Chapter 6
Interdisciplinary Research on the Blacks Mountain Experimental Forest

Martin W. Ritchie and Carl N. Skinner

Abstract The US Department of Agriculture (USDA) Forest Service Blacks Mountain Experimental Forest is a 4,000 ha, pine-dominated tract in northeastern California, in the Lassen National Forest. Between 1934 and 1960, research at Blacks Mountain focused on various methods of harvest and bark beetle activity. These studies demonstrated the effectiveness of harvesting on increasing tree growth and reducing widespread mortality from bark beetles.

After a period of inactivity, research efforts accelerated in the early 1990s when a large-scale interdisciplinary research program was initiated, building on the foundation laid with the early harvest method studies. Although early in the life of the study, researchers have found that prescribed fire reduced surface fuel levels in stands with a pre-burn harvest. However, burning untreated areas of the forest resulted in high levels of mortality and elevated risk of high-severity fire in the short term. Thinning treatments in stands with a cohort of large-diameter trees increased survival and number of low-risk trees. In the short term, there were no direct effects observed on small mammals from either treatment. Changes in stand structural diversity, while having no apparent effect on species richness of birds, did appear to cause shifts among a few individual species.

In the aftermath of a recent fire, additional research is being conducted on the effects of fire salvage and artificial regeneration.

Keywords Fire · Thinning · Silviculture · Harvest methods · Sustainability · Bark beetle

6.1 Introduction

Blacks Mountain Experimental Forest is a pine-dominated forest in northeastern California (40° 40′ N latitude, 121° 10′ W longitude) about halfway between Susanville and Old Station. Although easily accessed by well-maintained gravel roads,

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it is rarely visited by passersby because of its remote location and status as a wildlife refuge (Fig. 6.1). The forest roads to Blacks Mountain are usually closed on account of snow from mid-November to late April.

The elevation at Blacks Mountain ranges from 1,700 to 2,100 m above sea level, and the light precipitation (approximately 460 mm annually) falls primarily as snow during the winter months. The warm, dry summers are interrupted by infrequent thunderstorms, but precipitation during these months is very light. Mean daily temperatures range from −9 in winter to 29°C in summer.

The primary tree species are ponderosa pine (*Pinus ponderosa* Laws)[1] and Jeffrey pine (*P. jeffreyi* Grev. & Balf.), with incense cedar (*Calocedrus decurrens,* Torrey; Florin) and white fir (*Abies concolor,* Gordon & Glend.; Lindley) increasing with elevational gain within the forest. The only other conifer present, sugar pine (*P. lambertiana* Douglas), is found rarely; only two specimens have been located. In addition to these coniferous species, mountain mahogany (*Cercocarpus ledifolius* Nutt.) may be found in rocky outcrops, and several small cluster of aspen (*Populus tremuloides* was recently located near the center of the forest Michaux).

6.2 Beginnings

Blacks Mountain Experimental Forest was formally established by F.A. Silcox, the Chief Forester of the USDA Forest Service, in March 1934. The roughly 4,000 ha tract of land was carved out of the Lassen National Forest on the Modoc Plateau in an area northeast of Lassen Volcanic National Park (Fig. 6.1). The selection followed 2 years of scoping work by A.E. Wieslander[2] of the California Forest and Range Experiment Station (the early name given to the current Pacific Southwest Research Station, PSW). Wieslander settled on an area just southeast of a small butte called Blacks Mountain, in an area of gentle topography dominated by ponderosa pine and Jeffrey pine fairly typical of the yellow pine forests of the Modoc Plateau (Fig. 6.2).

The Experimental Forest was intended to be the center for forest management research in lower-site-quality ponderosa pine, commonly found in northeastern California. The initial research plan[3] laid out the purpose for the Experimental Forest: "It is hoped there may be concentrated here a series of coordinated studies of management, economics, utilization and silviculture with a single objective: determination of the measures necessary to make sustained yield forestry possible on lands of this character."

[1] Nomenclature follows Hickman (1993).

[2] Wieslander was very familiar with the forests of northeastern California; his first job after graduating from the University of California in 1915 was on the Lassen National Forest. He went on to a long and productive career with the California Experiment Station and is best known for spearheading an effort in the 1920s and 1930s to develop a Vegetation Type Map for the state of California.

[3] Duncan Dunning, "Outline Plan of Development and Research, Blacks Mountain Experimental Forest." February 18, 1937. Memorandum on file, PSW Research Station, Redding, CA.

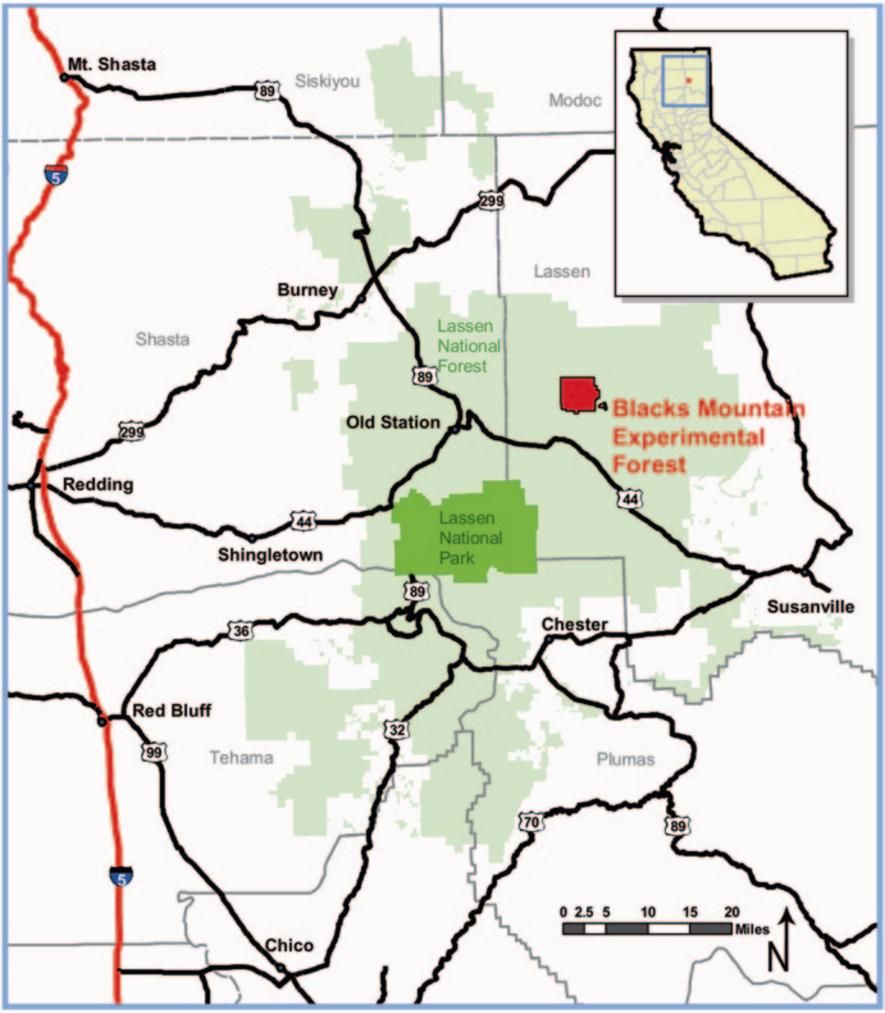

Fig. 6.1 Location of Blacks Mountain Experimental Forest in northeast California

Among the benefits of the location of Blacks Mountain Experimental Forest was its proximity to the Civilian Conservation Corps camp at nearby Halls Flat. The convenient labor supply allowed for the rapid development of an infrastructure needed to establish a research program in the forest. Researchers, led by Duncan Dunning, went to work quickly. In 1933 and 1934, they conducted a 100% inventory of all trees >9 cm in diameter, and shortly thereafter established a network of management units or compartments, each approximately 40 ha, and built 66 km of road designed to provide access to each compartment.

Dunning's philosophy was that research should support sound forestry practices rather than extractive "lumbering." He hoped to establish a sustained level of

Fig. 6.2 Blacks Mountain Experimental Forest near Halls Flat. (Photo by A.E. Wieslander 1934)

productivity of sawtimber and forage for deer and livestock in a regulated condition through a 140-year rotation. Because of the general lack of surface water flow in this area, watershed values are very limited.

Much of the early research at Blacks Mountain was influenced by the widespread bark beetle-induced tree mortality then being observed throughout the region (Fig. 6.3). At the time, the accepted method for dealing with this problem was to cut down beetle-killed trees and then strip and burn the bark, procedures that proved costly and produced only short-term benefits (Craighead et al. 1931). Furthermore, they treated symptoms rather than underlying causes of bark beetle outbreaks (Keen and Salman 1942). What managers needed was a way to anticipate the mortality so they could remove at-risk trees before they were killed. This would generate a financial return and reduce populations of bark beetles by denying them the stressed and susceptible trees needed to maintain populations. F.P. Keen (1936, 1943) developed and then refined an insect-risk rating system for interior ponderosa pine and then demonstrated the means by which the system could be applied to thin stands so as to reduce tree mortality and recover volume. Entomologists Kenneth Salman and J.W. Bongberg then set out to test a version of this risk-rating system at Blacks Mountain Experimental Forest (Salman and Bongberg 1942). After monitoring stands for 22 years, long-term results were published by Wickman and Eaton (1962). They found a substantial and sustained reduction in mortality that averaged approximately 80 % for a 22-year period after the initiation of the sanitation/salvage program (Fig. 6.4). The application of the risk-rating system to selective logging was widely applied in California pine forests in the 1940s and 1950s and is regarded as the first risk-rating system of its kind to be developed and applied.

Fig. 6.3 Accelerated mortality at Blacks Mountain. (Photo by A.A. Hasel 1939)

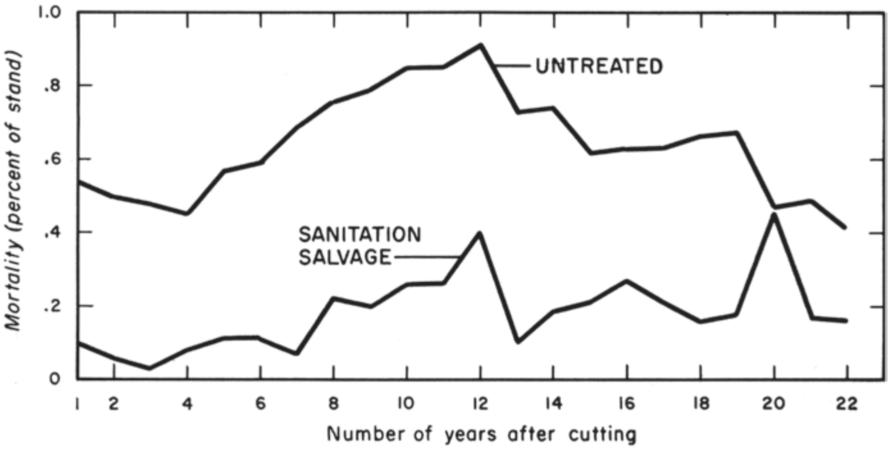

Fig. 6.4 Effect of sanitation harvesting at Blacks Mountain Experimental Forest between 1937 and 1959. (Source: Wickman and Eaton 1962)

Austin Hasel, drawing from an extensive time–motion study of the various harvest methods, concluded that light sanitation-salvage cutting described by Salman and Bongberg was economically feasible (Hasel 1946). The most important finding was that having trees of sufficient size for merchantability was the key factor, rather than intensity of cutting. His findings led to more widespread application of sanitation-salvage methods to reduce the threat posed by bark beetles on both Forest

Service and privately held timberland in California, and is still practiced today on some private commercial forestlands.

A key question for researchers at the time was**:** Could health be maintained, growth promoted, and forests regulated in an economically viable manner with intermediate harvests? Economic viability was an important element because if forest managers were to effectively move away from lumbering (the removal of sound merchantable material with little regard for future productivity) toward sustainable forestry, then it would be important to show that it was indeed economically feasible. A large-scale "methods of cutting" (MOC) study was established. In the MOC project, three different levels, or methods, of cutting would be compared with each other and with an uncut control.[4] The tree-cutting methods plus an untreated control were replicated ten times. The three harvest treatments included a heavy Forest Service harvest (removal of 80 % of the volume in a single cut), a modified Forest Service harvest (removing 40 % of the volume), and a silvicultural selection harvest, wherein a sanitation-salvage cut was applied and then followed some years later with an application of Dunning's unit area control. It was intended that over time, the silvicultural selection harvest would approach the retention level of the modified Forest Service harvest, but the initial harvest removed approximately 15 % of the volume (Dolph et al. 1995). This management approach was similar to group selection with focus on the natural mosaic pattern in the forest in determining units for management, as opposed to individual tree selection. These research plots were phased in annually with a complete set of treatments installed in blocks annually beginning in 1938.

Effects of cutting on growth shifted over time (Hallin 1959). During the first 5 years after establishment, growth was greatest in the light sanitation-salvage units, but during the next 5 years, observed growth was greatest among the heavy Forest Service harvests. Annual net growth in the uncut control was slightly negative (−0.04 % of standing volume[5]), while the heavy Forest Service harvest yielded the best growth rate (+1.5 % of standing volume). Furthermore, Eaton (1959) showed that while insect-caused 10-year mortality was highest in the untreated controls (0.44 %), there was little difference among the three primary treatments, where 10-year mortality ranged from 0.04 to 0.11 %.

Some additional research on artificial regeneration, pruning, and precommercial thinning was conducted after establishment of the MOC study (Hallin 1959), but little was published. Between 1960 and 1990, the experimental forest was used very little for research. In the early 1990s, Forest Service research priorities shifted, with greater emphasis on restoration and enhancing forest ecosystem function (Brooks and Grant 1992; Kessler et al. 1992). Blacks Mountain provided an ideal location to conduct interdisciplinary ecosystem research and there was a rejuvenation of research efforts on the experimental forest.

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[4] Austin Hasel, "Plan for Methods-of-Cutting Study, Blacks Mountain Sustained Yield Project." May 6, 1938. On File, PSW Research Station, Redding, CA.

[5] Volumes reported by Hallin (1959) were board-foot measure.

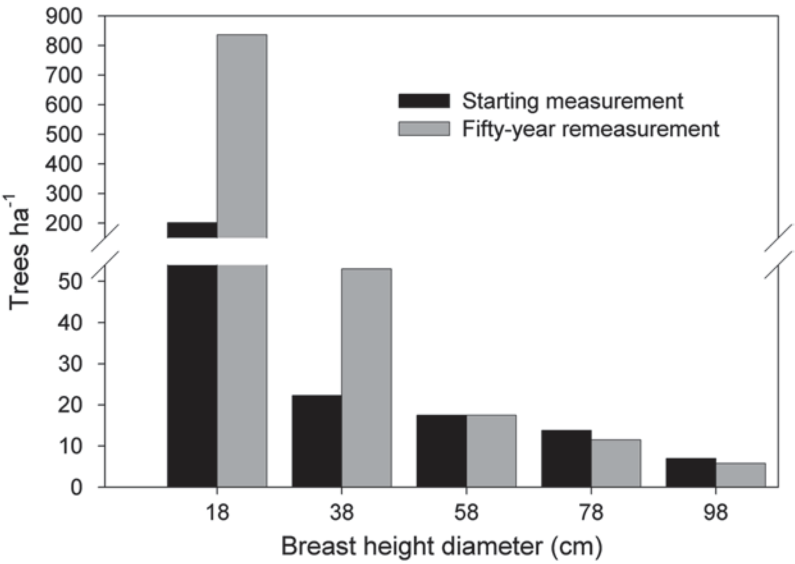


Fig. 6.5 Change in diameter distribution over 50 years at Blacks Mountain. (Source: Dolph et al. 1995)

6.3 Ecological Research at Blacks Mountain

In the late 1980s, Leroy Dolph and others at the Redding PSW Laboratory recognized that the MOC experiment provided an opportunity to quantify long-term changes in stand structure. After an extensive effort at re-monumenting and remeasuring the MOC study in 1990 and 1991, Dolph et al. (1995) reported substantial changes in the distribution of trees some 50 years after the initial establishment of the experiment (Fig. 6.5). Although there was some reduction in the number of large trees resulting from continued bark beetle mortality, the most striking change was in the influx of smaller-diameter trees in both harvested and unharvested stands. This is related to the effects of heavy grazing in the late nineteenth century followed by over 100 years of fire exclusion from these forests (Skinner and Taylor 2006). Fire exclusion as a general policy was instituted in the early twentieth century, resulting in removal of the periodic low-intensity fires that were common in interior pine stands before European settlement of the region and would have historically thinned young conifer regeneration (Norman and Taylor 2003). That the absence of frequent fires is likely the primary reason for the increased density of understory trees is evidence of similar stand structural changes from nearby Lassen Volcanic National Park in landscapes that have not experienced lumbering or other forms of timber harvesting (Taylor 2000). The increasing abundance of understory trees has contributed to an increase in the risk of high-intensity wildfire and an increase in competition for limited water and nutrients in these systems. Dolph et al. did not report a consistent increase in white fir, as expected, but did note that, in general, incense cedar increased in proportional representation, while pines filled in much of the remaining available space.

The early researchers did not understand the importance of fire as an ecological factor in the development of the forests at Blacks Mountain. The influence of fire in these forests was first altered in the late 1800s when widespread grazing was introduced to the area. Grazing was not managed until after the establishment of the Lassen National Forest in the early 1900s. Early grazing activity, through trampling and heavy consumption, removed much of the fine fuels (grasses, herbs, and pine needles) that carried frequent, low-intensity surface fires. This allowed for a flush of pine, incense cedar, and white fir regeneration that was not repeatedly thinned by fire (Norman and Taylor 2003, 2005). This grazing regime was followed by the introduction of systematic fire suppression early in the twentieth century, which effectively removed fire as an ecological process from the Blacks Mountain Experimental Forest area. The exclusion of fire thus promoted continued ingrowth and survival of young trees and created dense stands more susceptible to high-intensity fires than was typical of the original forests (Skinner and Taylor 2006).

These concerns, along with the growing questions about biological diversity, provided the emphasis for developing a long-term research project on the experimental forest. William Oliver, a research silviculturist with the research station, spearheaded the effort to bring together scientists specializing in fire, wildlife ecology, entomology, genetics, and forest mensuration to develop a single large-scale experiment that would allow an evaluation of many different ecological responses over time (Oliver 2000). Infrastructure such as the systematically located, spatially referenced grid points for recording baseline conditions and monitoring will facilitate future research efforts.

This experiment called for the creation of all combinations of two contrasting stand structures and two contrasting grazing treatments at a large scale (about 100 ha), replicated three times. Each of these 12 treatment units was then split so half could receive a prescribed fire treatment intended to represent the natural historical pattern and process of fire at Blacks Mountain. The strongly contrasting structures and the grazing treatments plus application of prescribed fire provided the strong response surfaces to test the hypothesis centered on biological diversity.

The experimental design, described in detail by Oliver (2000), is a randomized block experiment with split plots. Three blocks, related to slope position, have four large treatment areas each (about 100 ha each). The four treatments are a 2×2 factorial on grazing and structural diversity. The grazing treatments include grazing excluded (fenced) and grazing allowed (unfenced). The structural diversity treatments are high structural diversity (HD) and low structural diversity (LD). In the HD treatment, all canopy layers were maintained, and no trees in the dominant overstory were removed (almost all trees above 50 cm diameter at breast height, dbh, were retained). In the LD treatment, all of the large dominant trees over 50 cm were removed along with most of the smaller trees in the understory leaving mid-canopy trees with a quadratic mean diameter of about 25 cm in a fairly uniform density of approximately 280 trees ha^{-1} (Fig. 6.6). The large main plots were split in half, and prescribed fire was applied, post thinning, to one of the splits in each main plot.

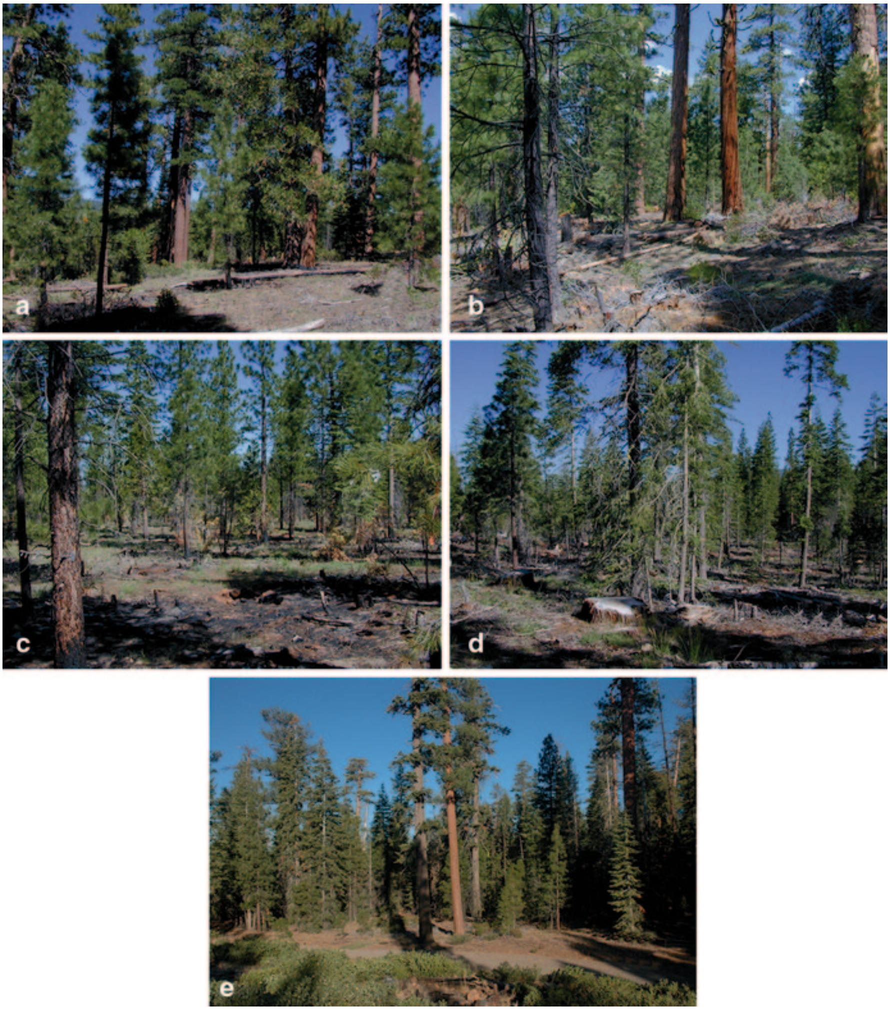


Fig. 6.6 Treatments in the Blacks Mountain Ecological Research Project: **a** high diversity, burned; **b** high diversity, unburned; **c** low diversity, burned; **d** low diversity, unburned; and **e** untreated research natural area

Owing to the large scale of the treatments, there was insufficient experimental area for an additional untreated control. However, an established research natural area (RNA) was used as a qualitative control. The Blacks Mountain RNA (Cheng 2004) was established in the 1950s as a site representative of mature interior ponderosa pine. There are five separate compartments designated for the RNA. Four of these RNA compartments were used as a contrast to the treatments within the experiment, but because they were preexisting, the treatments were not randomly applied, and they are not a part of the formal experimental design.

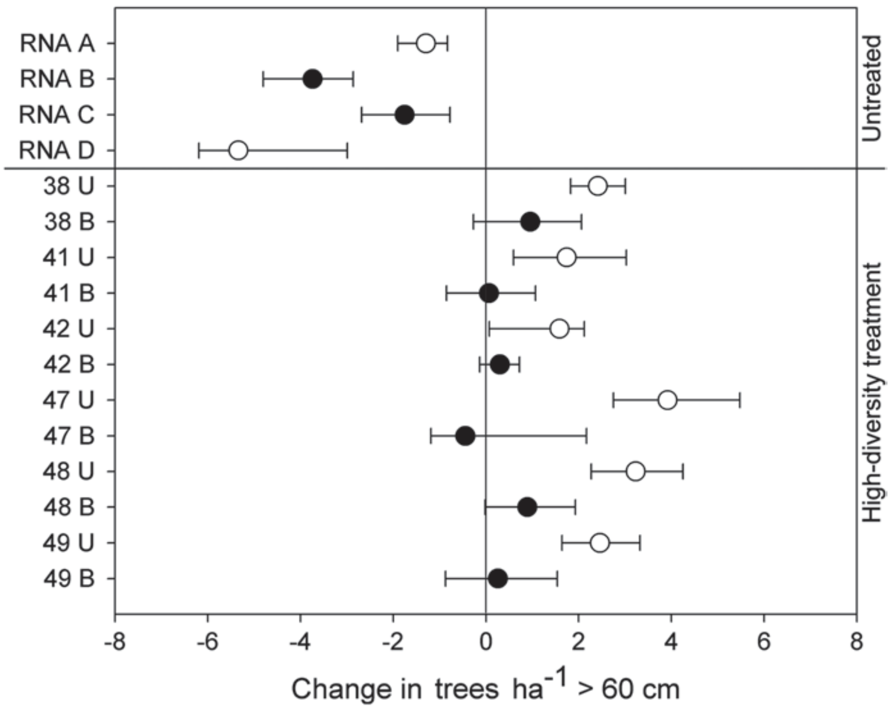


Fig. 6.7 Five-year median change (*first and third quartiles*) in large-tree (>60-cm dbh) density in high-diversity treatments and unthinned research natural areas at Blacks Mountain Experimental Forest (*closed circles* = burned, *open* = unburned)

Because of the scale of the project (about 1,300 ha treated and 160 ha in qualitative controls), planning and implementation of this project took a decade to complete. Treatments have now been in place for over 10 years, and the results are helping to shed more light on the earlier findings of the effects of thinning on tree health. The study was designed with a 50-year planning horizon, and we expect that the study will be fruitful for many years to come.

6.4 Results

A comparison of the untreated RNAs at Blacks Mountain with the HD showed that by thinning from below, ingrowth into the largest-diameter classes is increasing in the HD treatment areas (Fig. 6.7), while untreated "natural" stands are still losing the large-tree component at a rate not compensated by growth. Furthermore, treated stands actually show a reduction in the proportion of high-risk trees (Fig. 6.8), while the continued mortality in untreated "natural" stands indicates that there is little prospect for increasing the number of large-diameter trees without treatment (Ritchie et al. 2008).

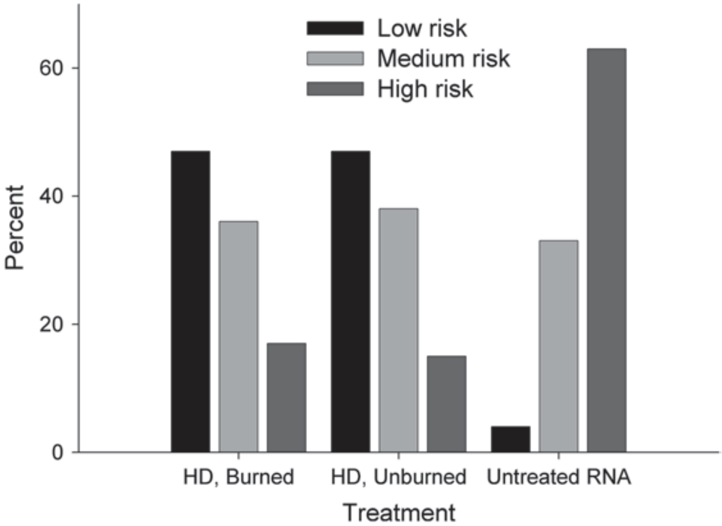


Fig. 6.8 Distribution of large trees (>60-cm dbh) by risk rating in high diversity and untreated units at Blacks Mountain Experimental Forest (observations made 5 years post treatment)

Some results from comparisons between stands with HD and LD are:

- Growth of both individual trees and stands (Fig. 6.9) is substantially higher in LD units (Zhang et al. 2008).
- The bird response to structural diversity has been subtle at Blacks Mountain. Species richness (the number of species present) showed no response to stand structure. However, four individual species showed differences in occupancy (preference). Occupancy was higher for American robins (*Turdus migratorius*) and chipping sparrows (*Spizella passerina*) in LD units, while occupancy was higher for the white-breasted nuthatch (*Sitta carolinensis*) and western tanager (*Piranga ludoviciana*) in HD units (George and Zack 2008).
- Small mammals showed minimal short-term response to stand structure and appeared to be more influenced by overstory density and, for some species, the presence of shrubs and coarse woody debris (CWD; Maguire et al. 2008).
- Surface CWD larger than 7.6 cm in diameter did not differ across treatment units regardless of the stand structure. There was less total CWD following treatments even in unburned plots. This reduction in CWD likely resulted from the harvest machinery breaking up CWD as the machinery moved about the units (Uzoh and Skinner 2009).
- Understory composition of shrubs is higher in terms of both cover and number of species in LD units (Zhang et al. 2008).

The prescribed fire treatments have been applied once, with re-burn planned as surface fuel levels rebuild over time. A number of researchers have published results of the effects of prescribed fire at Blacks Mountain.

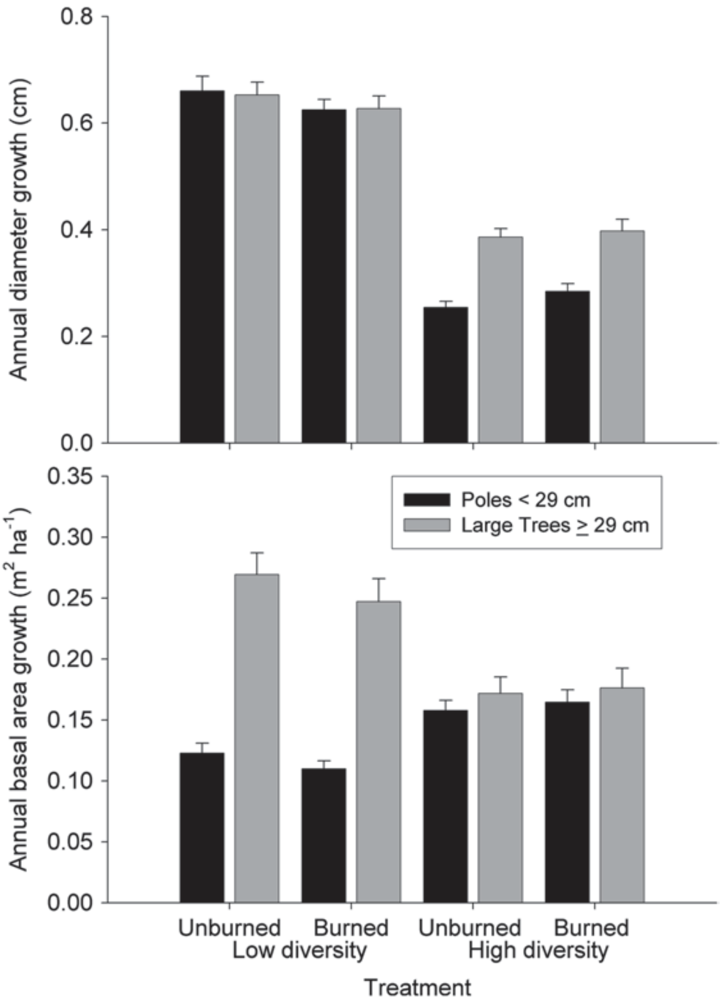


Fig. 6.9 Tree breast height diameter growth rates and stand basal area growth rates for treatments in the Ecological Research Project at Blacks Mountain. (Source: Zhang et al. 2008)

- The impact of fire on small mammals was difficult to determine with any precision. The effects of fire on small mammals appeared to be indirect in that some species are influenced by shrub cover and woody debris, both of which are influenced by prescribed fire (Maguire et al. 2008).
- Surface CWD decreased following the application of prescribed fire, with the most notable change in the CWD in an advanced state of decay. While CWD was significantly reduced in the LD following prescribed fire, the high variability in coverage of the burn treatment in HD led to an absolute but nonsignificant reduction in CWD in the latter areas (Uzoh and Skinner 2009).

Fig. 6.10 Aftermath of the Cone Fire, September 2002, at Blacks Mountain Experimental Forest. (Photo by M. Ritchie 2002)

- Prescribed fire had little influence on species richness of shrubs; however, the amount of shrub cover appears to be slightly higher in the more open LD burned units (Zhang et al. 2008).
- In a study focused on the RNAs, which have had no thinning, prescribed fire contributes to higher rates of mortality, fuel accumulation, and high-intensity fire risk in the short term, and it may take three applications of fire to achieve the reduction in high-intensity fire risk that can be obtained in one entry with a thinning treatment before fire (Skinner 2005).

6.5 The Cone Fire

More recently, a wildfire burned through part of the experimental forest in September 2002. The Cone Fire burned about 600 ha of the experimental forest including parts of three of the Ecological Research Project treatment units about 5 years after treatment implementation. At the time of ignition, 100-h fuel moisture and relative humidity were low (2 and 6 %, respectively). Owing to these extreme fire weather and fuel conditions, much of the area burned with high severity, killing most or all of the trees (Fig. 6.10). While the fire did some damage to research plots, it was apparent the treatments at Blacks Mountain had considerably moderated fire intensity and the associated severity within treated areas (Fig. 6.11). This offered an opportunity to record the effects of various management treatments on subsequent wildfire behavior.

With funding from the Joint Fire Science Program beginning in 2003, researchers initiated a study of the effects of thinning and prescribed fire on wildfire behavior (Ritchie et al. 2007, Symons et al. 2008). Fire effects were generally much less severe in all treatment units. The combination of thinning and prescribed fire

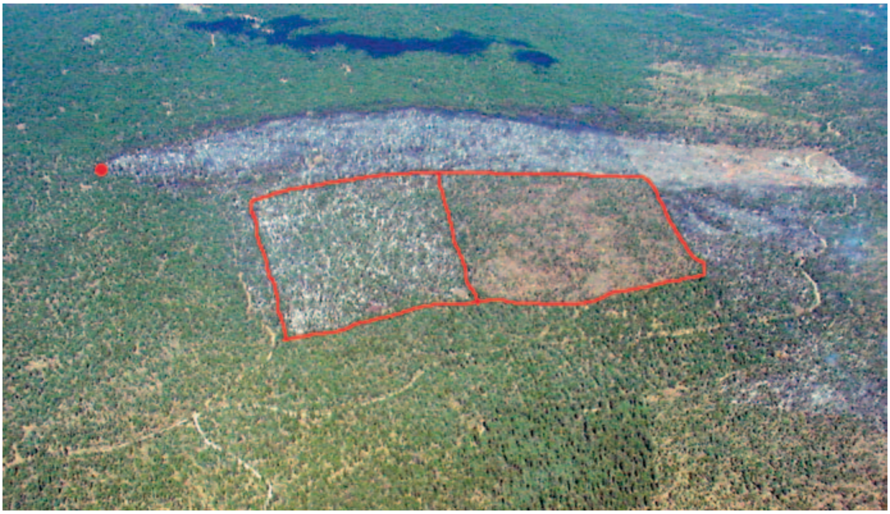


Fig. 6.11 The Cone Fire underburned the thinned-only split of low diversity unit 46 (*left-center*), but failed to burn through the half with prescribed fire (*right-center*) in the Ecological Research Project at Blacks Mountain Experimental Forest, while the untreated area to the north burned with high severity. (Forest Service File Photo 2002)

essentially limited mortality to those trees along the edge of the stand (Fig. 6.12). The crown scorch and bole scorch was also highest outside the treated units and along their edges (Fig. 6.13).

Researchers have also initiated an experiment designed to study the effects of postfire (salvage) logging on fuel buildup, regeneration success, and understory species composition (Fig. 6.14). These plots are being monitored biannually to evaluate the changes over time. This experiment will provide a longer-term look at how salvage logging affects fuel loading, stand development, biodiversity, and wildlife habitat.

6.6 Conclusion

Blacks Mountain Experimental Forest has been a productive site for ponderosa pine research for 75 years. Each successive generation of research has drawn upon the previous work for inspiration, experimental material, and established research records. One lesson from these efforts is that long-term research can often provide unanticipated benefits. The experimental design with strongly contrasting treatments provides the opportunity for subsequent research questions, new management ideas, and new investigations. Such is the legacy of the modern Blacks Mountain Experimental Forest.

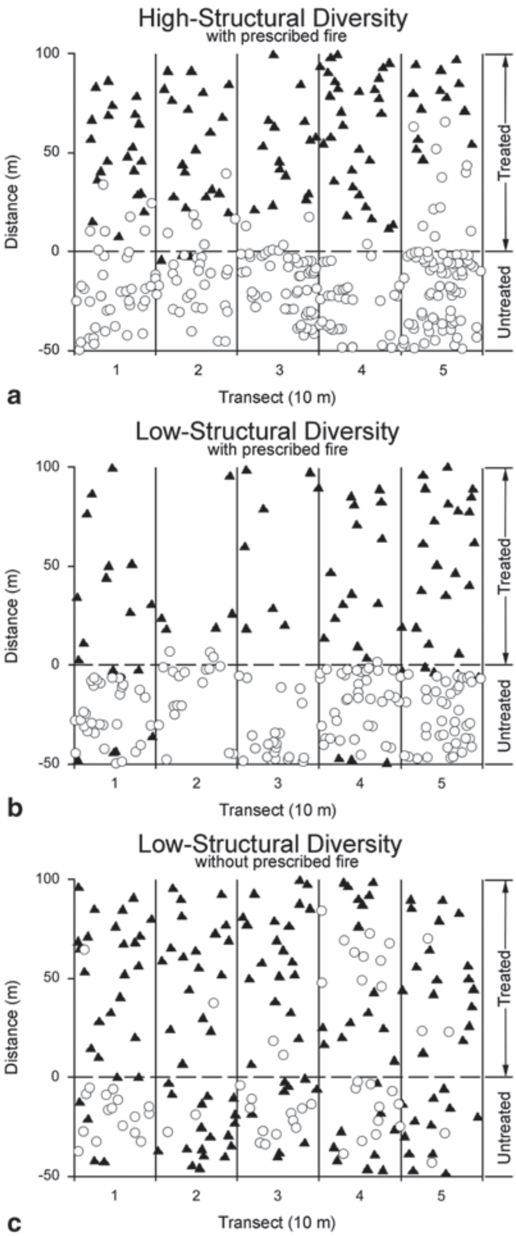
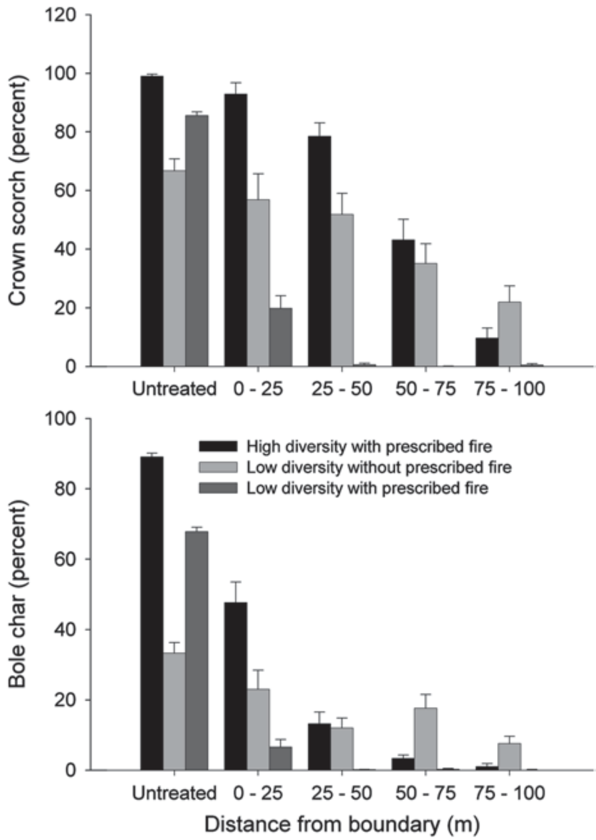


Fig. 6.12 Distribution of living (*solid triangles*) and dead (*open circles*) trees in transects on the border of treatment units within the Cone Fire at Blacks Mountain Experimental Forest shows the reduction in mortality in relation to distance from treatment boundary. (Source: Ritchie et al. 2007)

Fig. 6.13 Rates of crown scorch and bole char (with 1 standard error bar) decreased on the interior of treatment units at Blacks Mountain Experimental Forest; high levels of char were limited to the boundary. (Source: Ritchie et al. 2007)



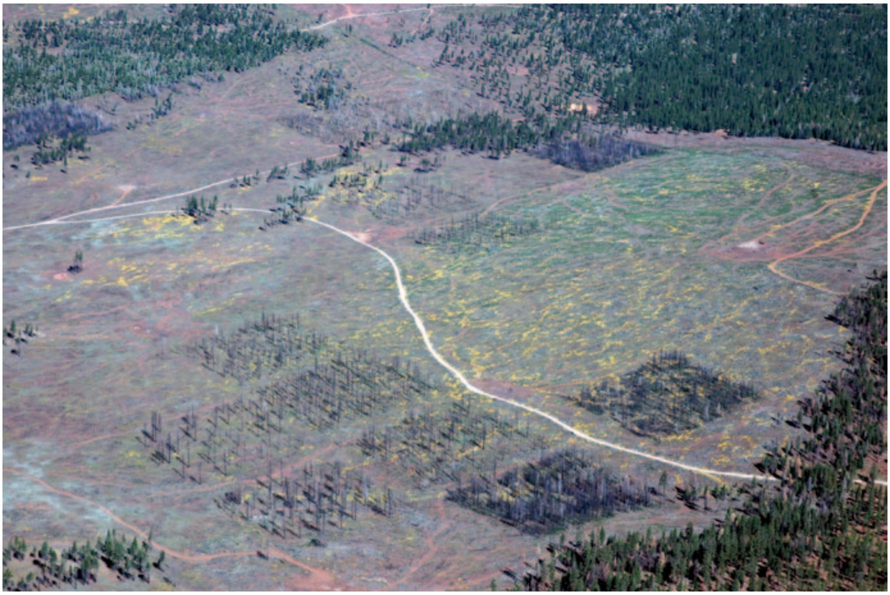


Fig. 6.14 Variable-retention salvage study plots in the Cone Fire at Blacks Mountain Experimental Forest after the Cone Fire. (Photo by M. Ritchie 2005)

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