FIRE ECOLOGY
at
BANDELIER NATIONAL MONUMENT

Final Report

Teralene S. Foxx
Research Assistant

and

Loren D. Potter
Principal Investigator

Biology Department
The University of New Mexico

Contract No. PX 7029-6-0769
No. PX 7029-7-0692
February 15, 1978

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

STATEMENT OF PURPOSE

Because Bandelier National Monument is a dissected plateau with canyons which rise from grassy, low plains of the Rio Grande up through juniper, pinyon-juniper, ponderosa pine, and into stands of mixed conifer, and because of the policy of total fire suppression over the past 40 years, the many even-aged stands, the heavy fuel accumulation, and the potential pathways for fire to sweep up-country as well as a high plateau susceptible to lightning strikes, Bandelier was a prime situation for a fire management plan. These factors combined with the recent acceptance by the National Park Service that fire is a natural and sometimes necessary component of the ecosystem (National Park Service 1976) led to the establishment of the initial study which was to be completed November 1977. The primary study had essentially six parts: 1) researching the complete fire history of the Monument, 2) correlation of the fire history with climatological data, 3) measurement of standing biomass of both mature and reproductive stock, 4) determination of fuel loading in selected areas, 5) inference of successional vegetation from a variety of age stands to determine normal recovery, and 6) to determine the influence of fire upon the growth rates of the dominant tree species.

Before the initial study could be completed, a holocaustic fire burned 15,270 acres of the Monument and surrounding areas. This interrupted the study and changed the complexity of information gained as the La Mesa fire burned 11 of the 13 previously measured study plots. A remeasure of these areas has allowed for some definite conclusions made from experimental evidence rather than from inference. The following report is a composite of both the Pre- and Post-La Mesa Fire data.

ACKNOWLEDGEMENTS

The completion of this study would not have been possible without the support and help of many individuals. Appreciation is expressed to the National Park Service for their financial support. Ro Wauer and John D. Hunter initiated the study. Members of the staff of Bandelier National Monument rendered assistance: John Lissoway helped in collecting samples and Jan Wobbenhorst assisted in obtaining information. Jerry Schmidt of the Forest Service supplied information about the La Mesa fire. Jean Ferner deserves credit for typing this voluminous manuscript. Sandy Cox and Roy Slice were invaluable field assistants. Last but not least we owe special thanks to Jim, Alison, Erin, and Kerri Foxx for their unpaid support, both moral and physical.

INTRODUCTION

Physiography

Bandelier National Monument is situated at the base of the eastern slopes of the Jemez Mountains in an area called the Pajarito Plateau. In the deep and precipitous canyons and on mesa tops of this plateau, early prehistoric inhabitants made their homes and utilized resources of the land. The area contains one of the largest concentrations of prehistoric Indian ruins of the Southwest--over 600 ruins are presently recorded (National Park Service 1976).

The plateau was formed by an ash flow from volcanic activity which resulted in the formation of the giant caldera called the Valle Grande or Great Valley, 12 miles west of the main gate. This giant depression approximately 12 miles in diameter was formed as a by-product of the volcanism resulting from tectonic disturbances which formed the mountains of the Rockies, Sangre de Cristo, Sierra Naciementos, and San Pedros. Forces of erosion have since carved generally narrow precipitous canyons from the plateau (Olinger 1974).

As a result of this volcanic activity the soils of the area are derived from rhyolite, tuff, ash, and other volcanic debris. Soils generally can be classified into three groups: 1) extremely stony, rocky shallow soils of less than 20 inches depth on extremely steep canyon side slopes; 2) moderately deep (20-36 inches) soils on mesa tops; and 3) sandy soils of the alluvial bottoms of the canyons (Wade 1965, Earth Environmental Consultants 1974).

The Monument is comprised of approximately 51 square miles or 32,737 acres, bordered on the eastern edge by the muddy Rio Grande (Wobbenhorst pers. comm.). The elevation varies from 5,312 ft near the Rio Grande to approximately 10,000 ft at the top of the highest peak, Cerro Grande. Tsankawi, a separate portion of the Monument, is situated approximately 10 miles north of the main gate.

The area is transected by three main canyons and a system of smaller secondary canyons. The terrain is rough and in some places virtually inaccessible. The Monument headquarters are situated in Frijoles Canyon where the major ruins are located. All other canyons, as well as the upper portion of Frijoles, are located in the backcountry, a wilderness area with many hiking trails. Although the upper portions of the canyons have water nearly year round, the streams are intermittent in the lower canyons, being swollen with water only during the rainy season or spring snow melts. Los Ritos de los Frijoles, located in Frijoles Canyon, is the only stream with year round water.

Pinyon-juniper, ponderosa pine, and mixed conifer forests dominate the mesa tops and sometimes extend into the canyons. Canyon bottoms have riparian communities which include narrowleaf cottonwood, boxelder, and numerous shrubs. The high peaks are dominated by spruce-fir and open meadows.

Pure juniper stands at low elevations near the Rio Grande intergrade into pinyon-juniper forest which extends upward to approximately 7,500 ft. The latter forests in turn intergrade with ponderosa pine at elevations of approximately 7,500 ft. This type merges with mixed conifer at elevations of 8,500-9,000 ft. The latter is composed of Douglas-fir, white fir, ponderosa pine, and ~~limber~~ southwestern white pine. At higher elevations spruce-fir and aspen are found. These border high meadows composed of many grasses and forbs. Aspen also occurs within the mixed conifer mostly on large burns, areas of previous logging, areas of blowdown, and moist north slopes at the heads of narrow, shaded canyons.

Climatology

Climatological records for the Monument are limited to file records of precipitation and temperature readings from the headquarters area dating from 1933. More extensive records have been maintained at Los Alamos, approximately 10 miles north of Bandelier National Monument.

A rainfall station was established at Alamos Ranch in November 1910 and temperature records were begun in October 1918. In 1942 the name of the ranch was changed to Los Alamos. In January 1943 the station was taken over by the Corps of Engineers and later operated by various divisions of the Atomic Energy Commission. Several changes in the location of the equipment have been made since 1943. The instruments were removed from roof top levels to ground exposure in 1956. There is now a network of 72 rain guages distributed throughout the county (Schiager and Apt 1973; Von Eschen 1961). Thus, the information here is a summary of data from both Los Alamos and the Monument headquarters (Bandelier National Monument xerox; Los Alamos Scientific Laboratory xerox; Environmental Data Service 1976; Von Eschen 1961; Schiager and Apt 1973; Clements and Barr 1976; and Los Alamos Scientific Laboratory 1972).

Summers on the Pajarito Plateau are cool with maximum temperatures reaching 90° F generally only two days of the year. The maximum temperature recorded at the Monument headquarters was 106° F. The nighttime summer temperatures average in the 50s. Freezes have been recorded for all months except July and August. Winter days are typically clear and sunny. Daytime shade temperatures even in January, the coldest month, may reach the high 30s under cloudless skies. The average winter has approximately 18 days when the mercury fails to rise above 32° F. Winter night temperatures drop below freezing from November through mid-April, but below zero readings occur, on the average, once a year. The minimum temperature recorded for the Monument is -23 and at Los Alamos -18° F.

The Bandelier area has a semiarid continental mountain climate. Annual precipitation for the Los Alamos area averages slightly more than 18 inches and at the Monument headquarters 15 inches. The most precipitation received in one year was 30.3 inches with 6.80 inches being the least. Seventy-five percent of the precipitation is received during the months of July and August--the monsoon season. The maximum 24-hour rain recorded for Los Alamos is 3.48 inches. On the average, a trace or more of precipitation occurs on 140 days of the year.

Shower activity reaches its peak in August, when rainfall of one-tenth inch or more can be expected one day out of four. These convective showers normally develop in the afternoon or early evening and are relatively brief. Hail may accompany the more severe thunderstorms. Most of the winter precipitation falls as snow, with an average snowfall of 50 inches. As much as 6 inches has been reported in 24 hours.

The precipitation patterns are indicated in studies done at Los Alamos Scientific Laboratory (Schiager and Apt 1973). Two primary thunderstorm tracts were recorded from June through October. The most common tract was the west to east movement of a convective cell originating in the Jemez Mountains, probably near Redondo Peak. These cells diminish as they travel eastward. The second tract led up the Rio Grande Valley from the south and often accounted for very heavy rains. This precipitation diminished as it moved westward. Total precipitation isohyets for June through October 1973 indicate a storm cell tract along Frijoles Canyon.

A summary of thunderstorm activity from 1965-1974 done at Los Alamos Scientific Laboratory shows the daily thunderstorms occurring with the greatest frequency during the month of August followed by July, June, and September. The first thunderstorm of the day generally occurs around 11:00 AM to 1:00 PM with another peak time from 5:00 to 6:00 PM. There appear to have been no studies to determine lightning strike frequency (Los Alamos Scientific Laboratory, xerox).

No records of wind velocity or turbulence have been kept at the Monument; however, observations of wind have been maintained at a number of Los Alamos locations for approximately 20 years. These show significant variation in wind with location. Locations nearest the mountains have a greater downslope component, whereas those at the lower end of the plateau reflect the channeled Rio Grande flow and mountain-valley wind influence (Los Alamos Scientific Laboratory 1972).

Observations made at the Los Alamos Airport show that the average wind speed is less than 10 mph about 75 percent of the time and over 30 mph less than 0.1 percent of the time, usually in gusts. Highest wind speeds generally have been recorded in the spring of the year. Winds 86 mph were recorded February 24, 1956 with some resultant damage to Los Alamos buildings. In May of 1956 there were 7 consecutive days with wind speeds over 40 mph. These winds may have contributed to several blowdowns in the Monument area. Homer Pickens, retired forester of the area, recalls another major blowdown in the early 30s, possibly May 30, 1934, when hard winds were recorded (Pickens, pers. commun.).

The complex wind flow patterns produced by the canyons have been studied by Clements and Barr of Los Alamos Scientific Laboratory (1976).

Importance of Fire in Ponderosa Pine

Ponderosa pine and ponderosa pine-pinyon-juniper mixture comprise 28 percent of the Monument and by virtue of the experimental design, ponderosa pine is the dominant tree species in this study. No major fires prior to 1977 were found in mixed conifer and the new accession was added in 1977.

Ponderosa pine, occurring at elevations of 7,000-8,500 ft, is the most drought-tolerant of the major coniferous forest trees of the Southwest. It is also a shade-tolerant, fire-climax species; however, it will not disappear without fire (Dieterich 1976a; Foiles and Curtis 1973; Schubert 1974).

Ponderosa pine forests of the Southwest have been subjected to frequent and periodic fires before the coming of white man. Evidence gained through dating of fire scars has shown that prior to modern fire suppression trees burned every 8 to 12 years (Weaver 1951; Weaver 1955). Ponderosa forests of the Southwest are in a lightning bioclimate (Komarek 1968, 1969). These forests are subject to high lightning frequency. In a 22-year period from 1945 to 1966, Komarek (1969) reported 33,965 lightning-set fires on the 20,407,885 acres comprising the national forests of Arizona and New Mexico. That averages one lightning-set fire per 601 acres during that period. During the same period of time, the Santa Fe National Forest which is adjacent to Bandelier National Monument recorded 1,431 lightning-set fires on 1,440,511 acres. Although man has been able to change the general nature of the forest through fire suppression, he cannot have changed the main source of ignition of historic and prehistoric fires.

Sixty years of fire suppression has changed the composition and character of the ponderosa forest. Early explorers described the forests as open and unencumbered by underbrush (Beal 1858; Dutton 1881; Muir 1894; Muir 1901). King (1871) gives an account of running his horse through the forests of the Sierra Nevada. Fires in those environments were not as destructive as the ones seen today. Those fires crept along the ground and only occasionally ignited treetops. Those fires reduced the pine needle accumulations, culled diseased trees, and thinned young stock, resulting in a forest with a more park-like appearance (Muir 1901).

Major changes in the Southwestern forests began in the late 1800s with logging, accumulations of slash, and suppression of fire in the 1900s. Grazing also had its impact. Livestock, first introduced by Coronado in the 1500s, grazed freely. Severe range deterioration did not begin, however, until the 1880s and early 1900s. Exposure of mineral soils and reduced stocking rates accompanied by fire suppression has resulted in dense, stagnant stands seen throughout the southwestern ponderosa pine forests (Komarek 1969; Weaver 1974; Cooper 1960).

Exclusion of fire from these forests has resulted in heavy fuel accumulations. Dieterich (1976a) collected samples from 54 stands of mature ponderosa in various areas of Arizona and New Mexico which indicated an average of 12.7 tons/acre of ground fuel and 10.6 tons/acre of down dead woody material. Fuel loadings of this magnitude have the potential of producing extremely hot fires. It is estimated that 12.5 tons/acre of accumulated fuel consumed by the fire front is 1,433 Btu's/sec/fireline ft. Excessive damage to mature overstories can be expected from 700 Btu's (Sackett 1976).

Biswell and co-workers (1966) have found 2.2 to 6.9 tons of litter per hectare are accumulated on the forest floor each year. This becomes a serious problem in the warm dry climates of the Southwest, where decay is slow. All these fuels are available to produce disastrous wildfires. Dodge (1972) indicates the effectiveness of an exclusion policy has been that 95 percent of the wildfires are extinguished while small; however, the 3 to 5 percent that get out of control cause 95 percent of the damage.

The accumulation of fuels and the closing of the forest canopy have had an important effect on the understory composition. Moir (1966) found a reduction of herbaceous material in closed canopy forests. This alteration of the understory has reduced the available habitats for deer, elk, antelope, and turkey as well as other wildlife which inhabit ponderosa pine forests. However, Moir found that fire increased the production of grasses such as Festuca. Other investigators have found an increase in the reproduction of various browse shrubs such as Ceanothus sp. in areas which have been burned (Went, Juhren, and Juhren 1952; Gratkowski 1962).

Studies in recent years have shown that fire is necessary to perpetuate as well as to produce healthy ponderosa pine forests (Weaver 1974; Vlamis 1956). Fire provides the bared soil necessary for the shade-intolerant ponderosa seedling (Foiles and Curtis 1973). Although prehistoric fires were generally cool, they provided some severely burned areas where windfalls and snags were consumed. The increased nutrification and fungal sterilization of these areas probably provided excellent seedbeds. Wagle and Kitchen (1972) have found that this increased nutrification can help override other environmental factors which often result in death of ponderosa seedlings. Ffolliott (1977) saw an increase in seedlings on burned areas vs. unburned areas, although many were short-lived.

Fire is a natural thinning agent. Ponderosa pine needs full sunlight for maximum photosynthetic activity. While young trees are susceptible to fire, older and more mature trees are protected by thick bark. The thinning reduces competition and over-stocking. In the dense, stagnant stands produced because of fire exclusion, trees are also weakened and more susceptible to disease and insect attack. Thinning of the forest, either mechanically or through prescribed burning, produces a more vigorous, rapidly growing stand of trees. This means a reduction in trees killed by such diseases as dwarf mistletoe (Wicker and Leaphart 1976) There is also some indication that smoke produced by fire may have a sterilizing effect on the forest--thus reducing certain disease organisms (Parmeter and Uhrenholdt 1976).

Researchers warned against the "Smokey the Bear" policy of total fire exclusion soon after its inception; however, the problem has only recently been of increasing concern. Weaver (1943, 1951, 1955, 1957, 1959, 1961, 1967a, 1967b) experimented early with prescribed burning--a technique of controlled fires. The principle of fuel reductions via this technique is recognized as being useful to the forest manager; however, a number of questions still need to be answered before such a plan can be initiated in any specific area.

MATERIALS AND METHODS

1976 Fire Ecology Study

Site selection

The main purpose of the initial study was to determine by inference the successional vegetational recovery and to predict future post-fire succession. To do this, previously burned areas of various ages were selected. Sites chosen were more than 10 acres because from preliminary field examination it was determined that fires of smaller acreage were difficult to relocate. Study of the fire atlas maintained at the Monument headquarters from 1931 to 1969 revealed there were only five fires larger than 10 acres. All of the recorded fires are indicated on the map of Figure 1. The five studied are indicated by irregularly-shaped darkened areas. These burned areas were Frijoles Canyon 1937, Upper Alamo Crossing 1945, Bear Mesa 1950, Boundary Peak 1955, Frijoles Canyon 1960. Aerial ~~maps~~ photos dating from 1935 (and?) to 1963 were utilized to locate the study areas as accurately as possible; then the location was confirmed by field examination. An adjacent control area was also selected to contrast with each burned area. The control was selected to be as similar to the burned area as possible in regard to topography, slope, and exposure.

Initially, 12 study areas were established including five burned areas with adjacent controls. The 1937 and 1960 Frijoles Canyon burns involved both the inner, north-facing slope of the canyon and the canyon rim; thus, plots were established both within the canyon and on the rim. One control was established for inner canyon sites and one for canyon rim sites.

During the course of the study, the site of a three-acre fire which burned in 1975 on Burnt Mesa was relocated by the park staff. This site along with two sites burned during the 1976 field season (the 5-acre Alamo Canyon fire and the 14-acre Escobas Mesa fire) were added to the study for the purpose of establishing photo stations to be used later in studying the succession.

Site analyses

The vegetational analysis was done by a modification of Lindsey's (1955) line intercept method. This method provides a measure of foliage cover of tree, shrub, and herb strata; the species composition in all strata; the density (number per area) of trees and shrubs; and the trunk diameters of mature trees. Measures of standing biomass of understory trees, shrubs, and herbs less than 3 ft tall were also obtained from clip plots.

The sampling unit was a 1000-ft line with a 10-ft strip on either side. A right angle, or elb, was made every 200 ft to account for variations in terrain. If it was not possible to make an elb every 200 ft and remain within the burned area, an elb was made at 100 ft. The 1000-ft x 20-ft strip was in turn divided into 20 x 50 ft plots so that frequencies could be calculated. A steel tape formed the line by which foliage intercept of mature and reproductive stock over 3 ft tall could be measured. The percentages of foliage cover of herbs and shrubs less than 3 ft tall and tree seedlings were estimated by use of a meter by one-half meter quadrat placed every 50 ft along the line. Every 100 ft along the line all vegetation was clipped, separated as to species and saved for oven-drying and weighing.

From the data gathered, measures of total foliage cover, relative foliage cover by species, total basal area of mature trees, relative basal area, total density, relative density, frequency index, and relative frequency were determined. From relative cover, relative density, and relative frequency, a single measure of importance value was calculated for each species.

Fuel loads

Fuel loading in each area was measured by collecting all litter, duff, and debris less than 3 inches in diameter from a meter by one-half meter quadrat placed every 100 feet along the line. All material down to mineral soil was placed in plastic bags for transport. The material was separated as to fine fuels, which included litter and duff less than 1 inch in diameter; sticks, which were 1-3 inches in diameter; and the standing herbaceous material collected in the clip plots. These components were placed in paper bags and dried at 80° C in a drying oven to a constant weight. The grams of weight were then converted to tons per acre as seen in Tables 6, 7, 8, 9, and 10.

Growth rates

Growth rates of mature, but varying sized trees, were determined by cores collected at random within the burned areas and the controls by use of a standard 16-inch Swedish increment borer. Samples were collected from the south side of the tree, placed in a foil tube to prevent breakage and desiccation, and transported to the laboratory. Before they were allowed to dry, they were glued into the grooves of pieces of corrugated cardboard. They were then lightly sanded and shellaced. The cores were examined with a binocular dissecting microscope having a calibrated eyepiece micrometer. The variations in annual ring widths were plotted on a graph overlaying a trend line which shows general growth patterns. The trend lines were established by using points of a twenty-year running mean as a guide. The twenty-year running mean was computed by averaging the ring widths of the first 10-year period of a given specimen with the second 10-year period and the results plotted at the ten and one-half year mark. The second decade was averaged with the third, and so on. If less than five years were averaged, then a point was plotted halfway between the decade points and was used as a guide point in fitting a smooth age trend curve to the specimen (Smiley et al. 1953).

Fire frequency

To obtain an indication of the frequency of fires, wedges were collected from standing snags which appeared to be sound on Escobas Mesa and the North Rim of Frijoles Canyon. Standing snags were utilized so that living trees would not have to be sacrificed. Since there was no way of cross-dating readily available, the numbers of annual tree rings between fire scars were counted. In addition to the snags collected in the spring of 1977, John Dieterich collected some samples within and adjacent to the Escobas Mesa fire. These were sent to the University of Arizona Tree Ring Laboratory for dating. The frequency between fires on these samples was also utilized in determining fire frequency. Also, a sample collected in the summer of 1977 from on top of a ruin along the North Rim of Frijoles Canyon fire road was utilized.

Weather data

As previously stated, climatological data was collected from records maintained at Monument headquarters and Los Alamos Scientific Laboratory. Trend lines were calculated from a twenty-year running average as in the determination of tree growth rates. This was done so that the information could be correlated with ring widths. Winter precipitation is of interest when determining growth rates so winter precipitation has been subjected to the same treatment. Winter was considered to be October-May; the monthly averages were calculated and plotted against a trend line as with growth rates.

Photo stations

Permanent photo stations were established in the Burnt Mesa 1975, Escobas Mesa 1976, and Alamo Canyon 1976 burns. Photo station posts which were machined in the shops of Bandelier National Monument were constructed of 5-ft lengths of iron pipe. At one end either 8 or 12 notches were cut as guides for orientating the direction of the camera. A plate to hold the camera was machined with extensions on the under surface which fit into the notches. Each notch represented a point and allowed for photographic observations through 360°. The pipes were placed in the ground so that the camera was 4 feet off the ground. Two photo stations were placed in the site of the Burnt Mesa fire, two in the Escobas Mesa fire, and three in the Alamo Canyon 1976 fire.

Post-La Mesa Fire Study

Re-examination of linestrip plots

On June 16, 1977 the La Mesa fire was accidentally ignited and it eventually burned across 11 (10?) of the 13 (12?) previously examined sites. While the vegetational studies of previously burned areas had been completed, providing the data to hypothesize the impact of wildfire and the nature of recovery, the La Mesa fire, unfortunate as it may have been, turned the descriptive study and its hypotheses into an actual experiment. A re-examination of the study plots to determine varying degrees of damage and recovery response became imperative. Thus, the Upper Alamo Crossing 1945, Bear Mesa 1950, Frijoles Rim 1960, and the respective controls were re-examined. Attempts were made at re-examination of the inner Frijoles Canyon plots, but due to the steepness of the terrain and lack of vegetation, it proved to be too dangerous. In addition, new line-strips were run on Escobas 1976 burn and an adjacent control as well as an area adjacent to the 1960 Frijoles Rim Burn which had been dated with samples as probably not having been burned since 1878 (99 yrs). In addition to measures of species composition and size classes, a classification of the degree of foliage damage and trunk singeing was also done. Foliar damage was classified as 1- 0-25%, 2- 26-50%, 3- 51-75%, 4- 76-100%, 5- all needles brown, and 6- all needles consumed. Measures were made of the extent of the trunk which was singed.

Selection of plots for post-La Mesa fire study

On July 6, 1977 a meeting between representatives of the National Park Service, Los Alamos Scientific Laboratory, and investigators of the fire ecology study was held to coordinate post-fire studies. At that meeting a verbal agreement was made concerning the establishment of plots for future successional studies. Los Alamos Scientific Laboratory was setting aside an area which was not to be reseeded. It was deemed advisable to have comparable data for future analyses. In a meeting July 20, 1977 between Kenneth Rea, David Dressen, and Teralene S. Fox, it was determined that permanently staked 20 x 50 meter plots would be utilized for measuring areas of varying degrees of fire damage. Each of these plots was to be divided into 50 shrub plots of 1 x 2 meters and 100 herbaceous plots of 5 x 5 decimeters (Fig. 2).

Previous to the La Mesa fire, Roland Wauer of the National Park Service had established transects for ornithological studies. At his request, the vegetative study plots were placed along these transects in areas of varying degrees of burn damage, i.e., severe, moderate, and light. Areas were considered to be severely damaged when tree crowns were completely consumed and the litter and duff were burned to the mineral soil. Moderate damage included areas where the tree crowns were only partly consumed and some trees were still green, although most of the understory vegetation was consumed and in some areas litter and duff to the mineral soil. Areas lightly damaged had a majority of trees remaining alive and the litter and duff were only lightly scorched.

The plots were aligned by a magnetic north compass setting with the 50 m line running either east-west or north-south and remaining entirely within the category of the damage. The plot was established by compass and lines 50 and 20 m in length. The 50 m rope was divided into 4 equal parts and the spot marked with flourescent paint. At each spot a stake was used to mark the shrub strip. The 20 m rope was marked off by flourescent paint into 2-meter increments. This allowed the placement of a small quadrat at each mark for the purpose of reading herbaceous and seedling vegetation. The corners were marked with 3/8 inch diameter rebar which was sprayed with orange flourescent paint to aid in relocation on the plots.

Photo stations were established at two opposite corners and photos taken with a Minolta SRT 101 with a 28 mm wide angle lens to obtain the widest coverage.

A summary of the plots, their locations, and pertinent physiographic data is given in Table 1. Locations are delinated on the map of Fig. 3.

In addition to plots set up to analyse the La Mesa fire, plots were also set up on Frijolito Mesa and Cerro Grande to provide baseline data for future studies. The location and results of analyses of plots are provided in the Appendix.

<u>Analysis of post-La Mesa fire plots</u>

The following data were recorded for vegetation occurring within the five study plots:

I. The trees were divided into the following age classes:

   A. Seedlings - <1 ft in height and less than 1 inch diameter
   B. Sapling - 1-3 ft in height and less than 2 inches diameter
   C. Pole - >3 ft in height and 4 inches in diameter
   D. Mature - 4 inches in diameter and greater

II. Damage assessment of the tree species:

A. Crown damage - the following categories were determined for crown damage modified from Wagle and Eakle (unpublished)

1. Over 75% of foliage green and alive
2. More than 50% but less than 75% foliage green and alive
3. More than 25% but less than 50% foliage green and alive
4. Less than 25% of foliage green and alive (little chance of survival)
5. All foliage brown and tree considered to be dead
6. All foliage consumed and tree dead

B. Trunk damage

1. Trunk severely scorched all around, or bark mostly burned away
   a. confined to first 2 ft
   b. covering first 5 ft
   c. covering over 5 ft of trunk
2. Trunk moderately scorched, cat faces formed in bark but generally bark not completely burned
3. Trunk lightly scorched or blackened, burned out new cat faces usually absent, bark structure generally well defined and easily visible

III. Shrubs. The numbers of sprouts and their size was recorded. In addition, the percentage foliage cover of each shrub species was determined in fifty 1 x 2 meter plots.

IV. Herbs and seedlings. The total foliage cover of each species was determined in one hundred 5 x 5 decimeter plots. To improve the accuracy of estimating the percentage cover, a small quadrat 5% of the area of the herb plot was used.

Other vegetative analyses

Reseeding. Success of the reseeding effort was of interest. On Escobas Mesa two adjacent plots were examined to determine the success of reseeding. Plot 4 was in a logged area and had foliar damage in classes 4-5, whereas plot 3 was in an unlogged area and had foliar damage in class 6. Seedlings were counted in fifty one-square-foot quadrats within each 20 x 50 meter plot. They were counted in the vicinity of the herbaceous subplots but excluded areas of root burnouts. Success of germination in percentage of average seeding rate was then determined.

Measurement of seed heads. Within the burn area the seed heads of various grass species appeared to be more robust and vigorous than those outside the burned area. In order to substantiate this observation, seed heads of *Bouteloua gracilis* were collected within the burn and various non-burned areas, measured, and the measurements of 50 heads averaged. These measurements were then compared.

RESULTS AND DISCUSSION

Pre-La Mesa Fire Studies

Fire history

Komarek (1969) mentions that the Southwestern Indians used fire in hunting; however, there appears to be no indication of such use by the pueblo Indians. Bandelier (1892) indicates in his final report of investigations of the Rio Grande area that the Cochiti did practice communal hunts, rounding up animals and forcing them off precipices near the Rio Grande, but there is no mention of fire. Although the pueblo Indian may not have utilized fire as a hunting tool, he did recognize it as a natural phenomenon. In a letter to Southwestern National Monuments, C.A. Thomas (1940) quotes an old Taos Indian as having said, "Before the White Man came to the mountains, bugs and disease seldom killed the forest, because when bugs attacked the trees, a few (trees) died, and the gods seeing the dead trees sent the lightning to set them afire. The fire burned up the dead trees and the bugs and no more trees were harmed for a long time."

There seems to be no definite indication of use of fire by early settlers of the area; however, a forester mentioned that sheepherders were known to burn the San Pedro Peaks Wilderness area every fall when they went to winter ranges in order to assure increased growth of spring grasses.

Although the area became a Monument in 1916 as a result of presidential proclamation for the "preservation, protection, and study of its archeological resources", there is no record of fire and its management until 1932 when the management was changed from the Forest Service to the National Park Service. Additional areas were added to the Monument in 1961, 1963, and 1977. There are no available records of fires for the areas of those accessions. Thus, the fire history is based upon information gained from fire atlases and fire reports maintained at the Monument until 1969. After 1969 fire atlases were not maintained and until the present administration of the Monument minimal records of fire occurrence were kept. As a result, there are a number of years for which no records could be located. All fires and the location as recorded in the fire atlases are summarized in Figure 1.

Records for approximately 39 years (1931-1977) were partially or wholly found. These records are summarized in Table 2 by classes of fire size, causes, and month, as well as the annual precipitation at Bandelier headquarters. As seen in Table 2, during the past 39 reportable years, a total of 224 fires were recorded. Seventy-two percent were less than 0.25 acre (Class A), 25% were 0.25 acre to 9 acres (Class B), and 3% were 10 or more acres (Class C). This is an average of approximately 6 fires per year of which 86% were lightning-caused. Over 30% of the fires occurred during July, which may be considered the peak fire month, followed by June, then August. The majority of the fires occurred between May and September.

The Bureau of Land Management (1974) has a Normal Fire Year Plan used to guide management decisions and budget submissions. It is based on the third highest problem year of fire frequencies and size in the past 10 years. Using the BLM formula (Table 3), a normal fire year for Bandelier is 13. This is certainly higher than the average of 6 when fire frequency is averaged over 39 reportable years. This formulation is based on the last 10 years during which time there has been, as seen in Figure 4, an increase in the number of lightning-caused fires.

The increase in lightning-caused fires is not a phenomenon isolated to Bandelier but has been reported by Komarek (1967) for all of the West. Similar patterns also apparently are present in the adjacent Santa Fe National Forest (Fig. 4).

Several factors may account for the increased frequency in lightning-ignited fires within the Monument. First, in 1963 the Monument acquired approximately 3,000 acres of ponderosa pine forest along the north rim of Frijoles Canyon. As previously mentioned, there may be a storm tract in this area, thus an increase in lightning and lightning-caused fires. As seen in Figure 4, the incidence of man-caused fires has remained fairly stable during the same 40 year period. This land acquisition would have little effect on the incidence of man-caused fires because it is not used for hiking and camping to any great extent other than the established Ponderosa Campground. However, the land acquisition cannot totally account for the increasing incidence of lightning-ignited fires because the trend line as seen in Figure 4 was increasing before 1963.

Another factor which must be taken into consideration is better reporting. In the late 1960s the Forest Service up-graded their detection by the use of aerial reconnaissance (Schmidt, personal communication). In addition, although the fire tower at the Monument was established in 1940 (Fulton 1940), it has only been manned consistently in recent years (Lissoway, personal communication). Again this cannot account for the rising trend line prior to the late 1960s.

Probably one of the more important factors is the condition created from 50 years of fire suppression. Fuel loads up to 24 tons/acre have been reported for the Monument (Forester 1976). The most important kindling material for lightning fire is accumulated needles and duff on the ground, then live trees, and finally dead trees (Morris 1934; Komarek 1967; Taylor 1969). These increasingly heavy fuel loads combined with appropriate climatic conditions may produce optimum conditions for lightning ignition.

Finally, a factor which may contribute, but is of questionable significance, is climatic cycles. Komarek (1967) discusses lightning frequency and sun spots. He found two peaks in fire activity: 1950-51 and 1960-61 which was comparable to the 11-year sunspot cycle. This pattern does not appear to hold for the Bandelier area since the peak lightning year was 1965. There does not appear to be any research in this area on lightning frequencies.

<u>History of fire sites</u>

<u>Fires of 1937-1955</u>. Earlier fires are difficult to document as information was confined to the atlas rather than fire reports with narratives. However, the 1975 Burnt Mesa fire, the 1976 Escobas Mesa fire, and the 1960 Frijoles Canyon fires are fairly

well narrated. To document other fires more closely, Homer C. Pickens, a former resident and forester from Los Alamos was contacted. He is now retired and residing in Albuquerque but lived in the area from 1927 until 1969. Although he could not supply much information, he remembered that the 1937 Frijoles Canyon fire was not particularly difficult to contain. A large fire is described in the Monthly Report of Southwest Monuments (Harkins 1937) which started in the bottom of the Canyon and crowned out on both sides. The location is described as being a mile below the west boundary and attacked from Sawyer Mesa. The fire was spotted at 1500 hours and contained by 2000 hours, apparently burning 100 acres. This fire may be the 1937 fire, but the acreage seems large.

In addition, Abro Rile, Fire Marshal of Los Alamos who has resided in the area since 1947, was contacted. He was on the 1950 Bear Mesa fire and confirmed that it was a lightning fire, a cool fire which never crowned, and that it was easily contained in 3 hours. The remainder of the information is excerpted from fire reports, narratives, and weather data collected from Bandelier National Monument and Los Alamos Scientific Laboratory.

Frijoles Canyon 1960 fire. This fire in Sec 7, T18N R6E was presumably started by a fisherman on Saturday, May 21, 1960 at approximately 1200 hours. It was first discovered by the Forest Service lookout on St. Peter's Dome and reported to Bandelier headquarters at 1345 hours. Its point of origin was pinpointed at approximately 0.75 mile down canyon from Upper Crossing.

The suppression of this fire was complicated by difficult detection and travel conditions, bad weather, and topography of extreme relief. At the point of origin of the fire, Frijoles Canyon is more than 500 ft deep. No smoke was visible above the rim of the canyon until 2 hours after the fire started. The last 1.75 miles of travel to the fire was on foot over a steep trail.

No precipitation was recorded in the area for 15 days prior to the fire; and less than 0.5 inch for the previous 50 days. The rate of spread was further increased by southwest winds of 25 mph and gusts up to 45 mph.

The canyon walls at the site of the fire have a 45% grade and the canyon bottom was inaccessible from the north rim because of sheer cliff walls. This made it necessary to carry out two separate control operations, one in the bottom and one on the rim. The fire was contained by May 24, 1960 with a total of 32 acres burned.

Burnt Mesa fire. This fire located in Sec 5, T18N R6E, reported at 1210 hours on July 16, 1975, was caused by lightning. The rate of spread was low (15 chains or less), although the fuel load was heavy in thick timber and the wind was gusty. Slurry was utilized and this fire was contained at 3 acres.

Alamo Canyon fire. This fire in Sec 27, T18N R6E, was first observed from the lookout at approximately 1320 hours Thursday, June 24, 1976. A trail crew in the vicinity was dispatched and arrived at the fire at 1405 hours. The fuels were heavy, the terrain was rough, and high winds drove the fire across the fire line. Slurry was ordered at 1705 hours. Three successful slurry drops were made and the fire was contained at 2000 hours, 6.5 hours after the initial sighting. It was determined that the fire was man-caused, either from smoking or a campfire. The rate of spread was moderate, 15-25 chains per hour. Logs continued to smolder for two months, and the fire was declared out August 24, 1977 with approximately 5 acres of canyon bottom burned.

Escobas Mesa fire. This Class C fire in Sec 6, T18N R6E was lightning-caused and was first observed at 1045 hours July 8, 1976. The fire spread at a night rate, approximately 35-60 chains per hour. Slurry was utilized to help bring it under control. Although the fire was contained in approximately 5 hours after initial observation, there were 14 acres burned.

Fire frequency

Ponderosa pine has a history of repeated fire. Cooper (1961) suggests southwestern pine areas burned every 3-10 years before the arrival of white man. Weaver (1951) examined fire-scarred stumps in Arizona and concluded fires were at intervals of 5-12 years. With more frequent fire the intensity was probably much less; ground fires consumed only a few years of accumulations

(Arno 1976).

Fire may affect a tree bole in a number of different ways from complete or partial destruction to mere scorching (Gill 1974). The most lasting record is the fire scar produced by the healing of a fire-induced wound. Once the tree has been scarred (protective bark is removed), it is more susceptible to repeated wounding; thus, through the use of dendrochronology, the scars can be dated. This can result in a frequency of past fires to which specific trees have been subjected. This does not preclude other fires but is an indication of fire in specific areas. A tree may survive a number of fires before scarring, and every fire may not be of sufficient intensity to produce scarring. Arno (1976) found that trees growing just a few yards from each other had scars of additional fires. Nevertheless, the examination of the fire scars can give an indication of the general frequency of fires in an area.

In the past few years the area has experienced increasing numbers of holocaustic fires. Old-timers of the area (Pickens, Rile personal communication) recall few fires other than small acreages. In the past 10 years, three destructive fires have occurred in the Santa Fe National Forest in this area of the Jemez Mountains (Porter Fire June 16, 1976, 4,000 acres; Cebollita Fire June 1971, 4,380 acres; and La Mesa Fire 15,270 acres). A total of 23,650 acres have been burned. This appears to be due to increased fuel accumulations from approximately 50 years of fire suppression. The possibility of other such major future fires is all too possible. Arno (1976) found that fires had diminished in the forest since 1900 and that this decreasing fire occurrence reflects the role of organized fire suppression.

By examining a number of samples, it may be possible to get an indication of the frequency of fires within a specific area and the time since the last fire. This is merely an indication because numbers can vary from few to many years, but it does give a possible measure of the natural ecology of an area. We have found an average fire frequency for samples collected to be approximately 18 years; however, the average time since the last fire has been 56 years (Table 4). However, when samples known to have fire dates prior to 1900 were examined (Fig. 5), we found a fire frequency of 13.7 or approximately 14 years. This is similar to the frequencies found in other ponderosa pine stands by other investigators for the Southwest (Weaver 1951).

Growth rates

A.E. Douglas (1928), a pioneer in dendrochronology, was able to show that annual rings in trees in the arid Southwest correlate with variations in climate. The favorable or unfavorable meteorological conditions affecting the tree's growth that particular year are reflected in the rings. Although most research has been done on the climatic correlation of tree ring variation (in fact they avoid anomolies), it appears that other factors can indeed affect ring width. Studies done by Schubert (1971) and Helvey (1975) have shown increases in diameter growth after thinning of dense ponderosa pine. Fire is nature's thinning agent and prescribed burning has been used as a tool to reduce fuels and to thin stagnant stands (Weaver 1951, Cooper 1961, Schubert 1971). It therefore follows that stands thinned by fire should show some variation in ring width.

There are a number of factors which affect ring width. Primary, of course, are those directly affecting photosynthetic activity thus the production of food and growth regulators. These may be external factors, such as precipitation and temperature, or internal factors, such as increasing size and competition of cells for available nutrients. As the tree becomes larger, the rings increasingly become narrower. The variation from a normal trend of an individual ring width, however, is closely correlated to climate, particularly precipitation prior to the growing season. The amount of precipitation and its effect on soil moisture, thus, water balance of the tree, indirectly influences the rate of cell growth during the growing season. Fritts (1966) indicated that the ring width in coniferous species growing in semi-arid sites represents the effect of climate of the 14 or 15 months prior to the period of food-making and accumulation in the crown of the tree. Schubert (1971) indicated that most of the growth occurs from May to September.

In a stagnant forest with crowns close together, the competition for sunlight used in photosynthesis is high. Crowns are narrow and sparse. In addition the competition for available water is also greater (Dahms 1973). Since both these factors affect ring width, the rings would be narrower under stress. The increased water stress within the tree, the reduced net photosynthesis, and the low accumulation of food would reduce cambial activity with a net result of the formation of a narrow ring. Helvey (1975) has shown that crowns are wider and thicker in areas which have been mechanically thinned. Fire is also a means by which competition can be reduced. Fire may thin the dense crowns and thus the competition for water and sunlight with resulting increase in growth rate of the trees. It appears that the increase in growth rate may be delayed perhaps due to several factors, the first being the amount of initial damage to the trees. In studies reported by Helvey (1975) and Dahms (1973) on mechanically thinned plots, the first few years following thinning there is a reduction of retention of water in the soil, probably due to the lack of shading of the soils. This might cause water stress within the tree and cause narrower rings until some herbaceous material shades the soil or crowns increase in area. Fire (particularly more severe fire) denudes the soil and reduces soil wettability and permeability for a period of time and this might explain initially reduced growth after fire (Weaver 1967). This effect may be the result of reduced soil moisture.

Nutrients released into the soils after fire may also have an effect on the rate of growth of trees. Wagle and Kitchen (1972) found nutrient increases in soils after fire. Vlamis et al. (1965) found that soils in heavily burned plots had substantial increases in both nitrogen and phosphate to a depth of 8 inches. This increase was prevalent for two years.

Fire is not always a thinning agent. If the fire is basically a cool, ground fire and does not torch crowns, the thinning actions previously described will not occur. In this case, increased width of rings following fire might be due to increased nutrient release or decreased water retention of soils and litter. If this is true, the growth may be only temporary and not sustained over the life of the tree.

It is difficult to determine if any one factor has influenced the growth rate of a specific tree, because as previously discussed, there are many factors which can affect ring width. To try and further understand whether an increase or decrease in ring width is due to influences by the fire or climatic conditions prior or subsequent to burning, winter precipitation from October to May, the period of time which most influences ring formation (Fritts 1966), was graphed (Fig. 6). In addition snowfall accumulations were tabulated for the same years (Table 5). Snowpack would be particularly important in protecting the tree roots from temperature extremes and would also influence the humidity, thus photosynthesis. This increased humidity does not only influence live trees but dead fuels. McCammon (1976) has shown that large dead forest fuels approach their fiber saturation point during the snowpack accumulation period and when the snowpack melts, these forest fuels have a fiber saturation of 32% by weight. Fuel moisture is particularly important in fire behavior resulting in either cool ground fires or hot crown fires. It may be noted from Figure 6 that with only one exception (the 1960 burn) the major fires in Bandelier occurred when there were several years of below normal winter precipitation and generally below normal annual precipitation. Snowpack was below normal (50 inches is average) (Los Alamos Scientific Laboratory) for the winters of 36-37, 49-50, 54-55, 75-76, and 76-77 and exceptionally low for the winters of 49-50 and 75-76, with only approximately 10 inches. Winters of 74-75 and 44-45 had above normal snowpack (Table 5).

Three different situations in relation to fire occurrence are observed from the data collected from cores extracted from trees within various aged burns and controls. The first is a temporary increase in growth evidenced by increased ring width; the second is depressed growth followed by increased growth; and the third is an immediate and sustained increase in growth.

The first situation is seen in samples 1 and 2 collected in the vicinity of Escobas Mesa 1976 burn, Figure 7. These samples show a general trend toward decreased ring width with increased age of the tree. This indicates that the area was not thinned to any great extent but examination of ring widths immediately after the fire indicates a temporary increase in growth. This may be due to the increased nutrient release after each fire.

The second situation is seen in sample 11, Fig. 8 and Fig. 9. These samples show several years of depressed growth of the tree subsequent to fire. After what appears to be an initial shock period there is a spurt in the growth of the tree. As evidenced from Figure 6, both annual and winter precipitation were below normal for the years after the 1955 fire. Thus, it is possible that damage, as well as increase water stress due to drought, contributed to these narrow rings. It is also evident from the condition of the vegetation that this was a relatively hot fire and probably was accompanied by many negative factors such as decreased soil wettability. A similar situation is seen in sample 5, Figure 10. In this case annual and winter precipitation are normal or above normal. As evidenced from the stand structure, the number of fire scars, as well as the fire narrative, this was a fairly hot fire. Possibly this tree suffered shock but with the resultant thinning of the stand after recovery from initial stress, it began to grow more vigorously.

In many other samples the increased thinning of the stands is indicated by the immediate and continued increased growth of the tree (Fig. 11, sample 13, 6; Fig. 12, sample 8, 5; Fig. 13, sample 6, 5, 3; Fig. 14, sample 4; Fig. 8, sample 2; and Fig. 10, sample 4 and 6). This growth may be contrasted to the stagnated growth and more usual decrease in ring width with increase in age as exhibited by tree rings from trees of the unburned controls.

The inner canyon sites have a greater degree of variation in the ring width than do the mesa sites. Since these sites were on the north-facing slope of the canyon, probably duration of the snow-pack is more important and may actually override the influence of the fire. White fir and ponderosa pine appear to be better indicators of fire impact than does the Douglas-fir,

Figure 15.

The growth rates of trees which were 2 inches in diameter and collected within burned areas of Boundary Peak and the North Rim of Frijoles Canyon as well as the adjacent controls were compared. As can be seen from Figure 16, sample 4, 5, and 7 and Figure 17, sample 7, 10, and 13, there is rapid growth after fire as compared with the control samples (Fig. 16, sample 3 and 6; Figure 17, sample 11 and 9). Although trees sampled within the control were also two inches in diameter, they were considerably older than those within the burn and showed suppressed growth with narrow rings. Those within the burn have wide rings and rapid growth. This is due to the thinning produced by the fire and the resultant lack of competition for nutrients and sunlight.

Interpretation of 1976 Phytosociological Data

The phytosociological data for each of the burn sites studied have been detailed in separate tables providing the analyses for mature trees, reproduction, herb and seedlings, and fuel loads.

Alamo Rim. The contrast in Table 6 indicates a stand dominated by ponderosa pine but with a lessening of dominance at the expense of increases in several species of junipers in the area burned in 1945. The young mature juniper trees showed up in the counts of density and basal area but not in the coverage data of the line intercept. The burned stand is relatively open in contrast to the unburned control which has 10x the density of mature trees and 2x the number of reproductive trees. The latter increase is due principally to more *Quercus*, *Pinus edulis*, and *Cercocarpus* in the control. Herb and seedling cover is much greater in the burned area, principally because of the increase in grass cover. This is also reflected by the sole increase of herbaceous material as a part of the fuel load, which in total is much less in the burned area.

Bear Mesa. The comparisons in Table 7 indicate only slight changes in species composition of mature trees between the control and the 1950 burned area. A slight increase of *Juniperus monosperma* in the burn area countered the low densities of *Juniperus scopulorum* and *Pseudotsuga* in the control. However, the total density and foliar cover have been considerably reduced in the burn. These reductions are not reflected in the basal areas, however, which would indicate that smaller trees had been removed by the burn and that the growth of the larger trees left has resulted in a total basal area nearly equalling that of the unburned stand. The density of the reproduction has been greatly reduced in the burned area principally by the decrease of *Quercus* species, as well as of ponderosa pine. The foliage cover of the reproductive stock is much more reduced than is the density. The understory herb cover is only slightly increased in the burned area. Fuel loads are essentially the same.

Boundary Peak. The data of Table 8 indicate a definite effect of the 1955 burn on the mature trees. Both ponderosa pine and Douglas-fir are drastically reduced in the burn area with no change in the few white fir. The foliage cover, although definitely reduced, is not reduced as much due to the thinning and release of competition which allowed for expansion of the canopies. This same effect is also revealed by the lower reduction of basal area than of density. In the reproductive class there is little change in total density but the species composition has shifted with the elimination of Douglas-fir and a great reduction of ponderosa pine in the burn. These have been replaced by increases of Quercus, Ribes, and Robinia. Though the total density is similar, the much lower coverage in the burn would indicate a greater percentage of young, small trees. Total fuel loads are about half as great in the burned area principally due to a reduction of the litter component.

Frijoles Rim. The data for the 1960 burn and control are given in Table 9. The reduction of total density of mature trees in the burn is great, principally due to the loss of ponderosa pine. In the burn there is some increase in junipers and oaks. The foliage cover is reduced more than the density, but the reduction of basal area of trunks is less than that of the density. This probably indicates loss of smaller trees with dense foliage and survival of large trees without lower branches. Conversely, in the reproductive class, the reduction in foliage cover from control to burn is less for foliage cover than for density, indicating a greater loss of small reproductive stock of little cover. Reproduction of ponderosa pine, Douglas-fir, Rocky Mountain juniper, and Gambel oak was absent in the burn area. But, in the openings provided there was a great increase in Cercocarpus. The herb and seedling cover was much greater in the burn due principally to the increases in grasses and woody plants. Comparisons of the fuel load are not possible because the June 1977 La Mesa fire occurred before the 1960 burn samples were obtained.

Frijoles Canyon (inner). The complexity of species composition for the inner Frijoles Canyon area is indicated in Table 10. This stand is located on the north-facing slope of the steep canyon where moisture conditions are more favorable due to slope exposure, snow accumulation and slow melt, and radiation protection. In addition to ponderosa pine, the principal species in the 1937 and 1960 burn areas are *Abies concolor* (White fir), *Acer negundo* (boxelder), *Pseudotsuga menziesii*, (Douglas-fir), and *Quercus gambelii* (Gambel oak). Although there is only a slight difference in the relative densities of ponderosa pine in the 1937 and 1960 burns there is a much greater number and cover of pine in the 1937 stand. This is also reflected in the basal area. The 1937 stand is equally dominated by pine and Douglas-fir. The 1960 burn area is definitely dominated by the latter, although the total density and coverage is only about one-tenth that of the 1937 burn or control.

In the reproductive category, however, the 1960 burn area has twice the density and coverage of the 1937 burn, which in turn has more than the older control. This site contains the greatest number of reproductive and shrub species of any site sampled in the study. Outstanding in abundance were species of *Quercus*, *Berberis*, *Physocarpus*, *Robinia*, and *Rubus*. The dense growth of this stratum produces a flammable layer and potential fire hazard.

The ground cover of the stands represents a similar picture to that of the shrub layer, with the 1960 burn having the greatest foliage cover. The majority of cover in the 1960 burn and control consists of grasses.

The fuel loads in the canyon show a decrease in total weight with the stands more recently burned. While the amount of the litter component decreases, the weight of herbs increases.

Summary. In Table 11 is a summary of the general stand characteristics of four plateau stands of ponderosa pine type as they appeared before the La Mesa fire. They are arranged in order of decreasing time since the last burn, namely, 34, 27, 22, and 17 years ago.

For the mature stratum, in all cases there is a dramatic decrease in total density which has resulted in densities of 10 to 35 percent of the controls. Reductions of foliage cover in burned sites were not as great (leaving 15 to 80 percent of coverage) as were the reductions in density. Part of this is due to foliar regrowth and because the time span is not long enough for pine reproduction to have reached the mature size class. The reductions in basal area resulted in trunk areas which vary from 24 to 82 percent of the controls.

It is apparent that ponderosa pine is the major dominant of all stands, as is indicated by its relative values for density, cover, and basal area. In all cases the burned areas have an equal or higher relative coverage of ponderosa pine than the adjacent controls. Basal areas of pine are also nearly equal or higher in the burned areas. Most outstanding is the presence of much larger trees in the burn areas as is indicated by the average diameters (dbh) which in the burn areas are 136 to 157 percent greater than in the controls.

In the comparison of the mature stratum no direct relationship to time since last burn is apparent. Overriding the time factor is the effect of varying burn severity. For example, the Bear Mesa stand was least reduced in total density and least in reduction of foliage cover, which would indicate a cool fire - which it has been reported to have been. The result of fire producing more open, park-like stands, with larger trees is apparent from the summary.

The total density of all reproductive trees and shrubs is reduced in the burns to 26 to 83 percent of the adjacent controls. And, the total cover of this stratum in the burns is 18 to 50 percent that of the controls. Again, there is no trend with time. While the relatively cool 1950 Bear Mesa burn had the highest density of mature trees, the greatest density of the shrub layer was in the 1955 Boundary Peak stand. This density, as previously mentioned, was principally due to an increase in *Quercus*, *Ribes*, and *Robinia*.

Herb and seedling ground cover is greater in all burn areas (114 to 6,250 percent) than in controls. This appears to be a variation due to site or burn conditions, not a trend with time since the burn. There also is not a consistent shift in the relative composition of the understory cover represented by the growth forms of forbs, grasses, and woody plants. In the Bear Mesa and Frijoles Rim stands the relative cover of woody species increased in the burns. In the Alamo Rim and Boundary Peak burns the percentage of woody cover decreased. Forbs remained about the same or greatly increased. Ground cover shifts were also not related to time since burning.

The total amount of fuel load was lower in all burned areas versus controls and showed less reduction in the Bear Mesa burn. Although no data was obtained from the 1960 Frijoles burn before the La Mesa fire it is apparent from the limited data that no trends would be found related to time alone. The most apparent changes include the reductions of litter in the two hot fires to 23 and 41 percent of the control, while in the Bear Mesa fire the burned area had 91 percent of the litter weight found in the control. The second outstanding difference is the great increase in herb fuel load in the two hot burns (533 to 4,600 percent) over the controls, but a reduction in the Bear Mesa burn.

From these data, no consistent trends were found corresponding to time since the last burn. The condition of the stand relating to the mature tree, reproductive, and herbaceous strata and the weight of fuel loads is apparently due to site factors and the nature of the last burn (and perhaps previous fire history) rather than a consistent successional trend. This is well illustrated by the contrasting conditions of the Bear Mesa 1950 burn area. Its indications of a cool fire in 1950 are still reflected after 27 years by a lesser reduction of total density, foliage cover, and basal area of mature trees; a lesser change in the relative role of ponderosa pine in the mature stratum of the community; lesser changes in the total herb foliage cover and its general growth form composition; and the lesser changes in total fuel load and its composition. Predictions of fire hazard would have to be made on individual stands and based on the several factors of mature, reproductive and herbaceous strata as well as the amount of fuel load.

La Mesa Fire

Description

The following information is summarized from Forest Service notes on fire behavior and weather prediction. The La Mesa fire was first reported at 1556 hours, June 16, 1977 by the St. Peter's Dome Lookout and within 20 minutes of the original sighting, flames and heavy smoke were noted. The initial attack was a Forest Service helitack crew. The location and spread of the fire is given in Figure 18.

The fire began in a pile of slash on Mesa del Rito approximately 2 miles from the western boundary of the Monument. Investigations by the Forest Service personnel deemed it to be man-caused, either deliberate or accidental. The area was dense ponderosa pine which had been logged 20 years previously. The slopes were 10-15% but steep in the draws and precipitous to the edge of the mesa which dropped into Alamo Canyon. At 1730 an aerial reconnaissance flight revealed the fire to be approximately 50 acres in size.

Hot, dry, windy weather, plus heavy fuel loads (16-20 tons/acre) (Forester 1976) produced prime conditions for a holocaustic fire. The fire season had begun exceptionally early with an Easter fire on April 10, 1977. In the 39-year fire history, only three other fires had been reported for April--the prime fire season being June and July, Table 2. Although the total precipitation for the previous year was not particularly below normal, there had been a very thin snow pack and the general precipitation for the first 6 months of the year was below normal (Table 5, Fig. 6). The day prior to ignition of the La Mesa fire, the relative humidity had dropped to 6% while the mean for the first 13 days of the month was 43.4% and for two months prior was 39.4%. The average temperature for June was recorded as 81.2^{o} F with an extreme of 90^{o}--recorded the day of the fire. In the previous 31 days there was only about 0.18 of an inch of rain which was spread over 4 days. The rain had been accompanied by thunderstorms which contributed to the seven reported fires. The fine fuel moisture had reached a low of 4% and the 1-hour time lag was 1. These exceptionally dry, hot conditions at the start of the fire and on the following 4 days probably contributed to the fire spread.

From 1730-1800 the fire was estimated to have increased from 50 to 100 acres with a spreading rate of 24 chains per hour. It was believed at that time, however, that the fire would be contained.

However, due to burning debris falling into Alamo Canyon and causing re-ignition, as well as long range spotting, by midnight Friday June 17, 1977, the fire had escaped Mesa del Rito and spread approximately 3 miles into Bandelier National Monument. At that time the total acreage of the burn was set at 740 but it was probably double that amount. The perimeter extended north across Frijoles Canyon to Escobas Mesa.

On Saturday, July 18, tractor lines, 20 to 40 ft wide, were constructed on Escobas Mesa in the hope of containing the fire. (A portion of this line ran directly through the 1976 Escobas Mesa fire.) However, the fire began to spread rapidly in a northeasterly direction at 1100 hours and there was nothing to hamper its spread until it reached State Route 4. The fire reached and crossed the highway on a mile-wide front at 1230. The forward rate of spread at this time was estimated at 38 chains per hour. Long distance spotting from 0.5 to 2 miles caused numerous spot fires. During the day and evening, the smoke levels were high and cinders were falling in White Rock, 8 miles away; occupants were warned of burning embers, and the headquarters' families were evacuated. By the end of the night shift on June 18, the northern flank within ERDA property was basically contained. The suppression activity had not commenced on the southwestern flank of the fire and it had extended just south and west of Rabbit Hill.

June 19, 1977 the fire spread rapidly to the west on Mesa del Rito and there was continued activity within Frijoles Canyon. The weather forecast called for the possible development of a convection column to 23,000 ft in the afternoon. This would cause extreme rates of fire spread and sustained fire crowning.

It was estimated at that time that the fire line intensity would be approximately 500-700 BTU ft/sec. At 1300 hours the estimated rate of spread for closed timber type with litter and understory was 12 chains per hour with a fireline intensity of 350 BTU ft per sec. Timber with moderate logging slash and loadings of downed fuels was projected to produce a rate of spread of 20 chains per hour and a fireline intensity of 900 BTU per sec.

At approximately 0100 hours June 19, 1977, backfiring was initiated along State Route 4 to Frijoles Canyon Bluffs. The object was to stop the spread north of and west along Frijoles Canyon and the possible spread into Los Alamos. The firing was completed by 0900 hours but was not particularly clean. In addition to the backfiring, a hand line was constructed from the Sandoval County line along the rim of Frijoles Canyon. It was approximately .5 to 1.5 chains wide.

June 20, 1977 the weather forecast called for increasing winds throughout the day and a low relative humidity. The fire was expected to make rapid advances with long distance spotting. At 1200 hours the rate of spread for timber litter and understory with no slope was expected to be 18 chains per hour with a fireline intensity of 400 BTU ft per sec and a flame length of 7 ft; for 80% slopes with effective wind speeds of 20 mph, the rate of spread was estimated to be 28 chains per hour and a fireline intensity of 850 BTU ft per sec with a flame length of 11 ft. For fuels composed of medium logging slash, or areas of heavy loading of natural accumulation of dead fuel, flat slopes, and effective wind speeds of 14 mph, the rate of spread was estimated to be 29 chains per hour with a fireline intensity of 1700 BTU ft per sec and a flame length of 13 ft. Areas with at least 80% slope and an effective wind speed of 20 mph were estimated at 45 chains per hour with a fireline intensity of 1800 BTU ft per sec and a flame length of 15 ft. It was noted that logging slash would probably not be encountered on 80% slopes but the natural down fuels in the La Mesa fire area could equal such loadings.

By the night shift on June 19 the fire weather forecast called for northwesterly winds of 4 to 8 mph, minimum temperature of 60° F, and a relative humidity of 50%. Since the fire behavior was determined to a large extent on the moisture in ground fuels and the increase in the relative humidity, fast fire movements experienced on the previous night were not expected.

On Monday, June 20 at 0200, the fire behavior forecast predicted winds with gusts up to 35-40 mph. Because of the unstable air, a convection column was predicted to reach 20,000 ft with a high probability of spot fire and long distance spotting (1-2 miles). Torching of individual tree crowns was expected to be common with the likelihood of sustained crown fires. The possibility of reburn through areas where only surface fires had been was noted. The fuel loadings in the area were reportedly extremely high (60-80 tons per acre) from logging slash and natural accumulations. At that time the rate of spread for timber type with ground litter and understory was estimated to be 23 chains per hour and with a timber type with logging slash or areas of heavy natural accumulations, 37 chains per hour. At 1300 hours the rates of spread for timber with litter and understory was predicted to be 10 chains per hour and in timber with slash or down natural fuels, 19 chains per hour.

Thunderstorms and higher relative humidities were predicted. It was indicated that if the precipitation reached the ground fuels, the rates of spread in timber with litter and understory would be 2 chains per hour with the fireline intensity of 60 BTU and a flame length of 2.5 ft. In timber with slash or downed natural fuels the prediction was 6 chains per hour, a fireline intensity of 200 BTU ft per sec, and a flame length of 5 ft.

On June 21 cumulus clouds began to form around noon. The projected fire behavior at noon was 12-16 chains per hour with a fireline intensity of 300-400 BTU ft per sec, with a flame length of 6-7 ft for timber type with litter and understory. Timber with slash or fuel accumulations had a predicted rate of spread of 18-22 chains per hour, fireline intensity of 800-860 BTU per sec, and a flame length of 9-10 ft. The moisture of large dead fuels remained critically low, although the weather had improved. Torching and intermittent crowning was probable on steeper slopes.

At this time the perimeter was estimated to be 1,770 chains and a total area of 11,000 acres.

By the evening of June 21, 1977 the minimum temperature was expected to be 48° and the maximum humidity 70%. Due to this projection, the rates of spread were reduced to 2-4 chains per hour with fireline intensity of 50-70 BTU per sec and a flame length of 2-4 ft in the timber with litter and understory. Timber with slash and or fuel accumulations was expected to produce rates of 6-8 chains per hour, a fireline intensity of 200-300 BTU ft per sec, and a flame length of 4-6 ft.

The fire weather forecast called for cumulus clouds to form in the late morning hours with isolated thunderstorms in the fire vicinity during the afternoon. The relative humidity had dropped to 20%.

Because of the lowering of the relative humidity and the low fuel moisture content, fast fire runs and spotting were again expected. By this time the manpower and equipment were 1,370 men, 9 bulldozers, 23 ground tankers, 5 helicopters, and 5 air tankers. There were enough men to man the entire perimeter and approximately 3 miles of open line was backfired to the edge of Frijoles Canyon This proved to be a good backfire.

Thundershowers began at about 1500 hours and ended about 2100 hours with winds nearly calm. The minimum temperature was 54° and the relative humidity 75%. This reduced the probability of fast fire runs and minimized the chances of spotting. At the end of this shift the perimeter was approximately 38 miles (a conservative estimate) and a total area of 15,000 acres. The fire was considered contained at 1600 hours.

On June 23, 1977 scattered thunderstorms produced heavy rains during the night shift and temperatures were in the 30s. The fire was declared controlled at 1600 hours.

The La Mesa fire had consumed approximately 15,270 acres of forested land in the Santa Fe National Forest, Bandelier National Monument, and Los Alamos National Environmental Research Park. Approximately 33% of the forested land of Bandelier had been subjected to the fire, a total of 10,630 acres. Figure 19 illustrates part of the entire area which was burned and the patchiness of severity of foliar damage which in part is related to previous fire history.

Post-La Mesa fire re-examination of 1976 line-strip plots

Due to many factors such as fire behavior resulting from existing fuels (both standing and ground) as well as weather, fire does not burn with one intensity. To provide baseline data for future evaluation of the viability of trees throughout the burn, degree of damage to the crown was determined. Herman (1954) found that only 5% of trees of sawtimber size with more than 60% of their crown killed were alive after 6 years. In contrast, 86% of trees survived which had a crown kill of 60% or less. He found trees of any size which lost more than 60% of their crown were not likely to survive. Herman also found that height of trunk scorching and the presence of nearby burned-out stumps did not affect survival.

In this study foliar damage was determined in six classes ranging from no needle scorching to complete needle consumption. This not only provides a good indicator of the future succession of any particular plot, but also indicates the amount of needle fall in specific areas. Needle fall may also affect the soil erosion and plant succession because of its shading and moisture retention properties.

Another indication of fire intensity is the damage to the understory and the amount of denuding of the soil (Herman 1954). This may be expressed in the measure of relative cover of herbaceous plants and shrubs within the plot.

The above classification was used for both the burn and control plots which were reexamined by the line-strip method in 1977 and for a series of comparative and baseline burn plots (20 x 50 m) established after the La Mesa fire. Each of the line-strip plots will be discussed and compared in a summary.

Alamo Rim 1945 burn. Re-examination of this plot took place July 13, 1977. It was burned during the period of 1430 and 2000 hours on June 17, 1977 during which time there was a predicted rate of spread of 24 chains per hour. Fuel loads within the area burned during this time interval were from 6.4 to 15.6 tons per acre (Forester 1976). Many areas along the trail which provides access to the 1945 burn were severely burned with trees showing explosive popping of the bark (Fig. 20). Fuel loads within the area burned in 1945 were 2.32 tons per acre of fine fuels and 9.06 tons per acre within the control (Table 6).

The open meadow created by the 1945 fire had been utilized as a heliport to supply men and materials for the La Mesa fire and many small trees had been cut down. As shown in Fig. 21, there was very little difference in the survival rate of the mature trees in either the 1945 burn or control. Within the 1945 burn 55.0% of the trees were in class 6 and 31.0% in class 5. Within the control 83.9% were in class 6 and 15.1 in class 5 (Table 12). Only 14% of the trees within the 1945 burn had foliar damage in class 3 and 4 compared to 1% in the control. In neither case are many trees expected to survive since Herman (1954) found that trees need at least 60% of foliage remaining to survive.

The total relative foliage cover of herbaceous plants was reduced from 37.1% in 1976 (Table 6) to 8.1% (Table 13), as compared to the control which was reduced from 5.1 to 0.4%. Sprouting of perennial grasses and herbs was seen within the 1945 burn but within the control only sprouting of deep-rooted shrubs was seen.

Bear Mesa 1950 fire. Attempts were made at re-examination of this plot in July, however the Forest Service had closed all accessible roads and it was not feasible to examine the area in a single field day under hiking conditions. Thus, this site was re-examined in September, 1977. The area burned during the period from June 17, 2000 hours to June 18, 2000 hours, during which time there was a predicted rate of spread of 38 chains per hour. Fuel loads within the area burned during that time interval and within the vicinity of these plots were from 6-8 tons per acre (Forester 1976). Fuel loads within the area burned in 1955 were 8.67 tons per acre and 9.39 tons per acre within the control (Table 7).

From the 1976 observations and from personal information communicated by Abro Rile, it was determined that the 1955 fire had been a relatively cool fire. This was reflected in the fuel loads, foliage cover, and densities obtained during the 1976 field season. Neither area was remarkably different. However, extent of foliar damage was much more severe for the control area than the burned area as seen in Figure 22. Over 66% of the trees within the control sustained foliar damage in classes 5 and 6, while only 6.6% sustained similar damage in the burn (Table 14). Sixty percent of the trees within the control sustained foliar damage less than 50% and prognosis for their survival is good, while the control has only 9.5% within the same category. The more dense stands will probably be substantially thinned.

Frijoles Rim 1960 burn. Re-examination of this plot took place June 30, 1977. It burned during the period of 1430 hours and 2000 hours on June 17, 1977 (Fig. 18), during which time there was a predicted rate of spread of 24 chains per hour. The site is located on the rim of Frijoles Canyon where the fire jumped the canyon. Fuel load within the control area was 12.33 tons per acre (Table 9). Unfortunately, fuel loads for the burn area had not been collected by the time of the La Mesa fire; the collection was to be done during the 1977 field season. It might be noted that remains of a vehicle were found just north of the 1960 burn and the chrome had been melted into pools, which is evidence of a hot fire.

The contrast between the control area and the 1960 burn was striking, Figure 23. The control area was completely devastated, while the burn area had no trees in classes 5 and 6 (Fig. 23) and 64% of the trees were in classes 1 and 2 (Table 16). It appeared to be an island of green in a sea of black. The 1937 fire was situated east of the 1960 fire, while the control was west. As seen in Figure 23, destruction of the trees within the 1937 burn was very extensive. This area provides an excellent comparison of the minimal damage in an area burned 17 years previously, close to the average pre-Monument fire frequency, and the severe loss in an area not burned for 40 years.

Total relative foliage cover of herbaceous plants was reduced from 43.6% in 1976 (Table 9) to 14.3% (Table 17) after the La Mesa fire. Figure 24 illustrates the comparison of the 1960 burn in August, 1976, pre-La Mesa fire and August, 1977, post-La Mesa fire. It also compares the appearance of the previously unburned control post-La Mesa fire with the 1960 burn.

Frijoles Canyon burn (inner). This site burned during the period of 1430 hours and 2000 hours June 17, 1977 (Fig. 18). It was along the path where the fire jumped the canyon. Attempts to re-examine the site were made on July 14, 1977 but met with defeat due to the lack of vegetation and the steepness of the slope. However, the changes wrought in this area by the La Mesa fire are seen in Figure 25. It might be noted that sprouting of *Robinia neomexicana* and *Quercus gambelii* was extensive just slightly less than one month after the La Mesa fire.

Frijoles Rim 1878 burn. This area was not measured during the 1976 field season. In an attempt to establish fire frequency, a tree which was atop a ruin in this area was cut down by the Park Service staff just prior to the La Mesa fire. Dating of this section indicated that there had not been a fire in the area since 1878. Examination of the site was done on September 21, 1977. The site had burned during the period of 1430 hours and 2000 hours on June 17, 1977 (Fig. 18), during which time there was a predicted rate of spread of 24 chains per hour. Although no fuel loads had been taken during the 1976 field season, the 1960 control is immediately south of the 1878 site. Fuel loads in that area were measured at 12.33 tons per acre (Table 9). Figure 26 illustrates the comparison of the appearance of the site prior to the La Mesa fire and subsequent to the La Mesa fire.

Although the site was not examined until September, the burning in the area had been so severe that little or no vegetation was coming back (0.1% relative foliage cover, Table 19). One hundred percent of the trees were in categories 5 and 6 (Fig. 27) with 99.4% in class 6 (Table 18). The area was devoid of any litter or duff and the mineral soil had been contracted and welded into polygons. Andropogon gerardii was the only grass species evident in the area. It appears that the accumulation of fuels from a lack of burning for 99 years combined with the fire behavior provided the factors necessary for complete destruction of trees and understory in this area, leaving it completely blackened and devoid of living material except several inches below the ground surface.

Frijoles Rim 1937 burn. This area was not measured during the 1976 field season due to lack of time and was to be examined during the 1977 field season. However, the studies were interrupted by the La Mesa fire. Examination of this plot took place September 21, 1977. The site burned during the period of 1430 hours and 2000 hours on June 17, 1977 (Fig. 18), during which time there was a predicted rate of spread of 24 chains per hour. It is in the immediate vicinity of the area where the fire jumped the canyon. There are no recorded fuel loads prior to the La Mesa fire but the control area west and separated by the 1960 burn was 12.33 tons per acre (Table 9).

Although the area which was burned in 1937 had been opened up into a meadow, damage to mature and reproductive trees was severe with 100% of the foliar damage in classes 5 and 6 (Table 20). This was slightly less than the damage in the control which was all in class 6. Figure 23 illustrates the extent of damage to this area.

Total relative foliage cover for herbaceous plants was 2.3% (Table 19) compared with the 1960 burn of 14.3% (Table 17) and the 1878 burn of .1% (Table 19). Perennial grass and herbs were regenerating (Fig. 29). Large quantities of Andropogon gerardii were found in the area and there was evidence that turkeys had returned to the area as evidenced by their tracks. It is evident that 40 years of fuel accumulation provided the conditions necessary for fairly complete destruction of the overstory, but did not completely destroy the rootstock of perennials.

Escobas Mesa 1976 burn. This area was burned prior to the La Mesa fire during the 1976 field season. At the time photo stations were established but measurements had not been taken. The site re-burned June 18, 1977 (Fig. 18) between 1100 and 2200 hours, during which time there was a predicted rate of spread of 38 chains per hour. Immediately after the 1976 burning on Escobas Mesa, fuel loads were 1.33 tons per acre, while an adjacent control measured 3.47 tons per acre (Forester, personal communication). Unfortunately, the fireline which was established on Escobas Mesa ran directly through the 1976 burn causing substantial bulldozer damage.

This area was measured July 7, 1977. It was easy to relocate the boundary of the previously burned 1976 fire because the La Mesa fire had jumped the narrow, barren 1976 hand lines (Fig. 30). The area apparently had been logged approximately 50 years ago, so an adjacent control was selected which had also been logged, but had not been subjected to recent fire. As can be seen from Figure 31, all trees within the area burned in 1976 are in classes 1-4, while those of the control are all in classes 1-6 with 92.4% in classes 5-6, Table 21. There also is considerable difference in the relative cover of herbaceous plants. Within the 1976 burn there was a total relative cover of 12.0%, while in the control there was only 0.1% (Table 22).

It is quite evident that the reduced fuel load in this area from the 1976 fire was responsible for the survival of these trees. Although there will probably be considerable thinning in the area of the 1976 fire, the prognosis for the survival of many of the trees is good. Although the logging thinned considerably the area of the control, there was still a high degree of foliar damage sustained and most of the trees must be considered dead.

Photographs taken at the photo stations established during the 1976 field season are compared with photographs taken immediately after the La Mesa fire and in September, 3 months after the La Mesa fire (Figs. 32, 33).

Reproductive ponderosa pine. Damage to ponderosa pine less than 4 inches in diameter was very dependent on the length of time since the last burn. As can be seen in Figure 34, there was extensive damage to reproductive trees in all plots except the Escobas Mesa 1976 burn where 96.3% (Table 21) of the trees were in classes 1 and 2. Fuel loads were apparently not sufficiently high in this area to produce a damaging fire. Reproductive trees in all other plots with the exception of the 1950 burn are not expected to survive. Only 24.6% (Table 14) of the trees in the 1950 burn have sufficient foliage remaining for survival; thus, it is expected that considerable thinning of this area will occur.

Burnt Mesa 1975 burn--unsampled. This was a small, severely burned, three-acre area in which photo stations had been placed during the 1976 field season. Measurements of this area were not done but comparative photographs of the area taken September 1976, immediately after the La Mesa fire, and 3 months post-fire are seen in Figure 35.

Summary of fire damage to ponderosa pine type from line-strip plots.

In Table 23 are summarized the principal features of a series of stands representing no burning prior to the La Mesa fire, for periods of 99 years to 1 year. Because these stands are of the ponderosa pine type and completely dominated by this species, only data for pines is given. Total densities and basal areas for pine versus all species vary by minor percentages for the mature stratum.

The density of mature pine in the unburned controls varies from 235 to 440 trees per acre. Except for the area burned in 1878, which still had a dense stand of 342 trees per acre, all other previously burned stands had greatly reduced density of stand. The variations did not correspond with time since the last burn, but most likely were dependent upon the severity of the burn at that time, a phenomenon for which good data is not available.

The figures for basal areas of pine indicate that the 1878 burn did not have as much increased basal area as would be indicated by the large number of trees, indicating that much of the stand was composed of small diameter size classes (but over 4 inches in dbh). Of the stands previously burned, the 1878 stand had the lowest average diameter, 7.0 inches. Two adjacent stands burned in 1937 and 1960 had average diameters of 8.8 and 13.1 inches, respectively, apparently indicating the removal of small diameter trees by fire. Given enough time for successful years of germination, seedling establishment, and growth, a population of young mature trees becomes reestablished. This high density and small size would result in a stand with trees close together, much total foliage, and with many branches close to the ground--a situation conducive to severe burn damage by wildfires. The above situation is further aggravated by the reproductive component, which usually increases with time after burning.

The limited amount of data on fuel loads indicates a considerably higher total amount for the control areas than for the burned stands. Again, the amount of litter and sticks in the fuel load is probably more a factor of the fire intensity than the time since the last burn. Several stand conditions, such as mature tree density, reproductive density, and high fuel load in the Bear Mesa stand indicate a relatively cool fire there in 1950.

The rate of fire spread is given as derived from the map on rate of fire spread and notes obtained from the U.S. Forest Service. Rates were slower in the Bear Mesa stand and faster in the Escobas Mesa 1976 burn.

The data of Table 23 on fire damage to foliage of mature trees provides the best evidence of the relation of time since the last burn to the severity of damage produced by a wildfire. Trees having foliage damage classifications greater than 3 (51-75% of the foliage singed) are not likely to recover. Note the complete loss of trees in the areas not burned since 1878 and 1937. The Alamo Rim stand, not burned for 31 years, has no trees with less than 50% foliar damage and probably none of the trees will survive. The Bear Mesa stand burned by a cool fire in 1950 has a low percentage of trees in classes 5 and 6 and 60% in classes 1 and 2. Trees in the 1960 Frijoles Rim burn and the 1976 Escobas Mesa burn have no trees in classes 5 and 6. The number of trees in classes 3 and 4 within the Escobas Mesa stand may reflect damage from the 1976 fire from which there was not time for recovery. Attention is directed to the contrast between the burned stands and the adjacent controls. The latter always have higher mean damage values. This set of data would indicate that an interval of time between wildfires of more than 25 years results in nearly complete loss of all mature trees when a fire does occur. This time interval is more than a decade longer than the naturally occurring fire interval recorded by fire-scarred trees on Escobas Mesa. Obviously, the damage produced by prescribed burning would be less severe than that of a wildfire. Under a management plan with prescribed burning, the survivorship after a wildfire of only 60% of the mature trees as in the case of the 1950 Bear Mesa burn and the 1960 Frijoles Rim burn might not be acceptable. The above examples represent fire intervals of 27 and 17 years.

The set of data for the damage to the foliage of pine reproduction indicates similar damage as to the mature trees. The mean damage decreases with the decreased interval of time since the previous fire.

In Figure 35.1 is summarized the effect of time interval since the last burn on the foliar damage produced by wildfire for six plateau stands of ponderosa pine representing a span of 99 years to 1 year of no burning. The classes of foliar damage range from 1, representing 0-25% foliar scorching, to 6, representing complete needle consumption. Values given are means of all mature ponderosa pine trees and of all reproduction of ponderosa pine. Recognizing that values greater than 3.0 will likely result in total tree mortality and that a stand with an average value of 2.5, as Bear Mesa, will suffer a loss of 40% or a survival of 60% of the mature trees, one can estimate from the slope of the curve the amount of damage or survival to be expected in stands not burned for various periods of time.

Analysis of the 20 x 50 meter plots

The 20 x 50 meter plots were established for the purpose of providing baseline data for future successional studies. Each plot within transects previously established for biological studies is discussed.

Transect I, Frijoles Mesa. Pinyon-juniper dominates this transect which is near the interface of the pinyon-juniper, ponderosa pine zone. The area was burned between 1100 and 2200 hours June 18, 1977 when the predicted rate of spread was 38 chains per hour. Fuel loads in the vicinity of plot 4 were 24 tons per acre but in other areas 2.2 tons per acre (Forester 1976). Burning was spotty throughout the area; however, in some areas the fire did crown in the pinyons and junipers, causing complete loss of foliage. In other areas burning was light with only one side of a tree being scorched. In both the light and moderately burned plots, burning was complete only near isolated trees. Figure 36 shows the degree of damage each plot sustained and Table 24 summarizes the data. Regeneration of the herbaceous and shrub understory was dependent on the degree of crowning (Table 25). Immediate sprouting of various species such as *Quercus* sp., *Rhus trilobata*, and *Cercocarpus montanus* was observed. Photographic records of the appearance of each plot are seen in Figure 37.

Transect II, Burnt Mesa. This area was moderately to severely burned and represents a variety of stand types from an open meadow, to park-like stand, to dense stand. The origin of the meadow is in question since there are no available records of recent fires and no evidence of logging. The area burned July 18, 1977, when the rate of spread was estimated to be 38 chains/hr.

Plot 1 was an open meadow which was completely burned but within a short time was covered by luxuriant growth of grasses and forbs (Fig. 38). Seed heads of *Bouteloua gracilis* were extremely large. Within the meadow there were no mature trees (Fig. 39); however, small trees of the area sustained extreme foliar damage (Fig. 40). Forbs still dominated the site but not by a very high percentage (Fig. 26).

Plot 2 was placed in an open stand of ponderosa pine. Although the area was open, all the trees suffered foliar damage with only a few green needles remaining to complete needle loss (Table 26). Small saplings in the area were noted to be sprouting from the terminal buds. Large patches of *Allium cernuum* were observed in the more severly burned areas. The recovering herbaceous plants were mostly grasses (Table 27).

Plot 3 was a dense stand of pine which had nearly complete foliar kill (Fig. 40). The sparse vegetation was made up entirely of forbs (Table 26).

A photographic record of the appearance of the plots within this transect can be seen in Figure 41.

Transect III, Escobas Mesa. Burning on Escobas Mesa was variable depending on factors such as terrain, presence of previously burned areas and logging. It burned between 1100 and 2200 hours July 18, 1977 when the predicted rate of spread was 38 chains per hour.

Plot 1 was in an area which was considered to be moderately burned. It was about 50 yards from an open meadow and immediately after the fire, had herbaceous cover returning. Small trees in this area sustained high degrees of foliar damage but sprouting from leaf buds was noted. *Andropogon gerardi* was producing large seed heads by the fall.

The origin of the meadow adjacent to this plot is unknown; however, it should be noted that the species composition seemed to be one of disturbed soil because it included large numbers of weedy species such as *Sitanion hystrix*, *Amaranthus retroflexus*, *Verbascum thapsus*, and *Lycurus phleoides*. This is not true of the meadow near plot 2.

In July of 1976 a fire burned the area in which plot 2 was placed. It was reburned by the La Mesa fire but only lightly. The area also contained a small ruin and from its condition, a light burning also was indicated. Foliar damage in this plot was from classes 1-4 (Figs. 42, 43; Table 28) which in turn indicates the nature of the fire in the area. Fuel loading in the area had been measured after the 1976 fire and found to be 1.33 tons/acre. Summary of the status of regenerating herbaceous plants is found in Table 29.

Plots 3 and 4 were placed in areas which were unlogged and logged, respectively; the history of logging of the area is not specific. The Timber Management Plan for the Los Alamos Working Circle indicates that the first management plan for the area was drawn up in 1923 but timber had been harvested without a plan since 1909. A sample collected by John Dieterich on Escobas Mesa was cut about 1970 (Fig. 5). From the condition of the stumps he estimated that the area was logged 50-60 years ago. Most of the logging done in the Los Alamos area (townsite and vicinity) during 1923-1931 was used by the Ranch School for building logs, poles, and cordwood. There is some indication that logging in the immediate area of the origin of the La Mesa fire was done to furnish timbers for the railroad which supplied the town of Buckman. Mr. Pickens indicated that logging was done after 1927 in the Ramon Vigil Grant area and what logging was being done was in conjunction with homesteading--particularly clearing of fields and building of homes. Monthly reports to the Southwest Monuments Association indicate some logging was done for the purpose of supplying vigas for the lodges in Frijoles Canyon during the early 30s on the Ramon Vigil Grant, but areas were not specified.

Plot 3 was in a dense doghair stand adjacent to an open logged area (Plot 4). Within the plot a ruin sustained considerable damage, evidenced by the presence of cracking and spalling of the rocks (Fig. 44). This phenomena was seen throughout areas which were severely burned. The foliar damage in this area was complete (Fig. 42) with 100% of the trees with foliar damage in classes 5-6 and 61.5 in class 6. Total herbaceous cover is summarized in Table 29.

Plot 4 was in an area which from all indications was logged 50-60 years ago. Foliar damage varied from 3-6 with 85% of the trees in classes 4-5. This resulted in a considerable amount of needle fall in the area. Measurement of percent coverage of seeded grass within these plots as measured in September 1977 are seen in Table 29. As can be seen, this plot has the highest percent foliage cover, although a low total foliage cover of resprouting grasses and forbs.

A photographic record of the appearance of these plots during the 1977 season is seen in Figure 45.

Transect IV, Apache Springs. Burning within the mixed conifer was variable and mostly due to backfiring. On June 20, 1977, depending upon the fuel type, the rate of spread was predicted to be from 10 to 37 chains per hour. Forester (1976) reported fuel loads varying from 5.8 to 11.7 tons per acre. Damage in the plots was dependent upon the species, aspen being the most easily damaged and ponderosa pine sustaining the least damage (Figs. 46,47,48,49,50).

Plot 1 was adjacent to the canyon rim and to a large fire-line dubbed by the park staff as Glendale Boulevard. Damage varied from class 4 to 6 depending upon the species. Ponderosa pine was the only species which had trees with foliar damage in class 4 (2.3%, Table 30, 31). Total herbaceous cover was .4% (Table 32).

Plot 2 was considered to be moderately burned. Ponderosa pine predominated the plot and sustained all degrees of foliar damage from 1-6 (Fig. 47). Total herbaceous cover was 3.1% (Table 32).

Plot 3 was considered to be lightly burned. Ponderosa pine predominated the plot and sustained all degrees of foliar damage from 1-6 with 49.6% in class 1 (Fig. 48, Table 30,31). All other species also sustained minimal foliar damage (Fig. 48). Total herbaceous cover was 1.5% (Table 32).

Plot 4 was not in the immediate vicinity of Wauer's transect but demonstrated a high degree of damage and was selected to observe sprouting of mixed conifer species. All species sustained a high degree of foliar damage with aspen being most severely scorched (Fig. 49, Table 30,31). Total herbaceous cover was .2% (Table 32).

Plot 5 is similar to plot 4 and was established to observe sprouting of aspen. All tree species sustained a high degree of foliar damage with aspen being most severely damaged (Fig. 50, Table 30,31) Total herbaceous cover was .1% (Table 32). Herbaceous cover was dependent on degree of burning, with the most in lightly burned plots and least in severely burned plots.

A photographic record of plots in this transect is seen in Figures 51 and 52.

<u>Transect V, Frijoles Canyon (inner)</u>. Burning within the canyon was variable and except for spotty areas can be considered light and moderate. The area burned June 17, 1977 during which time the

predicted rate of spread was 24 chains per hour. Two plots were placed along the transect, one on the south side in the vicinity of the 1960 burn and one on the north side. The species composition within the canyon is mixed conifer.

Plot 1 was placed on the south side of the trail in an area meadowed by the 1960 fire. Survival of all tree species was excellent, with the majority of the trees in classes 1 and 2 (Fig. 58, Table 33,34). Relative cover of herbaceous plants was also good (Table 35). The herbaceous vegetation was luxuriant with spiked muhly, which dominated the plot, exhibiting large seed heads.

Plot 2 was on the north side of the canyon in a dense stand of mixed conifer. Damage was highly dependent on the species, with oak being the most severely damaged, then white fir, Douglas-fir and ponderosa pine (Fig. 54). Due to the dense nature of the stand, the relative herbaceous cover was not high (Table 35). It appears that this stand will receive some badly needed thinning.

A photographic record of each plot is seen in Figure 55.

Rehabilitation of vegetation after La Mesa fire

The National Park Service participated in a joint project with the U.S. Forest Service to reseed native grasses by helicopter. Since only minimal portions of the area were considered to be lightly burned, all of the 15,270 acres were to be reseeded.

Gary Gregory and Roland Wauer of the National Park Service met with Teralene Foxx and Dorothy Hoard to determine what native grasses might be used for reseeding. They had been given a list of available seed by the Forest Service. Exotics were eliminated from the list and additional native grasses known to be growing in the area were suggested. Since seeds of most of the grasses suggested were not available, similar species were substituted for seeding. The grasses which were to be used were:

- Sand dropseed (Sporobolus cryptandrus)
- Blue grama (Bouteloua gracilis)
- Sheep fescue (Festuca ovina)--labels on sacks indicated "Hard Fescue"; according to Hitchcock (1950) this is Festuca ovina var. duriuscula, which if used, is an exotic introduced from Europe

Spike muhly (Muhlenbergia wrightii)

Western wheatgrass (Agropyron smithii)

Slender wheatgrass (Agropyron trachycaulum)

These species were chosen because of: 1) natural occurrence, 2) soil-holding properties, 3) availability of seeds, and 4) ease of seeding.

The canyon bottoms were to be hand-seeded with species such as Poa interior and Oryzopsis asperifolia, native to the canyon bottoms. Fire lanes were to be seeded by hand.

Due to heavy rains (the July 5 maximum was 654 cfs) and various other delays, helicopter reseeding did not commence until July 12, 1977. An attempt was made to spread 60 seeds per sq ft. In badly burned areas 70-75 seeds per sq ft was desirable and in less severely burned areas 50-55 seeds per sq ft was acceptable (Fig. 56) The reseeding efforts began on July 12 in the Apache Springs area. Escobas Mesa and Apache Springs were reseeded July 13; Burnt Mesa July 14; the south side of Frijoles Canyon July 15; and spot seeding in the Apache Springs and Backgate areas July 17. Germination was first observed the third week in August, after approximately 4.5 weeks. Another heavy rain followed reseeding on July 27 with a maximum of 397 cfs.

On Escobas Mesa two plots adjacent to each other provide excellent contrast of the effect needle fall has upon the reseeding efforts. McConnell and Smith (1971) observed litter fall on bared soil increased the production of hard fescue, while removal of all litter fall did not enhance production. A similar situation was noted in plots 3 and 4 of Escobas Mesa. In plot 3 the needles had been completely burned from the trees and the soil surface was barren ash and mineral soil. In plot 4, which had been thinned by logging about 50 to 60 years ago (Fig. 57), the needles were scorched and brown. In the latter plot, the ground surface was covered with a mantle of pine needle fall. Measurements on September 27, 1977 showed that the success of reseeding, based on number of seedlings per average rate of seeding, in the area without needle fall was 7.7% and in the area with needle fall was 51.8%. The needles provided a mulch to hold the seeds and soil from washing away and to improve the moisture and growth conditions (Fig. 58). It is interesting to note that Grigal and McColl (1975) found this increased litter fall for 3 years after the fire in burned areas vs. non-burned areas. They also found that needles from dead trees were significantly higher in concentrations of nitrogen, phosphorus, and potassium and lower in concentrations of calcium than needles falling in unburned areas. The former may provide increased nutrients. On the other hand, increased litter fall might eventually have a negative effect, however, by eventually choking out the seedlings, as seen in McConnel and Smith (1971). In areas of severe burn stumps and roots burn out into the ground leaving deep pits. These serve as traps for eroding soil, seeds, and accompanying moisture (Fig. 59). Without a protective covering of needles, the loose tuff soil is easily washed and eroded into gullies (Fig. 60).

Plant Succession

Ahlgren and Ahlgren (1960) suggested that few generalizations can be made about post-fire succession because of the many factors which may affect the survival and invasion of plant species. They, as well as Kozlowski and Ahlgren (1974), have reviewed and compiled information on studies dealing with the influence of fire on soil texture and permeability, on the opening of the forest canopy, on soil nutrification, and on the season of the fire. Went, et al. (1952) summarize the mechanisms which determine the plant associations into seven different categories: distribution and presence of seed, differential germination, competition, soil differences, climatic differences, pests and disease, and differential survival. When attempting to discuss a specific post-fire succession, all these factors must be kept in mind.

Information within the literature concerning specific species, or even genera, of plants and their relation to fire is somewhat limited and conclusions as to the reasons certain plants have increased or decreased in a burned area can only be inferred from the literature. Kujala (1926) divided fire-followers into four classes: 1) plants provided with underground reproductive structures which survive the fire and produce sprouts, 2) plants with seed which survive the fire in the soil, 3) plants with wind-disseminated seeds, and 4) plants with a combination of fire-surviving or wind-dissemination and vegetative sprouting. Lyon and Stickney (1976) divided immediate post-fire succession into two types. The first is on-site, which includes those plants that develop from remains of vegetative parts or from fire-resistant or fire-enhanced seeds which were on the site at the time of the fire. The second is off-site which includes those plants that develop from wind-disseminated seeds carried from adjacent unburned areas.

McLean (1969) further attempted to define the relationship of the on-site fire-followers by looking at the root system and then determining the relative resistance of those plants to fire. He divided the plants into susceptible, moderately resistant, and resistant species on the basis of their root structure. Plants without rhizomes but fibrous roots, species with fibrous roots and stolons, and species with fibrous roots and rhizomes which grow mostly in the duff layer or between it and the mineral soil are generally susceptible to fire. Based on information compiled by Ahlgren and Ahlgren (1960) it appears that plants with roots within the first 2.5 cm of soil will probably not survive fire since temperatures generally exceed 100° F. He found that species with fibrous roots and rhizomes which grow mostly 1.5 to 5 cm below the mineral soil surface were of intermediate fire damage resistance. Species with fibrous roots and rhizomes which grow mostly between 5 and 13 cm below the mineral soil surface showed signs of being able to regenerate from those depths and to creep along just above the textural soil horizon. Also, species without rhizomes but with taproots were found to creep sideways until they reached cracks in the soil horizon. Lyons and Stickney (1976) found plants which survived fire were those with root crowns, as in tall- and medium-sized shrubs, broadleaved trees and caudaceous herbs; with rhizomes, as in low shrubs and herbaceous plants; or with deep underground stems, such as bulbs and corms.

Another on-site adaptation is the survival of seeds either due to their fire-resistance or to mechanical protection such as animal caches or rocks. A number of studies have been done on the ability of some seeds to survive high temperatures produced by fire. Sampson (1944) reported that most dry seeds were killed when exposed to temperatures of 250° to 300° F for five minutes but some species were stimulated by heat. Went et al. (1952) repeated Sampson's studies and saw an increase in the germination of species of Avena, Rhus, and Ceanothus; as well as several other species. Stone and Juhren (1951) observed germination of seeds of Rhus species to be 17 to 60 times greater after heating soil containing the seeds; apparently the heat made the seeds more water permeable. Wright (1931) found that germination of seeds of Rhus, Avena, Bromus and Ceanothus was increased by temperatures exceeding 200° F. He also reported the heating of seeds of Pinus ponderosa slightly increased the germination. Gratkowski (1962) also reported heat-induced germination of a Ceanothus species. Lyons and Stickney (1976) concluded that species such as Geranium bricknelli, Dracocephalum parviflorum, Iliamna rivularis, and Carex had seeds in which germination was enhanced by fire. Martin et al. (1975) found the germination of eight species of legumes to be increased by moist heat and seven species by dry heat.

Other investigators have found that some plants produce two types of seeds, some which germinate under normal conditions and others which require fire or heat to break the seed coat dormancy. This seed polymorphism has been seen by Stocking (1966) in Astragalus congdonii and Trifolium ciliolatum. Williams (1962) reported a similar seed polymorphism for Chenopodium album. This type polymorphism may account for species which "suddenly" appear immediately after a fire but are conspicuously absent the following year.

Another explanation for the occurrence of increased numbers of plants in burned areas, although they occur in the area previous to a fire, is the presence of inhibitors (Sweeney 1967). It may be that germination and growth is inhibited by the chemical and biotic composition of the organic debris which is removed by fire, thus allowing more vigorous growth.

Absorption of solar heat by blackened soils and the resulting temperature increase might influence germination of certain seeds. Seeds of species such as Amaranthus were found to germinate in soils which were warmed but seeds of Helianthus and Oxalis grew more vigorously at low temperatures (Went et al. 1952).

The main source for "off-site" fire-followers is either wind-disseminated or animal-disseminated seeds. McLean (1969) noted several species which did not survive on-site temperatures but due to their wind-disseminated seeds increased in burned areas. Lyons and Stickney (1976) found that taxa such as Salix and Epilobium utilized two modes of reproduction: on-site sprouting from rootstocks and off-site wind-dissemination.

Although it is impossible to say that any single plant species has increased or decreased in the area due to any one factor, the immediate post-fire succession can be examined in view of the foregoing information and some observations recorded. Many of the species found to have increased in the burned area have not been specifically investigated, thus most information must be inferred from observation and the scanty knowledge of the physiology of each plant. Lyons and Stickney (1976) believe vegetal recovery from a large fire is variable but the eventual outcome will be reliably consistent. Examination of post-fire succession in the Rocky Mountains has a consistent pattern leading to a dominant overstory of coniferous trees with an understory of shade-tolerant shrubs and herbs. They found early vegetal succession to be less predictable but herbaceous plants dominated the earliest stages of succession. They also found that species which produced the bulk of the post-fire succession were present in the pre-fire environment and all were recorded in the flora of the first year. They also found that all plants that survived the fire, reestablished themselves in the first year after the fire. Similar general observations can be made concerning the immediate post-fire succession of the La Mesa fire, as observed from June through October 1977. Various species of herbaceous plants dominated sites quickly--depending mostly on the intensity of the burning in the area. Sprouting of shrubs was observed and by October most sprouts were from 6 to 12 inches in height. Even in the most severely burned areas, underground parts were undamaged and vigorous sprouting was seen (Fig. 61). With one exception, plants which were believed to have their origin "on-site" and "off-site" have been collected (Bandelier Herbarium and LASL Herbarium) in the area previously. Annotated checklists of forbs, grasses and grass-like plants and half-shrubs, and shrubs and trees are found in Tables 36, 37, and 38, respectively. Common and scientific names are taken from the U.S. Forest Service Field Guide to Native Vegetation of the Southwestern Region (1974).

On-site survival. There are a number of species which survived the La Mesa fire due to "on-site" factors listed by McLean (1969) and Lyons and Stickney (1976), such as regrowth by sprouting of the rootstock or crown. Vegetative regrowth by sprouting was seen in *Rhus trilobata*, *Quercus gambelii*, *Quercus undulata*, *Cercocarpus montanus*, *Robinia neomexicana*, *Rosa* sp., *Fallugia paradoxa*, *Opuntia* sp., *Mammillaria* sp., *Yucca glauca*, *Ceanothus fendleri*, and *Populus tremuloides*. These plants, as well as other half-shrubs, shrubs, and trees, along with location, importance as a browse species, and reported growth form as evidenced by the literature are tabulated in Table 38. A discussion of observations of each plant will be taken up in order. Few conclusions can be made at this time since these observations cover only a 5-month, post-fire period.

Rhus trilobata. This is a common shrub of the pinyon-juniper zone but is also seen in scattered areas within the ponderosa pine. Vegetative regrowth of this species by sprouting was seen in both areas (Fig. 62). Other investigators have observed vigorous sprouting of this species after fire (Pond and Cable 1960, Pase 1971, Pond and Bohning 1971). Kittams (1973) found *Rhus trilobata* at Carlsbad National Park sprouting 3 to 4 inches in 2 months and up to 2 feet in a year and reaching full size in 3 years if not held back by deer browsing. He found shoots to be thicker and more fully leaved than the foliage of the old canopy and speculated that decadent squawbush could be rejuvenated by fire. There should be continued observations of the growth of this species as well as possible browsing of regrowth by deer.

Quercus sp. There are several species of oak which grow within the study area including Quercus gambelii and Quercus undulata. Throughout the fire the crowns of these plants were completely destroyed; however, these species were the fastest sprouting shrub species with sprouts in some areas up to 6 inches high within 5 days after the fire (Fig. 62A). By October the oak sprouts in some areas were as much as 3 feet tall. Vegetative regrowth of this species by sprouting has been recognized by various investigators (Sweeney 1967, Kittams 1973, Pond and Cable 1960). Kittams (1973) found species of oak at Carlsbad National Park to grow 10 to 15 inches in 3 years. Similar response has been seen in live oak in Arizona by Pond and Cable (1960) and Pond and Bohning (1971). The oaks in this study appear to have a more rapid growth.

Cercocarpus montanus. Sprouting of this species was seen in pinyon-juniper and ponderosa pine zones (Fig. 62C). Kittams (1973) found rejuvenation of these plants very dependent on the degree of mechanical protection from deer browsing. Young and Bailey (1975) observed a 200-900% increase in browse production for at least several years after treatment by fire of this shrub during the dormant season. No evidence of browsing was noted during the period of observation but recovery of this plant could be dependent on it as Potter and Berger (1977) found it to be a valuable food source in Bandelier for mule deer.

Robinia neomexicana. One of the most rapid sprouters after the La Mesa fire was Robinia. Like Quercus it was observed producing vegetative regrowth immediately after the fire (Fig. 62B).

Rosa sp. Growth of rose bushes was observed in limited areas. It appears that most specimens seen were not associated with any rootstock, thus it is assumed that these plants were new seedlings. Rosa sp. is a shade intolerant species and the seeds are disseminated by animals (USDA Agric. Handbook 450 1974). Presently no studies have been found indicating heat resistance of the seed.

Fallugia paradoxa. This species, typical of coarse soils, was seen in very limited areas, generally associated with pumice soil. It was observed sprouting but with much less vigor than the other shrub species discussed.

Ceanothus fendleri. Deerbrush has been noted in limited areas of the Monument, mostly in previously burned areas or along trails or roadcuts. Sprouting of this species was seen in areas which were only lightly burned; however, a number of one-inch sprouts was seen throughout the study area by October 1977. This indicates possible sprouting from fire-resistant seeds. Sprouting in this genus is not common. At Carlsbad Kittams (1973) found several bushes which were top-killed by fire but did sprout. Ffolliott (1977) and Wagle and Ealke (unpublished) also have reported increases of Ceanothus after fire.

Opuntia sp. Sprouting of Opuntia sp. was observed in pinyon-juniper plots which were severely burned. Sprouting of pads from the base was noted soon after the fire (Fig. 63). Growth, however, appeared to be slow because by October the pads still were not fully developed. Cable (1973) found that killing of Opuntia sp. was highly dependent upon the fuel concentrations under and near individual plants. He noted that with prescribed burning where there was a lack of fuels accumulated 32% of prickly pear were killed in the first treatment but three years later there were no significant changes in the cactus density. He also found that in a cooler fire there was some indication that cholla, but not prickly pear, might be increased in numbers from sprouting of fallen, but otherwise undamaged, joints. Wright (1973) found Opuntia not well-adapted to fire. Heirman (1971) found 32% of the prickly pear plants died at the end of the first growing season and 82% after the second season, probably due to the interactions of fire, drought, and insect activity. Unlike Opuntia, Mammilaria cacti were observed recovering by terminal growth of the singed stems (Fig. 64).

Yucca glauca. The narrowleaf yucca was found to be sprouting even in severely burned areas of pinyon-juniper and ponderosa pine (within the latter type it is associated with ruins). Although the leaves were completely consumed by the fire, the plants were seen to sprout from the base (Fig. 65). Offsets from roots and occasionally from the centers of singed yucca have been observed by Kittams (1973) and Vogl (1967). Kittams (1973) also reported deer browsing new leaves which were 2 to 8 inches long.

Populus tremuloides. Aspen generally occurs in the mixed conifer areas of the Monument. Vegetative regrowth by sprouting of this species was observed in sites of mixed stands of this species and mixed conifer. By October 1977 the sprouts were as much as 2 feet tall (Fig. 66).

Sprouting of canyon species. Although the La Mesa fire study did not involve many observations within the canyons, during the 1976 season, subsequent to the 1976 Alamo Canyon fire, a number of species common to the canyon bottoms were seen sprouting. Among the sprouting species were Acer negundo (Fig. 67A), Ptelea angustifolia (Fig. 67B), Salix sp. (Fig. 67C), and Parthenocissus inserta (Fig. 67D). Lyons and Stickney (1976) have observed such species as Acer glabrum and Salix scouleriana sprouting from root crowns or caudex.

Another "on-site" factor which may account for some plant succession within the La Mesa fire is fire-induced germination. As previously discussed fire-induced germination has been reported for Ceanothus species (Gratkowski 1962). According to the USDA Agricultural Handbook 450 (1974), germination tests have not been made on C. fendleri, but it appears germination is anywhere from 30 to 90 days for most species. Abundant sprouts of Ceanothus were seen in September and October but not immediately after the fire (Fig. 68).

Enhanced germination of Rhus sp. and leguminous seeds have been reported by Stone and Juhren (1951) and Martin (1975), respectively. During the 1977 field season, no apparent germination of Rhus trilobata or Robinia neomexicana was observed.

Another taxa which has been reported to have seeds influenced by fire is Carex (Lyons and Stickney 1976). Kilgore (1973) and Swan (1970) found Carex to increase in burned areas. A related taxa (Cyperus esculentus) was found in abundance throughout the burned areas in the Monument (Table 36). Possibly this species may exhibit fire-induced germination, but it is more likely that it regenerates from deep, slender rhizomes with small tubers.

Seed polymorphism which favors fire-induced germination has been reported for Chenopodium album (Williams 1962). This species was observed within the burned area but not in large quantities (Table 36). A species which was seen extensively throughout the burn was Chenopodium graveolans.

McLean (1969) and Lyons and Stickney (1976) classified another group of "on-site" survivors as those with taproots or rhizomes. There were a number of perennial plants with taproots, bulbs, corms, or rhizomes which survived the La Mesa fire and quickly produced new plants from sprouts. These herbaceous plants, their location, and stage of development seen within the 20 x 50 meter plots are listed in Table 36. Several of these sprouting species will be specifically discussed.

Castilleja integra. McLean (1969) places a species of Castilleja in a moderately fire-resistant class. Castilleja integra was seen throughout the burned area in all communities but generally in the less severely and moderately burned areas with only isolated specimens in more severely burned areas (Fig. 69). It was particularly abundant in open meadows which had been burned. This species recovered rapidly and floral bracts were especially vivid in their coloration--perhaps from increased nutrification.

Lupinus caudatus. This lupine was abundant in open, burned meadows and flowered vigorously. McLean (1969) places a species of Lupinus in a fire-resistant category due to its rootstock.

Senecio multicapitatus. This species was a vigorous sprouter from the rootstock; however, flowering did not occur during the 1977 field season.

Allium cernuum. Onions were seen in abundance throughout all areas from severely to lightly burned. Allium has been observed in the area previously but not in such abundance. Allium has a bulbous rootstock and its conspicuous increase may be due to the stimulation of dormant bulbs, fire-resistant seeds, or increased stimulation of the flower-forming processes. Horton and Kraebel (1955) found that in the chaparral of Southern California various liliaceous plants such as Brodiaea capitata and Calochortus plummerae grew rapidly, apparently from bulbs present in the soils. Increased flowering was also seen.

Commelina dianthifolia. This plant was of particular interest due to the abundance attained within the burned area (Fig. 70). Commelina had been collected in the area by Ora M. Clark in 1932; however, it had not been observed by this investigator within the Monument until large patches were observed in 1976 after the severe burn on Burnt Mesa in 1975. This plant was seen in large patches throughout the area burned by the La Mesa fire, particularly in severely burned areas with a pumice soil base. The plant has a corm, thus it falls in a fire-resistant category (McLean 1969 and Lyons and Stickney 1976). It is conceivable that this plant may have been there in large quantities, but the fire provided for increased flowering thus making it more noticeable.

Grasses. In areas which were moderately to lightly burned, sprouting of grasses from rootstock (Fig. 71) was seen almost immediately after the fire. By September most of the surviving grasses were producing large and vigorous seed heads. There was also some indication of increase in size and vigor of the plants. Heads of Bouteloua gracilis (blue grama) collected in various burned areas showed an increase in size over those collected in non-burned areas (3.98 cm in the burn versus 3.05 cm in unburned areas).

Increased coverages of blue grama have been reported by Dwyer and Pieper (1967). However, they found that Lycurus phleoides (wolftail), Sporobolus cryptandrus (sand dropseed), and Hilaria jamesii (galleta) all decreased as a result of fire. Wright (1974) found fire had little or no effect on blue grama and was detrimental to Bouteloua curtipendula (side-oats grama).

Andropogon gerardii. Big bluestem (Fig. 72) was seen throughout the burned areas and often was the only surviving grass in severely burned areas. It appeared to respond vigorously to the post-fire conditions and sometimes produced fruiting stalks which attained a height of 7 ft. Komarek (1965) observed that bluestem grasses have a remarkable resistance to even the hot fires. He can be quoted as saying, "If any family of grasses can be called 'fire grasses', the Andropogoneae certainly can be so called."

In a review of research done by investigators over a number of years, Smith and Owensby (1973) concluded that mid- and late-spring burning of prairies in the Flint Hills of Kansas tended to increase the production of big bluestem. Similar responses were seen by Anderson (1973) after biennial burning of Curtis Prairies of Wisconsin. Hulbert (1969) reported an increased yield of *Andropogon gerardii* in response to the removal of deep litter when burned in the spring. He felt this to be the prime factor in the growth response rather than the nutrification. It is thus speculated that the factors of the time of year of the La Mesa fire combined with the reduction of competition and removal of litter as well as increased nutrification probably stimulated unusual growth of this species.

Anderson (1973) also recorded increases in frequencies of *Andropogon scoparius* (little bluestem) and *Sorghastrum nutans* (Indiangrass) due to biennial burning of the Curtis Prairie. Curtis and Partch (1950) noted an increase in production of flowering of major grass species and legumes following fire.

Ponderosa pine sprouting. There is no recorded evidence that ponderosa pine which has had complete needle scorch rejuvenates by vegetative sprouting from dormant buds. Few western conifers sprout after burning. Exceptions are *Pseudotsuga macrocarpa* (Big-cone Douglas-fir) (Vogl 1967) and *Sequoia sempervirens* (coast redwood). They produce epicormic shoots in the axils of branches or branchy stubs on trunks and larger stems. This growth is confined to mature trees because seedlings and saplings (under 4 inches dbh) are generally killed by fire.

Within Escobas Plot 1 and Burnt Mesa Plot 2, small trees 1 to 5 ft high had complete needle scorch; however, the plants were observed sending out new leaves at the end of the branches (Fig. 73). By October a significant amount of needle rejuvenation had occurred. Later studies will measure continued survival.

Ponderosa pine seedlings. New seedlings of ponderosa pine were observed during the post-La Mesa fire field season. Those seen were generally in areas of mechanical disturbance such as bulldozed firelines which probably provided for the crushing of the seed coat which aided germination. Sprouting, as seen in Figure 74, was rare during this period, but it is expected that increased germination will be seen in future years as evidenced by studies by Wright (1931) and Ffolliot et al. (1977). The effect of reseeded grass upon pine reproduction is not known, but investigators have found that grass competition inhibits growth of pine seedlings (Potter and Green 1964, Larson and Schubert 1969, Rietveld 1975).

Off-site origin. There are a number of plants which probably have their origin off-site, and these plants have been reported within the area (Foxx 1974, Yarnell 1958). Most of them are weedy species which have wind-disseminated seeds and generally occur in disturbed soils. Such plants were particularly abundant in areas where burning had been severe and had exposed mineral soil. They were also larger than their off-site counterparts. This may be due to the combination of increased nutrification and lack of competition. Within this category can be included *Amaranthus* sp., *Chenopodium* sp., and *Euphorbia* sp. It is also possible that some seed may have been mixed with the seed utilized to reseed the area. Seed contamination is based upon the appearance in the reseeded area of *Panicum miliaceum* which has not been reported in this immediate area.

Another plant which was seen in abundance in severely burned areas but does not appear to have wind-disseminated seeds is *Physalis* (Fig. 75). It, like *Chenopodium graveolans* (Fig. 76), showed signs of gigantism. These plants, like *Chenopodium* spp., *Amaranthus* spp., and *Euphorbia* spp. are found in disturbed areas such as ruins and along roadsides. *Physalis* is perennial or annual and may have originated from rootstock, but the abundance of the plant would indicate possible influence of fire on the seed. It may be possible that this species exhibits seed polymorphism as seen in various species by Stocking (1966) and Williams (1962). Wolfe (1973) did not find any increase of *Physalis* or *Amaranthus* in burned areas of the grasslands of the Nebraska Sandhills.

Numerous seedlings of *Bahia* were seen in severly burned areas late in the summer, indicating this may be a species with wind-disseminated seed. Bahia is common in disturbed soils of the area. Another plant found within the burn was Polygonum convolvulus (black bindweed), a particularly noxious weed. It has been seen in abundance in disturbed soils of Mortendad Canyon. The seed may be wind or animal disseminated. Lithospermum sp. has also been reported in disturbed areas (Yarnell 1958, Foxx 1976). It was often seen within severely burned areas very early in the summer. It is conceivable that this plant came up from rootstock, because it was found throughout the ponderosa pine areas previous to the fire.

Gigantism

Throughout the burned area there was a remarkable increase in the size of various species of forbs and grasses including Chenopodium graveolans, Physalis neomexicana, Andropogon gerardii, and Taraxacum sp. Figure 77 shows an example of this gigantism in the common dandelion found within the previously burned Escobas Mesa area.

The role fire plays in the nutrification of the soils has been summarized by Ahlgren and Ahlgren (1960) and Viro (1974). It is difficult to suggest a specific mechanism which produces such gigantism as seen in the La Mesa fire. Many factors are responsible for the presence of lack of certain constituents in the soil after fire. These may include soil type, soil moisture, and fire intensity. Extensive soil analyses would be required to specify the presence or lack of certain minerals. Basically, however, the influence of fire is the immediate release of minerals otherwise bound in plant tissues, which in the Southwest decay slowly. Under the proper conditions the release of these minerals and subsequent up-take by the plant can have a stimulating effect upon growth. There is an indication, however, that this will only be temporary, perhaps only 2 to 3 years (Ahlgren and Ahlgren 1960). During the period of gigantism, species may have growth forms which do not fit the usual taxonomic key characteristics and may easily be misidentified.

Fire and Ethnobotany

There is an indication that Indians used fire for hunting and foraging (Komarek 1969). It is interesting to note that several plants seen in abundance within the La Mesa fire area have been recorded as part of the forage plants of the Indians of the Southwest (e.g., *Allium* and *Physalis*). Several species have been reported and seen within ruins of the area (Foxx 1976, Yarnell 1958, Tierney 1977) and may have provided a food source. Although there is no evidence that burned-over areas were used, such areas would have provided excellent forage and probably were searched out. Plants found within the burned area and which are known to be edible are annotated in Table 36.

CONCLUSIONS

With the recognition of the serious fire hazard resulting from over 40 years of fire suppression, the National Park Service instigated a study of fire ecology. The location and dates of local fires were determined and study plots were located on sites representing different intervals of time since the last burn, namely, 1937, 1945, 1950, 1955, and 1960. Using the modified line-strip method of vegetational analysis, phytosociological measures of mature tree density, coverage, frequency, and importance values were determined for burn areas and adjacent controls. Analyses also included reproductive classes and shrubs as to density, coverage, and frequency. Herbs and seedlings were sampled by quadrats as well as fuel loads.

The phytosociological data for the mature tree stratum indicate in burn stands of various ages decreases to 10 to 35% of the control; coverage values were 15 to 80% of the control; and basal areas 24 to 84% of the control. The average diameters of ponderosa pine in burned areas were 136 to 157% greater in the controls. The density of all reproductive and shrub stock in burned areas was 26 to 83% of the controls; total reproductive cover was 18 to 50% of controls. Herb and seedling ground cover was greatly increased in burns. No consistent trends were found in the vegetation of stands corresponding to the time since the last burn. The condition of the stand relating to strata of mature trees, reproduction, and herbs and the weight of fuel loads are apparently due to site factors and the nature of the last and previous burns rather than consistent successional trends.

Fire records for 39 years indicate an average of six fires per year, 86% of which were lightning-caused. The incidence of man-caused fires has remained fairly stable. The frequency of extensive, destructive fires has increased and it is suggested that this is principally due to accumulated fuel loads after about 50 years of fire suppression.

Analysis of tree rings from Escobas Mesa indicated a fire frequency of 13.7 years between the dates of 1777 and 1907.

Analyses of wedges of fire-scarred trees from several plateau areas of Bandelier revealed an average fire frequency of 17.6 years and an average period of time of 56.1 years since the last fire scar.

From the examination of a representative set of increment borings of ponderosa pine from previously burned areas, it was concluded that three growth patterns occurred following fires: 1) temporary increase in growth, 2) depressed growth followed by increased growth, and 3) immediate and sustained increase in growth. Surviving seedlings and saplings in burned areas exceeded in growth rate those from adjacent unburned control areas.

The La Mesa wildfire of June 1977 burned over 15,270 acres including the 1976 study plots, converting a descriptive study into an actual demonstration and experiment. Within the area of the burn there were apparent variations in the degree of damage.

Having just completed the study of fire history, location, and stand conditions of sites not burned for 40 and less years, it was possible to revisit the same stands after the La Mesa fire and compare the burn damage. Other stands not burned since 1878 and comparative stands of previous thinning by logging versus unthinned were also examined. All stands previously burned had lower densities of trees but of larger size than the adjacent control stands. The 1878 burn had recovered with a high density of many small trees. Its fire damage was extreme in all regards. Trees were classified as to degree of foliar scorching from 1 to 6. Trees in classes 3 and greater (3 = 51-75% foliar singeing) are not likely to recover. Stands not burned for 99 and 40 years were a complete loss (classes 5 and 6). The Alamo Rim stand, not burned for 31 years, had no trees with less than 50% of foliar damage and few will survive. The Bear Mesa stand, burned by a cool fire 27 years ago, had very few trees in classes 5 and 6, but 60% in classes 1 and 2 from which one can expect survival. Stands not burned for 17 and 1 years had no trees in the 5 and 6 classes of damage. The mean damage values for control stands was always higher than for stands previously burned, with an increasing contrast for recently burned stands. Intervals of time between wildfires of more than 25 years in this area apparently result in nearly complete loss of all mature trees. To obtain survivorship percentages less than 60%, wildfire frequency would have to be at time intervals less than 25 years which would approach the natural interval of 15-18 years. Prescribed burning under correct conditions would, however, produce less damage. It was not the purpose of this study to compare that difference. Similarly, the damage to the reproductive foliage decreased with decreased time since the previous fire.

Rehabilitation by aerial reseeding of grasses was greatly influenced by the amount of dead needle fall. Grass seedling development on areas of complete needle consumption (class 6) was measured at 8% of seeding rate in contrast to adjacent stands with needle fall (class 5) at 52%. The latter areas also have increased protection from soil erosion.

Recovery by on-site sprouters was conspicuous for *Rhus trilobata*, *Quercus gambelii*, *Quercus undulata*, *Cercocarpus montanus*, *Robinia neomexicana*, *Rosa* sp., *Fallugia paradoxa*, *Opuntia* sp., *Mammilaria* sp., *Yucca glauca*, *Ceanothus fendleri*, and *Populus tremuloides*. Several species are thought to have reproduced by fire-induced germination, including *Ceanothus fendleri*, *Cyperus esculentus*, and *Chenopodium graveolans*. Rapid recovery by plants with taproots, bulbs, corms, or rhizomes included *Castilleja integra*, *Lupinus caudatus*, *Senecio multicapitatus*, *Allium cernuum*, and *Commelina dianthifolia*. Several grass species exhibited larger fruiting spikes in the burned area, rapid regrowth by tillering, and increased growth vigor, e.g., 7 ft tall fruiting stalks of *Andropogon gerardii*.

Possible off-site invaders included species of *Amaranthus*, *Chenopodium*, *Euphorbia*, and *Polygonum*.

Gigantism was noted in *Chenopodium graveolans*, *Physalis neomexicana*, *Andropogon gerardii*, and *Taraxacum* sp.

Several species, e.g., *Allium* and *Physalis*, have been found within ruins of the area and are known to have been used by the Indians of the Southwest. These species were abundant after the fire.

Missing 5 acre Alamo Canyon fire of 1976

Also, 1934 fire in upper Capulin Canyon

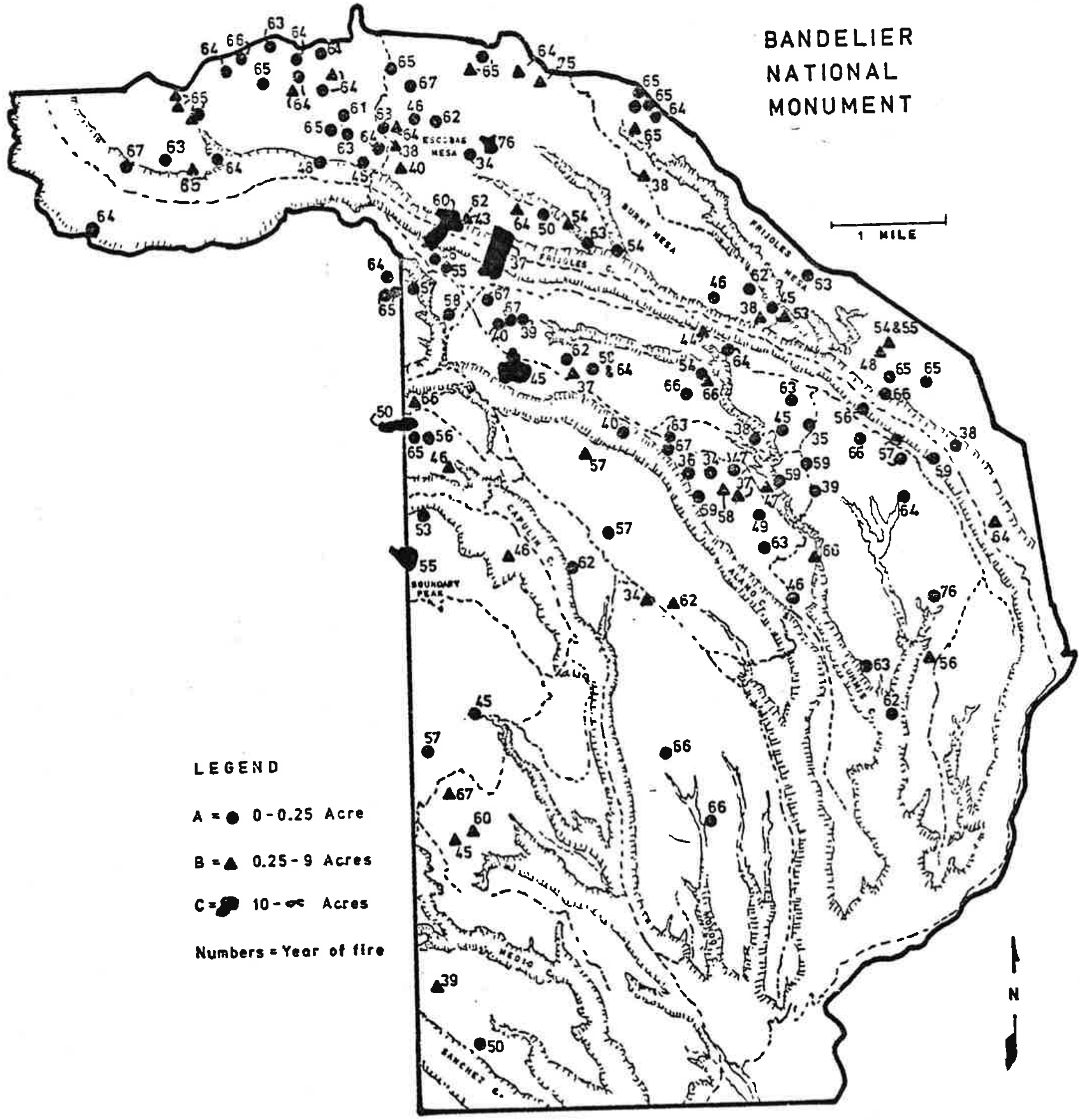


Fig. 1. Location and date of fires recorded in the fire atlas at Bandelier National Monument prior to the 1977 La Mesa fire.

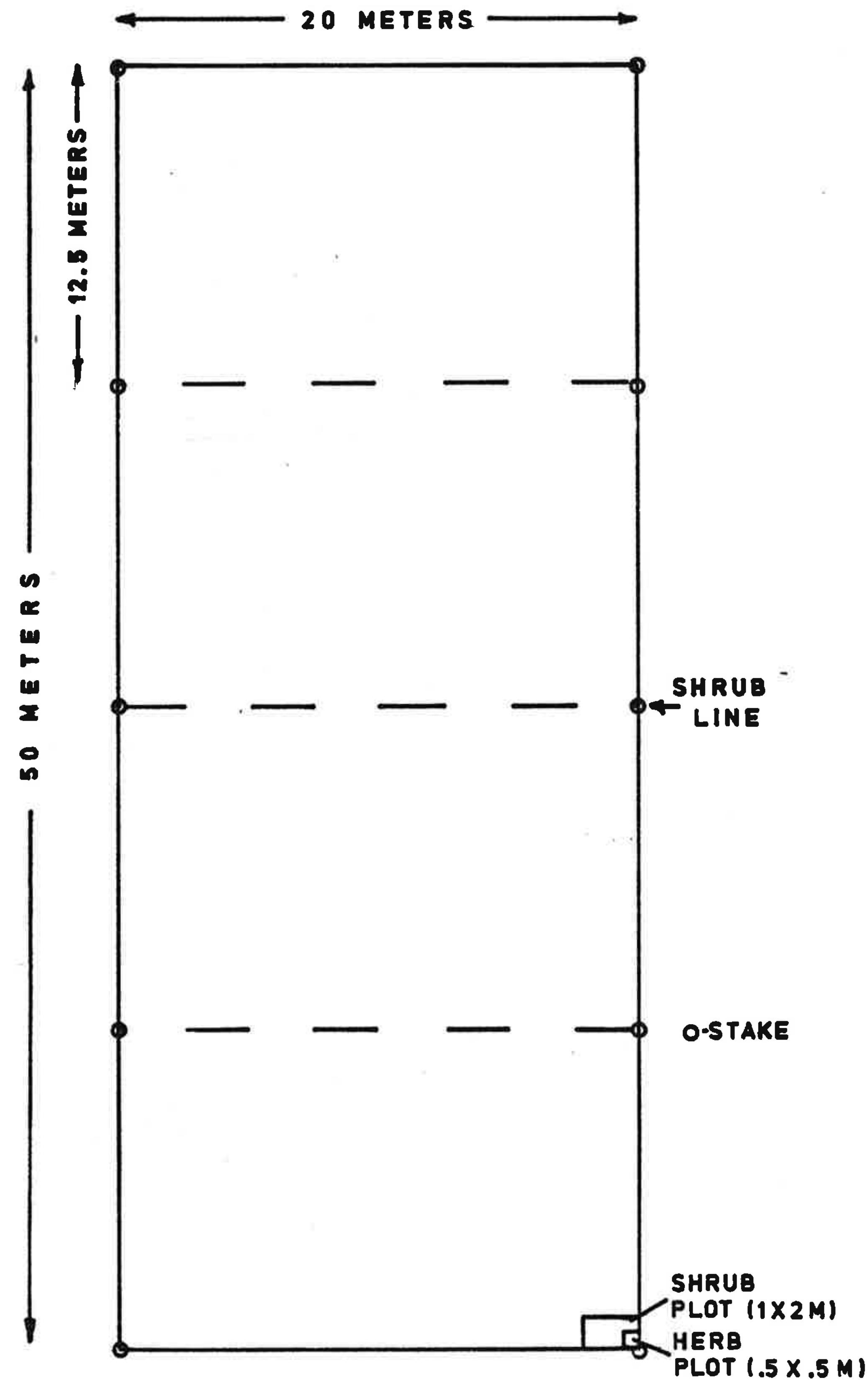


Fig. 2. Layout of permanent, staked, post-La Mesa fire plots (20x50 meter).

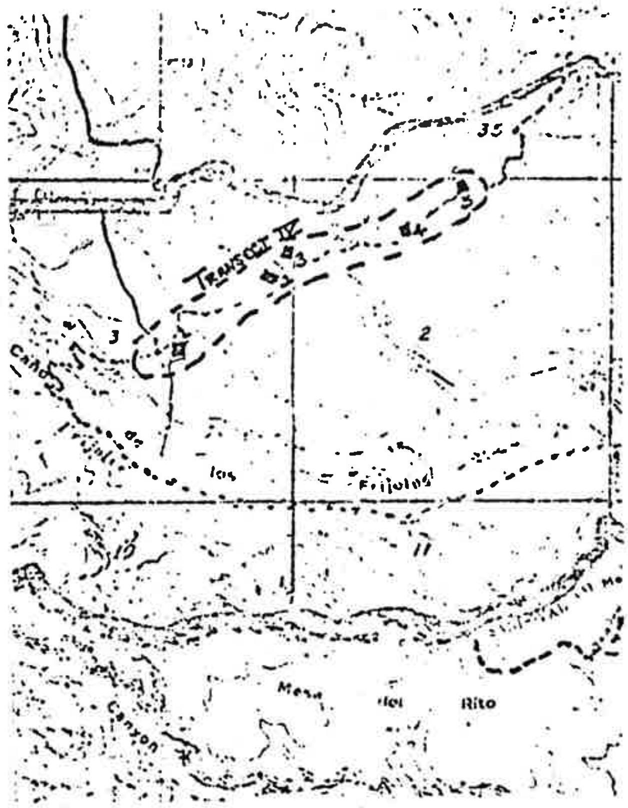


Fig. 3. Location of post-La Mesa fire study plots and Wauer transects.

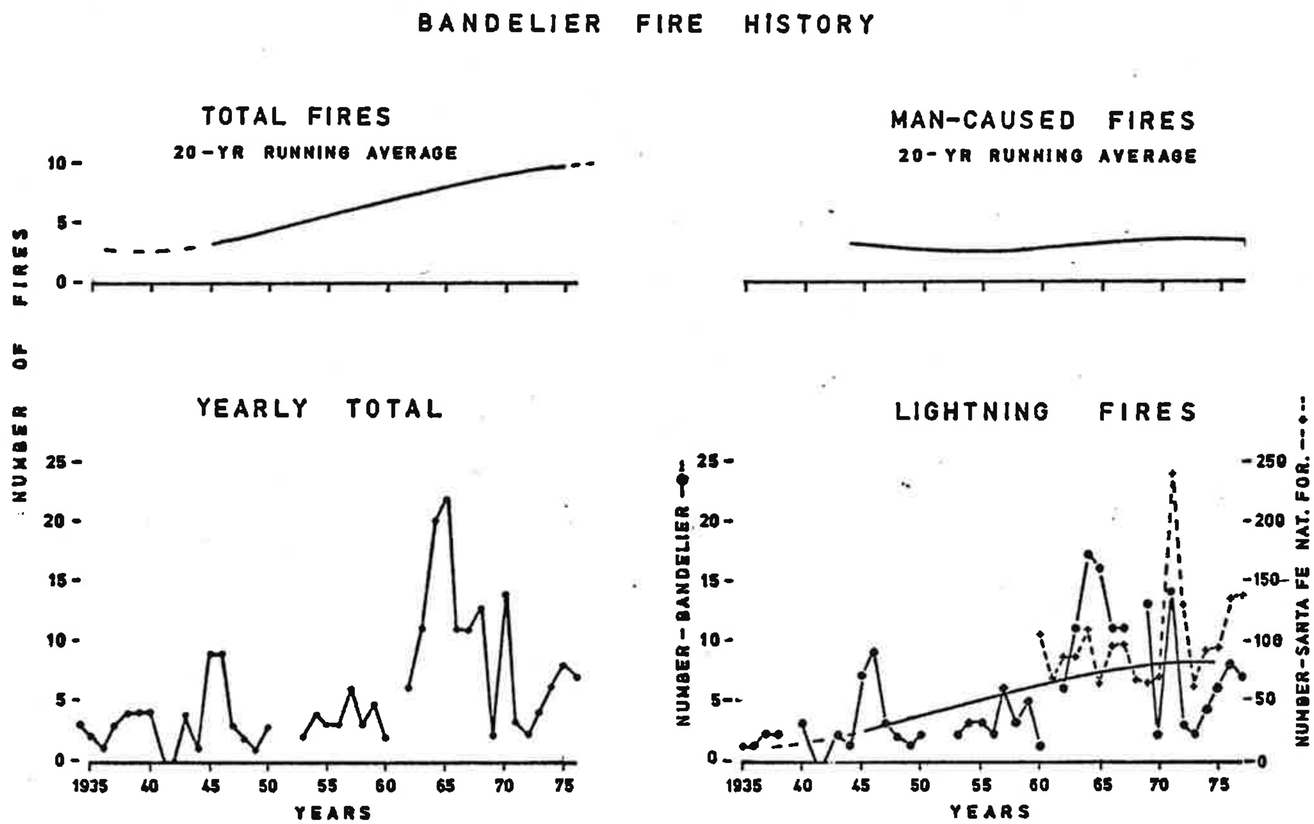


Fig. 4. Fire history at Bandelier, total, man-caused, and lightning.

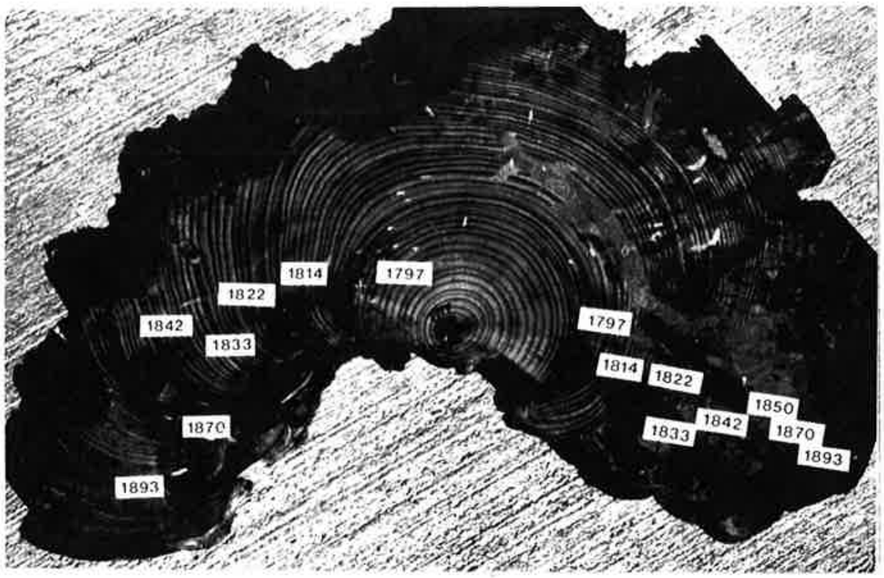


Fig. 5. Fire scars on ponderosa pine (1777-1907) from Escobas Mesa indicating fire frequency of 13.7 years.

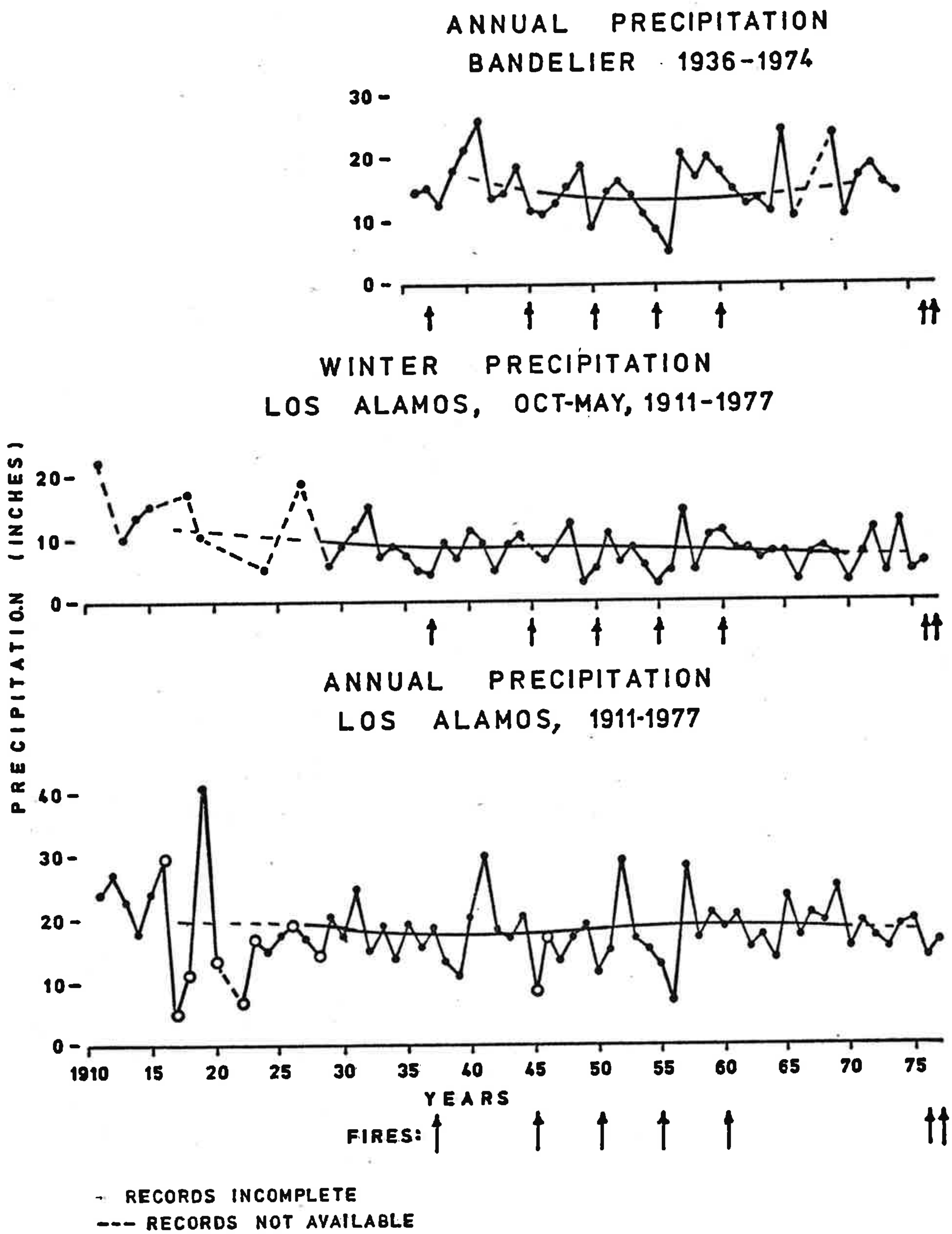


Fig. 6. Record of winter precipitation and annual precipitation at Los Alamos Scientific Laboratory and annual precipitation at Bandelier.

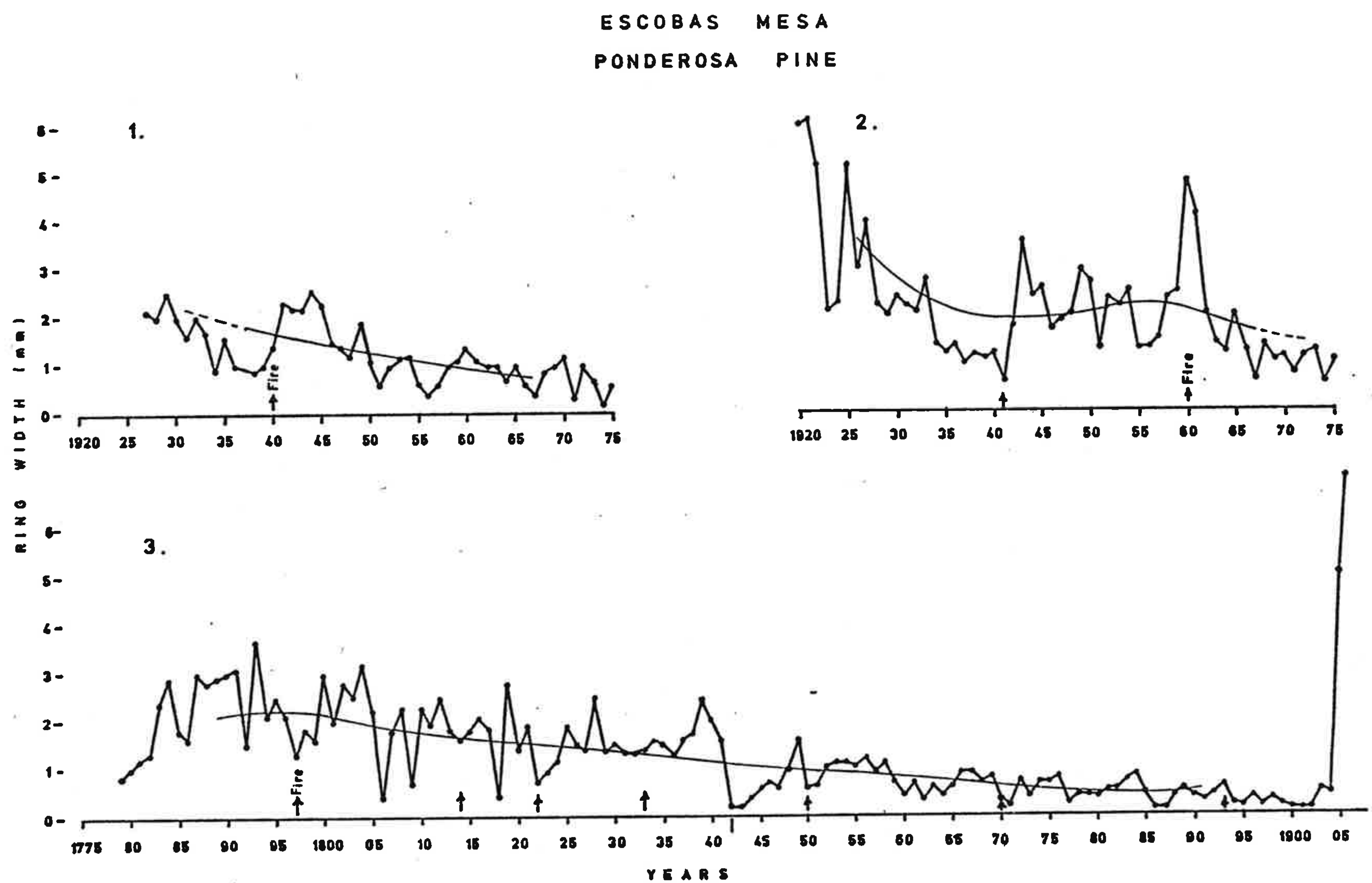


Fig. 7. Growth record from tree ring analysis of ponderosa pine from Escobas Mesa for 1976 burn as determined by Tree Ring Laboratory, Tucson.

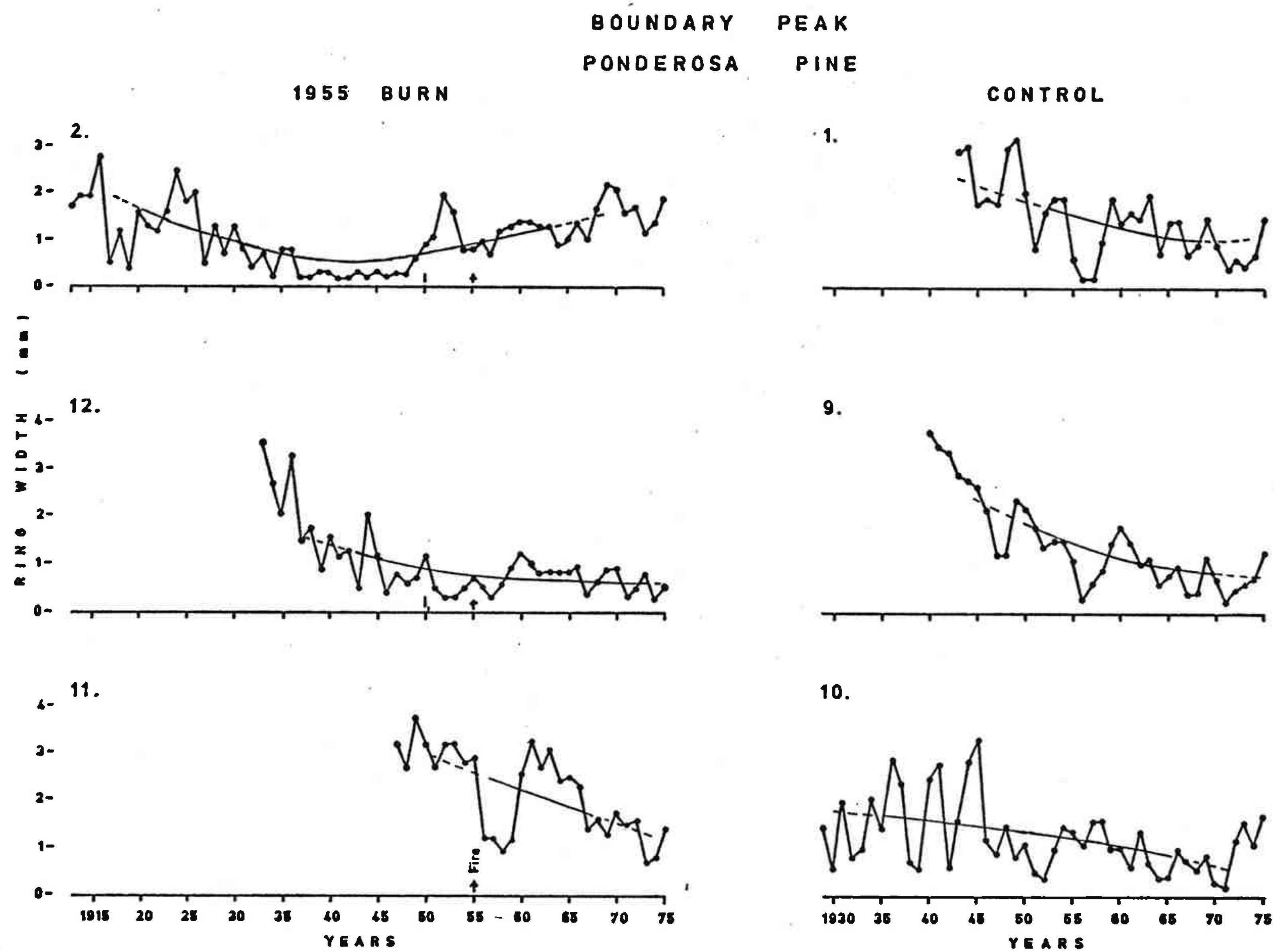


Fig. 8. Growth record from tree ring analysis of ponderosa pine from Boundary Peak for 1955 burn and control.

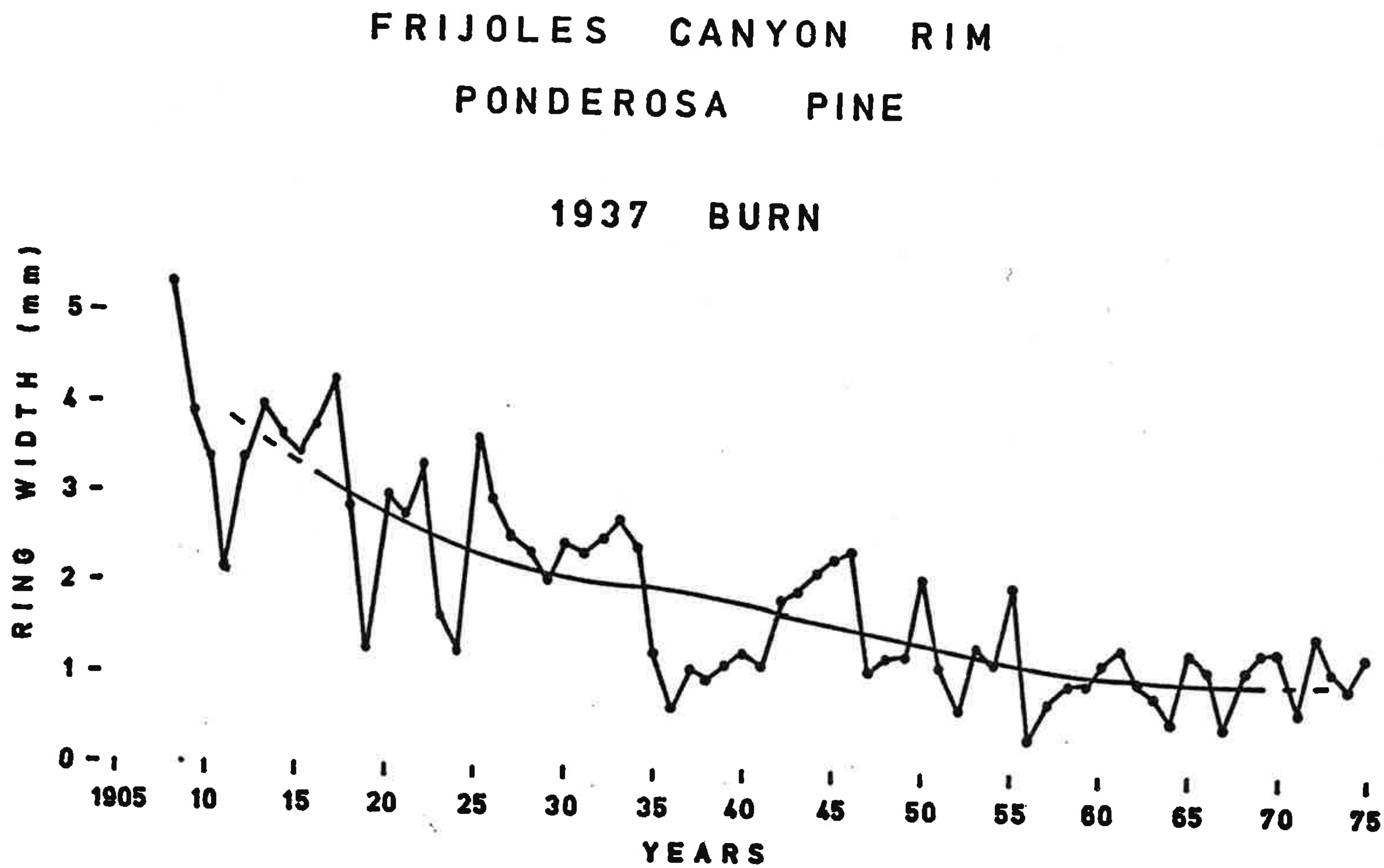


Fig. 9. Growth record from tree ring analysis of ponderosa pine from Frijoles Rim for 1937 burn.

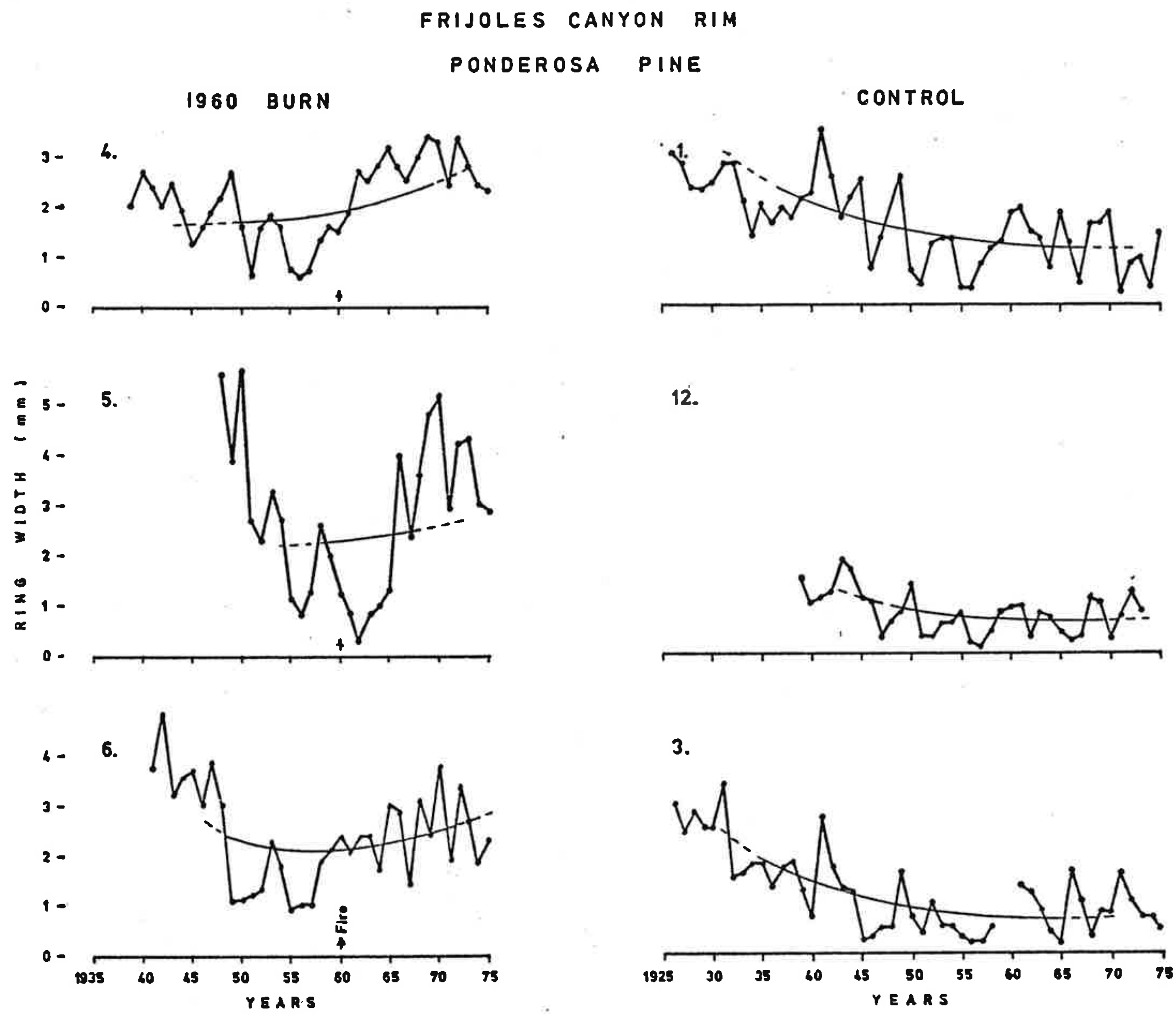


Fig. 10. Growth record from tree ring analysis of ponderosa pine from Frijoles Canyon Rim for 1960 burn and control.

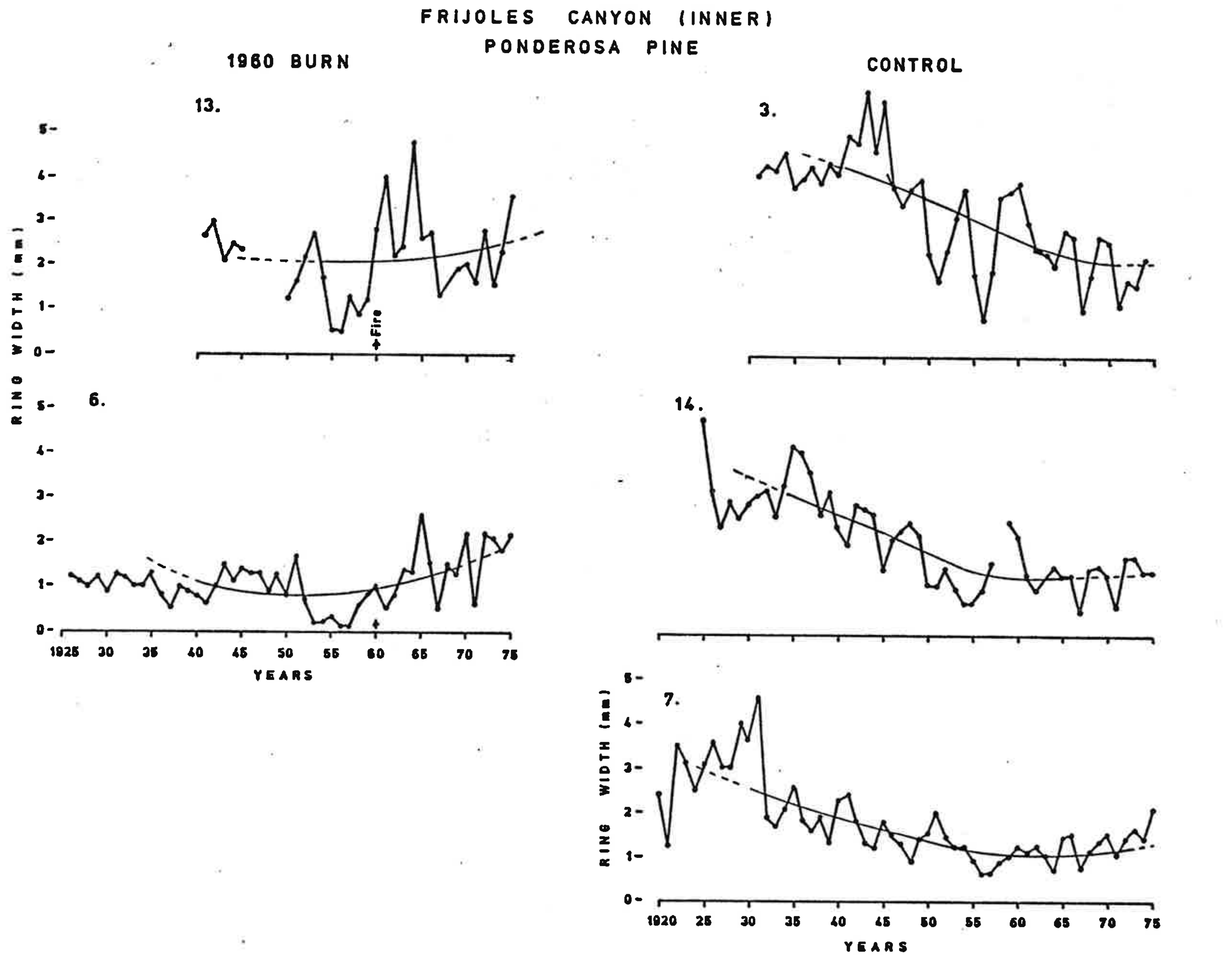


Fig. 11. Growth record from tree ring analysis of ponderosa pine from Frijoles Canyon (Inner) for 1960 burn and control.

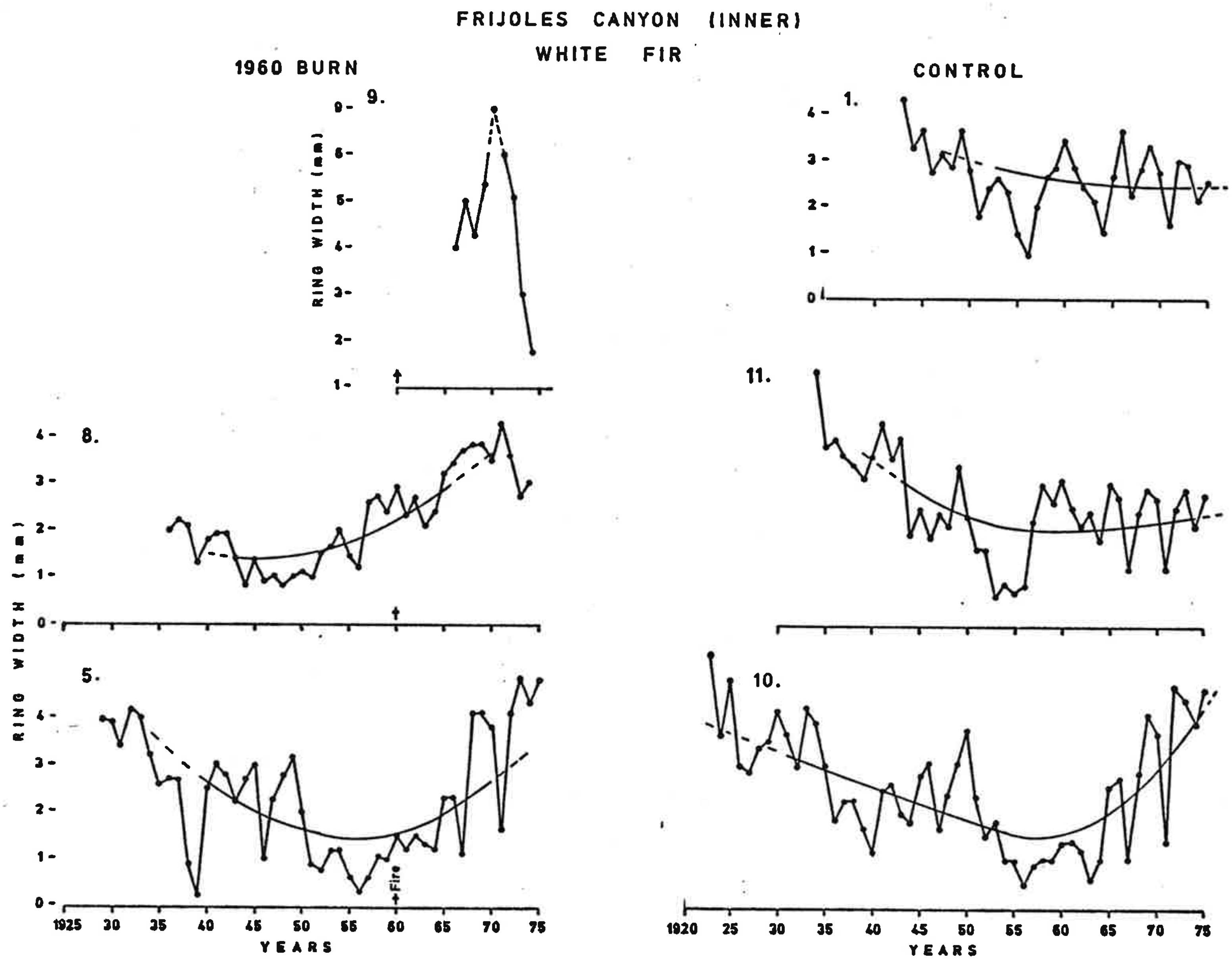


Fig. 12. Growth record from tree ring analysis of white fir from Frijoles Canyon (Inner) for 1960 burn and control.

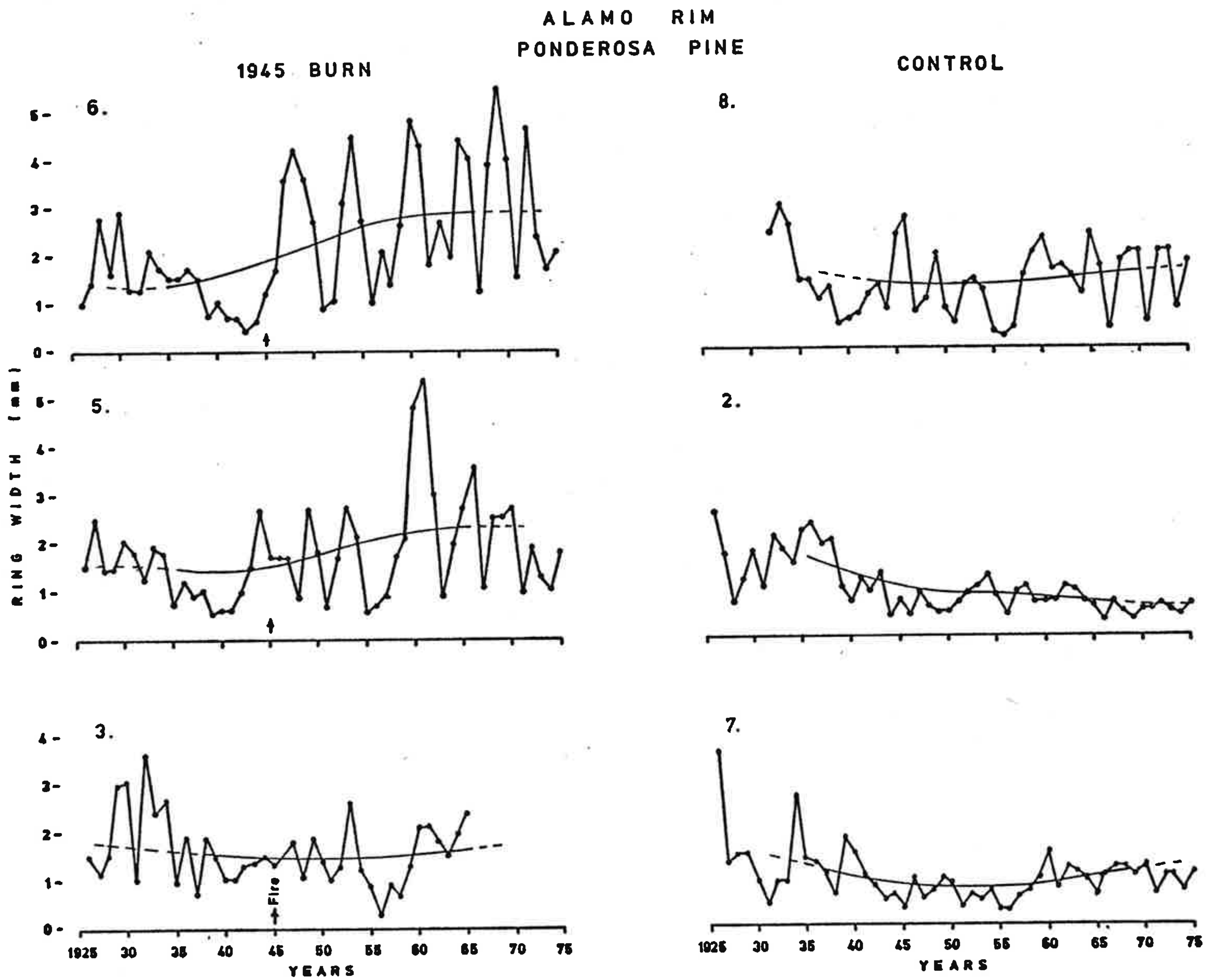


Fig. 13. Growth record from tree ring analysis of ponderosa pine from Alamo Rim for 1945 burn and control.

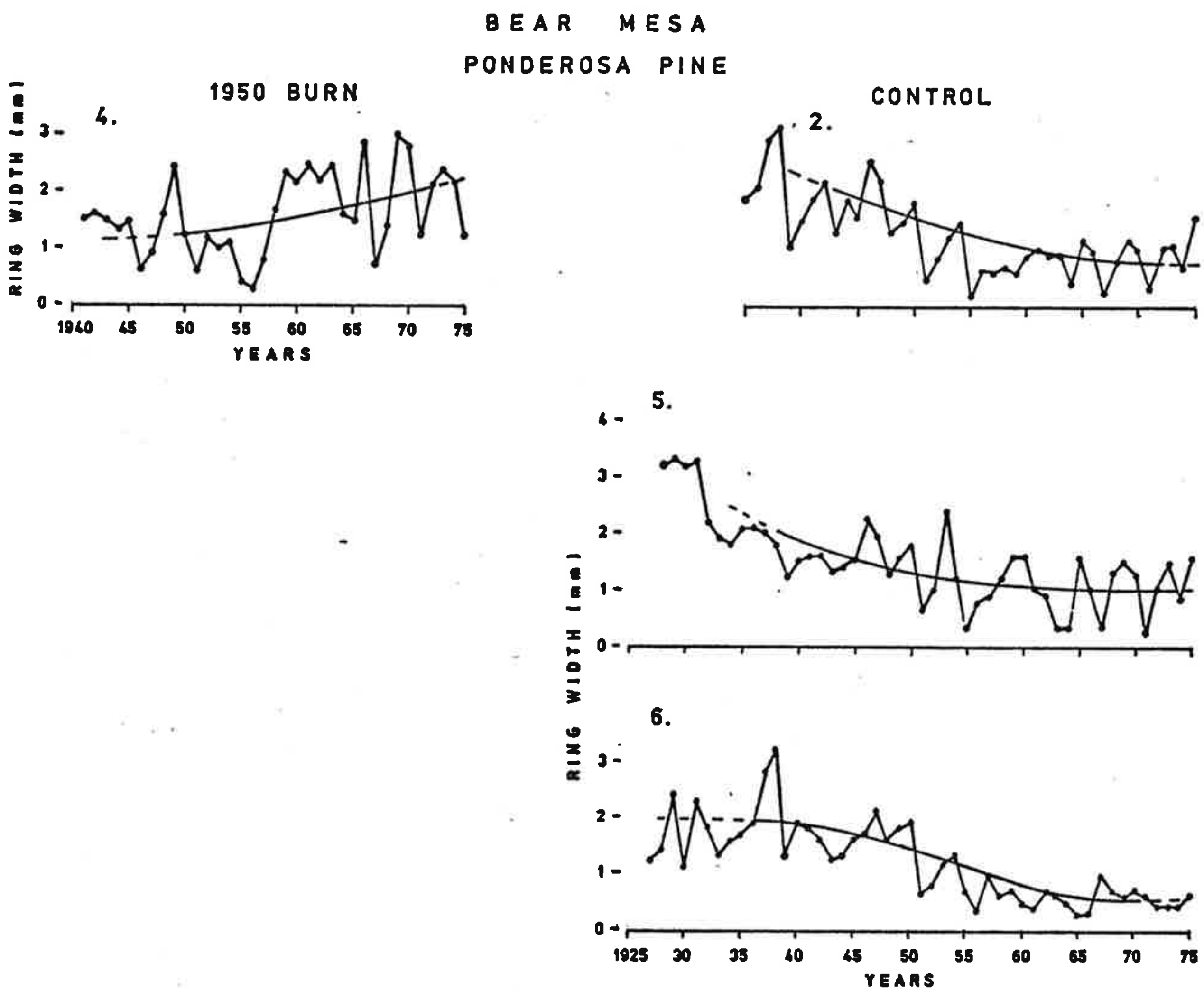


Fig. 14. Growth record from tree ring analysis of ponderosa pine from Bear Mesa for 1950 burn and control.

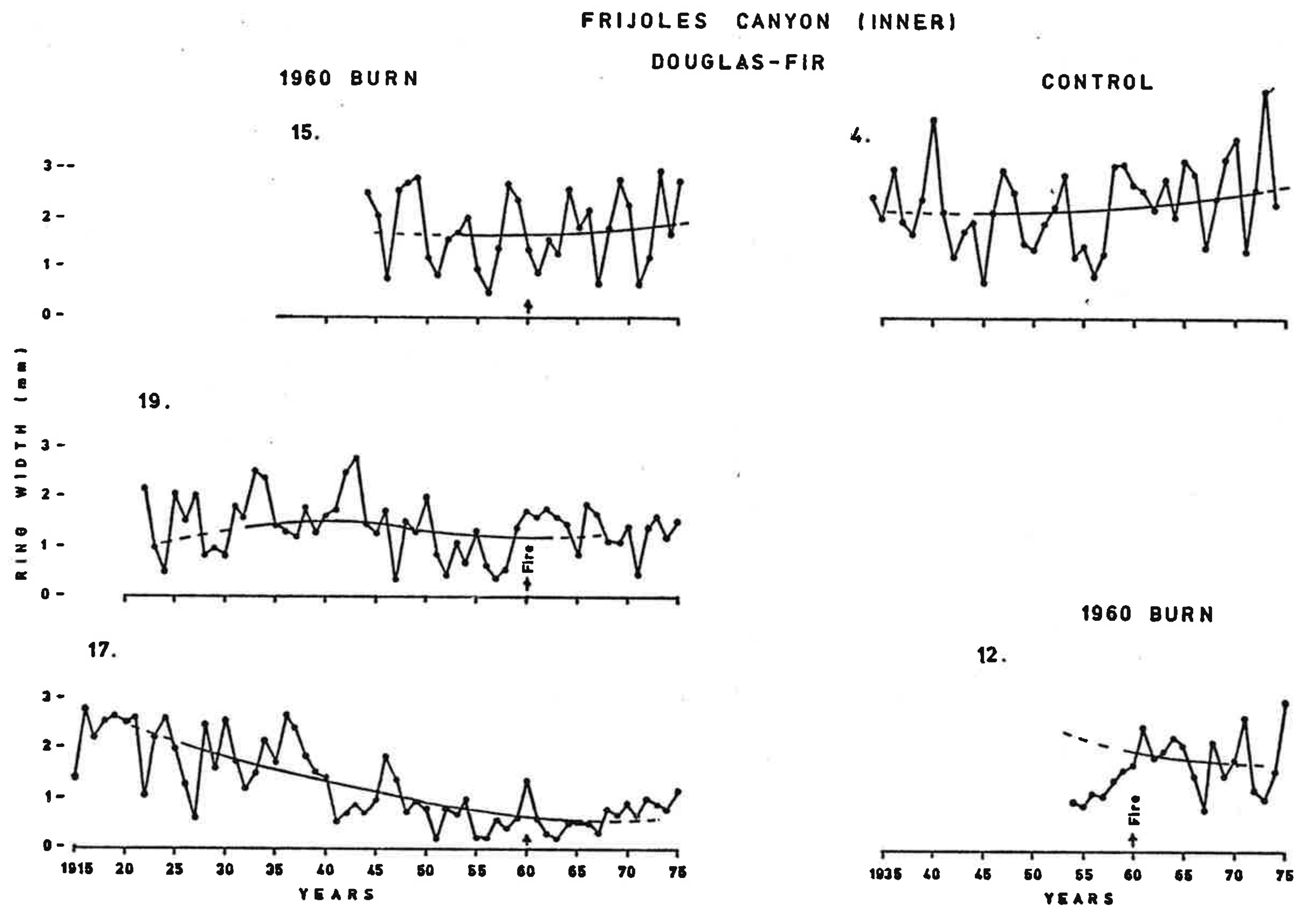


Fig. 15. Growth record from tree ring analysis of Douglas-fir from Frijoles Canyon (Inner) for 1960 burn and control.

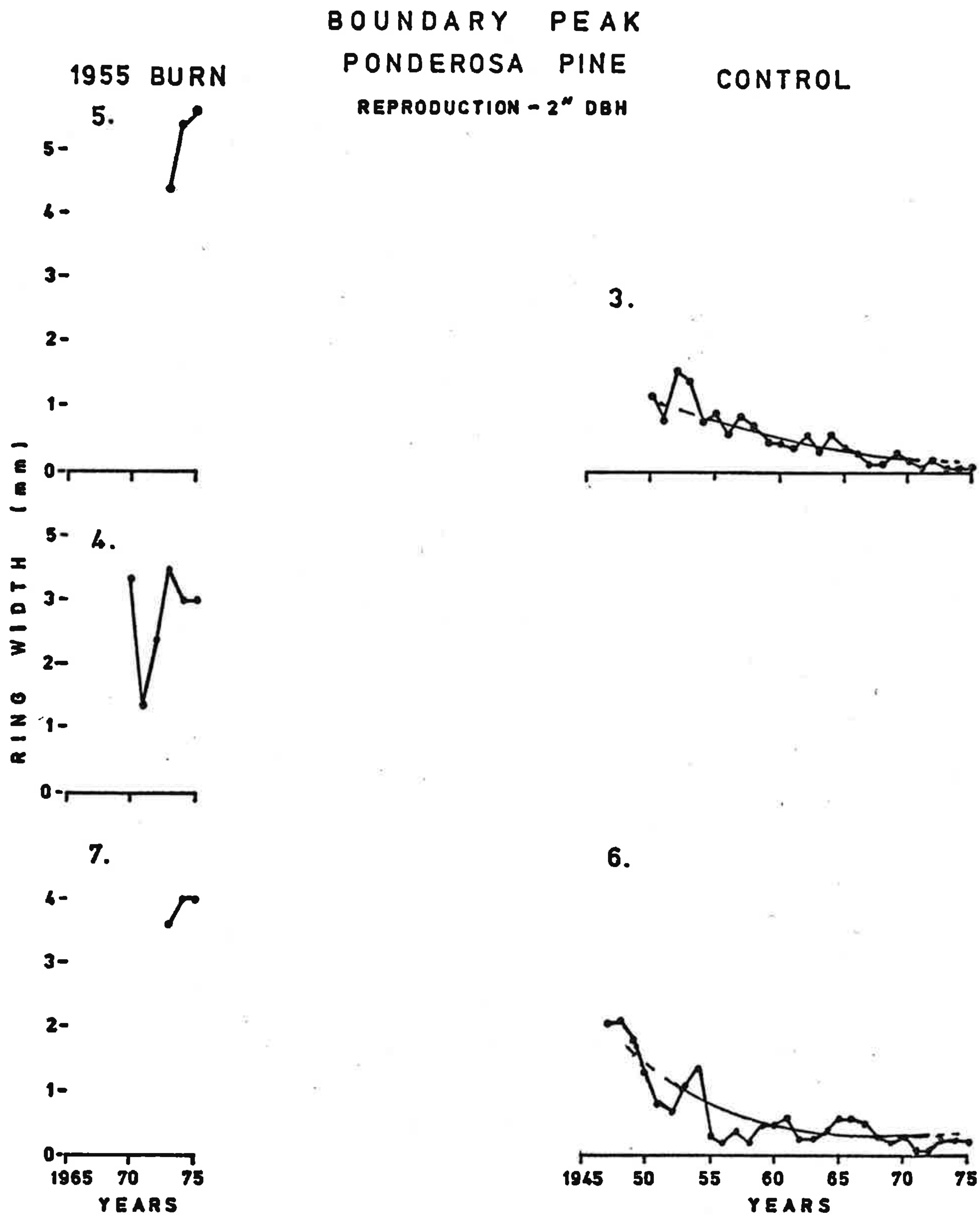


Fig. 16. Growth record from tree ring analysis of reproductive ponderosa pine from Boundary Peak for 1955 burn and control.

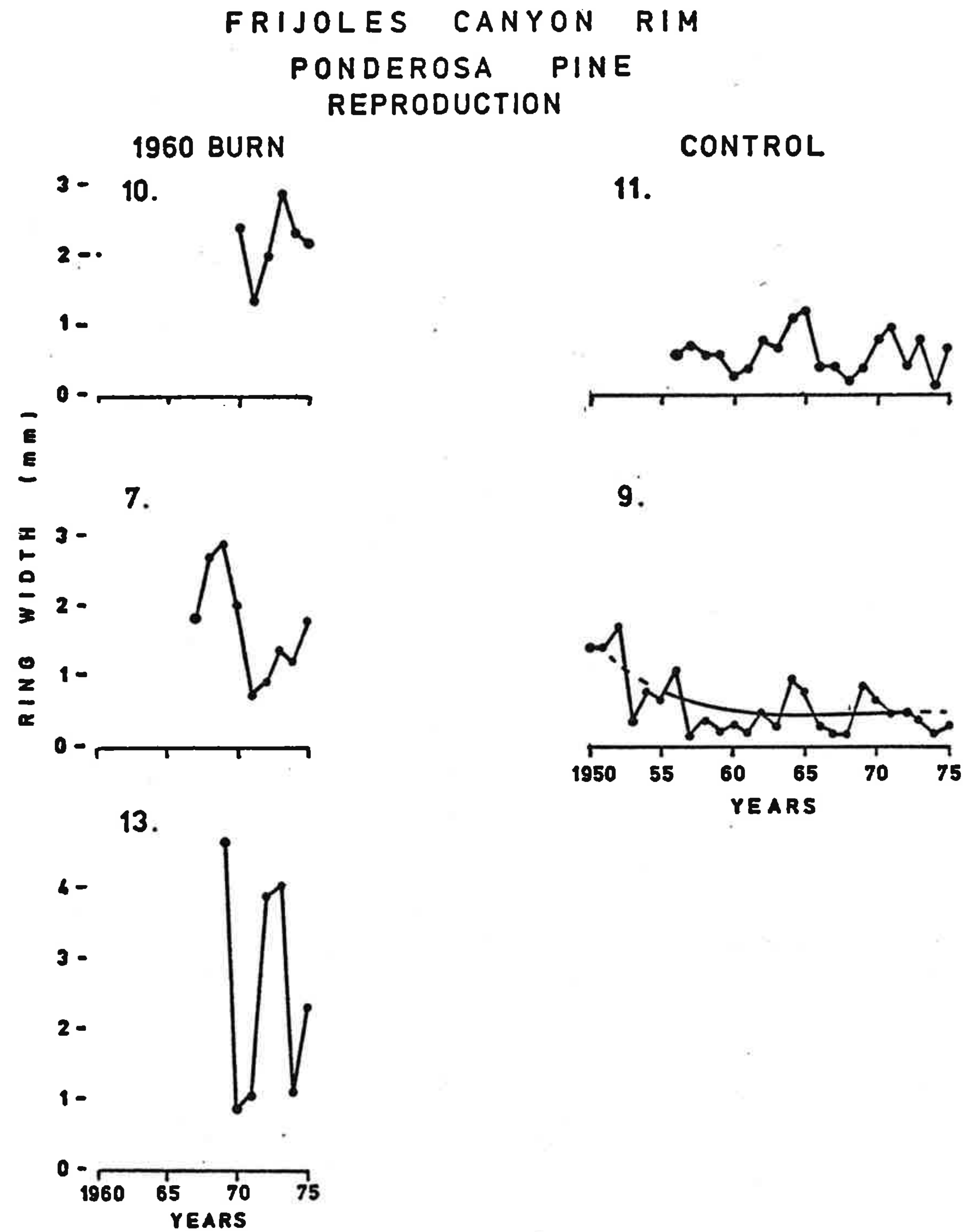


Fig. 17. Growth record from tree ring analysis of reproductive ponderosa pine from Frijoles Canyon Rim for 1960 burn and control.

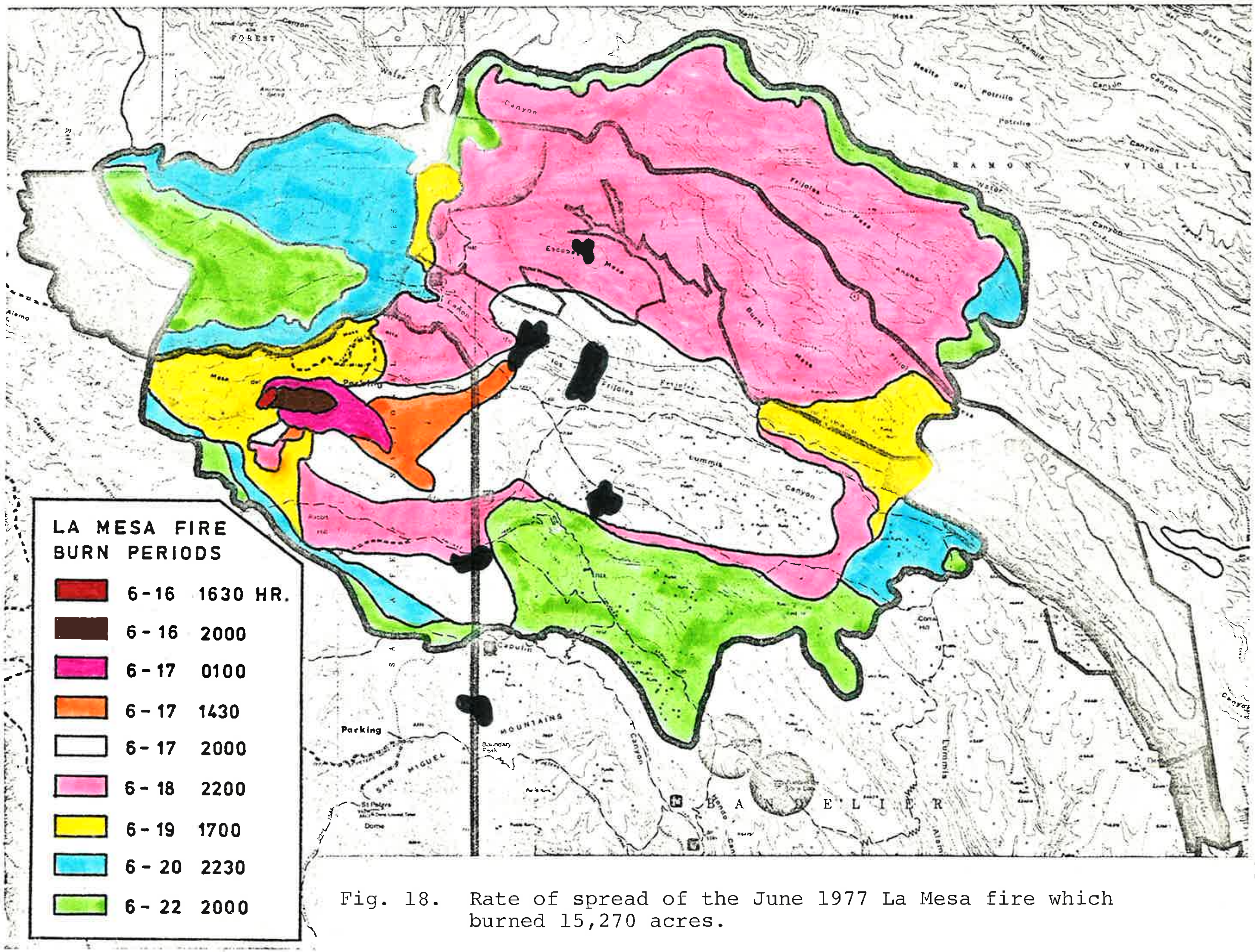


Fig. 18. Rate of spread of the June 1977 La Mesa fire which burned 15,270 acres.

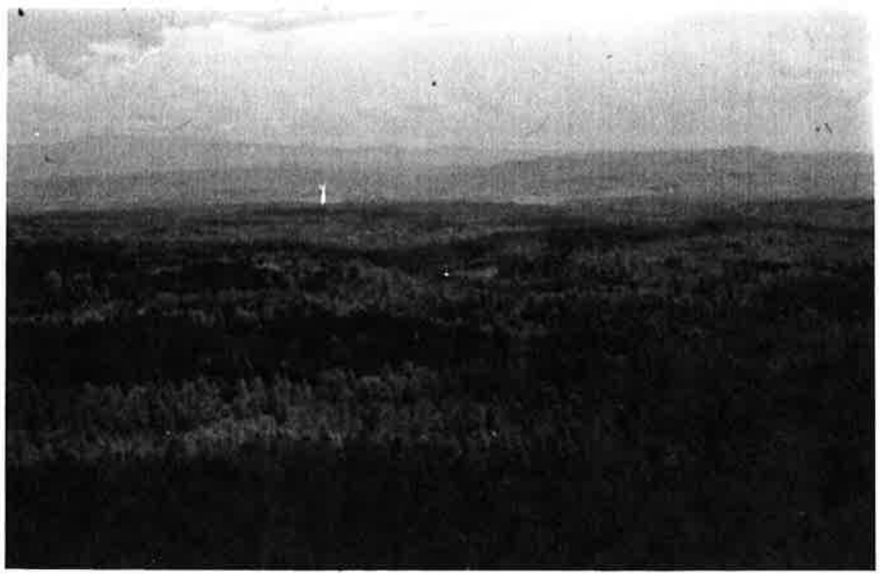


Fig. 19. General view of area of June 1977 La Mesa fire showing patches of varying degrees of fire damage.

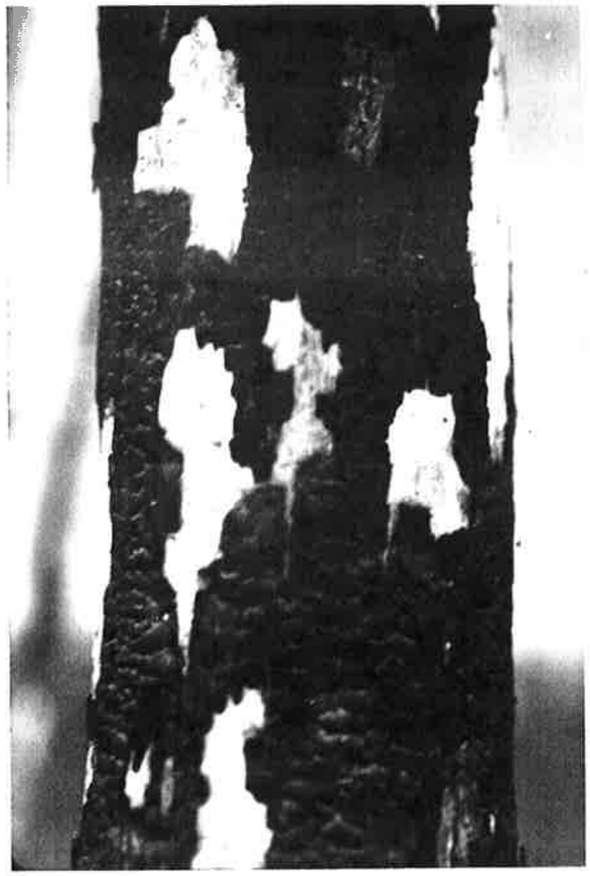


Fig. 20. Detail of effect of explosions of localized concentrations of volatile substances in bark or outer wood, common in severely burned pinyon and ponderosa pine.

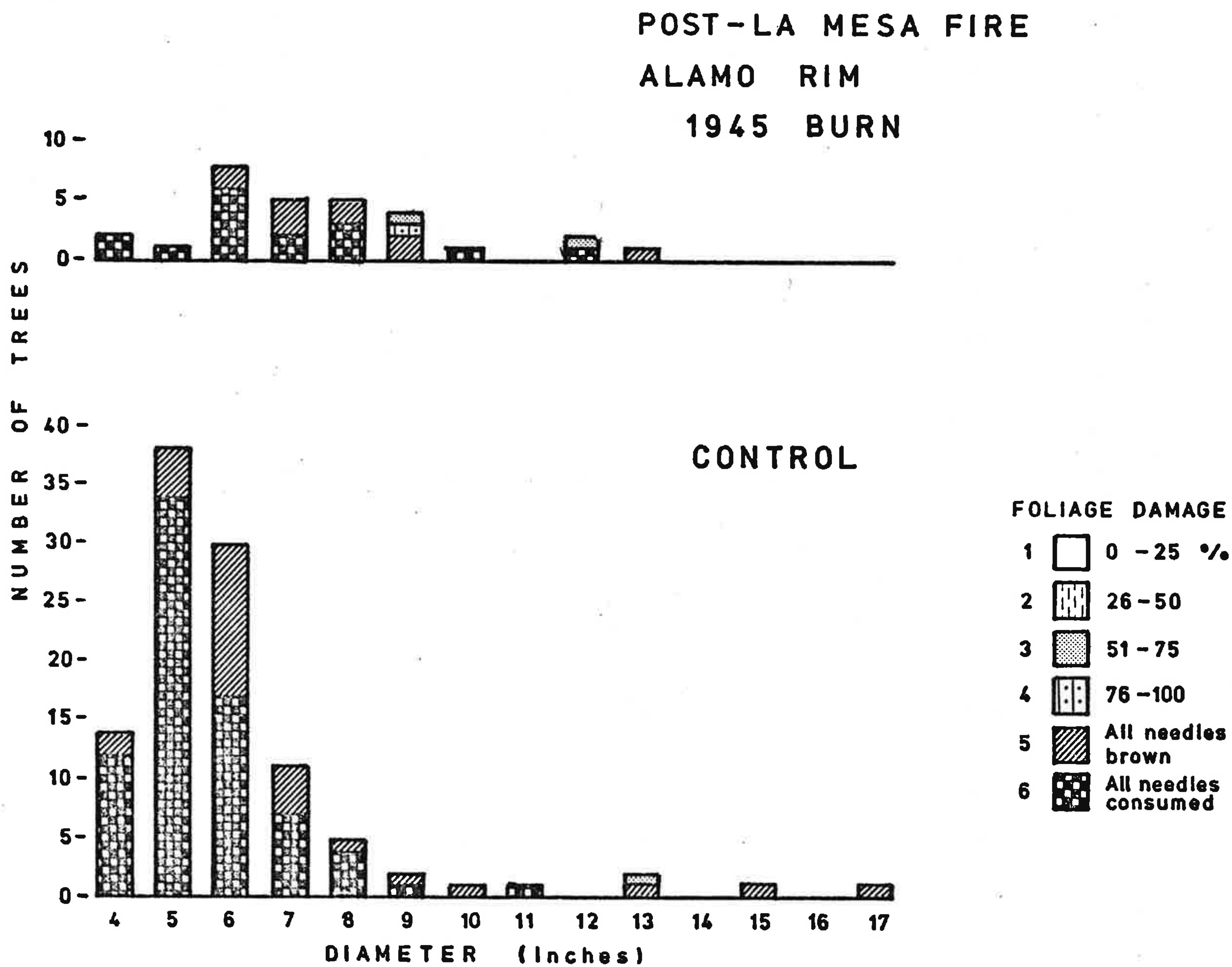


Fig. 21. Relative foliar damage in six categories to mature ponderosa pine on Alamo Rim based on the line-strip plots, 1977.

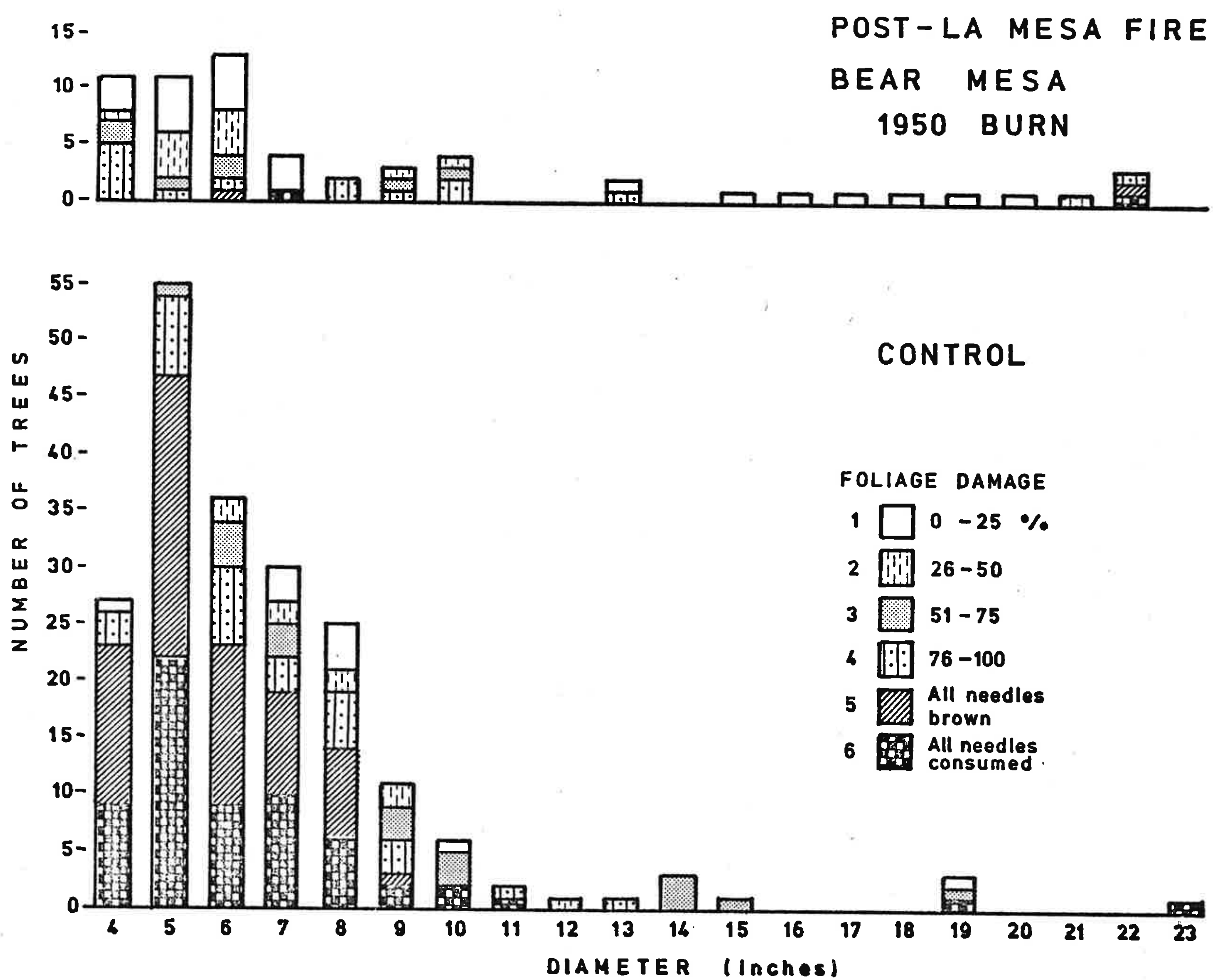


Fig. 22. Relative foliar damage in six categories to mature ponderosa pine on Bear Mesa based on the line-strip plots, 1977.

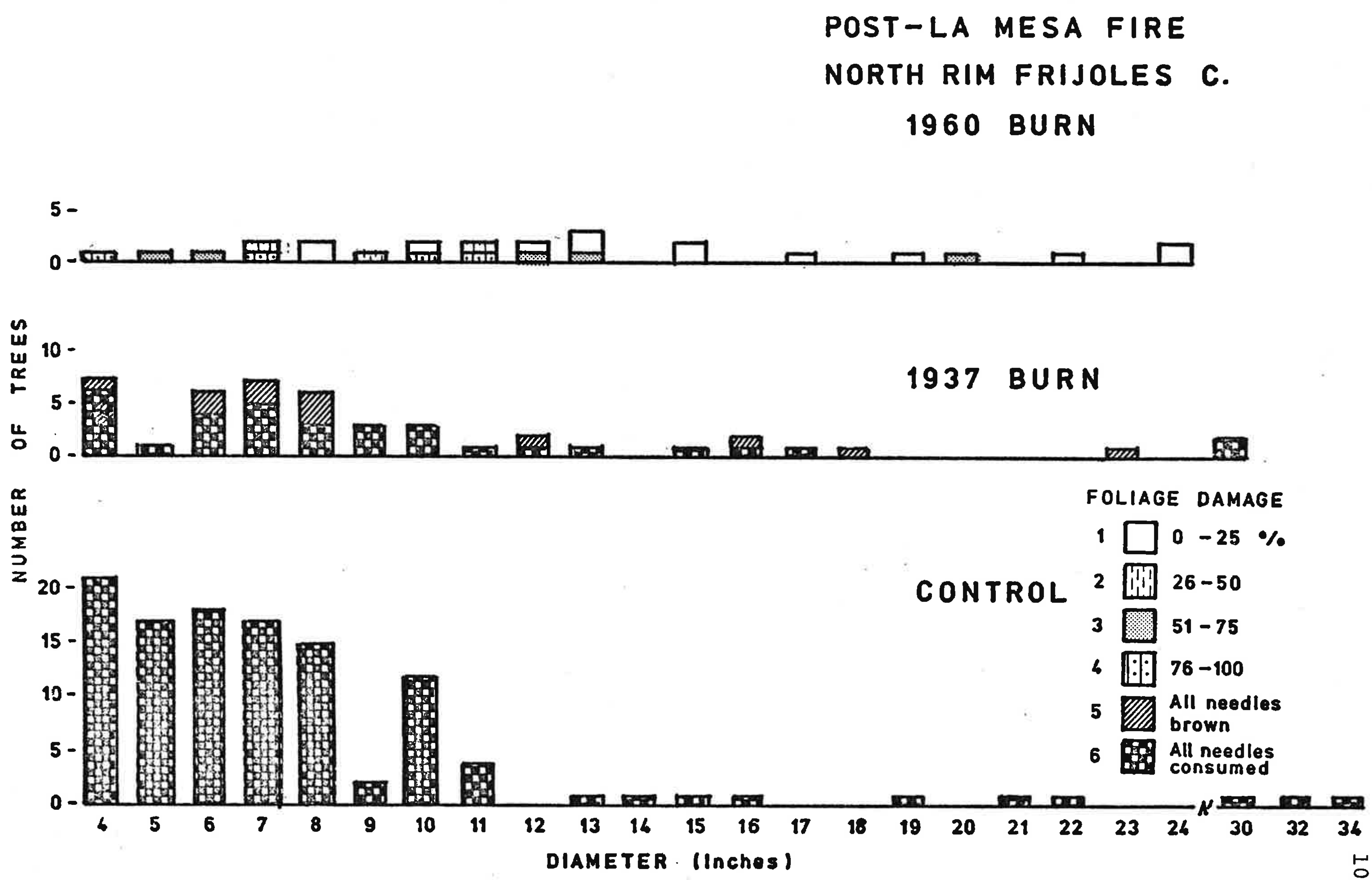
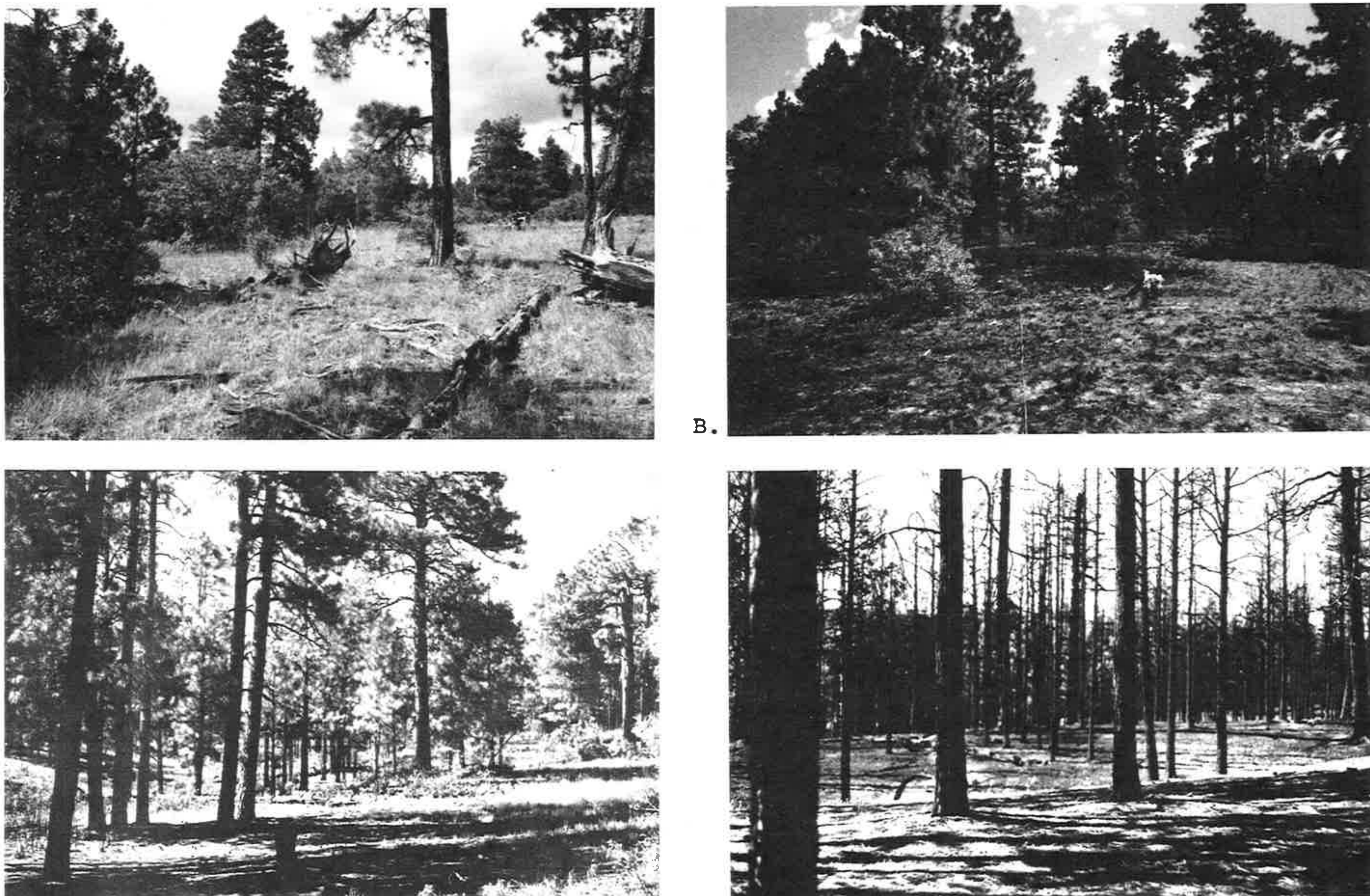
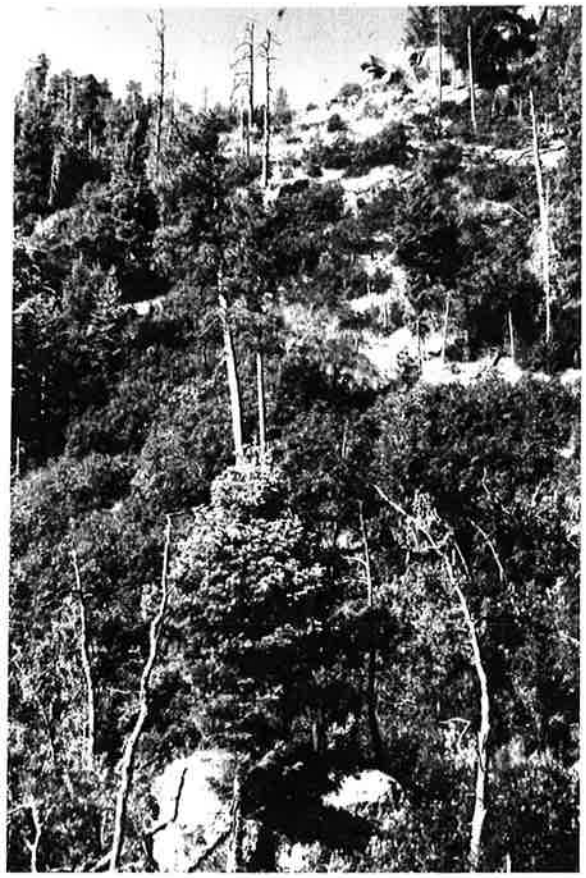


Fig. 23. Relative foliar damage in six categories to mature ponderosa pine on North Rim Frijoles Canyon based on the line-strip plots, 1977.



A. B. C. D.

Fig. 24. Comparative photos of 1960 burn on North Rim of Frijoles Canyon before the La Mesa fire (A) and immediately after (B). Comparison of post-La Mesa fire taken Aug. 1977 of 1960 burn (C) and control (D).

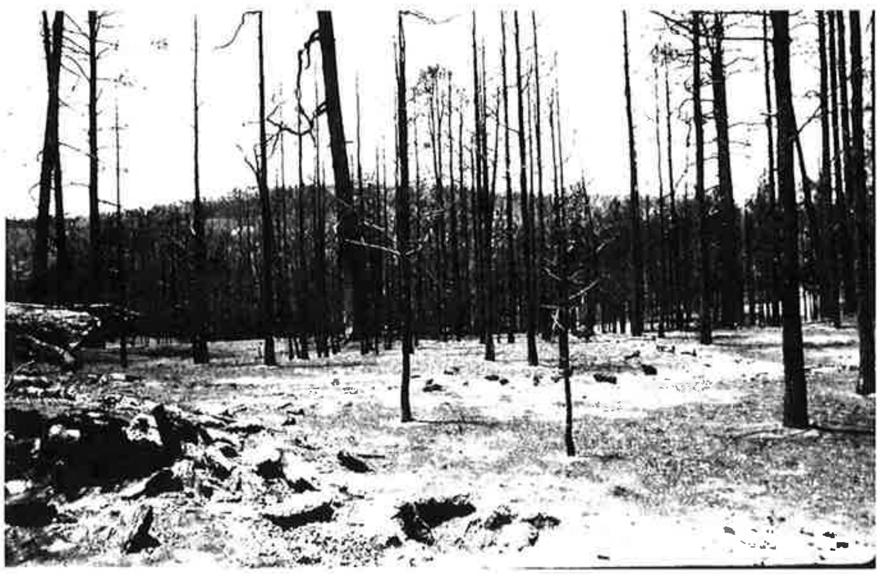


A.

B.

Fig. 25. Comparative photos of 1960 burn in Frijoles Canyon (Inner) before the La Mesa fire (A) and after (B).

A.



B.

Fig. 26. Comparative photos of 1878 burn on North Rim of Frijoles Canyon before the La Mesa fire (A) and after (B).

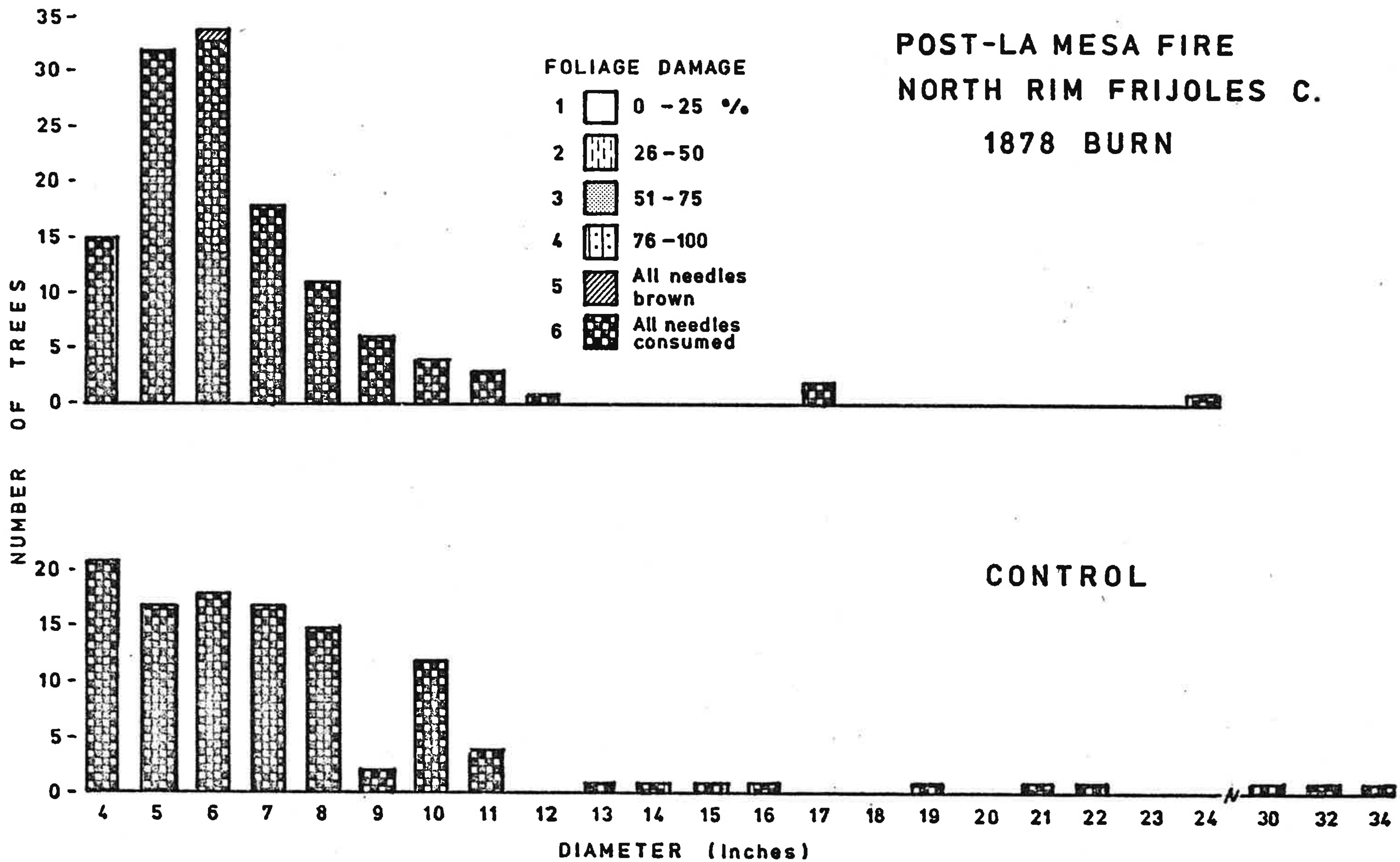


Fig. 27. Relative foliar damage in six categories to mature ponderosa pine on North Rim Frijoles Canyon based on the line-strip plots, 1977.

Fig. 28. Polygon cracking of mineral soil due to complete combustion of organic matter and extreme heat of La Mesa fire in area not burned since 1878.

Fig. 29. View of 1937 burn area of North Rim of Frijoles Canyon taken Sept. 1977 after the La Mesa fire.

Fig 30. Handline to control the 1976 Escobas Mesa burn, still apparent after the 1977 La Mesa fire.

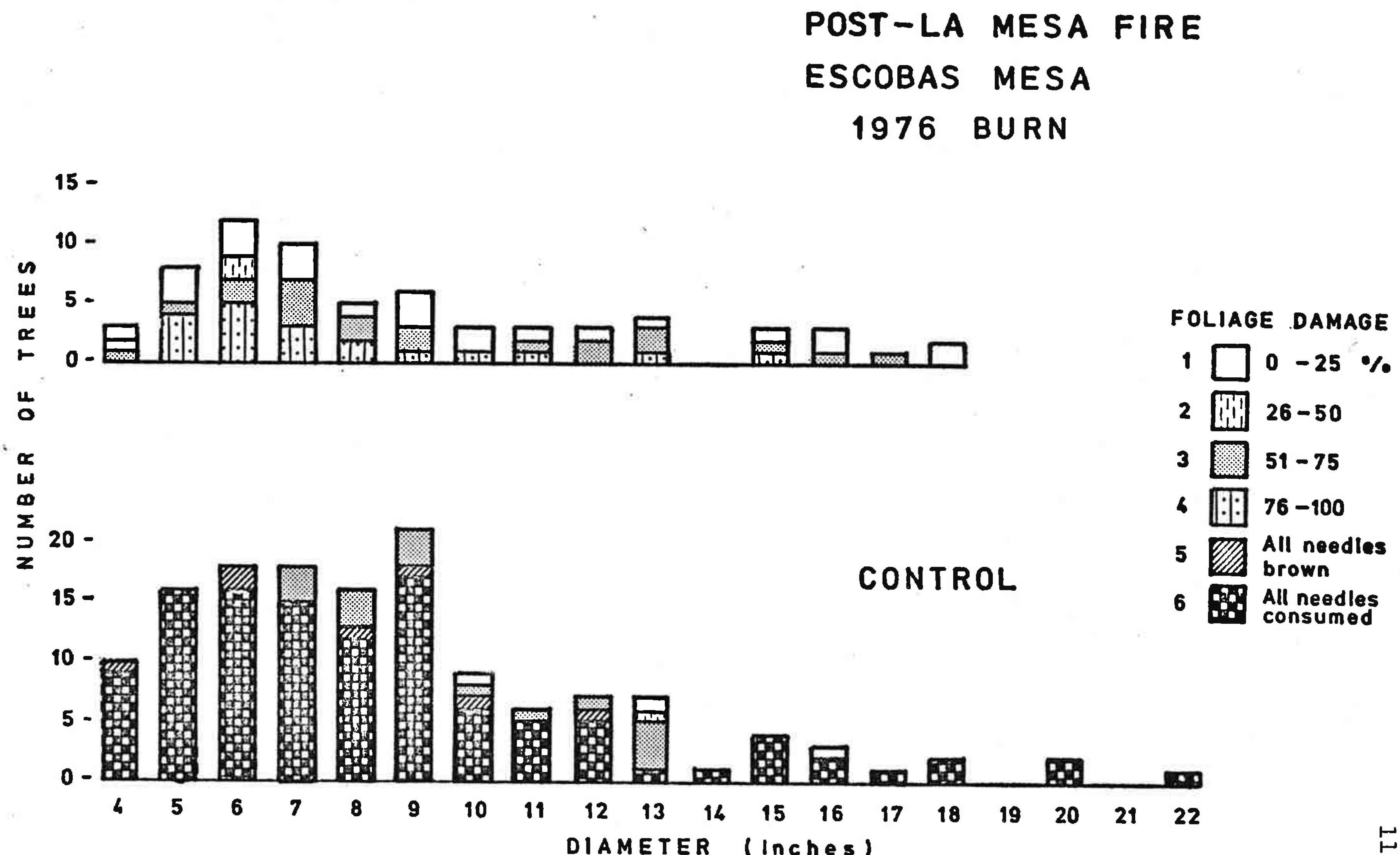


Fig. 31. Relative foliar damage in six categories to mature ponderosa pine on Escobas Mesa based on the line-strip plots, 1977.

A. 

B. 

C. 

Fig. 32. Escobas Mesa July 1976 burn area, photo station 1, notch 7, taken Sept. 1976 (A); post-La Mesa fire June 1977 (B); Sept. 1977 (C).

A.

B.

C.

Fig. 33. Escobas Mesa July 1976 burn area, photo station 2, notch 5, taken Sept. 1976 (A); post-La Mesa fire June 1977 (B); Sept. 1977 (C).

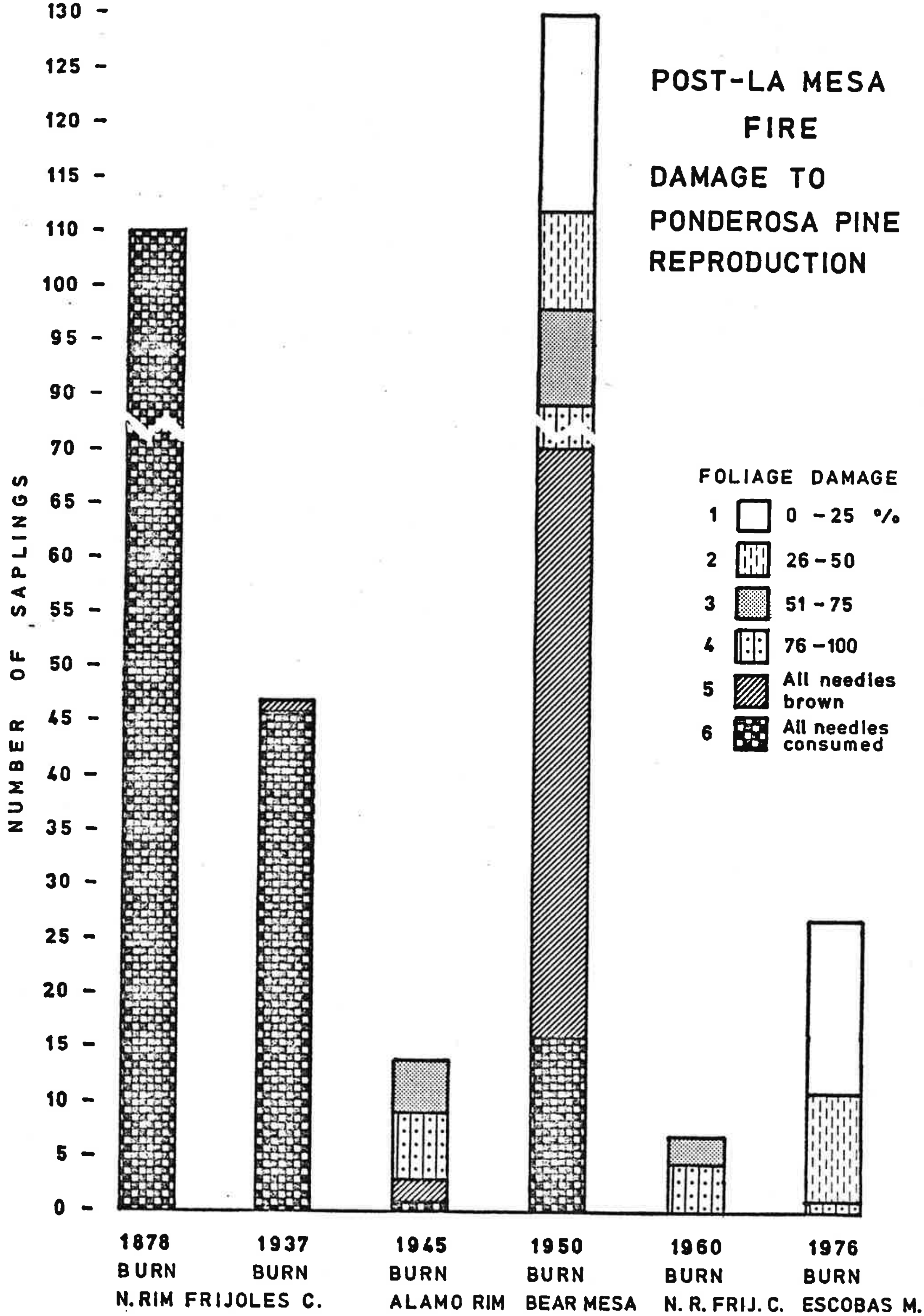


Fig. 34. Summary of relative foliar damage of La Mesa fire in six categories to reproductive ponderosa pine at six sites.

A.

B.

C.

Fig. 35. Burnt Mesa June 1975 burn area, photo station 1, notch 2, taken Sept. 1976 (A); post-La Mesa fire June 1977 (B); Sept. 1977 (C).

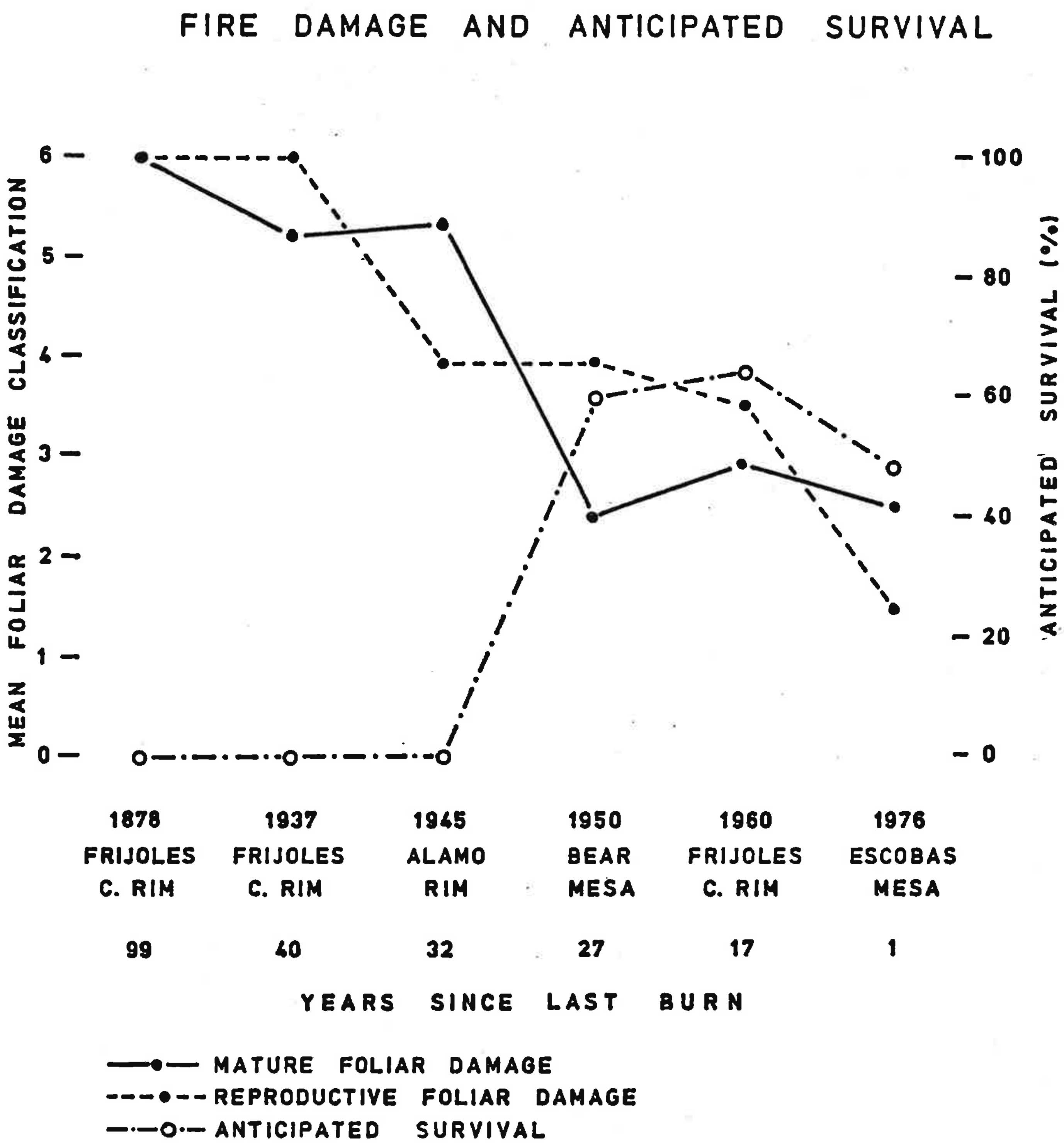


Fig. 35.1 Mean fire damage classifications to foliage of mature and reproductive ponderosa pine and the anticipated survival percentage of six stands burned by the La Mesa fire.

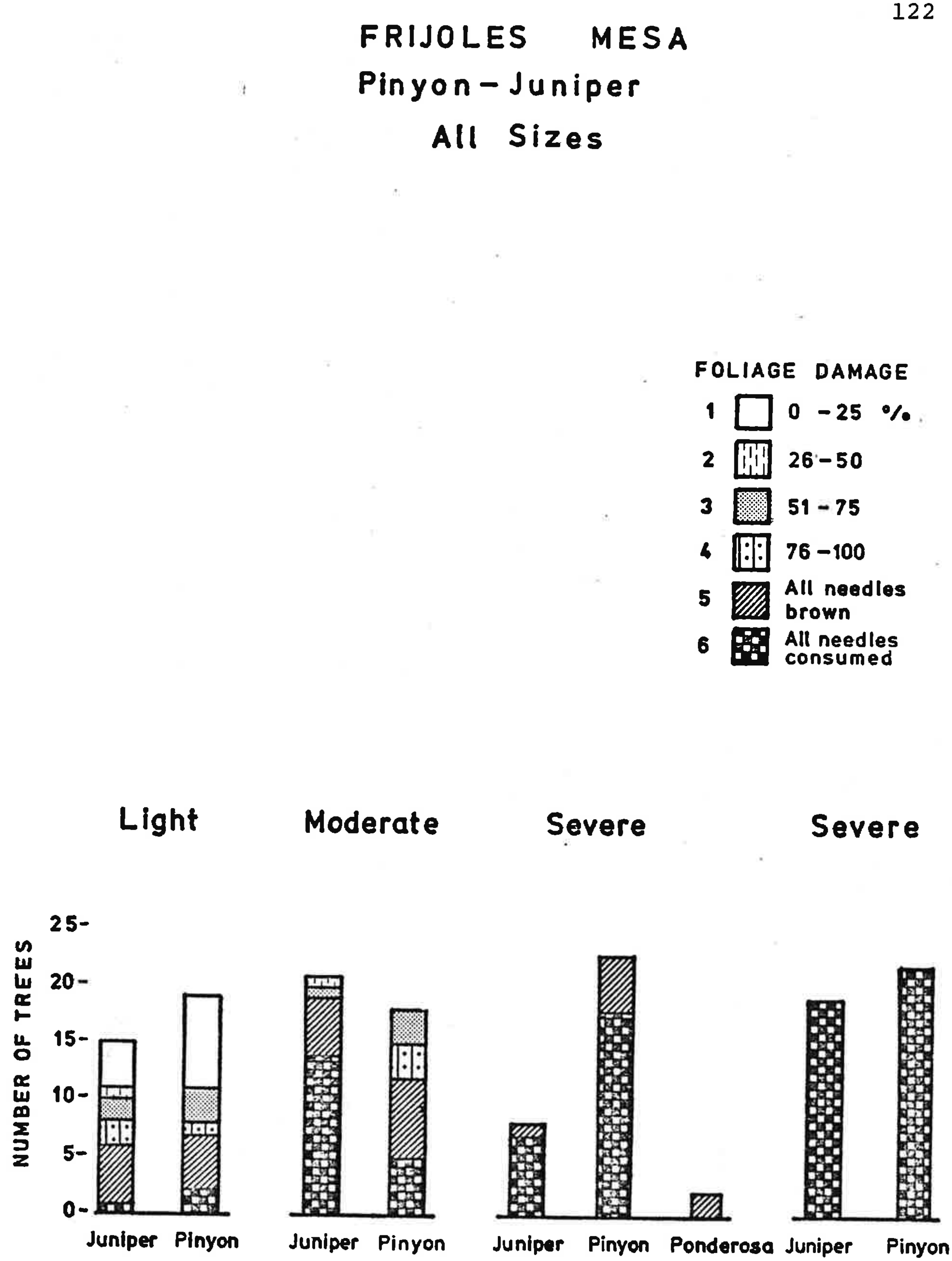


Fig. 36. Relative foliar damage in six categories to all sizes of trees in Pinyon-Juniper, Transect I, Frijoles Mesa.

Fig. 37. Frijoles Mesa, 20x50 meter plot 1, photo station NE-W (A); plot 2, NE-SW (B); plot 3, NE-SE (C).

Fig. 38. View of meadow on Burnt Mesa taken Sept. 1977 after being burned over by the La Mesa fire.

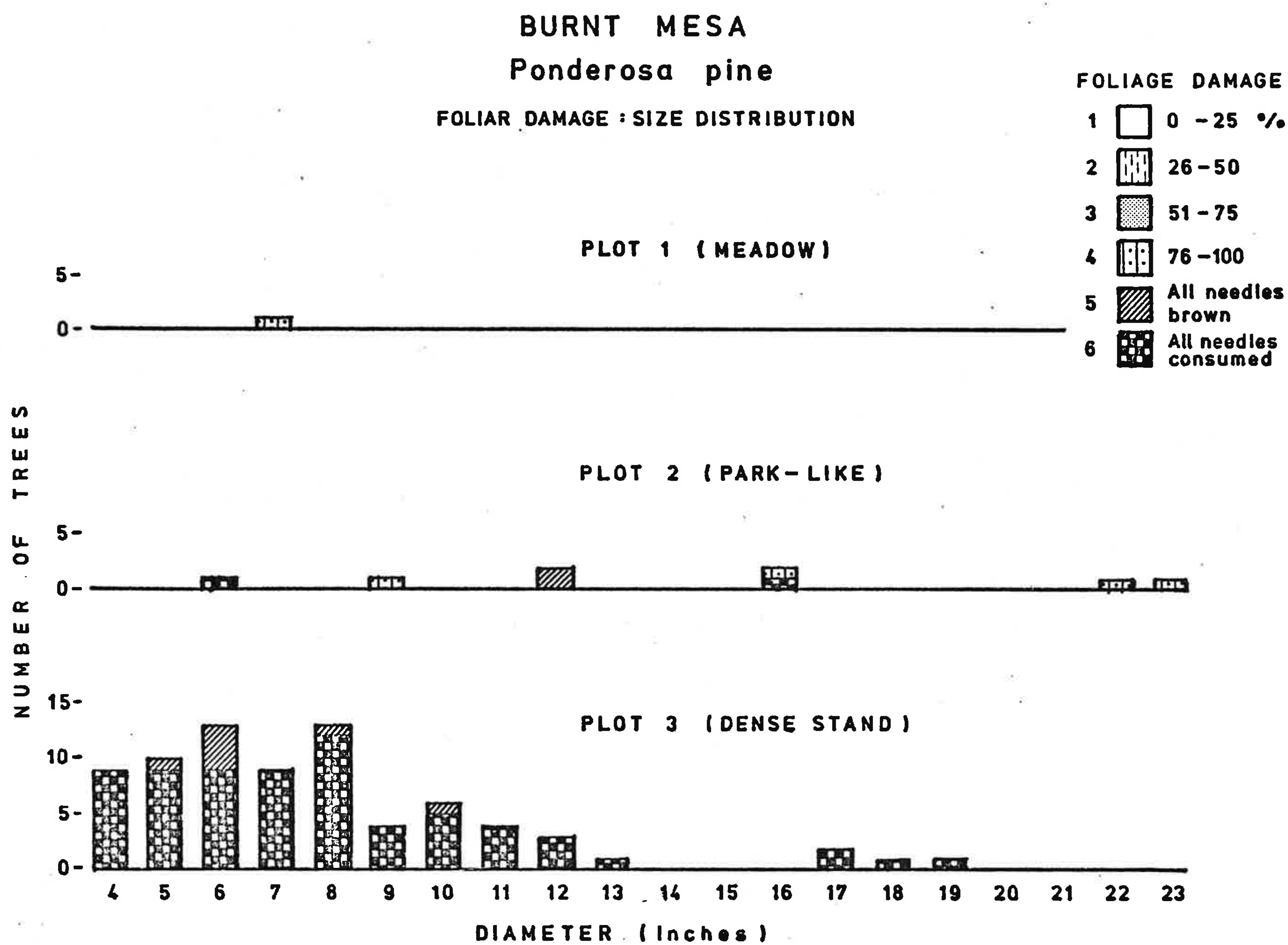


Fig. 39. Relative foliar damage in six categories as reflected by diameter size in mature ponderosa pine in three densities of stand on Burnt Mesa.

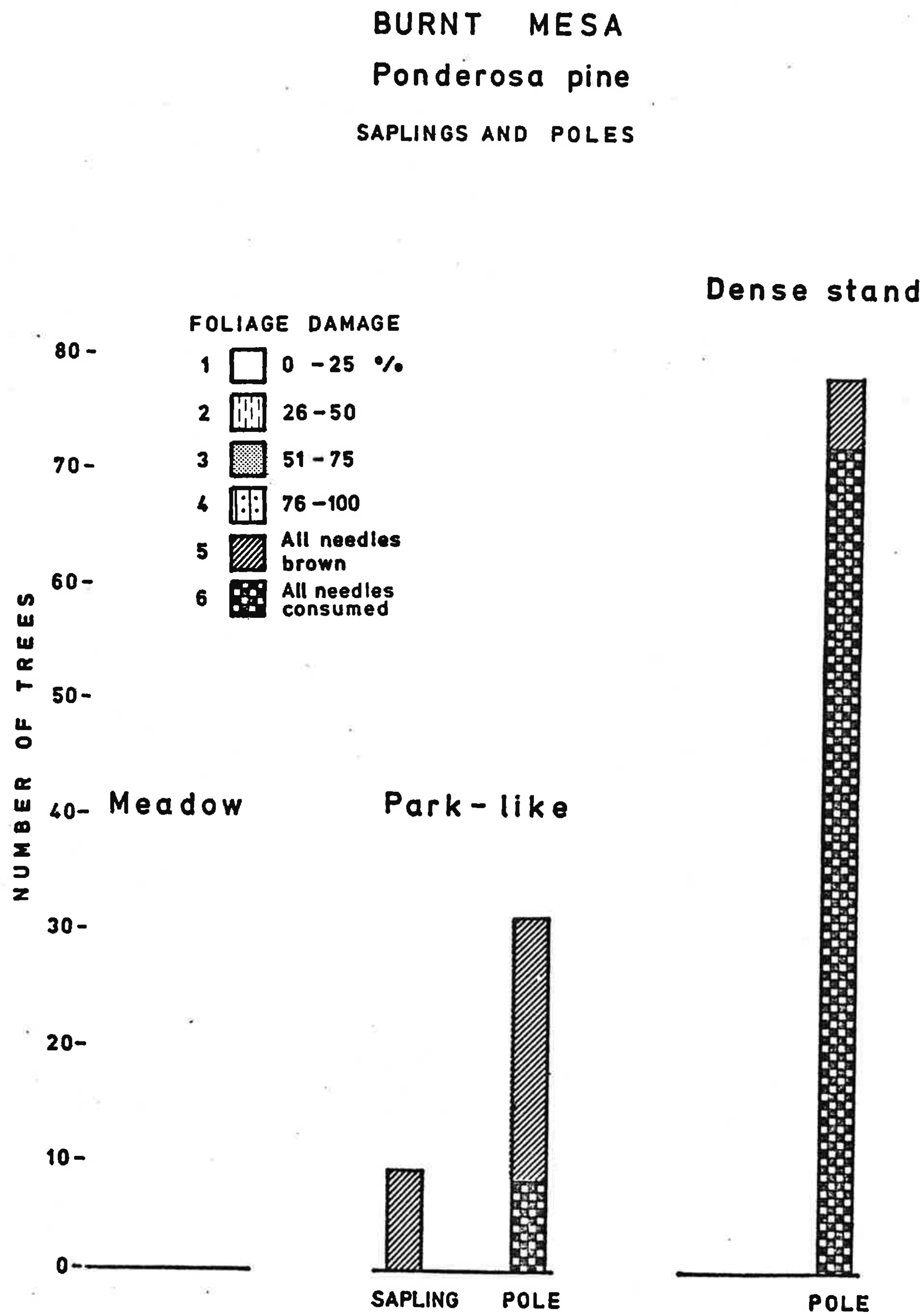
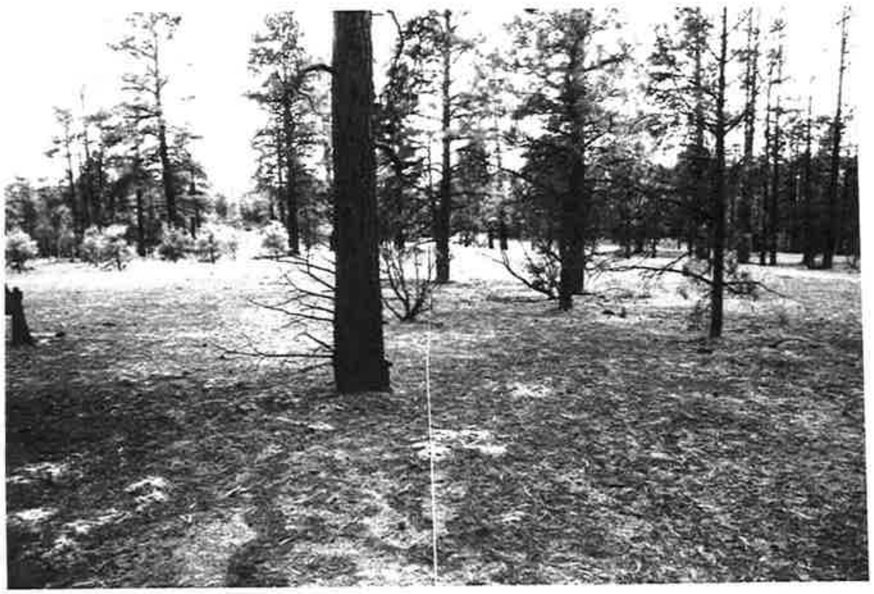


Fig. 40. Relative foliar damage in six categories as reflected by saplings and poles of ponderosa pine in three densities of stand on Burnt Mesa.

A.



B.

C.

Fig. 41. Burnt Mesa, 20x50 meter plot 1, photo station NW-N (A); plot 2, NW-S (B); plot 3, NW-SE (C).

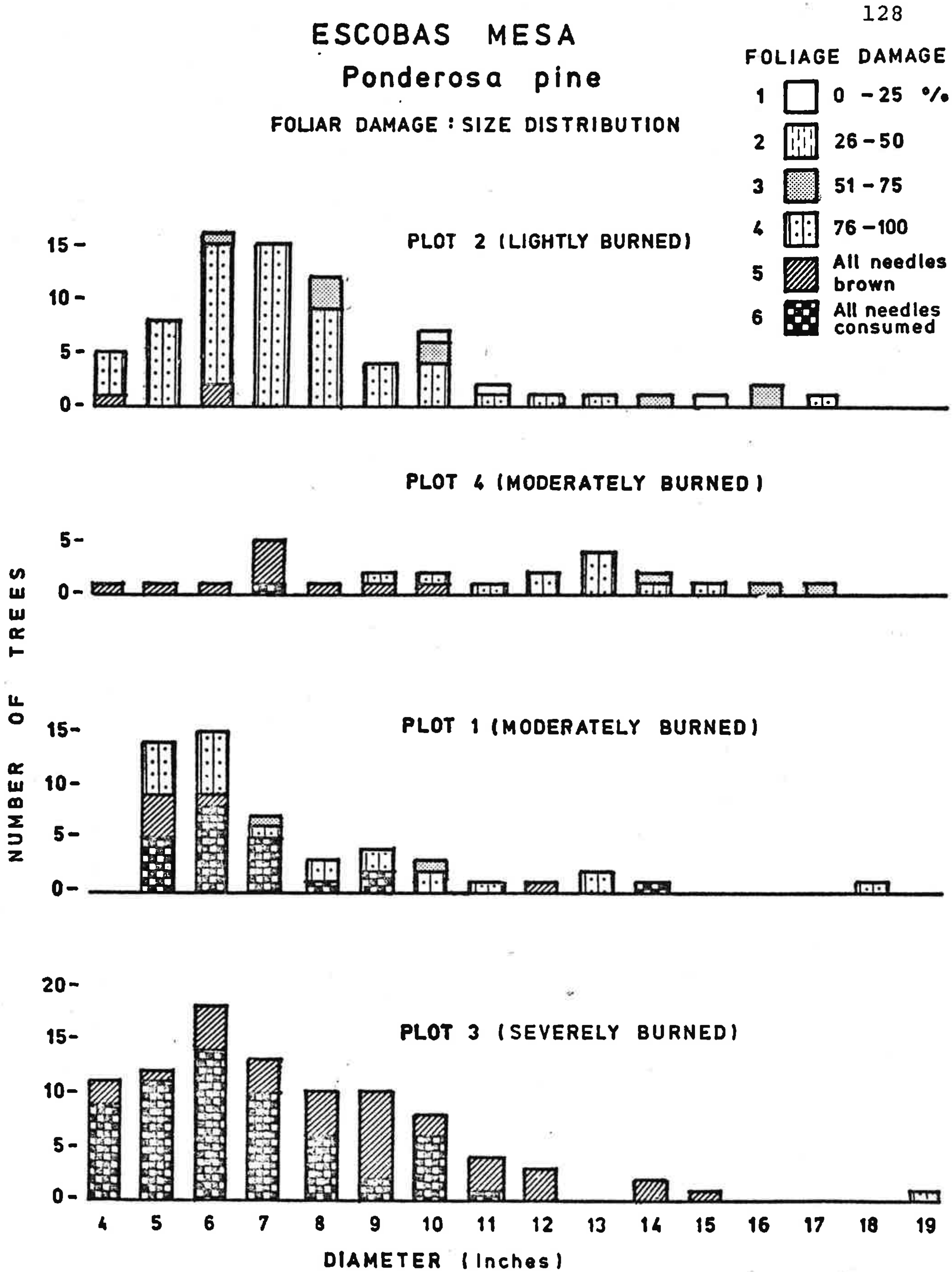


Fig. 42. Relative foliar damage in six categories as reflected by diameter size in mature ponderosa pine in four stands of varying intensity of damage on Escobas Mesa.

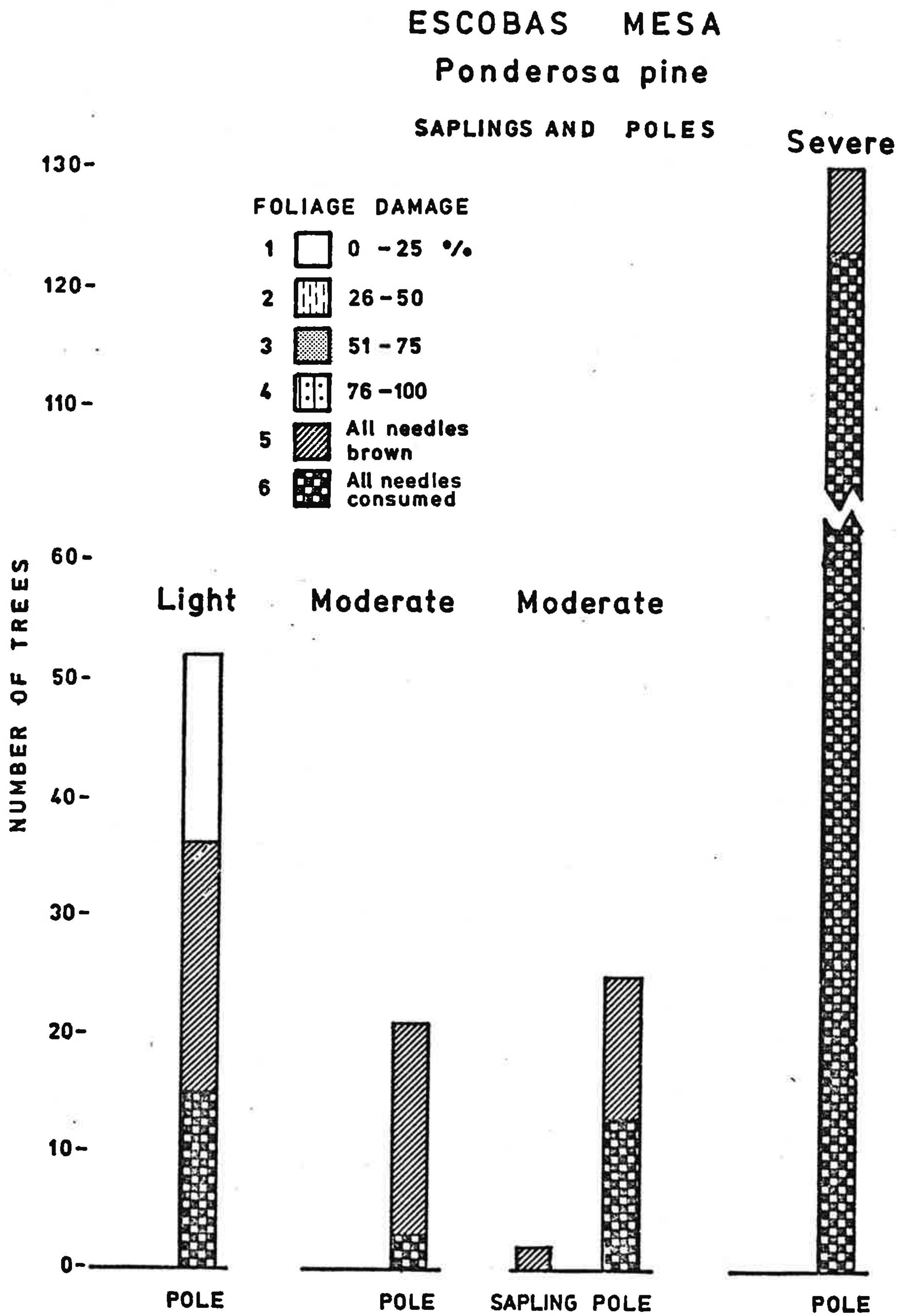
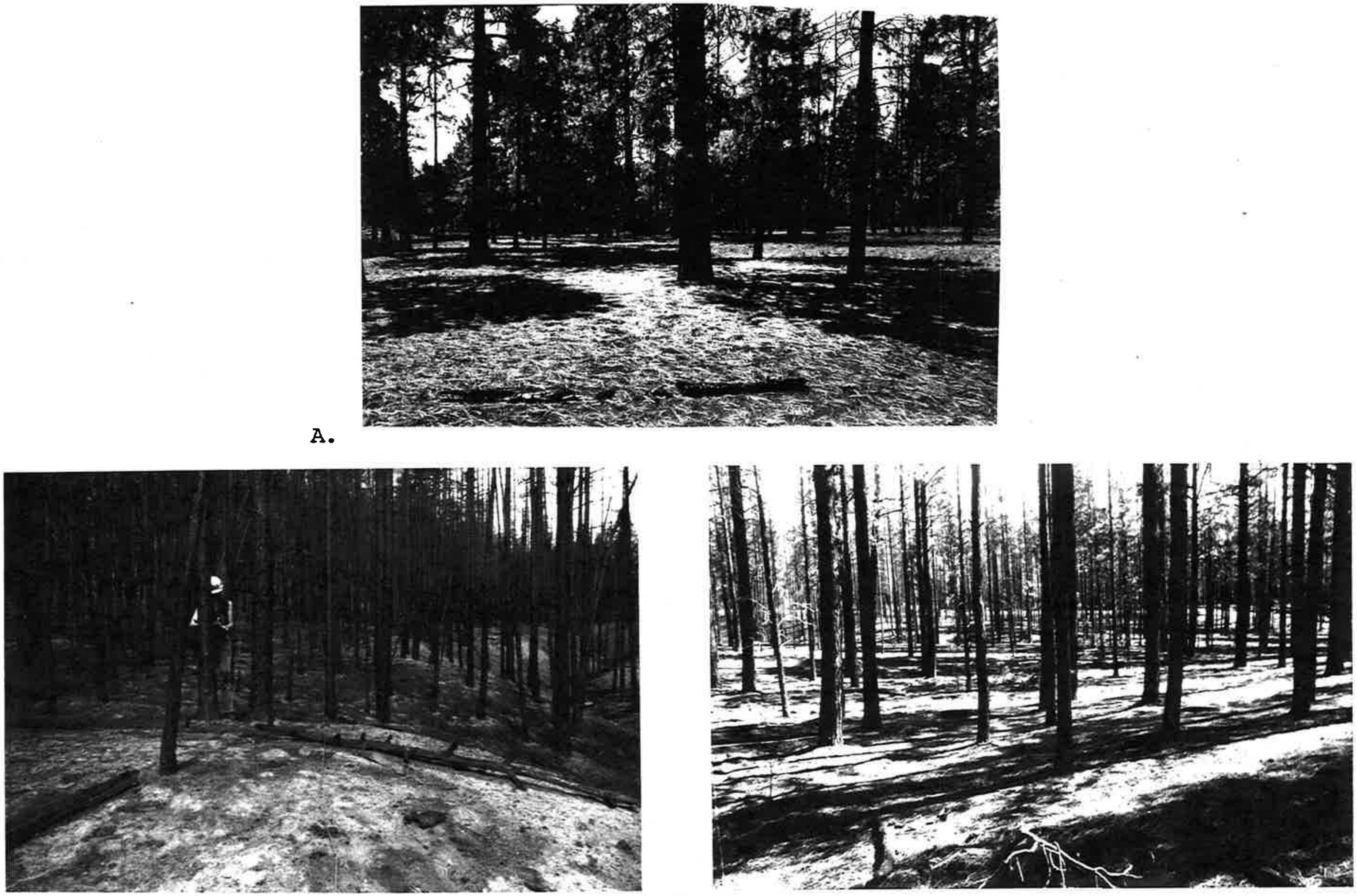


Fig. 43. Relative foliar damage in six categories as reflected by saplings and poles of ponderosa pine in four stands of varying intensity of damage on Escobas Mesa.

Fig. 44. Rock splitting and exfoliation due to extreme heat of La Mesa fire, common to areas of high fuel loads.



A. B. C.

Fig. 45. Escobas Mesa, 20x50 meter plot 1, photo station NE-S (A); plot 3, NE-W (B); plot 4 shrub plot, W-E (C).

APACHE SPRINGS
Plot 1
FOLIAR DAMAGE : SIZE DISTRIBUTION

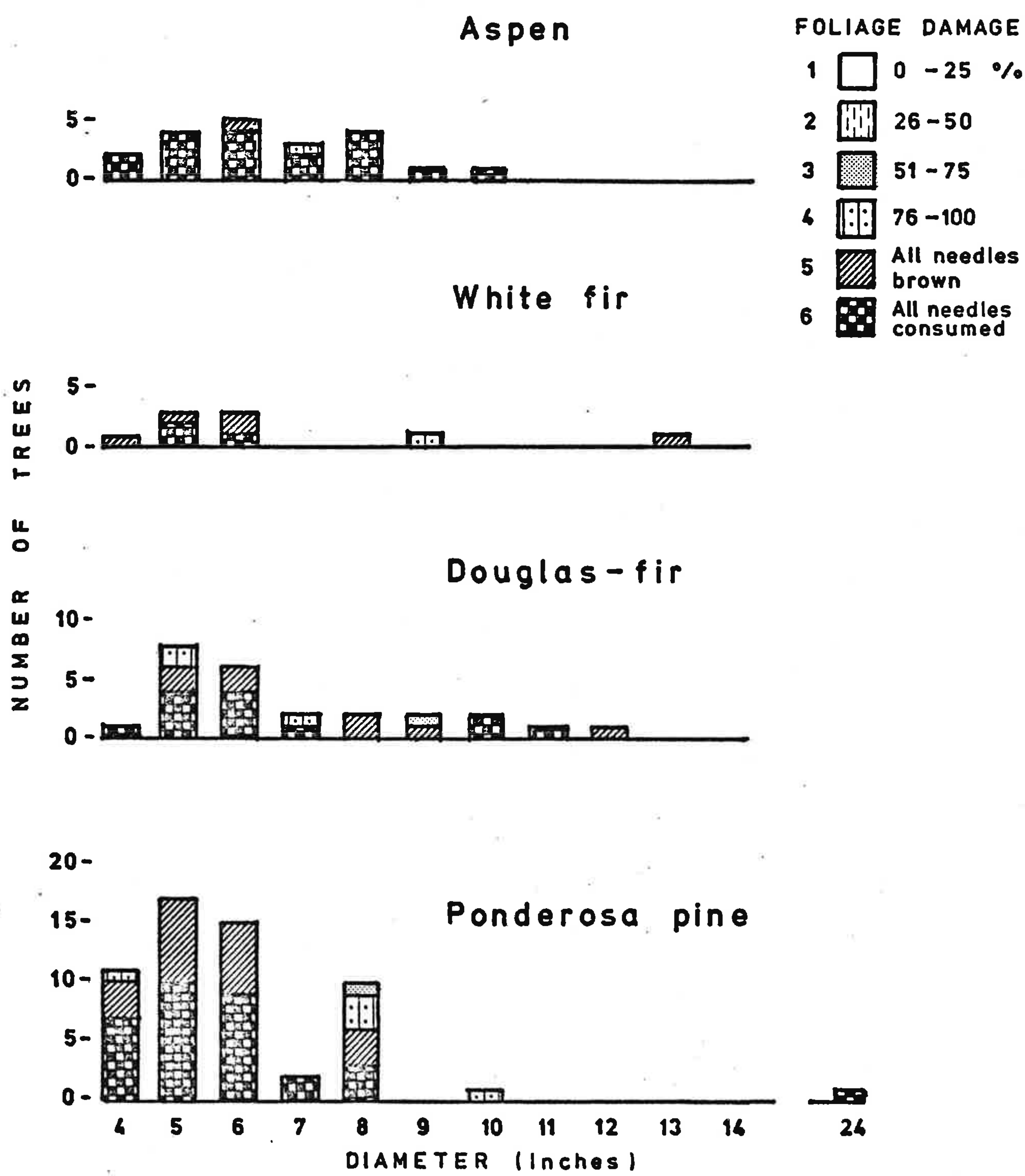


Fig. 46. Relative foliar damage in six categories as reflected by diameter size in mature tree species in Apache Springs, Plot 1.

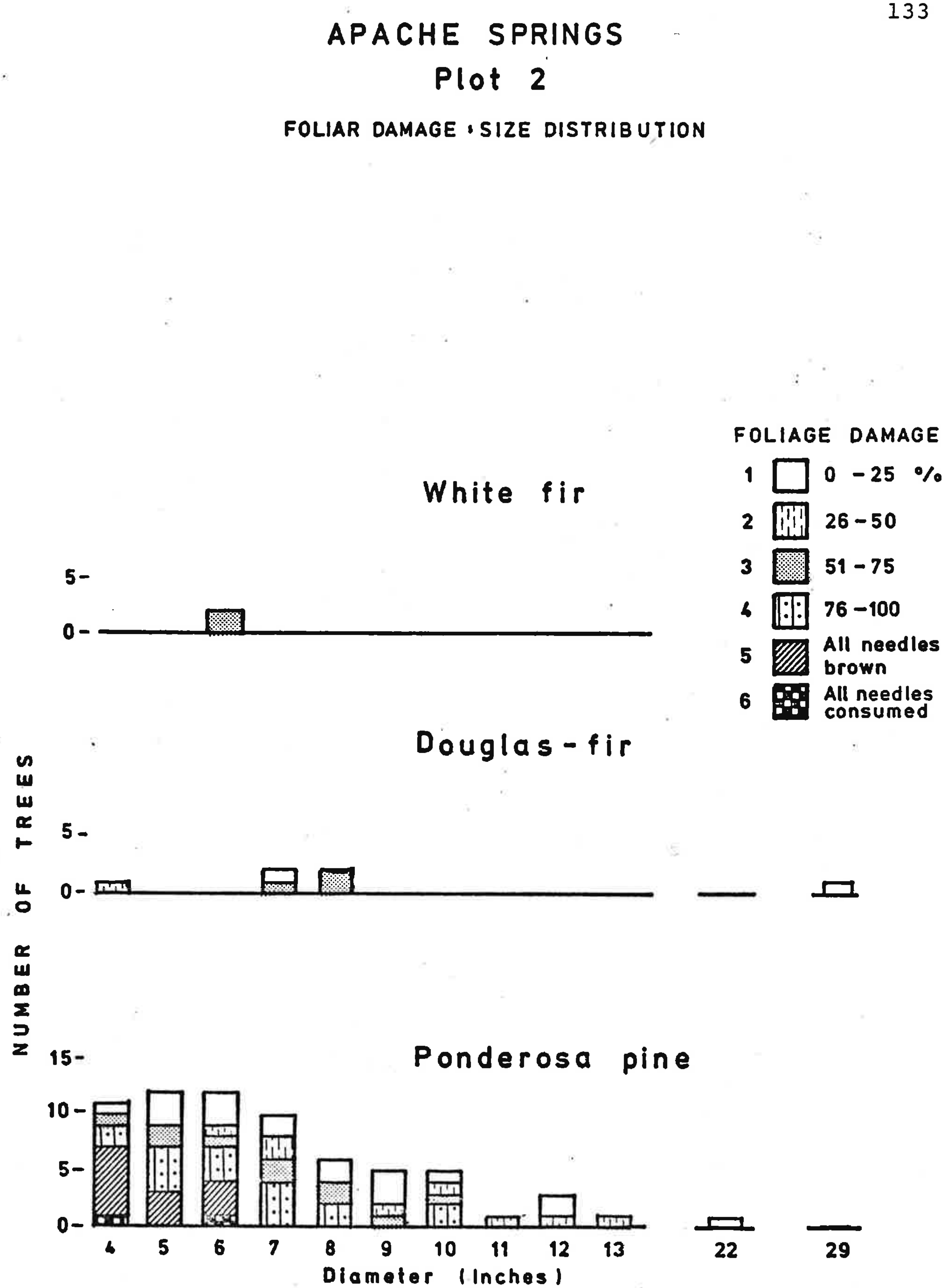


Fig. 47. Relative foliar damage in six categories as reflected by diameter size in mature tree species in Apache Springs, Plot 2.

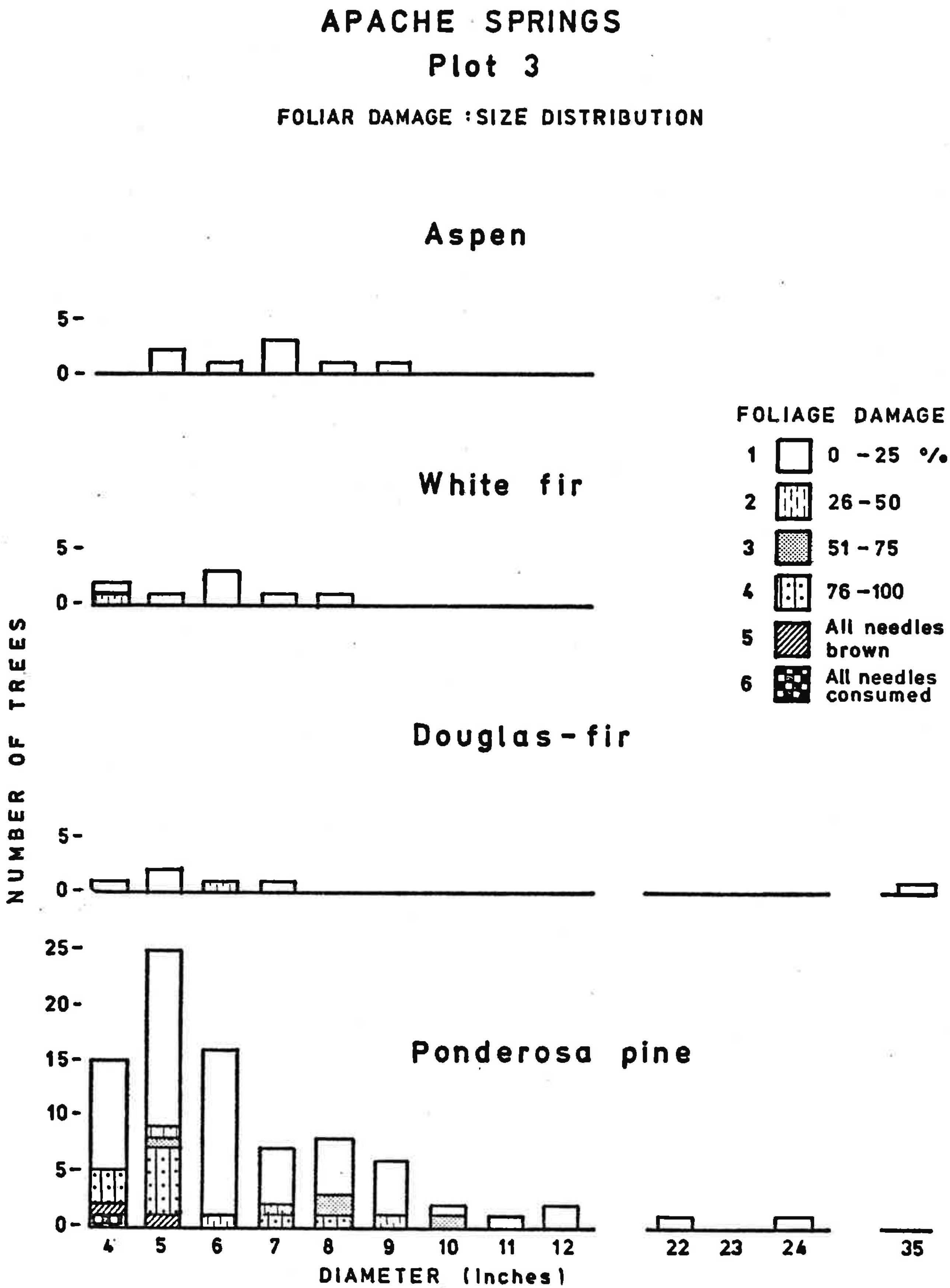


Fig. 48. Relative foliar damage in six categories as reflected by diameter size in mature tree species in Apache Springs, Plot 3.

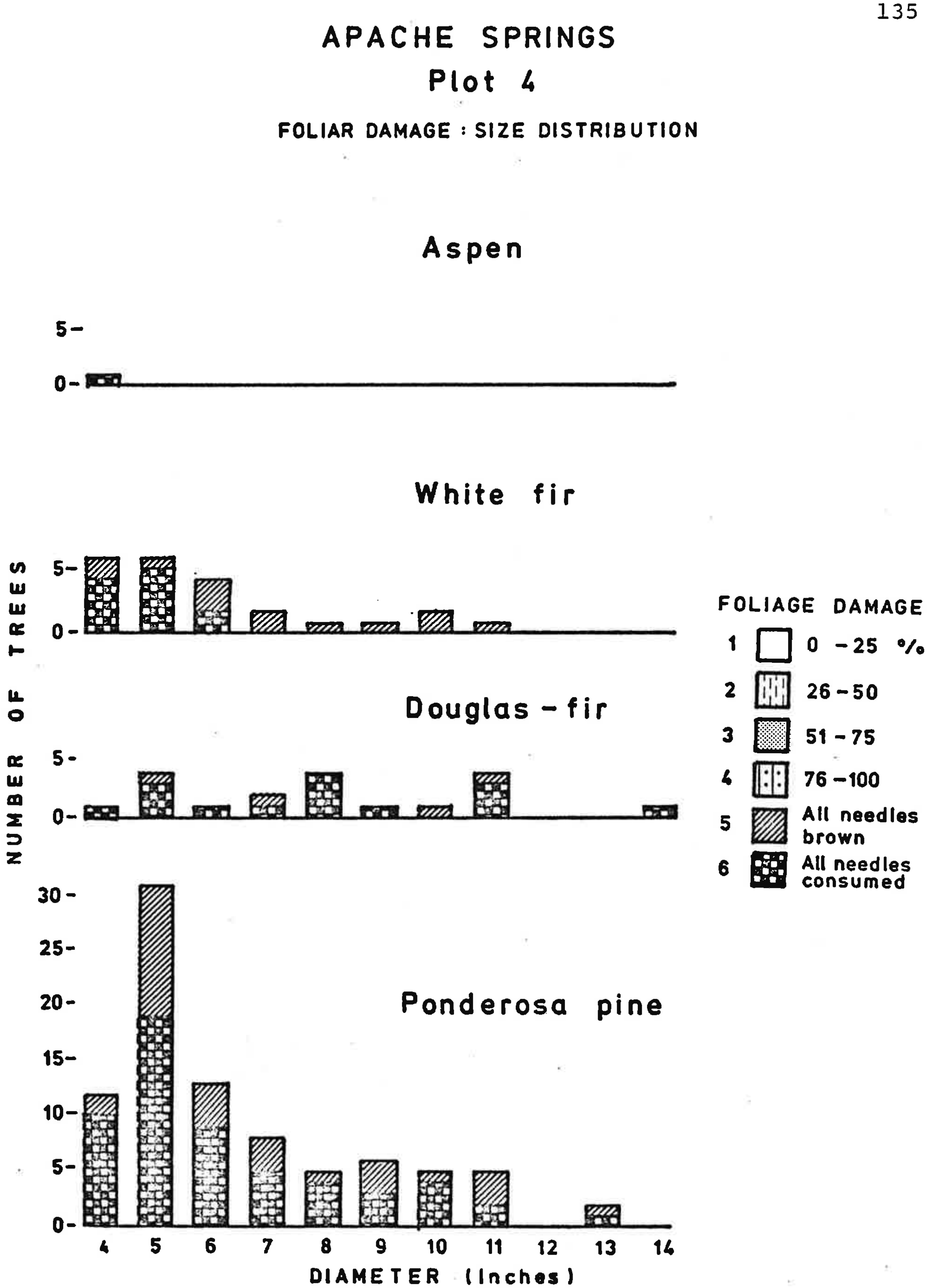


Fig. 49. Relative foliar damage in six categories as reflected by diameter size in mature tree species in Apache Springs, Plot 4.

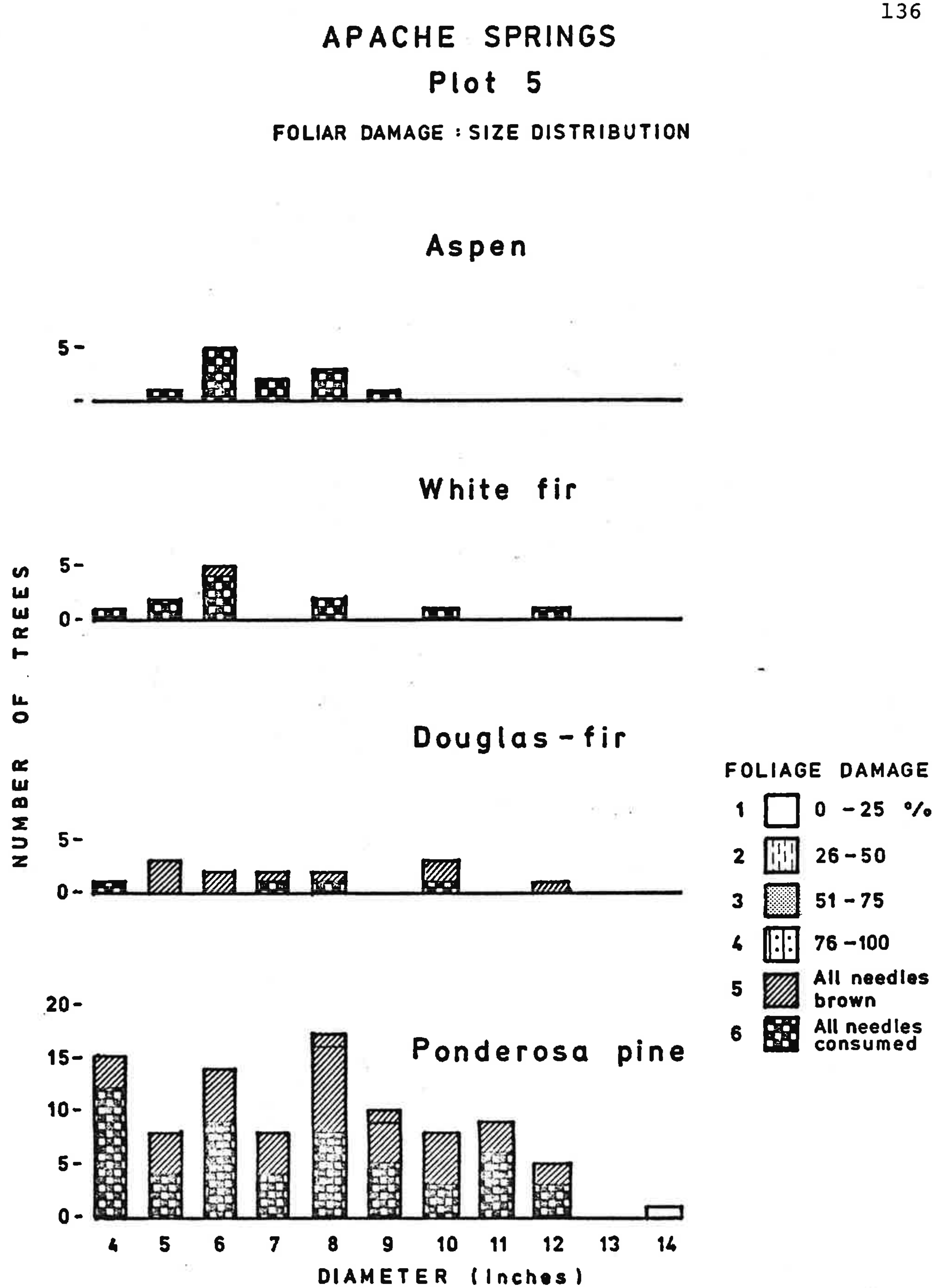
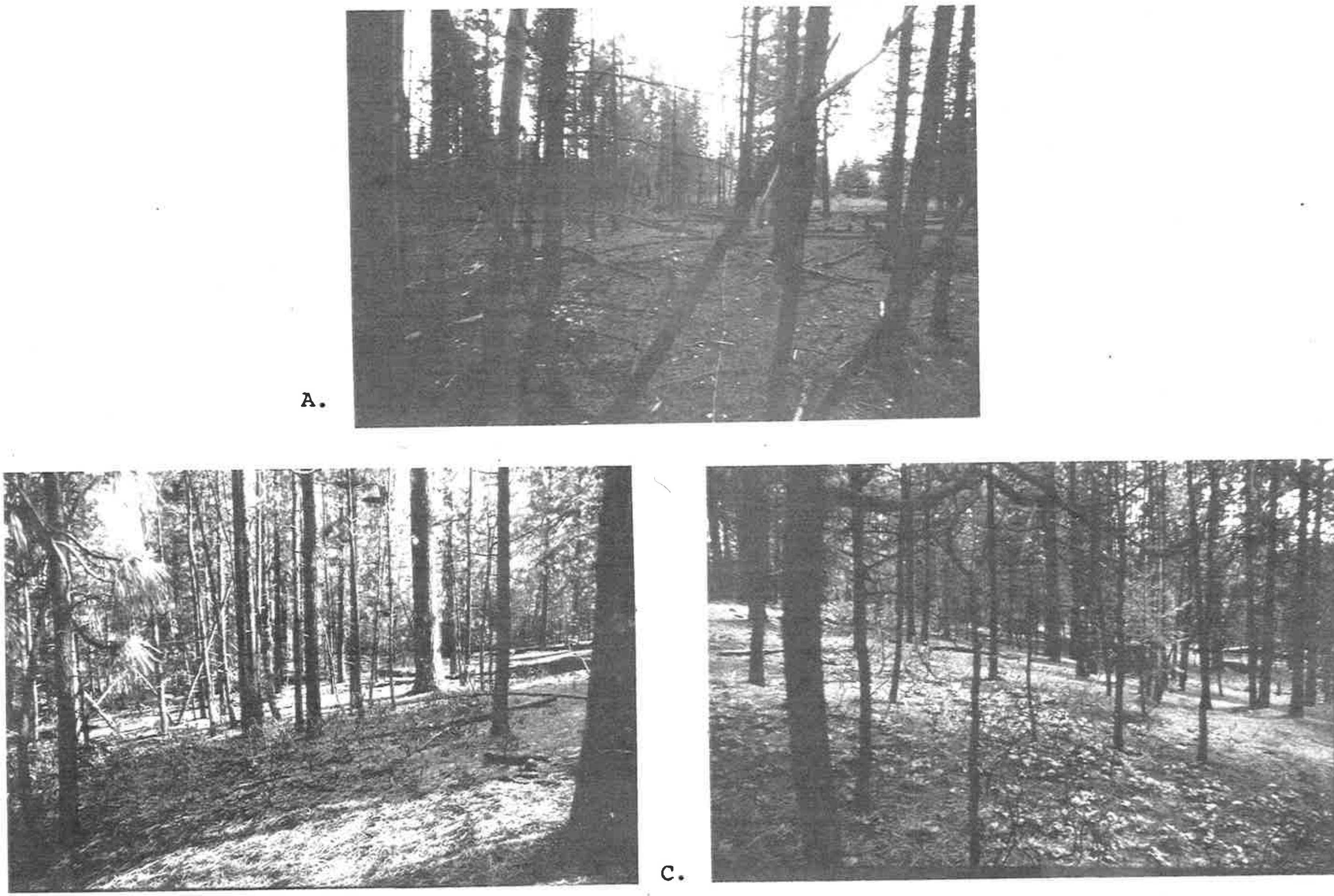


Fig. 50. Relative foliar damage in six categories as reflected by diameter size in mature tree species in Apache Springs, Plot 5.



A. B. C.

Fig. 51. Apache Springs, 20x50 meter plot 1, photo station NW-SE (A); plot 2, NW-SE (B); plot 3, NW-SE (C).

A.

B.

Fig. 52. Apache Springs 20x50 meter plot 4, photo station SE-NW (A); plot 5, SE-NW (B).

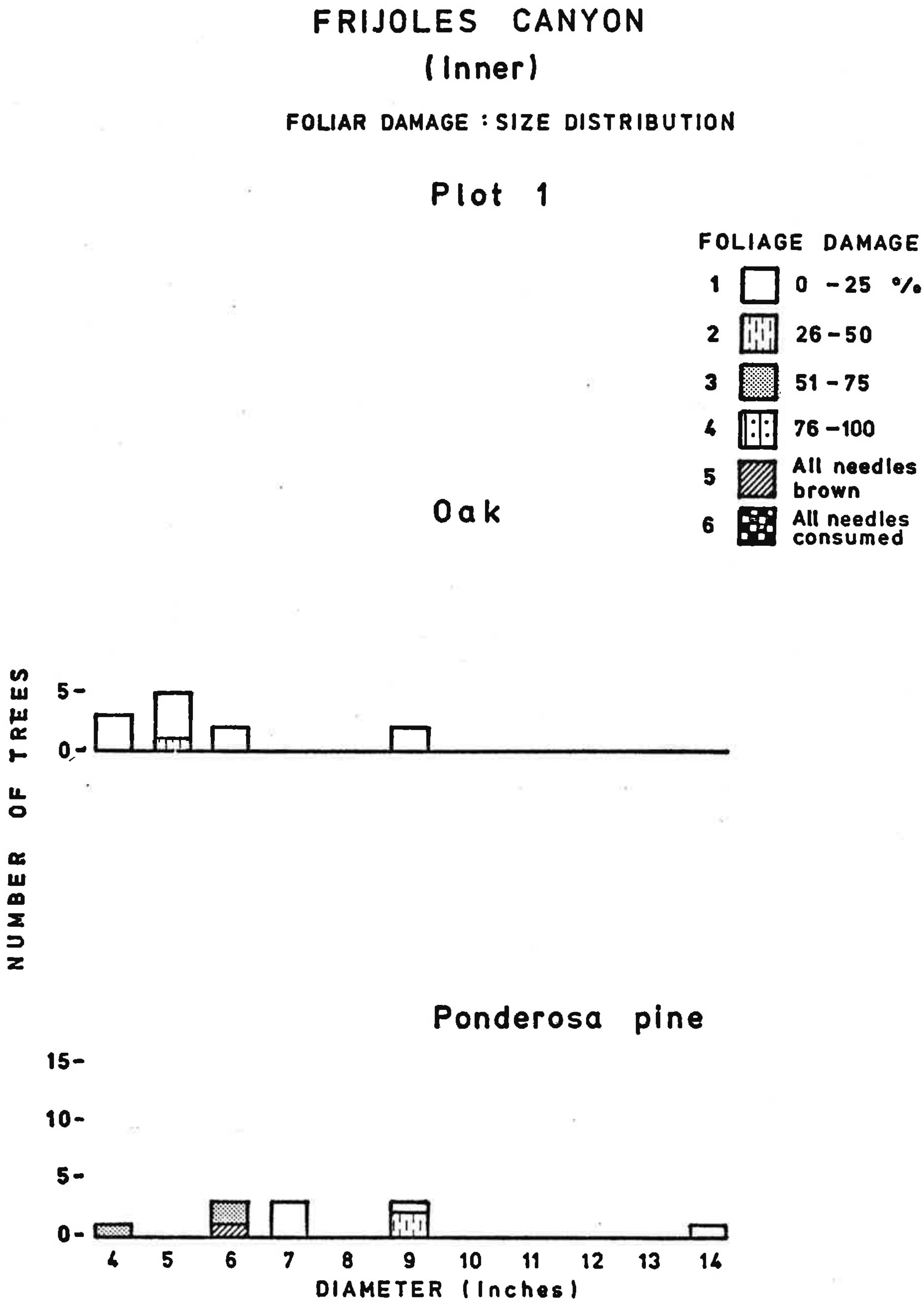


Fig. 53. Relative foliar damage in six categories as reflected by diameter size in mature oak and ponderosa pine in Frijoles Canyon (Inner), Plot 1.

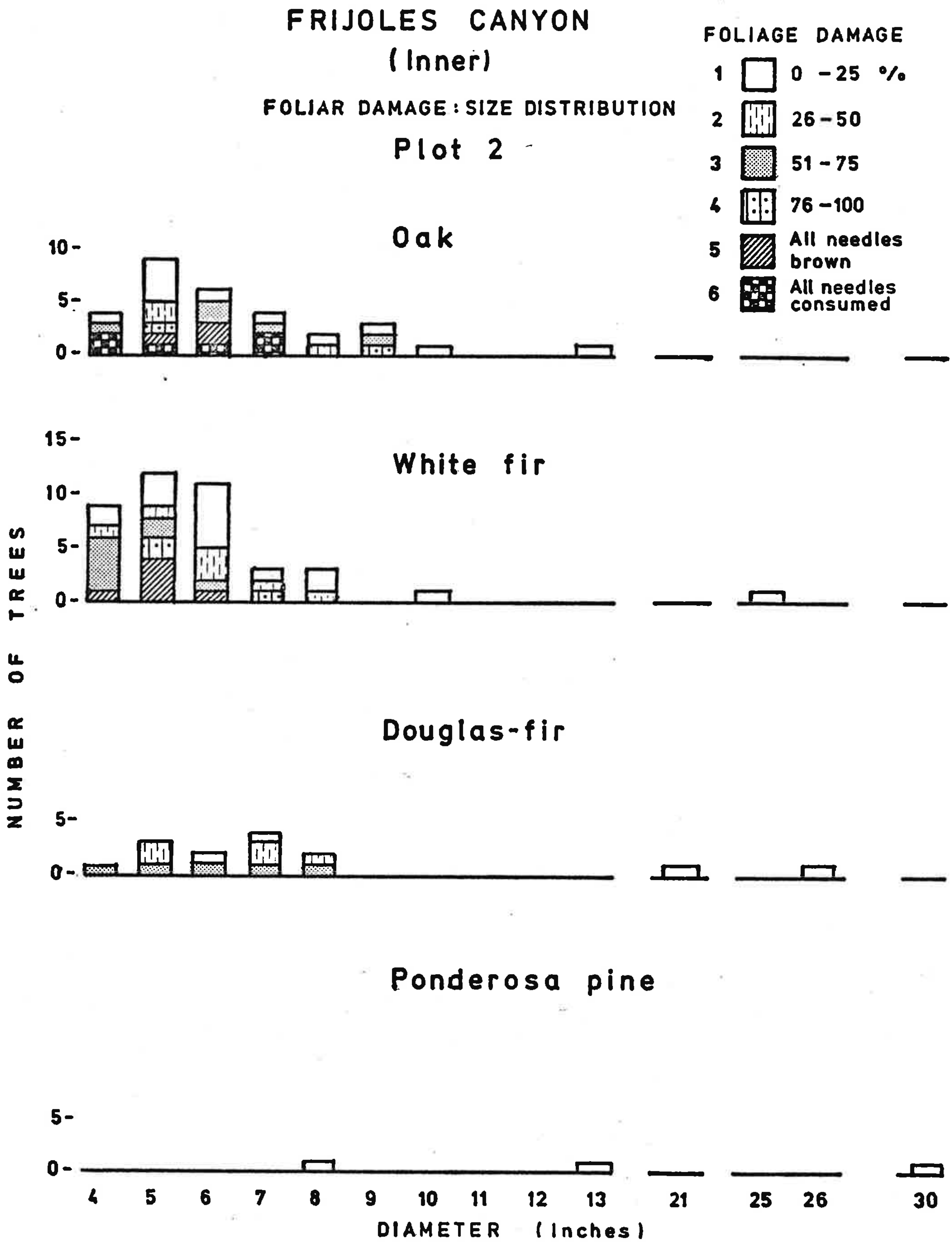


Fig. 54. Relative foliar damage in six categories as reflected by diameter size in mature tree species in Frijoles Canyon (Inner), Plot 2.

A.

B.

Fig. 55. Frijoles Canyon (Inner) 20x50 meter plot 1, photo station NW-SE (A); plot 2, NW-SE (B).

Fig. 56. Grass seeds from aerial reseeding after the La Mesa fire, indicating average density.

A.

B.

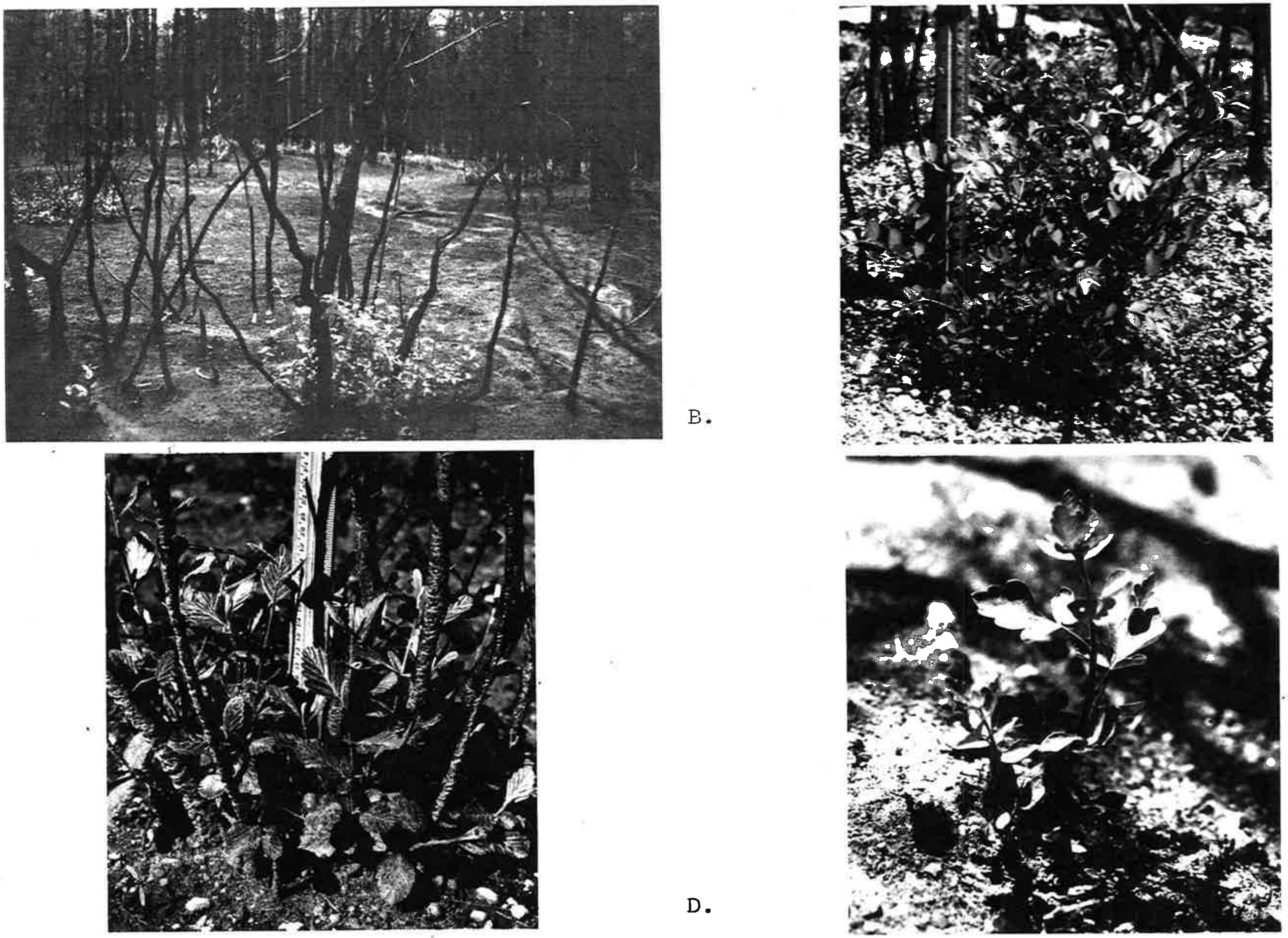
Fig. 57. Protective needle fall in Escobas Mesa stand previously thinned by logging and a fire damage of class 4-5 (A) contrasted to adjacent unthinned stand where needles were completely consumed leaving bare erodable soil (B).

Fig. 58. The protective cover of fallen scorched pine needles reducing soil erosion and favoring reseeded grass establishment.

Fig. 59. Deep pit from stump and root burn-out in severely burned areas which act as traps for eroded soil and seeds.

Fig. 60. Example of gully formation in loosely consolidated tuff after removal of surface litter by fire.

Fig. 61. In the most severely burned area, not fired since 1878, root sprouts of oak developing from lower side of horizontal roots 2-3 inches below the surface.



A. B. C. D.

Fig. 62. Vegetative regrowth by root sprouts of ponderosa pine understory species: Quercus gambelii (A), Robinia neomexicana (B), Cercocarpus montanus (C), and Rhus trilobata(D).

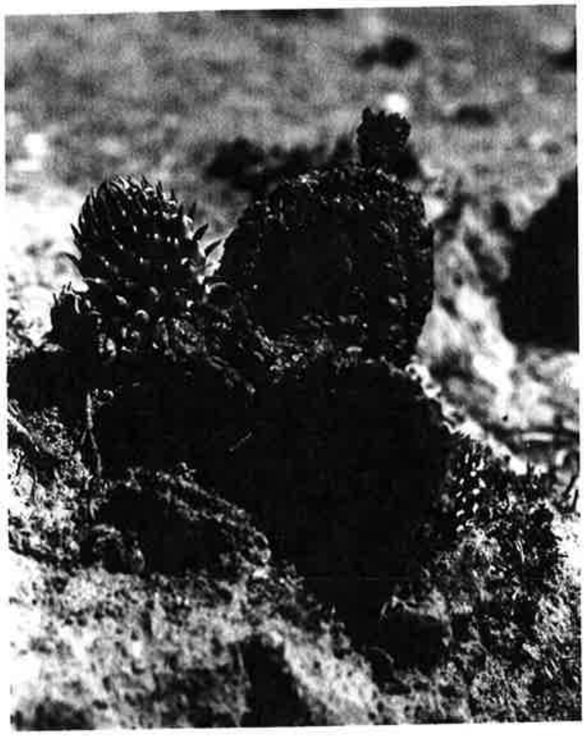


Fig. 63. Vegetative regrowth of Opuntia sp. pads from base of singed stems.

Fig. 64. Recovery by terminal growth from singed stems of spheroid Mammilaria cacti.

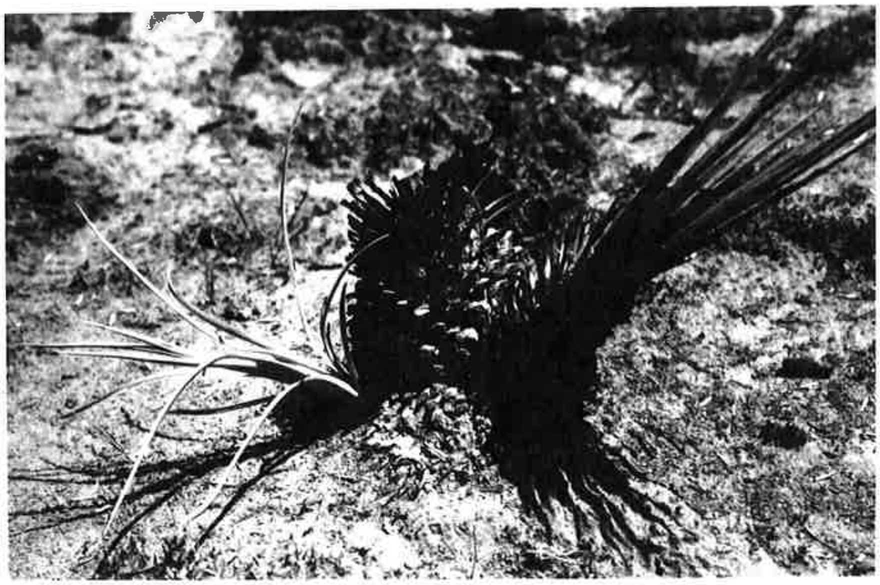


Fig. 65. Vegetative regrowth of Yucca producing new shoots from base of singed stems.

Fig. 66. Vegetative regrowth by common root sprouting of Populus tremuloides in stands of burned mixed-conifer.

A.

B.

C.

D.

Fig. 67. Vegetative regrowth by root sprouts of canyon bottom species: *Acer negundo* (A), *Ptelea angustifolia* (B), *Salix* sp. (C), and *Parthenocissus inserta* (D).

Fig. 68. Ceanothus seedling three months after the La Mesa fire. An example of seeds stimulated to germinate by fire.

Fig. 69. Rapid recovery and flowering of Castilleja integra after burning of meadows.

Fig. 70. Commelina dianthifolia, which was apparently stimulated in vigor and density by fire, especially in severe burns.

Fig. 71. Vegetative regrowth of Andropogon scoparius burned clumps within a week after the La Mesa fire, Escobas Mesa.

Fig. 72. Andropogon gerardii which has been stimulated in vigor with fruiting stalks to 7 ft in height.

Fig. 73. New growth Aug. 1977 from latent buds on twigs of young ponderosa pine which was completely scorched by La Mesa fire.

Fig. 74. Ponderosa pine seedling in burned mineral soil amongst twigs and cones, Sept. 1977. Not common.

Fig. 75. Physalis neomexicana occurring in large patches in severely burned areas.

Fig. 76. Chenopodium graveolans, a species which occurs in large patches in severely burned area.

Fig. 77. Example of gigantism in dandelion due to nutrification and reduced competition following fire.

A.

B.

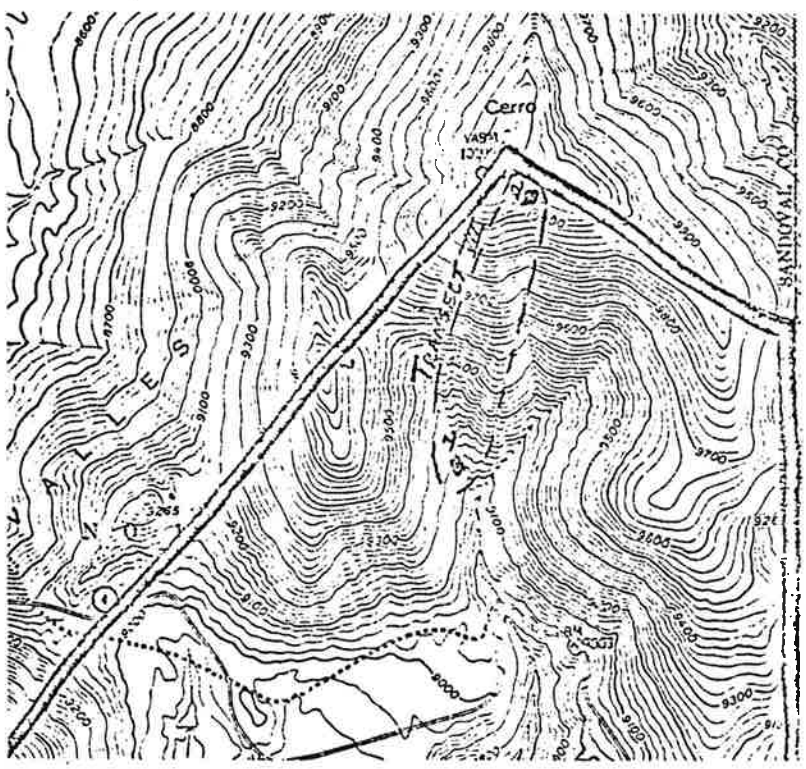
Fig. 78. Frijolito Mesa, 20x50 meter plot 1, photo station NW-S (A); plot 2, NW-S (B).

A.

B.

Fig. 79. Cerro Grande, 20x50 meter plot 1, photo station NE-SW (A); plot 2, shrub plot W-E (B).

A.



B.

Fig. 80. Location of 1977 established study plots (20x50 m) Frijolito Mesa (A), Cerro Grande (B).

Table 1. Post-La Mesa fire study plots, their location, features, and degree of damage

Transect	General Location	Vegetative Type	Plot No.	Location	Topography	Elevation (ft)	Slope	Exposure	Damage Classification
I	Frijoles Mesa	Pinyon-Juniper	1	Sec 10, T18N R6E	Wooded mesa top	7000	5%	full-SW	Light
			2	Sec 10, T18N R6E	Wooded mesa top	7000	5%	full-SW	Moderate
			3	Sec 10, T18N R6E	Wooded mesa top	7000	10%	SW	Severe
			4	Sec 4, T18N R6E	Wooded mesa top	7200	10%	SW	Severe
II	Burnt Mesa	Ponderosa Pine	1	Sec 5, T18N R6E	Meadow mesa top	7340	5%	full-NE	Moderate
			2	Sec 5, T18N R6E	Park-like mesa top	7340	10%	SE	Moderate
			3	Sec 5, T18N R6E	Wooded mesa top	7220	10%	NE	Severe
III	Escobas Mesa	Ponderosa Pine	1	Sec 6, T18N R6E	Wooded mesa top	7420	5%	S	Moderate
			2	Sec 6, T18N R6E	Wooded mesa top	7360	5%	SW	Light
			3	Sec 6, T18N R6E	Wooded mesa top	7360	5%	NE	Moderate
			4	Sec 6, T18N R6E	Wooded mesa top	7360	5%	NE	Severe
IV	Apache Springs	Mixed Conifer	1	Sec 3, T18N R5E	Canyon rim	8420	5%	SE	Severe
			2	Sec 3, T18N R5E	Wooded shelf	8460	10%	N	Moderate
			3	Sec 3, T18N R5E	Wooded mesa top	8420	10%	SE	Light
			4	Sec 2, T18N R5E	Wooded mesa top	8380	3-5%	N-NE	Severe
			5	Sec 2, T18N R5E	Wooded mesa top	8320	5-10%	NE	Severe
V	Frijoles Canyon	Mixed Conifer	1	Sec 7, T18N R6E	Canyon bottom	6800	5%	S	Moderate
			2	Sec 7, T18N R6E	Canyon bottom	6800	5%	N	Moderate

Table 2. Fire history from 1931 to 1977 by classes of fire size, causes, and month plus the annual precipitation at Bandelier headquarters

Yr.	Class of fires A	B	C	Total	Lightning	Man-caused	Month: Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Undated	Annual precipitation
31	No fires recorded																	23.68
32	No fires recorded																	14.26
33	No fires recorded																	14.61
34	1	2	0	3	1	2							3					(9.42)*
35	2	0	0	2	1	1	1				1							14.83
36	1	0	0	1	1	0			1									14.48
37	0	2	1	3	2	1				2		1						14.78
38	0	4	0	4	2	2											4	12.20
39	No information																	18.03
40	3	1	0	4	3	1				1	2	1						20.45
41	0	0	0	0	0	0												25.96
42	0	0	0	0	0	0												13.92
43	2	2	0	4	2	2	1		1	1			1					14.06
44	1	0	0	1	1	0						1						18.31
45	4	4	1	9	7	2			1	3	3		1			1		11.58
46	5	4	0	9	9	0					6	2	1					10.80
47	2	1	0	3	3	0						3						13.04
48	2	0	0	2	2	0				1		1						15.16
49	1	0	0	1	1	0	1											19.01
50	1	2	0	3	2	1			3									8.98
51	No information																	14.43
52	No information																	16.10
53	2	0	0	2	2	0					2							14.00
54	3	1	0	4	3	1			1	1	2							11.78
55	1	1	1	3	3	0					2	1						9.64
56	2	1	0	3	2	1			1	1	1							4.94
57	5	1	0	6	6	0					2	4						21.12
58	2	1	0	3	3	0					1	2						16.59
59	5	0	0	5	5	0			1		4							20.47
60	0	1	1	2	1	1			1				1					18.05
61	No information																	15.61
62	6	0	0	6	6	0				1	3	2						12.37
63	11	0	0	11	11	0				3	3	2	3					13.96
64	16	4	0	20	17	3			2	4	9	5						11.52
65	14	8	0	22	16	6		1	3	5	10	3						24.46
66	7	4	0	11	11	0			2	5	2	1	1					11.41
67	10	1	0	11	11	0			3	2	2	4						
68	No information																	
69	13	0	0	13	13	0			1	6	2	4						24.14
70	2	0	0	2	2	0						2						11.24
71	10	7	0	17	14	3		2	1	2	6	6						17.98
72	3	0	0	3	3	0				2	1							18.61
73	2	0	0	2	2	0					1	1						16.02
74	4	0	0	4	4	0				1	3							15.33
75	5	1	1	7	6	1				1	3		2	1				
76	8	1	1	10	8	2				4	5		1					
77	6	1	1	8	7	1		1	4	3								
Total (39 yr)	162	55	7	224	193	31	3	4	26	49	76	46	14	1		1	4	637.9 (41 yr)
Yr mean	4.2	1.4	.2	6.0	5.0	.8	.08	.1	.7	1.3	1.9	1.2	.4	.03		.03	.1	15.6
% Total	72	25	3		86	14	1.3	1.8	11.6	21.9	33.9	20.5	6.3	.4		.4	1.8	

*May-Oct--precipitation only

**A = 0-0.25 Acres; B = 0.25-9 Acres; C = 10-∝ Acres

Table 3. Normal fire year Bureau of Land Management Formulation

Year	Size Class of Fire A	B	C	Total
66	7	4		11
67	10	1		11
68	No Information			
69	13			13+
70	2			2
71	10←	7		17
72	3			3
73	2			2
74	4		0←	4
75	5	1←	1	7
76	8	1	1	10

Total Ranked Fire Year (←); 10 + 1 + 0 = 11

Ranked Year (+) = 13

Size Class Correction Factor (13 ÷ 12 = 1.2)

Calculated Normal Fire Year

A = 10 x 1.2 = 12.0
B = 1 x 1.2 = 1.2
C = 0 x 1.2 = 0

Total 13.2

Thus Normal Fire Year = 13.2

Table 4. Fire history of Bandelier National Monument based on wedges of mature fire-scarred ponderosa pine

Sample	Location	Years From Center To First Scar	Fire Scar Interval	Fire Scar Years	Years Since Last Fire[1]
I	Escobas Mesa	27	1-2	36	36
II	Escobas Mesa	31	1-2	21	
			2-3	14	14
III	Escobas Mesa	20	1-2	17	N.A.[2]
			2-3	8	
			3-4	11	
			4-5	9	
			5-6	8	
			6-7	20	
			7-8	23	
IV	Escobas Mesa	16	1-2	10	
			2-3	18	
			3-4	18	
			4-5	19	65
V	N. Rim Frijoles	≈(88)[3]	1-2	40	
			2-3	8	
			3-4	10	
			4-5	42	49
VI	Escobas Mesa	57	1-2	10	
			2-3	12	
			3-4	7	42
VII	Escobas Mesa	28	1-2	9	
			2-3	21	
VIII	N. Rim Frijoles	19	1-2	35	
			2-3	23	
			3-4	19	
			4-5	9	39
IX	Escobas Mesa	≈(21)	1-2	17	
			2-3	18	
			3-4	24	
			4-5	20	
			5-6	15	60
X	N. Rim Frijoles	N.A.	1-2	10	100
MEAN		28		17.6	56.1

[1]Prior to 1976
[2]N.A. - Information not available due to condition of sample. Mean frequency of Sample III = 13.7 years prior to 1907
[3]≈( ) - Data excluded and is only approximate because of condition of sample

Table 5. Snowfall recorded in inches at Los Alamos, New Mexico for winter period, Oct. 1 to June 1

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	Total
1910-11	-	4.5	4.0	T	23.2	0.0	0.0	0.0	(31.5)
11-12	0.0	12.0	6.0	T	15.0	8.5	0.0	4.0	45.5
12-13	0.0	0.0	8.0	18.0	0.0	10.5	1.0	0.0	37.5
13-14	0.0	8.0	24.3	3.0	.1	9.0	T	0.0	44.4
14-15	0.0	0.0	15.0	13.5	16.0	28.5	0.0	3.0	76.0
15-16	0.0	0.0	32.0	33.0	1.0	19.5	8.0	2.0	95.0
16-17	0.0	-	-	-	-	4.0	2.0	17.0	(23.0)
17-18	-	-	-	24.0	5.0	-	-	-	(29.0)
18-19	1.1	13.0	20.0	17.0	12.4	25.5	9.5	T	98.5
19-20	.5	6.0	3.0	14.0	0.0	6.0	0.0	0.0	29.5
20-21	-	-	-	-	-	-	-	-	-
21-22	-	-	-	-	-	-	0.0	0.0	-
22-23	1.5	7.8	-	0.0	0.0	3.0	0.0	0.0	(9.3)
23-24	0.0	0.0	7.4	3.5	5.2	19.2	2.0	0.0	37.3
24-25	0.0	0.0	23.8	6.0	20.0	0.0	0.0	0.0	49.8
25-26	0.0	0.0	8.0	5.2	T	9.8	0.0	0.0	23.0
26-27	0.0	-	13.0	3.0	2.0	11.5	8.5	0.0	38.0
27-28	0.0	0.0	6.7	0.0	6.2	4.0	14.5	0.0	31.4
28-29	0.0	1.5	-	0.0	10.0	4.0	0.0	0.0	(15.5)
29-30	9.0	15.0	1.5	17.5	8.0	5.0	T	0.0	56.0
30-31	0.0	1.0	.5	4.0	1.5	35.5	0.0	0.0	42.6
31-32	0.0	26.2	9.5	18.2	7.0	9.5	1.5	0.0	71.9
32-33	3.0	0.0	19.5	9.0	.5	1.0	2.5	0.0	35.5
33-34	0.0	9.5	3.0	5.0	5.3	T	0.0	0.0	22.8
34-35	0.0	0.0	0.0	5.5	5.5	.5	2.0	8.0	21.5
35-36	4.5	17.5	5.7	15.5	9.7	7.0	5.0	3.5	68.4
36-37	0.0	1.0	4.0	11.5	4.5	6.7	3.0	0.0	30.7
37-38	0.0	0.0	4.2	4.0	12.5	15.5	0.0	1.5	37.7
38-39	0.0	.5	5.5	16.0	11.0	11.5	0.0	0.0	44.5
39-40	0.0	5.0	6.5	14.5	17.5	14.0	3.5	0.0	61.0
40-41	0.0	20.5	20.0	17.0	10.0	22.5	14.5	0.0	104.0
41-42	0.0	2.0	19.2	.5	11.5	15.0	3.0	0.0	51.2
42-43	0.0	0.0	3.0	-	T	0.5	-	-	(3.7)
43-44	0.0	T	17.0	18.5	3.7	26.7	15.0	0.0	80.9
44-45	0.0	2.0	8.6	15.8	14.0	14.5	19.5	0.0	74.4
45-46	-	-	-	-	11.2	-	0.0	0.0	(11.2)
46-47	0.0	8.0	5.0	3.4	1.6	5.1	T	0.0	23.1
47-48	0.0	9.0	10.8	9.5	28.3	21.3	2.8	T	81.7
48-49	0.0	0.5	0.7	39.3	6.8	11.5	13.8	0.0	72.6
49-50	0.0	0.5	3.0	2.9	2.9	T	T	T	9.3
50-51	0.0	0.1	3.0	12.8	5.1	3.1	4.3	T	28.4
51-52	T	2.5	6.0	5.5	2.3	10.1	0.9	4.0	31.3
52-53	0.0	9.0	7.9	1.4	8.2	5.9	T	0.6	33.0
53-54	T	5.9	8.2	11.8	0.5	2.9	0.0	T	29.3
54-55	0.0	T	11.5	6.9	3.8	1.5	3.0	T	26.7
55-56	0.0	1.5	8.5	18.8	18.0	0.5	1.0	T	48.3
56-57	T	0.5	2.5	7.5	2.1	12.5	6.1	T	31.2
57-58	0.1	34.5	4.0	13.0	2.6	35.5	33.6	0.3	123.6
58-59	0.3	6.2	8.5	1.2	10.9	8.0	4.0	T	39.1
59-60	9.0	4.0	28.0	20.5	15.5	11.4	T	0.2	88.6
60-61	8.0	0.5	31.2	6.0	9.3	17.3	14.0	T	86.3
61-62	2.0	8.8	33.2	14.4	1.3	6.6	T	0.2	66.5
62-63	0.0	5.5	12.5	12.2	18.6	15.1	T	T	63.9
63-64	T	5.0	0.2	6.7	19.2	6.2	8.0	0.0	45.3
64-65	0.0	7.0	8.6	9.8	16.7	5.5	4.2	T	51.8
65-66	1.3	T	15.3	5.3	11.4	.7	.3	0.0	34.3
66-67	.7	3.5	7.0	1.3	2.8	1.5	T	T	16.8
67-68	1.0	2.1	41.3	1.8	11.7	12.7	5.4	0.0	76.0
68-69	0.0	1.7	7.2	6.0	10.2	21.4	5.9	1.5	53.9
69-70	5.0	3.0	11.5	1.5	3.2	22.4	1.7	.5	48.8
70-71	1.4	T	.9	11.5	4.0	5.9	3.6	T	27.5
71-72	.7	4.9	35.8	3.6	.6	.5	T	0.0	47.6
72-73	9.0	14.5	1.0	9.0E	7.2E	36.0	4.0	0.0	80.7E
73-74	0.0	1.5	1.0	23.2	3.6	7.0	3.5	0.0	39.8
74-75	0.0	.7	13.2	15.7	23.0	12.0	33.2	0.0	97.8
75-76	0.0	4.0	3.0	1.0	0.0	0.0	2.0	0.0	10.0
76-77	T	12.0	1.2	14.4	1.0	T	4.0	0.0	32.6
77-	0.0	2.0							

- indicates missing date
T indicates Trace, amount too small to measure
E amount wholly or partially estimated

Table 6. Phytosociological data of 1976 based on the line-strip method, Alamo Rim control and 1945 burn (mature and reproductive data based on twenty 20x50 ft quadrats; herb data based on twenty-one 0.5x1 m quadrats)

	Total		Pipo*		Jude		Jumo		Jusc	
MATURE	Con-trol	Burn 1945	Con-trol	Burn 1945	Con-trol	Burn 1945	Con-trol	Burn 1945	Con-trol	Burn 1945
Rel. Density (%)			97.5	90.5	1.0	0	1.5	4.8	0	4.8
Density (no./A)	444	46	433	41	4.0	0	7	2	0	2
Foliage Cover (%)	38.5	7.8	97.6	100	1.6	0	0.8	0		
Foliage Cover (sq ft/A)	16,775	3,398	16,370	8	266	0	139	0		
Rel. Basal Area (%)			97.9	94.3	1.9	0	0.9	2.3	0	3.4
Basal Area (sq ft/A)	103.6	24.9	101.4	23.5	1.94	0	1.0	0.6	0	0.9
Freq. Index (%)			100	50	10	0	15	5	0	5
Rel. Freq. (%)			100	83	8	0	12	8	0	8
Importance Value Index**			295	274	11	0	14	13	0	13

	Total		Pipo		Jude		Jumo		Jusc		Cemo		Fapa		Pied		Quga		Quun		Rhtr		Rone	
REPRODUCTIVE	Con-trol	Burn 1945	Con-trol	Burn 1945	Con-trol	Burn 1945	Con-trol	Burn 1945	Con-trol	Burn 1945	Con-trol	Burn 1945	Con-trol	Burn 1945	Con-trol	Burn 1945	Con-trol	Burn 1945	Con-trol	Burn 1945	Con-trol	Burn 1945	Con-trol	Burn 1945
Rel. Density (%)			54.7	19.3	6.7	0	0.5	1.4	0	0.5	1.2	0	9.3	75.6	1.0	0	3.1	0	23.4	0	0.2	0	0	3.3
Density (no./A)	913	464	499	89	61	0	4	7	0	2	11	0	85	351	9	0	28	0	213	0	2	0	0	15
Foliage Cover (%)	16.6	6.4	85.7	70.7	2.8	0	0	4.7	0	4.7			0	20.1			1.9	0	9.6	0				
Foliage Cover (sq ft/A)	7,209	2,796	6,181	1,973	200	0	0	131	0	131			0	562			135	0	693	0				
Freq. Index (%)			95	65	5	0	10	15	0	5	20	0	30	25	15	0	5	0	25	0	5	0	0	10
Rel. Freq. (%)			45	54	2	0	5	13	0	4	10	0	14	21	7	0	3	0	12	0	2	0	0	8
Importance Value Index			185	144	12	0	6	19	0	9	11	0	23	117	8	0	8	0	45	0	2	0	0	11

	Total		Grass		Forbs		Woody	
HERB AND SEEDLINGS	Con-trol	Burn 1945	Con-trol	Burn 1945	Con-trol	Burn 1945	Con-trol	Burn 1945
Foliage Cover (%)	5.1	37.1	4.4	31.0	0	3.2	0.7	2.9
Freq. Index (%)			86	63	0	27	15	10

FUEL LOAD (Tons/A)	Con-trol	Burn 1945
Litter	7.96	1.86
Sticks	1.09	0
Herbaceous	0.01	0.46
Total	9.06	2.32

*Pipo--*Pinus ponderosa*, Jude--*Juniperus deppeana*, Jumo--*J. monosperma*, Jusc--*J. scopulorum*, Cemo--*Cercocarpus montanus*, Fapa--*Fallugia paradoxa*, Pied--*Pinus edulis*, Quga--*Quercus gambelii*, Quun--*Quercus undulata*, Rhtr--*Rhus trilobata*, Rone--*Robinia neomexicana*

**Importance Value Index is a single measure of importance derived as the sum of relative density, relative cover, and relative frequency.

Table 7. Phytosociological data of 1976 based on the line-strip method, Bear Mesa control and 1950 burn (mature and reproductive data based on twenty 20x50 ft quadrats; herb data based on twenty-one 0.5x1 m quadrats)

MATURE	Total Con-trol	Total Burn 1950	Pipo* Con-trol	Pipo* Burn 1950	Jumo Con-trol	Jumo Burn 1950	Jusc Con-trol	Jusc Burn 1950	Psme Con-trol	Psme Burn 1950
Rel. Density (%)			98.8	98.4	0	1.6	0.7	0	0.5	0
Density (no./A)	388	137	38.3	135	0	3	2	0	2	0
Foliage Cover (%)	49.5	39.6	98.2	98.4	0	1.6	1.9	0	0.2	0
Foliage Cover (sq ft/A)	21,601	17,250	21,144	16,980	0	270	414	0	44	0
Rel. Basal Area (%)			99.5	99.7	0	0.3	0.3	0	0.2	0
Basal Area (sq ft/A)	120.8	98.5	120.2	98.2	0	0.3	0.4	0	0.3	0
Freq. Index (%)			100	100	0	5	5	0	5	0
Rel. Freq. (%)			91	95	0	5	5	0	5	0
Importance Value Index**			288	292	0	8	8	0	6	0

REPRODUCTIVE	Total Con-trol	Total Burn 1950	Pipo Con-trol	Pipo Burn 1950	Jumo Con-trol	Jumo Burn 1950	Jusc Con-trol	Jusc Burn 1950	Psme Con-trol	Psme Burn 1950	Cemo Con-trol	Cemo Burn 1950	Papa Con-trol	Papa Burn 1950	Pied Con-trol	Pied Burn 1950	Quga Con-trol	Quga Burn 1950	Quun Con-trol	Quun Burn 1950
Rel. Density (%)			39.7	66.4	1.6	0.8					0.8	0	0	17.9	0.8	0.8	28.7	17.9	28.4	0
Density (no./A)	828	303	329	194	13	2					7	0	0	52	7	2	238	52	235	0
Foliage Cover (%)	11.5	2.5	50.1	51.0	4.8	15.1									0	4.1	30.8	29.8	14.3	0
Foliage Cover (sq ft/A)	14,626	1,067	7,332	545	700	161									0	44	4,506	318	2,088	0
Freq. Index (%)			95	85	20	5					5	0	0	5	10	5	45	30	15	0
Rel. Freq. (%)			50	65	11	4					3	0	0	4	5	4	24	23	8	0
Importance Value Index			140	182	17	20					4	0	0	22	6	9	84	71	51	0

HERB AND SEEDLINGS	Total Con-trol	Total Burn 1950	Grass Con-trol	Grass Burn 1950	Forbs Con-trol	Forbs Burn 1950	Woody Con-trol	Woody Burn 1950
Foliage Cover (%)	14.2	16.2	10.6	11.8	0.7	0.8	2.9	3.6
Freq. Index (%)			71	71	24	33	24	5

FUEL LOAD (Tons/A)	Con-trol	Burn 1950
Litter	8.90	8.13
Sticks	0.41	0.49
Herbaceous	0.08	0.05
Total	9.39	8.67

*Pipo--*Pinus ponderosa*, Jumo--*Juniperus monosperma*, Jusc--*J. scopulorum*, Psme--*Pseudotsuga menziesii*, Cemo--*Cercocarpus montanus*, Fapa--*Fallugia paradoxa*, Pied--*Pinus edulis*, Quga--*Quercus gambelii*

**Importance Value Index is a single measure of importance derived as the sum of relative density, relative cover, and relative frequency.

Table 8. Phytosociological data of 1976 based on the line-strip method, Boundary Peak control and 1955 burn (mature and reproductive data based on twenty 20x50 ft quadrats; herb data based on twenty-one 0.5x1 m quadrats)

MATURE	Total Con-trol	Total Burn 1955	Pipo* Con-trol	Pipo* Burn 1955	Abco Con-trol	Abco Burn 1955	Psme Con-trol	Psme Burn 1955
Rel. Density (%)			76.3	83.9	0.8	6.5	22.7	9.7
Density (no./A)	518	68	396	57	4	4	118	7
Foliage Cover (%)	53.4	14.2	52.5	100	3.3	0	44.3	0
Foliage Cover (sq ft/A)	23,260	6,199	12,201	6,199	762	0	10,297	0
Rel. Basal Area (%)			76.4	89.6	0.5	0.7	23.2	9.8
Basal Area (sq ft/A)	104.5	28.7	79.8	25.7	0.5	0.2	24.2	2.8
Freq. Index (%)			100	50	10	10	75	10
Rel. Freq. (%)			54	71	5	14	41	14
Importance Value Index**			183	255	9	21	108	24

REPRODUCTIVE	Total Con-trol	Total Burn 1955	Pipo Con-trol	Pipo Burn 1955	Abco Con-trol	Abco Burn 1955	Psme Con-trol	Psme Burn 1955	Cemo Con-trol	Cemo Burn 1955	Jusc Con-trol	Jusc Burn 1955	Pifl Con-trol	Pifl Burn 1955	Quga Con-trol	Quga Burn 1955	RIBE Con-trol	RIBE Burn 1955	Rone Con-trol	Rone Burn 1955	RUBU Con-trol	RUBU Burn 1955
Rel. Density (%)			50.3	6.0	1.0	0	38.4	0	0.2	0	0.5	0	0.2	0	9.4	47.5	0	15.2	0	31.1	0	0.2
Density (no./A)	1,272	1,050	640	63	13	0	488	0	2	0	7	0	2	0	120	499	0	159	0	327	0	2
Foliage Cover (%)	38.1	6.8	57.7	5.9	0.8	0	38	0					0.4	0	3.2	64.9	0	4.4	0	24.7		
Foliage Cover (sq ft/A)	16,596	3,011	9,570	179	135	0	6,298	0					65.3	0	527	1,960	0	131	0	741		
Freq. Index (%)			100	50	15	0	100	0	5	0	10	0	5	0	40	30	0	20	0	45	0	5
Rel. Freq. (%)			36	33	6	0	36	0	2	0	4	0	2	0	15	20	0	13	0	30	0	3
Importance Value Index			144	45	8	0	112	0	2	0	5	0	3	0	28	132	0	33	0	86	0	3

HERB AND SEEDLINGS	Total Con-trol	Total Burn 1955	Grass Con-trol	Grass Burn 1955	Forbs Con-trol	Forbs Burn 1955	Woody Con-trol	Woody Burn 1955
Foliage Cover (%)	0.8	50.0	0.3	34.8	0	10.7	0.5	4.5
Freq. Index (%)			10	100	0	76	5	43

FUEL LOAD (Tons/A)	Con-trol	Burn 1955
Litter	12.03	4.92
Sticks	0.77	0.92
Herbaceous	0.03	0.16
Total	12.83	6.00

*Pipo--*Pinus ponderosa*, Abco--*Abies concolor*, Psme--*Pseudotsuga menziesii*, Cemo--*Cercocarpus montanus*, Jusc--*Juniperus scopulorum*, Pifl--*Pinus flexilis*, Quga--*Quercus gambelii*, RIBE--*Ribes* sp., Rone--*Robinia neomexicana*, RUBU--*Rubus* sp.

**Importance Value Index is a single measure of importance derived as the sum of relative density, relative cover, and relative frequency.

No pre-burn data for 1937 rim?

Table 9. Phytosociological data of 1976 based on the line-strip method, Frijoles Rim control and 1960 burn (mature and reproductive data based on twenty 20x50 ft quadrats; herb data based on twenty-one 0.5x1 m quadrats)

MATURE	Total Con-trol	Total Burn 1960	Pipo* Con-trol	Pipo* Burn 1960	Cemo Con-trol	Cemo Burn 1960	Jumo Con-trol	Jumo Burn 1960	Jusc Con-trol	Jusc Burn 1960	Psme Con-trol	Psme Burn 1960	Quun Con trol	Quun Burn 1960
Rel. Density (%)			95.6	63.6	0	13.6	0.9	13.6	2.7	4.5	0.9	0	0	4.5
Density (no./A)	246	48	235	31	0	7	2	7	7	2	2	0	0	2
Foliage Cover (%)	47.7	7.1	99.6	100			0.3	0			0.6	0		
Foliage Cover (sq ft/A)	20,603	3,084	20,603	3,084			57	0			118	0		
Rel. Basal Area (%)			98.3	97.6	0	0.7	0.1	1.1	1.1	0.7	0.5	0		
Basal Area (sq ft/A)	119.8	29.3	117.8	28.6	0	0.2	0.1	0.3	1.3	0.2	0.6	0		
Freq. Index (%)			95	45	0	10	5	15	15	5	5	0	0	5
Rel. Freq. (%)			79	56	0	13	4	19	13	6	4	0	0	6
Importance Value Index**			274	220	0	27	5	33	48	11	6	0	0	11

REPRODUCTIVE	Total Con-trol	Total Burn 1960	Pipo Con-trol	Pipo Burn 1960	Cemo Con-trol	Cemo Burn 1960	Jumo Con-trol	Jumo Burn 1960	Jusc Con-trol	Jusc Burn 1960	Psme Con-trol	Psme Burn 1960	Quun Con-trol	Quun Burn 1960	Quga Con-trol	Quga Burn 196
Rel. Density (%)			16.8	0	0	84.4	0.8	1.6	5.2	0	5.2	0	7.6	14.1	64.4	[illegible]
Density (no./A)	545	139	92	0	0	118	4	3	28	0	28	0	41	20	351	[illegible]
Foliage Cover (%)	9.6	4.8	1.0	0	0	20.7	0	2.1	7.7	0			10.6	77.3	79.4	[illegible]
Foliage Cover (sq ft/A)	4,130	2,126	44	0	0	440	0	44	322	0			449	1,642	3,315	[illegible]
Freq. Index (%)			50	0	0	40	10	5	40	0	10	0	20	50	35	[illegible]
Rel. Freq. (%)			30	0	0	42	6	5	24	0	6	0	12	53	21	[illegible]
Importance Value Index			48	0	0	147	7	9	37	0	11	0	30	144	165	[illegible]

HERB AND SEEDLINGS	Total Con-trol	Total Burn 1960	Grass Con-trol	Grass Burn 1960	Forbs Con-trol	Forbs Burn 1960	Woody Con-trol	Woody Burn 1960
Foliage Cover (%)	10.6	43.6	8.2	31.9	0.8	3.1	1.6	8.0
Freq. Index (%)			81	82	29	64	24	14

FUEL LOAD (Tons/A)	Con-trol	Burn 1960
Litter	8.33	-
Sticks	3.80	-
Herbaceous	0.20	-
Total	12.33	-

*Pipo--*Pinus ponderosa*, Cemo--*Cercocarpus montanus*, Jumo--*Juniperus monosperma*, Jusc--*J. scopulorum*, Psme--*Pseudotsuga menziesii*, Quun--*Quercus undulata*, Quga--*Quercus gambelii*

**Importance Value Index is a single measure of importance derived as the sum of relative density, relative cover, and relative frequency.

Table 10. Phytosociological data of 1976 based on the line-strip method, Frijoles Canyon control, 1937 and 1960 burns (mature and reproductive data based on twen
data based on twenty-one 0.5x1 m quadrats)

MATURE	Total Con-trol	Total Burn 1937	Total Burn 1960	Pipo* Con-trol	Pipo* Burn 1937	Pipo* Burn 1960	Abco Con-trol	Abco Burn 1937	Abco Burn 1960	Acne Con-trol	Acne Burn 1937	Acne Burn 1960	Alte Con-trol	Alte Burn 1937	Alte Burn 1960	Jumo Con-trol	Jumo Burn 1937	Jumo Burn 1960	Jusc Con-trol	Jusc Burn 1937	Jusc Burn 1960	Con-trol
Rel. Density (%)				95.6	18.3	14.3	0	0.8	14.9	0	2.4	7.1	0	0.8	0	0.9	0	0	2.7	0	0	0.9
Density (no./A)	246	274	30	235	50	4	0	3	4	0	7	2	0	1	0	2	0	0	7	0	0	2
Foliage Cover (%)	47.7	60.4	6.5	99.6	30.2	4.3				0	2.5	0				0.3	0	0				0.6
Foliage Cover (sq ft/A)	20,778	26,180	2,919	20,604	7,897	122				0	640	0				57	0	0				118 8
Rel. Basal Area (%)				98.3	48.4	3.1	0	2.2	6.4	0	2.6	1.0	0	0.2	0	0.1	0	0	1.1	0	0	0.5
Basal Area (sq ft/A)	119.8	87.2	18.5	117.8	42.3	0.6	0	2.3	1.2	0	2.2	0.2	0	0.2	0	0.1	0	0	1.3	0	0	0.6
Freq. Index (%)				95	65	10	0	5	5	0	15	5	0	5	0	5	0	0	15	0	0	5
Rel. Freq. (%)				79	36	100	0	3	50	0	8	50	0	3	0	4	0	0	13	0	0	4
Importance Value Index**				274	85	119	0	4	65	0	13	57	0	4	0	5	0	0	16	0	0	6

REPRODUCTIVE	Total Con-trol	Total Burn 1937	Total Burn 1960	Pipo Con-trol	Pipo Burn 1937	Pipo Burn 1960	Abco Con-trol	Abco Burn 1937	Abco Burn 1960	Acne Con-trol	Acne Burn 1937	Acne Burn 1960	Alte Con-trol	Alte Burn 1937	Alte Burn 1960	Jumo Con-trol	Jumo Burn 1937	Jumo Burn 1960	Jusc Con-trol	Jusc Burn 1937	Jusc Burn 1960	Con-trol
Rel. Density (%)				16.8	4.6	0.1	0	0.6	0.1	0	4.1	0.5				0.8	0	0	5.2	0.1	0	5.2
Density (no./A)	545	3,541	6,565	92	163	9	0	2	7	0	146	33				4	0	0	28	4	0	28
Foliage Cover (%)	9.5	28.5	50.9	1.0	4.3	0.8				0	0	2.5							7.7	0	0	0
Foliage Cover (sq ft/A)	4,130	12,415	22,172	44	527	174				0	0	549							322	0	0	0 3,
Freq. Index (%)				50	45	15	0	5	10	0	20	15				10	0	0	40	5	0	10
Rel. Freq. (%)				30	9	3	0	1	2	0	4	3				6	0	0	24	1	0	6
Importance Value Index				48	18	4	0	2	2	0	8	6				7	0	0	37	1	0	11

HERB AND SEEDLINGS	Total Con-trol	Total Burn 1937	Total Burn 1960	Grass Con-trol	Grass Burn 1937	Grass Burn 1960	Forbs Con-trol	Forbs Burn 1937	Forbs Burn 1960	Woody Con-trol	Woody Burn 1937	Woody Burn 1960
Foliage Cover (%)	12.7	23.8	43.7	8.1	9.3	27.9	2.8	2.5	3.3	1.8	12.0	12.3
Freq. Index (%)				52	65	91	33	70	62	24	80	76

FUEL LOAD (Tons/A)	Con-trol	Burn 1937	Burn 1960
Litter	5.51	2.60	2.64
Sticks	0.41	1.20	0.03
Herbaceous	0.05	0.47	0.51
Total	5.97	4.27	3.18

*Pipo--Pinus ponderosa, Abco--Abies concolor, Acne--Acer negundo, Alte--Alnus tenuifolia, Jumo--Juniperus monosperma, Jusc--J. scopulorum, Psme--Pseudotsuga menzic
Acgl--Acer glabrum neomexicanum, Befe--Berberis fendleri, Cemo--Cercocarpus montanus, Hodu--Holodiscus dumosus, Jaam--Jamesia americana, Pain--Parthenocissus inse:
microphyllus, Phmo--Physocarpus monogynus, Pien--Picea engelmannii, Pifl--Pinus flexilis, Prvi--Prunus virginiana var. melanocarpa, Ptan--Ptelea angustifolia, Quur
Ribes sp., Rone--Robinia neomexicana, ROSA--Rosa sp., RUBU--Rubus sp., SAMB--Sambucus sp.

**Importance Value Index is a single measure of importance derived as the sum of relative density, relative cover, and relative frequency.

data based on twenty 20x50 ft quadrats; herb

Jusc Burn 1937	Jusc Burn 1960	Psme Con-trol	Psme Burn 1937	Psme Burn 1960	Quga Con-trol	Quga Burn 1937	Quga Burn 1960
0	0	0.9	18.3	57.1	0	59.5	7.1
0	0	2	50	17	0	163	2
		0.6	31.1	95.7	0	36.4	0
		118	8,150	2,696	0	9,527	0
0	0	0.5	18.4	88.2	0	27.8	1.3
0	0	0.6	16.1	16.3	0	24.3	0.2
0	0	5	55	25	0	35	5
0	0	4	31	25	0	19	50
0	0	6	80	178	0	115	57

Jusc Burn 1937	Jusc Burn 1960	Psme Con-trol	Psme Burn 1937	Psme Burn 1960	Quga Con-trol	Quga Burn 1937	Quga Burn 1960	Acgl Burn 1937	Befe Burn 1937	Befe Burn 1960	Gemo Burn 1937	Hodu Burn 1937	Joam Burn 1937	Pain Burn 1937	Phmi Burn 1937	Phmi Burn 1960	Phmo Burn 1937	Phmo Burn 1960	Pien Burn 1937	Pifl Burn 1937	Prvi Burn 1937	Prvi Burn 1960	Ptan Burn 1937	Quun Con-trol	RIBE Burn 1937	RIBE Burn 1960	Rone Burn 1937	Rone Burn 1960	ROSA Burn 1937	ROSA Burn 1960	RUBU Burn 1960	SAMB Burn 1960
0.1	0	5.2	7.9	0.3	64.4	62.4	48.6	0.9	2.9	21.6	0.1	0.4	1.7	0.1	0.6	2.2	5.5	4.2	0.1	0.3	0.3	1.5	2.1	7.6	0.1	2.5	6.1	10.8	0.1	0.7	6.5	0.2
4	0	28	281	22	351	2,211	3,189	33	102	1,420	4	13	42	2	22	146	196	279	2	11	11	100	74	41	2	161	216	712	4	46	429	13
0	0	0	25.2	0.4	79.4	69.4	61.9	0	0	11.6	0	0	0	0	0	0	0	4.0	0	0	1.2	0.7	0	10.8	0	2.1	0	15.7	0	0	0	0.4
0	0	0	3,101	87	3,315	3,555	13,739	0	0	2,566	0	0	0	0	0	0	0	880	0	0	144	148	0	449	0	470	0	3,489	0	0	0	83
5	0	10	85	30	35	100	95	10	35	75	10	5	10	5	10	20	30	55	5	5	10	30	25	20	5	40	60	70	5	15	15	10
1	0	6	17	6	21	20	19	2	7	15	2	1	2	1	2	4	2	11	1	1	1	7	5	12	1	8	12	14	1	3	3	2
1	0	11	50	7	165	152	130	3	10	48	2	1	4	1	3	6	8	19	1	1	3	9	7	30	1	13	18	41	1	4	10	3

-Pseudotsuga menziesii, Quga--Quercus gambelii,
rthenocissus inserta, Phmi--Philadelphus
angustifolia, Quun--Quercus undulata, RIBE--

(no pre-burn data for 1937 burn?)

Table 11. Summary of phytosociological data of four plateau stands of ponderosa pine type, pre-La Mesa fire

	ALAMO RIM			BEAR MESA			BOUNDARY PEAK			FRIJOLES RIM		
	1945 Burn (Hot)	Control	% Burn/ Control	1950 Burn (Cool)	Control	% Burn/ Control	1955 Burn (Hot)	Control	% Burn/ Control	1960 Burn (Hot)	Control	% Burn/ Control
YEARS SINCE BURN:	34			27			22			17		
MATURE												
Tot. dens. (no./A)	46	444	10	137	388	35	68	518	13	48	246	20
Tot. cover. (%)	7.8	38.5	20	39.6	49.5	80	14.2	53.4	27	7.1	47.7	15
Tot. basal area (sq ft/A)	24.9	103.6	24	98.5	120.8	82	28.7	104.5	28	29.3	119.8	25
Aver. diam. (dbh inches)	9.96	6.54	152	11.48	7.55	152	8.80	6.08	145	10.58	9.41	112
Ponderosa rel. dens. (%)	90.5	97.5	93	98.4	98.8	100	83.9	76.3	110	63.6	95.6	67
Ponderosa rel. cover. (%)	100	97.6	103	98.4	98.2	100	100	52.5	191	100	99.6	100
Ponderosa rel. basal area (%)	94.3	97.9	96	99.7	99.5	100	89.6	76.4	117	97.6	98.3	99
Ponderosa aver. diam. (dbh inches)	10.25	6.55	157	11.55	7.59	152	9.09	6.08	150	13.01	9.59	136
REPRODUCTION:												
Tot. dens. (no./A)	464	913	51	303	828	37	1,050	1,272	83	140	545	26
Tot. cover. (%)	6.4	16.6	39	2.5	11.5	22	6.8	38.1	18	4.8	9.6	50
HERB & SEEDLING:												
Tot. cover. (%)	37.1	5.1	727	16.2	14.2	114	50.0	0.8	6,250	43.6	10.6	411
Rel. cover.												
Forbs (%)	8.6	0.0	-	4.9	5.0	98	21.4	0.0	-	7.1	7.6	93
Grass (%)	83.6	86.1	98	72.8	74.6	98	69.6	37.7	185	73.2	77.6	94
Woody (%)	7.8	13.9	56	22.2	20.4	109	9.0	62.3	14	19.7	15.1	130
FUEL LOAD:												
Total (tons/A)	2.32	9.06	26	8.67	9.39	92	6.00	12.83	47	-	12.33	-
Litter (tons/A)	1.86	7.96	23	8.13	8.90	91	4.92	12.03	41	-	8.33	-
Sticks (tons/A)	0	1.09	-	0.49	0.41	120	0.92	0.77	119	-	3.80	-
Herbs (tons/A)	0.46	0.01	4,600	0.05	0.08	63	0.16	0.03	533	-	0.20	-

Table 12. Stand conditions and classifications of shoot damage for mature and reproductive ponderosa pine following the June 1977 La Mesa fire for the Alamo Rim 1945 burn and control (data based on 20 quadrats, 20 ft x 50 ft)

Conditions	Post-Fire Damage*												Pre-Fire Conditions	
	Burn (1945)						Control							
	1	2	3	4	5	6	1	2	3	4	5	6	Burn 1945	Con-trol
MATURE PONDEROSA PINE														
Relative Density (%)	0	0	7.0	7.0	31.0	55.0	0	0	1.0	0	15.1	83.9	100	100
Density/Acre	0	0	4.4	4.4	19.6	34.8	0	0	2.2	0	34.8	193.8	63.2	230.8
Relative Basal Area (%)	0	0	13.0	10.0	20.5	56.6	0	0	4.0	0	31.3	64.7	100	100
Basal Area (sq ft/A)	0	0	2.6	2.0	4.1	11.3	0	0	2.0	0	15.7	32.4	20.0	50.1
Freq. Index (%)	0	0	10	10	20	35	0	0	5	0	25	75	25	95
ALL MATURE SPECIES														
Total Cover (%)														
Total Density/Acre													63.2	230.8
Total Basal Area (sq ft/A)													20.0	50.1
REPRODUCTIVE PONDEROSA PINE														
Relative Density (%)	0	0	35.6	42.8	14.4	7.2	0	0	0	0	97.0	3.0	100	100
Density/Acre	0	0	10.9	13.1	4.4	2.2	0	0	0	0	636.0	19.6	30.6	655.6
Freq. Index (%)	0	0	10	5	5	5	0	0	0	0	65	5	15	70
ALL REPRODUCTIVE SPECIES														
Total Density/Acre													30.6	655.6

*Damage categories are as follows: 1 0-25% foliage singed, 2 26-50%, 3 51-75%, 4 76-100%, 5 all needles brown, 6 all needles consumed.

Table 13. Herbaceous and seedling foliage cover following the June 1977 La Mesa fire at the sites of 1945 Alamo Rim burn and control (data based on 21 quadrats, 0.5 m x 1.0 m)

Post-La Mesa Fire Herbaceous and Seedling Cover

	Burn (1945)				Control			
Conditions	Woody	Forbs	Grass	Total	Woody	Forbs	Grass	Total
Rel. Cover (%)		1.0	7.1	8.1			0.4	0.4
Cover (sq ft/A)		436	3,093	3,528			174	174
Freq. Index (%)		42	47	57			9	9

Table 14. Stand conditions and classifications of shoot damage for mature and reproductive ponderosa pine following the June 1977 La Mesa fire for the Bear Mesa 1950 burn and control (data based on 20 quadrats, 20 ft x 50 ft)

Conditions	Post-Fire Damage*												Pre-Fire Conditions	
	Burn (1976)						Control							
	1	2	3	4	5	6	1	2	3	4	5	6	Burn 1950	Con-trol
MATURE PONDEROSA PINE														
Relative Density (%)	40.0	20.0	10.0	23.3	3.3	3.3	5.0	4.5	9.4	14.9	35.1	31.2	100	94.7
Density/Acre	52.3	26.1	13.0	30.5	4.4	4.4	21.8	19.6	41.4	65.3	154.6	137.2	130.7	440.0
Relative Basal Area (%)	52.1	30.6	2.8	12.4	0.9	0.9	10.6	5.4	18.9	13.0	15.9	35.8	100	99.5
Basal Area (sq ft/A)	38.8	22.8	2.1	9.3	0.7	0.7	12.1	6.2	21.7	14.9	18.2	41.1	74.5	114.2
Freq. Index (%)	60	30	15	40	10	10	10	25	40	30	60	35	90	90
ALL MATURE SPECIES														
Total Cover (%)													22.8	4.7
Total Density/Acre													132.8	444.3
Total Basal Area (sq ft/A)													74.9	114.8
REPRODUCTIVE PONDEROSA PINE														
Relative Density (%)	13.8	10.8	6.9	14.6	41.5	12.3	1.6	0	0	1.6	37.5	59.4	96.3	99.0
Density/Acre	39.2	30.5	19.6	41.4	117.6	34.8	6.5	0	0	6.5	156.8	248.3	283.1	418.1
Freq. Index (%)	25	40	20	25	55	25	5	0	0	5	60	50	80	95
ALL REPRODUCTIVE SPECIES														
Total Density/Acre													294	422.5

*Damage categories are as follows: 1 0-25% foliage singed, 2 26-50%, 3 51-75%, 4 76-100%, 5 all needles brown, 6 all needles consumed.

Table 15. Herbaceous and seedling foliage cover following the June 1977 La Mesa fire at sites of 1950 Bear Mesa burn and control (data based on 21 quadrats, 0.5 m x 1.0 m)

	1950 Burn				Control			
Conditions	Woody	Forbs	Grass	Total	Woody	Forbs	Grass	Total
Foliage cover (%)		1.5	3.2	4.7	.1	.3	.1	.5
Cover (sq ft/A)		653	1,394	2,047	43.6	130.7	43.6	217.8
Frequency index (%)		37	50	50	5.7	14.3	8.5	25.7

Table 16. Stand conditions and classifications of shoot damage for mature and reproductive ponderosa pine following the June 1977 La Mesa fire for the North Rim Frijoles Canyon 1960 burn and control (data based on 20 quadrats, 20 ft x 50 ft)

Conditions	Post-Fire Damage*												Pre-Fire Conditions	
	Burn (1960)						Control							
	1	2	3	4	5	6	1	2	3	4	5	6	Burn 1960	Con-trol
MATURE PONDEROSA PINE														
Relative Density (%)	52	12	20	16	0	0	0	0	0	0	0	100		95.6
Density/Acre	28.3	6.5	10.9	8.7	0	0	0	0	0	0	0	235.2	54.5	235.2
Relative Basal Area (%)	78.6	6.0	9.0	6.4	0	0	0	0	0	0	0	100		98.3
Basal Area (sq ft/A)	40.1	3.1	4.5	3.3	0	0	0	0	0	0	0	117.8	57.0	117.8
Freq. Index (%)	25	10	25	15	0	0	0	0	0	0	0	95	40	95
ALL MATURE SPECIES														
Total Cover (%)													7.1	47.7
Total Density/Acre													54.5	246.1
Total Basal Area (sq ft/A)													51.0	119.8
REPRODUCTIVE PONDEROSA PINE														
Relative Density (%)	0	0	42.8	57.2	0	0							100	
Density/Acre	0	0	6.5	8.7	0	0							15.2	
Freq. Index (%)	0	0	5	5	0	0							10	
ALL REPRODUCTIVE SPECIES														
Total Density/Acre													15.2	

*Damage categories are as follows: 1 0-25% foliage singed, 2 26-50%, 3 51-75%, 4 76-100%, 5 all needles brown, 6 all needles consumed.

Table 17. Herbaceous and seedling foliage cover following the June 1977 La Mesa fire at the sites of 1960 burn, North Rim of Frijoles Canyon (data based on 21 quadrats, 0.5 m x 1.0 m)

Post-La Mesa Fire Herbaceous and Seedling Cover

	Burn (1960)			
Conditions	Woody	Forbs	Grass	Total
Rel. Cover (%)	0.8	3.5	10.0	14.3
Cover (sq ft/A)	331	1,307	4,530	6,229
Freq. Index (%)	10	62	66	85

Table 18. Stand conditions and classifications of shoot damage for mature and reproductive ponderosa pine following the June 1977 La Mesa fire for the North Rim Frijoles Canyon 1878 burn and control (data based on 20 quadrats, 20 ft x 50 ft)

Conditions	Post-Fire Damage*												Pre-Fire Conditions	
	Burn (1878)						Control							
	1	2	3	4	5	6	1	2	3	4	5	6	Burn 1878	Con-trol
MATURE PONDEROSA PINE														
Relative Density (%)	0	0	0	0	0.6	99.4	0	0	0	0	0	100	98.7	95.6
Density/Acre	0	0	0	0	2.2	339.7	0	0	0	0	0	235.2	341.9	235.2
Relative Basal Area (%)	0	0	0	0	0.5	99.5	0	0	0	0	0	100	99.7	98.3
Basal Area (sq ft/A)	0	0	0	0	0.4	90.1	0	0	0	0	0	117.8	90.5	117.8
Freq. Index (%)	0	0	0	0	5	100	0	0	0	0	0	95	100	95
ALL MATURE SPECIES														
Total Cover (%)														47.7
Total Density/Acre													346.3	246.1
Total Basal Area (sq ft/A)													90.8	119.8
REPRODUCTIVE PONDEROSA PINE														
Relative Density (%)	0	0	0	0	0	100							97.3	
Density/Acre	0	0	0	0	0	239.5							239.5	
Freq. Index (%)	0	0	0	0	0	90							90	
ALL REPRODUCTIVE SPECIES														
Total Density/Acre													246.1	

*Damage categories are as follows: 1 0-25% foliage singed, 2 26-50%, 3 51-75%, 4 76-100%, 5 all needles brown, 6 all needles consumed.

Table 19. Herbaceous and seedling foliage cover following the June 1977 La Mesa fire at the sites of 1878 and 1937 burns, North Rim of Frijoles Canyon (data based on 21 quadrats, 0.5 m x 1.0 m)

Post-La Mesa Fire Herbaceous and Seedling Cover

	Burn (1878)				Burn (1937)			
Conditions	Woody	Forbs	Grass	Total	Woody	Forbs	Grass	Total
Rel. Cover (%)		<0.1	0.1	0.1		0.8	1.5	2.3
Cover (sq ft/A)		9	44	52		362	653	1,015
Freq. Index (%)		1	1	2		17	18	34

Table 20. Stand conditions and classifications of shoot damage for mature and reproductive ponderosa pine following the June 1977 La Mesa fire for the North Rim Frijoles Canyon 1937 burn and control (data based on 20 quadrats, 20 ft x 50 ft)

Conditions	Post-Fire Damage*												Pre-Fire Conditions	
	Burn (1937)						Control							
	1	2	3	4	5	6	1	2	3	4	5	6	Burn 1937	Con-trol
MATURE PONDEROSA PINE														
Relative Density (%)	0	0	0	0	75.5	24.5	0	0	0	0	0	100	93.8	95.6
Density/Acre	0	0	0	0	74	24	0	0	0	0	0	235.2	98	235.2
Relative Basal Area (%)	0	0	0	0	62.7	37.1	0	0	0	0	0	100	98.4	98.3
Basal Area (sq ft/A)	0	0	0	0	28.9	17.1	0	0	0	0	0	117.8	46.0	117.8
Freq. Index (%)	0	0	0	0	35	55	0	0	0	0	0	95	70	95
ALL MATURE SPECIES														
Total Cover (%)														47.7
Total Density/Acre													104.5	246.1
Total Basal Area (sq ft/A)													46.8	119.8
REPRODUCTIVE PONDEROSA PINE														
Relative Density (%)	0	0	0	0	1.9	98.1							89.1	
Density/Acre	0	0	0	0	2.0	100.8							102.8	
Freq. Index (%)	0	0	0	0	10	60							65	
ALL REPRODUCTIVE SPECIES														
Total Density/Acre													115.4	

*Damage categories are as follows: 1 0-25% foliage singed, 2 26-50%, 3 50-75%, 4 76-100%, 5 all needles brown, 6 all needles consumed.

Table 21. Stand conditions and classifications of shoot damage for mature and reproductive ponderosa pine following the June 1977 La Mesa fire for the Escobas Mesa 1976 burn and control (data based on 20 quadrats, 20 ft x 50 ft)

Conditions	Post-Fire Damage*												Pre-Fire Conditions	
	Burn (1976)						Control							
	1	2	3	4	5	6	1	2	3	4	5	6	Burn 1976	Con-trol
MATURE PONDEROSA PINE														
Relative Density (%)	35.8	3.1	31.3	29.8	0	0	2.3	0.8	4.6	0	68.9	23.5	100	100
Density/Acre	52.3	4.5	45.7	43.6	0	0	6.5	2.2	13.1	0	198.1	67.5	146.1	287.4
Relative Basal Area (%)	24.8	1.7	48.8	24.6	0	0	4.0	1.4	12.6	0	59.3	22.6	100	100
Basal Area (sq ft/A)	12.8	0.9	25.2	12.7	0	0	6.0	2.1	18.9	0	88.9	33.9	51.6	149.8
Freq. Index (%)	45	10	45	40	0	0	10	5	20	0	80	30	85	100
ALL MATURE SPECIES														
Total Cover (%)													9.7	3.8
Total Density/Acre													146.1	287.4
Total Basal Area (sq ft/A)													51.6	149.8
REPRODUCTIVE PONDEROSA PINE														
Relative Density (%)	59.2	37.1	0	3.7	0	0	0	0	0	0	0	0	58.7	
Density/Acre	34.8	21.8	0	2.2	0	0	0	0	0	0	0	0	58.8	
Freq. Index (%)	15	20	0	5	0	0	0	0	0	0	0	0	30	
ALL REPRODUCTIVE SPECIES														
Total Density/Acre													100.2	

*Damage categories are as follows: 1 0-25% foliage singed, 2 26-50%, 3 51-75%, 4 76-100%, 5 all needles brown, 6 all needles consumed.

Table 22. Herbaceous and seedling foliage cover following the June 1977 La Mesa fire at the sites of 1976 Escobas Mesa burn and control (data based on 21 quadrats, 0.5 m x 1.0 m)

	Burn 1976				Control			
Conditions	Woody	Forbs	Grass	Total	Woody	Forbs	Grass	Total
Foliage cover (%)		4.5	7.5	12.0			0.1	0.1
Cover (sq ft/A)		1,960	3,267	5,227			44	44
Frequency index (%)		38	57	66			4	4

Table 23. Summary of post-La Mesa fire damage and stand conditions, 1977, on ponderosa pine type

	FRIJOLES CANYON RIM				ALAMO RIM		BEAR MESA		FRIJOLES CANYON RIM		ESCOBAS MESA	
	1878 Burn	1878 Control	1937 Burn	1937 Control	1945 Burn	1945 Control	1950 Burn	1950 Control	1960 Burn	1960 Control	1976 Burn	1976 Control
FIRE INTERVAL (YRS)	99		40		32		27		17		1	
STAND CONDITIONS:												
Mature												
Pine density (no./A)	342	(235)	98	(235)	63	(231)	131	(440)	55	(235)	150	(288)
Pine basal area (sq ft/A)	91	(118)	41	(118)	20	(50)	75	(114)	51	(118)	52	(148)
Pine mean dbh (in.)	7.0	(9.6)	8.8	(9.6)	7.6	(6.3)	10.2	(6.9)	13.1	(9.6)	7.9	(9.7)
Fuel load												
Litter (tons/A)	-	-	-	-	1.9	(8.0)	8.1	(9.0)	-	(8.3)	-	-
Sticks (tons/A)	-	-	-	-	0.0	(1.1)	0.5	(0.4)	-	(3.8)	-	-
Herbs (tons/A)	-	-	-	-	0.5	(0.0)	0.1	(0.1)	-	(0.2)	-	-
Total (tons/A)	-	-	-	-	2.4	(9.1)	8.7	(9.5)	-	(12.3)	-	-
FIRE:												
Rate of spread (chains/hr)	24	(24)	24	(24)	24	(24)	12	(12)	24	(24)	38	(38)
Mature foliage damage (%)*												
1. 0-25%							40	(5)	52		36	(2)
2. 26-50%							20	(5)	12		3	(1)
3. 51-75%					7	(1)	10	(9)	20		31	(5)
4. 76-100%					7		23	(15)	16		30	
5. all brown	1		75		31	(15)	3	(35)				(69)
6. consumed	99	(100)	25	(100)	55	(84)	3	(31)		(100)		(23)
Mean damage class	5.99	(6.00)	5.25	(6.00)	5.35	(5.82)	2.40	(4.64)	2.96	(6.00)	2.49	(5.03)
Reprod. foliage damage*												
1. 0-25%							14	(2)			59	
2. 26-50%							11				37	
3. 51-75%					36		7		43			
4. 76-100%					43		15	(2)	57		4	
5. all brown			2		14	(97)	41	(37)				
6. consumed	100	(100)	98	(100)	7	(3)	12	(59)		(100)		
Mean damage class	6.00	(6.00)	5.98	(6.00)	3.93	(5.03)	3.96	(5.52)	3.57	(6.00)	1.48	(-)

* % = Number of ponderosa pine in damage category per acre/total number of ponderosa pine in plot x 100

Table 24. Stand conditions and classifications of shoot damage for mature trees and reproduction following the June 1977 La Mesa fire for the Frijoles Mesa Transect I area (data based on one quadrat, 20 m x 50 m)

Conditions	Post-fire Damage*																											
	Plot 1							Plot 2							Plot 3							Plot 4						
	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total
MATURE																												
PONDEROSA PINE																												
Relative Density (%)																			100		100							
Density/Acre																			8.1		8.1							
Relative Basal Area (%)																			100		100							
Basal Area (sq ft/A)																			17.5		17.5							
Freq. Index (%)																			50		-							
JUNIPER																												
Relative Density (%)	27.3	9.1	18.2	18.2	18.2	9.1	100		4.8	4.8		23.8	66.6	100						100	100						100	100
Density/Acre	12.1	4.0	8.1	8.1	8.1	4.0	44.5		4.0	4.0		20.2	56.7	84.9						28.3	28.3						48.6	48.6
Relative Basal Area (%)	34.5	7.5	8.4	11.8	32.1	5.7	100		9.1	.8		25.3	64.8	100						100	100						100	100
Basal Area (sq ft/A)	26.1	5.6	6.4	8.9	24.2	4.3	75.6		6.4	.6		17.8	45.7	70.5						11.3	11.3						24.8	24.8
Freq. Index (%)	50	25	25	50	50	25	-		25	25		75	75	-						100	-						100	-
PINYON PINE																												
Relative Density (%)	16.7		33.3		50.0		100			50	33.3	16.7		100					57.1	42.9	100						100	100
Density/Acre	4.0		8.1		12.1		24.3			12.1	8.1	4.0		24.2					16.2	12.1	28.3						64.8	64.8
Realtive Basal Area (%)	14.6		29.1		56.3		100			37.0	48.4	14.6		100					40.4	59.5	100						100	100
Basal Area (sq ft/A)	.4		.7		1.4		2.4			5.7	7.4	2.2		15.3					2.0	3.0	5.0						14.9	14.9
Freq. Index (%)	25		50		25		-			75	25	25		-					75	50	-						75	-
REPRODUCTIVE																												
JUNIPER																												
Relative Density (%)	100						100					20	80	100						100	100						100	100
Density/Acre	4.0						4.0					4.0	16.2	20.2						4.0	4.0						24.3	24.3
Freq. Index (%)	25						-					25	25	-						25	25						50	50
PINYON PINE																												
Relative Density (%)	53.8		7.7	7.7	23.1	7.7	100				16.7	83.3		100					6.3	93.8	100						100	100
Density/Acre	28.3		4.0	4.0	12.1	4.0	52.4				4.0	20.2		24.2					4.0	60.7	64.7						32.4	32.4
Freq. Index (%)	75		25	25	75	25	-				25	75		-					25	100	-						100	-

*Damage categories are as follows: 1 0-25% foliage singed, 2 26-50%, 3 51-75%, 4 76-100%, 5 all needles brown, 6 all needles consumed.

Table 25. Herbaceous and seedling foliage cover following the June 1977 La Mesa fire for Frijoles Mesa Transect I area (data based on 100 quadrats, 5 x 5 dm)

	Plot 1			Plot 2			Plot 3			Plot 4		
Conditions	Forbs	Grass	Total	Forbs	Grass	Total	Forbs	Grass	Total	Forbs	Grass	Total
Foliage cover (%)	2.4	8.0	9.6	2.0	4.5	6.5	2.6	1.0	3.6	1.5	.3	1.8
Cover (sq ft/A)	1,045	3,485	4,182	871	1,960	2,831	1,133	436	1,368	635	131	784
Frequency index (%)	50	82	88	31	56	65	44	11	45	42	7	42

Table 26. Stand conditions and classifications of shoot damage for mature trees and reproduction following the June 1977 La Mesa fire for the Burnt Mesa Transect II area (data based on one quadrat, 20 m x 50 m)

Conditions	Post-fire Damage*																				
	Plot 1							Plot 2							Plot 3						
	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total
MATURE																					
PONDEROSA PINE																					
Relative Density (%)				100			100				33.3	44.4	22.2	100					90.8	9.2	100
Density/Acre				4.0			4.0				12.1	16.2	8.1	36.4					279.2	28.3	307.5
Relative Basal Area (%)				100			100				75.7	10.6	13.8	100					92.1	7.9	100
Basal Area (sq ft/A)				0.9			0.9				35.1	4.9	6.4	46.3					97.8	8.4	106.2
Freq. Index (%)				25			-				50	50	25	-					50	100	-
REPRODUCTION																					
PONDEROSA PINE																					
Relative Density (%)												74.1	25.8	100					7.7	92.3	100
Density/Acre												129.4	32.4	161.8					24.3	291.4	315.7
Freq. Index (%)												75	50	-					25	100	-
JUNIPERS																					
Relative Density (%)													100	100							
Density/Acre													8.1	8.1							
Freq. Index (%)													50	-							
DOUGLAS-FIR																					
Relative Density (%)													100	100							
Density/Acre													4.0	4.0							
Freq. Index (%)													25	-							

*Damage categories are as follows: 1 0-25% foliage singed, 2 26-50%, 3 51-75%, 4 76-100%, 5 all needles brown, 6 all needles consumed.

Table 27. Herbaceous and seedling foliage cover following June 1977 La Mesa fire for Burnt Mesa Transect II area (data based on 100 quadrats, 5 x 5 dm)

	Plot 1			Plot 2			Plot 3		
Conditions	Forbs	Grass	Total	Forbs	Grass	Total	Forbs	Grass	Total
Foliage cover (%)	15.9	12.9	28.3	.9	2.8	3.7	.3		.3
Cover (sq ft/A)	6,926	5,401	12,327	392	1,220	1,612	131		131
Frequency index (%)	100	79	100	22	35	51	14		14

Table 28. Stand conditions and classifications of shoot damage for mature trees and reproduction following the June 1977 La Mesa fire for the Escobas Mesa Transect III area (data based on one quadrat, 20 m x 50 m)

Post-fire Damage*

Conditions	Plot 1: 1	2	3	4	5	6	Total	Plot 2: 1	2	3	4	5	6	Total
MATURE														
PONDEROSA PINE														
Relative Density (%)			3.8	42.3	11.5	42.3	100	3.9		11.8	80.3	3.9		100
Density/Acre			8.1	89.0	24.3	89.0	210.4	12.1		36.4	246.9	12.1		307.6
Relative Basal Area (%)			4.2	58.0	60.4	30.3	100	9.0		23.4	69.3	2.0		100
Basal Area (sq ft/A)			3.2	44.9	46.7	23.4	77.3	9.6		25.0	74.0	2.2		106.7
Freq. Index (%)			25	100	50	75	-	25		100	100	25		-
ROCKY MTN. JUNIPER														
Relative Density (%)					100		100							
Density/Acre					4.0		4.0							
Relative Basal Area (%)					100		100							
Basal Area (sq ft/A)					2.5		2.5							
Freq. Index (%)					25		-							
REPRODUCTION														
PONDEROSA PINE														
Relative Density (%)					40.1	43.2	83.3				30.8	40.4	28.8	100
Density/Acre					48.7	52.5	101.2				64.8	85.0	60.7	210.4
Freq. Index (%)					100	50	-				75	75	75	-
JUNIPERS														
Relative Density (%)					10.0		10.0						100	100
Density/Acre					16.2		16.2						4.0	4.0
Freq. Index (%)					50		-						25	-

Conditions	Plot 3: 1	2	3	4	5	6	Total	Plot 4: 1	2	3	4	5	6	Total
MATURE														
PONDEROSA PINE														
Relative Density (%)					38.5	61.5	100			12.0	44.0	40.0	4.0	100
Density/Acre					149.7	238.8	388.5			12.1	44.5	40.5	4.0	101.2
Relative Basal Area (%)					40.0	60.0	100			20.8	55.0	23.9	0.3	100
Basal Area (sq ft/A)					37.1	55.7	92.9			30.4	80.5	35.0	0.5	146.3
Freq. Index (%)					75	100	-			75	100	100	25	-
ROCKY MTN. JUNIPER														
Relative Density (%)														
Density/Acre														
Relative Basal Area (%)														
Basal Area (sq ft/A)														
Freq. Index (%)														
REPRODUCTION														
PONDEROSA PINE														
Relative Density (%)					5.3	94.7	100					85.7	14.3	100
Density/Acre					28.3	501.8	530.2					72.8	12.1	89.0
Freq. Index (%)					50	100	-					75	50	-
JUNIPERS														
Relative Density (%)													100	100
Density/Acre													4.0	4.0
Freq. Index (%)													25	-

*Damage categories are as follows: 1 0-25% foliage singed, 2 26-50%, 3 51-75%, 4 76-100%, 5 all ne edles brown, 6 all needles consumed.

Table 29. Herbaceous and seedling foliage cover following June 1977 La Mesa fire for Escobas Mesa Transect III area (data based on 100 quadrats, 5 x 5 dm)

	Plot 1				Plot 2				Plot 3				Plot 4			
Conditions	Forbs	Grass	Total	Seeded Grass	Forbs	Grass	Total	Seeded Grass	Forbs	Grass	Total	Seeded Grass	Forbs	Grass	Total	Seeded Grass
Foliage cover (%)	3.1	3.6	6.7	.6	.5	3.1	3.6	.1	.1	<.1	.1	.4	.2	<.1	.23	4.5
Cover (sq ft/A)	1,350	1,568	2,918	261	218	1,350	1,568	44	44	9	52	174	87	13	100	1,960
Frequency index (%)	50	33	55	29	19	20	35	8	5	2	5	33	3	8	11	95

Table 30. Stand conditions and classifications of shoot damage for mature trees following the June 1977 La Mesa fire for the Apache Springs Transect IV area (data based on one quadrat, 20 m x 50 m)

Conditions	Post-fire Damage*																																		
	Plot 1							Plot 2							Plot 3							Plot 4							Plot 5						
	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total
MATURE																																			
PONDEROSA PINE																																			
Relative Density (%)			1.8	8.8	33.3	56.1	100	26.5	11.8	14.7	26.5	17.6	2.9	100	73.8	4.8	4.8	13.1	2.4	1.2	100					37.9	62.1	100					44.2	55.8	100
Density/Acre			4.0	20.2	76.9	129.5	230.7	72.8	32.4	40.5	72.8	48.6	8.1	275.2	250.9	16.2	16.2	44.5	8.1	4.0	339.9					133.6	218.5	352.1					170.0	214.4	384.5
Relative Basal Area (%)			2.0	10.8	21.9	65.3	100	39.6	54.3	13.6	20.0	8.6	1.3	100	82.3	3.4	5.8	7.0	1.0	.5	100					36.3	63.7	100					50.6	49.4	100
Basal Area (sq ft/A)			1.3	7.0	14.1	42.1	64.5	34.7	47.6	11.9	17.5	7.5	1.1	87.7	76.8	3.1	5.5	6.5	10.0	.4	93.3					34.9	61.4	96.3					83.5	81.3	164.8
Freq. Index (%)			25	25	100	100	-	100	100	75	75	50	25	-	75	50	50	75	50	25	-					100	100	-					50	100	-
DOUGLAS-FIR																																			
Relative Density (%)			4.0	12.0	32.0	52.0	100	33.3	16.7	50.0				100	83.3	16.7					100					25.0	75.0	100					71.4	28.6	100
Density/Acre			4.0	12.1	32.4	52.6	101.2	8.1	4.0	12.1				24.3	20.2	4.0					24.3					20.2	60.7	80.9					40.5	16.2	56.7
Relative Basal Area (%)			7.2	5.5	40.6	46.7	100	82.8	1.5	15.7				100	97.5	2.5					100					22.5	77.4	100					73.5	26.5	100
Basal Area (sq ft/A)			10.0	1.5	11.0	12.7	27.2	19.2	.4	3.7				23.3	29.8	.8					30.6					7.3	25.0	32.2					13.0	4.7	17.7
Freq. Index (%)			25	25	100	75	-	25	25	25				-	50	25					-					50	75	-					50	50	-
WHITE FIR																																			
Relative Density (%)				11.1	66.7	22.2	100			100				100	77.8	11.1	11.1				100					48.1	31.9	100					15.4	84.6	100
Density/Acre				4.0	24.3	8.1	36.4			8.0				8.0	28.3	4.0	4.0				36.4					52.6	56.7	109.3					8.1	44.5	52.6
Relative Basal Area (%)				23.7	52.8	1.8	100			100				100	75.8	4.8	19.4				100					71.7	28.3	100					14.7	85.3	100
Basal Area (sq ft/A)				1.8	4.1	5.0	7.7			1.7				1.7	5.6	.4	1.4				7.4					16.1	6.4	22.5					2.3	13.1	15.4
Freq. Index (%)				25	50	25	-			25				-	25	25	25				25					40	60	-					25	100	-
ASPEN																																			
Relative Density (%)				5.0	5.0	90.0	100								100						100						100	100						100	100
Density/Acre				4.0	4.0	72.8	80.9								32.4						32.4						4.0	4.0						4.8	4.8
Relative Basal Area (%)				5.7	4.0	90.3	100								100						100						100	100						100	100
Basal Area (sq ft/A)				1.1	.8	18.1	20.0								8.5						8.5						.6	.6						12.6	12.6
Freq. Index (%)				25	25		-								100						100						25	25						100	100

*Damage categories are as follows: 1 0-25% foliage singed, 2 26-50%, 3 51-75%, 4 76-100%, 5 all needles brown, 6 all needles consumed.

Table 31. Stand conditions and classifications of shoot damage for reproduction following the June 1977 La Mesa fire for the Apache Springs Transect IV area (data based on one quadrat, 20 m x 50 m)

Post-fire Damage*

Conditions	Plot 1							Plot 2						
	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total
REPRODUCTIVE														
PONDEROSA PINE														
Relative Density (%)				2.3	40.9	56.8	100				9.7	87.1	3.2	100
Density/Acre				4.0	72.8	101.2	178.1				12.1	109.3	4.0	125.5
Freq. Index (%)				25	75	100	-				50	100	25	-
DOUGLAS-FIR														
Relative Density (%)					63.6	36.4	100	3.0	6.1		12.1	69.7	9.1	100
Density/Acre					28.3	16.2	44.5	4.0	8.1		16.2	93.1	12.1	133.6
Freq. Index (%)					50	50	-	25	50		25	100	50	100
WHITE FIR														
Relative Density (%)					17.8	82.2	100		11.1		16.7	66.7	5.6	100
Density/Acre					32.4	149.7	182.1		8.1		12.1	48.6	4.0	72.8
Freq. Index (%)					75	100	-		25		25	25	25	100
ASPEN														
Relative Density (%)					40	60	100							
Density/Acre					32.4	48.6	80.9							
Freq. Index (%)					25	50	-							
OAK														
Relative Density (%)								50				50		100
Density/Acre								8.1				8.1		16.2
Freq. Index (%)								25				25		-

Conditions	Plot 3						
	1	2	3	4	5	6	Total
REPRODUCTIVE							
PONDEROSA PINE							
Relative Density (%)	46.9	1.2	1.2	13.6	34.6	2.5	327.7
Density/Acre	153.8	4.0	4.0	44.5	113.3	8.1	100
Freq. Index (%)	100	25	25	75	100	25	-
DOUGLAS-FIR							
Relative Density (%)	73.5		2.9	8.8	5.9	8.1	100
Density/Acre	101.1		4.0	12.1	8.1	12.1	137.4
Freq. Index (%)	25		25	25	50	75	-
WHITE FIR							
Relative Density (%)	69.2		7.7	3.8	3.8	15.4	100
Density/Acre	283.1		16.2	8.1	8.1	32.4	347.9
Freq. Index (%)	25		50	25	50	50	-
ASPEN							
Relative Density (%)	100						100
Density/Acre	20.2						20.2
Freq. Index (%)	25						25
OAK							
Relative Density (%)	100						100
Density/Acre	4.0						4.0
Freq. Index (%)	25						25

Conditions	Plot 4							Plot 5						
	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total
REPRODUCTIVE														
PONDEROSA PINE														
Relative Density (%)					23.9	76.1	100					20	80	100
Density/Acre					44.5	141.6	186.1					20.2	80.9	101.1
Freq. Index (%)					50	100	-					50	100	-
DOUGLAS-FIR														
Relative Density (%)						100	100					8.3	91.7	100
Density/Acre						40.5	40.5					12.1	133.6	145.7
Freq. Index (%)						75	-					50	100	-
WHITE FIR														
Relative Density (%)					21.3	78.7	100					13.3	86.7	100
Density/Acre					80.9	299.5	380.4					8.1	52.6	60.7
Freq. Index (%)					50	100	-					100	25	-

*Damage categories are as follows: 1 0-25% foliage singed, 2 26-50%, 3 51-75%, 4 76-100%, 5 all needles brown, 6 all needles consumed.

Table 32. Herbaceous and seedling foliage cover following June 1977 La Mesa fire for Apache Springs Transect IV area (data based on 100 quadrats, 5 x 5 dm)

	Plot 1				Plot 2				Plot 3				Plot 4				Plot 5			
Conditions	Forbs	Grass	Total	Seeded Grass	Forbs	Grass	Total	Seeded Grass	Forbs	Grass	Total	Seeded Grass	Forbs	Grass	Total	Seeded Grass	Forbs	Grass	Total	Seeded Grass
Foliage cover (%)	.3	.1	.4	2.4	.5	2.6	3.1		1.4	.1	1.5		.2		.2	6.1	.1		.1	1.7
Cover (sq ft/A)	131	43.6	174	1,045	218	1,133	1,350		610	44	653		87		87	2,657	44		44	741
Frequency index (%)	11	7	18	51	7	27	30		28	4.	28		8		8	75	9		9	35

Table 33. Stand conditions and classifications of shoot damage for reproduction following the June 1977 La Mesa fire for the Inner Frijoles Canyon Transect V area (data based on one quadrat, 20 m x 50 m)

Conditions	Post-fire Damage*													
	Plot 1							Plot 2						
	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total
REPRODUCTIVE														
PONDEROSA PINE														
Relative Density (%)	100						100	33.3			66.6			100
Density/Acre	4.0						4.0	4.0			8.7			12.7
Freq. Index (%)	25						-	25			25			-
DOUGLAS-FIR														
Relative Density (%)								3.0	7.5	12.0	19.4	40.3	17.9	100
Density/Acre								8.1	20.2	32.4	52.6	109.3	48.6	271.1
Freq. Index (%)								25	75	75	100	100	75	-
WHITE FIR														
Relative Density (%)								2.3	3.2	6.0	12.8	65.6	10.1	100
Density/Acre								20.2	28.3	52.6	113.3	578.7	89.0	882.1
Freq. Index (%)								50	50	100	100	100	100	-
OAK														
Relative Density (%)	100						100	24.4	2.4	7.3	4.9	26.8	34.2	100
Density/Acre	24.3						24.3	40.5	4.0	12.1	8.1	44.5	56.7	161.9
Freq. Index (%)	50						-	75	25	25	50	50	50	-

*Damage categories are as follows: 1 0-25% foliage singed, 2 26-50%, 3 51-75%, 4 76-100%, 5 all needles brown, 6 all needles consumed.

Table 34. Stand conditions and classifications of shoot damage for mature trees following the June 1977 La Mesa fire for the Inner Frijoles Canyon Transect V area (data based on one quadrat, 20 m x 50 m)

Conditions	Post-fire Damage*													
	Plot 1							Plot 2						
	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total
MATURE														
PONDEROSA PINE														
Relative Density (%)	45.5	18.2	27.3		9.1		100	100						100
Density/Acre	20.2	8.1	12.1		4.0		44.4	12.1						12.1
Relative Basal Area (%)								100						100
Basal Area (sq ft/A)	10.3	3.3	1.8		.7		16.1	25.4						25.4
Freq. Index (%)	50	25	25		25		-	50						50
DOUGLAS-FIR														
Relative Density (%)								30.8	38.5	30.8				100
Density/Acre								16.3	20.2	16.3				52.6
Relative Basal Area (%)								78.3	13.0	8.6				100
Basal Area (sq ft/A)								27.3	4.5	3.0				34.8
Freq. Index (%)								100	75	50				-
WHITE FIR														
Relative Density (%)								42.5	15.0	22.5	5.0	15.0		100
Density/Acre								68.8	24.3	36.4	8.1	24.3		161.9
Relative Basal Area (%)								71.2	10.9	9.8	3.4	4.7		100
Basal Area (sq ft/A)								3.6	5.6	5.1	1.7	2.4		51.4
Freq. Index (%)								100	100	100	50	50		-
OAK														
Relative Density (%)	91.7	8.3					100	36.7	10.0	16.7	6.7	16.7	13.3	100
Density/Acre	44.5	4.0					48.5	44.5	12.1	20.2	8.1	20.2	16.2	121.4
Relative Basal Area (%)	92.7	7.3					100	49.2	11.5	15.2	9.7	19.3	14.5	100
Basal Area (sq ft/A)	7.0	.6					7.6	10.9	2.5	3.4	2.1	4.3	3.2	22.1
Freq. Index (%)	75	25					-	100	25	50	25	75	50	-

*Damage categories are as follows: 1 0-25% foliage singed, 2 26-50%, 3 51-75%, 4 76-100%, 5 all needles brown, 6 all needles consumed.

Table 35. Herbaceous and seedling foliage cover following June 1977 La Mesa fire for Frijoles Canyon (inner) Transect I area (data based on 100 quadrats, 5 x 5 dm)

	Plot 1			Plot 2		
Conditions	Forbs	Grass	Total	Forbs	Grass	Total
Foliage cover (%)	1.3	3.9	5.2	1.6		1.6
Cover (sq ft/A)	566	1,699	2,265	697		697
Frequency index (%)	38	44	45	55		55

Table 36. Annotated checklist of herbaceous plants and their location Aug.-Sept., 1977 within the 20 x 50 meter plots established after the La Mesa fire

Species Scientific Name, Common Name	Annual	Biennial	Perennial	Edible	Vegetative	Flower	Frijoles Mesa				Burnt Mesa			Escobas Mesa				Apache Springs					Frijoles Canyon	
							1	2	3	4	1	2	3	1	2	3	4	1	2	3	4	5	1	2
Achillea lanulosa, western yarrow			x		x		x											x		x				x
Allium cernuum, nodding onion			x	x		x					x	x	x	x			x							
Amaranthus retroflexus, redroot pigweed	x			x		x	x																	
Antennaria parvifolia, pussytoes			x		x										x		x	x	x					
Apocynum androsaemifolium, dogbane					x																		x	
Bahia dissecta, ragleaf bahia	x				x	x	x	x	x	x	x		x	x			x							
Castilleja integra, wholeleaf paintbrush			x			x	x			x	x			x										
Chenopodium album, lambsquarters	x					x			x		x			x	x		x	x						
Chenopodium fremontii, goosefoot	x					x									x									
Chenopodium graveolans, ragleaf goosefoot	x			x		x	x				x	x		x	x	x	x							
Chrysopsis villosa, hairy goldenaster			x			x	x		x		x			x										
Circium sp., thistle		x	x		x						x	x												
Commelina dianthifolia, birdbill dayflower			x			x							x											
Corydalis aurea, golden corydalis	x				x													x		x	x			x
Cryptantha jamesii, James hiddenflower			x			x	x																	
Erigeron flagellaris, trailing fleabane		x	x			x	x				x			x	x									
Eriogonum sp., buckwheat			x			x	x																	
Eriogonum jamesii*, wee Mary buckwheat			x			x	x																	
Pteridophyta, unidentified			x		x																			x
Euphorbia sp., spurge	x					x	x	x	x	x	x		x	x										
Fragaria sp., strawberry					x													x	x	x				
Galium sp., bedstraw			x		x														x	x				x
Gaura coccinea, scarlet gaura			x		x						x													
Geranium caespitosum, purple geranium			x		x																		x	
Goodyera oblongifolia, western snakeplantain			x			x														x				
Hymenopappus filifolius, white ragweed			x		x		x	x																
Hymenoxys acaulis, rubberweed			x		x					x								x	x					
Linum rigidum, flax	x				x				x						x									
Lithospermum multiflorum, stoneseed			x			x								x				x	x					
Lotus wrightii, red-and-yellow pea			x			x	x	x																
Lupinus caudatus, lupine			x			x			x		x	x												
Mirabilis linearis, four o'clock			x			x			x															
Orthocarpus purpureo-albus, purple-white owlclover	x					x					x													
Oxalis sp., woodsorrel			x		x																			x
Oenothera sp., evening primrose			x		x		x																	
Penstemon sp., beardtongue			x		x						x													
Petalostemum candidus, white prairieclover			x			x		x	x		x			x										
Physalis neomexicana, groundcherry			x	x		x	x	x	x		x	x	x	x										
Polygonum convolvulus*, black bindweed	x					x	x																	
Potentilla sp., cinquefoil			x		x	x				x	x			x						x				
Senecio multicapitatus, groundsel			x		x		x	x	x	x														
Smilacina sp., Solomonplume			x		x															x				
Solidago sp., goldenrod			x			x												x						
Stephanomeria sp., wirelettuce			x		x									x										
Thalictrum sp., meadowrue			x		x													x	x				x	x
Thelesperma trifidum, greenthread				x						x	x													
Thermopsis pinetorum, piney goldenpea			x		x										x								x	
Tragopogon pratensis, goatsbeard			x		x						x												x	
Verbascum thapsus, flannel mullein		x			x									x										
Vicia americana, American vetch			x			x					x	x		x				x		x	x		x	x
Viola sp., violet			x		x																			x

*Plants not found in herbaceous and shrub plots but common to area

Table 37. Annotated checklist of grasses and grass-like plants and their location Aug.-Sept., 1977 within the 20 x 50 meter plots established after the La Mesa fire

Species			Frijoles Mesa				Burnt Mesa			Escobas Mesa				Apache Springs					Frijoles Canyon	
Scientific Name, Common Name	Annual	Perennial	1	2	3	4	1	2	3	1	2	3	4	1	2	3	4	5	1	2
Andropogon gerardii, big bluestem		X								X	X									
Andropogon scoparius*, little bluestem		X		X															X	
Aristida sp., threeawn		X			X					X										
Blepharoneuron tricholepis, pine dropseed		X								X										
Bouteloua curtipendula, side-oats grama		X									X									
Bouteloua gracilis, blue grama		X	X	X	X	X	X	X		X										
Bromus anomalus, nodding brome		X																		
Cyperus esculentus, chufa flat-sedge		X				X	X	X	X	X		X	X							
Hilaria jamesii, galleta		X						X												
Lycurus phleoides*, wolftail		X								X										
Muhlenbergia minutissima, littleseed muhly	X						X	X												
Muhlenbergia montana, mountain muhly		X	X	X	X					X	X					X			X	
Muhlenbergia wrightii, spike muhly		X																	X	
Panicum miliaceum*, broom-corn millet	X				X															
Sitanion hystrix, bottlebrush squirreltail		X	X				X				X									
Sorghastrum nutans, Indian grass		X																	X	
Sporobolus cryptandrus, sand dropseed		X									X									

*Plants not found in herbaceous and shrub plots but common to area

Table 38. Annotated checklist of half-shrubs, shrubs, and trees and their location Aug.-Sept., 1977 within the 20 x 50 meter plots established after the La Mesa fire

Species		Dispersal				Frijoles Mesa				Burnt Mesa			Escobas Mesa				Apache Springs					Frijoles Canyon	
Scientific Name, Common Name	Sprouter	Wind	Animal	Fire-favored Germination	Deer Browse	1	2	3	4	1	2	3	1	2	3	4	1	2	3	4	5	1	2
Arctostaphylos uva-ursi, pointleaf manzanita			X		X												X		X				
Artemisia carruthii, flat sagebrush		X			X	X			X	X	X		X	X								X	
Berberis fendleri, Colorado barberry			X																			X	
Brickellia grandiflora*, tassel brickellia		X																				X	
Ceanothus fendleri*, buckbrush ceanothus			X	X	X										X								
Cercocarpus montanus, true cercocarpus	X	X			X	X	X	X															
Clematis pseudoalpina, mountain clematis		X																					X
Gutierrezia sarothrae, broom snakeweed		X				X																	
Opuntia sp., prickly pear			X				X	X															
Populus tremuloides, quaking aspen	X	X			X												X		X		X		X
Prunus sp., chokecherry	X		X																			X	
Quercus gambelii, Gambel oak	X		X		X						X	X		X	X			X	X		X	X	X
Quercus undulata, wavyleaf oak	X		X		X	X	X	X	X														
Rhus radicans, poison ivy	X		X																			X	X
Rhus trilobata*, squawberry	X		X	X	X		X																
Rubus sp., raspberry	X		X																			X	
Ribes sp., gooseberry, currant			X	X													X						
Robinia neomexicana, New Mexican locust	X		X	X											X		X		X	X		X	X
Rosa sp., rose			X												X		X	X	X			X	
Yucca sp.*, Spanish bayonet	X	X			X				X														

*Plants not found in herbaceous and shrub plots but common to area

Table 39. Analysis of mature trees and reproduction of Pinyon-Juniper of Frijolito Mesa Transect VI area. Stand was not burned by the June 1977 La Mesa fire but was established for baseline data (based on one quadrat, 20 m x 50 m)

Species	Plot 1				Plot 2			
	Juniperus monosperma	Juniperus scopulorum	Pinus edulis	Total	Juniperus monosperma	Juniperus scopulorum	Pinus edulis	Total
MATURE								
Relative Density (%)	81.5	1.8	16.7	100	63.0		37	100
Density/Acre	178.1	4.0	36.4	218.5	117.4		68.8	186.2
Relative Basal Area (%)	86.8	.6	12.6	100	83.4		16.6	100
Basal Area (sq ft/A)	128.0	1.0	18.5	147.5	109.9		21.9	131.8
Freq. Index (%)	100	25	100	-	100		100	-
REPRODUCTIVE								
Relative Density (%)	61.3		38.6	100	47.2		52.7	100
Density/Acre	109.3		68.7	178.0	68.7		76.9	145.6
Freq. Index (%)	100		100	-	100		100	-

Table 40. Herbaceous and seedling foliage cover for the pinyon-juniper of Frijolito Mesa, Transect VI area (data based on 100 quadrats, 5 x 5 dm)

	Plot 1				Plot 2			
Conditions	Woody	Forbs	Grass	Total	Woody	Forbs	Grass	Total
Foliage cover (%)	.5	1.6	4.9	7.0	.3	.2	2.0	2.5
Cover (sq ft/A)	240	697	2,134	3,071	92	109	871	1,089
Frequency index (%)	2	25	50	65	2	5	21	29

Table 41. Analysis of mature trees and reproduction of Mixed Conifer (Plot 1) and Meadow (Plot 2) of the Cerro Grande Transect VII area. Stand was not burned by the June 1977 La Mesa fire but was established for baseline data (based on one quadrat, 20 m x 50 m)

Species	Plot 1 (Mixed Conifer)								Plot 2 (Meadow) No Trees
	Pinus ponderosa	*Abies concolor*	*Picea engelmannii*	*Pinus flexilis*	*Populus tremuloides*	*Pseudotsuga menziesii*	*Quercus gambelii*	Total	
MATURE									
Relative Density (%)	12.1	19.0	5.2	1.7	46.6	15.5		100	
Density/Acre	28.3	44.5	12.1	4.0	109.3	36.4		234.6	
Relative Basal Area (%)	4.5	28.1	1.2	.5	57.5	7.9		100	
Basal Area (sq ft/A)	5.2	32.8	1.4	.6	68.2	9.3		117.5	
Freq. Index (%)	100	100	50	25	100	75		-	
REPRODUCTIVE									
Relative Density (%)	12.8	3.9	3.4	3.4	73.2	1.7	1.7	100	
Density/Acre	93.1	28.3	24.3	24.3	530.6	12.1	12.1	724.8	
Freq. Index (%)	100	100	75	25	100	75	50	-	

Table 42. Herbaceous and seedling foliage cover for the mixed-conifer (plot 1) and meadow (plot 2) of Cerro Grande, Transect VII area (data based on 100 quadrats, 5 x 5 dm)

	Plot 1				Plot 2			
Conditions	Woody	Forbs	Grass	Total	Woody	Forbs	Grass	Total
Foliage cover (%)		3.8	6.4	10.2		9.2	33.5	42.7
Cover (sq ft/A)		1,665	2,788	4,443		4,008	14,593	18,600
Frequency index (%)		84	77	94		92	94	97

LITERATURE CITED

Ahlgren, I.F., and C.E. Ahlgren. 1960. Ecological effects of forest fires. Bot. Rev. 26:483-533.

Alexander, M.E., and F.G. Hawksworth. 1975. Wildland fires and dwarf mistletoes: A literature review of ecology and prescribed burning. USDA Forest Service. Gen. Tech. Rep. RM-14.

Anderson, R.C. 1973. The use of fire as a management tool on Curtis Prairie. Proc. Tall Timber Fire Ecology Conf. 12:23-34. Tall Timber Res. Sta ., Tallahassee, Fla.

Anderson, R.C., O.L. Loucks, and A.M. Swain. 1969. Herbaceous response to canopy cover, light intensity, and throughfall precipitation in coniferous forests. Ecology 50:255-263.

Arno, S.F. 1976. The historic role of fire on the Bitterroot National Forest. USDA Forest Service Res. Paper INT-187.

Bandelier, A.F. 1892. Final report of investigations among the Indians of Southwestern United States, carred on mainly in the years from 1880-1885. Part II. Papers of Amer. Archeol. Inst. of Amer. Amer. Ser. IV. Cambridge.

Bandelier National Monument. 1976. Statement for management. US Dept. of Interior. National Park Service, 30 p.

Beal, E.F. 1858. Wagon road from Ft. Defiance to Colorado River. 35th Congress 1st Session, House Exec. Doc. 124, p. 49.

Biswell, H.H. 1973. Fire ecology in ponderosa pine-grassland. Proc. Tall Timber Fire Ecology Conf. 12:69-101. Tall Timber Res. Sta., Tallahassee, Fla.

Biswell, H.H., R.P. Gibbens, and H. Buchanan. 1966. Calif. Agr. 20:5. In Dodge, M. 1972. Forest fuel accumulation--a growing problem. Science 177:139-142.

Bureau Land Management. 1974. Normal fire year planning. Rough Draft. Dec. 12, 1974.

Cable, D. 1973. Fire effects in southwestern semidesert grass-shrub communities. Proc. Tall Timbers Fire Ecology Conf. 12:109-125. Tall Timbers Res. Sta., Tallahassee, Fla.

Clements, W.E., and S. Barr. 1976. Atmospheric transport and dispersal at a site dominated by complex terrain. Third Symposium on Atmospheric Turbulence, Diffusion and Air Quality. Amer. Metereol. Soc.

Cooper, C.F. 1960. Changes in vegetation, structure and growth of southwestern pine forests since white settlement. Ecol. Monogr. 30:129-164.

Cooper, C.F. 1961. The ecology of fire. Sci. Amer. 304:150-160.

Curtis, J.T., and M.L. Partch. 1950. Some factors affecting flower production in Andropogon gerardi. Ecology 31:488-489.

Cushwa, C.T., R.E. Martin, and R.L. Miller. 1968. The effects of fire on seed germination. J. Range Manage. 21:250-254.

Dahms, W.G. 1973. Tree growth and water use response to thinning in a 47-year-old lodgepole pine stand. USDA Forest Service Res. Note, PNW-194.

Dieterich, J.H. 1976a. Prescribed burning in ponderosa pine--state of the art. Presented at Region 6, Eastside Prescribed Fire Workshop, Bend, Ore.

Dieterich, J.H. 1976b. Fire histories from tree ring data. Abstracts and summaries for the joint meeting of Southwest Fire Council and National Fire Council, Albuquerque, N.M.

Dodge, M. 1972. Forest fuel accumulation--a growing problem. Science 177:139-142.

Douglass, A.E. 1928. Climatic cycles and tree-growth. Carnegie Inst. Wash. Pub. 289, Vol. 2. p. 97.

Dryness, C.T. 1976. Effect of wildfire on soil wettability in the High Cascades of Oregon. USDA Forest Service Res. Paper PNW-202.

Dutton, C.E. 1881. The physical geology of the Grand Canyon district. US Geol. Surv. 2nd Ann. Rep.:136-137.

Dwyer, D.D., and R.D. Pieper. 1967. Fire effects on blue grama-pinyon-juniper rangeland in New Mexico. J. Range Manage. 20:359-362.

Earth Environmental Consultants, Inc. 1974. Soil survey and survey of range and ecological conditions on a southern part of Bandelier National Monument. Report to National Park Service, Santa Fe, N.M.

Ffolliott, P.F., W.P. Clary, and L.R. Larson. 1977. Effects of a prescribed fire in an Arizona ponderosa pine forest. USDA Forest Service Res. Note RM-336.

Foiles, M.W., and J.D. Curtis. 1973. Regeneration of ponderosa pine in the Northern Rocky Mountain--Intermountain region. USDA Forest Service Res. Paper INT-145.

Forester, D. 1976. Downed woody materials inventory for Bandelier National Monument. Contract No. PX7029-6-01279, Final Report, National Park Service, Santa Fe, N.M.

Foxx, T.S. 1974. Checklist of plants of Bandelier National Monument. Unpublished.

Foxx, T.S. 1976. Botanical study, archeological salvage project, 1975 season, Bandelier National Monument. Report prepared for Office of Cultural Resourses, Southwest Retion, National Park Service, Santa Fe, N.M.

Fritts, H.C. 1966. Growth-rings of trees: their correlation with climate. Science 154:973-979.

Fritts, H.C. 1972. Tree rings and climate. Sci. Amer. 226:3-10.

Fulton, J.T. 1940. Bandelier forestry. Southwest Monuments Monthly Reports. Aug.:104.

Gill, A.M. 1974. Toward an understanding of fire-scar formation--field observation and laboratory simulation. Forest Sci. 20:198-205.

Gratkowski, H.J. 1962. Heat as a factor in germination of seeds of Ceanothus velutinus var. laevigatus. T & G. Unpubl. Ph.D. thesis. Oregon State Univ.

Grigal, D.F., and J.G. McColl. 1975. Litterfall after wildfire in virgin forests of Northeast Minnesota. Can. J. Forest Res. 5:655-660.

Harkins, C.G. 1937. Forest fires. Bandelier Southwestern Monuments Monthly Report. May:317.

Heirman, A.L. 1971. Effect of fire on noxious brush species in medium fuel types. M.S. thesis, Texas Tech. Univ.

Helvey, J.D. 1975. Soil moisture depletion and growth rates after thinning ponderosa pine. USDA Forest Service Res. Note PNW-243.

Herman, F.R. 1954. A guide for marking fire-damaged ponderosa pine in the Southwest. USDA Forest Res. Note RM-13.

Hitchcock, A.S. 1950. Manual of the grasses of the United States. USDA Misc. Publ. No. 200.

Horton, J.S., and C.J. Kraebel. 1955. Development of vegetation after fire in chamise chaparral of southern California. Ecology 36:244-261.

Hulbert, L.C. 1969. Fire and litter effects in undisturbed bluestem prairie in Kansas. Ecology 50:874-877.

Kilgore, B.M. 1973. Impact of prescribed burning on Sequoia-mixed conifer forest. Proc. Tall Timbers Fire Ecology Conf. 12:345-375. Tall Timbers Res. Sta., Tallahassee, Fla.

King, C. 1871. Mountaineering in the Sierra Nevada (reprinted by Norton, New York, pp. 48, 49, 54, 1935).

Kittams, W.H. 1973. Effect of fire on vegetation of Chihuahuan Desert region. Proc. Tall Timbers Fire Ecology Conf. 12:427-444. Tall Timbers Res. Sta., Tallahassee, Fla.

Koehler, D.A. 1974. The ecological impact of feral burros on Bandelier National Monument. M.S. thesis, Biology Dept., Univ. of N. Mex.

Komarek, E.V., Sr. 1965. Fire ecology--grasslands and man. Proc. Tall Timber Fire Ecology Conf. 4:169-220. Tall Timbers Fire Res. Sta., Tallahassee, Fla.

Komarek, E.V., Sr. 1967. The nature of lightning fires. Proc. Tall Timbers Fire Ecology Conf. 7:5-41. Tall Timbers Res. Sta., Tallahassee, Fla.

Komarek, E.V., Sr. 1968. Lightning and lightning fires as ecological forces. Proc. Tall Timbers Fire Ecology Conf. 8:169-197. Tall Timbers Res. Sta., Tallahassee, Fla.

Komarek, E.V., Sr. 1969. Fire and man in the Southwest. Proc. of the Symposium on Fire Ecology and the Control and Use of Fire in Wild Land Management. Ariz. J., Ariz. Acad. Sci.:3-22.

Kozlowski, T.T., and C.E. Ahlgren. 1974. Fire and ecosystems. Academic Press.

Kujala, V. 1926. Einfluss von waldbranden auf die waldvegetation in Nordfinnland, Metsatiebellisne Koelaitoksen Julkaisuja 10:1-36. In Ahlgren, I.F., and C.E. Ahlgren. 1960. Ecological effects of forest fires. Bot. Rev. 26:483-533.

Larson, M.M., and G.H. Schubert. 1969. Root competition between ponderosa pine seedlings and grass. USDA Res. Paper RM-54.

Lindsey, A.A. 1955. Testing the line-strip method against full tallies in diverse forest types. Ecology 36:485-495.

Los Alamos Scientific Laboratory. 1972. Preliminary safety analysis reported for the plutonium processing facility at TA 55. Los Alamos Sci. Lab., Los Alamos, N.M. Prep. by CMB-11, III/17-III-40.

Lyon, J.L., and P.L. Stickney. 1976. Early vegetal succession following large Northern Rocky Mountain wildfires. Proc. Montana Tall Timbers Fire Ecology Conf. 14:355-375. Tall Timbers Res. Sta., Tallahassee, Fla.

Martin, R.E., R.L. Miller, and C.L. Cushwa. 1975. Germination response of legume seeds subjected to moist and dry heat. Ecology 56:1441-1445.

Moir, W.H. 1966. Influence of ponderosa pine on herbaceous vegetation. Ecology 47:1045-1048.

Morris, W.G. 1934. Forest fires in Oregon and Washington. Oregon Hist. 35:313-339.

Muir, J. 1894. The Mountains of California. p. 163. Houghton, Boston.

Muir, J. 1901. Our national parks. pp. 68-69, 291-292, 307-308. Houghton, Boston.

McCammon, B.P. 1976. Snowpack influences on dead fuel moisture. Forest Sci. 22:323-328.

McConnell, B.R., and J.G. Smith. 1971. Effect of ponderosa pine needle litter on grass seedling survival. USDA Forest Service Res. Note PNW-155.

McLean, A. 1969. Fires resistance of forest species as influenced by root systems. J. Range Manage. 22:120-122.

National Park Service. 1976. Fire Management Policy. In-house paper.

Olinger, B. 1974. The geological features of the lower portion of Cañon de los Frijoles. VIP participant report. Bandelier National Monument. National Park Service, Santa Fe, N.M.

Parmeter, J.R., and B. Uhrenholdt. 1976. Effect of smoke on pathogens and other fungi. Proc. Tall Timbers Fire Ecology Conf. 14:299-304. Tall Timbers Res. Sta., Tallahassee, Fla.

Partch, M.L. 1950. Some factors affecting flower production in Andropogon gerardii. Ecology 31:488-489.

Pase, C.P. 1971. Effect of a February burn on Lehmann lovegrass. J. Range Manage. 6:159-164.

Pase, C.P., and F.W. Pond. 1964. Vegetation changes following Mingus Mountain burn. USDA Forest Service Res. Note RM-18.

Pond, F.W., and D.R. Cable. 1960. Effect of heat treatment on sprout production of some shrubs of the chaparral in central Arizona. J. Range Manage. 13:313-317.

Pond, F.W., and J.W. Bohning. 1971. The Arizona chaparral. Arizona Cattlelog 27:16, 18, 20, 22-28; 27:13-16, 18-24.

Potter, L.D., and D.L. Green. 1964. Ecology of ponderosa pine in western North Dakota. Ecology 45:10-23.

Potter, L.D., and S. Berger. 1977. Deer-burro utilization and competition study, Bandelier National Monument. Final Rep. National Park Service, Santa Fe, N.M.

Quick, C.R. 1954. Ecology of the Sierra Nevada gooseberry in relation to blister rust control. USDA Cir. 937.

Quick, C.R. 1962. Resurgence of gooseberry population after fire in mature timber. J. Forestry 60:100-103.

Rietveld, W.J. 1975. Phytotoxic grass residues reduce germination and initial root growth of ponderosa pine. USDA Forest Service Res. Paper RM-153.

Sachett, S. 1976. Study Plan, Prescribed burning intervals for continued hazard reduction in all age ponderosa pine stands. Rocky Mt. Forest and Range Exp. Sta., Tempe, Ariz. RM-2108.

Sampson, A.W. 1944. Effect of chaparral burning on soil erosion and soil moisture relations. Ecology 25:191-195.

Schiager, K.J., and K.E. Apt. 1973. Environmental surveillance at Los Alamos during 1973. Los Alamos Scientific Lab. Rep. 5586:42-50.

Schubert, G.H. 1971. Growth response of even-aged ponderosa pines related to stand density levels. J. of Forestry 69:857-860.

Schubert, G. 1974. Silviculture of Southwestern ponderosa pine: the status of our knowledge. USDA Forest Service Res. Paper RM-123.

Smiley, T.S., A. Stubbs, and B. Bannister. 1953. A foundation of dating of some late archeological sites in the Rio Grande area, New Mexico. Based on studies in tree-ring methods and pottery analysis. Laboratory of Tree-Ring Res. 24, Bull. 6. Univ. Ariz. Bull.

Smith, E.F., and C.E. Owensby. 1973. Effects of fire on true prairie grassland. Proc. Tall Timber Fire Ecology Conf. 12:9-22. Tall Timbers Res. Sta., Tallahassee, Fla.

Stocking, S.K. 1966. Influences of fire and sodium-calcium borate on chaparral vegetation. Madrono 18:193-203.

Stone, E.C. 1951. Stimulating affect of fire on flowering of the golden Brodianaea. Ecology 32:534-537.

Stone, E.C., and G. Juhren. 1951. Effect of fire on germination of seed of <u>Rhus ovata</u>. Amer. J. Bot. 38:368-372.

Swan, F.R. 1970. Post-fire response of four plant communities in south-central New York State. Ecology 51:1074-1082.

Sweeney, J.R. 1967. Ecology of some "fire type" vegetation in Northern California. Proc. Tall Timbers Fire Ecology Conf. 7:111-125. Tall Timbers Res. Sta., Tallahassee, Fla.

Taylor, A.R. 1969. Lightning effects on the forest complex. Proc. Tall Timber Fire Ecology Conf. 9:127-149. Tall Timbers Res. Sta., Tallahassee, Fla.

Thomas, C.A. 1940. From the mail bag--protection vs. use. Southwest National Monuments, Supplement. Oct:271-272.

Tierney, Gail D. 1977. A vegetative survey of White Rock Canyon 5280-5400 foot (1610-1646 meters) elevation. <u>In</u> Diella, J.V., and R.C. Chapman, eds. Archeological investigations in Cochiti Reservoir, New Mexico. Vol. 1, Dept. of Anthropology, Univ. N.M.

USDA. 1974. Field guide to native vegetation of the Southwestern region. Forest Service Southwestern Region.

USDA. Forest Service. 1974. Seeds of woody plants in the United States. USDA Handbook 450.

Van Cleve, K., and J.C. Zasada. 1976. Response of 70-year-old white spruce to thinning and fertilization in interior Alaska. Can. J. For. Res. 6:145-152.

Viro, P.J. 1974. Effects of forest fire on soil. pp. 7-45. In Kozlowski, T.T., and C.E. Ahlgren. Fire and ecosystems. Academic Press.

Vlamis, J., H.H. Biswell, and A.M. Schultz. 1955. Effects of prescribed burning on soil fertility in second growth ponderosa pine. J. For. 53:905-909.

Vlamis, J., Biswell, H.H., and A.M. Schultz. 1956. Seedling growth on burned soils. Calif. Agr. 10:13.

Vogl, R.J. 1967. Fire adaptions of some Southern California plants. Proc. Tall Timbers Fire Ecology Conf. 7:79-109. Tall Timbers Res. Sta., Tallahassee, Fla.

Von Eschen, G.F. 1961. Climate of Los Alamos, New Mexico. Climatological summary. U.S. Dept. of Commerce, Weather Bureau. In The Climate of New Mexico. Business Info. Ser. No. 37.

Wade, J.M. 1965. First plan, timber management plan, Los Alamos working circle, Los Alamos, New Mexico. Atomic Energy Commission.

Wagle, R.F., and T.W. Eakle. 1974. Evaluation of the fire control, esthetics, and other effects of a "green belt" fuel break designed to protect mountain communities from wildfire. Terminal Report, Cooperative Agreement 16-352-CA, Research Unit FS-RM-2108. Tempe, Ariz.

Wagle, R.F., and T.W. Eakle. (unpublished). Effect of controlled burn on damage caused by wildfire. Final report. Cooperative agreement 16-364-CA, Research Unit FS-RM-2108. Tempe, Ariz.

Wagle, R.F., and J.H. Kitchen, Jr. 1972. Influence of fire on soil nutrients in a ponderosa pine type. Ecology 53:118-125.

Wauer, R.H., and J.D. Hunter. 1977. La Mesa fire rehabilitation plan for Bandelier National Monument. In-house paper.

Weaver, H. 1943. Fire as an ecological and silvicultural factor in the ponderosa pine region of the Pacific Slope. J. Forestry 41:7-15.

Weaver, H. 1951. Observed effects of prescribed burning in ponderosa pine forests. J. Forestry 49:267.

Weaver, H. 1951. Fire as an ecological factor in Southwestern ponderosa pine forests. J. Forestry 49:93-98.

Weaver, H. 1955. Fire as an enemy, friend and tool in forest management. J. Forestry 53:499-504.

Weaver, H. 1957. Effects of prescribed burning in ponderosa pine. J. Forestry 55:133-137.

Weaver, H. 1959. Ecological changes in the ponderosa pine forest of Warm Springs Indian Reservation in Oregon. J. Forestry 57:15-20.

Weaver, H. 1961. Implications of the Klamath fires of September 1959. J. Forestry 59:569-572.

Weaver, H. 1967a. Some effects of prescribed burning on Coyote Creek test area, Colville Indian Reservation. J. Forestry 65:552-558.

Weaver, H. 1967b. Fire and its relationship to ponderosa pine. Proc. Tall Timber Fire Ecology Conf. 7:127-149. Tall Timbers Res. Sta., Tallahassee, Fla.

Weaver, H. 1974. Effects of fire on temperate forests: western United States. pp. 279-319. In Kozlowski, T.T., and C.E. Ahlgren. Fire and ecosystems. Academic Press.

Went, F.W., G. Juhren, and M.C. Juhren. 1952. Fire and biotic factors affecting germination. Ecology 33:351-364.

Wicker, E.F., and C.D. Leaphart. 1976. Fire and dwarf mistletoe (*Arceuthobium* spp.) relationships in the Northern Rocky Mountains. Proc. Tall Timbers Fire Ecology Conf. 14:279-298. Tall Timbers Res. Sta., Tallahassee, Fla.

Williams, J.T. 1962. Dormancy in *Chenopodium album* L. Appl. Biol. 50:352.

Wolfe, C. E. 1973. Effects of fire on a Sand Hills grassland environment. Proc. Tall Timbers Ecology Conf. 12:241-255. Tall Timbers Res. Sta., Tallahassee, Fla.

Wright E. 1931. The effect of temperatures on seed germination. J. Forestry. 29:679-686.

Wright, H. A. 1971. Effect of fire on North American shrubs. In Proc. of International Symposium on useful wildland shrubs. Utah State Univ., Logan, Utah.

Wright, H. A. 1973. Fire as a tool to manage tobosa grasslands. Proc. Tall Timber Fire Ecology Conf. 12:153-167. Tall Timbers Res. Sta., Tallahassee, Fla.

Wright, H. A. 1974. Effect of fire on southern mixed prairie grass. J. of Range Manage. 27:417-419.

Yarnell, R. A. 1958. Implications of pueblo ruins as plant habitats. MS thesis. Anthropology Dept., Univ. of N. M.

Young, L. D., and J. A. Bailey. 1975. Effects of fire and mechanical treatment on *Cercocarpus montanus* and *Ribes cernuum*. J. of Range Manage. 28:495-497.

APPENDIX

Baseline data for Frijolito Mesa and Cerro Grande

The following tables and figures are included in the Appendix because they do not have any relationship to the fire study. These plots were set up at the request of Roland Wauer to provide baseline data for future studies or in the event of other extensive fires.

Frijolito Mesa. The following tables and figures are associated with Frijolito Mesa: Table 39 provides baseline information on trees and shrubs; Table 40 records herbaceous material; Figure 78 provides a photographic record of the area.

Cerro Grande. The following tables and figures are associated with Cerro Grande: Table 41 provides baseline information on trees and shrubs; Table 42 records herbaceous material; Figure 79 provides a photographic record of the area

Locations for both of these transects and associated plots are noted in Figure 80.