USING LANDSCAPE-LEVEL FOREST MONITORING DATA TO DRAW A REPRESENTATIVE PICTURE OF AN ICONIC SUBALPINE TREE SPECIES

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Abstract—Whitebark pine (*Pinus albicaulis*) is an ecologically important species in high-altitude, mid-latitude areas of western North America due to the habitat and food source it provides for many wildlife species. Recent concerns about the long-term viability of whitebark pine stands have arisen in the face of high mortality due to a combination of fire suppression, white pine blister rust, and mountain pine beetle outbreaks. Most previous studies of whitebark pine have focused on pure stands, yet the spatially representative Forest Inventory and Analysis (FIA) dataset shows that whitebark pine is more widespread in other forest types than in pure stands. Because previous studies have focused on iconic, pure whitebark pine stands, managers may not be aware of the potential for ecological restoration of whitebark pine in other forest types. The purpose of this study was to use FIA's spatially representative sample grid to assess whitebark pine stands in a variety of environments in the Rocky Mountains, and to compare the structure and composition of pure versus mixed-species stands where whitebark pine is present. The results illustrate that metrics of whitebark pine viability, namely regeneration and mortality, may be comparable in the understory of other forest types to those observed within pure stands. Finally, this study demonstrates that the FIA dataset permits spatially representative evaluations of populations that tend to be studied purposively rather than strategically.

Whitebark pine (*Pinus albicaulis*) is a keystone species found in high-elevation ecosystems of western North America. It is specialized for dispersal by the Clark's nutcracker (Hutchins and Lanner 1982) and serves as a food source for many species of birds and small mammals, as well as black bears (*Ursus Americanus*) and threatened grizzly bears (*Ursus arctos horribilis*) (Keane and Arno 1993). Whitebark pine is frequently considered to be a pioneer species that is maintained on more productive sites by stand replacing fire (Keane et al. 2012).

Whitebark populations are declining range-wide and in 2011 whitebark pine was found scientifically warranted for protection under the Endangered Species Act due to a combination of mortality-causing factors (United States Fish and Wildlife Service 2011). Recent large-scale outbreaks of mountain pine beetle (*Dendroctonus ponderosae*) have caused mortality of mature whitebark pine trees at higher rates and over larger areas than has been historically observed (Keane et al. 2012; Raffa et al. 2008). Ongoing infection by the exotic white pine blister rust (*Cronartium ribicola*) has impacted whitebark pine's regeneration strategy at all life stages, causing rapid mortality in young seedlings, nearly eliminating cone production in mature trees, and causing mature tree mortality (McKinney and Tomback 2007). Following a severe mortality event, seed sources for post-outbreak recruitment of whitebark pine may be limited, and as a consequence, survivorship patterns of mature trees, saplings and seedlings may be the most important determinants of future forest development (McCaughey et al. 2009).

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To assess the outlook for whitebark populations, it is of primary importance to establish the extent and amount of whitebark pine regeneration and mortality across the landscape. The specific objectives of this project were to: (1) characterize whitebark pine seedling density at all plots in the Rocky Mountains with a whitebark pine component, and (2) compare the distribution of whitebark pine size classes, for both live and mortality trees, in the forest types that most commonly contain whitebark pine.

METHODS

The study area for this project is the range of whitebark pine in the U.S. Rocky Mountains. The analysis was constrained to all FIA plots in the states of Idaho, Montana, and Wyoming that contained at least one of the following: a live or dead whitebark pine tree (diameter at breast height, or d.b.h., of 5.0 inches or larger); a live whitebark pine sapling (d.b.h. between 1.0 and 4.9 inches); or a whitebark pine seedling (d.b.h. less than 1.0 inch and length of at least 6 inches). For all plots that met at least one of these criteria, data were obtained from the seedling, tree, and condition tables in FIADB (O'Connell et al. 2013).

Density of whitebark pine seedlings was queried directly from the variable TPA_UNADJ in the seedling table in the FIA database (FIADB), where TPA_UNADJ for seedlings of each species on each subplot is equal to the number of seedlings tallied times the seedling expansion factor (O'Connell et al. 2013); this variable was then summed to the plot level. Density of mortality trees and density of live trees and saplings were calculated by summing tree-level expansion factors for each condition and then for each plot, by 2-inch diameter class. The intermediate condition-level step was used to identify forest types that most frequently contained a whitebark pine component. Plot-level stem densities were adjusted by the proportion of the plot that was forested, as described in O'Connell et al. (2013).

RESULTS

In the Rocky Mountains, 1,036 FIA plots surveyed between 2003 and 2012 contained a component of whitebark pine (Fig. 1). Seedling density at these plots ranged from zero to over 6,000 seedlings per acre, with a mean density of 312 seedlings per acre and a median density of 150 seedlings per acre. Whitebark pine seedlings were present on 719 plots; about 18 percent of these plots occurred within the whitebark pine forest type (Table 1). Similarly, about 18 percent of the 938 plots with whitebark pine trees or saplings occurred in the whitebark pine forest type (Table 1). Both lodgepole pine and spruce-fir forest types contained more plots with whitebark pine components than pure whitebark pine stands.

Figure 2 shows the size-class distribution of live whitebark pine stems and whitebark pine mortality trees by forest type. Live whitebark pine densities in all diameter classes are highest in pure whitebark stands (Fig. 2a). The density of seedlings in the lodgepole pine forest type is nearly as high as that within pure whitebark pine stands, but in larger diameter classes there is a greater disparity between lodgepole pine and pure whitebark pine stands. However, the presence of whitebark pines in all diameter classes in lodgepole pine and spruce-fir forest types may represent a much larger areal distribution of whitebark pine than acknowledged in previous studies.

The whitebark pine forest type exhibited not only higher densities of live stems but also higher densities of whitebark pine mortality trees, in all size classes (Fig. 2b). Qualitative comparison of the densities of mortality trees (Fig. 2b) to live trees (Fig. 2a) in each size class suggests that lodgepole pine and spruce-fir forest types that contain whitebark pine components did not experience mortality any more severe, and possibly less severe, than the mortality observed in pure whitebark pine stands.

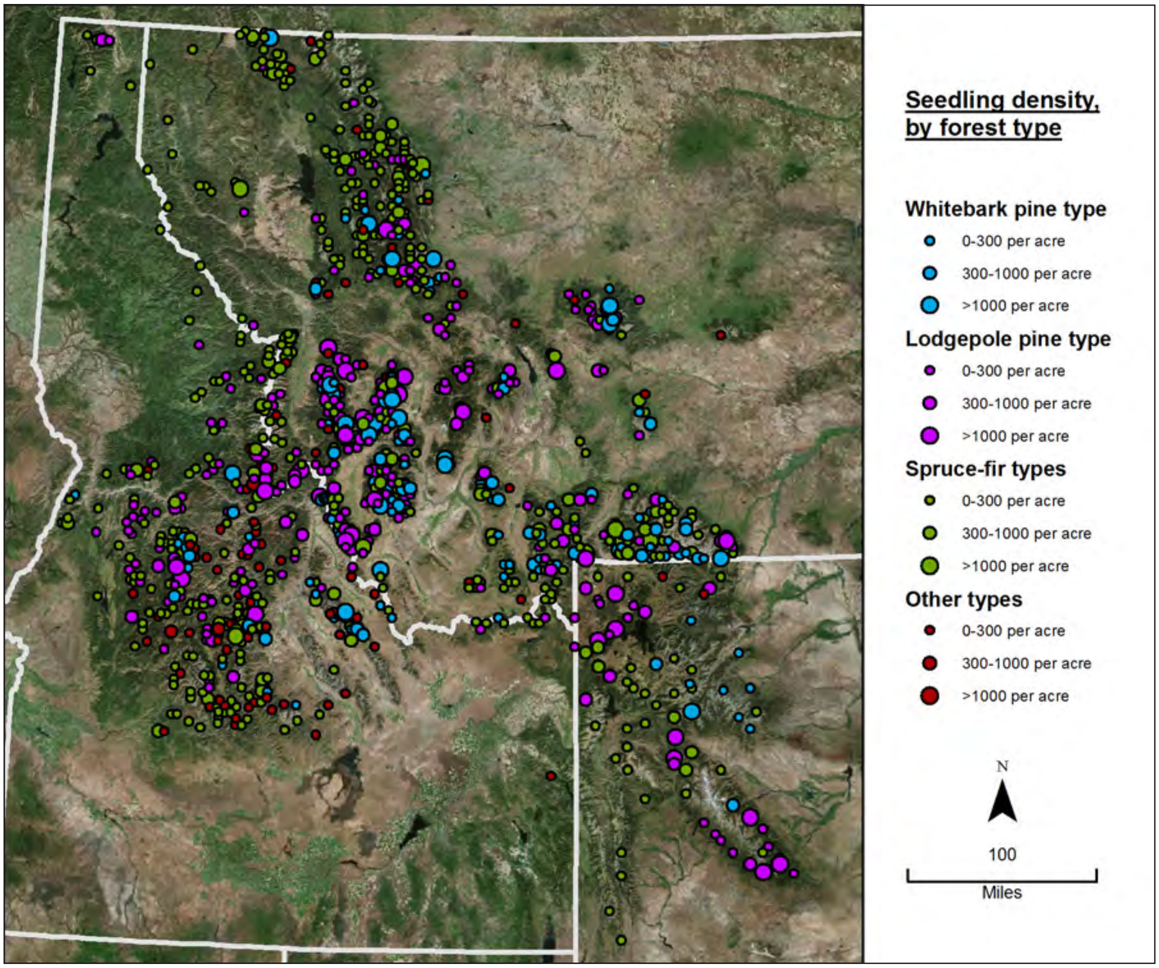


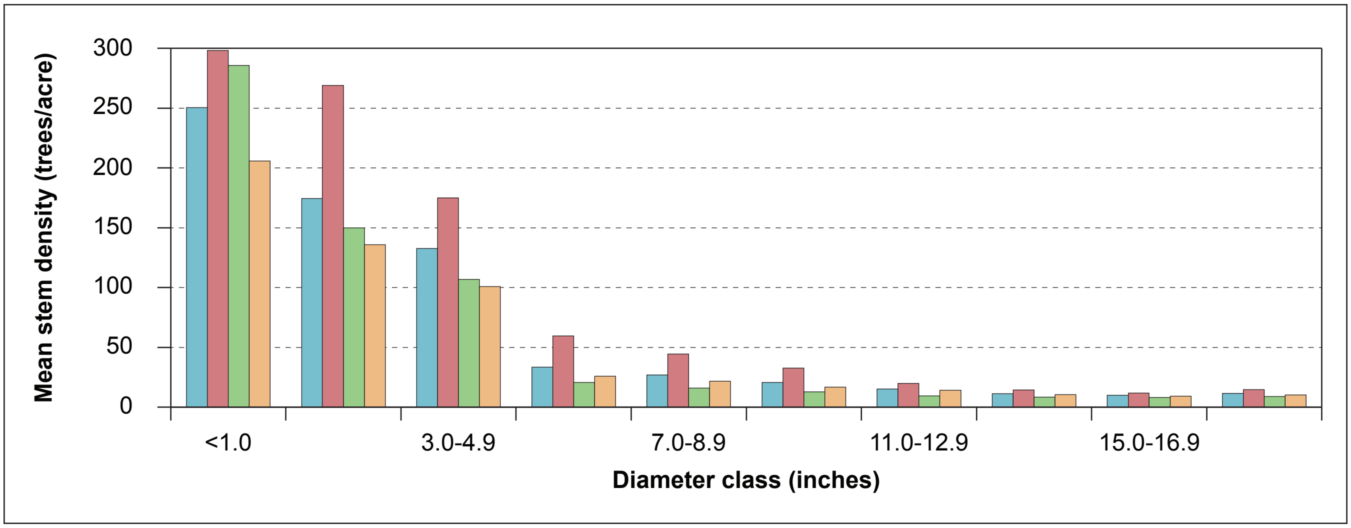
Figure 1—Map showing 1,036 FIA plots in the northern Rocky Mountains with a whitebark pine component, 2003-2012, by forest type and whitebark pine seedling density class. Plot locations are approximate.

Table 1—Number of plots, by forest type, that contain whitebark pine (WBP) trees (d.b.h. at least 5.0 inches) or saplings (d.b.h. 1.0 to 4.9) and number of conditions that contain WBP seedlings. Total are less than the total number of plots with a WBP component because some plots contain only seedlings and no trees or saplings, and others contain trees or saplings but no seedlings.

Forest type	Number of plots with WBP trees or saplings	Number of plots with WBP seedlings
Whitebark pine	172	131
Lodgepole pine	188	243
Spruce-fir types[1]	451	282
Douglas-fir	87	50
Other types	40	13
All types	938	719

[1] FIA's forest type classification includes several individual spruce-fir forest types, with four different spruce-fir types represented in this dataset. Because more than 95 percent of the plots in this dataset occur within the Engelmann spruce/subalpine fir type and the subalpine fir type, and because both types were present in nearly equal proportions and showed very similar densities of whitebark pine stems at all size classes, all spruce-fir types are aggregated here for simplicity.

A



B

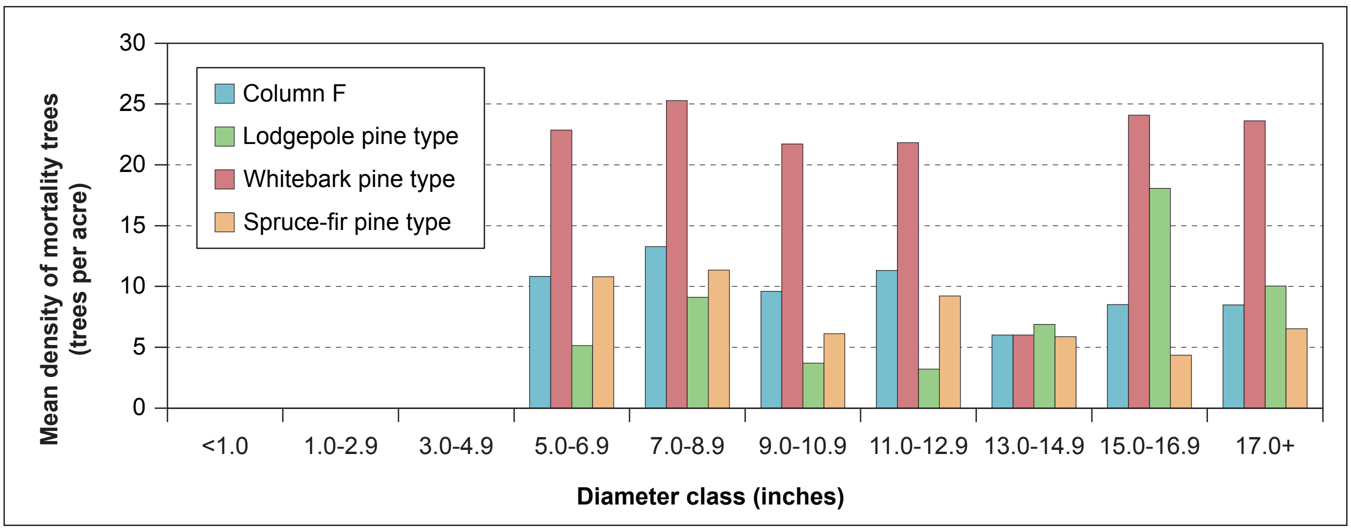


Figure 2—Mean density of live whitebark pines (A) and mean density of whitebark pine mortality trees (B), by diameter class, for the three forest types where whitebark pine is most abundant in the Rocky Mountains, 2003-2012. Estimates of mortality trees per acre were not available for trees smaller than 5.0 inches d.b.h.

DISCUSSION

The advantage of using FIA data for this type of analysis is that the FIA plot grid represents a spatially representative sample (Bechtold and Patterson 2005) across the landscape, rather than a purposive or targeted sample of sites with specific intrinsic characteristics, such as an overstory predominated by whitebark pine and/or signs of recent severe mortality. This analysis found that although the whitebark pine forest type contains the highest densities of seedlings, saplings, and trees, other forest types also have appreciable densities of whitebark pine stems in all diameter classes. Similarly, densities of whitebark pine mortality trees were higher in pure whitebark pine stands than in other forest types. However, other forest types occupy far more area than the pure whitebark pine forest type, as represented by the number of FIA plots that met the criteria for inclusion in this analysis. In particular, whitebark pine stems of all size classes occurred within lodgepole pine and spruce-fir forest types more frequently, although at lower densities, than in pure whitebark pine forests. Seedling densities in lodgepole pine forests were almost as high as those in pure whitebark pine forests, so further study is needed to identify the factors that affect recruitment into larger size classes.

To make this information useful to managers, future research should identify site factors that differentiate lodgepole pine and spruce-fir stands that contain a whitebark pine component from those that do not. Sites with a whitebark pine component may represent potential recruitment sites, either via future recruitment or competitive release of understory trees following overstory disturbances such as the mountain pine beetle epidemic. Campbell and Antos (2003) found that even small whitebark pine trees and saplings can respond favorably to disturbance-induced canopy gaps, and exhibit competitive release after growing slowly for 150-200 years. Although ecological succession from whitebark pine to subalpine fir is thought to be one cause of whitebark pine's decline (Keane and Arno 1993), it is possible that whitebark pine is not entirely seral in other forest types, and some spruce-fir and lodgepole pine stands may offer opportunities for managing for competitive release of whitebark pines in the understory.

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