CHAPTER 16.

The Impacts of Mountain Pine Beetle *(Dendroctonus ponderosae)* Outbreaks on Forest Conditions in the Intermountain West

(Project INT–EM–F–10–03)

Christopher J. Fettig
Kenneth E. Gibson
Carl L. Jørgensen
Steven Munson
Jose F. Negrón
Justin B. Runyon
Brytten E. Steed

INTRODUCTION

Mountain pine beetle (*Dendroctonus ponderosae*) is a major disturbance in conifer forests of western North America, where it colonizes several tree species, perhaps most notably lodgepole pine (*Pinus contorta*). Recent outbreaks have been severe, long lasting, and well documented, with more than 27 million ha impacted (British Columbia Ministry of Forests 2012, USDA Forest Service 2012). Mountain pine beetle is an important part of the ecology of these forests, but extensive levels of tree mortality resulting from outbreaks may have undesirable impacts, e.g., negatively affecting aesthetics, recreation, fire risk and severity, human safety, timber production, and real estate values, among many other factors. In some areas, the magnitude of recent outbreaks has exceeded the range of historic variability, triggering concerns about short- and long-term impacts (Bentz and others 2009).

The primary objective of this ongoing project is to document the long-term impacts of mountain pine beetle outbreaks on residual stand structure and composition in lodgepole pine forests of the Intermountain West. Specifically, we concentrate on impacts to surface and aerial fuel loads; tree age, size, and species diversity; regeneration; invasive weeds; fall rates; and snag composition within the same monitoring sites over time. The scope of our work encompasses areas where the majority of tree mortality attributed to mountain pine beetle has occurred in the United States.

METHODS

In 2010, 25 circular 0.08-ha plots were established in each of 5 Western States near Fort Collins, CO, Stanley, ID, Butte, MT, Kamas, UT (near Evanston, WY), and Jackson, WY (125 total plots) (fig. 16.1) in lodgepole pine forests recently impacted by mountain pine beetle. Within each plot, all trees ≥7.6 cm diameter at breast height (d.b.h.) were tagged, and the species, d.b.h., total height, height to the base of the live crown, status (live or dead), causal agent of mortality (if applicable), and year of tree death [if applicable, based on Klutsch and others (2009)], among other variables, were recorded. Three 16.1-m Brown's transects (Brown 1974) were established at 0°, 120°, and 240° from plot center to estimate surface fuels. A 1-m^2 plot was established at the end of each Brown's transect to determine forest floor composition, and a 0.004-ha plot was established at plot center to estimate tree regeneration. Increment cores were collected from the three tallest trees on each plot to determine stand age and site productivity.

Levels of tree mortality and fall rates of trees have been recorded on an annual basis since 2010 (table 16.1). In 2012, methods were expanded to include census of each plot for the presence of exotic, invasive plants; monitoring of bark retention and checking (cracks) on trees, as these influence wood quality and salvage potential; and reconstruction of stand histories through use of dendrochronology (Colorado only). In August 2012, five plots in Idaho were burned in the Halstead fire at high severity and

Table 16.1—Year of sampling for variables collected across a network of 125 monitoring plots in lodgepole pine forests impacted by mountain pine beetle in 5 Western States

Variables measured	2010	2011	2012	2013	2014	2015	2016
Levels of tree mortality[a,b]	X	X	X	X	X	X	X
Fall rates of trees[b]	X	X	X	X	X	X	X
Tree species, d.b.h., and height[b]	X	—	—	—	X	—	—
Height to base of live crown[b]	X	—	—	—	X	—	—
Live crown cover	X	—	—	—	X	—	—
Checking of snags[b]	—	—	X	X	X	X	X
Bark retention of snags[b]	—	—	X	X	X	X	X
Tree regeneration	X	—	—	—	X	—	—
Forest floor composition	X	—	—	—	X	—	X
Invasive plants	—	—	X	—	X	—	X
Ladder fuels	X	—	—	—	X	—	—
Surface fuels	X	—	—	—	X	—	—
Litter and duff	X	—	—	—	X	—	—
Stand age	X	—	—	—	—	—	—

X = variable measured; — = variable not measured in this year.

[a] For trees killed prior to 2010, time of death was based on parameters adapted from Klutsch and others (2009), including:
1 year previous = crown of lime, yellow or yellow/red-colored needles; 2 years previous = ≥50 percent needles remaining;
3 years previous = <50 percent needles remaining; 4 years previous = no needles remaining but small and large twigs present;
5 years previous = only large twigs remaining; ≥6 years = both small and large twigs absent.

[b] All trees ≥7.6 cm diameter at breast height (d.b.h.).

were removed from the network that year. All variables are remeasured every fifth year. For purposes of this summary, we largely focus on causes, distributions, and levels of tree mortality that occurred between 2004 and 2011.

RESULTS AND DISCUSSION

Between 2004 and 2011, levels of tree mortality ranged from <1 percent (Utah, 2004) to 37 percent (Utah, 2007) on an annual basis. By 2010, mortality declined to near preoutbreak (endemic) levels in all States except Colorado. In particular, a substantial loss of trees was observed in the larger diameter classes (>20 cm d.b.h.) (fig. 16.2), most of which was attributed to mountain pine beetle (fig. 16.3). This agrees with our basic understanding of mountain pine beetle outbreak dynamics. In endemic populations,

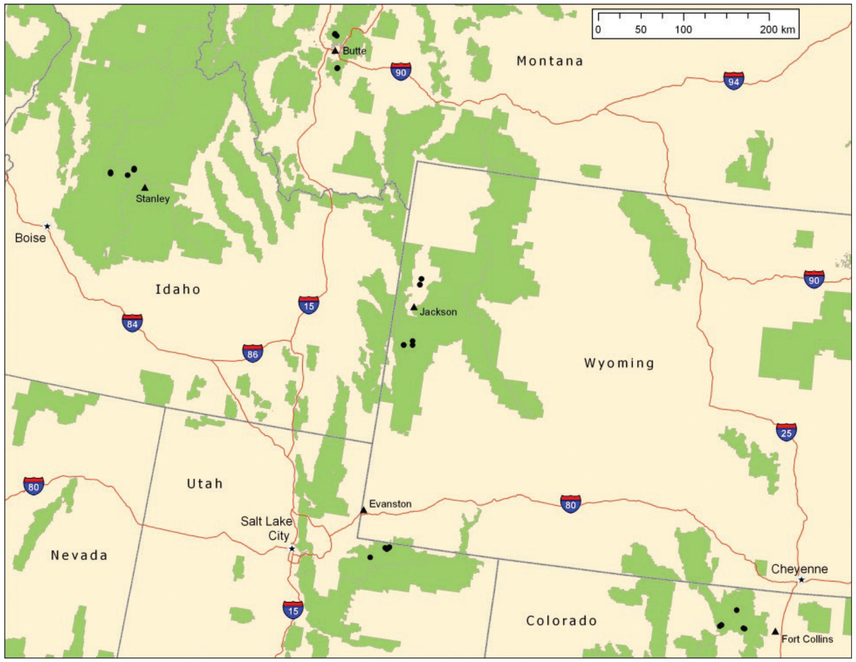

Figure 16.1—Evaluation monitoring plots (filled circles) installed to determine the impacts of mountain pine beetle outbreaks on lodgepole pine forests in the Intermountain West (25 per State, but many overlapped due to scale). Green represents National Forest System lands.

trees weakened by other agents are often first colonized and killed by mountain pine beetle (Boone and others 2011), but as an infestation develops, mountain pine beetle colonizes the largest trees (Shepherd 1966, Rasmussen 1972 for lodgepole pine), with progressively smaller trees being attacked over time as the proportion of uninfested larger trees declines. However, most of the mortality observed in the smallest diameter class (10 cm) was attributed to causes other than mountain pine beetle (fig. 16.3).

Large reductions in live pine volumes were observed between 2004 and 2011, ranging from 49 percent (Idaho) to 67 percent (Montana) (fig. 16.4). Ultimately, all of the woody biomass contained in these trees is transferred to the forest floor after tree fall. We expect these and other changes (Jenkins and others 2014) to have a significant effect on baseline fuel conditions (fig. 16.5) when remeasured in 2014. Mitchell and Preisler (1998) followed the fall rates of >600 lodgepole pines killed by mountain pine

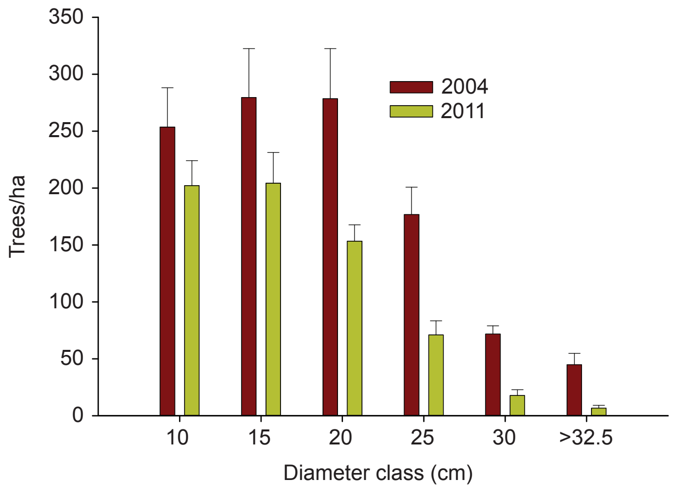

Figure 16.2—Mean (+ SEM, standard error of the mean) number of pines/ha by diameter class in 125 plots in the Intermountain West (midpoint of 5-cm diameter classes shown, except for largest).

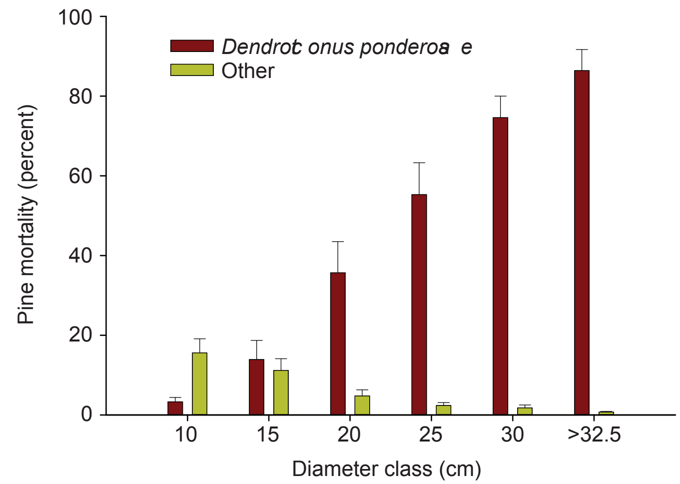

Figure 16.3—Mean (+ SEM, standard error of the mean) percentage of pines killed, by diameter class in 125 plots in the Intermountain West (midpoint of 5-cm diameter classes shown, except for largest).

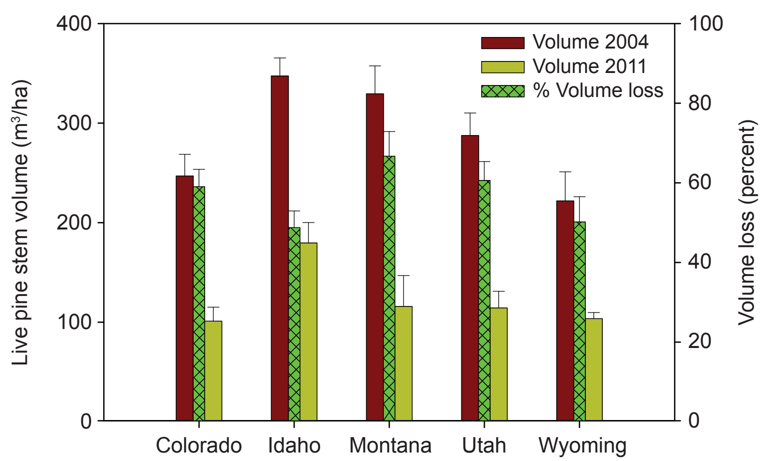

Figure 16.4—Mean (+ SEM, standard error of the mean) live pine stem volume and mean (+ SEM) percentage lost in 125 plots in the Intermountain West.

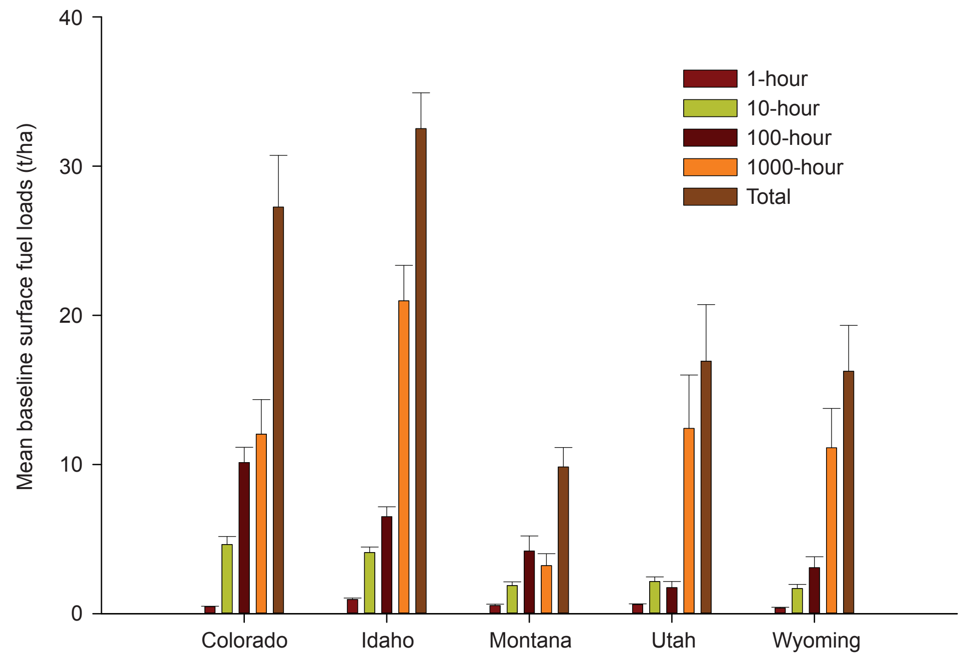

Figure 16.5—Mean (+ SEM, standard error of the mean) baseline surface fuel loads (t/ha) measured in 2010 by time lag categories in 125 plots in the Intermountain West. Fuels were to be remeasured across the network in 2014.

beetle in central Oregon and reported half-lives (i.e., the period of time it takes for half of the population to fall) of 8 years in thinned stands and 9 years in unthinned stands. These results are in contrast with Harvey (1986), who reported that only 25 percent of lodgepole pines killed by mountain pine beetle fell 11 years after death in northeastern Oregon. In our study, fall rates were negligible (<1 percent) for trees killed between 2004 and 2011, but have increased dramatically since (data not shown). Similarly, Lewis and Thompson (2011) reported negligible (<1 percent) fall rates for trees dead 0 to 6 years and 28 percent for trees dead 6 to 10 years in British Columbia.

Checking was observed on most trees killed by mountain pine beetle. The development of checks is simply a function of changes in wood moisture content over time. As wood dries, it initially releases free water not bound in cells until it reaches the fiber saturation point. As water is then drawn from the cell walls, they shrink, causing checks to develop. This can influence lumber recovery values and volumes if salvage is planned (Lewis and Thompson 2011).

To date, the invasion of exotic, invasive plants has been minimal. However, Lamb's quarter (*Chenopodium berlandieri*), Canada thistle (*Cirsium arvense*), and bull thistle (*Cirsium vulgare*) are increasing in Colorado plots that have experienced higher levels of tree mortality. Any activity that creates disturbance can promote plant invasions by increasing resource availability and/or decreasing plant competition. Accordingly, we expect to see higher levels of invasion in the future.

CONTACT INFORMATION

Christopher J. Fettig: cfettig@fs.fed.us.

ACKNOWLEDGMENTS

We thank John Nowak (Forest Health Protection, USDA Forest Service) and Robert Progar (Pacific Northwest Research Station, USDA Forest Service) for their helpful reviews of an earlier version of this summary, and the numerous colleagues who contributed to various aspects of this project. We thank the Forest Health Monitoring Program and Rob Cruz (Forest Health Monitoring Coordinator, R1 and 4) for their continued support.

LITERATURE CITED

Bentz, B.J.; Allen, C.D.; Ayres, M. [and others]. 2009. Bark beetle outbreaks in western North America: causes and consequences. Salt Lake City: University of Utah Press. 65 p.

Boone, C.K.; Aukema, B.H.; Bohlmann, J. [and others]. 2011. Efficacy of tree defense physiology varies with bark beetle population density: a basis for positive feedback in eruptive species. Canadian Journal of Forest Research. 41: 1174-1188.

British Columbia Ministry of Forests. 2012. Facts about B.C.'s mountain pine beetle. British Columbia Ministry of Forests, Lands and Natural Resource Operations. http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/Updated-Beetle-Facts_April2013.pdf. [Date accessed: May 27, 2014].

Brown, J.K. 1974. Handbook for inventorying downed woody material. Gen. Tech. Rep. INT–16. Ogden, UT: U.S. Department of Agriculture Forest Service, Intermountain Research Station. 24 p.

Harvey, R.D. 1986. Deterioration of mountain pine beetle-killed lodgepole pine in northeast Oregon. Report R6–86–13. Portland, OR: U.S. Department of Agriculture Forest Service, Pacific Northwest Region. 10 p.

Jenkins, M.J.; Runyon, J.B.; Fettig, C.J. [and others]. 2014. Interactions among the mountain pine beetle, fires, and fuels. Forest Science. 60(3): 489-501.

Klutsch, J.G.; Negrón, J.F.; Costello, S.L. [and others]. 2009. Stand characteristics and downed woody debris accumulations associated with a mountain pine beetle *(Dendroctonus ponderosae* Hopkins) outbreak in Colorado. Forest Ecology and Management. 258: 641-649.

Lewis, K.; Thompson, R.D. 2011. Degradation of wood in standing lodgepole pine killed by mountain pine beetle. Wood and Fiber Science. 43: 130-142.

Mitchell, R.G.; Preisler, H.K. 1998. Fall rate of lodgepole pine killed by the mountain pine beetle in central Oregon. Western Journal of Applied Forestry. 13: 23-26.

Rasmussen, L.A. 1972. Attraction of mountain pine beetle to small diameter lodgepole pines baited with *trans*-verbenol and alpha-pinene. Journal of Economic Entomology. 65: 1396-1399.

Shepherd, R.F. 1966. Factors influencing the orientation and rates of activity of *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae). The Canadian Entomologist. 98: 507-518.

U.S. Department of Agriculture (USDA) Forest Service. 2012. Areas with tree mortality from bark beetles: summary for 2000–2011, western U.S. 3 p.