FIRE HISTORY

OF THE

GILA WILDERNESS, NEW MEXICO

by

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ABSTRACT

A data base of fire occurrence was established for the Gila Wilderness by analyzing fire scars and compiling fire records. Cross sections of 44 fire scarred ponderosa pine trees (_Pinus ponderosa_ Laws.) were collected from three study areas. Crossdating of more than 800 individual fire scars revealed that extensive surface fires were a common occurrence prior to 1900. Mean fire intervals for a 250-year period prior to 1900 were approximately four to eight years and fire intervals ranged from one to 26 years. Intensive grazing and fire suppression efforts after 1900 resulted in a sudden decrease in number of fires recorded by the sample trees.

A 72-year record (1909-1980) of fire occurrence in the Gila National Forest was compiled from Forest Service records. The fire records and fire scar evidence suggest a need for continued emphasis on fuels reduction and greater flexibility in the Prescribed Natural Fire program.

CHAPTER 1

INTRODUCTION

Forest fires have long been viewed as a natural enemy of trees. When the U. S. Forest Service was established in 1905, control of wildfires was considered a necessity for successful forest management. Efforts continue today to prevent and control destructive wildfires and to educate the public of the hazards of carelessness with fire. However, this task has become very complex because researchers and managers have gained new understanding of the natural role and importance of fire to forest ecosystems, and this understanding has led to changes in policy and management practices. This new direction has been particularly important to fire management activities in Forest Service Wilderness Areas and in National Parks (Leopold et al. 1963, Heinselman 1980). The Wilderness Act (1964) required that land managers develop programs designed to maintain, and where necessary to restore, the biological naturalness of wilderness. The recognition that many of the plant and animal communities in the Gila Wilderness existed within a regime of naturally occurring wildfires resulted in the implementation of a Prescribed Natural Fire Program in 1974 (Garcia et al. 1979). It is fitting that the nation's first National Forest Wilderness Area (established in 1924) should also be one of the pioneers in the effort to reintroduce fire into wilderness.

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Between the fire seasons of 1974 and 1981, Prescribed Natural Fires (PNF's) burned over 12,000 acres (4,800 ha) within designated areas of the Gila Wilderness. By definition, a Gila Wilderness PNF is a fire ignited by lightning which is allowed to burn only if it is within one of the designated PNF blocks. The "Prescription" for these fires requires that specific fuel, weather and topographic conditions be such that fire is not expected to reach extreme intensities or rates of spread that may result in resource damage, damage to private property, threat to human life or spread beyond the designated PNF area. Meeting these requirements has meant that the Gila PNF program is fairly cautious in its approach to reintroducing fire, and justly so, considering the great consequences of an "escaped fire."

The stepwise development of the Gila PNF program is reflective of an acquired experience with natural fires over the past eight fire seasons. While fire behavior models, fuel models, and burning prescriptions have become increasingly refined, acquisition of basic data on the importance of fire to maintaining natural plant community characteristics has awaited further research.

Observations of on-site conditions following PNF burns lead directly to several questions. For example, numerous seedlings have germinated under some of the old growth stands, possibly because of recently exposed mineral soils. A follow-up fire may be necessary to remove or thin these seedlings, otherwise establishment of stagnated thickets may result. Questions that arise are: How often did fires occur within forests of the Gila Wilderness prior to livestock grazing and fire suppression and how soon should fires occur again within PNF

burns so that natural conditions can be restored? How intense and how large were pre-white settlement fires? Will lightning ignited fires burning under prescriptions that are necessary to avoid conflagration in today's forests return to PNF areas within an interval of time necessary for restoring or maintaining natural conditions?

Answers to these and other questions must be found if the objective of returning fire to the wilderness in order to restore natural conditions is to be met or determined unfeasible. If the so-called "natural role" of fire in the Gila Wilderness is defined by the fire regime that existed before grazing and fire suppression, then a reconstruction of that fire regime is needed.

Heinselman (1980) has defined the elements of a fire regime as: (1) fire type and intensity (crown fires or severe surface fires versus light surface fires); (2) size (area) of typical ecologically significant fires; and, (3) fire frequency or return intervals typical for specific land units. Fire histories are particularly useful for identifying these elements.

Fire frequencies may be computed directly from fire chronologies developed through fire scar analysis (Arno and Sneck 1977, Dieterich 1980a). The size of fires may also be inferred from fire chronologies and forest stand age structure analyses (Clements 1910, Heinselman 1973, Tande 1979).

Intensity of past fires is a more difficult element to identify although reasonable inferences can be made regarding the typical fire types which have characterized the history of forest stands. For

example, fires occurring only once every two or three centuries in forests of even-aged structure were probably high intensity crown fires. Uneven-aged forests with fire histories characterized by periodic fires occurring every few years probably experienced only low to moderate intensity surface fires.

By identifying the fire history and fire regimes for wilderness lands, managers and researchers gain historic and scientific perspective of the importance of fire to the ecosystem through time. This perspective can help in making decisions, formulating objectives and in guiding the implementation of programs designed to restore the natural element of fire to the wilderness.

Study Objectives

The need for quantitative data on the occurrence of wildfires in the Gila Wilderness prompted this investigation. Specific study objectives were as follows:

1. Develop two master tree-ring chronologies to serve as controls for dating of fire scarred specimens.

2. Develop master fire chronologies, by means of fire scar analyses, for each of three study areas (McKenna Park, Langstroth Mesa, and Gilita Ridge).

3. Compile Forest Service records of fire occurrence (number of fires and acres burned per year) for the Gila National Forest for the period 1909 to 1980.

In addition to the development of these three data bases (tree-ring chronologies, fire chronologies, and modern fire records), this

study includes a detailed discussion of their characteristics. It is hoped that this information will be used to answer questions about the pre-white settlement fire regime and help managers define long range objectives for the PNF program.

Description of the Gila Wilderness

The Gila River Forest Reserve (now Gila National Forest) was established in 1899 by Proclamation of President William McKinley. In 1924 Congress set aside approximately 750,000 acres (303,500 ha) as the nation's first Wilderness and Primitive Areas within the National Forest system. Today, the Gila Wilderness, the nearby Aldo Leopold Wilderness, and adjoining Primitive Areas comprise one of the largest areas under wilderness protection in the United States.

Physiography

The Gila Wilderness is approximately 430,000 acres (174,000 ha) in size and encompasses the headwaters of the Gila River (Figure 1). The mountains of the Gila form the Mogollon Plateau which rises southeast of the Colorado Plateau. Hunt (1967) includes the Gila country in the Basin and Range Province, although in some respects the area can be seen as an extension of the Mogollon Rim, which defines the southeastern edge of the Colorado Plateau.

The Mogollon Mountains dominate the western portion of the Wilderness Area, forming steep and rugged slopes on their southern and western sides. To the east of the Gila Wilderness lies the Black Range within the Aldo Leopold Wilderness. The Continental Divide runs along the top of this north-south trending mountain range, separating the Rio
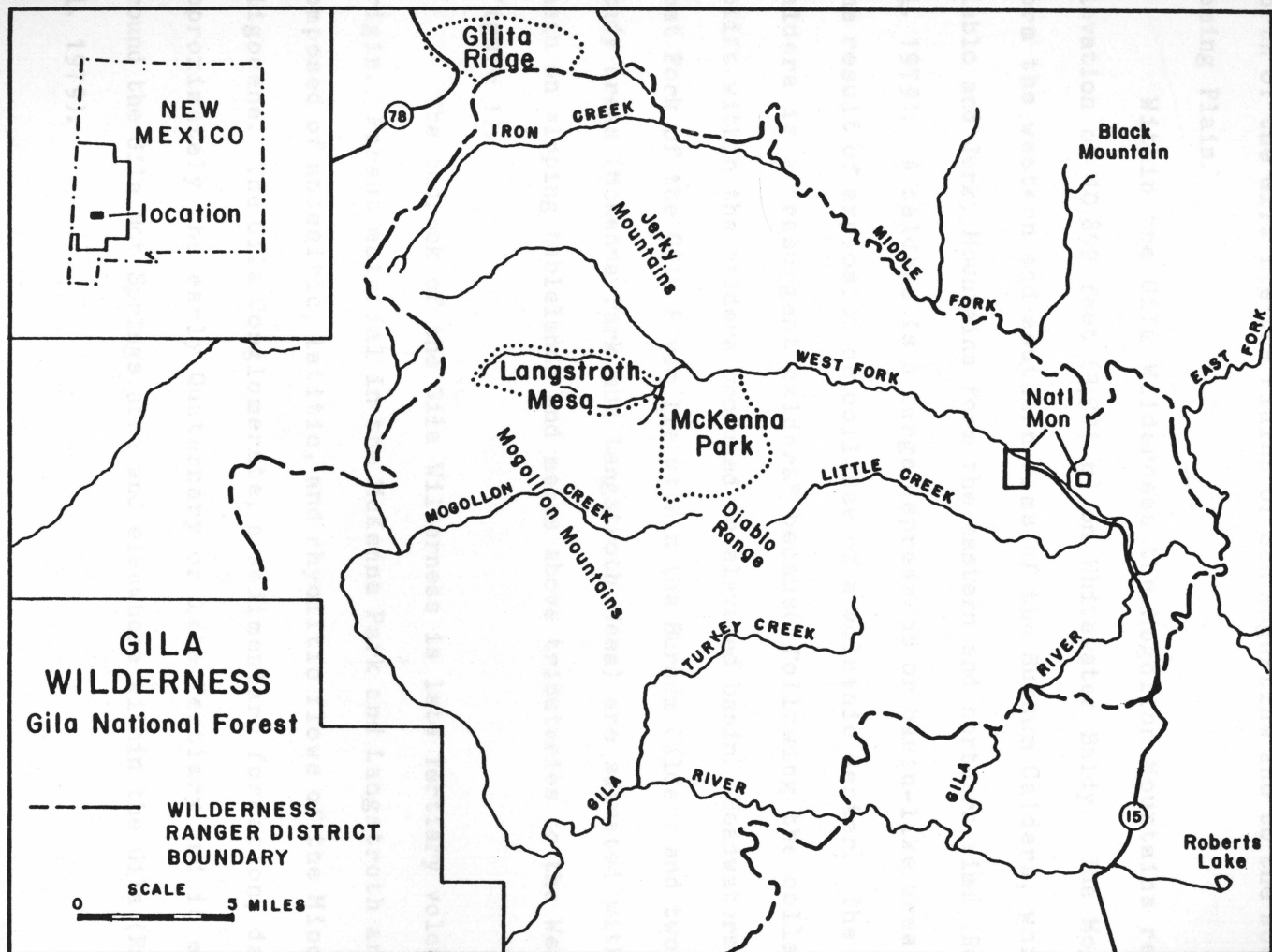
Figure 1. Map of the Gila Wilderness.

Grande Valley to the east from the Gila country to the west. To the north of the Gila lie the Plains of San Augustine and to the south the Deming Plain.

Within the Gila Wilderness the Mogollon Mountains reach an elevation of 10,892 feet (3,321 m) on Whitewater Baldy. The Mogollons form the western and southern rims of the Bursum Caldera, while the Diablo and Jerky Mountains form the eastern and northern rims (Ratte et al. 1979). A caldera is a large depression or basin-like area and is the result of explosion or collapse of a volcanic center. The Bursum Caldera is a "resurgent caldera" because following the collapse an uplift within the caldera produced an elevated basin. Headwaters of the West Fork of the Gila River lie within the Bursum Caldera and two of the study areas (McKenna Park and Langstroth Mesa) are situated within the basin on sloping tablelands and mesas above tributaries to the West Fork (Figure 1).

The bedrock of the Gila Wilderness is late Tertiary volcanic in origin. Parent material in the McKenna Park and Langstroth areas is composed of andesitic, latitic, and rhyolitic flows of the Miocene or Oligocene. The Gila Conglomerate, a sedimentary formation, dates to approximately the early Quaternary or late Tertiary and is exposed around the Gila Hot Springs area and elsewhere within the Gila (Ratte et al. 1979).

Climate

The Gila is mountainous country with variable climate. Annual precipitation varies from a low of 10 inches (25.4 cm) at lower

elevations to a high of 30 inches (76.2 cm) at higher elevations. Precipitation within the study area is estimated to be between 20 and 25 inches (50-64 cm) per year. Mean annual snowfall is estimated to be approximately 75 inches (190 cm) and mean annual temperature is approximately 44 degrees fahrenheit (7° C) (Beschta 1976). Prevailing winds are from the south and southeast.

Thunderstorms develop over the Gila during the summer months, usually as a result of moist air masses from the Gulf of Mexico. Typically, these air masses meet the southern and eastern slopes of the Mogollon Mountains and the Black Range. Rapid orographic lifting produces cumulus clouds and intense electrical storms over the National Forest and Wilderness Areas. The Gila National Forest has one of the highest lightning fire occurrences among any of the National Forests with an average rate of 124 fires per million acres protected each year. The Gila Wilderness may have the highest lightning fire occurrence of any wilderness in the National Forest system with a rate of 252 fires per million acres protected per year (Barrows 1978).

Vegetation

Vegetation of the Gila is about as diverse as can be found anywhere in the Southwest. A gradient of change in species composition can be recognized as elevation increases from around 5,000 feet (1,524 m) in the lower foothills to the south of the Wilderness to over 10,000 feet (3,048 m) in the Mogollon Mountains. Life zones represented include Upper Sonoran, Transition, Canadian, and, in the higher elevations, the Hudsonian. Biotic communities (Brown and Lowe 1980)

represented include Petran Montane Conifer Forest, Petran Subalpine

Conifer Forest, Subalpine Grassland, and Great Basin Woodland. Most of

the area within the Wilderness is within the Transition zone or Petran

Montane Conifer community, where the most common tree species is pond-

erosa pine (Pinus ponderosa Laws.).

Virgin stands of ponderosa pine in the Gila Wilderness are the

most extensive remaining in the Southwest. All three study areas are

located within ponderosa pine habitat types and all of the fire scar

specimens used in this study were ponderosa pine with the exception of

one Douglas-fir [Pseudotsuga menziessii (Mirb.) Franco] specimen

(McKenna Park specimen No. 13).

Ponderosa pine habitat types are similar to those described by

Hanks, Fitzhugh, and Hanks (1977), especially the following types and

phases:

1. Pinus ponderosa/Muhlenbergia virescens habitat type (PIPO/
   MUVI)

   a. Muhlenbergia virescens phase

   b. Quercus gambelii phase

2. Pinus ponderosa/Festuca arizonica habitat type (PIPO/FEAR)

   a. Festuca arizonica phase

   b. Quercus gambelii phase

3. Pinus ponderosa/Muhlenbergia virescens/Festuca arizonica
   habitat type (PIPO/MUVI/FEAR)

   a. Muhlenbergia virescens/Festuca arizonica phase

   b. Quercus gambelii phase

These habitat types are very similar to those described in a classification scheme soon to be published on ponderosa pine habitat types of the Apache/Sitgreaves and Gila National Forests (W. H. Moir, personal communication 1982). The habitat types and phases are typically characterized by grassy understory; however, other portions of the study areas had extensive understory cover of bracken fern (Pteridium aquilinum). These areas are probably included in the mesic border areas of any of the three habitat types.

Large stands of mixed conifer and spruce-fir exist at higher elevations in the Gila and include such species as Douglas-fir, white fir [Abies concolor (Gord. and Glend.) Lindl.], blue spruce (Picea pungens Engelm.), aspen (Populus tremuloides Michx.), and Gambel's oak (Quercus gambelii Nutt.).

Moir and Ludwig (1979) list seven mixed conifer habitat types that are found in the Mogollon Mountains. These authors also list three spruce-fir habitat types found in the Mogollons that which include corkbark fir [Abies lasiocarpa var. arizonica (Merriam) Lemm.] and blue spruce as dominant tree species.

At lower elevations (below 6,500 feet (1,981 m)) extensive stands of pinyon (Pinus edulis Engelm.) and juniper (Juniperus deppeana Steud.), and J. monosperma [Engelm.] Sarg.) are common. Riparian habitats along the major drainages include tree species such as Arizona alder (Alnus oblongifolia Torr.), Arizona sycamore (Platanus wrightii S. Wats.), narrowleaf cottonwood (Populus angustifolia James), and Arizona walnut [Juglans major (Torr.) Heller].

Description of Study Areas

Two study areas were chosen within the Gila Wilderness and a third just outside the Wilderness boundary on National Forest land. Several attributes of the study areas influenced their selection:

1. The study areas are representative of the Gila Wilderness with respect to vegetation and topography.

2. The study areas are within or near approved PNF areas, have experienced PNF burns in the past, and are likely to experience additional fires in the future.

3. The study areas are accessible by road or trail.

The acreage included in the study areas is small relative to the size of the entire Wilderness Area, and tree cover is pure ponderosa pine in most portions of the study areas. Nevertheless, it is felt that information derived from fire scar collections within the study areas provides information on fire regimes that are characteristic of the majority of wilderness lands being managed under the PNF program.

McKenna Park Study Area

McKenna Park is a broad tableland with a gentle slope to the north toward the West Fork of the Gila River (Figure 2). Elevations range from 7,600 to 8,000 feet (2,134 to 2,438 m). The Diablo Range borders the southern and eastern sides of this relatively flat area, and the West Fork and White Creek form the northern and western boundaries respectively.

McKenna Creek and Horse Creek watersheds drain the McKenna Park area. Headwaters of these drainages begin in the foothills of the
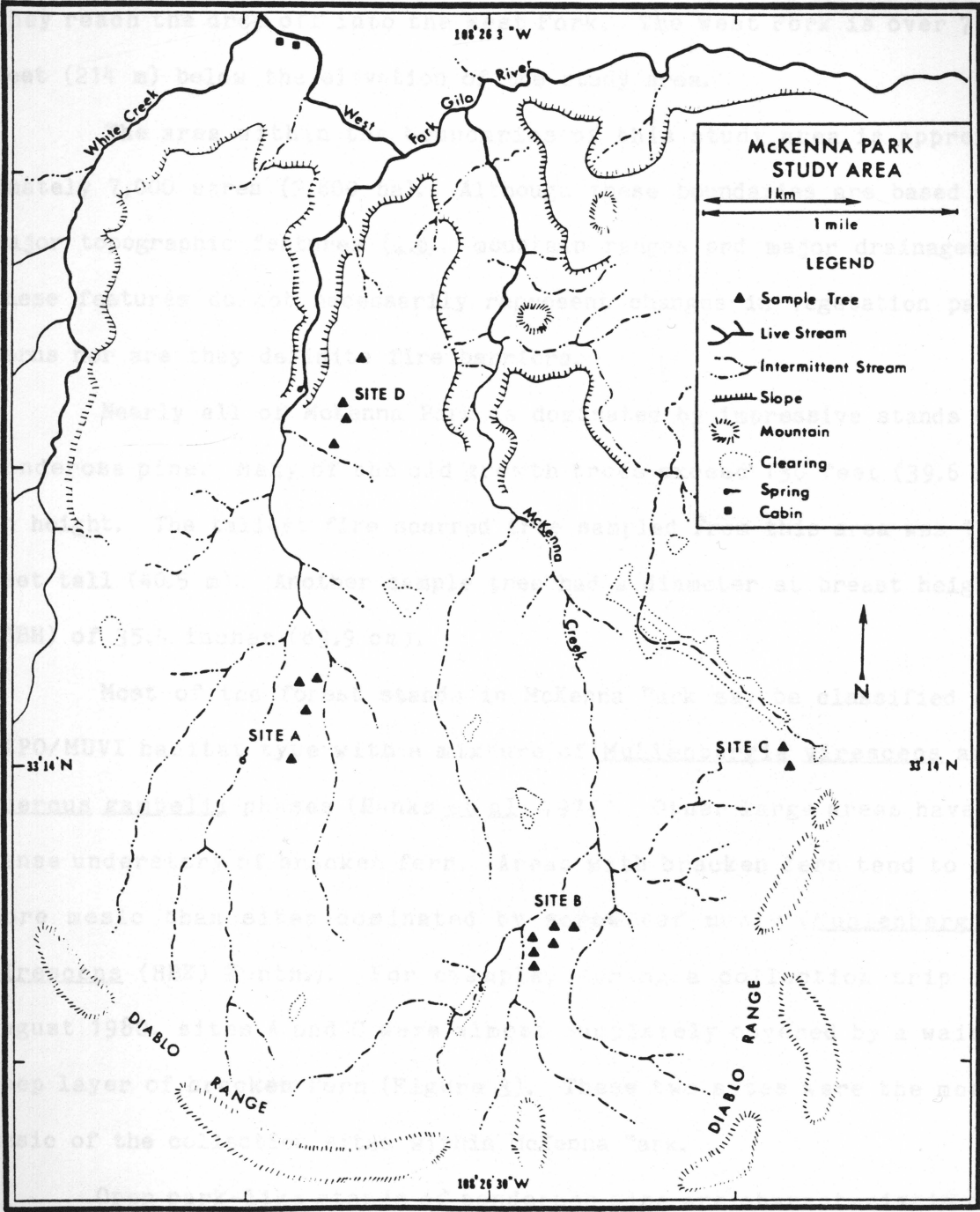
Figure 2. Map of the McKenna Park Study Area.

Diablos and flow northward across the park area. These drainages remain fairly shallow; generally not exceeding 150 feet (46 m) in depth until they reach the drop off into the West Fork. The West Fork is over 700 feet (214 m) below the elevation of the study area.

The area within the boundaries of this study area is approximately 7,000 acres (2,800 ha). Although these boundaries are based on major topographic features (i.e., mountain ranges and major drainages), these features do not necessarily represent changes in vegetation patterns nor are they definite fire barriers.

Nearly all of McKenna Park is dominated by impressive stands of ponderosa pine. Many of the old growth trees exceed 130 feet (39.6 m) in height. The tallest fire scarred tree sampled from this area was 133 feet tall (40.5 m). Another sample tree had a diameter at breast height (DBH) of 35.4 inches (89.9 cm).

Most of the forest stands in McKenna Park may be classified as PIPO/MUVI habitat type with a mixture of Muhlenbergia virescens and Quercus gambelii phases (Hanks et al. 1977). Other large areas have a dense understory of bracken fern. Areas with bracken fern tend to be more mesic than sites dominated by screwleaf muhly (Muhlenbergia virescens (HBK) Kunth.). For example, during a collection trip in August 1980, sites A and C were almost completely covered by a waist deep layer of bracken fern (Figure 3). These two sites were the most mesic of the collection sites within McKenna Park.

Open park-like stands of ponderosa pine are characteristic of most of the McKenna Park area (Figure 4); however, dense stands of saplings occur in scattered groups. These thickets of pine reproduction

Figure 3. Ponderosa pine with bracken fern understory.
This view is looking west across site A in McKenna Park study area.

Figure 4. Open stand of ponderosa pine in McKenna Park.

are most common at the eastern side of the study area within and around site C (Figure 5).

Natural openings are common throughout the park. These openings are often situated in depressions or poorly drained areas, are grass covered, and are usually boggy during wetter periods of the year. Some invasion of pine regeneration into these openings is evident. McKenna Park airstrip, located just northwest of site C, is the largest clearing in the area. Portions of it were natural openings prior to the construction of the airstrip in 1959. It is no longer used as an airstrip and is grown over by grasses.

Langstroth Mesa Study Area

This study area is confined to a mesa top bounded by steep slopes (exceeding 75%) and rock outcroppings on north and south sides (Figure 6). White Creek, one of the largest tributaries of the West Fork, flows southeast down a deep canyon on the north side of the mesa. Langstroth Creek flows southeast down a deep canyon on the south side of the mesa and enters White Creek below the eastern point of the mesa.

The mesa top slopes gently towards the east from an elevation of 8,500 feet (2,591 m) at site C to 7,300 feet (2,225 m) at the eastern point of the mesa. Elevation at the confluence of White Creek and Langstroth Creek is 7,000 feet (2,134 m), or about 600 feet (183 m) below the eastern point of the mesa.

A shallow drainage flows east across the mesa top. The northern and southern slopes of the mesa are steep and rocky. Vegetation is sparse on the southern side and is composed of oaks (Quercus gambelii,
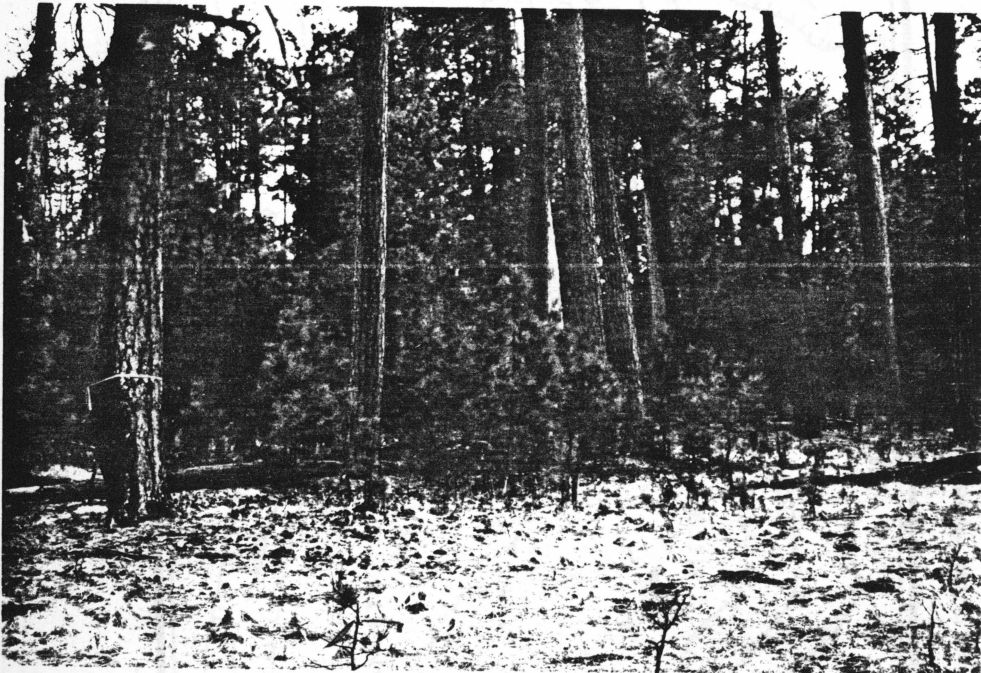
Figure 5. Ponderosa pine thicket under mature trees near site C in McKenna Park.
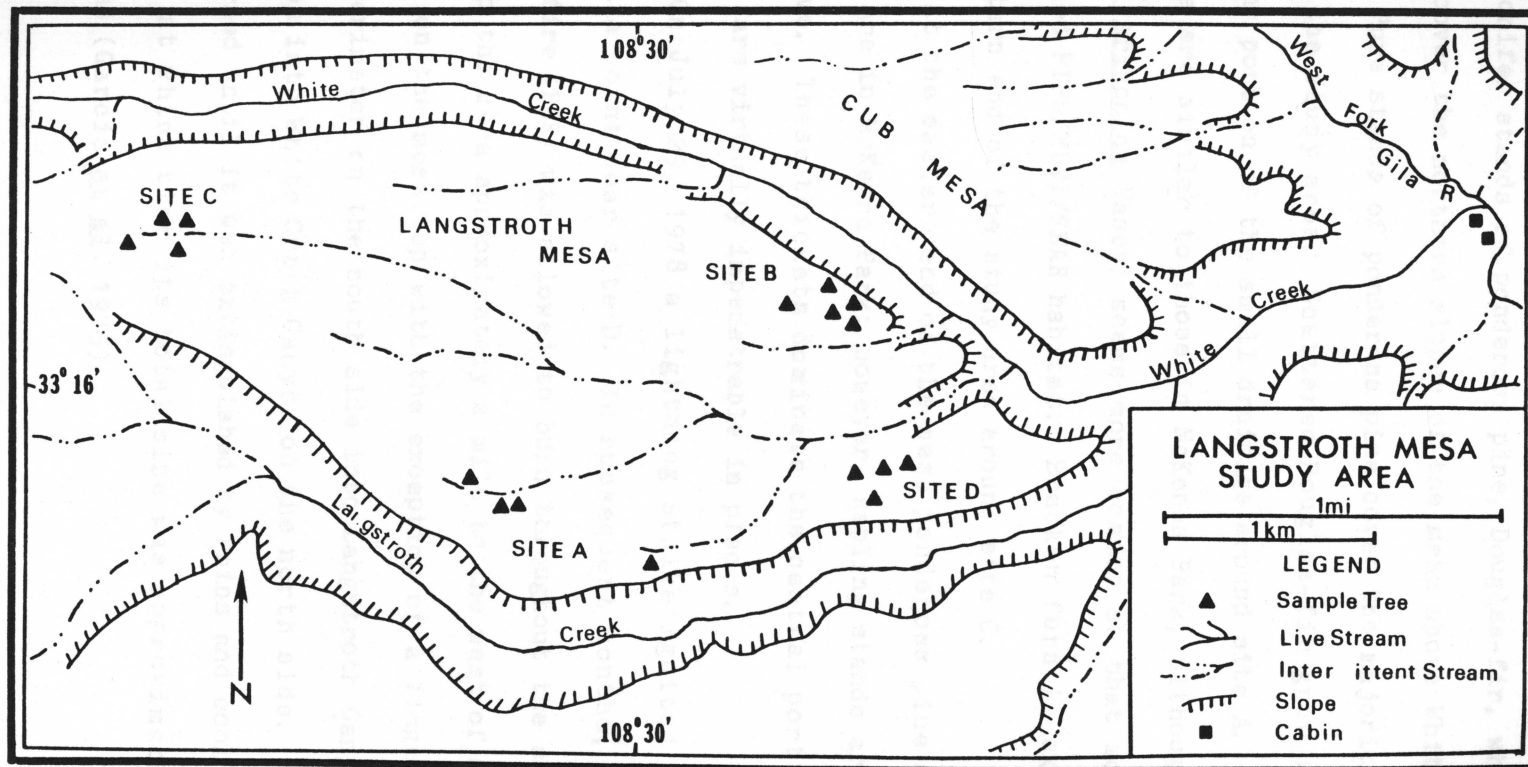
Figure 6. Map of the Langstroth Mesa Study Area.

Q. hypoleucoides A. Camus, and Q. grisea Liebm.) and ponderosa pine.
Mixed conifer stands of ponderosa pine, Douglas-fir, white fir, and blue
spruce cover the northern slopes of the mesa above White Creek.

Pure stands of ponderosa pine cover the majority of the mesa top
within the study area. Scattered Douglas-fir grow within the upper
(western) portion of the small drainage around site A. Habitat types on
the mesa are similar to those in McKenna Park, although Arizona fescue
(Festuca arizonica Vasey) seems more common so that some areas may be
classified PIPO/MUVI/FEAR habitat. Bracken fern is extensive only at
the western end of the study area around site C.

At the eastern end of the mesa ponderosa pine are not as large
as they are in McKenna Park; however, sapling stands are more dense and
extensive. These thickets dominate the central portion of the study
area and are virtually impenetrable in places.

On July 29, 1978 a lightning strike ignited the "Langstroth
Fire" at a point near site D. In subsequent months, this prescribed
natural fire (PNF) was allowed to burn throughout the study area and it
spread up the mesa approximately a mile to the west of site C. The fire
remained on the mesa top with the exception of a finger-like extension
of the perimeter on the south side into Langstroth Canyon and a narrow
extension into White Creek Canyon on the north side. The "Langstroth
Fire" burned until it was extinguished by rains and cool weather in late
October, at which time its total size was approximately 3,200 acres
(1,280 ha) (Garcia et al. 1979).

Gilita Ridge Study Area

Gilita Ridge is located on the Reserve Ranger District just outside the northern boundary of the Gila Wilderness (Figure 7). A group selection cut was carried out in this area in 1978. This area was chosen as a study area for several reasons. First, it is very near to an approved PNF area within the Wilderness where a large PNF burned in 1979 (the "Can Fire" burned approximately 4,200 acres (1,680 ha)). The vegetation and topography of the Gilita Ridge study area are very similar to that within the Wilderness. Finally, easy access to the area by dirt road and the convenience of removing fire scarred cross sections from stumps of harvested trees with chain saw, facilitated rapid sample collection (all other fire scarred material collected within the Wilderness was by means of crosscut saw).

As with the other study areas, Gilita Ridge is primarily a ponderosa pine forest. Elevations are higher than the other study areas and vary between 8,100 and 8,500 feet (2,470-2,590 m). The approximate size of this study area is 5,000 acres (2,020 ha).

To the south is Gilita Creek, Willow Creek, and Willow Creek Campground. The south facing slopes of the ridge above Gilita Creek are moderately steep (50%). The country to the north is very similar to Gilita Ridge and is broken by southeastward flowing drainages.

Grasses are more prevalent in the understory than in the other study areas. Habitat types include all three of the types previously listed. Scattered Douglas-fir and blue spruce are found on the western and northern slopes and a small patch of aspen grows at the head of the small drainage just south of the collection site.

108°35'

GILITA

GILA
N. F.

RIDGE

33°25'30"

Gilita
Creek

Gilita   Creek

GILITA RIDGE
STUDY AREA

1mi

1km

LEGEND

▲ Sample Tree
    Live Stream
    Intermittent Stream
    Slope
    Forest Road
••• Wilderness Boundary
    Spring
■ Cabin

GILA WILDERNESS

Willow   Creek

N

108°35'
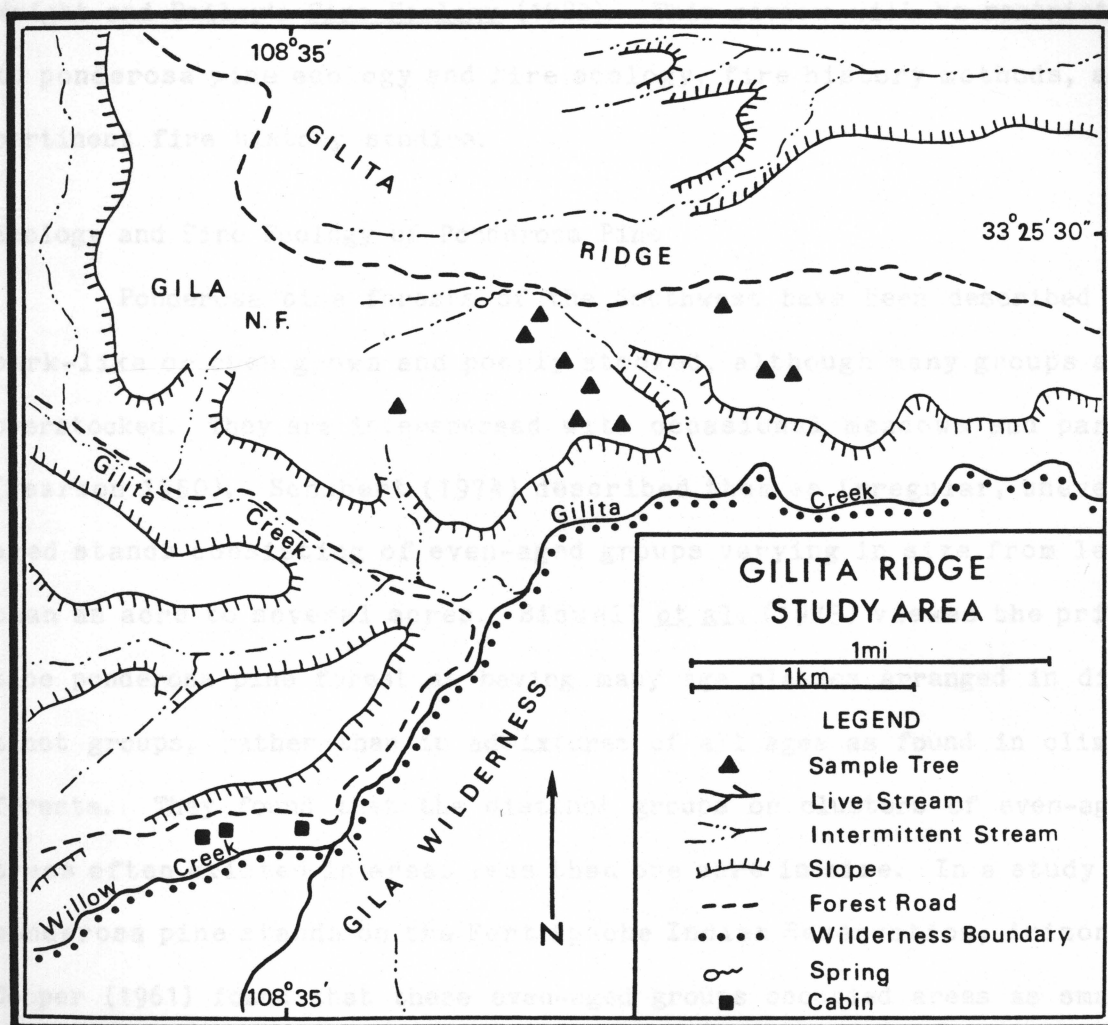
Figure 7. Map of the Gilita Ridge Study Area.

Literature Review

The study of fire and its relationship to biotic communities of the world has provided an ever increasing body of literature. Notable syntheses include Kozlowski and Ahlgren's Fire and Ecosystems (1974) and Wright and Bailey's Fire Ecology (1982). This review will be restricted to ponderosa pine ecology and fire ecology, fire history methods, and pertinent fire history studies.

Ecology and Fire Ecology of Ponderosa Pine

Ponderosa pine forests of the Southwest have been described as park-like or open grown and poorly stocked, although many groups are overstocked. They are interspersed with occasional meadows and parks (Pearson 1950). Schubert (1974) described them as irregular, uneven-aged stands consisting of even-aged groups varying in size from less than an acre to several acres. Biswell et al. (1973) viewed the pristine ponderosa pine forest as having many age classes arranged in distinct groups, rather than in admixtures of all ages as found in climax forests. They found that the distinct groups or clusters of even-aged trees often existed in areas less than one acre in size. In a study of ponderosa pine stands on the Fort Apache Indian Reservation, Arizona, Cooper (1961) found that these even-aged groups occupied areas as small as 1/10 of an acre.

Cooper (1960) felt that the observed pattern of spatial distribution was related to the species intolerance of shade, infrequency of reproduction establishment, and the regular recurrence of wildfires. Successful establishment of ponderosa pine reproduction is infrequent

because a number of critical environmental conditions must coincide (Schubert 1974):

1. A large supply of seed must be available.

2. The seedbed must be well prepared; mineral soil is best.

3. Competing vegetation must be at a minimum (ponderosa pine is shade intolerant).

4. The population of seed eating animals must be low.

5. There must be sufficient moisture for early seedling growth.

Several researchers have stated that the last widespread establishment of ponderosa pine reproduction in the Southwest was in the year 1919 (Pearson 1950, Arnold 1950, Schubert 1974).

The process of development of a ponderosa pine stand, as proposed by Weaver (1951, 1959, 1974) and Cooper (1961), was summarized by Wright (1978, pg. 5):

> Natural succession with fire in the ponderosa pine forest can be envisioned by the following sequence of events: windfall, insect attacks, mortality and then fire. Because of these events, openings are created naturally. Ponderosa pine seeds are blown on to the bare mineral soil of these openings from adjacent areas. Seedlings of ponderosa pine become established most easily on bare mineral soil surface (Schultz and Biswell 1959) in open sunlight (Schubert 1974).

If natural openings are large enough, needlefall from surrounding mature trees does not accumulate around small seedlings. Passing surface fires either do not spread into the openings, or if they do, the intensity of the fire may be so low that mortality of young seedlings is small, resulting in a thinning effect (Cooper 1961, Weaver 1974). Cooper (1960) stated the following hypothesis:

Intensity of fire in very young stands seems to be a self regulating feedback mechanism that provides the needed degree of thinning. Where there are many trees per acre, the volume of dry fuels builds up faster and to greater quantities than where trees are sparse. The greater fuel accumulation in turn supports a hotter fire that thins the stand in proportion to the fire's heat.

In contrast to Cooper's hypothesis, Sackett (1983 Personal Communication) found a larger accumulation of litter under large mature ponderosa pine than under saplings. Thus, the thinning effect of surface fires may be more pronounced in open stands of mature trees than in closed stands of young trees. Regardless of the magnitude of the thinning effect of surface fires in relation to the overstory, it is evident that surface fires helped to maintain the park-like appearance of ponderosa pine stands.

Mutch (1970) suggested that natural selection has favored inherently flammable properties of ponderosa pine foliage. This development would be analogous to allelopathy in other plants.

In addition to the thinning effect of surface fires, lower branches and foliage of surviving trees are often pruned (Hall 1977). Dieterich (1979) found that mature ponderosa pine trees with as much as 80% crown scorch may survive depending on factors such as site conditions and the season when fire occurs. From a management viewpoint, beneficial effects of surface fires includes increase of forage yields (Cooper 1960, Hall 1977), reduction of wildfire hazard (Knorr 1963, Kallander 1969, Wagle and Eakle 1977), and possible control of dwarf mistletoe (Alexander and Hawksworth 1975).

Nutrients in the forest floor are recycled by fire (Vlamis et al. 1955, Wells et al. 1979), although varied responses have been re-

ported, including nitrogen losses due to volatilization (Klemmedson 1976). Wells *et al.* (1979) emphasized the importance of frequency of burning and mitigating effects of management techniques (such as timing of prescription burning) when evaluating long term effects on soil conditions at a given site.

Present Condition of Ponderosa Pine Forests

Researchers and managers have recognized management problems associated with the conditions of some ponderosa pine stands which may be a direct result of grazing and fire suppression. Over thirty years ago Harold Weaver (1951) listed some of the changes which he considered most significant:

1. Dense even-aged stands of pine reproduction have established over the greatest portion of ponderosa pine forests.

2. Dense reproduction stands may in some cases be reducing the growth of the overstory trees.

3. The fire hazard has increased tremendously and is continuing to increase.

Recognition of the importance of fire to the natural ecology of ponderosa pine and possible consequences of the changes observed by Weaver, Cooper, Biswell, and others has led to publication of a number of syntheses of accumulated information, several of which have already been cited (Biswell *et al.* 1973, Weaver 1974, Wright 1978). This information and awareness has also led to a considerable increase in the amount of ponderosa pine acreage treated each year by prescribed fire, although the acceptance of fire as a management tool on a widespread

basis has been a relatively slow process. One of the reasons for delay is lack of information on effects of single and multiple applications of prescribed fire on forest ecosystems (Martin et al. 1979).

Also needed by managers are fire prescriptions designed to meet a wide variety of management objectives. One important input needed for developing prescriptions calling for multiple applications of fire is the frequency of burning (the interval between fires) that is necessary to achieve a specific goal and then to maintain those conditions. This is where fire history information can be particularly useful by providing historic and scientific bases for rotational burning.

Fire History Methods

Fire history studies have relied on several types of physical evidence to reconstruct the fire record. They include pollen and charcoal from lake bed sediments (Swain 1973, Cwynar 1978, Payette 1980), inventories of vegetation characteristics such as stand age class distributions (Clements 1910, Heinselman 1973, Van Wagner 1978, Tande 1979), historical documents (Wellner 1970, Barrows 1978, Burke 1979, Lorimer 1980) and fire scar analysis (Arno and Sneck 1977, Dieterich 1980a). Many fire histories have used a combination of these forms of data.

Alexander (1979, 1980) has compiled a bibliography of fire history studies and a workshop held at the University of Arizona Laboratory of Tree-Ring Research in October 1980 resulted in publication of the proceedings (Stokes and Dieterich 1980). Included in the latter publication is a glossary of fire history terms and definitions

recommended by the participants (Romme 1980). Terminology used in this study conforms to those definitions.

Fire Scar Analysis. The use of fire scars as a means of estimating the interval between fires that have passed through a forest stand has been known to foresters for a long time. A photograph (United States Department of Agriculture Forest Service Region 3 Office Photograph Files 1900) taken by Gifford Pinchot on the Sitgreaves National Forest, Arizona, and dated June 2, 1900, shows a fire scarred tree with a hatchet embedded in a cat face (that is, a large surface scar on a tree caused by fire damage). The caption reads, "Successive fires recorded on a living yellow pine. Successive fires at years from first dead wood inside the living wood, below the bark: First fire at 2 yrs; next at 11 yrs., 9, 9, 10, 11, 8, 3, 6, 10, 9, 7, 5, 5." This is probably the earliest documentation of a fire scar record.

Most early researchers emphasized the loss of timber values related to fire scars because of fungus and insect damage admitted through the lesions (Meinecke 1916, Boyce 1921, Lemon 1937). Others interpreted the evidence of successive fires as proof that pre-settlement forests were maintained in understocked conditions because of fire and that they were being reduced in extent through a process of "attrition" (Show and Kotok 1924).

Some of the first studies which estimated fire dates from fire scars relied on simple ring counts, usually beginning from the outside ring beneath the bark and proceeding in to the fire scar (Boyce 1921, Anonymous 1923, Show and Kotok 1924). Other studies have developed fire

histories by combining ring counting techniques, historic records, and various types of vegetation analysis (e.g., estimating ages of even-aged stands which probably resulted from catastrophic fires) (Clements 1910, Spurr 1954, Heinselman 1973, Houston 1973, McBride and Laven 1976, Hall 1977).

Accuracy of Dating Techniques. Craighead (1927) studied the growth of annual rings of fire scarred trees and fire defoliated trees following a fire in 1924. He found that in some of the sampled trees, annual growth rings failed to form for one or two years following the fire. In a comment attached to Craighead's paper, E. N. Munns emphasized the "inadvisability" of depending too strongly on fire scar dates derived by ring counting because of the possibility of missing rings. Soeriaatmadja (1966) demonstrated this problem in a fire history study of ponderosa pine in central Oregon. Ring counts of ten stumps showed a correct fire scar date of 1938 for a fire known to have occurred at that time, while 17 stumps indicated 1939 and eight carried a date of 1940.

In a re-examination of fire scar data used by Show and Kotok (1924) and Boyce (1921), Wagener (1961) pointed out the various possible sources of error in developing fire histories. He listed several types of environmental stress that may be imposed on trees resulting in temporary cessation of growth, including fire, insect defoliation, drought, and lightning. He concluded that a more accurate estimate of fire dates could be achieved by examining the data from a large number of samples and choosing the consensus data as the one most likely to be accurate.

A method similar to that proposed by Wagener has been developed by Arno and Sneck (1977). This method involves the removal of wedge

sections from living fire scarred trees, ring counting, vegetation analyses, and development of a master fire chronology by "adjustment" of ring counts for better correlation of fire dates. This method recognizes the problem of missing and false rings and proposes to account for them by relying on samples with the "clearest" annual ring sequences and careful adjustment of dates for trees that are consistently out of synchrony with dates for adjacent trees. Many recent studies have utilized this technique or modified versions of it (Arno 1976, 1980, Davis 1980, Barrett 1981, Kilgore and Taylor 1979, Tande 1979, Hawkes 1980, Madany 1981, Moir 1982).

Crossdating and Accuracy. In the 1920's A. E. Douglass developed a technique for precisely dating annual rings of trees, and in 1934 he established the Laboratory of Tree-Ring Research at the University of Arizona in Tucson, Arizona. Douglass' tree-ring dating technique, known as crossdating, sparked a revolution in Southwestern archeology. For the first time it became possible to accurately date the construction of many of the ancient ruins of the Southwest, including those of Mesa Verde and Chaco Canyon (Douglass 1935). Since that time, tree-ring dating and tree-ring analysis, or dendrochronology, has been applied to a variety of scientific disciplines (McGinnies 1963, Anonymous 1977).

Harold Weaver first delivered fire scarred specimens from Forestdale, Arizona to Douglass at the Laboratory of Tree-Ring Research in 1950. These specimens, and subsequently numerous others, were dated for Weaver (1951). Only a few individuals other than Weaver have utilized crossdating to develop fire histories (Keen 1937, Ahlstrand 1980,

Dieterich 1980a, 1980b, Fox and Potter 1980, Laven et al. 1980, Alexander 1980).

Madany, Swetnam, and West (1982) compared two methods of dating fire scar specimens. A subset of the specimens used to develop a master fire chronology for a study area in Zion National Park, Utah (Madany 1981) was dated by crossdating and by the adjustment technique (Arno and Sneck 1977). Only 26% of the fire dates arrived at by the two techniques were in agreement. In other words, if the crossdating technique was accurate to the year in dating fire scars, then 74% of the fire dates arrived at by the adjustment technique were in error. The differences between fire dates arrived at by these two methods illustrates the need for crossdating where it is possible, and when a data base of greater resolution of accuracy is needed.

Dieterich and Swetnam (In Press) emphasized the need for more accurate fire dates where the data is to be used in fire/climate correlation studies or for comparison of fire dates between study areas. If fire dates are off by one or two years, possible correlations may not be observed. The crossdating technique may also be needed for developing fire histories in forest types where typical fire intervals are short (two to ten years) and consecutive-year fires are possible. In such cases, the validity of adjusting fire dates for better correlation becomes questionable.

Southwestern Ponderosa Pine Fire Histories. Table 1 is a summary of selected fire histories that have been developed for areas in the Southwestern United States. The format of this summary is similar to one compiled by Madany (1981). Most of these studies involved pure

Table 1. Presettlement fire intervals of selected Southwestern forest ecosystems. Dominant overstory species abbreviations: _Pinus ponderosa_ = PIPO, _Pseudotsuga menziesii_ = PSME, _Pinus strobiformis_ = PIST, _Pinus cembroides_ = PICE, _Cupressus arizonica_ =CUAR, and _Juniperus deppeanna_ = JUDE.

Authors	Location	Dominant Overstory Species	Sample Size	Fire Intervals Mean (Years)	Fire Intervals Range (Years)	Date of Fire Decline
Weaver (1951)	White Mtn. Apache Ind. Res., E. Arizona	PIPO	3	5.7	1-16	1900
	San Carlos Apache Ind. Res., E. Arizona	PIPO	1	6.9	3-16	1943
	Kaibab Nat'l Forest, N. Arizona	PIPO	1	9.8	3-23	1885
Dieterich (1980a)	Ft. Valley Expt. Stn., N. Central Arizona	PIPO	7	2.4	1-17	1876
Dieterich (1980b)	Long Valley Expt. Stn., N. Central Arizona	PIPO	9	1.8	1-10	1900
	Apache/Sitgreaves Natl Forest, E. Arizona	PIPO/PSME	31	21.7	2-28	1900
	San Juan Nat'l Forest, SW Colorado	PIPO	10	3.9	2-4	1900
Fox and Potter (1980)	Bandelier Nat'l Monument, N. Central New Mexico	PIPO	Unknown	17.0	8-27	1893
Ahlstrand (1980)	Guadalupe Mtns Nat'l Park, SW Texas	PIST/PSME	48	17.4	6-30	1922
Madany (1981)	Zion Nat'l Park, SE Utah	PIPO	119	5.5	1-25	1900
Moir (1982)	Chisos Mtns, W. Texas	PICE/CUAR/JUDE	40	70.0	9-60	1940

ponderosa pine forests (Weaver 1951, Dieterich 1980a, 1980b, Fox and Potter 1980, Madany 1981), while others included mixed conifer stands (Dieterich 1980b, Ahlstrand 1980) and pinyon-juniper (Moir 1982). Mean fire intervals, or the average time in years between fires, are listed for each study. The approximate range of fire intervals found in each study are also listed. The mean and range of fire intervals found were in some cases derived from one sample and in other cases were derived from composite records of many samples. Several of the studies did not explicitly describe the range of fire intervals, and mean fire intervals were often only listed by subperiods and subunits within larger study areas. The values for fire intervals in Table 1 are, therefore, comparable only in a general way.

Mean fire intervals for Southwestern ponderosa pine vary from as short as 1.8 years (Dieterich 1980b) to as long as 17 years (Fox and Potter 1980). Other ponderosa pine fire histories, in the Southwest and elsewhere, have generally found mean fire intervals that range from two to 30 years; longer intervals being found in mixed conifer types (Dieterich 1980b, Kilgore and Taylor 1979, McNiel and Zobel 1980), and in pure ponderosa pine stands growing in the Northwest (Soeriaatmadja 1966). Laven et al. (1980) reported the longest mean fire interval, 45.8 years, for a stand of ponderosa pine growing in the Colorado Front Range. These authors also pointed out the necessity for caution when interpreting mean fire interval data because of decreasing evidence of fire in earlier portions of the record and confounding of the natural fire regime by Indian and White settlement impacts.

Several features of ponderosa pine fire histories appear to be in common: (1) the record of periodic fires declines or ends around 1900 when grazing and fire control began, (2) mean fire intervals are relatively short compared to other types (_e.g._, hemlock-cedar), and (3) most presettlement fire regimes were characterized by frequent low intensity fires (Kilgore 1981).

Despite these apparent similarities, it is evident that for different study areas, there is variation in mean fire intervals on the order of decades. The explanation for such differences probably lies in a combination of factors that are unique to specific areas, including climate, site productivity, and impacts of human activities. Sample size of fire scar collections and amount of area included within collection sites may also affect mean fire interval calculations.

Since there is a possibility of significant variation in fire history of ponderosa pine, and within other types, the development of fire histories for specific locales is especially desirable where the natural role of fire is to be restored or simulated.

CHAPTER 2

MASTER TREE-RING CHRONOLOGIES

Assigning accurate dates to annual growth rings is not merely a simple matter of counting back from a known bark date. Tree growth is dependent on the availability of water, nutrients, light, and other macro- and micro-environmental factors. If any one of these factors or a combination of them is at a minimum or maximum level that is tolerable to the tree, then photosynthetic processes will be reduced and cambial growth may cease. Obviously, if a tree experiences such severe stress during its lifetime that cambial growth ceases along portions of the bole for a year or more, then the number of annual rings present at those positions will be less than the actual number of years that have passed. Locally absent or missing rings are not an uncommon phenomenon in stressed trees, especially where a growth factor such as water is limiting. For this reason, simple ring counts are generally not reliable for accurate dating purposes.

Intra-annual rings or false rings are another source of error in simple ring counts. False rings may be mistaken for actual rings because a band of latewood-type cells may form during the growing season and subsequently the tree may resume growing earlywood-type cells. Thus, it may appear that two annual rings are present when actually there is only one.

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The problem of missing and false rings may be circumvented by crossdating. Douglass (1941) defined crossdating as the comparison together of like ring patterns in different trees and the selection of the exact place where correspondence between them is found. The need for accurate dating of the fire scarred specimens collected in this study required the technique of crossdating with a master tree-ring chronology which served as a dating control.

A master tree-ring chronology is a set of yearly indices of tree growth for a specific geographic area and time period. The purpose of this chapter is to describe the process of developing two master tree-ring chronologies for the Gila Wilderness and the characteristics of these chronologies.

Master tree-ring chronologies were considered dating controls because: (1) chronologies were developed from crossdated and measured ring sequences in which all missing and false rings were accounted for, (2) biological growth trends were removed by the process of standardization, therefore tree growth as expressed in indices was relatively independent of tree age, and (3) increment cores used in developing the chronologies were from trees with no visible fire scars, therefore the indices were relatively independent of the effects of fire compared to the fire scarred specimens.

Site Descriptions

McKenna Park Chronology

Increment cores were taken from selected ponderosa pine trees near and within proposed fire scar collection sites of both the McKenna

Park and Langstroth Mesa study areas. Characteristics of these study

areas are described in Chapter 1. One of the reasons for sampling these

trees was to determine if the proposed collection sites contained trees

which could be crossdated. As it turned out, nearly all of the sites

had trees with crossdatable ring series. Since the McKenna Park and

Langstroth Mesa study areas are geographically close to one another and

the tree-ring series of the two areas are very similar, data from the

measured cores were merged into one chronology.

White Creek Chronology

Trees that were sampled for this chronology are located north-
west of the confluence of White Creek and the West Fork of the Gila

River. This site is a steep south facing slope (approximately 75%) of

the West Fork canyon and is just north of White Creek Cabin. This cabin

is indicated at the top of the McKenna Park map (Figure 2).

All of the sample trees were Douglas-fir. These trees are

growing within a mixed conifer stand consisting of Douglas-fir, ponder-

osa pine, and an occasional white fir. Gambel's oak and New Mexican

locust (Robinia neomexicana A. Gray) are also present in the understory.

Methods

The methods of tree-ring dating, analyses, and chronology build-

ing have been described by a number of authors (Douglass 1941, Stokes

and Smiley 1968, Ferguson 1970, Fritts 1976). This section presents a

short description of these methods as they were applied to this study.

The skeleton plotting technique used to date the increment cores was the

same as that used to date the annual rings of the fire scarred speci-
mens.

Site Selection

In the southwestern United States and in many other arid, semi-
arid, and temperate regions of the world, variation in the width of
annual growth rings of trees is related to climatic factors (Fritts
1976). This relationship is pronounced in trees whose growth is limited
by temperature and the amount of water they receive through precipita-
tion. Such trees are said to be climatically sensitive, whereas trees
whose growth is not necessarily limited by temperature or precipitation
may be termed climatically complacent.

In order to develop climatically sensitive tree-ring chronol-
ogies, dendrochronologists seek out trees and collection sites which
have certain characteristics. The oldest trees available are usually
preferred for sampling because longer chronologies can be developed from
them. The best sites are often at the lower or upper elevational limits
of the tree species of interest and are typically situated on steep
slopes that do not retain soil moisture.

Collection of the McKenna Park increment cores did not strictly
follow the usual procedure of locating climatically sensitive tree-ring
sites because there was the additional objective of testing the tree-
ring characteristics of the potential fire scar collection sites. The
White Creek site is a more typical tree-ring site. It is situated on a
steep south-facing slope, and the Douglas-fir trees growing there appear
to be relatively old.

Collection of Increment Cores

Increment cores were taken from 15 trees in each of the two collection areas. Two cores were taken from each tree at approximately breast height or lower and usually from the side of the tree parallel with the contour of the slope (i.e., not from the up or down slope sides of the tree). Increment cores were placed in paper drinking straws and labeled. Specimen cards were filled out which included information on characteristics of each tree (lean degree, lean direction, height, diameter, crown description), characteristics of the site (associated species, stand density, soil type, soil depth, percent slope, slope aspect), and position of the cores relative to the bole of the tree.

Laboratory Preparation of Cores

Cores were removed from the paper straws and mounted in grooved wooden holders with tracheid cells aligned vertically. Each core was sanded by hand with sandpapers of increasing fineness of grit (from 120 to 400 grit).

Crossdating

Skeleton plotting is one way that annual ring widths are graphically represented for the purpose of crossdating. Stokes and Smiley (1968) describe the skeleton plotting technique in detail through words and by a series of excellent diagrams. Figure 8 demonstrates the crossdating between skeleton plots constructed from specimens collected in this study.
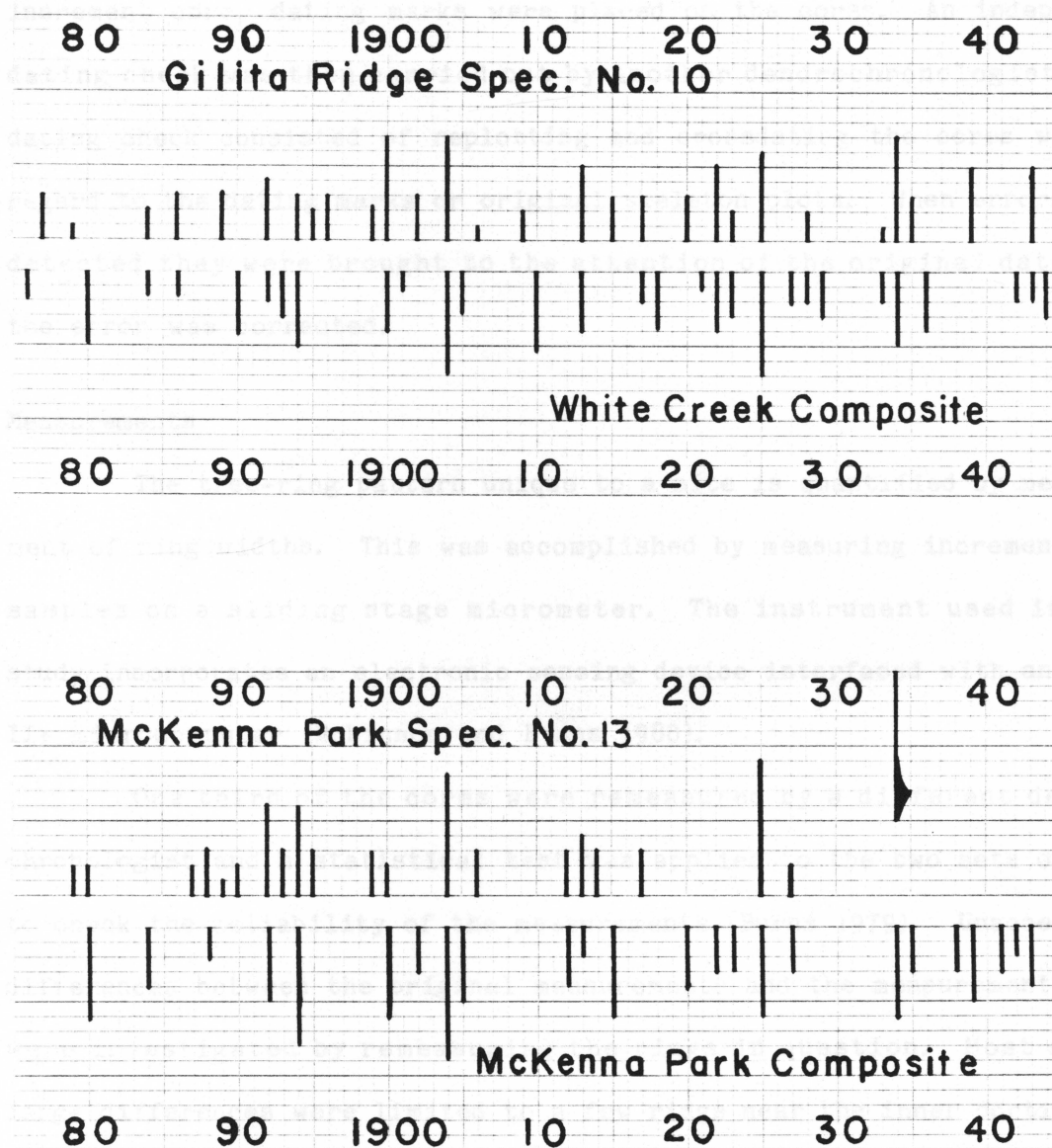
Figure 8. Crossdating with Skeleton Plots. Correspondence between plots of fire scarred specimens and composite plots derived from increment core collections is shown. Each line represents a smaller than average ring; the longest lines represent the smallest rings.

After missing rings and false rings were identified for each increment core, dating marks were placed on the cores. An independent dating check was then carried out by another dendrochronologist. The dating check consisted of replotting and crossdating the cores without regard to the dating marks or original skeleton plots. When errors were detected they were brought to the attention of the original dater and the error was corrected.

Measurements

The tree-ring pattern unique to a site is quantified by measurement of ring widths. This was accomplished by measuring increment core samples on a sliding stage micrometer. The instrument used in this study incorporates an electronic sensing device interfaced with an Apple II+ microcomputer (Robinson and Evans 1980).

One third of the cores were remeasured by a different dendrochronologist and a statistical test was applied to the two sets of data to check the reliability of the measurements (Burns 1979). Unacceptable differences between the original measurements and the measurement check were investigated by remeasuring the rings in question. Most of the large differences were limited to a few rings near the inner portions of a few cores. These differences were usually due to indistinct or irregular ring boundaries and not to measurement error. It was decided that the original measurements were acceptable.

Standardization

Standardization of tree-ring series is a procedure by which biological growth trends are removed. Because of processes of aging and

increase in tree circumference with age, ring widths tend to become narrower as the tree becomes older. In other words, the widths of annual rings near the pith tend to be relatively large and the rings near the outside or the bark tend to be relatively small. When the ring widths of a tree-ring series is plotted it typically has a descending or j-shaped curve with yearly fluctuations about this curve. Variation tends to be greater around the early portion of the curve (near the pith) than around the later portion (near the bark). In the standardization process a curve is fit to each measured series and then each ring width is divided by the corresponding value of the curve. The result is a set of growth indices which vary about the mean index value of the series which is approximately 1.00. The inhomogeneous variance of the raw ring widths (greater variance near the pith) is removed by this process and each index value is comparable to all other index values. For the White Creek and McKenna Park ring width series, either a straight line of negative slope or a negative exponential curve was fit to the data. After indices of individual trees were computed in this manner, they were averaged to produce a mean chronology for the collection site. The procedures of standardization were accomplished by computer programs (RWLIST, INDEX, SUMAC) which are described by Graybill (1979).

Results and Discussion

Master Tree-Ring Chronologies and Their Characteristics

Plots of the McKenna Park and White Creek chronologies are

presented in Figure 9. Index values for each year of the chronologies are listed in Appendix A. Statistics computed by the SUMAC program are listed in Table 2. These statistics describe the basic variance characteristics of the White Creek and McKenna Park chronologies.

First-order autocorrelation measures the correlation of a mean index value and the value of the preceding index (serial correlation). This value usually reflects growth persistence due to biological factors such as accumulation or depletion of stored food reserves. Mean sensitivity is a statistic developed specifically for tree-ring analyses and is a measure of average relative year to year variability in the indices. The standard deviation measures the dispersion of index values about the mean index of the entire chronology. The standard error measures how much variation there is in the mean value of individual indices from the true population mean for that year. Percent absent rings refers to rings that were missing from the measured radii of the specimens.

Tree-ring chronologies with high mean sensitivity, high standard deviation, and low autocorrelation have the best potential for dendroclimatic analyses (Schulman 1956, Fritts and Shatz 1975). The White Creek and McKenna Park chronology statistics were compared with a summary of statistics from selected western United States tree-ring chronologies (Fritts and Shatz 1975) to assess their dendroclimatic potential.

The mean of mean sensitivities for a set of 44 Douglas-fir (PSME) chronologies was 0.377 and for a set of 21 ponderosa pine (PIPO) chronologies was 0.348. Mean sensitivities of the White Creek
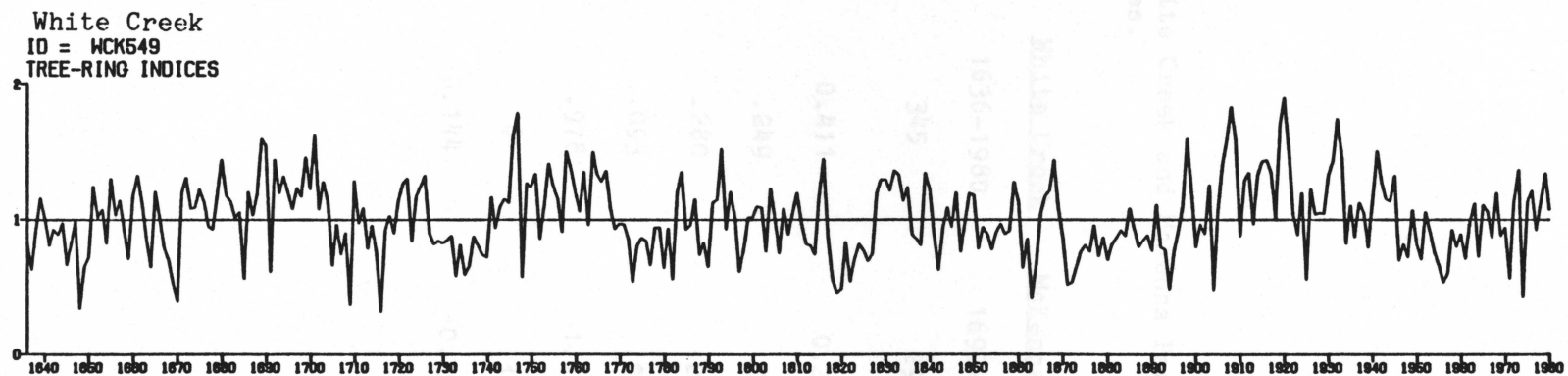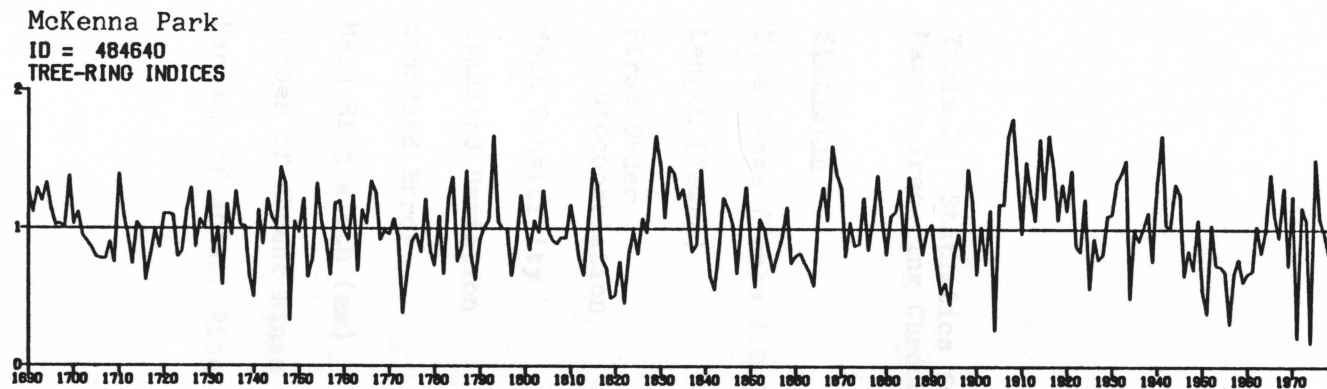
Figure 9. Plots of White Creek and McKenna Park Tree-Ring Indices.

Table 2. Statistics for White Creek and McKenna Park
Master Tree-ring Chronologies.

Statistic	White Creek	McKenna Creek
Time Range (Years A.D.)	1636-1980	1690-1979
Length (Years)	345	290
First Order Autocorrelation	0.411	0.256
Mean Sensitivity	.249	.286
Standard Deviation	.280	.281
Standard Error	.093	.077
Mean Ring Width (mm)	.978	1.470
Number of Absent Rings	6	30
Percent of Absent Rings	0.144	0.752

chronology (PSME) and McKenna Park chronology (PIPO) were 0.249 and 0.286 respectively. Mean sensitivity of the White Creek chronology was within two standard deviations of the mean, while mean sensitivity of the McKenna Park chronology was within one standard deviation of the mean. The fact that the McKenna Park chronology was less sensitive than average was not surprising because most of the specimens were growing in a fairly mesic environment. The White Creek specimens were initially expected to yield a more sensitive chronology because they were growing on a steep south-facing slope. One possible explanation for low mean sensitivity at this site may be that the soil was deep and retained water well enough that tree growth was not highly limited by precipitation.

First-order autocorrelation for the selected chronologies were 0.400 for PSME and 0.452 for PIPO. The White Creek chronology had a value of 0.411 and the McKenna Park chronology had a value of 0.256. The White Creek chronology was therefore very close to average while the McKenna Park chronology was much lower than average. This seems to indicate that growth of Douglas-fir trees at the White Creek site was somewhat dependent on previous conditions (although only slightly more than average) while growth of ponderosa pine trees in McKenna Park was relatively less dependent on previous conditions. Reasons for this difference are not apparent.

Mean standard deviations for the selected chronologies were 0.393 for PSME and 0.366 for PIPO. Both White Creek and McKenna Park chronologies were lower than these values with standard deviations of

0.280 and 0.281 respectively. These values are within two standard deviations of the means of the selected chronologies.

Lower than average standard deviations and mean sensitivities, compared to selected western chronologies, seems to indicate that the Gila chronologies may not be particularly good dendroclimatic data bases. On the other hand, the primary purpose of these collections was to serve as a dating control for the fire scar specimens, and as such they served adequately.

CHAPTER 3

MASTER FIRE CHRONOLOGIES

Detailed written records of fire occurrence in the Gila Wilderness began when the Forest Service initiated organized fire control in the early 1900's. Prior to this time, only scattered references to fires in the Gila can be found in journals and survey reports (Pattie 1905, Rixon 1905). There is, however, another source of available information. It is the record of fire that exists within fire scarred trees. This chapter describes the methods utilized to collect and analyze fire scar samples from three study areas within the Gila Wilderness and the resulting fire chronologies for each area. Each fire chronology and its unique characteristics are described.

Methods

The three study areas (McKenna Park, Langstroth Mesa, and Gilita Ridge) were described in Chapter 1 under "Description of Study Areas." The reasons for selecting these particular areas for study was also presented.

Selection of Collection Sites and Specimens

The process of selecting collection sites within each study area began by examining topographic maps and aerial photographs. Reconnaissance routes were drawn on the maps so that a transect of the various habitat types and other features of the study areas would be observed by

traveling along the route. Three days were spent in each study area traveling reconnaissance routes on horseback. Photographs were taken and notes were kept on observations of habitat types, topography, and distribution of fire scarred trees. Potential sample trees along the routes were examined and those with a large number of visible and well preserved scars were flagged with plastic ribbon.

During a second reconnaissance trip to the study areas, the increment core collections described in Chapter 2 were taken. These collections served two purposes: (1) they revealed the sensitivity of tree-ring series within potential collection sites, and (2) they provided specimens for development of master tree-ring chronologies which would serve as a dating control. All of the potential collection sites were found to be suitable for dating fire scarred specimens. The McKenna Park master tree-ring chronology was developed from these increment core collections.

Four collection sites were established within McKenna Park and Langstroth Mesa study areas and one within the Gilita Ridge study area. Each collection site represents slightly different environmental features that are present within the study areas (Table 3). The collection sites are generally well representative of the study areas. Only one site was established for Gilita Ridge because of time limitations for completing field work. This site includes more area than sites in the other study areas and all ten fire scar samples collected from Gilita Ridge were within this site.

Table 3. Description of Collection Sites Within Study Areas.

McKenna Park

| | No. of Specimens[1] | | | | Topography | |
Site	Live	Dead	Total	Elevation	Aspect	Slope (%)
A	3	1	4	7,760 feet (2,365 m)	NE	0-5
B	5	1	6	7,800 feet (2,377 m)	SW	5-100
C	2	0	2	7,700 feet (2,347 m)	Flat	-
D	0	4	4	7,640 feet (2,329 m)	NW	5-20
	10	6	16			

Langstroth Mesa

| | No. of Specimens[1] | | | | Topography | |
Site	Live	Dead	Total	Elevation	Aspect	Slope (%)
A	5	0	5	8,000 feet (2,438 m)	N & S	5-10
B	1	3	4	7,800 feet (2,377 m)	Flat	-
C	2	2	4	8,400 feet (2,560 m)	E	0-5
D	3	2	5	7,800 feet (2,377 m)	Flat	-
	11	7	18			

Gilita Ridge

| | No. of Specimens[1] | | | | Topography | |
Site	Live	Dead	Total	Elevation	Aspect	Slope (%)
A	0	10	10	8,300 feet (2,500 m)	S	0-5

[1]Dead specimens were collected from snags, downed logs, and stumps.

Sampling Strategy. There were several reasons for collecting fire scar samples from localized sites rather than collecting in a random or stratified random pattern. Researchers have found that more complete fire history data for an area can be obtained by sampling fire scar trees in groups or clusters of two or more (Kilgore and Taylor 1979, Madany 1981). Since trees do not incur scars from every fire that has burned around their base, a composite record including data from neighboring fire scarred trees provides a more complete record than the record of any individual tree (Dieterich 1980b, Dieterich and Swetnam In Press).

Another reason for sampling by collection site within larger study areas was that the number of live trees and snags that could be felled within the study areas was limited according to mitigation procedures specified in the Environmental Assessment Report prepared for this study (Swetnam 1980). Because the number of samples that could be taken was limited, it was imperative that the information content of each sample be maximized. By sampling intensively in collection sites within each study area, it was felt that more complete information would be obtained than by sampling less intensively over the entire study area. Even if a complete record of fire occurrence over the entire study area was not revealed by this strategy, at least a more complete record of fire occurrence within collection sites would be obtained. Finally, by selecting sites of different topographic and vegetative characteristics that were representative of the study areas, then any differences in fire regimes between sites would be detected.

Selection of Fire Scar Specimens. The strategy of specimen selection was to sample fire scarred trees that had the most fire history information. This strategy recognized the fact that some trees were better recorders of passing fires than others. There are many possible explanations of this phenomenon (e.g., rates of fuel accumulation around the base of the tree, amount of pitch exuded from wounds, lean of the bole, etc.) but, regardless of the reason that some trees scarred more consistently than others, this fact did not influence the fire history of the collection sites. Fires would have burned through the collection sites whether any trees recorded them or not. Sampling fire scarred trees with the highest number of well preserved scars within collection sites increased the chances for obtaining a more complete record.

Fire scar samples were selected by examining the catface and counting the number of healing ridges of callus that are characteristic of fire scars (Figure 10). Samples chosen were living trees, snags, and downed logs that had the largest number of visible and well preserved fire scars, were relatively free of rot or insect damage, and were not excessively large.

Several of the fire scarred trees apparently had incurred many more fire scars than those that remained visible, but subsequent fires had burned into the catfaces and removed all evidence of earlier fires except for a few fragile charcoal remnants. Several potential specimens were rejected because they were too large to cut with the crosscut saw in a reasonable length of time. The largest samples (38 and 39 inches) (96.5 and 99.1 cm) DBH required nearly a half day's work to fell and remove a cross section sample.

Figure 10. Fire Scarred Tree in McKenna Park, Specimen No. 8.

Collections

The Environmental Assessment stipulated that only primitive methods of collection would be allowed within the Gila Wilderness. The McKenna Park and Langstroth Mesa study areas are over 20 miles by trail from the Gila Cliff Dwellings National Monument, so all tools and supplies were packed in and out of the Wilderness by mule. Cross section samples were also packed out of the Wilderness by mules.

Collections within the Wilderness required two ten-day trips and one five-day trip. The Gilita Ridge collection required one day's travel by road and one day of field work. Including reconnaissance trips, the total time devoted to field collections was approximately 40 days for two researchers.

All of the specimens obtained from within the wilderness were felled and bucked with two-man crosscut saws. The process was difficult, and at times hazardous, because of the peculiarities of fire scar trees. Buttresses or swellings often form at either side of catfaces and rot and insect damage are common. Special cuts were usually required for safe felling and also to preserve the portion of the bole where the cross section sample was to be taken.

Procedures used in felling and bucking fire scar trees included the following steps:

1. The catface was examined to determine where the best cross section sample could be taken. This involved deciding where on the bole a two or three inch (5.1 or 7.6 cm) thick cross section would include the most number of fire scars from both sides of the catface.

2. Some trees had very fragile evidence of fire scarring.

Healing ridges are often the best evidence of a fire scar and if they break off, there may or may not be any sign on the cross section that can be positively identified as a fire scar. The crosscut saw had a tendency to rip or pull off these fragile ridges as it passed through the wood in their vicinity. This problem was avoided by carefully cutting through the ridges with a small bow saw and then finishing with the crosscut saw.

3. When possible, the pie cut or wedge cut was placed below the portion of the stem where the cross section was to be cut so that the sample could be bucked off the downed tree rather than off the stump. It is generally more difficult to make horizontal cuts with a crosscut saw than vertical cuts.

Cross sections were labeled with an indelible ink marker and wrapped with filament tape to prevent excessive breakage. They were then placed in burlap sacks to ensure that if fragile pieces broke off, they would not be lost.

Laboratory Preparation of Specimens

Fire scar samples were removed from the burlap sacks and placed in a warm storeroom for air-drying. Each sample was examined to determine if additional cutting was necessary to expose the best cross sectional view of fire scars and ring sequences. Some samples required cutting because they were too large to handle efficiently under the microscope. Others had rough or irregular surfaces due to turning or gouging of the crosscut saw.

Samples were cut with a bandsaw to achieve flat surfaces through the area where most fire scars were visible. Belt sanders were used to prepare the surfaces for microscopic viewing. A power sander with a 21 x 3-inch belt was used for most of the sanding while a sander with a 24 x 3-inch belt was used on some of the larger cross sections. A series of sanding belts were used, increasing in fineness from grits of 40 to 320 or 400. A gum cleaning bar was used to remove accumulated pitch and saw dust from the sanding belts.

The sanding process was extremely important because very smooth surfaces were necessary to identify small rings, and the exact location of fire scars relative to the rings. Positive identification of false rings also required a surface where tracheid cell walls were clearly visible.

Dating Fire Scar Specimens

Annual ring sequences of fire scar specimens were crossdated using the skeleton plot technique (Stokes and Smiley 1968). Master tree-ring chronologies and composite skeleton plots developed from increment core collections were used to crossdate fire scar specimens (Figure 8).

The first step in dating the specimens was inspection of growth characteristics of the tree around the circumference of the cross section. A straight line was then drawn with a lead pencil from the innermost ring or pith out to the outermost ring or bark. Skeleton plotting was based on the ring widths along this radius. Choice of the specific radius to skeleton plot and date depended on the following

considerations:

1. There is often distortion of ring widths in the area adjacent to the catface. When it was possible to avoid this distortion, the line was drawn away from the catface area.

2. Cracks, breaks, decay, and branch scars can cause difficulties in skeleton plotting. These areas were avoided whenever possible.

3. Other distorted growth areas around the cross section where the ring series appeared highly compressed (slow growth) or highly expanded (rapid growth) were also avoided.

In general, the radius that appeared to be most representative of the ring series and had the least amount of decay or cracks, was skeleton plotted. Crossdating problems along one radius were frequently solved by skeleton plotting a second radius. By comparing the two skeleton plots with each other, with the composite skeleton plot, and finally with rings of the specimen being dated, problems such as missing or false rings were resolved.

The advantages of using full cross section samples versus wedge or partial sections were apparent when the dating process was carried out. Full cross sections provided a choice of radii for skeleton plotting. They also permitted a search around the circumference of the cross section for locally absent rings within the ring series where the skeleton plotting suggested they might be. Another important advantage of full cross sections was that they included both sides of the fire scarred bole of the tree. Fires were frequently recorded on only one

side of the catface; therefore, full cross sections probably increased the chances of detecting them. Individual fires that were recorded by fire scars on both sides of a tree have effectively twice the record of individual fires recorded on only one side of the catface.

When a ring series was satisfactorily crossdated, the rings along the plotted radius were marked to indicate the exact dating. This was accomplished by placing pinprick holes in the wood as described by Stokes and Smiley (1968).

The next step involved carefully transferring dating marks from the plotted radius to the fire scar area. This was achieved by following decade and century rings around the circumference and placing pinprick holes in the appropriate ring adjacent to the fire scars. Alternatively, "signature" rings (rings that were consistently small in nearly all of the specimens, such as the 1748 and 1904 rings) were followed around the circumference. Accuracy checks were carried out by counting rings between pinprick holes and by observing the ring pattern to see if it conformed to the chronology.

Identification and Dating of Fire Scars. The next two steps in the dating procedure involved identification of fire scars and identification of the annual ring in which each fire scar occurred. Fire scars may be described as disconformities within an annual ring series and have the following characteristics (Stokes 1980):

1. A break or gap (a wound) is present in the xylem tissue within a ring or along a ring boundary.

2. There are overlapping growth layers (annual rings) over the break or gap.

3. Charcoal is present within the break or gap.

4. Tracheid cells along borders of the break or gap may appear
   to be distorted or of irregular shape. Distorted cells may
   appear to extend beyond the break or gap into the annual
   ring and they may also be present within that ring at other
   locations around the circumference of the specimen.

Disconformities identified as fire scars always included characteristics
1 and 2, and most included characteristics 1, 2, and 3. Disconformities
were not positively identified as fire scars if they only had one of the
characteristics.

Assigning dates to fire scars was essentially a matter of ident-
ifying the annual ring in which the fire scar occurred. This process
was easiest when there were overlapping annual rings curved over a
definite charcoal lined break in the xylem tissue. The process was more
difficult when there was decay, a compressed ring series in the area, or
when the curved overlapping growth (healing ridge) had broken or burned
off.

Position of fire scars within annual rings varied. The break or
gap typical of fire scars appeared in three general areas: (1) between
rows of earlywood-type cells (earlywood fire scar), (2) between rows of
latewood-type cells (latewood fire scar), and (3) along ring boundaries
between latewood cells of one season's growth and earlywood cells of the
next season's growth (dormant season fire scar).

If growth rings are of sufficient width it may be possible to
estimate the season in which fires occurred by relating position of fire

scars within rings to the typical growing season of the tree (Barrett 1981). This type of investigation was not carried out for this study. Since all of the specimens are in storage at the University of Arizona Laboratory of Tree-Ring Research, it may be possible to conduct such an examination in the future.

Dormant season fire scars were dated to the year corresponding to the growth of the earlywood cells adjacent to them. In other words, it was assumed that the fire occurred in the spring prior to onset of growth rather than in the previous fall after the tree had entered dormancy. Dormant season fire scars could have been caused by fires that burned during either of these periods (late fall or early spring). It is more likely, however, that they represent spring burns, because in the Gila Wilderness, and in the Southwest in general, there are typically many more lightning ignitions during the spring than in late summer or fall, and fuels are usually drier at this time as well. Weaver (1951) also considered this problem and concluded that, in the majority of cases, dormant season fire scars were probably related to spring or early summer fires.

Dating Check. After each of the fire scar specimens were dated they were independently checked by another dendrochronologist. Specimens with dating problems (i.e., poor crossdating, numerous missing or false rings) were given special attention during the checking procedure. If necessary, new skeleton plots were constructed and crossdated without regard to the original dating marks. Specimens which crossdated well were usually only visually examined by the checker.

All fire scars included in the fire chronologies were also independently identified and dated by another dendrochronologist. In some cases there were discrepancies between fire scar dates arrived at by the original dater and the checker. In these cases, the fire scar in question was re-examined by the dater and checker and, if possible, a consensus date was determined. Dating differences usually occurred with fire scars that were difficult to relate to a specific annual ring because of decay, charring, compressed ring sequences, or loss of the healing ridge. This problem was usually quickly resolved when some evidence relating the scar to a ring was pointed out by either the original dater or the checker. In other instances, no agreement was reached on the exact dating of a ring. Fire scars that could not be definitely assigned to a given annual ring (a year) were assigned the most likely date and were noted on the fire chronology chart by placing the assigned date within parentheses.

Occasionally, the original dater and checker could not agree that a particular scar was in fact a fire scar. Scars which could not be positively identified by both dater and checker as fire scars were not included in the final version of the master fire chronologies.

<u>Results and Discussion</u>

Results of the dating of 44 fire scar specimens are visually presented in charts (Figures 11, 12, and 13). The charts depict master fire chronologies for each of the three study areas. Horizontal lines represent the life span of each sample tree. The time scale is indicated along the top of the chart. Pith dates on the lefthand side and
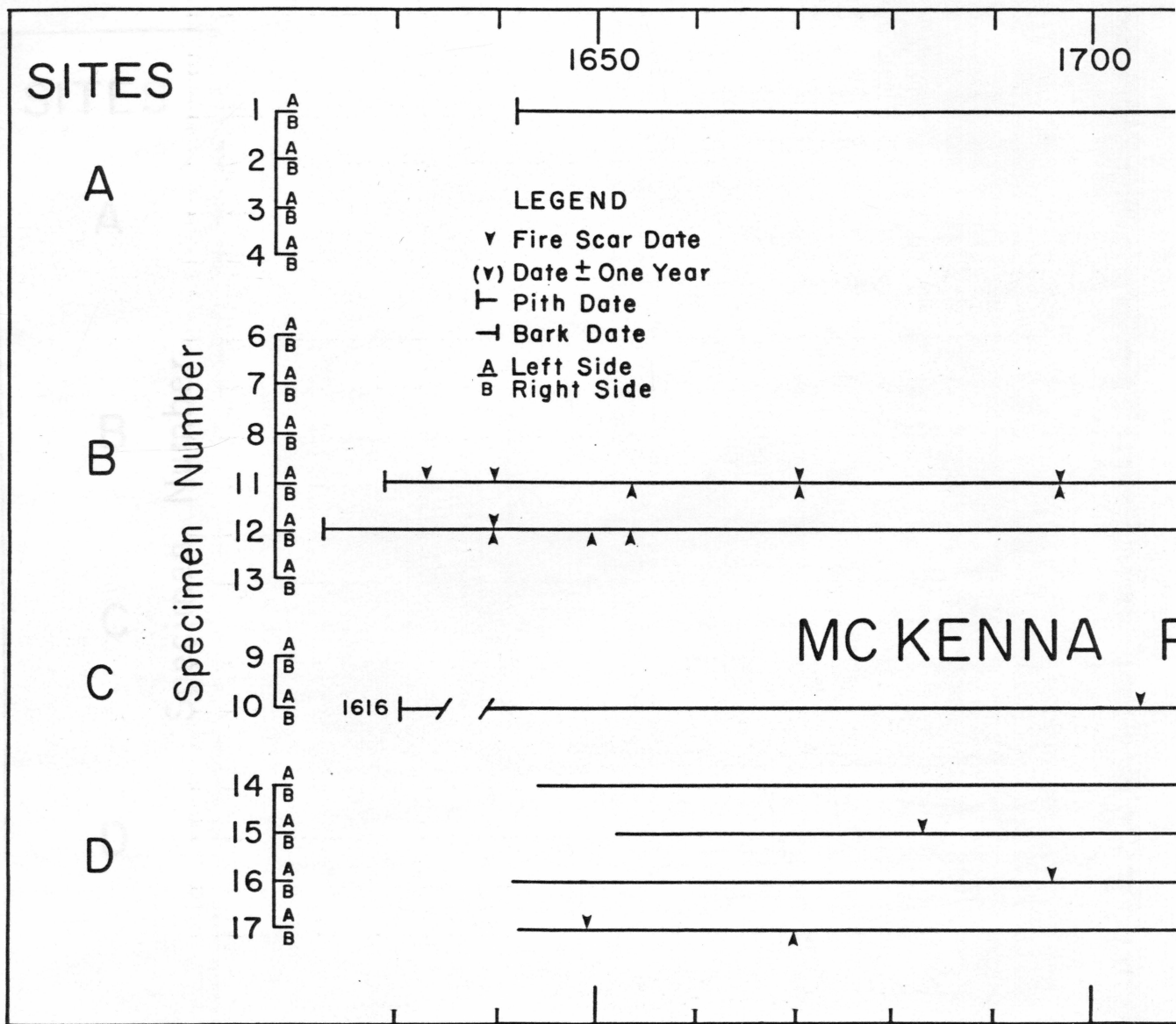
Figure 11. McKenna Park master fire chronology.

PARK

1750   1800

1772   1779   1801   1806   1811   1817   1825   1837   1847

(Y)
(A)

(Y)
(A)

(Y)

(A)

(Y)

(Y)
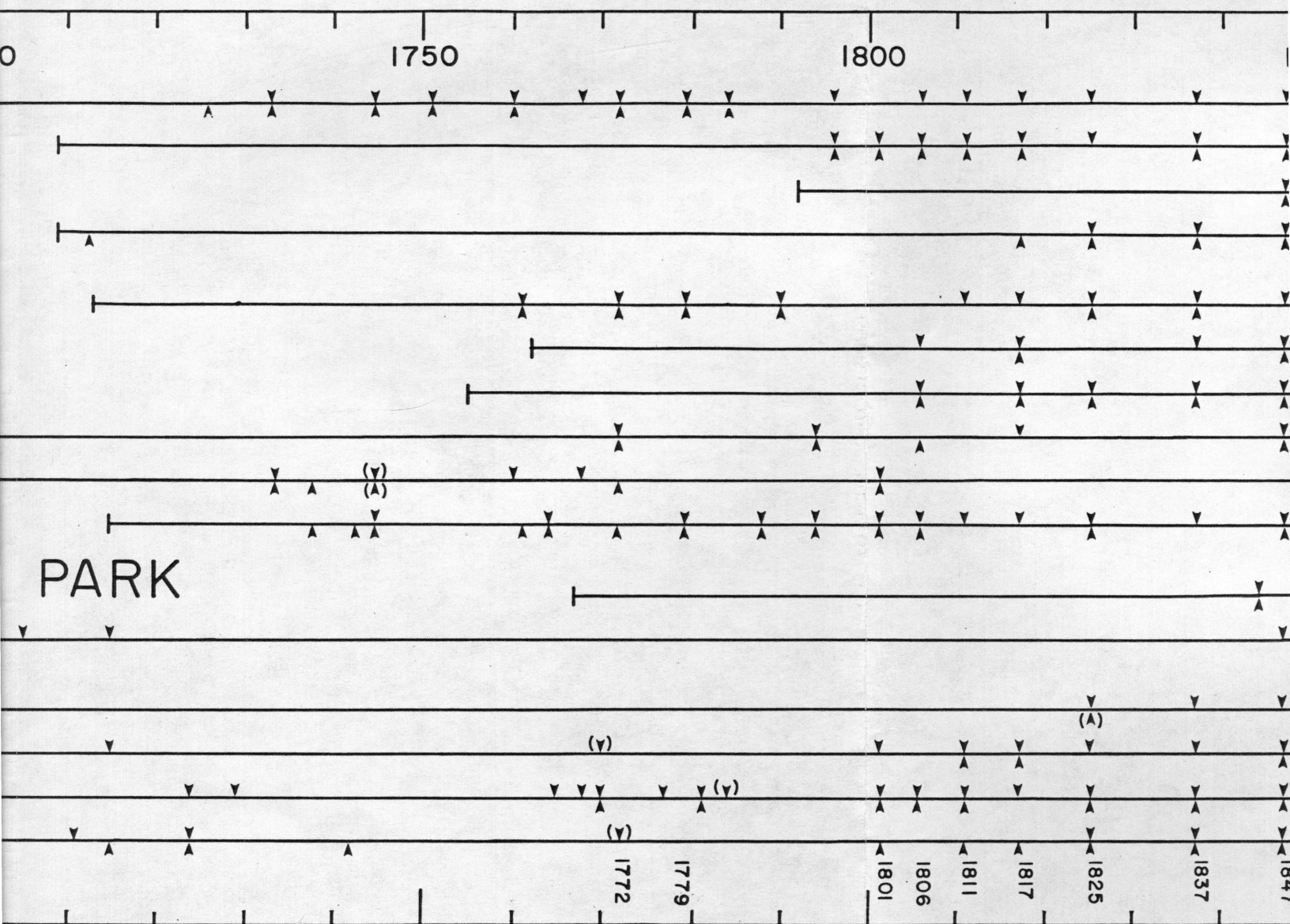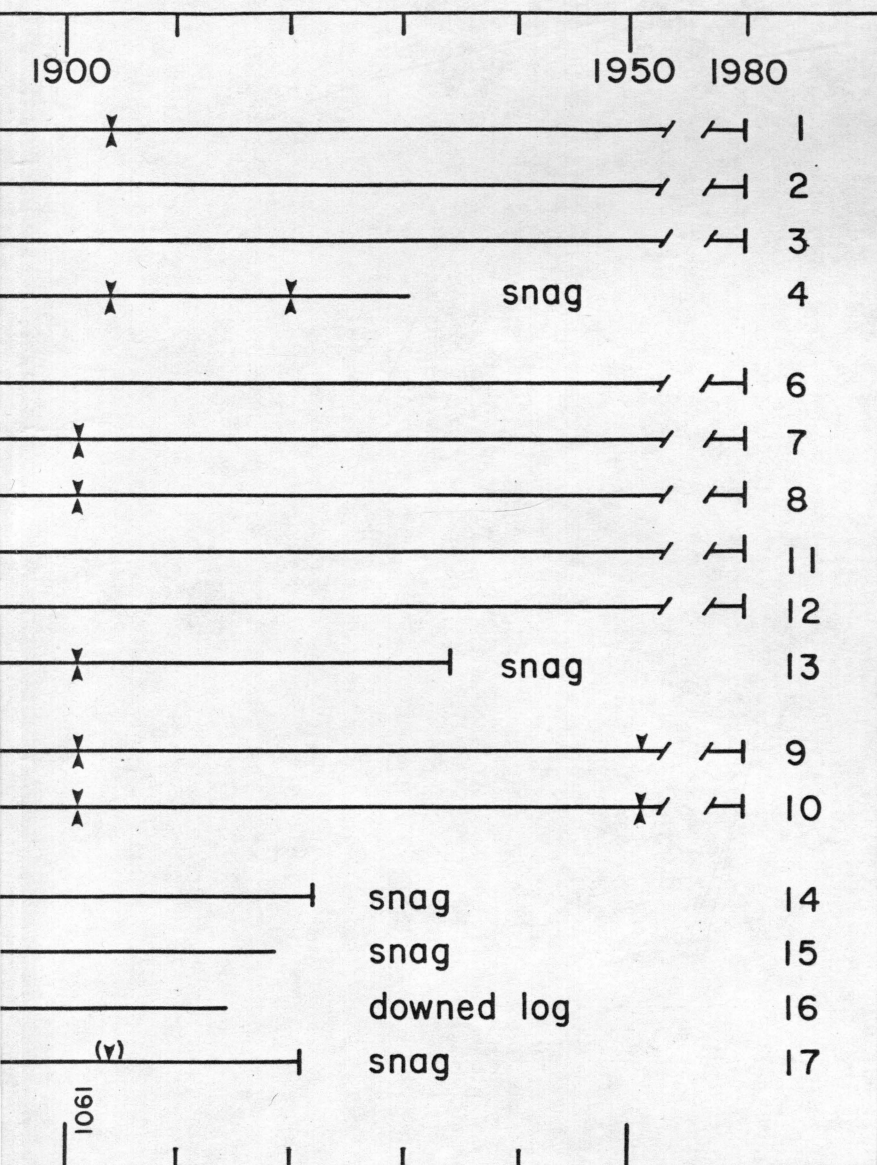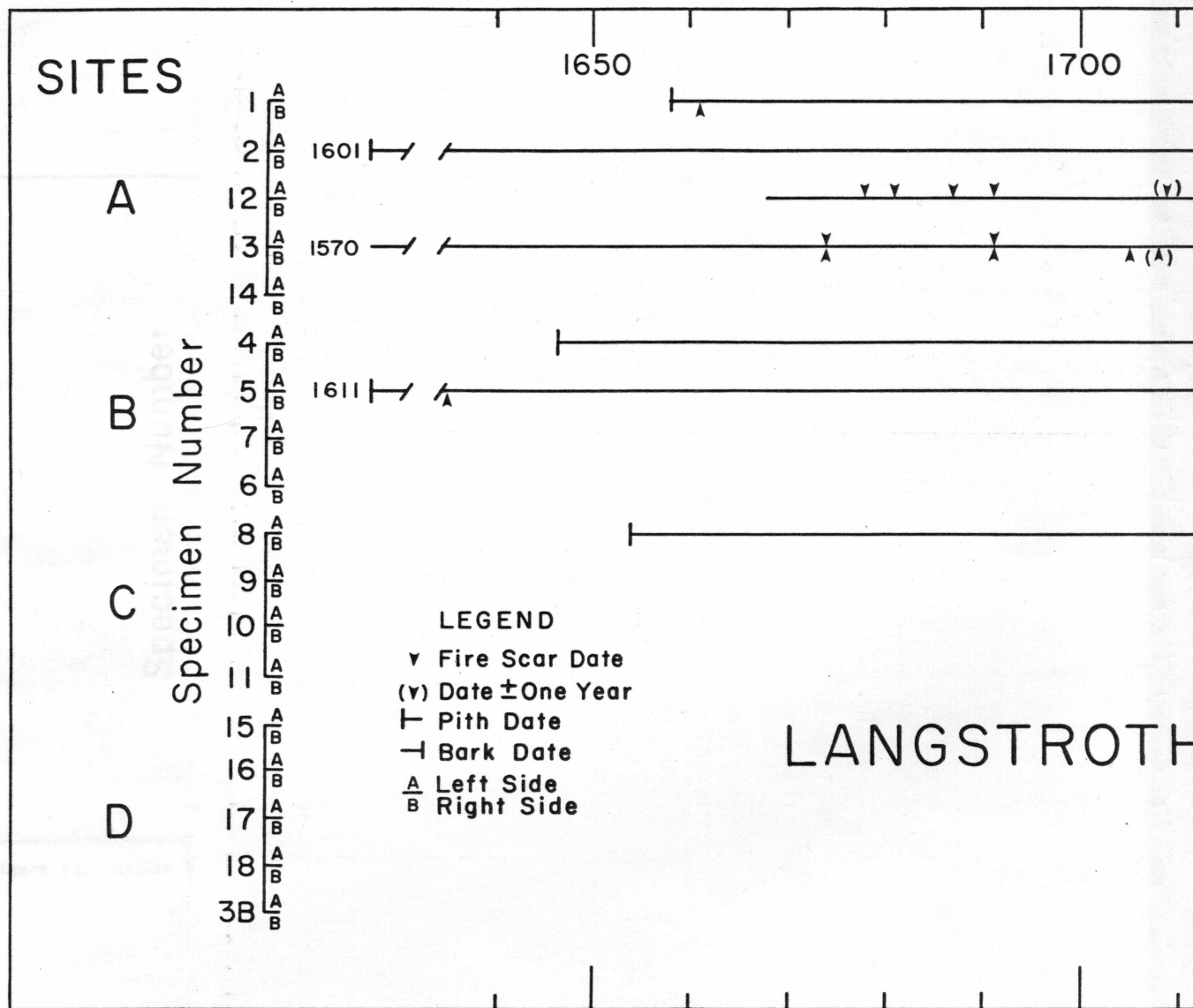
Figure 12. Langstroth Mesa master fire chronology.

1750　　　　　　　　　　　　1800　　　　　　　　　　　　1850

(Y)
(A)

(Y)
(A)

(A)

MESA

(Y)

1806　1811　　　　　　1837　1841　1847　1854　1857

1930 1960 1980

1

2

12

13

14

snag 4

(▲) snag 5

snag 7

(▼) 6

8

) 9

— downed log 10

snag 11

15

16

17

snag 18

snag 3B

1904

1650   1700

Specimen Number

1 A/B
2 A/B
3 A/B
4 A/B
5 A/B
7 A/B
8 A/B
9 A/B
10 A/B
11 A/B

LEGEND

∨ Fire Scar Date
(∨) Date One Year
⊢ Pith Date
⊣ Bark Date
A/B Left Side / Right Side
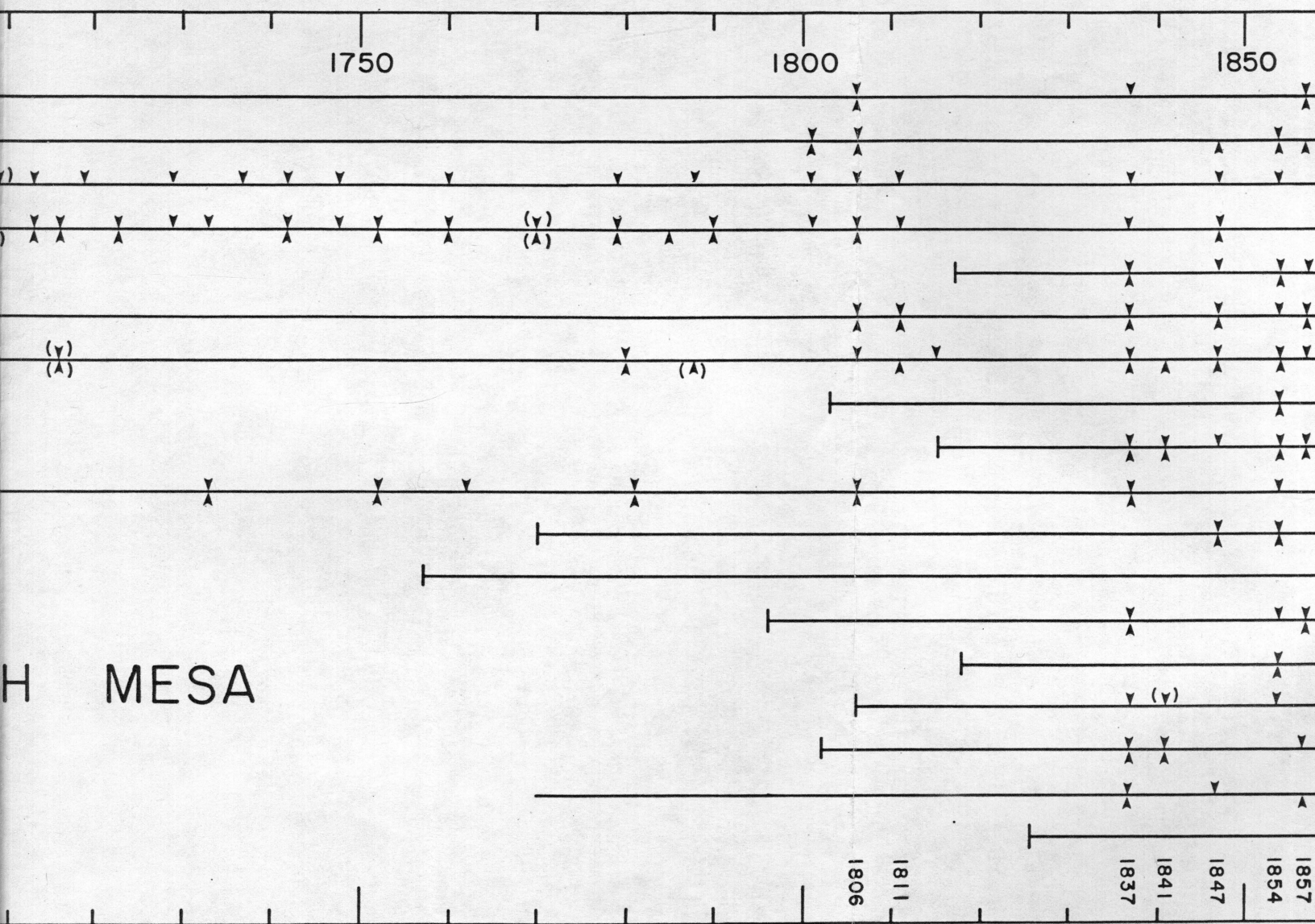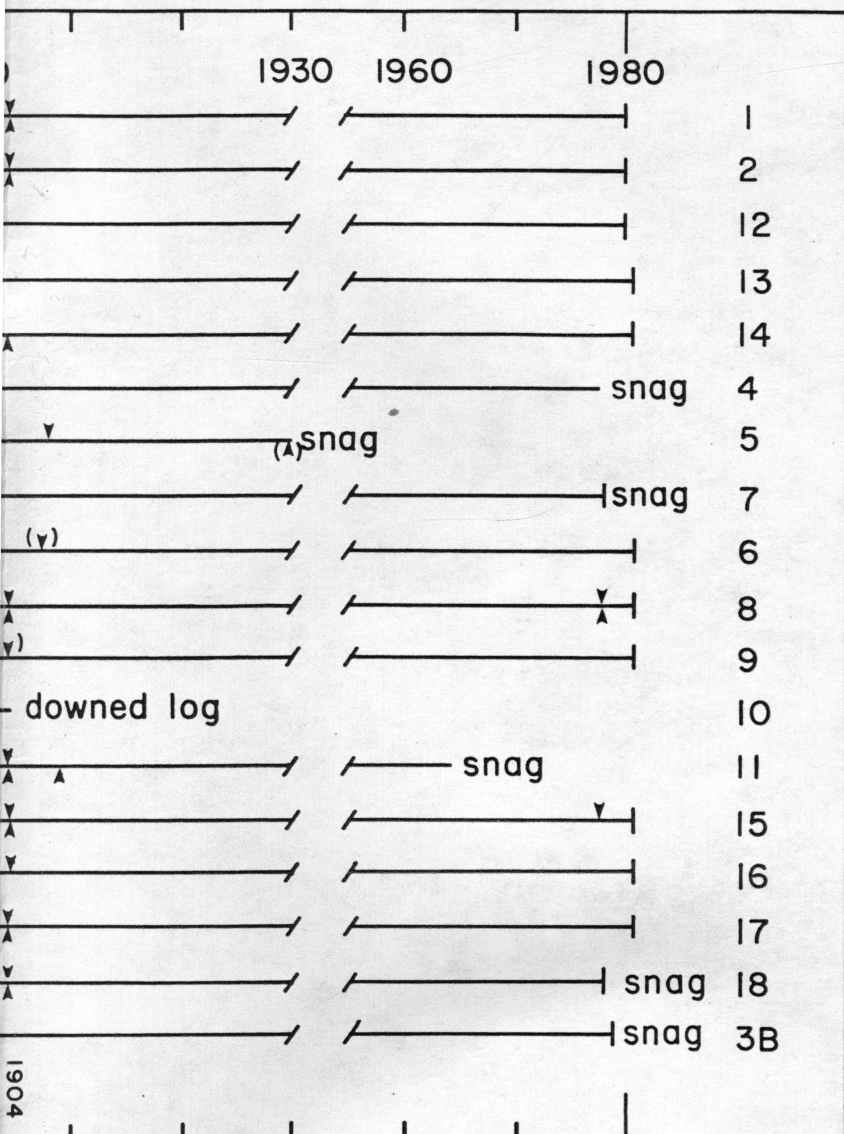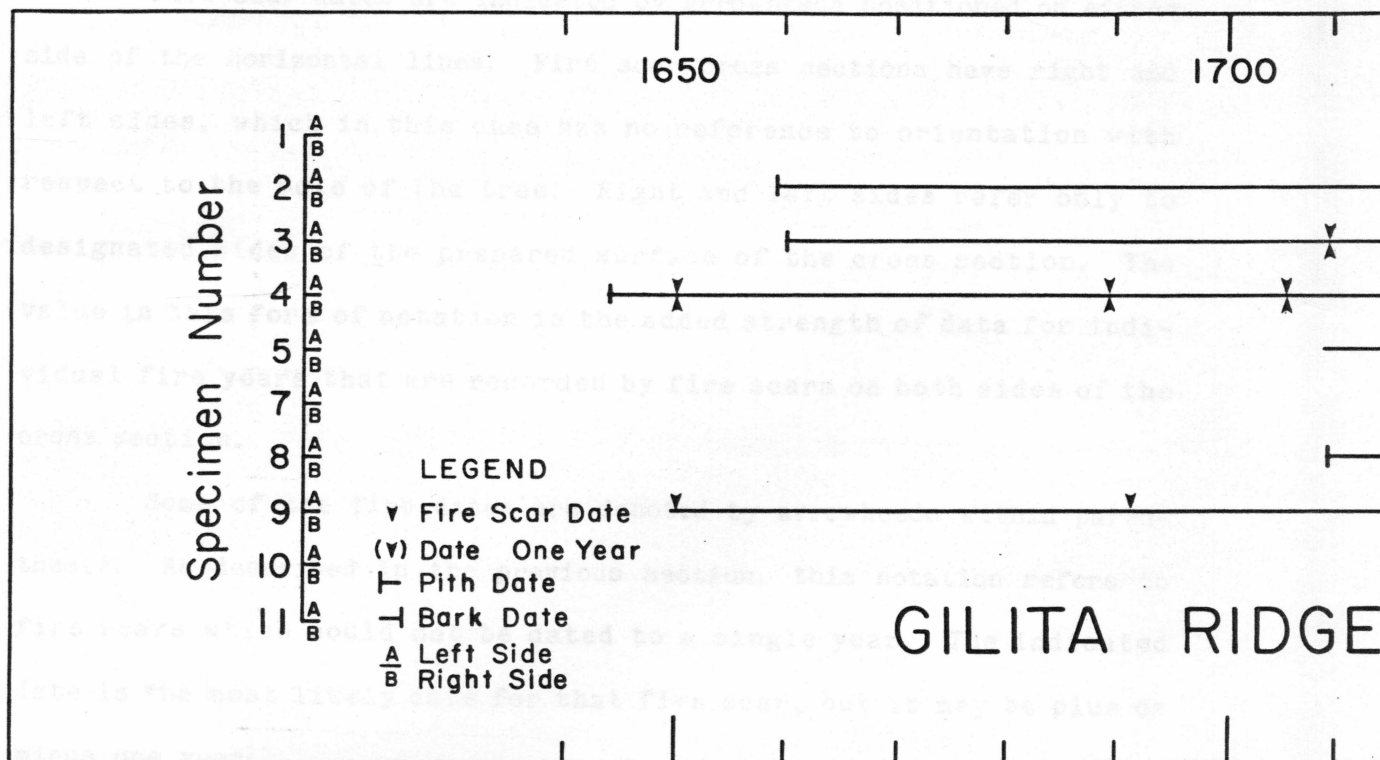
GILITA RIDGE

Figure 13. Gilita Ridge master fire chronology.

1750　　　　　　　　　1800　　　　　　　　　1850

(A)

(A)

SE

(V)

(V)

1837　1842　1847　1851

62
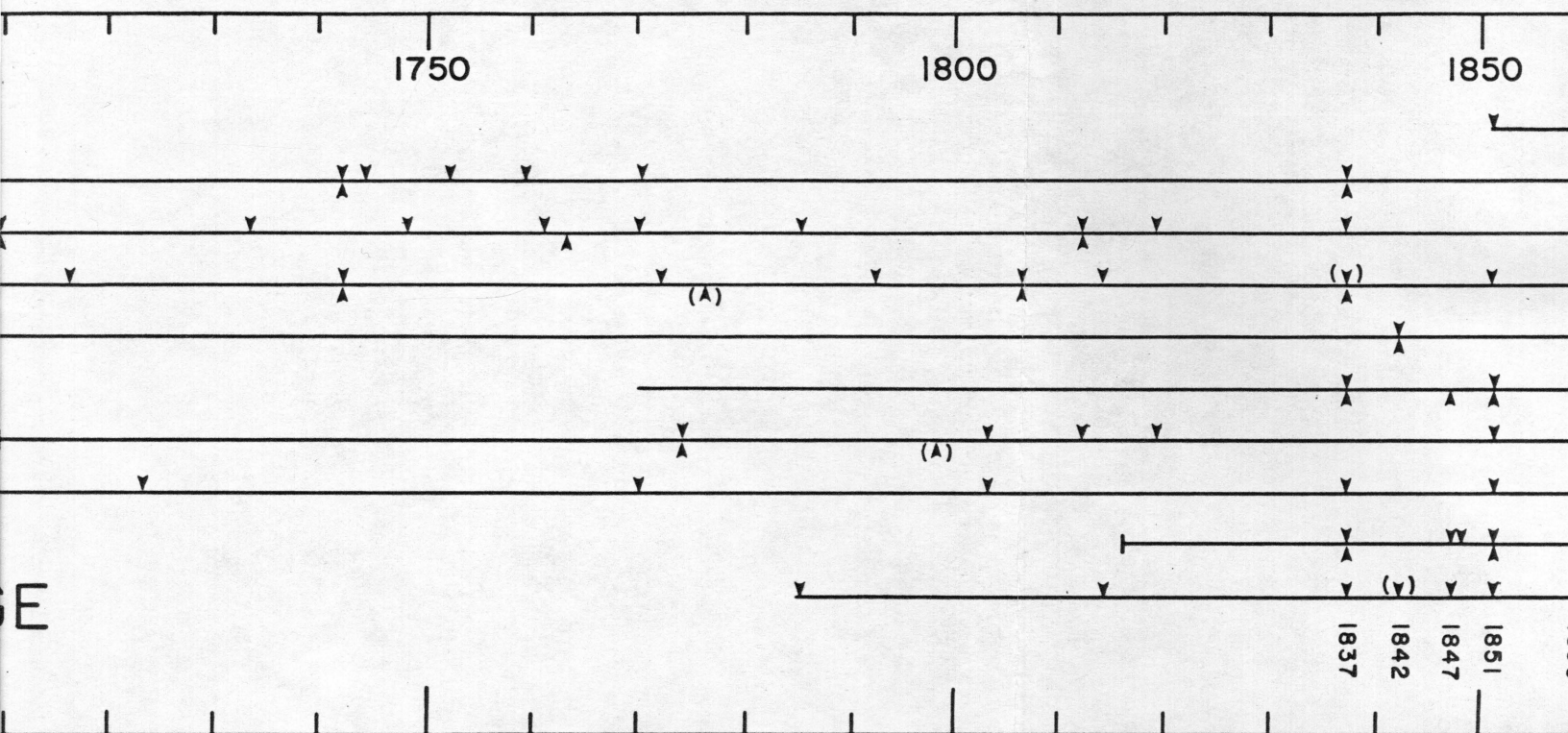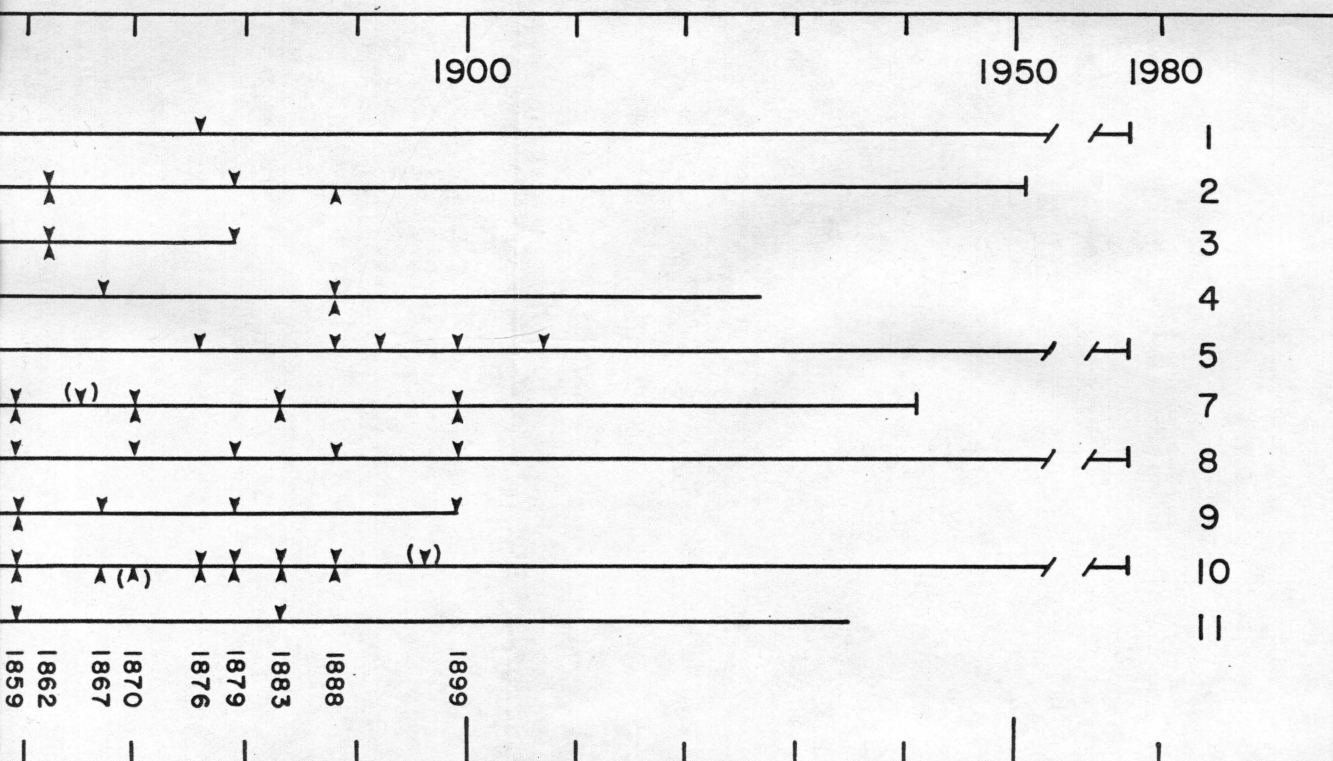
bark dates on the righthand side are indicated by short vertical lines. When the pith was not included in the cross section sample or when the outside date may not have been in the last annual ring formed (such as in the case of the "downed log," specimen No. 16 from McKenna Park) no vertical lines were added.

Fire scar dates are indicated by arrowheads positioned on either side of the horizontal lines. Fire scar cross sections have right and left sides, which in this case has no reference to orientation with respect to the bole of the tree. Right and left sides refer only to designated sides of the prepared surface of the cross section. The value in this form of notation is the added strength of data for individual fire years that are recorded by fire scars on both sides of the cross section.

Some of the fire dates are denoted by arrowheads within parentheses. As described in the previous section, this notation refers to fire scars which could not be dated to a single year. The indicated date is the most likely date for that fire scar, but it may be plus or minus one year.

Fire scar specimens were grouped within each fire chronology by the site in which they were collected. Samples were collected from four collection sites in McKenna Park and Langstroth Mesa study areas and from one collection site in the Gilita Ridge study area. Each specimen is numbered on the charts as it was numbered in the field and dead fire scar samples (i.e., snags and downed logs) are identified to the right of the horizontal lines. McKenna Park specimen No. 5 was not used because of unresolved problems in dating the ring series.

Tables B-1, B-2, and B-3 in Appendix B list fire years, number of fire scar-susceptible trees before each fire year, number of trees recording the fire year, number of fire scars recording the fire year, and the fire interval. Fire years are years or dates during which any specimen incurred a fire scar. Fire scar-susceptible trees are trees that have already been scarred at least once and have a relatively greater probability of being scarred by the next fire (Romme 1980). Fire intervals are the number of years between successive fires (Romme 1980). In this case, they are number of years since the previous fire year.

Characteristics of Fire Chronologies

Close examination of the fire chronologies reveals a number of significant features. Each of these features will be identified in this section and their implications, relationships, and possible explanations will be discussed.

Changes in the Fire Regime. Perhaps the most striking pattern observed in all three chronologies is the sudden decrease in fires recorded by sample trees after 1900 (Figures 11, 12, and 13). Only four fires were recorded in McKenna Park after 1904 (1911, 1920, 1938, and 1951). Five fires were recorded by Langstroth Mesa specimens (1907, 1908, 1909, 1930, and 1978) after 1904 and only one fire (1907) was recorded by Gilita Ridge specimens after 1899. All twentieth century fires were recorded by fewer than two sample trees each.

The period before 1900 was characterized by the periodic recurrence of many more fires than the period after 1900. Between the years

1640 and 1900, 58 fire years were recorded (each fire year recorded by at least two specimens) in the three study areas.

Tables 4 and 5 summarize the mean fire intervals (MFI's) for the three study areas by time period. Mean fire interval (MFI) is the arithmetic average of all fire intervals determined in a designated area during a designated time period (Romme 1980). The total period of fire scar record was divided into shorter periods according to the amount of fire scar evidence. Since there was an obvious decline in number of fires recorded after 1904, separate MFI's were computed for the periods 1904-1951 for McKenna Park and 1904-1978 for Langstroth Mesa. The years 1951 and 1978 were the last years that fires were recorded in McKenna Park and Langstroth Mesa study areas, respectively.

MFI's were computed for the periods 1801 to 1904 for McKenna Park and Langstroth Mesa and the period 1803 to 1899 for Gilita Ridge. These are periods of most complete record for the pre-1900 era because most of the specimens were fire scar susceptible during this time. MFI's computed for these periods are, therefore, the most accurate and representative of the pre-1900 fire regime. The record indicates that at least during the 1800's, large fires burned in McKenna Park every six to eight years and large fires burned on Langstroth Mesa and Gilita Ridge every four to seven years.

MFI's were also computed for the periods 1837-1904 for McKenna Park and Langstroth Mesa, and 1837-1899 for Gilita Ridge. These periods begin with the 1837 fire year because there was an apparent gap or absence of fire in all three study areas during the late 1820's and

Table 4. Mean Fire Intervals by Study Area and Time Period, All Fire
Years Included.

Study Areas and Time Periods	Fire Interval (Years)		No. of Fire Scar Susceptible Trees[1]	No. of Trees Collected
	Mean	Range		
McKenna Park				16
1633-1801	4.3	1-16	0/11	
1801-1904	6.4	3-12	11/16	
1837-1904	6.1	3-11	14/16	
1904-1951	23.5	16-31	16/16	
Langstroth Mesa				18
1635-1801	5.7	1-26	0/5	
1801-1904	5.4	1-22	5/18	
1837-1904	4.5	1-12	7/18	
1904-1978	14.8	1-48	18/18	
Gilita Ridge				10
1650-1803	16.9	2-39	0/6	
1803-1907	4.7	1-18	6/10	
1837-1907	4.1	1-8	6/10	

[1]The numerator is the number of fire scar susceptible trees at the be-
ginning of the period and the denominator is the number susceptible at
the end of the period.

Table 5. Mean Fire Intervals by Study Area and Time Period, Fire Years Recorded by More Than One Sample Tree Included.

Study Areas and Time Periods	Fire Interval (Years) Mean	Range	No. of Fire Scar Susceptible Trees[1]	No. of Trees Collected
McKenna Park				16
1640-1801	11.5	1-61	1/11	
1801-1904	7.4	3-12	11/16	
1837-1904	6.7	3-10	14/16	
1904-1951	47.0	-	16/16	
Langstroth Mesa				18
1691-1801	10.2	3-22	4/5	
1801-1904	6.9	1-26	5/18	
1837-1904	5.6	1-12	7/18	
1904-1978	74.0	-	18/18	
Gilita Ridge				10
1742-1803	20.3	15-28	3/6	
1803-1899	6.0	2-18	6/10	
1837-1899	5.2	3-11	6/10	

[1]The numerator is the number of fire scar susceptible trees at the beginning of the period and the denominator is the number susceptible at the end of the period.

early 1830's. For example, there were no fires recorded between 1815 and 1837 on Langstroth Mesa (a 22 year interval) and no fires were recorded between 1825 and 1837 in McKenna Park (a 12 year interval). By excluding this gap from the MFI computations, slightly different values were obtained. Possible explanations for this gap will be discussed later in this section.

MFI's were also computed for the earliest periods of record for each study area. The beginning year of these periods was the first year that a fire was recorded in the study areas by any of the specimens (Table 4) and the first year that a fire was recorded in the study areas by more than one specimen (Table 5). The reason for computing MFI's for all fire years, and only fire years recorded by more than one specimen, was to present the data in different perspectives. For periods after 1800, MFI's in Table 4 are more representative of the time interval between any fire, while MFI's in Table 5 are more representative of time intervals between larger fires. For the periods before 1800 this distinction cannot be made because of the scarcity of fire scar evidence.

Before 1800 fewer specimens have a record of fires because: (1) some of the trees were established after 1800, (2) many of the trees were not scarred by fire until after 1800, so they were not fire scar susceptible, and (3) some of the trees may have had more pre-1800 fire scars, but they were burned off by subsequent fires.

The scarcity of fire scar evidence in periods before 1800 may explain the relatively longer MFI values for these periods listed in Table 5. However, MFI values for the earliest periods listed in Table 4, where all fire years are included in the computation, are much closer

to the MFI values for the 1800's periods. As suggested by Dieterich (1980b), the composite of all fire scar dates is usually a better record of fire history than that recorded by multiple specimens, especially when fire scar evidence is sparse. In this case, MFI's computed from the composite of all fire years recorded by specimens during the 1700's and 1800's (Table 4) is probably closer to the actual MFI experienced than MFI's computed from fire years recorded by more than one specimen (Table 5).

MFI values for the post-1900 period are much longer than MFI values for the pre-1900 period. For example, the MFI for fires recorded by more than one sample tree during the period 1904 to 1951 in McKenna Park is 47 years, while the MFI's for pre-1900 periods is six to eight years. Comparing the equivalent periods for Langstroth Mesa and Gilita Ridge, respectively, yields values of 74 years versus five to seven years and 82 years versus four to six years. This demonstrates the fact that only a few large fires have occurred within the study areas since fire suppression efforts began.

The decline of periodic fires is a direct result of livestock grazing and fire suppression efforts. This relationship has been recognized and discussed in numerous fire histories and other ecological studies (Leopold 1924, Cooper 1960, Weaver 1951, Dieterich 1980, Madany 1981). Very briefly, the relationship can be described as follows: Grass serves as a fine flashy fuel that helps carry or spread fire. Grazing has the effect of removing grass from the understory. Although fire suppression efforts in the early 1900's was primitive and slow by

today's standards, the effect of these activities, coupled with that of grazing, was the cessation of the fire regime as it had existed for centuries.

Probable Extent of Fires. Another obvious feature of the fire chronologies is consistent agreement of fire scar dates between specimens within study areas. Although collection sites and specimens were widely scattered over the study areas, the agreement among fire scar dates suggests that most fires burned throughout the study areas. This is not too surprising since the study areas are not dissected by any major natural fire barriers and it is possible that fires could have ignited as early as April and burned through late October before being extinguished by cool weather. Fires that probably burned throughout the study areas (as indicated by fire scar agreement of widely scattered specimens) are listed at the bottom of each fire chronology chart (Figures 12, 13, and 14).

A conservative estimate of the areal extent of these fires within the McKenna Park and Langstroth Mesa study areas is approximately 3,000 acres (1,214 ha); however, it is likely that at least some were larger. This estimate is based on the approximate size of the study areas and the location of possible fire barriers such as the West Fork canyon. The Langstroth PNF which burned in 1978 remained for the most part on the mesa top and burned approximately 3,200 acres (1,296 ha). Although fuel conditions were undoubtedly different during the pre-1900 era, the extent of spread of this modern fire suggests that, at least for Langstroth Mesa, the estimate of 3,000 acres (1,214 ha) is reasonable.

Fires which burned throughout the study areas could have been caused by single or multiple ignitions. It is common for several lightning caused fires to show up in the study areas following passage of a dry thunderstorm. Regardless of the pattern of ignition and spread of fires, it is apparent that during certain years large acreages were burned. Evidence that most fires burned throughout the study areas suggests that there is essentially no difference in fire histories of individual collection sites even though these sites have slightly different characteristics.

A few fires were evidently more limited in areal extent. Fires that burned in McKenna Park in 1844, 1860, 1920, and 1951 were recorded by only one or two specimens. The 1920 Gila National Forest fire atlas indicates that a class B fire, which at that time was classified as a fire between 1/4 and 10 acres, occurred in the approximate location of collection site A (Figure 2). It is possible that McKenna Park specimen No. 4, which recorded a 1920 fire, was within the perimeter of this documented fire.

The 1951 fire, recorded by specimen Nos. 9 and 10, was probably the 14,000 acre (5,670 ha) "Little Creek Fire." This was one of the largest fires that has occurred in the Wilderness in modern times. According to a map prepared by the fire boss after the fire was controlled, bulldozer lines were constructed along the ridgeline east of McKenna Creek (Figure 2). The fire burned into McKenna Park from the east and did not spread beyond the bulldozer line. This explains why only specimens in site C recorded this fire.

The 1978 Langstroth PNF was also recorded by fire scar specimens. Although fire burned through all collection sites, only two of the 18 specimens collected from the mesa developed fire scars. It may be that in the intervening period since the last fire on the mesa, the fire scarred trees had become more resistant to rescarring. Many of the specimens had developed thick bark and large curls of growth over the last scar. The Langstroth Mesa PNF may also have been a relatively cooler fire than some pre-1900 fires because it burned only during the cooler and wetter portion of the season. On the other hand, the accumulation of fuels since the last fire, which was in 1904, may have counteracted the effects of cool weather. The explanation of increased resistance to fire scarring seems most likely; however, this uncertainty emphasizes a need for further research to identify the effects of different intensities of fire in creating fire scars.

Examination of the Langstroth Mesa fire chronology (Figure 12) provides another interesting example of interpretation of areal extent of past fires. Fires burned within the study area on three consecutive years: 1869, 1870, and 1871; however, these fires did not burn over the same collection site in consecutive years. In 1869, sites A, B, and D burned. These sites are all on the eastern side of the study area. In 1870 site C, located on the western side of the study area, burned over. Then, during 1871, fire again burned through sites A and B, although in site A this fire was recorded only by trees that were not scarred by fire two years earlier.

This pattern of burning suggests that the presence of adequate ground fuels was especially important in the timing and spread of fires.

When fuels in one portion of the study were not consumed by fire they were still available for burning the next year. Areas that had burned during the previous year probably had not built up enough fuels to carry fire. Thus, consecutive year fires on the same site were probably unlikely to have occurred within the study areas, although fires occurring every other year (a two year interval) were confirmed. This pattern of burning also suggests that while large fires were common for the pre-1900 fire regime, occasionally "patchy" burns also occurred, resulting in differences in levels of fuel available at different locations.

The Fire Interval of the 1820's-1830's. While evidence of patchy burns indicates the importance of fuel accumulation in the ignition and spread of fires, other evidence suggests the importance of climatic trends. As previously pointed out, there was apparently an unusually long interval in all three study areas when no large fires occurred. For McKenna Park this gap was 12 years (from 1825 to 1837). For Langstroth Mesa the gap was 22 years (from 1815 to 1837) and for Gilita Ridge 18 years (from 1819 to 1837). For all three study areas these fire free intervals were the longest for all periods between 1700 and 1900.

While it is true that 11 of the specimens from Langstroth Mesa did not receive their first scar until after 1837, and so were not fire scar susceptible during the gap, seven other specimens with longer records extending back before the gap also did not record any fires during this time. It is therefore probable that this gap reflects a genuine absence of large fires during this time period. It is probable

that small fires burned within the study areas during this period and just did not scar any of the specimens. The consistent absence of fire scars on all trees during this period, however, indicates a decrease in large fire occurrence.

Climate and Fuels. One possible explanation for the 1820's-1830's gap may reside in an examination of the tree-ring indices for this period. As mentioned in Chapter 2, annual ring widths are highly correlated with precipitation and temperature (Fritts 1976). Standardized tree-ring series have had the biological growth trend and nonclimatic low frequency variation removed from the series so that most of the remaining variation of the indices is related to climatic factors. A superficial inspection of the tree-ring indices may therefore provide some clue to the amount of precipitation that the trees were receiving during the gap.

The White Creek and McKenna Park indices during the period 1828-1835 were all greater than the mean value of the series (1.0) (Appendix A). These positive departures from expected growth suggest that this was a wetter and/or cooler than usual period. Schulman (1956) also analyzed tree-ring series from the Gila headwaters area. He listed periods with minimum and maximum departures from expected growth and suggested that they may indicate wetter than usual and drier than usual periods respectively. The period 1826-1840 was one of four listed as maximum departure or wetter than usual periods from a 350-year tree-ring series.

Finally, Conkey (1977) reconstructed winter precipitation (November through February) using a master tree-ring chronology from near

Reserve, New Mexico and modern weather records from Fort Bayard, New Mexico. These two stations are located on the southern and western sides of Gila National Forest respectively. The reconstruction indicates that this area received more winter precipitation than any other period in the 1800's. According to the reconstruction, however, there was relatively more winter precipitation during the late 1700's and yet several fires occurred during this period. Apparently, the evidence for a climatic explanation of the 1820's-1830's gap, at least based on winter precipitation, is far from conclusive. Future climate/fire scar studies should investigate various combinations of climatic records, tree-ring records, and fire events.

If the 1820's to 1830's gap was a wetter than usual period, then perhaps the absence of fires in the study areas was due to fewer ignitions and/or less spread of fire because of higher fuel moisture. Speculating a bit further, if there was more precipitation than usual, then grasses, forbs, and trees may have produced relatively more fuels, which would have accumulated during the gap. After a 12 to 22 year absence of fire, the stage would have been set for an intense fire. This may have been the case, because in 1837, which tree-ring indices suggest was a slightly drier than usual or close to average year (with index values of 0.837 for White Creek and 0.835 for McKenna Park), large fires burned in all three study areas and these fires scarred nearly all of the sample trees. As yet there is no independent verification that years during the gap were wetter than usual, nor is there any way to be assured that

fires were relatively more intense than other fires just because they scarred more trees.

Regardless of the true reason for the absence of fire scars during this period, such a change in the pre-1900 fire scar record suggests that there may be long term fluctuations in the fire regime. In other words, fires usually occurred at short intervals (four to eight years); however, longer periods (as long as 22 years) may also have occurred. One possible avenue of research of this subject would be an effort to develop longer records of fire occurrence by seeking out older fire scar trees and well preserved fire scarred logs and snags. Reconstructions of past climate may then be used to examine the relationship between long term changes in fire regime, climate, and fuels.

Agreement of Fire Years Between Study Areas. In addition to the 1837 fire year, there were a number of other fire years common to two or all three of the study areas. Table 6 lists the number and percent of fire years that were common to the study areas. A chi-square test was applied to the various combinations of fire chronologies to test the hypothesis that the records were independent. The null hypothesis was that the number of agreements of fire dates between the study areas was not more than the number that would be expected by chance alone.

The test was run on fire years recorded by more than one specimen and all fire years. The null hypothesis can be rejected in seven of the 16 classifications tested at a 0.05 level of significance (Table 6). These classifications include the periods 1801-1904 comparing fire year agreements between McKenna Park and Langstroth Mesa and fire year agreements between all three study areas. When all fire years were tested,

Table 6. Number (N) and Percent of Fire Years in Common Between Study Areas by Time Period. McKenna Park (MKP), Langstroth Mesa (LNG), and Gilita Ridge (GLR) fire chronologies are compared.

	Fire Years Recorded by More than One Tree					
	Time Periods					
	1640-1801			1801-1904		
Study Areas	Total[1]	N	%	Total[1]	N	%
MKP/LNG	24	3	12.5	22	9	40.9**
MKP/GLR	19	0	0.0	28	4	14.3
LNG/GLR	15	1	6.7	29	4	13.8
MKP/LNG/GLR	27	0	0.0	34	3	8.8**

	All Fire Years					
	Time Periods					
	1633-1801			1801-1904		
Study Areas	Total[1]	N	%	Total[1]	N	%
MKP/LNG	58	11	19.0	28	9	32.1**
MKP/GLR	53	8	15.1	34	5	14.7
LNG/GLR	43	9	20.9**	34	8	23.5*
MKP/LNG/GLR	67	4	6.0**	41	4	9.8**

[1]Total number of fire years recorded in study areas being compared.

*Significant at the 0.05 level of significance (See text).

**Significant at the 0.005 level of significance (See text).

the Langstroth Mesa and Gilita Ridge comparison was also significantly non-independent at the 0.005 level.

These results indicate that during the period 1801-1904 the occurrence of fire in any one of the study areas was not independent of fire occurrence in any of the other study areas. In other words, if a fire occurred in a study area during a given year, there was a greater than random chance that fires would have also occurred in one or both of the other study areas.

Results of the chi-square tests indicate that some factor may have been affecting fire occurrence over a large area including the three study areas. This factor may be climatic in nature. Drier than usual years or drought years would probably be experienced simultaneously by all three study areas. Lightning storms also tend to be widespread in the Gila during certain years. Both of these climatic factors probably resulted in fires occurring in more than one study area.

Effects of Human Activities on the Fire Regime

Indian Burning. Another of the possible influences of the pre-1900 fire history was intentional or unintentional fires set by Indians. The Gila was the traditional home of several bands of Western Apaches (Ogle 1940). In fact, Geronimo claimed to have been reared in the country around the headwaters of the Gila River (Turner 1970) and the famous warrior chieftains Victorio and Mangus Coloradas used the Gila country for hiding out (Bourke 1891).

Several early explorers and surveyors of the Southwest stated that Indians used fires for different purposes. These included the

driving of game (Powell 1879), warfare (Bell 1870), and bringing rain (Webb 1900). While on a tour of the sheep ranges in Arizona and New Mexico in May and June of 1900, Gifford Pinchot commented on an experience while in the White Mountains of Arizona: "From a high point next day we looked down and across the forest to the plain. And as we looked there rose a line of smokes. An Apache was getting ready to hunt deer. And he was setting the woods on fire because a hunter has a better chance under cover of smoke. It was primeval but not according to the rules" (Pinchot 1947, pg. 147). It was on this same trip that Pinchot took the photograph documenting a fire scar chronology that is mentioned in Chapter 1, above.

It appears likely that even if the Apaches did not practice burning in a regular manner, fires may have been set accidentally. Therefore, it is quite possible that the Apaches were a source of ignition for many of the fires recorded by the fire scar specimens. The possibility also exists that the 1820's-1830's gap was due to an absence of Apaches from the area or an absence of Apache burning for some other reason.

There are no detailed records of movement of Apaches through the Gila country, but it is evident that they were a highly mobile and nomadic people and that their home range covered literally thousands of square miles from northern Mexico to southern New Mexico and Arizona (Bourke 1891). Early records of military actions against Apaches which utilized the Gila indicate that several of the bands were virtually eliminated in the 1860's by campaigns of the California Volunteers (Ogle 1940). Sporadic outbreaks of violence between ranchers and Apaches

continued in the Gila as late as the 1880's (Bourke 1891, McKenna 1936).
Therefore, it is probable that at least small groups of Apaches were in
the general vicinity of the study areas as late as the 1880's. There
was no apparent change in the fire regime after the 1860's although
cessation of periodic fires closely followed the end of the 1880's.

    Pyne (1982) has pointed out that ranching in many areas in
southern Arizona and New Mexico was not really successful until the
Apaches were driven out. After the Apaches were gone, areas like the
Gila quickly became heavily exploited by large numbers of sheep and
cattle. Since introduction of livestock closely followed demise of the
Apache, it is difficult to distinguish between effects of heavy grazing
and removal of possible Indian ignitions.

    The last interval between large fires before organized fire
suppression began is longer than MFI's for the 1800's period in both
McKenna Park and Langstroth Mesa. The interval was 11 years long (1890-
1901) in McKenna Park and 12 years long (1892-1904) on Langstroth Mesa.
This longer than usual interval suggests that either grazing or lack of
Indian ignitions was beginning to affect the fire regime. It is also
possible that climate may have been a factor; however, neither climatic
reconstructions (Conkey 1977) nor the tree-ring indices (Appendix A)
indicate that this was a wetter than usual period.

    While the possible importance of Indian burning cannot be ruled
out, it is also true that a natural ignition source has been present for
a very long time. In Forest Service Region 3, the Gila National Forest

is second only to the Coconino National Forest in average number of
lightning caused fires per year (Barrows 1978).

As fire managers on the Gila can attest, nearly every year
brings at least one multiple fire period and usually two or three.
Multiple fire situations typically occur when electrical storms pass
over the mountains, resulting in as many as 30 or more fires scattered
over the National Forest and Wilderness Areas. Considering the high
occurrence of lightning fires, it would seem that regardless of the
presence of Indian ignitions, fires would still have been common in the
Gila Wilderness.

Grazing Activities. In the summer of 1903, Theodore Rixon of
the United States Geological Survey conducted a township by township
survey of the Gila River Forest Reserve (Rixon 1905). In reference to
grazing activities within the Reserve, he cautioned that almost the
entire Gila country was "carrying too many cattle" with the exceptions
of areas on the East Fork of the Gila River and the west slopes of the
Black Mountains. He described one severely overgrazed area located
approximately two miles north of Gilita Ridge as follows:

In T.9S, R.15W, a large area which was entirely given up to
sheep, has been overstocked, with the result that about half the
township is a barren desert, not a blade of grass being seen and
even the roots being entirely destroyed. When the wind blows,
the sand and soil rise in vast clouds. I have been informed
that this district, previous to the advent of sheep, was a fine
grazing area covered with the most succulent grasses.

When Henry Woodrow was assigned duties as fire guard in 1909 on
the McKinney Park District (changed to McKenna Park District in 1924 and
finally to Wilderness District in 1953), one of his first tasks was to
locate a campsite where summer fire operations could be headquartered

(Woodrow 1943). He apparently encountered some difficulty because he needed a place where there was grass for his horses, since at that time the Forest Service did not provide horse feed. He said, ". . .there were cattle all through the mountains and grass was hard to find, except in a few places."

Woodrow served as District Ranger on the McKenna Park District until he retired in 1942. In his History of the McKenna Park District, Gila National Forest, he often referred to his dealings with sheep and cattle herders in the area. He mentioned that in 1912 there were three sheep outfits on the district with a total count of 19,500 head.

When the Forest Service began its organized fire control efforts in the Gila around 1909, they also began to prevail on the ranchers to limit grazing activities. Today there is no grazing within the McKenna Park and Langstroth Mesa study areas with the exception of that by transient pack outfits. It is unknown exactly when the peak of grazing activity within the Wilderness took place, but it is likely that the largest numbers of livestock were in the area between 1890 and 1920.

The testimony of Rixon and Woodrow indicates that the grazing history of the Gila was no exception among the forests of the Southwest. Grazing and overgrazing was the first and perhaps greatest implement of change that affected the pre-1900 fire regime. When fire suppression began after the turn of the century, the combined effect was the end of a fire cycle which had persisted for centuries.

Summary

More than 800 individual fire scars on 44 ponderosa pine cross sections were dated for this study. The fire scar dates span a period of 345 years (1633-1978). The record from 1800-1900 indicates that fires occurred at mean fire intervals of four to eight years while the range of intervals was as short as one year and as long as 26 years.

Consistent agreement of fire dates within study areas suggests that most fires were extensive and probably burned throughout the study areas. A fewer number of fires burned smaller portions of the study areas and were only recorded within one or two collection sites, or only by one specimen.

An unusually long fire interval in the 1820's and 1830's in all three studies may be related to a wetter than usual period and higher fuel moistures. The end of this fire free period was marked in three study areas by a fire in 1837 which was recorded by nearly all of the specimens.

There was significant agreement of fire dates between study areas during certain time periods. Climatic factors such as drought, lightning occurrence, or both, may have been influencing fire occurrence over a regional area that included the study areas.

Periodic recurrence of extensive fires ceased after 1900. The cessation of the fire regime characterized by periodic fires followed the removal of Apaches from the Gila and roughly coincided with the advent of extensive livestock grazing and the beginning of fire suppression efforts.

CHAPTER 4

MODERN FIRE RECORDS, 1909-1980

Old fire records and other documents have provided a detailed look at fire occurrence over the entire Gila National Forest. By compiling some of these data, a long term record of numbers of fires and area burned per year has been assembled. This record provides fire statistics for each year from 1909 to 1980.

While fire scar data provide a view of natural fire regimes, modern fire data reflect other aspects of the relationships between fire and climate, fire and fuels, and fire and people. Just as a master tree-ring chronology is a data base of changes in tree growth over time, fire chronologies and fire records are data bases of change in fire occurrence over time. Both are a reflection of change in the environment, whether the changes are natural or human caused, and both can be useful in furnishing historical perspective.

Long term fire records also tend to reflect changes in fire detection and fire suppression techniques. Before actual changes in fire occurrence can be identified, it is necessary to identify changes in the record due to advances in fire control technologies.

This chapter describes the sources and methods that were used in compiling fire statistics and some of the characteristics of the resulting record. The primary objective of this effort was to develop a specific data base of fire occurrence in the Gila National Forest for

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the modern period (1909-1980). The existence of old fire documents

provided the opportunity to develop perhaps the longest such record

available for any National Forest. A second objective was to briefly

examine and discuss the more obvious features of this record.

Barrows (1978) carried out an extensive computer analysis of

lightning fire records (fires caused by human activities were excluded)

from the Southwestern Region. His study includes data from the Gila for

the period 1960-1974. His findings are pertinent to any study of the

effects of fuel, topography, and ignition on spatial and temporal fire

occurrence during the most recent portion of the modern period. The

following analysis and description of the 1909 to 1980 Gila fire record

is restricted to observable changes in fire statistics over the long

term and the relationship of these changes to fire management practices.

Methods

Most of the fire occurrence data for the period 1909 to 1939

were gathered by searching through old records and files that were

stored in the Gila National Forest Supervisor's Office in Silver City,

New Mexico. Documents included several large 18 x 22 inch (45.7 x 55.9

cm) binders which contained fire atlases (maps of fire occurrence),

ledgers of fire expenditures, and Supervisor's Annual Fire Reports (Form

No. 926). Various sets of loose files containing Individual Fire Re-

ports (Form No. 929) for the 1950's were also found.

Many of the fire atlases were colored cloth maps and several

particularly useful ones showed perimeters of all class C fires for

certain periods. (Size class ratings of areal extent of fires has

changed several times. Originally, any fire over ten acres was a class C fire. Current size class ratings in acres are as follows: A=0-0.25, B=0.26-9, C=10-99, D=100-299, E=300-999, F=1,000-4,999, and G=over 5,000.) Most of these maps were prepared by District Forest Inspectors E. L. Loveridge and L. J. Putsch for a fire study in 1926 (apparently unpublished). Loveridge and Putsch analyzed fire statistics for the period 1909-1925 and commented on ways to improve fire detection systems and dispatching.

Narrative reports of some of the larger fires that have occurred on the Gila were also found among the old documents. These were very useful in identifying acreage and location of these fires. Photocopies of Aldo Leopold's diary notes kept during a visit to the Gila in 1922 were also in a large binder. Leopold was Chief of Operations at the Forest Service District Office in Albuquerque at the time, and his trip to the Gila was an official inspection. As a result of this trip, Leopold included as a part of his report to the District Forester a recommendation for setting aside a part of the Gila National Forest to be administered as the Gila Wilderness Area (McFarland 1974). Most of Leopold's diary notes deal with aspects of several large fires that were burning during the visit, and which he helped to fight.

An invaluable source of information for the early period of record was Henry Woodrow's (1943) account of his many years as Forest Guard and District Ranger on the McKenna Park District. Most of this document is published in McFarland's (1974) Wilderness of the Gila and portions are included in Tucker and Fitzpatrick's (1972) Men Who Matched

the Mountains:A History of the Forest Service in the Southwest. Woodrow gives a short year by year narrative of his activities beginning in 1909 and proceeding to 1942 when he retired. He identifies fire seasons as good or bad and describes some of the larger fires. His history also documents the years that improvements such as telephone lines, lookouts, and fire cabins were installed.

Records for the period 1940-1959 were more difficult to find than for the earlier period. Although some of the Individual Fire Reports were among the old documents, they were incomplete. Data for most of this period were compiled from National Forest Fire Reports (1940-1959) and from Barrows (1982 Personal Communication).

Records for the period 1960-1980 were gathered from National Forest Fire Reports 1960 through 1980. Additional information was compiled from records located in the Regional Office in Albuquerque, New Mexico.

Results and Discussion

Fire occurrence data are listed by year in Table C-1, Appendix C. The data include number of fires by size class (A, B, and C to G), number of fires by major cause (lightning or person), total number of fires, and total area burned. This record reveals that over a period of 72 years there have been at least 14,083 reported fires that have burned over at least 265,819 acres (107,577 ha) of the Gila National Forest. This amount of burned area translates into approximately eight percent of the total area included in the National Forest today, about 3.3 million acres (about 1.3 million ha).

Looking at just the total number of fires reported per year, it can be seen that there is an obvious transformation in the record. Figure 14 is a plot of total number of fires by year. After 1933 the record shows a steady increase in number of fires reported until the 1960's where annual number of fires fluctuates around an average of approximately 350 fires. The increase in number of fires reported over a thirty year period (1930's-1960's) reflects continued improvement in fire detection and suppression technologies.

Changes in the fire record can be related to specific improvements in the Gila fire fighting organization. For example, in 1933 there were only 25 regular fire guards available during the summer months for fire fighting duties over the entire Gila National Forest. In 1934, Emergency Relief Administration (ERA) crews were stationed at the White Creek Ranger Station for trail maintenance and fish stream improvement, and in 1936 the Civilian Conservation Corps (CCC) constructed the Willow Creek Ranger Station and set up a camp there (Woodrow 1943). With CCC and ERA crews, manpower available for fire fighting duties increased to 137. This sudden increase in manpower enabled the Forest Service to send fire fighters to virtually every smoke that was visible over the forest canopy. Before this time, the limited number of fire guards necessitated a more selective strategy. In the earlier days, if a fire guard spotted several smokes from a high spot, he would go to the closest one or the one that appeared to have the most potential for spread. This strategy probably resulted in fewer fires reported because most fires were (and still are) single trees or

Figure 14. Plot of total number of fires by year. Approximate dates of introduction of significant fire suppression technology improvements are indicated.

snags and many of the smokes that were ignored in deference to others probably went out on their own.

The CCC programs also resulted in a significant improvement in fire detection and communications. Many of the lookouts still used today in the Gila were constructed by the CCC. Several telephone lines were also installed during this period and crews were used in construction of fire cabins and trail maintenance (Woodrow 1943). The combination of new lookouts from which more fires were spotted, and more firemen available to send to those fires, resulted in a significant increase in number of reported fires in the late 1930's.

In 1947, an eight man crew of smokejumpers (parachutist firefighters) from the Missoula, Montana base were assigned a sixty-day tour of duty on the Gila. They operated out of the Naval Air Station at Deming, New Mexico until 1954 when runways at Grant County Airport, east of Silver City, were lengthened and operations were moved there. The smokejumper crew was increased from eight to 18 members at that time (Hurst 1966). Not only were the smokejumpers an improvement in the speed and efficiency of fire control but the increased air traffic probably led to better detection of fires.

The next significant improvement came in the late 1950's with the addition of helicopters working out of airstrips and heliports within the National Forest, and with the establishment of a slurry bomber facility at Grant County Airport (Webb 1980 Personal Communication). By the early 1960's the Gila fire organization was one of the most diversified and sophisticated in the country.

Characteristics of the Fire Record by Time Period

Table 7 lists several statistics relating to observed changes in
the fire record. Computations were made of mean annual number of fires,
mean and median annual number of acres burned, and mean annual acres per
fire by time period. Standard deviations were computed to demonstrate
the spread about each mean value. Periods were chosen on the basis of
fire organization improvements and apparent changes in the record. The
mean annual number of fires equals the total number of fires during the
period divided by the number of years in the period. The mean annual
acres burned equals the total number of acres burned during the period
divided by the number of years in the period. The mean annual acres per
fire equals the total area burned during the period, divided by the
total number of fires during the period.

Median annual acres burned were computed because of large varia-
tion in the record of acres burned per year. Large fires in certain
years account for the majority of acres burned for the entire period.
Because of this bias, mean annual acres burned figures alone do not
adequately describe the typical number of acres burned during the aver-
age year.

The Period 1909-1933. Fire organization during this period was
characterized by a small force of horse-mounted fire guards. By the end
of this period fire cabins and lookouts had been built at strategic
locations throughout the National Forest and many of them were connected
by telephone line. The record indicates that an average of 38 fires
occurred per year during this period while the average area burned per
fire was 64.7 acres (26.2 ha). Large fires occurring in 1909, 1918,

1927. and 1929 inflate the acreage burned figures. This has the effect of raising the mean annual acres burned and mean acres per fire values. The median annual area burned during this period was 249 acres (100.8 ha).

Table 7. Gila National Forest Annual Fire Statistics, 1909-1980.

Period	Annual Number of Fires		Annual Number of Acres Burned			Annual Number of Acres/Fire	
	Mean	Std Dev.	Mean	Std Dev.	Median	Mean	Std Dev.
1909-1933 (25 Yrs.)	38	16	2,212	4,737	249	64.7	176.3
1934-1946 (13 Yrs.)	168	59	4,400	7,491	959	27.5	44.3
1947-1956 (10 Yrs.)	243	115	8,868	17,234	1,805	41.9	94.1
1957-1980 (24 Yrs.)	354	114	2,667	6,333	444	6.3	11.7

1922, and 1925 inflate the acreage burned figures. This has the effect of raising the mean annual acres burned and mean acres per fire values. The median annual area burned during this period was 249 acres (100.8 ha).

Table C-2 in Appendix C lists some of the large fires (over 300 acres or 120 ha) which have occurred on the Gila National Forest. This list is incomplete, especially for the period 1940 to 1960, because of lack of available records.

The Period 1934-1946. This period was characterized by increased manpower and improved facilities. An exception was during World War II when manpower dropped. Mean annual number of fires increased to 168 while mean area per fire decreased to 27.5 acres (11.1 ha).

The Period 1947-1956. This period was characterized by the introduction of smokejumpers and increased use of aircraft and radios. The mean number of fires per year increased to 243 and the average area of individual fires increased to 41.9 acres (17.0 ha). Two exceptionally bad fire seasons in 1951 and 1956 inflated the acreage burned values for this period. Two class G fires, the 40,000 acre (16,190 ha) McKnight Fire and the 14,000 acre (5,670 ha) Little Creek Fire, occurred in 1951. These fires accounted for more than 75 percent of the total acres burned during this period, and nearly 25 percent of the total acreage burned during the entire 1909-1980 record. The McKnight Fire is one of the largest fires on record in Forest Service Region 3.

The Period 1957-1980. With the addition of a larger smokejumper crew, helicopters, slurry bombers, and surveillance planes in the late fifties and early sixties, the Gila fire organization truly entered the

"air age" of fire fighting. Since then, the number of reported fires per year has always exceeded the 1955 level (145), and the maximum number of fires (670) was recorded in 1961. The average number of fires per year for the period 1957 to 1980 was 354, while the mean annual area burned per fire (6.3 acres, 2.5 ha) was lower than any of the other periods. Nearly half the area burned during this period was due to the 27,413 acre (11,094 ha) Salvation Fire which occurred in 1974. The median annual burned area (444 acres, 180 ha) was probably more representative of the acreage burned during any year of this period.

Change in Annual Number of Fires

While mean annual number of fires has increased over time, the variation in number of fires from year to year has also increased. The most extreme cases were the years 1955, when 145 fires were reported, and 1956, when 522 fires were reported; a difference of 372 fires. The standard deviation about the mean of 354 fires per year for the most recent period of record (1957-1980) was 114 fires. The possibility of such large differences in fire load from year to year points out the difficulty of long range fire planning on the Gila. Even with limited budgets fire managers must often plan for worst case situations.

Although differences in total number of fires from year to year increased over time, the proportional amount of variation about the mean annual number of fires has remained essentially unchanged. In other words, the observed increase in variation, or difference in the number of fires from year to year, was more or less proportional to the increase in mean annual number of fires. This was determined by calcu-

lating the standard deviation of annual number of fires and then dividing the standard deviations by the mean annual number of fires for each period. This results in a value known as the coefficient of variation which facilitates comparison of variations about different sized means (Freese 1972). Coefficients of variation for the periods were as follows: 1909-1933, 0.42; 1934-1946, 0.35; 1947-1956, 0.47; 1957-1980, 0.32. When multiplied by 100, these values are the relative percent variation about the mean. Since the coefficients of variation for all periods were within 32 and 47 percent, it seems apparent that relative variation has remained fairly constant through time.

Change in Size of Fires

As previously mentioned, the areas burned per year data tend to be biased by occurrence of large fires during certain years. Because of this effect, it is difficult to observe trends in the amount of area burned over time using only acres burned data. Mean annual acres burned data (Table 7) actually show more area burned per year in the 1957-1980 period (2,667 acres, 1,079 ha) than in the 1909-1933 period (2,212 acres, 895 ha), despite improvements in the fire organization. However, if known class G fires and PNF's are excluded from these calculations, mean annual area burned for the recent and earliest period are 889 acres (360 ha) and 1,696 acres (686 ha) respectively. This indicates that if the largest fires and PNF's are not considered, the average amount of acres burned per year in the modern era is almost half of what it was in the earlier period.

Another measure of change in area burned by fires is a

comparison of the distribution of size classes. The means for annual
number of fires by size class are included in Table 8. The number of
fires by size class were only available for a most recent period (1960-
1980) and an early period (1909-1939). In the early period all fires
over ten acres in size were listed as class C; therefore, comparisons of
larger fires are grouped under classes C to G.

The comparison indicates that a larger percentage of fires were
class A in the recent period (75%) than in the early period (66%). A
smaller percentage were class C to G in the recent period (3%) than in
the early period (8%). It appears then that the majority of increase in
numbers of fires per year were small fires. Most of this increase can
probably be attributed to improved protection, since small fires were
the ones most likely to have been overlooked in the days before air-
craft.

Total fire numbers, however, have increased in all size classes.
From 1909 to 1939 an average of five class C or larger fires occurred
per year, while from 1960 to 1980 an average of 11 class C or larger
fires occurred per year. Class B fires have increased from an average
of 16 per year to 79 per year.

The increase in class C to G fires was weighted by a larger
increase in class C to D fires than E to G fires. In other words, the
increase in this category was more reflective of an increase in the
number of fires ten to 50 acres in size rather than fires greater than
50 acres in size. Since these were larger fires, it is unlikely that
they would have gone unnoticed even in the earlier period. For this

Table 8. Gila National Forest Statistics of Annual Numbers of Fires by Size Class.

	Annual Number of Fires by Size Class					
	A		B		C to G	
Period	Mean	Std Dev.	Mean	Std Dev.	Mean	Std Dev.
1909-1939 (31 yrs.)	40 (66%)	43	16 (26%)	11	5 (8%)	5
1960-1980 (21 yrs.)	276 (75%)	103	79 (22%)	35	11 (3%)	10

mw p<0.001   P= 0.005

reason, improved protection does not necessarily explain the increase in class C and larger fires. It is true that the acreage under protection and regular surveillance was greater in the recent period than in the first part of the early period; however, by the end of the early period the National Forest included approximately the same amount of area that it does now. An increase in area under protection is not a satisfactory explanation for the increase in large fires. With reconnaissance aircraft, detection has certainly improved in the recent period. On the other hand, lookouts were well established by the end of the early period and it would have been unlikely that fires over ten acres in size would have gone undetected.

Unless some fires were ignored in the early period because they were in a remote area or for some other reason, the increase in class C or larger fires requires some other explanation. One possibility is that the recent period had more frequent extreme fire years than the early period because of climatic conditions. Another possibility is that fuel conditions (i.e., fuel types and fuel loadings) have changed in the National Forest to the point where fires are more difficult to extinguish and are consequently getting larger. Of course, these are only speculations and conclusive evidence for any explanation will require further research. At this point, considering all the unknown variables (i.e., changes in climate, changes in area under protection, incompleteness of record) it is not possible to conclude that fire occurrence and fire size are increasing because of on-site conditions in the National Forest, although the data may suggest this.

Changes in Causes of Fires

Table 9 lists mean annual number of fires by major cause and by period. Percent of each category are also listed under the mean values. Evidently there were proportionally fewer person caused fires in the recent period (1957-1980) than in the earliest period (1909-1933). However, on the average there were larger numbers of person caused fires per year in the recent period (16) than in the earliest period (11).

The increase in number of person caused fires was probably due to several factors. Among them were better detection, increased access, and increased visitation of the National Forest and Wilderness back-country areas. The latter factor has probably affected the number of person caused fires recorded in the Wilderness Areas the most, especially since the late 1960's and early 1970's when the number of visitors increased significantly. There was an apparent increase in number of person caused fires beginning in the 1970's with an all time high of 44 in 1972 (Table C-1).

Summary

The 72 year Forest Service record of fire occurrence shows a general increase in mean annual number of reported fires. As annual number of fires has increased, the difference in number of fires from year to year has also increased.

When large fires (Class G) and PNF's were included in the computations, the record indicates that the mean annual area burned has increased. When large fires and PNF's were excluded, the mean annual area burned during the recent period was about half the amount burned in

the earliest period. The mean annual area per fire has decreased considerably.

Changes in the number of reported fires and area burned per fire seem to be related to improvements in the fire organization. An increase in the mean annual number of fires in the larger size class categories (class C to G) cannot be fully explained by improved fire detection. An increase in number of person-caused fires was probably

Table 9. Gila National Forest Statistics of Annual Number of Fires by Major Cause.

	Annual Number of Fire by Cause			
	Lightning		Person	
Period	Mean	Std Dev.	Mean	Std Dev.
1909-1933 (25 Yrs.)	26 (70%)	16	11 (30%)	6
1934-1946 (13 Yrs.)	156 (92%)	58	14 (8%)	5
1947-1956 (10 Yrs.)	232 (95%)	118	12 (5%)	5
1957-1980 (24 Yrs.)	338 (95%)	109	16 (5%)	11

the earliest period.   The mean annual area per fire has decreased

considerably.

Changes in the number of reported fires and area burned per fire

seem to be related to improvements in the fire organization.   An in-

crease in the mean annual number of fires in the larger size class

categories (class C to G) cannot be fully explained by improved fire

detection.   An increase in number of person caused fires was probably

related to increased visitation.

CHAPTER 5

IMPLICATIONS FOR FIRE MANAGEMENT

On that June morning in 1900 when Gifford Pinchot counted the rings between fire scars on a ponderosa pine (see Chapter 1, above), he saw for himself the evidence that fires had been common to the forests of the Mogollon rim. Yet, his perspective and that of other foresters of the day was that all fires were destructive to the "managed forest." When he viewed a plume of smoke rising over the Arizona forest, he said, "It was primeval, but not according to the rules" as he defined them. Perhaps what he failed to recognize was that Indians were only a different source of ignition; they added more of an element already present in the system. Lightning fires were an inherent element of the environment and as natural and vital as rain, snow, or wind. The perspective of an additional eighty years of land management has taught us that, in the long run, altering basic elements of ecosystems to conform with human "rules," without first understanding the importance of those elements, often results in destabilization and eventual damage to, or loss of the resource.

One important value of fire history, and history in general, is that it can provide us with perspective. Historical and scientific perspective is especially important to wilderness managers because they are charged with the responsibility of preserving and maintaining the primeval land characteristics that have passed out of existence else-

where. The purpose of this chapter is to discuss the perspective that this study provides and to identify implications for carrying out wilderness fire management programs.

Implications of Modern Fire Records

The modern record of fire occurrence provides no great surprises for fire managers. The number of reported fires per year has risen steadily with improved fire detection and fire suppression technology advancements. The average area per fire is now much lower than it was in the first few decades of Forest Service administration. Large fires and PNF's in recent decades have increased the total number of acres burned so that the average number of acres burned per year is actually slightly greater than during the earliest period of record.

The occurrence of more large fires in the most recent period (1960-1980) than in the earliest period (1909-1939) may be a warning to managers. Although it is difficult to be certain that this is a genuine trend, the data suggests that it may be. Barrows (1982 Personal Communication) observed the same possible trend in fire occurrence data that he analyzed. He felt that the trend may be related to improved access to National Forest lands via roads built for logging, resulting in more man caused fires. Logging activities also tend to increase fuels and open forest stands so that fuels dry out more quickly. In many areas where fire has been absent for 70 or 80 years, fuels have accumulated to the point where the danger of conflagration fire is far greater than it was before 1900.

In addition to identifying long term trends in fire occurrence due to human activities, the 72 year modern fire record may also provide data for comparison with climatic records. If a relationship exists between precipitation, temperature, or drought and fire occurrence, then it may be possible to identify the relationship. This could prove to be valuable information, especially if certain climatic factors preceding a fire season are correlated with fire occurrence.

Implications for Prescribed Natural Fire

The Wilderness Act of 1964 states:

> A wilderness, in contrast with those areas where man and his works dominate the landscape, is hereby recognized as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain. An area of wilderness is further defined to mean in this Act an area of undeveloped Federal land retaining its primeval character and influence without permanent improvements or human habitation, which is protected and managed so as to preserve its natural condition and which generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable. . ..

The question remains: What were the "natural conditions" and "primeval character," and when did they exist? One interpretation is that "natural conditions" existed before grazing and fire suppression (Leopold 1969). If this is a valid interpretation, then conditions during this period may constitute a model for wilderness managers to restore, simulate, or maintain. Practical considerations overrule the possibility of achieving perfectly natural ecosystems or returning the wilderness to an area completely "untrammeled by man." The Wilderness Act stipulates that wilderness areas will be administered for the use and enjoyment of people as well as for preservation. Use by the public

necessarily entails some impact and some compromise of natural conditions.

Despite the impracticality of a totally natural role for fire in wilderness in the immediate future, descriptions of the pre-1900 fire regime can provide a baseline for managers to evaluate long range objectives of the Prescribed Natural Fire Program. If the PNF Program is to successfully achieve the reintroduction of fire as an effective force shaping the ecosystem, while at the same time reducing live and dead fuel accumulations and thus lowering fire hazard, then there are several aspects of the pre-1900 fire regime which may serve as guidelines.

Burning Intervals

Fires scar evidence shows that before 1900 fires burned through the understory of ponderosa pine stands every four to eight years. This may be the approximate burning interval that managers should achieve within approved PNF areas in order to (1) simulate "natural" or pre-settlement fire regimes and (2) to effectively reduce live and dead fuel accumulations.

Observations within PNF areas that have burned recently suggest a need for reburning. Many small seedlings are establishing under mature stands, and without subsequent fire these seedlings may gain increased resistance to fire and eventually develop into additional stagnated thickets. Fuels are also a concern because, due to the fall of scorched foliage and killed stems within some areas of PNF burns, fuel loadings have increased over a period of two or three years to

levels exceeding initial loadings before the burn (Garcia 1982 Personal Communication).

The "Langstroth PNF" of 1978 was the first large fire to have burned on Langstroth Mesa for more than 70 years. This fire consumed large amounts of dead fuels (i.e., duff, litter, logs, etc.) that had accumulated for decades; however, live fuels such as pine thickets were only scorched and thinned in patches. Effective removal of thickets, and the fuels that are generated with each thinning by fire, will require several burning cycles. Since the inception of the PNF program in 1974, no PNF's have burned over areas more than once.

If fire is to return to PNF areas at intervals of four to eight years, or at even longer intervals, then there may be a need for more flexibility in the PNF program. Under the present Forest Service policy of allowing only lightning caused fires to burn within PNF areas (United States Department of Agriculture Forest Service Manual 1976:Section 2324.2), PNF's have burned more than 12,000 acres (4,860 ha) in the Gila Wilderness. Although this is a significant accomplishment in restoring natural fire to the Wilderness and in developing a data base for managing natural fires, it is questionable whether this rate of burning will result in PNF areas burning at least once or twice per decade.

One option for providing flexibility and greater control over the process of restoring natural conditions to wilderness is the use of planned ignitions. The National Park Service has taken this step in several parks in the western United States (Kilgore 1975, Parsons 1981). The arguments for and against such a policy in Forest Service Wilderness Areas are not simple and a thorough discussion could entail a thesis

equal in length to this one. Regardless of the merits of either side of this issue, certainly it is one that should be given priority consideration in wilderness fire management planning.

APPENDIX A

TREE-RING INDICES

Table A-1. McKenna Park Master Tree-Ring Chronology.

484640   MCKENNA PARK (GILA WILDERNESS AREA) PINUS PONDEROSA
NEW MEXICO   S   PONDEROSA PINE
LATITUDE 33 1X   LONGITUDE 108 27X ELEVATION 7800 FEET (2377.4 METERS)
COLLECTED BY T. SWETNAM, J. DIETERICH, T. P. HARLAN   ON 27 MAY 1980

SERIAL CORRELATION = .256   STANDARD DEVIATION = .281   MEAN SENSITIVITY = .286   NO. YEARS = 290

DATE	TREE RING INDICES										NUMBER OF SAMPLES									
	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1690	127	112	129	120	133	114	103	104	101	138	2	2	2	2	3	3	3	3	3	3
1700	103	112	95	91	86	8C	78	78	90	76	3	3	3	3	3	3	3	3	3	3
1710	139	110	96	75	104	100	63	80	99	66	3	3	3	3	3	3	3	3	3	3
1720	110	111	110	80	83	113	13C	87	107	101	3	3	3	3	3	3	4	4	5	6
1730	126	82	101	59	118	95	127	103	102	65	6	6	6	6	6	6	6	6	6	6
1740	50	113	89	121	108	102	144	132	33	1C5	6	6	6	6	7	7	7	7	7	7
1750	97	121	65	78	133	104	92	66	118	120	7	7	7	7	7	7	7	7	9	9
1760	98	92	124	69	114	104	135	126	92	98	9	9	9	9	9	10	1C	10	10	10
1770	96	107	94	39	68	91	96	83	121	84	10	10	10	10	10	10	10	10	10	10
1780	73	109	67	122	137	76	86	142	81	63	10	10	10	10	10	10	1C	10	10	10
1790	92	101	106	167	105	100	100	66	87	124	11	11	11	11	11	11	11	11	11	11
1800	103	85	106	97	128	99	92	89	94	93	13	13	13	13	13	13	13	13	13	13
1810	117	99	78	67	106	144	132	78	72	50	13	13	13	13	13	13	13	13	13	13
1820	52	76	46	80	98	82	108	97	135	167	13	14	14	14	14	14	14	14	14	14
1830	146	108	145	141	122	129	11C	84	88	143	16	16	16	16	16	16	16	16	16	16
1840	101	66	56	85	123	115	103	68	105	130	16	16	16	16	16	16	16	16	16	16
1850	89	58	107	101	83	69	82	94	116	75	16	16	16	16	16	16	16	17	17	17
1860	60	83	75	69	59	112	130	106	160	14C	19	19	19	19	19	19	19	19	19	19
1870	13C	80	105	88	89	122	85	106	139	108	19	19	19	19	19	19	19	19	19	19
1880	82	110	112	128	85	138	118	103	82	98	20	20	2C	20	20	20	20	20	20	20

Table A-1. McKenna Park Master Tree-Ring Chronology, <u>Continued</u>.

DATE	TREE RING INDICES											NUMBER OF SAMPLES								
	0	1	2	3	4	5	6	7	8	9		0	1	2	3	4	5	6	7	8	9
1890	103	76	53	61	45	82	97	77	143	122		20	20	20	20	20	20	20	20	20	20
1900	67	102	75	114	27	118	118	167	180	138		20	20	20	20	20	20	20	20	20	20
1910	97	149	126	106	165	122	168	145	107	133		20	20	20	20	20	20	20	20	20	20
1920	113	142	88	84	121	57	93	78	81	110		20	20	20	20	20	20	20	20	20	20
1930	111	134	140	150	50	99	92	101	112	77		20	20	20	20	20	20	20	20	20	20
1940	134	168	104	101	133	126	66	85	71	107		20	20	20	20	20	20	20	20	20	20
1950	55	39	103	74	73	70	31	68	78	62		20	20	20	20	20	20	20	20	20	20
1960	68	70	103	83	98	140	109	94	130	74		20	20	20	20	20	20	20	20	20	20
1970	124	21	116	107	18	150	107	97	82	114		20	20	20	20	20	20	20	20	20	19

Table A-2. White Creek Master Tree-Ring Chronology.

WCK549   WHITE CREEK (GILA WILDERNESS AREA)   PSEUDOTSUGA MENZIESII
NEW MEXICO   DOUGLAS-FIR
LATITUDE 33 15   LONGITUDE 108 26   ELEVATION 7000 FEET (2133.6 METERS)
COLLECTED BY T. W. SWETNAM AND T. P. HARLAN   ON 2 JULY 1981

SERIAL CORRELATION = .411   STANDARD DEVIATION = .280   MEAN SENSITIVITY = .249   NO. YEARS = 345

| | | | TREE RING INDICES | | | | | | | | | | | NUMBER OF SAMPLES | | | | | | |
DATE	0	1	2	3	4	5	6	7	8	9		0	1	2	3	4	5	6	7	8	9
1636							82	63	93	116								2	2	2	2
1640	101	81	93	89	97	67	82	99	34	65		2	2	2	2	2	2	2	3	3	3
1650	72	124	102	108	83	130	103	114	92	71		3	3	3	3	3	3	3	3	3	3
1660	118	133	114	87	65	121	102	79	70	52		3	3	3	3	3	3	3	3	3	3
1670	39	120	131	108	109	123	113	95	93	118		3	3	3	3	3	3	3	3	3	3
1680	144	118	114	101	106	56	121	103	118	160		3	3	3	3	3	3	3	3	3	3
1690	155	62	144	120	132	120	108	124	117	146		3	4	4	4	4	4	4	4	4	4
1700	123	163	108	128	114	66	96	75	90	37		4	4	4	4	4	4	4	4	4	4
1710	129	97	109	79	96	76	32	92	103	90		4	4	4	4	4	4	4	4	4	4
1720	114	127	130	84	117	125	133	90	82	84		4	4	4	4	4	4	4	5	5	5
1730	83	85	88	59	81	60	65	87	81	74		5	5	5	5	5	5	5	5	5	5
1740	72	117	94	109	115	113	162	179	58	127		5	5	5	5	5	5	5	5	5	5
1750	124	134	86	111	141	126	116	91	150	139		5	5	5	5	5	5	5	5	5	5
1760	121	106	136	96	150	134	129	136	108	94		5	5	5	5	5	5	6	7	7	7
1770	97	97	86	54	81	87	85	67	94	95		7	7	7	7	7	8	8	8	8	8
1780	64	94	56	120	135	93	96	115	74	83		8	8	8	8	8	8	8	8	8	8
1790	65	113	115	152	93	121	102	62	78	102		8	10	10	10	10	10	10	10	10	10
1800	102	110	109	77	123	102	76	108	89	104		10	10	10	10	11	11	11	11	11	11
1810	120	98	82	81	75	118	145	88	56	48		12	12	12	12	12	13	13	13	13	13
1820	49	83	55	71	82	78	70	75	120	130		13	13	13	13	13	13	14	15	15	15
1830	130	122	136	134	114	124	89	66	81	134		16	16	16	16	16	16	17	17	17	17

Table A-2. White Creek Master Tree-Ring Chronology, <u>Continued</u>.

DATE	TREE RING INDICES										NUMBER OF SAMPLES									
	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1840	123	89	63	94	109	95	120	77	99	120	18	18	19	19	19	19	19	19	19	19
1850	119	79	95	90	78	91	97	90	92	128	19	19	19	19	19	19	19	19	19	19
1860	113	64	86	42	67	104	118	121	144	109	19	19	19	19	19	19	19	19	19	19
1870	87	52	54	64	76	81	77	96	73	87	19	19	19	19	19	19	19	19	20	20
1880	71	82	87	92	88	108	93	80	85	88	21	21	21	21	21	21	21	21	21	21
1890	77	111	80	78	49	77	91	109	160	120	21	21	21	21	21	21	21	21	21	21
1900	80	97	90	126	48	107	140	159	184	160	21	21	21	21	21	21	21	21	21	21
1910	88	129	135	97	133	143	144	136	101	171	21	21	21	21	21	21	21	21	21	21
1920	190	152	104	89	120	56	122	104	105	105	21	21	21	21	21	21	21	21	21	21
1930	133	144	175	148	82	110	87	113	106	80	21	21	21	21	21	21	21	21	21	21
1940	113	151	128	115	114	132	70	82	72	107	21	21	21	21	21	21	21	21	21	21
1950	82	71	106	91	76	66	54	60	92	80	21	21	21	21	21	21	21	21	21	21
1960	89	71	98	112	73	111	106	87	120	88	21	21	21	21	21	21	21	21	21	20
1970	94	57	114	137	43	114	121	92	112	134	20	19	19	19	19	19	19	18	18	18
1980	108										18									

APPENDIX B

FIRE SCAR DATA

Table B-1. McKenna Park Master Fire Chronology.

The table shows fire years, fire scar susceptible trees (see text),
number of trees scarred, total number of fire scars, and fire interval
(Romme 1980).

Date (A.D.)	No. of Fire Scar Susceptible Trees	No. of Trees Scarred	Total No. of Fire Scars	Fire Interval (Years)
1633	0	1	1	-
1640	1	2	3	7
1649	2	1	1	9
1650	3	1	1	1
1654	3	2	2	4
1670	3	1	1	16
1671	3	1	2	1
1683	3	1	1	12
1696	4	1	1	13
1697	5	1	2	1
1705	5	1	1	8
1711	6	1	1	6
1713	6	1	1	2
1715	6	3	3	2
1724	7	2	3	9
1726	7	1	1	2
1729	8	1	1	3
1733	8	1	2	4
1734	8	1	2	1
1738	8	2	2	4
1742	9	1	1	4

Table B-1. McKenna Park Master Fire Chronology, Continued.

Date (A.D.)	No. of Fire Scar Susceptible Trees	No. of Trees Scarred	Total No. of Fire Scars	Fire Interval (Years)
1743	9	1	1	1
1745	9	3	6	2
1751	9	1	2	6
1760	9	2	3	9
1761	9	2	3	1
1764	10	1	2	3
1765	10	1	1	1
1768	10	3	3	3
1770	10	1	3	2
1772	10	6	9	2
1777	10	1	1	5
1779	10	3	6	2
1781	10	1	2	2
1784	10	2	3	3
1788	10	1	2	4
1790	10	1	2	2
1794	10	2	4	4
1796	10	2	3	2
1801	11	6	10	5
1806	11	7	11	5
1811	13	7	10	5
1817	13	11	15	6
1825	13	10	17	8

Table B-1. McKenna Park Master Fire Chronology, <u>Continued</u>.

Date (A.D.)	No. of Fire Scar Susceptible Trees	No. of Trees Scarred	Total No. of Fire Scars	Fire Interval (Years)
1837	14	11	17	12
1844	14	1	2	7
1847	15	14	24	3
1854	16	11	19	7
1860	16	1	1	6
1863	16	16	29	3
1871	16	11	18	8
1879	16	12	23	8
1883	16	6	8	4
1890	16	11	19	7
1901	16	5	10	11
1904	16	3	5	3
1920	16	1	2	16
1951	16	2	3	31

Table B-2. Langstroth Mesa Master Fire Chronology.

The table shows fire years, fire scar susceptible trees (see text), number of trees scarred, total number of fire scars, and fire interval (Romme 1980).

Date (A.D.)	No. of Fire Scar Susceptible Trees	No. of Trees Scarred	Total No. of Fire Scars	Fire Interval (Years)
1635	0	1	1	-
1661	1	1	1	26
1674	2	1	2	13
1678	3	1	1	4
1681	4	1	1	3
1687	4	1	1	6
1691	4	2	3	4
1705	4	1	1	14
1708	4	1	1	3
1709	4	1	1	1
1713	4	2	3	4
1716	4	2	4	3
1719	4	1	1	3
1723	4	1	2	4
1729	4	2	2	6
1733	4	2	3	4
1737	5	1	1	4
1742	5	2	3	5
1748	5	2	2	6
1752	5	2	4	4
1760	5	2	3	8

Table B-2. Langstroth Mesa Master Fire Chronology, <u>Continued</u>.

Date (A.D.)	No. of Fire Scar Susceptible Trees	No. of Trees Scarred	Total No. of Fire Scars	Fire Interval (Years)
1762	5	1	1	2
1770	5	1	2	8
1779	5	2	3	9
1780	5	1	2	1
1781	5	1	2	1
1785	5	1	1	4
1788	5	2	2	3
1790	5	1	2	2
1801	5	3	4	11
1806	6	7	12	5
1811	7	4	5	5
1815	7	1	1	4
1837	7	12	20	22
1841	13	4	6	4
1847	13	9	13	6
1854	14	12	19	7
1857	16	9	13	3
1861	16	1	1	4
1862	16	1	1	1
1866	16	7	10	4
1869	17	7	12	3
1870	17	3	4	1
1871	17	6	9	1

Table B-2. Langstroth Mesa Master Fire Chronology, <u>Continued</u>.

Date (A.D.)	No. of Fire Scar Susceptible Trees	No. of Trees Scarred	Total No. of Fire Scars	Fire Interval (Years)
1876	17	1	1	5
1879	17	13	17	3
1886	17	13	16	7
1892	18	16	27	6
1904	18	10	17	12
1907	18	1	1	3
1908	18	1	1	1
1909	18	1	1	1
1930	18	1	1	21
1978	18	2	3	48

Table B-3. Gilita Ridge Master Fire Chronology.

The table shows fire years, fire scar susceptible trees (see text), number of trees scarred, total number of fire scars, and fire interval (Romme 1980).

Date (A.D.)	No. of Fire Scar Susceptible Trees	No. of Trees Scarred	Total No. of Fire Scars	Fire Interval (Years)
1650	0	2	3	-
1689	2	1	2	39
1691	2	1	1	2
1705	2	1	2	14
1709	2	1	2	4
1716	3	1	1	7
1723	3	1	1	7
1733	3	1	1	10
1742	3	2	4	9
1744	4	1	1	2
1748	4	1	1	4
1752	4	1	1	4
1759	4	1	1	7
1761	4	1	1	3
1763	4	1	1	2
1770	4	3	3	7
1772	4	1	1	2
1774	4	1	2	2
1776	5	1	1	2
1785	5	2	2	9
1792	6	1	1	7

Table B-3. Gilita Ridge Master Fire Chronology, <u>Continued</u>.

Date (A.D.)	No. of Fire Scar Susceptible Trees	No. of Trees Scarred	Total No. of Fire Scars	Fire Interval (Years)
1798	6	1	1	6
1803	6	2	2	5
1806	6	1	2	3
1812	6	2	3	6
1814	6	2	2	2
1819	6	2	2	5
1837	6	7	11	18
1842	8	3	4	5
1847	9	3	3	5
1848	9	1	1	1
1851	9	7	9	3
1859	10	5	8	8
1862	10	2	4	3
1865	10	1	1	3
1867	10	3	3	2
1870	10	3	4	3
1876	10	3	4	6
1879	10	5	6	3
1883	10	3	5	4
1888	10	5	7	5
1892	10	1	1	4
1896	10	1	1	4
1899	10	4	5	3

Table B-3. Gilita Ridge Master Fire Chronology, <u>Continued</u>.

Date (A.D.)	No. of Fire Scar Susceptible Trees	No. of Trees Scarred	Total No. of Fire Scars	Fire Interval (Years)
1907	10	1	1	8

APPENDIX C

MODERN FIRE DATA

Table C-1. Modern Fire Data, Gila National Forest, 1909-1980.

Year (A.D.)	Size Class A	B	C-G	Major Cause Person	Lightning	Total No. of Fires	Total Area Burned(Acres/ha)
1909	6	5	13	20	4	24	20,845/8,436
1910	18	5	2	13	12	25	841/340
1911	1	13	2	13	3	16	209/85
1912	22	10	3	7	28	35	66/27
1913	38	15	15	20	48	68	5,073/2,053
1914	16	12	0	11	17	28	60/24
1915	17	8	2	16	11	27	69/28
1916	12	9	5	20	6	26	1,101/446
1917	21	16	8	8	37	45	784/317
1918	22	15	14	13	38	51	6,131/2,481
1919	15	12	0	10	17	27	26/11
1920	9	8	5	6	16	22	330/134
1921	14	8	2	14	10	24	249/101
1922	25	20	9	7	47	54	7,286/2,949
1923	19	9	3	6	25	31	119/48
1924	13	4	3	1	19	20	95/38
1925	24	16	5	7	38	45	10,781/4,363
1926	29	3	1	1	32	33	30/12
1927	15	6	2	3	20	23	92/37
1928	41	22	0	10	53	63	68/28
1929	30	12	4	2	44	46	265/107
1930	33	19	1	17	36	53	107/43
1931	32	15	3	10	40	50	179/72

Table C-1. Modern Fire Data, Gila National Forest, 1909-1980, <u>Continued</u>.

Year	Size Class			Major Cause		Total No.	Total Area
(A.D.)	A	B	C-G	Person	Lightning	of Fires	Burned(Acres/ha)
1932	42	19	1	22	40	62	140/57
1933	42	14	8	11	53	64	467/189
1934	144	45	16	24	181	205	7,583/3,069
1935	53	19	2	18	56	74	124/50
1936	169	41	2	13	199	212	182/74
1937	98	28	4	17	113	130	554/224
1938	64	28	7	18	81	99	7,523/3,045
1939	156	53	6	14	201	215	577/234
1940				14	262	276	270/109
1941				5	103	108	70/28
1942				12	180	192	959/388
1943				13	210	223	2,700/1,093
1944				6	156	161	7,116/2,880
1945				17	115	132	2,219/898
1946				12	165	177	27,322/11,057
1947				11	168	179	1,600/648
1948				14	166	180	1,049/425
1949				16	247	263	1,054/427
1950				22	159	181	3,838/1,553
1951				14	170	184	56,677/22,937
1952				4	158	162	1,011/409
1953				10	272	282	9,997/4,046
1954				8	324	332	2,009/813

Table C-1. Modern Fire Data, Gila National Forest, 1909-1980, <u>Continued</u>.

Year (A.D.)	Size Class A	B	C-G	Major Cause Person	Lightning	Total No. of Fires	Total Area Burned(Acres/ha)
1955				9	136	145	371/150
1956				13	519	522	11,071/4,480
1957				4	264	268	226/91
1958				4	279	283	98/40
1959				8	274	282	91/37
1960	372	69	5	7	439	446	5,201/2,105
1961	580	87	3	12	658	670	380/154
1962	321	38	6	14	351	365	281/114
1963	262	31	1	5	289	294	137/55
1964	275	43	9	7	320	327	329/133
1965	204	40	7	7	244	251	206/83
1966	135	69	9	8	205	213	1,072/434
1967	182	64	7	9	244	253	1,546/626
1968	150	82	11	9	234	243	550/223
1969	167	92	16	14	261	275	2,050/830
1970	262	132	13	15	392	407	4,488/1,816
1971	277	146	18	25	416	441	2,949/1,193
1972	352	66	2	44	376	420	36/15
1973	224	54	3	20	261	281	213/86
1974	359	152	45	26	530	556	31,014/12,551
1975	221	54	2	22	255	277	183/74
1976	413	83	5	30	471	501	507/205
1977	301	70	11	21	361	382	507/205

Table C-1. Modern Fire Data, Gila National Forest, 1909-1980, <u>Continued</u>.

Year (A.D.)	Size Class			Major Cause		Total No. of Fires	Total Area Burned(Acres/ha)
	A	B	C-G	Person	Lightning		
1978	302	119	25	33	413	446	6,577/2,662
1979	187	55	12	19	235	254	4,748/1,922
1980	244	105	12	31	330	361	757/306
1981						408	986/399
1982						297	299/121
1983						270	178/72
1984						267	1,139/461
1985						403	21,433/8674

Handwritten notes in right margin: ~ 1,600 PNF / 3,950 PNF

Handwritten note: ← PNFS ?

Table C-2. Partial List of Large Fires on Gila National Forest, 1909-
1981,[1] Classes E, F, and Larger Fires (300+ Acres, 120+ Ha) Included.

Date (A.D.)	Approx. Size (Acres/ha)	Approx. Location[2] Township	Range	Fire Name[3]
1909	7,000/2,830	13S	16W	Mogollon Creek
1909	4,300/1,740	11S	16W	West Fork
1909	4,000/1,620	13S	14W	Little River
1909	3,500/1,420	14S	10W	Black Range
1909	800/320	12S	14W	Pryor
1909	300/120	12S	15W	McKinney Park
1909	300/120	13S	11W	Rocky Canyon
1912	300/120	12S	16W	Mogollon Creek ?
1912	308/125	11S	19W	Holt Spring ?
1913	600/240	13S	16W	Sycamore ?
1913	2,500/1,010	13S	15W	Little Turkey
1913	700/280	14S	14W	Granny Mountain
1913	400/160	14S	14W	Granny Mountain #2
1916	680/275	11S	19W	Whitewater ?
1917	300/120	13S	16W	Mogollon Creek ?
1918	3,200/1,300	13S	16W	East Fork Mogollon ?
1918	1,500/610	12S	19W	Dry Creek ?
1922	1,940/785	11S	18W	Willow Mountain
1922	2,256/910	13S	15W	Little Creek
1922	1,256/510	12S	15W	West Fork
1922	952/385	15S	9W	Curtis Canyon
1922	545/220	15S	14W	Sheep Corral Canyon

Table C-2, <u>Continued</u>.

Date (A.D.)	Approx. Size (Acres/ha)	<u>Approx. Location</u>[2]		Fire Name[3]
		Township	Range	
1925	4,420/1,790	15S	9W	Animas Canyon
1925	5,914/2,390	12S	18W	Dry Creek
1925	340/140	11S	18W	Spruce Creek
1934	300/120	8S	10W	Wahoo ?
1934	6,485/2,625	9S	15W	Canyon Creek
1937	360/145	13S	17W	Shelly Peak ?
1938	4,000/1,620	16S	9W	Hillsboro Peak ?
1938	600/240	12S	17W	Mogollon Creek ?
1938	600/240	12S	17W	Lookout Ridge
1938	600/240	10S	15W	Canyon Creek ?
1950	900/365	11S	15W	Middle Fork
1951	1,600/650	14S	12W	Loco Mountain
1951	40,400/16,350	14S	10W	McKnight
1951	14,000/5,665	12S	15W	Little Creek
1953	890/360	12S	16W	Trail Canyon #1
1953	7,400/2,995	12S	17W	Lookout Canyon
1956	1,660/670	11S	16W	Jerky #5
1967	712/290			
1969	970/390			
1970	900/365			Rincon
1970	1,400/565			Cox
1971	878/355			

Table C-2, <u>Continued</u>.

Date (A.D.)	Approx. Size (Acres/ha)	Approx. Location[2] Township	Range	Fire Name[3]
1971	640/260	8S	14W	O Bar O
1971	1,100/445	8S	15W	La Jolla
1974	750/300	9S	9W	Grassy
1974	27,413/11,094	8S	15W	Salvation
1977	600/240	12S	16W	Rain ------------- PNF
1978	3,200/1,295	12S	16W	Langstroth Mesa -- PNF
1978	860/350	10S	16W	Nite ------------- PNF
1978	1,600/650	11S	15W	Trotter ---------- PNF
1979	3,950/1,600	11S	17W	Can ------------- PNF

[1]No class E or larger fires were recorded in those years that do not appear in the list.

[2]Information not available in records if the space is left blank.

[3]Names for many of the historic fires could not be found in the records. Possible names are listed with a question mark (?) and are based on geographic features near the fire, as is the case with most fire names. Prescribed natural fires are indicated with the abbreviation "PNF."

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