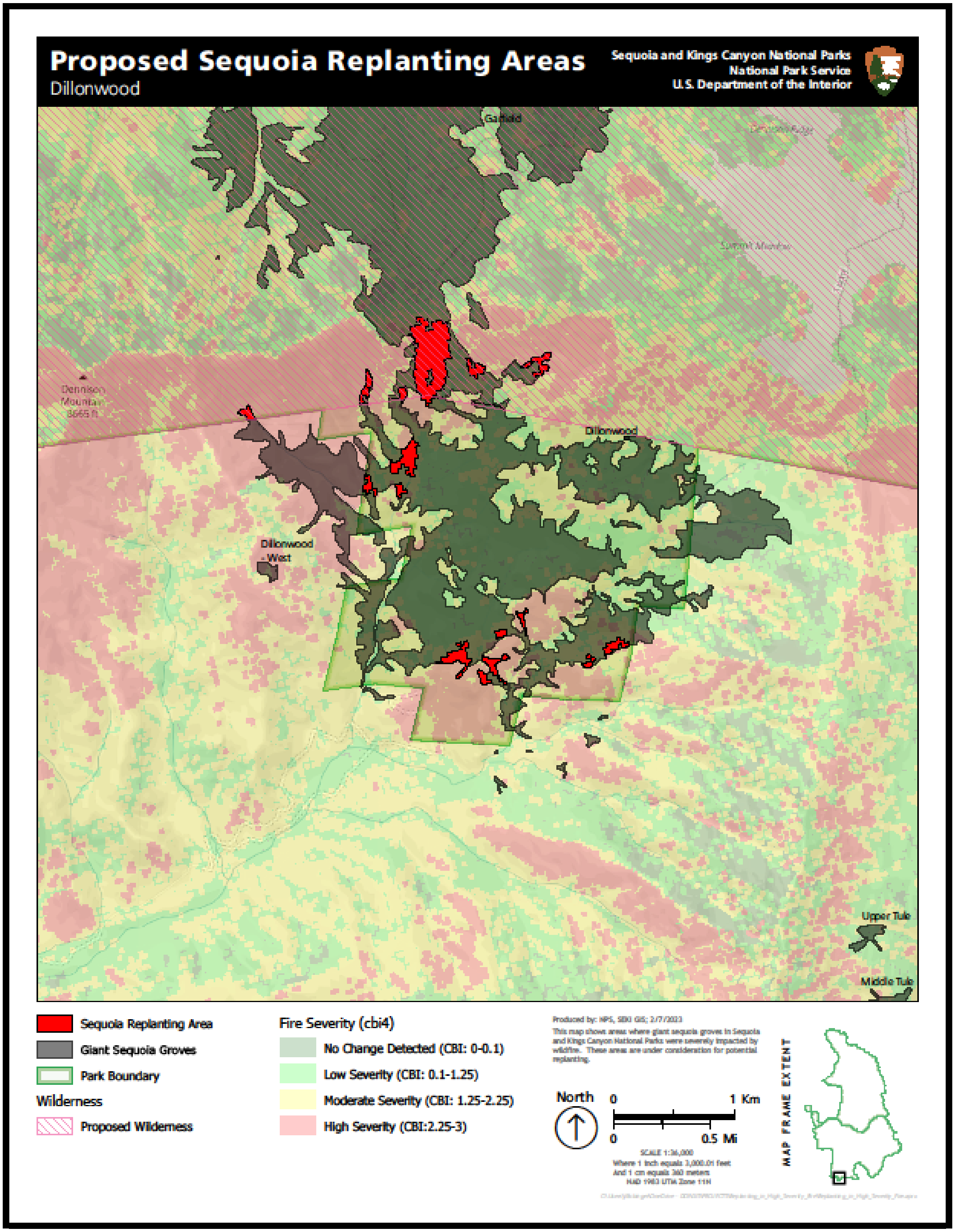


FIGURE 5. AREAS PROPOSED FOR RE-ESTABLISHING SEQUOIA AND OTHER CONIFER SEEDLINGS IN BOARD CAMP AND HOMERS NOSE GROVES

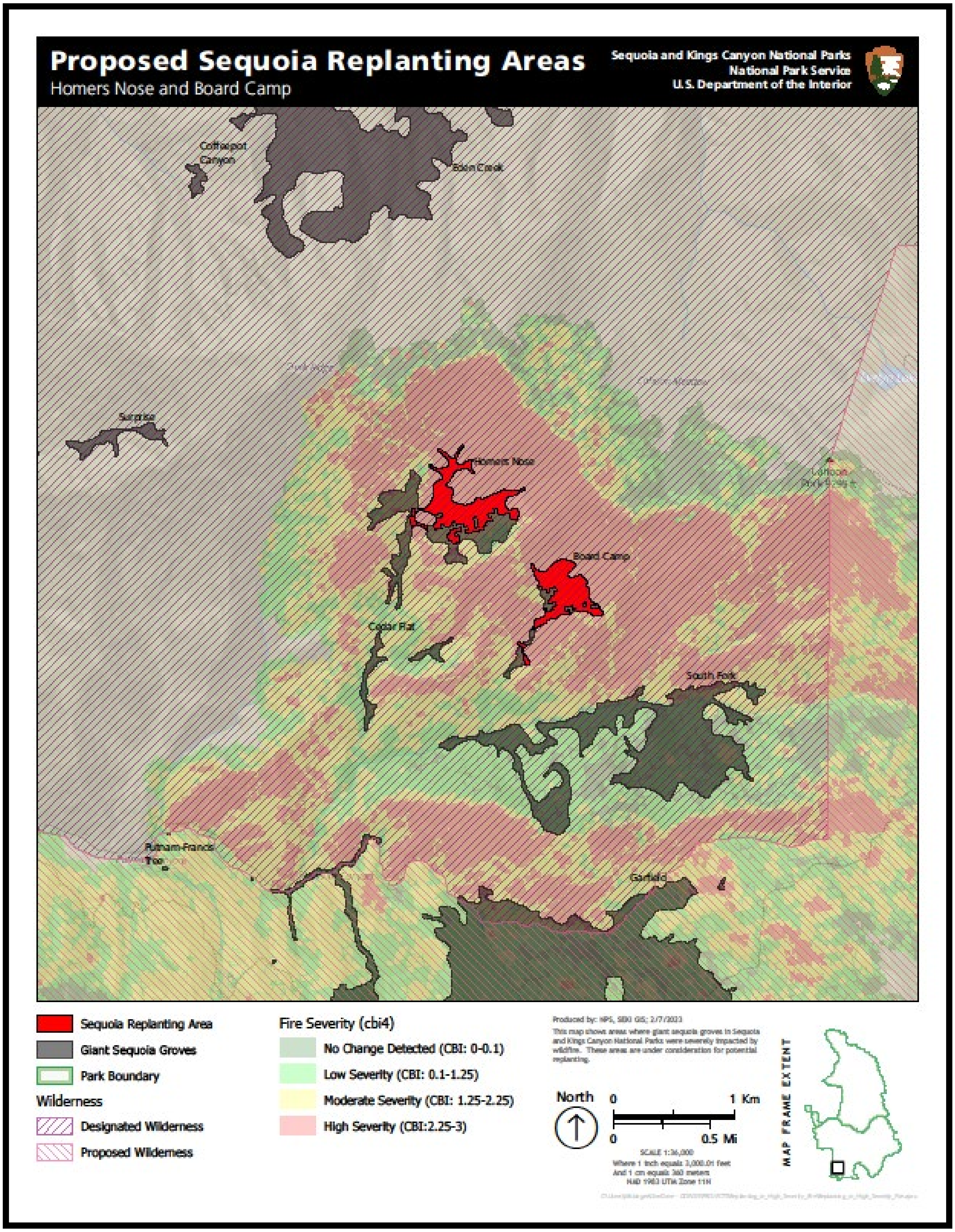


FIGURE 6. CORE PROPOSED FISHER CRITICAL HABITAT AREA 3 PROPOSED FOR RE-ESTABLISHING OTHER CONIFER SEEDLINGS

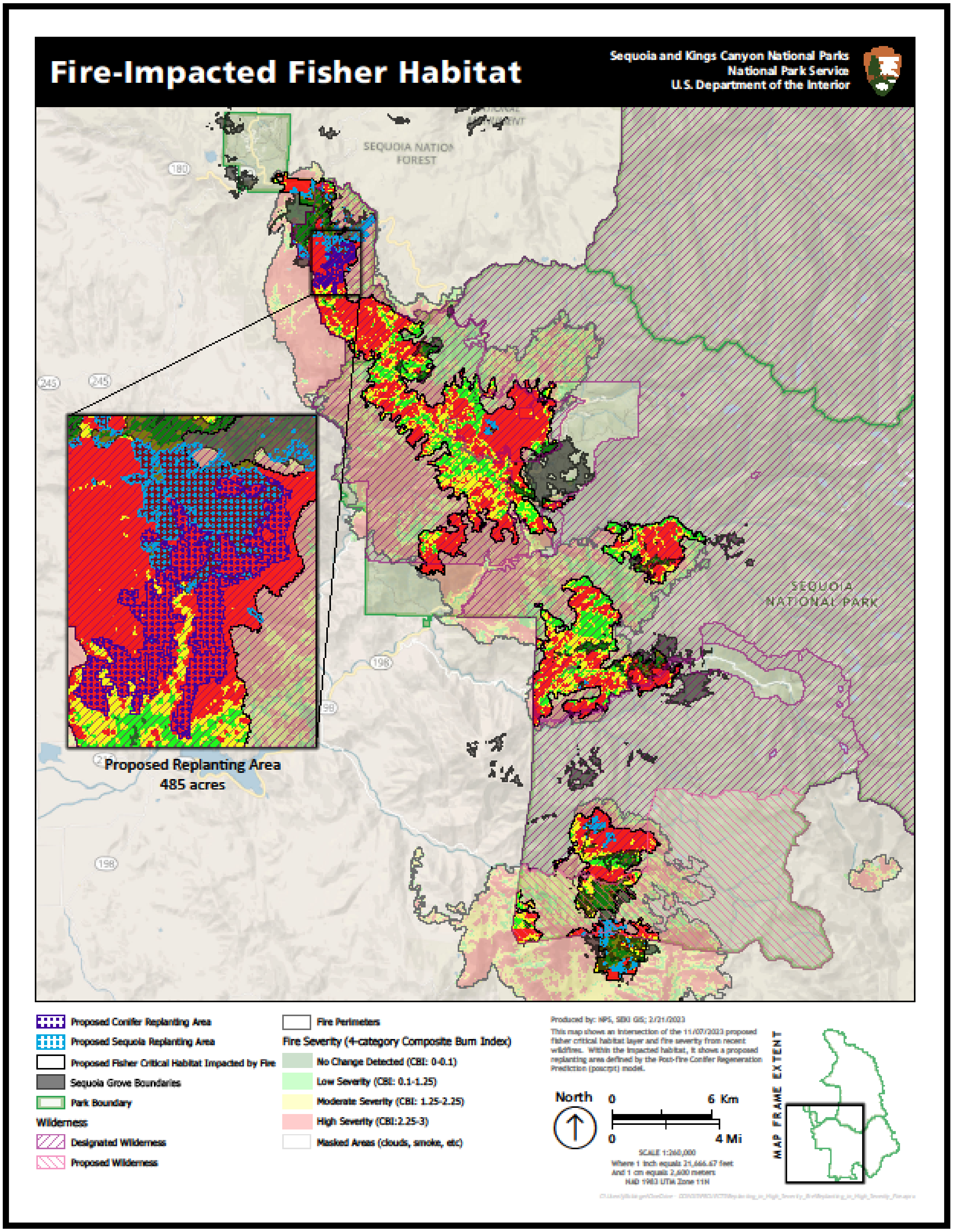
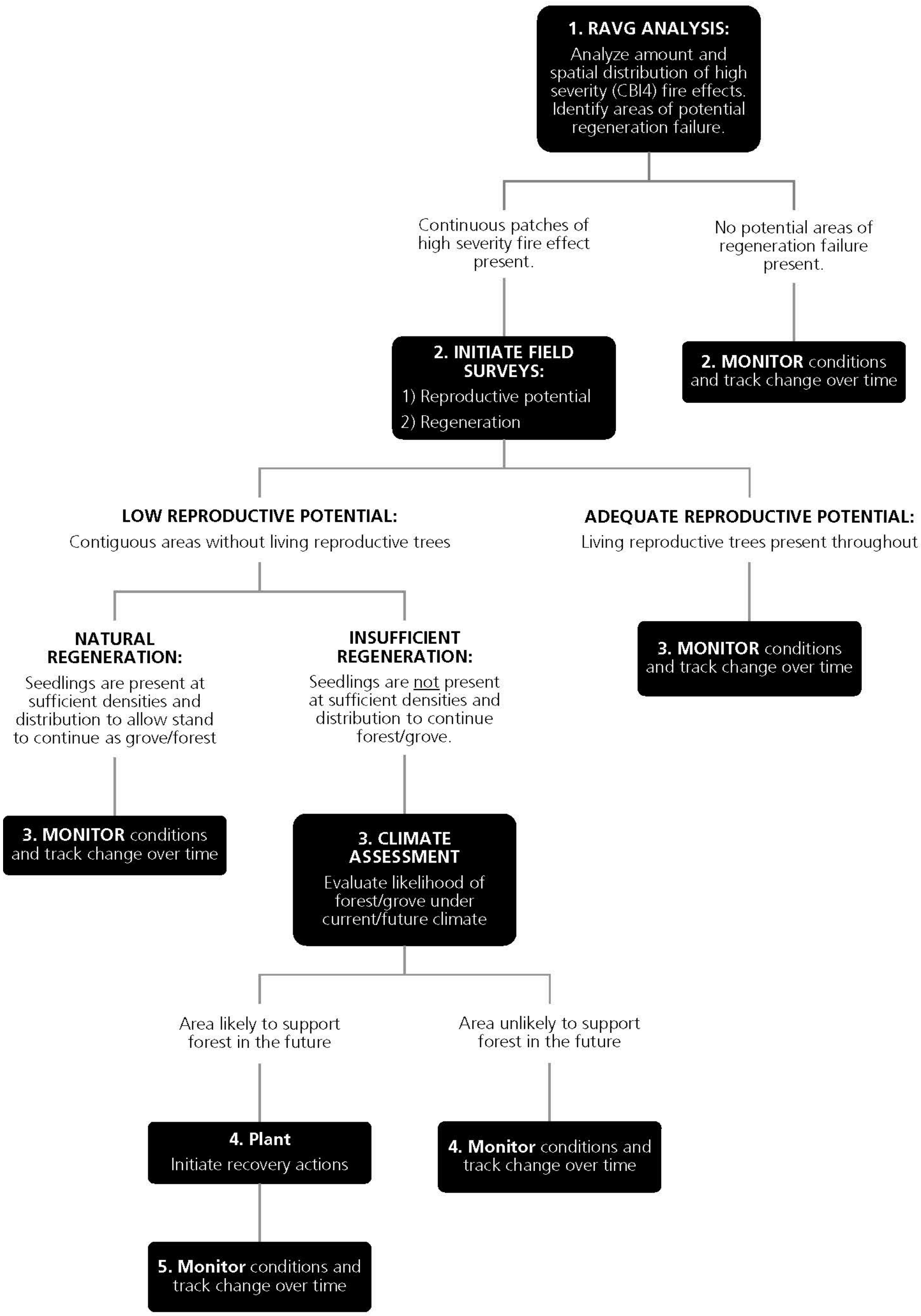


FIGURE 7. PROPOSED DECISION TREE FOR RE-ESTABLISHING SEEDLINGS IN SEVERELY BURNED AREAS



Climate Assessment (Completed)

To consider current and future effects of climate change on project need and success, an interagency team also completed an analysis evaluating the climate of the proposed planting locations and the likelihood that these sites can support forest cover in the future (Meyer et al. 2022). As of mid June 2023, this analysis has been completed for all of the proposed planting areas and the results indicate that all of the areas have a high likelihood of continuing to support forest under future climate conditions, although tree densities in some sites may need to be reduced in order to reduce future drought stress from lower water availability in the future (Meyer et al. 2022). This type of site-specific assessment of future water availability would be incorporated into site specific planting densities and planting plans as they are developed for sites that are currently drier or are anticipated to be drier in the future.

Site Planting Plans

For each grove or fisher habitat corridor where the decision tree indicates that action is necessary and warranted, the NPS would document tiered compliance documentation based on a site-specific planting plan that considers site conditions in determining the best way to achieve the purpose and need for action within that grove or habitat corridor. With a goal of planting 100 to 400 seedlings per acre (discussed on page 18 above), these planting plans would lay out a planting map that considers environmental variables critical to seedling survival, species composition, and site-specific forest structure such as slope percentage, slope aspect, elevation, microtopography, and soils to best mimic natural distribution of seedlings after fire (North et al. 2019; Marsh et al. 2022) as well as fine-scale presence of natural regeneration. This planning allows for spatial heterogeneity in planting and survivorship which is what would happen naturally. The planting plans would include the species to be planted, their proportions, and the overall planting density for each area. These planting plans would also consider other identified sensitive resources within the area to minimize disturbance to these resources. See Appendix F for further detail on planting plans.

Implementation

Seed Collection and Treatment

The NPS began collecting seed in Board Camp in 2021, following the Castle Fire, and collected additional seed in Redwood Mountain and Board Camp Groves in 2022, following the KNP Complex Fire.[13] Some of the collected seed was preserved in a seedbank to preserve sequoia

---

[13] Initial seed collection efforts in 2021 were completed in compliance with NEPA under Categorical Exclusion (CE) 3.2 which does not require documentation. The NPS completed additional review, analysis, and documentation for cone collection efforts under CE 3.3.E.2 in Fall 2022 in response to comments received during the initial public scoping period which questioned the impacts of such cone collection efforts and the activity's relationship to this larger proposed action. Specifically, NEPA regulations do not permit agency use of a CE if one or more defined "extraordinary circumstances" apply, two of which are: "whether the action would…[1] establish a precedent for future action or represent a decision in principle about future actions with potentially significant environmental effects; [or] [2] have a direct relationship to other actions with individually insignificant but cumulatively significant environmental effects" (NPS 2015b). Although implementation of the action alternatives outlined in this EA are contingent on having seedlings to replant, the NPS determined that collecting seed does not dictate that future planting in wilderness will occur. Rather, the collected seed is being banked *and* propagated, and seedlings that have been propagated may be planted outside the scope of this proposed action, consistent with the operations of the restoration program at Sequoia and Kings Canyon National Parks, where seed is regularly collected and propagated without necessarily a destination of planting in mind. For example, seedlings that are propagated can be used for planting outside the parks. Furthermore, the NPS has no indication that seed collection, combined with replanting of either sequoia and/or mixed conifer seedlings, would have significant

genetic diversity and for research—as called for in the park's Resource Stewardship Strategy. The NPS additionally germinated a portion of the collected seed to allow the option of planting seedlings within the necessary timeframe should the NPS ultimately decide to act on this replanting proposal.

Under this alternative, seed collection would continue—as described below—on a timeline that would allow seedlings to achieve necessary planting size within planting timeframes.

- All non-sequoia collection would occur within California Tree Seed Zone 534 (Buck et al.1970).
- Sequoia seed would be collected from a number of source groves, which may include a percentage of seed from natural sequoia groves that are outside the local seed zone. The NPS obtained guidance from an expert in giant sequoia conservation genetics to make recommendations for seed sourcing based on current literature (see Appendix E.)
- To reestablish the full complement of overstory community, species collected for this project would be the dominant tree species in the giant sequoia forest alliance, ponderosa pine – incense-cedar forest alliance, and white fir – sugar pine forest alliance vegetation communities (Haultain et al. 2020). Within those vegetation communities, target species for collection and propagation would include giant sequoia (*Sequoiadendron gigantea)*, sugar pine (*Pinus lambertiana)*, Jeffrey pine (*P. jeffreyii), ponderosa pine (P. ponderosa*), fir (*Abies concolor, Abies magnifica)*, incense-cedar (C*alocedrus decurrens*), and California black oak (*Quercus kelloggii*). Species would only be replanted in areas where field surveys have confirmed there is inadequate regeneration.
- To ensure that seed collection would have no measurable impact on the seed availability in the source locations, the NPS would collect a conservative quantity of cones/seed following established guidelines for seed collection developed by the BLM "Seeds of Success" Program, as well as the Center for Plant Conservation which directs that no more than 10% of seed should be collected from a given population. In Board Camp Grove, where the NPS estimates that only around 40 living sequoias remain in the grove, the cone collection effort in 2021 and 2022 equaled roughly 1.5% of the total cone crop potentially available in the grove that year.
- Cones would be collected by tree climbers, summer through fall, with oversight from NPS ecologists and would be supplemented by ground collections to increase genetic diversity.
- All collections would be labelled to track source and to ensure chain of custody from collection, through propagation, and planting, if approved.

Following collection, the NPS would continue to follow previously established and implemented protocols for seed collection and treatment. These include promptly transporting seed to cleaning facilities where cones would be dried and tumbled to extract seed, further drying seed for storage, and cool moist stratification of seed for 60-90 days to overcome dormancy and be able to germinate the seeds for growing seedlings.

---

environmental effects. Sequoia and Kings Canyon National Parks planted sequoias in areas impacted by development during the Giant Forest Restoration; the USFS has planted giant sequoias in several groves including Black Mountain Grove; UC Berkeley has planted giant sequoias in experimental plantations in Blodgett Forest; and Sierra Pacific Industries has planted giant sequoias in their plantations across the Sierra Nevada. Given these considerations, the NPS determined that no extraordinary circumstances applied, and a CE was appropriate. Notably, this EA evaluates cumulative impacts from past, present, and reasonably foreseeable actions along with the proposed action.

Seedlings would then be grown at multiple nurseries to reduce risk of unforeseen circumstances that could result in complete loss of seedlings. Those facilities include, but are not limited to, the Sequoia National Park Native Plant Nursery at Ash Mountain, Tsemeta Nursery that is owned and operated by the Hoopa Reservation in Northern California, and the USFS Nursery at Placerville, California. All nurseries would sow seed in January-March in sterilized soilless media following best management practices for nursery sanitation to prevent introduction of pathogens or non-native species (Griesbach et al. 2012). The seedlings would be grown in 3.5-7.25-ounce (108-215 milliliters) containers (styro 6 and 15) for one year to achieve a target seedling size of 0.1 inches (2.2mm) in diameter and 3 inches (8cm) high.

Seedling Planting

Schedule

As described above, in sequoia groves where there is not a 90% or greater probability of the project area Bayesian estimated mean seedling density being equal or to the Bayesian estimated mean threshold density, and once all decision documentation tiered to this EA are finalized, the NPS would move forward with planting seedlings as soon as possible—in the following fall or spring season—to establish seedlings prior to extensive regrowth of dense, tall, uniform shrub cover with the intent of mimicking, as closely as possible, natural post-fire conditions under which sequoia and other mixed conifer seedlings thrive.

Preliminary analysis of 2023 survey data from Redwood Mountain Grove and Suwanee Grove shows an average of 24% shrub cover per plot with a low of 1% and a high of 90%. (Meyer et al. 2023)) For this reason, the NPS would consider planting in Redwood Mountain Grove, Board Camp Grove, and the fisher corridor immediately to the south of Redwood Mountain Grove (where analyses indicate action is both necessary and warranted) as early as fall 2023. For any of the replanting areas though, the NPS could plant either in late October, just before the season's first snow, or in early spring, as sites become accessible and when soil moisture is highest, to improve chances of planting success. Although conifers are most often planted in spring, with hotter, drier summers becoming more frequent (see Stephenson et al. 2023 in preparation), fall may be a more effective planting time since it avoids the summer drought. For this reason, the NPS could plant in fall and/or spring. If determined planting is appropriate under the decision tree, the NPS would likely plant in Suwanee, New Oriole Lake, Dillonwood, and Homer's Nose Groves in spring or fall of 2024 or 2025.

Given the above, the NPS anticipates that initial planting in these potential seven areas would occur over the next two years, fall 2023-fall 2025, but additional supplemental plantings could occur per area through several more years (estimated through fall 2028 or 2029) if survivorship of planted seedlings is below 70% in year one and if there is greater than 10% mortality in years 2-4. Although the NPS anticipates high survivorship of seedlings based on similar planting efforts elsewhere, planting over this longer time period would improve probability of planting events aligning with years of above-average precipitation; a critical component of seedling success in the southern Sierra Nevada (Shive et al. 2022; York et al. 2009). It is anticipated that should supplemental planting be needed, planting area/planting effort would be much smaller than those in the initial planting and would be limited to 1-2 supplemental plantings per area over the course of this longer timeframe.

Each planting effort would be performed by crews of roughly 10-15 individuals per planting location over the course of an average of roughly 1-2 weeks for each location.

Planting Methods

As outlined in site-specific planting plans, seedlings would be planted following the Individuals, Clumps, and Openings methods outlined in North et al (2019) across the diversity of topography and microsites (ridges, flats, depressions, along drainages, etc.) to mimic natural distribution of seedlings after fire. Following this pattern, some individual trees would be widely spaced, and others would be clustered together in small clumps. This would also factor in where some natural regeneration may be occurring. The exact planting locations of specific species would be based on their adaptations (e.g., ponderosa pines would be planted on ridges more than along drainages, etc.). Where some naturally regenerating seedlings occur in an area where action is determined necessary under the planting plan, extra care would be taken to avoid trampling existing seedlings. Further, if there are dense patches of regeneration within planting areas comparable to densities found after prescribed fire, the NPS would avoid planting in these areas. See Appendix F for a sample planting plan.

To plant seedlings, the NPS would use hand tools (dibbles or small spade shovels) to create divots a maximum of 2" in diameter and 6" in depth (equivalent in size to the root plug). The soil around each seedling's roots would be loosened gently before it would be planted into the divot, and the divot would be backfilled by gently compressing soil back in place around the root base. The NPS could hand-build 2-3" wells with a rim of native soil on downslope sides of each seedling to capture incidental moisture.

Transport and Staging

The six sequoia groves and adjacent fisher critical habitat are distributed across both parks, primarily within wilderness and with varying degrees of access (see Appendix D: Minimum Requirement Analysis, Table D 2). Under Alternative 2, areas having adequate trail infrastructure, but too far to allow transport of all seedlings and gear by foot, would utilize pack stock transport. From staging sites where stock deliver materials, planting crews would transport seedlings to their planting locations on foot. Sites where pack stock would primarily be considered include parts of Redwood Mountain and the adjacent fisher critical habitat corridor. In the case of Redwood Mountain, which has some small and disparate patches proposed for planting, seedlings may be carried to smaller patches on foot from the nearest road if determined not to be a safety risk.

If, as anticipated, stock was determined the minimum necessary transport method in parts of the Redwood Mountain Grove and fisher habitat area, it would require a range of roughly 15-30 pack stock strings of 8 mules each (a total of roughly 120-240 mules total) for each site in the first year and roughly 5-10 each supplemental planting thereafter, if necessary. Each stock train would travel along existing routes a distance of roughly 4-5.5 miles to reach project sites (see Table 2 below). Stock would not travel cross-country and would not remain in wilderness overnight.

TABLE 2. FACTORS CONSIDERED FOR STOCK SUPPORT OVER A PERIOD OF ROUGHLY FIVE YEARS

Grove/Area Name	Total Mules	Total Proposed Mule Trains[14]	Miles Round Trip
Redwood Mountain Grove	426	53	8
Adjacent Fisher Habitat	360	45	11
Total	786	98	N/A

[14] Assumes each mule would carry roughly 120 lbs. and each string would be comprised of 8 mules.

Where barriers to stock or foot travel prevent safe access for seedling and tool delivery, including areas that have been determined prohibitively far from developed trails and roads or having terrain too difficult for stock or crews to transport seedlings and tools safely and feasibly, the NPS would utilize helicopters to transport seedlings and tools, via sling loads, to a centralized staging area; no staff would be transported via helicopter. Sites where helicopters would be considered include: Suwanee, New Oriole Lake, Dillonwood, Board Camp, and Homers Nose Groves. For Redwood Mountain Grove, the NPS would preferentially use stock and foot transport, though safety considerations may ultimately require use of a helicopter. Some groves may require sling load deliveries in multiple locations to deliver seedlings throughout the area due to the distances between planting patches.

The NPS assumes that a total of roughly one to four, 10–30-minute round trip helicopter flights would be needed to deliver sling loads during the first year of planting each of the sites where helicopter use is considered (see Table 3 on page 35). The NPS further assumes that roughly one to two helicopter flights would be used at each of these sites during each supplemental planting thereafter for a total of roughly 37 sling-load landings over the course of five to six years, assuming one to two supplemental plantings at each site. Finally, the NPS assumes that each helicopter would travel at a height of roughly 500 feet above ground level (AGL) while in route to each individual project site and helicopters would hover at a distance of roughly 150 feet AGL for a period of approximately five minutes to drop each sling load of materials. Slings would touch down for less than one minute (roughly a period of seconds) to deliver or pick up the loads.

The NPS would locate an area roughly 70-90 feet in diameter clear of trees 150-200 feet in height (estimated height of trees in these areas) to safely deliver sling loads to the project site. If a site of sufficient size cannot be located, the NPS would fall snags (dead trees) to create a safe landing zone. For the purposes of this analysis, the NPS assumes up to 10 snags of the size class above may be felled at each of the locations where creation of a safe zone is necessary. Snags would be felled using either explosives, or chainsaws, whichever is determined the safest (see Appendix D: Minimum Requirement Analysis for more discussion on safe felling considerations). A number of smaller snags (roughly 50) less than 12 inches in diameter may also be removed by hand or with chainsaw within the 70-90-foot diameter area should they pose a safety hazard to helicopter operations or crews camping.

Staging and spike camps would be needed for all proposed planting sites. Site selection would consider factors such as absence of sensitive resources, durability of camping surfaces, absence of unmitigated safety risks, location outside of wilderness (if feasible), and proximity to planting areas. Previously impacted locations, including developed administrative camps or helicopter landing zones (as described above) would be preferentially used to minimize impacts. Unless there are no existing administrative camps and landing zones are not needed within a planting area—in which case snags would be removed for safe camping location consistent with the size and scope of creating a landing zone as described above—campsites would not be improved, and all use of such areas would follow wilderness minimum impact restrictions.

TABLE 3. TOTAL PROPOSED HELICOPTER SUPPORT IN WILDERNESS OVER A PERIOD OF ROUGHLY FIVE YEARS

Grove/Area Name	Total Estimated Sling-Load Deliveries	Total Sling Load Landings in Wilderness[15]	Total Flight Distance in Miles[16]	Estimated Minutes of Hover Time (all trips)[17]	Snag Felling Needed
Dillonwood	8[18]	4	28	40	0-10
Homer's Nose	7	14	21	35	0-10
Board Camp	7	14	22	35	0
New Oriole Lake	5	10	13	25	0-10
Suwanee	6	12	15	30	0-10
Redwood Mountain Grove and Fisher Habitat Corridor	4	8	10	20	0-10
Total	**37**	**62**	**109**	**185**	**50**

Monitoring

The NPS would establish benchmarks and thresholds prior to planting and assess baseline site conditions, to follow grove conditions, track the survival and growth of planted seedlings, and to determine whether planting goals are being met. Groves, or areas of groves, where planting is ultimately not determined necessary would also continue to be monitored. This EA assumes, for the purposes of analysis, that monitoring would involve development of monitoring plots which may include installation of 600 small plot markers such as rebar as well as 60 other installations such as hobos[19] for the purpose of characterizing and understanding microclimatic factors such as light, temperature, and soil moisture within these areas. The NPS further assumes these markers would remain for at least 30-40 years to track conditions.

Alternative 3: Replant Seedlings Grown from Seed Collected from the Local Genetic Community of Each Replanted Area

Alternative 3 is the same as Alternative 2 in that the NPS would adopt a framework to consider future action within the same seven areas impacted by high severity fire and would implement the same methodologies for such action. However, under Alternative 3, the NPS would not add genetic diversity to replanted giant sequoia groves by sourcing cones/seed from arid groves and from groves with known higher levels of genetic diversity within the seed zone. Instead, all seed would

---

[15] Because each sling load would be dropped full and then picked up again, this number reflects the total actual "touchdowns" in wilderness. It also reflects the total estimated time the helicopter would affect undeveloped quality. This number overestimates landing time as slings typically take only seconds to drop and pick up.
[16] Note that helicopter flight distance is estimated here for the purpose of analyzing impacts on wilderness character and wildlife. This number would be multiplied by total flights and divided by mph to determine total flight time.
[17] Helicopter hover time is estimated for the purposes of analyzing impacts to wilderness character and to wildlife. For this calculation the NPS assumes 5 minutes of hover time per sling load.
[18] Up to six flights/sling-load landings would occur in the *non-wilderness* portion of Dillonwood to support planting in both non-wilderness and wilderness portions of proposed planting areas.
[19] A hobo is a monitoring device that captures data such as temperature, water level, humidity, or other environmental data.

be collected only from within the local genetic community (or neighborhood) of the grove being replanted as described in Appendix E.

All methods of seed collection, propagation, planting, and transport would follow methods previously outlined in Alternative 2.

Alternatives Considered but Dismissed

Avoid Any Action in Wilderness or Actions that Require Mechanized Transport or Motorized Equipment within Wilderness

Several respondents to NPS' public scoping indicated support for replanting sequoia groves affected by high severity fire but did not support action to plant sequoias in wilderness; suggesting instead that the NPS focus on action in non-wilderness groves and mixed conifer forests. Others suggested that the NPS should either consider only using non-motorized tools for all areas and/or consider planting only in areas that could be reached without the use of helicopters (only by stock or on foot).

Of the six sequoia groves that burned at high severity during the Castle and KNP wildfires, four occur entirely within designated wilderness (Board Camp, Homer's Nose, New Oriole Lake, and Suwanee Groves), one is partially located in designated wilderness (Redwood Mountain Grove), and one is partially located in recommended wilderness (Dillonwood Grove). No frontcountry sequoia groves were lost or partially lost to high severity fire. While fisher critical habitat burned at high severity in non-wilderness, the 485-acre habitat corridor was identified as integral to connecting fragmented fisher populations and is entirely within designated wilderness.

The NPS initially analyzed a no action in wilderness alternative as Alternative A of Appendix D (see page 13). However, because sequoia groves are ecologically valuable in large part to their location within the broader Sierra Nevada, and because they serve as an identified attribute of the natural quality of both the John Krebs and Sequoia-Kings Canyon wilderness areas, "replacement" or "restoration" of sequoias cannot be adequately achieved off-site and outside of wilderness, nor would such replacement serve to restore natural quality of wilderness character in areas where it has been diminished. Likewise, the fisher habitat where planting in wilderness is being proposed serves as a key habitat corridor between otherwise disjointed and fragmented surrounding habitat. Restoring forest in areas outside of wilderness would not create habitat corridors where the corridor is needed.

While the NPS anticipates that the fisher habitat area and Redwood Mountain Grove can primarily be accessed with stock, the majority of sequoia groves within the potential action area are remote and cannot be safely and reasonably reached by stock or entirely on foot without considerable impacts to wilderness character as explained in Appendix D (pages 19-21). As described in the MRA, the NPS did not carry this alternative forward in the EA as the alternative was considered unsafe and this rationale was documented via the MRA. Likewise, restoring only the areas that could be reached without the use of mechanized transport (as fully analyzed in Alternative D of Appendix D, pages 18-19) would have effects similar to the action alternatives in the Redwood Mountain Grove, and would have identical effects to the no action alternative in the five remaining groves including all groves in the John Krebs Wilderness, leaving those areas vulnerable to shrub conversion as described in the introduction of this EA.

TABLE 4. SUMMARY OF ALTERNATIVES FOR RE-ESTABLISHING TREE SEEDLINGS IN SEVERELY BURNED SEQUOIA GROVES AND FISHER HABITAT CORRIDOR

Action	Alternative 1: No Action	Alternative 2: Seedlings Grown from the Local Genetic Neighborhood and Other Sources	Alternative 3: Seedlings Grown from the Local Genetic Neighborhood
Seed Collection	• No seed would be collected specific to this action.	• The NPS would collect other conifer cones from within California Tree Seed Zone 534 (Buck et al. 1970). • The NPS would collect sequoia seed from a number of source groves including 20% from outside the local genetic neighborhood (i.e., groves that likely do not have natural gene flow). • The NPS would collect cones following established guidelines for seed collection developed by the BLM's "Seeds of Success" Program, as well as the Center for Plant Conservation.	• All methods would be like those under alternative 2 with the exception that the NPS would not source some sequoia seed from outside the local genetic neighborhood.
Seed Treatment	• The NPS would maintain all seeds in a seed bank. • The NPS would transfer seedlings to partner organizations.	• Following collection, the NPS would transport seed to cleaning and cold storage facilities. • Seedlings would be grown at multiple nurseries. • All nurseries would sow seed in January-March in sterilized soilless media following best management practices for nursery sanitation.	• Same as Alternative 2.
Seedling Planting	• N/A	• The NPS would plant 100 to 400 seedlings per acre in areas should all criteria in the framework/decision tree apply. • The NPS would create divots a maximum of 2" in diameter and 6" in depth. The seedling would be planted into the divot. • The NPS would hand-build 2-3" a rim of native soil on downslope sides of each seedling.	• Same as Alternative 2.
Tools, Transport	• N/A	• Dibbles or small spade shovels. • Foot, stock, and helicopter transport may be considered.	• Same as Alternative 2.
Monitoring	• The NPS would install long-term monitoring plots. • The NPS would install 60 installations such as temperature and moisture probes (hobos)	• All methods would replicate those of Alternative 1 except in Alternative 2, the NPS would track planted seedling survivorship, growth, and mortality in addition to that of naturally regenerated seedlings. The NPS would track any differences between seedlings planted using local genetic seed and seedlings planted using sources outside the local genetic community.	• Same as Alternative 2.

Several other considerations also make this alternative not viable. First, as identified in several scientific publications (see Appendix E), different groves contain different genetic material and thus loss of trees in these specific groves is damaging to the species ability to respond to future events through adaptation. Additionally, if seed was collected from these groves and planted elsewhere (whether in or outside of wilderness), these trees would not be able to exchange pollen with remaining trees in these groves or adjacent groves and thus long-term genetic exchange and adaptive potential would be disrupted. Finally, the NPS does not manage a lot of land that is both outside wilderness and suitable for sequoia groves besides the limited acres in the Dillonwood grove being considered in this proposal and those in front country areas of these parks. In fact, it is unclear whether any additional areas exist and, if so, where they would be, particularly as giant sequoia groves occupy hydrologic refugia (Baeza et al. 2021), meaning not all parts of the landscape would support giant sequoia groves in the long term.

For all reasons identified in the preceding paragraphs, planting only outside of wilderness, or excluding areas that cannot safely and reasonably be planted entirely with stock or on foot (again as Other Alternatives considered but dismissed or evaluated as Alternative D in Appendix D) would not resolve the identified purpose and need for action for either sequoias or fisher and was therefore dismissed from further analysis.

Plant Only Sequoia Seedlings in Sequoia Groves

Giant sequoia groves are naturally composed of a mix of sequoia and other conifer trees. Like sequoia, other conifer trees in the six groves identified for potential action in this plan were lost to high- severity fire and are unlikely to recover due to a lack of seed source. Because the purpose and need of NPS action is to promote post-fire recovery of sequoia groves, and because mixed conifer is an integral component of natural species assemblage in these groves, the NPS dismissed an alternative that does not include planting of mixed conifer seedlings in areas where the framework (i.e., decision tree) indicates it is necessary because, to a large degree, it would not resolve the identified purpose and need for action.

Plant Sequoia Groves, but do Not Plant Adjacent Fisher Critical Habitat

The NPS considered a proposal to plant sequoia groves but to either not plant in adjacent critical habitat or to consider planting this area under a separate proposed action. The NPS dismissed an alternative to not plant this area as it would not resolve the identified purpose and need for action. Due to the similarity in timing and overall nature of the proposal, the NPS determined that combining the actions under one analysis would be more efficient and would provide the most comprehensive review of proposed replanting actions. This alternative was therefore dismissed from further analysis.

Sow Seed to Re-establish Seedlings

Sequoia seeds have low germination rates and high seedling mortality in early years. The conditions that allow for successful seed germination and seedling survival rapidly disappear after fire (Harvey et al. 1980, Stark 1968a, Stark 1968b). Sequoia seeds require specific conditions to germinate—friable mineral soil free of litter and duff and adequate moisture—and germination is typically very low under natural conditions (Harvey et al. 1980, Stark 1968 a, Stark 1968b). Of the approximately 8 million seeds that fall per acre following fire (Harvey et al. 1980), a Bayesian estimated mean of only 70,312seedlings establish per acre in the first year post prescribed fire (Stephenson et al. 2023 in preparation). The low natural germination rate, combined with very high mortality of naturally sown seedlings during the few years of life (which is variable and can range from 56.5% to 98.4%;

Harvey et al 1980, Table 8), which is also reflected in a decrease in the mean number of seedlings after prescribed fire from an estimated 70,312 mean seedlings per acre in year one to an estimated mean of 3,850 seedlings per acre in year five (Stephenson et al. 2023 in preparation), mean that large numbers of seeds would have to be sown and would have to be sown in year one, two, or possibly year three post-fire. Further, Hartesveldt and Harvey (1967) tracked individual seedlings over time and found only 1.4% of the seedlings were still alive after two summers of growth. In other words, within 18 months of sowing seed, 98.6% mortality had occurred.

Thus, reestablishing trees by sowing seeds would require the NPS to collect 99 seeds for every two-year old seedling. In total, the NPS would need to collect approximately 405,900 cones (1,400 bushels) compared to approximately 4,100 cones (ten bushels) for the current proposal. This amount of cone collection is not feasible and would cause a temporary impact to the number of cones available in the population. Beyond moderate to low seed germination rates and very high mortality of natural seedlings, the NPS expects low seed rain and potentially lower amounts of seed in the project areas than typically found in sequoia groves during the first several years post-fire because cones opened during the fire and the small number of living sequoia trees that remain in these high severity fire areas have not had sufficient time to regrow new cones since the fire. Post-fire modeling of the Castle and KNP wildfires suggest that the high-severity areas are also at high risk of losing any seeds that survived the fire due to surface erosion; seeds broadcast by NPS are likely to suffer a similar fate (National Park Service 2020; National Park Service 2021). Additionally, as described elsewhere in this document, the window for establishing giant sequoias from seed due to seed germination and survival requirements of giant sequoia appears to be around two years post-fire (Harvey et al. 1980, Stark 1968b) so trying to seed in sequoias at this time is unlikely to be successful. Thus, reestablishing sequoias from seed would remove more than 100 times more seed from (i.e., pose a higher impact to) forests that are already struggling to recover, and is not considered to be a practical option that would meet the purpose and need for action, particularly given that it has been three years since the Castle Fire.

In contrast, germination rates of 20-40% can typically be achieved under controlled nursery conditions (Harvey et al. 1980; Stark 1968) —requiring less intensive cone collection, treatment, and distribution efforts—and most importantly nursery grown seedlings have very high survivorship within the nursery and when subsequently planted (between 80 and 90% survivorship; York 2009; R. York personal communication 2022).

Similar constraints impact the other six species considered under this proposal. Broadcast seeding of conifers is usually unsuccessful for the same reasons listed above and more: seeds falling on inhospitable environs (Castro et al. 2023), high early mortality of seedlings (Castro et al. 2004), and seed predation (Shannon and Elliot 2020).

Together, these factors result in extremely large seed collection requirements in order to overcome low success rates, which may impact regeneration of donor forests (Castro et al. 2023). Since sowing seed would not meet the purpose and need for action, the NPS dismissed this as an alternative.

Plant at Higher Density Than Alternatives 2 or 3 then Thin Seedlings to Achieve Desired Density

This alternative would plant higher densities of seedlings above those considered within the action alternatives and would then manually thin (remove) seedlings to desired densities once seedlings have achieved a size at which they would be expected to survive in order to improve chances of success. This alternative was dismissed as it is essentially a duplication with the actions alternatives that are less environmentally damaging and less expensive. Specifically, this alternative would be more expensive and would result in additional impacts to the untrammeled quality of wilderness character, and potentially other qualities depending on proposed tools, than the proposed action alternatives.

Remove Existing Fuels either via Manual Thinning or Prescribed Burning Prior to Planting

This alternative would manually thin or complete prescribed burns in these areas prior to planting to remove existing fuels onsite. Areas where planting may occur under the framework outlined in the action alternatives are those that burned at high severity during recent wildfires. There is currently little understory vegetation in these areas, though vegetation is beginning to recover, and planting conditions are therefore currently conducive to seedling survival absent fuels treatment. Because this alternative is not necessary, would involve additional impacts to the untrammeled quality of wilderness character, and could kill any naturally re-generated seedlings that are currently present from the site (which is counter to the purpose and need for action), this alternative was dismissed from further analysis.

Complete Site Preparation Including Herbicide and Crushing of Vegetation

One professional organization suggested that treating understory vegetation prior to replanting would improve the chances of successful seedling establishment.

It is common practice in silviculture reforestation efforts to use mechanical equipment and herbicide to control vegetation that may compete with planted seedlings. The NPS considered the need and feasibility of including such treatments in this proposal but rejected this alternative due to a number of factors including unclear need, high cost, impact to wilderness values, and difficulty of implementation, described below.

Unclear Need

Giant sequoia evolved with the shrubs, forbs, and other trees that occur in the areas proposed for replanting. These areas do not contain large numbers of non-native, invasive plants that compete with giant sequoia. After prescribed fires implemented by Sequoia and Kings Canyon National Parks where adult sequoias were not killed, the NPS has frequently seen successful establishment of sequoia seedlings with no treatment beyond the fire itself (NPS Fire Monitoring unpublished data reviewed in York et al. 2013 and contained in Stephenson et al. 2023 in preparation). These data indicate that under conditions found after prescribed fire, giant sequoia seedlings that establish in appropriate microsites are able to compete with native shrubs and trees—evidence that removing this vegetation is not necessary. This is a primary reason the NPS is focused on planting sequoias in a similar time window to when they re-establish naturally, which is within the first two to three years after fire (Hartesveldt and Harvey 1967; Harvey et al. 1980; Harvey and Shellhammer 1991). Given the time needed to complete post-fire field surveys to inform the decision-tree and review the proposal for compliance with resource protection laws, the NPS is now looking to complete an initial planting in the first two to four years post-fire.

The assumption of the need to remove other vegetation is based in the idea that this vegetation competes with the planted seedlings for light, water, or other needed resources. The conditions present in the large high severity areas proposed for replanting in this project may not meet this assumption. First, based on field observations completed to date, the proposed planting areas contain large patches of bare ground. These openings would be targeted for planting of seedlings. Second, given the complete removal of overstory canopy, these sites are at greater risk for high heat and soil erosion (surface erosion models showed high likelihood of significant soil loss). Shrub and forb cover has been shown to reduce surface temperatures, increase relative humidity, and improve seedling survival, and reduce soil erosion, all of which could increase survivorship of planted seedlings (Marsh et al. 2023; Marsh et al. 2022; Holmgren et al. 2012).

Previous studies have also shown that giant sequoia is one of the most competitively dominant conifer species in the Sierra Nevada. While sequoia is not a commonly planted species and most silviculture treatments involve removing competing vegetation, various studies still show that giant sequoia grow quickly. York et al. (2007) found that giant sequoia seedlings outgrow all competing conifers, giving them a competitive advantage shortly after fire. Meyer and Safford (2011) surveyed giant sequoia planted one to two years after prescribed burning with no vegetation control. At two or more decades after treatment, they found giant sequoia seedlings and saplings in these areas, indicating that sequoias were able to establish despite competing vegetation.

The above factors combined indicate there is not clear and overwhelming evidence that planted seedlings will not survive without control of competing vegetation. This uncertainty combined with the other factors described below, led to the dismissal of this alternative at this time.

Feasibility

Many reforestation/silviculture projects are undertaken in areas with easy access for both people and equipment. All the areas proposed in this project are not accessible to heavy equipment due to terrain and location. Additionally, most areas require long hikes both on and off trail to access. These factors make the implementation of crushing of shrubs using equipment difficult if not extremely impractical. Applying herbicide to kill native vegetation in these areas would also be logistically difficult due to the need to bring in chemicals, spraying equipment, and the difficulty of cleaning equipment and people in the wilderness.

Impacts to Wilderness

Depending on the methods and equipment used, control of competing vegetation would have additional impacts to wilderness character. Regardless of the methods, control of competing vegetation would constitute additional trammeling due to the manipulation of the native vegetation present at the site. Second, if motorized tools were needed for shrub removal or application of herbicide, this would be an additional impact to the undeveloped quality of wilderness character.

Cost

From consultation with other reforestation specifications, the NPS estimates that control of competing vegetation would be approximately $240/acre (KNP BAR mixed conifer specification) although given the difficulty of accessing these sites, it could be significantly more than this. At $240/acre this treatment would cost $284,000.

Summary

While true that vegetation treatment prior to replanting is common, the severity at which these forests burned is un-precedented. Under these novel conditions, there is no comparable treatment prescription indicating that such treatment is necessary. At this time there is no conclusive evidence that vegetation treatments are necessary to achieve purpose and need, and, in keeping with the goal of limited intervention in wilderness, the NPS dismissed this alternative from further analysis.

If, through monitoring, the NPS measures high sequoia seedling mortality such that project success is in jeopardy, and if this mortality appears to be rooted in competition with native vegetation, feasible treatments to control competing vegetation around seedlings could be considered and evaluated in accordance with the Wilderness Act, National Environmental Policy Act, and other resource protection laws.

Use other Planting Pattern

At least one correspondent suggested the NPS reconsider planting in the Individual, Clump, Gap spatial pattern as it has been difficult to implement in other locations. Rather than reject this methodology based on a handful of experiences in one national forest, the NPS plans to be flexible in approach and implementation. The goal would be to mimic natural patterns of regeneration as much as possible both to replicate the conditions under which giant sequoia thrive and also to maintain the natural appearance of these areas. Thus, the NPS would continue to plan with the individuals, clumps, and openings approach and dismissed this alternative from further consideration.

Plant Understory Vegetation in Addition to Sequoia Mixed-Conifer Seedlings

The NPS considered whether planting of understory vegetation was necessary to achieve project goals and determined that native shrubs and forbs in the understory are expected to regenerate naturally absent intervention and doing so is not necessary to meet the purpose and need for action. Planting such vegetation would also increase the impacts to wilderness character and would increase project costs. Further, planting understory vegetation would result in increased competition and crowding for newly established seedlings—the avoidance of which is one of NPS' primary reasons for proposing to conduct this project as near to post-fire as feasible. The NPS therefore dismissed from further consideration an alternative that included planting understory vegetation due to duplication with other, less environmentally damaging, or less expensive alternatives considered and may inhibit the ability to resolve the purpose and need for action.

Inoculate Soils with Native Mycorrhizal Fungi Where Planting

The NPS considered whether inoculation of soils was necessary to further improve seedling survival (Fahey et al. 2012). Soil microorganisms across the landscape are diverse, and the NPS has not studied the arbuscular mycorrhizae in these groves. Soil sampling to assess baseline soil conditions and monitor changes over time may be considered as part of a long-term monitoring plan, but no soil amendments are being considered as part of this project at this time due to the high level of technical unknowns associated with what mycorrhizal species or other soil amendments would be appropriate and effective, whether growing and transporting them would be feasible, and the unknown risk of introducing harmful pathogens. This alternative was therefore dismissed from further analysis as beyond the scope of this environmental assessment.

Monitor Regeneration and Take Action at a Later Time if Necessary

Several commentors asked the NPS to wait several years to determine if more seedlings naturally regenerate; then plant seedlings if conclusively determined that sequoias and mixed conifers are not naturally regenerating.

The proposed action integrates field surveys, analyses, and a decision tree that would lead the NPS to forgo action in an area should data indicate natural recovery is likely (see description of Pre-Planting Site Assessments and Decision Tree). However, initial analysis of remote imagery has indicated that significant portions of the six groves targeted for survey and evaluation and potential planting may have such high tree mortality and limited natural seedling recruitment that they are not expected to recover on their own, and subsequent field sampling, observation, and analysis in four of the six groves supports this concern (two of the proposed areas have not yet been surveyed). See Background starting on page 3 and the Affected Environment for Sequoia Grove Recovery and Resilience starting on page 45 for more information on the conditions under which sequoia and mixed conifer forests naturally regenerate and how those conditions differ with what the NPS is finding through field surveys, observations, and analyses in the areas proposed for action.

Although these field surveys, observations, and analyses are based on less than three years of data—following precedent-setting impacts from wildfires throughout the Sierra Nevada—the NPS has little to no indication that conditions found within these forests will improve (i.e., substantially more sequoia and mixed conifer seedlings become established) in the next several years to such an extent that the NPS is confident no intervention is needed to avoid type-conversion of these forests, prevent an unacceptable loss of giant sequoias in the limited number of groves where they naturally occur, and restore a corridor of proposed fisher critical habitat. In other words, the lack of observed natural regeneration at this time in high severity burn areas of sequoias groves and mixed conifer forests, and the lack of a mechanism and limited research to suggest that more seedlings will occur in future years, suggests that further monitoring will not reveal changed conditions that indicate no intervention is necessary.

In fact, monitoring and delaying implementation by several years, as these commenters suggest, could threaten, or at least certainly impact, project success for several reasons.

First, as stated above, the first two to three years after fire is the natural window for sequoia re-establishment via seed. While the NPS expects that planting *seedlings*—rather than trying to re-establish trees directly from *seed* in the field—will extend the window in which sequoias can successfully establish because they will already have germinated and grown roots and shoots in the greenhouse, the NPS assumes that the seedlings would grow best under conditions that are most closely aligned with those the species has evolved to regenerate and establish within (i.e., post-fire conditions).

Second, as long as tree planting is delayed, shrubs and other vegetation can regenerate and grow within these areas without competition—decreasing the likelihood that tree seedlings can later outcompete the shrubs and increasing the likelihood that these areas will type-convert to shrub-dominated communities. Because of this competition, once shrub communities are established, successful re-introduction of sequoia and other conifer seedlings within these previously forested areas could require more intensive, pre-planting intervention, especially as these shrub communities alter the soil seedbank overtime (Coop et al. 2020; Coppoletta et al. 2016). See discussion on Alternatives Considered but Dismissed: Remove Existing Fuels either via Manual Thinning or Prescribed Burning Prior to Planting and Complete Site Preparation Including Herbicide and Crushing of Vegetation. The sooner tree cover can be established, the sooner forest will be re-established, and the sooner shrubs will return to a part of the community—not the dominant vegetation type.

Third, there is some additional urgency to establishing seedlings soon so that they have as much time as possible to grow to a size that can withstand a subsequent fire, whenever that occurs. This is particularly of concern if shrubs come to dominate these forests before trees fully establish such that fires increase in frequency and severity—a characteristic of shrub-dominated forests—and threaten the remaining grove and mixed conifer forests surrounding these areas. In addition, the longer the NPS delays implementation, the higher the risk of falling dead trees and the higher the threat to field workers.

In summary, the NPS believes that the current field surveys, observations, analyses, and decision tree are sufficient to prevent action being taken in areas that are likely to recover on their own. NPS data clearly indicate that the risk of regeneration failure is very high and waiting several years to monitor the fate of these areas is unlikely to generate additional information that would indicate grove recovery is likely without intervention. Furthermore, delaying the project timeline away from the natural regeneration ecology of giant sequoia and mixed conifer forest could reduce the success of planted seedlings and/or result in the need for more complex and intensive interventions, both of which lower likelihood of achieving purpose and need and may result in field conditions that are less safe for workers. The NPS therefore eliminated this alternative from further consideration as it would duplicate other, less environmentally damaging alternatives.

Chapter 3: Affected Environment and Environmental Consequences

This chapter provides a description of the existing conditions of specific resources that would be affected by the alternatives if implemented and the likely environmental consequences from implementing either the no action or action alternatives considered in this EA. The chapter is organized by resources/impact topics that were derived from internal and public scoping (see Issues) and includes: Sequoia Grove Recovery and Resilience, Fisher Habitat Connectivity, and Wilderness.

Sequoia Grove Recovery and Resilience

Affected Environment

Exclusion (i.e., agency suppression) of lightning-caused fire in these parks and surrounding lands began only 125 years ago, yet it has had long-term consequences for the fire adapted forests of the Sierra Nevada (Hagmann et al. 2021; Lydersen et al. 2019). Before the Castle and KNP wildfires, the legacy of suppression (or exclusion) had left affected forests with such high and contiguous fuel accumulations that many areas were no longer resilient to the fires with which they evolved (Hessburg et al. 2019). Fire exclusion resulted in dramatic changes to forest structure with a higher density of small trees (ladder fuels), shifts in species composition, and increases in stand densities. Factors driven by climate change, including extended periods of hotter, drier drought, and less snowfall (Diffenbaugh et al. 2015; Griffin and Anchukautus 2014) contributed to fuels accumulations from the die-off of millions of trees in the Sierra Nevada. These factors likely contributed to certain sequoia groves—including roughly 750 acres of the sequoia groves—burning at high severity during the Castle and KNP wildfires.

Though high severity fire fueled by high fuel loading occurred in areas where planting is being considered, the NPS has a long history of managing fuels for ecological benefit in sequoia groves under the parks' Fire and Fuels Management Plan (FFMP). As well, the NPS approved an action in October 2022 to reduce fuels in 11 sequoia groves where high fuel loading would put additional sequoias at risk should a wildfire occur. As well, actions including prescribed burning and understory thinning routinely occur in Yosemite National Park and are ongoing on the Sequoia and Sierra National Forests. Though all of these actions are occurring both temporally and spatially distant from the action areas, all such actions are expected to beneficially affect sequoia grove recovery and resilience on a regional scale.

Recent Fire Effects

The areas of the six sequoia groves where planting is proposed burned in contiguous patches of high severity fire—a number of which were identified by the RAVG analysis as being up to 300 acres in size. This high severity fire left these forests with very little litter or duff on the forest floor, little vegetative re-growth, and many standing dead trees that lack needles or leaves. Most areas experienced near total overstory tree mortality, and thousands of dead or dying trees remain standing, including hundreds of dead large sequoias. Little to no regeneration of any species were visible in the initial site assessments in Board Camp Grove during the spring in years one and two following the Castle Fire (A. Caprio and A. Bishop personal communication 2022). Seedlings that were present were primarily restricted to small patches in drainages or other protected microsites, and densities across groves were low. However surveys in 2022 and 2023 did find areas of dense sequoia regeneration in some portions of the proposed project area in Redwood Mountain Grove. Below are grove specific details for each area where action is being considered, including the total number of sequoias by class size that predated the Castle and KNP wildfires based on the Sequoia Tree Inventory (STI) conducted in the 1960s and 1970s[20] and (Hammon, Jensen, and Wallen Mapping and Forestry Services 1973; Soderberg et al. 2023 in review).[21]

Like affected sequoia groves, the fisher habitat corridor south of Redwood Mountain Grove also experienced severe fire effects, and while the focus of this impact topic is on sequoia grove recovery and resilience, fire effects in the fisher habitat corridor are mentioned briefly, due to their potential to influence future fire effects in the Redwood Mountain Grove, in particular. See Fisher Habitat Connectivity for more information on the fisher habitat corridor.

Sequoia Grove Post-Fire Conditions

Redwood Mountain

At 2,074 acres pre-fire, Redwood Mountain Grove is the second largest sequoia grove by area with the largest area of old growth and the most mature sequoias in the world (Willard 2000). It is located on lands managed by Kings Canyon National Park, Sequoia National Forest, and UC Berkeley (known as Whitaker Forest). The grove ranges from 5,000 feet to 7,200 feet in elevation (Willard, 2000). It is one of the only groves which has a maintained trail to and through the grove that is accessible by foot and stock. According to the STI, there were 95,939 living sequoias, with 17,052 over 1' dbh, 5,959 at least 4' dbh, 5,358 at least 5' dbh, and 2,697 over 10' dbh (Hammon, Jensen, and Wallen Mapping and Forestry Services 1973).

Four-hundred-ninety-three acres (24%) of this grove burned at high severity during the KNP Fire. Post-fire, USGS sampled mature sequoia mortality and seedling regeneration from a subset of the area rather than across the entire grove because of the grove area and time required to complete full inventory (Soderberg et al. 2023 in review). In fall of 2022, one season post-KNP Fire, samples in high-severity fire areas of Redwood Mountain Grove recorded 90.5% mortality of sequoias (Soderberg et al. 2023 in review). Despite some regeneration in the grove, the NPS did not observe sequoia and mixed conifer seedlings in patterns or densities similar to what has been observed after previous wildfires and prescribed fires within the high severity areas that are identified for further evaluation and possible replanting within this proposal. Sequoia seedlings measured within Redwood Mountain Grove in the first season post-fire had a mean of 4,266 sequoia seedlings per acre; well below the numbers typically seen after fire and associated with a stable sequoia population (Stephenson et al. 2023 in preparation) (see Giant Sequoia Ecology).

Suwanee

Suwanee Grove, at roughly 69 acres in size, is located within the Sequoia-Kings Canyon Wilderness and in the Marble Fork of the Kaweah River; reachable by a few miles of moderate cross-country travel (Willard 2000). It had older and larger than average sequoias, with the STI counting 653 live sequoias, with 196 over 4' dbh, 174 at least 5' dbh, and 77 over 10' dbh prior to the KNP Fire

---

[20] STI data is used in the following section as a comparison tool between all groves, as one consistent data set. Notably, Soderberg et al. 2023 in review includes STI data that is not directly comparable to these numbers because all groves have not yet been fully surveyed and there are differences in what tree sizes are counted and included.

[21] Notably, the percentage of large tree mortality exceeds the percentage of acres within these groves that burned at high severity because some tree mortality occurred across the groves, including in areas that burned at low- and moderate-severity and is not limited to areas that burned at high-severity.

(Hammon, Jensen, and Wallen Mapping and Forestry Services 1973). It also had enormous sugar pines (Willard 2000). Twenty-seven acres (39%) of this grove burned at high severity during the KNP Fire. Post-fire assessments conducted by Soderberg et al. (2023 in review) found 60.6% mortality of sequoias in the high severity areas. Post fire seedling densities for Suwanee in the fall one year after the KNP Fire were a mean of 4,763 sequoia seedlings/acre across the entire grove (not just in the high severity areas under consideration for planting). This value is well below the numbers typically seen after fire and associated with a stable sequoia population (Stephenson et al. 2023 in preparation) (see Giant Sequoia Ecology).

New Oriole Lake

New Oriole Lake Grove spans 15 acres within the Sequoia-Kings Canyon Wilderness (Willard 2000). The grove is off trail, less than a mile south of Oriole Lake Grove, in the Lake Canyon drainage on the East Fork of the Kaweah River. STI data showed 89 living sequoias, with 40 trees at least 4' dbh, 39 at least 5' dbh, and 15 at least 10' dbh (Hammon, Jensen, and Wallen Mapping and Forestry Services 1973). This grove is at the lower end of the sequoia range, at 5,900 feet in elevation (Willard 2000). Three acres (20%) of this grove burned at high severity during the KNP Fire. Post-fire assessments conducted in 2022 (Soderberg et al. 2023 in review) found 76.7% mortality of sequoias in high severity areas. Post fire seedling densities for New Oriole Lake were a mean of 6,875 seedlings/acre which is well below the numbers typically seen after fire and associated with a stable sequoia population (Stephenson et al. 2023 in preparation) (see Giant Sequoia Ecology).

Dillonwood

The Dillonwood Grove—which includes portions of the Garfield Grove located in the same drainage—totals 1,160 acres and covers lands managed by NPS and USFS on steep north and south facing slopes of Mt. Dennison in the Tule River (Willard 2000). Dillonwood Grove is thought to have some of the lowest elevation sequoias in the world at 4,600 feet (Willard 2000). STI data for Dillonwood Grove included 1,099 living trees, with 407 of at least 4' dbh (Hammon, Jensen, and Wallen Mapping and Forestry Services 1973). 102 acres (9%) of this grove burned at high severity during the Castle Fire. In August of 2021, all large giant sequoias immediately on the south side of Dennison Ridge were sampled in a 52-acre high severity area. Seventy-three of 88 large sequoia trees (83%) identified under the STI were dead, though five of these appear to have died or fallen prior to the Castle Fire (NPS unpublished data 2022). In the first-year post-fire, the NPS found extremely low regeneration—an average of 33 seedlings per acre—within a small, sampled portion of the Dillonwood Grove (NPS unpublished data 2022). Like Redwood Mountain Grove detailed above, this density of seedlings is far below the over 60,000 seedlings typically measured in the first-year post fire (Stephenson et al. 2023 in preparation) (see Giant Sequoia Ecology). During summer of 2023, mortality and seedlings will be more fully measured in a comprehensive stratified random sampling procedure targeting the high severity areas proposed for planting following the methods of Soderberg et al. 2023 in review.

Board Camp and Homer's Nose

Board Camp and Homers Nose Groves, totaling 48 and 119 acres respectively, are located in the John Krebs Wilderness on south-facing slopes in the South Fork drainage of the Kaweah River (Willard 2000). These groves offer a remote, extremely steep, off trail wilderness grove experience for those with a desire to explore off the beaten path. STI data from Board Camp showed 270 total living sequoias, with 99 (4 of them are double stemmed trees) sequoias at least 4' dbh, 83 (3 double stem) at least 5' dbh, and 29 (2 double stem) at least 10' dbh (Hammon, Jensen, and Wallen Mapping and Forestry Services 1973). STI data from Homer's Nose Grove showed 720 living trees, with 277 over 4'dbh (Hammon, Jensen, and Wallen Mapping and Forestry Services 1973).

Thirty-eight acres (79%) of Board Camp burned at high severity during the Castle Fire and sequoia mortality in high severity areas was 91.4% (Soderberg et al. 2023 in review); 52 acres (44%) of Homer's Nose Grove burned at high severity during the Castle Fire but this grove has not yet been surveyed so we do not known how many remain alive. Measured sequoia seedling densities within Board Camp Grove during year two post-fire had a mean of 651 seedlings per acre (Soderberg et al. 2023 in review). This seedling density is far below the roughly 14,000 seedlings typically measured two years post fire (Stephenson et al. 2023 in preparation) (see Giant Sequoia Ecology).

Current Sequoia Genetic Structure

Based on estimated and field measured losses of large reproductive sequoias within burned groves, these groves have lost genetic diversity since the fires, which translates into less capacity to adapt to a changing environment, disease, and pests. Genetic diversity (variation in genes), and the various ways that genes are expressed when interacting with the environment, are fundamental for species' resiliency in response to environmental changes such as novel diseases, insect pests, or changes in the abiotic environment. This is especially true for stationary organisms, such as sequoia and other plants, that cannot "move away" from an environmental stressor (DeSilva and Dodd 2021).

The genetic structure within and across sequoia populations is not static. Rather, it changes over time in response to gene flow, population reduction (i.e., bottlenecks), genetic drift (i.e., loss of genetic diversity in small, isolated populations subject to chance changes), and natural selection (Allendorf et al. 2007). Given the loss of large numbers of mature sequoia and limited regeneration that the NPS has documented in post-fire surveys, the project areas now contain smaller populations of sequoia, with lower genetic diversity, that are more susceptible to genetic drift moving forward (Aitken and Whitlock 2013).

In addition, the groves within the project areas likely lost local genetic structure during the Castle and KNP wildfires. Giant sequoia groves have local genetic structuring, where neighboring trees are more genetically similar than trees further away in the grove. This occurs because most genetic exchange from seeds and pollen occurs at a small scale (approximately 200-meter radius) (DeSilva and Dodd 2021). Due to a combination of large areas with loss of mature trees over many hectares and poor regeneration, the NPS assumes this local structure has likely been at least partially diminished in the project areas in comparison to pre-fire conditions (DeSilva and Dodd 2021).

Finally, the climate in the Southern Sierra has warmed 1.2 degree Celsius since mature trees germinated 1,000-3,000 years ago and is predicted to warm between 1.5-4.8 degrees Celsius by 2100 (Cayan et al. 2008; Gonzales et al. 2018). Coupled with predicted reductions in snowpack (Sun et al. 2019) and earlier snow melt (Schwartz et al. 2017), conifer trees will likely experience less available water and increased evapotranspiration in the future (Thorne et al. 2015). These rates of change are anticipated to outpace the ability of trees to shift locations to track their environment (Aitken et al. 2008; DeSilva 2020). In addition, long generation times and limited genetic exchange through pollen and seed dispersal are likely inadequate to facilitate adaptation to a changing environment through natural selection at the rate of environmental change such as drought or novel pests or diseases (Aitken et al. 2008). Their extreme longevity means that today's mature trees germinated in much different environmental conditions, and the species has known low diversity from a past bottleneck and the small number of groves and trees remaining range-wide (Fins and Libby 1982; De La Torre et al. 2021). Giant sequoia in Sequoia and Kings Canyon National Parks showed physiological stress during recent hot drought (Stephenson et al. 2018; Baeza et al 2021) and may lack genes that code for drought tolerant traits (De La Torre et al. 2022). Together, these factors likely limit genetic diversity and make the grove areas more vulnerable to further impacts in a changing environment. Despite the above, conditions in the project area are projected to be suitable for conifer forests in the future; there is no indication that sequoia would not have continued to persist in these forests if high fuel loading in the affected groves had not led to the high severity fire effects. In fact, although over 100 million trees died in the Sierra Nevada during the 2012-2016 drought, there was limited mortality of mature sequoia trees attributed to drought (Nydick et al 2018). Less than 40 mature sequoias across the entire range were recorded as dying from drought related mortality sources during the 2012-2016 drought—demonstrating their resistance to this event in comparison with all other conifers.

Alternative 1: No Action

Direct and Indirect Effects—Sequoia Grove Recovery and Resilience

Sequoia Grove Recovery

While the extent of high severity fire in these sequoia groves is unprecedented, the NPS is using the best available science to assess adequacy of regeneration. Assuming that the NPS data collection indicates that there is inadequate regeneration in the affected grove areas to restore a self-sustaining grove, the No Action Alternative, has a greater chance of resulting in the long term loss of sequoia groves compared to other alternatives. If, as data suggest, regeneration is ultimately insufficient to restore a self-sustaining grove. This could result in up to roughly 700 acres of giant sequoia grove footprint lost, or partially lost. This acreage is important for several reasons. First, for some groves (Board Camp, Homer's Nose, Suwanee) the acreage potentially lost represents over a third of the total grove area. Loss of this much area within a grove, again were it to occur, would likely decrease each of these groves' ability to withstand and recover from future impacts such as fire, drought, and disease, since a smaller area dominated by sequoias would remain. Second, as discussed earlier, genetic diversity within sequoia groves changes across space within a grove, so lost grove area represents loss of genetic diversity. In other words, each grove is important and maintaining as much grove area as possible within each grove is important for both grove and species level resilience.

For example, the loss of acreage within in Dillonwood Grove (even though it would be the smallest percentage of grove lost) would remove connectivity between Dillonwood and Garfield Groves. Furthermore, mortality of reproductive sequoia and inadequate regeneration to replace dead sequoias across large areas would likely result in type conversion of these acres to shrublands (Guiterman et al. 2022), and the vegetative state change characterized by loss of giant sequoia would be expected to be persistent and therefore continue to adversely affect sequoia grove recovery into the future (Coop et al. 2020; Guiterman et al. 2022). See Table 5 which provides a breakdown of grove specific loss. Additionally, the losses in these groves are part of the greater range wide losses that occurred over the 2020 and 2021 fire seasons—estimated to represent a loss of 13-19% of all giant sequoias in the world.

Future species composition in areas where regeneration is in fact insufficient to restore a self-sustaining population of sequoias absent intervention would be expected to be similar to those described in the Affected Environment, with sequoias and mixed conifer species largely absent (Coppoletta et al. 2016). Under such a scenario, full shrub dominance would increase over time with each fire cycle, further increasing fuel continuity and converting former grove footprints to fire-initiated shrub-dominated communities long-term (Coppoletta et al 2016; Coop et al. 2020; Tepley et al. 2016). Likewise, the total number of future large sequoias within the grove would be expected to either remain reduced (due to of large areas with regeneration failure) or further decline depending on fire effects from reburn and other impacts to large sequoias going forward (Coop et al. 2020).

Table 5: Estimated Acres of Sequoia Groves Potentially Lost in the Long-Term Under Alternative 1 and the Percent of the Groves these Acres Represent[22]

Grove Name	Grove Area Pre-Fire	Large (<4' dbh) Trees Lost	Grove Area Potentially Lost	Precent of Grove Potentially Lost
Dillonwood	1,160	180	102	9%
Homer's Nose	119	109	52	44%
Board Camp	48	79	38	79%
New Oriole Lake	15	6	3	20%
Suwanee	69	54	26	38%
Redwood Mountain	2,074	1,030	493	24%
Total	3,485	1,457	714	N/A

Sequoia Grove Resilience to Future Change

The NPS anticipates that were the reduction of total grove area, or failure to replace the total number of sequoias lost in these areas as described above ultimately to occur, it would in turn adversely impact sequoia grove resilience to future change in three primary ways.

First, a diminished grove footprint would mean fewer trees occupy a reduced and less diverse geographic space across which they can respond to potential environmental changes or random events. For example, outside of drainages, much of the Board Camp Grove area currently suffers from both high mortality and low seedling regeneration. If no action were taken, the grove is expected to remain confined to drainages. Were these drainages to experience an environmental stressor in the future—such as an extreme flood, another high severity wildfire, or a moisture mediated pathogenic fungus—the remaining diminished grove would be at greater risk to further loss or potential elimination.

Second, loss of grove area is also an indicator that the grove has lost genetic diversity. Under the No Action Alternative, the genetic diversity of the groves would remain as they are today, with an assumed reduced diversity compared to pre-fire conditions and a corresponding greater risk of decline in the face of future environmental changes and genetic drift described above in affected environment.

---

[22] Killed sequoias were estimated using data from Stephenson and Brigham (2021) and Soderberg et al. (2023 in review). Because not all mortality surveys are complete for all proposed planting areas, and in an effort to provide consistent information across all groves, the number of sequoias over four feet in diameter in each planting area was estimated by multiplying the area in acres by the average large sequoia density across all sequoia groves in the parks from Stephenson and Brigham 2021. This estimated number of large sequoias in the planting area was then multiplied by the average mortality rate in the high severity areas in the four groves proposed in this project that have been surveyed by Soderberg et al. (2023 in review) in order to obtain an estimated number of large sequoias killed per proposed planting area. Although consistent, these estimates may be a bit of an underestimate of large sequoia loss. For example, actual survey data for Board Camp Soderberg et al. (2023 in review) found 151 sequoias, over 3 feet in diameter, that were killed; in the New Oriole Lake planting area, 12 sequoias over 3 feet in diameter were killed.

Third, the long-term (centuries if not longer) loss of hundreds of reproductive sequoias (see estimates in Table 5) would reduce regeneration potential for a period of centuries or more. Without a soil seedbank, sequoia rely on cones in the canopy to scatter seed across an area after fire. This aerial seed bank also acts as a bet-hedging strategy; if a seedling cohort fails, the trees would have another opportunity after each fire that occurs during their immense lifespan. Therefore, under no action, the future of the six grove areas proposed for planting would be wholly dependent on this one seedling cohort established post-fire that NPS has found to be likely inadequate in many locations.

Although cones with fertile seeds have been observed on sequoias as young as ten years old, sequoias reach maturity with full cone crops at around 150-200 years (Weatherspoon 1986). An individual large sequoia tree can hold as many as 30,000 cones, with each cone having an average of 200 seeds per cone which are held until the right conditions for germination occur (Hartesveldt et al. 1975; Harvey et al. 1980; Weatherspoon 1986). Given the low germination rate of seeds (average 22.5%; Stark 1968) and the high mortality of seedlings (as high as 98% within the first two years; Hartesveldt and Harvey 1967) the long-term absence of large living sequoias, as is more likely to occur under Alternative 1, would result in continued low regeneration potential of these sequoia groves. Again, should this occur, it would adversely affect each grove's ability to respond to disturbance and environmental change. Based on NPS' understanding of sequoias and conditions in these groves, this diminished resilience would effectively be permanent.

Future Fire Effects

Giant sequoias are adapted to frequent, low to mixed severity fires. Fire history studies in sequoia groves show a fire return interval prior to European colonization and subsequent fire suppression of 6 to 35 years (Swetnam 1993; NPS 2022). Since 2015, the NPS and others have seen wildfires burning with such high intensity that they can kill large, mature giant sequoias. Thus, future fire effects are critical to understanding how groves would respond under different alternatives. Future large areas of high severity are likely to result in additional losses of mature giant sequoias and kill any sequoia seedlings (for sequoia losses in high severity fire, see Shive et al. 2022).

Under the No Action Alternative, the continued absence of forest cover and vigorous re-establishment of shrubs is more likely to result in an adverse vegetation driven shift from a mixed severity fire regime that is natural in sequoia groves to a high severity fire regime typical of shrub-dominated landscapes (Coop et al. 2020; Coppoletta et al. 2016). In the absence of vigorous competition from conifers, shrubs would be expected to grow together in continuous patches that, combined with the high fuel loads from dead trees, would reburn at high severity (Lyderson et al. 2019; Nemens et al. 2022). The resulting change in fire regime would result in a feedback loop that further drives conversion from forest to a fire-initiated shrub-dominated landscape (Coop et al 2020). It is anticipated that these areas may have a greater likelihood of experiencing high severity reburn within 7-20 years while giant sequoia seedlings and saplings that have successfully regenerated are still vulnerable to wildfire. Should this occur, it would perpetuate shrub dominance by killing vulnerable saplings and would expose/threaten the surrounding groves and forests to high severity fire (Prichard et al. 2017; Stevens-Rumann and Morgan 2019; Coop et al. 2020).

Like sequoia groves, the vegetation composition in the fisher habitat corridor adjacent to Redwood Mountain Grove is also anticipated to shift toward a fire-initiated shrub-dominated landscape which would adversely affect forest recovery. While such a transition would not affect all groves, this shift would be anticipated to increase contagion between large contiguous shrub-dominated landscapes increasing fire frequency and severity of reburn in Redwood Mountain Grove due to its proximity to the proposed fisher habitat planting area. Such a transition would therefore be anticipated to result in adverse fire effects in Redwood Mountain Grove in particular.

Genetic Structure of Sequoia Groves

As discussed in the affected environment, the genetic structure in affected sequoia groves has already been modified from its pre-fire conditions. However, the living trees that remain within and adjacent to the proposed planting areas would retain their genetic diversity and continue to contribute to the future genetic structure, and some of the seedlings that have naturally regenerated following the Castle and KNP wildfires could survive to reproductive age and contribute to the genetic variation within the grove as well (i.e. not all the genetic variation in the trees killed by the fires has been lost). That said, under the No Action Alternative, the existing genetic diversity, which is less diverse than was there before the wildfires, would continue and groves would remain at increased risk of genetic drift (Allendorf et al. 2007), particularly if high severity fire threatens trees within the remaining portions of the groves or another natural event wipes out the isolated populations of tree seedlings that are currently regenerating. Under Alternative 1, the NPS therefore anticipates genetic structure of sequoia groves to be adversely affected to a greater degree than other alternatives considered.

Cumulative Effects —Sequoia Grove Recovery and Resilience

Following a similar regiment to seed collection actions being proposed under the EA, the NPS collected sequoia cones in 2021, 2022, and 2023 in order to protect the diversity of sequoias through seed banking and to maintain an option to support planting sequoia seedlings were a decision made to replant proposed areas. Because the NPS collected limited quantities (<10% of cones from any population) of seed following best management practices, these collections would not cumulatively affect sequoia grove recovery and resilience (see Seed Collection and Treatment in Chapter 2, page 30 for further information).

Actions implemented under the FFMP (NPS 2003)—such as suppression of wildfire or monitoring and managed use of wildfire—may influence sequoia mixed conifer recovery and resiliency in the project areas (NPS 2003). Although, fuel levels are not anticipated to be high enough to carry a high-severity fire in these areas for five to seven years post-fire, suppression or managed wildfire use may be necessary in 7-15 years, as fuel loads increase, and wildfire returns to the project areas. Continued suppression over time could adversely affect overall resiliency of recovering areas (if any) and lead to adverse conditions which caused the original degradation (high fuel loading). On the other hand, the decision to not suppress wildfire or inability to manage wildfire entering these areas when seedlings are very young could lead to loss of some, if not all, of the few seedlings that have naturally become established.

Alternative 2: Replant Seedlings Using Seed Propagated from Seed Collected from both the Local Genetic Community and Other Source Populations (Preferred Alternative)

Direct and Indirect Effects—Sequoia Grove Recovery and Resilience

Sequoia Grove Recovery

If, as data suggest, natural regeneration is ultimately insufficient to restore stable sequoia populations, replanting portions of up to six affected sequoia groves is expected to restore seedlings to roughly 700 acres of affected groves at densities expected to direct the trajectory of severely burned areas toward forest recovery (a sustainable population) of their pre-fire conditions.

If, as anticipated, planting is successful, Alternative 2 has a greater chance of resulting in beneficial effects to sequoia grove recovery than Alternative 1. Once seedlings were established, the NPS anticipates that natural and dynamic post-fire recovery processes would continue, and the seedlings would mature over a period of centuries, such that large sequoias would be the dominant feature within most, if not the entire, grove footprint. Overall, the NPS anticipates that grove area and large sequoia density would largely be restored to pre-fire conditions in each of the six groves and that these groves would continue to naturally adapt to future conditions.

Sequoia Grove Resilience to Future Change

Given the overall low genetic diversity of this species and the anticipated future changes due to climate change and other stressors, increasing the genetic diversity of local populations, as proposed in Alternative 2, is expected to beneficially affect the overall ability of the species to persist in the long term for several reasons when compared to other alternatives considered.

Some sequoia groves in more arid environments show evidence of adaptations to summer temperatures and precipitation (DeSilva and Dodd 2020; De La Torre et al. 2021), suggesting that groves which are currently more arid have genetic adaptations to improve their survival and fitness to higher temperatures and drought. Based on this finding, De La Torre et al. (2021) concluded that some groves, including Redwood Mountain Grove, would need increased genetic diversity to adapt to a warming climate. In addition to selecting for adaptation to drought, adding genetic diversity, particularly to small groves, would provide more options for sequoias to adapt to unforeseen factors in the future (Broadhurst et al. 2008; Aitken and Bemmels 2016). Based on these studies, the ecology of conifers, and their responses to past environmental changes, the NPS expects that increasing genetic diversity would boost overall grove resilience to future environmental changes including potential new pathogens, altered wildfire regimes, increasing temperatures, and hotter drought (see Appendix E: for more information).

In addition, regardless of the seed source, the restored grove would increase the areas across which each grove could recover from environmental events (e.g. extreme flooding, the next high severity wildfire, or pathogens) because groves that occupy a larger area with more varied topography and microhabitats are both buffered by size and variable conditions from being lost due to a single event or stressor. Similarly, over a period of many decades, Alternative 2 is anticipated to result in observed re-establishment of reproductive sequoias, restoring the regeneration potential to the affected groves to a greater degree than Alternative 1 (and equivalent to Alternative 3). As the trees mature, they would create greater quantities of cones and seed and across a broader geographic area, bolstering their ability to respond to disturbance and environmental change in the future.

Future Fire Effects

As the standing dead trees fall and shrubs and herbaceous plants become established, there would be an increased potential for reburn at high severity, which could kill planted seedlings and those naturally regenerating (Coop et al 2020; Coppoletta et al. 2016). Planted seedlings' risk to reburning would be expected to peak between roughly 7 and 20 years, as fuels accumulate but a large percentage of saplings are not yet able to survive wildfire, depending on fire intensity, to ensure grove recovery (A.Caprio personal communication 2022; York et al. 2021; Coppoletta et al. 2016). Similar to alternative 1, future fire effects are not fully known due to the unprecedented scale of high severity fire experienced by these groves and associated unknowns with how fuels will accumulate post-fire. However, under Alternative 2, the NPS anticipates long-term re-establishment of tree cover through replanting such that established trees would shade out some of the shrub cover and return fire and fuel dynamics to those of the fire return interval characteristic of sequoia groves. This would result in more beneficial and natural fire effects when compared to Alternative 1.

Sequoia Grove Genetic Structure

Under Alternative 2, up to 20% of nonlocal genotypes would be introduced into a population during replanting. Since the remaining 80% of seedlings would be sourced from the genetic neighborhood and some of the genotypes and genetic structure of the original groves are retained through the natural regeneration, the risk of swamping (loss of genetic diversity currently existing in the population) is low (Aitken and Whitlock 2013) and is not expected to affect sequoia grove genetic structure. Retention of original grove genetic diversity and use of 80% locally sourced seedlings means that any unique phenotypes such as twisted bark—if any such trees were present and survived the fire—would likely be retained since most of the genetic material would still be local in origin and some natural regeneration has occurred and would continue to occur from any remaining live large sequoias in the groves.

The main concern when moving individuals to a new habitat is outbreeding depression—where offspring are less well adapted to the site because of long-divergence or poor adaptation to local conditions (Aitken and Whitlock 2013). However, the NPS would use seeds sourced from the southern range of giant sequoia, which show genetic evidence of not being long diverged. In addition, adding no more than 20% from non-local groves and using seeds sourced from known high-diversity groves, would provide a buffer against non-drought stressors (Broadhurst et al. 2008), increase the probability of tree survival and therefore project success.

Regardless of NPS action or inaction, the NPS anticipates that the genetic structure of the groves within the action areas will change in the future in response to immigration, emigration, and selection (Allendorf et al. 2007). There is little risk of Alternative 2 negatively impacting population fitness as those individuals not adapted to future stressors will perish and fail to pass their genes to the next generation. Based on NPS understanding of sequoia genetics and outbreeding depression, the NPS concludes that adding 20% nonlocal genotypes would limit potential risks and maximize adaptive benefits to recovery and resilience of giant sequoia groves, which would increase the potential for long-term success and tree survival (see also Appendix E:).

Cumulative Effects —Sequoia Grove Recovery and Resilience

Actions affecting sequoia grove recovery and resilience would be those described in the Affected Environment and Alternative 1; however, the decision to either suppress wildfire, allow fire to burn, or implement other fire management activities when seedlings are young would affect planted seedlings in addition to all other vegetation and would in turn influence long-term recovery and resilience of these groves specifically. On a parks-wide and regional scale, this alternative would be expected to cumulatively contribute to beneficial effects to sequoia grove recovery and resilience from ongoing Emergency Fuels Reduction within SEKI Sequoia Groves, and other similar actions being undertaken by partner agencies and organizations.

Alternative 3: Replant Seedlings Propagated from Seed Collected from the Local Genetic Community of Each Replanted Area

Direct and Indirect Effects —Sequoia Grove Recovery and Resilience

Sequoia Grove Recovery

Like Alternative 2, replanting the six affected sequoia groves, if, as anticipated, planting is successful, would restore seedlings to roughly 700 acres of affected groves at densities expected to direct the trajectory of severely burned areas toward forest recovery to their pre-fire conditions, beneficially affecting sequoia grove recovery to a self-sustaining population. Once seedlings were established, the NPS would anticipate that natural and dynamic post-fire recovery processes would continue, and the seedlings would mature over a period of centuries, such that large sequoias would be the dominant feature within most, if not the entire, grove footprint. Overall grove area and large sequoia density would largely be restored to pre-fire conditions in each of the six groves that could change in response to future natural processes; the NPS anticipates that the population would be self-sustaining into the future.

Sequoia Grove Resilience to Future Change

Under Alternative 3, replanted seedlings would be sourced from the groves within a local genetic neighborhood only. Sequoia grove resilience to future environmental changes would be beneficially affected to a greater degree over Alternative 1 in two main ways, but remain diminished when compared to Alternative 2, as further described below.

First, should planted tree seedlings successfully become established as expected, they would functionally replace those sequoias lost in high severity fire. The restored grove would increase the areas across which each grove could recover from environmental events (e.g. extreme flooding, the next high severity wildfire, or pathogens) because groves that occupy a larger area with more varied topography and microhabitats are both buffered by size and variable conditions from being lost due to a single event or stressor.

Second, over a period of a many decades, Alternative 3 is anticipated to result in observed re-establishment of reproductive sequoias, restoring the regeneration potential to the affected groves to a greater degree than Alternative 1. As the trees mature, they would create greater quantities of cones and seed and across a broader geographic area, bolstering their ability to respond to disturbance and environmental change in the future.

While grove resilience would be improved to a greater degree than Alternative 1, long-term resilience to future change would remain diminished when compared to Alternative 2 due to seed being sourced only from trees that are already genetically connected (from the same genetic neighborhood). This is primarily because, while giant sequoia likely has local adaptation to local climate, future conditions are expected to be substantially different from the climate 1,000 to 3,000 years ago, when today's mature trees germinated. Sourcing seed only from the local genetic community under Alternative 3 would result in seedlings adapted to a climate that has now changed several degrees Celsius (see Affected Environment). Therefore, the overall genetic variation available to respond to any future environmental stressors would remain as it is today.

Future Fire Effects

Future fire effects under this alternative would be the same as in Alternative 2.

Sequoia Grove Genetic Structure

Under Alternative 3, genetic structure of the impacted groves would be increased over the No Action Alternative through addition of material from the genetic neighborhood (see Alternative 2: Replant Seedlings Using Seed Propagated from Seed Collected from both the Local Genetic Community and Other Source Populations (Preferred Alternative) for details) and would therefore likely have similar—though not exactly the same—genetic makeup as the groves being replanted. The resulting genetic structure would most closely match the pre-fire condition as planted seedlings would contain some of the genetic diversity lost through the destruction of large sequoia trees but is still available in the neighborhood. Since these groves are connected through gene flow already, this alternative does not introduce genetic material that could not have otherwise occurred naturally had groves remained intact. Rather, some of the diversity that may have been lost through the impacts of the fire would be returned but likely not all because of the local post-fire genetic structure of giant sequoia that was present in the grove would not likely be entirely replicated by inclusion of seeds from other local groves (see Affected Environment).

Cumulative Effects —Sequoia Grove Recovery and Resilience

Cumulative effects would be like those described in Alternative 2.

Fisher Habitat Connectivity

Affected Environment

This section of the analysis focuses on the proposed 485-acre fisher habitat corridor, rather than all areas where planting is proposed, because Sequoia Grove Recovery and Resilience is analyzed under the previous section and impacts from project related to disturbance to wildlife are evaluated in issues considered but dismissed.

Fisher (*Pekania pennanti*) are medium-sized carnivores within the Mustelidae family (the "weasel family") which historically inhabited a broad swath of the forested landscapes within North America (Lofroth et al. 2010). While not exclusively dependent on old-growth forests, fishers are associated with many of the characteristics found in mature forests such as dense canopy cover, large diameter trees, and fine-scale habitat features created over time by decay (e.g., cavities in trees; Weir et al. 2013; Purcell et al. 2009; Green et al. 2019).

The United States Fish and Wildlife Service (USFWS) listed the Southern Sierra Nevada distinct population segment of the fisher as endangered under the Endangered Species Act (ESA), effective June 15, 2020 (USFWS 2020). Some primary causes of endangerment noted at the time of listing included "loss and fragmentation of habitat resulting from high-severity wildfire and wildfire suppression (i.e., loss of snags and other large habitat structures on which the species relies), climate change, and tree mortality from drought, disease, and insect infestations" (USFWS 2020).

This southernmost population within the Sierra Nevada is also isolated from any extant populations to the north (Zielinski et al. 2005). Although fishers and the forest types in which they occur in the Sierra Nevada evolved with fire as a natural disturbance, the general pattern of occurrence was frequent, low to moderate severity fire with occasional patches of high severity (as reported for mixed conifer and yellow-pine forests; Safford and Stevens 2017). However, more than a century of fire exclusion, more frequent drought, and a warming climate are now contributing to wildfires that are larger in scale and severity than would have occurred historically (e.g., Meyer et al. 2022).

Landscape level habitat models for this region represent fisher habitat in a roughly north-south collection of large but narrow habitat patches ("cores") over elevations ranging from approximately 3,000 – 9,000 feet and which are separated by major river canyons including the Merced, San Joaquin, Kings, and Kaweah Rivers (Zielinski et al. 2005; Spencer et al. 2016). Habitat types of relatively high value for fisher in this area include Montane Hardwood-Conifer, Ponderosa Pine, Sierran Mixed Conifer, and White Fir forests (based on the California Wildlife Habitat Relationship (CWHR) systems) (R. Green personal communication.; https://wildlife.ca.gov/Data/CWHR/Wildlife-Habitats). Spencer et al. (2016) mapped the predicted fisher distribution in this area as a series of seven core areas (six of which are currently occupied) and six corridor areas, as consistent with data on fisher space-use patterns and landscape genetic patterns. While fishers are thought to be able to move and establish home ranges relatively freely within habitat cores, dispersal between them is thought to be relatively rare, especially by females (Tucker 2013; Tucker et al. 2014).

Fisher Habitat Status, Trends, and Fire Effects

Over much of the Sierra Nevada, the fisher's mixed-conifer forest habitat is outside the natural range of variation (NRV) due to historic logging, fire suppression, and climate change (Safford et al. 2012; Mallek et al. 2013; Safford and van de Water 2013). This may elevate the risk of forest loss and fragmentation by large, severe fires and other disturbances (Miller et al. 2009; Churchill et al. 2013) and consequently, at least the temporary loss and fragmentation of fisher habitat (Scheller et al. 2011; Spencer et al. 2016). Actions implemented under the Fire and Fuels Management Plan (FFMP) (NPS 2003)—including both continued suppression of wildfire or monitoring and managed use of wildfire—as well as Emergency Fuels Reduction within SEKI Sequoia Groves, will continue to influence fisher and fisher habitat in the proposed action area and at a landscape scale (NPS 2003).

Between 2012 and 2015, a widespread drought led to massive tree mortality across Sequoia and Kings Canyon, and over 140 million trees may have died in California, including large areas in the lower and mid elevation conifer zones in the parks. Greater than 20% of trees may have died in the lower elevation mixed-conifer zone with mortality decreasing with an increase in elevation (Stephenson et al. 2018). An unknown number of tree mortalities continue as bark beetles kill trees in the Sierran mixed conifer and subalpine forests within the parks. Thompson et al. (2020) described the amount of reduced fisher habitat available as a result of these events. Current habitat conditions will continue to change as forest dynamics are altered by climate change and subsequent tree mortality events—including high severity fire.

Though sequoia groves are a subtype of the mixed conifer forest fisher rely on, there has been limited study on the specific use of sequoia groves by fisher—although current studies in both Yosemite National Park and Sequoia-Kings Canyon National Parks hope to provide new insights in the next year or two. In the southern Sierra Nevada, fishers have been detected in and around sequoia groves using non-invasive methods (remote cameras, track plates), and on-going studies using GPS collars have documented some fisher home ranges which encompass all or portions of individual sequoia groves (Green unpublished data 2023). While the NPS expects that the severely burned condition of groves proposed for replanting has also resulted in reduced fisher habitat value of these roughly 700 acres, female fishers in this region have home ranges that are approximately 1,800 to 2,500 acres in size; the NPS therefore assumes they may be able to navigate around severely burned patches in areas where a network of suitable live forest remains (R. Green personal communication April 2023). Therefore, despite the extent to which high severity fire affected sequoias in these groves, denning, foraging, resting, or dispersal habitat for any fisher who continue to occupy these areas remains available in surrounding areas (R. Green personal communication April 2023).

In contrast to sequoia groves, the NPS expects that the loss of suitable habitat in the severely burned 485-acre proposed critical habitat corridor will be a barrier to fisher movement across the landscape. This concern stems primarily from the size of the burned patch and the context of this area in relation to remaining green forest patches located on either side and that fisher continue to use. Currently the corridor area has very little litter or duff on the forest floor, limited or spotty vegetative re-growth (varies across the landscape), and most standing dead trees lack needles or leaves. This area, unlike other mixed conifer areas that burned at moderate to low severity, currently provides very little habitat value for fisher. While many burned snags remain standing, many of these do not retain suitable microsites (e.g., cavities), and they occur in relatively open areas which may be risky for fishers to use and are likely very hot in summer.

To consider where the KNP Fire may have impacted fishers and fisher habitat within the boundaries of Sequoia and Kings Canyon National Parks, the NPS quantified and compared the extent of potential fisher habitat within the parks pre-fire with how much occurred within the KNP footprint (in the parks) in a GIS analysis. Specifically, the NPS combined available spatial data into two categories: 1) "reproductive fisher habitat", and 2) "all fisher habitat". The basis for the fisher reproductive habitat category was the post-drought fisher reproductive habitat model (CBI 2021), but to be sufficiently inclusive, the NPS also incorporated the slightly older pre- and post-drought denning habitat models from CBI. The goal of the "all habitat" category was to represent any areas where fishers might forage, travel, or disperse, as well as core resting and reproductive habitat; thus, for this broad category, the NPS included all data in the reproductive habitat category plus fisher foraging and high-quality habitat from CBI (2015).

Using this approach, the NPS calculated 102,009 acres of modeled "reproductive fisher habitat" in the parks, with 43,733 acres in the park portion of the KNP Complex footprint (42.9% burned). The NPS calculated 229,983 acres of modeled "all fisher habitat" in the parks, with 60,183 acres in the park portion of the KNP Complex fire footprint (26.2% burned). In addition, Meyer et al. (2022) used a circuit-scape modeling approach to identify areas, including the 485-acre proposed fisher critical habitat corridor located in core area 3 proposed for replanting under this EA[23], where habitat connectivity for fisher has been severely reduced or constricted by recent high severity fire within the southern Sierra Nevada. These "pinch points" typically occur in areas where high severity fire has created large areas of open land (i.e., little to no live tree cover) in between remaining green (or predominately green) forest. Notably, fishers were detected in the area proposed for replanting just prior to the KNP Fire and are known to currently occur in remaining intact adjacent green forest on either side (Green unpublished data 2023).

Alternative 1: No Action

Direct and Indirect Effects – Fisher Habitat Connectivity

The No Action Alternative would leave the identified vital 485-acre fisher habitat corridor vulnerable to conversion from its pre-fire forested state to a fire-initiated shrub-dominated

---

[23] Total critical habitat acreage is subject to change once critical habitat designation is finalized.

community in the long term. Though the acreage lost under Alternative 1 represents 3% of the over 12,000 acres of fisher habitat lost to high severity during the KNP wildfire, the context of the area within the matrix of remaining habitat, combined with the size and continuity at which this forest patch burned, means that lack of forest recovery in this particular area would continue to restrict fisher movement across the landscape.

Under Alternative 1, type conversion is likely in the middle of large heavily burned patches where few (or no) live conifers remain to provide a seed source. While some burned snags would remain standing in the short-term (a period of 10-15 years or more depending on species), many of these have limited value for resting or denning as they do not retain suitable microsites (e.g., cavities), they occur in relatively open areas which may be risky for fishers to use and very hot in summer, and regardless, the snags will eventually fall. While the resulting logs would provide some cover for fishers and their prey in this corridor, a landscape dominated entirely by burned logs and shrubs does not meet all the habitat requirements for fishers to meet daily survival needs, successfully reproduce, and/or safely disperse. As well, shrub dominance could contribute to future high severity fires due to the combination of heavy fuel loads and high shrub flammability. Such large unforested patches on the landscape could become barriers to movement for fisher between forested patches remaining on either side, further restricting dispersal options for young animals and limiting gene flow in a population that already has limited genetic diversity.

In the long term, the NPS expects that implementing Alternative 1 would be more likely than the action alternatives to result in this vital fisher habitat corridor having limited or lower suitability value to fishers due to lack of high-quality standing rest and den structures and limited availability of key high calorie prey (e.g., tree squirrels such as Douglas squirrel, Humboldt's flying squirrel). While the forest-shrub edge areas may continue to provide some opportunities for foraging and travel, the central areas may become barriers to movement.

Specifically, fishers may be reluctant to explore or cross large areas with limited tree cover to get to other remaining suitable green forest on the other side – thus limiting dispersal options for young fishers, mating opportunities for adult male fishers, and foraging opportunities for fishers in general. Additionally, if fishers do venture into these more open or shrub-dominated habitats during dispersal or other activities, they may be at increased risk of predation by larger carnivores (e.g., mountain lion, bobcat) due to limited safe escape routes or resting structures. This is especially relevant in the proposed action area because suitable green forest for fishers is currently still available on either side of the area proposed for re-planting conifers and fisher are known to occur in these surrounding areas (Green unpublished data 2023.)

While resource managers and researchers are still learning about fisher use of the landscape under postfire conditions, findings from Thompson et al. (2021) and preliminary findings from on-going work in the southern Sierra Nevada (Green unpublished data 2023) suggest that large open and/or shrub-dominated areas within relatively recent fire footprints tend to be used infrequently, if not avoided, by fishers while patches of low, moderate or mixed-severity fire, "fire skips," and/or areas with concave topography in fire footprints are more likely to correspond with use. Should habitat suitability remain low and this area remain a barrier, it would adversely affect fisher habitat connectivity for the foreseeable future.

Cumulative Effects – Fisher Habitat Connectivity

Actions implemented under the Fire and Fuels Management Plan (FFMP) (NPS 2003)—such as suppression of wildfire or monitoring and managed use of wildfire—would continue to influence fisher and fisher habitat in the proposed action area (NPS 2003). Although fuel levels are not anticipated to be high enough to carry a fire in these areas for five to seven years post-fire, suppression or managed wildfire use may be necessary in 7-15 years, as fuel loads increase and wildfire returns to the project areas (L. Mathiesen, personal communication March 2023).

Continued suppression over time would adversely affect overall habitat suitability by maintaining overly dense forest stands which could ultimately lead to conditions which caused the original degradation (high fuel loading and subsequent high severity fire effects). On the other hand, the decision to not suppress wildfire entering these areas, or to implement other fire management activities such as prescribed burning, when seedlings are very young could lead to the loss of some, if not all, of the few seedlings that have naturally become established, further reducing the likelihood that a mixed conifer forest will recover in the area. When considered together this alternative has a greater likelihood of cumulatively contributing to adverse effects on habitat connectivity .

Alternative 2: Replant Seedlings Grown from Seed Collected from the Local Genetic Community and Other Source Populations (Preferred Alternative)

Direct and Indirect Effects – Fisher Habitat Connectivity

Over a period of up to 20-50 years, as shrub cover remains dominant and tree seedlings have not yet achieved the size where stand structure has improved, fisher habitat value and associated effects on fisher would continue to be like those described in the affected environment and under Alternative 1, though continually improving as canopy cover develops. Over a period of 50-100 years and beyond, stand structure would continue to improve and habitat value would continue to increase across the 485-acre fisher habitat corridor project area. Improving habitat value in this area, as is more likely under the action alternatives, would, in turn, facilitate fisher movement dispersal and associated gene flow vital to the species conservation and meet fisher habitat requirements for foraging, resting, denning, and predator avoidance.

Focusing restoration at this location would presumably help to speed up the growth of tree cover in areas where facilitating safe movement of fisher can yield the greatest relative benefit on the landscape.

Because this area of mixed conifer forest is one of the “pinch points” identified as a high priority for restoration, restoring this area is particularly important for providing a linkage between forested areas on either side that were unchanged or burned at low to mixed severity and therefore retain green trees (Meyer, et al. 2022). As mentioned previously, not only was this habitat modeled as important for fisher, but fishers were detected in the proposed planting area just prior to the KNP complex and are known to currently occur in remaining intact adjacent green forest (Green unpublished data 2023). At some point, this 485-acre area of core area 3 would become indistinguishable in terms of habitat suitability and use from green forest patches currently occupied by fisher on either side of the proposed planting area.

In addition to direct beneficial effects on habitat suitability and connectivity, re-establishment of tree cover would indirectly benefit fisher by improving habitat suitability for key fisher prey species (e.g., tree squirrels) and large-bodied primary cavity excavators (e.g., pileated woodpecker) that play an important role in creating reproductive den cavities for female fishers.

Cumulative Effects – Fisher Habitat Connectivity

Cumulative effects would be like those described in Alternative 1; however, the decision to either suppress wildfire, allow fire to burn, or implement other fire management activities would additionally affect planted seedlings. These decisions would in turn influence long-term recovery and resilience of fisher habitat. What actions, if any, might be necessary to address fire resilience and the impacts of those actions in the action area would need to be evaluated and addressed in the future, as fuels accumulate across the action area. However, this project, when considered with previously approved actions to manage fuels through thinning and prescribed burning, as is ongoing in many developed areas as well as some areas of wilderness in these parks, would cumulatively and beneficially affect fisher habitat connectivity by restoring landscape conditions for fisher.

Alternative 3: Replant Seedlings Grown from Seed Collected from the Local Genetic Community of Each Replanted Area

Direct and Indirect Effects – Fisher and Fisher Habitat Connectivity

Same as Alternative 2.

Cumulative Effects – Fisher and Fisher Habitat Connectivity

Same as Alternative 2.

Wilderness Character

Affected Environment

The six groves and proposed critical habitat corridor are located within a matrix of designated and recommended wilderness whose combined 840,000 acres comprise nearly 97% of the lands managed within Sequoia and Kings Canyon National Parks. The proposed action within three groves, Redwood Mountain, Suwanee, New Oriole Lake, and the fisher proposed critical habitat corridor total roughly 989 acres and occur entirely within the 735,000 Sequoia-Kings Canyon Wilderness, while the proposed actions within Homers Nose and Board Camp Groves, totaling 90 acres, occur entirely within the 40,000-acre John Krebs Wilderness. The remaining grove area, Dillonwood, where roughly 52 acres of lands managed as wilderness are proposed for replanting, occurs primarily within the 30,000-acre Hockett Area Recommended Wilderness, though overlaps slightly with the John Krebs Wilderness to the North, and more extensively with non-wilderness areas at the very southern end of Sequoia National Park. As mentioned in Chapter 1, areas that are designated wilderness or recommended wilderness will be referred to jointly as wilderness for the purposes of this EA.

In order to secure for the American people of present and future generations the benefits of an enduring resource of wilderness, the NPS is charged by statute with preserving "wilderness character." However, the Wilderness Act does not define this term. Rather, the four federal land management agencies that steward wilderness worked together on a common framework to define, quantify, and monitor wilderness character to meet this statutory requirement. This interagency framework defines wilderness character as a holistic concept comprised of five tangible "qualities" found in the language of the Act: untrammeled, natural, undeveloped, opportunities for solitude or primitive and unconfined recreation, and other features of value.

- Untrammeled: Wilderness is essentially unhindered and free from the intentional actions of modern human control or manipulation.
- Natural: Wilderness is comprised of ecological systems that are substantially free from the effects of modern civilization.
- Undeveloped: Wilderness is essentially without permanent improvements or the sights and sounds of modern human occupation.
- Opportunities for solitude or primitive and unconfined recreation: Wilderness provides outstanding opportunities for solitude or a primitive and unconfined type of recreation.
- Other features of value: Wilderness may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value.

The first four of these qualities, including their status and trends within the Sequoia-Kings and John Krebs Wilderness areas, are described further below; other features of value, though they may be present and may contribute to wilderness character, are not described further as identification of specific features has not been completed or mapped relative to the project areas.

Wilderness character across the areas where action would be considered is moderately degraded when compared to more eastern and northern areas of these wilderness areas (Tricker et al. 2014). While some qualities of wilderness character in the project area(s) are stable, others are regionally declining (Tricker et al. 2014, NPS 2015c). The following are descriptions of wilderness character and influences on wilderness character within the proposed action areas.

Influences on Untrammeled Quality

Ongoing actions in wilderness including restoration projects (meadow, lake, wildlife, vegetation), tree hazard management (when such actions remove high concentrations of trees across large areas), and unauthorized marijuana grow sites influence the untrammeled quality of wilderness character in the Sequoia-Kings Canyon and John Krebs' wildernesses as a whole. However, at this time these impacts have not directly influenced this quality in the project area (see Tricker et al. 2014).

Fire management activities, as implemented by federal land management agencies, has included hundreds of fire exclusion actions in the drainage vicinity where the proposed planting areas are located and have been documented as early as 1922 (NPS unpublished data n.d.) (see also Appendix C:Evaluating Ecological Intervention Proposals in Wilderness). Although the extent to which suppression as the primary response to wildfire has decreased with shifts in NPS policy, fire management actions—including suppression, prescribed fire, or other fuels reduction actions to restore ecological integrity—as prescribed under the FFMP or through Emergency Fuels Reduction within SEKI Sequoia Groves —is likely to continue to affect the untrammeled quality of wilderness character both within the action areas and the wilderness as a whole.

Full suppression wildfires with extensive suppression activities (fire line construction and aerial retardant drops), such as what occurred during the 2020 Castle and 2021 KNP wildfires, represent the most significant recent trammeling actions within these wilderness areas and or near the project areas, though the removal of cones from these groves (both those from live remaining trees and those scattered on the ground) between 2021 and 2023 have likewise trammeled several of the project areas and other groves within the seed zone.

Though some impacts to the untrammeled quality resulting from NPS wilderness stewardship or emergency responses (in case of wildfire) routinely occur (though in other areas of wilderness spatially removed from the action areas), they are of limited duration and these two wildernesses generally remain dominated by natural processes as fully described in the parks 2015 WSP (NPS 2015c).

Influences on Natural Quality

Departure from historic fire regime has been judged by subject matter experts to be the most important negative influence affecting biophysical resources throughout Sequoia-Kings and the John Krebs Wilderness areas (Tricker et al. 2014). Prior to the Castle and KNP wildfires, the low to mid-elevation forests in these areas of the wilderness areas—including many sequoia groves in wilderness—were significantly departed from the historic fire regime (Caprio et al. 1997; Caprio et al. 2002; Keifer et al. 2000). While the Castle and KNP wildfires may have regionally benefitted natural quality in areas where moderate to mixed severity fire occurred, RAVG analysis indicates that over 23,000 acres of wilderness, including 13,000 acres of proposed fisher critical habitat and sequoia groves, burned at high severity and therefore experienced unnaturally severe fire effects—fully incinerating fuels and killing thousands of trees, including sequoias, other mixed conifers, and their seed (see Table 1: Grove and Area Acreage of Areas Where Planting Would Be Considered Under Alternatives 2 and 3 and Table D1. Total Acreage Burned Across Wilderness in Appendix D). In locations where large contiguous areas of severe fire effects occurred, natural quality, as it relates specifically to fire regime, has therefore been further degraded rather than restored.

Because giant sequoia are an attribute of the natural quality of wilderness character (NPS 2014), their loss across 750 acres of wilderness contributes considerably to a decline in natural quality of wilderness character across these wilderness areas but most particularly within the action area itself. As mentioned in previous sections, fisher is a federally endangered forest dependent species, and all wildlife contribute to natural quality. Therefore, the implications of forest loss—especially loss of over 12,000 acres proposed as critical fisher habitat—also negatively influences natural quality.

Other negative and long-term influences on natural quality (wilderness wide) include: presence of non-native species (i.e., fish and plants), marijuana grow sites, unoccupied habitat for endangered species, and livestock grazing (primarily NPS stock and recreational users; some cattle trespass also occurs within the vicinity of Redwood Mountain), and a number of negative regional influences that originate outside the wilderness including air pollution from regional sources, deposition of contaminants, and ambient light from the nearby population centers. Climate change is a global problem that also has implications for the natural quality of wilderness character across all wildernesses in these parks (NPS 2015c). Conversely, ongoing NPS stewardship actions that beneficially influence the natural quality include control of livestock grazing and restoration projects (meadows, lakes, wildlife, vegetation) (Tricker et al. 2014). Overall, the sum of current NPS wilderness stewardship direction—as fully described in the parks 2015 WSP—serve to protect, and in localized cases enhance, the natural quality of wilderness character (NPS 2015c).

Influences on Undeveloped Quality

Within the proposed project area in Redwood Mountain Grove there is one trail where occasional chainsaw use for trail clearing is the primary factor affecting the undeveloped quality of wilderness. Any helicopters used to transport materials for cone collection or mechanized use to maintain administrative wilderness camps, along with the camps themselves (see footnote 13 on page 30), also intermittently and temporarily degrade this quality in the action area. There are also a few Fire Monitoring Handbook (FMH) plots located in Redwood Mountain and Suwanee Groves. There are no other non-recreational developments in the wilderness portion of the action area.

Beyond the action area, ongoing NPS stewardship actions that negatively affect the undeveloped quality include buildings (e.g., ranger stations), long-term research and monitoring installations, administrative developments or support equipment, authorized non-NPS infrastructure, inholdings, the use of mechanized or motorized tools including helicopter support for administrative actions including fire and fuels management, and use of chainsaws, rock drills, or other trail maintenance and construction equipment (Tricker et al. 2014). However, current wilderness stewardship actions beneficially affecting the undeveloped quality include a reduction in many types of administrative developments including food storage boxes, privies, fencing, and hitch rails such that the undeveloped quality is improving in many areas of wilderness (NPS 2015a).

Influences on Opportunities for Solitude or Primitive and Unconfined Recreation Quality

Of the portions of the action areas that fall within wilderness, opportunities for solitude or primitive and unconfined recreation are most limited in Redwood Mountain Grove , due to the presence of a trail and associated sights and sounds of other visitors, trail crews maintaining the trail, or other administrative crews in the area. Due to trail closures post KNP, this quality has likely improved when compared to pre-fire conditions, though trail crews continue to work in the area and the trail will reopen as soon as a planned reroute through a degraded area is completed. Overall, much of the wilderness in the action area is seldom visited due to steep terrain and lack of trails in most areas. Despite the fact that these areas are severely burned, opportunities for solitude or primitive and unconfined recreation therefore continue to exist to the extent that those desiring to visit or recreate in such areas are not deterred by high numbers of burned snags and can access such areas without trails. In this regard, these areas offer greater opportunities for solitude or primitive and unconfined recreation.

The presence of crews hiking to, camping within, and conducting post-fire monitoring or seed collection in all groves included in this EA and those within the seed zone of these groves (see footnote 13 on page 30), as well as any potential use of helicopter to transport equipment for these purposes, also influences opportunities for solitude in affected areas when crews are present. In all of these areas—due in part to remoteness and in part due to fire effects and subsequent hazards within these areas—visitation is anticipated to be currently very low (likely less than 200 visits per year) such that it is rare to see another person within these areas at this time.

Wilderness wide, ongoing stewardship actions influencing this quality include wilderness permit requirements, party size limits, and trail maintenance. While some of these actions involve restrictions on use/trail corridors (impacting unconfined), they also increase opportunity for solitude that may not otherwise be available for all users. Further, wilderness operations often result in the sights and sounds of mechanized or motorized equipment and the presence of work crews—again, degrading this quality of wilderness character. As well, the sights and sounds from other human-generated noise, including aircraft sounds, may be audible up to nearly 10% of a given day even in remote wilderness (NPS 2005-2006). Finally, sights and sounds emanating from work being conducted in non-wilderness developed areas of the parks also negatively influence this quality.

In consideration of these influences, stewardship direction under the WSP maintains outstanding opportunities for solitude or primitive and unconfined recreation throughout these wildernesses.

Alternative 1: No Action

Direct and Indirect Effects—Wilderness Character

Untrammeled

There would be no effect on this quality.

Natural

Should sequoia and mixed conifer remain either absent or at densities below that needed to support recovery of affected sequoia groves, as would be more likely to occur under this alternative than the other two alternatives considered (see Sequoia Grove Recovery and Resilience on page 45), the total acreage of sequoia groves in wilderness would remain diminished by roughly 700 acres in the long term. Due to type conversion and high severity fire feedback loops, this timeframe would be expected to be indefinite. Likewise, the total number of sequoias within wilderness, including the total number of potential future large sequoias, may also be reduced in the long term—again, expected to be indefinite. Though this number is difficult to quantify, the NPS assumes that the number of sequoias remaining in wilderness in the long term could be as high as 720 fewer than those that existed pre-fire (see Table 5: Estimated Acres of Sequoia Groves Potentially Lost in the Long-Term Under Alternative 1 and the Percent of the Groves these Acres Represent.)

Because giant sequoias are an attribute of wilderness character in these parks, their long-term loss from affected areas of the landscape, were it to occur, would adversely affect the natural quality of wilderness in the long term as well as contribute to the overall adverse trajectory of wilderness character in these parks toward less natural, given that their loss is determined to be the result of human influence. The natural quality would be further adversely affected if, as expected, cycles of high severity fire resulting from conversion to fire-initiated shrub-dominated systems increase risk that adjacent areas, including surviving sequoias, were negatively influenced by the shorter fire intervals, typical of shrub-dominated areas. Likewise, natural quality would further deteriorate were an environmental event further degrade or eliminate remaining portions of affected groves (see Alternative 1: No Action, Sequoia Grove Recovery and Resilience, beginning on page 49).

As mentioned in previous sections, fisher is a federally endangered forest dependent species, and, though not specifically identified in the parks' wilderness character assessment, are also a component of the natural quality of wilderness character in these parks. Should the 485-acre proposed critical habitat corridor where action is being considered convert in the long term to a fire-initiated shrub-dominated system, fisher dispersal to suitable habitat found on either side of the burn patch would be severely limited, restricting gene flow between these two areas. To the extent that the loss of this habitat corridor would reduce the ability of the species to share genetic material across the full species range in the Sierra, or otherwise influence long-term viability of this population, the natural quality would also be adversely affected (see Alternative 1: No Action, Fisher Habitat Connectivity on page 58 for additional information/context).

Undeveloped

Though monitoring plans have yet to be developed, this EA assumes up to 600 small plot markers and 60 other installations would be installed across the action area to monitor vegetation and other resources within areas that burned at high severity. Though small in visibility and function, these minor installations would negatively influence undeveloped quality for at least 30-40 years.

Opportunities for Solitude or Primitive and Unconfined Recreation

Taking action to monitor natural regeneration in these areas would result in this quality being impacted by the sights and sounds of work crews installing plot markers for monitoring purposes. These impacts would last the duration of the installation process.

Cumulative Effects – Wilderness Character

Untrammeled

Because this action would not affect this quality, there are no cumulative effects from this alternative to the untrammeled quality of wilderness character.

Natural

Past, present, or reasonably foreseeable actions, as described in the affected environment, would continue to influence natural quality in the action area (NPS 2003), though in the near term, fuel levels are not expected to be high enough to carry a fire of substantial size or intensity in or through these areas and consideration of fire management action would therefore unlikely be necessary for roughly five to seven years post wildfire (L. Mathiesen personal communication March 2023).

Once fuels become sufficient to carry fire, and were fire to occur, a decision to not suppress wildfire entering these action areas when seedlings are very young could lead to loss of some if not all of the few seedlings that have naturally become established, thereby potentially diminishing natural quality as it relates to post-fire recovery. However, continued fire suppression over time, would serve to further degrade overall natural quality and could lead to conditions which caused the original degradation (high fuel loading and changes in vegetative structure).

When considered together with other ongoing negative influences described in the affected environment, as well as the unknowns related to fire suppression, this alternative has a greater chance of cumulatively contributing to negative impacts on natural quality than other alternatives considered, particularly in the south-western portion of the parks where natural quality is degraded to a greater degree than other areas of the parks (Tricker et al. 2014).

Undeveloped

Past, present, and reasonably foreseeable influences on the undeveloped quality as described in the affected environment would continue to a similar degree. This alternative would cumulatively and negatively contribute to those identified negative impacts to the undeveloped quality of wilderness character by adding an additional 600 small plot markers and 60 other minor monitoring installations within the project area that would extend into the future for at least 30-40 years. However, such impacts would, at least partially, be offset by continued reduction in the number of long-term, and in some cases highly visible (bear boxes, hitch rails, fences), developments in wilderness such that the undeveloped quality may be impacted by a greater overall number of installations, but such installations would decrease overall size and function. Though these installations would continue to negatively contribute to cumulative impacts over a period of 40 years they would still be temporary, thus, the undeveloped quality of wilderness as a whole would be preserved in the long-term.

Opportunities for Solitude or Primitive and Unconfined Recreation.

Past present, and reasonably foreseeable influences on opportunities for solitude or primitive and unconfined recreation within the action area would continue as described in the affected environment. This action would result in cumulative increase in impacts to opportunities for solitude or primitive and unconfined recreation occurring on an annual basis from the presence of 2-3 additional work crews conducting work and being stationed in remote areas of wilderness for periods of up to several weeks while installing monitoring equipment. Once monitoring equipment is installed, smaller crews would likewise continue to visit these sites for short durations continuing to cumulatively impact this quality on an annual basis for up to 40 years.

Alternative 2: Replant Seedlings Grown from Seed Collected from both the Local Genetic Community and Other Source Populations (Preferred Alternative)

Direct and Indirect Effects—Wilderness Character

Untrammeled

Under Alternative 2, untrammeled quality would be negatively affected by planting seedlings over an area up to 1,131 acres in wilderness for the first planting year though this acreage would be less should the NPS determine action is not warranted in some areas. In locations where a high number of concentrated tree hazards needed to be removed, this would also impact the untrammeled quality though these impacts would occur only in the first year[24]. Should additional planting be necessary after the first year, trammeling would continue to occur in smaller portions of the action area each year planting is completed for a period of up to a total of approximately five to six years (estimated at one to two times per grove following the initial planting). The total area where trammeling actions would occur would decrease annually as high seedling survival is anticipated in the first year and every year after. As well, trammeling actions would occur over a shorter timeframe if planting achieved minimum densities during initial planting attempts.

The degree of short-term trammeling actions would be greater under this alternative when compared to Alternative 3 due to the introduction of non-local genetic material in seedlings grown from non-local seed sources which would result in a different genetic makeup than was present prior to the fire. These trammeling actions would occur for the duration of the project while actions are actively being implemented. Once planting actions entirely cease (after approximately five to six years), the untrammeled quality would return to pre-project levels such that the untrammeled quality would be preserved in the long term. In other words, intentional actions to manipulate these areas within wilderness would cease after replanting actions have been completed (one to three times per grove over the course of approximately five to six years) and these forests would be left to recover (or not) on their own, "essentially unhindered and free from the intentional actions of modern human control or manipulation."

Natural

Replanting of up to six affected sequoia groves and adjacent fisher critical habitat would have a greater likelihood than Alternative 1 of restoring sequoia and mixed conifer seedlings in up to

---

[24] Under interagency guidance (Landres et al.2015) removing a few tree hazards is not likely to be considered a trammel, though removing all hazards over a large area is likely considered a trammel

1,130 acres of wilderness. Were the restoration to be successful, this alternative would be expected to direct the trajectory of severely burned areas toward forest recovery to their pre-fire conditions, beneficially affecting sequoia grove recovery and proposed fisher critical habitat and connectivity. As described in impacts from Alternative 2 to Sequoia Grove Recovery on page 52 and to Fisher Habitat Connectivity on page 60, the NPS anticipates that once seedlings were established, natural and dynamic post-fire recovery processes would continue, and the seedlings would mature over a period of centuries, such that large sequoias would be the dominant feature within most, if not the entire, grove footprints.

Similarly, over a period of 50-100 years and beyond, stand structure would continue to improve and habitat value would continue to increase across the 485-acre fisher habitat corridor project area which would, in turn, facilitate fisher movement dispersal and associated gene flow vital to the species conservation and meet fisher habitat requirements for foraging, resting, denning, and predator avoidance.

These impacts would thereby long-term restore and beneficially affect, to the same degree as it impacts the species mentioned above, the currently diminished natural quality of wilderness character in planting areas. As also described in the impacts from Alternative 2 to Sequoia Grove Recovery and Resilience, Alternative 2 would also be more likely than Alternative 1 to prevent the long-term conversion of these forests to shrub-dominated communities and the transition to a fire regime typical of these communities—one that is characterized by more frequent, high severity fire. In doing so, this Alternative when compared to Alternative 1 best maintains the fire regime of these forests and reduces the chances that high severity fire from shrub-dominated communities travels to and through surrounding groves and mixed conifer forests that remain intact.

Though genetic diversity is low in Sequoias, the species does show some evidence of local adaptation, specifically related to summer temperatures and precipitation (DeSilva and Dodd 2020; De La Torre et al. 2021), meaning that groves which are currently more arid have adaptations to improve their survival and fitness to high temperatures and drought. Therefore, while speculative, seedlings propagated from a variety of sources may demonstrate increased survival capacity, increasing the likelihood of success and long-term resilience to climate change. Likewise, should seedlings grown from other sources prove key to successful replanting of these areas, Alternative 2 would beneficially affect natural quality of wilderness character to a greater degree than Alternatives 1 and 3; though the characteristics of the population would be different from what would otherwise be present. See impacts from Alternative 2 to Sequoia Grove Recovery and Resilience.

Undeveloped

The potential effects from monitoring would be as those described under Alternative 1 should installations be determined necessary for that purpose. The undeveloped quality would also be negatively affected by up to one to six sling load helicopter landings and roughly two to three hours of chainsaw use (when determined necessary) at each planting location the first year of planting and up to one to two sling-load landings during each subsequent planting (estimated as one to two per planting location over the next five to six years) (see Table 3 on page 35). The negative effects on undeveloped quality from motorized tool use and transport would return to pre-project levels once those tools were no longer being used.

If chainsaws, rather than explosives, were used to fell snags, evidence of up to ten large cut stumps per delivery location would result in additional, though minimal, negative effects on undeveloped quality until stumps deteriorate naturally—a period of 10-20 years, depending on stump diameter and tree species. The small tree wells created around each seedling would likewise have a minor, though negative, effect on undeveloped quality until the wells are no longer evident on the landscape—a period of one to two years post planting. Despite these temporary impacts to undeveloped quality, the undeveloped quality would be preserved in the long term as all impacts to this quality would entirely cease within approximately five years but for the potentially few visible stumps across the landscape, which would diminish in the 10-20 year timeframe.

Opportunities for Solitude or Primitive and Unconfined Recreation

This project would not affect opportunities for primitive and unconfined recreation, however, as with undeveloped quality, if use of helicopters and chainsaws are determined the minimum necessary to administer the area as wilderness, opportunities for solitude would be negatively affected by sights and sounds of up to roughly 37 helicopter flights traveling over wilderness for up to 30 minutes per flight to each location over the course of approximately five to six years though the number of flights would likely be less than ten the first year and decrease annually thereafter. The use of chainsaws running for up to an estimated two to three hours at each location to potentially fell snags within the first year of planting would further negatively affect opportunities for solitude (see Table D1. Total Acreage Burned Across Wilderness). But if explosives were used to fell snags (instead of chainsaws), the impacts to opportunities for solitude would be more intensive and far reaching, but of shorter duration—a period of seconds. Finally, the sights and sounds of mule strings (8 mules per string for a total of up to 98 strings in Redwood Mountain area only) and roughly 10-15 tree planters per planting location would negatively affect solitude up to roughly 2-3 weeks annually per area over the course of up to five years per area (see Table 3 and Table D1. Total Acreage Burned Across Wilderness). Impacts to opportunities for solitude would be greatest in cases where personnel would camp overnight in wilderness and in the Redwood Canyon area where project work would occur for a longer duration (roughly 4 weeks total: 2 weeks for the Grove and 2 weeks for the proposed fisher critical habitat area).

Outstanding opportunities for solitude will remain throughout the surrounding wilderness to a similar degree as typical within these wilderness areas. Post project, opportunities for solitude or primitive and unconfined recreation would return to pre-project levels, and opportunities for solitude would be preserved in the long term. As opportunities for primitive and unconfined recreation would not be affected by this project, this quality as a whole would also be preserved in the long term.

Cumulative Effects – Wilderness Character

Untrammeled

Past, present, and reasonably foreseeable influences on the untrammeled quality within the action area and wilderness wide would be as described in the Affected Environment. This alternative would increase the cumulative total number of acres where the untrammeled quality is impacted annually within these wildernesses by roughly 1,000 acres the first year planting would occur and decreasing annually thereafter. Annually, the cumulative period of time over which trammeling actions would occur within these wildernesses would also increase by roughly four weeks the first year and to a lesser degree annually thereafter for the next five to six years as planting efforts and areas decrease.

Natural

Past, present, and reasonably foreseeable influences on natural quality would primarily be those described in the Affected Environment and under Alternative 1 with the exception that any fire management decisions would affect planted seedlings in addition to natural regeneration and could lead to either adverse or beneficial effects depending on the decision made. On a wilderness wide basis, Alternative 2 when considered with other ongoing restoration actions is more likely to result in cumulative beneficial effects to natural quality than Alternative 1 if, as anticipated sequoia groves and mixed conifer forests were restored over approximately 1,131 acres of these areas of wilderness.

Undeveloped

Past, present, and reasonably foreseeable influences on the undeveloped quality within the action area would continue as described in the Affected Environment and Alternative 1. Alternative 2, would cumulatively increase negative impacts to undeveloped quality occurring annually by up to three to six hours of motorized tool use and up to a total of roughly 20 minutes total helicopter landings in the first year and decreasing annually thereafter. Finally, this alternative would cumulatively increase the total number of monitoring installations in wilderness by 600 small plot markers and 60 small monitoring devices.

Opportunities for Solitude or Primitive and Unconfined Recreation

Past, present, and reasonably foreseeable influences would be as those described in the Affected Environment and this Alternative would contribute to a cumulative increase in impacts on opportunities for solitude occurring on an annual basis with similar intensity and duration to those described under the undeveloped quality above. However, this Alternative would also cumulatively contribute to the annual total number of crew camps (roughly three additional camps) and administrative workers (roughly 30-40 additional workers) in wilderness for roughly four weeks annually. As well it would result in an increase in helicopter sounds can be heard within the wilderness by roughly 6-10 hours total per year (see Table 3 for details on proposed helicopter flights and travel distances.).

Alternative 3: Replant Seedlings Grown from Seed Collected from the Local Genetic Community of Each Replanted Area

Direct and Indirect Effects—Wilderness

Wilderness Character

Direct and indirect effects on wilderness character would be primarily as described under Alternative 2. However, the degree of impacts to the untrammeled quality would be lower under this alternative when compared to Alternative 2 due to use of seedlings grown from only local genetic material. On the other hand, should seedlings grown from only locally collected seed lack resilience to climate change stressors, the natural quality of wilderness character under Alternative 3 would be diminished in the long term when compared to Alternative 2, though again the benefits of introducing non-local seedlings to natural quality are speculative in nature (see Sequoia Grove Resilience to Future Change53).

Cumulative Effects – Wilderness

Cumulative effects on wilderness character would be like those described under Alternative 2.

Table 6. Comparison of Impacts Across Three Alternatives Considered

Resource	Alternative 1: No Action	Alternative 2: Replant Seedlings Grown from Variety of Source Populations	Alternative 3: Replant Seedlings Grown from the Local Genetic Community
Sequoia Grove Recovery and Resilience	• Affected areas convert to shrub long-term. • Footprint of each grove remains diminished. • Resilience to future change remains diminished.	• Affected areas maintained as sequoia groves in the long term. • Grove footprints maintained at pre-fire acreage. • Resilience to future change improved over existing conditions.	• Similar to Alternative 2 with the exception that resilience to future change may be decreased due to no incorporation of additional genetic material.
Fisher and Fisher Habitat	• Affected areas convert to shrub in the long term. • Fisher habitat connectivity remains severed. • Barriers to safe fisher dispersal between remaining green forest patches. • Barriers to gene flow.	• Affected areas maintained as mixed conifer habitat in the long term. • Fisher habitat connectivity restored in long term. • Fisher use of area, including for denning, foraging, and dispersal, restored. • Habitat suitability increased for key fisher prey (e.g., tree squirrels) and primary cavity excavators.	• Same as Alternative 2.
Wilderness Character	• Undeveloped, diminished in for roughly 40 years by monitoring installations. • Natural, diminished in the long term (centuries). • No change in Opportunity for Solitude or Primitive and Unconfined Recreation. • No change in Untrammeled quality.	• Undeveloped quality, diminished over the course of several hours from, helicopter transport/sling load landings, and potentially chainsaw or explosive use, and up to 40 years by monitoring installations if determined the minimum necessary. • Natural quality, restored over the course of 50-100 years or up to centuries as forests recover. • Opportunities for Solitude or Primitive and Unconfined Recreation, short-term impacts during project implementation (2 weeks per site) due to sights and sounds of helicopters, chainsaws, and work crews. • Untrammeled quality, diminished during project implementation through planting efforts and introduction of seedlings grown from non-locally sourced seeds.	• Undeveloped quality, same as Alternative 2. • Natural quality, similar to Alternative 2 with the exception that natural quality would be improved to a lesser degree than Alternative 2 if, as speculated, the lack of genetic material from other sequoia groves diminishes overall grove resilience to environmental change. • Opportunity for Solitude or Primitive and Unconfined Recreation, same as Alternative 2. • Untrammeled quality, similar to Alternative 2 except that impacts to untrammeled quality would occur to a lesser degree due to use of only locally sourced seed.

Chapter 4: Consultation and Coordination

Public Scoping

The NPS solicited public feedback in Spring 2022, on a proposed action which only included a proposal to plant seedlings in the Board Camp Grove. A 30-day public comment period occurred from February 22 to March 25, 2022. On February 17, 2023, the NPS re-initiated another 30-day public comment period for an Environmental Assessment (EA) which outlined the NPS' expanded proposal to re-establish tree seedlings in Board Camp Grove and up to six other areas.

The NPS posted the original proposed action and associated scoping materials for public review and comment on the National Park Service's (NPS) Planning, Environment, and Public Comment (PEPC) website: https://parkplanning.nps.gov/SEKIBoardCampSequoiaRestoration2022, and the expanded proposal on https://parkplanning.nps.gov/ReEstablishGiantSequoiaPostFire2021. Both efforts were posted on the parks' website: Public Participation - Sequoia and Kings Canyon National Parks (U.S. National Park Service) (nps.gov).

The availability of scoping documents, comment period dates, and associated public meetings were announced through two separate press releases, one for each scoping effort. Both press releases were sent directly to the public affairs contacts list, which included media; congressional members; non-profits; local businesses; community members; local, state, and federal government stakeholders; and members of the public. The press release for the second effort was also sent directly to all functional email addresses of correspondents to the Board Camp scoping effort as well as other parties who had demonstrated a high level of interest in the proposals. Public comments were accepted via email, letter, and the PEPC website.

The NPS held virtual public meetings on the proposed actions on March 1, 2022, and again on March 7, 2023, where staff presented on the purpose and need for action, the full scope of the proposed action, resources of concern, and the overall project timelines. NPS staff also accepted and responded to questions from the public. Approximately 22 members of the public joined the hour-long meeting for Board Camp while 41 people joined the public meeting on the expanded proposal evaluated under this EA.

NPS' public scoping effort for Board Camp resulted in the receipt of 2,800 pieces of correspondence while the expanded project scope resulted in the receipt of approximately 1,937 pieces of correspondence. The majority of correspondences from both scoping efforts were form letters. All correspondences were reviewed by park staff and considered in the decision-making process.

Consultation with Tribes

The NPS initiated consultation with Tribal Chairs of the parks' 14 formally recognized affiliated tribes and additional Native American interested parties on February 17, 2023, and continued consultation through letters dated July 17 and 18, 202, and a tribal forum on September 8, 2023. As of this writing, the NPS had received two responses from Native American interested parties requesting additional maps and expressing both a willingness to help the NPS and overall support of the proposed action.

National Historic Preservation Act

The NPS informed the State Historic Preservation Officer (SHPO) on the development of this EA on February 17, 2023 through a press release shared directly with agency partners. The NPS determined that the project, as defined for the purposes of NEPA, need not necessarily equate to the undertaking as defined pursuant to 36 CFR § 800.3(a) and determined that the NEPA project planning area will not be used to define the undertaking or Area of Potential Effect (APE) for the purposes of the National Historic Preservation Act (NHPA). Each treatment area will have independent utility, individual approval processes, and is not inextricably connected to other treatments. Because the areas are independent and undergo separate approval processes, each treatment or subset of treatments addressed by an implementation plan will be considered individual undertakings under NHPA, and Section 106 compliance will be fulfilled in accordance with provisions of the 2008 Nationwide Programmatic Agreement. A representative of the SHPO agreed with this approach in June 2023.

While the NPS has completed background research and has initiated consultation with tribal partners to identify historic properties within the areas of potential effect, field surveys in all portions of the areas of potential effect have not been completed as of this writing. Therefore, as consistent with 36 CFR 800.1(c), if site specific, non-destructive, analyses indicate planting is necessary to achieve the purpose and need for action (this process is articulated in both action alternatives as part of the decision tree; see Figure 7 in Chapter 2), cultural resources surveys would be completed, as appropriate, on a site-by-site basis, and consultation with the State Historic Preservation Officer and tribes, in accordance with 36 CFR 800.3 through 36 CFR 800.7, would be completed to assess the effects of each undertaking and seek ways to avoid, minimize, or mitigate any adverse effects on historic properties (should they be present within the area of potential effect) through the refinement of an area's specific planting plan. Through this additional identification of historic properties and consultation process on an area's site-specific planting plan, and again, given the limited degree of potential disturbance from the proposed action, the NPS anticipates avoiding adverse effect to historic properties.

Endangered Species Act

The NPS informed the U.S. Fish and Wildlife Service (USFWS) of the development of this EA on February 17, 2023 through a press release shared directly with agency partners. Per the USFWS' Programmatic Biological Opinion on Proposed Activities of the National Park Service that May Affect the Southern Sierra Nevada Distinct Population Segment of Fisher (08ESMF00- 2020-F-2011-1), the NPS initiated Section 7 consultation for proposed actions related to this proposal that may affect the endangered fisher on July 7, 2023. The USFWS responded on August 21, 2023, concurring with the determination that the project may affect but is not likely to adversely affect fisher for the following reasons 1) the proposed project area currently does not contain suitable fisher habitat due to the impacts of recent fires; and, therefore, fishers are not expected to be present in the project area; 2) the small scope of noise disturbance from creating safety zones and delivering supplies via helicopter will not cause long-term disturbance in the planting areas. Fishers in the vicinity of these areas may avoid the immediate area for a short time, but they would use other areas available during this time and this is not expected to result in a disruption of necessary foraging and other activities; 3) although denning fishers are not expected in the project area, the limited operating period for felling of trees with den features will further ensure no adverse impacts to denning fishers occur; and 4) restoration of habitat connectivity and fire-resilient forest conditions is expected to provide an overall benefit to fisher (FWS-2023-0111204-S7-001.)

IDT Members and Reviewers

Sequoia and Kings Canyon National Parks

Andrew Bishop, Restoration Ecologist, Vegetation Management
Elly Boerke, Branch Chief, Environmental Planning and Compliance
Danny Boiano, Branch Chief, Wildlife and Physical Sciences
Juanita Bonnifield, Program Manager, Cultural Resources
Christy Brigham, Chief, Resource Management and Science
Amy Brown, Environmental Protection Specialist, Environmental Planning and Compliance
Tony Caprio, Fire Ecologist, Vegetation Management
Theresa Fiorino, Environmental Protection Specialist, Environmental Planning and Compliance Dave Fox, Sequoia District Ranger, Visitor, Fire, and Resource Protection
Josh Flickinger, GIS Specialist, Information Resources
Linn Gassaway, Cultural Resources Compliance (Section 106) Coordinator
Rebecca Green, Wildlife Biologist, Wildlife and Physical Sciences
Rick Hall, Chief, Facilities, Maintenance, and Construction
Ann Huber, Ecologist, Vegetation Management
Sintia Kawasaki-Yee, Branch Chief, Communications and Management Support
Edward Kelleher, Chief Ranger
Clayton Jordan, Superintendent
Lief Mathiesen, Fire Management Officer
Erik Meyer, Physical Scientist, Wildlife and Physical Sciences
Marc Neidig, Chief, Division of Interpretation
Tom Warner, Program Manager, Vegetation Management
Erika Williams, Visual Information Specialist, Division of Interpretation

Department of Interior, National Park Service Regions 8, 9, 10, and 12

Alison Ainsworth, Science Advisor/Ecologist
Erik Frenzel, Regional Wilderness Coordinator
Brent Johnson, Regional Vegetation Ecologist
Nick Mitrovitch, Regional Environmental Protection Specialist
Rachel Wolstenholme, Regional Wildlife Biologist
Danette Nolan Woo, Regional Environmental Coordinator

Department of Interior, National Park Service, Washington Area Service Office

Roger Semler, Chief, Division of Wilderness Stewardship

References

Aitken, S.N. and Bemmels, J.B. 2016. Time to get moving: assisted gene flow of forest trees. Evolutionary applications, 9(1), pp.271-290.

Aitken, S.N., Yeaman, S., Holliday, J.A., Wang, T. and Curtis-McLane, S. 2008. Adaptation, migration or extirpation: climate change outcomes for tree populations. Evolutionary applications, 1(1), pp.95-111.

Aitken, S. N., and Whitlock, M. C. 2013. Assisted gene flow to facilitate local adaptation to climate change. Annual Review of Ecology, Evolution, and Systematics, 44: 367-388.

Allendorf, F.W., Luikart, G. and Aitken, S.N. 2007. Conservation and the genetics of populations. Mammalia, 2007, pp.189-197.

Baeza, A., Martin, R.E., Stephenson, N.L., Das, A.J., Hardwick, P., Nydick, K., Mallory, J., Slaton, M., Evans, K. and Asner, G.P. 2021. Mapping the vulnerability of giant sequoias after extreme drought in California using remote sensing. Ecological Applications, 31(7), p.e02395.

Broadhurst, L. M., Lowe, A., Coates, D. J., Cunningham, S. A., McDonald, M., Vesk, P. A., and Yates, C. 2008. Seed supply for broadscale restoration: maximizing evolutionary potential. Evolutionary Applications, 1(4), 587-597.

Caprio, A.C., Conover, C., Keifer, M., and Lineback, P.. 2002. Fire management and GIS: a framework for identifying and prioritizing fire planning needs. In: *Proceedings: Fire in California Ecosystems: Integrating Ecology, Prevention, and Management, Nov. 18-20, 1997, San Diego, CA. Association for Fire Ecology Misc. Publ. No.* 1:102-113.

Caprio, A.C., C. Conover, M. Keifer, and P. Lineback. 1997. Fire management and GIS: a framework for identifying and prioritizing fire planning needs. In: Proceedings: 1997 ESRI GIS Conference,San Diego, CA

Caprio, A.C. and Swetnam, T. 1995. Historic fire regimes along an elevational gradient on the west slope of the Sierra Nevada. Retrieved from: (PDF) Historic fire regimes along an elevational gradient on the west slope of the Sierra Nevada (researchgate.net).

Caprio, A.C. et al. 1994. Temporal and spatial patterns of giant sequoia radial growth response to a high severity fire in A.D. 1297. Final Report of California Department of Forestry and Fire Protection, Mountain Home State Forest, Contract No. 8CA17025, Laboratory of Tree-Ring Research, University of Arizona, Tucson.

Caprio, A.C. et al. n.d. Untitled [Unpublished fire effects data]. Sequoia and Kings Canyon National Parks, National Park Service.

Castro, J., Zamora, R., Hódar, J.A. and Gómez, J.M. 2004. Seedling establishment of a boreal tree species (Pinus sylvestris) at its southernmost distribution limit: consequences of being in a marginal Mediterranean habitat. Journal of Ecology, pp.266-277.

Castro, J., Morales-Rueda, F., Alcaraz-Segura, D. and Tabik, S. 2023. Forest restoration is more than firing seeds from a drone. Restoration Ecology, 31(1), p.e13736.

Cayan, D.R., Maurer, E.P., Dettinger, M.D., Tyree, M. and Hayhoe, K. 2008. Climate change scenarios for the California region. Climatic change, 87, pp.21-42.

Churchill, D.J., Larson, A.J. Dahlgreen, M.C., Franklin, J.F., Hessburg, P.F., and Lutz, J.A. 2013. Restoring forest resilience: from reference spatial patterns to silvicultural prescriptions and monitoring. Forest Ecology and Management 291:422-457. 57 pp.

Clark, J.S., R. Andrus, M. Aubry-Kientz, Y. Bergeron, M. Bogdziewicz, D.C. Bragg, D. 656 Brockway, N.L. Cleavitt, S. Cohen, B. Courbaud, R. Daley, A.J. Das, M. Dietze, T.J. Fahey, 657 I. Fer. J.F. Franklin, C.A. Gehring, G.S. Gilbert, C.H. Greenberg, Q. Guo, J. 658 HilleRisLambers, I. Ibanez, J. Johnstone, C.L. Kilner, J. Knops, W.D. Koenug, G. Kunstler, 659 JLaMontagne, K.L. Legg, J. Luongo, J.A. Lutz, D. Macias, E.J.B. McIntire, Y. Messaoud, 660 C.M. Moore, E. Moran, J.A. Myers, O.B. Myers, C. Nunez, R. Parmenter, S. Pearse, S. 661 Pearson, R. Poulton-Kamakura, E. Ready, M.D. Redmond, C.D. Reid, K.C. Rodman, C.L. 662 Scher, W.H. Schlesinger, A.M. Schwantes, E. Shanahan, S. Sharma, M.A. Steele, N.L. 663 Stephenson, S. Sutton, J.J. Swenson, m. Swift, T.T. Veblen, A.V. Whipple, T.G. Whitham, 664 A.P. Wion, K. Zhu, and R. Zlotin. 2021. Continent-wide tree fecundity driven by indirect 665 climate effects. Nature Communications 12: 1242.

Coop, J. D., Parks, S. A., Stevens-Rumann, C. S., Crausbay, S. D., Higuera, P. E., Hurteau, M. D., ... and Rodman, K. C. 2020. Wildfire-driven forest conversion in western North American landscapes. *BioScience*, *70*(8), 659-673.Demetry, A. 1995. Regeneration patterns within canopy gaps in a giant sequoia-mixed conifer forest: implications for restoration. M.S. thesis. Northern Arizona University. Flagstaff, AZ. Google Scholar. Accessed December 15, 2022.

Coppoletta, M., Merriam, K.E., and Collins, B.M. 2016. Post-fire vegetation and fuel development influences fire severity patterns in reburns. Ecological Applications 26: 686–699. https:// doi. org/ 10. 1890/ 15- 0225.1.

Department of Transportation. 2017. 9.0 Construction Equipment Noise Levels and Ranges - Handbook - Construction Noise - Noise - Environment - FHWA (dot.gov). Accessed March 20, 2023.

DeSilva, R. 2020. Pattern and process: An examination of how evolutionary forces shape patterns of genetic diversity and adaptive potential in the long-lived tree species, giant sequoia. PhD Dissertation. University of California, Berkeley.

DeSilva, R., and Dodd, R. S. 2020. Association of genetic and climatic variability in giant sequoia, Sequoiadendron giganteum, reveals signatures of local adaptation along moisture-related gradients. *Ecology and evolution*, *10*(19), 10619-10632.

DeSilva, R. and Dodd, R.S. 2021. Patterns of Fine-Scale Spatial Genetic Structure and Pollen Dispersal in Giant Sequoia (*Sequoiadendron giganteum*). Forests, 12(1), p.61.

De La Torre, A. R., Sekhwal, M. K., and Neale, D. B. 2021. Selective sweeps and polygenic adaptation drive local adaptation along moisture and temperature gradients in natural populations of coast redwood and giant sequoia. Genes, 12(11), 1826.

De La Torre, A. R., Sekhwal, M. K., Puiu, D., Salzberg, S. L., Scott, A. D., Allen, B., and Buckley, T. N. 2022. Genome-wide association identifies candidate genes for drought tolerance in coast redwood and giant sequoia. The Plant Journal, 109(1), 7-22.

Diffenbaugh, N.S., Swain, D.L. and Touma, D. 2015. Anthropogenic warming has increased drought risk in California. Proceedings of the National Academy of Sciences, 112(13), pp.3931-3936.

Fahey, C. et al. 2012. Arbuscular mycorrhizal colonization of giant sequoia (Sequoiadendron giganteum) in response to restoration practices. Mycologia, 104(5), 988-997. DOI: 10.3852/11-289.

Fins, L. and Libby, W.J. 1982. Population variation in Sequoiadendron: seed and seedling studies, vegetative propagation, and isozyme variation. Silvae Genet, 31(4), pp.102-110.

Fontaine, J.B., and Kennedy, P.L. 2012. Meta-analysis of avian and small-mammal response to fire severity and fire surrogate treatments in U.S. fire-prone forests. Ecological Applications 22:1547-1561.

Furniss, T.J. et al. 2019. Multi-scale assessment of post-fire tree mortality models. International Journal of Wildland Fire, 28, 46–61.

Gray, L.K. and Hamann, A., 2011. Strategies for reforestation under uncertain future climates: guidelines for Alberta, Canada. PloS one, 6(8), p.e22977.

Gonzalez, P., Wang, F., Notaro, M., Vimont, D.J. and Williams, J.W. 2018. Disproportionate magnitude of climate change in United States national parks. Environmental Research Letters, 13(10), p.104001.

Griesbach John A., Jennifer L. Parke, Gary A. Chastagner, Niklaus J. Grünwald, and John Aguirre. 2012. Safe Procurement and Production Manual A Systems Approach for the Production of Healthy Nursery Stock.

Green, R.E., Purcell, K.L., Thompson, C.M., Kelt, D.A. and Wittmer, H.U., 2019. Microsites and structures used by fishers (Pekania pennanti) in the southern Sierra Nevada: A comparison of forest elements used for daily resting relative to reproduction. Forest Ecology and Management, 440, pp.131-146.

Green, R. 2023. Untitled [Unpublished fisher (Pekania pennanti) data from recent and on-going research and surveys in the southern Sierra Nevada]. Sequoia and Kings Canyon National Parks, National Park Service.

Griffin, D. and Anchukaitis, K.J. 2014. How unusual is the 2012–2014 California drought?. Geophysical Research Letters, 41(24), pp.9017-9023.

Guiterman, C.H., Gregg, R.M., Marshall, L.A.E., Beckmann, J.J., Van Mantgem, P.J., Falk, D.A., Keeley, J.E., Caprio, A.C., Coop, J.D., Fornwalt, P.J. et al. 2022. Vegetation type conversion in the US Southwest: frontline observations and management responses. Fire Ecology 18: 1–16.

Hagmann, R.K., P.F. Hessburg, S.J. Prichard, N.A. Povak, P.M. Brown, P.Z. Fule, R.E. Keane, E.E. Knapp, J.M.Lyderson, K.L. Metlen, M.J. Reilly, A.J. Sanchez Meador, S.L. Stephens, J.T. Stevens, A.H. Taylor, L.L. Yocom, M.A. Battaglia, D.J. Churchill, L.D. Daniels, D.A. Falk, P. Henson, J.D. Johnston, M.A. Krawchuk, C.R. Levine, G.W. Meigs, A.G. Merschel, M.P. North, H.D. Safford, T.W. Swetnam, and A.E.M. Waltz. 2021. Evidence for widespread changes in the structure, composition, and fire regimes of western North American forests. Ecological Applications 00(00):e02431. 10.1002/eap2431

Hammon, Jensen, and Wallen Mapping and Forestry Services and Western Timber Service. 1973. Sequoia Tree Inventory (STI) Sequoia and Kings Canyon National Parks California, prepared for US DOI, NPS, Sequoia and Kings Canyon National Parks, Three Rivers, California.

Handler, S.; Pike, C.; St. Clair, B.; 2018. Assisted Migration. USDA Forest Service Climate Change Resource Center. https://www.fs.usda.gov/ccrc/topics/assisted-migration

Hartesveldt, R.J. and Harvey, H.T. 1967. The fire ecology of sequoia regeneration. Tall Timbers Fire Ecology Conference No. 7. Tall Timbers Research Station, Tallahassee, FL, 65–77. Retrieved from: 65-HartesveldtandHarvey1967_op.pdf (talltimbers.org).

Hartesveldt, R.J., Harvey, H.T., Shellhammer, H.S. and Stecker, R.E. 1975. The giant sequoia of the Sierra Nevada. U.S. Department of the Interior, National Park Service, Washington, DC. Retrieved from: https://www.nps.gov/parkhistory/online_books/science/hartesveldt.

Harvey, H.T., Shellhammer, H.S., and Stecker, R. E. 1980. Giant sequoia ecology. U.S. Department of the Interior, National Park Service, Scientific Monograph Series 12. Washington, DC. 182 p.

Haultain, S. A., Reyes, E. T., Menke, J. M., Johnson, D. N., and Karavidas (Cline), D. L. 2020. Sequoia and Kings Canyon National Parks vegetation classification and mapping project report. Natural Resource Report NPS/SIEN/NRR—2020/2101. National Park Service, Fort Collins, Colorado.

Holmgren, M., Gómez-Aparicio, L., Quero, J.L., and Valladares, F. 2012. Non-linear effects of drought under shade: reconciling physiological and ecological models in plant communities. Oecologia, 169, pp.293-305.

Jones, G.M., Kramer, H.A., Whitmore, S.A. et al. 2020. Habitat selection by spotted owls after a megafire reflects their adaptation to historical frequent-fire regimes. *Landscape Ecol* **35**, 1199–1213. Retrieved from: https://doi.org/10.1007/s10980-020-01010-y.

Keifer, M., Caprio, A., Lineback, P., and Folger, K. 2000. Incorporating a GIS model of ecological need into fire management planning, in Neuenschwander, L. F., Ryan, K. C., and Gollberg, G. E., Joint Fire Science Conference and Workshop Proceedings: 'Crossing the Millennium: Integrating Spatial Technologies and Ecological Principles for a New Age in Fire Management'. Boise, Idaho. University of Idaho and the International Association of Wildland Fire, Moscow, ID and Fairfield, WA. Vol. I, p. 122-130.

Kilgore, B.M. 1972. Fire's role in a sequoia forest. Naturalist 23:26-37.

Kilgore, B. M., and Taylor, D. 1979. Fire history of a sequoia-mixed conifer forest. Ecology, 60, 129-142. Retrieved from: Kilgore and Taylor 1979.doc (npshistory.com).

Kilgore, B. M. and Biswell, H.H. 1971. Seedling germination following fire in a giant sequoia forest. California Agriculture, 25, 8-10. Retrieved from: Seedling germination following fire in a GIANT SEQUOIA FOREST (ucanr.edu).

Koontz, M.J., North, M.P., Werner, C.M., Fick, S.E., Latimer, A.M. 2020. Local forest structure variability increases resilience to wildfire in dry western U.S. coniferous forests. Ecology Letters, 23, 483–494. doi: 10.1111/ele.13447.Lydersen, J.M., Collins, B.M., Coppoletta, M., Jaffe, M., Northrop, H., Stephens, S.L. 2019. Fuel dynamics and reburn severity following high-severity fire in a Sierra Nevada, USA, mixed-conifer forest. Fire Ecology 15(43), 1-14. Retrieved from: https://doi.org/10.1186/s42408-019-0060-x.

Mallek, C.R., Safford, H.D., Viers, J.H., and Miller, J.D. 2013. Modern departures in fire severity and area vary by forest type, Sierra Nevada and southern Cascades, California, USA. Ecosphere 4(12):1-28 article 153.

Marsh, C., Krofcheck, D., and Hurteau, M.D. 2022. Identifying microclimate tree seedling refugia in post-wildfire landscapes. Agricultural and Forest Meteorology, 313, p.108741.

Marsh, C., Blankinship, J.C., and Hurteau, M.D. 2023. Effects of nurse shrubs and biochar on planted conifer seedling survival and growth in a high-severity burn patch in New Mexico, USA. Forest Ecology and Management, 537, p.120971.

Meyer, M.D. and Safford, H.D. 2011. Giant Sequoia Regeneration in groves exposed to wildfire and retention harvest. Fire Ecology, 7(2), 2-15. doi: 10.4996/fire ecology.0702002.

Meyer, M. et al. 2021. Postfire restoration framework for national forests in California. Gen. Tech. Rep. PSW-GTR-270. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 204 p. Retrieved from: Postfire restoration framework for national forests in California (usda.gov).

Meyer, M.D., White, A., McGregor, E, Faber, K., Green, R., and Eckert, G. 2022. POST-FIRE RESTORATION STRATEGY FOR THE 2021 WINDY FIRE, KNP COMPLEX, AND FRENCH FIRE. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.

Meyer, Marc D., David Soderberg, Adrian Das, Christy Brigham, and Rebecca Wayman. 2023. KNP Complex Post-Fire Regeneration Assessment: 2022 Field Inventory Sampling Report.

Miller, J.D., Safford, H.D., Crimmins, M. and Thode, A.E. 2009. Quantitative evidence for increasing forest fire severity in the Sierra Nevada and southern Cascade Mountains, California and Nevada, USA. Ecosystems 12:16-32.

National Park Service. 2003. Fire and Fuels Management Plan (as updated in 2021). Sequoia and Kings Canyon National Parks.

National Park Service. 2005-2006. Sequoia and Kings Canyon National Parks. Acoustic Monitoring Report. 432446 (nps.gov). Accessed May 2023.

National Park Service. 2006. NPS Management Policies 2006. Sequoia and Kings Canyon National Parks.

National Park Service. 2014. Sequoia and Kings Canyon National Parks Wilderness Character Assessment. An examination of the characteristics and conditions of designated and proposed wilderness in Sequoia and Kings Canyon National Parks.

National Park Service. 2015a. Initial Condition Assessment of Sequoia Groves within the Rough Fire: Report for Sequoia N.F. and Kings Canyon N.P. Rough Fire Interagency BAER Team, Anthony Caprio, Fire Ecologist, Sequoia and Kings Canyon N.P. – October 2015

National Park Service 2015b. National Park Service NEPA Handbook.

National Park Service. 2015c. Wilderness Stewardship Plan. Sequoia and Kings Canyon National Parks.

National Park Service. 2020. Emergency Stabilization and Rehabilitation Plan: Castle and Rattlesnake Fires, Sequoia and Kings Canyon National Parks, CA.

National Park Service. 2021. Emergency Stabilization and Rehabilitation Plan: KNP Complex, Sequoia and Kings Canyon National Parks, CA.

National Park Service. 2022. Sequoia and Kings Canyon National Parks. Wildfires kill unprecedented numbers of large sequoia trees. Sequoia and Kings Canyon National Parks web article. Retrieved from: Wildfires Kill Unprecedented Numbers of Large Sequoia Trees (U.S. National Park Service) (nps.gov).

Nemens, D.G., Kidd, K.R., Varner, J.M., and Wing, B. 2022. Recurring wildfires provoke type conversion in dry western forests. Ecosphere, 13(8), p.e4184.

North, Malcolm P., Jens T. Stevens , David F. Greene , Michelle Coppoletta, Eric E. Knapp, Andrew M. Latimer , Christina M. Restaino , Ryan E. Tompkins , Kevin R. Welch , Rob A. York , Derek J. N. Young , Jodi N. Axelson , Tom N. Buckley, Becky L. Estes, Rachel N. Hager, Jonathan W. Long, Marc D. Meyer, Steven M. Ostoja, Hugh D. Safford, Kristen L. Shive, Carmen L. Tubbesing , Heather Vice , Dana Walsh, Chhaya M. Werner, Peter Wyrsch. 2019. Tamm Review: Reforestation for resilience in dry western U.S. forests. Forest Ecology and Management. Volume 432-209-224

Nydick, K.R. et al. 2018. Leaf to landscape responses of giant sequoia to hotter drought: An introduction and synthesis for the special section. Forest Ecology and Management, 419-420, 249-256. Retrieved from: https://doi.org/10.1016/j.foreco.2018.03.028.

Pater Larry L., Delaney, David K., and Grubb, Teryl G. 1995. Effects of helicopter noise on spotted owls: Methodology The Journal of the Acoustical Society of America 98, 2940.; U.S. Army Construction Eng. Res. Labs., Champaign, IL. https://doi.org/10.1121/1.414113

Prichard, S.J., Stevens-Rumann, C.S., and Hessburg, P.F. 2017. Tamm Review: Shifting global fire regimes: Lessons from reburns and research needs. Forest Ecology and Management, 396, pp.217-233.

Purcell, K.L., Mazzoni, A.K., Mori, S.R. and Boroski, B.B., 2009. Resting structures and resting habitat of fishers in the southern Sierra Nevada, California. Forest Ecology and Management, 258(12), pp.2696-2706.

Safford, H.D. and Stevens, J.T., 2017. Natural range of variation for yellow pine and mixed-conifer forests in the Sierra Nevada, southern Cascades, and Modoc and Inyo National Forests, California, USA (p. 241). United States Department of Agriculture, Forest Service, Pacific Southwest Research Station.

Safford, H.D., and Van de Water, K.M. 2013. Using fire return interval departure (FRID) analysis to map spatial and temporal changes in fire frequency on national forest lands in California. USDA Forest Service, Pacific Southwest Research Station, Albany, California. Research Paper PSW-RP-266.

Safford, H.D., North, M.P., and Meyer, M.D. 2012. Climate change and the relevance of historical forest conditions. Pp. 23-46 *In* Managing Sierra Nevada forests (M.P. North, editor). USDA Forest Service, Pacific Southwest Research Station, Albany, California. General Technical Report GTR-PSW-237.

Scheller, R.M., Spencer, W.D., Rustigian-Romsos, H., Syphard, A.D., Ward, B.C., and Strittholt, J.R. 2011. Using stochastic simulation to evaluate competing risks of wildfires and fuels management on an isolated forest carnivore. Landscape Ecology 26:1491-1504.

Schwartz, M., Hall, A., Sun, F., Walton, D., and Berg, N. 2017. Significant and inevitable end-of-twenty-first-century advances in surface runoff timing in California's Sierra Nevada. Journal of Hydrometeorology, 18(12), pp.3181-3197.

Shannon, D.P. and Elliott, S. 2020. Developing aerial seeding by UAVs: lessons from direct seeding. Automated Forest Restoration FORRU-CMU, pp.75-83.

Shellhammer, H.S. and Shellhammer, T.H. 2006. Giant Sequoia (*Sequoiadendron giganteum*) seedling survival and growth in the first four decades following managed fires. Madrono, 53(4), 342-350.

Shive, K., Brigham, C., Caprio, T., and Hardwick, P. 2021. 2021 Fire Season Impacts to Giant Sequoias. National Park Service, Sequoia and Kings Canyon National Parks.

Shive, K.L., Wuenschel, Amarina, Hardlund, Linnea J., Morris, Sonia, Meyer, Marc D., Hood, Sharon M. 2022. Ancient trees and modern wildfires: Declining resilience to wildfire in the highly fire-adapted giant sequoia. Forest Ecology and Management, 511, 1-13.

Soderberg, David, Das, Adrian J., Stephenson, Nathan L., Meyer, Marc D., Brigham, Christy A., and Flickinger, Joshua. 2023. Assessing giant sequoia (*Sequoiadendron giganteum*) mortality and recruitment following high severity wildfire within SQF- and KNP-Complex fire-affected groves within Sequoia National Park, CA. USGS internal technical review completed, In review for publication in Ecological Applications.

Spencer, W.D., Sawyer, S.C., Romsos, H.L., Zielinski, W.J., Thompson, C.M., and Britting, S.A. 2016. Southern Sierra Nevada fisher conservation strategy. Version 1.0. Unpublished report produced by Conservation Biology Institute, Corvallis, OR.

Stark, N. 1968a. Seed ecology of *Sequoiadendron giganteum*. Madroño 19(7):267-277.

Stark, N. 1968b. The environmental tolerance of the seedling stage of Sequoiadendron giganteum. American Midland Naturalist 80:84-95.

Stephenson, Nathan L., Caprio, Anthony C., Soderberg, David N., Das, Adrian J., Lopez, Eva L., and Williams, A. Park. 2023. Post-fire Reference Densities for Giant Sequoia Seedlings. Report to NPS from USGS. Completed USGS technical peer-review and will be formatted as NPS Natural Resources Report or submitted to journal for publication.

Stephenson, N. and Brigham, C. 2021. Preliminary estimates of sequoia mortality in the 2020 Castle Fire. National Park Service Natural Resource Report series. Retrieved from: Preliminary Estimates of Sequoia Mortality in the 2020 Castle Fire (U.S. National Park Service) (nps.gov).

Stephenson, N.L., Das, A.J., Ampersee, N.J., Cahill, K.G., Caprio, A.C., Sanders, J.E., and Williams, A.P. 2018. Patterns and correlates of giant sequoia foliage dieback during California's 2012–2016 hotter drought. Forest ecology and management, 419, pp.268-278.

Stephenson, N.L. 1999. Reference conditions for giant sequoia forest restoration: structure, process, and precision. Ecological Applications, 9(4), 1253–1265.

Stephenson, N. L. 1996. Ecology and management of giant sequoia groves.

Stephenson, N.L. 1994. Long-term dynamics of Giant Sequoia populations: Implications for managing a pioneer species. The Symposium on Giants Sequoias: Their place in the ecosystem and Society, June 23–25, 1992, Visalia, CA. U.S. Department of Agriculture, Forest Service, General Technical Report PSW-151, 56–63.

Stephenson, N.L., Parsons, D.L., Swetnam, T.W. 1991. Restoring natural fire to the Sequoia-mixed conifer forest: Should intense fire play a role? Tall Timbers Fire Ecology Conference No. 17, High Intensity Fire in Wildlands: Management challenges and options, Tall Timbers Research Station, Tallahassee, FL, 321–337.

Stevens-Rumann, C.S. and Morgan, P. 2019. Tree regeneration following wildfires in the western US: a review. Fire Ecology, 15(1), pp.1-17.

Stewart, W. (2020). Reforesting California. Reforestation Practices for Conifers in California Technical editor: William Stewart. *University of California, Berkeley*.

Stewart, J.A., Van Mantgem, P.J., Young, D.J., Shive, K.L., Preisler, H.K., Das, A.J., Stephenson, N.L., Keeley, J.E., Safford, H.D., Wright, M.C., and Welch, K.R. 2021. Effects of postfire climate and seed availability on postfire conifer regeneration. Ecological Applications, 31(3), p.e02280.

Sun, F., Berg, N., Hall, A., Schwartz, M., and Walton, D. 2019. Understanding end-of-century snowpack changes over California's Sierra Nevada. Geophysical Research Letters, 46(2), pp.933-943.

Su, Y., Bales, R.C., Ma, Q., Nydick, K., Ray, R.L., Li, W., and Guo, Q. 2017. Emerging stress and relative resiliency of giant sequoia groves experiencing multiyear dry periods in a warming climate. Journal of Geophysical Research: Biogeosciences, 122(11), pp.3063-3075.

Swetnam, T.W. 1993. Fire history and climate change in giant sequoia groves. Science, 262: 5135, 885-889. DOI: 10.1126/science.262.5135.885.

Swetnam, T.W., Baisan, C.H., Caprio, A.C., Brown, P.M., Touchan, R., Anderson, R.S., and Hallett, D.J. 2009. Multi-millennial fire history of the giant forest, Sequoia National Park, California, USA. Fire Ecology, 5, 120–150. https://doi.org/10.4996/fireecology.0503120.

Tempel, D.J., Keane, J.J., Gutiérrez, R.J., Wolfe, J.D., Jones, G.M., Koltunov, A., Ramirez, C.M., Berigan, W.J., Gallagher, C.V., Munton, T.E. and Shaklee, P.A. 2016. Meta-analysis of California Spotted Owl (Strix occidentalis occidentalis) territory occupancy in the Sierra Nevada: Habitat associations and their implications for forest management. *The Condor: Ornithological Applications*, *118*(4), pp.747-765.

Tepley, A. J., Thomann, E., Veblen, T. T., Perry, G. L., Holz, A., Paritsis, J., ... & Anderson-Teixeira, K. J. (2018). Influences of fire–vegetation feedbacks and post-fire recovery rates on forest landscape vulnerability to altered fire regimes. Journal of Ecology, 106(5), 1925-1940.

Thorne, J.H., Boynton, R.M., Flint, L.E., and Flint, A.L. 2015. The magnitude and spatial patterns of historical and future hydrologic change in California's watersheds. Ecosphere, 6(2), pp.1-30.

Thompson, C., Smith, H., Green, R., Wasser, S., and Purcell, K. 2021. Fisher use of postfire landscapes: implications for habitat connectivity and restoration. Western North American Naturalist, 81(2), 225–242. Retrieved from: 00 WNAN 2007 new PAGE template (d2k78bk4kdhbpr.cloudfront.net).

Thompson, C., Spencer, W., Rosmos, H., Sawyer, S. 2020. Southern Sierra Nevada Fisher Conservation Strategy Interim Recommendations. Unpublished report produced by the Conservation Biology Institute.

Tricker, J., Landres, P., Fauth, G., Hardwick, P., and Eddy, A. 2014. Mapping wilderness character in Sequoia and Kings Canyon National Parks. Natural Resource Technical Report NPS/SEKI/NRTR—2014/872, 82 pp.

United States Fish and Wildlife Service. 2021. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Southern Sierra Nevada Distinct Population Segment of Fisher. Federal Register 86 (199), 57773-57801. Retrieved from: Federal Register: Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Southern Sierra Nevada Distinct Population Segment of Fisher.

United States Fish and Wildlife Service. 2020. Endangered and Threatened Wildlife and Plants; Endangered Species Status for Southern Sierra Nevada Distinct Population Segment of Fisher; Final Rule, May 15, 2020. Federal Register 85, 28532-29589. Retrieved from: Federal Register: Endangered and Threatened Wildlife and Plants; Endangered Species Status for Southern Sierra Nevada Distinct Population Segment of Fisher.

Weatherspoon, C.P. 1986. *Sequoiadendron giganteum*, Silvics of Conifers, Volume 1. Gen. Tech. Rep. PSW-95. Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture.

Ying, C.C. and Yanchuk, A.D., 2006. The development of British Columbia's tree seed transfer guidelines: Purpose, concept, methodology, and implementation. Forest Ecology and Management, 227(1-2), pp.1-13.

York, R.A., Battles, J.J. and Heald, R.C., 2007, January. Gap-based silviculture in a Sierran mixed-conifer forest: Effects of gap size on early survival and 7-year seedling growth. In Restoring Fire-adapted Ecosystems: Proceedings of the 2005 National Silviculture Workshop. USDA Forest Service, Pacific Southwest Research Station, Albany, CA (pp. 181-191).

York, R.A., Thomas, Z., and Restaino, J. 2009. Influence of ash substrate proximity on growth and survival of planted mixed-conifer seedlings. Western Journal of Applied Forestry, 24(3), pp.117-123.

York, R.A., Battles, J.J., Eschtruth, A.K., and Schurr, F.G. 2011. Giant sequoia (Sequoiadendron giganteum) regeneration in experimental canopy gaps. Restoration Ecology, 19(1), pp.14-23.

York, R.A., Stephenson, N.L., Meyer, M., Hanna, S., Moody, T., Caprio, A.C., and Battles, J.J. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 11a – giant sequoias. (Natural Resource Report No. NPS/SEKI/NRR—2013/665.11a). National Park Service, Fort Collins, Colorado.

York, R.A., Noble, H., Quinn-Davidson, L.N. and Battles, J.J., 2021. Pyrosilviculture: Combining prescribed fire with gap-based silviculture in mixed-conifer forests of the Sierra Nevada. Canadian Journal of Forest Research, 51(6), pp.781-791.

Zielinski, W.J. et al. 2013. An assessment of fisher (*Pekania pennanti*) tolerance to forest management intensity on the landscape. Forest Ecology and Management, 310, 821-826. Retrieved from: http://dx.doi.org/10.1016/j.foreco.2013.09.028.

Appendix A: Mitigations

Employee Safety

- A job hazard analysis would be developed and would be shared with crews for their awareness of hazards and how to reduce safety risks.
- Workers would wear appropriate personal protective equipment, including hardhats, and would receive safety briefings daily prior to beginning work.
- A risk assessment would be conducted daily to ensure employees operate only within the limits of acceptable risk. If risk is deemed too high on a given day, work would not occur.
- Comply with Sequoia and Kings Canyon National Parks' Management Directive (MD) 44 for tracking employees in remote locations.

Vegetation – Exotic Species and Soil Pathogens

- NPS stock, fed weed free hay, will primarily be used.
- If non-NPS stock are used, they will follow standard protocol for being fed weed-free hay a minimum of three days prior to transporting materials.
- All seedlings will be grown using best management practices for nurseries:
    - Seedlings will be isolated from those of other regions to reduce the chances of cross contamination of pathogens.
    - Well water or treated surface water will be used to water seedlings.
    - Pots will be sterilized between use.
    - Seedlings will be grown using sterile soilless media.
    - Seedlings will be grown off the ground (e.g. on tables).
- Clothing and equipment would be inspected prior to crews entering the field each day.
- Disturbance would be limited to roadsides, trails, and other developed areas as much as practicable. Overall soil disturbance would be minimized as much as practicable.
- No hay or straw bales would be used for temporary erosion control.
- Staging areas outside the park would be inspected for invasive plants and approved prior to use.
- Surveys for and treatment of invasive plants would be completed for one to three years after mitigation. If invasives are discovered, remedial actions would include controlling nonnative plant species by hand pulling or with herbicide depending on the species and extent of spread.

Vegetation – Special Status Plants

- For areas outside of the project areas where crews might be traveling through or camping areas where naturally regenerating sequoia seedlings occur would be flagged and avoided to prevent trampling.
- Crews to plant and monitor would be provided with information and training on how to identify naturally regenerating giant sequoia seedlings prior to project activities.
- Seedlings would not be planted in areas of high density natural regeneration where within that area naturally regenerating sequoia seedlings appear to be similar to reference densities.
- Monitoring crews that complete field surveys would have experience performing conifer seedling sampling throughout forests of the southern Sierra Nevada and careful training and calibration to

minimize, if not avoid, impacts to the plots that they are surveying. (The whole purpose of surveys is to understand the numbers of seedlings present; any damage to seedlings would therefore be counter-productive and contrary to the purpose and need of the survey).

- Plots would be sampled from the outside of the circle in, working in quadrants (1/4 of the circle at a time). This method is common in forest ecology and minimizes the amount of walking within the plot.
- Field assistants would take care to move vegetation out of the way with their hands in order to locate giant sequoia seedlings and other conifer seedlings and be especially careful to minimize trampling of seedlings within regeneration and survival and growth plots.
- Crews would take care when walking through groves to prevent inadvertent trampling of unmapped naturally regenerating sequoia seedlings.
- Crew leads would have sufficient botanical identification skills to be able to identify special status plants that have the potential to occur within the project areas, and the parks plant ecologist (or designee) would provide crews with a list of potential to occur special status plants and distinguishing characteristics prior to project activities.
- Crews would take care when walking through vegetated areas to prevent inadvertent trampling of undetected special status plant species by avoiding walking on understory native vegetation whenever possible.
- When walking on native vegetation cannot be avoided, crews would refrain from trampling native vegetation to the extent that it would likely result in mortality (e.g., broken main stem, extensive root damage, upturned plants).
- Prior to planting activities, the crew lead (and any other crew members with sufficient botanical identification skills), would survey the planting area for potential to occur special status plants, other than giant sequoias.
- If found, plants would be flagged for avoidance.
- Special status plant detections and location information would be communicated immediately to crew members working in the area and to the project lead(s).
- Populations of special status plant species would be protected by limiting disturbance to the actual project footprint when working in the vicinity of the plant.

Wildlife – General

- Personnel would be informed of the occurrence and status of special status wildlife species and would be advised of the potential impacts on the species and penalties for taking or harming a special status species.
- Workers must attend park-led training on food storage and garbage removal.
- All food would be stored in bear-proof containers, and staging, camping, and other work areas would be maintained (e.g., spilled food cleaned up, food stored properly, etc.) such that wildlife cannot access human food or other scented materials.
- Feeding or approaching wildlife would be prohibited.
- The park biologist or ranger would be notified if bears loiter in the area or if fisher sightings occur.

Wildlife – Nesting Birds

- Project would be implemented over the shortest timeframe feasible.
- To the extent feasible, if necessary, tree felling would be conducted outside the nesting season (all birds 1 February – 1 August; raptors 1 February – 1 August).

- If tree felling is to occur during this time, nesting surveys would be conducted before any activity occurring within 500 feet of suitable nesting habitat. Surveys shall be timed to maximize potential to detect nesting migratory birds and should be repeated within 5 days of the start of project-related activity.
- A minimum 500-foot buffer would be implemented around any active special-status species nest.
- If an active bird nest of other bird species is found, an appropriate no-disturbance buffer shall be determined by the park terrestrial ecologist based on site-specific conditions, the species of nesting bird, nature of the project activity, noise level of the project activity, visibility of the disturbance from the nest site, and other relevant circumstances.
- If establishing a buffer zone is not feasible, contact the U.S Fish and Wildlife Service for guidance to minimize, if not avoid, impacts to migratory birds associated with the proposed project.

Wildlife—Herpetofauna

- If herpetofauna (primarily salamanders, but also frogs, toads, and snakes) are observed during field activities, the following care should be taken.
    - First, document what was detected by taking photo(s) if possible and recording the observation on paper or in a digital device [date, time, location, possible species, lifestage estimate (juvenile or adult), and abundance (how many detected)].
    - Delicately move the animal(s) away from any area that is or would be disturbed by project activities and place in like-type habitat a safe distance away.
    - Share all data with the aquatic and wildlife programs.

Threatened and Endangered or Special Status Species

Fisher

- The park wildlife biologist (or trained wildlife technician) would teach NPS work crews how to identify high quality potential den trees and cavities based on characteristics (e.g., dbh, decay, tree species) documented in previous studies (Green et al. 2019). Trees meeting these characteristics would not be removed during the fisher LOP for tree felling activities (March 1-June 30) and would be avoided entirely if possible.
- If a fisher is spotted in, on the trunk of, or near a hazard tree that is marked to be felled (i.e., may have just climbed down, remains in area, or appears interested in climbing up), work would cease until the animal moves on without harassment. The wildlife biologist would be contacted for guidance.
- If a fisher is seen in the project areas when hazard trees are being felled, felling would cease until the animal moves on without harassment.
- If a fisher is seen in the project areas during tree planting activities, it would not be approached and would be allowed to move through the area without harassment.

California Spotted Owl (anticipated listing in fall 2023)

- If tree felling or helicopter project work needs to occur within the March 1-August 15 timeframe, the area would be surveyed for active owl nesting and roosting prior to conducting these activities. Surveys would be conducted in April of each year where project activity is planned.
- If nesting or roosting sites are detected, no action would occur within a 0.25 mile buffer until after August 15th unless a wildlife biologist determines the owl pair is no longer nesting or non-reproductive.

- No identified nesting trees would be removed.

Wetlands and Riparian Areas

- Avoid planting in a wetland area.
- Avoid traversing wetland or riparian areas.

Wilderness Minimum Impact Restrictions

- To prevent erosion and preserve vegetation, do not shortcut trails.
- Do not build rock cairns or other trail markers.
- Pets are not allowed in the wilderness.
- Pack out all trash including toilet paper.
- Discharge of any firearm or weapon is prohibited. Possession of weapons, including bear spray, is prohibited. The possession of firearms is subject to state regulations.
- Please close all gates behind you to protect wilderness resources.
- No camping within 25 feet of water. From 25 to 100 feet from water, camping is only allowed in previously established campsites.
- Camp on durable surfaces (rock, sand, dirt, snow, etc.) or in designated campsites. Do not camp on vegetation or in meadows.
- Do not construct rock walls, trenches, new fire rings (or add rocks to existing fire rings), bough beds, camp furniture, etc.
- Do not camp before reaching the first camping area for your specific trailhead.
- Do not camp under leaning trees or dead branches.
- Human waste must be buried at least 6 inches deep and 100 feet from trails, camps, and all water sources. Pack out used toilet paper.
- All soap, including biodegradable soap, should be used and disposed of away from water sources. Carry water 100 feet from the source before washing. This includes washing clothes, dishes, and yourself.
- Wilderness is a place where self-reliance and preparedness is essential. Be prepared for a wide variety of hazardous situations.
- Most wilderness illnesses are attributable to poor hygiene. Wash your hands often.
- Boil, treat, or filter drinking water.
- Properly store food items and other attractants when not in use to prevent bears and other wildlife from becoming conditioned to human food. Report any wildlife-related injuries, property damage, or unusual encounters to a ranger.
- Food items include: any food meant for human or pack stock consumption; food-tainted garbage, recyclables, and trash, such empty can, bottles, or food wrappers; any equipment with food residue or odor; toiletries such as soap, toothpaste, ointments, and lotions.
- The only proper food storage methods are: using an allowed portable animal-resistant food-storage container; using a permanent animal-resistant food-storage box; or using the counter-balance hanging technique. When camping in an area without food-storage boxes or adequate trees for hanging food, you must carry a park approved animal-resistant food-storage container.
- Note that during times of high fire danger, additional campfire restrictions may be implemented. Campfire restrictions also apply to the use of wood-burning camp stoves (e.g. Biolite or "Zip stoves").
- Where campfires are allowed, use existing fire rings. Do not build new ones or add rocks to existing fire rings.

- Use only dead or down wood found on the ground. Do not chop live vegetation or remove dead branches from standing trees.
- Fires must be attended at all times.
- Do not burn trash (this includes plastic and foil).
- Put out fires with water 1/2 hour before leaving your campsite and stir the ashes.

Cultural Resources

- Archeological sites (eligible or those treated as eligible for listing on the National Register of Historic Places) would be identified prior to planting and would be avoided during planting, along with a 100 foot buffer along the boundaries of the site.

Appendix A References

Green, R.E., Purcell, K.L., Thompson, C.M., Kelt, D.A. and Wittmer, H.U., 2019. Microsites and structures used by fishers (Pekania pennanti) in the southern Sierra Nevada: A comparison of forest elements used for daily resting relative to reproduction. Forest Ecology and Management, 440, pp.131-146.

Appendix B: Relevant Law, Policy, and Management Guidance

Laws, policies, and management guidance are summarized here in the order of their adoption.

Enabling Legislation for Sequoia National Park, 1890

"Whereas the rapid destruction of timber and ornamental trees in various parts of the United States, some of which trees are the wonders of the world on account of their size and the limited number growing, makes it a matter of importance that at least some of said forests should be preserved…" These lands are to be managed "for the preservation from injury of all timber, mineral deposits, natural curiosities or wonders . . . [and for] their retention in their natural condition."

Enabling Legislation for General Grant National Park, 1890

General Grant National Park (which was later incorporated into Kings Canyon National Park) was established in 1890 to protect "all timber, mineral deposits, natural curiosities, or wonders within the parks" and to "retain their natural conditions."

The NPS Organic Act of 1916

The Organic Act directs the NPS to "…conserve the scenery and natural and historic objects and the wildlife therein…by such means as will leave them unimpaired for the enjoyment of future generations".

Enabling Legislation for Kings Canyon National Park, 1940

"That the National Park Service shall… administer for public recreational purposes the lands withdrawn" (Sec. 3.).

Senate Report 1134 on the Creation of Kings Canyon National Park to accompany 54 Stat. 41, 16 USC 80a (March 4, 1940):

The major portion of the privately own lands comprise of the Redwood Mountain Grove of giant sequoias, the finest large grove remaining in private ownership, which the bill would authorize for addition to the park… [In 1890], General Grant National Park, only about 2,500 acres in extent, was established to preserve the General Grant Grove of sequoia trees. By that time, private ownership of some of the sequoia forest lands of importance for park purposes already had been established…. In 1926 the Kern country and Mount Whitney were added to Sequoia National Park, but there still remained many thousands of the California big trees (*Sequoia gigantea*) in private ownership, subject to destruction by commercial cutting operations."

The 1978 Amendment to the NPS Organic Act

This amendment clarified and enhanced the protective functions of the National Park Service and states: "Congress further reaffirms, declares, and directs that the promotion and regulation of the various areas of the National Park System, as defined in section 1c of this title, shall be consistent with and founded in the purpose established by section 1 of this title [the Organic Act provision quoted above], to the common benefit of all the people of the United States. The authorization of activities shall be construed, and the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress."

The Wilderness Act of 1964

Section 2 (c) "A wilderness, in contrast with those areas where man and his works dominate the landscape, is hereby recognized as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain. An area of wilderness is further defined to mean in this Act an area of undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions and which (1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable; (2) has outstanding opportunities for solitude or a primitive and unconfined type of recreation; (3) has at least five thousand acres of land or is of sufficient size as to make practicable its preservation and use in an unimpaired condition; and (4) may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value."

Section 4 (a) (3) "Nothing in this Act shall modify the statutory authority under which units of the national park system are created. Further, the designation of any area of any park, monument, or other unit of the national park system as a wilderness area pursuant to this Act shall in no manner lower the standards evolved for the use and preservation of such park, monument, or other unit of the national park system in accordance with section 100101(b)(1), chapter 1003, and sections 100751(a), 100752, 100753, and 102101 of title 54, United States Code, the statutory authority under which the area was created, or any other Act of Congress which might pertain to or affect such area, including, but not limited to, section 3(2) of the Federal Power Act (16 U.S.C. 796(2)); and chapters 3201 and 3203 of title 54, United States Code."

Section 4 (c) "Except as specifically provided for in this Act, and subject to existing private rights, there shall be no commercial enterprise and no permanent road within any wilderness area designated by this Act and except as necessary to meet minimum requirements for the administration of the area for the purpose of this Act (including measures required in emergencies involving the health and safety of persons within the area), there shall be no temporary road, no use of motor vehicles, motorized equipment or motorboats, no landing of aircraft, no other form of mechanical transport, and no structure or installation within any such area."

Endangered Species Act of 1973 (as amended)

(1) "The Secretary shall review other programs administered by him and utilize such programs in furtherance of the purposes of this Act. All other Federal agencies shall, in consultation with and with the assistance of the Secretary, utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species listed pursuant to section 4 of this Act."

NPS Management Policies 2006

4.4.1.1 Plant and Animal Population Management Principles

"The Service will adopt park resource preservation… strategies that are intended to maintain the natural population fluctuations and processes that influence the dynamics of individual plant and animal populations, groups of plant and animal populations, and migratory animal populations in parks."

4.4.2.4 Management of Natural Landscapes

"Natural landscapes disturbed by natural phenomena, such as… fires, will be allowed to recover naturally unless manipulation is necessary to (1) mitigate for excessive disturbance caused by past human effects…"

6.1 General Statement, Wilderness Preservation and Management

"The National Park Service will manage wilderness areas for the use and enjoyment of the American people in such a manner as will leave them unimpaired for future use and enjoyment as wilderness. Management will include the protection of these areas, the preservation of their wilderness character, and the gathering and dissemination of information regarding their use and enjoyment as wilderness. The purpose of wilderness in the national parks includes the preservation of wilderness character and wilderness resources in an unimpaired condition and, in accordance with the Wilderness Act, wilderness areas shall be devoted to the public purposes of recreational, scenic, scientific, educational, conservation, and historical use."

6.3.5 Wilderness Minimum Requirement

"All management decisions affecting wilderness must be consistent with the minimum requirement concept. This concept is a documented process used to determine if administrative actions, projects, or programs undertaken by the Service or its agents and affecting wilderness character, resources, or the visitor experience are necessary, and if so how to minimize impacts. The minimum requirement concept will be applied as a two-step process that determines:

- whether the proposed management action is appropriate or necessary for administration of the area as wilderness and does not cause a significant impact to wilderness resources and character, in accordance with the Wilderness Act; and

- the techniques and types of equipment needed to ensure that impacts on wilderness resources and character are minimized.

Although park managers have flexibility in identifying the method used to determine minimum requirement, the method used must clearly weigh the benefits and impacts of the proposal, document the decision-making process, and be supported by an appropriate environmental compliance document. Parks must develop a process to determine minimum requirement until the plan is finally approved. Parks will complete a minimum requirement analysis on those administrative practices and equipment uses that have the potential to impact wilderness resources or values. The minimum requirement concept cannot be used to rationalize permanent roads or inappropriate or unlawful uses in wilderness."

Sequoia and Kings Canyon National Parks General Management Plan (2007)

Parks' Mission: "protect forever the greater Sierran ecosystem – including the sequoia groves and high Sierra regions of the parks – and its natural evolution, and to provide appropriate opportunities to present and future generations to experience and understand park resources and values."

Management Prescription: "The giant sequoia groves — particularly Giant Forest — and the ecosystems they occupy are restored, maintained, and protected."

Sequoia and Kings Canyon National Parks Wilderness Stewardship Plan (2015)

The parks' WIlderness Stewardship Plan outlines the following desired conditions:

- "The untrammeled quality of wilderness character will be preserved by limiting deliberate manipulation of ecological systems *except as necessary to promote another quality of wilderness character*" (emphasis added).

- "The natural quality of wilderness will be preserved by mitigating the impacts of modern civilization on ecosystem structure, function, and processes...In the wilderness, natural process would dominate: *ecosystem structure and function*; *native biodiversity*; water quality and quantity; decomposition, nutrient cycling, and soil forming processes; meadow and wetland productivity; *fire regimes*; and soundscapes, dark skies, and viewsheds" (emphasis added).

Sequoia and Kings Canyon National Parks Foundation Document (2016)

The Parks' purpose and need is identified in this document as the following: "Sequoia and Kings Canyon National Parks preserve and provide for the enjoyment of present and future generations the wonders, curiosities, and evolving ecological processes of the southern Sierra Nevada— including the largest giant sequoia trees in the world, free flowing wild and scenic rivers, and the heart of the vast High Sierra wilderness" (NPS 2016).

Furthermore, giant sequoia trees are identified as a fundamental resource and value of the Parks: "Giant sequoia trees are endemic to the western slope of the Sierra Nevada and are among the largest and oldest trees on Earth. The protection of giant sequoia trees from logging was one of the primary forces for the creation of Sequoia National Park. The groves, and the magnificent trees contained therein, have inspired generations of visitors from around the world with a sense of awe. The parks contain 39[25] giant sequoia groves, which account for roughly 40% of all giant sequoia grove areas in the world, including the largest unlogged giant sequoia grove (Redwood Canyon Grove). The four largest giant sequoia trees—by trunk volume—are in these parks (including the General Grant Tree, the nation's only living war memorial). Giant sequoias are also unique due to their evolutionary adaptations that make them resilient to many stressors.

[25] At the time of the writing of the Foundation Document the number of groves was considered to be 39. That number has since been revised down to 37 to exclude small tree clusters or individual trees no longer considered by park managers to be individual groves.

Research into giant sequoias influenced the field of fire ecology and provided the impetus for prescribed fires in the parks" (NPS 2016).

Sequoia and Kings Canyon National Parks Resource Stewardship Strategy (2017)

The parks' Resource Stewardship Strategy (RSS) outlines the following goals associated with sequoia protection:

1. Maximize persistence of large, living giant sequoias.
2. Maximize persistence of structurally and compositionally complex giant sequoia groves that are sustainable, resilient (to drought, fire, insects, etc.), and support native biodiversity.
3. Manage for ecological functions essential to giant sequoia groves (fire, hydrology).
4. Prepare for potential shifts in giant sequoia distribution to enable its persistence in the broader Sierra Nevada landscape.
5. Prioritize persistence of giant sequoia in areas of highest social value.

At the time of its writing, the RSS states that only 20% of sequoia groves in the Parks are within desired fire return interval and that small trees are overly dense in most groves. Both of these stressors were identified as moderate concern just five years ago.

Finally, the parks' RSS identified such direct management priorities to "…include continuing and expanding the use of fire and fuels treatments, reducing other stressors like invasive plants, establishing seed banks, and research with new or expanded treatments that may increase resistance and resilience to climate change, drought, insects, disease, and uncharacteristically severe fires" (NPS 2017, 84).

Appendix B References

National Park Service. 2006. NPS Management Policies 2006. Sequoia and Kings Canyon National Parks.

National Park Service. 2007. General Management Plan. Sequoia and Kings Canyon National Parks.

National Park Service. 2010. National Park Service Climate Change Response Strategy. National Park Service Climate Change Response Program, Fort Collins, Colorado.

National Park Service. 2015. Wilderness Stewardship Plan. Sequoia and Kings Canyon National Parks.

National Park Service. 2016. Sequoia and Kings Canyon National Parks Foundation Document.

National Park Service. 2017. A Climate-Smart Resource Stewardship Strategy for Sequoia and Kings Canyon National Parks. Sequoia and Kings Canyon National Parks.

United States. 1964. Wilderness Act of September 3, 1964 (P.L. 88-577, 78 Stat. 890 as amended; 16 U.S.C. 1131(note), 1131-1136).

United States. 1973. The Endangered Species Act of 1973 P.L. 93-205, as amended by P.L.9-304). Washington: U.S.G.P.O.

Appendix C: Evaluating Ecological Intervention Proposals in Wilderness

The following analysis is completed in accordance with the *Guidelines for Evaluating Ecological Intervention Proposals in National Park Service Wilderness* as incorporated within Director's Order #41, Reference Manual: Wilderness Stewardship on April 14, 2022.

Factor to Consider	Favors Intervention	Does NOT Favor Intervention	Rationale
1. Cause of Degradation	☒ If the ecological degradation was primarily caused by human action as opposed to natural causes	☐ If the ecological degradation was primarily caused by natural forces as opposed to human action	This factor favors intervention because the primary cause of the degradation to sequoia groves and proposed fisher critical habitat was high severity fire fueled by a century of human fire suppression. Fire is a primary ecosystem process shaping sequoia mixed conifer forests in the Sierra Nevada and most fires prior to European settlement—save those traditionally ignited by Native Americans—would have been ignited by lightning. These lightning fires would have burned through these fire adapted forests in a patchy mosaic of severity ranging from no fire to low and moderate burn severity. Some patches would also have burned at higher severity—though not necessarily high severity which connotes high mortality—and these patches, or gaps, would have been spaced across the landscape in such a way that gaps created by fire would naturally recover to their pre-fire forest conditions and species composition in a period of 10-20 years (Stephenson et al. 1991; Stephenson 1994; 1999; Demetry 1995). As documented by the NPS and others, suppression of lighting caused fire in these parks and surrounding lands began only 125 years ago yet has had long-term consequences for the fire adapted forests of the Sierra Nevada (Kilgore 1972; Parsons 1978). The legacy of fire suppression (or exclusion) has left these forests with such high and contiguous fuel accumulations that they are no longer resilient to the fires they evolved with. Fire exclusion has resulted in dramatic changes to forest structure with a higher density of small trees (ladder fuels), shifts in species composition, and increases in stand densities. Because of this fuel loading, nearly every fire ignition has the potential to lead to severe fire effects or stand replacing fire (A. Caprio personal communication January 2023).

Factor to Consider	Favors Intervention	Does NOT Favor Intervention	Rationale
			Notably, these risks are not prevalent in areas where fire has been maintained, or re-introduced, including areas of these parks that have successfully re-introduced fire (A. Caprio personal communication January 2023). The fire return interval for sequoia mixed conifer groves ranges from 6-35 years and mixed conifer alone ranges from 1-30 years (Swetnam 1993; Caprio and Swetnam 1995; Swetnam et al. 1998; Caprio and Graber 2000; Swetnam et al. 2009; NPS 2003; NPS 2022). Notably, many of the most recent fires in sequoia groves within Sequoia and Kings Canyon National Parks have been due to prescribed burning which has occurred in the drainages where some groves occur and, in the case of Redwood Mountain, the upper part of the grove itself, but had not occurred in the areas that burned at high severity during these fires. The patches of forest that burned at high severity had not had recent recorded unsuppressed fire as documented by the fire history in drainage vicinities where the proposed replanting areas are located (NPS 2023). • South Fork Kaweah Drainage (Board Camp, Homers Nose): Since 1932 and through 2019, 116 ignitions had been recorded within the South Fork Kaweah Drainage. Ninety-two of these—including 72 lightning caused fires—were suppressed. Zero acres burned within the proposed planting areas within Board Camp and Homers Nose between 1932 and 2019 (NPS Fire History Data unpublished). • Oriole Lake Drainage Vicinity: Since 1924, and through 2019, 104 ignitions had been recorded in the Oriole Lake Drainage. Seventy-six of these—including 65 lightning caused—were suppressed; 11 starts (2 in Oriole Lake drainage), were prescribed or pile burns outside the action area. Other than one pile burn that was less than an acre in size, New Oriole Lake Grove did not see fire between 1970 and 2019 (NPS Fire History Data unpublished). • Suwanee Grove Vicinity: Since 1925 and through 2019, 183 ignitions had been recorded. One hundred and forty-nine of these—including 108 lightning caused fires—were suppressed; 22 starts were prescribed treatments outside the action area; and one broadcast treatment occurred in the area in 1992. Zero acres burned with the proposed planting area within

Factor to Consider	Favors Intervention	Does NOT Favor Intervention	Rationale
			Suwanne Grove between 1993 and 2019 (NPS Fire History Data unpublished). • Redwood Mountain Drainage: Since 1922 and through 2019, 104 ignitions had been recorded. Seventy-four of these—including 36 lightning caused fires—were suppressed; 20 were prescribed treatments and occurred in upper half of the drainage outside the action area. Portions of the proposed planting areas within Redwood Mountain Grove have seen prescribed fire in the last 15 years but burned at high severity in the KNP Fire. Fifteen percent of the grove was burned in a prescribed fire in 2009; 14% was burned in a prescribed fire in 2011; and 6% was burned in a prescribed fire in 2016. The remaining portions of the proposed planting areas did not see fire between the mid 1980s and 2020. (NPS Fire History Data unpublished). • Dillonwood: No suppression data is available. Zero acres burned within the proposed planting area within Dillonwood Grove between 1932 and 2019 (NPS Fire History Data unpublished). Factors driven by climate change, including extended periods of hotter, drier drought, and less snowfall (Diffenbaugh et al. 2015; Griffin and Anchukautus 2014) have contributed to fuels accumulations from the die-off of millions of trees in the Sierra Nevada. These factors likely contributed to certain sequoia groves and mixed conifer forests burning at high severity during the Castle and KNP wildfires. However, while all 27 groves in Sequoia and Kings Canyon National Parks that burned during these fires were subjected to these same climate-driven factors, not all experienced high-severity effects. In fact, groves with recent natural or prescribed fire, and thus less fuel accumulation, experienced largely beneficial effects; in comparison the six groves with a history of fire exclusion, and therefore higher fuel loads (e.g. surface fuel accumulations and standing ladder fuels), experienced severe effects (Shive et al. 2021; York et al. 2013). This key difference in pre-fire fuel conditions has led fire ecologists and sequoia experts to conclude that, were it not for high pre-fire fuel loading in the groves where severe fire effects were documented, more sequoias would have survived (A. Caprio personal communication January 2023).

Factor to Consider	Favors Intervention	Does NOT Favor Intervention	Rationale
			Fire and fuels monitoring data from other areas and post-fire assessments in these groves suggest that high fuel loading in the affected groves, as well as topography and weather conditions, led to the high severity at which these groves burned and was the primary factor contributing to sequoia mortality and near total loss of seed sources that would otherwise promote natural regeneration post-fire.
2. Timing of Degradation	☒ If the cause of the ecological degradation occurred in the past and will not potentially compromise the success of the intervention	☐ If the cause of the ecological degradation is ongoing and will potentially compromise the success of the intervention	As outlined above, mortality of large sequoias and mixed conifer forests during the Castle and KNP wildfires would not likely have occurred but for high fuel loading resulting from direct human action to suppress wildfires within a naturally fire adapted forest ecosystem. Notably, all areas (and the surrounding forests) where intervention is proposed have experienced fire in the last three years and no longer retain the same heavy fuels accumulation post-fire suppression/pre-Castle and KNP wildfires. As fuels re-accumulate post-fire, the awareness of the impacts of high severity fire provides a new framework for fire managers to prioritize maintenance of low fuel loading across the landscape, especially in high priority areas such as in and around sequoia groves. NPS policy and plans continue to support and enable the NPS to utilize a variety of tools, including wildland fire, to meet these fuel loading objectives.
3. Origin of Degradation	☒ If the origin of the ecological degradation occurs in a location where the agency has authority to act	☐ If the origin of the ecological degradation is regional or global, or occurs outside the wilderness with little chance for a successful outcome within wilderness	This factor favors intervention because the origin of degradation (fire suppression) within each of these groves, fisher habitat corridor, and surrounding forests 1) occurs on lands that are managed by the NPS, and 2) is within the jurisdiction of NPS's authority for managing wildfire. While other agencies (USFS, BLM, and NPS managers for surrounding NPS lands) actions to suppress fires may influence fuel loading within Sequoia and Kings Canyon National Parks, particularly near shared boundaries, the NPS increasingly coordinates with these agencies on fire management activities. Notably, the fire history documented in the previous section were NPS management activities.

Factor to Consider	Favors Intervention	Does NOT Favor Intervention	Rationale
4. Urgency of Degradation	☒ If the degradation warrants a need to intervene quickly to prevent the degradation from becoming worse	☒ If the degradation does not warrant a need to intervene quickly to prevent the degradation from becoming worse	This factor could either favor or not favor intervention, depending upon the intensity of action. Acting now, when these areas are at their closest to post-fire conditions—when re-establishment would have occurred naturally had it not been for the impacts of fuel loading and resulting high severity fire—would increase the likelihood of success. Additionally, conversion to fire-initiated shrub communities, if not halted now by timely intervention, is likely to exacerbate a high severity fire cycle and increase the likelihood of degradation that could occur should high severity fire spread from these new shrub communities to other areas, including remnant portions of affected groves (Coop et al. 2020; Coppoletta et al. 2016). Once shrub communities become dominant, this degradation will be self-perpetuating and irreversible without substantial intervention (e.g. mastication, herbicide). Note that though the NPS recognizes the window for action is closing (without needing to take additional measures), the opportunity for successful correction is still open due primarily to 1) the impact of the high severity fire, which created patches where little to no vegetation is yet establishing (the shrub seed bank may have incinerated or did not exist due to previously forested conditions) (i.e., openings still exist) and 2) seedling size at planting would be roughly the size of seedlings expected to be present in the second-year post-fire; a size which allows them to increasingly compete with shrub growth. Furthermore, giant sequoia and Sierra Nevada mixed conifer forests are adapted to frequent low to moderate severity fire with small pockets of high severity. Regeneration for sequoias in particular relies on the conditions created by moderate to high severity fire in small gaps, where there is reduced competition for light and moisture and the forest floor is free of litter and duff down to bare mineral soil. Therefore, sequoia germination and seedling establishment is greatest in the first ear post-fire with a much smaller germination pulse in year two (Kilgore and Biswell 1971; Harvey et al. 1980; Shellhammer and Shellhammer 2006).

Factor to Consider	Favors Intervention	Does NOT Favor Intervention	Rationale
			Similarly, the dominant pine species of the mixed conifer forest are adapted to frequent low-severity fire (Welch et al. 2016). After high-severity wildfire, with large patch sizes, they are at risk of regeneration failure because they lack the ability to resprout, cone serotiny, or a soil seed bank and therefore rely on living trees for recruitment (Stewart et al. 2021; Guiterman et al. 2022). Study of large contiguous areas of high-severity fire in the Sierra Nevada shows that shrubs—with adaptations to resprout and/or soil seed banks—are stimulated by fire and are likely to become dominant over a period of years. In addition, downed fuels and continuous shrub cover increase the likelihood of high severity reburn which would kill any surviving seedlings and further select for shrubs (Copolletta et al. 2016; Nemens et al. 2022). The reproductive biology of the trees and the competitive advantage of shrubs makes successful conifer establishment, without more intensive intervention, increasingly unlikely as the post-fire time lengthens—especially as the area continues to burn and shrubs gain a stronger foothold. Prior to any reburn event, if shrubs were the dominant vegetation, they would have a larger seed bank and would resprout vigorously following fire. Therefore, planting trees following a reburn would decrease the likelihood of success because shrub competition will continue to increase with every burn. By fall of 2023, it will have been three years since the Castle Fire and two years since the KNP, and while the window for planting is not yet closed (see outcome of intervention below), the window for conifer establishment to restore natural conditions in a manner that minimizes trammeling is nearing its end. Should the NPS not act in a timely manner (within the next 1-2 years for initial efforts as proposed), the opportunity to restore the ecological function of these previously forested areas in a manner that most closely mimics natural post-fire recovery and is most sensitive to wilderness character will be lost. In addition, the standing dead trees will become weakened with time, which will pose increasing operational safety risks for planting crews and reduce the potential for action to

Factor to Consider	Favors Intervention	Does NOT Favor Intervention	Rationale
			be considered in the future until at least such time as those snags are no longer a risk or are removed through further trammeling actions.
5. Sustainability of Intervention	☒ If climate-driven or other broad-scale, persistent ecological drivers will not interfere with correcting the degradation	☒ If climate-driven or other broad-scale, persistent ecological drivers will likely interfere with correcting the degradation	This factor may either favor or not favor intervention depending upon future fire management activities, the climate vulnerability of planted areas, and the resiliency of the species in question. **Wildfire Management** Though NPS policy from 1904 through 1968 was to extinguish all fires within the parks, law and policy now allow wildfires to run their course to the maximum extent feasible; and the NPS is committed to a managed wildfire strategy when state air quality standards do not require fires to be suppressed, when such strategy would not threaten communities, when fire would be beneficial to the landscape, and when fire does not place resources at risk. More specifically, the Fire and Fuels Management Plan for Sequoia and Kings Canyon National Parks (2003) states that the NPS, through the plan and its implementation, "seeks to benefit park resources and society by restoring and maintaining the natural fire regime in a manner consistent with firefighter and public safety," and chief among the tools available to the NPS through that plan includes wildland fire use (i.e., non-suppression). Given these changes in management policy, planning in the last 50 years, more recent changes in fuels accumulation in these areas, and the severity of effects recently experienced in these groves and the renewed impetus to correct past degradations resulting from suppression, the NPS can state with relative certainty, that future fire management activities will increasingly reflect the lessons learned from these and other devastating fires experienced throughout California in the past 10 years. **Climate Change** The parks' Resource Stewardship Strategy (RSS) outlines three plausible future climate scenarios and their effects on Sequoias through 2040: 1) Much warmer/drier climate where stress levels and pockets of mortality increase; 2) Warmer climate with similar precipitation where effects are similar to scenario 1,

but of smaller magnitude; and 3) Much warmer and wetter where mature giant sequoia persist in similar footprint but forests become more dense with other species intermixed with young giant sequoia (NPS 2017). Scenarios are similar for mixed conifer forests where vulnerability to species such as those proposed for planting is greatest under scenario 1; though some species would continue to find refuge in sequoia groves.

Due in part to the uncertainties over the future of forest systems in the Sierra Nevada, as well as whether and how the distribution of sequoias on the landscape may change, the NPS cannot say with 100% certainty that climate change will not limit the effectiveness of this correction of the degradation. However, as evidenced by modeling scenarios conducted for the RSS, neither is there evidence that sequoia would not have continued to persist within these grove footprints in the future had it not been for the loss of seed sources in these fires. There is also no evidence that seedlings will not be able to survive in areas where planting is proposed. In fact, if adequate moisture is available for seedlings during the years when planting would occur, giant sequoia has higher post-planting seedling survival than the other mixed-conifer tree species (York et al. 2007). Likewise, there is no evidence that the fisher mixed conifer habitat where action is being considered will not support mixed conifer forest in the future (Meyer et al. 2022).

During the 2012-2016 drought, over 100 million trees died in the Sierra Nevada. However, there was limited mortality of mature sequoia trees attributed to drought (Nydick et al 2018). Less than 40 mature sequoias across the entire range were recorded as dying from drought related mortality sources during the 2012-2016 drought—demonstrating their resistance to this event in comparison with all other conifers. While sequoia have extremely high water demands (Ambrose et al. 2016) research suggests the groves exist in hydrologic refugia (Su et al. 2017; Baeza et al. 2021; Stephenson 1996).

Therefore, while climate had an impact on the fire weather and severity of fire effects, there is no indication that sequoia would not continue in these locations if high fuel loading in the affected groves had not led to the high severity at which these groves burned and was the primary factor contributing to sequoia mortality and near total loss of the seed bank. Given the commitment of NPS managers to protect the natural fire regime in these areas (see factors 2 and 5

Factor to Consider	Favors Intervention	Does NOT Favor Intervention	Rationale
			above), the ecological correction being proposed has a strong likelihood of being a sustainable correction and addressing the ecological degradation. In addition, as the planted trees grow, they will shade competing shrubs, breaking up the fuel continuity and reducing risk of fire spread.
6. Outcome of Intervention	☒ If the intervention has a clear and identifiable point at which an achievable outcome is reached	☐ If the intervention does not have a clear and identifiable point at which an achievable outcome is reached	This factor favors intervention because the proposed project has an achievable outcome and a clear point at which the outcome would be reached. The desired outcome of this proposed intervention is to establish a sufficient amount of sequoia and mixed conifer seedlings, and at sufficient densities, so as to direct the trajectory of these forests toward recovery to their pre-fire forest assemblages—as they would have done naturally had high fuel loading not led to severe fire effects. For this reason, the proposed planting densities and planting timeframe have been scoped for species resiliency to single year droughts and future mortality sources, such as future fires. As proposed, planting would extend for up to 5 years to account for natural variables, such as winter precipitation, but would cease as soon as the target densities of established seedlings are achieved. Once seedlings are established, the NPS anticipates that natural and dynamic post-fire recovery processes would continue *without* additional intervention (i.e., additional planting or seedling care). Over a period of centuries, the NPS anticipates trees would mature and that large sequoias (monarchs) would be the dominant feature within most, if not the entire, former grove footprints and mixed conifer would persist in the fisher habitat corridor. The NPS also recognizes that the footprint of all sequoia groves will vary (grow, shrink, or shift) over time due to natural factors (fire, weather, etc.) and the influences of climate change.
7. Intensity of Intervention	☒ If the intervention is a less intense undertaking due to the	☐ If the intervention is a more intense undertaking due to the size of the area trammeled,	This factor favors intervention as the intensity of the intervention is relatively low-to-moderate in context of the size of the area trammeled as compared to the area of forest impacted by high severity fire and the wilderness areas as a whole, the tools used, and the intermittent nature and short duration of on-site intervention (see Wilderness Stewardship Plan; NPS 2015). In all, the NPS is proposing action across roughly 700 acres of sequoia groves and 485 acres of mixed conifer habitat in wilderness out of a total of roughly

Factor to Consider	Favors Intervention	Does NOT Favor Intervention	Rationale
	size of the area trammeled, tools used, number and frequency of interventions	tools used, number and frequency of interventions	840,000 acres designated or managed as wilderness within these parks and of over 750 acres of giant sequoia groves and over 12,000 acres of fisher habitat that burned at high severity in both fires. Although planting could occur for up to 5 years (up to 2 years initially and then only as necessary to replace seedlings that have dies), actual on-site work would be intermittent and would occur over the course of weeks across these 1,130 acres and across this much longer time frame. The planting crew would also complete on-site work by hand, utilizing hand tools (such as small spades or "dibbles") to move aside sufficient soil to create a gap to plant each seedling. Each gap would be closed after seedling was planted. The soil profile would not be modified, and soil would not be removed from its native location. A small well of soil and duff up to three inches high would-be hand built downhill of each seedling to capture incident moisture, however there would be no additional care of seedlings once seedlings were planted. Planting would involve small crews of up to 15 individuals. Helicopter flights would be considered in areas where transporting seedlings and tools to the site would otherwise be infeasible. Removal of several trees may be proposed to facilitate safe sling-loading of tools and seedlings. An MRA would be developed to determine the minimum requirement for all 4c prohibited activities and tools. The use of these tools is expected to be intermittent and of low intensity (measured in hours, not days) over the course of the project. All planting crews and monitoring staff would walk into the worksite to conduct planting activities. Higher intensity interventions such as flying crews into the sites, using motorized equipment to aid in planting, using motorized equipment to prepare sites for planting, removing dead trees prior to planting, and removing shrubs using mechanical or chemical means are not being considered at this time as they are not considered the minimum necessary to achieve the purpose and need of the project so long as work could be completed in the current timeline proposed.

Factor to Consider	Favors Intervention	Does NOT Favor Intervention	Rationale
			As well, the NPS and cooperators are utilizing analyses regarding fire severity, natural regeneration, and habitat suitability to constrain this action to forest areas that are highly unlikely to regenerate naturally and that are modeled to persist as forest under future climate scenarios. Long-term monitoring would be conducted to track restoration success, and alternatives for monitoring would be evaluated through a Minimum Requirements Analysis (MRA) to preserve wilderness character, though some monitoring is likely appropriate regardless of whether or not intervention is taken.
8. Experience with Intervention	☒ If the intervention has been successfully conducted previously and has low risk of unintended consequences	☐ If the intervention has not been successfully conducted previously or has unknown or high risk of unintended consequences	The NPS and others have extensive experience with successful planting of giant sequoias and other conifer species within these parks and within and outside of the species' natural range. SEKI planted sequoias in areas impacted by development during the Giant Forest Restoration, and USFS has planted giant sequoias in several groves including Black Mountain Grove. UC Berkeley has also planted giant sequoias in experimental plantations in Blodgett Forest, and Sierra Pacific Industries has planted giant sequoias in their plantations across the Sierra Nevada. Planting absent supplemental water has likewise been conducted and has been highly successful; sequoia from different genetic sources have also been successfully planted in many areas (i.e., Mountain Home, Whitakers Forest, McKinley Groves). There is no documented evidence of unintended consequences from planting sequoia or mixed conifer species. Though the opportunity to introduce non-native, invasive, species or pathogens exists, sterile soil media and other mitigations—with which the NPS and other experts have extensive experience—would be implemented to reduce the potential for invasive species introduction or establishment. Additional analysis of environmental consequences would be completed through an Environmental Assessment.

Appendix C References

Ambrose, A. R., Baxter, W. L., Wong, C. S., Burgess, S. S., Williams, C. B., Næsborg, R. R., and Dawson, T. E. 2016. Hydraulic constraints modify optimal photosynthetic profiles in giant sequoia trees. Oecologia, 182(3), 713-730.

Baeza, A., Martin, R.E., Stephenson, N.L., Das, A.J., Hardwick, P., Nydick, K., Mallory, J., Slaton, M., Evans, K. and Asner, G.P., 2021. Mapping the vulnerability of giant sequoias after extreme drought in California using remote sensing. Ecological Applications, 31(7), p.e02395.

Caprio, A.C. and T.W. Swetnam. 1995. Historic fire regimes along an elevational gradient on the west slope of the Sierra Nevada, California. pp. 389-398. In: J.K. Brown, R.W. Mutch, C.W. Spoon and R.H. Wakimoto (tech. coord.). Proceedings: Symposium on Fire in Wilderness and Park Management: Past Lessons and Future Opportunities, March 30-April 1, 1993, Missoula MT. USDA, For. Serv. Gen. Tech. Rep. INT-GTR-320.

Caprio, A.C. and Graber, D.M. 2000. Returning fire to the mountains: can we successfully restore the ecological role of pre-Euroamerican fire regimes to the Sierra Nevada? pp 233-241. In: Proceedings: Wilderness Science in a Time of Change, Missoula, MT. May 23-27, 1999.

Coop, J. D., Parks, S. A., Stevens-Rumann, C. S., Crausbay, S. D., Higuera, P. E., Hurteau, M. D., and Rodman, K. C. 2020. Wildfire-driven forest conversion in western North American landscapes. *BioScience*, *70*(8), 659-673.Demetry, A. 1995. Regeneration patterns within canopy gaps in a giant sequoia-mixed conifer forest: implications for restoration. M.S. thesis. Northern Arizona University. Flagstaff, AZ. Google Scholar. Accessed December 15, 2022.

Coppoletta, M., Merriam, K. E., and Collins, B. M. 2016. Post-fire vegetation and fuel development influences fire severity patterns in reburns. Ecological applications, 26(3), 686-699.

Demetry, A. 1995. Regeneration Within Canopy Gaps in a Giant Sequoia-Mixed Conifer Forest: Implications for Forest Restoration. M.S. thesis. Northern Arizona University, Flagstaff, AZ.

Diffenbaugh, N.S., Swain, D.L. and Touma, D. 2015. Anthropogenic warming has increased drought risk in California. Proceedings of the National Academy of Sciences, 112(13), pp.3931-3936.

Eyes, S.A., Roberts, S.L., and Johnson, M.D. 2017. California spotted owl (Strix occidentalis occidentalis) habitat use patterns in a burned landscape. The Condor 119:375-388.

Harvey, H.T., Shellhammer, H.S., and Stecker, R.E. 1980. Giant Sequoia Ecology: Fire and Reproduction. DOI National Park Service, Washington, D.C., Scientific Monograph Series No. 12

Griffin, D. and Anchukaitis, K.J. 2014. How unusual is the 2012–2014 California drought?. Geophysical Research Letters, 41(24), pp.9017-9023.

Guiterman, C.H., Gregg, R.M., Marshall, L.A., Beckmann, J.J., Van Mantgem, P.J., Falk, D.A., Keeley, J.E., Caprio, A.C., Coop, J.D., Fornwalt, P.J., and Haffey, C. 2022. Vegetation type conversion in the US Southwest: frontline observations and management responses. Fire Ecology, 18(1), pp.1-16.

Hagmann, R.K., Hessburg, P.F., Prichard, S.J., Povak, N.A., Brown, P.M., Fulé, P.Z., Keane, R.E., Knapp, E.E., Lydersen, J.M., Metlen, K.L., and Reilly, M.J. 2021. Evidence for widespread changes in the structure, composition, and fire regimes of western North American forests. Ecological Applications, 31(8), p.e02431.

Hammon, Jensen, and Wallen Mapping and Forestry Services and Western Timber Service. 1964, 1967, 1973. Sequoia Tree Inventory (STI) Sequoia and Kings Canyon National Parks California, prepared for US DOI, NPS, Sequoia and Kings Canyon National Parks, Three Rivers, California.

Hessburg, P.F., Miller, C.L., Parks, S.A., Povak, N.A., Taylor, A.H., Higuera, P.E., Prichard, S.J., North, M.P., Collins, B.M., Hurteau, M.D., and Larson, A.J. 2019. Climate, environment, and disturbance history govern resilience of western North American forests. Frontiers in Ecology and Evolution, 7, p.239.

Kilgore, B.M. and H.H. Biswell. 1971. Seedling germination following a fire in a giant sequoia forest. California Agriculture 25:8-10.

Kilgore, B.M. 1972. Fire's role in a sequoia forest. Naturalist 23:26-37.

Kilgore, B. M., and D. Taylor. 1979. Fire history of a sequoia-mixed conifer forest. Ecology 60:129-142.

Lydersen, J.M., Collins, B.M., Coppoletta, M., Jaffe, M.R., Northrop, H., and Stephens, S.L. 2019. Fuel dynamics and reburn severity following high-severity fire in a Sierra Nevada, USA, mixed-conifer forest. Fire Ecology, 15(1), pp.1-14.

Meyer, M.D., White, A., McGregor, E, Faber, K., Green, R., Eckert, G. 2022. POST-FIRE RESTORATION STRATEGY FOR THE 2021 WINDY FIRE, KNP COMPLEX, AND FRENCH FIRE. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.

National Park Service. 2015. Wilderness Stewardship Plan. Sequoia and Kings Canyon National Parks.

Nemens, D. G., Kidd, K. R., Varner, J. M., and Wing, B. 2022. Recurring wildfires provoke type conversion in dry western forests. Ecosphere, 13(8), e4184.

Nydick, K. R., Stephenson, N. L., Ambrose, A. R., Asner, G. P., Baxter, W. L., Das, A. J., and Paz-Kagan, T. 2018. Leaf to landscape responses of giant sequoia to hotter drought: An introduction and synthesis for the special section. Forest Ecology and Management,419-420, 249-256.

Parsons, D.J. 1978. Fire and fuels accumulation in a Giant Sequoia Forest. J. For. 76:104-105.

Shellhammer, H.S and Shellhammer, T.H. 2006. Giant Sequoia (*Sequoiadendron giganteum* [Taxodiaceae]) Seedling Survival and Growth in the First Four Decades Following Managed Fires. Madrono, Vol.53, No.4, pp.342-350.

Shive, K., Brigham, C., Caprio, T., and Hardwick, P. 2021. 2021 Fire Season Impacts to Giant Sequoias. National Park Service, Sequoia and Kings Canyon National Parks.

Stephenson, Nathan L., Parsons, David J., Swetnam, Thomas W. 1991. Restoring natural fire to the sequoia -mixed conifer forest: should intense fire play a role? Proceedings of the Tall Timbers Fire Ecology Conference Proceedings 17:321-338.

Stephenson, N.L. 1994. Long-Term Dynamics of Giant Sequoia Populations: Implications for Managing a Pioneer Species. 56-63 In: P.S. Aune, technical coordinator. Proceedings of the Symposium on Giant

Sequoias: Their Place in the Ecosystem and Society 1992 June 23-25, Visalia, CA, USDA For. Serv. Gen Tech. Rep. PSW-GTR-151.ology Conference 17:321-337

Stephenson, N. L. 1996. Ecology and management of giant sequoia groves.

Stephenson, N.L. 1999. Reference Conditions for Giant Sequoia Forest Restoration: Structure, Process and Precision. Ecological Applications Vol. 9, No. 4, pp. 1253-1265.

Stewart, J. A., Van Mantgem, P. J., Young, D. J., Shive, K. L., Preisler, H. K., Das, A. J., and Thorne, J. H. 2021. Effects of postfire climate and seed availability on postfire conifer regeneration. Ecological Applications, 31(3), e02280.

Soderberg, D. N., Das, N. J., Stephenson, N. L., Meyer, M. D., Brigham, C. A., and Flickinger, J. 2023. Assessing giant sequoia mortality and regeneration following high severity wildfire [unpublished manuscript]. U.S. Geological Survey, Western Ecological Research Center, Sequoia and Kings Canyon Field Station, Three Rivers, CA 93271, USA.

Su, Y., Bales, R. C., Ma, Q., Nydick, K., Ray, R. L., Li, W., and Guo, Q. 2017. Emerging stress and relative resiliency of giant sequoia groves experiencing multiyear dry periods in a warming climate. Journal of Geophysical Research: Biogeosciences, 122(11), 3063-3075.

Swetnam, T.W. 1993. Fire History and Climate Change in Giant Sequoia Groves. Science 262: 885-889.

Swetnam, T.W., Baisan, C.H., Caprio, A.C., Brown, P.M., Touchan, R., Anderson, R.S., and Hallett, D.J. 2009. Multi-millennial fire history of the Giant Forest, Sequoia National Park, California, USA. Fire Ecology 5:120-150.

Swetnam, T.W., Baisan, C.H., Morino, K., and Caprio, A.C. 1998. Fire history along elevational transects in the Sierra Nevada, California. Final Report, Sierra Nevada Global Change Program, USGS, Biological Resources Division, Yosemite Field Station and Sequoia and Kings Field Station. 42 p.

Welch, K. R., Safford, H. D., and Young, T. P. 2016. Predicting conifer establishment post wildfire in mixed conifer forests of the North American Mediterranean-climate zone. Ecosphere, 7(12), e01609.

York, R.A., Battles, J.J., and Heald, R.C. 2007. Gap-based silviculture in a sierran mixed conifer forest: effects of gap size on early survival and 7-year seedling growth. Powers, R.F., tech. editor. In: Restoring fire-adapted ecosystems: proceedings of the 2005 national silviculture workshop. Gen. Tech. Rep. PSW-GTR-203, pp. 181–191.

York, R.A., Stephenson, N.L., Meyer, M., Hanna, S., Moody, T., Caprio, A.C., and Battles, J.J. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 11a – giant sequoias. (Natural Resource Report No. NPS/SEKI/NRR—2013/665.11a). National Park Service, Fort Collins, Colorado.

Appendix D: Minimum Requirement Analysis

GENERAL INFORMATION

Project Title: Establish Tree Seedlings in Severely Burned Giant Sequoia Groves and Adjacent Fisher Critical Habitat in Sequoia and Kings Canyon National Parks

Project Duration: 2023-2028/2029

STEP 1: Determine if any administrative action is necessary

Description of Situation

What is the situation that may prompt administrative action? What is the reason that you are proposing an action (or actions) in wilderness?

The Castle and KNP Complex (KNP) wildfires burned across roughly 98,361 acres within the parks in 2020 and 2021—roughly 90,000 acres of which burned in the John Krebs and Sequoia-Kings Canyon Wilderness areas and the Hockett-Area Recommended Wilderness (see Table D1 below). Although Sierra-Nevada mixed coniferous forests, including those that contain giant sequoia, are adapted to frequent, low to moderate severity fire, large patches of high severity fire (which equates to high tree mortality) is not documented within the natural fire regime of these forests (Shive et al. 2022). And yet, 2,132 acres of the John Krebs Wilderness, 20,068 acres of the Sequoia-Kings Canyon Wilderness, and 1,646 acres of the Hockett-Area Recommended Wilderness—representing close to 3% of these wilderness areas, combined, and more than a quarter of the acres that burned in recent wildfires within these wilderness areas—burned at high severity during these recent wildfires, with severe impacts to these forests and, subsequently, the wilderness character of these wilderness areas.

TABLE D1. TOTAL ACREAGE BURNED ACROSS WILDERNESS

	Total Acres of Wilderness	Acres Burned	Acres Burned as Percent of Total	Acres Burned at High Severity (HS)	Acres Burned at HS as Percent of Total Acres
John Krebs Wilderness	39,967	5,812	14.5%	2,132	5.3%
Sequoia-Kings Canyon Wilderness	768,110	73,427	9.6%	20,068	2.6%
Hocket Area Recommended Wilderness	29,516	10,678	36.2%	1,646	5.6%
Fisher Proposed Critical Habitat in Wilderness	65,003	40,380	62.1%	11,260	17.3%
TOTAL WILDERNESS	**837,593**	**89,917**	**10.7%**	**23,846**	**2.8%**

In fact, the Castle and KNP wildfires (along with the 2021 Windy Fire) burned at such unprecedented high severity across such large contiguous acres that an estimated 9,760 to 14,237 large giant sequoias were outright killed by or are otherwise dying from high intensity fire range-wide. This amount of loss within this species is unprecedented and accounts for 13-19% of the total population of large sequoias. Total mortality of large sequoias in the groves of concern is estimated at 720 individual large trees and a range of 4-40 percent total grove loss. See Table 5 of Re-establish Tree Seedlings in Severely Burned Giant Sequoia Groves and Adjacent Fisher Habitat Environmental Assessment (EA).

In addition to the high mortality of sequoias, approximately 11,260 acres of proposed fisher critical habitat within the John Krebs and Sequoia-Kings Canyon Wilderness areas and the Hockett-Area Recommended Wilderness burned at high severity during the Castle and KNP wildfires, including a roughly 485-acre proposed critical habitat corridor within Fisher Core Habitat Area 3 south of Redwood Mountain Grove (Spencer et al, 2016; Meyer et al, 2022).

Contiguous high severity areas in groves and mixed conifer forests are vulnerable to long-term type conversion to shrub-dominated systems because:

1) They lack adequate seed sources as most reproductive trees are now dead, and
2) There are inadequate seedlings to regenerate forest (Coop et al. 2020; Guiterman et al. 2022). Post-fire seedling surveys indicate numbers significantly lower than what the NPS has documented in previous post-fire plots. See EA, Chapter 1 (specifically Re-planting Proposal Development on page 7) and Chapter 3 (specifically Sequoia Grove Recovery and Resilience) for details about individual sequoia groves.

Although high severity fire from these recent fires burned through close to 24,000 acres of wilderness areas within Sequoia and Kings Canyon National Parks, the NPS completed a RAVG analysis to identify areas of particular concern—where large contiguous patches of high severity fire align with sequoia groves (given their nexus with the establishment of the national parks) or fisher habitat (given its status as an endangered species and its reliance on mixed-conifer forests). Through this RAVG analysis, the NPS found large patches of high severity fire within six sequoia groves (Redwood Mountain, Suwanee, New Oriole Lake, Dillonwood (which as mentioned previously includes the small portion of Garfield Grove that is in the same drainage as Dillonwood), Board Camp, and Homers Nose) and the 485-acre proposed fisher critical habitat south of Redwood Mountain Grove.

Post-fire assessments within Redwood Mountain Grove, Suwannee Grove (surveys in process), Dillonwood Grove (surveys in process) by NPS and partner agencies, Board Camp Grove (completed), and the fisher habitat corridor south of Redwood Mountain Grove (completed) show low seedling regeneration and high sequoia mortality leading to a lack of adequate seed source within these contiguous high severity patches. In a recent analysis of post-fire sequoia regeneration across 26 different fires spanning a 48-year period in Sequoia and Kings Canyon National Parks, Stephenson et al. 2023 (in preparation) found that the Bayesian estimated mean sequoia seedling density in the first-year post-fire was 70,312 95% CI 25,625-344,126 per acre, and in the second year after fire, the mean density was Bayesian estimated mean was 16,011 95% CI 5,739-73,254 seedlings per acre. A lifetable analysis of giant sequoia by York et al. (2013) indicates that these post-fire densities are representative of the numbers needed to create a stable population as only a handful of these seedlings survive to become the majestic trees that we see today. In comparison to these densities, when the NPS and partners completed field surveys of sequoia seedlings in 2022 of Redwood Mountain Grove (high severity fire effects areas only), Board Camp Grove (sampled entire grove), New

Oriole Lake Grove (sampled the entire grove), and Suwanee Grove (sampled the entire grove), crews found the following densities of sequoia seedlings:[26]

- Board Camp Grove: Bayesian estimated mean of 651 seedlings/acre; <0.1% probability of the estimated mean meeting the second-year seedling densities after fire;
- Redwood Mountain Grove (only high severity area of the grove): Estimated mean of 4,266 seedlings/acre; 1.1% probability of meeting the second year seedling densities after fire;
- Suwanee Grove: Estimated mean of 4,763 seedlings/acre; 2.4% probability of meeting the second-year seedling density after fire;
- New Oriole Lake Grove: Estimated mean of 6,875 seedlings/acre; 11.2% probability of meeting the second-year seedling density after fire (Soderberg et al 2023 in review).

Based on the above findings, it is apparent that current sequoia seedling densities in these areas are well below what is estimated as needed to re-establish sequoias and generate a stable population (Soderberg et al. 2023 in review; Stephenson et al. 2023 in preparation). Seedlings that are present in the proposed action areas are also primarily restricted to small patches in drainages or other protected microsites. Additionally, areas of this size contain large patches that are beyond the distance that the majority of sequoia seeds disperse (Clark et al. 2021). In high severity patches, this combination of factors (insufficient natural seedling densities and lack of living sequoias), combined with previous studies that demonstrate a high mortality rate of post-fire germinated sequoia seedlings and low (if not zero) seedling regeneration at more than three years post-fire, indicate that these areas are highly vulnerable to conversion from forest to fire-initiated shrub-dominated communities in the long term (Coop et al. 2020). Again, see EA, Chapter 1 (specifically Re-planting Proposal Development) and Chapter 3 (specifically Sequoia Grove Recovery and Resilience) for additional details.

For these areas with insufficient natural seedling densities and lack of living trees, particularly sequoias,[27] action is needed to give these forests an opportunity to recover and thereby prevent the loss of acreage within these sequoia groves and fisher habitat which is expected to otherwise type-covert to shrub-dominated communities. See Tables Table 1 and Table 5 and Figure 7. Proposed Decision Tree for Re-Establishing Seedlings in Severely Burned Areas in the associated Environmental Assessment for more information on impacted areas and decision process.

See Chapter 1 (specifically "Background") in the EA for more information and details on the situation that may prompt administrative action within wilderness.

Wilderness Considerations

A. Options Outside of Wilderness

Can actions taken outside of wilderness adequately address the situation and meet project goals?

No. Of the six sequoia groves that burned at high severity during the Castle and KNP wildfires, four occur entirely within designated wilderness (Board Camp, Homer's Nose, New Oriole Lake, and Suwanee Groves),

[26] For Board Camp, New Oriole Lake, and Suwanee, seedlings were measured throughout the entire grove, not just the high severity target planting areas. For Redwood Mountain, only the high severity target planting area was measured (Soderberg et al 2023 in review).

[27] Notably, data is still being collected for Suwanee, Dillonwood, Homer's Nose, and New Oriole Lake Groves, which should be completed in summer 2023. Should there be sufficient reproductive trees remaining and/or sufficient natural regeneration post-fire in these areas, action would not be needed.

one is partially located in designated wilderness (Redwood Mountain Grove), and one is partially located in recommended wilderness (Dillonwood Grove). No frontcountry sequoia groves were lost or partially lost to high severity fire. While fisher critical habitat burned at high severity in non-wilderness, the 485-acre habitat corridor was identified as integral to connecting fragmented fisher populations and is entirely within designated wilderness.

Because sequoia groves are ecologically valuable in large part to their location within the broader Sierra Nevada (see Chapter 3 (specifically the Affected Environment within Sequoia Grove Recovery and Resilience) of the EA for additional information about the groves and their significance) and because they serve as an identified attribute of the natural quality of both the John Krebs and Sequoia-Kings Canyon wilderness areas, "replacement" or "restoration" of sequoias cannot be adequately achieved offsite and outside of wilderness, nor would such replacement serve to restore natural quality of wilderness character in areas where it has been diminished. Likewise, the fisher habitat where planting in wilderness is being proposed serves as a key habitat corridor between otherwise disjointed and fragmented surrounding habitat. Restoring forest in areas outside of wilderness would not create habitat corridors where the corridor is needed.

Several other considerations also make this alternative not viable. First, as identified in several scientific publications (see Appendix E:
), different groves contain different genetic material and thus loss of trees in these specific groves is damaging to the species ability to respond to future events through adaptation. Additionally, if seed was collected from these groves and planted elsewhere (whether in or outside of wilderness), these trees would not be able to exchange pollen with remaining trees in these groves or adjacent groves and thus long-term genetic exchange and adaptive potential would be disrupted. Finally, the NPS does not manage a lot of land that is both outside wilderness and suitable for sequoia groves besides the limited acres in the Dillonwood Grove being considered in this proposal and those in front country areas of these parks. In fact, it is unclear whether any additional areas exist and if so, where they would be, particularly as giant sequoia groves occupy hydrologic refugia (Baeza et al. 2021), meaning not all parts of the landscape would support giant sequoia groves long-term. Thus, planting only outside of wilderness would put the future of sequoias at higher risk and has a significant potential for long-term failure.

Because the need for action is to prevent an unacceptable loss of giant sequoias in the limited number of groves where they naturally occur, restore proposed critical habitat for an endangered species and avoid type conversion of these forests to high severity, frequent fire shrub communities, and these areas primarily occur in wilderness, acting outside of wilderness would not address the lack of seedling regeneration in affected areas.

Furthermore, the situation described above and in supporting materials is not just a loss for the sequoia or fisher, as components of a larger ecosystem, but are also part of the wilderness character of the John Krebs and Sequoia-Kings Canyon Wilderness areas and the Hockett-Area Recommended Wilderness. Restoration of sequoia or fisher habitat elsewhere (outside of wilderness) does not address the loss to these areas.

B. Valid Existing Rights or Special Provisions of Wilderness Legislation

Is action necessary to satisfy valid existing rights or a special provision in wilderness legislation (the Wilderness Act of 1964 or subsequent wilderness laws)?

Though not necessary to conform with a special provision, Section 4(a) of the Wilderness Act establishes that the supplemental purposes of wilderness shall not lower the standards evolved for use and preservation of national park units established under the Organic Act: "Nothing in this Act shall modify the statutory authority under which units of the national park system are created. … Further, the designation… as a wilderness area pursuant to this Act shall in no manner lower the standards evolved for the use and preservation of such park, monument, or other unit of the national park system in accordance with section 100101(b)(1)…of Title 54, United States Code, [or] the statutory authority under which the area was created…" The proposed action serves to preserve Giant Sequoias; both Sequoia and Kings Canyon National Parks were designated in large part for the protection of this species.

C. Requirements of Other Legislation

Is action necessary to meet the requirements of other federal laws?

Yes. The persistence of mature giant sequoia and preservation of fisher habitat connectivity is required to meet the park enabling legislation and other federal laws governing the National Park Service as follows.

1890 Enabling Legislation of Sequoia National Park, 26 Statute 478

> "Whereas the rapid destruction of timber and ornamental trees in various parts of the United States, some of which trees are the wonders of the world on account of their size and the limited number growing, makes it a matter of importance that at least some of said forests should be preserved…". These lands are to be managed "for the preservation from injury of all timber, mineral deposits, natural curiosities or wonders . . . [and for] their retention in their natural condition."

Sequoia National Park was established, in a large part, to preserve trees that are "the wonders of the world on account of their size and the limited number growing." This passage is referring to Sequoias, recognizes their limited distribution, and directs that they should be preserved within the park. As the distribution of the species has been reduced, and current conditions are not the "natural condition" but instead will threaten recovery of these groves, the NPS is obligated to act to achieve one of the primary purposes for which these parks were established.

1890 Enabling Legislation of General Grant National Park

> "all timber, mineral deposits, natural curiosities, or wonders within the parks, and to retain their natural conditions."

General Grant National Park, the predecessor to Kings Canyon National Park, was similarly set aside for the purposes of protecting "wonders" [sequoias] within the park, specifically the General Grant Tree and surrounding trees.

The NPS Organic Act of 1916 (54 USC 100101(a))

The Organic Act directs the NPS to "…conserve the scenery and natural and historic objects and the wildlife therein…by such means as will leave them unimpaired for the enjoyment of future generations".

The 1978 Amendment to the NPS Organic Act (54 USC 100101(b)(2))

This amendment clarified and enhanced the protective functions of the National Park Service and states:

> "Congress further reaffirms, declares, and directs that the promotion and regulation of the various areas of the National Park System, as defined in section 1c of this title, shall be consistent with and founded in the purpose established by section 1 of this title [the Organic Act provision quoted above], to the common benefit of all the people of the United States. The authorization of activities shall be construed, and the protection, management,

> and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress."

The Organic Act and amendments direct the NPS to conserve "natural objects and wildlife therein" in an unimpaired manner. Sequoias and fisher are natural objects and wildlife naturally occurring within the park boundaries. Sequoias in particular are specifically referred to in the park's enabling legislation thus a resource that is necessary to fulfill identified park purposes. Both species are key to the natural integrity of the parks, though sequoia, in particular, holds special significance for park management and public enjoyment.

As well, both species are under threat of habitat loss due to recent high-severity fire. The threats to sequoias directly relate to a loss of occupied land area and associated total population decline which would remain diminished should affected areas convert in the long term to shrub communities. While overall populations of fisher may not have declined due to recent fire (this is unknown however as NPS does not have data on direct fisher mortality during the fires), loss of habitat connectivity in the identified area (Core Area 3) restricts natural gene flow necessary for long-term species survival.

As current conditions threaten the natural distribution and survival of both species, the NPS is obligated to conserve these species in a manner consistent with the Act in order to prevent degradation through a long-term, if not permanent, loss of these resources within these areas.

Kings Canyon Enabling Act of 1940

> "That the National Park Service shall… administer for public recreational purposes the lands withdrawn." and "to insure (sic) the permanent preservation of the wilderness character of the Kings Canyon National Park." (Sec. 3.)

The enabling legislation of Kings Canyon National Park is notably the first legislation to incorporate the term "wilderness character". Lands designated under this legislation include, among other resources, giant sequoia and fisher, and sequoias have been specifically identified as an attribute of the natural quality of wilderness character in the Sequoia-Kings Canyon Wilderness (Tricker et al. 2014). The park's enabling legislation therefore directs the NPS to act to direct areas diminished by recent high severity impacts toward recovery in order to preserve or restore wilderness character—specifically the natural quality of which fisher and sequoias are a component—in areas where it is currently diminished.

Endangered Species Act (16 USC 1536(c))

> "(1) The Secretary shall review other programs administered by him and utilize such programs in furtherance of the purposes of this chapter. All other Federal agencies shall, in consultation with and with the assistance of the Secretary, utilize their authorities in furtherance of the purposes of this chapter by carrying out programs for the conservation of endangered species and threatened species listed pursuant to section 1533 of this title"

The Southern Sierra Nevada distinct population segment of fisher is a federally endangered species under the Endangered Species Act (Federal Register 85, 28532-29589) and the proposal to designate critical habitat was released in October of 2021 and expected to be finalized by fall of 2023 (FWS-R8-ES-2021-0060). The NPS' use of agency authorities to restore fisher habitat connectivity lost to high severity fire directly serves the NPS' obligations to conserve this species.

D. Wilderness Character

Untrammeled: NA

Undeveloped: NA

Natural: Giant sequoia is an attribute of the natural quality of wilderness character for both the John Krebs and Sequoia-Kings Canyon Wildernesses (Tricker et. al. 2014). High severity fire during two recent fire events (2020 Castle and 2021 KNP Complex wildfires) has contributed to the death of thousands of individual large (> 4 feet in diameter) sequoia trees and reduced the intact acreage of six wilderness sequoia groves; resulting in diminished natural quality of wilderness character. A documented lack of seedling regeneration leaves affected areas highly vulnerable to long-term type conversion to shrub-dominated systems. Because sequoia already have limited distribution (as recognized in the parks' enabling legislation), taking action is necessary to prevent conversion of sequoia forests to non-forest and direct these areas—over a period of centuries—toward recovery of pre-fire distribution and population levels of large giant sequoias, thus preserving in the long term, the natural quality of wilderness character.

Fisher is a forest-dependent carnivore which is federally endangered. The area where action is proposed is within a habitat corridor for proposed fisher critical habitat, core area 3 (Meyer et al. 2022). Restoration of this area would help speed up the return of tree cover and suitability for fisher movement, thus facilitating dispersal and associated gene flow vital to the species conservation. As this species is a natural component of the wilderness areas where they are located, restoring areas such that natural dispersal and gene flow can continue is therefore also necessary to preserve the natural quality of wilderness character.

Outstanding Opportunities for Solitude or Primitive and Unconfined Recreation: Action is not necessary to preserve this quality.

Other Features of Value: NA

E. Other Guidance

Is action necessary to conform to direction contained in agency policy, unit and wilderness management plans, species recovery plans, or agreements with tribal, state and local governments or other federal agencies?

Yes. NPS Management Policies (MP) require the NPS maintain natural population processes (MP 4.4.1.1) and strive to protect a full range of native plant and animal genotypes (MP 4.4.1.2) such as those that would be protected and preserved under this proposed action. These policies also require that the NPS meet its obligations under the Organic Act and Endangered Species Act to protect threatened or endangered species and their habitat (MP 4.4.2.3). Further, these policies permit the NPS to manipulate landscapes and plant or animal populations if necessary to correct excessive disturbance caused by past human actions (MP 4.4.2.4) and when such actions would not cause unacceptable impacts to the species in question or the ecosystem in question (MP 4.4.2). The parks' internal management guidance further directs the parks to re-establish the function of human disturbed natural systems (NPS 2007, Vegetation: desired conditions).

NPS Management Policies 2006

The Service manages the natural resources of parks to maintain them in an unimpaired condition for present and future generations in accordance with NPS-specific statutes, including the NPS Organic Act and the National Parks Omnibus Management Act of 1998; general environmental laws such as the Clean

Air Act, the Clean Water Act, the Endangered Species Act of 1973, the National Environmental Policy Act, and the Wilderness Act; executive orders; and applicable regulations.

1.4.5 WHAT CONSTITUTES IMPAIRMENT OF PARK RESOURCES AND VALUES

"An impact to any park resource or value may, but does not necessarily, constitute an impairment. An impact would be more likely to constitute impairment to the extent that it affects a resource or value whose conservation is:

- necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park, or
- key to the natural or cultural integrity of the park or to opportunities for enjoyment of the park, or
- identified in the park's general management plan or other relevant NPS planning documents as being of significance."

1.4.6 WHAT CONSTITUTES PARK RESOURCES AND VALUES

- "the park's scenery, natural and historic objects, and wildlife, and the processes and condition that sustain them, including, to the extent present in the park: the ecological, biological, and physical processes that created the park and continue to act upon it; scenic features; natural visibility, both in daytime and at night; natural landscapes; natural soundscapes and smells; 11 water and air resources; soils; geological resources; paleontological resources; archeological resources; cultural landscapes; ethnographic resources; historic and prehistoric sites, structure, and objects; museum collections; and native plants and animals;
- appropriate opportunities to experience enjoyment of the above resources, to the extent that can be done without impairing them;
- the park's role in contributing to the national dignity, the high public value and integrity, and the superlative environmental quality of the national park system, and the benefit and inspiration provided to the American people by the national park system; and
- any additional attributes encompassed by the specific values and purposes for which the park was established."

4.4.1.1 PLANT AND ANIMAL POPULATION MANAGEMENT PRINCIPLES

"The Service *will* adopt park resource preservation… strategies that are intended to *maintain the natural population fluctuations and processes* that influence the dynamics of individual plant and animal populations, groups of plant and animal populations, and migratory animal populations in parks" (emphasis added).

4.4.1.2 GENETIC RESOURCE MANAGEMENT PRINCIPLES

"The Service *will strive to* protect the full range of genetic types (genotypes) of native plant and animal populations in the parks by perpetuating natural evolutionary processes and minimizing human interference with evolving genetic diversity" (emphasis added).

"The need to maintain appropriate levels of genetic diversity *will guide decisions on what actions to take to manage isolated populations of species or to enhance the recovery of populations of rare, threatened, or endangered species*" (emphasis added).

4.4.2 MANAGEMENT OF NATIVE PLANTS AND ANIMALS

"Whenever possible, natural processes will be relied upon to maintain native plant and animal species and influence natural fluctuations in populations of these species. The Service may intervene to manage individuals or populations of native species only when such intervention will not cause unacceptable impacts to the populations of the species or to other components and processes of the ecosystems that support them."

4.4.2.3 MANAGEMENT OF THREATENED OR ENDANGERED PLANTS AND ANIMALS

> "The Service will fully meet its obligations under the NPS Organic Act and the Endangered Species Act to both proactively conserve listed species and prevent detrimental effects on these species."

Further, the NPS will "manage designated critical habitat, essential habitat, and recovery areas to maintain and enhance their value for the recovery of threatened and endangered species."

4.4.2.4 MANAGEMENT OF NATURAL LANDSCAPES

> "Natural landscapes disturbed by natural phenomena, such as… fires, will be allowed to recover naturally *unless manipulation is necessary to (1) mitigate for excessive disturbance caused by past human effects*…" (emphasis added).

Sequoia and Kings Canyon National Parks General Management Plan (NPS 2007)

Parks Mission: "protect forever the greater Sierran ecosystem – including the sequoia groves and high Sierra regions of the parks – and its natural evolution, and to provide appropriate opportunities to present and future generations to experience and understand park resources and values" (Page 1).

Management Prescription: "The giant sequoia groves — particularly Giant Forest — and the ecosystems they occupy are restored, maintained, and protected" (NPS 2007, Page 53).

DESIRED CONDITIONS

Vegetation (including Sequoia Groves):

> "Intervention in natural biological or physical processes will be allowed only (1) when directed by Congress, (2) in some emergencies when human life and property are at stake, or (3) *to restore native ecosystem functioning that has been disrupted by past or ongoing human activities*" (emphasis added) (NPS 2007, Page 13).
>
> "The National Park Service *will* re-establish natural functions and processes in human-disturbed natural systems in the parks unless otherwise directed by Congress" (emphasis added) (NPS 2007, Page 14).

Wildlife:

> "Populations of native plant and animal species function in as natural a condition as possible except where special management considerations are warranted" (NPS 2007, Page 15).

Sequoia and Kings Canyon National Parks Wilderness Stewardship Plan (NPS 2015)

The Executive Summary of the parks' Wilderness Stewardship Plan (Page v.) outlines the following desired conditions:

> "The natural quality of wilderness would be preserved by mitigating the impacts of modern civilization on ecosystem structure, function, and processes. The NPS aspires to minimize or localize adverse impacts caused by visitor use and administrative activities. In the wilderness,

natural processes would dominate:

- *ecosystem structure and function* (emphasis added)
- *native biodiversity* (emphasis added)
- water quality and quantity
- decomposition nutrient cycling, and soil forming processes
- meadow and wetland productivity
- *fire regimes* (emphasis added)
- and soundscapes, dark skies, and viewsheds"

Sequoia and Kings Canyon National Parks Resource Stewardship Strategy (NPS 2017)

The parks' Resource Stewardship Strategy (RSS) outlines the following goals associated with sequoia protection:

1. "Maximize persistence of large, living giant sequoias.
2. Maximize persistence of structurally and compositionally complex giant sequoia groves that are sustainable, resilient (to drought, fire, insects, etc.), and support native biodiversity.
3. Manage for ecological functions essential to giant sequoia groves (fire, hydrology).
4. Prepare for potential shifts in giant sequoia distribution to enable its persistence in the broader Sierra Nevada landscape.
5. Prioritize persistence of giant sequoia in areas of highest social value" (NPS 2017, Page 41).

At the time of its writing, the RSS stated that only 20% of sequoia groves in the Parks were within desired fire return interval and that small trees were overly dense in most groves. Both of these stressors were identified as moderate concern just five years ago (NPS 2017, Page 41).

Finally, the Parks' RSS identified such direct management priorities to "…include continuing and expanding the use of fire and fuels treatments, reducing other stressors like invasive plants, establishing seed banks, and research with new or expanded treatments that may increase resistance and resilience to climate change, drought, insects, disease, and uncharacteristically severe fires" (NPS 2017, Page 84).

MANAGEMENT OBJECTIVES: TERRESTRIAL WILDLIFE
The RSS listed monitoring, protecting, and restoring (when feasible) was listed as a high priority for the NPS.

> "Contribute to/review species recovery plans and evaluate opportunities to facilitate recovery of T&E and candidate species and other species of concern (Sierra Nevada bighorn sheep, California spotted owl, California condor, Pacific fisher)" (NPS 2017, Page 94).

NPS Climate Change Response Strategy (NPS 2010)

Under the Climate Change Response Strategy, the NPS will analyze potential climate change impacts and adaptively apply the information to improve planning, resource conservation, and visitor experience.

Goal 2: Collaborate with partners to develop, test, and appropriately apply climate change models to NPS activities (NPS 2010, Page 12).

Objective 2.3: Facilitate development of models that can be used by managers to plan for and adapt to climate change impacts (NPS 2010, Page 14).

Goal 6: Implement adaptation strategies that promote ecosystem resilience and enhance restoration, conservation, and preservation of park resources (NPS 2010, Page 15).

Objective 6.1: Collaborate with federal, state, and local partners and programs to acquire, evaluate, and develop tools, such as vulnerability assessments and scenario planning, to inform the development of adaptation plans at appropriate scales (NPS 2010, Page 14).

Objective 6.3: Collaborate to develop cross jurisdictional conservation plans to protect and restore connectivity and other landscape scale components of resilience (NPS 2010, Page 14).

NPS Guidelines for Ecological Intervention in Wilderness Reference Manual 41 (RM41 2022)

As of 2022, Reference Manual (RM) 41 includes an analytical tool, *Guidelines for Evaluating Ecological Intervention Proposals in National Park Service Wilderness*, developed to assist NPS unit managers in applying the provisions of NPS management policy and other guidance when determining whether or not intervention is or is not favored in wilderness. The parks' analysis of the eight factors outlined within this guidance document resulted in several factors favoring intervention and several factors neither strongly favoring nor strongly dis-favoring as follows:

1. Cause of Degradation: This factor favors intervention because the primary cause of the degradation to sequoia groves and proposed critical habitat was high severity fire fueled by a century of human fire suppression.

2. Timing of Degradation: This factor favors intervention because NPS policy under which high fuel loads began to build is no longer in effect. NPS policy now supports wildland fire use to maintain and restore fire in these areas.

3. Origin of Degradation: This factor favors intervention because the origin of degradation (fire suppression) within each of these groves, fisher habitat corridor, and surrounding forests 1) occurs on lands that are managed by the NPS, and 2) is within the jurisdiction of NPS's authority for managing wildfire.

4. Urgency of Degradation: This factor could either favor or not favor intervention depending upon the intensity of action desired. Acting now, when these areas are at their closest to post-fire conditions—when re-establishment would have occurred naturally had it not been for the impacts of fuel loading and resulting high severity fire—would increase the likelihood of success. Once shrub communities become dominant, correcting this degradation may still be feasible, but would require additional intervention to create conditions conducive to replanting (e.g. mastication, herbicide).

5. Sustainability of Intervention: This factor may either favor or not favor intervention depending upon future fire management activities, the climate vulnerability of planted areas, the resiliency of the species in question, whether climate driven drought returns to the area before seedlings are established, and the future climate in these areas.

6. Outcome of Intervention: This factor favors intervention because the proposed project has an achievable outcome and a clear point at which the outcome would be reached. The desired outcome of this proposed intervention is to establish a sufficient amount of sequoia and mixed conifer seedlings, and at sufficient densities, so as to mimic natural regeneration of these species post wildfire and thereby direct the trajectory of these forests toward recovery to their pre-fire forest assemblages—as they would have done naturally had high fuel loading not led to severe fire

effects. For this reason, the proposed planting densities and planting timeframe have been scoped for species resiliency to single year droughts and future mortality sources, such as future fires.

7. Intensity of Intervention: This factor favors intervention as the intensity of the intervention is relatively low-to-moderate in context of the size of the area trammeled as compared to the area of forest impacted by high severity fire and the wilderness areas as a whole, the tools used, and the intermittent nature and short duration of on-site intervention (see Wilderness Stewardship Plan, 2015).

8. Experience with Intervention: This factor favors intervention as the NPS and others have extensive experience with successful planting of giant sequoias and other conifer species within these parks and within and outside of the species' natural range. Planting absent supplemental water has likewise been conducted extensively and has been highly successful; sequoia from different genetic sources have also been successfully planted in many areas (i.e., Mountain Home, Whitakers Forest, McKinley Grove).

STEP 1 DETERMINATION

Is administrative action necessary in wilderness?

Yes, administrative action is necessary in wilderness.

Section A: These groves and adjacent habitat primarily occur in wilderness. Acting entirely outside of wilderness would not address the lack of seedling regeneration in affected areas.

Section B: There is no wilderness legislation specifically directed toward the preservation of sequoias or fisher.

Section C: Sequoia and Kings Canyon National Parks were created, in large part, to preserve giant sequoia forests. Action is therefore necessary to meet the purposes of park enabling legislation, and the NPS Organic Act, as consistent with section 4(a) of the Wilderness Act as well. Further, the Endangered Species Act directs the NPS to preserve the endangered fisher and its habitat (critical habitat anticipated to be listed in fall 2023).

Section D: Giant sequoia trees are an identified attribute of the natural quality of wilderness character, and fisher are a component of the natural faunal makeup for both the John Krebs and Sequoia-Kings Canyon Wildernesses. Because sequoias have been severely impacted and fisher habitat connectivity has been lost, action is necessary to preserve (and restore) the natural quality of wilderness character in these wilderness areas.

Section E: Action is necessary to conform to NPS Management Policies and Park Management Plans. Six factors in the parks' RM 41 analysis favored intervention while the other two neither strongly favored nor dis-favored intervention.

STEP 2 Determine the Minimum Activity

Below is the initial minimum requirement determination to address the situation outlined in Step 1. See Chapters 1 and 2 of EA for full details on all alternatives, including those considered but dismissed in the process of evaluating this proposal. As well, see Chapter 3 for finalized analysis on impacts to wilderness character.

Alternative A: No Action

Under Alternative A, the NPS would take no action to restore post-fire succession. The NPS would continue to monitor within former sequoia grove and adjacent mixed conifer footprints; though a monitoring design has not been finalized and would be considered under a separate MRA. Previously collected sequoia seed would remain in a seed bank to preserve genetics of the species, for research, and potential planting in the future.

Wilderness Character

How does this alternative affect the qualities of wilderness character in both the short and long-term? Include both positive and negative effects. What mitigation measures will be taken?

Untrammeled: There would be no effect on this quality.

Undeveloped: Though monitoring plans have yet to be developed, the NPS estimates up to 600 small plot markers and 60 other installations would be installed across the action area to monitor vegetation and other resources within areas that burned at high severity. These installations would negatively influence undeveloped quality for up to 30-40 years.

Natural: Sequoia mixed conifer and mixed conifer seedlings would remain either absent or at densities below that needed to support forest recovery in affected areas. Based on current assessments, 700 total combined acres across six sequoia groves and roughly 500 acres of adjacent fisher critical habitat would remain highly vulnerable to conversion from giant sequoia mixed conifer forest to disturbance related/maintained shrub community. Note that rounding of these numbers results in an estimated 1,200 acres total, however the total acreage within wilderness is 1,130; roughly 80 acres lie outside of wilderness. Because giant sequoia is a primary attribute of wilderness character in these parks, the diminished grove footprint would adversely affect the natural quality of wilderness and contribute to the overall trajectory toward less natural. As well, the natural quality could further deteriorate if cycles of high severity fire resulting from the conversion to shrub-dominated systems spread to other nearby areas.

As mentioned above, fisher is a federally endangered forest dependent species and, though not specifically identified in the parks' wilderness character assessment, is a component of the natural quality of wilderness character in these parks. The area where action is proposed is within a habitat linkage for critical habitat core area 3 (Meyer et al. 2022). Should this area convert, fisher dispersal to suitable habitat found on either side of the burn patch would be severely limited, restricting gene flow between these two areas. To the extent that the loss of this critical habitat linkage reduces the NPS' ability to preserve the species, natural quality would be adversely affected.

Opportunities for Solitude or Primitive and Unconfined Recreation: Taking no action would have no effect on this quality.

Other Features of Value: There would be no effect on this quality.

Alternative B: Replant Seedlings Propagated from Seed Collected from the Local Genetic Community of Each Replanted Area; Support Project Using a Combination of Helicopter, Stock Support, and Foot Travel

Under Alternative 2, the NPS would consider replanting giant sequoia (*Sequoiadendron giganteum*) and other mixed conifer seedlings in up to six giant sequoia groves in Sequoia and Kings Canyon National Parks: Redwood Mountain, Suwanee, New Oriole Lake, Dillonwood, Board Camp, and Homers Nose where these forests are otherwise unlikely to naturally recover following the impacts of high severity fire (see

Table 1 of the EA) following the Decision Tree outlined in Figure 7 of the EA. Dillonwood Grove is mostly outside of wilderness and this MRA therefore only applies to a small portion of that grove. The NPS would also consider planting conifer seedlings other than sequoia in the mixed conifer forest immediately south of the Redwood Mountain Grove where these seed sources were also lost and where natural regeneration is lower than what is necessary to re-establish this important fisher habitat corridor (see Figures 1-6 of the EA).

Considering the purpose and need for action outlined above, the goal of this proposed action is to have sequoia and mixed conifer seedlings at sufficient densities in these areas to direct the trajectory of these forests toward recovery. Based on evaluation of site-specific climate, use of other recommendations from published literature, and general technical reports from the USFS, the NPS is proposing to plant 100-400 seedlings per acre in areas where intervention is determined to be necessary. The planting rate is much lower than the seedlings per acre found after fire due to the substantially higher survival rate of planted seedlings compared to those established from seeding (Stewart 2020; York et al. 2009). See Chapter 2, Alternative 3: Replant Seedlings Grown from Seed Collected from the Local Genetic Community of Each Replanted Area in the EA for detailed description of components of this Alternative.

Transport Methods and Landing Clearance

The six sequoia groves and adjacent fisher critical habitat are distributed across both parks in wilderness (in the case of Dillonwood partially within recommended wilderness) with varying degrees of access (see Table D2 on page 15 of this MRA). Under Alternative B, areas having adequate trail infrastructure, but too far to allow transport of all seedlings and gear by foot, would utilize pack stock transport. From staging sites where stock deliver materials, planting crews would transport seedlings to their planting locations on foot. Sites where pack stock could be used include parts of Redwood Mountain and the adjacent fisher critical habitat corridor. In the case of Redwood Mountain, which has some small and disparate patches proposed for planting, seedlings may be carried to smaller patches on foot from the nearest road if determined not to be a safety risk.

Where barriers to stock or foot travel prevent safe access for seedling and tool delivery, including areas that have been determined prohibitively far from developed trails and roads or having terrain too difficult for stock or crews to transport seedlings and tools safely and feasibly, the NPS would utilize helicopters to transport seedlings and tools, via sling loads, to centralized staging areas from landing sites, seedlings would then be transported by foot to their planting locations (see Table D1). No staff would be transported via helicopter. Some groves may require sling load deliveries in multiple locations to deliver seedlings throughout the area due to the distances between planting patches.

For Redwood Mountain Grove, the NPS would preferentially use stock and foot transport, though safety considerations may ultimately require use of helicopter. The following therefore represents a reasonable worst-case scenario over the course of three years as would occur if planting is determined necessary beyond the first or second year and safe transport of materials in these locations cannot be otherwise achieved.

To safely transport a 150 foot-long sling load, a helicopter requires a roughly 20 x 20 foot opening for trees up to 150 feet tall and 75 x 75 foot opening for trees roughly 150 feet tall. Sites meeting these criteria, where a sling load can be safely dropped without removing snags, would be selected where feasible. However, in locations where one or more snags would be required, the NPS estimates that roughly 5-10 snags (dead trees) may be felled; again, this may be necessary in multiple sites for one or more groves. For the purposes of this analysis, the NPS assumes that a total of up to 6 landing zones may be needed across all sites and snags may inhibit safe landing at least 4 of these. Under this scenario, a total of up to 40 snags would be removed across the combined 1,200-acre action areas (1,130 in wilderness).

TABLE D2. FACTORS CONSIDERED FOR MINIMUM TRANSPORT REQUIREMENT

Grove/Area Name	Weight of Seedlings in Pounds	Weight of Tools and Supplies in Pounds[28]	Total Stock Needed for Weight	Miles of Maintained Access Trail	Miles of Abandoned Trail[29]	Non-Existing Route Miles[30]	Approximate Elevation Difference from Nearest Trail Access in Feet [31]
Dillonwood	3,100	800	31	5.5	0.8	0	489
Homer's Nose	1,650	800	19	3.1	3.1	.6	2,352
Board Camp	950	800	13	2.7	2.7	0	1,673
New Oriole Lake	105	250	3	3.1	0	0.7	643
Suwanee	945	800	13	0	2.7	0	738
Redwood Mountain Grove	18,100	2,000	163	2.7	0	0	0
Fisher Habitat	14,500	1,500	130	3.6	0	0	0

---

28 Including food, gear, and tools to support 10-15 crew members for 7-14 days.

29 This distance conveys the length of abandoned trail that the NPS would need to re-construct in order for stock to travel the distance between the nearest maintained trail to reach each proposed planting area. Trails for stock travel are typically graded at 10% and would traverse across a slopes while avoiding drops in elevation in order to reach a given destination.

30 The distance of non-existing route demonstrates how many miles of "new" trail would need to be constructed to make the area accessible by stock and was determined using a geoprocessing tool called 'least-cost path' which delineates a feasible travel route. This tool produced a route that was only slightly better than 'as-the-crow-flies' direct line and is not reflective of the path an individual or stock would take to avoid ravines/hills/other topography. Therefore, this distance would be the minimum length of trail the NPS would need to conduct to reach the center of the planting area and does not reflect the total length needed.

31 This elevational difference was calculated by subtracting the maximum elevation from the minimum elevation of a given route profile. For this calculation, only abandoned trail miles and non-existing route miles were included, and elevational drops and gains between the two points are not considered. This elevational gradient is meant to partially convey the steepness of terrain that would be necessary to traverse (on foot or via stock) from the nearest maintained access point. Though the abandoned trail and non-existing access route distances must also be considered as those routes would more closely represent the distance one would need to traverse to avoid elevational loss between the two points.

TABLE D3. PROPOSED HELICOPTER SUPPORT IN WILDERNESS OVER A PERIOD OF FIVE TO SIX YEARS

Grove/Area	Total Estimated Flights/Wilderness Sling-Loads	Total Flight Distance in Miles[7]	Estimated Minutes of Hover Time (all trips)[32]	Snag Felling Needed
Dillonwood	8	28	40	0-10
Homer's Nose	7	21	35	0-10
Board Camp	7	22	35	0
New Oriole Lake	5	13	25	0-10
Suwanee	6	15	30	0-10
Redwood Mountain Grove	4	10	20	0-10
Total	**37**		**185**	**50**

Snags would be felled using a combination of chainsaw, explosives, or crosscut if hazard can be safely felled in less than 30 minutes. The tool selected would be whichever is determined the safest tool. If chainsaws or crosscuts are used, stumps would be flush cut and camouflaged with duff to reduce visibility. Explosives would be expected to result in a generally "natural" look so would not require additional camouflage.

Wilderness Character

How does this alternative affect the qualities of wilderness character in both the short and long-term? Include both positive and negative effects. What mitigation measures will be taken?

Untrammeled: Under Alternative B, planting of tree seedlings would result in trammeling actions occurring over an area of roughly 1,131 acres (again, some areas where actions would occur are non-wilderness) for a period of up to five to six years—though would occur over a shorter timeframe if planting achieved minimum densities during initial planting attempts. Up to three plantings could be implemented per project area over the course of this longer timeline; post project, the untrammeled quality would be restored to pre-project levels.

Undeveloped: The undeveloped quality would be negatively affected by 37 sling load deliveries and up to roughly 6.5 hours of chainsaw use (at 10 minutes per tree when chainsaws are determined the only safe alternative though this number may be lower if other tools can be safely used). The temporary negative effects on undeveloped quality from motorized tool use and mechanical transport would return to pre-project levels once those tools were no longer being used. Though evidence of stumps from trees cut with chainsaw would be visibly abated, they would still be present and result in additional, though minimal, negative effects on undeveloped quality until stumps deteriorate naturally – a period of 10-20 years. The small tree wells would likewise have a minor, though negative, effect on undeveloped quality until the wells are no longer evident on the landscape—a period of one to two years post planting. In addition, similar to Alternative 1, the undeveloped quality would also be

[32] The estimated hover time reflects length of time wildlife would be disturbed as well as the length of time that undeveloped quality would be affected by a 4c prohibited use.

negatively affected by the installation of small monitoring equipment which would be in place for atleast an estimated 30-40 years.

Natural: Replanting of up to six affected sequoia groves and adjacent fisher critical habitat would restore sequoia and mixed conifer seedlings in up to 1,131 acres of wilderness at densities expected to direct the trajectory of severely burned areas toward forest recovery to their pre-fire conditions—as they would have done naturally had unnaturally high fuel loading not led to severe fire effects. Once seedlings are established, the NPS anticipates that natural and dynamic post-fire recovery processes would continue, and the seedlings would mature into trees. Over a period of centuries, the NPS further anticipates trees would continue to mature and that large sequoias (monarchs) would again become the dominant feature within most, if not the entire, grove footprint, thus preserving the natural quality of wilderness character in these groves.

The genetic structure within and across sequoia populations is not static. Rather, it changes over time in response to gene flow, population reduction (bottlenecks), genetic drift (loss of genetic diversity in small, isolated populations subject to chance changes), and natural selection (Allendorf et al. 2007). Given the loss of large numbers of mature sequoia and limited regeneration that the NPS has documented in post-fire surveys, the project areas now contain smaller populations of sequoia, with lower genetic diversity, that are more susceptible to genetic drift moving forward (Aitken and Whitlock 2013).Though speculative, should seedlings grown from only locally collected seed prove unsuccessful due to lack of resilience to climate change, the natural quality of wilderness character would be diminished.

Opportunities for Solitude or Primitive and Unconfined Recreation: This quality would be negatively affected by sights and sounds of aircraft and motorized equipment for up to a total of 1-2 hours of aircraft hovering over the course of three years and for up to several minutes in the vicinity of the 10-30-mile flight paths as helicopters approach, pass overhead, and recede. As well, opportunities would be negatively affected for the duration of crews working and camping in the areas for the duration they are present. Opportunities would be restored to pre-project levels once project activities cease.

Other Features of Value: There would be no effect on this quality.

Alternative C: Replant Seedlings Using Seed Propagated from Seed Collected from both the Local Genetic Community and Other Source Populations; Support Project Using a Combination of Helicopter, Stock Support, and Foot Travel

This Alternative is the same as Alternative B except the NPS would add genetic diversity to replanted giant sequoia groves by sourcing cones/seed from arid groves and from groves with known higher levels of genetic diversity within the seed zone. This approach would use current sequoia-specific research and general understandings of adaptation in trees to increase the likelihood of project success in an uncertain future. Proportions of supplementation would be based on available seed and recommendations of experts in giant sequoia genetics with the goal of increasing potential for success in a changing climate while also preserving local genetic stock containing any local adaptation and long-term genetic diversity of the species. The NPS anticipates that seed from outside the local genetic community, but still within the seed zone, would account for roughly 20% of all seedlings replanted.

All methods of seed collection, propagation, planting, and decision making would follow those outlined in Alternative B.

Transport Methods and Landing Clearance

All transport methods would follow those outlined in Alternative B.

Wilderness Character

How does this alternative affect the qualities of wilderness character in both the short and long-term? Include both positive and negative effects. What mitigation measures will be taken?

Untrammeled: Same as Alternative B except up to 20% of the sequoias planted under this alternative would come from a larger seedbank, beyond the grove. This would increase the degree to which the untrammeled quality would be negatively affected during project implementation. Post project, the untrammeled quality would be restored to pre-project levels.

Undeveloped: Same as Alternative B.

Natural: Same as Alternative B except up to 20% of planted sequoias would come from a more diverse genetic pool, increasing the likelihood that the intervention would be successful and enough giant sequoia would grow to full maturity and become monarchs over centuries as described further in the impacts from Alternative 2 in the EA (see Chapter 3: Affected Environment and Environmental Consequences). The natural quality for the proposed critical habitat corridor for fisher would be the same as Alternative B.

Opportunities for Solitude or Primitive and Unconfined Recreation: Same as Alternative B.

Other Features of Value: There would be no effect on this quality.

Alternative D: Only Plant Areas Safely and Feasibly Accessed by Foot, Stock, or Road Support

Under Alternative D, the NPS would plant seedlings with seed grown from either local sources and regional sources as described under Alternative C but would only do so in areas that are accessible via road, foot, and stock. Due to limited access, this alternative would result in planting only some areas of Redwood Mountain and adjacent proposed fisher critical habitat; all other areas would not be planted.

All methods for planting would follow those outlined in Alternative C, but all transportation of plants, equipment, supplies, and crew would occur via road, stock, or foot; no helicopters would be used for transportation.

Transport Methods and Landing Clearance

Under this alternative, crews, seedlings, and tools would be staged in a roadway area nearest to each trailhead where trail infrastructure allows stock to be staged to carry supplies. Areas having adequate trail infrastructure would utilize pack stock transport. From these sites, planting crews would transport seedlings to their planting locations on foot. As well, some areas, primarily in Redwood Mountain Grove may be near enough to the road and in terrain moderate enough that seedlings and tools could be safely and reasonably transported on foot. If such is the case, they would be transported on foot.

Wilderness Character

How does this alternative affect the qualities of wilderness character in both the short and long-term? Include both positive and negative effects. What mitigation measures will be taken?

Untrammeled: Same as Alternative C, except action would occur across 978 acres.

Undeveloped: Installation of small tree wells and subsequent monitoring would occur across 978 acres for a period of one to two years post planting for tree wells and at least 30-40 years for roughly 300 monitoring markers negatively affecting the undeveloped quality.

Natural: Replanting, or partially replanting, the Redwood Mountain Grove and adjacent fisher critical habitat would restore seedlings to the areas of wilderness that can be reached via these methods at densities they would be expected to occur under a natural post-fire conditions had seed sources as described under Alternative C. However, as outlined in Alternative A, this quality would remain diminished, or may deteriorate further (should high severity fire return) in groves, or areas of groves, that remain unplanted and convert to shrub-dominated communities.

Opportunities for Solitude or Primitive and Unconfined Recreation: There would be some limited affect to this quality from the sights and sounds of work crews planting trees in the Redwood Mountain area for the duration of planting efforts (one to two weeks annually).

Other Features of Value: There would be no effect on this quality.

Additional Alternatives

See EA, Chapter 1: Purpose and Need for full details on alternatives fully considered but dismissed under NEPA requirements. The following were considered in the initial MRA primarily for the purposes of determining the minimum 4(c) methods and tools. Transport methods dismissed in this MRA were not considered or further discussed in the EA.

Broadcast seed

Given the technical infeasibility and cost of gathering, storing, treating, and broadcast seeding the quantity of seed required, the low survival rates of seed, and the tendency for seed to be washed away in high storm events, the NPS dismissed an alternative to sow tree seed rather than plant tree seedlings (see EA, Chapter 1: Purpose and Need for further details).

Treat or Develop Fuels Management Prescription Prior to Planting

This alternative would include treatment of understory vegetation through burning, herbicide, crushing, or cutting prior to replanting. Areas where planting is being considered are those that burned at high severity during recent wildfires. There is currently little, litter, duff, or understory vegetation and planting conditions are therefore currently conducive to seedling survival absent fuels treatment. The NPS determined that additional treatment was therefore unnecessary prior to replanting seedlings and was not the minimum necessary at this time (see EA, Chapter 1: Purpose and Need for further details).

Transport all Seedlings and Tools to All Groves with Non-Motorized Transport

Various alternative components to transporting materials and equipment to all areas without the use of helicopters were considered but dismissed for the reasons outlined below. Please see also Table D1 and Table D2.

Transport seedlings and tools to all affected groves on stock and foot

The NPS considered the use of only roads, stock, and foot to transport materials to Redwood Mountain Grove and the associated proposed fisher habitat corridor in Alternative D, but the other five areas considered for replanting in Alternatives B and C are not accessible via trail, much less trail that is accessible for stock. As shown in Table D1, other than the Redwood Mountain area, none of the proposed planting areas are accessible via maintained trails. Further, the distance that would need to be traversed from the nearest maintained trail ranges from 2.7 to 5.5 miles and would require stock or foot traffic to traverse steep elevational gradients. While abandoned trail alignments do exist in many of these areas, they are not passable to stock and are either obliterated or not feasible for human use due to their condition—including downed trees and lack of tread surfaces. Again, see Table D1 for additional information.

The steep terrain, lack of maintained trails in most areas, distance to sites and weight of plant materials, tools, food, and gear therefore make this alternative infeasible to achieve the purpose and need for action and in some cases would present an unacceptable safety risk to tree planting crews and stock traveling to and from work sites. This alternative was therefore dismissed due to safety considerations and infeasibility. This alternative component for transport is not considered further in the EA.

Allow cross-country travel of stock to re-planting sites to transport seedlings and tools

Under this alternative, stock would travel from existing access routes cross-country in trail-less areas to deliver seedlings and tools. This alternative was dismissed outright as trail-less areas where planting would occur are too steep and rugged to allow for safe stock travel. This alternative component for transport is not considered further in the EA.

Construct stock trails in currently trail-less areas to transport tools and seedlings

Under this alternative, the NPS would utilize hand tools—including chainsaws, crosscuts, or pulaskis—to construct or restore several miles of administrative stock trails to support mobilization of seedlings, tools and equipment (see Table D1 for information on existing access and terrain). Administrative trails would be restored to pre-project conditions at the conclusion of project.

Constructing and/or re-opening and then commissioning one mile of trail in forested terrain in the middle of a high severity burn scar is estimated to require one full month for a 6–8-member trail crew. Work required would include tread work (scraping of a tread surface with digging tools), log clearing (using chainsaws), and ultimately recontouring and revegetation of duffing. An additional one month per trail mile would be required if cross-cut saws and pulaskis were used to clear trail rather than chainsaws. While abandoned trail alignments ranging from 2.7 - 5.5 miles in length do connect to existing trail system in some places, these trails have been abandoned for decades in part due to poor alignment and have been restored to prevent continued damage resulting from erosion. In the case of Homers Nose and New Oriole Lake, a minimum of 0.6-0.7 miles of new trail would be needed to provide access for stock requiring an estimated 2-3 weeks of additional work were chainsaws to be used and 4-6 weeks using cross-cut saws and pulaskis.

Restoring abandoned trails, or building new trail would lead to extensive soil, vegetation, and sound disturbance (from crew presence and tool use). As well, during construction and re-closure of any trail located through a burn scar, crews would be continually exposed to snags that are numerous in all of the planting areas. Exposure would be much greater than that to which planting crews would be exposed—four months vs. 1-2 weeks—increasing the risk for a tree failure to occur when crew members are present than tree planting alone (see below for more information on safety components routinely considered by NPS). For additional information on abandoned trails and how trail construction or the presence of trails impacts wilderness character please see Appendix K of the parks' 2015 Wilderness Stewardship Plan.

Due to reasons outlined above, an alternative that involves construction and then de-commissioning of stock trails through currently trailless areas was dismissed from further consideration for both safety purposes and because constructing such trails would have greater impact to wilderness character—including the opportunity for solitude or primitive and unconfined recreation, undeveloped, and natural qualities—than other alternatives considered and would therefore not be the minimum requirement to achieve project objectives. Therefore, the NPS determined that it was not necessary to document a full wilderness character analysis in this MRA.

Use Only Non-Motorized Tools (i.e., Crosscut Saw or Axe) or Explosives to Clear Snags from Sling-Load Landing Zones

Tree felling is consistently one of the top five most dangerous jobs in America (BLS 2020); when requiring crews to complete this type of work, safety must be of utmost concern. NPS often uses the Severity, Probability, Exposure (SPE) model of risk as described further below:

- **Severity:** Tree falling mishaps are easily fatal; there's only so much risk personal protective equipment (PPE) can mitigate. The choice of tool does not change *severity*.
- **Probability:** Method of mitigation affects skill needed, with greater *probability* of mishap when the required skill level is high. Felling trees with non-motorized tools or explosives is a highly technical skill, and though skill can be partially mitigated through training and crew selection firefighters available to complete the work, most staff do not have the skills to safely fall trees with these tools. Complexity of the surrounding environment further increases the *probability* of mishap. As action areas are located within high severity burn scars, there are other numerous dead/dying trees and those requiring felling would be over 150 feet in height (see Transport Methods and Staging Page 14 of MRA) and would have a high dbh., complexity, and therefore *probability*, of mishap is therefore likely to be high in locations where trees would require felling depending on the density of trees in the action area.
- **Exposure:** *Exposure* is the factor most influenced by the choice of tool or methods. Given that felling trees of the size class needed to create a safe landing zone (>100 feet in height) with a crosscut saw would take roughly 2-4 hours to complete and would require additional staff to complete the cuts, the risk/exposure to crews of falling objects (i.e., "widow-makers") during this extended period of stationary work would be considerable. In comparison, cutting a single tree with a chainsaw would take an estimated 10 minutes or 17% of the time needed to use a crosscut saw. Felling the tree with explosives would require 30 minutes to an hour to set up the blast.

Due to the conditions in the proposed action area, the NPS cannot assume that any snags within wilderness could be safely felled with a crosscut saw and will not impose this requirement on staff when the work could be completed more safely (via substantially less exposure to surrounding hazards) with a chainsaw. The use of crosscut saws to fell snags was dismissed from further consideration as it is not recommended as a reasonable alternative from a safety standpoint.

Conducting blasting in a forest where numerous snags exist would be technically challenging, and in some cases would present a high level of safety and operational risk—as experienced by NPS staff in previous situations within the parks, though explosives may be the safer tool in some cases where snags are extremely decayed and rigging cannot be employed, it is not always recommended as a reasonable and safe alternative for all situations (Ned Aldrich personal communication September 2022). Furthermore, trees felled with explosives can easily catch fire in the process, increasing risk for additional wildfire within the project areas. Given these safety concerns, explosives are not often recommended as the safest tool for felling snags particularly in light of the high density of snags and other dead/dying trees in the project areas and the susceptibility of the project areas to future high severity fire. Given these considerations, an alternative to only use explosives was also dismissed from further consideration as it would not safely meet the purpose and need for action and is again, not always recommended as a reasonable alternative from a safety standpoint.

Appendix D References

Aitken, S. N., and Whitlock, M. C. 2013. Assisted gene flow to facilitate local adaptation to climate change. Annual Review of Ecology, Evolution, and Systematics, 44: 367-388.

Allendorf, F.W., Luikart, G. and Aitken, S.N. 2007. Conservation and the genetics of populations. Mammalia, 2007, pp.189-197.

Baeza, A., Martin, R.E., Stephenson, N.L., Das, A.J., Hardwick, P., Nydick, K., Mallory, J., Slaton, M., Evans, K. and Asner, G.P. 2021. Mapping the vulnerability of giant sequoias after extreme drought in California using remote sensing. Ecological Applications, 31(7), p.e02395.

Bureau of Labor Statistics (BLS). 2020. Civilian occupations with high fatal work injury rates, 2020. Website https://www.bls.gov/charts/census-of-fatal-occupational-injuries/civilian-occupations-with-high-fatal-work-injury-rates.htm [accessed 28 September 2022].

Clark, J.S., R. Andrus, M. Aubry-Kientz, Y. Bergeron, M. Bogdziewicz, D.C. Bragg, D. 656 Brockway, N.L. Cleavitt, S. Cohen, B. Courbaud, R. Daley, A.J. Das, M. Dietze, T.J. Fahey, 657 I. Fer. J.F. Franklin, C.A. Gehring, G.S. Gilbert, C.H. Greenberg, Q. Guo, J. 658 HilleRisLambers, I. Ibanez, J. Johnstone, C.L. Kilner, J. Knops, W.D. Koenug, G. Kunstler, 659 JLaMontagne, K.L. Legg, J. Luongo, J.A. Lutz, D. Macias, E.J.B. McIntire, Y. Messaoud, 660 C.M. Moore, E. Moran, J.A. Myers, O.B. Myers, C. Nunez, R. Parmenter, S. Pearse, S. 661 Pearson, R. Poulton-Kamakura, E. Ready, M.D. Redmond, C.D. Reid, K.C. Rodman, C.L. 662 Scher, W.H. Schlesinger, A.M. Schwantes, E. Shanahan, S. Sharma, M.A. Steele, N.L. 663 Stephenson, S. Sutton, J.J. Swenson, m. Swift, T.T. Veblen, A.V. Whipple, T.G. Whitham, 664 A.P. Wion, K. Zhu, and R. Zlotin. 2021. Continent-wide tree fecundity driven by indirect 665 climate effects. Nature Communications 12: 1242.

Coop, J. D., Parks, S. A., Stevens-Rumann, C. S., Crausbay, S. D., Higuera, P. E., Hurteau, M. D., ... and Rodman, K. C. 2020. Wildfire-driven forest conversion in western North American landscapes. BioScience, 70(8), 659-673.Demetry, A. 1995. Regeneration patterns within canopy gaps in a giant sequoia-mixed conifer forest: implications for restoration. M.S. thesis. Northern Arizona University. Flagstaff, AZ. Google Scholar. Accessed December 15, 2022.

Guiterman, C.H., Gregg, R.M., Marshall, L.A.E., Beckmann, J.J., Van Mantgem, P.J., Falk, D.A., Keeley, J.E., Caprio, A.C., Coop, J.D., Fornwalt, P.J. et al. 2022. Vegetation type conversion in the US Southwest: frontline observations and management responses. Fire Ecology 18: 1–16.

Meyer, M.D., White, A., McGregor, E, Faber, K., Green, R., and Eckert, G. 2022. POST-FIRE RESTORATION STRATEGY FOR THE 2021 WINDY FIRE, KNP COMPLEX, AND FRENCH FIRE. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.

National Park Service. 2006. NPS Management Policies 2006. Sequoia and Kings Canyon National Parks.

National Park Service. 2007. General Management Plan. Sequoia and Kings Canyon National Parks.

National Park Service. 2010. National Park Service Climate Change Response Strategy. National Park Service Climate Change Response Program, Fort Collins, Colorado.

National Park Service. 2015. Wilderness Stewardship Strategy. Sequoia and Kings Canyon National Parks.

National Park Service. 2017. A Climate-Smart Resource Stewardship Strategy for Sequoia and Kings Canyon National Parks. Sequoia and Kings Canyon National Parks.

Shive, K.L., Wuenschel, Amarina, Hardlund, Linnea J., Morris, Sonia, Meyer, Marc D., Hood, Sharon M. 2022. Ancient trees and modern wildfires: Declining resilience to wildfire in the highly fire-adapted giant sequoia. Forest Ecology and Management, 511, 1-13.

Soderberg, David, Das, Adrian J., Stephenson, Nathan L., Meyer, Marc D., Brigham, Christy A., and Flickinger, Joshua. 2023. Assessing giant sequoia (Sequoiadendron giganteum) mortality and recruitment following high severity wildfire within SQF- and KNP-Complex fire-affected groves within Sequoia National Park, CA. USGS internal technical review completed, In review for publication in Ecological Applications.

Spencer, W.D., Sawyer, S.C., Romsos, H.L., Zielinski, W.J., Thompson, C.M., and Britting, S.A. 2016. Southern Sierra Nevada fisher conservation strategy. Version 1.0. Unpublished report produced by Conservation Biology Institute, Corvallis, OR. Stephenson, Nathan L., Caprio, Anthony C., Soderberg, David N., Das, Adrian J., Lopez, Eva L., and Williams, A. Park. 2023. Post-fire Reference Densities for Giant Sequoia Seedlings. Report to NPS from USGS. Completed USGS technical peer-review and will be formatted as NPS Natural Resources Report or submitted to journal for publication.

Stewart, W. (2020). Reforesting California. Reforestation Practices for Conifers in California Technical editor: William Stewart. *University of California, Berkeley*.

Tricker, J., Landres, P., Fauth, G., Hardwick, P., and Eddy, A. 2014. Mapping wilderness character in Sequoia and Kings Canyon National Parks. Natural Resource Technical Report NPS/SEKI/NRTR—2014/872, 82 pp.

York, R.A., Thomas, Z., and Restaino, J. 2009. Influence of ash substrate proximity on growth and survival of planted mixed-conifer seedlings. Western Journal of Applied Forestry, 24(3), pp.117-123.

York, Robert A., Kevin L. O'Hara, and John J. Battles 2013. Density Effects on Giant Sequoia (Sequoiadendron giganteum) Growth Through 22 Years: Implications for Restoration and Plantation Management, Western Journal of Applied Forestry 28(1) 2013 American Journal of Forestry

Appendix E: Utilizing Genomic Insights to Inform Seed Selection for Post-Fire Replanting of Giant Sequoia Groves

Rainbow DeSilva Ph.D.

Introduction

The fire seasons of 2020 and 2021 led to widespread high-severity fire in many giant sequoia groves in the southern Sierra Nevada. The combined effects of these fires caused the mortality of nearly 20% of all mature giant sequoia trees. In addition, minimal post-fire regeneration is occurring in areas where fire not only killed standing trees but also burned aerial cones. In these areas, it is likely that burned areas will not recover unaided due to large distances to live sequoia trees that serve as seed source for recruitment. To address this issue, Sequoia and Kings Canyon National Park (SEKI) has planned strategic reforestation efforts within six giant sequoia groves. SEKI seeks to identify appropriate seed sources that can maximize the future resilience of restored groves. The traditional practice in reforestation has been to plant locally collected seed, a custom that began with the assumption that local seed would be adapted to current environmental conditions. However, given the climatic shifts both recorded and expected for the Sierra Nevada region, seed stock that harbors genetic adaptations to historic conditions may be maladapted to the future climate at reforested sites. Therefore, a re-assessment of seed selection strategy that explicitly considers which gene pools are likely to thrive under future conditions is warranted. An additional complication for giant sequoia is that few studies have investigated how to determine local seed. Groves have been loosely interpreted as representing populations (a gene pool of interbreeding individuals), but giant sequoia distribution is spatially complex, and some grove designations have been pliable over time. Understanding how genetic variation changes over space can inform foresters on the historical continuity of groves and the potential genetic differences between seeds collected from various locations across the giant sequoia range. Moreover, current patterns of genetic diversity and local adaptation contain clues as to the possible extent of future maladaptation and the potential to mitigate this phenomenon through the deliberate introduction of seed from other groves (hereafter assisted migration) to facilitate adaptive responses to climate change. Thus, to support giant sequoia reforestation efforts, I provide background on genetic differentiation among groves and patterns of local adaptation and genetic diversity. This information serves as the basis for an examination of what constitutes local seed and the potential benefits and risks of assisted migration in giant sequoia reforestation.

Genetic Continuity Among Giant Sequoia Groves

Giant sequoia occurs in ~70 groves in a narrow elevation band (mostly within 1400–2200 m) along the western slope of the Sierra Nevada. Giant sequoia range is highly fragmented from Placer County to the Kings River and becomes more contiguous from the Kings River south (hereafter the southern region) to the southernmost grove, Deer Creek. In the southern region, some groves are spatially separated by large non-grove areas, while others occur in grove complexes. Given the spatial complexity of giant sequoia distribution, it is surprising that no formal studies have examined how/whether grove units correspond to genetic populations. Genetic data, specifically the level of differentiation among groves (how much genetic variation is contained within each grove in comparison to among all sampled groves) can provide information on what is local vs. non-local in terms of continuity of genetic variation. For giant sequoia, patterns of genetic differentiation suggest that groves north of the Kings River are genetically distinct from each other and from southern groves (Dodd and DeSilva 2016, DeSilva and Dodd 2020a, DeSilva and Dodd 2020b). This finding has been corroborated by a recent study that found significant range-wide genetic structure using a large genome-wide dataset (De La Torre et al. 2021). South of the Kings River, groves show a larger degree of genetic continuity that degrades at the extreme southern parts of the range (Dodd and DeSilva 2016, DeSilva and Dodd 2020a, DeSilva and Dodd 2020b). When examining the southern populations alone, average F_{ST}, a common measure of genetic differentiation, ranges between 0.033 – 0.080 with larger/more central giant sequoia groves showing low levels of genetic differentiation ($F_{ST} < 0.05$), and extreme southern groves that become increasingly distinct (Table E1; DeSilva and Dodd 2020a, DeSilva and Dodd 2020b, DeSilva unpublished data). Yet, populations in the southern range do not show a significant trend of increasing differentiation with geographic distance (isolation by distance) (Figure E1; DeSilva unpublished data). Comparisons of grove pairs show a signal of genetic similarity between large groves in areas of high grove density and less similarity between the southernmost small groves (DeSilva and Dodd 2020a). Small population sizes at the range periphery may contribute to the observed increase in genetic differentiation in the both the northern and southernmost range because small populations show higher rates of genetic drift (Eckert 2008 and references therein). If this pattern holds, it is likely that small groves in the southern range will be more genetically distinct. Indeed, average F_{ST} values in the southern range show a negative correlation with grove area (Correlation = -0.77; P-value 0.006; DeSilva unpublished data). Although small groves in the core of the southern range are underrepresented in DeSilva and Dodd (2020a), Lost Grove shows higher levels of differentiation than larger groves in the same geographic area (Table E1). It is important to note that many studies investigating genetic structure in giant sequoia have examined a limited number of southern populations (between 10 - 15), (Dodd and DeSilva 2016, DeSilva and Dodd 2020a). More comprehensive sampling of the range will provide a better understand the genetic continuity in this region.

FIGURE E1: GEOGRAPHIC DISTANCE BETWEEN 11 SAMPLED SOUTHERN POPULATIONS OF GIANT SEQUOIA IN COMPARISON TO PAIRWISE F_{ST}.

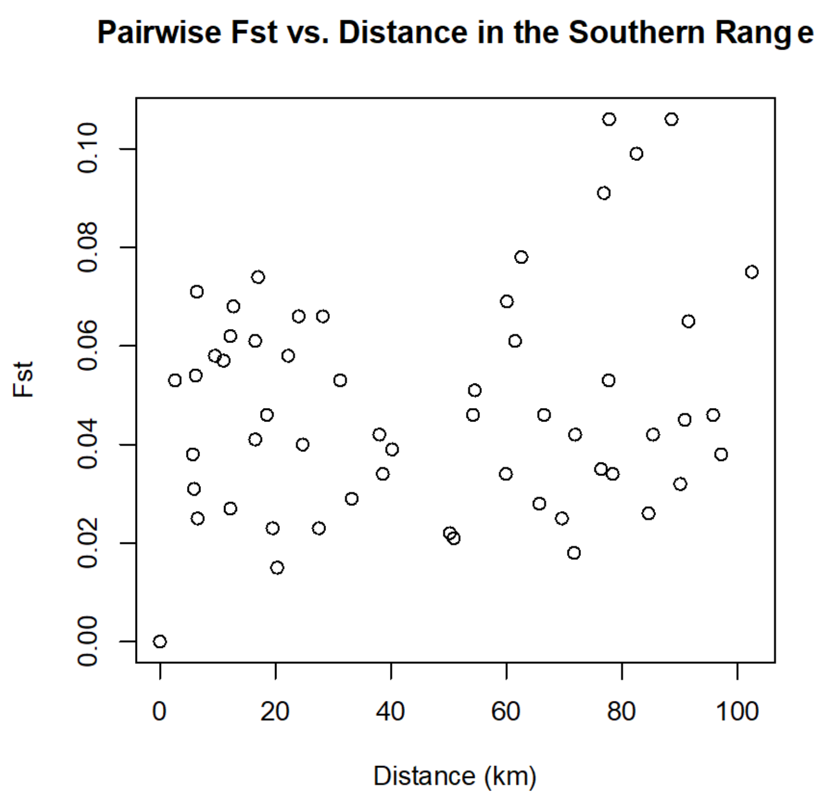


TABLE E1. F_{ST} FOR THE 11 SOUTHERN POPULATIONS SAMPLED IN DESILVA AND DODD 2020A

	GRNT	RMNT	LOST	GFOR	ATWL	MCTR	FMAN	LMDW	CNHM	PKSD	DCRK
GRNT	--	--	--	--	--	--	--	--	--	--	--
RMNT	0.025	--	--	--	--	--	--	--	--	--	--
LOST	0.074	0.058	--	--	--	--	--	--	--	--	--
GFOR	0.023	0.015	0.057	--	--	--	--	--	--	--	--
ATWL	0.039	0.029	0.066	0.027	--	--	--	--	--	--	--
MCTR	0.035	0.025	0.061	0.022	0.042	--	--	--	--	--	--
FMAN	0.034	0.018	0.078	0.021	0.034	0.031	--	--	--	--	--
LMDW	0.045	0.026	0.091	0.028	0.046	0.041	0.023	--	--	--	--
CNHM	0.065	0.042	0.106	0.046	0.051	0.061	0.046	0.053	--	--	--
PKSD	0.038	0.032	0.099	0.042	0.034	0.058	0.040	0.038	0.054	--	--
DCRK	0.075	0.046	0.106	0.053	0.069	0.066	0.053	0.062	0.068	0.071	--
Average	0.045	0.031	0.080	0.033	0.044	0.044	0.038	0.045	0.059	0.051	0.067

Continuity in genetic variation over space is maintained through historical and/or current genetic exchange among populations (i.e., gene flow). Estimates of gene flow among paired giant sequoia groves indicate a likelihood of ongoing and/or recent genetic exchange among the south groves General Grant and Redwood Mountain, Giant Forest and Atwell, and Freeman Creek and McIntyre (DeSilva and Dodd 2020a). Further south, groves pairs Long Meadow and Cunningham, and Packsaddle and Deer Creek do not show strong evidence of ongoing genetic exchange although these groves are separated by comparable distances (DeSilva and Dodd 2020a). This dichotomy could reflect the capacity of large populations to produce more pollen and seed, increasing the opportunities for gene flow through long-distance dispersal events (Nathan et al., 2008; Purves, 2009), or higher grove density in some areas allowing for step-wise gene-flow among population networks (DeSilva and Dodd 2020a). Even low levels of gene flow can reduce diversity loss via genetic drift and maintain genetic continuity (Slatkin 1987). Estimates of gene flow in the core parts of giant sequoia range are somewhat incongruent with the apparent predominance of short distance dispersal in the species (DeSilva and Dodd 2021). Research on pollen rain within, and adjacent to, two small giant sequoia groves suggest restricted pollen dispersal in giant sequoia (Anderson 1990). In a slightly more comprehensive study where genetic data was used to infer dispersal, effective dispersal of pollen and seed was found to predominantly occur over distances < 370m (DeSilva and Dodd 2021). Yet, fat-tailed pollen dispersal kernels indicate potential for long distance pollen movement among populations (DeSilva and Dodd 2021). Because of these conflicting lines of evidence, it remains obscure whether the genetic connectivity within portions of the southern range reflects ongoing gene flow, perhaps at higher rates among large populations, or that giant sequoia had a more contiguous range in the recent past and not enough time has passed to allow populations to diverge. Indeed, genetic data has supported the inference that giant sequoia has suffered from a long-term population decline (over the last 2 million years) with a more severe contraction prior to the last glacial maximum (Dodd and DeSilva 2016). Certainly, twenty thousand years would likely represent a short time interval for evolutionary changes to accumulate in a species with long generation times and extreme longevity.

Evidence of Trait Variation Among Populations

Studies in which different provenances of giant sequoia are grown in common environments have provided information on the extent of genetically based phenotypic variation. These studies have demonstrated variation in cold hardiness among five southern giant sequoia populations (Du and Fins, 1989), variation in growth-related traits among 23 populations, including 15 in the southern range (Valness 2016), differences in height and diameter growth among four provenances (1 northern, 3 southern) (Melchior and Hermann

1987), variation in frost resistance in 22 provenances (Guinon et al. 1982), and variation in rates of seed germination among 26 populations distributed across the range (Fins and Libby 1982). Moreover, a study investigating traits related to water balance and drought response noted only minor (or non-significant) differences among three giant sequoia populations that represented the northern, central, and southern parts of the species' range (Ambrose et al. 2016). Variation in drought-related traits has been noted in a range-wide set of 23 populations with some observed differences showing correlations with latitude (De La Torre et al. 2022). The majority of provenance studies in giant sequoia provide range-wide assessments of trait differences (Fins and Libby 1982, Valness 2016, De La Torre et al. 2022), which makes it more difficult to assess the signal of trait divergence among southern populations alone. Taken together, this evidence demonstrates that important variation in functional traits exists across the giant sequoia range. However, fully understanding the degree of variation among population in the southern region and the spatial scales at which trait variation becomes evident would require studies with increased representation of southern provenances.

Local vs. Non-Local in the Southern Range of Giant Sequoia

Although an accurate determination of genetic populations for giant sequoia is not possible given the available research on the species, levels of genetic structure and gene flow can provide information on the likely degree of genetic divergence among seed sources. Within the southern range of giant sequoia, many lines of evidence suggest that spatially proximal groves are likely to have similar genetic composition. This pattern is more likely to be maintained in large vs. small populations, and in areas of higher grove density. If the pool of genetic variation among proximal groves is continuous, seeds collected from a grove of interest (i.e., local seed) will exhibit a large degree of genetic overlap with seeds from other groves nearby (i.e., non-local seed). Unfortunately, the distance that is considered 'nearby' cannot be reduced to a general statistic. In other plant species, delineations of 'local' provenance that use genetic data have been informed by relationships between genetic differentiation and geographic distance (Kraus et al. 2013, Hufford et al. 2016). Because no significant patterns of isolation by distance were found in the southern range of giant sequoia (DeSilva unpublished data), any threshold distance to delineate the bounds of local vs. non-local would be artificial. Instead, a grove-specific approach should be considered, where for any particular grove, small groves in the immediate vicinity (< 2 km) and medium-large groves at larger spatial radius can be considered 'local' because they are likely to have a high degree of genetic similarity to the grove in question. In regard to the six populations where reforestation is proposed, Table E2 provides additional information in regard to potential groves that could be considered within the local provenance. It is important to note that many giant sequoia populations show a high level of genetic structure within groves (DeSilva and Dodd 2021). This means that the genetic diversity present within a single grove is spatially clustered, with related individuals tending to exist in close proximity. Thus, seed collections within groves need to occur at multiple spatial localities in order to adequately capture the genetic diversity. Based on the degree of spatial genetic structure and average gene dispersal distances (DeSilva and Dodd 2021), seed collection sites should be > 250 m apart and occur in multiple locations within targeted groves, with the number of collection sites being related to grove area (10 being sufficient for small groves and 20-25 needed in large groves). Ideally, collection sites should systematically maximize spatial distances between collection sites and attempt to make collections within all sections of the grove.

TABLE E2. GROVES WHERE REPLANTING WILL OCCUR. PROXIMAL GROVES WITH HIGH LIKELIHOOD OF GENETIC SIMILARITY ARE NOTED

Grove Name	Groves within the 2km; groves > 100 acres within 10km (grove to grove perimeter)
Redwood Mountain	Big Stump (2.6), Grant (4.9), Muir (6.8), Converse Basin (9.8)
Suwanee	Giant Forest (2.9), Muir (5.2), Pine ridge (5.8)
New Oriole Lake	Oriole lake (1.9), Redwood Creek (2.5 – as it is fairly contiguous with Atwell), Atwell (3.0), Eden creek (4.1), East fork (4.9), Castle Creek (7.4), Homers Nose (8.1)
Homers Nose	Board Camp (0.4), Cedar Flat (0.5), South Fork (1.6), Surprise (1.9), Eden Creek (2.1), Garfield (2.9), Dillonwood (6.2)
Board Camp	Homers Nose (0.4), South Fork (0.5), Cedar Flat (0.6), Garfield (2.0), Eden Creek (3.2), Dillonwood (5.9)
Dillonwood	Garfield (0.0), Middle Tule (3.6), South Fork (4.2), Mountain Home (4.8) Homers Nose (6.2)

Genetic Diversity and Local Adaptation in Giant Sequoia

Giant sequoia populations exhibit relatively low genetic diversity as compared to some other conifer species, with the smallest and most isolated groves often being the most depauperate (Fins and Libby 1982; Dodd and DeSilva 2016, DeSilva and Dodd 2020a, De La Torre et al. 2021). Observed levels of genetic diversity are related to grove size with the smallest groves showing reduced genetic diversity and medium to large groves exhibiting similar diversity levels (Figure E2; Table E3).

FIGURE E2: THE RELATIONSHIP BETWEEN HETEROZYGOSITY (A MEASURE OF GENETIC DIVERSITY) AND GROVE SIZE

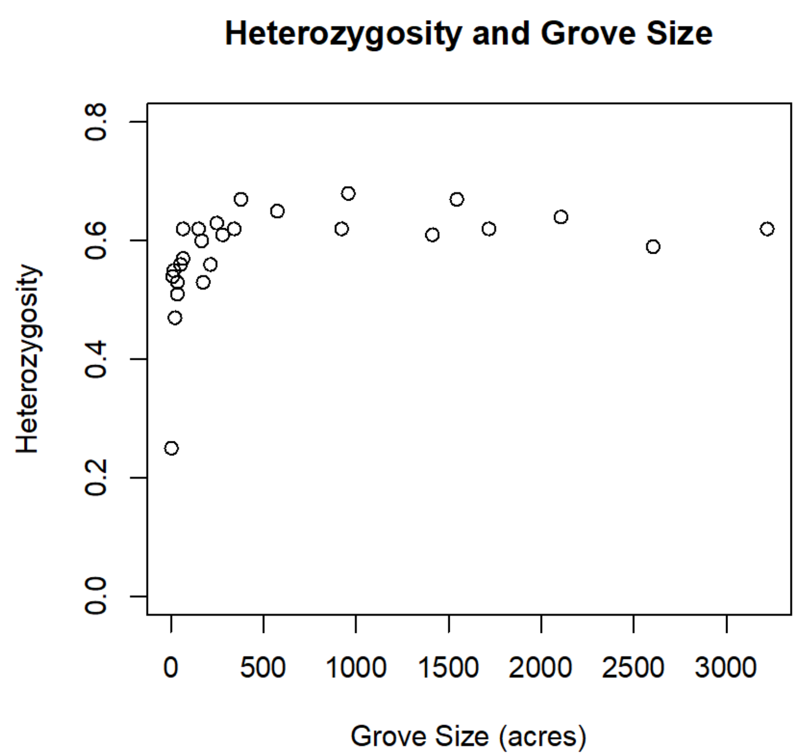


TABLE E3: DIVERSITY AND DIFFERENTIATION STATISTICS FOR 26 GIANT SEQUOIA GROVES*

Grove	H_E	A_R	AREA**
Placer	0.25	1.9	3
North Calaveras	0.57	3.3	66
South Calaveras	0.62	3.7	342
Tuolumne	0.47	2.5	23
Merced	0.55	3.0	16
Mariposa	0.63	3.4	248
Nelder	0.67	3.5	379
McKinley	0.56	3.3	53
Cabin Creek	0.62	3.4	150
Converse Basin	0.67	3.7	1544
Lockwood	0.62	3.5	66
Windy Gulch (Evans)	0.68	4.1	958
Grant	0.60	3.8	167
Redwood Mountain	0.59	3.7	2604
Lost	0.53	3.2	35
Giant forest	0.64	3.9	2106
Atwell	0.62	3.7	922
Mtn Home	0.62	3.7	3220
Black Mountain	0.62	3.7	1717
McIntyre	0.61	3.9	279
Freeman	0.61	4.0	1413
Wheel Meadow	0.65	3.8	575
Long Meadow	0.56	3.6	214
Cunningham	0.54	3.2	10
Packsaddle	0.53	3.0	175
Deer Creek	0.51	2.9	35

*Diversity Stats heterozygosity and allelic richness (H_E and A_R respectively): represent data or averages (where applicable) from Dodd and DeSilva 2016, DeSilva and Dodd 2020(a).
**Area (in acres) from updated grove perimeter GIS layer.

Extensive research using common garden and reciprocal transplant experiments has demonstrated the prevalence of local adaptation in forest trees (Morgenstern 1996, Savolainen et al. 2007, Alberto et al. 2013). In giant sequoia, patterns of association between climate and genome-wide genetic variation (likely containing both neutral and functional genomic regions) show signatures of local adaptation to gradients in water availability (DeSilva and Dodd 2020b). Similar results were found by De La Torre et al. (2021) in a study that utilized a dataset consisting of > 50k genetic markers (De La Torre et al. 2021). In support of these findings, variation in drought-related traits has shown strong correlations with potential candidate genes for drought tolerance (De La Torre et al. 2022). Moreover, variation in growth-related traits from the most comprehensive common garden trial of giant sequoia (Foresthill Seed Orchard) suggest that trees originating from larger and less isolated groves grow best when planted in Foresthill, a location that tends to be warmer than much of giant sequoia range (Valness 2016). This study demonstrates the existence of adaptive genetic variation across the species' range and suggests that large southern groves may perform better in warmer conditions (Valness 2016), a likely signal of local adaptation. Other provenance studies (also see above) showing trait variation among giant sequoia trees grown in common environments further support the existence of functional variation in the species (Melchior and Hermann 1987; Du and Fins 1989). Overall, this indicates that genetic differences among populations impact growth and drought related traits. Ecological studies add to our knowledge of the environmental factors that are important for giant sequoia success. A broad set of ecological studies have noted that giant sequoia seedlings grow best under conditions of high resource availability and are especially sensitive to moisture conditions, as desiccation is a main cause of seedling mortality (Rundel 1972, Hartesveldt et al. 1975, Weatherspoon 1990, York et al. 2003, Shellhammer and Shellhammer 2006). In addition, a common understanding is that the lower elevational range limit of giant sequoia is controlled by a lack of sufficient soil moisture (Rundel 1972). Taken together, evidence suggests that giant sequoia are both sensitive to the moisture conditions of their habitat and that populations are locally adapted to gradients in water availability, supporting the idea that populations currently inhabiting drier areas are likely better-adapted to those conditions (DeSilva and Dodd 2020b, De La Torre et al. 2021, De La Torre et al. 2022). It is important to note that although many giant sequoia populations are likely to show some local adaptation, large populations are expected to be more locally adapted than small populations due to loss of genetic diversity in smaller populations because of higher rates of genetic drift (Aitken and Whitlock 2013, and references therein). To date, few studies have investigated the genetic underpinnings of important functional traits in giant sequoia and much remains to be learned about giant sequoia adaptation to its environment.

The Case for Assisted Gene Flow

Climate change is causing a warming and drying trend in the Sierra Nevada region. The predicted changes by 2100 include average temperature increase of 1.5-4.5 °C (Cayan et al. 2008), an estimated 75% reduction in mid-elevation snowpack (Sun et al. 2019, Siirila-Woodburn et al. 2021), and snowmelt occurring 30-80 days earlier (Schwartz et al. 2017). Within SEKI under high emission scenarios (RPC 8.5), average predicted warming from 2000 to 2100 ranges from 4.7 - 4.8°C (Gonzalez et al. 2018). Precipitation is also predicted to show modest increases in SEKI, however overall drier conditions (as indicated by increased Climate Water Deficit) are likely to occur due to higher rates of evapotranspiration (Thorne et al. 2015). These long-term trends in climate are coupled with increased potential for regional droughts in California (Diffenbaugh et al. 2015).

As we progress through the 21st century, Sierra Nevada climate will likely become more arid with reductions in snow-pack leading to effective increases in the length of summer dry periods. As a water sensitive species, giant sequoia is likely to experience rapid changes to a resource needed for their ongoing success. For long-lived species that lack the capacity for rapid migratory or evolutionary responses, in part due to long-generation times, populations that are adapted to historic climate regimes are likely to become maladapted to future conditions (Aitken et al. 2008, Aitken and Whitlock 2013, DeSilva 2020). Indeed, signs of maladaptation have already been observed in some tree species (Gellie et al. 2016, Browne et al. 2019, Etterson et al. 2020), and are predicted for many others (Bradley ST Clair and Howe 2007, Frank et al. 2019, Dougherty et al. 2021). As maladaptation becomes more pronounced, tree populations will likely suffer ongoing declines in growth and survival. For giant sequoia, the recent foliage dieback during the 2012-2016 drought highlights the potential risks posed by a more arid future coupled with increased drought frequency (Stephenson et al. 2018). Additionally, some giant sequoia trees within SEKI have shown reduced photosynthetic rates after drought, another sign of drought sensitivity (Baeza et al. 2021).

The movement of genetic material within the range of a species (i.e., assisted gene flow) could mitigate maladaptation by enhancing the ability of populations to adapt to climatic changes (Sgró et al. 2011, Aitken and Whitlock 2013, Aitken and Bemmels 2016). Assisted gene flow as a tool for conservation is gaining support, with numerous scientists recommending adjustments to seed collection and transfer strategies that explicitly consider future climatic conditions (Sgrò et al 2011, Aitken and Whitlock 2013, Prober et al. 2015, Ramalho et al. 2017, Castellanos-Acuna et al. 2018). Updated seed transfer guidelines that include assisted gene flow have been recommended for a multitude of tree species (O'Neill et. al. 2008, Grey et al. 2011, Browne et al. 2019, Milesi et al. 2019, Etterson et al. 2020). The major strategies in assisted gene flow are to enhance overall genetic diversity or attempt to capture and introduce preadapted variation (e.g., add warm or arid-adapted genotypes into populations in areas that are becoming warmer and drier). Since genetic diversity is the fuel for adaptive evolution, capturing and spreading genetic variation creates a larger pool from which selection can act, effectively providing options to populations. Bolstering levels of genetic diversity within a population increase the likelihood of adaptation to climate change as well as provide potential benefits in relation to unforeseen factors of importance (e.g., resistance to insect or pathogen attack, adaptations to non-target climatic factors) (Broadhurst et al. 2008, Aitken and Bemmels 2016). Adding diversity increases the spectrum of possible trait variation and allows natural selection to determine the best suited individuals. When considering adaptation to climate change, not all genetic variation will be equally beneficial in facilitating adaptation to future conditions. Populations that currently inhabit warm or arid regions of the distribution have higher potential to contain genetic variants that are preadapted for conditions predicted to occur in other areas of giant sequoia range (see Appendix 1; Aitken and Bemmels 2016, DeSilva and Dodd 2020b). The genetic variation that underlies any local adaptation to aridity will likely be crucial additions for recipient populations that are headed into a drier future. The potential benefits of assisted gene flow in mitigating the negative impacts of climate change are clear, yet operational frameworks on how to implement these programs are lacking for many tree species. Some studies suggest attempting to mimic and enhance natural processes of gene flow by adding more seed from nearby provenances and smaller amounts from more distant locales (Broadhurst et al. 2008), others advocate for regional seed mixtures in order to gain benefits of increased genetic diversity while minimizing potential risks associated with assisted gene flow (Bucharova et al. 2019), and some strategies, termed 'climate matching', advocate for incorporating seeds across a climate gradient with emphasis on planting seeds collected from areas where present-day climate is similar to expected climate at the planting site (Prober et al. 2015). Recommendations for assisted gene flow have also suggested a maximum of 20% influx from source populations can aid in genetic adaptation to future environmental changes while minimizing potential risks (Weeks et al. 2011, Aitken and Whitlock 2013). Although adaptation to aridity is vital to ongoing giant sequoia persistence, many other environmental factors will likely be important as well (e.g. resistance to insect or pathogen attack, adaptations to other climatic factors, resistance to fire). Thus, a successful path forward may be a diversified approach that considers the potential benefits of bolstering overall genetic diversity as well as targets preadapted variation to a more arid future.

The Risks of Introducing Non-Local Seeds into Populations

It is important to consider the potential negative impacts of assisted gene flow. Outbreeding depression is the most commonly cited concern. Outbreeding depression is when the mixing of genetically distinct lineages results in subsequent offspring with reduced fitness. The risks of outbreeding depression are most important when highly divergent lineages are mixed (Frankham et al 2011, Aitken and Whitlock 2013). In simulation studies of outbreeding depression, the addition of 20% outside gene flow caused moderate dips in fitness, however reductions were temporary, and fitness recovered within relatively few generations of selection (Aitken and Whitlock 2013). Moreover, when the influx of gene flow included preadapted variants, long-term gains in fitness far outweighed any short-term losses (Aitken and Whitlock 2013). Some researchers suggest that the risks of outbreeding depression have likely been overstated for wind-pollinated forest trees (Aitken and Whitlock 2013), as this phenomenon appears to be less common than previously believed (Whiteley et al. 2015). In addition, as local conditions shift with ongoing climate change, natural populations (those where planting has not taken place) are likely to suffer declines due to maladaptation (Aitken and Whitlock 2013), an effect that is being observed in multiple tree species (Gellie et al. 2016, Browne et al. 2019, Etterson et al. 2020). A newly published work by Hall et al. (2023) suggests widespread climate mismatches between conifers and their environments in the Sierra Nevada, noting that temperatures suited for conifers have already shifted upslope by 182 meters. Thus, populations of Sierra Nevada conifers will likely experience reduced fitness both without management and under the status quo of planting local seed only.

Another concern with assisted gene flow is the potential disruption of local adaptation to non-target environmental factors (Aitken and Whitlock 2013). For example, if aridity or heat tolerance is targeted for assisted gene flow, then other important ways populations can be locally adapted could be disrupted.

Populations of forest trees are likely adapted to a suite of environmental conditions including climate, soil type, biotic interactions, photoperiod, fire regimes, etc. If populations targeted as seed sources differ from recipient populations in their adaptation to unaccounted for factors, reductions in fitness could occur (Aitken and Whitlock 2013, Schiffers et al. 2013). Any risks associated with maladaptation to non-target environmental factors will be related to the proportion of outside materials introduced and can be mitigated by keeping non-local seed to 20% or less (Aitken and Whitlock 2013).

The risks for assisted migration in the southern range of giant sequoia are minimal. Outbreeding depression is a concern when combining long-diverged lineages (Aitken and Whitlock 2013). In the southern range of giant sequoia, there is a high degree of genetic continuity among populations, meaning most lineages are not long-diverged. Giant sequoia is potentially adapted to other site-specific conditions (e.g., difference in soil type, pest resistance). However, within the southern portion of giant sequoia range, differences in population adaptation to photoperiod or fire regime are likely minimal, as this section of the range covers about two degrees latitudinal and most areas experience similar fire regimes (Stephenson 1999, and references therein). Also, diversified approaches to choosing seed which seek to enhance genetic diversity as well as facilitate adaptation to future climate can provide buffers against unforeseen environmental stressors (Broadhurst et al. 2008). In addition, a conservative approach where non-local seed constitutes less than 20% of the total numbers of trees in the recipient population can provide adaptive benefits while keeping the genetic risks low. Lastly, if reductions in fitness do occur after assisted migration due to outbreeding depression or maladaptation to non-target factors, natural selection could likely help giant sequoia rebound quickly. Giant sequoia undergoes a strong selective filter for establishment (DeSilva 2020). The species generally displays bursts of reproduction after fire in which thousands of seeds can be dropped within small areas. The vast majority of these seeds will perish in the first few years of life, ultimately leaving only a few individuals that grow to maturity. This selective filter can be highly effective in removing lower performing seeds, allowing the environment to determine which seeds are best. Ultimately, with careful employment, the genetic risks associated with assisted gene flow in giant sequoia will be low and likely outweighed by potential gains (Aitken and Whitlock 2013, Weeks et al. 2013).

Summary

The 'local-is-best' rationale for replanting trees needs to be re-examined in our current era of unprecedented change. As aridity increases in the Sierra Nevada and droughts become commonplace, the risks of inaction are looming. Climatic change is creating novel climatic conditions within giant sequoia range, increasing the likelihood that populations will become maladapted to their environment. Assisted migration can mitigate this phenomenon by providing an influx of genetic variation to aid in adaptation. This benefit can be achieved by enhancing overall diversity, which can increase a populations ability to withstand a diverse array of potential stressors, or by targeting aridity tolerance, which can be crucial for the success of populations that will soon be subjected to drier conditions. Groves that currently occupy arid regions of the distribution have higher potential to contain genetic variants that are preadapted to a drier future. In addition, medium to large groves of giant sequoia tend to contain higher diversity. Thus, a planting approach that combines local seed with regional non-local seed sourced from high diversity groves and groves that inhabit arid conditions can restore groves and help them thrive into the future. For giant sequoia, the risks associated with this approach appear minimal. Thus, replanting of giant sequoias is an opportunity to build resilience into giant sequoia groves and give these trees a fighting chance at long-term persistence.

Appendix E References

Aitken, S. N., Yeaman, S., Holliday, J. A., Wang, T., & Curtis-McLane, S. (2008). Adaptation, migration or extirpation: climate change outcomes for tree populations. *Evolutionary applications*, *1*(1), 95-111.

Aitken, S. N., and M. C. Whitlock. 2013. Assisted gene flow to facilitate local adaptation to climate change. *Annual Review of Ecology, Evolution, and Systematics,* **44:** 367-388.

Aitken, S.N. and Bemmels, J.B. 2016. Time to get moving: assisted gene flow of forest trees. Evol Appl, 9: 271-290. https://doi.org/10.1111/eva.12293

Ambrose, A. R., Baxter, W. L., Wong, C. S., Næsborg, R. R., Williams, C. B., & Dawson, T. E. (2015). Contrasting drought-response strategies in California redwoods. *Tree Physiology*, *35*(5), 453-469.

Alberto, F.J., Aitken, S.N., Alía, R., González-Martínez, S.C., Hänninen, H., Kremer, A., Lefèvre, F., Lenormand, T., Yeaman, S., Whetten, R. and Savolainen, O. (2013). Potential for evolutionary responses to climate change—evidence from tree populations. *Global Change Biology*. **19**, 1645–1661.

Anderson R.S. 1990. Modern pollen rain within and adjacent to two giant sequoia (Sequoiadendron giganteum) groves, Yosemite and Sequoia national parks, California. *Canadian Journal of Forest Research*, 20 (9): 1289-1305.

Baeza, A., Martin, R. E., Stephenson, N. L., Das, A. J., Hardwick, P., Nydick, K., Mallory, J., Slaton, M., Evans, K., and Asner, G. P. (2021). Mapping the vulnerability of giant sequoias after extreme drought in California using remote sensing. *Ecological Applications*, *31*(7), e02395.

Bradley ST Clair, J. and Howe, G.T. (2007), Genetic maladaptation of coastal Douglas-fir seedlings to future climates. Global Change Biology, 13: 1441-1454. https://doi.org/10.1111/j.1365-2486.2007.01385.x

Broadhurst, L. M., Lowe, A., Coates, D. J., Cunningham, S. A., McDonald, M., Vesk, P. A., and Yates, C. (2008). Seed supply for broadscale restoration: maximizing evolutionary potential. *Evolutionary Applications*, *1*(4), 587-597.

Browne, L., Wright, J.W., Fitz-Gibbon, S., Gugger, P.F. and Sork, V.L. (2019). Adaptational lag to temperature in valley oak (*Quercus lobata*) can be mitigated by genome-informed assisted gene flow. *Proceedings of the National Academy of Sciences*. **116:**(50), 25179- 25185; Doi:10.1073/pnas.1908771116

Bucharova, A., Bossdorf, O., Hölzel, N. *et al.* Mix and match: regional admixture provenancing strikes a balance among different seed-sourcing strategies for ecological restoration. *Conserv Genet* **20**, 7–17 (2019). https://doi.org/10.1007/s10592-018-1067-6

Castellanos-Acuna, D., Vance-Borland, K. W., St. Clair, J. B., Hamann, A., López-Upton, J., Gómez-Pineda, E., ... & Sáenz-Romero, C. (2018). Climate-based seed zones for Mexico: guiding reforestation under observed and projected climate change. *New forests*, *49*, 297-309.

Cayan, D.R., Maurer, E.P., Dettinger, M.D. *et al.* Climate change scenarios for the California region. *Climatic Change* **87** (Suppl 1), 21–42 (2008). https://doi.org/10.1007/s10584-007-9377-6

De La Torre, A. R., Sekhwal, M. K., & Neale, D. B. (2021). Selective sweeps and polygenic adaptation drive local adaptation along moisture and temperature gradients in natural populations of coast redwood and giant sequoia. *Genes*, *12*(11), 1826.

De La Torre, A.R., Sekhwal, M.K., Puiu, D., Salzberg, S.L., Scott, A.D., Allen, B., Neale, D.B., Chin, A.R.O. and Buckley, T.N. (2022), Genome-wide association identifies candidate genes for drought tolerance in coast redwood and giant sequoia. Plant J, 109: 7-22. https://doi.org/10.1111/tpj.15592

DeSilva, R. 2020. Pattern and process: An examination of how evolutionary forces shape patterns of genetic diversity and adaptive potential in the long-lived tree species, giant sequoia. PhD Dissertation. University of California, Berkeley.

DeSilva, R., and Dodd, R. S. 2020a. Fragmented and isolated: Limited gene flow coupled with weak isolation by environment in the paleoendemic giant sequoia (*Sequoiadendron giganteum*). *American Journal of Botany*. 107(1): 45–55

DeSilva, R., and Dodd, R. S. 2020b. Association of genetic and climatic variability in giant sequoia, *Sequoiadendron giganteum*, reveals signatures of local adaptation along moisture-related gradients. *Ecology and Evolution*. 10: 10619–10632.

DeSilva, R., and Dodd, R. S. 2021. Patterns of fine-scale spatial genetic structure and pollen dispersal in giant sequoia (*Sequoiadendron giganteum*). *Forests.*_*12*(1): 61.

Diffenbaugh, N.S., D.L. Swain, D. Touma, J. Lubchenco. 2015. Anthropogenic warming has increased drought risk in California. PNAS 112 (13): 3931–3936.

Dodd, R. S., and R. DeSilva. 2016. Long-term demographic decline and late glacial divergence in a Californian paleoendemic: *Sequoiadendron giganteum* (giant sequoia). *Ecology and Evolution* 6: 3342–3355.

Du, W., and Fins, L. (1989). Genetic variation among five giant sequoia populations. *Silvae genetica*, *38*(2), 70-76

Eckert, C. G., K. E. Samis, and S. C. Lougheed. 2008. Genetic variation across species' geographical ranges: The central–marginal hypothesis and beyond. *Molecular Ecology* 17: 1170–1188.

Etterson, J. R., Cornett, M. W., White, M. A., & Kavajecz, L. C. (2020). Assisted migration across fixed seed zones detects adaptation lags in two major North American tree species. *Ecological Applications*, *30*(5), e02092.

Fins, L., and Libby, W. J. (1982). Population variation in Sequoiadendron: seed and seedling studies, vegetative propagation, and isozyme variation. *Silvae Genet*, *31*(4), 102-110.

Frank A, Howe GT, Sperisen C, Brang P, Clair JBS, Schmatz DR, Heiri C. Risk of genetic maladaptation due to climate change in three major European tree species. (2017). *Global Change Biolgy*. 23(12):5358-5371. doi: 10.1111/gcb.13802.

Frankham, R., Ballou, J. D., Eldridge, M. D., Lacy, R. C., Ralls, K., Dudash, M. R., & Fenster, C. B. (2011). Predicting the probability of outbreeding depression. *Conservation Biology*, *25*(3), 465-475.

Gellie, N. J., Breed, M. F., Thurgate, N., Kennedy, S. A., & Lowe, A. J. (2016). Local maladaptation in a foundation tree species: Implications for restoration. *Biological conservation*, *203*, 226-232.

Gonzalez, P., F. Wang, M. Notaro, D.J. Vimont, J.W. Williams. 2018. Disproportionate magnitude of climate change in United States National Parks. Environmental Research Letters 13: 104001.

Gougherty, A. V., Keller, S. R., & Fitzpatrick, M. C. (2021). Maladaptation, migration and extirpation fuel climate change risk in a forest tree species. *Nature Climate Change*, *11*(2), 166-171.

Gray, L. K., Gylander, T., Mbogga, M. S., Chen, P. Y., & Hamann, A. (2011). Assisted migration to address climate change: recommendations for aspen reforestation in western Canada. *Ecological applications*, *21*(5), 1591-1603.

Guinon, M., Larsen, J. B., & Spethmann, W. (1982). Frost resistance and early growth of Sequoiadendron giganteum seedlings of different origins. *Silvae Genetica*, *31*(5-6), 173-178.

Hartesveldt, R. J., Harvey, H. T., Shellhammer, H. S., and Stecker, R. E. 1975. The giant sequoia of the Sierra Nevada. U. S. Department of the Interior, National Park Service, Washington, DC; 1975

Hill, A. P. Nolan, C. J., Hemes, K. S., Cambron, T. W., and Field, C. B. (2023) Low-elevation conifers in California's Sierra Nevada are out of equilibrium with climate, *PNAS Nexus*, 2 (2), pgad004, https://doi.org/10.1093/pnasnexus/pgad004

Hufford, K. M., Veneklaas, E. J., Lambers, H., & Krauss, S. L. (2016). Genetic delineation of local provenance defines seed collection zones along a climate gradient. *AoB Plants*, *8*.

Krauss, S. L., Sinclair, E. A., Bussell, J. D., & Hobbs, R. J. (2013). An ecological genetic delineation of local seed-source provenance for ecological restoration. *Ecology and Evolution*, *3*(7), 2138-2149.

Melchior, G. H., & Hermann, S. (1987). Differences in growth performance of four provenances of giant sequoia (Sequoiadendron giganteum (Lindl) Buchh.). *Silvae genetica*, *36*(2), 65-68

Milesi, P., Berlin, M., Chen, J., Orsucci, M., Li, L., Jansson, G., ... & Lascoux, M. (2019). Assessing the potential for assisted gene flow using past introduction of Norway spruce in southern Sweden: Local adaptation and genetic basis of quantitative traits in trees. *Evolutionary Applications*, *12*(10), 1946-1959.

Morgenstern, E.K. (1996). Geographic variation in forest trees: Genetic basis and application of knowledge in silviculture. Vancouver, BC: UBC Press.

Nathan, R., F. M. Schurr, O. Spiegel, O. Steinitz, A. Trakhtenbrot, and A. Tsoar. 2008. Mechanisms of long-distance seed dispersal. *Trends in Ecology & Evolution* 23: 638–647.

O'neill, G. A., Ukrainetz, N. K., Carlson, M. R., Cartwright, C. V., Jaquish, B. C., King, J. N., ... & Yanchuk, A. D. (2008). Assisted migration to address climate change in British Columbia: recommendations for interim seed transfer standards. BC Min. For. Range, Res. Br., Victoria. *Forest Sci Branch. Tech Rep*, *48*.

Prober, S. M., Byrne, M., McLean, E. H., Steane, D. A., Potts, B. M., Vaillancourt, R. E., & Stock, W. D. (2015). Climate-adjusted provenancing: a strategy for climate-resilient ecological restoration. *Frontiers in Ecology and Evolution*, *3*, 65.

Purves, D.W. 2009. The demography of range boundaries versus range cores in eastern US tree species. *Proceedings of the Royal Society, B, Biological Sciences* 276: 1477–1484.

Ramalho, C. E., Byrne, M., & Yates, C. J. (2017). A climate-oriented approach to support decision-making for seed provenance in ecological restoration. *Frontiers in Ecology and Evolution*, *5*, 95.

Rundel P. 1972. Habitat Restriction in Giant Sequoia - Environmental Control of Grove Boundaries. American Midland Naturalist 87:81-99

Savolainen, O., Pyhajarvi, T., and Knurr, T. (2007). Gene flow and local adaptation in trees. *Annual Review of Ecology Evolution and Systematics*, ***38:*** 595–619.

Schwartz, M., Hall, A., Sun, F., Walton, D., & Berg, N. 2017. Significant and Inevitable End-of-Twenty-First-Century Advances in Surface Runoff Timing in California's Sierra Nevada, *Journal of Hydrometeorology*, *18*(12), 3181-3197.

Shellhammer, H. S., and T. H. Shellhammer. 2006. Giant sequoia (Sequoiadendron giganteum Taxodiaceae) seedling survival and growth in the first four decades following managed fires. Madrono 53:342-350.

Siirila-Woodburn, E. R., Rhoades, A. M., Hatchett, B. J., Huning, L. S., Szinai, J., Tague, C., ... & Kaatz, L. (2021). A low-to-no snow future and its impacts on water resources in the western United States. *Nature Reviews Earth & Environment*, *2*(11), 800-819.

Sgrò, C. M., Lowe, A. J., & Hoffmann, A. A. (2011). Building evolutionary resilience for conserving biodiversity under climate change. *Evolutionary applications*, *4*(2), 326-337.

Schiffers, K., Bourne, E. C., Lavergne, S., Thuiller, W., & Travis, J. M. (2013). Limited evolutionary rescue of locally adapted populations facing climate change. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *368*(1610), 20120083.

Slatkin M. 1987. Gene flow and the Geographic Structure of Natural Populations. *Science* 236: 787-792

Stephenson, N. L. (1999). Reference conditions for giant sequoia forest restoration: structure, process, and precision. *Ecological Applications*, *9*(4), 1253-1265.

Stephenson, N. L., Das, A. J., Ampersee, N. J., Cahill, K. G., Caprio, A. C., Sanders, J. E., & Williams, A. P. (2018). Patterns and correlates of giant sequoia foliage dieback during California's 2012–2016 hotter drought. *Forest ecology and management*, *419*, 268-278.

Sun, F., Berg, N., Hall, A., Schwartz, M., & Walton, D. (2018). Understanding end-of-century snowpack changes over California's Sierra Nevada. *Geophysical Research Letters*, *46*, 933–943. https://doi.org/10.1029/2018GL080362

Thorne, J.H., R.M. Boynton, L.E. Flint, A.L. Flint. 2015. The magnitude and spatial patterns of historical and future hydrologic change in California's watersheds. Ecosphere 6: 24.

Valness, C. M. 2016. Performance and Morphology in Sequoiadendron Genotypes Outside of Their Range. Master's Thesis. Humboldt State University, Arcata, CA, USA.

Weatherspoon, C. P., 1990. Sequoiadendron giganteum (Lindl.) Buchholz Giant Sequoia. In: Burns, R.M., Honkala, B.H. (Eds.), Silvics of North America, USDA Forest Service Agricultural Handbook 654, Washington, DC, pp. 552–562.

Weeks, A. R., Sgro, C. M., Young, A. G., Frankham, R., Mitchell, N. J., Miller, K. A., ... & Hoffmann, A. A. (2011). Assessing the benefits and risks of translocations in changing environments: a genetic perspective. *Evolutionary Applications*, *4*(6), 709-725

Whiteley, A. R., Fitzpatrick, S. W., Funk, W. C., & Tallmon, D. A. (2015). Genetic rescue to the rescue. *Trends in ecology & evolution*, *30*(1), 42-49.

York R., J. Battles, and R. Heald. 2003. Edge effects in mixed conifer group selection openings: tree height response to resource gradients. Forest Ecology and Management 179:107-121

APPENDIX 1: ARIDITY RANKING FOR ALL GIANT SEQUOIA GROVES. GROVES INHABITING THE MOST ARID CONDITIONS WITHIN THE RANGE ARE SCORED AS '10' AND '1' IS USED TO INDICATE THE MOST MESIC CONDITION. GROVES ARE RANKED FROM MESIC TO XERIC USING A METRIC CREATED FROM THREE CLIMATE VARIABLES INVOLVED IN ARIDITY: CLIMATE WATER DEFICIT, SUMMER PRECIPITATION, AND APRIL SNOWPACK.

Grove	Aridity Rank
Putnam-Francis	10.0
Wishon	10.0
Clough Cave	9.7
Belknap (includes McIntyre)	9.0
Cunningham	9.0
Deer Creek	9.0
Black Mountain	8.7
Starvation	8.7
Peyrone	8.3
Long Meadow	8.0
Pine Ridge	8.0
Cedar Flat	7.7
Packsaddle	7.7
Sequoia Creek	7.7
Big Stump	7.3
Freeman Creek	7.3
South Peyrone	7.3
Redwood Mountain	7.0
Abbott	6.7
Converse Basin	6.7
East Fork	6.7
General Grant	6.7
Redhill	6.7
Silver Creek	6.7
Squirrel Creek	6.7
Tuolumne	6.7
Cahoon	6.3
Coffeepot	6.3
Dennison	6.3
Monarch	6.3
Redwood Creek	6.3
Castle Creek	6.0
Cherry Gap	6.0
Horse Creek	6.0
Indian Basin	6.0
Nelder	6.0
New Oriole Lake	6.0
Alder	5.7
Case Mountain	5.7
Forgotten	5.3
Homers Nose	5.3
McKinley	5.3
Mountain Home	5.3
Atwell	5.0
Board Camp	5.0
Merced	5.0
Surprise	5.0
Burro Creek	4.7
Devil's Canyon	4.7
Eden Creek	4.7
Granite Creek	4.7
Little Redwood Meadow	4.0
Mariposa	4.0
Bearskin	3.7
Big Baldy	3.7
Dillonwood	3.7
Calaveras North	3.7
Oriole Lake	3.7
Garfield	3.3
Calaveras South	3.3
South Fork	3.3
Deer Meadow	3.0
Skagway	3.0
Evans	2.7
Agnew	2.0
Douglass	2.0
Middle Tule	2.0
Placer	2.0
Giant Forest	1.7
Landslide	1.7
Muir	1.7
Suwanee	1.7
Maggie Mountain	1.3
Upper Tule	1.3
Lost	1.0

Appendix F: Discussion of Proposed Planting Plans

Introduction

In compliance with the Re-establish Tree Seedlings in Severely Burned Giant Sequoia Groves and Adjacent Fisher Habitat EA and to fulfill the purpose and need of that project, the NPS would develop site specific planting plans. This document provides an overview of the methods and rationale that would be used to develop site specific planting plans and a brief overview of different treatments that would provide critical insight into improving future post-fire reforestation efforts.

Planting Plans

Sequoia Groves

The estimated mean sequoia seedling densities in project areas that would be targeted for planting would be those areas that do not meet the estimated mean sequoia seedling reference densities as described in the Decision Tree in the EA. However, some individual areas within the project areas do have high sequoia seedling densities and at a local scale would not require planting. These areas would be identified both ahead of time and during planting by project leads and would be identified to planting crews as no planting zones.

The NPS would split each grove into different landscape units based on topographic characteristics to capture landscape heterogeneity as recommended in Forest Service General Technical Report (GTR) 220 (North et al. 2009). We would use a geographic information systems (GIS) tool from GTR 237 to parse the landscape into six different landscape unit categories based on slope position and aspect (ridge, valley, Southwest mid-slope <30 percent, Southwest mid-slope >30 percent, Northeast mid-slope <30 percent, and Northeast mid-slope >30 percent; Figure F1). The mid-slope percent would be split above and below 30 percent due to the pattern of steeper slopes increasing fire intensity and drought stress which can increase the potential for tree mortality (Fettig et al. 2019; Kolb et al. 2007; Safford et al. 2009), therefore requiring different management approaches.

To promote drought and fire resiliency in young stands, planting density would be carefully considered. Current recommended planting densities range between 200-600 trees per acre (tpa) for giant sequoia (York et al. 2021; York personal communication August 2023) and 125 – 300 tpa for mixed conifer (USDA Forest Service 1989). These densities are chosen when follow-up treatment of thinning and release from competition are done in order to match the historical mature stand range of 24 – 133 tpa (Safford and Stevens 2017). Under increased frequency and severity of drought and fire, tree mortality has increased and been correlated with stand density, where higher stand density increased competitive effects of water stress and susceptibility to stand-replacing fire (Young et al. 2017; Stevens-Rumann et al. 2018; Zald and Dunn 2018). This suggest lower planting densities may reduce inter-tree competition and be better suited for changing climatic conditions and fire regimes, especially when follow-up thinning treatments are not feasible (North et al. 2019). In 2019, the California Board of Forestry and Fire Protection reduced the minimum stocking requirement to 100 – 150 tpa, dependent on site conditions (Stewart 2020).

Because the NPS would not be doing follow up thinning treatments, and in consideration of drought and other factors as outlined above, as described in the EA, the total trees per acre planted of all species would range between 100 and 400. The NPS anticipates that the overall planting density in giant sequoia groves will be around 250 tpa , with different planting densities and species mixes for the six different landscape planting units. For each landscape unit, density would be chosen based on the topographic characteristics of the unit, as planting at a higher density in areas that have less soil moisture available to plants can create a competitive environment leading to reduced growth rate and tree mortality. Southwest slopes and ridges would be planted at lower densities of around 150 – 200 tpa due to their dry, hot conditions which support fewer individuals. Northeast slopes and valleys would be planted at higher densities of around 200 – 300 tpa due to their wet, cool conditions supporting more individuals.

For each landscape unit, species mixes would be chosen based on the dominant forest composition identified from the Sequoia and Kings Canyon National Parks Vegetation Classification and Mapping Project (Haultain et al. 2020). The proportion of each species within mixes would be adjusted for each landscape unit based on slope position and habitat preference. Species that are sensitive to drought and prefer wetter habitat, such as white fir (*Abies concolor*) and incense cedar (*Calocedrus decurrens*), would be selected in higher proportions for the valleys and Northeast landscape units, while species that persist in dryer conditions, such as sugar pine (*Pinus lambertiana*) and Jeffery pine (*Pinus jeffreyi*), would be selected in higher proportions for the ridges and Southwest planting units (Zald et al. 2008; McDonald and Fiddler, 2010). To build resiliency to drought and fire, species sensitivity to climate change and fire would also be incorporated into species mixes, such that proportions of white fir and incense cedar would be further reduced on Southwest aspects due to their sensitivity to drought and fire (Nemens et al. 2022), especially at lower elevations (Fettig et al. 2019; Hill et al. 2022).

Stand resilience to stressors like drought and fire is influenced by tree spatial pattern (Larson and Churchill 2012). Historically, reforestation efforts have planted in an evenly spaced and high density plantation arrangement, but research has shown that this spatial pattern is associated with lower fire and drought resilience and a poor forest structure that does not promote species diversity or optimal habitat for wildlife (Larson and Churchill 2012). Instead, spatially heterogeneous panting patterns at lower densities may be more resilient to fire and drought when they mimic mature, historically frequent-fire forest of individual scattered trees, clumps of trees, and openings with no trees (ICO pattern; North et al. 2019). The ICO pattern provides resilience to fire by creating fuel and structural heterogeneity (North et al. 2019) as the variable densities scattered across the landscape splits up continuous crown cover, creates variability in surface fuel loads, and creates small fire breaks in openings (North et al. 2019 and references therein). We would implement the ICO planting pattern within 1 acre planting blocks (Figure F2) for each landscape unit.

Planting spots will prioritize suitable microsites including but not limited to shade objects (ex. snags, logs, stumps, boulders, shrubs), depressions, and springs or wetter locations (Figures F3, F4). Shade objects improve seedling establishment and survival (Marshall et al. 2023) by buffering against intense solar insolation and soil and air temperatures (Marsh et al. 2022; Marshall et al. 2023) and increasing available soil moisture (Hoecker et al. 2020). Additionally, planting on the North facing sides of nurse objects improves seedling success as the cooler, wetter environment reduces water stress (Simeone et al. 2019). Because seedlings planted by shade objects are more likely to die if the object combusts during a fire (Collins et al. 2018), we would ensure a subset of seedlings (ex. 20%) be planted away from combustible shade objects (ex. boulders, open areas; North et al., 2019). Depressions, defined as microtopographic concavities of the soil surface where water could collect, were shown to increase summer soil moisture and seedling survival (Marshall et al. 2023). Shade and drought tolerance would be considered when selecting species specific microsites (Andivia et al 2020), such as planting giant sequoias in wetter microsites (DeSilva and Dodd, 2020). To reduce density mediated water stress, microsites would be selected based on water availability and aligned with the variable planting densities of the ICO pattern, where high density clumps would be planted in wetter locations and depressions while lower density or scattered individuals would be planted in dryer conditions (North et al. 2019).

This landscape-scale reforestation project provides an opportunity to not only improve forest resilience to future stressors but also to test the effectiveness of different planting treatments in creating a resilient forest. While variation in planting spatial arrangement is a key step in building resilience, current practices set a standard spacing between trees with a small amount of flexibility to that distance to prioritize microsites (ex. 9 m ± 2 m), with less implementation and guidelines for planting in clumps (North et al. 2019). Varying factors such as the size, density, and spacing of clumps, or the number of individuals per microsite when implementing the ICO pattern would provide insight into identifying and implementing optimal planting spatial arrangements to promote forest resilience in future reforestation efforts. Additionally, as the climate becomes warmer and drier, local seed adapted to current environmental conditions may be maladapted to future conditions. To build resilience to climate change and altered fire regimes in giant sequoia groves, planting a high genetic diversity of giant sequoia seedlings including both locally sourced seed and non-locally sourced seed adapted to warmer, drier environments and from groves of known higher levels of genetic diversity can bolster the range of growth and survival responses to future stressors (see Appendix E; DeSilva and Dodd 2020). We would plant a maximum of 20% non-local genotypes to aid genetic adaptation to future climatic changes while minimizing potential risks (Aitken and Whitlock 2013) and study differences in growth and survival of the non-local genotypes compared to the local genotypes over time to assess if the addition of non-local genotypes improves forest resilience.

Fisher Habitat Corridor

The planting plan for the fisher habitat corridor would be prepared using the same methods as the giant sequoia groves. The giant sequoia genetic diversity treatment would not be included in the fisher habitat corridor due to giant sequoias not being historically present at this site and therefore excluded from the species mix. The average density of planting in the fisher habitat corridor would be lower than in giant sequoia groves (150 to 200 tpa) taking into consideration that mixed conifer species do not reproduce at the high rates of giant sequoia (Demetry 1995) but have lower survival of planted seedlings compared to giant sequoia (York et al. 2007).

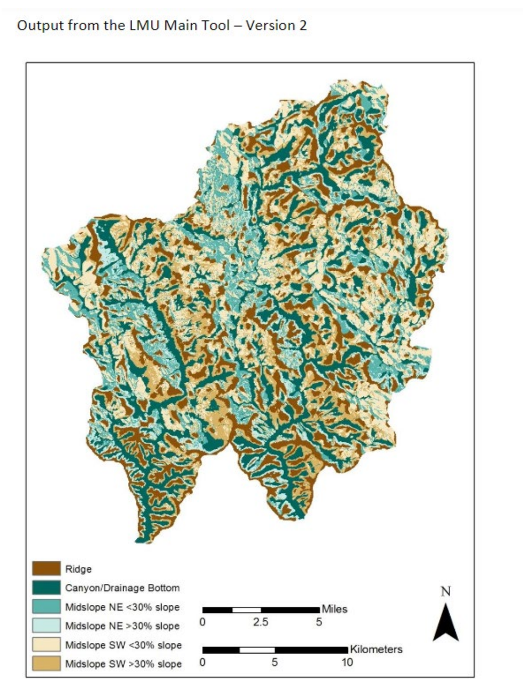


Figure F1. Example output map of the GIS Landscape Management Unit tool (map from Ryan Boynton, unpublished; GIS tool used in North et al. 2009). This example map is not of land in Sequoia and Kings Canyon National Parks, but rather it is used here to demonstrate what the six different landscape unit categories would look like in an output map. The landscape units are determined based on slope position and aspect (ridge, canyon/drainage bottom, Southwest mid-slope <30 percent, Southwest mid-slope >30 percent, Northeast mid-slope <30 percent, and Northeast mid-slope >30 percent) and color coded in the map.

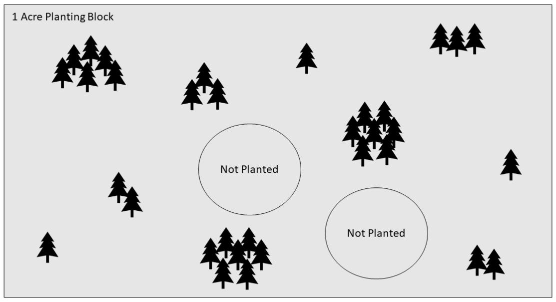


Figure F2. Diagram of planting spacing using the individuals, clumps, and openings (ICO) pattern from North et al. 2019. Within a 1acre planting block, clumps would be planted in wet microsites and depressions, individuals would be scattered throughout the landscape in dryer microsites, and open areas with less suitable habitat would be left unplanted. The goal of the ICO planting pattern is to improve forest resilience to stressors by creating a spatially heterogenous forest structure and fuel load, rather than the evenly space plantation style planting pattern.

Figure F3. Image of adequate giant sequoia density and regeneration in the 2015 Rough Fire burn scar in Kings Canyon National Park. Image taken in 2023, 8 years post-fire, showing naturally clumped spatial arrangement.

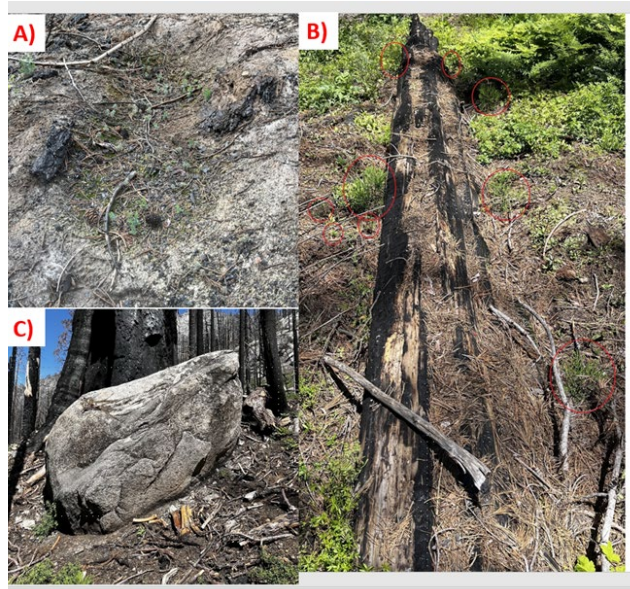


Figure F4. Microsite planting location examples of a A) depression from former tree bole, B) log with seedlings on either side, and C) large bolder providing shading on North and West side.

Appendix F References

Aitken, S. N., and M. C. Whitlock. 2013. Assisted gene flow to facilitate local adaptation to climate change. Annual Review of Ecology, Evolution, and Systematics, 44: 367-388.

Andivia, E., P. Ruiz-Benito, P. Díaz-Martínez, N. Carro-Martínez, M.A. Zavala, and J. Madrigal-González. 2020. Inter-specifc tolerance to recurrent droughts of pine species revealed in saplings rather than adult trees. Forest Ecology and Management 459: 117848

Collins, B.M., Lydersen, J.M., Everett, R.G. and Stephens, S.L., 2018. How does forest recovery following moderate-severity fire influence effects of subsequent wildfire in mixed-conifer forests?. Fire Ecology, 14(2), pp.1-9.

Demetry, A. 1995. Regeneration patterns within canopy gaps in a giant sequoia-mixed conifer forest: implications for restoration (Doctoral dissertation, MS thesis. Northern Arizona University, Flagstaff, AZ).

DeSilva, R., and Dodd, R. S. 2020. Association of genetic and climatic variability in giant sequoia, *Sequoiadendron giganteum*, reveals signatures of local adaptation along moisture-related gradients. Ecology and Evolution. 10: 10619–10632.

Fettig, C. J., Mortenson, L. A., Bulaon, B. M., & Foulk, P. B. 2019. Tree mortality following drought in the central and southern Sierra Nevada, California, US. Forest Ecology and Management, 432, 164-178.

Haultain SA, Reyes ET, Menke JM, Johnson DN, Karavidas (Cline) DL. 2020. Sequoia and Kings Canyon National Parks vegetation classification and mapping project report. Natural Resource Report. NPS/SIEN/NRR—2020/2101. National Park Service. Fort Collins, Colorado.

Hill, A. P., Nolan, C. J., Hemes, K. S., Cambron, T. W., & Field, C. B. 2022. Low-elevation conifers in California's Sierra Nevada are out of equilibrium with climate. PNAS nexus, *2*(2), pgad004.

Hoecker, T.J., Hansen, W.D. and Turner, M.G., 2020. Topographic position amplifies consequences of short-interval stand-replacing fires on postfire tree establishment in subalpine conifer forests. Forest Ecology and Management, 478, p.118523.

Kolb, T.E.; Agee, J.K.; Fule, P.Z.; McDowell, N.G.; Pearson, K.; Sala, A.; Waring, R.H. 2007. Perpetuating old ponderosa pine. Forest Ecology and Management. 249: 141–157.

Larson, A.J. and Churchill, D., 2012. Tree spatial patterns in fire-frequent forests of western North America, including mechanisms of pattern formation and implications for designing fuel reduction and restoration treatments. Forest Ecology and Management, 267, pp.74-92.

Marsh, C., D. Krofcheck, and M. D. Hurteau. 2022. Identifying microclimate tree seedling refugia in post-wildfire landscapes. Agricultural and Forest Meteorology 313: 108741.

Marshall, L.A., Fornwalt, P.J., Stevens-Rumann, C.S., Rodman, K.C., Rhoades, C.C., Zimlinghaus, K., Chapman, T.B. and Schloegel, C.A., 2023. North-facing aspects, shade objects, and microtopographic depressions promote the survival and growth of tree seedlings planted after wildfire. Fire Ecology, 19(1), pp.1-12.

Nemens, D. G., Kidd, K. R., Varner, J. M., and Wing, B. 2022. Recurring wildfires provoke type conversion in dry western forests. Ecosphere, 13(8), e4184.

North, M.P., Stevens, J.T., Greene, D.F., Coppoletta, M., Knapp, E.E., Latimer, A.M., Restaino, C.M., Tompkins, R.E., Welch, K.R., York, R.A. and Young, D.J., 2019. Tamm Review: Reforestation for resilience in dry western US forests. Forest Ecology and Management, 432, pp.209-224.

North, M.; Stine, P.; O'Hara, K.; Zielinski, W.; Stephens, S. 2009. An ecosystem management strategy for Sierran mixed-conifer forests. 2nd printing, with addendum. General Technical

Report PSW-GTR-220. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 49.

Safford, H.D.; Schmidt, D.A.; Carlson, C.H. 2009. Effects of fuel treatments on fire severity in an area of wildland-urban interface, Angora Fire, Lake Tahoe Basin, California. Forest Ecology and Management. 258, 773–787.

Safford, H.D., Stevens, J.T., 2017. Natural Range of Variation (NRV) for yellow pine and mixed conifer forests in the Sierra Nevada, southern Cascades, and Modoc and Inyo National Forests, California, USA. USDA Forest Service, Pacific Southwest Research Station. General Technical Report PSW-GTR-256, Albany, CA.

Simeone, C., Maneta, M.P., Holden, Z.A., Sapes, G., Sala, A. and Dobrowski, S.Z., 2019. Coupled ecohydrology and plant hydraulics modeling predicts ponderosa pine seedling mortality and lower treeline in the US Northern Rocky Mountains. The New Phytologist, 221(4), pp.1814-1830.

Stevens-Rumann, C.S., Kemp, K.B., Higuera, P.E., Harvey, B.J., Rother, M.T., Donato, D.C., Morgan, P., Veblen, T.T., 2018. Evidence for declining forest resilience to wildfires under climate change. Ecol. Lett. 21, 243–252.

Stewart, W., 2020. Reforestation practices for conifers in California. Univ. California, Berkeley, Calif. UCANR Press, Davis, Calif.

USDA, 1989. Region 5 Silvicultural Practices Handbook. Forest Service Handbook 2409.

Young, D.J.N., Stevens, J.T., Earles, J.M., Moore, J., Ellis, A., Jirka, A.L., Latimer, A.M., 2017. Long-term climate and competition explain forest mortality patterns under extreme drought. Ecol. Lett. 20, 78–86.

York, R.A., Battles, J.J. and Heald, R.C., 2007, January. Gap-based silviculture in a Sierran mixed-conifer forest: Effects of gap size on early survival and 7-year seedling growth. In Restoring Fire-adapted Ecosystems: Proceedings of the 2005 National Silviculture Workshop. USDA Forest Service, Pacific Southwest Research Station, Albany, CA (pp. 181-191).

York, R.A., Noble, H., Quinn-Davidson, L.N. and Battles, J.J., 2021. Pyrosilviculture: Combining prescribed fire with gap-based silviculture in mixed-conifer forests of the Sierra Nevada. Canadian Journal of Forest Research, 51(6), pp.781-791.

Zald, H.S. and Dunn, C.J., 2018. Severe fire weather and intensive forest management increase fire severity in a multi-ownership landscape. Ecological Applications, *28*(4), pp.1068-1080.

Zald, H., Gray, A., North, M., Kern, R., 2008. Initial regeneration responses to fire and thinning treatments in a Sierra Nevada mixed-conifer forest, USA. For. Ecol. Manage. 256, 168–179.