Site characteristics and fire interact to shape juvenile tree populations in high-elevation whitebark pine forests

RESEARCH BRIEF 21 • SEPTEMBER 2026

In the Northern Rocky Mountains, high-elevation forests make up the core range of whitebark pine (*Pinus albicaulis*), a threatened, keystone species. Whitebark pine regeneration is often considered fire-dependent, with fire removing competing vegetation and encouraging seed caching by Clark's Nutcrackers (*Nucifraga columbiana*). Yet, whitebark pine are highly vulnerable to fire mortality, and losing cone-bearing trees has grown more consequential as populations have declined due to infection by invasive white pine blister rust (*Cronartium ribicola*) infection and native mountain pine beetle (*Dendroctonus ponderosae*) outbreaks. Understanding how fire and site conditions govern the presence and abundance of juvenile whitebark pine and co-occurring tree species is essential for managing these forests.

METHODS

Researchers paired seedling and sapling counts with field-based and remotely sensed predictor variables at 10 high-elevation sites across the Selway-Bitterroot Wilderness (SBW), using a burned/unburned × lower/upper-elevation design. The study fit models for presence and abundance of four high elevation tree species: whitebark pine, subalpine fir (*Abies lasiocarpa*), alpine larch (*Larix lyallii*), and Engelmann spruce (*Picea engelmannii*). Researchers also developed a map of predicted whitebark pine abundance across the Bitterroot Range.

KEY MANAGEMENT FINDINGS

- Fire occurrence was associated with fewer whitebark pine juveniles 25-44 years after fire.
- Fire-caused mortality has a net-negative effect on whitebark pine populations when too few cone-bearing trees remain to offset losses with new seedling establishment.
- Researchers provide spatially explicit predictions of whitebark pine juvenile abundance to help managers identify high-quality sites for planting rust-resistant whitebark pine in the Bitterroot Range.

The Northern Rockies Fire Science Network (NRFSN) serves as a go-to resource for managers and scientists involved in fire and fuels management in the Northern Rockies. Funded by the Joint Fire Science Program, NRFSN is one of 15 Fire Science Exchange Networks across the country. The network facilitates knowledge exchange by bringing people together to strengthen collaborations, synthesize science, and enhance science application around critical management issues. This project was completed in collaboration with the University of Montana Wilderness Institute.

NORTHERN ROCKIES FIRE SCIENCE NETWORK

UNIVERSITY OF MONTANA WILDERNESS INSTITUTE

JOINT FIRE SCIENCE PROGRAM

RESULTS

Fire occurrence was associated with fewer whitebark pine juveniles. Whitebark pine saplings were half as likely to be present in burned stands and seedling abundance was approximately 50% lower when they did occur. Among co-occurring species, alpine larch was the only clear beneficiary of fire: burned stands had more than double the odds of larch seedling presence, consistent with its need for high light and bare mineral soil.

Across species, biophysical site conditions were often stronger predictors than fire history, and elevation mattered most. Whitebark pine and alpine larch juveniles were more common with increasing elevation, while subalpine fir declined with increasing elevation except in burned stands or where adult firs were abundant.

Whitebark pine juveniles were concentrated on warmer, drier, more exposed sites and near living adults — underscoring the continued importance of topography and a nearby, healthy seed source to whitebark pine establishment.

Within burned stands, the effect of fire severity on juvenile tree populations was also dependent on terrain. Higher-severity fire favored whitebark pine juveniles on more exposed ridgelines, but not on wetter, more sheltered sites (Figure 1). Juvenile whitebark pine trees were rarer in burned stands than in paired unburned stands, contrary to expectations that fire would benefit whitebark pine establishment.

The landscape predictions showed that greater whitebark pine juvenile densities were associated with warmer aspects and ridgeline topography at higher elevations (Figure 2). Most of the area predicted to support whitebark pine juveniles, and a disproportionate share of the highest-quality sites, fell within designated wilderness (Figure 2). The proportion of area expected to meet or exceed minimum restoration targets (≥ 275 juveniles ha^{-1}) was more than twice as large inside the SBW as outside.

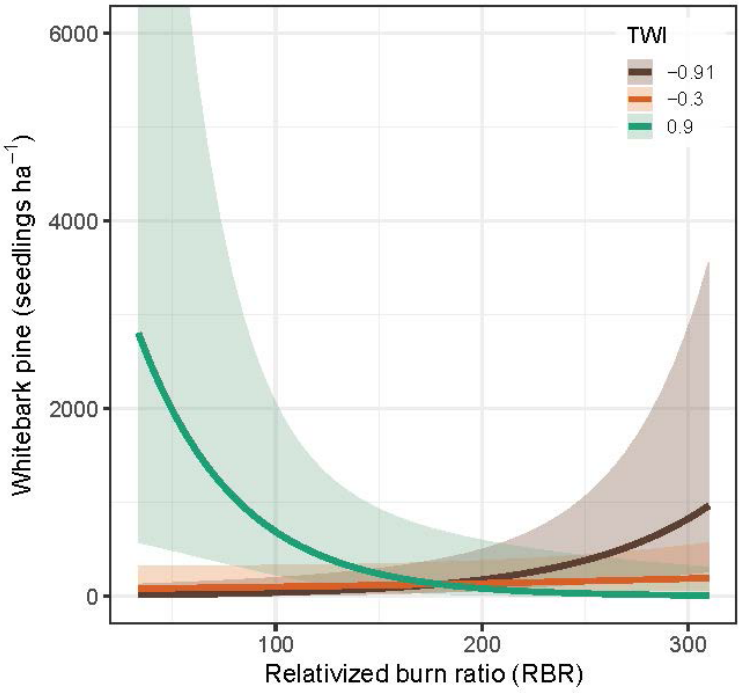

Figure 1. *Estimated seedling density across a gradient of burn severity (RBR; higher=more severe fire) for whitebark pine. Each line shows the relationship across different site moisture values (10th, 50th, & 90th percentiles of the Topographic Wetness Index; higher values = greater topographic site moisture); shaded bands are 95% confidence intervals.*

MANAGEMENT IMPLICATIONS

The continued loss of cone-bearing adult trees to blister rust and beetles has created a seed-limited landscaped where increasing fire activity is unlikely to promote sufficient natural whitebark pine establishment.

Planting rust-resistant seedlings, widely regarded as the most effective restoration action, will likely be necessary to retain whitebark pine as a component of many stands, both burned and unburned, particularly where adult density is low. The spatial predictions (Fig. 2) offer a practical first-pass tool for locating high-quality but seed-source-limited whitebark pine habitat, helping managers prioritize monitoring and planting where conditions favor whitebark pine establishment, as well as where those sites intersect with access, ownership, and land-use consideration.

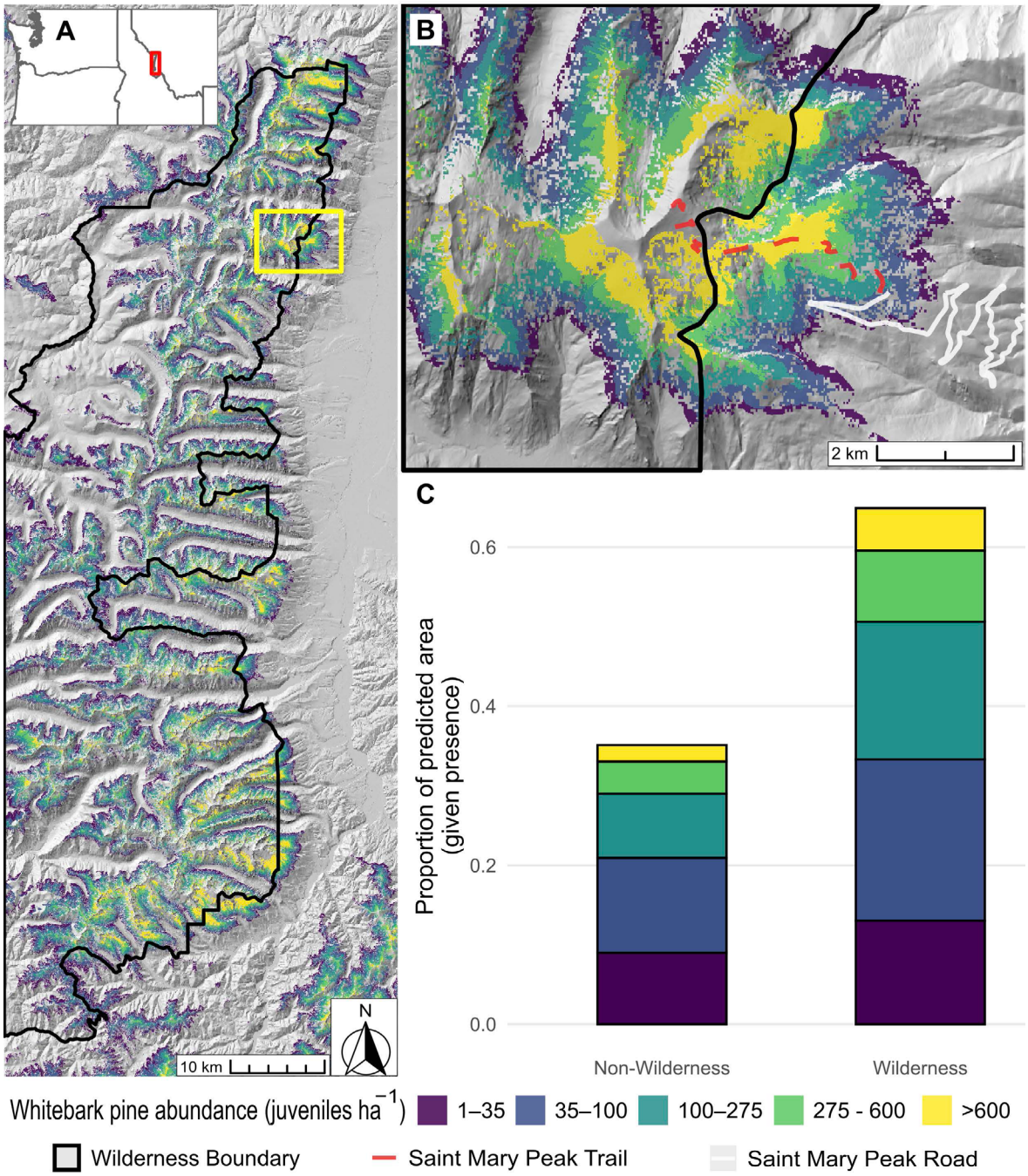

Figure 2. *Spatial prediction of juvenile whitebark pine (Pinus albicaulis; stems < 8 cm DBH) abundance across the Bitterroot Range expressed as density (juveniles ha-[1]) with the Selway-Bitterroot Wilderness (**A**). Inset of the St. Mary Peak area, illustrating local variation in predicted juvenile abundance across topographic gradients. St. Mary Peak Trail (dashed red line) and road (solid white line) are shown for reference (**B**). Proportion of total predicted regeneration area inside versus outside the wilderness, partitioned into density classes (**C**).*

ADDITIONAL INFORMATION

Beisel, J., Parks, S. A., Cansler, C. A., Affleck, D. L. R., Ballantyne, A. P., & Larson, A. J. Site characteristics and fire interact to shape juvenile tree populations in high-elevation whitebark pine forests. Fire Ecology (2026). https://doi.org/10.1186/s42408-026-00543-y

Beisel, J. (2026). Data and code for: Site characteristics and fire interact to shape juvenile tree populations in high-elevation whitebark pine forests. figshare. Dataset. https://doi.org/10.6084/m9.figshare.32882234.v1

NRFSN Hot Topic Page: Whitebark Pine Restoration and Management https://nrfirescience.org/hot-topics/whitebark-pine-restoration-and-management

Scan to find this document on our website.

This brief was written by Josh Beisel (josh.j.beisel@gmail.com) with editing and review from Ella Hall and Darcy Hammond.