Post-fire Monitoring of Ponderosa Pine (*Pinus ponderosa* P & C Lawson) Mesa Verde National Park, Colorado



Lynn Moore, Botanist
Windom Floristics
Durango, CO
18 April 2005

Post-fire Monitoring of Ponderosa Pine (*Pinus ponderosa* P & C Lawson) Mesa Verde National Park, Colorado

Botanist Lynn Moore

Windom Floristics

361 So. Camino Del Rio #222, Durango, CO 81303. E-mail: lmflora@earthlink.net, Telephone: 970-749-5720, Fax: 970-385-9552.

Abstract

Post-fire monitoring of ponderosa pine in Mesa Verde National Park following the Bircher Fire in 2000 found that 76% of the ponderosa pine trees in the park were destroyed. The greatest survivorship occurred where trees were protected by a lack of surface fuels, such as those trees located on open bedrock or trees located in areas of relatively low burn severity. Seedlings were found in only one location, reflecting the high burn severity and on going drought conditions present at MEVE during the years following the fire. Sites with the greatest potential to undergo recruitment were identified. Ponderosa pine stands at risk for future fire activity were noted.

Keywords: Mesa Verde National Park, Ponderosa Pine, *Pinus ponderosa*, Post-fire Monitoring

Cover photos:

Center: Bobcat Canyon (50-2)
Clockwise from top left: Morefield Homestead (50-4), East Rim (50-9), Prater Ridge (50-43), Prater Ridge (50-38).

Table of Contents

Abstract	ii
Table of Contents	iii
List of Tables	iv
List of Figures	v
Introduction	1
Methods	3
Results	5
Discussion	9
Survivorship of Ponderosa Pine in MEVE	9
Reestablishment of Burned Ponderosa Pine Stands in MEVE	15
Ponderosa Pine Stands at Risk from Future Fire Activity	18
Recommendations	19
Acknowledgements	21
Literature Cited	22

List of Tables

Table 1. Known ponderosa pine sites in MEVE showing historic number of trees per site and total number of trees in the Park. 24

Table 2. Identifying characteristics of ponderosa pine trees at different life stages. Taken from Huckaby and others (2003). 25

Table 3. Historical and 2003-2004 survey results of ponderosa pine sites in MEVE showing site number, number of live trees, visit status (yes/no), general location, and geologic formation. 26

Table 4. Summary of geologic substrates by site, showing number of trees per formation and number of sites per formation. Constructed from field observations and data provided by Marilyn Colyer. 28

Table 5. Summary of all trees surveyed in 2003-2004 showing height class, number of trees per height class (feet), diameter class (inches) within each height class, and number of trees per diameter. 30

Table 6. Summary statistics of tree height (ft), dbh (in), and needle growth (in) by site and park wide. Includes average, maximum, minimum, and standard deviation. 31

Table 7. Summary of estimated age of ponderosa pine trees per site, includes number of trees per site and average height (ft) and average dbh (in) per age class. 33

Table 8. Comparison of trees with identifiable past tags showing 2004 height (ft) and diameter (in), the year the data was previously recorded, past height (ft) and diameter (in) and the net change in height (ft) and diameter (in). 34

Table 9. Summary of past reproductive activity, showing site number, number of trees per site, percent crown of woody cones greater then two years old (cone class), number of trees per cone class, and average height (ft) and diameter (in) per cone class. 35

Table 10. Summary of current reproductive activity, showing site number, number of trees per site, percent crown of current cone crop or flowers (cone class), number of trees per cone class, and average height (ft) and diameter (in) per cone class. 37

List of Figures

Figure 1. Monthly climate averages for Mesa Verde National Park, 1948-2004. (WRCC 2005). 3
Figure 2. Typical gnarled decumbent tree growing in bedrock. Site 50-38 WF-15. 10
Figure 3. Decumbent, tree with cones at site 50-43 WF-6. 11
Figure 4. Fire history of MEVE showing locations of ponderosa pine stands. Taken from Floyd-Hanna et. al. (2000). 13
Figure 5. Bircher Fire burn severity map showing ponderosa pine sites. 14
Figure 6. Seedling site at the 50-4 ponderosa stand, showing proximity to cone producing tree. 16
Figure 7. Seedlings at site 50-4 illustrating litter on top of burned ground. 17
Figure 8. Map 1, Ponderosa pine sites in MEVE Attached

Introduction

Mesa Verde National Park (MEVE) has been of interest to botanists and ecologists because of its unique diversity, species composition, and vegetation structure. Of particular interest is the contribution of ponderosa pine (*Pinus ponderosa* P. & C. Lawson) to the overall vegetation composition of Mesa Verde National Park. In Mesa Verde, the ponderosa pine stands are restricted to certain substrates on the cuesta. Marilyn Colyer found that the stands were found only on the white beach layer of the Cliff House Sandstone, the Point Lookout Sandstone (including alluvium), and the paleosol layer of the Menefee Formation. In the adjacent ecosystem, the cuesta ponderosa pine occurs on the glacial gravels, the Greenhorn member of the Mancos Formation, and on Dakota Sandstone derived soils. The red loess soils common on the mesa tops do not support ponderosa pine. The ponderosa pine on the Mesa Verde cuesta are considered Pleistocene relicts (Marilyn Colyer, personal communication MEVE). Environmental conditions exist that would predict an ecotonal gradient from piñon-juniper woodlands to ponderosa pine, a gradient common to the Southwest. This gradient is for the most part absent in MEVE where Douglas-fir dominated stands intermix with piñon-juniper.

Ponderosa pine makes up less than 0.007% of the vegetation of MEVE. This approximation is based upon GIS vegetation mapping projects accomplished in 2003 and 1996 (Floyd et al. 1996). Vegetation cover types constructed by ecologists in 1996 estimated 1.07 ha (2.65 acres) of ponderosa pine in the Park; this may be an underestimate as it is derived from a preliminary mapping project and does not include the Bobcat Canyon population (Floyd et al. 1996). The GIS office at MEVE recently delineated 1.54 ha (3.8 acres) of ponderosa pine using infrared imagery (Gardiner and Loy 2003). This total is also an approximation, because the post-fire survivorship of *Pinus ponderosa* has yet to be determined.

The climate at MEVE is typically dry with mild winters and warm summers. The MEVE 50-year climate average is approximately 45.21 cm (17.8 in) of precipitation per year with an average maximum temperature of close to 32.22 °C (90 °F) and a low temperature average between -12 and -6.7 °C (10-20 °F) (WRCC 2005). Figure 1 is a graph illustrating the mean monthly precipitation and maximum and minimum temperatures from 1948-2004 (Figure 1). Drought information complied by the USDA Drought Monitor website reported severe to exceptional drought conditions in mid-July from the years 2000 to 2004. This classification is based upon regional climate data and actual drought conditions in MEVE may have been more

or less intense (USDA 2005). When the Bircher Fire of 2000 hit in July, the Park had received 19.61 cm (7.72 in) of precipitation for the precipitation year (October 1, 1999 to July 31, 2000) or 57 percent of normal (Marilyn Colyer, personal communication). This was the first year of the five year drought.

The MEVE Natural Resource Office invested several years (1984-1992) into documenting and monitoring the ponderosa pine populations in MEVE. They tagged and measured over 600 trees. According to the data provided to the investigator, there were approximately 945 trees located in 45 sites before the fires in 1996 and 2000 including early estimates of the Bobcat Canyon population. According to data provided by the MEVE Natural Resources Office, there are 45 ponderosa pine locations in the Park. Data gathered by MEVE biologists between 1984 and 1992 and compiled during this study resulted in an estimate of approximately 945 ponderosa pine trees in MEVE before the fires. Table 1 is a list of historic ponderosa pine sites including number of trees per site before the fire, number of trees per site after the fire, and total number of trees known in MEVE (Table 1) There are an additional 16 ponderosa pine sites located on Ute Mountain Ute Tribe land and Bureau of Land Management land adjacent to MEVE. These sites were not included in the present study but are considered part of the greater historical ponderosa pine population on the cuesta.

The purpose of the current monitoring study is to ascertain the survivorship of *Pinus ponderosa* following the recent series of large fires since 1989. Sites were investigated for living trees, saplings, or seedlings that may be present at the sample sites. The Bircher Fire of 2000 is responsible for the majority of damage to the ponderosa pine stands in the Park. Additionally, several sites were burned by the Chapin 5 Fire of 1996 after the vegetation coverage was constructed by Floyd and others (Floyd et al. 1996).

The results of this survey will aid Mesa Verde National Park in managing ponderosa pine stands through answering several important questions; what is the survivorship following the Bircher Fire, what is the probability that the lost stands will reestablish themselves, and which sites are at the most risk for a stand replacing fire.

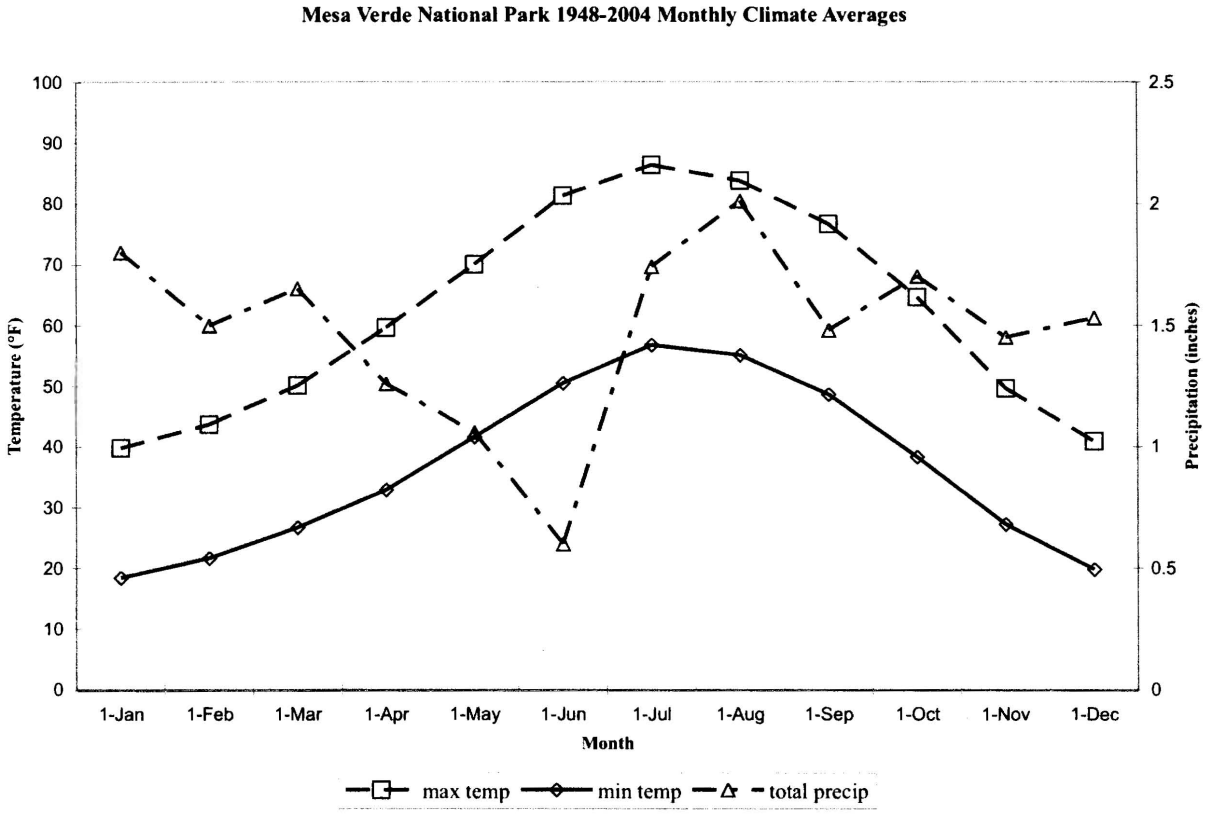


Figure 1. Monthly climate averages for Mesa Verde National Park, 1948-2004. (WRCC 2005).

Methods

The MEVE Natural Resource Office tagged and measured the majority of ponderosa pine trees between 1984 and 1992 (Colyer 2003). Data was gathered for all the large populations except for the Bobcat Canyon population. MEVE biologists measured several statistics for each tree including diameter at breast height (dbh), height, past cone crop, current cone crop, shape, growth (needle length), presence and type of scars, evidence of faunal activity or disease, slope, and aspect. The 2003-2004 ponderosa pine monitoring was accomplished by pedestrian surveys of known ponderosa sites as identified by the Natural Resources Office. The same data was recorded as given above. Height was visually estimated or, when terrain or vegetation cover allowed, was calculated by clineometer using percent slope at 100 feet. Diameter was measured using a dbh tape in centimeters at 1.37 m (4.5 ft) from the base or at half height in trees less than 1.37 m (4.5 ft) tall. Units were converted from metric to standard for use in the tables of this report and to facilitate comparison between earlier data. Additionally, a number of trees

survived with tags previously placed by MEVE biologists allowing a comparison between the current and past data sets. Living trees were tagged, measured, assessed, photographed, and mapped using Trimble GPS.

Age was estimated for each tree based upon visual characteristics as proposed by Huckaby et al. (2003a, 2003b). Huckaby's methods were developed for trees located on the front range of the Colorado Rocky Mountains, therefore, some error maybe present for determining the age of the western slope trees in MEVE. The general criteria she developed for estimating ponderosa pine age likely holds true for trees in any location, although the actual age categories in years may differ from place to place. Huckaby and others identified three life stages, young canopy trees <150 years, transitional 150-250 years, and older trees >200 years. An additional age class was created for the purpose of the MEVE monitoring (<50 years). It is applied to saplings, seedlings, and trees of known age. Huckaby and others constructed a table identifying characteristics of the life stages of ponderosa pine; it is reproduced here to show how the trees were aged in this study (Table 2). For more detailed information about estimating age of ponderosa pine, see the original work by Huckaby and others (2003a, 2003b). The term "extirpated" is used to indicate a population as totally destroyed, i.e. no signs of survivorship. Trees of unknown age are from sites not visited, but located in areas where no fires occurred and it is presumed these trees are extant.

The reproductive effort of MEVE ponderosa pine trees was assessed in several ways. Past reproductive effort was determined through open, woody cones on the tree or on the ground surrounding the tree, indicating that a cone crop had occurred at least two years ago. This past reproductive effort was recorded as none or as a percent of the crown of each tree. Closed cones, those that will open in the fall of the current year, and flowers (assumed to produce a cone crop next year) were recorded as a percent of the crown of each tree. Flowers were identified in the field notes when possible. Percent cover of flowers is difficult to record on large trees due to problem of seeing the flowers within the needles at the tops of the trees. The ground within a 100-foot radius under trees with past or current cones was searched for any indication of seedlings.

Each tree was assessed for general health and any indication of faunal damage or disease. All live trees surveyed in this study were tagged using flexible aluminum tags nailed into the bark at breast height. Tags were labeled with the site number and a tree number. Trees with historical tags were left unchanged and noted in the records with the original tree number. New

tags were numbered beginning with WF (Windom Floristics) to indicate the investigator and specific survey. Additionally, each tree was mapped using Trimble GPS and differentially corrected to determine an accurate position of each tree within the site. The mapping was done to aid future investigators in locating individual trees. The mapping was augmented with detailed location notes made for each tree. The majority of tags that were placed by MEVE biologists in 1984-1992 were lost during the Bircher Fire. An attempt was made here to provide a means to relocate trees regardless if the tags survive or not.

Results

During this post-fire monitoring study 35 of the 45 known sites were visited. Map 1, attached to the report, shows the location of all 45 ponderosa pine sites in MEVE. Yellow symbols show survey sites with live trees, purple symbols show survey sites with no living trees, and green symbols show sites that were not surveyed. The results of the post fire monitoring collected data on 219 live trees. Additionally, there are five live trees located in unburned areas that were documented in the past by MEVE biologists and are associated with eight of the un-surveyed sites. These include one tree from site 50-44 (West Chapin Spur), two trees from 50-17 (East Escarpment below the Vulture cliffs), and two trees from 50-22 (Long Mesa). This brings the total number of live ponderosa pine trees in MEVE to approximately 224. Survivorship is estimated to be 24% of the original population. The complete data set for all trees surveyed in 2003-2004 is located in a separate data base and hardcopy accompanying this report.

The remaining five un-surveyed sites are presumed to have no living trees. Site 50-66 (Whites Canyon) is the location where a ponderosa pine limb was discovered before the fire by the Natural Resource Office. Two of the un-surveyed sites are located on Prater Ridge (50-36 and 50-37). The 50-36 site was overlooked, it is located near the Prater Ridge Trail where the investigator traveled past on several occasions. The investigator was unaware of the presence of a site in that location and never observed a living tree or snag in passing. The location is in an area where the Bircher Fire burned rather intensively and it is assumed that the tree was destroyed. The 50-37 site was originally documented as one dead tree. Site 50-58 is located in the School Section Canyon and was likely burned by the Bircher Fire. Site 50-34 (Chickaree Canyon) reports the location of one dead tree above the aspen site. For a summary of all sites showing both historical and 2003-2004 visit status, general location, number of trees per site and geologic substrate (Table 3).

There was some confusion concerning the location and labeling of two ponderosa sites. For the purpose of this report and to aid future survey work, two of the stands were renamed and one of the site numbers retired. The stands in question are located on west Prater Ridge. One site is located at the head of the check dam side canyon and includes two clusters of trees situated in the northwest and northeast forks of the canyon. This site will be numbered 50-43; it includes both clusters of trees and the tags on site are labeled 50-43. The stand that is located on the bedrock slightly northeast of the Montezuma Valley Overlook and situated directly above and to the west of cultural site #3844 is labeled site 50-70. The trees at this site are labeled 50-UN (un-numbered) due to confusion during the field season. The site number 50-33 is retired, as it could not be reconciled with the current mapping and available data.

The majority of ponderosa pine populations in MEVE occur on the Point Lookout Sandstone (25 sites, see Table 4) and the Menefee Formation (11 sites). The Morefield Homestead population (50-4) is mapped on Quaternary colluvium, however this substrate is derived from parent materials primarily consisting of Point Lookout Sandstone and Menefee Formation. The Wetherill Mesa sites (50-2, 50-24, and 50-25) are growing on the white beach deposits of the Cliff House Sandstone as well as those populations located along the southern section of the Park and on Long Mesa (50-22, 50-26, 50-50, 50-56, and 50-44).

More than half of the trees are < 9.14 m (30 ft) tall (70%, 152 trees), with 32% (69 trees) < 3 m (10 ft) tall and 38% (83 trees) between 3.35 and 9.14 m tall (11 and 30 ft).The majority of trees alive in the Park (38%) are between 3.35 and 9.14 m tall (11 and 30 ft). Table 5 summarizes the height and diameter for all trees surveyed in the Park. The table shows height class (ft), diameter class (in) within each height class, and the number of trees in each class. These size classes were chosen because the data showed natural breaks and because identifying trees over 9.14 m (30 ft) tall is important for predicting seedling recruitment (Bonnet et al. 2004).

Most of the smaller trees (< 3 m or (10 ft) had diameters 12.7 cm (< 5 in), a few of these had larger diameters and were generally trees located on exposed bedrock. Some of the trees between 9.14 m tall (11 and 30 ft) had small diameters (<12.7 cm or 5 in), but the majority of trees in this size class had diameters between 15.24 and 38.1 cm (6 and 15 in). Trees between 9.45 and 18.29 m (31 and 60 ft) tall had an almost equal number of diameters 15.24 to 38.1 cm (6 to 15 in) and 40.64 to 63.5 cm (16 to 25 in) with a few trees having larger diameters of 66.04 to 88.9 cm (26 to 35 in). Trees over 18.29 m (60 ft) tall generally had diameters over 66.04 cm

(26 in), with half of the trees in this size class recording a diameter of > 91.44 cm (> 36 in) (Table 5).

The largest tree in MEVE is approximately 36.58 m (120 ft) tall with a diameter of 107 cm (42.1 in) and is located at site 50-4 (Morefield Homestead). This tree was estimated to be >200 years old. This tree is one of those that was able to be identified as a tagged tree through its distinctive broken limbs. Measurements taken 20 years ago in 1984 recorded the tree to be 22.86 m (75 ft) tall showing 13.72 m (45 ft) of growth. This growth rate may not be accurate due to differences of methodology in estimating height. This tree had a diameter of 121.92 cm (48 in) in 1984 and 107 cm (42.1 in) in 2004. The net loss of diameter is likely due to the loss of bark following the Bircher Fire. This tree was blackened and appeared to be shedding bark at 1.37 m (4.5 ft) from the base. The smallest tree in the Park is approximately 20.32 cm (8 in) tall with a diameter at half height of approximately 1.52 cm (0.6 in), growing in the bedrock above North Valley on Prater Ridge (50-38). The smallest diameter (1.02 cm or 0.4 in) measured in the Park was for a sapling located in Bobcat Canyon (50-2). A summary of tree height, diameter, and needle length per site for the 2003-2004 survey can be found in (Table 6). Data presented in the tables are given in English measurement. The mean length of needles on ponderosa pine trees in MEVE is 13.72 cm (5.4 in), ranging from less than 1.2 cm (0.5 in) to 20 cm (8 in).

Estimates of ponderosa pine tree age found individuals in all age classes. The majority of trees were estimated to be <150 years old (72%, 158 trees), with 10% of the trees <50 years old (22 trees), 12% between 150 to 250 years old (26 trees), and 6% >200 years old (13 trees). The Bobcat Canyon (50-2) population consisted of trees of all ages with the majority of trees in the <150 year class. The Morefield Homestead (50-4) population also consisted of trees of all age classes, with the majority of trees likewise found in the <150 year old age class. The Morefield Homestead population was damaged in the Bircher Fire where as the Bobcat Canyon population has not burned in recent history. For a summary of estimated age class per site, number of trees per age class and average height (ft) and diameter (in) per age class see Table 7.

Several trees were identified from past monitoring tags. A comparison showing net change in height and diameter is given in Table 8. The table summarizes 2004 height and diameter, the year the data was previously recorded, past height and diameter and the change in height and diameter. Negative numbers in diameter reflect either a loss of bark from the Bircher Fire, an error in measurement, or error in the identification of site or tree. A loss in height is

either due to the top breaking off, an error in measurement, or error in the identification of site or tree.

Reproductive ability of ponderosa pine in MEVE was noted in two ways. First, evidence of past reproduction through presence of open woody cones in the crown (percent of crown) or on the ground underneath the tree (recorded as default of 1-10%) was recorded. Secondly, evidence of current reproductive activity through percent crown of closed cones (current year seed crop) or female flowers for next years seed crop was noted. Two tables were constructed to consolidate information about past and current reproductive activity. Table 9 summarizes past reproductive activity including site number, number of trees per site, summary of cone classes per site (percent crown), number of trees per cone class, and the average height and diameter of trees within each cone class. Table 10 reports the same information as Table 9 but focuses on current reproductive activity. Results showed that 37% (80 trees) of the 219 trees show evidence of past reproductive output and 39% (86 trees) show evidence of current reproductive output. There are nine trees (4%) that showed indication of past reproduction but no evidence of current reproductive activity and fifteen trees (6%) showing no evidence of past reproduction but were noted to have closed cones or flowers showing current reproductive activity. Trees that show both past and current reproductive ability make up 32% (71 trees) of the 219 surveyed trees.

The survey for seedlings within a 100 foot radius of trees showing reproductive ability (past or current cone activity) resulted in a single occurrence of 10 seedlings located underneath one tree in the Morefield Homestead site (50-4).

Discussion

The results section presents a great deal of information concerning the ponderosa pine stands in MEVE. The most useful information to MEVE focuses on the answers to the following questions; what is the survivorship of ponderosa pine following the Bircher Fire, what is the probability that the lost stands will reestablish, and which sites are at the most risk for a stand replacing fire.

Survivorship of Ponderosa Pine in MEVE

There are approximately 224 ponderosa pine trees alive in MEVE at this time. Most of the larger trees between 9.45 and 18.29 m (31 to 60 ft) in the Park are located along the base of the cliff forming sandstone where moisture is greater and the soils can be deep yet well drained. A few of the larger trees have become established in depressions in the bedrock on top of the rims, mostly in places where soils have developed and access to moisture through cracks is available to the trees. The largest trees in the Park (> 18.29 m, 60 ft) are located in the bottom of the canyons where sandy alluvial soils are deeper and the moisture content is greater. Several of the trees at site 50-4 were planted following the construction of the tunnel in 1957. These trees are a different genotype then the native stands located elsewhere in the Park (Marilyn Colyer, personal communication). These trees are approximately 50 years old and one individual doubled its height and tripled its diameter since 1984 (50-4, tree 15, Table 8).

A small portion of the surviving trees are decumbent (23 trees). These gnarled little trees primarily occur in the drier sandy soils formed in the cracks of the bedrock along the rim of the canyons (see Figure 2). These little trees were found on Prater Ridge (50-3, 50-43 and 50-70, and 50-38), Chickaree Canyon (50-1), and Bobcat Canyon (50-2). On Prater Ridge several of these trees are relatively large with thick diameter trunks. One of these trees was observed producing flowers (Figure 3). Two of the larger historical populations were survived by only one or two decumbent individuals. The Chickaree Canyon stand (50-1) consisted of approximately 150 trees before the fire. At the time of the current survey two trees were reported alive, one of which is a damaged small tree and the other is a decumbent tree that grew approximately six inches since 1987. The 50-3 (East Prater Ridge) population numbered over 70 trees in 1984 and is solely survived by one decumbent tree. It is speculated that these trees can be quite old, but there is no way of knowing without examining tree ring data.

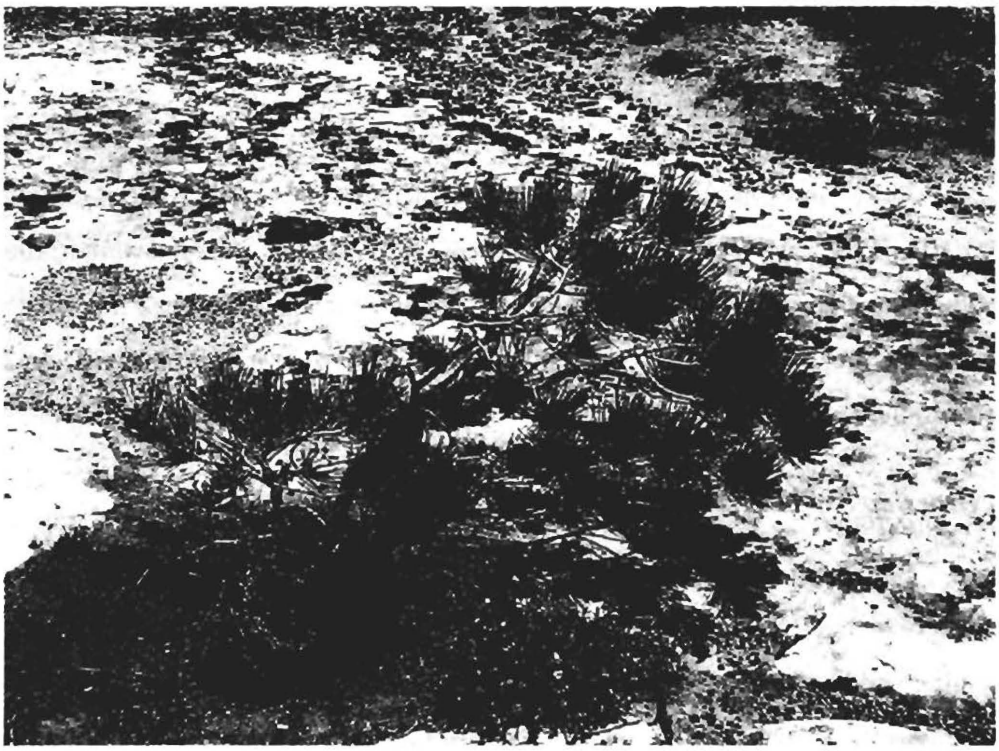


Figure 2. Typical gnarled decumbent tree growing in bedrock. Site 50-38 WF-15.

The general health of the remaining trees in MEVE is good. There are some trees that have dying tops likely due to damage from the fire. There was no indication of beetle activity. Woodpecker holes were common on the larger trees throughout the Park. Some of the saplings had a cottony scale in the axils of the branch tips and also appeared to have the bark stripped off some of the branches and bole. This is likely due to browse by deer, elk, or horse (at site 50-4). The fact that the fire scorched trees have lived four years following the fire is a good indication that these trees will likely continue to survive. Some trees had yellowing needles and/or needles with spots, likely due to drought conditions.



Figure 3. Decumbent, tree with cones at site 50-43 WF-6.

The Bircher Fire burned from July 20, 2000 to August 3, 2000 burning over 8903 ha (22,000 acres). The greatest loss of ponderosa pine trees occurred on July 22-23, 2000 when the Bircher Fire consumed over 5662 ha (14,000 acres), destroying 76% of the ponderosa pine trees (BAER 2000). The greatest survivorship occurred where trees were protected by a lack of surface fuels, such as those trees located on open bedrock, grasslands, or trees located in areas of relatively low burn severity, such as the Morefield Homestead population (50-4). There is no doubt that the Bircher Fire significantly affected the ponderosa pine population in MEVE. Only 24% of the original 942 trees are present in MEVE at the current time and 21 ponderosa stands were extirpated as a result of the Bircher Fire. This high mortality rate is a result of high burn severity in combination with the fact that ponderosa pine was not a common vegetation type in the Park to begin with.

Ponderosa pine is considered a fire-enhanced species with an average fire-turnover time of ca. 5 to 30 years (Howard 2003). It is well adapted to low severity surface fires through its thick bark and greater distance from the ground to the lower limbs of the crown. Seed germination is enhanced by fire through reduction of litter, post-fire nutrients, and reduced competition (Howard 2003). In MEVE, the lack of natural fires over the last 75 years has increased ladder fuels adjacent to the existing stands and eliminated favorable post fire

conditions. In the case of the Bircher Fire, the increased ladder fuels combined with the low fuel moisture due to the drought, contributed to the high mortality of ponderosa pine in MEVE. Since the ponderosa stands are restricted to well drained soils types and the distance between sites is 0.8 to 3.22 km (0.5 to 2 miles) some of the extirpated sites may never recover.

The fire history of MEVE has been a focus of research by Floyd-Hanna and others (Floyd-Hanna et al. 2000). They were able to establish a turnover time of ca. 100 years for the mountain shrub community. Their efforts resulted in developing spatial data of the fire history of MEVE. When the spatial data from this survey is placed over the fire history coverage by Floyd-Hanna and others, the approximate time that these ponderosa pine stands last burned can be estimated. Figure 4 shows the ponderosa sites of MEVE overlaid on the fire history map. Most of the stands previously burned in 1870, some in 1825, 1860, and one each in 1840 and 1825. None of these past fires could rival the extent of the Bircher Fire. Based on these past dates and the 100-year average turnover time, these stands were due to burn at any time. It is possible that the 100-year average turnover time may contribute to the relative rarity of ponderosa pine in MEVE, due to the increased fire severity with a longer interval in which ladder fuels can accumulate.

The Floyd-Hanna and others (2000) believed that low-severity surface fires were never extensive. They found little evidence of fire-scarred wood in the piñon-juniper woodland zone of the Park. However, low-severity surface fires have occurred in the ponderosa pine as evidenced by the larger trees in upper Bobcat Canyon. Several of the larger trees located near the head of Bobcat Canyon, including the tree pictured on the cover page of this report had fire scars.

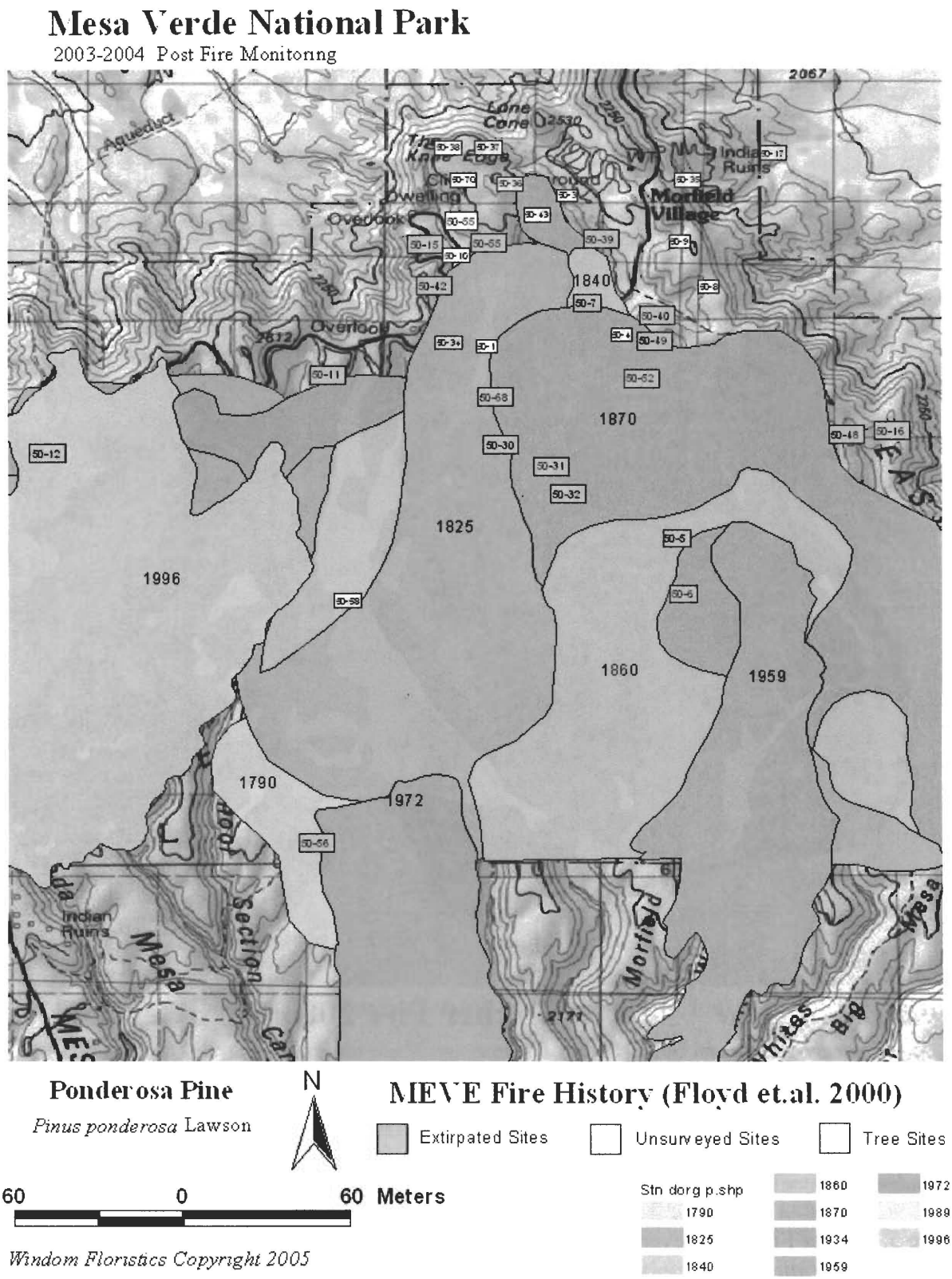


Figure 4. Fire history of MEVE showing locations of ponderosa pine stands. Taken from Floyd-Hanna et. al. (2000).

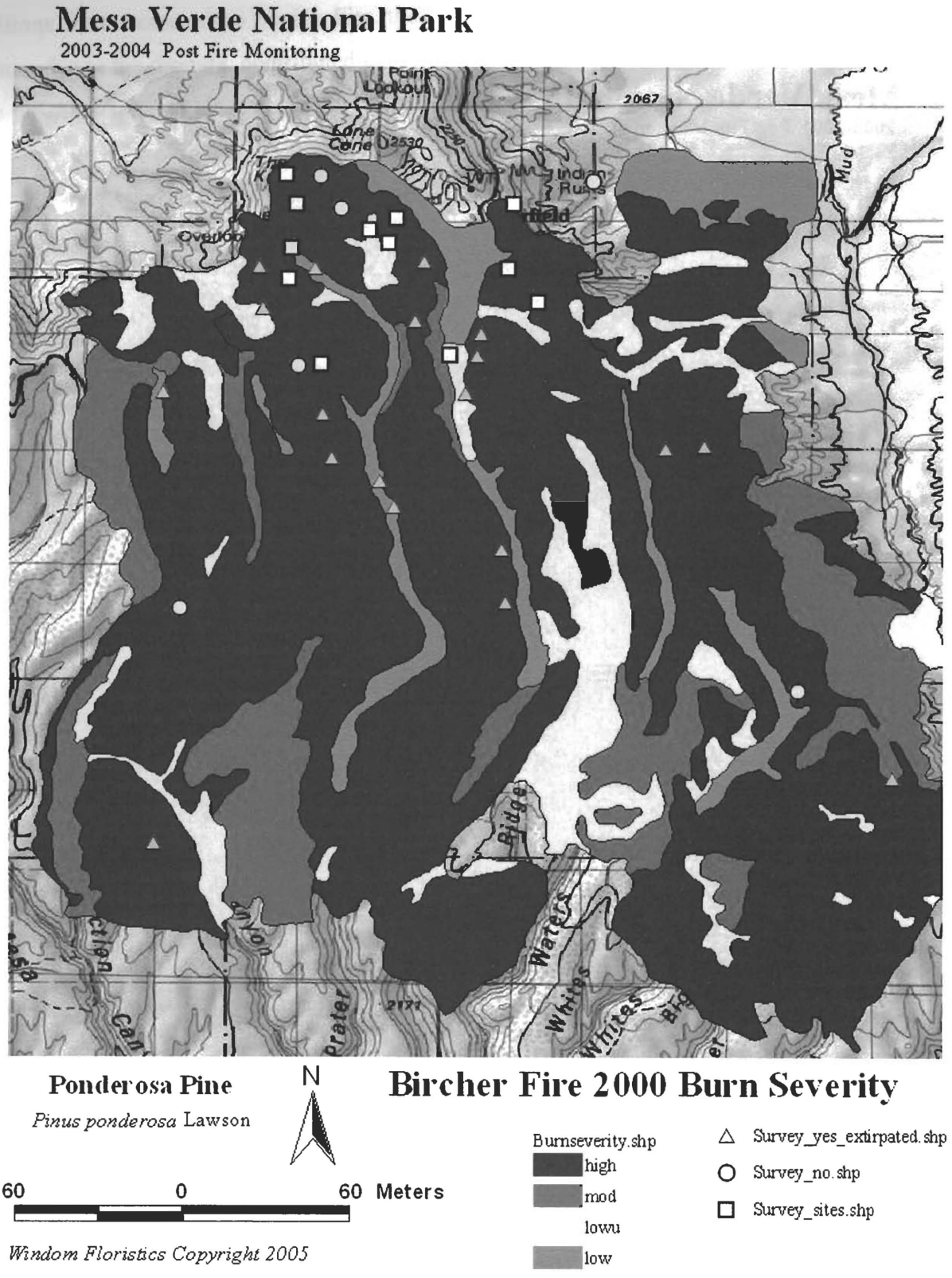


Figure 5. Bircher Fire burn severity map showing ponderosa pine sites.

Figure 5 is a burn severity map showing location of ponderosa pine sites in the Bircher Fire burn area (Loy 2005). Note that some of the survey sites (yellow squares) are located within the high-severity areas. The trees that survived in these locations were situated on the western edge of Prater Ridge and the East Rim and were protected by the bedrock through a lack of surface fuels. This map does not show the small patches of unburned vegetation but it generally matches what was observed in the field.

Reestablishment of Burned Ponderosa Pine Stands in MEVE

It is very unfortunate that survivorship following the fire is so low (24%). What is more significant is the fact that only one small cluster of ponderosa seedlings was discovered over the course of this survey. There was a study done by United States Forest Service biologists in the Black Hills investigating the spatial distribution of ponderosa pine seedlings within burned areas (Bonnet et al. 2004). The Jasper Fire of 2000 burned over 32,000 ha (81,000 acres) in the Black Hills National Forest. The Jasper Fire was very patchy, creating a mosaic of unburned ponderosa pine stands surrounding and adjacent to burned patches of ponderosa pine. The Bircher Fire showed some patchy patterns with occasional small patches of Douglas-fir and piñon-juniper scattered throughout the burn area. Unfortunately 76% of the ponderosa pine trees were completely destroyed, limiting the number and size of unburned areas of ponderosa pine important for recruitment.

The Black Hills biologists found that the greatest seedling densities occurred within 0 to 24 m (0 to ca. 75 ft) from unburned patches showing a form of edge affect. They also found correlations of higher seedling densities where there was a greater abundance of trees larger than 10 m (30+ ft). Other correlated environmental gradients found to be significant were the presence of scorched litter (such as needles) on top of burned ground, low vegetation cover, and low floristic richness. Ponderosa pine seedlings prefer a mineral seed bed with loose, un-compacted soils that tend to hold moisture and lessen obstructions for emergence. Soil beds following a fire generally have these characteristics, except where the intensity of the fire was great. In this case the fire may completely consume the litter and the soil bed may develop a fire-induced water impermeability. The other factor that affects seedling establishment is available moisture during the first two months following germination. Competition can greatly affect soil nutrient and water availability. During a 1987 study to document these affects on ponderosa pine seedlings it was found that the spring and summer drought conditions were

responsible for 90% of seedling mortality during the first growing season following a fire, before any grasses or forbs were established (Elliott and White 1987). The single seedling site discovered in MEVE was found within an area of low burn severity. It was located close to large trees that are producing cones, on a substrate comprised of needle covered burned ground, and low competition in the immediate area. Below are two photographs showing the seedling site and the microenvironment in which they were observed growing in (Figure 6 and Figure 7).



Figure 6. Seedling site at the 50-4 ponderosa stand, showing proximity to cone producing tree.

2002 was the driest year in the 74 years of Park weather records. Even if seedlings had germinated in the fall of 2000 following the Bircher Fire or in the spring of 2001, they may have perished in 2002 when soil moisture was nearly nonexistent and the Park had received only 32% of normal precipitation by the end of May in 2002 (Marilyn Colyer soil moisture station data, personal communication). Additionally, in the late summer of 2003, rodent populations increased and reached a peak in 2004 (Marilyn Colyer, personal communication). If ponderosa seed numbers were high, these rodents may have cached the seeds or if numbers were low immediately consumed the seeds further reducing the germination rate following the Bircher Fire.



Figure 7. Seedlings at site 50-4 illustrating litter on top of burned ground.

The southwest has been ravaged by drought conditions before and since the Bircher Fire. These environmental conditions are likely responsible for the very low seedling presence in the Park. In addition, the lack of edge affect, low numbers of seed producing trees over 30 feet tall, and the lack of suitable substrate has prevented successful establishment of seedlings following the fire. Some of the stands are survived by small decumbent trees. It is possible that these little trees can eventually produce a cone crop, but it is not likely that they will produce enough seed to reestablish a population after a stand replacing fire. The stands that survived because of protection from a lack of surface fuels on the bedrock are generally less then 30 feet tall and the substrate surrounding the bedrock was typically burned with such intensity that no litter cover is available thus rendering the soils less than optimal for seedling establishment. It is possible that with several years of consistent spring and summer rain, several of these stands may still be able to establish seedlings.

The stands with the greatest probability of recruitment, if climate conditions improve, include two on the west side of Prater Ridge (50-43 and 50-38), the East Rim stands (50-8 and 50-9), and the Morefield Homestead population (50-4). These stands all have trees over 30 feet tall and have suitable substrate surrounding the bedrock and in the deeper depressions. The Morefield Homestead (50-4) population has the greatest chance of reestablishing itself. It is not known exactly how many trees were present at 50-4 before the Bircher Fire because the

historical survey was incomplete. This stand has the best conditions due to the low fire severity, relatively better substrate conditions, and the presence of healthy trees greater than 30 feet tall capable of producing seed. It must be noted that although the conditions seem optimal at this site, chances for seedling establishment in the future may be hindered by competition from grasses and forbs.

Ponderosa Pine Stands at Risk from Future Fire Activity

There is no hard and fast rule that says a stand will not burn again in the near future. Any of the stands that burned during the Bircher Fire could potentially be burned again in the immediate future. If drought conditions persist and climate factors favor increased lightening strikes it is conceivable that fire could burn the stands that survived the Bircher Fire. Vegetation cover from shrubs such as *Quercus gambelii* (Gambel oak) produce large amounts of litter that can be volatile if the conditions are very dry. Additionally, reseeded grasses and invasive species provide a fast burning fuel source that could ignite and cause further fire damage to the remaining ponderosa pine stands. Nonetheless, it is less likely that these stands will be burned again in the near future.

One stand exists that is at great risk for a stand replacing fire, the Bobcat Canyon ponderosa pine site (50-2). This population is the largest unburned ponderosa pine stand in MEVE. The stand is primarily situated along the east side of the canyon along the base of the cliff forming sandstone. Individuals are also present in the cracks of the bed rock on top along the east rim, a few along the west rim, and several very large and old trees are situated at the head of the canyon just below the spring. It consists of ca. 69 trees from saplings to trees older than 200 years. Fire dating has not been accomplished on this stand, although the presence of fire scars and a burned snag indicate that the trees located in the upper canyon have survived a fire. No formal study has been done to determine if this population is a climax stand. It does have trees in all age classes and these trees appear to be grouped in clusters of like age throughout the canyon. Some of the trees show that fire has been a past factor (well-defined fire scars) and a few of the trees are quite large and old. The trees in this stand seem healthy for the most part, although a few of the larger and older trees were infested with ants and one tree appeared to have a rotten center. There was no indication of beetle activity but woodpecker holes were common on the larger trees.

The under story in Bobcat Canyon consists of extremely dense thickets of *Quercus gambelii* (Gambel oak). Under the thickets is a very thick layer of leaf litter along with dead branches forming a significant amount of coarse woody debris. Some of the larger ponderosa pine trees along the base of the Upper Cliff House Formation on the east side of the canyon have developed very thick piles of needle litter and duff, sometimes a foot or more thick. There are occasional gaps in the thickets, mostly located toward the southern end of the stand. Because of the dense oak thickets and the presence of coarse woody debris and thick needle litter, this site is at considerable risk of a stand replacing fire.

Recommendations

This survey focused upon ascertaining the survivorship and health of ponderosa pine trees in MEVE following the Bircher Fire. The results of the survey are useful in directing future work on ponderosa pine sites in MEVE. An opportunity is presented to contribute to the study of the fire history of MEVE through available tree ring data left by the numerous standing dead ponderosa pine. Additionally, there are a number of decumbent trees that did not survive the fire and these dead individuals provide an opportunity to determine an accurate age of these small trees.

The Bobcat Canyon population could provide fire history data through tree ring data of the standing snag and aging the larger trees with fire scars through bole cores. If all trees in this stand were cored and aged it would be possible to determine if this stand is a climax stand. Due to the history of logging ponderosa pine in southwestern Colorado, this could be one of the few remaining climax stands in the Four Corners Region, warranting further protection. This stand should be considered for thinning or other management. A high-severity wildfire would likely destroy this stand and reduce its chances for reestablishment due to the heavy surface fuels present in the canyon. Thinning of brush or other fuel reduction tool could provide a natural stimulus for recruitment and reduce the chances of losing the only large stand that occurs on the Cliff House Formation. The MEVE fire management team should consider this ponderosa pine stand when developing its fire management plan. The relatively few seedlings, saplings, and young trees warrant protection from fire including prescribed burning. The Bobcat Canyon stand provides habitat for the Mexican spotted owl, a federally listed threatened species (Coon and Wong 2000).

The lack of recruitment following the Bircher Fire is of concern. Drought conditions have contributed greatly to this problem. Sites that have conditions conducive to seedling establishment should continued to be monitored on an annual basis. When climate conditions improve, surveys of the remaining stands should be increased to determine if recruitment is occurring. Planting ponderosa pine seedlings in known stands that could easily be accessed such as the Prater Grade sites, may be considered. These plantings would require additional watering during the dry season in order to increase chances of survival. If plantings could be accomplished during a wet year the probability of survival would increase.

The seedling site at 50-4 should be monitored and protected from trampling and grazing from the Park horses. More than half of the Morefield Homestead stand is located in the Park horse pasture south of the barn.

Acknowledgements

Windom Floristics wishes to thank the Southern Colorado Plateau Network for funding this project. I am very grateful for the warm, and cooperative help received from the Mesa Verde National Park employees. Allan Loy took time from his busy schedule to provide species, water site, and various fire related shape files as well as assistance in acquiring sensitive data. Alisa Gardiner kindly provided a shape file of the geology of the Park. The Natural Resources office deserves my gratitude for all the support they provided. George San Miguel acquired the necessary research and back country permits and provided a radio for field use. Ed Jordan provided field assistance and generously shared his knowledge of forestry. Brandy Randall's assistance in the field was appreciated. Without a doubt, I am most grateful to Marilyn Colyer. Her vast knowledge of the natural history of Mesa Verde National Park spans decades, and few biologists in the Park have the experience that Marilyn has. The information and observations that Marilyn has recorded over the years provided vital support in the relocation and logistics of accessing the back country of the Park. Without Marilyn's detailed records of the ponderosa pine sites the results would not be as accurate or significant. Several people reviewed this report contributing to the quality of the manuscript, including Lisa Thomas, Anne Cully, George San Miguel and Marilyn Colyer. I am very grateful to my family/field crew who provided logistical support and company during the field season and patients during the report phase.

Literature Cited

BAER. 2000. Burned area emergency rehabilitation plan for the Bircher fire in Mesa Verde National Park. Unpublished spatial data available from Mesa Verde National Park United States Department of the Interior.

Bonnet, V. H., A. W. Schoettle, and W. D. Shepperd. 2004. Spatial distribution of ponderosa pine seedlings along environmental gradients within burned areas in the Black Hills, South Dakota. USDA Forest Service Proceedings RMRS-P-34, Fort Collins, CO.

Colyer, M. 2003. Baseline data of ponderosa pine trees in Mesa Verde National Park, 1984 to 1992. *in.* Mesa Verde National Park, Natural Resource Office.

Coon, C., and F. Wong. 2000. Biological assessment, field season 2000, at ancestral puebloan cliff dwellings in Mesa Verde National Park, Colorado. Mesa Verde National Park.

Elliott, K. J., and A. S. White. 1987. Competitive effects of various grasses and forbs on ponderosa pine seedlings. Forest Science **33**:356-366.

Floyd, L. M., W. H. Romme, and D. D. Hanna. 1996. Vegetation cover types of Mesa Verde National Park spatial data. Data on file at Mesa Verde National Park.

Floyd-Hanna, L., W. H. Romme, and D. D. Hanna. 2000. Fire history and vegetation pattern in Mesa Verde National Park, Colorado, USA. Ecological Applications **10**:1666-1680.

Gardiner, A. M., and A. Loy. 2003. Vegetation cover types of Mesa Verde National Park spatial data. Data on file at Mesa Verde National Park.

Howard, J. L. 2003. *Pinus ponderosa* var. *scopulorum.* In. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Library. Available: http://www.fs.fed.us/database/feis/. (Accessed March 2005).

Huckaby, L. S., M. R. Kaufmann, P. J. Fornwalt, J. M. Stoker, and C. Dennis. 2003a. Field guide to old ponderosa pines in the Colorado Front Range. Gen. Tech. Rep. RMRS-GTR-109, Fort Collins, CO.

Huckaby, L. S., M. R. Kaufmann, P. J. Fornwalt, J. M. Stoker, and C. Dennis. 2003b. Identification and ecology of old ponderosa pine trees in the Colorado Front Range. Gen. Tech. Rep. RMRS-GTR-110, Fort Collins, CO.

Loy, A. 2005. Burn Severity of Bircher Fire 2000, Mesa Verde National Park spatial data. Data on file at Mesa Verde National Park.

USDA. 2005. US Drought Monitor. United States Department of Agriculture. Available: http://drought.unl.edu/dm. (Accessed February 2005).

WRCC. 2005. Daily temperature and precipitation, 30 year average, Mesa Verde National Park. Western Regional Climate Center. Desert Research Institute. Available: http://www.wrcc.dri.edu. (Accessed February 2005).

Table 1. Known ponderosa pine sites in MEVE showing historic number of trees per site and total number of trees in the Park.

Site Number	Pre-fire # Trees per Site	Post-fire # Trees per Site	Site Number	Pre-fire # Trees per Site	Post-fire # Trees per Site
50-1	155	2	50-43	18	17
50-2	75	69	50-44	1	1
50-3	73	1	50-48	3	0
50-4	59	58	50-49	1	0
50-5	1	0	50-50	1	0
50-6	1	0	50-52	1	0
50-7	99	0	50-55	1	1
50-8	41	11	50-56	1	0
50-9	29	6	50-58	1	0
50-10	48	5	50-66	1	0
50-11	4	0	50-68	4	0
50-12	1	0	50-70	1	17
50-13	2	2	50-71	3	0
50-15	48	0			
50-16	77	0	Total Number of Trees	945	224
50-17	2	2	Total Number of Sites	45	
50-22	2	2			
50-24	5	2			
50-25	1	1			
50-26	1	0			
50-30	13	0			
50-31	3	0			
50-32	1	0			
50-33	30	0			
50-34	1	0			
50-35	2	1			
50-36	1	0			
50-37	1	0			
50-38	100	26			
50-39	5	0			
50-40	27	0			
50-42	1	0			

Table 2. Identifying characteristics of ponderosa pine trees at different life stages. Taken from Huckaby and others (2003).

	Crown shape	Live crown ratio	Branches	Trunk shape	Bark	Likely injuries
Old trees (>200 years)	flattened, "bonsai" shape, sparse and open, may be lopsided	small; often fire-pruned	few but large	columnar	smooth, small flakes, pale orange or gray	fire scars, dead tops, broken branches, lightning scars, rot, burls, exposed roots
Transitional trees (150-250 years)	ovoid, flattening on the top, full and rounded	moderate; perhaps half the trunk, beginning to self-prune	fine branches in the interior of the crown dying, longer branches thickening	beginning to lose taper	orange or gray flakes with dark edges, shallow fissures, becoming smoother	relatively few; possibly healed or mostly healed fire scars, lightning scars, mistletoe
Young canopy trees (<150 years)	pointed top, "teardrop" or "Christmas tree" shape, dense foliage	large	many fine branches, dense foliage near the trunk	tapered	large, coarse flakes, deep fissures, dark gray or black with dark orange	very few; possible mistletoe or lightning scars

Table 3. Historical and 2003-2004 survey results of ponderosa pine sites in MEVE showing site number, number of live trees, visit status (yes/no), general location, and geologic formation.

Site Number	Number of Live Trees	Site Visit (Y/N)	General Location	Substrate
50-1	2	Y	Chickaree Canyon	Point Lookout Sandstone
50-2	69	Y	Bobcat Canyon	Cliff House Sandstone
50-3	1	Y	Prater Ridge	Point Lookout Sandstone
50-4	58	Y	Morfield Homestead	Colluvial Point Lookout
50-5	0	Y	Morefield Canyon	Point Lookout Sandstone
50-6	0	Y	Morefield Canyon	Point Lookout Sandstone
50-7	0	Y	Prater Ridge	Point Lookout Sandstone
50-8	11	Y	East Rim	Point Lookout Sandstone
50-9	6	Y	East Rim	Point Lookout Sandstone
50-10	5	Y	Prater Grade Ridge	Point Lookout Sandstone
50-11	0	Y	Head of School Section Canyon	Menefee Sandstone
50-12	0	Y	West Little Soda Canyon	Menefee Paleosol layer
50-13	2	Y	Head of Navajo Canyon	Menefee Paleosol layer
50-15	0	Y	Prater Grade Ridge	Point Lookout Sandstone
50-16	0	Y	Whites Canyon	Menefee Paleosol layer
50-17	2	N	East Escarpment, Below Vulture Cliffs	Colluvial Point Lookout
50-22	2	N	Long Mesa	Cliff House Sandstone
50-24	2	Y	Wetherill Mesa	Cliff House Sandstone
50-25	1	Y	Wetherill Mesa	Cliff House Sandstone
50-26	0	Y	Navajo Watch Tower, Long Mesa	Cliff House Sandstone
50-30	0	Y	Prater Canyon	Menefee Paleosol layer
50-31	0	Y	Prater Canyon	Point Lookout Sandstone
50-32	0	Y	Prater Canyon	Point Lookout Sandstone

*** indicates questionable site number and/or location;**
? indicates unconfirmed substrate

Table 3. comtinued historical and 2003-2004 survey results of ponderosa pine sites in MEVE showing site number, number of live trees, visit status (yes/no), general location, and geologic formation.

Site Number	Number of Live Trees	Site Visit (Y/N)	General Location	Substrate
50-34	0	N	Chickaree Canyon*	Point Lookout Sandstone
50-35	1	Y	Nusbuam cut	Colluvial Point Lookout
50-36?	0	N	Prater Ridge	Point Lookout Sandstone
50-37?	0	N	Prater Ridge	Point Lookout Sandstone
50-38	26	Y	Prater Ridge	Point Lookout Sandstone
50-39	0	Y	Prater Ridge	Point Lookout Sandstone
50-40	0	Y	Morefield Ridge	Menefee Paleosol layer
50-42	0	Y	Chickaree Ridge	Menefee Paleosol layer
50-43	17	Y	Prater Ridge	Point Lookout Sandstone
50-44	1	N	West Chapin Spur	Cliff House Sandstone
50-48	0	Y	Waters Canyon	Menefee Paleosol layer
50-49	0	Y	Morefield Canyon	Point Lookout Sandstone
50-50	0	Y	Big Mesa	Minette dike influence?
50-52	0	Y	Morefield Canyon	Colluvial Point Lookout
50-55	1	Y	Prater Canyon	Colluvial Point Lookout
50-56	0	Y	Moccasin Mesa	Unknown influence
50-58?	0	N	School Section Canyon*	Menefee Paleosol layer
50-66	0	N	Whites Canyon	Menefee Paleosol layer
50-68	0	Y	Chickaree Canyon	Point Lookout Sandstone
50-70	17	Y	Prater Ridge*	Point Lookout Sandstone
50-71	0	N	W. Navajo Canyon	Menefee Paleosol layer
Total Trees	224			
Total Number of Sites		44		

*** indicates questionable site number and/or location;**
? indicates unconfirmed substrate

Table 4. Summary of geologic substrates by site, showing number of trees per formation and number of sites per formation. Constructed from field observations and data provided by Marilyn Colyer.

Specific Substrate	Site Number	Number of Trees per Site
Cliff House Sandstone Beach Deposit		
	50-2	69
	50-22	2
	50-24	2
	50-25	1
	50-26	0
	50-44	1
Total Number of Trees per Formation		75
Total Number of Sites per Formation		6
Colluvial Point Lookout Sandstone influence		
	50-4	58
	50-17	2
	50-35	1
	50-52	0
	50-55	1
Total Number of Trees per Formation		62
Total Number of Sites per Formation		5
Menefee Paleosol layer		
	50-12	0
	50-13	2
	50-16	0
	50-30	0
	50-42	0
	50-48	0
	50-58?	0
	50-66	0
	50-71	0
Total Number of Trees per Formation		2
Total Number of Sites per Formation		9
Menefee Paleosol layer influence or strictly Point Lookout Sandstone		
	50-40	0
Total Number of Trees per Formation		0
Total Number of Sites per Formation		1
Menefee Sandstone layer? or paleosol layer		
	50-11	0
Total Number of Trees per Formation		0
Total Number of Sites per Formation		1
Minette dike influence? or unknown		
	50-50	0
Total Number of Trees per Formation		0
Total Number of Sites per Formation		1

Table 4. continued summary of geologic substrates by site, showing number of trees per formation and number of sites per formation. Constructed from field observations and data provided by Marilyn Colyer.

Specific Substrate	Site Number	Number of Trees per Site
Point Lookout Sandstone		
	50-1	2
	50-3	1
	50-5	0
	50-6	0
	50-7	0
	50-8	11
	50-9	6
	50-10	5
	50-15	0
	50-31	0
	50-32	0
	50-34	0
	50-36?	0
	50-37?	0
	50-38	26
	50-39	0
	50-43	17
	50-49	0
	50-68	0
	50-70	17
Total Number of Trees per Formation		85
Total Number of Sites per Formation		20
Unknown influence		
	50-56	0
Total Number of Trees per Formation		0
Total Number of Sites per Formation		1

Table 5. Summary of all trees surveyed in 2003-2004 showing height class, number of trees per height class (feet), diameter class (inches) within each height class, and number of trees per diameter.

Height Class (ft)	Number of Trees per Height Class	Diameter Class (inch)	Number of Trees per dbh Class
≤ 10	69		
		≤5	64
		6-15	5
11-30	83		
		16-25	5
		≤5	17
		6-15	61
31-60	53		
		16-25	26
		26-35	6
		6-15	21
≥ 61	14		
		16-25	2
		26-35	5
		≥36	7

Table 6. Summary statistics of tree height (ft), dbh (in), and needle growth (in) by site and park wide. Includes average, maximum, minimum, and standard deviation.

Site Number	Number of trees		Mean	Maximum	Minimum	Standard Deviation
50-1	2	Height (ft)	2.5	4.0	1.0	1.5
		dbh (in)	2.2	3.5	0.8	1.4
		Needle Length	4.9	5.9	3.9	1.0
50-2	69	Height (ft)	29.8	85.0	1.0	21.3
		dbh (in)	13.0	40.2	0.4	10.4
		Needle Length	5.7	7.9	0.4	1.1
50-3	1	Height (ft)	1.0	1.0	1.0	0.0
		dbh (in)	1.0	1.0	1.0	0.0
		Needle Length	3.1	3.1	3.1	0.0
50-4	58	Height (ft)	27.8	120.0	1.5	25.6
		dbh (in)	11.5	42.1	1.0	9.9
		Needle Length	5.7	5.9	3.9	0.4
50-8	11	Height (ft)	27.7	50.0	8.0	15.1
		dbh (in)	12.6	24.0	2.6	6.8
		Needle Length	5.2	5.9	0.4	1.5
50-9	6	Height (ft)	28.8	40.0	18.0	8.3
		dbh (in)	12.4	18.1	5.7	4.4
		Needle Length	5.8	5.9	5.5	0.2
50-10	5	Height (ft)	19.0	35.0	2.0	13.8
		dbh (in)	9.4	17.1	1.4	6.5
		Needle Length	5.4	5.9	3.9	0.8
50-13	2	Height (ft)	55.0	75.0	35.0	20.0
		dbh (in)	22.6	34.6	10.6	12.0
		Needle Length	5.9	5.9	5.9	0.0
50-24	2	Height (ft)	12.0	18.0	6.0	6.0
		dbh (in)	13.7	25.6	1.8	11.9
		Needle Length	5.7	5.9	5.5	0.2

Table 6. continued, summary statistics of tree height (ft), dbh (in), and needle growth (in) by site and park wide. Includes average, maximum, minimum, and standard deviation.

Site Number	Number of trees		Mean	Maximum	Minimum	Standard Deviation
50-25	1	Height (ft)	75.0	75.0	75.0	0.0
		dbh (in)	17.7	17.7	17.7	0.0
		Needle Length	5.9	5.9	5.9	0.0
50-35	1	Height (ft)	55.0	55.0	55.0	0.0
		dbh (in)	20.5	20.5	20.5	0.0
		Needle Length	5.9	5.9	5.9	0.0
50-38	26	Height (ft)	15.6	40.0	0.7	14.2
		dbh (in)	7.1	15.9	0.6	5.5
		Needle Length	4.8	5.9	2.0	1.2
50-43	17	Height (ft)	17.8	50.0	2.0	14.1
		dbh (in)	11.0	32.7	3.5	8.2
		Needle Length	4.9	6.3	3.1	1.0
50-55	1	Height (ft)	12.0	12.0	12.0	0.0
		dbh (in)	4.7	4.7	4.7	0.0
		Needle Length	5.5	5.5	5.5	0.0
50-70	17	Height (ft)	8.2	25.0	2.0	5.9
		dbh (in)	5.8	15.6	2.4	3.7
		Needle Length	4.6	5.9	2.0	1.2
All Trees, Park Wide		Height (ft)	24.5	120.0	0.7	21.5
		dbh (in)	11.0	42.1	0.4	9.2
Total Number of Trees	219	Needle Length	5.4	7.9	0.4	1.1

Table 7. Summary of estimated age of ponderosa pine trees per site, includes number of trees per site and average height (ft) and average dbh (in) per age class.

Site Number	Number of trees per Site	Age class	Number of trees per age class	Average height (ft) per age class	Average dbh (in) per age class
50-1	2				
		< 150 years	2	2.5	2.2
50-2	69				
		< 50 years	7	4.1	1.1
		< 150 years	44	24.1	9.2
		> 200 years	8	61.0	31.1
		150-250 years	10	48.3	23.8
50-3	1				
		< 150 years	1	1.0	1.0
50-4	58				
		< 50 years	12	9.1	4.8
		< 150 years	38	23.6	9.0
		> 200 years	4	105.0	39.3
		150-250 years	4	46.3	19.8
50-8	11				
		< 150 years	5	13.0	6.0
		150-250 years	6	40.0	18.0
50-9	6				
		< 150 years	4	24.5	10.7
		150-250 years	2	37.5	15.6
50-10	5				
		< 50 years	1	2.0	1.4
		< 150 years	4	23.3	11.5
50-13	2				
		< 150 years	1	35.0	10.6
		> 200 years	1	75.0	34.6
50-24	2				
		< 50 years	1	6.0	1.8
		150-250 years	1	18.0	25.6
50-25	1				
		150-250 years	1	75.0	17.7
50-35	1				
		150-250 years	1	55.0	20.5
50-38	26				
		< 150 years	26	15.6	7.1
50-43	17				
		< 150 years	16	15.8	9.7
		150-250 years	1	50.0	32.7
50-55	1				
		< 50 years	1	12.0	4.7
50-70	17				
		< 150 years	17	8.2	5.8

Table 8. Comparison of trees with identifiable past tags showing 2004 height (ft) and diameter (in), the year the data was previously recorded, past height (ft) and diameter (in) and the net change in height (ft) and diameter (in).

Site Number	Tree Number	2004 Height (ft)	2004 dbh (in)	Year	Past Height (ft)	Past dbh (in)	Net Height (in)	Net dbh (in)
50-1	107	1.0	0.8	1987	.42	.25	0.6	0.5
50-4	3	15.0	4.1	1984	3	3	12.0	1.1
50-4	11	23.0	6.9	1984	3.5	2.5	19.5	4.4
50-4	12	25.0	8.5	1984	7	2.5	18.0	6.0
50-4	15	30.0	11.8	1984	15	4.5	15.0	7.3
50-4	21	27.0	7.9	1984	17	5	10.0	2.9
50-4	22	30.0	8.1	1984	10	2.5	20.0	5.6
50-4	23	50.0	20.5	1984	32	15	18.0	5.5
50-4	25	25.0	7.9	1984	6	2	19.0	5.9
50-4	29	80.0	36.6	1984	77	42	3.0	-5.4
50-4	38	55.0	29.9	1984	55	32	0.0	-2.1
50-4	4	18.0	5.7	1984	2.5	4	15.5	1.7
50-4	43	15.0	6.1	1984	6	1.5	9.0	4.6
50-4	46	120.0	42.1	1984	75	48	45.0	-5.9
50-4	49	35.0	15.6	1984	27	10	8.0	5.6
50-4	50	15.0	6.7	1984	15	5	0.0	1.7
50-4	51	15.0	6.3	1984	6	1.5	9.0	4.8
50-4	52	30.0	9.1	1984	17	5.5	13.0	3.6
50-4	53	25.0	9.8	1984	14	10	11.0	-0.2
50-4	54	25.0	9.1	1984	14	4	11.0	5.1
50-4	59	56.0	19.3	1984	39	13	17.0	6.3
50-8	11	50.0	51.0	1986	40	19	10.0	32.0
50-8	13	15.0	8.3	1986	10	5.5	5.0	2.8
50-8	14	12.0	8.7	1986	11	7	1.0	1.7
50-10	34	30.0	17.1	1984	22	11	8.0	6.1
50-10	44	25.0	9.1	1984	8	5	17.0	4.1
50-24	1	18.0	25.6	1987	38	25.5	-20.0	0.1
50-24	3	6.0	1.8	1989	3.5	1	2.5	0.8
50-35	1	55.0	20.5	1986	50	36	5.0	-15.5

Table 9. Summary of past reproductive activity, showing site number, number of trees per site, percent crown of woody cones greater then two years old (cone class), number of trees per cone class, and average height (ft) and diameter (in) per cone class.

Site Number	Number of Trees per site	Percent Crown	# of Trees per Cone Class	Average Height (ft) per Cone Class	Average dbh (in) per Cone Class
50-1	2				
		0	2	2.5	2.2
50-2	69				
		0	47	19.4	7.8
		1-10%	8	49.4	22.3
		10-25%	10	47.5	23.1
		25-50%	4	68.8	31.6
50-3	1				
		0	1	1.0	1.0
50-4	58				
		0	40	17.6	7.2
		1-10%	9	26.3	13.2
		10-25%	3	63.3	21.1
		25-50%	5	82.2	31.9
		50-75%	1	70.0	25.6
50-8	11				
		0	4	11.8	6.3
		1-10%	3	27.7	12.8
		10-25%	3	41.7	16.9
		25-50%	1	50.0	24.0
50-9	6				
		0	3	21.0	8.3
		1-10%	1	40.0	16.9
		10-25%	1	35.0	18.1
		25-50%	1	35.0	14.4
50-10	5				
		0	2	2.5	2.3
		1-10%	1	25.0	9.1
		10-25%	2	32.5	16.8
50-13	2				
		10-25%	1	35.0	10.6
		25-50%	1	75.0	34.6
50-24	2				
		0	1	6.0	1.8
		1-10%	1	18.0	25.6
50-25	1				
		1-10%	1	75.0	17.7

Table 9. continued, summary of past reproductive activity, showing site number, number of trees per site, percent crown of woody cones greater then two years old (cone class), number of trees per cone class, and average height (ft) and diameter (in) per cone class.

Site Number	Number of Trees per site	Percent Crown	# of Trees per Cone Class	Average Height (ft) per Cone Class	Average dbh (in) per Cone Class
50-35	1				
		25-50%	1	55.0	20.5
50-38	26				
		0	18	9.9	4.9
		1-10%	7	26.9	11.9
		10-25%	1	40.0	15.0
50-43	17				
		0	9	7.7	5.1
		>75%	2	45.0	28.4
		1-10%	1	12.0	9.8
		10-25%	1	22.0	11.4
		25-50%	3	32.3	17.8
		50-75%	1	12.0	10.2
50-55	1				
		0	1	12.0	4.7
50-70	17				
		0	11	6.2	4.1
		1-10%	5	10.6	7.7
		10-25%	1	18.0	14.2

Table 10. Summary of current reproductive activity, showing site number, number of trees per site, percent crown of current cone crop or flowers (cone class), number of trees per cone class, and average height (ft) and diameter (in) per cone class.

Site Number	Number of Trees per site	Percent Crown	# of Trees per Cone Class	Average Height (ft) per Cone Class	Average dbh (in) per Cone Class
50-1	2				
		0	2	2.5	2.2
50-2	69				
		0	44	17.3	7.0
		1-10%	13	45.8	21.2
		10-25%	8	52.5	23.8
		25-50%	2	80.0	35.4
		50-75%	2	60.0	26.7
50-3	1				
		0	1	1.0	1.0
50-4	58				
		0	39	18.0	7.4
		1-10%	9	28.4	11.7
		10-25%	5	54.3	26.7
		25-50%	4	87.8	32.0
		50-75%	1	30.0	11.8
50-8	11				
		0	4	14.3	6.9
		1-10%	3	24.3	11.9
		10-25%	2	47.5	19.5
		25-50%	2	40.0	17.9
50-9	6				
		0	3	26.0	10.9
		1-10%	2	30.0	13.6
		10-25%	1	35.0	14.4
50-10	5				
		0	2	2.5	2.3
		1-10%	1	35.0	16.5
		10-25%	2	27.5	13.1
50-13	2				
		1-10%	1	35.0	10.6
		25-50%	1	75.0	34.6
50-24	2				
		0	2	12.0	13.7
50-25	1				
		1-10%	1	75.0	17.7
50-35	1				
		50-75%	1	55.0	20.5

Table 10. continued, summary of current reproductive activity, showing site number, number of trees per site, percent crown of current cone crop or flowers (cone class), number of trees per cone class, and average height (ft) and diameter (in) per cone class.

Site Number	Number of Trees per site	Percent Crown	# of Trees per Cone Class	Average Height (ft) per Cone Class	Average dbh (in) per Cone Class
50-38	26				
		0	19	9.0	4.4
		1-10%	7	33.6	14.7
50-43	17				
		0	7	7.1	5.3
		>75%	1	22.0	11.4
		1-10%	1	12.0	9.8
		10-25%	6	25.2	14.8
		25-50%	2	33.5	20.2
50-55	1				
		0	1	12.0	4.7
50-70	17				
		0	9	6.7	4.3
		1-10%	7	8.7	6.4
		10-25%	1	18.0	14.2