Characterizing aerial spread of white pine blister rust in relation to host phenology in whitebark, limber, and bristlecone pine habitat

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Background and Objectives

White pine blister rust (WPBR) is a disease fatal to five-needle white pine trees caused by the invasive fungal pathogen *Cronartium ribicola*. Since the introduction of WPBR to North America in the early 1900s, it has caused widespread tree decline and mortality of white pines (Brar *et al*. 2015), notably affecting whitebark pine (*Pinus albicaulis*: WBP) (USFWS 2022). WBP holds great ecological significance as a keystone species, particularly in mountainous, high-elevation regions, where it serves as a vital food source for wildlife and stabilizes rocky slopes, preventing erosion (Resler and Tomback 2008). Climate change is expected to expand the distribution of WPBR to previously inhospitable areas (Dudney *et al.* 2021), namely high-elevation white pine forests that are particularly vulnerable to the combined effects of WPBR and climate change (Schoettle *et al.* 2022, Burns *et al.* 2023). This study is part of a multi-year project to monitor the aerial movement of the fungus responsible for white pine blister rust in forests that contain WBP, limber pine (*P. flexilis*: LP), and bristlecone pine (*P. aristata*: BCP), and to link terrestrial sources of WPBR inoculum to aerial disease detection.

WPBR requires an alternate host to complete its life cycle, and can infect plant species in *Ribes, Castilleja,* and *Pedicularis* genera (McDonald *et al.* 2006, Zambino *et al.* 2007, Brar *et al.* 2015). Plant phenology is triggered by environmental stimuli, whereby warmer conditions at lower latitude and elevation can yield a longer growing season compared to sites at higher latitude and elevation. This change in phenology provides a longer time for host plants to be infected with WPBR, increasing the accumulation of inoculum over the summer. With climate change models predicting increased temperature and shifts in rainfall patterns, host phenology will likely shift in response. Understanding the dynamics between WPBR and the phenology of its host plant species will allow us to capture timing in which WPBR is most likely to spread and relate it back to environmental and site factors.

This project aims to (1) characterize the temporal patterns of aerial movement of WPBR spores across five western states, and (2) analyze the environmental conditions associated with the presence and advancement of WPBR. We will incorporate plant phenology data of pine and alternate host species throughout the growing season, which will allow us to characterize phenological patterns of WPBR disease over time, gain insight into the respective roles of host species in contributing to aerial inoculum, and explore differences in quantity of inoculum originating from local (within-plot) or distant (out-of-plot) sources.

Study Plans

Ten sites that were previously established in Utah, Wyoming, Colorado, New Mexico, and Arizona in the 2022 and 2023 field seasons will be re-visited from May-October 2024 in partnership with the U.S. Forest Service. These sites contain either WBP, LP, BCP, or a combination thereof. Each site contains three plots with a spore trap in plot center. Air samples

will be collected weekly from each trap. These samples will undergo DNA extraction and real-time quantitative PCR (qPCR) with primers specific to WPBR for absolute DNA quantification following a protocol successfully utilized previously. Using DNA standards from solutions with known WPBR spore counts, the qPCR results will be transformed into spore equivalents, providing a total spore count per air sample per week. Phenology data of all host species, such as bud burst and leaf senescence, will be recorded weekly in each plot. The presence and progression of WPBR will be observed and quantified on all host species throughout the season. Associations will be identified between quantity of aerial WPBR spores and weather data, host-species presence, abundance, and phenology, spore production on host plants, and site factors such as slope, elevation, and tree canopy density.

Measures of Success

Monitoring WPBR is instrumental in maintaining the health of white pine forests, which provide innumerable ecosystem services. Re-visiting sites established in 2022 and 2023 will enhance our understanding of how environmental conditions change disease epidemiology annually and provide insights into the potential impacts of climate change on vulnerable white pine populations. With the addition of host plant phenology data, we will be able to better link the inoculum source to the quantity of *C. ribicola* DNA captured in air samples. This is an important addition to the project as it will expand our understanding of which plant species significantly contribute to airborne inoculum and characterize the timing of inoculum production on plant hosts across a latitudinal and elevational gradient. These data will be used to further produce predictive disease models for WPBR in forests with white pine under climate change scenarios.

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