**Rocky Mountains Cooperative Ecosystem Studies Unit (RM-CESU)**
**RM-CESU Cooperative Agreement Number: H1200090004 (IMR)**

**Project Final Report**

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TITLE OF PROJECT: Investigation into relationships between disturbance history and mountain pine beetle outbreak severity and consequences in the lodgepole pine forest type of Rocky Mountain National Park, Colorado

NAME OF PARK/NPS UNIT: Rocky Mountain National Park

NAME OF UNIVERSITY PARTNER: Colorado State University

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DISSEMINATION OF RESULTS:

This research will be presented to the general public and scientists in a total of four presentations. I presented this research at the Mountain Pine Beetle Science Symposium at Colorado State University on December 11, 2009, the Rocky Mountain National Park Research Conference on March 30-31 in Estes Park, to the general public in a Saturday Night in the Park talk in Grand Lake on August 28, 2010, and research results will be incorporated into a presentation titled “Are the trees falling?” for the State of the Rockies lecture series at Colorado College, Colorado Springs on September 13, 2010.

A manuscript of the research results will also be submitted in fall, 2010 to a scientific journal for review for publication.

## INTRODUCTION

Rocky Mountain National Park (ROMO) is experiencing an unprecedented mountain pine beetle (MPB; *Dendroctonus ponderosae*) outbreak that is significantly reshaping subalpine forest characteristics. Differences in disturbance characteristics between MPB outbreaks and wildfires, the disturbance type that has traditionally shaped subalpine forest landscapes in ROMO for centuries to millennia (Buechling and Baker 2004; Sibold *et al.* 2006; Higuera, P. unpublished data), mean that the current outbreak will likely create novel forest characteristics outside of historic range of variability. Specifically, MPB outbreaks and wildfires interact with pre-disturbance vegetation characteristics in unique ways to shape patterns of disturbance spread and severity (Bebi *et al.* 2003; Kulakowski *et al.* 2003), as well as post-disturbance site conditions and stand development (Sibold *et al.* 2007). This study examines the influence of disturbance and ecosystem management history on MPB outbreak severity and post-outbreak stand development trajectories in lodgepole pine-dominated stands in Rocky Mountain National Park, with the goal of elucidating stand development trajectories.

Prior to the recent MPB outbreak, lodgepole pine and mixed lodgepole pine-Engelmann spruce-subalpine fir forests of the southern Rocky Mountains were shaped by relatively infrequent stand-replacing fires, with return intervals of ca. 100-250 years (Buechling and Baker 2004; Sibold *et al.* 2006). Wildfires in the subalpine occur in extreme drought years (Kipftmueller and Baker 2000, Sibold and Veblen, 2006), and generally burn large portions of individual basins (Sibold *et al.* 2006). While variations in burn severity are ecologically significant to post-disturbance patterns of regeneration (Turner and Romme 1994), within burn patches fires generally kill all trees, seedlings and saplings of the thin-barked subalpine species. Post-fire site conditions are characterized by few remnant trees, bare mineral soil and harsh conditions including low soil moisture levels and high diurnal temperature variations. The opening of serotinous cones during fire and lodgepole pine's drought tolerance favor establishment of lodgepole pine. In contrast, spruce and fir require seed dispersal from burn patch edges and do not tolerate harsh site conditions. Consequently, post-fire sites are often dominated by abundant lodgepole pine establishment in the first decades following fire (Peet 2000, Sibold *et al.* 2007). In subsequent decades stands can go through a self-thinning phase at ca. 70-100 years of age and succession to shade-tolerant spruce and fir is likely on mesic sites (Peet 2000).

While the current MPB outbreak is unprecedented in scale and severity, MPB outbreaks are a natural disturbance agent in lodgepole pine forest ecosystems (Schmid and Mata 1996). Outbreaks can occur approximately every 20-50 years with MPBs primarily attacking and killing larger diameter lodgepole pine (Schmid and Mata 1996, Hawkes *et al.* 2003). The northern Colorado Front Range experienced outbreaks in the 1930s, late 1970s, and from approximately 2000 to the present. In contrast to wildfire, the selective nature of MPB attacks can create significant heterogeneity in mortality among stands in relation to variations in the diameter and density of lodgepole pine. Within stands the existence of surviving trees following outbreaks, even in patches that experienced high stem mortality, contrasts with the effects of wildfires. In general, post-outbreak site conditions are less extreme than in post-fire sites, with the existence of live remnant trees, unaffected seedlings and saplings of all species, and limited areas of bare mineral soil. The combination of more moderate post-disturbance site conditions, mortality of only host lodgepole pine, and shade intolerance of lodgepole pine can accelerate succession to Engelmann spruce and subalpine fir (Roe and Amman 1970, Hawkes et al. 2003). Even though lodgepole pine is rare as advanced regeneration and outbreaks do not produce the heat required to open serotinous lodgepole pine cones, most stands nevertheless have some degree of new lodgepole establishment associated with outbreaks (Sibold et al. 2007). Following the late 1970s outbreak in ROMO, both stand age and outbreak severity influenced post-outbreak stand development. Specifically, increased stand age was associated with a shift in dominance of new establishment from lodgepole pine to spruce and fir. Outbreak severity (measured as a percentage of stems killed) influenced both the abundance of post-outbreak regeneration, with a positive correlation between severity and the amount of new establishment, and the species composition of new establishment with higher severity patches dominated by lodgepole pine.

Whereas a simple model of post-outbreak stand development would project a shift toward two-cohort stands with new establishment dominated by spruce and fire, the diverse stand types in the landscape mean that projecting future forest stand and landscape conditions is considerably complex. The current MPB outbreak in ROMO is affecting lodgepole pine stands that regenerated primarily following extensive burning in the 1851-1901 period with some older stands that date to the mid-1600s to late 1700s (Sibold *et al.* 2006). The long fire-free period for most stands means that many stands have experienced subsequent non-stand-replacing disturbance events including surface fires, MPB outbreaks and wind blowdowns, which have altered stand characteristics (Sibold *et al.* 2007). The ecological legacies of these secondary disturbances will interact with the current outbreak to shape patterns of severity and post-outbreak stand development. Moreover, in addition to secondary disturbance events, the lodgepole pine forest type has been the focus ecosystem management treatments. Prescribed fire has been used to return fire to the landscape and tree-thinning treatments have been prescribed to create fuel breaks close to communities that are within or adjacent to post-fire lodgepole pine forests (e.g. Grand Lake, CO). Because of their influences on stand characteristics, the ecological legacies of both prescribed fires and fuel reduction treatments have the potential to influence forest-MPB outbreak interactions and future stand characteristics.

While much of the public concern and policy reaction to the current outbreak is focused on short-term concerns regarding increases in fire hazard in a forest type with already high fire hazard, the longer-term ecological consequences of the outbreak for stands and landscapes is receiving much less attention. In this context, in the present study I address some of the key stand-level forest change questions surrounding the outbreak including: How different will post-outbreak stands be from post-fire stands? How will future outbreaks interact with the legacies of the current outbreak and what will stand conditions be after multiple outbreaks? And, how do pre-outbreak ecosystem management treatments influence outbreak severity and post-outbreak stand development?

## STUDY AREA

This research was conducted in pure, post-fire lodgepole pine stands (stand type D1 from Peet, 1981) in the southern portion of the west side of Rocky Mountain National Park. This lodgepole pine forest type is dominant on lower-elevation (2,650 to 3,100 m), xeric, south-facing sites in the northern Colorado Front Range. All of the lodgepole pine stands in the study area regenerated following stand-replacing fires between 1695 and 1901 (Sibold *et al.* 2006) and, in general, the lodgepole pine forest cover type reflects a history of large-scale, stand-replacing fires that reset large portions of the landscape. Periods of widespread fire occurred in the second half of the 17$^{th}$, 18$^{th}$ and 19$^{th}$ centuries. In the time since the last stand-replacing fire, some stands have experienced secondary disturbance events including limited-extent surface fires (Sibold *et al.* 2007), as well as patchy MPB outbreaks in the 1930s and late 1970s. The current MPB outbreak spread to the study area in approximately 2004, peaked in ca. 2007 when it was widespread throughout the lodgepole pine forest cover type and has subsequently started to subside (USDA Forest Service aerial survey maps).

Until the last few decades land-use influences on these stands has been minimal. Prior to the area becoming a National Park in 1915, mining, ranching and logging were relatively limited in the area (Buchholtz 1983). Fire suppression began in ROMO in 1920 and was changed to a let-burn policy in 1972 which was then rescinded in 1978 following the 1978 Ouzel fire on the east side of ROMO that threatened the community of Allens Park (Hess 1993). While it is likely that fire suppression practices extinguished some fires that would have likely burned larger areas, the forested landscape is not outside of the historic range of variability for the pre-EuroAmerican settlement period (Sibold *et al.* 2006). Nonetheless, the forest landscape is relatively old with most stands ranging from ca. 110 to >300 years old. More recently, ecosystem management treatments, including the Green Mountain prescribed burn in 1999 and tree-thinning prescriptions within ca. 100 m of the park boundary, have significantly influenced stand characteristics in treated areas.

## METHODS

To investigate the influences of ecological legacies related to past disturbance history and ecosystem management treatments, I quantified mortality and new establishment in stands with different disturbance and management histories. The goal of the sampling design was to compare MPB outbreak severity and post-outbreak stand development trajectories for paired stands that have similar abiotic characteristics and stand-initiating fire event, but different subsequent disturbance or management histories. The majority of stands were stands that were originally sampled in 2003, just prior to the MPB outbreak in ROMO. The stands were originally sampled as part of a paired-plot analysis comparing stands with and without a history of secondary disturbances (MPB, surface fire, wind blowdown) to identify the influence of secondary disturbances on stand development in post-fire lodgepole pine stands (Sibold *et al.* 2007). In addition to these previously sampled stands, I sampled new stands with a prior history of MPB outbreak, prescribed fire, and tree-thinning prescriptions both with and without burning of slash piles. These additional sampled stands were randomly located within areas of homogeneous disturbance or management testament history.

To quantify the influences of pre-outbreak disturbance and management history on outbreak severity and post-outbreak stand development trajectories I measured all live and dead stems within rectangular plots. Plot sizes varied from 150 to 600 $m^2$ depending on tree density with the goal of measuring at least 100 stems in each plot. In addition to recording if stems were alive or dead, for each stem I recorded the species and diameter at breast height (dbh), and for lodgepole pine seedlings I recorded the number of whorls which is an approximate measure of seedling age. Lodgepole pine mortality resulting from the current MPB outbreak in contrast to other causes of mortality was verified by the presence of pitch tubes, red or brown needles and beetle galleries on dead trees. To verify stand disturbance history in previously unsampled stands I collected tree-core samples from the base of the largest diameter lodgepole pine in each stand to identify the date of the last stand-replacing fire. The presence of the 1970s MPB outbreak was verified though ring-width growth releases on canopy lodgepole pine trees that survived the outbreak. In the laboratory tree-ring core samples were processed using stand dendrochronological techniques (Stokes and Smiley 1968).

## RESULTS

I measured mortality and regeneration in a total of 37 lodgepole pine-dominated stands in the southwest portion of ROMO (Table 1). All sampled stands were post-fire lodgepole pine stands that are similar to the D1 stand type in Peet's (1981) stand classification for the east side of the Northern Colorado Front Range. Of the sampled stands, 20 were stands that had detailed dendroecological demographic reconstructions completed in 2003 and published in Sibold *et al.* 2007. I was not able to relocate two stands from the 2007 publication because the plots do not have permanent markers and the severity of the MPB outbreak made it too difficult to relocate the exact position of the original plots. In addition to the remeasured stands, I revisited four stands that were sampled in 2003 but were not included in the 2007 publication, and 13 new plots that targeted stands that had a history of management treatments. Management influenced stands included stands that were mechanically thinned or burned in the high-severity prescribed fire on Green Mountain in 1999. In total, I sampled 11 stands of varying original stand-replacing fire history (stand age; from 136 to 314 years old), seven stands with a history of surface fire, six stands that were affected by the 1970s MPB outbreak, seven stands that had been mechanically thinned (3 thinned, 4 thinned and burned), and six stands that were affected by the 1999 prescribed fire on Green Mountain (3 low to moderate severity, 3 high severity).

### Key findings by stand history type

#### *Stand Age*

MPB-outbreak severity is related to tree diameter in contrast to stand age (Table 1, stands 1-11). Outbreak severity, measured as a percent of trees killed within a stand, varies greatly among stands (0 to 73% tree mortality) and is strongly related to tree diameter with no clear relationship between severity and stand age (time since fire). The importance of tree diameter is evident from the varying degrees of mortality among the stands that regenerated following the 1873 fire (0 to 45% mortality) with the Chickaree Lake (13%), Onahu Creek (0%), and Timber Creek (0%) post-1873 stands having average tree dbh values <18 cm while the Grand Lake Lodge (45%) and Kawuneechee VC (51%) post-1873 stands both had average tree dbh values of >24 cm. The relationship between severity and tree diameter is a result of MPB targeting and successfully attacking larger diameter trees (Schmid and Mata 1996). The lack of a relationship with stand age is due to weak relationships between stand age and tree diameter in ROMO. Based on field observations, tree diameter within stands is related to tree density, with higher density stands having smaller diameter trees, and site moisture, with more mesic sites supporting larger diameter trees.

Overall, new establishment that resulted from the MPB outbreak was low (Table 1, stands 1-11). There was a general positive relationship between outbreak severity and the abundance of new establishment, with stands that experienced no to low mortality recording little to no new establishment. Only two stands (Chickaree Lake and Onahu Creek) had spruce and fir establish in the post-outbreak period. These two stands are older post-fire stands that both established following the 1782 fire. This pattern of spruce and fir establishment in relatively older stands fits the expected pattern of increased probability of establishment of shade tolerant species with increasing time since fire (Peet 1981; Veblen *et al.* 1991; Sibold *et al.* 2007). The general dominance of post-MPB outbreak cohorts by lodgepole pine reflects the unique dynamics of these relatively dry post-fire lodgepole pine stands in which an acceleration of succession to spruce and fir appears to be restricted as compared to more mesic sites. If patterns of post-outbreak regeneration are similar to those following the 1970s outbreak in ROMO (Sibold *et al.* 2007), it is likely that more new establishment will occur in the coming decade.

***Surface fire***

Stands with a history of surface fires (Table 1, stands 12-18) did not differ in severity or post-outbreak stand development trajectories from stands that did not have a history of surface fires. Comparing stands with similar tree ages (time since fire) and diameters (e.g. stands 1 and 12; 5 and 14; 7 and 15) there are no detectable differences in severity or post-outbreak establishment.

***Previous MPB outbreak***

Stands with a prior history of MPB outbreak significantly differed in patterns of severity and post-outbreak stand development trajectories compared with stands that were not affected by the 1970s outbreak. In contrast to stands that did not experience the 1970s outbreak, stands that experienced a high-severity 1970s outbreak (Table 1, stands 21-24) had higher mortality in the original post-fire cohort that survived the 1970s outbreak. Stands with low- to moderate-severity 1970s MPB outbreak (stands 19 and 20) had similar levels of mortality to stands that were not affected by the 1970s outbreak. However, among stems that established following the 1970s outbreak, there was no mortality from the current outbreak.

The high mortality among trees in the original post-fire cohort would be expected to create opportunities for new seedling establishment, new regeneration in these stands varied significantly. Some stands had high amounts of new regeneration while other stands had low amounts of regeneration. In stands with low amounts of new regeneration, completion with the post-1970s outbreak cohort likely retarded new seedlings. Thus, a range of new stand types are possible following the current outbreak. One possible stand development trajectory is for stands that were converted into two-cohort stands as a result of the 1970s outbreak to become three-cohort stands with some individuals from the original post-fire cohort, individuals from the post-1970s MPB-outbreak cohort, and new establishment related to canopy openings created by the current outbreak. Another possible stand-development trajectory for these 1970s MPB affected stands is a conversion back to single-cohort stands that more closely resemble the single cohort stand demographics of post-fire stands. In these stands the original post-fire cohort is removed in the current outbreak and dense regeneration following the last MPB outbreak is limiting new establishment.

### *Pre-outbreak tree-thinning treatments*

Stands that were mechanically thinned prior to the current MPB outbreak differed in severity and post-outbreak stand development trajectories as compared to similar stands that were not treated. MPB outbreak severity was higher in thinned stands as compare to untreated stands with similar disturbance history and site characteristics (Table 1, stands 1, 2, 4, 6, 8 with 25-31). Thus, thinning treatments did not decrease severity as a result of increased moisture availability and associated increased tree vigor and ability to resist MPB attack. The higher MPB-outbreak severity in thinned stands is likely because thinning prescriptions targeted the removal of smaller-diameter trees, which are more resistant to MPB attack. In treated plots the mean diameter of cut trees was 10 cm (measured at soil level) while uncut trees had a mean dbh of 18.5 cm. This difference in diameter is actually larger between the cut and uncut stems because the diameter of the cut trees was measured at the soil level where tree diameter is a larger than at breast height.

Post-outbreak stand development trajectories were more closely related to post-thinning treatment of slash piles instead of outbreak severity in thinned stands. Surprisingly, the higher severity of the outbreak in thinned stands did not result in increased establishment as compared to lower-severity outbreak in similar stands that were not thinned. However, burning or not burning slash piles following treatments had a significant influence on patterns of regeneration. Stands in which slash piles were burned following thinning had abundant lodgepole pine regeneration that was clustered primarily in the bare mineral soil on the perimeter of the burned slash pile (Table 1, stands 28-31). In contrast, stands in which slash piles were not burned had little to no regeneration. Although the timing of regeneration in stands in which slash piles were burned is more or less coincident with the MPB outbreak, it is unlikely that the regeneration is related to the outbreak. Instead the regeneration is most likely the result of the combination of the opening of serotinous cones and creation of patches of bare mineral soil resulting from the burning of slash piles.

### *Pre-outbreak Prescribed Fire*

The influence of pre-outbreak prescribed fire on MPB outbreak severity and post-outbreak stand development is contingent on fire severity. Low-severity burn stands in the

Green Mountain prescribed fire had approximately half of the canopy trees killed in the fire (Table 1, stands 33, 35, and 36) and low levels (from 559 to 1092 seedlings $ha^{-1}$) of post-fire seedling establishment prior to the MPB outbreak. In these stands, the current MPB outbreak killed approximately half of the original post-fire trees that survived the prescribed fire. This level of MPB-outbreak severity was similar to levels in similar older post-fire stands that did not burn in 1999 (Table 1, stands 2, 7, and 9). There was no mortality among the seedlings that established following the 1999 fire. New seedling establishment in response to canopy mortality from the MPB outbreak was similar to unburned stands and was limited to roughly 50 to 150 lodgepole pine $ha^{-1}$. Only one sampled stand had small amounts of spruce and fir establishment (Table 1, stand 36).

Stands that experienced high-severity fire in the 1999 prescribed burn, in which all pre-fire trees were killed, were the only sampled stands that were not affected by the MPB outbreak (Table 1, stands 32, 34, and 37). High-severity burn stands experienced high post-fire lodgepole pine seedling establishment with densities ranging from 8,228 to 24,288 seedlings $ha^{-1}$. No MPB-caused mortality was recorded in this post-fire cohort. While these stands were the only sampled stands that did not have any MPB related mortality, they had the highest density of seedlings establish in the post-2004 period (1,276 to 1,848 seedlings $ha^{-1}$). Because these stands did not have any MPB-caused mortality, post-2004 seedlings are not a response to the outbreak but instead are continued establishment in response to the fire. Overall, the abundance of lodgepole pine establishment in these high-severity fire stands emphasizes the importance of catastrophic fire in creating high-density, single-cohort lodgepole pine stands that characterize the historic range of variability for this forest type. Moreover, the abundance of lodgepole establishment in these stands in the 2004-2009 period suggests that the limited amount of lodgepole pine establishment in MPB-affected stands is a result of differences in disturbance type in contrast to unfavorable climate conditions for lodgepole pine establishment.

## CONCLUSION

Disturbance and management histories in post-fire lodgepole pine stands were generally influential in shaping patterns of MPB-outbreak severity and post-outbreak stand development trajectories. Despite the appearance that all lodgepole pine stands in the landscape in southwest ROMO are experiencing a high-severity MPB outbreak, many stands with smaller diameter trees (<18 cm dbh) have not been affected by the outbreak. Other stands, primarily stands with larger diameter trees, have mortality in the range of 40 to 65% of canopy trees and varying levels of new establishment that is dominated by lodgepole pine. Many of these stands are converting to two-cohort stands. Nonetheless, in the dry lodgepole pine forest type that was the focus of this research, these two-cohort stands are dominated by lodgepole pine with little evidence that spruce and fir will be significant components of future stands. In the context of the influence of past disturbance and management histories on the outbreak, only past surface fires did not influence the current outbreak or patterns of establishment. The 1970s-MPB outbreak, thinning and fire treatments all influenced patterns of severity and establishment. As a result, spatial patterns of severity and establishment are considerably heterogeneous from stand to stand and reflect pre-outbreak tree diameters, as well as disturbance and management histories. This fine-scale heterogeneity in stand characteristics contrasts dramatically to the extensive, single-cohort, even-aged patches of lodgepole pine that dominated the landscape for centuries to millennia prior to the outbreak. As evident from the influences of the 1999 Green Mountain prescribed fire, a return to single-cohort, even-aged lodgepole pine stands can be achieved through the use of high-severity prescribed fire.

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Table 1. Stand characteristics for stands with varying pre-MPB outbreak disturbance and management histories.  Information for each stand includes the original stand-replacing fire year (SR fire yr), the density of pre-MPB outbreak lodgepole pine (LPP) by hectare, the percentage of these trees that were killed in the MPB outbreak (Severity % mortality), lodgepole pine per hectare that established following disturbance or management events that occurred between the original stand-initiating fire event and the current MPB outbreak, the percentage of these trees that were killed in the current outbreak, and the abundance of post-MPB outbreak seedling establishment per hectare  (LPP = lodgepole pine; SF = subalpine fir; ES = Engelmann Spruce).

| Stand No. | Stand Name | SR fire yr | Original post-fire cohort | | Post-secondary event establishment | | Post-MPB establishment | | |
|---|---|---|---|---|---|---|---|---|---|
| | ***No Pre-Outbreak event*** | | **Pre-outbreak LPP density (trees/ha)** | **Severity (% mortality)** | **LPP density** | **Severity (% mortality)** | **LPP** | **SF** | **ES** |
| 1 | Grand Lake Lodge | 1851 | 2079 | 56 | | | 0 | 0 | 0 |
| 2 | Grand Lake Lodge | 1873 | 3551 | 45 | | | 0 | 0 | 0 |
| 3 | Chickaree Lake | 1782 | 260 | 0 | | | 140 | 20 | 60 |
| 4 | Chickaree Lake | 1873 | 6213 | 13 | | | 0 | 0 | 0 |
| 5 | Onahu Creek | 1782 | 1406 | 73 | | | 19 | 285 | 114 |
| 6 | Onahu Creek | 1873 | 4400 | 0 | | | 0 | 0 | 0 |
| 7 | Timber Creek | 1782 | 1950 | 38 | | | 225 | 75 | 200 |
| 8 | Timber Creek | 1873 | 7169 | 0 | | | 0 | 0 | 0 |
| 9 | Kawuneechee VC 1 | 1695 | 1300 | 75 | | | 325 | 300 | 100 |
| 10 | Kawuneechee VC 2 | 1873 | 2050 | 51 | | | 100 | 0 | 0 |
| 11 | North Inlet | 1851 | 864 | 76 | | | 544 | 32 | 0 |
| | ***Surface Fire*** | | | | | | | | |
| 12 | Grand Lake Lodge | 1851 | 775 | 55 | | | 275 | 0 | 0 |
| 13 | Chickaree Lake | 1782 | 0 | | | | | | |
| 14 | Onahu Creek | 1782 | 3036 | 86 | | | 220 | 220 | 176 |
| 15 | Timber Creek 1 | 1782 | 2050 | 34 | | | 200 | 100 | 100 |
| 16 | Timber Creek 2 | 1695 | 611 | 43 | | | 91 | 65 | 0 |
| 17 | Kawuneechee VC SF-1 | 1695 | 875 | 62 | | | 825 | 125 | 0 |
| 18 | Kawuneechee VC SF-2 | 1695 | 1452 | 56 | | | 396 | 132 | 176 |

Table 1 continued

| Stand No. | Stand Name | SR fire yr | Original post-fire cohort Pre-outbreak LPP density (trees/ha) | Original post-fire cohort Severity (% mortality) | Post-secondary event establishment LPP density | Post-secondary event establishment Severity (% mortality) | Post-MPB establishment LPP | Post-MPB establishment SF | Post-MPB establishment ES |
|---|---|---|---|---|---|---|---|---|---|
| | ***1970s MPB*** | | | | | | | | |
| 19 | Grand Lake Lodge (low severity) | 1851 | 775 | 55 | 320 | 0 | 475 | 0 | 0 |
| 20 | Grand Lake Lodge (moderate severity) | 1851 | 2100 | 57 | 2050 | 0 | 425 | 0 | 0 |
| 21 | Grand Lake Lodge (high severity) | 1851 | 2520 | 94 | 15080 | 0 | 0 | 0 | 0 |
| 22 | Chickaree Lake | 1782 | 792 | 87 | 7986 | 0 | 2900 | 225 | 175 |
| 23 | Kawuneechee VC | 1695 | 480 | 100 | 10480 | 0 | 200 | 400 | 0 |
| 24 | North Inlet | 1851 | 680 | 100 | 3020 | 0 | 1020 | 40 | 0 |
| | ***Mechanically Thinned*** | | | | | | | | |
| 25 | Park Boundary 5 | 1851 | 1364 | 71 | 352 | 0 | 44 | 0 | 0 |
| 26 | Park Boundary 6 | 1873 | 1584 | 67 | 132 | 0 | 88 | 0 | 0 |
| 27 | Park Boundary 7 | 1873 | 1716 | 72 | 220 | 0 | 0 | 0 | 0 |
| | ***Mechanically Thinned and Burned*** | | | | | | | | |
| 28 | Park Boundary 1 | 1851 | 1452 | 42 | 1848 | | 1100 | 0 | 44 |
| 29 | Park Boundary 2 | 1851 | 1320 | 69 | 880 | | 440 | 0 | 0 |
| 30 | Park Boundary 3 | 1873 | 1364 | 76 | 1452 | | 484 | 0 | 0 |
| 31 | Park Boundary 4 | 1873 | 1672 | 64 | 1716 | | 572 | 0 | 0 |
| | ***Green Mountain Prescribed Fire*** | | | | | | | | |
| 32 | PF #1 (100% mortality) | 1999 | 0 | 0 | 13860 | 0 | 1628 | 0 | 0 |
| 33 | PF #2 (48% mortality) | 1999 | 702 | 56 | 1092 | 0 | 104 | 0 | 0 |
| 34 | PF #3 (100% mortality) | 1999 | 0 | 0 | 24288 | 0 | 1848 | 0 | 0 |
| 35 | PF #4 (43% mortality) | 1999 | 691 | 45 | 559 | 0 | 52 | 0 | 0 |
| 36 | PF #5 (39% mortality) | 1999 | 280 | 50 | 988 | 0 | 156 | 65 | 104 |
| 37 | PF #6 (100% mortality) | 1999 | 0 | 0 | 8228 | 0 | 1276 | 0 | 45 |