Effectiveness Monitoring Committee

Initial Concept Proposal

Deadline: 5:00 pm PDT September 14, 2022

Date Submitted: 5/24/2023

Project Title: Climate-Adaptive Post-Fire Oak Restoration through Upslope Migration and Seed Provenance in the Angeles National Forest

Project # (to be assigned by EMC):

Principal Investigator(s), Affiliation(s), and Contact Information (email, phone):

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Collaborator(s) and Affiliation(s): Blair McLaughlin, Ph.D., University of California at Santa Cruz

Research Theme(s), Critical Monitoring Question(s), and Rules or Regulations Addressed.

This proposal addresses the State Board of Forestry and Fire Protection's Effectiveness Monitoring Committee (EMC) Research Theme 12: Resilience to Disturbance in a Changing Climate. Specifically, we propose to consider whether California Forest Practices Rules (FPRs) are effective in priorities 12 (a), (c), and (d), namely: "(a) improving overall forest wildfire resilience and the ability of forests to respond to climate change"... "(c) meeting ecological objectives and adaptation to future climate"... and (d) "maintaining …wildlife habitats which are well adapted to future climate." In particular, this proposal considers these research themes in the context of the following FPRs: Z'Berg-Nejedly Forest Practice Act Provision 4512.5 states, FPR 912.7, 932.7, 952.7, PRC § 4528(b), and Provision 4629.7(c).

Project Duration and Dates (MM/YY - MM/YY): August 2023 - March 2026

Estimated Funds Requested for Project: Please provide the total amount of funding requested from the EMC, broken down by year of expenditure, with a brief justification of costs not to exceed 200 words.

- ☐ **< $10,000**
- ☐ **$10,000 - $25,000**
- ☐ **$25,000 - $75,000**
- ☐ **$75,000 - $150,000**
- ☑ **> $150,000**

Over the project duration, we request $16,480 for supplies, $104,453.52 for field labor to set up the experiment, $9,114 for travel costs, $42,390 for subcontracts with Conservation Biology Institute (CBI), $6,060 for scientific consultation with UC Santa Cruz, and $20,778 in indirect (11.64% of total costs) **for a total of $199,275**. In the first year, we request $12,480 for supplies, $20,891 for labor, $3,110 for travel costs, $15,140 for subcontractor costs for experiment design, and $6,009 in indirect costs, for a total of $57,629. In year two, we request $31,336 for labor, $4,200 for travel costs, $2,000 for supplies, $12,880 for subcontractor costs to begin data collection, and $5,868 for indirect costs, for a total of $56,285. In year three, we request $2,000 for supplies, $52,227 for labor costs, $1,804 for travel costs, $20,430 for subcontractor fees for data collection and analysis, and $8.900 for indirect costs, for a total of $85,361.

Project Description: *In not more than 2,000 words*, describe the project, including (1) Background and Justification, (2) Research Question(s), including Objective and Scope, (3) description of Research Methods, (4) Scientific Uncertainty and Geographic Applicability, including identified monitoring location(s), and (5) a description of the roles of Collaborators and Project Feasibility.

Please see attached due to formatting for space and wordcount.

Board of Forestry, Effectiveness Monitoring Committee: Request for Research to test California Forest Practice Rules

Climate-Adaptive Post-Fire Oak Restoration through Upslope Migration and Seed Provenance in the Angeles National Forest

Background and Justification

Foundational to California ecosystems, oak species provide the following ecosystem services: (i) habitat for tremendous biodiversity, (ii) increased moisture availability through deep roots and understory shading, (iii) historical vigorous recovery from disturbances (such as fire), and (iv) cultural significance. Climate change is threatening California oak populations, where species distribution models project that large portions of current oak distributions will be climatically unsuitable by 2100. Further, declines in seed production and seedling regeneration may occur before adult mortality, leading to recruitment failure within stands of existing adult trees. These problems are more acute at the trailing edge of species ranges, where recent large-scale mortality events support model predictions of range contraction.

Where species distributions are predicted to remain stable, populations may not have the necessary local adaptations to persist under projected climate warming and drying. Local adaptation can confer an adaptive advantage under equilibrium conditions, but in long-lived species, such as oaks, local adaptation to historical conditions may become maladaptive with rapid climate shifts. Given that oaks appear to be locally adapted to climate, the influx of arid-adapted genes - potentially from distant locations - may be needed to allow for the persistence of populations under a future warmer, drier climate.

Nowhere are the problems of climate and altered disturbance more pressing than in Southern California, where increasing wildfire frequency dominates low-elevation shrublands, adjacent to the low-latitude limit of Western forests. Oak populations are contending with increasingly severe fires as a function of increasing human ignitions, longer fire seasons, and, in some locations, historical fire suppression. Thus, studies that address post-fire recruitment are critically important to oak conservation and restoration under the combined and interacting effects of climate change and changing wildfire regimes. Further, drought-adaptive traits, such as higher root/shoot ratios, have been hypothesized to increase resilience to wildfire.

To adapt to changes in climate and disturbance, researchers have begun to explore the potential for assisted migration and field gene banking. In the context of climate change, assisted migration refers to the movement of individuals or populations to locations where the future climate is likely to be suitable to the species. Assisted field gene banking describes the deliberate movement of genetic material within a species distribution. The goal is to introduce future-climate-adaptive genotypes to the site population currently existing. Both assisted migration and field gene banking are especially important for oaks, as acorns cannot tolerate conventional seed storage and have no soil seed bank, making acorns preservation for later re-establishment virtually impossible.

Initial field gene banking has been shown to be successful for blue oaks, where seeds sourced from arid sites had high survival when transplanted in higher latitude sites (McLaughlin et al. 2021, *Restoration Ecology* e13573). Compared to local seed sources, seeds from arid sites had lower survival, but improved defenses against herbivory and pathogens. The study did not consider the survival of local and arid-adapted seed sources (provenances) under warming, a research gap we propose to address.

Research Questions and Scope

Together with partner researchers, TreePeople is engaging in oak restoration to minimize the projected upslope expansion of shrublands, following high-severity fires at the shrub-forest transition. Two questions are critically important to the effectiveness of our restoration efforts:

1. *Where should new populations be planted: In the center of their historical range or, because of projected climate change, at the cool edge of their range?*
2. *Where should seeds be collected: From local populations, or from populations at the warm, dry edge of a species range?*

These questions are directly relevant to FRPs, where providing guidance for FPRs is a specific goal of Research Theme 12. Specifically, the Z'Berg-Nejedly Forest Practice Act Provision 4512.5 states, "there is increasing evidence that climate change has and will continue to stress forest ecosystems, which underscores the importance of proactively managing forests." Further, FPR 912.7, 932.7, 952.7 mandates the "appropriate stocking for resilient forests in a changing climate." These provisions articulate the threat of climate change and recommend action in stocking climate-resilient species. To address appropriate stocking, we propose to compare two candidate species for oak seedling restoration: one species at the high-elevation, cold edge of its range, and one in the center of its elevation range. Both species will be transplanted into control (ambient climatic conditions) and warming treatment plots in the field. The objective is to determine best practices for designing species palettes consistent with projected climate change. Specifically, we seek to explore whether a species at the cold-edge of its range is better suited to the warmed treatment, consistent with the projected future climate. In contrast, under control conditions, will survival be higher for the species at the center of its range? The overall survival of both species is also critically important, because restoration activities should not include species that have very low probability of surviving to reproductive maturity, either now or in the future. The results of these experiments will provide detailed guidance to amend relevant FPRs.

PRC § 4528(b) also states, "a tree must be a commercial species from a local seed source or …[is] well-suited for the area involved." With a changing climate, determining seed sources for the future conditions at a given site can be challenging. Thus, we propose to compare two seed sources: a local source, and a more distant seed source where the current climate at the seed source is consistent with projected warming at the restoration site. Both provenances will be transplanted into control and warming treatment plots in the field. The objective is to determine which genotype provides a better trade-off of immediate seedling survival, and/or seedling survival under projected change. If arid-adapted genes have high survival in this experiment, our results will contribute important justification for making exceptions to the "local is best" recommendations embraced in the FPRs and beyond.

Overall, Provision 4629.7(c) states that grants should, "promote climate change adaptation strategies for the forest." By recommending the most appropriate species and seed source for restoration activities after recent fire, our proposal advances this FPR objective, furthering forest resilience in Southern California and beyond.

Research Methods

We propose to explore the trade-offs of moving oak populations to the cool edge of their range and using seeds sourced from more arid provenances. Specifically, the proposal team has secured funding to support the transplant of oak seedlings, *Quercus agrifolia* and *Quercus wislizeni*, within the impact area of the 2002 Copper and 2013 Powerhouse Fires. We request funds to design an experiment associated with this oak restoration project and subsequently monitor the survival of transplanted *Q. agrifolia* and *Q. wislizeni* seedlings. We propose to compare *Q. agrifolia* and *Q. wislizeni* transplant survival across two seed sources (provenances) and two treatments: Warmed and control. At 1400 meters elevation, our existing Grass Mountain restoration site is at the leading edge of *Q. agrifolia*'s range, with approximately 90% of recorded occurrences located below 1400 meters. Thus, transplanting *Q. agrifolia* at the site represents a forward-thinking, climate-adaptive approach to restoration. We will also plant *Q. wislizeni* at the site, a common species in the middle of its elevation range, as 60% of recorded occurrences are at lower elevation.

For both species, we will collect seeds from two different provenances – local sites, and sites where the historical climate at the seed source matches the expected future climate in the Grass Valley restoration site. To determine the best sites for collecting acorns we will use the following Seedlot Selection Tool created through a partnership among the Conservation Biology Institute, Oregon State University, and the US Forest Service: http://seedlotselectiontool.org/sst/. While the use of seeds from local sites is consistent with traditional restoration best practices, seeds from a provenance adapted to the future climate could provide adaptive genes to existing populations, increasing overall population resilience.

In warming plots, we will employ passive warming chambers described in Welshofer et al. 2017 (*Methods in Ecology and Evolution* 9(2): 254-259), which warm plots by ~1.8 degrees Celsius, and are tall enough to support seedling growth for the first few years. To ensure the effectiveness of the chambers, we will install temperature and moisture monitors to track conditions in warmed and control plots. We will use a randomized complete block design, in which each of 8 blocks will monitor 8 plots across all combinations of two species, two provenances, and warmed and control treatments. Each plot within a block will grow five seedlings. Seed collection will occur in fall 2023; propagation will occur until planting in fall 2024; monitoring first-year survival will occur in spring/fall 2025; and the final project report (for later peer-reviewed publication) will be completed by the spring 2026 grant deadline. In addition to seedling survival monitoring, we will visually inspect seedlings for signs of herbivory and disease, consistent with the methods for measuring blue oak survival described in McLaughlin et al. 2021 (*Restoration Ecology* e13573).

Geographic Applicability and Scientific Uncertainty

The experimental site, Grass Mountain (34.641 N, 118.414 W), is within the footprint of suitable habitat for *Q. agrifolia* and *Q. wislizeni* from species distribution model projections we created. Having been impacted by recent fire, it allows for an exploration of the combined effects of wildfire and climate change. The site is on Angeles National Forest (ANF) land, and is part of an existing restoration partnership between TreePeople and the US Forest Service (USFS). Given that the land is public, we will post signs to explain the purpose of the experiment and make every effort to place warming chambers in sites not likely to be seen or visited by the public.

We have no a priori expectations about whether *Q. agrifolia* or *Q. wislizeni* will have higher survival in control plots. While the site is more solidly in *Q. wislizeni*'s elevation range, recent warming could have already shifted the site's climatic conditions away from *Q. wislizeni*'s recruitment niche. Similarly, we have no a priori expectations about which seed provenance will have higher survival under warming conditions. Under warming, we expect that *Q. agrifolia* and the arid seed provenance to have higher survival. Beyond these expectations of survival, there is also the possibility of unexpectedly extreme weather conditions that lead to very low survival across all species, treatments, and provenances. This creates a certain degree of implementation risk, where very low survival will increase uncertainty in experimental results. Overall, the biggest source of uncertainty is the potential for herbivory that biases results. For example, herbivores have been observed to prefer to consume plants in warmed plots. Thus, we have budgeted for seedling cages for all plots, and will monitor for initial signs of herbivory.

Collaborators

This project will build on the results of existing forest practice research conducted by TreePeople and study partners, currently underway on the ANF. TreePeople and the USFS also maintain active Memoranda of Understanding for ongoing restoration work throughout ANF. All permitting for this project has been completed, and activities are projected to begin immediately upon notification. The TreePeople in-house propagation nursery applies best management practice for certified Phytophthora-sanitary production, as required by the USFS. With 40+ years of wildland reforestation efforts, TreePeople is currently conducting work over more than a thousand acres of wildland, implementing post-fire reforestation, habitat restoration, fuel management, and studies involving multiple partners. Through extensive field work across the region, we have gained expertise in native tree and plant species, planting conditions for resilient habitat restoration (across different elevations, slopes, exposures, and soil types), and establishment methods to ensure project survival and sustainability.

Project partner Conservation Biology Institute adds extensive scientific research expertise with over a quarter-century of experience, in a range of integrated technological services to support ecological sustainability, effective scientific modeling, and conversion of research findings into data-driven, real-world solutions. PI Conlisk brings multiple peer-reviewed publications, exploring the impacts of warming and seed provenance on forest recruitment. Collaborator McLaughlin is an expert in California oak field research.

(Word Count: 1,997)