Patterns of Clark's nutcracker *(Nucrifraga columbiana*) occupancy in a post-fire whitebark pine (*Pinus albicalus*) ecosystem

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Whitebark pine (WBP) is a foundational subalpine species that provide habitat structure, snowpack retention, and nutrient-rich seeds that are consumed by numerous species (Podruzny *et al.* 1999, Lorenz *et al.* 2008, Tomback *et al.* 2022). WBP and Clark's nutcrackers (CLNU) have evolved a mutualistic relationship that sustains the WBP ecosystem (Hutchins and Lanner 1982, Tomback 1982), including portions of the North Cascades in Washington. In this region, WBP produces the largest and most nutritious seeds of all the conifers (Lorenz *et al.* 2008), is one of the CLNU primary food sources (Lorenz *et al.* 2009), and may be critical for successful breeding (Schaming 2015). In turn, WBP relies nearly exclusively on CLNU to disperse its wingless seeds (Hutchins and Lanner 1982, Tomback 1982). This mutualism enables WBP regeneration while providing important winter forage for CLNU (Tomback 1982).

WBP is declining throughout most of its range due to multiple, interrelated threats, including white pine blister rust (*Cronartium ribicola*) infection, climate change, mountain pine beetle (*Dendroctonus ponderosae*) outbreaks, and an increase in fire frequency and intensity (Tomback *et al.* 1995, Lorenz *et al.* 2008, Murray *et al.* 2018). Climate change has influenced the fire regime within subalpine habitats, primarily due to rising temperatures, increasingly arid conditions, and higher fuel loads (Higuera *et al.* 2021). Consequently, the frequency and severity of wildfires in these areas have increased (Murray *et al.* 2018, Higuera *et al.* 2021, Clark-Wolf *et al.* 2023). WBP is susceptible to fire and CLNU are the only species that effectively facilitate seed dispersal into post-fire habitat. However, CLNU response to fire disturbance and use of post-burn habitat is poorly understood, and the majority of what we know is based on anecdotal observations (Peters *et al.* 2023). If CLNU regularly occupy and cache seeds in recent fire footprints, there is potential for natural regeneration to sustain WBP. Otherwise, regeneration of WBP may not occur without human intervention, putting both species and their unique relationship at risk. In this study, we will evaluate which habitat characteristics in post-burn locations predict lowest occupancy of CLNU, and hence lowest probability of seed dispersal, so that managers can use this information to determine where to focus WBP planting efforts.

Objectives

The overall objective of this study is to assess CLNU occupancy in WBP habitat following a mixed severity burn. My hypothesis is that the probability of CLNU occupancy will increase with proximity to live WBP stands, health and density of those stands, and presence and density of WBP cones. Preliminary results from a pilot study in the North Cascades within the Schneider Springs footprint by my advisor Dr. Alison Scoville, and Dr. Taza Schaming, suggest that CLNU are more likely to be active in live stands compared with severely burned stands but are present in both. Furthermore, detection probability varied within each burn category, suggesting the influence of additional, unmeasured habitat variables. The proposed study will add detailed habitat information, expand the number of sites from 12 to 30, and add an additional study area in the Cedar Creek fire footprint. My results will elucidate critical aspects of this system, including where CLNU have a high versus low probability of effectively facilitating post-fire regeneration, which areas may require human intervention to re-establish WBP following a fire, and to what degree this mutualism is resistant and resilient in the face of environmental change. In addition to a thesis and manuscript to be submitted for publication, I will use the results of my analysis to create a shapefile mapping probability of CLNU occupancy in post-burn WBP habitat in the Okanagan-Wenatchee National Forest in Washington.

Methods

I will conduct my research in the Okanogan-Wenatchee National Forest, within two 2021 fire footprints, Schneider Springs and Cedar Creek, that include live, moderately, and severely burned habitats. I will use the USFS Burn Area Emergency Response (BAER) soil burn severity database and ArcGIS 10.8.1 to choose 30 random points at least 400 m apart evenly apportioned in severely burned, moderately burned, and unburned WBP habitat. In June 2024, I will deploy Audiomoth autonomous recording units (ARUs) in these 30 locations. Beginning in July, I will conduct habitat surveys in the area surrounding each monitor, including belt transects to measure blister rust infection rates and forest composition, and distance sampling surveys to measure cone density. I will also measure distance to the nearest live stand. In late September, I will retrieve all monitors and use BirdNET and RavenPro 2.0 to document CLNU daily presence/absence in our study sites, based on a protocol we have developed and refined. I will evaluate CLNU occupancy using a single species, multi-seasonal occupancy model with the "unmarked" package in R as a function of time, fire disturbance, and habitat metrics listed above.

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