a. **Submitted:** May 15th 2024
b. **Title:** Root disease prevention for fuels treatments and post-fire forest recovery in California conifer forests

c. **Project #**
d. **Investigators**

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i. **Collaborators:** NA
j. **Project Description (1696 words):**

i. **Project Duration:** 30 months (October 1st 2024 to March 31st 2027)
ii. **Background:**

Synopsis: This proposal builds on a work initiated by a previous EMC funded proposal "Effectiveness Monitoring and Evaluation: Do Rules Minimize Fir Mortality From Root Disease and Bark Beetle Interactions" (agreement number 9CA04087). Using the antagonistic fungus *Phlebiopsis gigantea* we previously developed the first test of a low-cost biological control for Heterobasidion root disease, the most common and impactful native root disease of fire-prone conifer forests throughout the state. A subsequent study funded by the Agricultural Research Institute of the CalState University system showed the disease creates persistent canopy openings and restricts tree regeneration for at least 50 years, that fuels treatments can lead to Heterobasidion disease reemergence, and expanded our collection of *P. gigantea* isolates. This proposal builds on these previous efforts by testing biocontrol isolates across a greater range of environmental conditions and in Jeffrey pine forests, evaluating *P. gigantea* efficacy over longer time periods, and quantifying canopy fuel dynamics with Terrestrial Laser Scanning in the context of Heterobasidion root disease and wildfire (including wildfire impacts and post-fire forest recovery).

Justification: Heterobasidion root disease is the most widespread and impactful native root pathogen of coniferous forests across the northern hemisphere. In California, two *Heterobasidion* pathogens are widespread in the conifer forests of the Sierra Nevada, Cascade Range, and pine and fir forests of the northern coast ranges. Both pathogens are long-lived (at least 50 yrs) and create persistent canopy openings that restrict tree regeneration (Flores et al. 2023). These long-lived pathogens readily establish on freshly cut stumps and emergence of the disease is associated with historical logging or current fuels reduction treatments (Poloni et al. 2021; Cobb *unpublished data*).

Without cost-effective disease reduction techniques, the current campaign to increase the pace and scale of fuels treatments in the state's major coniferous forests will also increase pathogen establishment which will diminish the efficacy of these treatments via growth reduction in pine and fir as well as causing canopy tree mortality s. The long-lived nature of *Heterobasidion* pathogens creates potential for interactions with the two other most impactful forest disturbances, wildfire and bark beetle. The chronic nature of the disease may contribute to persistence of bark beetle populations during non-outbreak years and wildfire often overlaps with Heterobasidion in the context of both wildfire impacts and post-fire forest recovery in ways that may exacerbate both problems. As state and federal agencies increase the pace and scale of fuels treatments in response to the unprecedented injection of public funds for fuels treatments.

iii.Objectives:

1 – This project will evaluate the efficacy of *Phlebiopsis gigantea*, a low cost Heterobasidion biocontrol, on 6-yr time scale and across the range of environmental conditions and Heterobasidion pathogens which impact California pine and fir dominated forests

2 – We will quantify *Heterobasidion* impacts to post-fire recovery in the Jeffrey Pine dominated forests within the Dixie Fire footprint using a combination of traditional forestry-based measurements of long-term Heterobasidion monitoring within and outside the fire, and remote sensing measurements (Terrestrial Laser Scanning; TLS)

3 – Using TLS, we will quantify shifts in live canopy fuels for both Heterobasidion pathogens by contrasting changes in canopy fuels in eastern and western slope forests of the Sierra Nevada

4 – We will monitor non-outbreak bark beetle populations in east and western Sierra slope forests to contrast landing rates within and outside of Heterobasidion disease centers

iv.Research Methods: This project employees a combination of long-term monitoring, new and existing *P. gigantea* field trials, laboratory biocontrol trials, and application of remote sensing (TLS) to quantify canopy fuels.

Obj 1: *Phlebiopsis gigantea* field trials on stumps were established at the Blodgett Experimental forest in a previous EMC funded project (Poloni et al. 2021) and in the Inyo NF via USDA Forest Service funding. While the initial evaluation suggested *P. gigantea* inhibited pathogen growth, this project will evaluate the longer-term efficacy of these studies and critically, *P. gigantea* performance under a greater range of temperature and moisture conditions. Although commercial products using *P. gigantea* strains are available for east-coast pine and Scandinavian pine and spruce forests they are clearly genetically distinct from commercial strains and may even be a new species (Dovana et al. 2021). Commercial *P. gigantea* products are prohibited in California to prevent introduction of potentially invasive fungi and California strains *P. gigantea* have limited evaluation. We will conduct a series of growth-chamber *P. gigantea* growth studies in combination a new field trial contrasting their performance across a range of temperatures reflective of current and future temperatures in at risk forests. We will also resample two existing experiments on stumps, the Blodgett study (*H. occidentale*) and the Inyo NF study (*H. irregulare*) to determine efficacy 5 years after treatment.

Objs 2&3: Our group has maintained a +50-yr old set of Heterobasidion monitoring plots distributed across east-side forest running from the Inyo NF to the Modoc NF and a corresponding set of plots in the El Dorado NF, Stanislaus NF, and Yosemite NP (Flores et al. 2023); these monitoring networks

encompass the two primary *Heterobasidion* species that impact California forests: *H. irregulare* ("pine type") and *H. occidentale* ("fir-type"). In 2020, 12 of 24 plots in the Plumas NF suffered in the Dixie Fire 95-100% tree mortality during the Dixie Fire. We have resurveyed plots in the Plumas NF (including the Dixie Fire plots) in 2021 & 2022 to capture initial wildfire impacts. In 2023, we collected TLS data for Plumas NF plots as well to establish post-wildfire baseline measurements. For this project, all plots will be fully remeasured for diameter growth, mortality, and root disease symptoms in each location (126 study plots – project yrs 2&3). Plot monitoring informs objectives 2-3 by quantifying disease dynamics and canopy fuels in locations with a range of fuels (including thinning with and without prescribed fire) treatments and disease severity.

(Obj 2) To understand the ecological context of each of these long-term plots, we will also conduct a mapping exercise using a series of 5-m wide belt transects at 20m intervals in a 200x200m square area with the long-term disease monitoring plot located within the center. This effort will 1) determine the frequency of disease centers within the stand overall and 2) quantify the total disease impacted area in a representative sample of the surrounding stand.

(Obj 3) We will expand our set of Terrestrial Laser Scanning (TLS) measurements in west-side fir dominated forests. TLS uses LiDAR to visualize forest stands in 3D and allows for rapid quantification of forest structural parameters, such as canopy fuels. TLS is precise enough to distinguish 1) major canopy species, 2) disease-symptomatic trees based on branching structure, and 3) live and dead trees. The Bentley Lab is in the process of using TLS measurements to quantify canopy fuels in the Dixie Fire plots in 2023 contrasting burned/unburned and disease/no disease conditions (Flores et al. *unpublished data*). These measurements will be repeated in west-slope forests (unburned) where Heterobasidion root disease centers are smaller but shift stand composition to greater dominance of Incense cedar (Flores et al. 2023).

Obj 4: During plot remeasurement we will deploy sticky traps on trees within and outside of 12 Plumas NF plots outside of the Dixie Fire footprint and 12 plots in the Stanislaus NF using leftover materials from our previous EMC grant to quantify bark beetle landing rates for two years. As west-side fir engraver beetle does not have a suitable trapping pheromone, these traps are the most appropriate for contrasting east and west side forests. Traps will be deployed at four locations within each plot and at a paired non-disease impacted plot located beyond 50m of any disease center using the belt transects as a guide for location of any new monitoring site (Obj 2). We expect higher landing rates on symptomatic trees, or within active disease centers if bark beetle populations interact with Heterobasidion (Garbelotto et al. 1997, Healey et al. 2016).

v. Scientific Uncertainty and Geographic Application: Preliminary data on *P. gigantea* suggests its efficacy in California is comparable to regions where commercial products are available (Poloni et al. 2021; Cobb and Garbelotto *unpublished data*). While these results are encouraging, a broader evaluation of the biocontrol in realistic field conditions and in future temperature conditions are critical to developing a widely available product for forest managers. As borate compounds are in the process of phase-out in California, there is a growing imperative to replace these tools in areas with significant Heterobasidion root disease impacts which are also targeted for fuels treatments.

The association between Heterobasidion and native bark beetles has received considerable speculation in the literature, but very little rigorous evaluation. As our experimental wounding treatment did not result in a single successful infection, despite confirmed high pathogen ambient levels (Poloni et al. 2021), this portion of the project has considerable uncertainty. This proposal

focuses on what may be a simpler association between the two biological tree mortality agents, and perhaps most importantly is a low-cost and low-risk measurement as landing-rates will be quantified using sticky traps purchased by the previous EMC study and will be performed in conjunction with other field measurements.

The geographic application includes private timber, Federal, State, and other conifer-dominated forests of the Southern Cascade, Sierra Nevada, transverse, and northern Costal ranges. Heterobasidion root disease is broadly distributed in California's conifer forests with the exception of coast redwood forests. In the northern coast ranges, Heterobasidion is common in the range of red and white fir. In the Sierra Nevada and adjacent ranges (Cascades, Transverse, etc), the disease is common in forests with a significant component of red and/or white fir, as well as giant sequoia, incense cedar, and yellow-pines (Ponderosa and Jeffry pine). The disease is distributed from Northern Baja, throughout the national forests of Southern California, and increases significantly in the Sierra Nevada and northwards (Garbelotto et al. 1997, Maloney and Rizzo 2002, Flores et al. 2023). It is likely that any suitable Pg isolates from Northern California will be appropriate for treating this disease in Oregon and Washington where 1) preliminary data suggests the isolates are genetically similar, 2) the disease causes significant tree mortality, 3) is widely distributed as a cause of defects such as wet-wood, and 4) overlaps extensively with wildfire and bark beetle.

k. Critical Themes addressed: This concept proposal addresses the following priority thematic questions: 6c, 6d, & 12a - Wildfire and Resilience to Climate change. The study directly addresses disease-driven challenges associated with increasing the pace and scale of fuels treatments as well as forest resilience to drought and bark beetle. In addition, this proposal addresses questions: 6e, 6g, & 12c. Specifically, we address post-fire recovery in the Dixie Fire footprint and forest carbon storage, timber quantify (6g&12c; wetwood is an important defect), and tree-size distribution challenges.

l. Estimated Funds Requested: approximately $250,000 with a request of $30,000-50,000 in year 1, and $100,000-120,000 requested in yr2&3. Actual budgets are created in consultation with our respective sponsored programs offices and this estimate is not an official proposed budget. Budgets will vary among institutions but will emphasize graduate (salary and tuition) and undergraduate participation, particularly at CalPoly and SSU with requests for several months of skilled technician participation at UCB and CalPoly. These personnel costs will represent the majority of each budget (65-80%) after IDC. We will also request travel support (between $4,000-8,000 with higher costs for CalPoly and SSU who will handle the majority of field work), supplies (low at CalPoly and SSU, between $4,000-8,000 for the lab-focused UCB portion), faculty summer salary (no more than 1 month in yrs 2,3), and indirect costs (%15 as indicated in the RFP).

Literature cited:

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