Understanding threats to whitebark and foxtail pines in the Klamath Mountains, California

Jennifer Hedin, Cal Poly Humboldt

Background

Five-needle pines, such as whitebark (*Pinus albicaulis*) and foxtail (*Pinus balfouriana*) pines, play a key role in upholding the ecological integrity of high-elevation forest ecosystems and are increasingly threatened by multiple interacting stressors including white pine blister rust (*Cronartium ribicola*), mountain pine beetle (*Dendroctonus ponderosae*), fire suppression, and climate change. Such threats can interact to hasten pine mortality and dampen pine regeneration. Understating these threats, their interactions, and their effects on pine mortality and regeneration is a pressing ecological and conservation priority (Keane *et al.* 2012, 2017). My study focuses on these priorities in isolated, range-edge populations of whitebark and foxtail (ssp. *balfouriana*) pines in the Klamath Mountains Ecoregion (KME) of northern California.

The KME marks the western and northern limits of whitebark and foxtail pines' respective ranges with distinct differences from other parts of their respective ranges (Kauffmann *et al.* 2019). Unlike continuous stands in other regions, KME populations are restricted to sky islands and may be particularly vulnerable to threats due to minimal genetic diversity arising from bottlenecks and limited terrain for upward range expansion (Kauffmann *et al.,* 2019, Oline *et al.* 2000). Additionally, the KME holds remarkable diversity in conifers, climate, topography, and geology, presenting an ideal mix of biotic and abiotic characteristics to investigate potential drivers of ecological integrity and processes in high-elevation forests (Kauffmann and Garwood 2023).

Forests in the KME have recently experienced ecological decline, but there are knowledge gaps about this trend in the five-needle pines (DeSiervo *et al.* 2018, Bost *et al.* 2019). White pine blister rust is established in the KME, with multiple reports documenting moderately low to absent (0-18%) regional infection rates (e.g., Maloney 2011, Meyer *et al.* 2023). However, it is hard to unravel these rates due to grouping among five-needle pine species, grouping among localities (e.g., Cascade-Klamath), low sample sizes, and regional heterogeneity. Finer landscape-scale information about this pathogen's spatial distribution and extent of infection is needed to guide management and restoration activities (Tomback and Sprague 2022). Mountain pine beetle is another threat in the KME (DeSiervo *et al.* 2018); in response to climate change, this mortality agent is moving from lodgepole pines (*Pinus contorta* ssp. murrayana) upslope to other suitable hosts, especially large diameter whitebark pines (Raffa *et al.* 2008, Larson 2011, Jules *et al.* 2016). The potential negative impacts from this pest on high-elevation pines in the KME are poorly understood, especially as age densification produces preferrable large diameter host trees (Meyer *et al.* 2023). In addition to these concerns related to pests and pathogens, a long history of fire suppression in the KME has enabled shade-tolerant conifers to encroach into high-elevation habitats, increasing competitive stress for five-needle pines, a threat that is amplified under changing climate (Kauffmann *et al.* 2019, Jules *et al.* 2022, Meyer *et al.* 2023). Collectively, these pressures have the potential to reduce the KME's ability to serve as a stable, high-elevation refugium capable of supporting world-renowned biological diversity through dramatic changes across deep time (Olson *et al.* 2012, Kauffmann and Garwood 2023).

Objectives

Despite these threats to whitebark and foxtail pines in the KME, the processes driving these threats, their interactions, and how they unfold spatially across the region are poorly understood. This study will address these knowledge gaps about whitebark and foxtail pines in the KME by answering the following questions:

1. What are the current rates of white pine blister rust infection, mountain pine beetle infestation, mortality, and regeneration?
2. How do climate and biotic and abiotic stand characteristics influence infection, infestation, mortality, and regeneration rates?
3. How does infection affect infestation?
4. How do infection and infestation affect mortality?

Findings will provide needed insights into the current regional status of whitebark and foxtail pines, informing management efforts to maintain biodiversity and ecosystem function and resilience in high-elevation forests facing ongoing environmental challenges.

Study Plan and Methods

My study will use a combination of field data, geospatial data, and statistical analyses to answer the above questions. Field data were collected from 92 0.10 ha (100× 10 m) belt transects throughout whitebark and/or foxtail pine stands in the KME. Additional field data will be collected in summer 2027. Data collected from each transect include target tree data (regeneration, mortality, tree characteristics, and threat-based variables) and non-target tree data (counts and percent cover per species, including regeneration). Geospatial data include climatic data from various external sources (e.g., PRISM). Statistical analyses will provide descriptive summaries about regeneration, mortality, infection, and infestation rates in regional high-elevation five-needle pine stands. Additionally, correlation, generalized linear regression (tree-level data), and generalized logistic regression (stand-level data) analyses will yield insights about the complex relationships among numerous explanatory and response variables.

References Cited

Bost, DS, MJ Reilly, ES Jules, MH DeSiervo, Z Yang, and RJ Butz. 2019. Assessing spatial and temporal patterns of canopy decline across a diverse montane landscape in the Klamath Mountains, CA, USA using a 30-year Landsat time series. *Landscape Ecology* 34(11):2599-2614. https://doi.org/10.1007/s10980-019-00907-7.

DeSiervo, MH, ES Jules, DS Bost, EL De Stigter, and RJ Butz. 2018. Patterns and drivers of recent tree mortality in diverse conifer forests of the Klamath Mountains, California. *Forest Science* 64(4):371-382. https://doi.org/10.1093/forsci/fxx022.

Jules, ES, MH DeSiervo, MJ Reilly, DS Bost, and RJ Butz. 2022. The effects of a half century of warming and fire exclusion on montane forests of the Klamath Mountains, California, USA. *Ecological Monographs* 92(4):e1543. https://doi.org/10.1002/ecm.1543.

Jules, ES, JI Jackson, PJ van Mantgem, JS Beck, MP Murray, and EA Sahara. 2016. The relative contributions of disease and insects in the decline of a long-lived tree: a stochastic demographic model of whitebark pine (*Pinus albicaulis*). *Forest Ecology and Management* 381:144-156. https://doi.org/10.1016/j.foreco.2016.09.022.

Kauffmann, M, and J Garwood. 2023. *The Klamath Mountains: a natural history*. Backcountry Press, Kneeland, CA.

Kauffmann, M, K Sikes, J Buck-Diaz, J Jackson, R Floreani-Buzbee, and J Evens. 2019. *An Interagency Conservation Strategy for* Pinus albicaulis *(Whitebark Pine) in California*. Sacramento, CA. 93 pp.

Keane, RE, LM Holsinger, MF Mahalovich, and DF Tomback. 2017. *Restoring whitebark pine ecosystems in the face of climate change* (RMRS-GTR-361). U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. https://doi.org/10.2737/RMRS-GTR-361.

Keane, RE, DF Tomback, CA Aubry, AD Bower, EM Campbell, CL Cripps, MB Jenkins, MF Mahalovich, M Manning, ST McKinney, MP Murray, DL Perkins, DP Reinhart, C Ryan, AW Schoettle, and CM Smith. 2012. *A range-wide restoration strategy for whitebark pine* (Pinus albicaulis) (RMRS-GTR-279). U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. https://doi.org/10.2737/RMRS-GTR-279.

Larson, ER. 2011. Influences of the biophysical environment on blister rust and mountain pine beetle, and their interactions, in whitebark pine forests: status of whitebark pine. *Journal of Biogeography* 38(3):453-470. https://doi.org/10.1111/j.1365-2699.2010.02430.x.

Maloney, PE. 2011. Incidence and distribution of white pine blister rust in the high-elevation forests of California: incidence and distribution of white pine blister rust. *Forest Pathology* 41(4):308-316. https://doi.org/10.1111/j.1439-0329.2011.00732.x.

Meyer, MD, MR Slaton, SE Gross, RJ Butz, and C Clark. 2023. Ecological integrity of whitebark pine ecosystems in California's national forests. *Canadian Journal of Forest Research* 53(5):328-342. https://doi.org/10.1139/cjfr-2022-0189.

Oline, DK, JB Mitton, and MC Grant. 2000. Population and subspecific genetic differentiation in the foxtail pine (*Pinus balfouriana*). *Evolution* 54(5):1813-1819. https://doi.org/10.1111/j.0014-3820.2000.tb00725.x.

Olson, D, DA DellaSala, RF Noss, JR Strittholt, J Kass, ME Koopman, and TF Allnutt. 2012. Climate change refugia for biodiversity in the Klamath-Siskiyou Ecoregion. *Natural Areas Journal* 32(1):65-74. https://doi.org/10.3375/043.032.0108.

Raffa, KF, BH Aukema, BJ Bentz, AL Carroll, JA Hicke, MG Turner, and WH Romme. 2008. Cross-scale drivers of natural disturbances prone to anthropogenic amplification: the dynamics of bark beetle eruptions. *BioScience* 58(6):501-517. https://doi.org/10.1641/B580607.

Tomback, DF, and E Sprague. 2022. The National Whitebark Pine Restoration Plan: restoration model for the high elevation five-needle white pines. *Forest Ecology and Management* 521:120204. https://doi.org/10.1016/j.foreco.2022.120204.