Limber Pine (*Pinus flexilis*) Stand Conditions After White Pine Blister Rust- and Mountain Pine Beetle (*Dendroctonus ponderosae*)-caused Mortality in the Central and Southern Rocky Mountains

C.M. Cleaver[1, *], W.R. Jacobi[1], K.S. Burns[2], and R.E. Means[3]

[1] *Colorado State University, Department of Bioagricultural Sciences and Pest Management, Fort Collins, Colorado, USA*

[2] *USDA Forest Service, Forest Health Protection, Golden, Colorado, USA*

[3] *USDI Bureau of Land Management Wyoming, Cheyenne, Wyoming, USA*

[*] *christycleaver@fs.fed.us*

Mountain pine beetle (*Dendroctonus ponderosae*) and white pine blister rust (causal agent: *Cronartium ribicola*) are causing extensive crown dieback and mortality in limber pine (*Pinus flexilis*) in the central and southern Rocky Mountains. Ecologically valuable limber pines often grow in fragile ecosystems where few other trees can grow. The combined effects of mountain pine beetle, white pine blister rust, dwarf mistletoe (*Arceuthobium cyanocarpum*), and climate change could greatly reduce the biodiversity of these ecosystems. Current status and long-term monitoring of limber pine trees and seedlings are needed to advise land managers and to implement restoration. The study objectives were to: (1) assess site, stand, and health characteristics of seedlings and mature limber pines in Colorado, Wyoming, and Montana (USA); (2) determine factors that influence the occurrence and incidence of white pine blister rust, bark beetles, and dwarf mistletoe; and (3) determine factors that affect seedlings, including site, stand, and meteorological characteristics, and white pine blister rust. In 2011 and 2012, we assessed 22,700 limber pines on 508 plots in limber pine-dominated stands in 25 study areas in Colorado, Wyoming, and Montana. Mean density of live limber pine was 311 stems ha^{-1}. Fifty percent of standing limber pine trees were classified as healthy, 26 percent were declining or dying, and 24 percent were dead. White pine blister rust was the primary damage agent and was widespread, occurring in 23 of the 25 study areas, on 73 percent of plots with a mean incidence of 26 percent. Bark beetle-caused mortality occurred in all 25 study areas, and 18 percent of standing limber pines were killed by bark beetles. Limber pine dwarf mistletoe occurred within 20 study areas, on 29 percent of plots, with a mean incidence of 9 percent. Live limber pine seedling density averaged 141 stems ha^{-1}. Of all standing live and dead limber pine seedlings, 1.5 percent were dying, 4.4 percent were dead, and white pine blister rust occurred on 5.3 percent of live seedlings.

We used statistical modeling to determine the meteorological, macrosite, and microsite factors and stand factors that influenced the occurrence and incidence of white pine blister rust, bark beetles, and dwarf mistletoe on limber pines. We also used statistical modeling to determine factors that predict density (stems ha^{-1}) of limber pine seedlings and proportion of limber pine seedlings with white pine blister rust. The widespread occurrence of limber pine stands heavily affected by mountain pine beetle and white pine blister rust, combined with low regeneration density, suggests that these areas should be monitored so land managers can decide if restoration efforts are warranted.

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