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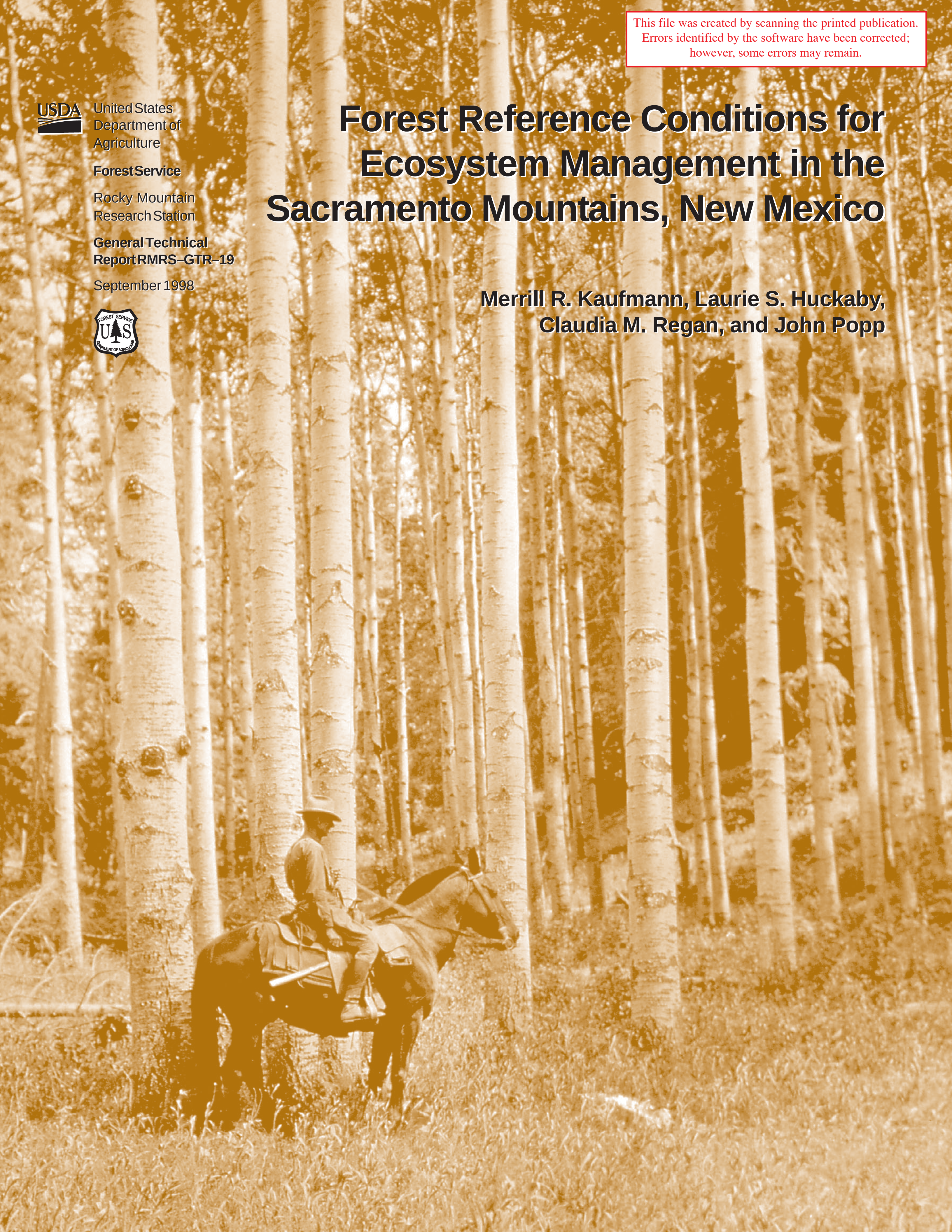
Forest Reference Conditions for Ecosystem Management in the Sacramento Mountains, New Mexico

Merrill R. Kaufmann, Laurie S. Huckaby, Claudia M. Regan, and John Popp



Abstract

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We present the history of land use and historic vegetation conditions on the Sacramento Ranger District of the Lincoln National Forest within the framework of an ecosystem needs assessment. We reconstruct forest vegetation conditions and ecosystem processes for the period immediately before Anglo-American settlement using General Land Office survey records, historic studies and accounts, and reconstructive studies such as dendrochronological histories of fire and insect outbreak and studies of old growth. Intensive grazing, clearcut logging, fire suppression, and agriculture in riparian areas have radically altered forest structure and processes since the 1880s, when intensive settlement began in the Sacramento Mountains. Present forests are younger and more dense than historic ones, and in areas that were previously dominated by ponderosa pine, dominance has shifted to Douglas-fir and white fir in the absence of frequent surface fire. Landscapes are more homogeneous and contiguous than historic ones, facilitating large-scale, intense disturbances such as insect outbreaks and crown fires.

Keywords: Sacramento Mountains, New Mexico, environmental history, ecosystem management, fire, logging, grazing

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Cover: Water Canyon, 1928

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PART I. ECOSYSTEM MANAGEMENT

Most people agree that certain troubling natural resource issues exist, generally involving unintended biological consequences of human activities. These include threats to rare and endangered species, fragmentation or destruction of habitats, and disruption of natural disturbances and other ecological processes. Disagreement exists, however, over the degree to which humans have affected forests and the extent to which these changes are acceptable. Responsible resource managers deal daily with the difficulty of conserving natural resource features and values for future generations while trying to meet human needs and wants for today.

The concept of ecosystem management was brought to the forefront of natural resource management in most land management agencies in the early 1990s. The concept's appeal is in holistically addressing the biological, social, and economic issues facing our use of natural resources (Kaufmann et al. 1994). The transition from management for multiple use to management that includes a focus on sustaining ecosystems has affected activities in and among many agencies at national, state, and local levels. The task is not easy, however. On one hand, we often have inadequate knowledge of how ecosystems function and how much we can use them without destroying important ecosystem functions and characteristics. On the other hand, we have a long history of human use of forested systems that is difficult to change, even in cases where our patterns of use appear unsustainable.

While examining the social and economic patterns and practices of human use of natural ecosystems is beyond the scope of this paper, our focus here is on understanding ecosystem characteristics that should be taken into account when evaluating management alternatives, so that goods and services can be provided while sustaining ecosystems for future generations. Recent conclusions from the Interior Columbia Basin Ecosystem Management Project illustrate the magnitude of the problems faced in sustaining ecosystems (Haynes et al. 1996, Quigley and Bigler-Cole 1997, Quigley et al. 1996, USDA Forest Service 1996). A scientific assessment of the Interior Columbia Basin demonstrated that more than half (55 percent) of lands administered by the USDA Forest Service and USDI Bureau of Land Management were found to have a high or moderate rating of ecological integrity, but 45 percent were found to have a low rating of ecological integrity. In this assessment, ecological integrity was judged on the basis of factors such as the risk of severe, stand-replacing fire and loss of old forests and grasslands, and on the likelihood of the system rebounding from negative ecological trends, while continuing to provide predictable flows of resources for human consumption.

At the center of sustaining ecosystems is the conservation of ecosystem structure, composition, and function across the full range of spatial and temporal scales. Kaufmann et al. (1994) and Grumbine (1994) provide guiding principles for conserving these features. They may be paraphrased as follows:

Think long term. Ecosystems must be sustained for the well-being of humans and other forms of life.

Save all the pieces. Ecosystems must have the potential for keeping all the naturally occurring organisms, their assemblages into communities, and the physical environment supporting them present in the system.

Save all the processes. Natural ecosystem processes, including their frequency and intensity, should be retained to allow ecosystems to self-regulate.

Assure sustainability. Human impacts should not affect ecosystems in such a way that they would not return to their natural state if left alone.

Applying these principles in the management of natural resources requires a framework for analyzing ecosystems. This framework has been developed during the last several years as an ecosystem assessment process. Assessments have developed primarily at two degrees of scope (not to be confused with scale). The larger scope, represented for example by the Columbia Basin Assessment, includes both the ecological considerations related to ecosystem sustainability and the social and economic considerations associated with sustainable natural resource management as a whole. At a smaller scope (but not smaller scale), the ecosystem needs assessment process focuses on identifying ecosystem needs and capabilities associated specifically with ecosystem sustainability (Kaufmann et al. 1994). While this approach requires integration with social and economic considerations in management decision processes (as was done in the Columbia Basin assessment), its advantage is that it focuses clearly on the well-being of ecosystems at multiple spatial and temporal scales. This focus is crucial to developing an understanding of how human activities impact ecosystem sustainability.

Detecting Ecosystem Changes

Detecting changes in forests is relatively easy when done in terms of resource inventories and land use practices. Detecting changes in ecosystems and evaluating their importance to ecosystem sustainability is far more difficult, however. Forests in most areas have been altered from their natural state as a result of human activity, such as timber harvest, grazing, suppression of wildfires, introduction of weedy and exotic species, and encroachment by rural and urban development. Even though certain features of forests have been adversely impacted by these activities, past treatment of forests in many cases has not resulted in obvious loss of tree health at the individual level, and this has made it difficult to recognize certain ecosystem or forest health problems. For example, forests that were harvested in past decades, even by clearcutting large areas, often have regenerated and are growing vigorously. In many grazed stands, trees appear to be productive. Where fire suppression has seriously altered stand structure in forest types that normally experienced fire, stands usually contain large numbers of trees that appear healthy. To the casual observer, such forests appear to be in a satisfactory condition.

Even when forests appear to be healthy, however, their condition may be far from ideal for sustaining their productivity and for sustaining features in the landscape important for conserving biodiversity. For example, fire suppression in ponderosa pine, caused initially by heavy grazing and later by a policy of putting out small fires, has resulted in much higher stand densities than might have occurred historically (Covington and Moore 1994, Fulé et al. 1997). In turn, this may have contributed to outbreaks of mountain pine beetles that have been much more severe and widespread in some heavily stocked stands than they were historically (Dahms and Geils 1997). When fires occur in dense stands, they often burn much more intensely than they would have historically, killing many trees and either resetting the stand back to the regeneration stage or even putting the site on an entirely new successional trajectory. Similar conditions are found in mixed conifer and other forest types in the Southwest.

Conditions have also been altered at larger scales, leaving landscapes considerably different from their historical condition. These changes are often subtle, but their effects can be serious. The landscape mosaic may consist of healthy forest stands, but if a significant component has been removed or reduced in occurrence, or if the landscape has become fragmented or unnaturally connected, the condition of the forest landscape may be far from ideal. As an example, old-growth forests have been depleted in many regions, resulting in a loss of habitat and forest function not readily substituted by other seral stages (Kaufmann et al. 1992).

Detecting the more subtle changes in forest ecosystems and evaluating their ecological consequences requires an approach that evaluates ecosystem characteristics and human effects on ecosystems in different ways than has been done in the past. Through much of this century, forests and grasslands have been managed to assure production of timber, wildlife, water, livestock, and recreational opportunities, with the primary focus on outputs rather than on the condition of the ecosystems left behind.

An Ecological Assessment Process

Managing forests and grasslands as sustainable ecosystems is difficult, in part because forest, grassland, and riparian ecosystems are very complex. Ecosystems are characterized by their structure and composition, and by the processes that regulate them. A critical component of understanding ecosystems and their sustainability is that structure, composition, and function are important at multiple scales in space and time. Traditional forest management has occurred at the stand level. Ecosystem management requires an understanding of structure, composition, and processes at spatial scales ranging from trees to patches to stands to landscapes, and changes over time scales from years to millennia. For example, stand management often focuses simply on number of trees per hectare (or acre), their diameter distribution, and perhaps their height, selected to achieve certain conditions or outputs of timber, forage production, etc. Such management usually overlooks spatial and temporal heterogeneity — patterns of distribution, including species of trees within patches, patches within the stand, and stands within the landscape, and changes in their distribution over time — that may be critical for supporting plant and animal diversity and sustaining ecosystems.

What are the consequences of human activities on ecosystem sustainability, and how can management practices resolve ecological concerns? The consequences of human impacts can be evaluated using an ecological assessment approach based on conservation biology and several subdivisions of ecology, including landscape ecology. The ecosystem needs assessment process outlined by Kaufmann et al. (1994) includes specific components that help address these questions (Fig. 1). The steps outlined in Figure 1 lead to improved understanding of (1) the reference or historic conditions of the analysis area, which can be used to evaluate the present condition; (2) the existing state of the analysis area, including additional ecological information not typically found in traditional inventories; (3) an assessment of components of the landscape mosaic that are presently under- or over-represented

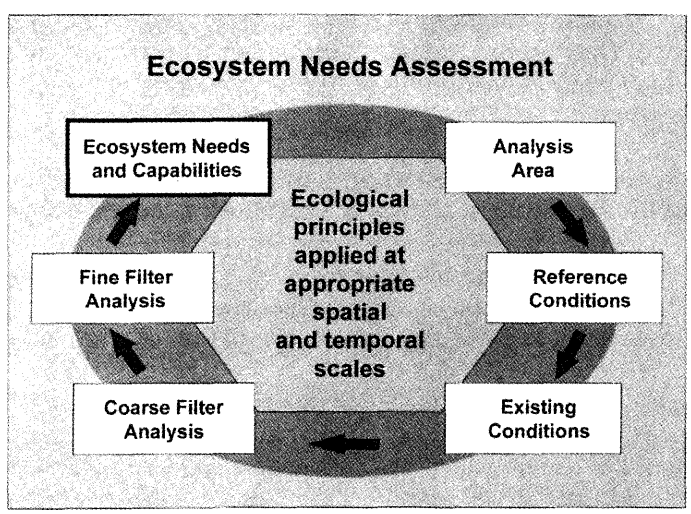


Figure 1. Ecosystem needs assessment flow diagram. Reference conditions and existing conditions are described in more detail in Fig. 2, and the coarse filter and fine filter components are described in more detail in Fig. 30.

or poorly distributed (coarse-filter analysis); (4) an assessment of human impacts that have created problems in ecosystems within the analysis area, including the disruption of natural disturbance processes (also part of the coarse-filter analysis); and (5) an assessment of plant and animal diversity of the area, including rare or threatened components (fine-filter analysis). These analyses help identify ecosystem needs and capabilities, based on conservation principles applied at relevant spatial and temporal scales. Individual components of Fig. 1 are described in more detail later.

Ecosystem needs assessments address a number of questions. At the landscape scale, for example, what is a reasonable model of the patch and stand structure of the reference landscape, i.e., what would the landscape have looked like without the effects of modern human activities? How did natural processes contribute to the makeup of the reference landscape? What is the structure of the existing landscape, and what natural events or human activities contributed to the development of existing conditions in the landscape? What temporal changes affect landscape structure? How have past and present conditions affected species, biotic communities, or ecosystems? What are the ecological implications of different management strategies? And what management practices help mitigate negative impacts to ecosystems? A similar range of questions is relevant at both smaller and larger spatial scales.

The Role of Reference Conditions in Ecological Assessments

Reference conditions generally refer to the properties of ecosystems that are free of major influence by humans. Examining the condition of forests generally free of significant human impacts provides insight into the characteristics of sustainable ecosystems (Kaufmann et al. 1994). Because most ecosystems have been modified by human activities, the usual approach for understanding reference ecosystem conditions is to study sources of information that help describe the properties of ecosystems during some relevant past period; in the case of the American west, the period is generally just prior to European-American settlement in the 19th century. Reference conditions include information about potential vegetation, soil properties, the structure and composition of landscapes, patterns of natural disturbances such as fire and insect or disease outbreaks, and the abundance/rareness of individual species, successional stages, or biotic associations (Fig. 2).

Reference conditions are not a single snapshot in time, but rather reflect the historic variability of the structure,

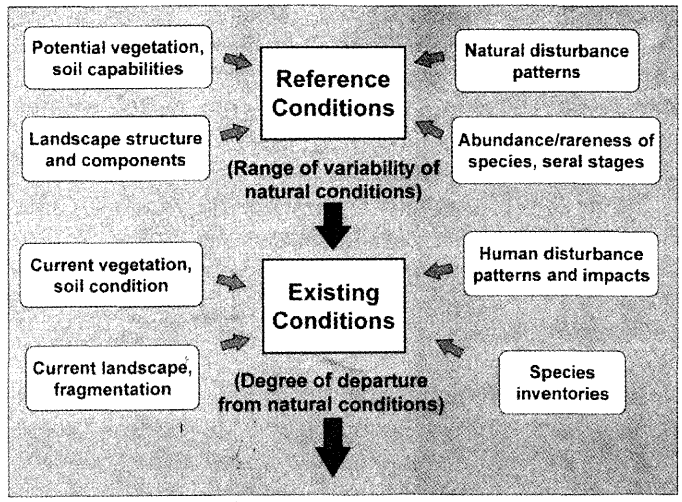


Figure 2. Factors that contribute to reference conditions and existing conditions of the ecosystem needs assessment process shown in Fig. 1.

composition, and processes of ecosystems over time (Fulé et al. 1997). Existing conditions may reflect only the results of recent human-induced changes, rather than the patterns sustained by centuries of natural processes. Historic reference conditions are useful in managing ecosystems by telling us which processes and pieces we need to preserve to sustain ecosystems. If current conditions are the only criteria used to make management decisions, there is no basis to determine whether management practices or impacts will lead to ecological outcomes that fall within the historic range of variability; yet, until recently, many resource management activities were based solely on current resource conditions and opportunities. If management activities are conducted in such a way that the ecological outcome is consistent with conditions that existed historically, the activities are more likely to sustain or restore ecological properties. Reference conditions provide a basis for determining management options that are most desirable for ecosystem sustainability and restoration.

The study of reference conditions has both strengths and limitations. As noted above, knowledge of historic or reference forest conditions is especially useful for comparison with existing forest conditions (a coarse-filter analysis) to determine how current management practices succeed or fail to maintain a healthy forest landscape. Logging, grazing, and reductions in fire frequency have occurred through much of the West, and it is widely hypothesized that forests today are more dense and tend to be younger and less heterogeneous structurally than they were at the time of European settlement. It is generally perceived that the old-growth component of landscapes has been decreased in spatial extent, and current forests may be composed of more uniform stands with limited discernible patch structure. A scientific evaluation of reference conditions for comparison with current conditions helps document the degree to which these perceived changes are real. The study of reference conditions helps identify meaningful dimensions of patches and stands in the landscape and the vegetation structural stages to be expected, including their frequency and distribution.

Reference and existing conditions are both moving targets, however, because vegetation is constantly changing. Thus reference conditions are not useful for providing detailed maps and descriptions of geographically specific patterns in the landscape that can or should be restored to their historic condition. Rather, reference conditions help determine characteristics such as the amount and kinds of heterogeneity in spatial patterns that existed before significant human impacts occurred, and the natural disturbance patterns and conditions that created these patterns over time. This knowledge can provide a basis for evaluating existing conditions and identifying places in the landscape where management activities might efficiently bring current forests into alignment with historic landscape features. Reference conditions can help clarify which management activities work in the direction of improving ecosystem sustainability and which ones might further exacerbate ecosystem unsustainability.

A limitation of reference conditions is that Native American effects might have been significant at certain places or times, but these effects are rarely recorded or measurable separate from natural processes. Identifying the condition of forest landscapes in the absence of all human activities is impossible because of the lack of any descriptive material. Consequently, where Native American influences may have been significant, information about historical ecological conditions may rely more heavily on characterizing natural disturbance processes such as fire and insect activity, often done through models of these processes. Gradual climate changes during the last several centuries may reduce the value of reference condition information, because forest development and landscape patterns depended on earlier environmental conditions that may no longer exist. Models are being developed to assess the incremental effects of climate change on forests, and they may provide insight regarding the analysis conditions where concern about climate change is warranted, particularly during the last half of the 20th century.

PART II. SOURCES FOR REFERENCE CONDITIONS

Reference Conditions

Ecosystems are extremely complex, and that complexity evolved through the interaction of many dynamic elements. Reference conditions characterize the variability associated with biotic communities and native species diversity, provide insights to natural disturbance regimes and distributions and abundances of plants and animals, and can be used to define target conditions for sustainability or to estimate how current ecosystems differ from historical ones (Kaufmann et al. 1994). Reference conditions include past natural frequency, intensity and scale of disturbances, demographics of plant and animal species and their interactions and distributions, physical properties such as the condition and cycling of soil, water, and climate, and patterns of heterogeneity across the landscape and through time.

While it would be preferable to study present undisturbed ecosystems to obtain reference conditions, few, if any, ecosystems have been unaffected by humans. Aboriginal peoples are known to have had profound and widespread effects on the ecosystems in which they lived. However, the rapidity, intensity, and spatial scope of ecological change precipitated by American settlement of the West during the 19th century was unprecedented. Therefore, we must search for evidence of what the landscape was like before or at the time of European-American settlement to get a glimpse of more natural conditions and processes. The Sacramento Mountains were settled and developed relatively late in the history of westward expansion, in part because of their harsh climate and inaccessibility, and in part because of the ferocity of the Mescalero Apaches who lived there after 1600. However, changes happened very quickly once settlement began in the 1880s. The largest number of sources are available for the settlement period, and these are perhaps the most relevant because they reflect ecosystem conditions under climatic conditions similar to those of the present day.

Sources

We used multiple types of sources to reconstruct reference conditions for the Sacramento Mountains landscape at the time of European-American settlement. Many sources were not quantitative in nature, or were only partly quantitative, such as historic records and studies (Table 1). Other sources, such as tree-rings, are censored; the full range of data may not be available because we can now sample only what has survived by chance from earlier times.

None of the earliest observers in the Sacramento Mountains were trained scientists, nor did they observe the ecosystems in a quantitative way. The things they reported were relevant to the military significance of the mountains, or to their potential as sources of wealth in the form of water, timber, or grass. Archaeological evidence is necessarily incomplete, including only what has been preserved by chance, recording some history of human land use and those plants and animals of importance to the people who lived at the sites, but with no reliable indication of their relative abundance or distribution. Subsequent disturbances such as fire, logging, and development have destroyed many potential sources of evidence of past environments, such as stands of old, fire-scarred trees. Tree-ring studies are limited temporally by the lifespans of tree species, the rarity of ancient trees, and the unusual environmental conditions that allow them to persist. Therefore, we have few long quantitative records of the composition and distribution of forests in pre-settlement times. The pre-settlement condition of riparian environments is virtually unknown because no evidence of their condition has survived.

Some of the sources are derived from negative evidence: records of the last wolf or bear killed, remembrances of when the bison (*Bison bison*) still roamed the plains to the east, records of how much timber was cut in a given area. Some of the first scientific, or at least quantitative, studies were done as settlement began, in the form of General Land Office surveys and Bureau of Biological Survey studies. It was a time of rapid change, as Anglo-American settlers streamed into the area and began to exploit the land in unprecedented ways and at an unprecedented pace. Settlers, intent on making their fortunes on this last frontier, ran cattle, cut trees, and used water with little regard for sustaining the ecosystems that provided their livings and little thought to the future. The exploitation of the resources, and the acute effects on the ecosystem, reached their peak in the first half of the 20th century. Observations after that time reflect conditions much altered from their natural state.

Historical Records and Studies

General Land Office Survey Notes

Some of the earliest and most quantitative information about pre-settlement landscapes comes from the General Land Office Survey notes. The General Land Office was formed in 1812 to oversee the survey of public lands in the United States (Galatowitsch 1990). Generally, surveys were done in an area just prior to settlement. Survey techniques evolved during the first half of the 19th century, and surveys were contracted to the lowest bidder until 1908. New Mexico was surveyed between 1854 and 1925, using the 1855 guidebook, which was the standard until the end of the contract system (Bourdo 1956). After 1908, surveys were done by federal employees, due in part to the high incidence of fraud by contractors (Galatowitsch 1990).

Table 1. Sources for reference conditions.

Sources	Information provided	Period covered	References
Historical records and studies USFS Documents, General Land Office surveys, Bureau of Biological Survey, logging company records, climate measurements	Somewhat quantitative data on vegetation pattern and distribution, wildlife distribution, climate, historic disturbances, historic land use, rates of environmental change	Settlement period to present	Anderson 1915, 1923, Bailey 1931, Bronson 1908, Bourdo 1956, De Mastus 1976, Galatowitsch 1990, Habeck 1994, Holmes 1906, Kerr 1909, Kent 1905, Kent and Reynolds 1906, Lee 1923, Neal 1909, Krauch 1936-1956, Plummer and Goswell 1904, Regan 1997, Regan et al. 1997, Smith 1907a,b, Strickland 1927, USFS 1908, 1918-1952, 1946, 1978, 1977, 1980, Woolsey 1911.
Historic accounts Literature, personal accounts, interviews, photographs, newspapers	Non-quantitative records of vegetation distribution, wildlife distribution, notable disturbances, historic and recent land ownership and use	Settlement period to present	Baker et al. 1988, Charles 1954, Betancourt 1981, Glover 1984, Hawthorne 1980, Jenkins 1988, Lincoln Grazing Advisory board 1944-1975, Longwell 1914, Neal 1966, Nolan 1992, Opler 1983, Sonnichsen 1973, 1980, Tucker 1989, 1991, 1992.
Archaeology and paleontology Digs of pre-historic habitations, historic structures, reconstruction of past land use, packrat middens	Censored but quantitative evidence of pre-historic vegetation and wildlife distribution, human land use, climate	Pre-settlement to settlement period	Broster and Harrill 1983, Driver 1985, Kelley 1984, Tainter 1981, Sebastian and Larralde 1989, Spoerl 1981a,b,c, Tainter and Tainter 1995, Stuart and Farwell 1983, Van Devender and Spaulding 1979, Van Devender et al. 1984.
Reconstructive studies Packrat middens, tree-rings, fire history, forest age structure, insect signals in tree-rings, repeat photography, climate reconstruction	Censored but quantitative evidence of pre-historic to recent vegetation composition, pattern, and distribution, climate, and disturbance regimes	Pre-settlement to present	Betancourt et al. 1990, Brown et al. 1995, Cooper 1960, Covington and Moore 1994, Dick-Peddie 1993, D'Arrigo and Jacoby 1991, Davis and Brown 1988, Huckaby and Brown 1995, Lynch and Swetnam 1992, Regan 1997, Sallach 1986, Swetnam and Brown 1992, Swetnam and Baisan 1996, Swetnam and Betancourt 1990, Swetnam 1990 Touchan et al. 1995, Wilkinson 1997.
Present conditions Vegetation studies, tree age structure, wildlife distribution, insect outbreaks, fires, present land use	Quantitative records of recent vegetation composition, pattern and distribution, wildlife distribution, climate, land use, disturbances	Present	Alexander et al 1984, Dick-Peddie 1993, Findley et al. 1975, Hawksworth 1990, Hawksworth and Conklin 1990, Hawksworth et al. 1989, Harrington and Hawksworth 1990, Kennedy 1983, Kinloch 1994, Lang 1957, Lee-Chadde and Huenneke 1997, Negron 1996, Regan 1997, Scott and Ramontick 1992, Sublette et al. 1990, USFWS 1995, Wilson and Tkacz 1994, Wood 1993.

Surveys were done using the range and township method. Each township was 36 square miles (93.6 square km), divided into 36 sections of one square mile each (2.6 square km). Surveyors marked section and quarter section corners by marking four "witness trees," the nearest tree to the corner in each quadrant (Leitner et al. 1991). Information recorded about the witness trees included their species, diameter, distance and direction from the corner. Trees along the survey lines were also recorded; species were listed in order of dominance. The location of every major change of cover type was noted, and prominent understory features were also recorded. Ideally, witness trees were randomly selected, though crews were instructed to choose trees that were likely to be long-lived, so very small and very large trees were usually not selected. In general, survey records resemble plotless, point-centered sampling methods (Habeck 1994).

Survey records have been used to reconstruct past landscapes and forest structure at many locations (Bourdo 1956, Galatowitsch 1990, Habeck 1994, Leitner et al. 1991, Whitney 1986). The strengths of these methods are that the data were collected by trained observers using a standardized set of methods, and they are first-hand accounts of vegetation, soil, and landscape features from pre-settlement times. In some cases, researchers have been able to reconstruct approximate tree density and basal area from survey notes (Leitner et al. 1991). However, the usefulness of survey notes is hampered by inconsistencies in observations between crews, varying levels of detail, ambiguous plant identification, and bias in sampling (and rarely, outright fabrication). Surveyors used common names for plants that are not in use today, such as "red spruce" for Douglas-fir and "balsam" for white fir, or sometimes Engelmann spruce. Surveyors were not always consistent with the usage of common names. Because the notes represent only one point in time, they do not adequately describe past disturbance regimes, though they do note effects of disturbances when the surveyors encountered them. Descriptions included some standardized terms no longer in use: "heavy timber" indicated large-sized trees, though not necessarily densely stocked forests; "scattered timber" indicated a savanna-like woodland.

General Land Office surveys began in the Sacramento Mountains in 1884 and continued into the 1930s, though most of the higher parts of the range had been surveyed before 1910. Much of the land now part of the Lincoln

National Forest was private land until after the turn of the century and so was surveyed after considerable human effects had accumulated. Settlement had already begun in some canyons by 1884, but surveys done before the advent of logging in 1899 probably represent the presettlement landscape in terms of structure. Regan (1997) used General Land Office survey notes to reconstruct the distribution of old-growth mixed conifer forest in the Sacramento Mountains before 1899.

Other Government Records

In addition to regulating land use, after 1907 the Forest Service (Fig. 3) began to assess what resources were present on the land and their condition. The boundaries of the Alamo National Forest were not set until the 1940s, and throughout the first two decades of the 20th century, requests to add to or subtract land from the Forest were accompanied by detailed reports of the resources available on the lands, descriptions of the vegetation communities, climate, known disturbances, streams, settlements, and present and past land use (Anderson 1915, Anderson 1923, Kent 1905, Kent and Reynolds 1906, Longwell et al. 1914, Neal 1909, Plummer and Goswell 1904, Reynolds 1909, Smith 1907 a,b). The descriptions are qualitative for the most part, except for some quantitative measures of timber, but they are quite detailed and spatially explicit. Letters document the exchange of lands with private owners (Lee 1923). The Forest Service assessed the operations of the Alamogordo Lumber Company (Holmes 1906) and later obtained those lands after logging was finished. The Forest Service also kept records of grazing after 1908, and after the allotment system was in place, the records of how many animals grazed in the mountains in a given year were spatially explicit. Careful records were maintained of how many animals were allowed to graze in any given area, though trespass grazing was very common and allotment records probably represent a minimum number of animals that were actually present. Early scientific studies on the forest have also been preserved (Krauch 1936–1956, Woolsey 1911).

The Bureau of the Biological Survey published the results of their survey of New Mexico fauna in 1931 (Bailey 1931), though most of the data were collected around 1900. By that time, many large predators and game were being hunted to extinction, but the report contained detailed life histories of species and range maps as far as they were known.

Historic Accounts

Historic accounts are non-quantitative, often biased, and rarely directly about the ecosystem features of interest, but they do reflect the observations of people who were there at the time. Most preserved historical accounts are from the settlement era, and they reflect the values of the time. Such accounts document the land ownership and use, rapid changes in vegetation and wildlife, and notable disturbances as they affected people. Historic accounts include written and oral histories, literature, personal accounts and interviews, newspapers, and photographs.

Figure 3. The Alamo National Forest Supervisor's Office around 1910. Lincoln National Forest Heritage Resource Program collection in Alamogordo, on file at the Lincoln National Forest Supervisor's office.

Archaeology and paleontology

These methods provide censored but quantitative evidence of pre-historic human presence and land use, and the availability of animal and plant species used by past peoples. Environment strongly influences the development of human cultures. How people lived within ecosystems, whether their lifeways were sustainable or not, and what parts of their environment they used tell us much about the structure and function of past ecosystems.

The environments documented by paleontology and such methods as carbon dating, packrat middens, and palynology may not be directly relevant as reference conditions for management purposes because they occurred so long ago and probably under different climate regimes. However, such documentation is useful for understanding the potential magnitude of environmental change over time and for tracking the development of modern communities and processes.

Reconstructive studies

Reconstructive studies are those that use evidence surviving in present ecosystems to reconstruct past conditions. They provide censored but quantitative evidence of prehistoric to recent forest structure, climate, and disturbance regimes. Such studies include reconstructions of vegetation communities from material found in packrat middens, histories of fire and insect outbreaks and reconstructions of climate from tree-rings, and documentation of vegetation changes through repeat photography.

Present conditions

The present is the product of the past. Because present ecosystems evolved from past environmental conditions, the present distribution of species, composition and structure of communities, and disturbance regimes can give us clues about past ecosystems and the changes they have undergone. Most importantly, recent studies provide testable, quantitative records of vegetation composition, pattern, and distribution; wildlife populations; climate; disturbance frequency, intensity, and effects; and land use. This knowledge can be compared with what we know of past landscapes and records of known land use changes. If we know what changes have occurred as the result of human activities (such as which species are exotics, which forest structures are the result of logging and fire suppression, which species have been extirpated), we can begin to extrapolate from present conditions to those of the past.

PART III. HISTORY OF THE SACRAMENTO MOUNTAINS

The Study Area

The Sacramento Mountains are located in south-central New Mexico, south of the contiguous Rocky Mountains, between 32°30' and 33°00' north latitude and 106°00' and 106°30' longitude, within the Basin and Range Physiographic province (Fig. 4; Regan 1997). The range is oriented north-south, with the Tularosa Basin and San Andres mountains to the west, and the Pecos River and Great Plains to the east. Elevation ranges from 1300 m (4225 ft) at the base of the mountains to 3693 m (12,003 ft) at the summit of Sierra Blanca. The highest point on the Sacramento Ranger District is an unnamed peak, at 2983 m (9695 ft). Soils under forested areas are mostly Argiborolls, derived from limestone and siltstone parent material (USDA Forest Service 1977, 1986, Regan 1997). Like many Southwestern mountain ranges, the Sacramentos are an island of forest surrounded by desert or desert grassland. This isolation has influenced development of endemic species in the Sacramentos.

Much of the Sacramento Mountain range is administered by the Lincoln National Forest, which includes several fragmented mountain ranges: the White Mountains to the north, the Capitan Mountains to the northeast, the Carrizo Peak area, and the Guadalupe Mountains to the south. Our area of interest is the Sacramento Ranger District, which includes most of the Sacramento Mountains. It extends from the boundary with the Mescalero Apache Reservation in the north to the boundary with the MacGregor military range and the southern extent of the mountains in the south. The eastern boundary of the Forest is in the foothills just east of Alamogordo, and the western boundary is a few miles east of Mayhill, where the mountains slope gradually to the Pecos valley. The Sacramento Ranger District includes several large inholdings of private land, including the area around Timberon, the Harvey ranch, and MacDonald flat, as well as many smaller holdings that are concentrated along watercourses. Livestock grazing, tourism, and logging are the primary uses on the Forest.

Water is critical to forests in the Sacramento Mountains, and its availability is highly variable. Mean annual precipitation ranges from 500 mm (12.7 inches) to 750 mm (19.05 inches). More than 60 percent of this falls during July and August as rain from convective thunderstorms. The rest of the precipitation falls during the winter as snow from frontal systems (DeMastus 1976). Spring (April-June) and fall (October-November) are typically dry (Alexander et al. 1984). Mean temperatures vary with elevation, from about 20 °C (60 °F) at the lower National Forest boundary, to about 4 °C (40 °F) in the central part of the range. The mean annual growing season at Sacramento Peak (2843 m; 9240 ft) is 143 days, with the average date of the last freeze May 17, and the first freeze October 7 (DeMastus 1976). Prevailing winds are generally from the west, though they have a more northerly component in the winter and more southerly and easterly components in the summer. Gusts of more than 100 miles per hour were observed several times during 20 years of observation (DeMastus 1976).

Mountains modify local climates through orthographically induced precipitation and adiabatically cooled temperatures. The temperature lapse rate from Alamogordo at 1326 m (4310 ft) to Mountain Park at 2048 m (6656 ft) to Cloudcroft at 2652 m (8619 ft) is -0.72 °C per 100 m (-1.3 °F per 325 ft) of elevation (Van Devender et al. 1984). Cold air drainage and inversions produce differences between winter and summer lapse rates. Mean annual precipitation increases considerably with elevation, from 250 mm (9.8 inches) annually at Alamogordo to 436 mm (17.2 inches) at Mountain Park to 654 mm (25.8) at Cloudcroft (Van Devender et al. 1984). Vegetation distribution in the Southwest is strongly dependent on precipitation. A long growing season and fertile soils make Sacramento Mountains forests very productive.

Biotic Communities

Biotic communities of the Sacramento Mountains are similar to those of the Southern Rocky Mountains and to other Southwestern mountain ranges, and they are distributed largely in response to elevation and moisture gradients (Fig. 5). The lower foothills from 1380 m to 1830 m (4485 to 5948 ft) are covered with desert scrub-grassland mosaic. The foothills formerly supported extensive desert grassland, which has been altered by intensive livestock grazing. Above about 1700 m (5525 ft) on the steep west escarpment and about 1800 m (5850 ft) on the gentler east slope, pinyon-juniper (*Pinus edulis/Juniperus monosperma* or *Juniperus deppeana*) woodland and dense oak (*Quercus gambelii* or *Quercus undulata*) scrub cover canyon walls and ridges. Above 2100 m (6825 ft), ponderosa pine (*Pinus ponderosa*) forms open stands that are often mixed with pinyon-juniper on dry slopes, or Douglas-fir (*Pseudotsuga menziesii*) on moist slopes, often with a shrubby understory dominated by oaks.

Above 2200 to 2500 m (7150 to 8125 ft), the Sacramento Mountains are covered with nearly continuous mixed conifer forest, dominated by white fir (*Abies concolor*) or Douglas-fir, and mixed with ponderosa pine, southwestern white pine (*Pinus strobiformis*), aspen (*Populus tremuloides*), and occasional pockets of blue spruce (*Picea pungens*) or Engelmann spruce (*Picea engelmannii*). Perennial streams are rare in the Sacramentos, and riparian vegetation is sparsely distributed. Cottonwood (*Populus angustifolia*), willow (*Salix* sp.), and walnut (*Juglans major*) are found in low-elevation canyons. Shallow canyons at higher elevations are grassy, and many are cultivated or used as pasture. There is no alpine vegetation in the Sacramentos. Fire and insect outbreaks are the primary natural disturbances that have shaped the forest structure of the Sacramento Mountains.

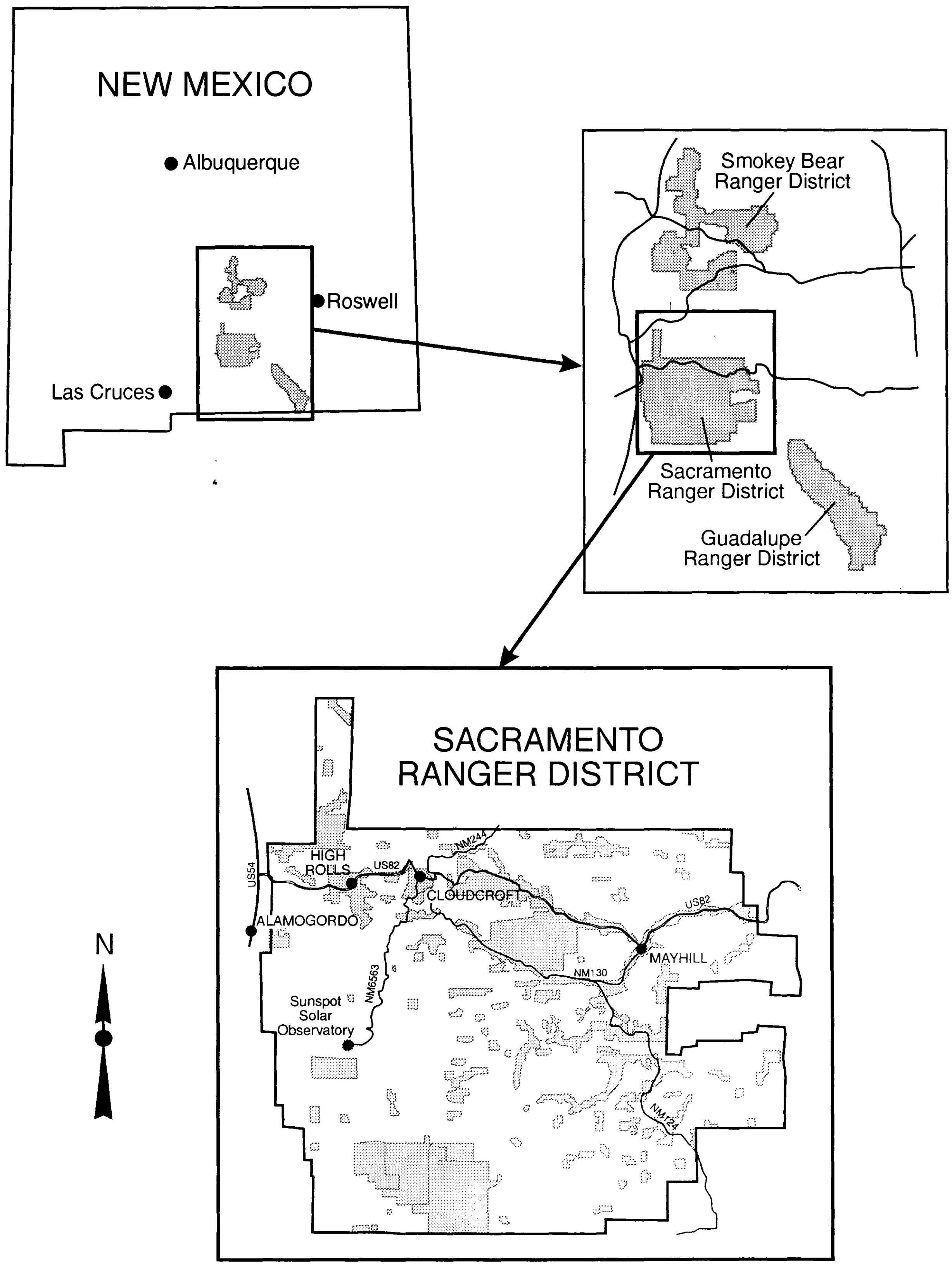


Figure 4. Map of the Sacramento Mountains and surrounding area. Shaded areas in Sacramento Ranger District map at bottom indicate privately owned land.

Geology

The Sacramento Mountains area was under a succession of seas until about 60 million years ago, when the modern Rocky Mountains began to rise (Table 2). Around 49 million years ago, a period of geological instability began in the region, including volcanic activity, uplift, and crustal sinking. By the end of this period, many of the present mountain ranges in New Mexico had formed (Dick-Peddie 1993). About 30 million years ago, a pair of parallel fault zones began to develop in what is now central New Mexico, running north-south from what is now Colorado to Texas. A long piece of crust dropped down between these faults, creating the Rio Grande Rift which traverses central New Mexico (Chronic 1987).

The Tularosa Valley and the Sacramento and San Andres Mountains were created by pull-apart faulting, and the valley is considered the easternmost part of the Rio Grande rift. During the early Cenozoic era (66 to 24 million years ago), it was part of a large anticline of Paleozoic sedimentary rocks arching across what is now the Tularosa valley from the San Andres Mountains to the Sacramento Mountains. When the crust pulled apart during the Miocene epoch (24 to 5 million years ago), the center of the arch collapsed, dropping the valley nearly 5000 ft and leaving the two mountain ranges at the faulted edges. Increased tension in the Earth's crust during this period created many of the tilted ranges and deep basins of the Southwest. The Tularosa valley has no outlet; water flowing into it from the mountains sinks below the

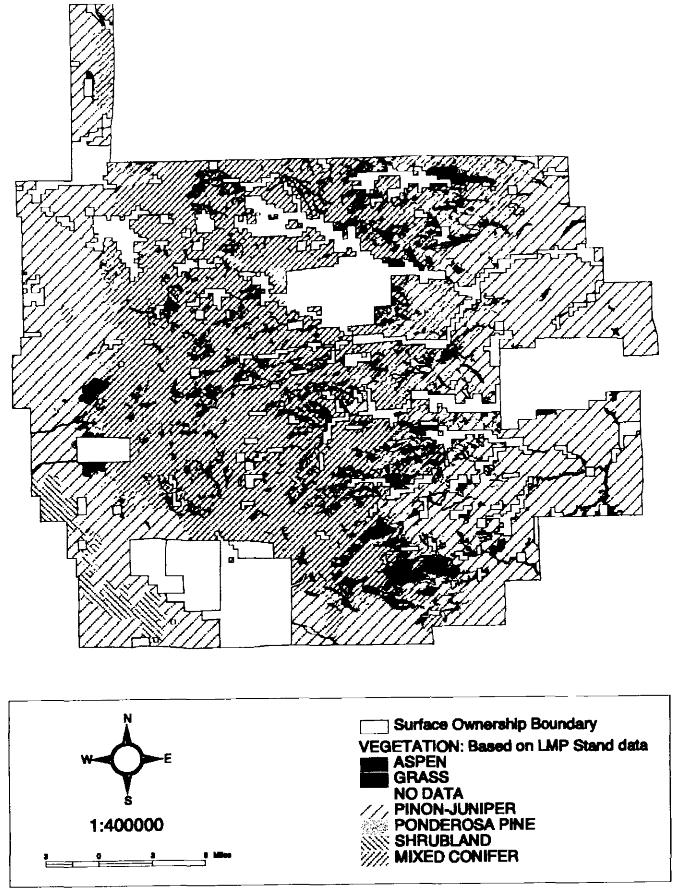


Figure 5a. Geographic extent of the major biotic communities of the Sacramento Mountains.

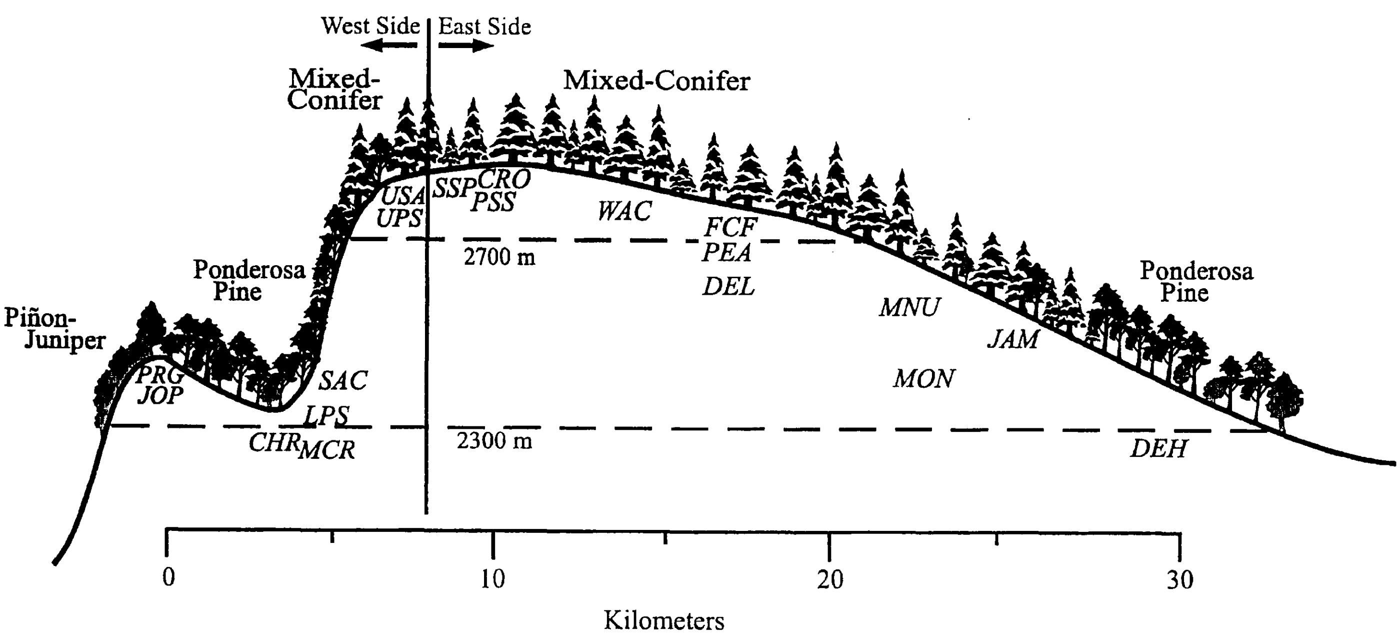


Figure 5b. Elevational distribution of major biotic communities on the steeper west escarpment and the more gradual eastern slope. Abbreviations indicate sampling locations described in Table 8 (page 62). From Brown et al. (1988).

Table 2. Timeline of Sacramento Mountains history.

Cultural events	Date	Ecological events
	60 million years ago	Sacramentos under shallow seas
	30–24 million years ago	Rio Grande Rift formed
	24–5 million years ago	Tularosa valley and Sacramento and San Andres ranges formed
	2 million–11,000 years ago	Pleistocene era; glaciation on Sierra Blanca, Lake Lucero formed
	11,000 years ago	Holocene era begins
	10,000 years ago	Ponderosa pine range expands dramatically, moves into Sacramentos
Archaic period: Paleo-Indian hunter-gatherers in Tularosa Basin and surrounding area	9000 years ago	Altithermal climate—warmer and drier than now
	5400 years ago	Desert scrub-grass community in place at lower elevations
	4000 years ago	Monsoon climate begins, cooling. Modern vegetation types in place. Rocky Mountain juniper becomes more restricted in range; alligator juniper increases.
	2500 years ago	Gradual warming until about 800 years ago
Fresnal Canyon shelter site occupied	2000 BC to 0–100AD	
Jornada Branch of Mogollon Culture:		
Mesilla phase—pithouses, rudimentary agriculture	250 AD	
	900 AD	Little Black Peak erupts, creates lava flow; Medieval Warm Period begins
Doña Ana phase—pithouses, agriculture	1100 AD	Agriculture concentrated in riparian areas, especially Rio Peñasco and westside canyons
El Paso phase—pueblos, agriculture	1200 AD	Settled peoples cut timbers for buildings
	1217–1226	Drought
Pueblos and farms abandoned	1400 AD	End of Medieval Warm Period; Little Ice Age begins
	1429–1440	Wet period
	1487–1498	Wet period
Coronado passes through New Mexico	1540 AD	Horses re-introduced to New Mexico
	1577–1598	Severe drought
	1579	Earliest tree-ring record in Sacramentos
	1609–1623	Wet period; tree establishment
First confirmed record of Apaches in Sacramentos	1630	Apaches bring livestock into the mountains
First recorded battle between Spanish and Apaches in the Sacramentos	1653	
Famine	1660	
Jumanos Pueblo abandoned	1672	
Pueblo revolt; Spanish temporarily leave New Mexico	1680	
Commanches defeat Apaches, who move west	1723	Apaches concentrated in the mountains
	1748	Regional fire year
Only Mescaleros in Sacramentos	1750	
	1773	Regional fire year
	1778–1787	Drought
Sawmill in existence above Tularosa around this time	1800	Limited logging above Tularosa
	1801	Regional fire year
Period of relative peace between Apaches & Spanish	1810	Spruce budworm outbreak begins
	1820	Spruce budworm outbreak ends
Mexico declares independence from Spain	1821	
	1835–1849	Wet period
	1840	Spruce budworm outbreak begins
	1842	Regional fire year
Texas statehood; Apaches driven out of Texas	1845	
Mexican-American War	1846	
	1847	Regional fire year
Treaty of Guadalupe-Hidalgo	1848	
California gold rush; Americans come to New Mexico	1849	
First U.S. Military expedition in Sacramentos	1850	Little Ice Age ends; Game scarce in Sacramentos
	1851	Regional fire year
Gadsden purchase	1853	
Rio Penasco expedition; Fort Stanton established	1855	
American Civil war; Apaches at Bosque Redondo	1860–1865	Spruce budworm outbreak ends; bison exterminated on the plains
Tularosa founded	1862	Farming begins in river valleys; water diverted for irrigation
Lincoln County war	1872–1881	
Mescalero Apache Reservation established	1873	
Three Rivers Ranch founded	1874	Intensive livestock grazing begins

continued on next page

valley floor or pools to the south of the White Sands. North of Three Rivers, the Valley of Fire lava flow fills the center of the Tularosa valley. It erupted from Little Black Peak less than 1000 years ago (Chronic 1987).

Though there has been considerable volcanic activity nearby, the Sacramento Mountains are composed of sedimentary rocks formed on the bottoms of shallow seas, and marine fossils are common in the mountains. Sierra Blanca,

Table 2. (Continued) Timeline of Sacramento Mountains history.

Cultural events	Date	Ecological events
	1876	Last fire recorded at JAM (see Fig. 21)
	1879	Regional fire year; last fire recorded at SSP, WAC, DEL, MNU, MON, MCR, LPS, USA (see Fig. 21)
Texas cattlemen begin to arrive	1880	Period of high rainfall, good grass; livestock grazing intensifies
Apaches confined to Reservation; railroad reaches El Paso	1881	Apache influence removed from Sacramentos
General Land Office survey begins	1884	Settlement accelerates; development in canyons
	1886	Last fire recorded at CHR, SAC, LPS (see Fig. 21)
	1889	Sudden drought, collapse of livestock industry
	1890	Spruce budworm outbreak; last fire recorded at FCF (see Fig. 21)
	1893	Drought ends
Fountain murder	1896	Last fire recorded at PSS (see Fig. 21)
Railroad reaches Alamogordo	1898	Water diversion for railroad
Railroad reaches Cloudcroft; logging begins; Lodge built; Biological survey begins	1899	Last sighting of Merriam's elk, Fresnal Canyon flood, Last fire recorded at UPS (see Fig. 21)
Golf course built	1901	Last fire recorded at DEH (see Fig. 21)
	1902	Drought
Railroad reaches Russia	1903	Logging begins in mixed conifer forests
	1904	Drought; last fire recorded at PEA (see Fig. 21)
Sacramento National Forest Reserve created	1907	Active fire suppression begins
Alamo National Forest created	1908	2000 ac burned in human-caused wildfires
Lodge rebuilt	1910	Fir looper outbreak
New Mexico statehood	1912	
Longwell petition	1913	
Circle Cross Ranch founded	1914	Intensive grazing on southwestern part of range
Modern Lincoln National Forest	1917	
	1920	Peak years of railroad logging 1920–1936
Title to Apache reservation confirmed	1922	Insect outbreaks
	1923	Big blowdown on southwest side of range; insect outbreaks
	1927	Last grizzly bear shot in New Mexico
	1928	Insect outbreaks, spruce beetles
	1930	Mule deer population explosion; grazing allotments established to regulate stock.
Civilian Conservation Corps begins	1933	Flood control structures built in canyons, road construction
	1934–1937	Drought, insect outbreaks (*Ips*)
Cloudcroft Experimental Forest established	1935	
Developed campgrounds established	1940	Spruce budworm outbreaks; goats removed from grazing on USFS lands
Ski Cloudcroft established	1941	
Holloman Air Force Base established	1942	
End of Civilian Conservation Corps	1944	
White Sands proving grounds (missile range)	1945	First atomic bomb exploded on Jornada del Muerto
Railroad abandoned	1947	End of railroad logging; most State land acquired by U.S. Forest Service, logged and overgrazed
Smokey Bear found in Capitan Mountains	1950	
Sunspot Solar Observatory opened	1951	Severe drought 1951–1957; Allen Canyon fire 15,820 ac
	1952–1954	Spruce budworm outbreak; aerial pesticide spraying
	1953	Circle Cross fire 25,874 ac
	1956	Pendelton fire, 5,825 ac
	1966	Rocky Mountain Elk introduced to Sacramentos
	1967	Danley fire 2,400 ac
	1974	Spring fire 15, 354 ac
	1980	Spruce budworm outbreak; cable logging
	1990	White pine blister rust detected
	1993	Burgett fire burns 4277 ac
	1994	Bridge fire burns 4946 ac
Present as of this writing	1998	

the highest peak in the Sacramento-White Mountains, is an intrusion of Tertiary rocks surrounded by volcanic material. The west slope of the Sacramento Mountains is abrupt, with steep cliffs and much exposed rock. Paleozoic sedimentary rocks ranging in age from Cambrian to Permian, the complete Paleozoic sequence, overlie Precambrian granite. The visible cliffs on the west side are Devonian and Mississippian limestone; older rocks are buried under alluvial fans at the base of the mountains. Caves and springs are common in the Sacramentos because the rock is very porous, in part because salt and gypsum have been leached out, and in part because the limestone itself is also slightly soluble. The mountains slope gradually to the east toward the Pecos Valley.

During the Pleistocene epoch, small mountain glaciers developed in some of the isolated mountain ranges. A cirque and moraines on Sierra Blanca peak are evidence of the southernmost extent of glaciation in the United States (Richmond 1964). The Pleistocene climate in New Mexico was cooler and much wetter than that of today. Lakes formed in the closed valleys, including the Tularosa Valley to the west of the Sacramento Mountains, and frequent floods carried huge amounts of material into the intermountain basins, building alluvial fans along the valley margins. At the deepest part of the Tularosa valley is a playa, the dry bed of ancient Lake Otero. At its southern end, Lake Lucero, a smaller playa, still holds water after heavy rains. These dry lake beds are the source of the gypsum that forms the dunes of the White Sands. Water washes the gypsum from the Permian rocks in the San Andres mountains and deposits it in the playas, where strong southwest winds in early spring pick it up and blow it into the dune field (Chronic 1987).

Quaternary Environment

Reconstruction of past vegetation must necessarily be based on incomplete evidence; the further back into the past, the less complete the evidence. Most useful for such reconstructions are fossils of plant parts, fossil and subfossil pollen, and preserved plant parts from packrat middens preserved in caves or crevices, some of which have been carbon-dated to more than 40,000 years old. The vegetation of the Sacramento Mountains and of New Mexico in general has been determined by topography, climate, and, after about 11,000 years ago, by human activities. The rise of the Rocky Mountains in the Tertiary Period created a cooler, drier climate than had existed before. Grasslands developed in the rain shadow of the mountains. Communities of more or less modern aspect existed in New Mexico by the beginning of the Quaternary period 2 to 3 million years ago (Dick-Peddie 1993).

The Pleistocene epoch lasted from the beginning of the Quaternary period (about 2 million years ago) until about 11,000 years ago and was characterized by a cooler, wetter climate than at present, punctuated by periods of glaciation and glacial retreats. Vegetation advanced and retreated both elevationally and latitudinally before the glaciers. By about 18,000 years ago, vegetation zones in general were displaced 900 to 1200 m (2925 to 3900 ft) below their present elevations. The plant species did not retreat south or downward as intact communities; some species migrated, while others stayed as small components of new communities or concentrated in refugia. When the vegetation migrated northward or upward again, it formed communities different in species composition from those that had been there before.

During the Pleistocene, the Sacramento Mountains were forested with subalpine conifers and supported an area of alpine tundra along the summit. Most of New Mexico was covered by montane coniferous forest dominated by Douglas-fir, southwestern white pine, and white fir, similar to modern mixed conifer forests, with very little woodland or grassland in the entire state (Van Devender and Spaulding 1979). Limber pine (*Pinus flexilis*) is now found in the northern third of the state and southwestern white pine in the southern part. Dwarf juniper (*Juniperus communis*) was found in the Guadalupe mountains; the nearest dwarf juniper today is 417 km (250 miles) to the north. The high plains to the east were dominated by spruce forest from 17,000 to 12,000 years ago, when dominance changed to pinyon pine woodland. Much of the area now occupied by desert grassland or Chihuahuan desert scrub was dominated by pinyon pine woodland 24,000 years ago. Grassland and desert vegetation did not appear in New Mexico until about 18,000 years ago (Dick-Peddie 1993).

Thirteen packrat and two porcupine middens from the Sacramento Mountains, located between 1555 and 1690 m (5054 to 5493 ft) in elevation, document vegetation assemblages in their immediate areas from 390 to 18,300 years ago (Betancourt et al. 1990; Van Devender et al. 1984). Packrats (rodents of the genus *Neotoma)* and other small mammals build houses that may be occupied by generations of animals for thousands of years. They collect plants and other materials, and over time, these collections, along with fecal pellets, become cemented and preserved by crystallized urine.

Fossil and subfossil midden sites have been located in dry rock shelters in Big Boy Canyon, San Andres Canyon, Marble Canyon, and Dog Canyon, all on the western escarpment of the Sacramento Mountains. The vegetation of these areas is presently classified as Chihuahuan desert scrub, but evidence from the middens indicates that this vegetation has apparently only been in place since the late Holocene, about the last 4000 years. During the Wisconsin full glacial period 18,000 to 16,000 years ago, the oldest site, at 1555 m (5054 ft) elevation, was dominated by Colorado pinyon and Rocky Mountain juniper in association with one-seed juniper, wavyleavf oak, and Douglas-fir, and was probably near the upper elevational limit of woodland. The high species richness compared to pinyon-juniper woodlands at similar elevations to the north suggests that winters were not much colder than today. Precipitation occurred mostly in the winter and spring (Van Devender et al. 1984).

During the early Holocene, between 11,000 and 8000 years ago, under warmer and somewhat drier conditions, the same area supported a juniper-oak woodland under a climate that was still characterized by winter precipitation. During the dry period of the middle Holocene between 8000 and 4000 years ago known as the Altithermal, the area supported desert grassland, and the climate had changed from cool, with winter precipitation, to the period of maximum Holocene warmth and a shift to dominant summer precipitation, the beginnings of the monsoons. About 4000 years ago, the present desert scrub vegetation was in place under a climate much like that of today, with summer monsoon rains and less frequent frost. Rainfall may have been more irregular, with more frequent annual droughts (Van Devender et al. 1984). There was a general cooling until about 2500 years ago, when the temperature began to warm again. The Medieval Warm Period (1000 AD to 1350 AD) saw temperatures warmer than the present, including prolonged summer drought from 1130 to 1180 AD. From about 1450 until 1850, the Little Ice Age was a period generally cooler and wetter than the present. The climate has become relatively stable over the last 600 years (Dick-Peddie 1993). With the development of the summer monsoon and winter-spring drought, many species changed their distributions. Rocky mountain juniper (*Juniperus scopulorum*) retreated to high elevations and riparian areas, while one-seed juniper (*Juniperus monosperma*) became more widespread, and alligator juniper (*Juniperus deppeana*) increased its range, to become the dominant juniper species in modern pinyon-juniper-oak woodlands in the Sacramentos.

Ponderosa pine is not present in the Sacramento Mountains midden records. Forests dominated by ponderosa pine probably developed in the Sacramento Mountains at higher elevations during the early or middle Holocene, when ponderosa pine was dispersing widely throughout the West, where it had been only a minor component before. The expansion of dominance by ponderosa pine may have been due to new fire regimes that came into being with the establishment of the monsoonal climate. Ponderosa pine is more tolerant of fire than the other mixed confer species it replaced. Mixed conifer forests at higher elevations were dominated by Douglas-fir and southwestern white pine, which had retreated with the advent of a warmer and drier climate. Subalpine forests of Engelmann spruce were reduced to small pockets at the highest elevations and in areas of cold air drainage.

History of Human Occupation

Prehistoric Habitation

It is impossible to separate the historic condition of ecosystems from the history of the human populations who have lived there. The Sacramento Mountains have a long and sometimes bloody history of human occupation. See Table 2 for a timeline of historic events in the Sacramento Mountains. Evidence of the hunter-gatherer peoples who roamed the area before about 900 AD is sketchy (Driver 1985). The earliest known Paleo-Indian occupation of the Tularosa basin was around 9000 BC (Tainter 1981). A shelter site occupied from around 2000 BC to 100 BC has been excavated near the tunnel on US Highway 82 in Fresnal Canyon (Tainter 1981). Other sites of Archaic occupation were found in the Hueco mountains to the south (Hueco period; Kelley 1984), and a Folsom point was found at Burnet Cave (Kelley 1984), indicating that prehistoric big-game hunters used the region.

The prehistory of southeastern and south-central New Mexico is among the least known in the Southwest. The change to a warmer, drier climate beginning 9000 years ago caused people to migrate seasonally and to move into the mountains where water was more readily available. The Archaic period began with this change, and lasted until 100–250 AD. The nomadic hunter-gatherer peoples of the Sacramentos may have practiced some rudimentary agriculture to supplement foraging during the later Archaic. The early cultures of the Sacramento Mountains are classified as the Jornada branch of the Mogollon. The Mesilla phase (250–1100 AD) saw people settling into a more sedentary life in pithouses, using pottery, and probably growing crops to supplement hunting and gathering. During the Doña Ana phase (1100–1200 AD) people began the transition to living in pueblo-style buildings with many contiguous rooms, though pithouses persisted.

Agriculture became more important during this period, and there are indications of an increasing population. It is not known whether the people who had been living in the area evolved a sedentary way of life, or whether the gather-farmers moved in from elsewhere, but by 1100 AD, agriculture was practiced at several locations in the Sacramento Mountains, several hundred years after agriculture had become the primary means of support among the peoples of the Rio Grande valley (Broster and Harrill 1983, Tainter and Tainter 1995). Several prehistoric farming villages were excavated in the Sierra Blanca Region in the 1950's (Kelley 1984), and others in the Sacramento Mountains near Timberon (Spoerl 1981a) and in Snaky Canyon (Tainter 1981). After 1200 AD, during the El Paso phase, pithouses were abandoned in favor of pueblos, and agriculture flourished until about 1400 AD, when the pueblos and fields were abandoned. The Sacramentos may have been largely uninhabited by humans from this time until the arrival of the Apaches in the early 17th century.

Prehistoric farming villages tended to be located in areas most conducive to primitive agriculture: on the eastern slope of the Sacramento Mountains within the pinyon-juniper zone, between 1662 and 1908 m (5400 to 6200 ft) elevation (Kelley 1984), in alluvial valleys with deep soils and more or less permanent water, or on the western slope at the base of the escarpment near drainages originating in the mountains (Tainter 1981). Within the Sacramento District, two sites were located near the modern village of Mayhill along the Rio Peñasco, which included some pithouses and pottery of early Pueblo III date (Doña Ana phase, 1100 AD to 1200 AD; Stuart and Farwell 1983). These were damaged by highway construction and have subsequently been destroyed. Site 2000, a few miles downstream, also appears to have been occupied during Pueblo III times (Kelly 1984). Farther north, along the Rio Ruidoso, a larger village has been located on the Bonnell Ranch that appears to have been occupied from Pueblo III to Pueblo IV (Doña Ana and El Paso phases; 1200 AD to 1325 AD) periods. More villages were scattered to the north and east, in the Capitan Mountains and near Roswell.

On the western escarpment, sites like the one in Snaky Canyon may have been outposts of the permanent settlements in the Tularosa Valley. The Snaky Canyon site was probably cultivated between 1100 and 1200 AD but may not have been occupied year-around. It was excavated in 1978 because it was threatened by erosion and proposed erosion control measures. Eighteen sites in the valley yielded ceramics and projectile points of the Doña Ana or El Paso phases (Tainter 1981). Evidence of hunting and gathering camps is common throughout the Sacramentos. A typical site was excavated in the pinyon-juniper woodland near Timberon in 1980, which had a long history of use from the pre-ceramic through the early ceramic periods (200–500 AD). This site was disturbed by road repair (Spoerl 1981a).

The Sacramento Mountains seem to have been abandoned by agricultural peoples between 1300 (Kelley 1984) and 1450 AD (Driver 1984). The reason or reasons for the relatively sudden abandonment of these sites, which corresponds with the abandonment of other agricultural sites farther north, is unknown, though several theories have been put forward. There is evidence of a change in the climate at this time. Worldwide, the period known as the Little Ice Age was beginning, a time of cooler and wetter conditions following a long period of conditions generally warmer than the present. In the Sierra Blanca region, the significance of the change may have had more to do with the timing of precipitation than with temperature. Total annual rainfall may not have changed much, but the pattern of rainfall may have shifted from precipitation dispersed throughout the year to rainfall concentrated into more intense summer storms resembling the current pattern. Such torrential storms increase flooding, erosion, and arroyo cutting, and lower the water table, all of which make farming more difficult. Repeated crop failures would have left the people vulnerable to disease and to attacks from their neighbors who were also enduring hard times, or from Athabaskan invaders, nomadic ancestors of the Apaches and Commanches. There is evidence of warfare at Bloom Mound, located on the present Mescalero Apache Reservation, which coincides with the abandonment of the farming villages.

Hunter-gatherer groups tend to use upland areas of topographic diversity, where they can find a variety of edible plants and wildlife habitats within a relatively small area (Tainter and Tainter 1995). It is likely that the earliest human inhabitants of the Sacramento Mountains migrated seasonally up and down the mountain range, were widely dispersed, and were probably never very numerous. The highest parts of the range may not have been inhabited at all. The effects of these early peoples on the landscape are unknown, though they may have affected wildlife populations and the populations of food plants locally.

With the advent of agriculture, people were concentrated in the river valleys along permanent streams. Faunal remains from the sites along the Rio Peñasco, such as muskrat, indicate that this was a permanent water course (Driver 1985). The farmers had no domestic animals except dogs, but they supplemented their crops by hunting, and remains of turkeys, rabbits, deer, and pronghorn were found at village sites. The effects of the farmers on their landscape no doubt included cutting of trees near villages for firewood and possibly to clear fields, and their cultivation may have resulted in some erosion in riparian areas. However, the prehistoric farmers in the Sacramento Mountains were widely scattered and never numerous, and the effects of their use of the land have been swamped by subsequent disturbances.

The Apaches and the Spanish

The date of the Apaches' arrival in the Sacramento Mountains is not known for sure. Spanish expeditions reached the area by the mid-16th century, but the Apaches were not mentioned recognizably in the area by Spanish records until around 1600. Coronado's expedition (1540–1542) encountered the Apaches on the plains to the north and east, where they lived by following the bison herds. The Apaches were not initially hostile to the Spanish, but that did not last long. The Spanish did not recognize any Indian claims to land and subjected the natives to cruelty and slavery. By the early 1600s, there was constant warfare between the Apaches and the Spanish colonists and their settled native converts. Sometime between 1541 and 1600, the Apaches acquired horses from the Spanish and learned to ride. With horses, their range expanded by hundreds of miles, and their raids became more effective.

The Mescalero Apaches were the historical native people most closely identified with the Sacramento Mountains (Fig. 6). They were an Eastern Apache group who occupied the region between the Rio Grande and the Pecos rivers, south of the 34th parallel and mostly north of the Mexico border. They lived in loosely organized bands and probably did not practice agriculture. The Mescaleros were first recognized by that name in the early 1700s, when they apparently shared the area with several other Apache groups. After 1750, only one other group, the Natage, were noted in the area (Betancourt 1981).

Most of the Spanish settlements were located to the north and west of the Sacramento Mountains, among the

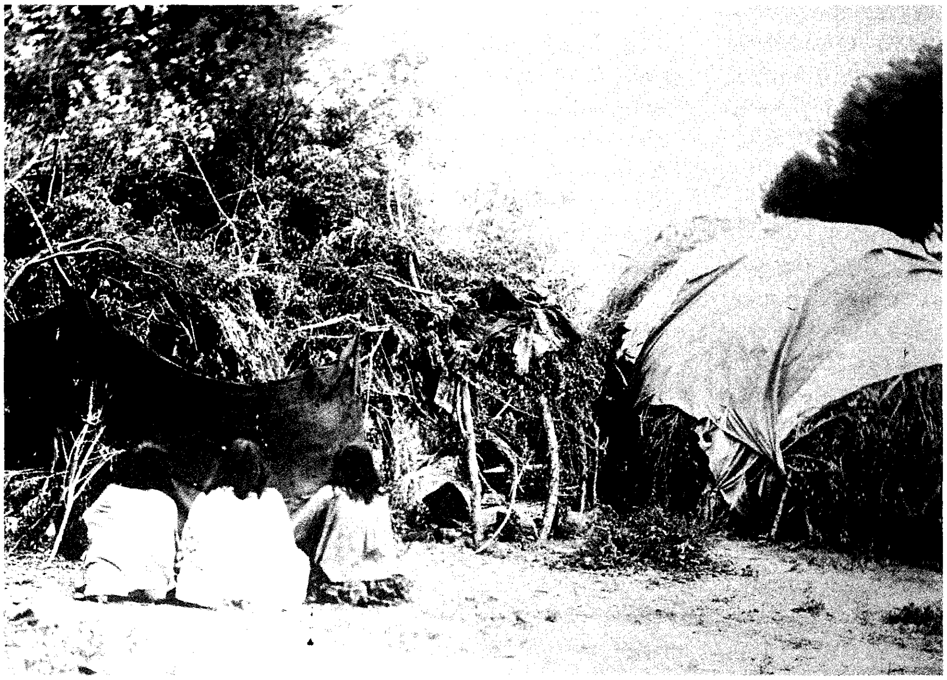


Figure 6. A Mescalero Apache camp in the early 1900s. Photo by Alexander, Lincoln National Forest Heritage Resource Program collection in Alamogordo, on file at the Lincoln National Forest Supervisor's office.

settled agricultural tribes of the Rio Grande Valley and northern mountains. There is no record of any early Spanish settlement in the Sacramento Mountains, but Spanish records do indicate that the Mescalero Apaches were established there by the 1630s, using the Sierra Blanca region as the base for their raids on the Jumanos pueblo to the north. This established their pattern for the next 250 years: lightning raids on settlements for livestock and whatever supplies they required, then disappearance into the mountains where they could elude or ambush their pursuers easily. The first recorded Spanish conflict with the Mescalero Apaches was in 1653, in the Sierra Blanca territory (Opler 1983).

The Spanish colony in New Mexico nearly failed in the 17th century, due in part to their mistreatment of the natives, their disagreements among themselves, and the relentless Apache raids. Famine struck in the 1660's, followed by disease, probably smallpox. In 1672, the Apache raids on the pueblo at Jumanos were so devastating that Spanish and Indians alike abandoned it. In 1680, the settled Indians all over New Mexico rebelled against their Spanish masters, supported and encouraged by the Apaches, and the Spanish were driven out of New Mexico for the next two decades.

However, sometime around 1700, new players arrived on the scene: the Commanches, who came from the high plains east of the Pecos. They put severe pressure on the Apaches, who in turn raided the pueblos and Spanish settlers. There are vague reports of a huge battle sometime between 1720 and 1723, in which the Commanches decisively defeated the Apaches and their allies the Lipans somewhere east of the Pecos river (Sonnichsen 1973). This caused a great movement of Apaches south and west, even into Mexico. Some of the Mescaleros seem to have stayed in their home territory of Sierra Blanca despite the Commanches; some moved to the Guadalupe mountains to the south and to the Organ mountains to the west; and some were raiding as far away as 1000 miles into Mexico.

During all this movement and warfare, the Apaches continued to live a hunting and gathering lifestyle, and their presence must have had at least local effects, probably concentrated on wildlife populations and near water sources, though they moved frequently and lived in small bands. The bands do not appear to have had specific territories or home ranges, though they did repeatedly occupy places where they had access to particular resources or to a number of resources within a relatively short distance (Sebastian and Larralde 1989). Important prey species for Mescalero hunters were deer, pronghorn, and bison, as well as rabbits and prairie dogs when necessary. Mule deer were probably their most important source of meat after they moved off the plains, though they still went to the plains to hunt bison until the herds were destroyed in the 1860s, and access routes to bison-hunting grounds were important considerations in the locations of their camps. The Mescaleros used wild plants for as much as 50 percent of their diet, particularly mescal, datil, pinion nuts, and mesquite beans, as well as cactus fruits, other nuts, grass seeds, tubers, and greens (Sebastian and Larralde 1989).

The most significant effect of the Spanish presence was the introduction of domestic livestock, especially sheep, goats, cattle, and horses. Though the Spanish themselves did not practice grazing in the Sacramentos, they recorded that the Apaches stole hundreds of horses or cattle at a time. The Apaches do not appear to have kept herds of their own, except riding horses; when they had eaten all the stock they had taken, they made another raid. However, the animals they took into the mountains and the horses they kept were enough to be considered the beginnings of livestock grazing in the Sacramentos.

From the time of their arrival in the Sacramento Mountains, the Mescalero Apaches were nomadic, following game and crops of wild plant foods as they ripened. They used higher elevations in summer and ranged at lower elevations in winter, without building any permanent structures. They traveled east to the plains to hunt bison and to the borders of the desert to harvest the mescal plant, their staple food, from which they derive their name. While their activity seems to have been concentrated around Sierra Blanca where water may have been more consistently available than elsewhere in the mountains because of greater snowfall, the Apaches ranged all over the Sacramentos and are known to have used Dog Canyon as a thoroughfare from the Tularosa valley to the top of the Sacramento Mountains, sometimes ambushing pursuing enemies in the steep, rocky canyon (Betancourt 1981, Wilkinson 1997).

The environmental effects of the Apaches' hunting and gathering are unknown and probably unknowable. It may be significant, however, that they made much of their living through raiding, and their numbers were never very large (fewer than 1000 according to Sonnichsen 1973; 2000 to 3000 according to Opler 1983). Availability of food and water in the Sacramento Mountains was unpredictable at best, and despite their efficient use of their environment, the Apaches were often hungry during the 18th and 19th centuries. The Apaches are known to have set fires for hunting and warfare purposes (Cooper 1960, Sonnichsen 1973, Swetnam and Baisan 1996), but the extent to which they affected the local fire regime is not well known (Wilkinson 1997). As Swetnam and Baisan (1996) point out, there was no lack of potential lightning ignitions to cause the historic pattern of frequent surface fires, so the influence of the Apaches may have been more significant to the timing and location of fires rather than to their overall frequency.

A period of warfare continued through the 18th century, and a concerted Spanish campaign was launched in the 1780s during which Spanish expeditions penetrated the Sacramento Mountains and other Apache strongholds. Toward the end of Spanish rule, as their resources were diverted to other conflicts, the Spanish turned to conciliation with the Apaches. Relative peace existed between the Spanish and the Apaches into the early 1800s. In 1821, Mexico became independent from Spain and continued the policy of conciliation, though there were lapses into hostilities and the peace was never stable.

The Americans

The American army arrived in New Mexico soon after the declaration of war against Mexico in 1846 and took over most of New Mexico peacefully. The treaty of Guadalupe-Hidalgo in 1848 transferred all the territory between the Colorado River and Texas, as well as California, to the United States, and the area became the Territory of New Mexico in 1850. The southern parts of New Mexico and Arizona were added by the Gadsden Purchase in 1853. Arizona became a separate territory in 1863 (Baker et al. 1988). The Americans continued the Spanish-Mexican precept that recognized no Indian claim to the land. When Texas entered the Union in 1845, the Federal government retained no lands there and so was unable to provide any lands for the Indians who lived there, including some of the Mescaleros, who were subsequently driven out of Texas.

Americans began arriving in New Mexico in large numbers around 1849. Most of them were on their way to the gold fields of California and did not stay in southeastern New Mexico. The first recorded American military expedition into the Sierra Blanca region occurred in June of 1850, an exploratory mission out of Doña Ana to see what was on the other side of the Organ Mountains. The soldiers were turned back by threats from the Apaches without a shot being fired. A report from Brevet Captain A. W. Bowman, army quartermaster, dated April 23, 1850, remarked that so many Apaches were concentrated in the mountainous country (because of pressure from Commanches, Americans, and Mexicans) that game had become very scarce.

In January 1855, a campaign was launched against the Apaches in the Sacramento Mountains by soldiers from Fort Thorn. The Apaches had apparently stolen cattle from the Pecos valley. This was the first American expedition to penetrate the Sacramentos, the Apaches' stronghold. The troops marched up the Rio Peñasco from the east, into "country [that] was broken into high hills with deep ravines crossing the line of march," according to Captain Ewell (Sonnichsen 1973:84). They were attacked constantly but drove the Apaches from their lodges, pursuing them to the top of the range above the source of the Rio Peñasco. A private Bennet, who kept a diary of the trip, said: "No one of our number has ever traveled this country before. It is nothing but snow and ice." (Sonnichsen 1973:86–87). The soldiers lost much of their stock and several men; the Apaches, their stronghold invaded, fled into the Guadalupes. As a result of this battle, Fort Stanton was established at the junction of the Rio Bonito and the Rio Ruidoso, near present day Lincoln. For several years in the 1860s, the Mescaleros were forced onto a reservation at Bosque Redondo near Fort Sumner. Conditions there were terrible, and most of the Mescaleros escaped back into the mountains. In 1873, a reservation was established by Executive Order for the Mescalero Apaches, and Mescalero chiefs signed a treaty confining the Apaches to the reservation south of Fort Stanton, 45 km (27 miles) wide and extending (then) from the mountains east to the Pecos. However, the US Congress never ratified the treaty, and title to the land was not confirmed by Congress until 1922 (Opler 1983). Disease, mismanagement, dishonesty of government officials, lack of food, and mistreatment by the Americans reduced Mescalero numbers. They generally tried to keep the peace, but the inconsistent behavior and treatment by the Americans made that difficult, and they fought the Americans periodically, occasionally getting involved in uprisings that started elsewhere. But by the early 1880's, their population ravaged by war and disease, they were forcibly disarmed and settled down on their reservation, to become wards of the United States government (Fig. 7). In 1881, 431 Mescalero Apaches were left alive. Because the boundaries of the reservation had not been surveyed, the Apaches continued to endure conflicts over encroachments by Anglos for mining, farming, and logging, had their horses and other livestock stolen, and were blamed for raids actually perpetrated by Anglo outlaws.

It was only after the Apaches were no longer a factor that the Sacramento Mountains were settled and exploited by Anglo-Americans; the Apaches had effectively kept Spanish and Mexican settlers out of the mountains. The beginning of the Civil War slowed American settlement of New Mexico. The Territory was under martial law for the duration of the war, administered by volunteer troops from California, and the Americans' concern was focused on thwarting Confederate invasion from Texas, not exploration, Indians, or settlements. Fort Stanton was abandoned, and the Apaches regained control of the area for a short time (Sebastian and Larralde 1989). In 1862, a group of Mexican farmers, driven out of the Rio Grande valley by floods, founded a settlement that became the town of Tularosa. The name of the place tells something of its ecological character. Tularosa means "full of reedy places" (Sonnichsen 1980). A sawmill had existed upriver from Tularosa since before 1800, which had supplied timbers for churches and other buildings along the Rio Grande, indicating at least limited logging activity on the west side of the Sacramentos during that time (Sonnichsen 1980).

After the Civil War, Americans came to New Mexico in large numbers, and with them came rapid environmental change (Fig. 8). Cattlemen and entrepreneurs flooded in from Texas and elsewhere, determined to make their fortunes on the frontier no matter what the cost. They were "a microcosm of money-mad, power-hungry nineteenth-century America, America before the dream had soured, America on the brink of becoming a world power, America the promised land where a pushcart immigrant could overnight become a millionaire, America in the Gilded Age when the robber barons of Wall Street were the uncrowned kings" (Nolan 1992). The range war in Lincoln County in the late 1870's (Nolan 1992) and the murders and lawless periods in the 1890's in the area around Alamogordo (Sonnichsen 1980) were indicative of the ruthless character of many people who settled in the area of the Sacramento Mountains. That ruthlessness was also expressed in their inconsistent and cruel treatment of the Indians, the poor farmers both Anglo and Hispanic, and in their relentless exploitation of the natural resources. The Sacramento Mountains, with the Apaches now disarmed and no longer a factor, became a hiding place for rustlers and outlaws and the battleground in the fight for land and water.

The Cattlemen

The cattlemen and other stock raisers arrived in the years following the Civil War and changed the social order of the Sacramento Mountains. Texas had escaped much of the destruction suffered by the other Confeder-

Figure 7. The Mescalero Apache village and agency at the turn of the 20th century. Photo by Alexander, Lincoln National Forest Heritage Resource Program collection in Alamogordo, on file at the Lincoln National Forest Supervisor's office.

ate states and, after the war, became the new frontier where land was cheap, cattle-raising was profitable, and there were still opportunities. Simultaneously, the Texas Rangers subdued the Indians and outlaws, opening up the wild grasslands of west Texas for settlement. People flowed west in great numbers, and as the country began to fill up, they continued to drift west into the Pecos valley and southeastern New Mexico. They arrived in great numbers in the early 1880s, about the same time the Apaches were subdued and during a period of unusually high rainfall.

The native bunchgrasses were reported to be as high as a horse's shoulder, and the bounty encouraged settlers intent on making their fortunes to run many more cattle than the range could support. Tom Fraser, an early resident of Alamogordo, reported that 85,000 animals were rounded up between Three Rivers and Dog Canyon in 1889 (Sonnichsen 1980). The Texans had immediate conflicts with the Mexican farmers and ranchers who were already living in the area, with the Indians even on their reservation, and with the Yankee settlers, many of whom had come with the California Column during the war. All of the mountains were open range, and the ranchers often helped themselves to each other's cattle, sometimes precipitating violence. All the while people streamed into the country, many of them moving up into the mountains. *The Rio Grande Republican* reported that the population of the area doubled in four weeks in the spring of 1888 (Sonnichsen 1980).

A three-year drought began in 1889, and suddenly the rich virgin country was enduring hard times. Many small farmers and ranchers went broke and left. Where people had been growing corn 12 ft tall and 64-pound cabbages in the canyons, now no one could make a living. Rumors of a railroad had drawn even more settlers in the late 1880's, but it was to be another decade before the railroad became a reality. By 1890, cattle were dying of hunger and thirst, fouling the water holes and streams. People began fighting over range and water rights, and by the time the drought broke in 1893, a major conflict erupted between the small ranchers and the big cattle companies, which was exacerbated by the nation-wide economic depression in that year caused by the demonetizing of silver. The conflict was waged in the courts, the Territorial government, and by violence in the mountains. Most of the early ranchers were small operators. Only a few were able to build empires, sometimes employing murder, violence, and intimidation as well as controlling the local legal system to wrest land and water away from small farmers and ranchers and consolidate their empires, which were often short-lived.

Huge numbers of cattle, sheep, and goats grazed all over the Southwest in the last two decades of the 19th century, and the Sacramento Mountains were no exception (Fig. 9). A report proposing the creation of the Sacramento National Forest estimated that 17,000 head of cattle and horses, 10,000 sheep and 40,000 goats were grazing in the proposed Forest at the turn of the century (Spoerl 1981b). As the land became more and more overgrazed, the animals had to travel farther for food and water and became concentrated around water sources, increasing the damage. During dry years, such as 1902–1904, more than 30 percent of the stock in the Sacramentos died. Weakened animals ate much dirt with the roots of the plants they pulled up, then had to travel as much as 33 km (20 miles) to reach water, where they often became stuck in the mud and died, polluting the water sources (Spoerl 1981b).

Two large ranches in the Sacramento Mountains were the Three Rivers and the Circle Cross. Three Rivers was

Figure 8. The Jim Lewis homestead at the head of Lewis Canyon, 1896. Photo by E. Miller, Lincoln National Forest Heritage Resource Program collection in Alamogordo, on file at the Lincoln National Forest Supervisor's office.

Figure 9. Cattle grazing along the Sacramento River on land owned by the Sacramento Land and Cattle Company, 1928. US Forest Service photo #233411, Lincoln National Forest Heritage Resource Program collection in Alamogordo, on file at the Lincoln National Forest Supervisor's office.

located west of Tularosa and bordered the Mescalero Indian Reservation. It was organized in 1874 by Pat Coughlan, a Tularosa landowner, who bought out or forced out others living in the area and at one time did business with Billy the Kid, buying his stolen beef. Coughlan eventually went bankrupt and was bought out in 1906 by Albert Fall, a prominent New Mexico politician, who enlarged the ranch by buying up surrounding ranches. The Three Rivers ranch still exists.

The Circle Cross ranch was organized around 1914, on the south end of the Sacramentos from the Mescalero Reservation almost to Ysleta, Texas, and at its peak it included 400,000 ha (a million acres), with headquarters on the Sacramento River near Timberon. Formed by buying up smaller ranches and financed by El Paso businessmen, the ranch was managed by the well-known stockman, Oliver Lee. Lee had been involved in the conflicts of the 1890s and later became a State politician. The Circle Cross was too large to manage effectively and eventually broke up in the 1920s.

In 1908, the Alamo National Forest, in the first effort to regulate grazing in the Sacramentos, made a list of grazing permittees on the Forest and how many cattle and horses they were allowed, a total of 15,454 cattle and 2,093 horses. Most of the 228 permittees had fewer than 50 head (US Forest Service 1908). Many of these people had been grazing stock on the land before the National Forest was established, and were now given the opportunity to continue under permit. Grazing allotments were established in the early 1930s. The present allotment arrangement was established by 1957, when the National Forest acquired much of the State-owned land in the Sacramentos, which had been leased for timber cutting and grazing with little or no control over the exploitation. Efforts to reduce stocking rates and recover the grazing resource have depended not only on reducing the number of stock on the range, but on simultaneously rotating available range, so that the animals do not continue to concentrate near the same water sources and canyon bottoms (US Forest Service 1978).

Mining

The Sacramento Mountains were never mined extensively or very successfully, and the effects of mining have been very localized. Coal, gold, and silver were mined around White Oaks in the Capitan Mountains to the north. Around the turn of the century, copper was mined by the Hunt Copper Company of High Rolls, and also in Caballero Canyon (Jenkens 1988). Marble was quarried in Marble Canyon on the west slope of the Sacramentos until the late 1930s. General Land Office survey notes from the 1880s recorded very little evidence of useful minerals anywhere in the Sacramento Mountains.

The Railroad

The advent of steam railroads made possible the large-scale logging and tourism industries in the Sacramento Mountains (Glover 1984). The timber and the railroads were inextricably linked, because railroad construction required huge quantities of timber for crossties, trestles, and buildings, and the timber could not be hauled out of the mountains without the railroad. The Santa Fe and Southern Pacific main lines arrived in El Paso in 1881, and plans to build a railroad to the Sacramento Mountains began soon after, both for the potential timber and for coal and gold being mined near White Oaks to the north. However, despite abortive attempts, it was not until 1896 that the El Paso and Northeastern Railroad was incorporated

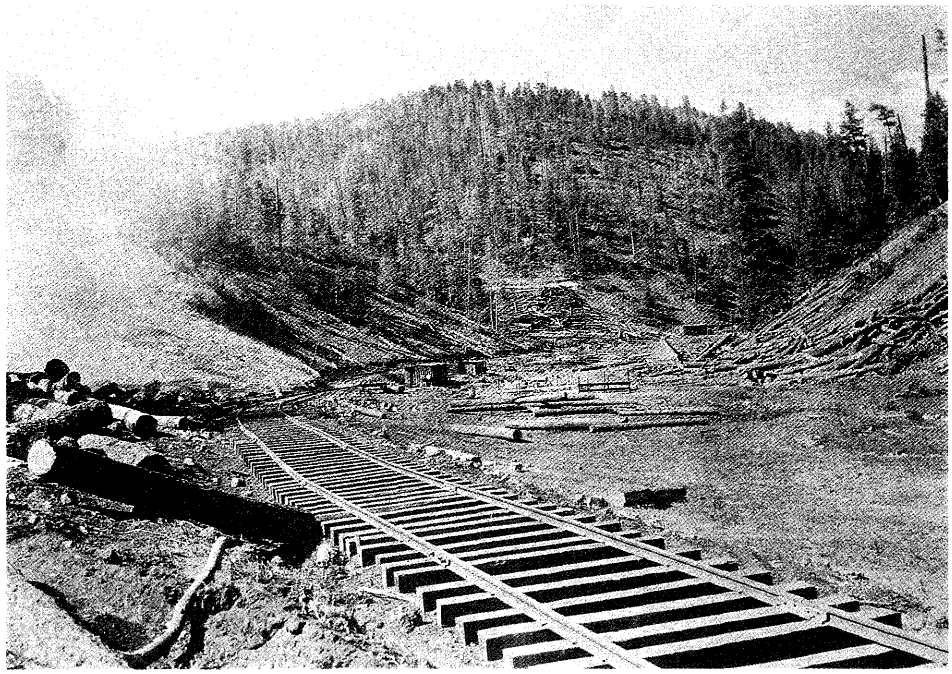


Figure 10. The Southwest Lumber Company laying railroad track in Hubble Canyon, 1928. US Forest Service photo #233280, Lincoln National Forest Heritage Resource Program collection in Alamogordo, on file at the Lincoln National Forest Supervisor's office.

and construction began. The city of Alamogordo was officially founded in 1898, near the site of a settlement begun in 1871 at the mouth of Alamo Canyon. Oliver Lee owned the Alamo Canyon Ranch and water until 1897, when it was bought by the Eddy brothers, who built the El Paso-Northeastern Railroad north from El Paso. The railroad reached the site in June of 1898, and the city of Alamogordo was born (Charles 1959).

Within weeks of reaching Alamogordo, the railroad was extended into the mountains and north toward Carrizozo and the coal mines near Capitan. The Alamogordo Lumber Company was organized to buy land, build a sawmill, and begin logging in the mountains. The first section of the Alamogordo and Sacramento Mountain Railway was opened in November 1898, from Alamogordo Junction to Toboggan in Fresnal Canyon, where the present highway runs. In just 32 km (19.3 miles), the standard gauge railroad climbed from 1345 m (4372 ft) elevation to 2332 m (7580 ft), with grades exceeding 5 percent, sometimes as steep as 6.5 percent, steeper than the famous Colorado narrow gauge railroads. The next section of the railroad was begun in 1899, encompassing an elevation gain of another 615 m (2000 ft) to Cloudcroft and Cox Canyon. This section includes the famous s-trestle still visible just below Cloudcroft. The final extension of the Alamogordo and Sacramento Mountains Railroad was from Cox Canyon to the logging camp at Russia, completed by 1903. The maze of further extensions was built by the various lumber companies (Fig. 10). The peak years of logging and railroad hauling were the late 1920s.

In addition to logs, the railroad also carried passengers along the scenic route. Special open cars were used to bring tourists to Cloudcroft, many of them coming from Alamogordo and El Paso to escape the summer heat. The Cloudcroft Lodge was a center of tourist activity. The original wooden building burned in 1909 and was rebuilt on a grander scale in 1910–1911. The railroad also hauled produce, livestock, and lumber down from the mountains, and mail, coal, and supplies back up. Eventually, automobile travel became safer and more reliable, and passenger rail service ceased in February 1938. Railroad logging around Russia stopped in 1941, and the entire line was abandoned in 1947. Tracks were taken up and sold for scrap, as were the old locomotives that could not be brought down (Neal 1966). Logging continued in the Sacramento Mountains after that time, but logs were brought down using trucks.

Logging

Large-scale logging began in the Sacramentos with the arrival of the railroad. The Alamogordo Lumber Company bought up more than 23,000 ha (58,000 ac) of land, mostly at high elevations in the Sacramentos. By 1906, some 3480 ha (8,700 ac) had already been clearcut (Holmes 1906). The Company land was not one solid block, but was interspersed with other private holdings. The Company's sawmill was located in Alamogordo and had a daily capacity of 75,000 board feet. Logs were hauled to the mill on the Alamogordo and Sacramento Mountains Railway from Cloudcroft and Russia (Fig. 11). Side tracks were laid down the main canyons at grades of 5 percent or 6 percent, and spurs in side canyons did not exceed 12 percent grades (Fig. 12). The logs were skidded to the track with horses. The primary timber trees cut were Douglas-fir and white fir. Holmes (1906) estimated that Douglas-fir made up about 60 percent of the entire forest on Company lands, and white fir 25 percent. He also noted that ponderosa

Figure 11. The Southwest Lumber Company loading logs with a mechanical loader in Water Canyon, 1928. US Forest Service photo #233068, Lincoln National Forest Heritage Resource Program collection in Alamogordo, on file at the Lincoln National Forest Supervisor's office.

pine was common below 2769 m (9000 ft) elevation, sometimes in nearly pure stands, and that Engelmann spruce and blue spruce were found in some higher canyons. Southwestern white pine was scattered "all over the slopes in small quantities, and aspen is found everywhere."

Fires following logging were common and caused considerable damage. Holmes (1906) observed that when a logged area caught fire "it burns so fiercely that it not only kills all the live trees and seedlings left, but burns up all the vegetable matter in the soil. It is almost impossible to stop it till it strikes virgin timber or previously burnt cut-over land." More than 800 ha (2,000 ac) of cut-over land burned in 1906 alone, all the result of human-caused fires.

In 1906, the Company wanted to know whether it would behoove them to cut the lumber conservatively and retain the land for a second cutting, or to clearcut the land and then sell it for taxes (and no profit) or turn it over to the government. Very little of the land held by the Company was considered fit for agriculture or grazing and so was not considered salable. The company opted for the latter option, with the agreement to protect the regeneration from fire, leaving the government in possession of large areas of young timber. Originally, only trees 12 inches in diameter and larger were cut, but it was decided that this was not cost effective, and the diameter limit was dropped once it was decided not to keep the land for a second cutting, and the regeneration became unimportant. The prudent method of piling slash away from the cut and burning it, which prevented fire in the cut and prevented insect outbreaks, was abandoned as not cost effective. Even in 1906, the Company realized that the railroad was not likely to outlast the logging, and they were correct. Intensive logging lasted for about 30 years, and within a decade after that, the railroad was gone.

Logging has continued in the Sacramentos on a smaller scale. Cable logging was first done in the 1980s to minimize the effects of logging on the soils of steep slopes. Logging continues to be the second most important commercial activity on the Lincoln National Forest, next to recreation.

Tourism

The Sacramento Mountains have been popular for recreation since the turn of the 20th century, when the railroad to Cloudcroft made it easier for people to travel there. The first Lodge was built in 1899 and was instantly popular with people from Alamogordo and El Paso as a place to escape the summer heat. The golf course, at 2831 m (9200 ft) the highest in the country, opened in 1901 (Jenkins 1988, Fig. 13). The Forest Service began constructing permanent campgrounds in the 1940s, and presently maintains 16 camping areas and many hiking trails and picnic areas, including a special trail for the blind. Recreation in the Sacramento Mountains is more popular now than ever. Hiking, camping, spelunking, and wildlife viewing are popular pursuits. Many other nearby historical and natural attractions draw tourists from all over the country, including the White Sands National Monument, Ruidoso Downs horse race track, Three Rivers Petroglyphs, and the Space Museum in Alamogordo. Hunting, particularly of mule deer and turkeys, is a major public use of the forest resource. There are no wilderness areas on the Sacramento District.

Winter sports such as skiing began to be popular in the United States in the 1920s, but it was not until the 1960s and 1970s that they became a major recreational activity in the Southwest. Improved access after World War II en-

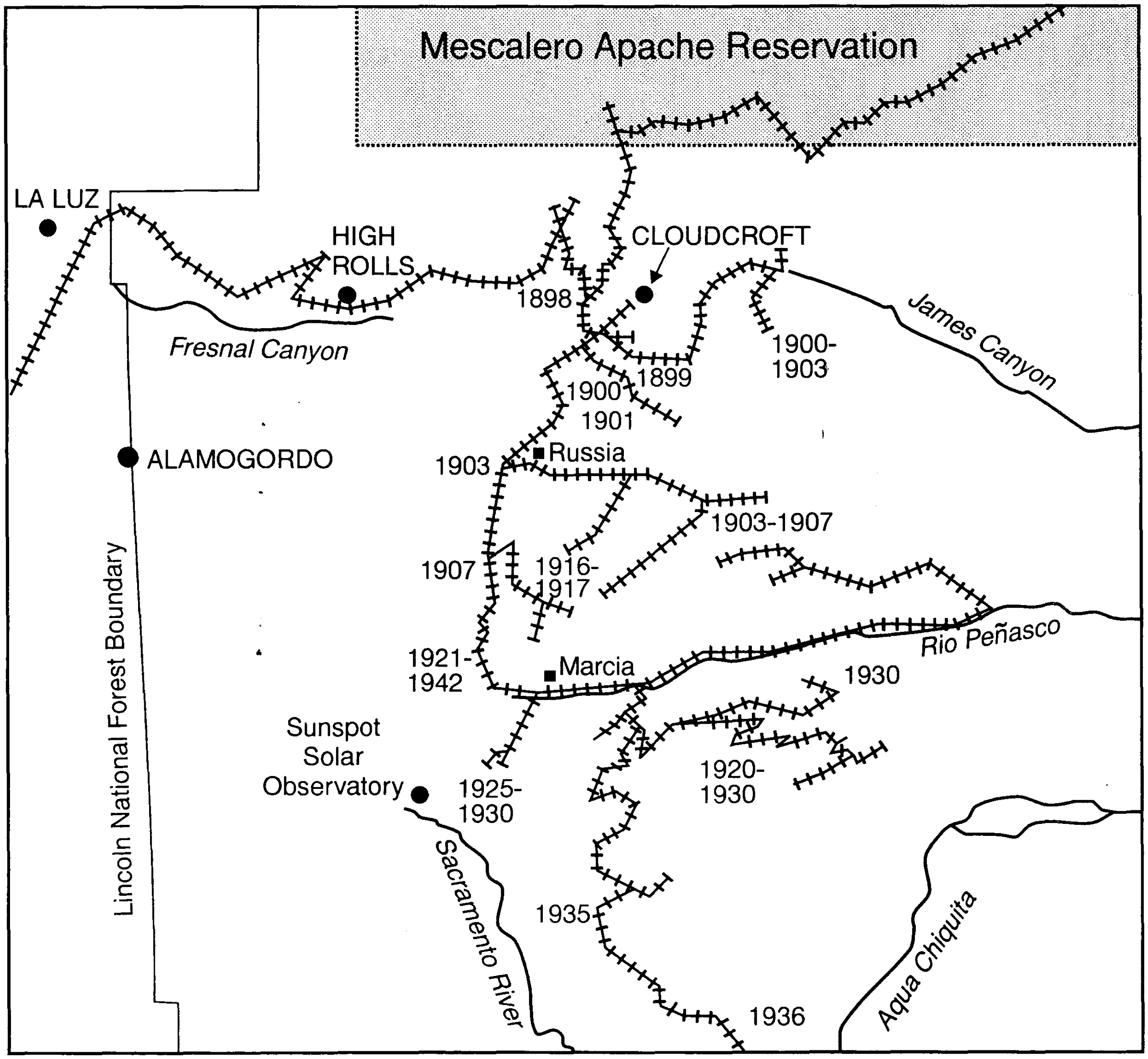


Figure 12. Map of the logging railroads in the Sacramento Mountains and approximate dates when logging occurred in the vicinity of the tracks. Generally the logging progressed from north to south. Based on Glover (1984).

couraged the development of the ski industry. The Cloudcroft ski resort began to be developed in the 1940s on private land within the Lincoln National Forest (Baker et al. 1988). Ski Cloudcroft now operates on the Sacramento Ranger District, three miles east of Cloudcroft, under a Special Forest Permit. There are also two designated snowplay areas on the district.

Agriculture

When the United States took over New Mexico in 1848, most of the land was open and available for settlement through homesteading (Fig. 14). Most of the arable land and good pasture in the Sacramento Mountains was quickly settled between 1880 and 1900, though a surprising number of settlers did not file their claims until much later, making them susceptible to being driven from the land by larger operators, but minimizing their losses if their enterprise failed. After 1900, the remaining lands, mostly those not useable for farming or ranching, were taken over by the state or federal governments or bought up by lumber companies and railroads, which ultimately turned much of the land over to the government after it was logged.

Spanish and Mexican land grants did not exist in the Sacramento Mountains proper, but a few were located to the east in the Pecos Valley. The traditional Hispanic pattern of land use was centered upon the village, where several families gathered for mutual defense and to share agricultural tasks, such as constructing irrigation systems. This pattern was in direct conflict with the Anglo pattern of dispersed, individual farmsteads and ranches. The smaller scale of the Anglo farms allowed them to settle along streams in the mountains that would have been insufficient to support a Hispanic village. However, ranchers discouraged agricultural settlement of all kinds, be-

Figure 13. Golf at Cloudcroft around 1920. Photo by Alexander, Lincoln National Forest Heritage Resource Program collection in Alamogordo, on file at the Lincoln National Forest Supervisor's office.

Figure 14. Homestead belonging to Mrs. Pendergrass, just northwest of Mayhill, 1905. Photo by E. Miller, Lincoln National Forest Heritage Resource Program collection in Alamogordo, on file at the Lincoln National Forest Supervisor's office.

cause their success on the open range depended upon their control of water sources. Nonetheless, agriculture continued in the valleys of the Sacramento Mountains, and homesteading boomed in the late 19th to early 20th centuries. Potatoes were a favored crop, and orchards flourished on the western slope of the Sacramentos. Where water was available, the long growing season and fertile valley soils made agriculture a successful venture. Farmers raised garden vegetables for local consumption, and hay and grain for livestock, especially on the eastern slope (Jenkins 1988).

However, diversion of water for irrigation was a major source of trouble. Diversion of water on the upper Rio Hondo caused the abandonment of the downstream community of Missouri Plaza, which had existed since the 1860s. Many homesteaders failed in the first few years because they brought preconceived ideas of land use and which crops to plant that were based on experience in the Midwest. When they sold out, their lands were often bought for raising livestock (Sebastian and Larralde 1989).

The Forest Service

By the 1890s, the same unregulated, unsustainable use of natural resources rampant in the Sacramento Mountains was occurring all over the United States. At the same time, a conservation movement was being born, with the realization that such use could not go on forever. The Forest Reserve system was created by an Act of Congress in 1891 (Tucker 1989). These lands were reserved from "entry or settlement." The first Forest Reserve in the Southwest (the Southern District which was to become Region 3) was the Pecos River Forest Reserve, created by presidential proclamation in 1892. The Lincoln Forest Reserve, which included much of the Sacramento Mountains not within the Mescalero Apache Reservation, was created July 26, 1902 (Tucker 1989). The Sacramento National Forest was created in 1907, including the area from the southern border of the Mescalero Apache Reservation to the south end of the Sacramento Mountains.

The Forest Reserves were originally administered by the Washington Office of the General Land Office, under the Department of the Interior. In 1905, Congress transferred administration of the Forest Reserves to the Department of Agriculture. The Division of Forestry had existed since 1876 as an advisory body; now it took over running the Forest Reserves as the Forest Service. An act of Congress in 1907 renamed the Forest Reserves National Forests. In 1908, the Southern District reorganized into District 3, and the Forest Service administration became decentralized from its Washington Office to District Offices in the field (Tucker 1989).

As a part of that reorganization, the Lincoln National Forest was created from the Lincoln and Gallinas National Forests, incorporating 238,782 ha (596,955 ac) with its headquarters at Capitan, New Mexico, and administering the same general area as the northern part of the modern Lincoln National Forest. In the same year, the Alamo National Forest was created from the Sacramento and Guadalupe National Forests, covering some 465,962 ha (1,164,906 ac) corresponding roughly to the southern part of the modern Lincoln National Forest, with headquarters in Alamogordo.

The borders of the new Forests were flexible for some time after their creation. In 1909, parts of the Mescalero Apache Reservation were added to the Alamo National Forest (Kent 1905), only to be returned to the reservation in 1912. Other additions included several thousand acres south and east of Mayhill in 1924 (Anderson 1923); removals included elimination of some lands around Alamogordo, some along the southern border of the Forest and on the east side near Elk and Piñon (Spoerl 1981b).

The primary purpose for creating National Forests in the Sacramento, Guadalupe, and White Mountains was for watershed protection and erosion control. A resolution passed by the Texas legislature in 1905 encouraged the federal government to create forest reserves in New Mexico to protect the watersheds of the Canadian and Pecos Rivers and the underground water of the high plains. The Texans recognized that the "timber and brush are fast being destroyed, and no provision made for restoring the same," endangering the water supply (Kent and Reynolds 1906). Grazing continued to be the dominant industry on the Alamo National Forest in the years just after the turn of the century. Logging only became important after the arrival of the railroad, and the real value of the timber was realized.

During 1913 and 1914, there was a strong effort by local people who wanted 360,000 ha (900,000 ac) of the Alamo National Forest returned to the public domain, effectively eliminating the Alamo National Forest. They circulated a petition that was signed by 640 people, 60 of whom contributed money to finance the campaign, and they selected Thomas B. Longwell, an ex-Forest Service employee, to be their spokesman in Washington (Longwell 1914). The petitioners claimed that most of the land was not suitable for timber, that it was not useful for watershed conservation, and most importantly, that the Forest Service had impaired their freedom of action by regulating livestock numbers and improvements such as irrigation structures. The petition failed, as did a movement to establish a National Park in the Sacramento Mountains, to be composed of land from the Mescalero Apache Reservation and the National Forest and including the White Sands (Bronson 1908). This proposal was initiated and kept alive by Albert B. Fall, New Mexico politician and the owner of the Three Rivers Ranch, which just happened to border the proposed National Park. His efforts were unsuccessful and the idea died about 1920.

In June of 1917, administration of the entire Alamo National Forest was transferred to the Lincoln National Forest, and the two forests were combined into the modern Lincoln National Forest, with headquarters at Alamogordo (Tucker 1992). Ranger districts were originally smaller and therefore more numerous than at present because the rangers did most of their patrolling on horseback (Fig. 15). Of the original ranger districts on the Alamo National Forest, the Carson Seep district was renamed the Guadalupe district upon the transfer to the Lincoln in 1917 and retains that name to this day. The Fairchild district was combined with the La Luz district in 1911 and renamed La Luz; it eventually became part of the Cloudroft district. The Fresnal district was renamed Cloudcroft with the transfer to the Lincoln. In 1930, the Mayhill district was combined with the Weed district, both from the original Alamo forest, to create the Peñasco district; it resumed the name Mayhill in 1952. The name Weed was used for a district again in 1959 and was changed to the Sacramento district in 1961. The Cloudcroft and Mayhill districts were combined in 1995 to form the present Sacramento District, which includes most of the Sacramento Mountains. There are presently three ranger districts on the Lincoln National Forest: the Smokey Bear, near Ruidoso; the Guadalupe near Carlsbad; and the Sacramento. The Lincoln National Forest presently totals 441,552 ha (1,103,220 ac; 1980 Forest fact sheet).

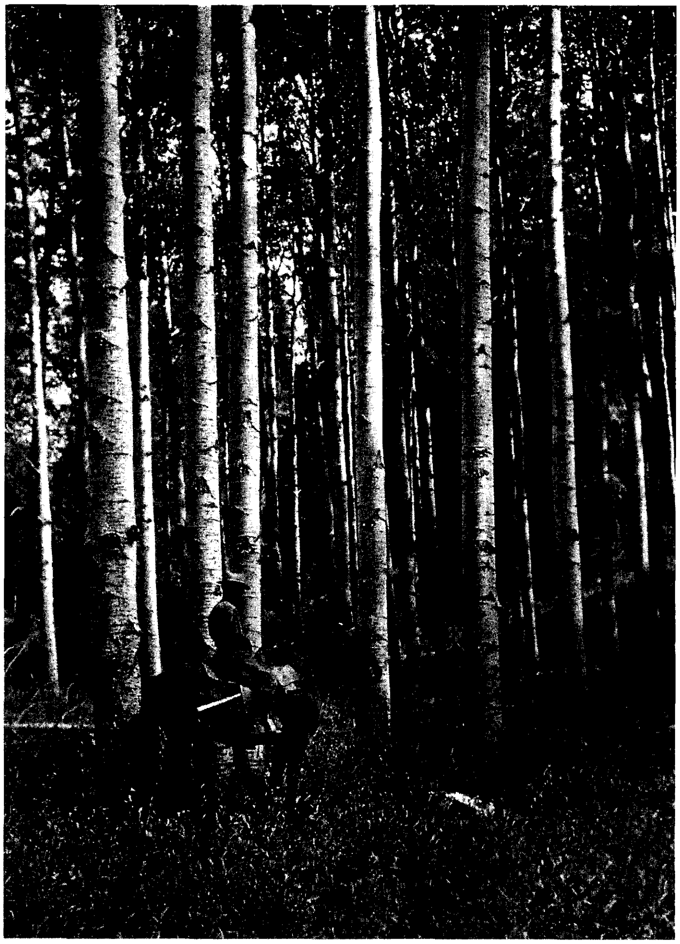


Figure 15. Ranger Jacob A. Work and his horse Prunes, in Water Canyon, 1928. Note the nearly pure stand of very large aspen. US Forest Service photo #233411, Lincoln National Forest Heritage Resource Program collection in Alamogordo, on file at the Lincoln National Forest Supervisor's office.

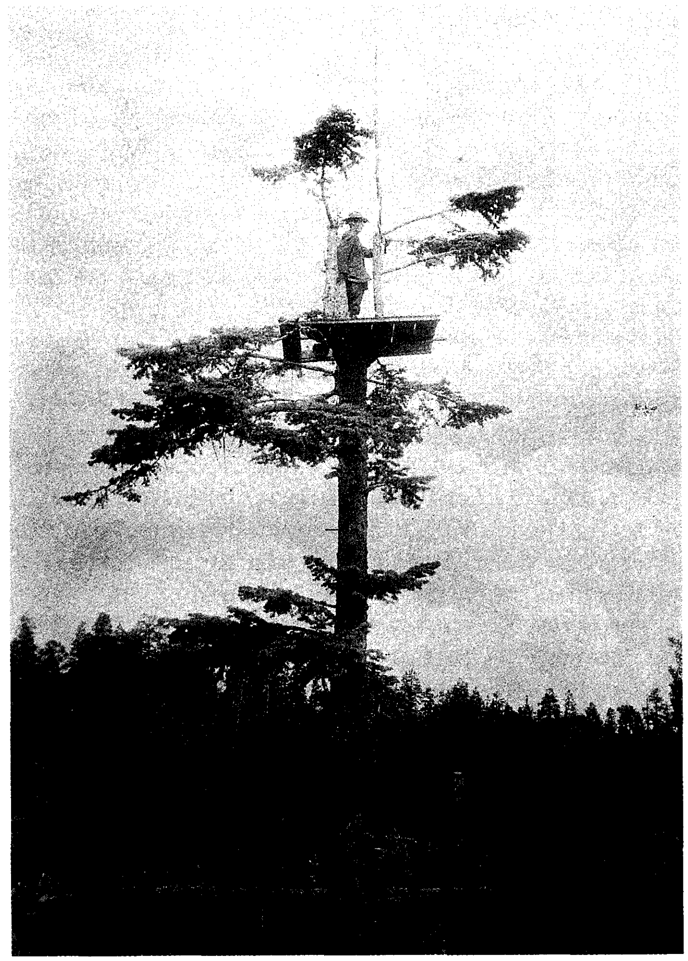


Figure 16. A lookout tree near the logging camp at Russia, 1927. US Forest Service photo #233319, Lincoln National Forest Heritage Resource Program collection in Alamogordo, on file at the Lincoln National Forest Supervisor's office.

The establishment of the National Forests was greeted with a mixed reception; their purpose was conservation, fire suppression, and regulation of grazing and logging. Cattlemen and others deeply resented having their herds regulated and paying to use the range they had previously used for free. However, some of the ranchers, particularly the larger operators, realized that it was often less expensive to pay the grazing fees for their cattle on Forest Service land than to pay the taxes on the land if they owned it. Ranchers sometimes sold land to the government or exchanged lands less suitable for grazing for others, such as a proposed exchange in 1923 by Oliver Lee, president of the Sacramento River Cattle Company, which offered: "... these lands are located within the main timber producing belt of the Sacramento Division of the Lincoln Forest and are areas intermingled with other lands proposed for exchange in separate applications. These lands have been used by us for stock grazing purposes and it is the desire and expectation of the Company that if the exchange is consummated, its prior use of the lands will be recognized by the Forest Service as establishing a grazing preference which will be continued under paid permit subject to the grazing regulations of the Secretary of Agriculture. There are some small areas of arable lands within the unit which we desire to retain..."(Lee 1923).

Early forest rangers lived a rough and sometimes dangerous life, enforcing regulations, rounding up trespass cattle, and putting out fires, mostly from horseback. They covered huge areas of rough country in all weather, sometimes encountering violent opposition to their mission. A few were trained professional foresters; many were not. In the Southwest, the fire season of spring and early summer was their busiest time. Rangers watched for smoke from lookouts, the earliest of which were set up in the tops of tall trees—not particularly safe from the lightning for which they were watching (Fig. 16). When smoke was sighted, a ranger rode out, often alone with a shovel, to put the fire out (Tucker 1991).

The Civilian Conservation Corps

The Lincoln National Forest benefited from the work of the Civilian Conservation Corps, begun in 1933 to alleviate unemployment during the Depression. Young men of the CCC helped build roads such as the West Side Road, trails, bridges, and buildings, including the Monjeau Lookout Tower on the Smokey Bear District and an administrative site with offices and residences at Mayhill. They also worked to prevent and mitigate erosion on the forest and fought many fires. There was a women's Civilian Conservation Corps camp, one of very few, near Capitan. The program was discontinued in 1942 (Brown 1983).

The Experimental Forest

The Cloudcroft Experimental Forest was officially established in 1935 in the vicinity of Cloudcroft, to study Douglas-fir forests. At that time, much of the forest in the area had been cut and was checker-boarded with private, federal, and state holdings. The Forest Service tried to acquire as much of the privately owned land as possible to facilitate management of the forests. The Experimental Forest was in three separate units, located within four miles of one another: Unit A, of 288 ha (720 ac), including old-growth Douglas-fir with patches of aspen, was located just north of Cloudcroft where Fir Campground is now, mostly uncut; Unit B was 304 ha (760 ac) of old-growth Douglas-fir, white fir, and ponderosa pine, located southwest of the town, mostly uncut except for 64 ha (160 ac) cut by the Forest Service in 1911; and Unit C, of 256 ha (640 ac) including Douglas-fir and white fir, was located in Cox Canyon west of Chippeway Park, which was mostly cut over by the Forest Service except for 40 ha (100 ac). The land was considered excellent for timber, poor for farming and grazing.

Permanent plots had actually been established in 1925, which were cut using seed tree, shelterwood, diameter limit, and selection methods to measure effects of partial cutting on Douglas-fir regeneration. Another set of permanent plots was established in 1937 on the private Cloudcroft Reserve. Most of the research at the Cloudcroft Experimental Forest was done by one scientist, Hermann Krauch, and addressed questions about managing virgin stands for water and recreation, promoting Douglas-fir regeneration in heavily cutover stands, and how to convert burned areas from aspen to Douglas-fir forest (Krauch 1936, 1937, 1938a,b,c, 1939a,b, 1940a,b,c,d, 1942a,b,c,d, 1943, 1945a,b, 1949a,b, 1956, USDA Forest Service 1935). Much of the research at Cloudcroft became the basis for early management and reforestation guidelines and practices in the Southwestern Region. By 1980, no studies were active and had not been for 25 years, and it was recommended that the Cloudcroft Experimental Forest be declassified. This was done in 1983, returning the Experimental Forest lands to regular National Forest status and use. The Experimental Forest tracts preserved several stands of old-growth mixed conifer forest. Some parts of the Experimental Forest were judged to have value as research natural areas, including old-growth in Units A and B and canyon blue spruce habitat types in Unit C, which are rare in the Sacramento Mountains. No research natural areas have been established.

The Solar Observatory

The Sacramento Peak Observatory was located in 1947 and began operation in 1951 under the auspices of the US Air Force. It is located on 21,718 ha (54,294 ac) on Sacramento Peak at 2800 m (9200 ft), where the dry air, abundant clear days, and isolation from major sources of pollution make it an excellent site for observing solar phenomena. In 1976, the observatory was transferred from the Air Force to the National Science Foundation. Most of the scientists and other observatory workers live in the observatory complex, parts of which are open to the public.

PART IV. FAUNA OF THE SACRAMENTO MOUNTAINS

Historic Fauna

From archaeology (Kelley 1984, Driver 1985) and from accounts by the Apaches of their hunting habits (Opler 1983), we know something about the pre-settlement fauna of the Sacramento Mountains, though not as much about small mammals, birds, or fish as we know about large mammals that were hunted. Remains of animals found at archaeological sites are likely to be those used as food or in ceremonies by the people who lived there, or animals that occupied the ruins after the humans abandoned them, so the remains do not necessarily represent the complete spectrum of animals present in the area. However, large mammals, particularly predators and game animals, were among those most strongly affected by the changes of the late 19th century, and evidence of their presence in pre-settlement times is important.

Mule deer were the staple of the Apache diet and were apparently numerous, though their abundance in any given year depended on the forage quality and therefore on the amount and timing of rainfall. The Apaches also hunted white-tailed deer *(Odocoileus virginiana)*, pronghorn (*Antilocapra americana*), elk (*Cervus elphus*), bison, cottontail rabbits (*Sylvilagus* sp.), and jackrabbits (*Lepus sp.*; Opler 1983). All of these species were found in prehistoric archaeological sites in the Sacramentos, along with ground squirrels, pocket gophers, white-footed mice, packrats, muskrats (along Rio Peñasco), wolves, kit foxes, gray foxes, coyotes, grizzly bears, black bears, long-tailed weasels, badgers, cougars, bobcats, and prairie dogs (Driver 1985). Wild turkeys and eagles were represented in archaeological sites, along with eight other species of birds. Neither the prehistoric Indians nor the Apaches made use of fish for food; the Apaches had certain taboos about fish. Very few fish remains survive in archaeological sites in the Sacramentos, though fish bones usually do not preserve well. The carapace of a turtle was found at one site (Driver 1985).

Naturalists began exploring New Mexico as early as the 1820s (Bailey 1931), but their descriptions were not quantitative and few of them worked in the Sacramento Mountains. The most comprehensive information we have about the distribution and abundances of animals in the Sacramentos during the pre-settlement and settlement periods comes from the studies done by the Bureau of Biological Survey (BBS), then the Division of Economic Ornithology and Mammalogy of the Department of Agriculture, beginning in 1889 and continuing intermittently until 1924. These studies were supplemented by other work that was included in the BBS publication: Charles M. Barber made collections in the Sacramento Mountains from 1895 to 1900, and James A. G. Rehn and Henry L. Viereck spent 11 weeks in 1902 collecting mammals, birds, and reptiles (Bailey 1931). Forest Service and state game and fish records as well as reports from local residents were also included. The final report on the mammals of New Mexico (Bailey 1931) was published some years later.

Predators

Large predators immediately came into conflict with ranching interests in the Sacramento Mountains, and private citizens and government agencies alike practiced predator control and elimination by trapping, hunting, and poison. People were concerned with the destruction of domestic stock and game animals such as deer, pronghorn, and elk by large predators.

Wolves were considered the worst menace to livestock and were persecuted mercilessly, with the intent of eliminating them from the state, a campaign that ultimately succeeded. Wolves reportedly killed large numbers of cattle, sheep, and goats; they also preyed heavily upon deer, but they seemed to prefer cattle to other types of prey. Most were killed by trapping, and professional trappers and hunters, often hired by the State and Federal governments, were responsible for most of the wolves taken during this period, mostly after the turn of the century. Adult wolves were trapped, and dens were located and all pups were killed, though Bailey (1931) noted that when trapping pressure was relaxed for a few years, wolf populations rebounded quickly. Bailey reported two subspecies of wolves in the Sacramentos: the Mexican wolf (*Canis lycaon baileyi*) and the gray wolf (*Canis lycaon nubilus*). In 1907, the Forest Service reported 76 gray wolves were killed on the Lincoln National Forest and 22 on the Sacramento National Forest. By 1915, of the 57 wolves killed in all of New Mexico, 10 were trapped on the Alamo National Forest. For the entire calendar year of 1916, only one wolf was killed on the Alamo-Lincoln National Forest.

Coyotes, though more omnivorous than their relatives, the wolves, were noted to prey upon goats, sheep, and sometimes poultry. They were reported to have taken as much as 1 percent to 3 percent of the sheep flocks in the state annually. Coyotes were hunted and trapped and were successfully eliminated from some areas, though professional hunters targeted coyotes less frequently than wolves and with less prejudice. Coyote numbers have increased in the Sacramento Mountains during the last century, perhaps in part due to the extirpation of wolves. Coyotes once occurred primarily on the plains and at lower elevations, but they can now be found at all elevations in the mountains.

Black bears were considered both destructive predators and game animals. In the Sacramento Mountains, they were also called cinnamon bears because some of them had brownish coats, but they seem to have been all of the same species. Bears are omnivorous but were reported to occasionally kill sheep and goats. In 1900, black bears were reportedly becoming scarce in the Sacramento Mountains where they had formerly been common; in 1914, 5 were reported killed on the Lincoln National Forest, and in 1916, 2 were reported killed on the Alamo-Lincoln. In 1917, it was estimated that 157 black bears remained in New Mexico (Bailey 1931). In 1910, the Forest Service attempted to assess how many black bears were on Forest lands and whether they should be eliminated as predators or protected as game animals. The Supervisor of the Alamo National Forest reported: "At the present time there are only a few black bears within the boundaries of the Alamo Forest, and consequently the detriment to stock is reduced to a minimum. Even when this species of game was more plentiful their destructive qualities were never much in evidence. In the Mescalero Indian Reservation, where most of the big game is found, no reports have ever reached me which indicated that the black bear had done any damage. It is my firm belief that the people generally and forest officers certainly, in this section, would prefer this animal to remain as a game animal protected by law, and not have it considered as a predatory animal" (Bailey 1931).

Grizzly bears, on the other hand, were considered dangerous and were killed at every opportunity, and they were probably effectively eliminated from southern New Mexico by 1927 (Bailey 1931). Grizzlies had a reputation for attacking both humans and cattle and were at one time "almost as bad as the big wolves in their depredation on the range cattle" (Bailey 1931:360). Ranchers sometimes banded together to hunt grizzly bears with dogs. Locals said in 1900 that grizzlies had been common in the Sacramentos but were becoming scarce at that time, though the Forest Service reported that grizzlies were present in the Sacramento Mountains as late as 1907. They were apparently found in the lower elevations in chaparral vegetation on both sides of the range. Bailey reported 5 species or subspecies of grizzly bears in New Mexico at the turn of the century, though he only designated one in the Sacramento Mountains specifically, the Texas grizzly (*Ursus texensis texensis* Merriam).

Cougars were considered "among the most destructive of predacious animals, not only to game but to a great variety of domestic animals" (Bailey 1931:290). They appear to have been particularly prone to attack horses. Cougars were not susceptible to trapping but were successfully hunted with dogs, and their numbers were much reduced during the settlement period. Bailey recorded two subspecies, *Felis hippolestes* (Rocky Mountain cougar) and *F. aztecus* (Mexican cougar) in the Sacramento Mountains, and stated that they were common in the Sacramento Mountains as late as 1903. Six cougars were reported killed in the Lincoln National forest in 1908 and another five were killed in the Sacramento National Forest (which became the Alamo National Forest) in 1907; by 1915, only one cougar was killed on the Lincoln and 4 on the Alamo (Bailey 1931). Cougar populations in New Mexico have rebounded since the 1950s, when government-sponsored control was de-emphasized (Evans 1983). Cougars remain uncommon in the Sacramento District.

Bobcats were historically very common in rough country. Their natural prey was rabbits and small mammals, but they were known to prey upon domestic chickens and sheep, and because of this, the Forest Service made "special effort to catch and kill as many as possible" (Bailey 1931:293). In 1908, 95 bobcats were killed on the Sacramento National Forest and 98 on the Lincoln, either by trapping or hunting with dogs, and those numbers do not include those taken by non-government hunters or trapped for their fur. Bounties were paid for bobcat pelts. Bobcat populations have rebounded in the Sacramento Mountains in the later half of the 20th century.

Jaguars (*Felis onca*) were always rare in New Mexico, but they were reported in the Sacramento Mountains at the turn of the century. The skin of a jaguar killed in Otero county was in the possession of Governor Otero in 1903. Jaguars were generally killed whenever they were encountered but seem to have been very rare and do not now occur in the Sacramento Mountains. Gray foxes (*Urocyon cinereoagrenteus scottii*) were reported as being common in rockier areas of the Sacramento mountains and were not considered serious threats to domestic fowl or wild game, nor were their skins particularly valued, so they were mostly left alone.

Game and Other Animals

Some species recognized as desirable game animals were sometimes hunted to extinction or near extinction, either because they were perceived to compete with livestock for forage, damaged crops, or were perceived to have infinitely renewable populations.

Bison probably did not actually occur within the Sacramento Mountains, though they may have wandered onto the eastern slopes. They were once abundant on the plains in the Pecos valley and were important prey for the Apaches and other Native Americans. The Sacramentos appear to have been an effective ecological barrier, because bison were never reported from the Rio Grande valley to the west of the range. Bison were eliminated from New Mexico by over-hunting relatively early in the settlement process, possibly as early as the 1840s (Bailey 1931); certainly they were gone by the 1880s, though their trails were still visible in some places (Opler 1983). By the early 1900s, bison had been reintroduced to the Pecos Valley as tame herds on a few ranches.

The Texas or desert bighorn (*Ovis canadensis texiana*) sheep was once present in the desert mountain ranges around the Sacramentos, including the San Andres, the Organs, and the Guadalupes, but no sheep were reported from the Sacramento Mountains at the turn of the century, though habitat existed for them there. They once occupied the northern and southern reaches of the Sacramentos. The last record for bighorns in the nearby Guadalupe Mountains was in the 1950s. Pronghorn were once common on the plains east of the Sacramentos and may have ranged onto the east slopes. They were also important prey for the Apaches. Bailey reported that pronghorn populations in New Mexico underwent a dramatic decline between 1899 and 1918.

Mule deer were abundant in the Sacramento Mountains and were considered common as late as 1900. Sacramento Mountains mule deer were reported to attain very large sizes. Forest Service records show that during the open season of 1914, 86 mule deer were killed on the Alamo National Forest and 34 on the Lincoln; the following year 57 were killed on the Alamo and 28 on the Lincoln; in 1916, 127 deer were killed on the Alamo-Lincoln. Mule deer were important prey for the Apaches and were heavily hunted by white settlers as well, and their numbers were greatly reduced around the turn of the century. However, with the elimination of large predators, mule deer populations exploded in the 1930s (Lang 1957) and eventually declined to sustainable levels with management. They were particularly abundant in the 1970s and 1980s but began to decline in the 1990s, possibly due to development encroaching on their habitat.

Plains white-tailed deer were also present in the Sacramentos, particularly on the eastern slopes and along streams. In 1902 they were reported to be common along the east slope of the Sacramentos, especially in the "willow-bordered stream valleys," in the northeastern corner of the Mescalero Reservation, and near Ruidoso. Apparently settlement in the stream valleys, in addition to persistent hunting, reduced their numbers considerably. Bailey (1931) predicted that they would soon be extinct in New Mexico without protection, and that the east slope of the Sacramento Mountains was an ideal place for their preservation. The largest herd of Texas whitetail deer today is found in the Sacramento Mountains (Lang 1957), in the Sixteen Springs Canyon, James Canyon, the upper Sacramento River, and the Aqua Chiquita.

The Merriam's elk was not so fortunate. Native to the southern half of New Mexico, Merriam's elk was reported as common in the Sacramento, White, and Guadalupe Mountains before the 1880s. But even by the 1880s, settlers reported that while there had recently been hundreds of elk in the Sacramentos, fewer than 20 were left. Two Merriam's elk were reported killed in the Sacramentos in the fall of 1898, and a track was seen in 1899. Merriam's elk was extinct by the turn of the century, a victim of overhunting. Overgrazing by cattle may have hastened their demise by destroying forage.

How many less conspicuous animals were either much reduced in numbers or driven to extinction during the settlement period is unknown. In general, if an animal was either useful to the settlers in some way or came into conflict with farming and ranching interests, it was hunted mercilessly. Some rodents were considered destructive to crops and were destroyed wherever possible, including prairie dogs, ground squirrels, and pocket gophers. Black-footed ferrets may have occurred at lower elevations in the Sacramentos but were eliminated along with black-tailed prairie dogs by the 1940s. The red spruce squirrel (*Tamiasciurus hudsonicus lychnuchus*) seems to have been endemic to the Sacramento, White, and Capitan mountains, living at high elevations in Douglas-fir forests, which provided its primary food. The forest in which they were found near Cloudcroft and near Weed was described by Bailey as being open and sunny, with an understory of oaks and with yellow pine at the lower borders of their range.

Beavers (*Castor canadensis*) were reported from the northern part of the Sacramentos, on Ruidoso Creek, in 1898. These beavers apparently had not built a conventional dam, but were living on cultivated corn as well as willows and aspens. As late as 1902, a few beavers were reported living along Ruidoso creek, but in many places the dams had been destroyed and the meadows had become "dried-up marsh, overgrown with a tangle of willows, which had crowded out even the aspens from the two or three acres of creek bottom that had been occupied by the beaver colony" (Bailey 1931:215). Beavers were not reported from the southern part of the Sacramento Mountains, perhaps due to the intermittent nature of most of the streams there and the possible lack of willows.

Present Fauna

Hunting is one of the most popular pursuits on the Lincoln National Forest. Abundant mule deer are the most popular prey. Deer numbers fluctuate widely with weather conditions from year to year. Rocky Mountain elk, black bears, white-tailed deer, and turkeys are also hunted on the forest. Of the large predators once common in the Sacramentos, only cougars and black bears remain, and cougars are rarely seen. Smaller predators, such as bobcats and coyotes, are fairly common.

Introductions

The minutes of the Lincoln National Advisory board (March 24, 1945) record that the Board recommended that the Lincoln National Forest should not be stocked with Rocky Mountain elk. Most of the opposition was from grazing permittees, who were concerned that the elk would compete with cattle and deer (valued as game) for forage, and the opposition continued until 1966, when Rocky Mountain Elk were introduced to the Mescalero Apache Reservation to replace the native, extinct Merriam's elk. Approximately 78 elk were introduced in 1966 and another 80 in 1967. Elk eventually wandered onto Forest lands, where initially attempts were made to control their numbers, but they have lived and multiplied there ever since. As of 1980, there were approximately 200 elk on the Sacramento district (Lincoln National Forest fact sheet 1980), of which 14 were taken by hunters in that year.

Unsuccessful efforts were made in 1955 and 1969 to introduce Abert's squirrel (*Sciurus abertii*; Davis and Brown 1988), which was believed to have occurred in the Sacramentos. Subsequent research has shown that Abert's squirrel was probably never native there. Barbary sheep (*Ammotragus iervia* pallas), native to North Africa, have been introduced to southern New Mexico for hunting purposes (Findley et al. 1975).

Threatened and Endangered Species

Animals

The endemic Sacramento mountain salamander (*Aneides hardii*) is currently listed as endangered by the New Mexico Department of Game and Fish. Its range is restricted to mixed conifer forest in three high elevation areas above 2400 m (7800 ft): one in the Capitan Mountains, one on Sierra Blanca Peak, and along the crest of the Sacramentos from Cloudcroft to the southern end of the range (Ramotnik 1997). Salamanders are found in mesic forests that include Engelmann spruce, large white fir, Douglas-fir, and large downed logs. Future logging may disrupt the salamander's habitat, and while they seem to be able to survive a single cut, repeated logging cycles may destroy their subterranean habitats (Scott and Ramotnik 1992).

The peregrine falcon (*Falco peregrinus*), until recently on the endangered species list, occurs on all three districts of the Lincoln National Forest. The Peñasco Least Chipmunk (*Eutamias minimus atristriatus*), determined to be a subspecies distinct from the least chipmunk, may be extirpated from its range in the Rio Peñasco drainage, though

Figure 17. The Sacramento Mountain (Mescalero) thistle, a rare plant endemic to the Sacramento Mountains. It grows on travertine around flowing springs. Photo courtesy of the US Forest Service, Lincoln National Forest.

Figure 18. Todsen's pennyroyal, an endangered plant endemic to New Mexico. It is probably pollinated by hummingbirds. Photo courtesy of the US Forest Service, Lincoln National Forest.

populations are present in the Sierra Blanca area. The Arizona prairie dog (*Cynomys ludovicianus arizonensis*) and the black-tailed prairie dog (*Cynomys ludovicianus*) were historically abundant and widespread at lower elevations of the Sacramento Mountains. Control programs intended to improve range for livestock resulted in their extirpation from the Lincoln National Forest. The last record of a prairie dog town on the Lincoln was in the late 1940s. Reintroduction of prairie dogs to the Forest has been discussed (Rivers 1992). The recently listed Mexican spotted owl (*Strix occidentalis lucida*) occurs in the Sacramento Mountains, and research is ongoing regarding management of suitable habitat (US Fish and Wildlife Service 1995).

Plants

Lee-Chadde and Huenneke (1996) identified 50 species of rare, threatened, and endangered plants in the Sacramento Mountains and determined the vulnerability of each species using both a linear ranking system and a multivariate approach. Many of the species are endemic to the Sacramento Mountains as well as rare or endangered. Among these are the Sacramento prickle-poppy (*Argemone pleiacantha*), the Mescalero thistle (*Cirsium vinaceum;* Fig. 17), Kuenzler's hedgehog cactus (*Echinocerus fendleri*), Villard's pincushion cactus (*Escobaria villardii*), Todsen's pennyroyal (*Hedeoma todsenii;* Fig. 18), golden bladderpod (*Lesquerella aurea*), and Alamo Canyon beardtongue (*Penstemmon alamosensis*). Many rare plants have always been rare, due to endemism, very narrow ranges, and rarity of habitats; but some have become rare because their habitats are disturbed or shrinking due to human land use, particularly livestock grazing and urban development. Fire suppression, flood control, water diversion, and overcollection (especially of cacti) have also contributed to the rarity of some plants. Those at high elevations, dependent on seasonal wetlands, or located on the western escarpment, have been particularly susceptible to habitat alteration.

PART V. HISTORIC VEGETATION IN THE SACRAMENTO MOUNTAINS

To facilitate describing the past and present vegetation of the Sacramento Mountains, we have divided the southern half of the Lincoln National Forest (Sacramento district) into five areas, as defined by the major watersheds, so the divisions are ecological in nature. Each of the divisions represents a range of elevations and environments that are reflected by the vegetation habitat types (Fig. 19). Parts of each area have been described in historical documents, including General Land Office survey notes, Forest Service records, eyewitness accounts, and railroad and logging records. Other descriptions are provided by ecological histories of fire (Huckaby and Brown 1995, Wilkinson 1997), old growth (Regan 1997), and insect outbreaks (T. Swetnam, pers. comm., Univ. Ariz., 1997) addressed in more detail in later sections.

The General Land Office Survey and other historic vegetation surveys used the common names for plant species that were in use at the time. These names varied from region to region and even between survey crews, so determining species composition from historic descriptions can be problematic and sometimes must be considered within the known ecological context. Douglas-fir

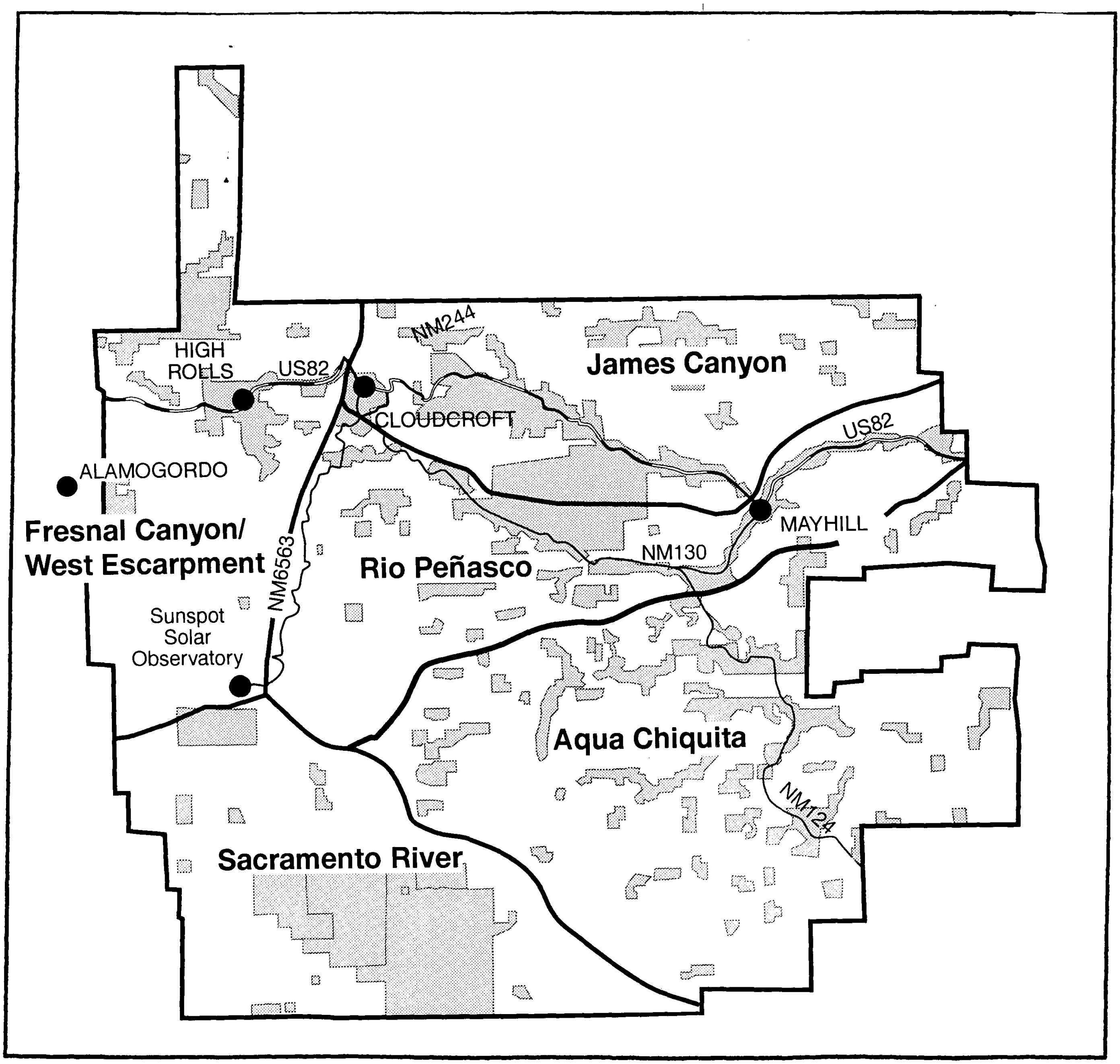


Figure 19. Map showing the five divisions used to organize information to reconstruct historic vegetation on the Sacramento Ranger District.

(*Pseudotsuga menziesii)* was historically referred to as "fir" or "red spruce"; later surveys called it "Douglas fir" or "Douglas spruce." "Balsam" referred to white fir (*Abies concolor)* but was also used for Engelmann spruce (*Picea engelmannii)*. To add to the confusion, white fir (*Abies concolor)* was sometimes referred to as "spruce." "Pine" usually meant ponderosa pine (*Pinus ponderosa)*, the most common pine in the mountain range, but southwestern white pine (*Pinus strobiformis)* was usually lumped into that designation, too; only in the later surveys was it mentioned separately, as "white pine." "Yellow pine" or "bull pine" meant *Pinus ponderosa*. Surveyors did not distinguish between the species of pinyon pine; all were called "pinyon." Likewise, all of the *Juniperus* species were called "juniper" or "cedar."

The General Land Office surveys of the Sacramento Mountains were completed over a long period of time (between 1884 and 1941) and did not necessarily cover the mountain range in any sort of order, though areas that were settled or logged earliest were generally surveyed first. Most of the range was surveyed in the 1880s and 1890s.

Fresnal Canyon/West Escarpment

This area includes Fresnal Canyon, La Luz Canyon, and the western escarpment, from the northern boundary of the Forest with the Mescalero Apache Reservation south to Dog Canyon, and from the western boundary of the Lincoln National Forest just east of Alamogordo to the summit of the Sacramento Mountains (Fig. 19). The towns of High Rolls and Mountain Park are located in Fresnal Canyon, where State Highway 82, the main thoroughfare from Alamogordo to Cloudcroft, runs. The area also includes the Sunspot Solar Observatory and one section of the old Cloudcroft Experimental Forest, at the head of Haynes Canyon. Two high-elevation fire history sites (Sunspot and Sunspot Pines in Table 8; Huckaby and Brown 1995) and three old-growth sites (Sunspot, Cathey Peak, San Andres Canyon; Regan 1997) are located in the area, near the summit; three packrat midden sites (Van Devender et al. 1984) and five low-elevation fire history sites (Wilkinson 1997) are located between 2200 and 2800 m (7150 and 9100 ft). The area ranges in elevation from 1500 m (4875 ft) at the base of the escarpment to 2983 m (9695 ft) at the summit of an unnamed peak; the summit of Sacramento Peak is 2915 m (9475 ft).

Historic Conditions

General Land Office surveys in 1885 recorded that the lower elevations supported mostly open grassland, with scattered pinyon and juniper interspersed with occasional ponderosa pines (Table 3). Openings were filled with dense growth of oak shrubs or grasses: "This country is covered with excellent gramma grass" (General Land Office Survey notes). At higher elevations, surveys indicated that ponderosa pine was mixed with pinyon and juniper, with a dense oak understory and dense oak shrubs in openings. The ponderosa pine was often referred to as "heavy timber," which implied large trees, though not necessarily dense forest. Above about 2154 m (7000 ft), the pinyon and juniper were no longer noted, leaving "heavy pine timber"— stands dominated by large ponderosa pines, with scattered "spruce" (white fir or Douglas-fir) and aspen, with a dense oak understory. The survey made reference to several localized stands of pure aspen.

Mixed conifer forests dominated the crest of the Sacramento Mountains in the past as they do now. These forests were probably somewhat more open than those of the present due to more frequent surface fires. General Land Office survey notes recorded that ponderosa pines made up a larger proportion of the canopy than they do at present, and dense thickets of white fir and Douglas-fir saplings were infrequent, though white pine, "spruce" (white fir), "fir" (Douglas-fir), and aspen were common in the heavy timber.

Aspect can be an important factor in determining fire frequency and species composition of the forest because it affects the water balance at a site. The Sunspot mixed conifer old-growth site, located on mostly flat ground near the summit at 2923 m (9500 ft) elevation, is presently dominated by a mixture of Douglas-fir, white fir, and southwestern white pine, with only occasional ponderosa pine in the canopy and no recent ponderosa pine establishment. This stand includes white fir/maple and white fir/*Erigeron exemius* habitat types. Historic mean fire interval (MFI; see section on Fire below) in this stand, based on tree-ring dating of fire scars, was 11.3 years. The south-facing slope just above the Sunspot stand was also sampled for fire history. There, the forest is composed primarily of large, old, open-grown ponderosa pines, and was classified as a Douglas-fir/gambel oak habitat type. The Douglas-fir and white pine presently in this stand are all young saplings. Tree-ring dating revealed a historic mean fire interval on the slope of 4.8 years, comparable to those found at much lower elevations.

Even as late as the survey in 1914, the western escarpment was sparsely settled, except for Fresnal Canyon. Agriculture was limited to gardens in a few canyons, due to lack of available water. Settlers in the area after the turn of the century raised hogs. The Rio Fresnal, though not a perennial stream, was the most abundant and reliable source of water. This stream flooded severely in 1899 (Wuersching 1988), wiping out many farms in the valley and destroying a length of the railroad track. It was speculated at the time that extensive clearcut logging at higher elevations had contributed to the excessive runoff from an intense summer storm that caused the flood.

The gramma grass on the western slope was described as being very good, even under dense oak scrub. In general at lower elevations, open forests and woodlands were very grassy despite the steep slopes and rockiness. General Land Office surveyors commented that their work was complicated by the steep, rocky terrain and extremely dense brush. This is the only part of the Sacramento Mountains where any valuable minerals were found. Small deposits of copper, lead, and silver were mined early in the 20th century in the vicinity of Fresnal Canyon.

Surveys done in the years following settlement indicate how rapidly profound changes in vegetation occurred. A range survey done on the Alamo National Forest in 1909 (Kerr 1909) found the range in poor condition in the Dry Canyon area, after 30 years or so of grazing. Assessments done in 1946 for the Range Management Plan (US Forest Service 1946) covered much of the west escarpment and found the range in fair to poor condition, with generally increasing erosion problems and declining range quality. The Dry Canyon allotment, between 1508 m and 2308 m (4900 and 7500 ft), was subject to destructive erosion and drying winds in 1946, with parts of the range rated as fair and some parts poor. The grass cover was thinning and the existing grasses showed poor vigor; some were dying from root exposure. Palatable browse plants were over-used. Even beargrass, not usually considered palatable, was eaten to a stubble.

*Table 3. Historic and present conditions for Fresnal Canyon/Western Escarpment division. ABCO = white fir (*Abies concolor*), JUDE = alligator juniper (*Juniperus deppeana*), PIED = pinyon pine (*Pinus edulis*), PIEN = Engelmann spruce (*Picea engelmannii*), PIPO = ponderosa pine (*Pinus ponderosa*), PIST = southwestern white pine (*Pinus strobiformis*), POTR = aspen (*Populus tremuloides*), PSME = Douglas-fir (*Pseudotsuga menziesii*), QUGA = gambel oak (*Quercus gambelii*), and MFI = mean fire interval.*

Fresnal Canyon	**Pre-settlement**	**Post-settlement (20th century)**
Vegetation	At lower elevations, open grassland was interspersed with scattered PIED-JUDE and occasional PIPO. Openings were filled with dense oak scrub, with continuous grass cover underneath. Mid-elevations were covered by scattered PIPO mixed with PIED and JUDE with dense oak understory and grass; above 7000', no PIED, occasional PSME was mixed with PIPO and scattered POTR stands. Above 8000', mixed conifer forest had PIPO, PSME, PIST, ABCO, POTR in canopy and in thickets. Zones were compressed due to steep elevational gradient. The canyon effect was common; cottonwood, walnut, blue spruce were found in moist canyons.	Dense, young PIED-JUDE covers lower elevations, with dense oak scrub understory. Very little grass remains even under shrubs. Large areas without trees are filled with very dense oak scrub. PIPO zone has shrunk in elevational range, and most large PIPO are gone. At higher elevations, in mixed conifer there has been a shift to dominance by PSME and ABCO, and little pure aspen exists. PSME and ABCO saplings are dense in the understory. There is little grass under the forest canopies. The canyon effect still allows for cottonwoods and walnuts in canyons, but they are reduced by water diversion, and blue spruce is rare due to logging.
Ecosystem processes	*Soil*: Intact under dense grass and shrub cover.	Badly eroded with elimination of grasses, much gullying.
	Water: No perennial streams. Seasonal water in canyons sank before reaching the desert. Few springs.	No perennial streams. Seasonal flooding in canyons causes erosion. A few constructed tanks exist. Diversion for agriculture in Fresnal Canyon.
	Fire: Frequent, low-intensity surface fire; more frequent but localized at lower elevations, less frequent with occasional localized crown fire in mixed conifer. PIED-JUDE MFI=28 y; PIPO MFI=3-6 y; PSME/QUGA MFI=4-10 y; ABCO/QUGA MFI=11-14 y (Wilkinson sites).	Natural fire regime ended about 1900. Complete fire suppression after 1907, allowing only occasional wildfire under extreme conditions. Large fires created oak-filled openings 1880–1910.
	Insects: None noted in GLO notes-probably endemic levels of pine bark beetles.	Huge outbreaks of *Ips* killed PIED in the 1920s.
Landscape structure	Topography was steep and rocky. Open, patchy, multiple-aged forest of mixed PIPO and PIED-JUDE was common at low elevations, with oak scrub understory, and large openings filled with oak shrubs, and some large (probably old) PIPO. PIPO also dominated mixed conifer forests, along with PSME, and patchy POTR groves indicated sites of localized crown fires.	PIED-JUDE is much more dense, homogeneous, and young than historically. PIPO zone compressed. Very few large, old trees are found in PIPO or mixed conifer forest, except for isolated patches at the crest. Trees in all zones are dense, young, and continuous. Following logging, there has been a shift in dominance of mixed conifer to PSME and ABCO, with very dense PSME and ABCO saplings in the understory, and POTR has been reduced. Large openings are filled with dense oak shrubs at lower elevations.
Human land use	Mescalero Apaches used Dog Canyon as a thoroughfare into the mountains from the west. They hunted and gathered, migrated seasonally, and may have set some fires. Archaic occupation of lower elevations.	Sparsely settled until after 1915. Farming in Fresnal Canyon but little elsewhere due to lack of water. Intense grazing after 1880 even though the land was considered unsuitable due to lack of water. Some mining occurred at low elevations. There was extensive clearcut logging in upper canyons and along the crest 1903-1947, mostly before 1910. Development includes the towns of High Rolls and Mountain Park in Fresnal Canyon, the Sunspot Solar Observatory at the crest, main road in the canyon, and west side road (built in 1930s).

In the Alamo Canyon area, between 1477 and 2400 m (4800 and 7800 ft), the vegetation was semi-desert grassland grading into pinyon-juniper woodland, with a mix of shrubs. The range was rated as fair, though the vigor of perennial grasses was low due to heavy grazing and erosion was accelerating over the area. Range in the Laborcita allotment north of La Luz, in the foothills between 1846 and 2462 m (6000 and 8000 ft), was rated as fair to poor. The area was covered with oak brush and with ponderosa pine, fir, and spruce on higher, north-facing slopes. "Old fires caused extensive damage to this country. Gullies are large and occur frequently...Intense local storms move tremendous amounts of soil, rock, and debris" (US Forest Service 1946). An area that had been fenced as a stock exclosure for 10 years showed little improvement. Weeds were more prominent than grasses, and vegetation and litter were spotty, with much exposed soil.

The La Luz allotment at slightly lower elevations showed similar conditions, worse in some places, including a part of the watershed that was being managed for irrigation water jointly by the Forest Service and the Town of Alamogordo. Range in the lower elevations of Mule Canyon area was also rated as fair to poor, with considerable erosion. The steeper country at the head of Nelson canyon was covered by chaparral extending into mixed conifer forest. It was not considered appropriate for cattle but had nonetheless been grazed and was subject to gully erosion even under forest cover. Grasses had been almost entirely replaced by brush, and no vegetation grew in the gullies. Haynes Canyon was noted as being particularly over-used. Erosion was extreme in the low-elevation San Andres canyon allotment, where steep slopes were only thinly vegetated. Native perennial grasses had been replaced by cacti and shrubs, and most remaining plants were left on pedestals of soil. In general, the west escarpment that had supported excellent, continuous native grass cover in the 1880s was by 1946 severely over-grazed and badly eroding.

Present Conditions

Lower elevations on the western escarpment are covered by pinyon-juniper woodland on ridges and canyon walls, grading into desert scrub at the base of the mountains (Kennedy 1983). Mixtures of pinyon pine *(Pinus edulis)* and one-seed juniper (*Juniperus monosperma)* occur on xeric, lower elevation sites; pinyon and alligator juniper (*Juniperus deppeana)* occur at higher elevations up to about 2154 m (7000 ft), and on more mesic sites or those with deeper soils. Most pinyon-juniper associations have grassy understories, which have been much depleted by overgrazing. Similar communities occur at lower elevations on the east side of the Sacramentos. Pinyon-juniper woodland has become much more dense than the historic conditions described by the General Land Office Survey notes, and most of the pinyon trees are relatively young (Kennedy 1983). Many of them are probably regeneration following the severe *Ips* engraver beetle outbreak early in 20th century.

Large openings dominated by oak scrub are believed to have been created by fires that burned around the turn of the century, though according to the General Land Office Survey, large oak thickets were common before the settlement period. Abundant oak brush now covers as much as 70 percent to 90 percent of the understory of pinyon-juniper stands and fills openings in the woodlands. Kennedy (1983) surmised that the oak brush is much more abundant now, in the absence of fire and the aftermath of overgrazing, than it had been in pre-settlement times. However, the General Land Office survey notes from the 1880s indicated both considerable oak brush and luxuriant grass cover under a more open pinyon-juniper woodland.

Ponderosa pine-dominated forests are more common on the east slope of the Sacramentos but may be found on the west side in narrow elevational ranges that grade immediately into pinyon-juniper woodlands below and mixed conifer forests above. In some places the ponderosa pine band is absent and pinyon-juniper borders mixed conifer forest. Ponderosa pine forests have understories dominated either by gambel oak or wavy-leaf oak at lower elevations, and they represent the warmest and driest forest conditions found in the Sacramentos. Douglas-fir and southwestern white pine are less common components of these forests.

In general, the geographic extents of ecosystems on the western escarpment are compressed due to the steepness of the grade. The canyon phenomenon, common in arid mountain ranges, is apparent in this area. Cooler, wetter conditions at the bottoms of the canyons create environments suitable for vegetation normally found at higher elevations. Thus, on the west escarpment, one may see pinyon-juniper woodland on the slopes above a canyon and ponderosa pine forest or elements of mixed conifer forest in the canyon bottom. At lower elevations, cottonwoods and walnuts are found along both permanent and intermittent watercourses. Blue spruce is found in a few mid-elevation canyons on the west side, as well as above 2462 m (8000 ft) in a few locations on the east side. Most blue spruce stands are young and heavily impacted by human activity.

At higher elevations, mixed conifer forest covers most of this division. The coolest, wettest sites at high elevations along the crest support white fir habitat types (Alexander et al. 1984). Pines are infrequent in these forests. Douglas-fir may share dominance in younger stands and is a frequent canopy component in older stands, but white fir regeneration is always abundant. Understories are often shrubby, dominated by maple (*Acer)* species on drier sites and oceanspray (*Holodiscus* sp.) on wetter sites, often mixed with gambel oak. Grasses are uncommon.

Drier high-elevation sites are covered with white fir-gambel oak forests, the most common habitat type in the mountain range (Alexander et al. 1984). Grassy phases are not as common as the shrubby phase, which is dominated by gambel oak. Wetter sites may have up to 25 percent oceanspray in the shrub layer. Drier sites may include pines and pinyon and juniper, and this type may grade directly into pinyon-juniper woodland at low elevations. White fir and Douglas-fir are the principal species, but ponderosa pine and southwestern white pine are common seral trees and are abundant on drier sites. Species dominance and proportions vary with environmental conditions, but most of the regeneration is white fir (Alexander et al 1984).

Douglas-fir-dominated habitat types are common on canyon sideslopes and ridgetops between 2215 and 2615 m (7200 and 8500 ft) elevation. The most common Douglas-fir forest has an understory dominated by gambel oak, and may include oceanspray on more mesic sites such as north-facing slopes. White fir is not common in these forests, which are found along the west side at the top of the escarpment. Southwestern white pine is abundant, and ponderosa pine historically has been a canopy dominant in the presence of frequent fire (Alexander 1984). Old fire-scarred ponderosa pines are common in the overstories of these forests, but ponderosa pines are not regenerating in the absence of fire.

James Canyon

The James Canyon area is the most heavily developed part of the Sacramento Mountains. It includes the town of Cloudroft, the Ski Cloudcroft ski area, several developed campgrounds, and many homes and ranches in the James Canyon along State Highway 82, the primary road to Roswell in the east. Our division extends from the northern boundary of the Forest with the Mescalero Apache Reservation, south to the edge of the watershed above Chippeway Park, east along the canyon to the confluence with the Rio Peñasco near the town of Mayhill (Fig. 19). One fire history site is located in the ponderosa pine zone at about 2554 m (8300 ft; James Ridge in Table 8; Huckaby and Brown 1995) and another near the campgrounds in one of the sections of the old Cloudcroft Experimental Forest, where an old-growth mixed conifer site is also located at about 2738 m (8900 ft; Fir Campground; Regan 1997). Some of the oldest trees known from the Sacramento Mountains are located in this area (Regan 1997).

Historic Conditions

The General Land Office Survey passed through the present location of Cloudcroft in 1884, before the town existed. The survey crew described the vegetation as scattered pine timber with a dense oak understory, intermixed with pinyon and juniper. The occasional "spruce" (white fir or Douglas-fir) was noted, as was an area of "dead and fallen timber" (Table 4). The area immediately to the south was surveyed in 1891. It was described as supporting mixed ponderosa pine and Douglas-fir timber (implying trees large enough to be commercially logged) with a dense oak understory, and occasional oaks in the canopy. The survey crew occasionally noted groups of pure aspen, mostly as dense saplings in the understory. This forest seems to have been fairly continuous over a large area and would probably have been classified as a Douglas-fir/gambel oak habitat type. At higher elevations, the forest was less open, and Douglas-fir was more prominent in the canopy. Large areas along the crest were described as heavy pine and fir timber with a dense oak scrub understory.

The survey described a site where all the trees were dead and presumably still standing—perhaps victims of an insect outbreak? Forest Service records mention an outbreak of a defoliating moth in the Douglas-fir that had occurred sometime before 1918 (US Forest Service 1918–1952). The 1891 survey passed through patches of cultivated land and a couple of marshes. The General Land Office Survey of the Cloudcroft area was finished in 1937; by then, surveyors passed through the golf course and much more cultivated land and noted more aspen and "spruce" (Douglas-fir or white fir) in the forest overstory, though the dominant trees were still ponderosa pine and Douglas-fir with a dense oak understory.

The area east of Cloudcroft was first surveyed in 1884, and the survey was finished in 1892. This area was forested primarily by ponderosa pine, sometimes in nearly pure stands. Trees varied considerably in diameter and density and were scattered amid open patches. The pine was occasionally mixed with "spruce" (probably Douglas-fir), pinyon, and aspen, and it occasionally had a shrubby oak understory, though the understory here seems to have been much more open than elsewhere. This area seems to have supported stands of more pure ponderosa pine than any other on the forest, probably as close to a ponderosa pine savanna as existed on the Lincoln National Forest. As the survey headed east, they encountered vegetation that they described as scattered ponderosa pine timber mixed with juniper, with a dense oak understory. Pinyon pine and juniper were mixed with the ponderosa pine and Douglas-fir, and dense young aspen in scattered patches in the understory. The timber varied considerably in density, from scattered to occasionally dense. Even in 1884, there were many cultivated fields in this division, and the surveyors noted a cienega (unforested seasonal marsh).

Farther south and east, the survey was completed in 1936. Changes in the vegetation had begun. Pinyon and juniper were the dominants in a fairly continuous and closed stand, with the occasional ponderosa pine and dense oak and "cedar" (*Juniperus* sp.) brush. Douglas-fir was also present in the mix. Pinyon and juniper had filled

Table 4. Historic and present conditions for James Canyon division. See Table 3 for species acronyms.

James Canyon	Pre-settlement	Post-settlement (20th century)
Vegetation	At higher elevations, fairly continuous mixed conifer forest was dominated by PIPO and PSME, with ABCO and PIST components and a shrubby oak understory, and occasional dense thickets of young aspen. Nearly pure PIPO forest covered mid to low slopes to the east, mixed with occasional PSME and PIED. Oak shrubs were less dense than on the west side. POTR was scattered in the canopy, large oaks were common in canyons. Farther east and lower, very open forest of PIPO was mixed with PIED-JUDE, with a shrubby oak understory. Trees were highly variable in size; grasses grew even under the oak and forest canopy. Timber was described as "quite heavy" in places.	Mixed conifer is dense and young, dominated by ABCO and PSME at high elevations. A few isolated pockets of old growth remain with very large trees dating to the 16th century. Mixed conifer is found on north-facing slopes even below 6000'. At mid-elevations, slopes and ridges are dominated by PIPO with large, old trees in the canopy and dense PSME and ABCO saplings, with some large old PIED and JUDE mixed in and a spotty oak brush understory. Patchy grass occurs only in openings. Very little aspen remains, and there has been a shift to dominance by PSME at mid-elevations and to ABCO at high elevations.
Ecosystem processes	*Soil*: Deep, fertile soil in shallow canyons; soil intact under forest; sandy to rocky, not fertile on slopes.	Considerable erosion, especially in canyons, gullying on steep slopes, especially where logging occurred.
	Water: No perennial streams. Occasional seeps and springs.	Seasonal flooding; water diverted for agriculture, marshes drained.
	Fire: Frequent, low-intensity surface fires interspersed with patchy crown fires. High elevation mixed conifer (ABCO types) MFI=9-11 y (Fir Campground); mid-elevations (PSME types) MFI=4-6 y (James Ridge); low elevations (PIPO/PSME types) MFI=3-5 y (Denny Hill).	Surface fire regime disrupted by complete fire suppression after 1907. Considerable area burned by wildfire after logging in the early 20th century. Rare, destructive crown fire now occurs at all elevations under extreme conditions.
	Insects: An outbreak before 1890 created an area of dead and fallen timber in the upper part, as well as another area of dead standing timber; an outbreak of a defoliating moth was recorded before 1918; spruce budworm outbreaks in mixed conifer occurred in approximately 20 year cycles at high elevations back to 1800.	Five known outbreaks of western spruce budworm at Fir Campground in the 20th century, at least 2 severe; outbreaks synchronous with northern New Mexico.
	Disease: Rot fungi, mistletoe noted at high elevations.	Exotic white pine blister rust at high elevations since 1990.
Landscape structure	Mesic to dry mixed conifer forest was continuous at high elevations, with patches of old growth, a shrubby understory, and some very large, old trees. At mid to low elevations, PIPO forest very open, mixed with PSME and PIED, with understory patchy shrubs, and trees variable in size. POTR was a patchy component. PIPO witness trees varied considerably in size and the forest was described as scattered, with openings. Old-growth in high elevation mixed conifer comprised more than 35%, and was extensive. In lower elevation dry mixed conifer and PIPO forest, old-growth was more than 15% and patchy.	The mixed conifer forest is now dense, young, and continuous, with only a few isolated patches of old-growth and ABCO becoming dominant. The PIPO zone is compressed from its historic extent, with a shift in dominance to PSME and ABCO. The large, old PIPO are dying. Very little aspen remains. Little grass exists under the forest canopy, and oak shrubs are more continuous than historically. Very little old-growth is found in any zone. PIED-JUDE at lower elevations is also young and more dense than historically.
Human land use	Occasional use by Mescalero Apaches for hunting and gathering, mostly in summer.	Irrigated farming has occurred in valleys and on some gentle slopes since 1890s. Grazing by cattle on summer range at high elevations began in the 1880s, but this area was not so badly over-grazed as areas to the south. Railroad logging began in mixed conifer and PIPO forests in 1903, and mostly ended by 1910. Flood control structures were built on all streams in the 1930s. Considerable erosion occurred after logging, especially on private land. Considerable development began early with the town and resort of Cloudcroft in 1899, the ski area, summer and year-round homes, ranches and camps along Highway 82, and developed campgrounds in mixed conifer forest.

in the open pine forest, and oak shrubs had moved into the open understory. Surveyors noted dense Douglas-fir and white fir saplings that were not mentioned in the earlier survey.

The General Land Office Survey made assessments of soils that were less than specific. Surveyors described soils in the upper part of James Canyon as sandy to rocky and not fertile (2nd to 3rd rate), but the grass was "very fair" and the timber was "of good quality, and is quite heavy in places"(General Land Office Survey). Despite the relatively poor soils, farming was not always confined to the canyon bottoms, but was done on the mountainsides as well, where potatoes were the primary crop. By 1936, "nearly all of the land is [sic] the bottom of James, Cox, and Eight-mile Canyons is cultivated, and a small amount in the bottoms of other canyons as well."

John Kerr's range inspection in 1909 included the goat ranges north of Mayhill and the cattle ranges in James Canyon, and he found them in relatively good condition. By the time of the Range Management Plan of 1946, the area near Cloudcroft at the top of James Canyon was still being used for summer cattle range. Flood control structures had been constructed on every canyon during the Civilian Conservation Corps program, and no flooding had occurred since 1934. When active cattle range in the area was compared with a part of the Cloudcroft Experimental Forest, which had been fenced to exclude livestock for nearly 10 years, surveyors found similar plant composition at both sites, but grasses that grew well under the forest canopy in the Experimental Forest were sparse and did not grow under the trees in the grazed area. Old browse lines on shrubs were evident in the exclosure but were beginning to grow out by 1946. Lower in the canyon, much of the range was privately owned. The private lands were in poorer condition than those administered by the Forest. Logged or cultivated areas showed considerable erosion, particularly on south slopes. Mixed conifer forests had grassy understories that were not reproducing. The range was considered overused, though in fair condition.

In the Wofford allotment, including Silver Springs and Zinker Canyons around 2769 m (9000 ft) elevation, most of the land was acquired by the Forest Service after 1940. The vegetation was mostly mixed conifer forest, with little grass under the closed canopy, though grasses were more frequent in openings. The range was considered overused, and its condition was rated fair. Gullying was infrequent except on private land, and vegetation density was not good but was improving by 1946. Just north of Cloudcroft, an area had recently been set aside for recreation use, and livestock were excluded. This became Fir Campground and associated campgrounds.

Present Conditions

The top of the canyon around the town of Cloudcroft, the developed campgrounds, the ski area, and many summer and year-round homes are surrounded by dense, young, mixed conifer forest, most of it white fir habitat types (Alexander et al 1984). Much of the upper and middle parts of the division were logged between 1900 and 1940. A few areas of old growth are found around the campgrounds north of town, which were originally encompassed by the Cloudcroft Experimental Forest. These forests include some very large, old white fir and Douglas-fir trees (Regan 1997). As James Canyon slopes gently down to the east, white fir habitat types give way to Douglas-fir and ponderosa pine habitat types, at first on dry south- and west-facing slopes and ridges, then widespread on all aspects. Many of these forests have a few large, old, fire-scarred ponderosa pines in the overstory, surrounded by dense young growth of Douglas-fir and patchy gambel oak scrub. Such forests were dominated by ponderosa pine before logging and the cessation of surface fires; most of the Douglas-firs are saplings. Pinyon and juniper are also found scattered among the ponderosa pines at middle elevations. Even below 1846 m (6000 ft), where slopes and ridges are covered with grassy pinyon-juniper woodland, mixed conifer forests of the Douglas-fir types are found on north-facing slopes.

Rio Peñasco

This area includes the upper watershed of the Rio Peñasco, which was heavily logged around the turn of the century. The logging camps of Russia and Marcia were abandoned with the end of railroad logging, and this area remains relatively undeveloped. Our division extends from Cox Canyon in the north to the watershed of Wills Canyon in the south, and from the summit of the Sacramento Mountains and the headwaters of the Rio Peñasco, east along the river to Mayhill (Fig. 19). Five fire history sites (Peake Canyon, Delworth Spring, Denny Hill, Water Canyon, and Cosmic Ray Observatory in Table 8; Huckaby and Brown 1995) and three old-growth sites (Peake Canyon, Water Canyon, Telephone Canyon; Regan 1997) are located within this area, at a range of elevations. A section of the Cloudcroft Experimental Forest was located in the northern part of this area (Peake Canyon).

Historic Conditions

The highest part of this division slopes gradually eastward from near the summit. The General Land Office Survey of 1889 described upper elevations covered by mixed conifer forest, probably not unlike that of today, composed of heavy pine and "fir" timber, which seems to have been more or less continuous over a large area. Aspen was sometimes found in dense, pure stands; oak scrub, sometimes very dense, comprised much of the understory (Table 5). "Fir" (Douglas-fir) and pine (ponderosa pine) seem to have been fairly evenly mixed in the canopy. Understory vegetation, though variable in composition at higher elevations, was consistently described as "dense."

The survey continued in 1891 and 1896 and was completed in 1905. Just east of the crest around Hubbell and Wills Canyons, the surveyors recorded some very large trees including "firs" (Douglas-fir) of 152.4, 132.8, 121.9 cm (60, 52, and 48 inches) in diameter. Trees in the rest of the area varied from 25.4 to 76.2 cm (10 to 30 inches) in

Table 5. Historic and present conditions for the Rio Peñasco division. See Table 3 for species acronyms.

Rio Peñasco	Pre-settlement	Post-settlement (20th century)
Vegetation	Above 7000', mixed conifer was relatively dense and continuous over a large area. General Land Office notes described much of this division as "heavy pine and fir timber," indicating dominance by PIPO and PSME, with ABCO in the canopy and PIST also present. Some very large trees were recorded in places, up to 60" dbh. Scattered POTR was present in the canopy, with a few large oaks. The understory was of mixed shrubs. Few large openings existed except for shallow canyon bottoms, which were grassy. Farther east, PIPO dominance was stronger, mixed with scattered PSME and ABCO, and tree size declined. The shrubby understory became pure oak. PIED-JUDE was interspersed with PIPO and PIST at lower elevations. There was less grass under the forest canopy than in more open areas. Below 6000', the forest broke up into scattered PIPO, PIED, and JUDE, and shrubs were less dense than above.	Higher elevations are covered with continuous mixed conifer forest of the ABCO habitat types, composed of young, dense trees, with very little PIPO. Cold sites have forb-dominated understories; warmer sites have mixed shrubs, mostly oak. Farther east, mixed conifer stands are of the PSME types, also young and dense with a very small PIPO component and a shrubby oak understory. PIPO-dominated stands below 7000' grade quickly into PIED-JUDE woodland with a sparse shrub oak understory and a depleted grass layer. Most of the forests of this division are second growth following logging. The Rio Penasco valley is mostly under cultivation.
Ecosystem processes	*Soil*: Deep and fertile in canyons; thin and rocky on slopes, poor at lower elevations.	Considerable erosion on logged-burned slopes and overgrazed canyon bottoms, especially where agricultural fields have been abandoned.
	Water: Rio Peñasco was the only perennial stream in the range that did not sink; runs into the Pecos. The canyon was 1/4 to 1/2 mile wide. Springs were present at higher elevations, marshes at lower elevations.	Water diverted for irrigation. Flood control structures on Rio Peñasco and other streams constructed starting in 1930s.
	Fire: Frequent, low-intensity surface fire, patchy crown fire which created openings in canopy and aspen groves. No data for fire in PIPO or PIED-JUDE; lower elevation mixed conifer (PSME types) MFI=6.4 y (Denny Hill); Higher elevation mixed conifer (ABCO types) MFI=11-13 y (Peake Canyon, Water Canyon, Delworth, Sunspot).	Severe fires in logged areas burned to mineral soil in the 1920s—most were human-caused. Complete fire suppression since 1907 disrupted natural surface fire regime, allowing only rare, extensive crown fires that escape control under extreme conditions.
	Insects: Areas of "dead fir timber" noted in 1896, possibly victims of a defoliator attack some years before.	Severe outbreaks of bark beetles in and around logged areas in 1920s and 1930s eliminated much PIPO regeneration; PIEN killed by moths and beetles in 1920s.
	Disease: none noted	Exotic white pine blister rust detected in 1990 at high elevations.
	Windthrow: several small areas noted	
Landscape structure	The forest was very heterogeneous, with vast areas of high large tree density, indicating extensive old-growth mixed conifer covering more than 35% of the area. Scattered POTR stands were found amid fairly continuous mixed conifer, where tree sizes (and probably ages) varied considerably. PIPO and ABCO shared dominance of mixed conifer; PSME was prominent in mid- to low elevation mixed conifer. Some very large PSME were noted. PIEN stands were local at highest elevations. At lower elevations, scattered PIPO was mixed with PIED-JUDE in an open forest with an oak understory.	POTR is much reduced. Mixed conifer forest is all young and even-aged following logging. The PIPO component is much reduced due to logging, lack of fire, and insects, and dominance by ABCO is stronger, with dense ABCO and PSME regeneration in the understory. Shrubs and shrub diversity in the understory is reduced. The extent of grassy canyon bottoms is reduced by erosion and tree encroachment. Old growth stands are rare and isolated; PIEN stands are reduced in area. PIED-JUDE woodland contains less PIPO, is more dense than before. The grass component under shrubs is reduced.
Human land use	Apaches used upper elevations in summer; their use of the east slope is unknown, though they probably passed through to hunt bison on the plains and used the reliable water in the river. Pre-1400 agriculture at several sites.	Extensive irrigated agriculture occurs all along the Rio Peñasco valley. Extensive clearcut logging occurred in mixed conifer forest from 1903 through the 1930s; some logging continues. Summer grazing at higher elevations, mostly cattle, is now much reduced from earlier in the century. Goats grazed at lower elevations until the 1940s. There is little development except along the river. Logging camps at Russia and Marcia are abandoned. Cutting of PIED-JUDE at lower elevations for fence posts and firewood was destructive until 1917.

diameter. The size and density of large trees in this area makes it apparent why it was the target of intense logging some 20 years later. Survey notes compared the quality of the Douglas-fir timber to the "celebrated fir timber on Puget Sound" (General Land Office Survey). "Spruce" (probably white fir) was mixed in the overstory, as was the occasional oak. Pine was uncommon, while white fir and aspen were more frequent near the crest, indicating mesic conditions. In general, the composition of the forest was very mixed, including "pine, fir, aspen, spruce, oak timber." "Balsam" (probably Engelmann spruce, though it may have been white fir) was also noted in this area in small amounts, the only place it was recorded by the surveys in the Sacramentos.

The surveyors noted several large areas of windfall, perhaps trees killed by an earlier insect outbreak. Otherwise there were few openings, compared to the west side and to lower elevations to the east; timber was only occasionally described as "scattered" and was more often called "heavy" or "dense." A few areas of "open ground" were recorded. Surveyors encountered areas of "dead fir timber" in 1896, which were probably patches of standing dead Douglas-fir, perhaps victims of spruce budworm or another insect outbreak sometime before the survey. These trees may have been dead for some years, as an aspen thicket and dense shrubs were described amid the dead fir in one area.

Some cultivated fields were interspersed with forest even at high elevations. Willow (probably forest willow, *Salix scouleriana*; not necessarily a riparian indicator) was rarely present in the understory along with small oaks and small aspen. The shrubby understory included oceanspray, locust, gooseberry, maple, and dogwood. The mixture of shrubs in the understory, as opposed to the nearly pure oak on the west side and at lower elevations farther east, was indicative of the more abundant moisture near the summit.

The logging village of Marcia, located on the Rio Peñasco nine miles south of Cloudcroft, was occupied from 1919 until 1942. It functioned as headquarters and locomotive maintenance center for the lumber company and as a source of water from the nearby river and springs. The average population of Marcia was about 75 people, comprising from 25 to 30 families, and the buildings included a schoolhouse/church, a commissary, a company barn, and a repair shop. The village was abandoned when railroad logging ceased, and the buildings were burned by the Crossheart ranch a few years later, to alleviate the potential hazard to livestock (Spoerl 1981c).

The General Land Office Survey notes of the 1890s described the bottoms of the canyons as having small areas of slightly to heavily rolling land that could be cultivated. The rest of the land was considered too steep and rocky even to be good pasture. The bottoms of Hay, Wills, and Rio Peñasco canyons were cultivated, but those farms had been mostly abandoned by the 1930s. Water was scarce in this area; permanent springs were noted in some canyons, but the only perennial stream was the Rio Peñasco. The surveyors noted the abundance of fossil seashells near the crest.

Sections farther east were surveyed in 1889, 1902, and 1938. At lower elevations, Douglas-fir became less frequent and dominance by ponderosa pine was stronger. The timber was sometimes described as scattered, and pinyon and juniper were occasionally mixed with pine and Douglas-fir, especially on ridges, while white fir became rare. Scattered aspen was still present. Occasional pockets of pinyon pine were observed amid the "heavy pine and fir (Douglas-fir) timber." In general, the size of the trees declined as the surveyors worked eastward. The forest became less continuous, interspersed with aspen or oak thickets. Shrubs such as oceanspray, dogwood, willow, and gooseberry were not noted as the survey moved east and down in elevation. Cultivated fields became more common, and several small marshes were noted.

In notes from the 1902 survey, ash was occasionally recorded in the overstory, and white pine was also recorded as a species separate from ponderosa pine (usually called just "pine" in the survey notes). Surveyors described dense shrub growth along the Rio Peñasco, though the species were not enumerated. Dense shrubs were also recorded along the open edge of an area of heavy timber, perhaps the edge of a crown fire or windthrow. Sections farthest east were surveyed in 1938 and were described as a mixture of pine, fir, pinyon, and juniper timber (implying large trees), with scattered oak scrub; the trees were noted to occur only on south slopes (north facing?) in some places. The surveyor noted that "a great deal of oak brush grows over all these mountains." He also said that stock raising was the primary industry in the area, and that grain and vegetables were raised on nearly all of the tillable land. The soil was described as generally very good. Cox Canyon was described as especially suitable for agriculture. "Fair grass in the canyons," but grass was poor everywhere else.

The area around Mayhill was first surveyed in 1884. The forest had broken up into scattered ponderosa pine and juniper, with much open space between groups of trees and a less dense understory of oak and juniper species. The timber was occasionally described as dense, but mostly as scattered, with little pinyon pine relative to the ponderosa pines. A couple of marshes and a pasture were noted, but little cultivated land was recorded. The soil and grass were described as second rate, the timber scattered, scrubby and of poor quality, though there were patches of high quality timber here and there. Settlement and cultivation were confined to the good soils of the river valleys, the Rio Peñasco and the Aqua Chiquita.

The survey was finished in 1941, filling in areas that had been missed in earlier surveys. The trees were described as being much more dense than in 1884 and having a much broader mix of species. Middle elevations supported a mix of ponderosa pine, pinyon pine, Douglas-fir, white fir, cedar, juniper, and oak timber, with second growth ponderosa pine, Douglas-fir, white fir, juniper, and oak. Timber was described as "heavy" and "dense," with "second growth"— presumably saplings established after clearcut logging of previous decades. There was much more cultivated land than in 1884. The understory was described as dense, primarily oak shrubs. Most of the witness trees were under 10 inches in diameter, and were ponderosa pine, pinyon pine, or juniper. The forest was much more continuous than in 1884, though several areas of "grassy land" were noted. The canyon of the Rio Peñasco was described as a quarter to half a mile wide and was the location of considerable irrigated farming. The lower Aqua Chiquita was described as a small perennial stream with a canyon too narrow for agriculture.

John Kerr's 1909 assessment found range conditions along the Rio Peñasco in varying condition. Goat range south of Dark Canyon was in "fairly good condition," while cattle range along the river was in "bad condition." Both of these ranges were in the lower part of the canyon. By 1946 (US Forest Service 1946), the upper canyon between 2462 and 2923 m (8000 and 9500 ft) elevation had been heavily logged and burned severely in the 1920s, "burning even the north slopes down to mineral soil." The old burns were occupied by aspen, and the unburned areas were covered by mixed conifer forest with shrubby, not grassy, understories; grasslands were found along the canyon bottoms. The condition of the range was fair, though concentration of animals in canyon bottoms and on flat areas had reduced perennial grass vigor. Erosion was still occurring on the old burns and in canyon bottoms that had been cultivated and abandoned, though some eroded areas were beginning to recover.

The Russia Canyon area south of Cloudcroft, between 2462 and 2954 m (8000 and 9600 ft) elevation, was acquired by the Forest in 1940, and by 1946, much of the canyon bottom land was still privately owned, some of it cultivated and much of it fenced. Clearcut logging followed by intense fires in the 1920s had destroyed much of the forest vegetation at higher elevations, and unregulated grazing before 1940 had depleted the grasses and forbs. Despite the severity of the disturbances, the vegetation was recovering by 1946 and secondary gullies were healing, though primary gullies were still bare and eroding. Grasses were spreading on deeper soils on flats and canyon bottoms. Better soils and more abundant water encouraged regeneration of the vegetation at these higher elevations.

Present Conditions

The upper parts of the Rio Peñasco canyon near the crest are now covered by dense, young, mixed conifer forests of the white fir habitat types. On cold sites where snow stays late, understories are dominated by forbs (Alexander et al. 1984). On drier sites and at lower elevations, understories are dominated by shrubs, especially gambel oak. Stands dominated by Engelmann spruce are scattered at the highest elevations on the wettest, coldest sites. Farther east, at middle elevations, dry white fir/gambel oak-dominated forests grade into Douglas-fir/oak-dominated types. Most of these stands have been logged and are less than 100 years old, with a small ponderosa pine component. Stands dominated by ponderosa pine occur in narrow bands below 2154 m (7000 ft) and intergrade with pinyon-juniper woodland. The woodland has a sparse, shrubby understory; the grass component has been much depleted. Much of the valley of the Rio Peñasco is presently under cultivation.

Aqua Chiquita

This relatively large area extends from the summit of the range (where it curves to the east) to the confluence of the Aqua Chiquita with the Rio Peñasco and the eastern boundary of the Lincoln National Forest and includes the Bluewater Canyon drainage (Fig. 19). It encompasses the small towns of Sacramento and Weed, but is otherwise ranch country that is relatively undeveloped. None of the old-growth or fire history sites occur on this division, though the Monument Canyon sites near the western boundary probably reflect conditions in the upper elevation mixed conifer forest. The Denny Hill site, near the northeastern boundary, reflects conditions typical of the lower elevations, where ponderosa pine-mixed conifer forest intergrades with pinyon-juniper woodland, and where fire frequency was historically high. An intense crown fire burned 6000 ha (15,000 ac) in this section in April 1974. It was the most severe fire recorded on the Lincoln National Forest in the 20th century.

Historic Conditions

General Land Office surveys of 1889 and 1891 recorded higher elevations as covered with "heavy pine and fir timber," often with a dense oak or aspen understory, much locust, and occasional patches of juniper. Such vegetation was continuous for many kilometers. This area was subsequently heavily logged in the early 20th century. Farther east and at lower elevations, General Land Office survey notes recorded "numerous little valleys of rich black loam where abundant crops of all kinds of cereal and vegetables are produced to perfection without the aid of irrigation." There were many small springs in this part of the range. The slopes above the valleys were covered with "abundant growth of mountain grasses," except where oak and aspen were dense ("impenetrable"), especially on north-facing slopes. Timber in the form of pine (ponderosa pine), fir (Douglas-fir), oak, and aspen was also abundant in the area, though the topographic position was not recorded. The relative openness of the forest and density of shrubs, the presence of considerable aspen, and the grassy understories were indicative of fairly frequent surface fires (Table 6).

Farther east, at mid to lower elevations, vegetation in 1889 was dominated by ponderosa pine mixed with pinyon and juniper with a dense oak understory. Douglas-fir occurred on wetter microsites. Low elevations surveyed

Table 6. Historic and present conditions for the Aqua Chiquita division. See Table 3 for species acronyms.

Aqua Chiquita	Pre-settlement	Post-settlement (20th century)
Vegetation	The westernmost part of the division is near the summit, and supported ABCO and PIEN forests. Most of the upper end of this division is at mid-elevations and was covered with mixed conifer forest with "heavy pine and fir timber"—large trees, PIPO and PSME dominant, a little ABCO in the canopy and dense oak shrub understory; locust and juniper were also present in the understory on some sites. Patches of POTR were found at higher elevations, much of it young. Continuous PIPO-dominated mixed conifer forest extended for miles. Grassy valleys and canyon bottoms were treeless, except for areas of oak or aspen. At lower elevations, the forest became more open, with grass under the canopy and dense oak shrubs. Farther east (R 14), PIPO was mixed with PIED-JUDE and dense oaks, with PSME in wetter sites; "scattered timber and dense to scattered undergrowth" described a typical patchy PIPO forest with patchy oak scrub understory. Lower elevations were rocky.	Higher and mid-elevations are covered with continuous mixed conifer forest that is young, dense, and dominated by PSME and ABCO. Dense oak understory occurs at all elevations. Grass cover under scrub and forest is much reduced at lower elevations. PSME and ABCO saplings are common under a canopy of old PIPO. At lower elevations, PIED-JUDE is very dense and is mostly young regeneration following cutting for firewood and fence posts.
Ecosystem processes	*Soil*: Deep and fertile in canyons and valleys.	Erosion in valleys due to overgrazing.
	Water: Many small springs; Aqua Chiquita and Bluewater were semi-permanent streams, tributaries of the Rio Peñasco.	Many water storage tanks created for livestock.
	Fire: Frequent, low-intensity surface fire. Higher elevations (mixed conifer) MFI=6-11 y; PSME types and PIPO at lower elevations MFI=3-5 y (based on Denny Hill and Monument Canyon).	Complete fire suppression after 1907, allowing only rare, intense crown fires under extreme conditions. The Spring fire, 1974, human-caused, burned over 15,000 ac in lower mixed conifer.
	Insects: no notes	Outbreaks of defoliators and bark beetles during the 1950s that were treated with aerial spraying.
Landscape structure	Lower elevations were covered by open forest, patchy trees that were highly variable in size, dominated by PIPO. Continuous mixed conifer forest (mostly PSME habitat types) dominated mid-elevations, with patches of POTR and shrubby oak understories. There were isolated patches of high densities of large trees, indicating as much as 30% of mixed conifer was old-growth. Mixed conifer forest was patchy and very heterogeneous. The highest parts of this division were covered with ABCO habitat types, with embedded stands of PIEN in areas of cold air drainage.	At higher and mid-elevations, mixed conifer forest dominated by PSME and ABCO forms continuous forest, dense and mostly less than 100 years old, with dense ABCO regeneration. Lower elevations are covered by continuous young PIED-JUDE, with reduced dominance by PIPO. Oak is more continuous now. Small patches of PIEN persist at highest elevations, embedded in ABCO types.
Human land use	Uncertain. Mescalero Apaches may have occupied the area at times, but lack of water probably limited their activity.	There is relatively little development in this division except for the small towns of Sacramento and Weed. There was extensive clearcut logging in mixed conifer forests, 1920-1942, and extensive cutting of PIED and JUDE for fenceposts, 1880-1920. Considerable and locally intense grazing by cattle and goats at lower elevations occurred 1880-1940s. Lighter cattle grazing continues.

in 1884 supported "scattered timber and dense to scattered vegetation [undergrowth]"; species were not recorded, but this was likely open ponderosa pine forest grading into pinyon-juniper woodland and oak scrub. Pinyon was occasionally referred to as "timber," indicating fairly large trees, but more often "timber" meant ponderosa pine at lower elevations. The surveyors repeatedly noted the extreme density of the oak scrub and sometimes of the juniper. Forest cover was referred to as "dense to scattered," indicating a patchy landscape, with clusters of trees typical of open ponderosa pine forest (Covington and Moore 1994). The lower elevations were described as rocky, except for small patches of "very desirable land" in Bluewater Canyon, where a stream of "considerable size" ran but sank in the eastern portion of the division. Settlement was concentrated along this stream where grass was described as "generally very good."

The 1909 range assessment (Kerr 1909) found that the cattle range in the Aqua Chiquita and Bluewater drainages was overgrazed and in poor condition. In many cases the stock tanks were too small, and not enough water was available for the animals on the land year around. The range around Piñon was in better condition, but water was too scarce. The goat ranges in the area were also "closely grazed." None of the allotments described in the 1946 Range Management Plan fell into this division; much of it may have still been private land at that time.

Present Conditions

The Spring fire in April 1974 burned 6142 ha (15,354 ac) in 3 days, despite suppression efforts. A child playing with matches started the fire on private land, and it destroyed the villages of Sacramento and Weed, causing millions of dollars worth of damage. The intense crown fire was driven by extreme winds during a very dry period and burned through ponderosa pine and mixed conifer forests. Forest regeneration has been slow and spotty following the Spring fire; much of the area is still covered by oak brush. The higher elevations of this division are somewhat east of the summit and are covered with mixed conifer forests of the white fir habitat type series, primarily the white fir/gambel oak type. Douglas-fir/oak forests are found on drier sites. There is more area of true ponderosa pine/oak forest in this division than elsewhere on the forest. The pine types grade into large areas of pinyon-juniper/oak woodland as the range slopes gradually to the east.

Sacramento River

This division includes the southern half of the west escarpment, extending south from Dog Canyon to the southern boundary of the Lincoln National Forest with the McGregor Military Range, and southeast from the summit of the Sacramentos to the eastern Forest boundary (Fig. 19). It includes the settlement of Timberon and the headquarters of the Circle Cross Ranch but is otherwise sparsely developed and includes a large inholding of private land. Two high-elevation fire history sites (Monument Canyon and Monument Canyon Upper in Table 8; Huckaby and Brown 1995), three low-elevation fire history sites (Wilkinson 1997), three old-growth sites (Monument Canyon, Pine Spring, and Scott Able Canyon; Regan 1997), and one packrat midden site (Wild Boy Canyon, Van Devendever et al. 1984) are located in this area.

Historic Conditions

General Land Office survey notes from 1885 described the upper elevations of this division as covered with heavy ponderosa pine timber. The very highest elevations also had heavy "spruce" timber (probably white fir, but there is also Engelmann spruce in the upper reaches of Scott Able Canyon). In some areas, the pine was mixed with juniper (species not specified), and dense oak scrub in the understory was common. Some of the oaks and junipers were large enough to be described as "timber." Patches of aspen were noted among the pines. "Spruce" seems to have been scattered even in areas that were primarily dominated by pines, probably indicating forests of the white fir/oak habitat type series (Alexander et al. 1984). Grassy openings of some size, described as "parks," occurred occasionally. As elevation dropped off quickly to the west, the "spruce" (white fir) dropped out, and "fir timber" (Douglas-fir) became common among the pines and aspen stands. The trees became more scattered and patches of oak brush more dense (Table 7).

The rest of the survey occurred in 1905 and 1908 and by this time passed through cultivated fields nestled in valleys between slopes covered by scattered ponderosa pine and Douglas-fir, with dense understories of scrub oak. Farther west, larger oaks and aspen thickets were interspersed with ponderosa pine and Douglas-fir timber and occasional junipers. As elevation dropped off quickly to the west, pinyon and juniper were mixed with pine and Douglas-fir. Surveyors noted maple and box-elder in intermittent riparian areas and canyons. Aspen was a common component of the coniferous overstory and formed thickets or groves of larger trees. Locust was patchy, and dense oak scrub occupied openings.

Lower elevations in the southern half of the division were described in 1885 as covered with scattered pinyon and juniper timber, with a dense oak shrub layer. At higher elevations, the surveyors abruptly entered heavy ponderosa pine, which was interspersed with "spruce" (Douglas-fir or white fir). Dense oak scrub understory was continuous into higher elevations. Along the southern boundary of the Forest, in 1908, surveyors found scattered ponderosa pine, pinyon, juniper, and "cedar," without much oak scrub.

In general, forest cover of mixed ponderosa pine and Douglas-fir became more open and patchy with decreasing elevation. Openings supported dense oak scrub, and aspen was a frequent forest component, indicating a very patchy, frequently disturbed landscape. The understory appears to have been highly variable in composition, perhaps reflecting the differences in moisture regimes between canyon bottom, wall, and intervening ridges.

Agriculture was concentrated at middle elevations. Many of the settlers had occupied and improved land in the canyons but had not yet filed claims on them. Gentle hillsides and canyon bottoms were described as having rich loam soil that could be farmed without irrigation. As of 1908, a few settlers farmed in the southern Sacramentos, using irrigation from the Sacramento River, which sank before it left the mountains. Scattered farming settlements were concentrated in the Piñon creek watershed. The principal crops were corn, beans, and cane which was raised for hay. The lower elevations, with their dense shrub cover, were considered good pasture for goats, which were grazed there in large numbers until the 1940s (Hawthorne 1980). Most people did not rely on farming for their sole income, however; in 1915, Ranger Anderson estimated that favorable seasons for farming occurred in only about one of five years (Anderson 1915).

Despite the density of the shrubby understory, General Land Office Survey notes stated that the "entire township is covered with a luxuriant growth of grass. Almost the entire township is covered with heavy timber of pine and fir of very good quality." This would seem to indicate grassy understories in forests, even under oak scrub. In 1905, the surveyor noted that a "large body of land, composing the best of the timber, has been secured by an Alamogordo Lumber Company."

Table 7. Historic and present conditions for the Sacramento River division. See Table 3 for species acronyms.

Sacramento River	Pre-settlement	Post-settlement (20th century)
Vegetation	High elevation forests were composed of heavy PIPO timber, with areas of mostly pure PSME, though PSME and PIPO shared dominance along the crest, probably in PSME/QUGA communities, with occasional grassy openings. To the west, descending steeply from the crest, PSME dropped out, ABCO occurred with PIPO. Trees became more scattered at lower elevations and oak brush more dense. POTR thickets were common at higher elevations, and POTR was a common canopy component at lower elevations. PIED-JUDE was mixed with PIPO and PSME at lower elevations, with dense oak understory and oak in openings. Grass grew under the shrub layer at all elevations. The south end of the range was covered by scattered PIED-JUDE with a dense oak shrub layer, which became less dense farther south.	Vegetation zones are compressed on the steep west escarpment; canyon effect allows walnut and cottonwood in canyons, which are depleted with water diversion. This division is drier than the north part of the west escarpment, so desert scrub ascends to higher elevations. Lower elevations are covered by dry PIED-JUDE woodland with a dense oak understory, and oak scrub fills openings. The grass component is gone. PIPO intergrades with PIED-JUDE below and mixed conifer immediately above. Most of the mixed conifer forests are of the drier PSME/QUGA types on the west side of the summit; ABCO types and scattered PIEN are found near the summit. Mixed conifer at higher elevations is mostly dense, young forest less than 100 y old, second growth after logging. POTR is reduced by conifer encroachment.
Ecosystem processes	*Soil*: Rich loam in shallow canyon bottoms and on less steep slopes.	Extreme erosion, especially along the western Forest boundary; agriculture in canyons.
	Water: Few springs in the Sacramento River drainage; the river sank before reaching the desert.	Sacramento River diverted early in the century for the railroad and for irrigation; sinks before it reaches the foothills.
	Fire: Frequent, low-intensity surface fire with patchy crown fire. Monument Canyon mixed conifer site showed a variable frequency — more frequent (6.2 y MFI) before 1810, more typical of mesic mixed conifer (11.4 y MFI) after that date. Pine Spring mixed conifer MFI=10 y; Pine Spring PIPO=7 y MFI; Pine Spring PIED-JUDE=28y MFI.	By 1915, a ranger estimated that 90% of the Sacramento River drainage had burned in human-caused wildfires following logging. Overgrazing and complete fire suppression since 1907 disrupted the surface fire regime; a few intense, extensive crown fires that escaped control have burned in the second half of the century.
	Insects: no notes	Defoliating moth in PSME and ABCO in 1924.
	Disease: no notes	Exotic white pine blister rust in high-elevation mixed conifer after 1990.
	Windthrow: periodic windthrow along the crest and canyon walls.	Big windthrow event in 1923, possibly exacerbated by logging edge effects.
Landscape structure	Very heterogeneous forest with patchy distribution, especially on the west side. Old-growth mixed conifer was probably extensive in most canyons and near the crest. Patches of dense trees were interspersed with oak-filled openings. Many openings in the canopy were created by localized crown fires, and filled in with aspen at mid-elevations and oak scrub at lower elevations. Species were very mixed at most elevations, with local variation in dominance. Mid-elevation dominance was shared by PIPO and PSME. Old PIEN was local near the summit. PIED-JUDE was open and scattered at low elevations. Grass layer continuous under oak scrub at mid- and low elevations.	There are a few scattered old trees present in inaccessible areas along the summit; very little old growth. Mixed conifer at high elevations is uniformly dense, young second growth following logging, with rare isolated patches of old growth and increased dominance by ABCO and PSME. Regeneration of ABCO and PSME is dense in the understory of mixed conifer at all elevations. PIED-JUDE is filling in, and is now dense and continuous; PIPO-dominated forest rare. Large openings caused by intense fires are covered by dense oak scrub. The grass component at all elevations has been eliminated by grazing and erosion. POTR is much reduced.
Human land use	Apaches used the canyon seasonally, with its semi-permanent water supply; evidence of peeled trees exists in canyons. Pre-1400 farming occurred in a few canyons, and there is evidence of temporary hunting and gathering camps spanning many centuries.	Very heavy grazing by cattle and goats in the first half of the 20th century; less intense grazing continues. Large ranches exist but there is otherwise little development. Agriculture in the canyons at mid-elevations early in the century, irrigated with water diverted from the river. Extensive clearcut logging at higher elevations before 1950.

John Kerr devoted the better part of a week of his 1909 range survey to this area. Much of the land east of the Sacramento River was either part of Oliver Lee's ranch or was used by him. In general, the land was overgrazed and overstocked, though developments had been made along the Sacramento River to provide adequate water for the stock. Range at the head of the river on Fairchild's ranch was also in poor condition. Kerr did not describe any forest vegetation from this area. Some places were spared overgrazing by the lack of available water for stock. Ranger Anderson noted in 1915 that in the Sacramento River drainage, where springs were scarce, there was good grass except right along the river, and even the overgrazed area had improved considerably in the seven years since its administration by the Forest Service (Anderson 1915). Forest Service records noted an infestation of spruce and fir trees (white fir and Douglas-fir) by a defoliating moth during the fall of 1924 in the Sacramento River watershed. South- and west-facing slopes were affected; north-facing slopes were not (US Forest Service 1918–1952).

By 1946, there were many grazing allotments on Forest Service land in the area. At low elevations along the western Forest boundary, in some of the driest and roughest parts of the forest, erosion was extreme (US Forest Service 1946). The primary vegetation was a great variety of grasses and shrubs, but the range condition was rated fair to poor. Perennial grasses died from root exposure, and palatable shrubs were severely hedged. Many deer were concentrated in the area, which exacerbated damage to the shrubs. At the head of the Sacramento River, near McAfee Canyon and for some distance both east and west of the river, the land had been acquired by the Forest Service in 1940 and had been severely disturbed by overgrazing, clearcut logging, repeated fires, insect outbreaks, and a massive blow-down in 1923.

Between 2554 and 2985 m (8300 and 9700 ft) elevation, the natural vegetation in 1946 was mixed conifer forest interspersed with aspen, with ponderosa pine on south-facing slopes. Grasses were dominant on flats and in canyon bottoms, and bunchgrasses were in good condition on ridges. Despite past abuses, erosion was minimal except on steep slopes, and vegetation was recovering well. Livestock were concentrated in the grassy canyon bottoms, where they caused some damage, and large numbers of deer damaged browse shrubs. Once again, greater abundance of water at higher elevations speeded recovery of vegetation.

In the vicinity of Scott Able Canyon, Bridge Canyon, and Appletree Canyon, between 2308 and 2769 m (7500 and 9000 ft) elevation, ponderosa pine dominated forest cover, with mixed conifer forest on north-facing slopes. Tree reproduction was recorded as dense over large areas. Stringers of bluegrass were found on open flats along the Sacramento River and in the canyon bottoms, though grasses were not common under forest. Brush was scattered and infrequent. The grasses and more palatable shrubs were not vigorous, and erosion was accelerating. Willows were noted as absent from the permanent stream banks except where they had been planted in exclosures. The range was rated fair and overused.

The summit, the present location of the Sunspot solar observatory, was covered with mixed conifer forest, with aspen occupying old burns and ponderosa pine on south-facing slopes. Douglas-fir and aspen reproduction were plentiful, despite browsing. A large open area on the western slope was covered with dense brush. Much of the area had been logged, partly under Forest Service administration, but considerable damage had been done by poor logging practices. The area was part of the massive blowdown in 1923. Canyon bottoms supported grasses and forbs, and brush was scattered. Erosion damage was considerable and continued at a more moderate rate than in the past. The range was rated as fair and was considered overused (US Forest Service 1946).

Present Conditions

As with the northern part of the west escarpment, the vegetation zones in this division are compressed by the steepness of the relief. This part of the west escarpment is somewhat drier than the northern part, since most of the canyons face southwest into the strongest drying winds. Desert scrub ascends to higher elevations here than farther north. The lower portions of the division are covered by dry pinyon-juniper woodland that has experienced severe overgrazing and much erosion. The grass component of the understory is very sparse. The canyon effect is in evidence here, with ponderosa pine and elements of mixed conifer forest occurring in cooler, moister canyon bottoms below their usual elevational limits. Walnut and cottonwood are present in the lower reaches of better-watered canyons. The Sacramento River is diverted for irrigation at higher elevations and sinks underground long before it reaches the foothills. Much of the lower canyon is still privately owned.

The ponderosa pine-dominated zone is much compressed, intergrading with pinyon-juniper below and mixed conifer above. On the west side of the summit, most of the mixed conifer forests are of the drier Douglas-fir habitat type series (Alexander et al. 1984). A few old stands are found on inaccessible sites near the summit. Near the summit and immediately to the east, forests of white fir habitat types form a nearly continuous, dense cover of young trees less than 100 years old. At the highest elevations, white fir/maple and white fir/forb types are found, but the common habitat type is white fir/gambel oak, with a strong Douglas-fir component. Small, scattered stands of Engelmann spruce occur on cool, wet sites (Alexander et al. 1984).

Riparian Areas

Historic Conditions

Most of the canyons in the Sacramento Mountains are intermittent watercourses that carry above-ground flows of water only during the rainy season in mid-late summer, or that flow for a short distance from a spring, then sink back underground again. This aspect of the Sacramento Mountains does not seem to have changed since the time of the General Land Office surveys in the 1880s and 1890s. One of the early reasons for establishing the Alamo National Forest (and later the Lincoln NF) was for watershed protection (Kent and Reynolds 1906, Reynolds 1909). It was recognized even at the turn of the century that water captured as snow and rain in the Sacramento Mountains flowed underground to supply the aquifer beneath the Pecos valley to the east. During the period in which the National Forest boundaries were being defined, eliminations of land were proposed based on the premise that because there were few perennial streams, the land had no watershed value. However, by 1915, Forest Service officials and others had realized that underground flows, fed by the sinking of intermittent streams, were in fact part of the Pecos River drainage. This was an argument for the retention of lands by the Forest Service for their watershed value, which was a source of debate (Anderson 1915).

Riparian vegetation was not often specifically mentioned in the General Land Office surveys, though the survey lines crossed most of the major canyons and many minor ones. At low elevations in the canyons on the west side of the escarpment, the surveys mentioned cottonwood and walnut trees in some of the cool canyon bottoms. These deciduous trees were not recorded in the shallower canyons on the east side, nor was any particularly different vegetation recorded in the shallow canyons at higher elevations. Most of the comments about the canyons involved observations of their relative flatness and the deep, fertile soils found there, which made the canyons the only areas suitable for agriculture in the mountains. Most of the canyons were probably covered then, as now, with grass, which also made them attractive for summer grazing. Shrub cover was usually mentioned when it occurred, but none was recorded for high-elevation riparian areas except for a few notes of willows in the vicinity of the Rio Peñasco.

It is not known what combination of conditions maintained these seasonal watercourses as grassy openings. Frequent fires and periodic floods may have contributed to the lack of tree or shrub cover, but the inability of most trees to compete with grasses on deep soils may also have been a factor. The lack of trees and shrubs meant that the canyons did not need to be cleared for cultivation, another reason why they were exploited for this purpose fairly early in the settlement of the mountain range. However, lack of perennial water for irrigation limited agriculture and prompted settlers to build "tanks" to trap water for use in the dry season.

It is likely that most of these canyons flooded periodically, especially in high precipitation years, but nothing is known about historic flood regimes in the Sacramentos. Flash floods following heavy monsoon rains are common today and may cause considerable erosion damage. Though there have been climatically induced periods of arroyo cutting in the Southwest since prehistoric times (Dahms and Geils 1997), severe gullying in intermittent watercourses in the Sacramentos has become apparent following intensive human land use. This sort of erosion began with the onset of heavy grazing pressure at the end of the 19th century, which eliminated stabilizing grass cover in the seasonal watercourses. However, natural environmental changes may have contributed to the phenomenon. Livestock concentrated around water sources have caused much damage by trampling. Clearcut logging has also altered interception of precipitation, allowing more water to run off downhill. Elimination of cover on hillsides has contributed to considerable erosion following logging and heavy grazing (Reynolds 1909). Roads in canyon bottoms have also contributed considerably to erosion.

Historically, the Sacramento River flowed only during and immediately following wet seasons, and the water spread out and sank in Township 21 South, Range 14 East. Most of this flow was diverted into reservoirs feeding pipelines that diverted water out of the watershed, the largest of which belonged to the El Paso and Southwestern Railroad Company (Anderson 1915). Piñon Creek sank before it reached confluence with the Sacramento River. Small reservoirs for stock watering were built all over the Sacramentos; some were fed by springs, while many were filled by seasonal rainfall. Large cattle operators controlled much of the water on the southwest part of the mountain range (Smith 1907a).

Springs and seasonal lakes and marshes such as Sacramento Lake in the Sacramento River canyon are among the few places where true "riparian" vegetation is found. Such vegetation is mostly herbaceous in character and is capable of persisting through periods of drying out. These wet places may have persisted longer into the growing season before water was drawn off for irrigation.

The scarcity of perennial streams in the Sacramentos limits available habitat for fishes in the mountain range. The Rio Grande cutthroat trout (*Oncorhynchus clarki virginalis*) is native to high-elevation streams in the drainage of the Pecos River (Sublette et al. 1990), most of which are in the White Mountains (specifically, Indian Creek and Bonito Lake). The Rio Grande cutthroat readily hybridizes with exotic salmonids, which have been introduced for recreational fishing. Most streams in which it occurs have been affected by overgrazing and by altered stream nutrient, sediment load, and flow regimes. Rio Grande cutthroat broodstock is being developed at the Mescalero National Fish Hatchery.

Rio Peñasco

The Rio Peñasco is the only perennial stream in the Sacramentos that does not sink before leaving the mountains. It is a major tributary of the Pecos River to the east (Smith 1907b). Much of the land immediately adjacent to the river and within the canyon is privately owned, while most of the watershed is administered by the Forest Service. Flooding, gullying, and erosion have been a problem along the river during the 20th century. Floodwater damage occurs almost annually, but destructive floods were recorded in 1941, 1951, 1954, and 1955 (Otero Soil Conservation District 1957). Most damaging floods occur in the lower reaches of the watershed, usually as the result of intense thunderstorms from July through September.

Riparian areas in the Sacramentos, as elsewhere in New Mexico, have received intensive human use over the last century. Losses of riparian land and reductions in productivity may exceed 50 percent since European-American settlement (Wood and LaFayette 1993). Removal of beaver, overgrazing by livestock, logging, construction of roads and agriculture in riparian areas, diversion of water for irrigation, and modification of channels have altered riparian areas, sometimes irreparably (Dahms and Geils 1997).

Present Conditions

Intermittent watercourses and canyons have been among the most heavily grazed areas in the Sacramento Mountains, especially at higher elevations. Livestock eliminated palatable species quickly and introduced exotic species, especially around springs. Exotic thistles (*Carduus nutans* and *Dipsacus sylvestris*) now occupy the same habitat as the endemic Mescalero thistle (*Cirsium vinaceum*) around springs and seeps, threatening to take over its habitat (Lee-Chadde and Huenneke 1997). Grazing has eliminated grasses that provided fuel for surface fires and stabilized soils during periods of water flow. Trampling around water sources has increased erosion. Many springs are now fenced to keep livestock away from the water source.

Diversion of water for irrigation and storage and construction of flood control structures have changed the hydrologic cycles on perennial and intermittent streams. Shortly after the period of intensive logging, surface runoff increased dramatically; now, with dense regeneration and more trees than existed in the pre-settlement forest, it is likely that evapotranspiration of water by the trees has reduced the availability of surface water and may have lowered the water table (Dahms and Geils 1997). Streamflow has generally been reduced, and patterns of erosion and deposition have changed. Where flood control structures have been built, floods are less frequent but more intense when they occur, causing more severe erosion and less deposition of sediment. Sediment deposited by natural floods created seedbeds for willows and cottonwoods, which are now reduced in their regeneration. When floods cut deep channels through alluvial soils in wet meadows, the water flows through more quickly, lowering the water table and draining hydric soils.

Canyons and watercourses are the locations of most of the development in the Sacramento Mountains. The canyon of the Rio Peñasco has been cultivated since the 1100s and continues to be farmed, as is the Rio Fresnal canyon. Because the canyons are sites of intensive occupation and travel corridors, they are the areas most susceptible to invasion by exotic species.

Historic Disturbance Regimes

The most common historic disturbances for which we have evidence in the Sacramento Mountains are fire, insect outbreaks, windthrow (often following insect kills), floods, and droughts. Changes in disturbance regimes due to human land use have precipitated some of the most apparent changes in Sacramento Mountains forests. Before Anglo-American settlement, forests were more patchy in age and size structure than they are at present and more strongly dominated by ponderosa pine. Within this heterogeneous landscape, disturbances were variable in intensity but generally their intensity was moderated, and they were usually local in extent, perpetuating the patchy nature of the forests. Disturbance regimes (timing, intensity, and extent of disturbance) often have interactive effects; for example, bark beetle attacks often follow drought, and mistletoe-infested trees are more susceptible to fire.

Some historic disturbances are easier to document than others. Disturbances that are discrete events usually leave more traces. Because fire leaves its mark on individual trees in the form of basal scars and on the landscape through forest age structure, reconstructing fire history is easier than reconstructing past incidence of dwarf mistletoe infestation and other diseases that leave less clear evidence. For disturbances such as insect outbreaks and floods, we must rely more heavily on human-kept records, most of which post-date settlement. It is also easier to document individual events than to reconstruct historic patterns of disturbance. We include some 20th century data on fire and insect outbreaks for comparison with the historic data. These data are not complete, but serve to illustrate changes that have occurred under post-settlement land use.

Climate

Past climates have been reconstructed for the Southwest using tree-ring analysis (D'Arrigo and Jacoby 1991, Swetnam and Baisan 1996). In past centuries, as in the 20th century, climate was variable from year to year and on decadal scales. Periods of drought, from a few years to a decade long, were common, often followed by periods of wetter than average weather. The most severe drought recorded by tree rings in New Mexico was in the late 1500s from about 1577 to 1598, followed by a wet period in the early 1600s (D'Arrigo and Jacoby 1991). Other periods of drought in the pre-settlement era include 1217–1226 and 1778–1787. Some of the wettest years during the pre-settlement period, in order of magnitude, include 1835–1849, 1429–1440, 1609–1623, and 1487–1498.

Most of the trees dated in the Sacramento Mountains, both living and dead, established after the late 1500s drought. Very few trees in the Sacramento Mountains germinated before 1600, and most of the oldest trees date to the early 1600s (Huckaby and Brown 1995, Regan 1997). The oldest trees sampled in the Sacramentos date to the late 1500s (Regan 1997). There is a marked increase in trees having innermost ring dates from the early 1600s throughout the Southwest, especially among Douglas-fir and pinyon pine (Swetnam and Brown 1992). Studies of old trees throughout the Southwest indicate that fewer trees established in or survived from the late 1500s than from subsequent periods. Trees more than 400 years old are rare in the Southwest, and this is true of the Sacramento Mountains. (Huckaby and Brown 1995, Regan 1997). This is due in part to the maximum lifespans of the species and to the frequency of disturbance in the Southwest.

The most important restricting factor for vegetation distribution in the Sacramento Mountains is moisture. One of the major influences on climate and especially precipitation in the Southwest is the El Niño-Southern Oscillation (ENSO), which are global-scale climatic events that occur at intervals of 2 to 10 years at variable intensities. El Niño conditions occur when weak tradewinds and high sea-surface temperatures off the west coast of the Americas in mid-winter (hence the name, El Niño, for the Christ Child), cause wetter than average spring and fall seasons in the Southwest by displacing the jet stream to the south. The Southern Oscillation is measured as normalized differences in monthly mean pressure anomalies between Tahiti and Darwin, Australia. Both are linked to a complex of ocean currents, ocean temperatures, and atmospheric pressure and temperature gradients (D'Arrigo and Jacoby 1991, Swetnam 1990, Swetnam and Betancourt 1990). Strong ENSO years are usually wet years of low fire activity, though weak ENSO events may merely increase thunderstorm activity and therefore lightning ignitions.

Two of the most severe droughts in the last 1000 years of climate as reconstructed from tree rings in the Southwest have occurred in the last 100 years. The most abrupt shift from drought to high precipitation occurred following the 1890s drought (D'Arrigo and Jacoby 1991). Sudden and severe drought in the early 1890s caused the near-collapse of the cattle industry in the Sacramentos. Drought continued intermittently through the early 1900s, until the mid-teens; 1904 was a notable year. Drought also occurred in the mid-1920s, precipitating severe insect outbreaks. Several years of drought occurred in the early to mid-1930s. The most severe drought recorded since the 1580s occurred in the 1950s. Drought rarely kills trees outright; drought casualties usually result from drought-stressed trees succumbing to insect attacks or fire, but the droughts of the 1580s and the 1950s killed trees through water stress.

Dry periods followed by torrential monsoon rains cause localized flash flooding most years. Some events are particularly noteworthy, such as the Fresnal Canyon flood of 1899 following an intense thunderstorm at the top of the canyon.

Native American Influences

The only extant record of the exact location of the Apaches at any specific time are trees scarred by the Apaches when they peeled away the bark to get to the cambium, which they used as food when little else was available or to obtain pitch or sap for various purposes. Peeled trees indicate periods of Apache activity near Dog Canyon around 1799–1800, 1823–1824, and 1877–1878. Peelings were nearly annual from 1833 to 1865. No peel scars have been found in the Dog Canyon area that date to any time after 1878, when the Apaches were relocated to the reservation. At times, the Apaches appear to have increased fire frequency above the natural period in the vicinity of peeled trees (Wilkinson 1997). Contemporary reports give evidence that the Apaches deliberately set fires for hunting and warfare; how often this occurred and how it influenced the fire regime in the Sacramento Mountains is unknown, but given the fuel conditions and frequency of lightning ignitions, it is not likely that the Apaches increased the overall fire frequency in the Sacramentos. However, if they repeatedly burned favorite hunting grounds or travel corridors, they may have kept vegetation in those locations in an early successional state, and they may have started fires in the fall and winter when lightning ignitions are unlikely to occur (Wilkinson 1997).

After 1600, the Apaches kept horses and cattle in the mountains, but we do not know how many or where at any given time. The Apaches moved often enough that their stock may not have had much effect on the ecosystems of the Sacramento Mountains. The Apaches hunted wild game and gathered wild plants for food; these activities no doubt had local effects, and the fact that they often needed to supplement their income by raiding indicates that game may not always have been plentiful. Game abundance was in part dependent on the quality of the vegetation and the amount and timing of moisture, but overhunting by the Apaches may have been a factor for some species. Their staple food animals were mule deer and pronghorn and small game such as rabbits. They apparently did not use fish as food. In general, however, the Apaches were never very numerous and moved often. Consequently, their effects on the disturbance regimes of the Sacramento Mountains were probably not great, and these effects have been obscured by subsequent disturbances.

Fire

Probably the most frequent and defining natural disturbance in the Sacramento Mountains has been fire. The frequency of fire in the pre-settlement Sacramento Mountains varied with elevation, vegetation type, and climate, but in general, the fire regime was one of frequent, low-intensity surface fires, interspersed periodically in space and time with stand-replacing crown fires. The grassy forest understories reported by early sources probably served as fast-burning fuel for the surface fires, which retarded tree regeneration without killing overstory trees. In general, fires were more frequent at lower elevations and in drier vegetation types.

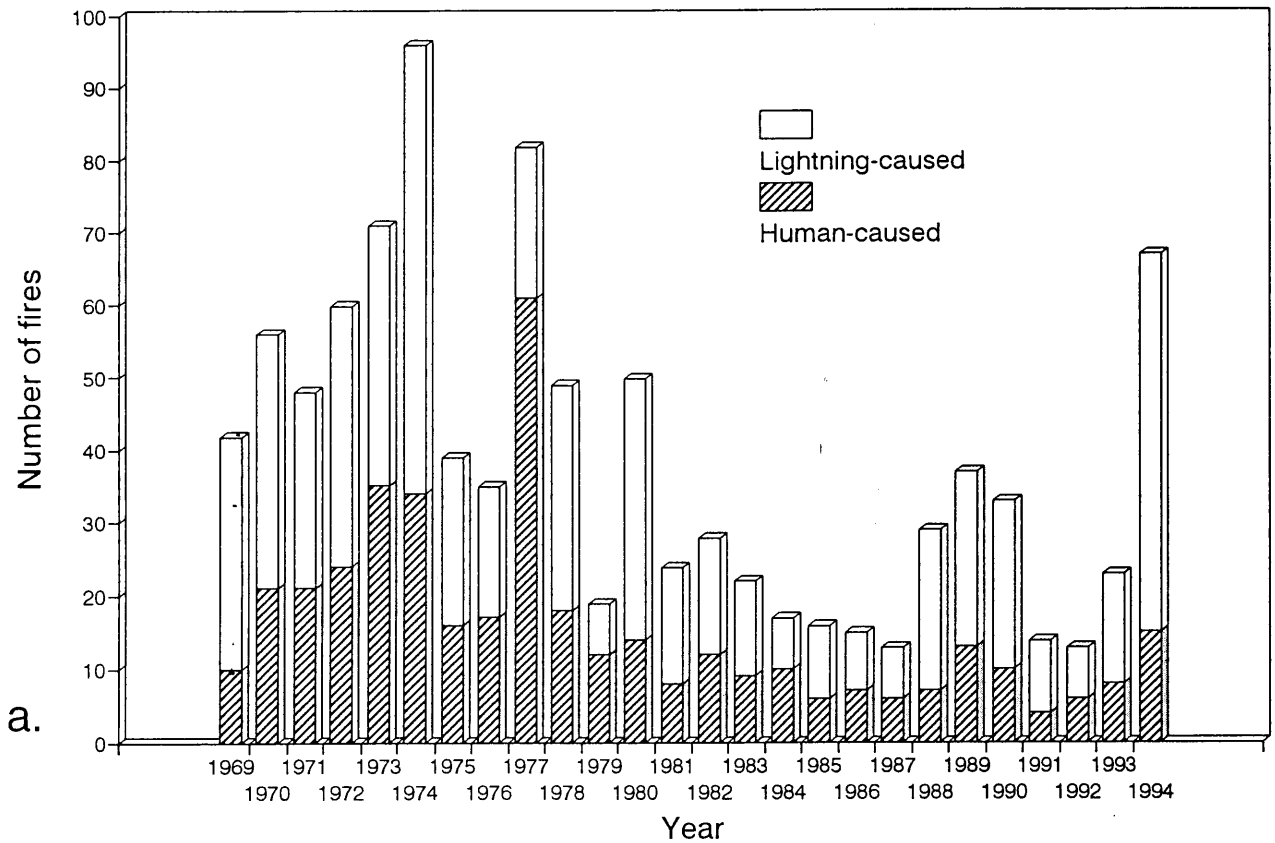
Fire records kept by the Lincoln National Forest from 1969 to 1994 (Fig. 20 a, b) show that about 60 percent of fires started on the Sacramento District (594 out of 999 for the combined Cloudcroft and Mayhill Districts) during that period were lightning ignitions. Of all the lightning ignitions over those 25 years, 60 percent occurred in the dry period from April to June; 28 percent occurred during the monsoon from July to September. Some 40 percent of all fires from 1969 to 1994 were human-caused, and most of these ignitions occurred in the fall and winter. Most fires were successfully suppressed before they burned more than one acre; only 4 percent of fires during the period exceeded 4 ha (10 ac) in size.

When trees survive a surface fire, they may be scarred when the cambium is scorched without girdling the tree. Once a tree has been scarred by fire, it is more susceptible to being scarred again because of flammable resin and dead wood around the wound. Because trees add a ring of growth every year and these rings can be assigned calendar dates through the dendrochronological technique of crossdating ring width patterns, fire scars can be dated by locating the annual ring in which the scar occurs (Stokes and Smiley 1968, Swetnam 1990). It is sometimes possible to determine when during the year a tree was scarred by the position of the scar within the annual growth ring. Not every tree records every fire that occurs in an area; one tree may record most of the fires that burn during its lifetime, while an adjacent tree may be completely unscarred. Some species are better recorders than others. In the Sacramentos, ponderosa pine is the best recorder of fires, because its thick bark allows it to survive most surface fires. Southwestern white pine also records fires, though it is not as resistant to fire as ponderosa pine. Douglas-fir also scars, but not as easily. White fir and aspen are usually killed by surface fire and are not good recorders.

Fire-scarred trees are scattered across the landscape like archaeological ruins. Often stumps, snags, and downed logs can be used to extend the fire scar record back in time, and in the young forests of the Sacramentos, fire-scarred stumps of trees cut early in the 20th century are the best source of historic fire information. However, remnant wood rots or burns within decades in the Sacramentos, and this resource is quickly disappearing. The presence of fire scars on pines was noted in a 1927 report (Strickland 1927), which stated that as many as 90 percent of southwestern white pines and most of the ponderosa pines on the east side were fire-scarred. For a fire history study, multiple fire-scarred samples are collected at each site, and when the fire scars have been dated, the average period of time between all recorded fires is computed as the mean fire interval (MFI). This statistic allows comparison of the relative frequency of fire over time and between sites.

Huckaby and Brown (1995) and Wilkinson (1997; Brown et al. 1998) reconstructed fire frequency using dendrochronological methods at 19 sites in the Sacramento Mountains. The sites were distributed along elevational and ecological gradients to include west-side pinyon-juniper, ponderosa pine, and mixed conifer; mesic mixed conifer along the crest; and drier mixed conifer forest grading into ponderosa pine on the east side (Fig. 21; see Fig. 5b for gradients). Wilkinson's (1997) study sites were located in the ponderosa pine and lower mixed conifer zones at 8 sites along the western escarpment, from Alamo Canyon south to Pine Spring Canyon (CHR, USA, SAC, MCR, LPS, UPS in Fig. 21). Nearly 70 percent of fire scars sampled occurred during the dormant or early growing season, the dry period from April to June, before the monsoons begin. About 25 percent of fires occurred in the mid-growing season. Mixed conifer forests were more likely to burn during the dormant season, but this may reflect the later onset of growth at higher elevations. The timing of fires in the spring may be the origin of the old Apache belief that smoke and fire bring rain (Cooper 1960). Fire scar records in ponderosa pine go back to 1754 and were divided into two periods: a period of small, patchy fires from the early 1700s to about 1780, and a period of larger, less frequent, synchronous fires from about 1800 until 1886, after which time fires at lower elevations all but ceased (Fig. 22).

Mean fire intervals among ponderosa pine-dominated forests were around 4 years (Table 8). From 1686 until about 1800, fires in lower mixed conifer forests were small and patchy in distribution, scarring a few scattered trees. After 1800, fires became more synchronous, scarring many trees over a large area, until fires ceased around 1900. The last recorded fire was in 1899. The mean fire interval in lower mixed conifer forests on the west side was around 5 years, an interval similar to that found in lower elevation mixed conifer on the east side of the range (Brown et al. 1998, Huckaby and Brown 1995).



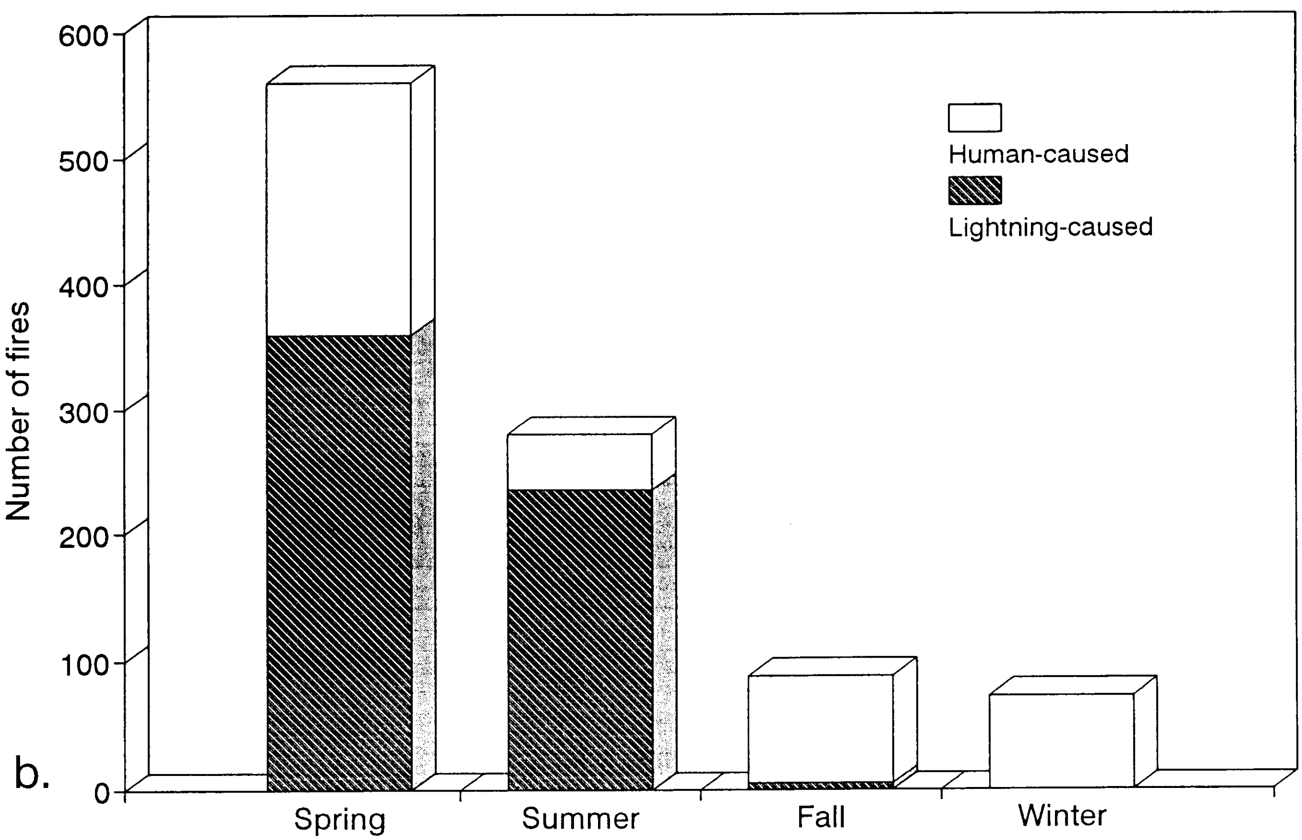


Figure 20. ***a.*** *The number of fires caused by lightning and those caused by human activity, 1969 through 1994. Data from Lincoln National Forest database.* ***b.*** *Seasonality of lightning-caused and human-caused fires between 1969 and 1994. Spring includes April, May, June; summer includes July, August and September; Fall includes October, November, December; Winter includes January, February and March. Data from Lincoln National Forest database.*

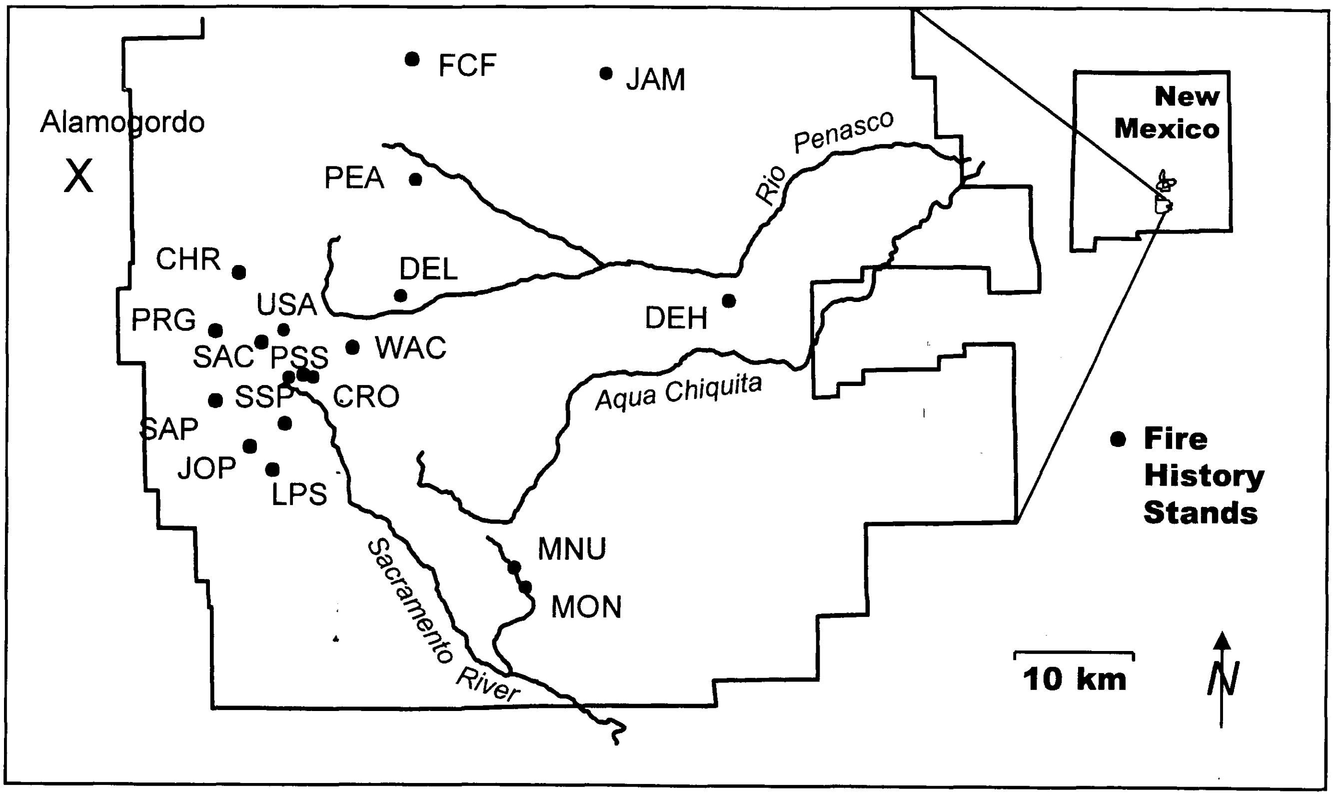


Figure 21. Locations of fire history sites sampled by Huckaby and Brown (1995) and Wilkinson (1997). From Brown et. al. (1998). Abbreviations indicate sampling locations defined in Table 8.

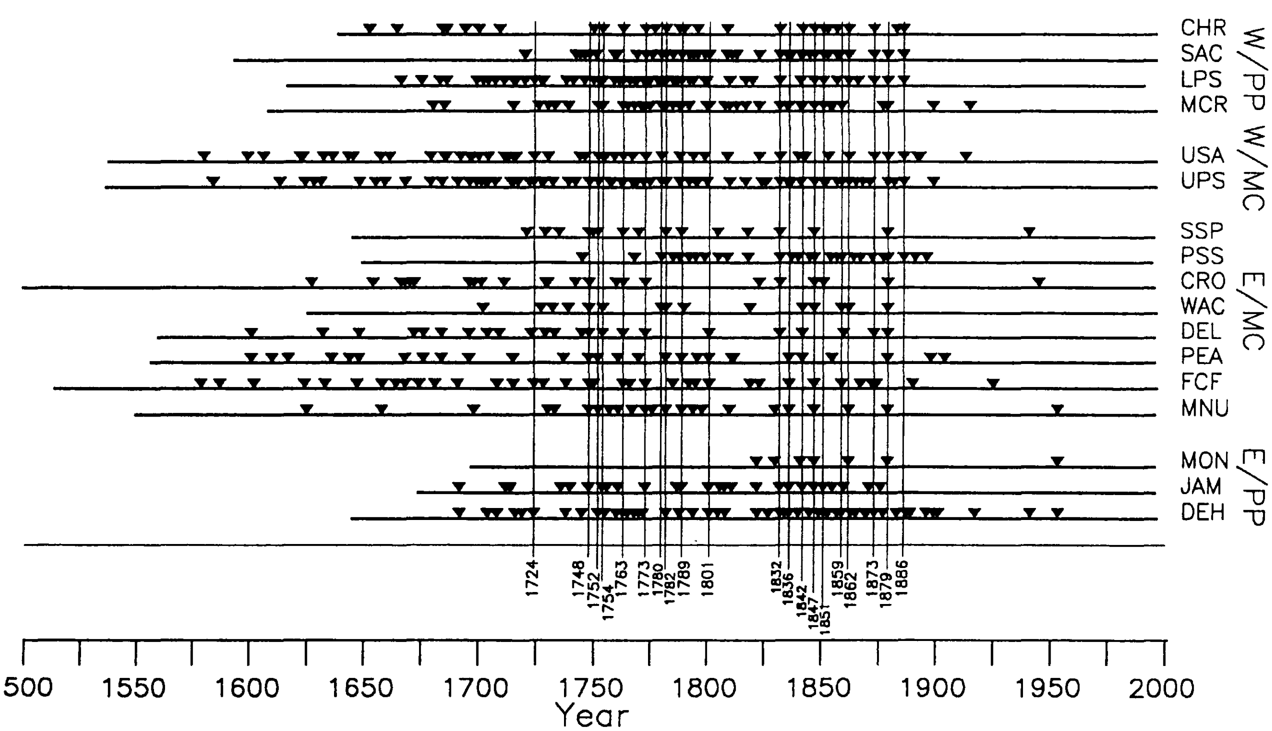


Figure 22. Fire years recorded by scarred trees in the Sacramento Mountains. W/PP designates ponderosa pine sites on the west side of the range; W/MC designates westside mixed conifer sites; E/MC designates eastside mixed conifer sites; and E/PP designates eastside ponderosa pine sites. From Brown et al. (1998).

Table 8. Fire history sampling sites in the Sacramento Mountains, with vegetation type, analysis period, number of fire scar intervals, and mean fire interval (MFI, with standard deviation). MC = mixed conifer, PIPO = ponderosa pine, PJ = pinyon-juniper. From Brown et al. (1998).

Site	Acronym	Vegetation type	Analysis period	Number of intervals	MFI ± Std. Dev.
Cherry Canyon	CHR	PIPO	1652–1886	26	9.0 ± 8.3
Cosmic Ray Observatory	CRO	MC	1627–1879	21	12.0 ± 12.1
Delworth Spring	DEL	MC	1601–1879	22	12.6 ± 8.7
Denny Hill	DEH	MC	1692–1901	45	4.6 ± 3.1
Fir Campground	FCF	MC	1579–1890	34	9.1 ± 4.9
James Ridge	JAM	MC/PIPO	1736–1876	22	6.4 ± 3.7
Lower Escondido Canyon	MCR	PIPO	1730–1859	35	3.7 ± 2.8
Lower Pine Spring Canyon	LPS1	PIPO/PJ	1699–1800	39	2.6 ± 1.8
Lower Pine Spring Canyon	LPS2	PIPO/PJ	1800–1886	13	6.6 ± 2.5
Lower San Andres Canyon	SAC	PIPO	1742–1886	37	3.9 ± 2.7
Monument Canyon	MON	MC	1822–1879	5	11.4 ± 4.6
Monument Canyon Upper	MNU1	MC	1730–1810	13	6.2 ± 3.5
Monument Canyon Upper	MNU2	MC	1810–1879	5	13.8 ± 5.5
Peake Canyon	PEA	MC	1601–1904	27	11.2 ± 6.5
Sunspot	SSP	MC	1721–1879	14	11.3 ± 7.5
Sunspot Pines	PSS	MC/PIPO	1780–1896	24	4.8 ± 2.5
Upper San Andres Canyon	USA	MC/PIPO	1580–1913	52	6.4 ± 4.9
Upper Pine Spring	UPS	MC/PIPO	1648–1899	61	4.1 ± 2.6
Water Canyon	WAC	MC	1702–1879	14	12.6 ± 9.4

Fire scars on pinyon pines at low elevations (JOP, PRG in Fig. 21) yielded a mean fire interval of 28 years, over 14 intervals. The fire scars on pinyon pines indicate that not all fires in pinyon-juniper woodland are stand-replacing crown fires, as has been thought. In general, Wilkinson (1997) found that fires were more frequent at low elevations. Fire dates from higher elevations usually coincided with fire dates at lower elevations, though it is not possible to determine whether the scars were from the same ignition, and not all low-elevation fires also occurred at higher elevations. Fires at lower elevations, especially those starting in pinyon-juniper woodlands, seem to have been localized.

Huckaby and Brown (1995) reconstructed fire history for sites in the mixed conifer forest at high elevations along the crest and east slope of the Sacramento Mountains, using dendrochronological techniques for dating fire scars on living and remnant wood samples (FCF, JAM, PEA, DEL, WAC, CRO, PSS, SSP, DEH, MNU, MON in Fig. 21). Some of these sites were the same as Regan's (1997) old-growth studies (FCF, PEA, WAC, SSP, MON in Fig. 21). Their data showed a general decrease in fire frequency with elevation, but even the coolest, wettest sites near the summit experienced frequent surface fires (Table 8).

Drier mixed conifer sites of the Douglas-fir habitat types were historically dominated by ponderosa pine and showed the highest historic fire frequency for mixed conifer forests (4–8 years; JAM, DEH, MNU, MON, PSS in Fig. 21), regardless of topographic position. The Denny Hill site, the lowest site on the east side at 2326 m (7560 ft) elevation, is located on a north-facing slope that supports mixed conifer forest surrounded by ponderosa pine, pinyon-juniper, and oak scrub on other aspects. The James Ridge site, at 2554 m (8300 ft) elevation in the middle James Canyon, and the Sunspot Pines site, on a south-facing slope at 2831 m (9200 ft) elevation, had similar stand structures and historic fire frequencies. Large, old ponderosa pines dominate the canopies, with occasional large Douglas-fir and many Douglas-fir saplings that have established in former openings since fire suppression began.

At Monument Canyon, two distinctly different fire patterns emerged in a Douglas-fir/oak forest. Samples were collected both inside the canyon at 2462 m (8000 ft) and along the rim at about 2615 m (8500 ft). Between 1730 and 1810, fire frequency on the top was similar to the other Douglas-fir habitat types, with a mean fire interval of 6.2 years. After 1810, the fire pattern shifted abruptly to one more like those found in white-fir habitat types, with a mean fire interval of 13.8 years. Of the samples collected in the canyon, none date to before the early 1800s, and the mean fire interval there was 11.4 years. A severe crown fire or some other disturbance may have changed the structure of fuels, or changing Apache activity could have affected fire frequency.

Huckaby and Brown (1995) also sampled forests of white fir habitat types at a variety of elevations (FCF, PEA, DEL, WAC, SSP, CRO in Fig. 21). The oldest trees and longest fire records occurred in the vicinity of Fir Campground north of Cloudcroft, in typical white-fir/oak and white fir/maple habitat types. Between 1579 and 1890, trees recorded 34 fires, at a mean interval of 9.1 years. Peake Canyon (2646–2769 m; 8600–9000 ft), Water Canyon (2708 m; 8800 ft), Delworth Spring (2578–2646 m; 8380–8600 ft), and Sunspot (2831 m; 9200 ft), all forests of the white fir types, had long fire scar records with similar mean fire frequencies of between 11 and 13 years. Most of these sites recorded a regional, climatically induced gap in fire frequency in the early 1800s. The most recent fire within the historic fire regime recorded by any of the sampled trees occurred at Peake Canyon in 1904. After that, surface fires ceased in the mixed conifer forests of the Sacramentos; at most sites, fires ceased in the 1890s. A few trees recorded fires at Denny Hill and Monument Canyon in the 20th century.

Differences in fire frequency between ponderosa pine/Douglas-fir-dominated habitat types and white fir habitat types may be due to differences in elevation and precipitation but also to site productivity, differing times of needle retention among species, fuel build-up rates, and fuel moisture (Swetnam and Baisan 1996). Slope, aspect, and continuity of habitat over the landscape were also important in determining fire regimes, as were past land use practices. In less productive ponderosa pine forests, the amount of fuel was important to fire spread. In more productive mixed conifer forests, amount of fuel was probably rarely limiting to fire occurrence, but its condition (dryness) was. Twentieth century land use practices such as grazing and fire suppression have altered fuel conditions throughout the Southwest (Swetnam and Baisan 1996).

In general, historic fire frequency in the Sacramento Mountains was highest on the west escarpment and at middle elevations. Surface fire was less frequent in dry, less productive pinyon-juniper woodlands and in the mesic high-elevation mixed conifer forests than in the ponderosa pine-dominated mixed conifer at middle elevations. The two fire history studies did not specifically address historic crown fires, but given the historic existence of pure aspen stands and openings filled with oak scrub, it would seem that crown fires were localized in area and infrequent in occurrence in any given spot. Frequent surface fires controlled the spread of insects, diseases, and mistletoe, and maintained an open stand structure by retarding the establishment of seedlings except during unusually long periods without fire.

Trees in the Sacramento Mountains recorded fires in years that are known to have been regional fire years (Swetnam and Baisan 1996), such as 1724, 1748, 1752, 1763, 1773, 1801, 1842, 1847, 1851, and 1879. Such years were climatically conducive to fires. They were usually dry years following a series of wet years or following a period of low fire frequency, conditions that encouraged fuel build-up. Not all drought years were regional fire years, nor were all wet years low fire years. Cyclic climate oscillations such as the El Niño-Southern Oscillation phenomenon probably drove regional fire events by synchronizing fuel production and condition over large areas. Regional synchronous fire years in the Southwest and the sizes of areas burned have been linked to periods of high Southern Oscillation, which cause low spring precipitation and reduced tree growth (Swetnam and Betancourt 1990). During regional fire years, fires burned simultaneously over large areas throughout the Southwest. Fire frequency dropped off precipitously throughout the Southwest after 1900 due to widespread land-use patterns (Swetnam and Baisan 1996, Touchan et al. 1995).

Some early observers were aware that fire had long been a part of the forests. Holmes (1906) noted that "fires have been of fairly frequent occurrence but of no very great extent on these mountains for the last 175 years, and probably since the forests began. Probably started by lightning in a very dry season, they have destroyed timber in patches. These have gradually grown up to aspen and deciduous shrubs and then to conifers." Holmes noted many old burns in the mountains, though none of "very great extent," and estimated them to make up 10–15 percent of the uncut forest. The most recent of them was estimated to be about 30 years old. Aspen regeneration was very dense in burns, and it took about 30–40 years for conifers to come up under the aspen.

Fires following logging were very common in the Sacramento Mountains in the early years of the 20th century and were very damaging. Most were human-caused; many were started by the coal-fired locomotives. Eventually locomotives were converted to use oil as fuel, both to save money and to prevent fires. In areas that were not grazed due to lack of water, considerable grassy and shrubby fuels could develop in logged areas, resulting in intense, destructive fires that retarded regeneration and converted former forest to oak scrub. Holmes (1906) observed that fires in cut-over areas destroyed not only remaining live trees and regeneration, but burned so hot that they destroyed organic matter in the soil and retarded regeneration for a very long time. Forest Ranger William Anderson estimated in 1915 that 90 percent of the steep west and south slopes in the Sacramento River drainage had experienced stand-replacing fires (Anderson 1915). He blamed these fires on lightning and Indians, though it seems unlikely that the Apaches, who by that time were confined to their Reservation, had much to do with those late fires. Anderson noted that in the pockets of ponderosa pine in the Sacramento River drainage, which apparently had once been sparse and open, very dense pine regeneration was coming in. The effects of fire suppression had begun.

In the latter half of the 20th century, extensive surface fires have ceased in the Sacramento Mountains. Fires that escape suppression occur under extreme conditions and burn large areas as intense crown fires. Between 1950 and 1997, the following large fires have occurred on the Sacramento district: the Allen Canyon fire in May of 1951 burned 6405 ha (15,820 ac; Fig. 23); the Circle Cross fire in April of 1953 burned 10,475 ha (25,874 ac); the Pendleton fire in April of 1956 burned 2358 ha (5,825 ac); the Danley fire in April of 1967 burned 972 ha (2,400 ac); and the Spring fire in April of 1974 burned 6217 ha (15,354 ac). The 1980s were an unusually wet period with little fire activity. The Burgett fire burned 1732 ha (4277 ac) in 1993, and the Bridge fire burned 2010 ha (4964 ac) in 1994.

Insects

Tree-rings have been used to reconstruct historic outbreaks of western spruce budworm and other defoliating

Figure 23. The aftermath of the Allen Canyon fire, Curtis Canyon, 1951. Photo from the Lincoln National Forest Heritage Resource Program collection in Alamogordo, on file at the Lincoln National Forest Supervisor's office.

insects. The Sacramento Mountains are the southern limit of spruce budworm's geographic range. Douglas-fir and white fir are the primary host trees of these defoliators in the Sacramentos. Spruce budworms are attracted to shade-tolerant conifers in uneven-aged, multi-storied stands that are exposed to sunlight, creating a warm environment. Multiple crown layers and crown closure increase the chances that larvae will land on suitable food sources (Lynch and Swetnam 1992). Many of the post-logging forests in the Sacramentos meet these criteria despite the fact that the trees are relatively young, and this stand structure may predispose the forest to large-scale budworm attacks. Historic stand structures, which were more open and more strongly dominated by ponderosa pine, may have been less susceptible to large-scale infestations.

Using evidence from tree-ring patterns, T. Swetnam (pers. comm., Univ. Ariz., 1997) has preliminary data documenting historic defoliation events from 1800 to the present, including at least seven major regional outbreaks. Ring-width patterns from host trees are compared with those from non-host trees at multiple sites to filter out effects of climate. Tree-rings record five major outbreaks in the Sacramento Mountains in the 20th century: 1890s-1900, 1910s-1920s, 1940s, 1960s, and 1980s; the last two outbreaks are confirmed by USDA Forest Service survey records. Recent outbreaks, which have occurred since extensive logging and fire suppression, have been more synchronous among stands than those recorded in the previous century.

Tree-rings also recorded major defoliator outbreaks in the 1810s-1820s and the 1840s-1860s. The 1920s event was probably caused by the New Mexico fir looper (*Galenara consimilis*) rather than by spruce budworms. The event in the 1940s is not confirmed by Forest Service records, but was observed consistently in 5 of 6 sites and may have been unnoticed because of low levels of defoliation. However, it does coincide with an outbreak in northern New Mexico, as do the 1960s and severe 1980s outbreaks. The recorded event of 1952–1954 may in fact have been the tail end of the 1940s outbreak (T. Swetnam, pers. comm., Univ. Ariz., 1997).

Regionally, the three defoliation events from 1800 to the 1940s are 5–10 years out of phase, with trees in northern New Mexico recording them a few years earlier. The pre-1900 events are generally less synchronous than those of the 20th century. The long gap between early 20th century events (1890s to 1940s; 1910s-1920s being fir looper) may be due to the amount of human-caused disturbance occurring in the stands at that time. Triggering agents for spruce budworm outbreaks seem to operate on a regional scale and are probably related to climate. Ecosystem changes caused by human land use practices, such as altered species composition and stand structure (homogenization, increased density, increased proportion of host species, more closed canopies), have changed spruce budworm dynamics, causing more intense and synchronous outbreaks (Dahms and Geils 1997). In some cases, trees defoliated by spruce budworms and other defoliating insects may be predisposed to subsequent attacks by bark beetles.

Written records of insect outbreaks are relatively recent. General Land Office Survey notes from the 1880s and 1890s recorded occasional patches of dead trees, some standing and some fallen, which may have been the result of locally intense insect outbreaks, some possibly from the 1860s spruce budworm outbreak. Most of these patches were noted on the west side of the summit or near the top. Some of the dead trees were noted to be Douglas-fir and some ponderosa pine. Holmes (1906), while inspecting trees on the Alamogordo Lumber Company's land near the summit, observed that "there is very little noticeable injury from insects." The Forest Service began keeping records of insect activity in National Forests early in the 20th century. As early as 1918, Forest Service entomologists observed that harvest practices had a profound effect on insect outbreaks in the Southwest. Wherever ponderosa pine was cut, heavy infestations of bark beetles followed in surrounding forests, remaining seed trees, and a few years later in regenerating trees. Beetles multiplied in scattered slash, in stacked logs, and in stripped bark. The problem was worse when trees were milled near where they were cut. Most of the logs cut in the Sacramentos were hauled to Alamogordo for milling, so the problem was not as bad as it might have been on the Lincoln National Forest, but an increase in pine bark beetles was observed in cutover areas (USDA Forest Service 1918–1952).

During the early 1920s, several serious insect infestations began in the Sacramentos, coinciding with a period of drought. In 1924, Douglas-fir and white fir on south and west-facing slopes in the Sacramento River watershed were attacked by a defoliating moth. The following year, insect outbreaks were in progress at all elevations. Pinyon pines at lower elevations were under attack by *Ips* beetles. Ponderosa pines, especially in the northern part of the forest and on the Mescalero Reservation, experienced epidemics of pine bark beetles (*Dendroctonus brevicomis, D. adjunctus,* and *Ips* species). In many places, the beetles attacked 30-year-old regeneration in cutover areas. At higher elevations, Douglas-fir on 800 ha (2000 ac) at the heads of Wills, Hubbell, Scott Abel, and Logan canyons were defoliated by a geometrid moth, and the infestation was spreading. The situation on the Lincoln was described as "distinctly alarming."

By 1926, most of the outbreaks were subsiding, after causing considerable damage. Engelmann spruce defoliated by the moths were then attacked by spruce beetles (*Dendroctonus engelmanni).* The defoliators in the Douglas-fir had also subsided. *Ips* bark beetles had killed much of the pinyon pine along the west slope of the range near High Rolls but had subsided. Much of the ponderosa pine reproduction in the clearcuts on the east side had been killed by bark beetles, especially on south-facing slopes. The bark beetle outbreak near Cloudcroft and on the Mescalero Reservation was still in progress. By 1927, all of the insect populations had subsided to endemic levels again, though spruce beetles continued to be a problem in an isolated stand of Engelmann spruce in Hay Canyon in 1928.

By the early 1930s, these outbreaks were over, and the next few years were free of insect problems until drought struck again in 1934. *Ips* species became active on Cox Canyon and the Rio Peñasco wherever cutting had taken place, mostly in regenerating trees. This phenomenon was considered unusual; beetles were generally thought to attack old, weakened trees exclusively. For the next couple of years, bark beetles attacked ponderosa pines on the east slope, concentrated primarily in pole-sized trees regenerating in the clearcuts. By 1937, conditions had improved again. Control efforts had been made, with some success, but inholdings of untreated private land complicated treatment (USDA Forest Service 1918–1952).

Generally, insect levels subsided to endemic levels during the 1940s. A low-level infestation by bark beetles continued east of Cloudcroft. A severe infestation of *Dendroctonus* species occurred in the White Mountains to the north in 1948. By 1950, drought had struck again, quickly followed by outbreaks of bark beetles in ponderosa pine. Douglas-fir beetles, Douglas-fir looper, and western spruce budworm were widespread, and defoliation was particularly intense on 2875 ha (7100 ac) of mixed conifer forest in the upper Aqua Chiquita canyon. This outbreak was aerially sprayed with DDT in oil in 1952. Another outbreak of western spruce budworm occurred between 1964 and 1967, when 36, 400 ha (90,000) ac were defoliated each year. The defoliation was not considered severe enough to merit chemical control.

Historic records of insect outbreaks focus on situations in which economically valuable or highly visible resources were threatened, and so may exclude some outbreaks. Detailed reports and maps of known insect outbreaks have been maintained by the Forest Service since the 1950s. A major outbreak of roundheaded pine beetles (*Dendroctonus adjunctus*) coincided with a drought in the early 1970s, and another widespread infestation began in 1988 that is ongoing (Geils et al. 1995, Negron 1996). This infestation is actually a complex of roundheaded pine beetle, western pine beetle (D. *brevicomis*), and Mexican pine beetle (*D. approximatus*). The roundheaded pine beetle prefers to attack small, slow-growing trees in dense stands. The young, dense forests of the Sacramento Mountains that have resulted from logging and fire suppression in the 20th century are highly susceptible to roundheaded pine beetle infestation (Negron 1996).

Wetter conditions in the early 1980s may have contributed to an outbreak of western spruce budworm that defoliated 1640 ha (4100 ac) of mixed conifer forest in 1982. This outbreak was suppressed with insecticides. Western spruce budworm was active again in 1988, along with New Mexico fir looper. These insects defoliated nearly 6,000 ha (15,000 ac) of mixed conifer forest that had been stressed by winter drying. Table 9 summarizes insect outbreaks and other disease conditions for the period 1976 through 1996 for the Lincoln National Forest (data from Forest Pest Management Reports, Annual Southwestern Region Pest Conditions Reports 1976–1996).

Diseases and Parasites

Dwarf Mistletoe

The greatest incidence of dwarf mistletoe infestation in the Southwest occurs in the Sacramentos (B. Geils, pers.

Table 9. Summary of insects and diseases on the Lincoln National Forest, 1976-1996. See Table 3 for species acronyms.

Year	Bark beetles	Defoliators	Other
1976	Region-wide, less PIPO mortality than in 1975; attacking pole-sized trees.	Low level Douglas-fir tussock moth outbreak on Mayhill RD; NM Fir Looper defoliated 6000 ac of PSME, ABCO.	
1977	Round-headed pine beetle caused scattered losses on Lincoln National Forest, heavy losses on Reservation in PIPO	Western spruce budworm defoliated 500 ac of PSME, ABCO on Smokey Bear RD.	
1978	Round-headed pine beetle killed pole-sized PIPO near Cloudcroft. Scattered mortality from western pine beetle in large trees already weakened. Spruce beetle caused isolated mortality on Lincoln National Forest.	Spruce budworm decreased region-wide in 1978; fir looper populations collapsed in 1978 but 90% of defoliated trees died.	
1979	Round-headed pine beetle decreased region-wide; caused minor PIPO death in Sacramentos; western pine beetle caused PIPO mortality on Lincoln National Forest.		Pinyon needle scale scattered; black stain rot found in beetle-killed PIPO.
1980	Western pine beetle killed small groups of trees; scattered pockets of roundheaded pine beetle activity; fir engraver beetle killed isolated pockets of 2-10 trees.		Black stain root rot found in PSME, a new host record for R-3.
1981	Scattered mortality from western pine beetle; fir engraver beetles killed scattered groups of 2-10 trees; Douglas-fir beetle killed scattered groups of trees; fir engraver killed scattered groups of trees.	Western spruce budworm increased region-wide; small areas of defoliation on Smokey Bear RD.	Spruce gall aphid noted.
1982	Lower tree mortality from beetles region-wide.	New infestations of western spruce budworm on Lincoln National Forest and Reservation; of 4100 ac on Lincoln National Forest, defoliation levels were: 3710 light, 80 moderate, 310 heavy.	
1983	Endemic populations of beetles region-wide; true fir mortality noted, due to a complex of root disease and fir engraver beetle.	Increase in spruce budworm region-wide, extensive defoliation on Lincoln National Forest. Aspen defoliation increased on Lincoln National Forest, Cloudcroft RD by western tent caterpillar, and large aspen tortrix and marssonina blight.	
1984	Pine beetles at low levels region-wide.	Western spruce budworm defoliation increased region-wide; populations successfully suppressed on Lincoln National Forest with insecticide.	Root rot losses exceed mistletoe losses region-wide; shoestring rot in PIPO, annosus rot in PSME, ABCO, PIEN; aspen defoliation continues.
1985	Pine beetles at endemic levels region-wide.	Small, isolated pockets of western spruce budworm defoliation found on Lincoln National Forest, mostly Smokey Bear RD, small due to suppression efforts. Aspen defoliation decreased to undetectable levels on Lincoln National Forest.	
1986	Bark beetle populations increased region-wide. *Ips* engraver beetles caused group and individual mortality on Lincoln National Forest in post-fire or post-logging stands.	Defoliation continues to decrease on Lincoln National Forest. Aspen defoliation increased region-wide.	
1987	*Ips* caused minor PIPO mortality on Lincoln National Forest.	Western spruce budworm decreased region-wide; defoliated 1680 ac on Lincoln National Forest.	*Lophodermella cerina* needlecast disease affected PIPO; 560 ac on Cloudcroft RD.
1988	*Ips* caused 58% of the PIPO mortality on Lincoln National Forest: 450 ac on Cloudcroft RD; 175 ac on Mayhill RD; 2300 ac on Smokey Bear RD; 300 ac on Reservation. Western pine beetle caused mortality on PIPO: 900 ac on Cloudcroft RD; 175 ac on Mayhill RD; 225 ac on Reservation; an 8X increase in PIPO mortality.	Western spruce budworm defoliated 11,830 ac on Lincoln National Forest; NM fir looper defoliated 2600 ac in mixed conifer stressed by winter drying.	*Lophodermella* needle cast disease increased slightly in PIPO: 1300 ac affected, much more on the Reservation.

continued on next page

Table 9. (Continued) Summary of insects and diseases on the Lincoln National Forest, 1976-1996. See Table 3 for species acronyms.

Year	Bark beetles	Defoliators	Other
1989	70% increase in beetles region-wide, mostly in AZ; *Ips* caused single tree and small group mortality on Lincoln National Forest; western pine beetle killed 130 ac on Lincoln National Forest.	Spruce budworm decreased region-wide; defoliated 600 ac on the Reservation.	Precipitation below average 1989-1990. *Lophodermella* continues to infect PIPO; *Rhabdocline pseudotsugae* needle cast disease affected PSME near Cloudcroft.
1990	3X increase in bark beetles region-wide; small group mortality from *Ips* on Lincoln National Forest	Increase in spruce budworm region-wide.	Below average precipitation 1989-1990; white pine blister rust first detected on 80 square miles in the Sacramentos; *Lophodermella* infection continues on PIPO.
1991	*Ips* caused small group mortality on Lincoln National Forest; western pine beetle increased; in combination with roundheaded pine beetles, killed drought-stressed trees on 71,785 ac on the Reservation, 10,135 ac on Lincoln National Forest.	Western spruce budworm decreased region-wide; defoliated 300 ac on Lincoln National Forest; Douglas-fir beetle caused single tree and group mortality; increase in aspen defoliator complex (aspen tortrix, western tent caterpillar, and marssonea blight) in pockets on Lincoln National Forest.	300,000 ac infected with white pine blister rust, causing branch mortality, top-kill, dead saplings. True fir mortality in small groups from complex of fir beetle and *Armillaria* rot; *Atropellis* canker, similar to blister rust, found on pole-sized white pine.
1992	Pine beetle complex (roundheaded pine beetle, western pine beetle, and larger Mexican pine beetle) caused mortality on 9,313 ac on Lincoln National Forest, 11,385 ac on the Reservation. Douglas-fir beetle caused small group mortality on 15 ac, spruce beetle killed scattered groups of 2-5 trees.	Western spruce budworm defoliated 40 ac on the Smokey Bear RD.	Precipitation above normal. Pinyon needlecast disease severe but not positively identified.
1994	Pine beetle complex killed trees on 15,370 ac in the Sacramentos, 16,750 ac on the Reservation. *Ips* caused small group mortality in PIPO. Spruce beetle killed scattered groups of 2-5 trees.	Western spruce budworm defoliated 240 ac on Lincoln National Forest. Aspen defoliator complex active in pockets on Lincoln National Forest.	True fir mortality continued from fir beetle and *Armillaria*; *Lophodermella* needlecast continues on 40 ac of PIPO.
1996	*Ips* active near Cloudcroft. Roundheaded pine beetle infested 4,305 ac on Lincoln National Forest; both populations in decline. Spruce beetle infested 35 ac, fir engraver 165 ac.	Western spruce budworm defoliated 40 ac on Lincoln National Forest. Aspen defoliator complex affected 960 ac on Lincoln National Forest.	Drought 1995-1996, with increased wildfire and beetle outbreaks.

comm. USDA Forest Service, 1997). Dwarf mistletoes (*Arceuthobium* sp.) have been parasites of conifers in the Southwest since at least the Pleistocene. They are co-evolved, species-specific parasites. In the Sacramento Mountains, *A. vaginatum speryptopodum* infects ponderosa pine and *A. douglasii* infects Douglas-fir (Wilson and Tkacz 1993). Unlike other pathogens such as root rots, dwarf mistletoes do not usually kill their hosts outright, but they do reduce diameter, height, and volume growth of trees and accelerate mortality when infestations are severe. They predispose ponderosa pines to attacks by bark beetles (Hawksworth et al. 1989). By 1986, 36 percent of the commercial ponderosa pine in the Southwest region was infected by dwarf mistletoe (Hessburg and Beatty 1986). Dwarf mistletoes are considered the most significant disease-causing organisms in the Southwestern region (Forest Pest Management Reports, above).

Past distribution of dwarf mistletoe may have been largely controlled by fire. Infected trees are less likely to survive fires because of the flammable "brooms" low in the crowns, and because infected trees are less vigorous, they are less likely to recover from even moderate amounts of crown scorch. Prescribed fires may be effective in controlling dwarf mistletoe, provided that infected trees are scorched or killed to prevent mistletoe spread (Harrington and Hawksworth 1990). Past attempts to control dwarf mistletoe have had undesired effects. Following a treatment in 1953 in which infected branches and young trees were cut and the slash was scattered, bark beetles, particularly *Ips*, multiplied in the slash and attacked the remaining trees.

Fire suppression and harvest practices have increased the incidence of mistletoe infection in the Sacramento Mountains. Hessburg and Beatty (1986) surveyed 500 ha (1,240 ac) of commercial ponderosa pine forest in the Lincoln National Forest, along 124 km (77 miles) of road. The survey found that 70 percent of the stands were infected by dwarf mistletoe, and in 42 percent of those stands, more than two thirds of the trees were infected. The incidence of dwarf mistletoe was greatest on the Sacramento Ranger District, with 77 percent of surveyed ponderosa pine stands infected on the old Cloudcroft Ranger District, and 71 percent of surveyed stands infected on the old Mayhill Ranger District. When the survey results were compared with data from a region-wide study done between 1954 and 1957 (Andrews and Daniels 1960), it appeared that the incidence of dwarf mistletoe had increased by 6 percent in 25 to 30 years, and the incidence of dwarf mistletoe in the Sacramentos was twice the regional average. Incidence had increased the most in pole-sized stands. Hessburg and Beatty (1986) attributed this change to selective harvest practices that took the largest, healthiest trees and left infected trees, and to a lack of priority given to treatment of infected stands in the past.

Fungal Diseases and Other Pathogens

Holmes (1906) observed that "there is considerable defect from 'punk' on some slopes; as much as 10 percent of the timber is damaged; sometimes it affects chiefly balsam [white fir], while in other canyons it is nearly all red fir [Douglas-fir] that is affected." He was probably referring to some of the various stem rots that are prevalent in the Sacramento Mountains. *Armillaria* root disease is caused by a fungus that spreads outward by fungal transfer from tree to tree at up to 1 m (3 ft) per year, from disease centers that may survive for centuries, infecting subsequent regenerating trees. *Armillaria* can cause mortality in ponderosa pine but generally does less damage to pines than to white fir and Douglas-fir (Harrington and Hawksworth 1989). Shifts in dominance to susceptible species and increases in tree density have increased the incidence of *Armillaria* root disease in the Sacramento Mountains. Trees infected with *Armillaria* may eventually die of root disease but more often are killed by windthrow or breakage (Geils et al. 1995). *Annosus* root disease also affects ponderosa pines, particularly seedlings established around infected stumps. Large white fir may also be infected. Spores are spread by the wind and establish especially well on freshly cut stumps. Needle cast fungi, which cause reddening and premature cast of foliage, damaged nearly 8,000 ha (20,000 ac) of ponderosa pine on the Mescalero Apache Reservation and the Lincoln National Forest in 1987 (Harrington and Hawksworth 1989).

White Pine Blister Rust

White pine blister rust (*Cronartium ribicola*) is an exotic fungus that kills white pines throughout the west, particularly whitebark pine (*Pinus albicaulis*). It was first introduced into the Northwest around 1910 (Dahms and Geils 1997) and was discovered on the Lincoln National Forest on southwestern white pine near Cloudcroft in March 1990 (Hawksworth 1990, Hawksworth and Conklin 1990, Wilson and Tkacz 1993). In the Sacramento Mountains, five species of *Ribes*, particularly the common orange gooseberry (*Ribes pinetorum*), serve as obligate intermediate hosts for white pine blister rust.

The first infestations may have occurred as early as 1970 and have continued in waves. By 1994, in Pendelton Canyon, Water Canyon, and Silver Springs Canyons, up to 90 percent of the southwestern white pines were infected. Young trees are the most susceptible to damage. Because of 20th century changes in forest structure, much of the southwestern white pine in the Sacramentos, one of the largest populations in the world, is young regeneration. The outbreak of white pine blister rust is expected to remain chronic and severe in the Sacramento Mountains and is likely to result in a population crash of the species, though less likely to cause its extinction. The damage and the epidemic are predicted to get worse (Kinloch 1994). The Sacramento Mountains may serve as an inoculum source that threatens other white pine populations in the Southwest and Mexico (Dahms and Geils 1997).

Comparison and Summary of Historic and Existing Forest Conditions

Unlike much of New Mexico, the Sacramento Mountains were not occupied intensively or continuously by humans until the late 1800s. The White Mountains and the area around Sierra Blanca to the north had more reliable water sources and were therefore more intensively occupied by both the Apaches and the European-Americans than were the Sacramentos, until the 1880s. Therefore, it seems safe to assume that the conditions observed by the early surveyors and settlers in the 1880s were very close to the pre-settlement, or "natural," state of ecosystem structure and processes as they had existed for centuries. Rapid settlement and exploitation in the form of logging, grazing, and development quickly altered these conditions, disrupting regimes of frequent, patchy, low-intensity disturbance that had maintained an open, heterogeneous forest over most of the mountain range.

Pre-settlement ecosystems are still in place, albeit structurally and compositionally altered. At the lowest elevations that supported trees, open pinyon-juniper woodland covered the slopes. According to the General Land Office Survey, these woodlands often had an understory of dense oak scrub that also filled large openings between trees, and a carpet of bunchgrasses that was continuous under trees and shrubs alike. Ponderosa pine was scattered through much of the woodland even at low elevations. Historically, most of the mountain range was covered with mixed conifer forest. Large areas dominated by ponderosa pine are now experiencing dense ingrowth of Douglas-fir and white fir in the absence of frequent surface fires. Based on recorded observations and ecological reconstructions, it seems unlikely that the Sacramento Mountains ever supported an extensive, pure ponderosa pine/grass savanna such as was common in parts of Arizona, except possibly some areas on the eastern slope. None of these stands remain. Even the forests that may have been classified as ponderosa pine habitat types had shrubby oak understories. The presence of Douglas-fir as a historic canopy component is attested to by the age distribution of old-growth stands (Fig. 24).

However, frequent surface fires maintained a forest that was more open than that of today, and one that was more strongly dominated by ponderosa pine. Douglas-fir was interspersed with ponderosa pine even on the warmest, driest slopes, forming forests of the Douglas-fir/oak habitat types. Aspen was also a common, though patchy, component of the canopy, occasionally forming pure groves or thickets (See Fig. 15 for an example of a pure aspen stand with very large trees as late as 1928). Dense oak shrubs underlain by bunchgrasses formed a continuous understory throughout the mountain range. Above about 2462 m (8000 ft) and on cooler, wetter sites such as north-facing slopes, aspen, white fir, and southwestern white pine were components of the canopy along with scattered Douglas-fir and ponderosa pine, forming forests of the white fir habitat type series. Juniper persisted on drier sites. The mix of Douglas-fir and ponderosa pine varied according to site conditions. At higher elevations and on cool, wet sites, Douglas-fir was more common than ponderosa pine, forming nearly pure stands in some places but usually still mixed with pines, white fir, and other species. Douglas-fir has an affinity for limestone-derived soils, which are the primary soils in the Sacramentos. Holmes (1906) noted that Douglas-fir was the most common tree in the Sacramentos and that it generally grew the largest; it was "nearly always present in greater or less quantities, but it is occasionally outnumbered by the Engelmann spruce on high northern slopes, and by the yellow pine [ponderosa pine] on low southern slopes" (Fig. 25 a, b).

Near the summit, dominance of the understory by oak shrubs weakened, and the oaks were mixed with other shrubs in a continuous shrubby understory: oceanspray, New Mexican locust, gooseberries, wild cherry, maple, dogwood, and forest willow were noted understory shrubs. Only the coldest and wettest sites, where snow stayed late, lacked a shrubby understory and were dominated by forbs. At higher elevations, the grass cover under the shrubs was infrequent, confined to openings and riparian areas. A few pockets of Engelmann spruce occurred in areas of cold-air drainage at the highest elevations along the crest. For the most part, the present high-elevation ecosystems have been less radically changed from historic ones in terms of species composition, but their age and size structures have shifted from more open forests with large trees of uneven ages to even-aged young stands.

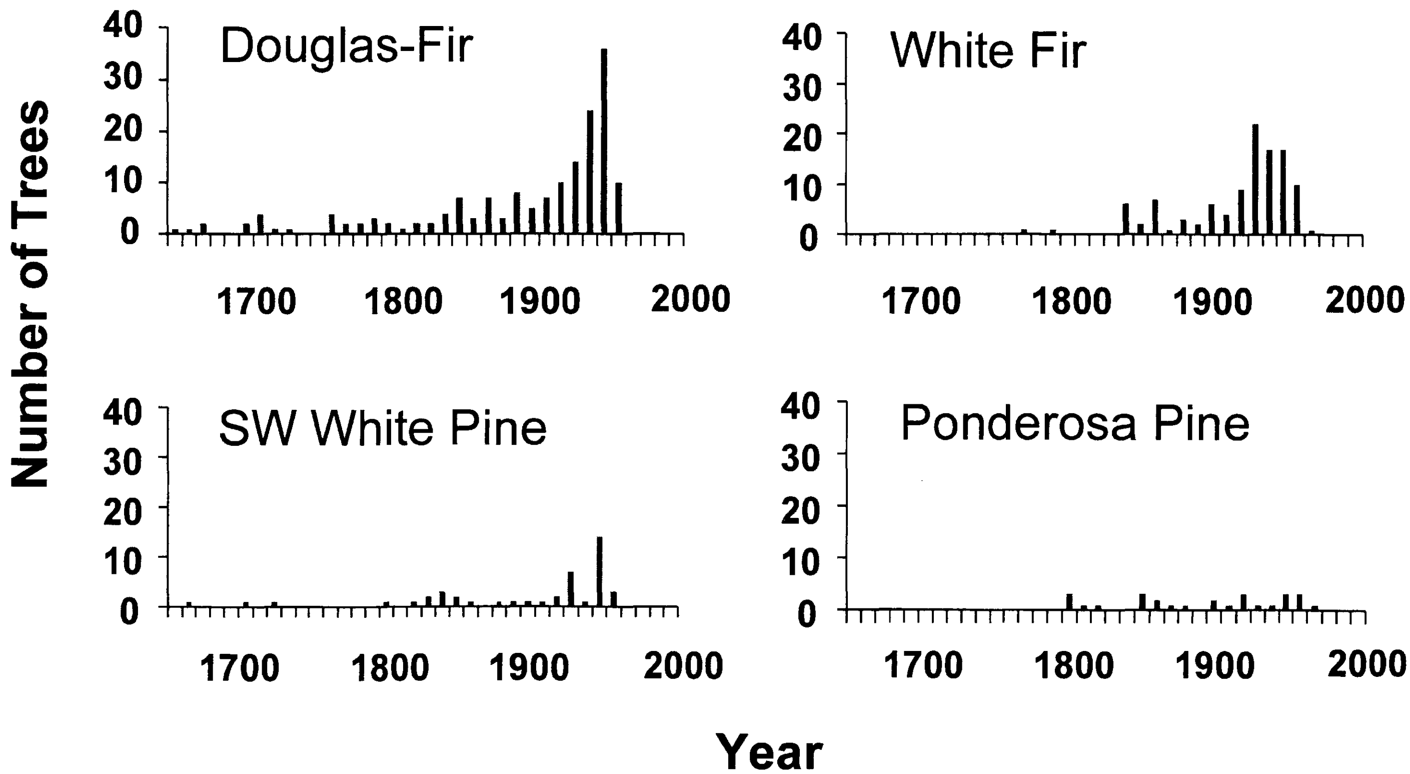


Figure 24. Number of trees recruited in 10-year intervals for Douglas-fir, white fir, southwestern white pine, and ponderosa pine in old-growth forests in the Sacramento Mountains. These data are a composite of old-growth mixed conifer stands that encompass the full elevational and moisture gradients on which mixed conifer forests are found. While the white fir component has few trees older than 150 years, Douglas-fir shows steady establishment for nearly 400 years, with a spike of recruitment in the 20th century. From Regan et al. (1997).

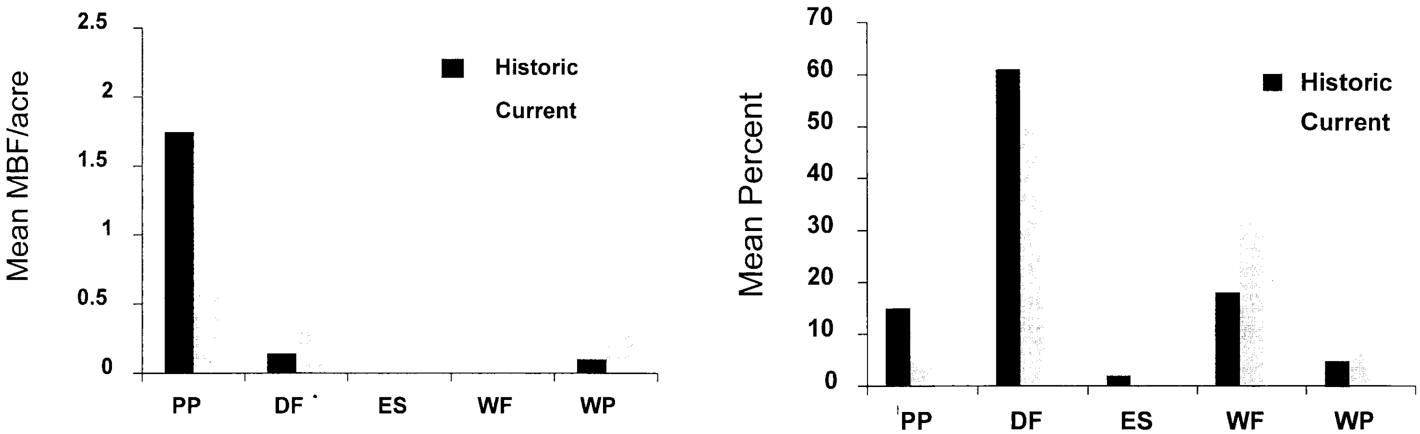


Figure 25 ***a.*** *Percentage species composition of the historic Douglas-fir (mixed conifer) forest type compared with that of the existing mixed conifer forest. PP=ponderosa pine; DF=Douglas-fir; ES=Engelmann spruce; WF=white fir; WP=southwestern white pine. The percentages of ponderosa pine and Douglas-fir have declined, while white fir and southwestern white pine have increased. Engelmann spruce, always a small component of mixed conifer stands, has declined also.* ***b.*** *Percentage species composition of the historic ponderosa pine forest type compared with that of existing pine forest. Abbreviations are the same as 25a. Ponderosa pine has declined by about 25%, while Douglas-fir has increased by about 20%. White fir and southwestern white pine volumes have not changed much. Historic data are from the Lincoln National Forest historic timber atlas, modern data from the RMRIS database. These sites were inventoried before they were logged, and represent the inventory for merchantable timber volume, so the focus is on the larger, dominant or co-dominant trees.*

The most outstanding feature of the historic forest of the Sacramento Mountains was its heterogeneity, and the most profound effect of European-American presence has been the homogenization of the forest, in terms of structure across the landscape and disturbance regimes. Woolsey (1911) noted "the open and grouplike character of even the heaviest existing stands of western yellow pine (ponderosa pine) in the Southwest" (Fig. 26). Like many of his contemporaries, Woolsey made some fairly astute observations about the ecosystems he observed but interpreted them through the cultural filters of his time: "Most of the stands on the National Forests in the Southwest are virgin, and consequently the mature timber that goes to waste each year is a great loss...full use is not made of the forest unless the mature timber is cut and the thrifty growing immature stands left for future needs...it is the desire of the Forest Service not only to maintain a sustained annual yield, but to improve the quality of the timber...the Forest Service is bound to dispose of all over-mature timber, and if this is done the annual cut must be more than the estimated annual growth of the normal forest" (Woolsey 1911:48). The patchy structure and areas of old-growth in the natural forest were noted but were not considered a desirable condition. The paradigm of the time was that humans could improve upon the natural condition of the forest to use it more efficiently, and that was what was done.

Overgrazing coupled with drought and erosion quickly eliminated continuous grasses under the tree and shrub canopy, effectively retarding the spread of surface fires some 20 to 30 years before active fire suppression began (Fulé et al. 1997, Touchan et al. 1995). By the time grazing pressure was alleviated, a policy of aggressive fire suppression was in place. Elimination of the patchy surface fire regime has eliminated the primary mechanism for creating patches of different size and age structures (Fig. 27 a, b). Clearcut logging has created large areas of young forest of nearly uniform age and size. Stands that were not cut were either inaccessible or were not structurally desirable—young stands or trees on poor sites. In the absence of fire, species composition has shifted to dominance by Douglas-fir and white fir at lower elevations, and increasing stand density at higher elevations has reduced the ponderosa pine component. This effect was compounded by severe outbreaks of pine bark beetles in the regenerating ponderosa pine during the 1920s and 1930s, which killed many of the pine saplings and left Douglas-fir and white fir saplings to dominate the young forest. Subsequent canopy closure precluded further ponderosa pine regeneration.

The proportion of the forest that might have been classified as "old growth" was historically larger than what exists today. Stands with old trees, a high percentage of large trees, and a complex structure were probably always scattered across the landscape but were more common among the cooler, wetter forests at higher elevations, where stand-replacing fires were less frequent (Fig. 28; Regan 1997). Old-growth stands at lower elevations probably existed under slightly different conditions, with fewer large trees on drier sites and a less complex structure due to more frequent surface fires, but including old trees nonetheless. Regan (1997) recommended a revised definition of old-growth forest that can accommodate such stands. Based on reconstructions by Regan (1997) using her revised definition of old-growth, as much as 74 percent of Engelmann spruce stands, 10–26 percent of mixed conifer stands, and 3 to 6 percent of ponderosa pine-dominated stands would have been considered old growth in

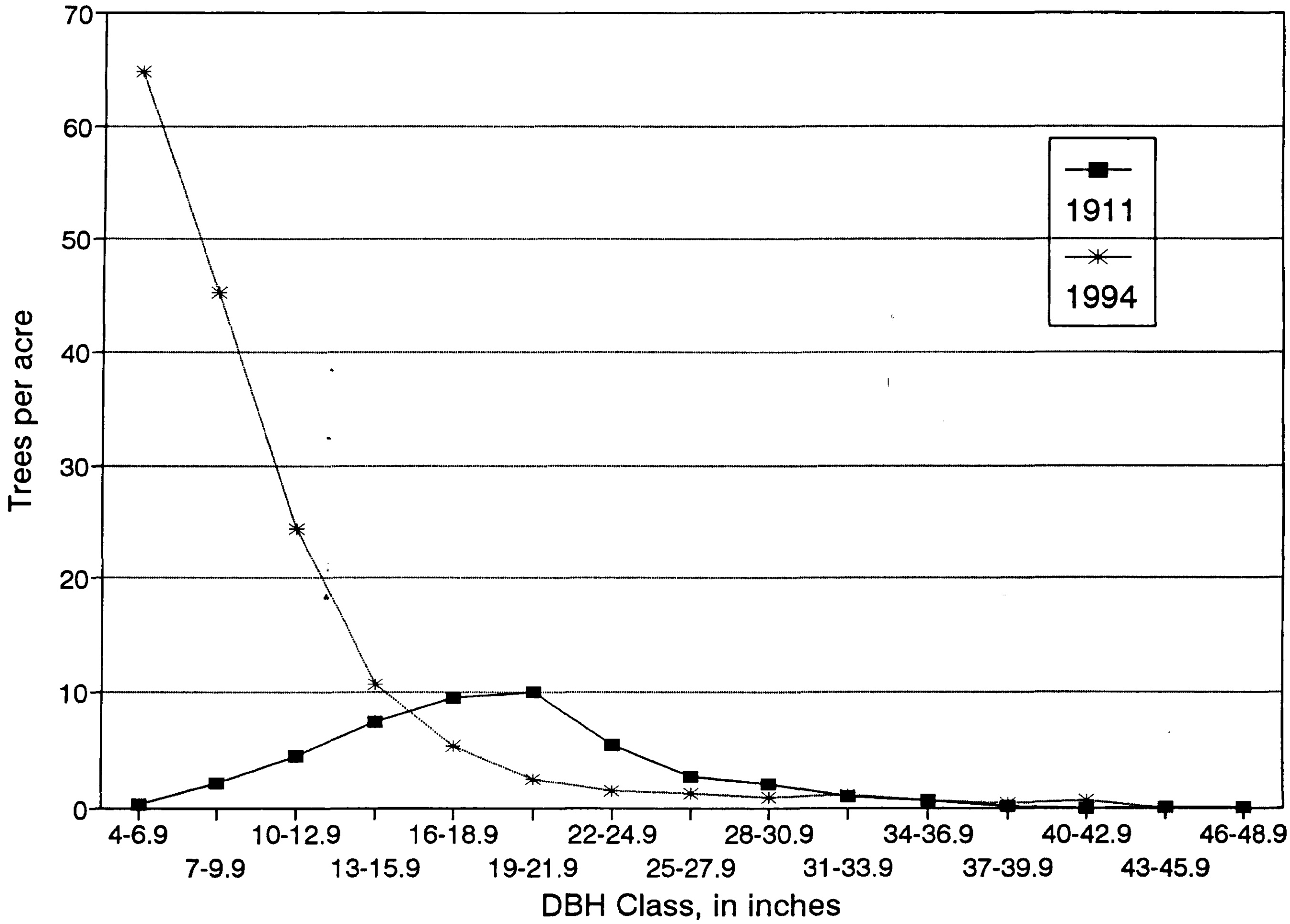


Figure 26. Number of trees by size class in ponderosa pine forests of the Sacramento mountains, 1911 and 1994. There are many more trees in the smallest size classes in the modern forest than in the 1911 forest, where there were fewer trees in general and more of the middle size classes. The 1994 forest shows the inverse-j curve typical of a young forest, while the 1911 forest shows more of a bell-shaped curve. 1911 data are from Woolsey (1911); 1994 data are from the Lincoln National Forest RMRIS database.

1880, compared with less than 5 percent of the total forest of all habitat types today. Ponderosa pine old-growth is probably underestimated because no reliable age-diameter data exist. No old-growth ponderosa pine remains in the Sacramentos today.

The homogenization of size and age structure, the increase in density, and the shift to dominance by Douglas-fir and white fir in areas previously dominated by ponderosa pine have left the forest more susceptible to more intense and spatially widespread disturbances by increasing connectivity. Insect outbreaks now occur more frequently, kill more trees, and affect larger areas in this homogeneous forest than in the historical forest. Dwarf mistletoe infects a larger percentage of the forest. Fires now often burn as intense crown fires over huge areas, rather than burning as surface fires that only occasionally erupt into localized crown fires to create stands of aspen. Fires can now burn only under extreme conditions that exceed suppression capability, and fuels have built up to high levels after nearly a century without less intense surface fires to reduce them. The species that now dominate the forest are not generally fire-resistant, as the ponderosa pines were, and the density of saplings in the understory, which have established in great numbers in the absence of surface fires, provide ladder fuels into the canopy. Because these conditions are uniform and continuous over large areas, fires can spread quickly rather than being stopped by natural structural fire breaks that existed in the more heterogeneous historic forest.

Elements of the historic forest persist, however. The prevalence of a dense, shrubby oak understory does not seem to be solely the product of fire suppression or grazing, as has been thought; the oaks were, if anything, even more ubiquitous in the historic forest than they are now. Gambel oak and wavy-leaf oak are susceptible to fire but are prolific sprouters following surface fires. Most of the mountain range was covered with a mixture of species that would probably have been classified as mixed conifer forest, though in many areas ponderosa pine was dominant. Holmes (1906) observed that only one type of forest

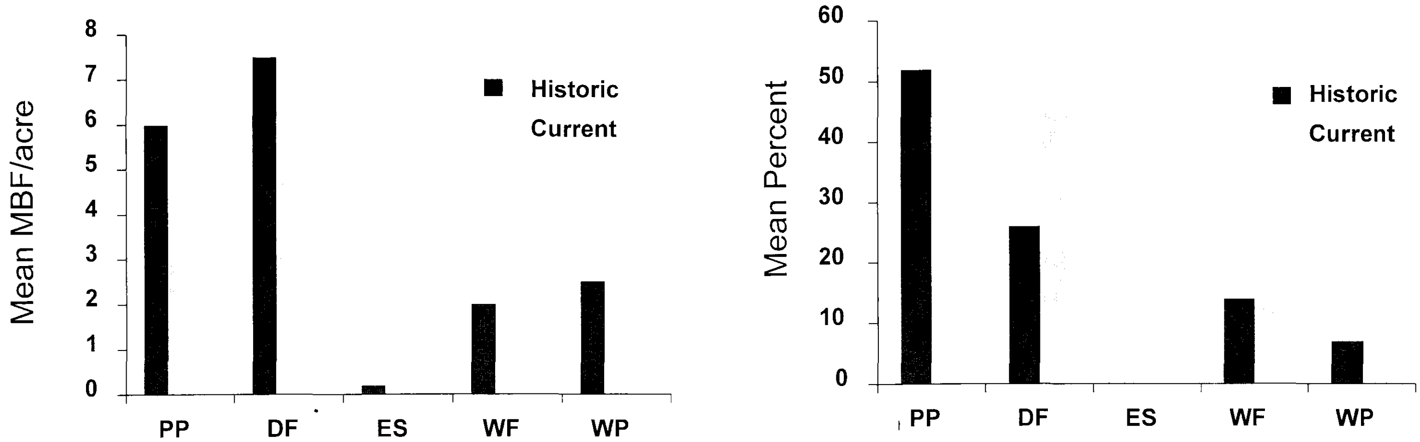


Figure 27 ***a.*** *Comparison of wood volume by species in the historic and contemporary Douglas-fir (mixed conifer) forest type in the Sacramento Mountains. Wood volume reflects not only the number of trees, but the size of trees as well. The increase in volume in white fir and southwestern white pine is due mostly to large numbers of young, small trees.* ***b.*** *Wood volume by species in contemporary and historic ponderosa pine forests. Increases in volume are mostly due to large numbers of young, small trees. Note the small total wood volume compared with the mixed conifer forests, indicative of the relatively low productivity of the ponderosa pine stands. Data are from Lincoln National Forest databases.*

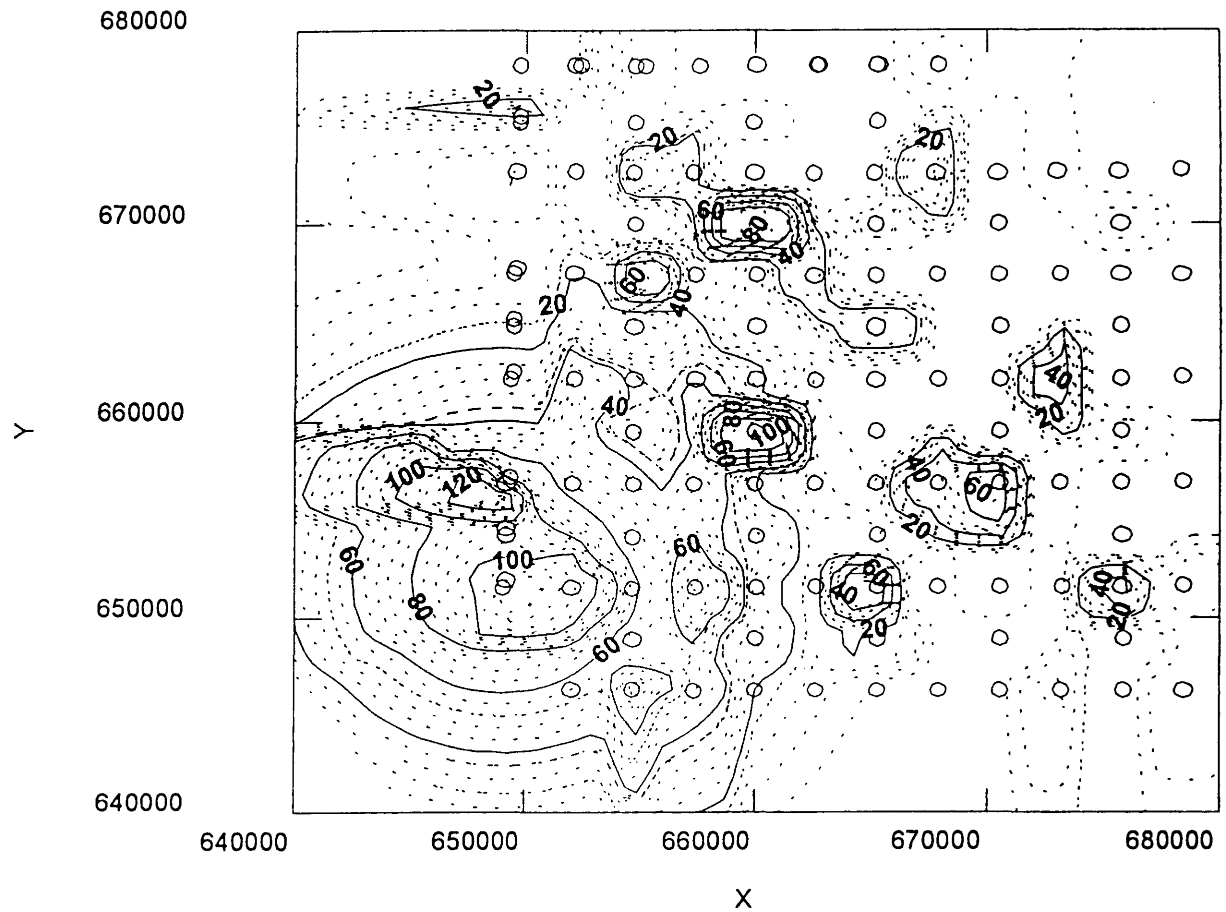


Figure 28. Large tree (≥ 53 cm dbh) density in reconstructed old-growth forest in Block 4, based on General Land Office survey data. Density is depicted using a "contour interval" format, where lines represent specified numbers of large old trees/ha. Block 4 was a mesic mixed conifer forest at the crest of the Sacramentos that was sampled before logging began in 1899; numbers along the axes are State Plane coordinates. Large old trees are concentrated in patches. Of the total area, 33.2 percent had 11-20 stems/ha; 14.6 percent had 21-40 stems/ha; 11.0 percent had 41-60 stems/ha; 6.0 percent had 61-80 stems/ha; 5.1 percent had >80 stems/ha. A total of 36.7 percent of the total area of Block 4 would have been classified as old-growth before 1899 based on the definition of old-growth derived from large tree densities. From Regan (1997).

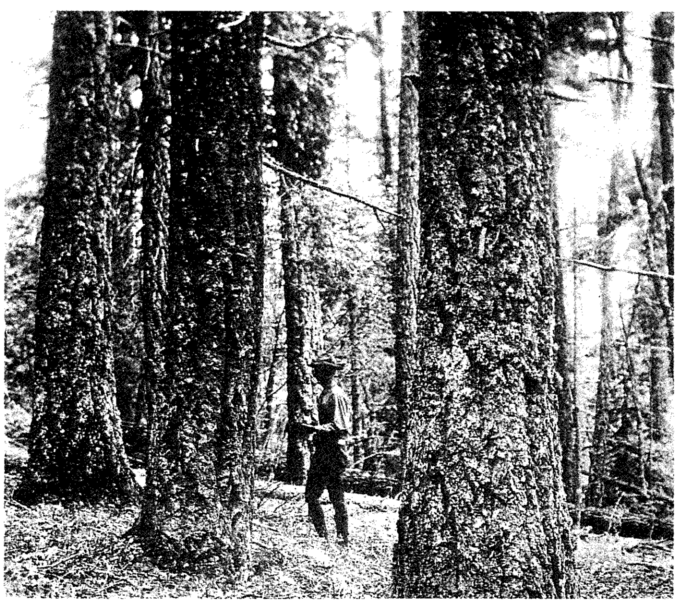
was found above 2462 m (8000 ft), a fir type with white fir, Douglas-fir, and occasional Engelmann spruce, with an open, shrubby understory and a ground cover of grass and perennial herbs—a good description of the present white fir/oak and white fir/maple habitat types.

Aspen stands occurred as inclusions within the historic mixed conifer forest. Aspen is considered a seral tree in the Sacramento Mountains and is usually found in openings caused by fire or other disturbance, though it may persist in the canopy of mixed conifer forest as well. Aspen is a clonal species that sprouts readily from rootstocks that can survive for long periods of time. Aspen is generally declining in New Mexico, mostly as a consequence of fire suppression (Dick-Peddie 1993, Sallach 1996). In the Sacramento Mountains, as elsewhere in the Southwest, many aspen stands are being invaded by conifer saplings. Aspen sprouts are very attractive to wildlife and domestic livestock and are often eaten back as quickly as they emerge. Aspen is also susceptible to a variety of insects and diseases, which usually attack mature stands. A complex of western tent caterpillar (*Malacosoma californicum*) and large aspen tortrix (*Choristoneura conflictana*), combined with Marssonina leaf blight (*Marssonina populi*), has been observed to defoliate aspen in recent years, and various trunk rots and stem cankers cause significant reductions of growth and vigor in mature stands.

In some parts of New Mexico, aspen has been observed to invade meadows that have been over-grazed and from which fire has been excluded, though this does not seem to be happening in the Sacramentos (Dick-Peddie 1993). Individual aspen trees rarely live more than 150 years, and many stands initiated at or before the turn of the century are old, susceptible to disease, and overtopped by conifers. The aspen component of the modern forest is probably smaller than in the historic forest.

Subalpine forest is more common in the northern part of the Lincoln National Forest, around Sierra Blanca, above 3077 m (10,000 ft) elevation. The diagnostic species is Engelmann spruce, an indicator of cold temperatures, here found at its southernmost distribution. Around Sierra Blanca, Engelmann spruce occurs with subalpine fir in zones of high snowfall and accumulation, forming communities similar to spruce-fir communities in the Rocky Mountains to the north. In the Sacramento district, spruce forests are found in pockets of cold air drainage at high elevations (2738–2831 m; 8900–9200 ft), notably in Hubbell and Sacramento Canyons (Alexander et al. 1984). Subalpine fir is absent, and Douglas-fir is the common co-dominant tree; Rocky Mountain maple is the common understory shrub. Engelmann spruce was probably never very common or widespread in the Sacramentos, as the General Land Office survey and early observers agreed.

Historic forests were generally much more open than those of the present, with more large, older trees, more widely spaced and generally without the dense thickets of evergreen saplings present today (Fig. 29 a,b). Historic



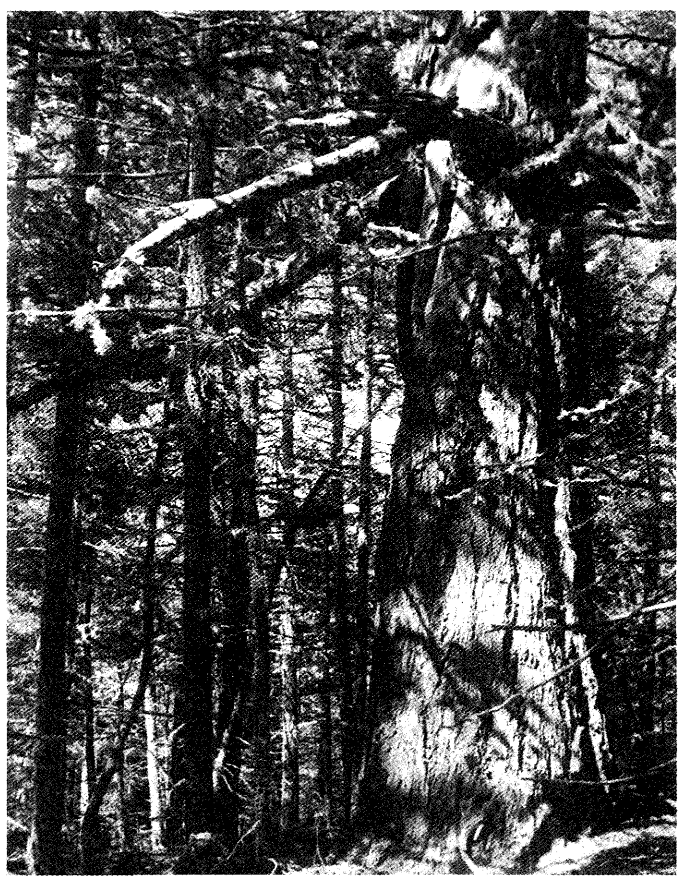


Figure 29 ***a.*** *(above) Cruising Douglas-fir, 1928. Note the tremendous size of the trees and the openness of the understory. US Forest Service photo 233423, Lincoln National Forest Heritage Resource Program collection in Alamogordo, on file at the Lincoln National Forest Supervisor's office.* ***b.*** *(right) Large, old Douglas-fir surrounded by dense ingrowth, Peake Canyon, 1994. Photo by Laurie Huckaby.*

forests were more variable in age and size of trees across the landscape. Patches of old trees were interspersed with patches of young trees, aspen, and openings, where surface fires had become localized crown fires or had burned more intensely in a particular area.

In addition to disrupting the historic disturbance regime in the ecosystems of the Sacramento Mountains, the homogeneity of the vegetation also makes those ecosystems less resilient in the face of other disturbances that may be secondary to those that had the homogenizing effect. Invasions of non-indigenous species, such as white pine blister rust, are severe and widespread. Extreme weather events have had dramatic effects on an already stressed ecosystem (witness the droughts of 1904 and the 1950s). The effects of possible future climate changes are yet unknown.

PART VI. USING INFORMATION IN THE ECOSYSTEM NEEDS ASSESSMENT PROCESS

The extensive information of the previous sections is useful for understanding the cultural and natural history of the Sacramento Mountains and provides considerable insight into human-induced changes in the Sacramento Mountains ecosystem. In the introductory section on Ecosystem Management, the concept of an ecosystem needs assessment was discussed as a more specific way to determine how human activities have altered ecosystems. The assessment process may be used to evaluate the ecological consequences of human activities to ecosystems that need attention if important features of ecosystems are to be conserved or restored. While this document focuses on the reference or historic ecological conditions of the Sacramento Mountain ecosystem, we will illustrate how reference conditions might be used in an ecosystem needs assessment process. This is done here only as an example and only qualitatively. An actual assessment requires careful consideration of both historic and current conditions, including considerable mapping and quantitative analysis of data. Such an effort is best left to local professionals who have ready access to all pertinent and available data and information and who can garner the resources needed for such an analysis.

The assessment process may be done in various ways, but most assessments have certain common features (Dahms and Geils 1997, Haynes et al. 1996, Kaufmann et al. 1994, Quigley and Bigler-Cole 1997, Quigley et al. 1996, US Forest Service 1996). We list the following as steps that should be included, based on Figure 1:

1. Review applicable ecological principles.
2. Set the spatial and temporal framework for the issues being addressed.
3. Describe the existing condition of the analysis area at relevant scales of time and space.
4. Examine reference or historical ecological information relevant to the analysis area.
5. Compare existing conditions with reference conditions (the coarse-filter process).
6. Evaluate the uncommon, sensitive, or threatened components of the system, both current and past (the fine-filter process).
7. Identify ecological concerns or needs about existing conditions *based on ecological principles applied at appropriate scales of space and time.*

A common difficulty of ecological assessments is that they often quickly become more complex and bogged down by detail than is necessary. It is helpful to treat the assessment process as an iterative one, as software development has been done for personal computers. The first version can be quite simple, focusing for example on a qualitative review of all the information available to identify the most obvious ecological problems, which are usually related to individual ecological issues. It might be done by experienced professionals meeting for only a few days. The second version focuses more clearly on a quantitative examination of the differences between existing and reference ecological conditions, including both the coarse-filter and fine-filter components of the ecosystem assessment process. Earlier versions may address only a single ecological issue. Their value should not be underestimated, however, because even rather gross generalizations, if adequately documented, may change the course of resource management. They also provide a learning experience and serve as a basis for later versions that address ecological integrity more thoroughly by incorporation of multiple ecological issues. The fourth or fifth version will be much more complex than the earlier versions. The more advanced version should be a more thorough qualitative and quantitative analysis of ecological problems, often in relation to multiple identified issues at multiple spatial and temporal scales, and should identify spatially explicit changes that are needed to assure or improve ecological integrity.

In the Sacramento Mountains, a number of ecological issues may be raised that are either coarse-filter or fine-filter in nature (Fig. 30). We have selected potential issues for which a range of information is available for the assessment process, and we will use these to illustrate what might be accomplished during progressive cycles or versions of the assessment process. The following partial list includes the type of information available for addressing each issue.

Coarse-filter issues and types of information available:

- Old-growth forests — Patch and stand characteristics, limited landscape characteristics, very general maps
- Fire as an ecosystem process — Fire histories, stand conditions, recent maps
- Riparian areas — Limited data on historic features, more data on uses of riparian areas since settlement

Fine-filter issues and types of information available:

- Wolf — Records of historic presence, limited data on population densities before extirpation
- Mexican spotted owl — Limited data on historic populations, extensive data on current status
- White pine blister rust — Evidence of introduction by 1990, limited information on long-range consequences to the ecosystem

For each of these issues, we suggest the specific types of information that might be available and appropriate for successive versions of the assessment process, and a possible conclusion that might be reached for each version. *Note that these are hypothetical and are not based on an actual selection and use of appropriate data in the assessment process, even though the possible conclusions might seem reasonable in some cases.*

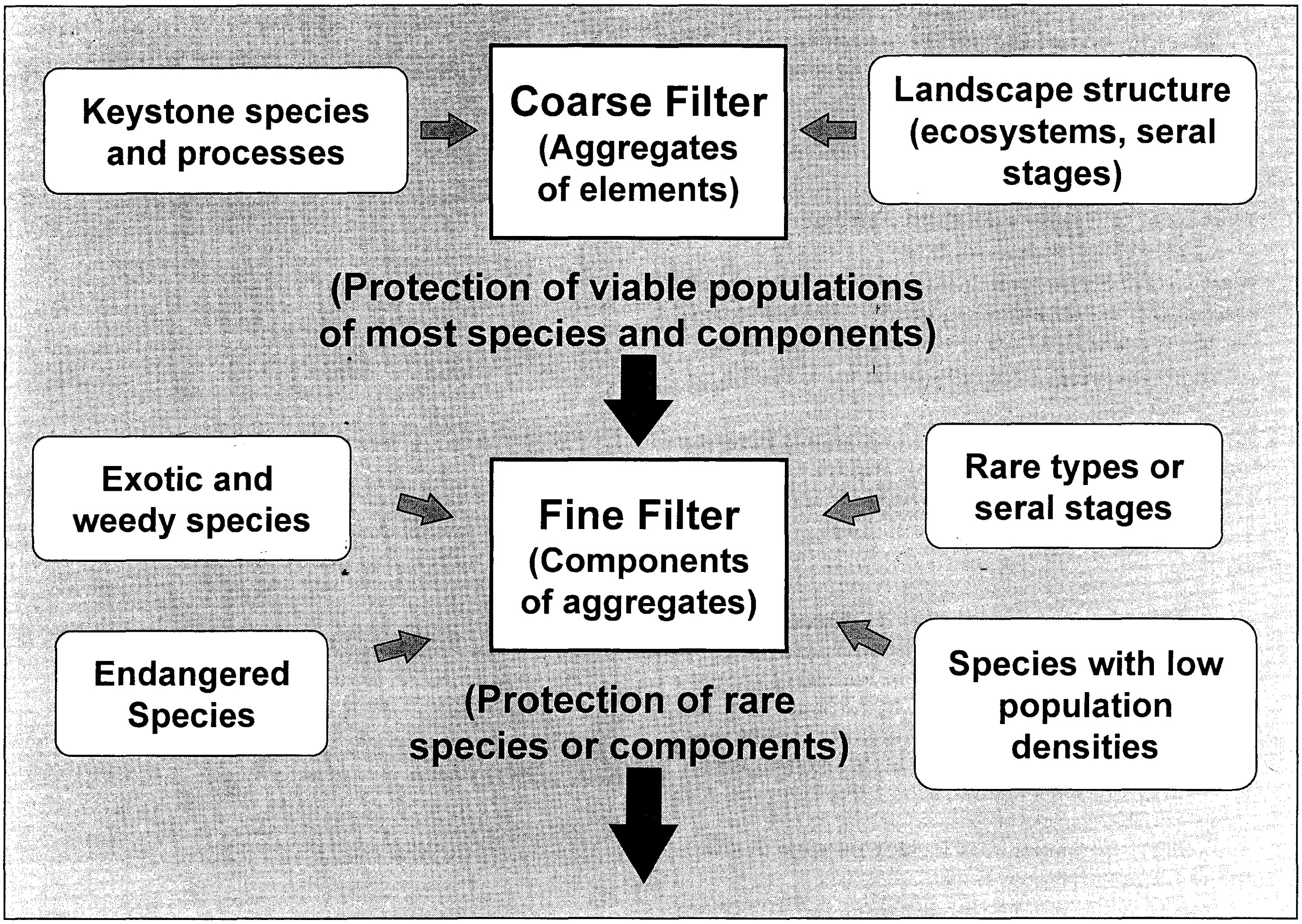


Figure 30. Additional features of the relationship between coarse filter and fine filter components of the ecosystem needs assessment process shown in Fig. 1.

Iterative Assessment Processes

Old Growth

Defining what constitutes old-growth forest in different vegetation types and determining where it is located are vital to managing them sustainably. Reference conditions derived from various sources, including remaining old-growth stands, are important to understanding the historic role of old-growth on the landscape. Some of this work has been done in the Sacramentos (Regan 1997, Regan et al. 1997; Fig. 31).

Version 1 – Information may include general effects of logging and fire suppression on old-growth forests.

Possible conclusion: present forests contain only a fraction of the old-growth component that existed historically.

Version 2 – Information may include a general description of past and present extent of old-growth forests by forest type, the relation of these forests to natural disturbance phenomena (especially fire) and logging, and the ecological consequences of the present condition.

Possible conclusion: extensive logging and altered fire regimes have drastically reduced the spatial extent of old growth, resulting in multi-layered forest stands with younger trees and higher than normal densities of fire-intolerant species.

Version 4.x – Information may include spatially explicit present and past age structure, size distribution, and species composition of forests that characterize past and present spatial and temporal heterogeneity in the landscape, and lists of changes that will mitigate these problems.

Possible conclusion: most large ponderosa pine trees in [name area] have been removed, resulting in forests having [describe present species, age and size structure]. Rem-

nant stands of old growth have increased numbers of fire-intolerant species [describe]. To restore some of the historic spatial and temporal heterogeneity, forest structure in this area can be improved by [identify treatments].

The following questions might assist the assessment of old-growth forests:

- What were the spatial extent and distribution patterns of old growth for each forest type?
- What were the structural characteristics of old-growth patches and stands, including species composition and the age and size structure for the major forest types?
- What processes regulated old-growth forests in the historic landscape?
- What was the understory plant and animal diversity found in old-growth landscapes, and how has diversity changed with the loss of old-growth forests?

Fire

Historic landscapes were shaped by disturbance processes that have been altered by recent human activity. Restoration of those processes may be necessary on some level to manage forests sustainably. In the Southwest, fire has historically been a defining process on landscapes. Information about historic fire regimes is available for the Sacramento Mountains (Brown et al. 1998, Huckaby and Brown 1995, Wilkinson 1997).

Version 1 – Information may include the general effects of fire suppression on forests.

Possible conclusion: present forests are at risk of abnormally intense wildfires and insect/disease outbreaks.

Version 2 – Information may include historic mean fire return intervals for specific areas and forest types and the ecological consequences of changes in these patterns.

Possible conclusion: reduced fire frequencies and timber harvest practices have resulted in multi-layered forest canopies and higher than normal stand densities.

Version 4.x – Information may include spatially explicit present and past age structure, size distribution, and species composition of forests that characterize past and present spatial heterogeneity in the landscape and lists of changes that will mitigate these problems.

Possible conclusion: much of the ponderosa pine type in [name area] has been altered from nearly pure pine to a mixture of species having [describe species, age and size structure]. The present forest is at risk of extensive crown fires, and it is insufficient to provide habitat for [groups of animal and plant species favoring more open ponderosa pine habitat]. Forest structure in this area can be improved by [identify treatments].

The following questions might assist the assessment of fire:

- What was the historic mean fire return interval for each major forest type and topographic setting?

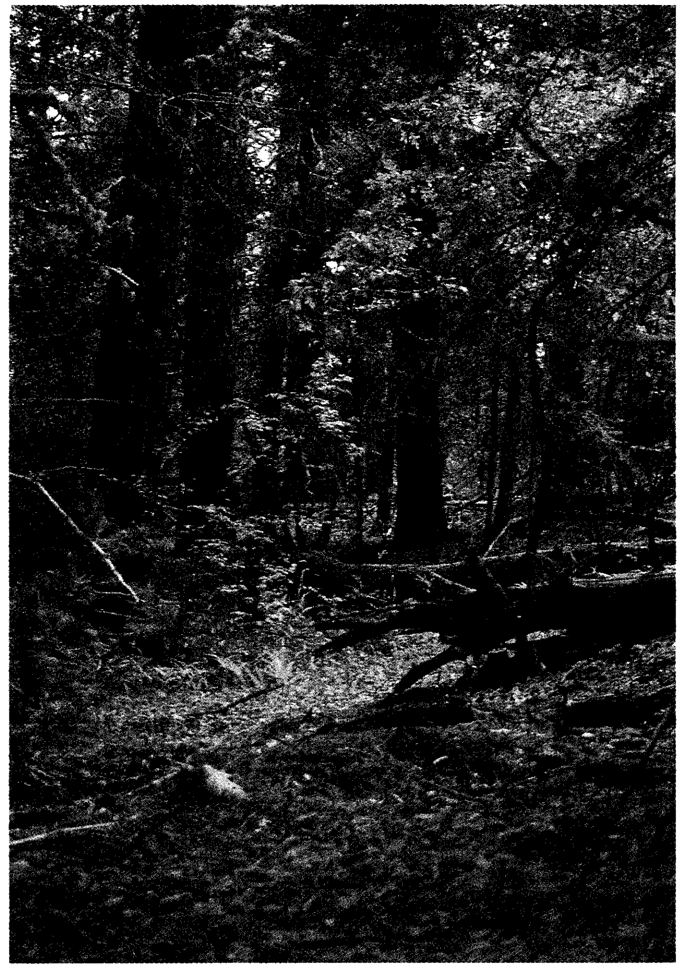


Figure 31. Old-growth mixed conifer forest at Sunspot. Note the standing snags, coarse woody debris on the ground, and the heterogeneity of tree sizes. Photo by Claudia Regan.

- Was the historic fire return interval relatively constant or variable over time?
- What were typical historic fire intensities and areas, e.g., what was the geographic extent of historic fires, and how many acres burned as surface fires vs. stand-replacing crown fires?
- What was the historic effect of fire on vegetation patterns in the landscape, including the species composition, age structure, and size classes of patches and stands comprising the landscape?
- What changes in forest structure have resulted from fire suppression?
- What risks or costs would be involved in restoring historic fire regimes?

Riparian Conditions

The historic condition of riparian areas is poorly understood, in part because they have been more heavily impacted by recent human activities than other parts of the landscape (Fig. 32).

Version 1 – Information is generally lacking for historic riparian areas, and no undisturbed riparian areas exist for study.

Possible conclusion: virtually all riparian areas have been heavily grazed since the 1880s, and all except those in steep topography were farmed extensively by European-American settlers. No riparian areas exist in their historic condition.

Version 2 – Information may include a record of human activities that have influenced the condition of riparian areas.

Possible conclusion: excessive past and present grazing, water diversion, erosion control, grading, and tilling altered riparian plant communities and most of the processes regulating these communities, especially natural flood cycles.

Version 4.x – Information from other locations and from research may provide insight regarding riparian structure, composition, and ecological processes.

Possible conclusion: historic riparian areas may have been characterized by higher hydrologic flows, meandering stream channels, and much higher plant and animal diversity. Historic regional floral and faunal lists suggest that the following species and communities were common in riparian areas [provide list]. Riparian areas would be improved by [list].

The following questions might assist the assessment of riparian areas:

- What is known from riparian areas in other portions of the Southwest that is helpful in understanding riparian ecology in the Sacramento Mountains?
- What was the species composition of historic riparian plant communities?
- What was the historic hydrologic regime of riparian areas in each major forest type?
- What are the known animal species historically associated with riparian areas?
- How much of the present riparian plant community structure consists of introduced species?
- What is a reasonable model of restored riparian areas? Is it possible to reintroduce natural flood cycles?

Gray Wolf

Elimination of large predators and habitat alterations by humans have altered the populations of many animals. In some places large predators have been reintroduced to ecosystems in an attempt to restore more natural animal population dynamics. However, this method may not be feasible everywhere, due to concentrations of human population and land use (Fig. 33).

Version 1 – Information may include records of extirpation of the gray wolf in the Sacramento Mountains.

Possible conclusion: all gray wolves were eliminated from New Mexico early in the 20th century by hunting and trapping.

Version 2 – Information may include the role of gray wolves as large, wide-ranging predators that preyed on both large and small animals.

Possible conclusion: the ecological role played by gray wolves has been partially assumed by coyotes, but coyotes do not regularly prey on the larger species such as deer and elk.

Figure 32. Eroded banks in a riparian meadow, Sacramento Mountains. Photo by Merrill Kaufmann.

Version 4.x – Information may include the roles of hunting and coyotes as surrogates for gray wolves.

Possible conclusion: hunting of larger animal species by humans and predation of smaller species by coyotes partially substitute for the ecological function of wolves, but do not provide the biological regulation and natural selection processes found in animal communities that contain a wolf population. The predator/prey structure of the ecosystem would be improved by [list].

Mexican Spotted Owl

Human land use practices have altered habitats for many organisms. Some have already been eliminated; others are threatened or endangered. Managing ecosystems for sustainable conditions based on reference conditions may help restore habitat for endangered species (US Department of the Interior 1995).

Version 1 – Information may include identification of the Mexican spotted owl as a species requiring special protection.

Possible conclusion: habitat for the Mexican spotted owl is to be managed to protect owl populations.

Version 2 – Information may include examination of the historic forest as habitat for the Mexican spotted owl.

Possible conclusion: historic forests were [or were not] likely to have supported a viable population of Mexican spotted owls.

Version 4.x – Information may included projected historic population levels of the Mexican spotted owl.

Possible conclusion: based on present knowledge of Mexican spotted owl requirements and the range of habitat conditions suitable for the species, the historic landscape had the following amounts of suitable habitat [provide list]. Thus the historic landscape may have had [more or less] habitat for Mexican spotted owls than the present landscape. In a historic ecosystem context, reasonable populations of the Mexican spotted owl would be [list]. Keystone ecological processes regulated historic owl habitat [list].

White Pine Blister Rust

Human activities introduce organisms that are not native to ecosystems. Often these organisms are able to outcompete, prey upon, or parasitize native organisms that have no evolved defenses against them, radically altering species composition and distribution in a landscape.

Version 1 – Information may characterize the introduction of the non-native white pine blister rust in the Sacramento Mountains.

Possible conclusion: white pine blister rust is believed to have been introduced into the Sacramento Mountain ecosystem by transplanting of tree seedlings.

Version 2 – Information may include the effects of white pine blister rust on southwestern white pine.

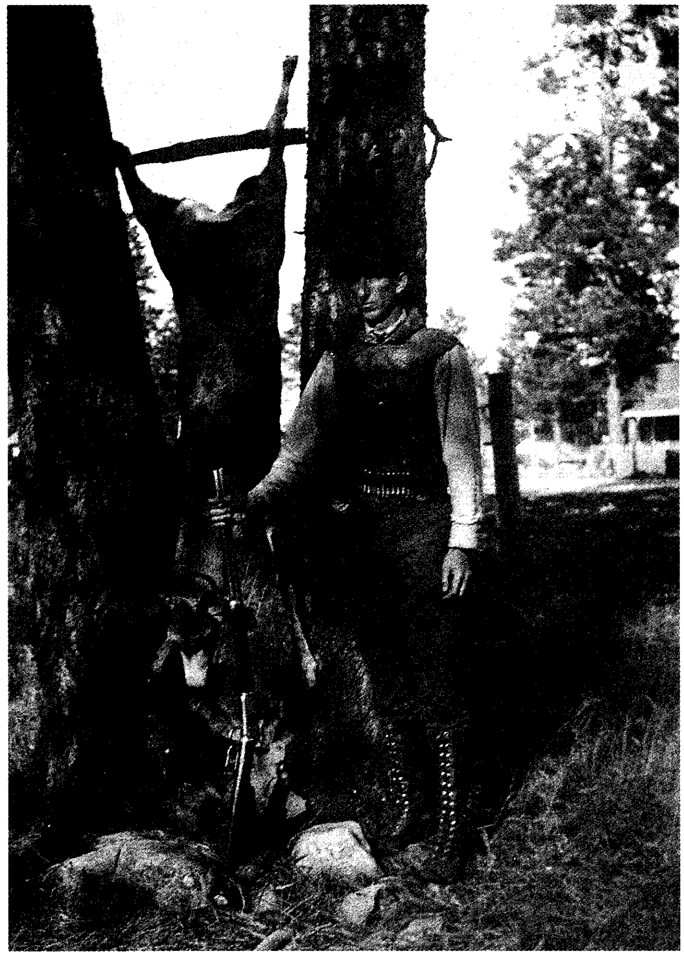


Figure 33. Can hunting of deer by humans replace the ecological function of the gray wolf in the Sacramento mountains? A hunter in the early 1900s, Lincoln National Forest Heritage Resource Program collection in Alamogordo, on file at the Lincoln National Forest Supervisor's office.

Possible conclusion: white pine blister rust is a new disease threatening white pine trees throughout the Sacramento Mountain ecosystem.

Version 4.x – Information may characterize the ecological consequences of the decreasing role of southwestern white pine in the Sacramento ecosystem.

Possible conclusion: continued spread of white pine blister rust may drastically limit the presence of southwestern white pine in the Sacramento Mountains, thus threatening the structure of plant and animal communities where white pine existed historically.

Blending Ecosystem Needs With Social and Economic Needs

The assessment process illustrated above should result in an understanding of the ecological status of an analysis area, considered in the context of ecological principles applied over the appropriate scales of space and time. This process identifies ecological issues of concern, and it documents in a scientific way the features and characteristics of present ecosystems that are satisfactory and those that are in need of protection or restoration. In a perfect world, all ecosystem integrity problems could then be solved through management actions. In reality, however, most ecological problems are very complex and are difficult to solve, and often the most effective solutions may conflict with social and economic concerns of people at local, regional, and national scales.

Natural resource managers and decision-makers regularly deal with social and economic interests. In the past, this has been done with limited understanding of or interest in the ecological integrity of the natural resource systems that are impacted. The strength of the ecosystem needs assessment process is that it helps provide a scientifically based analysis of the integrity of the ecosystems on which people depend and ranks that along with social and economic interests. Consequently, decision-makers can address economic and social issues that affect natural resources with a much more complete and balanced understanding of the benefits and risks to the integrity of ecosystems. The goal of the ecosystem needs assessment process is not to force all land management decisions to solve all ecological problems. Rather, the goal is to provide those involved in land management decisions with the information needed to make intelligent and balanced choices, based on anticipated consequences to long-term ecological integrity.

LITERATURE CITED

Alexander, B.G. Jr.; Ronco, F. Jr.; Fitzhugh, E.L.; Ludwig, J.A. 1984. A classification of forest habitat types of the Lincoln National Forest, New Mexico. General Technical Report RM-GTR-104. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 29 p.

Anderson, W.J. 1915. Report on proposed elimination along south side of Alamo National Forest in the Sacramento River and Piñon Draw watersheds because of an apparent lack of watershed value. Report on file in Lincoln National Forest Supervisor's Office, Alamogordo, NM.

Anderson, W.J. 1923. Boundary report, McDonald-Mesa project, Sacramento Division, Lincoln National Forest, New Mexico. Report on file in Lincoln National Forest Supervisor's Office, Alamogordo, NM.

Andrews, S.R.; Daniels, V.P. 1960. A survey of dwarf mistletoes in Arizona and New Mexico. Station Paper no. 49. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 17 p.

Bailey, V. 1931. Mammals of New Mexico. North American Fauna No. 53. Washington, DC: U.S. Department of Agriculture, Bureau of Biological Survey. 412 p.

Baker, R.D.; Maxwell, R.S.; Treat, V.H.; Dethloff, H.C. 1988. Timeless heritage: a history of the Forest Service in the Southwest. FS-190, Washington DC: U.S. Department of Agriculture, Forest Service, Government Printing Office. 208 p.

Betancourt, J. 1981. A history of Mescalero Apache-US Army encounters in Dog Canyon, New Mexico: 1849–1880. In: Cultural Resources on the Lincoln National Forest. Cultural Resources Miscellaneous Paper No. 35. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwest Regional Office:50–66.

Betancourt, J.; Van Devender, T.R; Martin, P.S. 1990. Packrat middens. The last 40,000 years of biotic change. Tucson, AZ:University of Arizona Press. 467 p.

Bourdo, E.A., Jr. 1956. A review of the General Land Office survey and of its use in quantitative studies of former forests. Ecology 37(4): 754–768.

Bronson, D.D. 1908. Report on future disposition of unalloted lands, Mescalero Indian Reservation, New Mexico. Report on file, Lincoln National Forest Supervisor's Office, Alamogordo, NM.

Broster, J.B.; Harrill, B.G. 1983. Investigations of prehistoric remains of high-altitudes in the Sacramento Mountains of south-central New Mexico. In: Winter, J.C., editor. High-altitude adaptations in the Southwest. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwestern Region Cultural Resources Management Report Number 2:159–167.

Brown, G. 1983. Lincoln County was center of CCC activity. Thurs. April 7, 1983 Ruidoso (NM) News.

Brown, J.K.; Mutch, R.W.; Spoon, C.W.; Wakimoto, R.H. 1995. Proceedings: Symposium on fire in wilderness and park management. March 30–April 1,1993, Missoula, Montana. General Technical Report GTR-INT-320. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 283 p.

Brown, P.M.; Kaye, M.W.; Huckaby, L.S. 1998. Fire history in relation to local and regional factors along a forest gradient in the Sacramento Mountains, New Mexico. Manuscript in preparation.

Charles, Mrs. Tom. 1954. Tales of the Tularosa. Alamogordo, New Mexico. 69 p.

Chronic, H. 1987. Roadside geology of New Mexico. Missoula, MT: Mountain Press Publishing Company. 255 p.

Cooper, C. F. 1960. Changes in vegetation, structure, and growth of Southwestern pine forests since white settlement. Ecological Monographs 30(2):129–164.

Covington, W.W.; Moore, M.M. 1994. Southwestern ponderosa pine forest structure. Changes since Euro-American settlement. Journal of Forestry 1:39–47.

D'Arrigo, R. D.; Jacoby, G.C. 1991. A 1000-year record of winter precipitation from northwestern New Mexico, USA: a reconstruction from tree-rings and its relation to El Niño and the Southern Oscillation. The Holocene 1,2:95–101.

Dahms, C.W.; Geils, B.W., tech. eds. 1997. An assessment of forest ecosystem health in the Southwest. General Technical Report RM-GTR-295. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 97 p.

Davis, R.; Brown, D.E. 1988. Documentation of the transplanting of Abert's squirrels. The Southwestern Naturalist 33(4):490–492.

DeMastus, H. L. 1976. A twenty-year summary of Sacramento Peak weather, August 1954 through July 1974. Scientific Report No. AFGL-TR-760096. Hanscomb AFB, MA: Air Force Geophysics Laboratory. 30 p.

Dick-Peddie, W.A. 1993. New Mexico vegetation: past, present and future. Albuquerque, NM: University of New Mexico Press. 244 p.

Driver, J. C. 1985. Zooarchaeology of six prehistoric sites in the Sierra Blanca region, New Mexico. Ann Arbor, MI: Research Reports in Archaeology, Contribution 12, Museum of Anthropology, University of Michigan Technical Reports Number 17. 103 p.

Evans, W. 1983. The cougar in New Mexico. Biology, status, depredations of livestock and management recommendations. New Mexico Department of Game and Fish, in response to House Memorial 82.

Findley, J. S.; Harris, A.H; Wilson, D.E.; Jones, C. 1975. Mammals of New Mexico. University of New Mexico Press, Albuquerque.

Fulé, P.Z.; Covington, W.W.; Moore, M.M. 1997. Determining reference conditions for ecosystem management of southwestern ponderosa pine forests. Ecological Applications 7(3):895–908.

Galatowitsch, S.M. 1990. Using the original land survey notes to reconstruct presettlement landscapes in the American west. Great Basin Naturalist. 50(2):181–191.

Geils, B.W.; Lundquist, J.E.; Negron, J.F.; Beatty, J.S. 1995. Disturbance regimes and their relationships to forest health. Eskew, L.G., editor. Forest Health Through Silviculture. Proceedings of the 1995 National Silviculture Workshop, May 8–11, 1995, Mescalero, NM. General Technical Report RM-GTR-267. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station:67–73.

Glover, V. J. 1984. Logging railroads of the Lincoln National Forest, New Mexico. Cultural Resources Management Report No. 4. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwestern Region. 65 p.

Grumbine, R.E. 1994. Ghost bears: exploring the biodiversity crisis. Washington DC: Island Press. 290 p.

Habeck, J. 1994. Using General Land Office records to assess forest succession in ponderosa pine/Douglas-fir forests in western Montana. Northwest Science 68(2):69–77.

Harrington, M.G.; Hawksworth, F.G. 1990. Interactions of fire and dwarf mistletoe on mortality of Southwestern ponderosa pine. In: Krammes, J.S., technical coordinator. Effects of fire management of Southwestern natural resources. Proceedings of the Symposium, November 15–17, 1988. General Technical Report RM-GTR-191. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station:234–240.

Hawksworth, F.G.; Shaw, C.G.; Tkacz, B. 1989. Damage and control of diseases of Southwest ponderosa pine. In: Tecle, A.; Covington, W.W; Hamre, R.H., technical coordinators. Multiresource management of ponderosa pine forests. Nov. 14–16, Flagstaff, AZ. General Technical Report RM-GTR-185. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station:116–129.

Hawksworth, F.G. 1990. White pine blister rust in southern New Mexico. Plant Disease 74:938.

Hawksworth, F.G.; Conklin, D. 1990. White pine blister rust in New Mexico. In: Hoffman, J.; Spiegel, L.H., editors. Proceedings of the 38th Western International Forest Disease Work Conference. Sept. 17–21, 1990, Redding, CA. Boise, ID: U.S. Department of Agriculture, Forest Service, Forest Pest Management: 43–44.

Hawthorne, L. 1980. "I don't want no goats...": Historical documentation of sites along West Side Road, Lincoln National Forest, Otero County, New Mexico. Unpublished report on file in Lincoln National Forest Supervisor's Office, Alamogordo, NM.

Haynes, R.W.; Graham, R.T.; Quigley, T.M., tech. eds. 1996. A framework for ecosystem management in the Interior Columbia Basin including portions of the Klamath and Great Basins. Portland, OR: General Technical Report PNW-GTR-374. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 66 p.

Hessburg, P.F.; Beatty, J.S. 1986. Incidence, severity, and growth losses associated with ponderosa pine dwarf mistletoe on the Lincoln National Forest, New Mexico. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwestern Region, State and Private Forestry, Forest Pest Management. 30 p.

Holmes, J. S. 1906. A report on the timberlands and operations of the Alamogordo Lumber Company, Alamogordo, New Mexico. Unpublished report on file at the Lincoln National Forest Supervisor's Office, Alamogordo, NM. 24 p.

Huckaby, L.; Brown, P.M. 1995. Fire history in mixed-conifer forests of the Sacramento Mountains, southern New Mexico. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station Tree-Ring Laboratory, Unpublished Report.

Jenkins, K. 1988. The land and the people of the Sacramento Mountains. Pamphlet, Sacramento Mountains Historical Society, Cloudcroft, NM.

Kaufmann, M.R.; Graham, R.T.; Boyce, D.A., Jr.; Moir, W.H.; Perry, L.; Reynolds, R.T. Bassett, R.L.; Mehlhop, P.; Edminster, C.B.; Block, W.M.; Corn, P.S. 1994. An ecological basis for ecosystem management. General Technical Report RM-GTR-246. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 22 p.

Kaufmann, M.R.; Moir, W.H.; Bassett, R.L., technical coordinators. 1992. Old-growth forests in the Southwest and Rocky Mountain Regions. Proceedings of a Workshop, March 9–13, 1992, Portal, Arizona. General Technical Report RM-GTR-213. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 201 p.

Kelley, J. H. 1984. The archaeology of the Sierra Blanca region of southeastern New Mexico. Ann Arbor, MI: Museum of Anthropology, University of Michigan, No. 74. 527 p.

Kennedy, K. L. 1983. A habitat type classification of the pinyon-juniper woodlands of the Lincoln National Forest, New Mexico. In Moir, W.H.; Hendzel, L., tech. coordinators. Proceedings of the workshop on Southwestern habitat types, April 8–10, 1983, Albuquerque, New Mexico. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwestern Region:54–61.

Kent, W.H.B. 1905. Report on the Mescalero Apache Indian reservation, Otero County, Territory of New Mexico. U.S. Department of Agriculture, Forest Service, report on file in Lincoln National Forest Supervisor's Office, Alamogordo, NM.

Kent, W.H.B.; Reynolds, R.V.R. 1906. A favorable report on the proposed Sacramento Forest Reserve, Territory of New Mexico. U.S. Department of Agriculture, Forest Service, report on file in Lincoln National Forest Supervisor's Office, Alamogordo, NM.

Kerr, J. 1909. Transcript of John W. Kerr's Diary. Alamo National Forest. On file in Lincoln National Forest Supervisor's office, Alamogordo, NM, received 1947.

Kinloch, B.B., Jr. 1994. Blister rust epidemic on southwestern white pine, Sacramento Mountains, NM. Report on file, Lincoln National Forest Supervisor's Office, Alamogordo, NM.

Krauch, H. 1936. Some factors influencing Douglas-fir reproduction in the Southwest. Journal of Forestry 34(6):601–608.

Krauch, H. 1937. Use of protective screens in seed-spot sowing found to serve two-fold purpose. Research Note 22. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwest Forest and Range Experiment Station. 3 p.

Krauch, H. 1938a. Covering seed spots with screens still remains the only effective method of deflecting rodents. Research Note 29. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwest Forest and Range Experiment Station. 2 p.

Krauch, H. 1938b. Seedlings safe from rodent destruction after a year's protection. Research Note 43. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwest Forest and Range Experiment Station. 5 p.

Krauch, H. 1938c. Does screening of seed spots do more than protect the spots against rodents and birds? Research Note 49. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwest Forest and Range Experiment Station. 4 p.

Krauch, H. 1939a. Analysis of a 36-year record of precipitation at Cloudcroft, New Mexico. Research Note 60. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwest Forest and Range Experiment Station. 5 p.

Krauch, H. 1939b. Douglas-fir seedlings successfully transplanted without artificial watering. Planting Quarterly 8(2):7–8.

Krauch, H. 1940a. Factors affecting establishment of Douglas-fir seedlings. Journal of Forestry. 37(8):667–668.

Krauch, H. 1940b. Vigor, release, and tree forms as guides to marking. Journal of Forestry. 38(7):595.

Krauch, H. 1940c. Tests show Douglas-fir seed stored in sealed containers retains its viability. Planting Quarterly 9(2):10–12.

Krauch, H. 1940d. Merchantable length of white fir and limber pine in relation to total height of trees. Research Note 83. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwest Forest and Range Experiment Station. 3 p.

Krauch, H. 1942a. Successful natural regeneration of Douglas-fir cutover stands is dependent on effective control of rodents. Research Note 97. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwest Forest and Range Experiment Station. 2 p.

Krauch, H. 1942b. Successful seed spotting of Douglas-fir is not possible unless rodents are completely controlled. Research Note 98. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwest Forest and Range Experiment Station. 2 p.

Krauch, H. 1942c. Control of rodents in Douglas-fir cutover stands relatively more important than seed supply. Research Note 100. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwest Forest and Range Experiment Station. 2 p.

Krauch, H. 1942d. Scarifying soil to promote natural regeneration in Douglas-fir cutover stands shows no marked benefit. Research Note 101. Albuquerque, NM: U.S. Department of Agriculture Forest Service Southwest Forest and Range Experiment Station. 2 p.

Krauch, H., and G. Peterson. 1943. Two new board-foot volume tables for Douglas-fir. Research Note 107. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwest Forest and Range Experiment Station. 7 p.

Krauch, H. 1945a. The influences of release on diameter growth of trees in Douglas-fir cutover stands in the Southwest. Research Note 111. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwest Forest and Range Experiment Station. 3 p.

Krauch, H. 1945b. Influences of rodents on natural regeneration of Douglas-fir in the Southwest. Journal of Forestry 43(8):585–589.

Krauch, H. 1949a. Silvicultural treatment of virgin Douglas-fir stands in the Southwest. Journal of Forestry 47(3):200–203.

Krauch, H. 1949b. Douglas-fir trees make best growth during mature stage. Journal of Forestry 47(3):217–218.

Krauch, H. 1956. Management of Douglas-fir timberland in the Southwest. Research Paper 21. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 59 p.

Lang, E.M. 1957. Deer of New Mexico. Bulletin #5. Santa Fe, NM: New Mexico Department of Game and Fish.

Leitner, L.A.; Dunn, C.P.; Guntenspergen, G.R.; Stearns, F.; Sharpe, D.M. 1991. Effects of site, landscape features, and fire regime on vegetation patterns in presettlement southern Wisconsin. Landscape Ecology 5(4):203–217.

Lee, O.M. 1923. Application #3, for land exchange, Lincoln National Forest-Sacramento River Cattle Company, May 7, 1923. To the District Forester, Albuquerque, through the Forest Supervisor, Alamogordo, NM. On file, Lincoln National Forest Supervisor's Office, Alamogordo, NM.

Lee-Chadde, S.; Huenneke, L.F. 1997. Rare plants of the Sacramento Mountains. Report produced as a contribution to the Ecosystems

Needs Assessment for the Sacramento Mountains, for the U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 114 p.

Lincoln National Forest Grazing Advisory Board Minutes. 1975, 1972, 1968, 1967, 1961, 1959, 1958, 1956, 1954, 1953, 1952, 1950, 1947, 1945, 1944. On file, Lincoln National Forest Supervisor's Office, Alamogordo, NM.

Longwell, T.B. 1914. Letters to Honorable Representatives in Congress. On file in Lincoln National Forest Supervisor's Office, Alamogordo, NM.

Lynch, A.M.; Swetnam, T.W. 1992. Old-growth mixed-conifer and western spruce budworm in the southern Rocky Mountains. In: Kaufmann, M.R.; Moir, W.H.; Bassett, R.L, technical coordinators. Old Growth Forests in the Southwest and Rocky Mountain Regions. Proceedings of a Workshop, March 9–13, 1992, Portal, AZ. General Technical Report RM-GTR-213. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station:66–80.

Neal, A.M. 1909. A favorable report upon proposed eliminations from the Alamo National Forest, Otero County, New Mexico. Forest Service. Report on file, Lincoln National Forest Supervisor's Office, Alamogordo, NM.

Neal, D. J. 1966. The cloud-climbing railroad. A story of timber, trestles and trains. Alamogordo, NM: Alamogordo Printing Company. 81 p.

Negron, J.; Bennett, D.; Wilson, J. 1996. Estimating the probability of infestation by the round-headed pine beetle, *Dendroctonus adjunctus* Blandford, in the Sacramento Mountains of New Mexico. Abstract. Proceedings: North American Forest Insect Work Conference, Forest Entomology: Vision 20:21, San Antonio, TX April 8–12, 1996. Texas Forest Service Publication 160:180.

Nolan, F. 1992. The Lincoln County war. A documentary history. Norman, OK: University of Oklahoma Press. 607 p.

Opler, M.E. 1983. Mescalero Apache in Southwest. Ortiz, A., editor. Washington DC: Handbook of North American Indians, Volume 10. Smithsonian Institution.

Otero Soil Conservation District. 1957. Watershed Work Plan, Upper Rio Peñasco Watershed, Otero County, New Mexico.

Plummer, F. G. and M. G. Goswell. 1904. Forest conditions in the Lincoln Forest Reserve, New Mexico. Professional Paper Number 33, Series H, Forestry, 11. Washington DC: U.S. Department of the Interior, Geological Survey Government Printing Office.

Quigley, T.M.; Bigler Cole, H. 1997. Highlighted scientific findings of the Interior Columbia Basin Ecosystem Management Project. General Technical Report PNW-GTR-404. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; U.S. Department of the Interior, Bureau of Land Management. 34 p.

Quigley, T.M.; Haynes, R.W.; Graham, R.T., technical editors. 1996. Integrated scientific assessment for ecosystem management in the interior Columbia basin and portions of the Klamath and Great Basins. General Technical Report PNW-GTR-382. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 303 p.

Ramotnik, C.A. 1997. Conservation assessment of the Sacramento Mountains salamander. General Technical Report RM-GTR-293. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 19 p.

Regan, C. M. 1997. Old-growth forests in the Sacramento Mountains, New Mexico: characteristics, stand dynamics, and historical distributions. Ph.D. dissertation, Colorado State University, Fort Collins, CO. 116 p.

Regan, C.M.; Reich, R.; Stohlgren, T.J. 1997. A spatial model of old-growth forest distribution in a 19th century Southwestern landscape. Abstract. Ecological Society of America 1997 Annual Meeting. 10–14 August 1997, Albuquerque, NM. Supplement to the Bulletin of the Ecological Society of America 78(4):168.

Reynolds, RR. 1906. Favorable report on the proposed Guadalupe Forest Reserve, New Mexico. U.S. Department of Agriculture, Forest Service, report on file in Lincoln National Forest Supervisor's office, Alamogordo, NM.

Richmond, G.M. 1964. Glacial deposits on Sierra Blanca Peak, New Mexico. Guidebook of the Ruidoso country. Fifth Field Conference, New Mexico Geological Society, Bureau of Mines and Mineral Resources, Socorro:79–81.

Rivers, G. Jan. 31, 1992. Letter to D.C. Carlton, executive director of the Biodiversity Legal Foundation. On file, Lincoln National Forest Supervisor's Office, Alamogordo, NM.

Sallach, B.K. 1986. Vegetation changes in New Mexico documented by repeat photography. M.S. Thesis, New Mexico State University, Las Cruces, NM.

Scott, N.J.; Ramotnik, C.A. 1992. Does the Sacramento Mountain salamander require old-growth forests? In: Kaufmann, M. R; Moir, W.H.; Bassett, R.L., technical coordinators. Old-Growth Forests in the Southwest and Rocky Mountain Regions. Proceedings of a workshop, March 9–13, 1992, Portal, Arizona. General Technical Report RM-GTR-213. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station:170–178.

Sebastian, L.; Larralde, S. 1989. Living on the land: 11,000 years of human adaptation in southeastern New Mexico. Cultural Resources Series No. 6. Santa Fe, NM: New Mexico Bureau of Land Management. 174 p.

Smith, S.G. 1907a. Favorable report upon a proposed elimination from the Alamo National Forest, Otero County, New Mexico. U.S. Department of Agriculture, Forest Service. Report on file in Lincoln National Forest Supervisor's Office, Alamogordo, NM.

Smith, S.G. 1907b. An unfavorable report on proposed addition to the Alamo National Forest, Chaves County, New Mexico. Report on file in Lincoln National Forest Supervisor's Office, Alamogordo, NM.

Spoerl, P. 1981a. Test excavations at a small site along the Sacramento River. Cultural Resources on the Lincoln National Forest. Albuquerque, NM: Cultural Resources Miscellaneous Papers No. 35. U.S. Department of Agriculture, Forest Service, Southwest Regional Office:1–10.

Spoerl, P. 1981b. A brief history of the early years on the Lincoln National Forest. Cultural Resources on the Lincoln National Forest. Cultural Resources Miscellaneous Papers No. 35. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwest Regional Office:28–41.

Spoerl, P. 1981c. A summary description of the historical settlement of Marcia. Cultural Resources on the Lincoln National Forest. Albuquerque, NM: Cultural Resources Miscellaneous Papers No. 35. U.S. Department of Agriculture, Forest Service, Southwest Regional Office:42–49.

Sonnichsen, C. L. 1980. Tularosa, Last of the Frontier West. Albuquerque, NM: University of New Mexico Press. 336 p.

Sonnichsen, C. L. 1973. The Mescalero Apaches. Norman, OK: University of Oklahoma Press. 341 p.

Strickland, S. 1927. Stumpage appraisal report, Lincoln National Forest. Land exchange between Lincoln National Forest and Cadwallader and Harvey. Report on file, Lincoln National Forest Supervisor's Office, Alamogordo, NM.

Stokes, M.A.; Smiley, T.L. 1968. An introduction to tree-ring dating. Chicago, IL: University of Chicago Press.

Stuart, D.E.; Farwell, R.Y. 1983. Out of phase: late pithouse occupations in the highlands of New Mexico. In: Winter, J. C., editor. High altitude adaptations in the Southwest. Cultural Resources Management. Report Number 2. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwestern Region:115–158.

Sublette, J.E.; Hatch, M.D.; Sublette, M. 1990. The fishes of New Mexico. Albuquerque, NM: The New Mexico Department of Game and Fish. 389 p.

Swetnam, T. W. 1990. Fire history and climate in the Southwestern United States. In: Krammes, J. S., technical coordinator. Effects of fire management of Southwestern natural resources. Proceedings of a symposium. November 15–17, 1988, Tucson, Arizona. General Technical Report RM-GTR-191. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station:6–17.

Swetnam, T.W.; Baisan, C.H. 1996. Historical fire regime patterns in the Southwestern United States since AD 1700. In: Allen, C.D. editor. Proceedings of the Second La Mesa Fire Symposium, March 29–30, 1994, Los Alamos New Mexico. General Technical Report RM-GTR-286. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station:11–32.

Swetnam, T.W.; Betancourt, J.L. 1990. Fire-Southern Oscillation relations in the Southwestern United States. Science. 249:1017–1020.

Swetnam, T.W.; Brown, P.M. 1992. Oldest known conifers in the Southwestern United States: temporal and spatial patterns of maximum age. In: Kaufmann, M.R.; Moir, W.H; Bassett, R.L., technical coordinators. Old-growth forests in the Southwest and Rocky Mountain regions. Proceedings of a Workshop, March 9–13, 1992, Portal, Arizona. General Technical Report RM-GTR-213. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station:24–38.

Tainter, J.A. 1981. Survey of the Wright Spring watershed. Cultural Resources on the Lincoln National Forest. Cultural Resources Miscellaneous Papers No. 35. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwest Regional Office:19–27.

Tainter, J.A.; Tainter, B.B. 1995. Riverine settlement in the evolution of prehistoric land-use systems in the Middle Rio Grande Valley, New Mexico. In: Shaw, D.W.; Finch, D.M., technical coordinators. Desired future conditions for Southwestern riparian ecosystems: bringing interests and concerns together. September 18–22, 1995, Albuquerque, New Mexico. General Technical Report RM-GTR-272. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station:22–32.

Touchan, R.; Swetnam, T.W.; Grissino-Mayer, H.D. 1995. Effects of livestock grazing on pre-settlement fire regimes in New Mexico. In: Brown, J. K.; Mutch, R.W; Spoon, C.W.; Wakimoto, R.H., technical coordinators. Proceedings: Symposium on fire in wilderness and park management. Missoula, Montana, March 30–April 1, 1993. General Technical Report INT-GTR-320. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station:268–272.

Tucker, E.A. 1989. The early days: a sourcebook of Southwestern Region History. Book I. Cultural Resources Management Report #7. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwestern Region. 314 p.

Tucker, E.A. 1991. The early days: a sourcebook of Southwestern Region History. Book II. Cultural Resources Management Report #11. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwestern Region. 120 p.

Tucker, E.A. 1992. The early days: a sourcebook of Southwestern Region History. Book III. Cultural Resources Management Report #12. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwestern Region. 255 p.

U.S. Department of Agriculture, Forest Service. 1908. List of stock grazing permitteees for seasons 1908 and 1909. On file, Lincoln National Forest Supervisor's Office, Alamogordo, NM.

U.S. Department of Agriculture, Forest Service. 1918–1952. Forest Insect Conditions, Region 3. Photocopied letters and annual reports on file in Forest Pest Management Library, Regional Office, Albuquerque, NM and Flagstaff, AZ. Arizona Zone Entomology and Pathology.

U.S. Department of Agriculture, Forest Service. 1935. Report on the Establishment of the Cloudcroft Experimental Forest. Unpublished report on file at the Lincoln National Forest Supervisor's office, Alamogordo, NM.

U.S. Department of Agriculture, Forest Service. 1946. Range management plans, written section, Cloudcroft District, Lincoln National Forest. Unpublished report on file at the Lincoln National Forest Supervisor's office, Alamogordo, NM. 46 p.

U.S. Department of Agriculture, Forest Service. 1978. Grazing in the Sacramento Mountains. A conceptual plan. Lincoln National Forest. Unpublished report on file at the Lincoln National Forest Supervisor's office, Alamogordo, NM. 20 p.

U.S. Department of Agriculture, Forest Service. 1977. Soil and water survey for Cloudcroft and Mayhill Districts. Unpublished report. Forest Service Southwest Region, Lincoln National Forest, Alamogordo, NM.

U.S. Department of Agriculture, Forest Service. 1980. Lincoln National Forest fact sheet. Revised June 10, 1980. On file in Lincoln National Forest Supervisor's Office, Alamogordo, NM.

U.S. Department of Agriculture, Forest Service. 1986. Terrestrial Ecosystem Handbook. USDA Forest Service Southwestern Region, Albuquerque, NM.

U.S. Department of Agriculture, Forest Service. 1996. Status of the interior Columbia basin: summary of scientific findings. General Technical Report PNW-GTR-385. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; U.S. Department of the Interior, Bureau of Land Management. 144 p.

U.S. Department of the Interior, Fish and Wildlife Service. 1995. Recovery plan for the Mexican spotted owl: Vol. I. Albuquerque, NM. 172 p.

Van Devender, T.R.; Spaulding, W.G. 1979. Development of vegetation and climate in the Southwestern United States. Science. 204:701–710.

Van Devender, T.R.; Betancourt, J.L.; Wimberly, M. 1984. Biogeographic implications of a packrat midden sequence from the Sacramento Mountains, south-central New Mexico. Quaternary Research. 22:344–360.

Whitney, G.G. 1986. Relation of Michigan's presettlement pine forests to substrate and disturbance history. Ecology. 67(6):1548–1559.

Wilkinson, M.C. 1997. Reconstruction of historical fire regimes along an elevation and vegetation gradient in the Sacramento Mountains, New Mexico. MS Thesis, University of Arizona, Tucson, AZ. 124 p.

Wilson, J.L.; Tkacz, B.M. 1994. Status of insects and diseases in the Southwest: implications for forest health. In: Sustainable ecological systems: implementing an ecological approach to land management. July 12–15, 1993. Flagstaff, AZ. General Technical Report RM-GTR-247. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 196–203.

Wood, M.K.; LaFayette, R.A. 1993. New Mexico's riparian areas. New Mexico Wildlife, Vol. 38(2):20–26.

Woolsey, T.S. 1911. Western yellow pine in Arizona and New Mexico. Forest Service Bulletin 101. U.S. Department of Agriculture, Forest Service. Washington DC: Government Printing Office.

Wuershching, M. 1988. Railroad to Cloudcroft. Cloudcroft, NM: Brochure by the Sacramento Mountains Historical Society, Inc. 15 p.

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