Kenney Flats Resource History

Introduction

This appendix describes the major historical processes that shaped forest stands within the Kenney Flats Analysis Area during the reference period (1500–1880), referred to as the "indigenous settlement" period. To depict forest conditions before Euro-American settlement, we used the following information: fire histories from similar forest types, fire-history data from the Kenney Flats Area, Forest stand-structure data, and life-history characteristics of the major tree species found in the Kenney Flats Analysis Area.

Spatial and Temporal Scope

The Kenney Flats Analysis Area is in the South Central Highlands Section of the southern Rocky Mountains province (Ecomap 1993). The South Central Highlands Section comprises 11,475,000 acres of the southern Rocky Mountains in southwestern Colorado and northwestern New Mexico, and includes all or portions of the San Juan, Rio Grande, Uncompahgre, Gunnison, Carson, and Santa Fe National Forests. Most of the information presented here is specific to ecosystems in the South Central Highlands Section and the Kenney Flats Analysis Area. Also discussed are similar ecosystems in Arizona, New Mexico, and Utah that are outside the South Central Highlands Section, but which have historical relevance.

The period between 1500 until the mid to late 1800s. This period is referred to as the period of "indigenous settlement," in contrast to the period of Euro-American settlement that began in the mid to late 1800s (Romme et al., 1997).

Reference Period and Reference Conditions

To evaluate current ecological conditions (the discussion that follows this section) in the South Central Highlands Section, including the Kenney Flats Analysis Area, there is a need to have a benchmark or reference period of relative stability and ecological health to compare with the present (Leopold 1966). This indigenous settlement time frame (1500–1880) represents a period of relative stability in climate, vegetation, and human influences (Romme et al., 1997). Ecological conditions that existed during this time frame are referred to as "reference" conditions. For each forest ecosystem's reference condition there exists a historic range of variation (HRV) within which forest conditions existed, and within which they appear to have been resilient to natural disturbances such as fire, wind, insects, and disease. Using the range of historic variation as a yardstick enables us to compare the structure, composition, and function of existing forest conditions to those of reference-period forest conditions, while still acknowledging that forest ecosystems are heterogeneous and dynamic systems.

The reference conditions are described in terms of their historic range of variability (HRV). The concept of HRV recognizes forests as dynamic ecosystems. After a definition of the HRV of the reference period and a description of the structural characteristics of the reference period, there is a description of how 20th-century Euro-American settlement activities have influenced, and in many cases altered, numerous historic reference conditions within these ecosystems. Current and projected future conditions that are the result of 20th century activities are compared to the HRV of the reference period. The consequences of continuing these altered forest conditions and trends are then discussed in terms of what it may mean to the long-term health and sustainability of these forests.

Forest Ecosystems of the South Central Highlands Section and the Kenney Flats Analysis Area

The primary forested cover type in the South Central Highlands Section that occurs in the Kenney Flats Analysis area is ponderosa pine. Some mixed conifer and pockets of aspen also occur. There are also large, unforested areas dominated by Gambel oak. The following describes historic reference conditions for the ponderosa pine, mixed conifer and aspen cover types and the changes in these forest ecosystems resulting from Euro-American settlement. Very little information is available that describes historic conditions in Gambel oak, so that cover type is not included here.

Ponderosa Pine

DISTRIBUTION

Ponderosa pine forests exist at lower elevations throughout the South Central Highlands Section, just above the piñon-juniper zone (Romme et al., 1997). On the SJNF, this forest type occupies 16% of the Forest. Within the Kenney Flats Analysis Area, ponderosa pine occupies 7,289 acres, or 52% of the analysis area.

INDIGENOUS SETTLEMENT PERIOD PONDEROSA PINE FORESTS

During the indigenous settlement period, the disturbance agents influencing ponderosa pine forest development were human uses and natural disturbance events. Human uses included basic agriculture, hunting, fuelwood gathering, and settlement impacts. Natural disturbance events included, but were not limited to: insect and disease outbreaks, wind events, fire, landslides, and ice and freeze damage. The primary natural disturbance agents that shaped the indigenous settlement period ponderosa pine forests were fire and insect attack, with fire being the predominant disturbance factor (Lynch 1998).

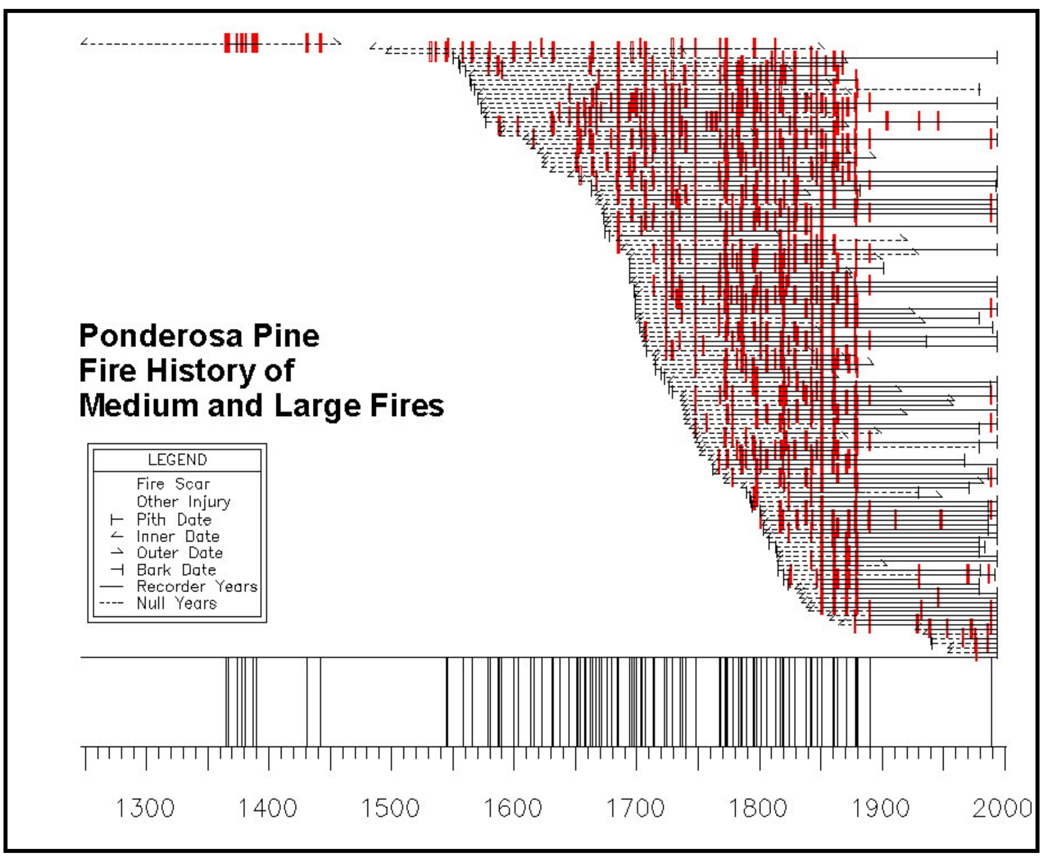
The effect of fire in each forest type varies, depending on variations in fire characteristics such as frequency and intensity (Agee 1993). The combination of fire frequency and fire intensity is described by the term “fire regime.” Fire regimes can also be described by the effects of fire in a given forest type.

THE HISTORIC ROLE OF FIRE IN PONDEROSA PINE FORESTS

Research indicates that throughout the period of indigenous settlement, most of the ponderosa pine forests of the South Central Highlands Section were characterized by a fire regime of frequent, low-intensity fires. These fires generally burned in the understory, were not lethal to the dominant vegetation, and did not substantially change the structure of the dominant vegetation. Approximately 80% or more of the dominant vegetation would survive such a fire (Touchan et al., 1996). This high-frequency, low-intensity fire regime has been documented for ponderosa pine forests throughout the Southwest, including Utah, Arizona, and New Mexico (Romme et al., 1997).

Romme et al.'s (1997) findings in ponderosa pine stands in the SJNF are consistent with the findings of other studies conducted in the Southwest. Figure 1 represents fire histories from stands on both the east and west sides of the SJNF. Before 1880, fires were a frequent occurrence. Over the entire area, the shortest interval was 1 year; the longest, 37. Median fire intervals ranged from 6–14 years (refer to Table 2 in Appendix II). This pattern abruptly changed in the late 1800s. After 1880, no large fires burned in the area. The current, unusually long fire interval, which is over 100 years, exceeds the longest fire-free interval found during the reference period.

Figure 1: Ponderosa Pine Fire-History Plot



This fire-history plot is a composite of six ponderosa pine sites on the SJNF that are listed in Table 2 in Appendix II. Horizontal lines represent individual trees. The innermost, or oldest, rings of each tree are at the left side of the horizontal line, and the outermost ring is at the right side. A vertical bar intersecting a horizontal line represents a fire that scarred that tree. Vertical bars that line up across many trees are fires that scarred many trees, thus burning a larger area in a stand or across the landscape. The composite fire line at the bottom of the plot shows fires recorded by at least 10% of the scarred trees for that year. The 10% cut-off was used to filter out single-tree fires. This filter clearly shows how the ponderosa pine fire regime has changed from a frequent-surface-fire regime to an infrequent-fire regime.

Figure 1 shows that in most fire years there was a fire at one or two of the sites, but not at any others. Romme et al. (1997) state, "However, there were a few fire years when many or most of the sites experienced fire. More than half the sites recorded fires in 1729, 1735, 1748, 1786, 1851 and 1879. During these summers the San Juans must have been shrouded in smoke for several weeks or months as several large fires burned across the landscape." The years 1729, 1735, 1748, 1851, and 1879 were also major fire years throughout the Southwest, apparently because of dry conditions across the entire region (Swetnam and Baisan, 1996).

The combination of variable fire intervals and the heterogeneous nature of how fire burns over an area strongly influenced ponderosa pine stand structure. The frequent, low-intensity fire regime helped maintain open stands of large ponderosa pines. Fires probably consumed grass, dead leaves, and dead, woody material, and killed most small pine trees and the aboveground portions of herbaceous shrubs and herbs. Large, stand-replacing wildfires were rare (Fiedler et al., 1998). Fires at short intervals also played an essential role in ponderosa pine seedling recruitment, by creating patches of mineral soil and pruning back competing understory vegetation such as Gambel oak (Harrington 1985, 1987). Even though these short fire intervals would kill young pine, many fires were small and localized; thus there would have been patches that escaped fire long enough for new pine seedlings to become established, even though entire stands were burning frequently (Romme et al., 1997).

OTHER DISTURBANCE AGENTS

Along with fire, forest insects and pathogens are among the more important regulators of forest density, composition, and structure. The most common and important forest insects and pathogens in ponderosa pine forests of the South Central Highlands Section are the mountain pine beetle and dwarf mistletoe (*Arceuthobium* sp.). Although the overall historic importance of these disturbance agents is not as well understood as the historic role of fire (Schmid and Mata, 1996), knowledge of their fundamental biology and what we know about past climate and vegetation conditions shows that they had significant ecological importance through their ability to cause widespread tree mortality, defoliation, decay, or deformity (Dahms and Geils 1997).

Mountain Pine Beetle

Bark beetles usually occurred in ponderosa pine forests at low populations, with periodic increases to outbreak levels. Endemic populations were restricted to scattered individual trees that had been weakened by disease, injury, old age or competition, and to fresh logs and slash caused by windthrow or snow breakage. In outbreaks, small groups of killed trees eventually merged into large stands of dead trees. By selectively killing trees of certain sizes and species, bark beetles change the tree density, species composition, and size structure of the forest (Schmid and Frye, 1977). Factors that lowered tree resistance, such as poor site, overcrowding, drought, injury, and disease, favored outbreaks (Dahms and Geils, 1997).

Southwestern Dwarf Mistletoe

Although there is little information on the previous abundance of dwarf mistletoes, they were probably well distributed throughout the forests of the Southwest (Dahms and Geils, 1997). In the historic period, fire had been a significant factor in determining mistletoe distribution and persistence (Alexander and Hawksworth, 1976). Even in low-intensity fires, the increased fine fuels and "brooms" (infected areas in crowns exhibiting dense and profuse branching) in infected trees reduced their survival rate. However, these low-intensity fires often left many patches unburned, and scattered infected trees were often left to ensure re-infection of regeneration. Therefore, populations of dwarf mistletoe were very persistent and affected forests annually, rather than periodically. Site quality, host vigor and age, stand density, composition, and structure were some of the more important factors (Parmeter, 1978) in determining the rate of dwarf mistletoe increase. Based on present understanding of mistletoe ecology (Parmeter, 1978) and evidence of previous forest conditions and fire frequency, we can infer that mistletoe abundance may have been lower in the historic period (Dahms and Geils, 1997).

Historic Stand Structure and Composition

The most detailed records available concerning historic stand structure and composition in ponderosa pine forests come from Arizona. Although these areas are not in the South Central Highlands Section, they are similar ecosystems that have relevance when discussing historic conditions.

While traveling through Arizona in 1858, E. F Beale described ponderosa pine stands in his report, *Wagon road from Fort Defiance to the Colorado River*. Cooper (1960) quoted this report:

> *We came to a glorious forest of lofty pines, through which we have traveled for ten miles. The country was beautifully undulating, and although we usually associate the idea of barrenness with pine regions, it was not so in this instance; every foot being covered with the finest grass, and beautiful broad grassy vales extending in every direction. The forest was perfectly*

> *open and unencumbered with brush wood, so that the traveling was excellent.*

Cooper continued, "The overwhelming impression one gets from the older Indians and white pioneers of the Arizona pine region is that the entire forest was once more open and park like than it is today." Dahms and Geils (1997) suggest a ponderosa pine forest of this period would appear as a mosaic not only of an open, grass savanna with clumps of large yellow-bark ponderosa pine, but also with a few dense clumps and stringers of small, young "blackjack" pine.

According to Woosley (1911), "The typical western yellow pine forest of the southwest (Arizona and New Mexico) is a pure park like stand made up of scattered groups from 2 to 20 trees, usually connected by scattered individuals. Openings are frequent and vary greatly in size." Pearsons (1923) stated, "rarely does [ponderosa pine] crown cover reach more than 30% and usually not over 25%." White (1985) and Covington and Sackett (1986) also found low canopy coverage by trees in the indigenous settlement period, with ranges of 17% to 22% of the surface area. White (1985) found that historically tree groups ranged from 3 to 44 stems in a group, with group size varying from 0.05 to 0.70 acre. White (1985) stated "Ages of stems within groups were also variable, with the most homogeneous group having a range of 33 years and the least homogeneous group having a range of 268 years."

Limited historic information is available describing ponderosa pine forests in the San Juans during early Euro-American settlement. Some information can be gathered, however, from a 1903 *Report on the Proposed San Juan Forest Reserve*, a 1908 Silvical Report, and the *Cumulative Silvical Report for the San Juan National Forest* from 1909 and 1913. The 1903 report states, "the forest is nearly pure bull pine [ponderosa pine], with aspen only along creeks and in blanks on north hillsides. It varies greatly in density, with parks in every bottom..." The report continues, "throughout the type [ponderosa pine] there is good cattle range, consisting of blue-stem grass beneath the trees and bunch grass in the parks (DuBois, 1903). The following description of the western yellow pine type (ponderosa pine) comes from the *Cumulative Silvical Report for the San Juan National Forest*.

> *The pine never occurs in broad dense stands evenly distributed, but always in clumps. These clumps vary in density and in their proximity to each other. Sometimes, over large areas, the clumps will be close together, connected by scattering trees, giving at a distance, the appearance of a continuous stand, but in reality this group tendency of the pine is never lost. The age varies, of course, as is common in a wild forest, but most stands would be designated as mature. In some few [sic] the blackjack predominates, the mature trees being old and defective. The ground cover is composed almost entirely of grass and oak brush. Both are found everywhere, in some places scattering, but usually in considerable amounts. The grass nowhere forms a sod. Oak brush, especially on north hillsides, is often dense. Humus and litter are nowhere abundant and in some places entirely lacking. Signs of old fires are seen everywhere. [Cumulative Silvical Report, 1909, 1913]*

Figure 2 shows an example of what it calls the "best western yellow pine on west slope of Continental Divide". This picture comes from the 1908 Silvical Report.

Figure 2: Example of Historic Ponderosa Pine Stand; 2 Miles West of Pagosa Springs

Research by Romme et al. (1997) in the SJNF indicates that late-1800s ponderosa pine forests contained an average of 10–26.3 live trees/acre. Average stump diameter ranged from 20–26 inches (Romme et al., 1997). (Romme et al. caution that the sampling procedure used probably underestimates density and overestimates average size, since some of the smaller- diameter stumps may have completely decomposed.) The historic range of variability for San Juan sites sampled was from 4.4–40.4 trees/acre. The pre-1900 trees were arranged in distinctly clumped patterns, which was conspicuous visually and statistically (Romme et al., 1997). In general, seedling establishment was infrequent during this period, with up to three to four decades between regeneration events (White, 1985). Covington and Moore (1994) found similar historic conditions in ponderosa pine forests in Arizona.

Effects of Euro-American Settlement

There has been dramatic alteration of the ponderosa pine forests in the South Central Highlands Section during the last century (Romme et al., 1997). Native Americans cut trees and ignited fires during the indigenous settlement period, and some tribes grazed substantial amounts of livestock. The livestock grazing, logging, and fire exclusion introduced by Euro-American settlers in the late 1800s, however, were unprecedented in their intensity and extent (Romme et al., 1997). These human influences, combined with physical, biological, and climatic factors, shaped the ponderosa pine forests we see today.

Early Uses and Fire Suppression

Heavy grazing associated with Euro-American settlement began in the late 1800s and continued into the early 1900s, affecting much of the West. Because of the changes brought about by heavy grazing, it is difficult to reconstruct the structure, composition, and dynamics of herbaceous plant communities in the South Central Highlands Section (Romme et al., 1997). In many areas of the South Central Highlands Section, however, it is apparent that historic livestock grazing has caused shifts in species composition and reductions in overall herbaceous ground cover, while cover by woody vegetation (shrubs and tree saplings) has increased.

This heavy grazing had additional, unforeseen effects. The frequent, low-intensity ground fires common during the period of indigenous settlement ended abruptly around 1880 in most ponderosa pine forests throughout the Southwest (Swetnam and Baisan, 1996). Romme et al. (1997) state,

> *The current consensus among researchers is that the single most important cause for the initial alteration of fire regimes in the southwest was the introduction of large herds of livestock by Euro-American settlers. These animals grazed off grasses and herbs that formerly carried light fires through the forest. Lightning and humans still started fires, but they could not spread across bare ground.*

Timber harvest in the West also began with Euro-American settlement in the late 1800s. On the SJNF , the scale of timber harvest increased dramatically in the 1890s with the advent of railroad logging. Until 1915, most timber cutting in the Pagosa Springs area was confined to ponderosa pine (Scott, 1932). This early logging usually involved “highgrading,” which selectively removed the highest-quality, largest trees, leaving smaller individuals or species of lesser value.

One of the main arguments in favor of creating a San Juan National Forest Reserve in 1905 was to “prevent and control the repeated forest fires” (DuBois, 1903). Apparently, early forest managers were very successful; as Scott (1932) reported, “since the creation of the San Juan National Forest in 1905 fire control work has been pushed to the utmost and not since that time has there been any disastrous fires, although many small fires have burned, the highest number being recorded in 1910 when there were 160 fires.” In the 1930s, the aggressive and effective “10 A.M. policy,” was instituted by the US Forest Service, which sought to control any wildfire by 10 A.M. the morning after it was discovered (Pyne, 1982). The historic patterns of low-intensity fire in the inland West ponderosa pine forests have been essentially eliminated (Fiedler et al., 1998).

Current Ponderosa Pine Forest Conditions

The combined effects of fire suppression, timber harvesting, and livestock grazing have significantly altered stand density and canopy closure, compared with reference period conditions. Madany and West's (1983) research suggests that ponderosa pine seedling regeneration was greater in the early 1900s than in the indigenous settlement period because there was less competition from grasses, due to grazing and reduced thinning effects from fire. Research by Covington and Moore (1994) shows how densities have increased since the historic reference period. They found 19 trees per acre during the indigenous settlement period, compared with 851 trees per acre in 1990.

Johnson (1994) provided corroborative data from the north rim of the Kaibab National Forest, by comparing a Southwest forest inventory done in 1910 (Lang and Stewart, 1910) with a recent 1989 Forest Service inventory. In 1910, Lang and Stewart measured 15 trees per acre that were 16 inches in diameter or larger, compared with the 1989 inventory that measured 27 trees per acre. Not only has the number of trees per acre increased, but so has the percent of canopy closure. Johnson (1994), comparing Southwest inventory data for 1962 and 1989, noted canopy coverage today varies from 40% to 70%. Comparing this with Woosley's (1911) data verifies a loss of openness and closing of ponderosa pine canopies, with Woosley showing a range in 1911 of 7% to 12% closure.

During the last 75–100 years, with a greatly altered natural fire cycle, unprecedented and unnaturally large amounts of surface and ground fuels have accumulated (Kallander, 1969). Covington and Moore's (1994) research in Arizona indicates Southwest ponderosa pine forests' fuel loads have ranged from 0.9 tons per acre in 1867 to 30.1 tons per acre predicted in 2007. Sackett (1979) reported average loading of naturally fallen fuels at 22 tons per acre for 62 Southwestern ponderosa pine stands. Harrington (1982) verified the heavy fuel loading with an average of 34 tons per acre in southeastern Arizona. Barring fire, these fuels persist for long periods, since decomposition rates are extremely slow (Lynch 1998).

Numerous studies show that the ponderosa pine forests of the Southwest are outside their historic range of variability for fire-return intervals, and that several structural characteristics are at risk:

- "*Many of the forest ecosystems in the Inland West are showing serious forest health stress…the concern for forests today is not simply that trees will die from bugs or disease–it is the entire forest systems are so far out of normal ecological range that virtually every element in the system is affected and may be at risk*" (American Forests, 1995).
- "*While there can be little doubt that much remains to be discovered about ponderosa pine ecosystem structure and function, what we do know is that inaction is indefensible, with long term negative ramifications for ecosystem structure and function*" (Covington and Moore, 1994).
- "*Today the pine-fir forests of the American West are the primary focus of concern about the declining forest health*" (Mutch et al., 1993; American Forests, 1995).

- "*Elimination of the historic pattern of frequent low intensity fire in these forests has contributed to ecological disruptions that underlie current forest health problems*" (Fiedler et al., 1998).
- "…*there is a growing sense that ponderosa pine forests covering much of the South Central Highland Section today are at risk. With no action, or a continuation of current management, there is a real possibility that an uncontrollable fire or bark beetle outbreak will produce a disturbance event far outside the historic range of natural variability, thereby introducing additional undesirable ecological changes*" (Romme et al., 1997).

Continuing Changes in Stand Structure and Composition

Changes in stand structure and composition first begun during Euro-American settlement continue as we move into the twenty-first century. The ponderosa pine stands of today are very different from those present during the indigenous settlement period. Covington and Moore (1994) state, "The open, pre-settlement [indigenous settlement period] forest structure stands in stark contrast to today's dense post settlement stands containing 200 to 1200 trees per acre with very few remaining old growth trees."

It is estimated that 4 million acres may be occupied by stands in which trees have too little space for optimum growth and are in need of thinning (Lynch, 1998). The research of Romme et al. (1997) from sites on the west side of the SJNF indicates, "the forest is overwhelmingly dominated by relatively small young trees." Eighty percent of the stems are 12 inches or smaller in diameter, and 95% percent are 16 inches or less in diameter. Ninety percent of the trees sampled were 90 years old or less, with 95% being 110 years old or less.

While the density of ponderosa pine forests in the Southwest is much greater today than it was during the reference period, many stands are essentially a monoculture with a single story of trees, mostly void of understory pine regeneration. Less than 20% of the west-side pine zone stands on the SJNF have adequate regeneration (defined as 50+ trees/acre with a diameter at breast height of 2.0 inches or less) (Romme et al., 1997). On the east side of the Forest, except the Turkey Springs area, most of the ponderosa pine forests are wholly lacking adequate pine regeneration (observations from several Pagosa R.D. Staff). Should disturbance agents such as fire or insect and disease outbreaks continue outside historic ranges, as predicted by many scientists, forests lacking diverse age structures and younger understories likely would have little ability to regenerate themselves.

The structural characteristics associated with old-growth ponderosa pine also continue to change. Fiedler et al. (1998) state, "Fire exclusion has led to the establishment of extensive conifer understories in unlogged areas which currently have an old-growth component. These developing understories are, in many cases contributing to the elimination of the old growth in two ways. Intense competition for limited resources results in physiological stress and fuel laddering allows wildfires to severely damage these large trees."

The combination of increasing mortality of the largest, oldest overstory pine, increased competition from firs, stagnating younger stands, and increasing risk of stand-replacement fires may have ramifications relative to the continued presence and/or recruitment of old growth in some areas. Covington and Moore (1994) caution, "Setting aside old-growth ponderosa pine stands that most closely meet current old-growth definitions may have unexpected consequences. Such stands, whose canopy closures are higher than in the indigenous settlement period, are susceptible to crown fire, low tree vigor and mortality from drought, insects, and diseases."

Decades of fire exclusion have allowed thick litter layers to build up beneath forest canopies. This layer is probably suppressing seedling establishment (Romme et al., 1997).

Increased Risk of Fire

Increases in tree density and forest-floor fuels, coupled with dry climate conditions, have resulted in a dramatic increase of severe wildfires in recent decades (Bissell et al., 1973; Harrington, 1982). The effective elimination of fire in ponderosa pine forests has altered the fuel structure beyond the historic range of variability. Romme et al. (1997) echo related concerns, stating, "The Forests…are at risk of uncontrollable, destructive wildfire…fuel loads appear to be substantially higher in many stands than they would have been before 1870, because of the lack of recent, extensive fires."

Because fuels have not been periodically reduced or eliminated by frequent surface fires, fuel loads are now at historic highs and have become more horizontally and vertically continuous than they had been during the reference period. Heavier fuel loads on the forest floor can support hotter fires. Radiant heat can cure the closed canopies, increasing the probability of the fire moving from the ground surface into the canopy. Abundant ladder fuels also facilitate this transition from surface to crown fire. Before Euro-American settlement, ponderosa pine fuel types would have been characterized as open timber over grass, Fuel Model 2: characterized by fast-moving fires with low flame length (Anderson, 1982). Many of today's ponderosa pine forests are classified as Fuel Model 9, closed timber. Under severe conditions, crown fires are highly probable in Fuel Model 9, with high rates of spread (4–7 miles/hour) and flame lengths of 80–150 feet (Rothermel, 1991).

Barrows (1978) and Swetnam (1990) provided evidence for a shift from low-intensity to high-intensity fire regimes in Southwest ponderosa pine. They determined that lighting-caused crown fires had increased from 10,127 acres per year in the 1940s to 15,117 acres per year in the 1980s. They also observed that lighting-caused wildfires in the Southwest are getting larger over time, with some fires reaching 10,000 to 20,000 acres. This represents a three- to six fold increase in average fire size, compared with fire size during the reference period (Lynch, 1998).

Almost 70% of the 100,000 acres burned since 1915 has burned during the 1970–90 period, indicating a worsening problem (Sackett, Haase, and Harrington, 1995). In 1994, roughly half of the 3 million acres burned in the western United States was in ponderosa pine (pine and pine-fir types), much of it charred by stand-replacement fires.

Ironically, exclusion of low-intensity fires likely ensures the eventual occurrence of high-intensity fires that kill most trees (including large ones) and may affect soils, watersheds, and wildlife habitat values (Fiedler et al., 1998). Because of increases in tree densities, high fuel loading, and possible climatic changes (more frequent drier periods) in Southwestern ponderosa pine forests, the risk of stand-replacement fires has clearly increased in the last two decades, along with the potential for associated adverse ecosystem ramifications. If the structural characteristics of stands that promote torching and crowning do not change, the risk of destructive fires in the ponderosa pine forests will continue to increase.

Locally, in southwest Colorado, within the past 7 years there have been four high intensity wildfires in ponderosa pine forests. The Dipping Vat Fire burned approximately 12,000 acres; the Archuleta Mesa Fire, roughly 16,000 acres; the Black Ridge Fire, 14,000 acres; and, during the summer of 2000, 800 acres burned on the Cabezon Fire, east of the Chimney Rock archeological site. In addition to these fires, the 2003 Missionary Ridge Fire burned over 72,000 acres. Approximately 17% of the acerage burned was ponderosa pine. Of that ponderosa pine, 32% burned at high intensity and 33% burned at moderate intensity. The remaining pine either did not burn or burned at low intensity (USFS 2002).

An *American Forests* policy paper entitled “Forest Ecosystem Health in the Inland West” (1995) stated:

> *Starting in 1979, … wildfire acres began to increase despite increasingly sophisticated fire fighting techniques. This led the National Commission on Wildfire Disasters to conclude in 1994 that it was no longer possible to hold wildfires in check by simply increasing sophistication and capacity of fire fighting technology. The paradox of wildfire control, the Commission noted in its report, is that every success in suppressing fire in these forests results in buildup of larger fuel supplies.*

The summer of 2000 found the western U.S. experiencing its worst fire season in 50 years. There were 27,262 fires that burned over 5 million acres of forest and range land, with suppression costing an estimated 1 billion dollars. On the Pagosa Ranger District (R.D.), there were 81 fires totaling 447 acres, with $758,327 in suppression costs. Before this fire season, the largest fire season on the District was 1996, when there were 63 fires totaling 500 acres. Jack Ward Thomas, former Chief of the Forest Service, commenting in a September 2000 interview with the *Missoulian* newspaper, stated, “We pretend that a year like this is unusual or unlikely…Well, it is not unusual and it is absolutely not unlikely. It will happen.”

With the extreme fire behavior that the West is experiencing, additional concerns have arisen about firefighter safety. For agencies and municipalities charged with combating wildfires, there has been a notable increasing risk to firefighter safety.

INSECT AND DISEASE RISKS

As stated earlier, forest insects and pathogens are important regulators of forest density, composition, and structure. Forest conditions, in turn, affect the distribution and reproduction of forest insects and pathogens (Dahms and Geils, 1997). Changes in stand structure and composition brought about by fire suppression, logging, and grazing appear to have changed the frequency, extent, and synchronicity of outbreaks of some of these disturbance agents (Wilson and Tkacz, 1996; Dahms and Geils, 1997). The potential for more severe outbreaks has also increased (Wilson and Tkacz, 1996).

Mountain Pine Beetle

Several factors that lower tree resistance to mountain pine beetle (MPB) attack are present in today's ponderosa pine forests. The most notable of these are overcrowding and increased disease (mostly mistletoe infection). Schmid and Mata (1996) predict that stand conditions could become more conducive for MPB epidemics if current fire suppression policies are continued and silvicultural activities are minimized in the pine type.

During epidemics, widespread tree mortality can be expected, especially in larger-diameter trees, which the MPB prefers. However, the MPB will also attack trees down to 8 inches in diameter during epidemics. Extensive and severe outbreaks of bark beetles can increase fire hazard (Martin and Mitchell, 1980).

Southwestern Dwarf Mistletoe

In their *Assessment of Forest Ecosystem Health in the Southwest*, Dahms and Geils (1997) state: "present forest conditions are especially suitable for development of infestation levels [of dwarf mistletoe] not previously experienced in [ponderosa pine] forests." Romme et al. (1997) observed that the clumpy structure of ponderosa pine forests has been replaced by more uniformly dense stands, thus the risk of mistletoe is probably greater than it was in the reference time period (Romme et al., 1997).

Dwarf mistletoe can weaken trees to the point that they become more susceptible to mountain pine beetle attack. The increased fine fuels and presence of brooms on dwarf-mistletoe-infected trees increase their flammability. If large stands are heavily infected by dwarf mistletoe, the likelihood of a low-intensity ground fire becoming a stand-replacing crown fire is increased.

Mixed Conifer

Mixed conifer forests are highly variable and complex in terms of species composition and structure. As a result, the mixed conifer probably also has the most complex disturbance regime of forest types found on the San Juan National Forest. Stand structure, species composition, and disturbance regime vary in the mixed conifer, changing with site-specific moisture conditions, topographic location, and fire history. For simplification purposes, the mixed conifer is categorized along a continuum from warm and dry to cold and wet. Stands at the extremes of the spectrum are referred to as the warm/dry and cold/wet mixed conifer. The stands that form a continuum between the extremes are placed under the descriptive umbrella of cool/moist mixed conifer. Warm/dry mixed conifer is the most commonly occurring mixed conifer type in the Kenney Flats Analysis Area. A limited amount of cool/moist mixed conifer also occurs. There is no cold/wet mixed conifer in the analysis area, therefore, it will not be discussed here.

Table 1: Different Phases of Mixed Conifer

	Species composition	Site conditions	Disturbance regime
Warm/dry	ponderosa pine, Douglas-fir and white fir	Lower elevations, south facing slopes at higher elevations	High frequency-low intensity fires
Cool/moist	White fir, Douglas-fir, ponderosa pine, aspen, Engelmann spruce, subalpine fir, southwestern white pine, blue spruce	Variable	Mixed fire regime
Cold/wet	White fir, Douglas-fir, Engelmann spruce, subalpine fir, aspen	Higher elevations, north facing slopes at lower elevations	Low frequency-high intensity fires. Also Wind/blowdown

Warm/Dry Mixed Conifer: Warm/dry mixed conifer occurs at the lower elevations of this forest type or at higher elevations on warmer, drier southerly and westerly aspects. This phase of mixed conifer is typically dominated by ponderosa pine with a minor component of Douglas-fir and white fir. Gambel oak can also be a component of the warm/dry mixed conifer. Frequent, low intensity surface fires maintained ponderosa pine dominance in the warm/dry mixed conifer. It's historic fire regime along with the other mixed conifer types' fire regimes are discussed on page 15 under the Historic Role of Fire in Mixed Conifer.

Cool/Moist Mixed Conifer: Although the cool/moist mixed conifer is labeled as a single category, this phase is extremely diverse and heterogeneous. Site conditions in the cool/moist phase are often suitable for all the following tree species: Douglas-fir, white fir, ponderosa pine, aspen, southwestern white pine, blue spruce, Engelmann spruce and subalpine fir. The relative species abundance of any species is heavily influenced by site conditions and disturbance history. The fire regime is a mixed fire regime, meaning occasional lethal fires or crown fires occur in a regime of low to moderate intensity fires (Caprio and Swetnam 1993, Abolt 1997, Wu 1999). Fire adapted species such as ponderosa pine can dominate stands that experience frequent fire. Stands that do not experience frequent fire have more fire intolerant species such as white fir. Eventually stands that experience very long fire intervals will lose their ponderosa pine component. Insects, wind and disease also played an important role in shaping forest structure

Distribution

Across the San Juan National Forest, there are approximately 225,511 acres of mixed conifer forests. Mixed conifer forests occur over only 5.8% of the Kenney Flats Analysis Area, or 824 acres.

Indigenous Settlement Period Mixed Conifer Forests

During the indigenous settlement period, the primary disturbance agents influencing the development of mixed conifer forests were much the same as those influencing ponderosa pine forests: human uses and natural disturbance events. The primary disturbance agents were fire, insect attack, wind and disease.

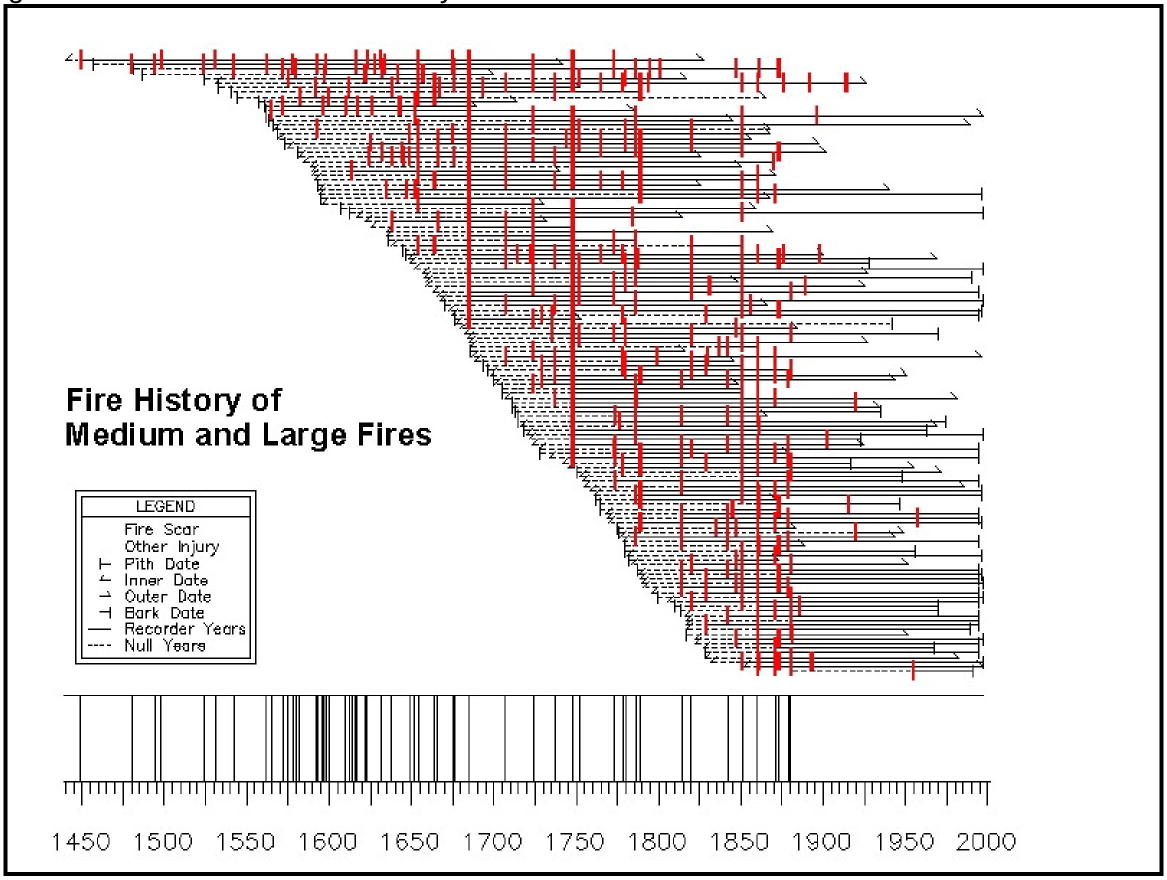
The Historic Role of Fire in Mixed Conifer Forests

The historic fire regime of the mixed conifer forest is complex due to the heterogeneous and diverse nature of its species composition and structure. Many of the documented large fires on the Pagosa District in the late 1800's and early 1900's occurred in mixed conifer forests. Scott (1932) in his *History of the San Juan National Forest*, described the following fires:

> *"in 1898, a large fire burned uncontrolled along the west side of Middle Fork Creek and up Oak Brush Hill in the Piedra Country. It burned until extinguished by heavy rains."*
>
> *"1900 proved another bad fire year. The summer was hot and dry, when a fire started down the Piedra River and traveled up Sand Creek and Weminuche Creek. This fire was uncontrolled for over three weeks and is believed to have been started by lightning. During the same summer another fire burned over the country between Middle Fork and the East Piedra Rivers. This fire burned for ten days with only four men to fight it. These men trenched and backfilled but were unsuccessful in extinguishing it, rain finally coming to the rescue."*
>
> *"Sometime during the period 1899-1905, the exact year being unknown, several large fires burned in the transitional and spruce types in the Pagosa Country. Apparently no efforts were made to extinguish these fires and many of them burned nearly all summer. Some of them threatened to get down into the lower altitudes.*

Although these historic accounts rarely give details about a fire's intensity or effects, research has been done on the role of fires in mixed conifer forests. The mixed conifer's fire regime is best described as 'mixed', meaning occasional lethal fires or crown fires occur in a regime of low- to moderate-intensity fires (Caprio and Swetnam 1993; Abolt 1997; Wu 1999). Despite this variability, some generalizations can be drawn about historic fire regimes for warm/dry and cool/moist mixed conifer forests. On the San Juan National Forest, the historic range of variability (HRV) in warm/dry and cool/moist mixed conifer was determined from fire interval statistics derived from fire history studies. The HRV was expressed in terms of the median fire interval statistic.

Figure 3: Mixed Conifer Fire History Plot



The plot shows fire history of selected mixed conifer stands across the San Juan National Forest. Each horizontal line represents a single tree. The red vertical bars intersecting tree lines represent fires that scarred that tree. When fires scar many trees in the same year, the vertical bars line up to form a continuous vertical bar. Because trees were sampled over a broad area, continuous vertical lines are interpreted as fires that burned over large areas. The bottom timeline (composite) clearly shows fire frequency over time. Only fires that scarred at least 10% of the trees in the plot above it are drawn on the composite. The percent scarred limit is used as a proxy for relative historic fire size. 10% is the designated cut-off for medium size fires and is an attempt to reduce noise in the plot so that patterns and trends are easier to see. Therefore, fires scarring less than 10% are not drawn on the timeline. Note that no fires appear on the timeline after 1880.

Figure 3, Mixed Conifer Fire History Plot is the compilation of historic fire occurrence in select warm/dry and cool/moist mixed conifer stands that are spread over a 20-mile transect on the Pagosa Ranger District. The plot shows that the mixed conifer over a large landscape experienced frequent fire over time. Before 1880, fire intervals greater than 25 years were rare and widespread fires periodically occurred across the landscape. After 1880, a few small fires burned at the sites that were sampled, but no major fires occurred.

Fire in Warm/Dry Mixed Conifer: Warm/dry mixed conifer forests historically had a high frequency, low-intensity fire regime with fire return intervals similar to, but slightly longer than those that occurred in the ponderosa pine type. On the San Juan National Forest, the median fire intervals ranged from 11-22 years. Minimum and maximum intervals ranged from 2 – 3 years and 36 – 97 years respectively. (Romme et al. 1999a, Wu 1999). Research by Romme et al. (1999a) indicates that fires in the warm/dry mixed conifer were relatively extensive, this differing from the ponderosa pine historic fires that were relatively small and patchy.

Fire's role in the warm/dry mixed conifer is similar to its role in ponderosa pine forests. Frequent, low intensity fires maintained an open stand structure with a broad range of tree sizes and ages and maintained ponderosa pine as the dominant species in the canopy (Romme et al. 1999a). Frequent fires limited white fir and Douglas-fir establishment and survival under the dominant ponderosa pine canopy. Small white fir is extremely fire susceptible and Douglas-fir does not gain fire resistance until it is larger, therefore frequent fires would kill most of these species and prevent the majority of them from reaching the canopy. However, during longer intervals between fires, understory species increased in density and more white fir and Douglas-fir would survive and grow into the upper canopy.

Fires in Cool/Moist Mixed Conifer: The cool/moist mixed conifer has the most complex fire regime of the mixed conifer phases. Its 'mixed' fire regime makes it highly variable in terms of species composition and structure. The frequency and intensity of fires in cool/moist stands are heavily influenced by moisture conditions that vary with aspect, elevation, and topographic position. Median fire intervals in the cool/moist mixed conifer range from 14 to 55 years (Refer to Table 3 in Appendix II). Minimum and maximum fire intervals for some stands across the San Juan National Forest range from 1 to 24 years and 28 to 125 years respectively. Ponderosa pine appears to need both frequent fire and occasional long fire intervals to persist in these stands. Keane, Arno and Brown's (1990) successional process model shows that irregular fire intervals favor ponderosa pine and prevents Douglas-fir saplings from surviving and becoming part of the overstory in a ponderosa pine/Douglas-fir forest. This model appears applicable in the mixed conifer of the San Juans since the major tree species in his model are found in the San Juans' mixed conifer. Frequent fires would prevent both white fir and Douglas-fir saplings from reaching the canopy and the occasional long fire interval within the high frequency fire regime would allow greater regeneration success in ponderosa pine.

OTHER DISTURBANCE AGENTS

As in the ponderosa pine forests, insects and pathogens are important regulators of forest density, composition and structure. The most common and important insects and pathogens affecting mixed conifer forests are western spruce budworm and root diseases. Wind events also played an important role, especially in the cold/wet mixed conifer, and were important in producing patch-scale openings.

Western Spruce Budworm

Western spruce budworm is a defoliator, feeding primarily on the foliage of true firs, Douglas-fir and spruce. These defoliators were usually present in low populations, but would periodically increase to outbreak levels. When outbreaks persisted for several years, complete defoliation would occur. Sustained heavy defoliation resulted in decreased growth, tree deformity, top-killing and death. Changes in stand structure and composition would result from such sustained outbreaks. In mixed conifer stands with ponderosa pine and Douglas-fir, budworm outbreaks increased the relative abundance of early seral species such as ponderosa pine (Hadley and Veblen 1993). In mixed conifer stands with a large component of Douglas-fir and white fir, outbreaks would thin the stand from below, removing understory trees and stimulating growth of overstory trees. Swetnam and Lynch (1989) compiled a record of budworm outbreaks for southern Colorado and northern New Mexico and found that outbreaks occurred in this region at 20-33 year intervals during the 18th and 19th centuries.

Root Diseases

Root diseases are common in mixed conifer stands throughout the Southwest (Wilson and Tkacz 1994) and have always been important disturbance agents, especially on more mesic sites (Wood 1983). These fungi injure trees by decaying and killing roots. Spread occurs by wind, infection through wounds and through root contact between healthy and infected trees. Root diseases change the structure of forests by killing canopy trees, either as single individuals or groups in slowly expanding patches. Composition can also be altered because of species differences in susceptibility and tolerance (Dahms and Geils 1997).

Historic Stand Structure and Composition of Mixed Conifer Forest

As described earlier, a wide range of stand structures and dynamics are possible within the mixed conifer elevation zone, depending on local climate and soil conditions and local disturbance history (Romme et al. 1999a). Unlike ponderosa pine, we are not aware of any existing research that has quantitatively reconstructed mixed conifer stand structure during the reference period. Therefore, our perception of historic mixed conifer stand structure and composition is inferred from our knowledge of local fire history and our understanding of the ecology of the tree species that populate the mixed conifer. See Table 4 in Appendix II for life history characteristics of tree species in the mixed conifer. The dynamic nature of forest systems and issues of scale (large areas versus smaller areas) are well illustrated in the mixed conifer. Forest stands are always changing over time and space. For example, a cool/moist stand dominated by ponderosa pine for centuries can shift to white fir or other late successional species if undisturbed. Meanwhile, another stand somewhere else on the forest landscape burns and is converted to an earlier successional stage. Similarly, an aspen stand in one part of the mixed conifer landscape may be turning into a conifer stand where another stand in another location is reinitiated after a lethal fire. Romme et al. (1999a) notes that under very long fire intervals, (hundreds of years) the successional trajectory of all phases of mixed conifer leads to a classic cool/wet mixed conifer forest.

A fire chronology (1616 to 1997) has been constructed for select mixed conifer stands on the Pagosa Ranger District. From this chronology, fluctuations in fire frequency were determined. Distinct periods of higher and lower frequency fire were identified from the chronology (Wu 1999). Relative species abundances were influenced by the frequency of fire whereas age structure appeared to be a function of the time since last lethal fire. By following the fluctuations in fire frequency over time, we can reconstruct general historic stand conditions for the mixed conifer. Refer to Figure 1 in Appendix II for the fire history plot's composite timeline.

Period I (1616-1684) was dominated by a high occurrence of small and medium fires. Warm/dry stands were probably very open and closely resembled ponderosa pine stands except for the small amounts of white fir and Douglas-fir found in the understory. Cool/moist stands were also probably very open and the relative abundance of ponderosa pine in them could have been at an historic high since frequent fires would have reduced white fir and Douglas-fir to some of the lowest levels in our record. The mean fire interval during Period I was around 2 years. Fires were very frequent, but the absence of any large fires except for one in 1654 implies that the period was not particularly dry. Therefore we may hypothesize that very little of the cold/wet mixed conifer burned during this period and that most of the burning occurred in the lower elevation, drier mixed conifer forests.

Fires are less frequent in Period II (1685-1790) than they were in Period I. However, more large fires occurred during this time. Mean fire interval during Period II was around 6 years. Ponderosa pine regeneration was still favored by this fire frequency and white fir and Douglas-fir were kept in check. The conditions established in Period I in the warm/dry and cool/moist mixed conifer were probably maintained through Period II. One explanation for the increase in large fires may be that Period II was drier than Period I. Drier conditions probably allowed fire in the cold/wet mixed conifer. During Period II, some of the cold/wet may have burned and burned intensely enough to reset their successional seres back to the beginning. Most notably is the fire year 1748. This is a major fire that not only burned across the San Juans but all over the Southwest.

Period III (1791-1850) is a fairly wet period during which no widespread fires were recorded in the tree ring record. Mean fire interval during this time is about 6 years, however all the fires recorded were small and no large or medium fires occurred. During this 60 year period, white fir and Douglas-fir regeneration over a large portion of the mixed conifer was not thinned by periodic fire. Therefore a thick understory and secondary canopy probably established in the warm/dry and cool/moist stands. Ponderosa pine regeneration was probably stifled due to the lack of fire and heavy competition. In general, the mixed conifer across the different types became denser and heavy fuels accumulated. The probability for lethal fires increased with heavier fuel loads. The fire year that ended this period in 1851 probably burned intensely in many stands.

Period IV (1851-1880) is a brief time when the mixed conifer returned to a period of frequent fire. Mean fire interval was about 3 years and fires of all sizes occurred. The fires that burned served to maintain pine dominance by reducing the white fir and Douglas-fir that had established in the previous period. White fir and Douglas-fir may have been more prevalent in warm/dry and cool/moist stands than Period I, however, the shift towards white fir and Douglas-fir dominance was probably being reversed in many stands during this brief period. For many stands, this was the last period of successful ponderosa pine establishment.

Period V (1881-1997) is the current period, remarkable for the lack of any widespread fire . The abrupt cessation of fire is generally attributed to Euro-American settlers' land-use activities such as logging, grazing, and fire suppression. The effects on forest structure have been dramatic. The current conditions are discussed in the section below.

In addition to relative species abundance in the mixed conifer, fire also influences age structure. The age structure of a stand is the function of the time since the last lethal fire. A lethal fire resets the successional clock. After a lethal fire, the initial recruitment of post-fire trees creates an even-age cohort of trees in the stand. Even-age stand structure persists for around 200 years. If the stand does not experience another lethal fire, it will transition into an all-age structure. Just as relative species composition fluctuation over time and space was described for Periods I through V, the stand age structure mosaic also fluctuated.

EFFECTS OF EURO-AMERICAN SETTLEMENT

The major Euro-American settlement impacts on mixed conifer stands were fire suppression and timber harvesting.

EARLY USES AND FIRE SUPPRESSION

Although livestock grazing did occur in mixed conifer forests, the removal of fine herbaceous fuels by livestock had less of an effect on fire spread in mixed conifer forests than it did in lower elevation ponderosa pine forests. This is due to the fact that fire frequency and behavior in higher elevation forests is controlled primarily by weather conditions, not fine fuels, and most fires that covered large areas were severe, stand-replacing fires (Romme et al. 1999a).

In warm/dry mixed conifer stands, early timber harvest and fire suppression efforts were similar to those discussed for ponderosa pine. In many cool-moist and cold-wet mixed conifer forests, selective timber harvest during the 1950's – 1970's concentrated on removing more valuable Douglas-fir and Engelmann spruce from the overstory canopies, leaving the smaller trees of all species. As in the ponderosa pine, it was policy to suppress all fires by 10 am the morning after they were discovered. Wu (1999) found that since 1880, no widespread fires have occurred on the Pagosa District mixed conifer study sites (refer to Figure 1 and Figure 3, fire history plots for mixed conifer and ponderosa pine). This has effectively eliminated fire as a natural force in determining mixed conifer stand structure and species composition.

CURRENT MIXED CONIFER FOREST CONDITIONS

Before Euro-American settlement, fire was a key determinative process that shaped both the species and age composition of the mixed conifer forest. Currently (1880-present), mixed conifer forests are outside their historic range of variability (HRV) in terms of fire intervals on either a stand level, landscape level or both (Wu 1999). Continued fire suppression in the mixed conifer will cause this trend to continue. Because we have determined the stands are outside the HRV in terms of fire intervals, we can infer that certain stand structure characteristics that are dependent on fire, such as tree density, fuel loads and relative species composition, are also outside their HRV's.

Current Conditions in Warm/Dry Mixed Conifer: Forest structure and relative species composition in warm/dry mixed conifer stands has changed due to fire exclusion. The most notable changes have been an increase in white fir, particularly in the understory, lack of pine regeneration, higher fuel loads and increased canopy closure. Early timber harvests accelerated the shift towards white fir by removing the overstory dominant ponderosa pine and Douglas-fir. Within these warm-dry mixed conifer sites, white fir levels are probably at an historic high (Wu 1999). Although these mixed conifer stands still have the same species composition, the relative abundance of those species has changed. Continued fire exclusion will result in the continuing loss of ponderosa pine and aspen in these stands. Ponderosa pine regeneration is virtually non-existent due to thick litter layers on the forest floor and competition from the dense white fir understory.

The warm/dry mixed conifer is probably outside its HRV in terms of its fire return interval on the stand and landscape scale. Because of this, it is also outside its HRV in terms of stand structure characteristics governed by fire. These stands typically burned five or more times a century but have now gone without fire for over a century. Stands over the landscape are all continuing to age and move down their successional paths. The proportion of young stands will decrease as they mature and the age structure mosaic will become more homogeneous over time. This may cause loss in habitat diversity for both vegetation and wildlife.

Current Conditions in Cool/Moist Mixed Conifer: Cool/moist mixed conifer forests are extremely diverse and heterogeneous, supporting a multitude of tree species. White fir and ponderosa pine are two of the most prominent species in these stands, with fire controlling their relative abundances. Historically, frequent fires thinned white fir regeneration. In the absence of fire, more white fir regeneration is able to survive and more individuals will become part of the canopy. Dense white fir understories curtail ponderosa pine regeneration because ponderosa pine requires open conditions and fares poorly in highly competitive situations. Within these cool/moist mixed conifer sites, white fir levels are probably at an historic high while ponderosa pine numbers are at an historic low (Wu 1999). Therefore under current conditions, ponderosa pine will eventually be lost from these stands because virtually no regeneration exists to replace the overstory ponderosa pine when they die. Higher white fir density has caused resultant changes in forest structure such as increased canopy closure and increased vertical and horizontal continuity in the fuel arrangement.

The cool/moist mixed conifer is outside its HRV in terms of its fire return interval on the stand and landscape scale. Because of this, it is also outside its HRV in terms of relative species abundance and stand structure characteristics governed by fire. Concerns about landscape heterogeneity in the cool/moist mixed conifer are the same as those discussed for the warm/dry mixed conifer.

Increased Risk of Fire

As discussed above, mixed conifer forests are outside their historic range of variability (HRV) in terms of fire intervals on either a stand level, landscape level or both (Wu 1999). Continued fire suppression in the mixed conifer will cause this trend to continue. Fuels loads in the warm/dry and cool/moist mixed conifer stands appear to have reached historically high and possibly critical levels (Wu 1999). High fuel loading, enhanced fuel connectivity and increased ladder fuels has increased the risk of widespread, high intensity fires in the warm/dry and cool/moist mixed conifer forest (Wu 1999). This is a significant change in the warm/dry mixed conifer, which historically experienced frequent surface fire. Although crown fires were a part of the cool/moist fire regime, changes in fuel loading have put larger, more continuous areas at risk for lethal crown fires.

Insect and Disease Risks

As in the ponderosa pine forests, changes in stand structure and composition have changed the frequency, extent, and synchronicity of forest insects and pathogens.

Western Spruce Budworm

Swetnam and Lynch (1989, 1993) found that the frequency of western spruce budworm outbreaks has not changed in this century, but the spatial and temporal pattern has changed. Fire suppression and timber harvest activities that results in the removal of ponderosa pine from warm/dry mixed conifer stands has favored establishment of multi-storied stands of young shade-tolerant species that are the preferred hosts for the budworm. These changes in forest composition and structure may account for the changes in budworm outbreaks.

Western spruce budworm is also adding to higher fuel loads in stands where a dense understory of white fir is being attacked by the budworm. These standing dead trees create well-developed ladder fuels that threaten the larger overstory ponderosa pine and Douglas-fir (Wu 1999).

Root Diseases

Many of the structural and composition changes seen in mixed conifer stands are likely causing greater incidence of root diseases in southwestern forests. As described by Dahms and Geils (1997) in their Assessment of Forest Ecosystem Health in the Southwest: “species conversion allows new opportunities for host-preferring fungi; increased tree density permits greater root contact; increased competition and insect activity further weakens trees; and more stumps provide additional and long-lasting sources of inoculum. The life histories of root disease fungi and bark beetles complement each other as a positive feed back system that could potentially lead to larger and more persistent outbreaks." In warm/dry mixed conifer stands, the extent or distribution of root disease is also likely to expand since Douglas-fir and white fir have recently replaced ponderosa pine (Johnson 1994).

Aspen

Aspen is a shade intolerant tree that reproduces mainly by root suckering. Large stands of aspen are often multi-stemmed clones sharing one root system, but large stands can also be composed of more than one clone. Suckering is often stimulated by disturbances such as fire that kill the above ground portions of the tree. Aspen is a relatively short-lived tree, but certain individuals can reach ages beyond 200 years. However most stands over 120 years are considered overmature. Many diseases attack aspen, but few kill or seriously injure living trees. Older stands are more susceptible to disease and mortality (Hinds 1985). Individuals in stands of 120 years or more are often in poor condition because of the advance stages of the various pathogens that affect them.

Distribution

Aspen stands and individual trees are widespread and often abundant in mixed conifer forests in the southern Rocky Mountains and the southwest (Jones 1974). Across the San Juan National Forest, there is approximately 291,140 acres of aspen (USFS 1992). Within the Kenney Flats Analysis Area, there are only 229 acres (1.6%).

Indigenous Settlement Period Aspen Forest Conditions

Aspen occurs as both stable and seral stands on the San Juan National Forest. Fire along with windthrow and insect and disease are the major disturbance factors that shaped the structure and distribution of indigenous settlement period aspen.

Historic Stand Structure and Historic Fire Regime

The most important natural disturbance agent in aspen forests is fire. The 1903 report on the Proposed San Juan Forest Reserve, states that 12¼% of the total forest area within the reserve boundaries had been burned over. "The result is a stand of aspen of varying ages, containing scattering small bodies of conifers." In a description of the subalpine forest type, it was noted that "the blanks caused by fire or windfall come up to aspen first, hence in the sub-alpine type large areas of pure even-aged aspen are found varying, according to age." The report stated that aspen formed about 30% of the (species) mixture in the sub-alpine forest during the early 1900's (DuBois 1903). Almost all even-aged aspen stands in the west seem to be the result of severe fire. Uneven-aged aspen stands appear to develop where fires have been light or absent for a long time (Jones and DeByle 1985a). Pockets of aspen also exist in mixed conifer stands, reflecting in part the varying intensities of old fires. Unfortunately, there is a lack of information about historic fire regimes and forest structure for aspen. However, on the San Juan National Forest, a limited study by Romme et al. (1996) found the fire rotation1 in aspen to be about 140 years for a 77 km² aspen dominated area. The results of this study define the historic range of variability (HRV) for the aspen fire regime on the San Juan National Forest.

OTHER DISTURBANCE AGENTS

Other disturbance agents that affected aspen stand development included windthrow, fungal diseases, tent caterpillars and other insects, snow damage, hail, lightning and sunscald (Jones and DeByle 1985b, Jones, DeByle and Bowers 1985)

EFFECTS OF EURO-AMERICAN SETTLEMENT

Early Uses and Fire Suppression

Fire frequency and extent in aspen forests have been substantially reduced during the twentieth century in comparison with the pre-1880 reference period (Romme et al. 1999b). Across the southwest, livestock grazing and fire suppression contributed to the reduction in fire occurrence in aspen. However, grazing effects are very site specific (Touchan et al. 1995). In this area, stocking levels do not appear to have been high enough to have altered the fire regime. Fire suppression had a greater impact on changes in the fire regime in aspen.

Logging has been very limited in the aspen, therefore, its impacts have been minor. On the Pagosa District, little logging in aspen occurred before 1950. The most extensive logging occurred in the 1970's. As of 1992, only 1% of the aspen on the San Juan National Forest had been harvested.

CURRENT ASPEN FOREST CONDITIONS

Historic stand structures of aspen probably were not dramatically different than those observed today. However, the current age structure pattern of aspen across the landscape has likely changed since the indigenous settlement period. Romme et al. (1996) states that preliminary data "suggests that there may be a greater proportion of older aspen stands in the landscape of the SJNF today than during the 1760-1900 reference period, at least in areas that have not been subjected to recent logging." Research conducted in an aspen dominated landscape on the west side of the Forest indicated that during the reference

[1] *Fire rotation is defined as the length of time necessary for an area equal to the entire area of interest to burn. This fire history statistic is scale dependent, therefore the size of the area of interest much be clearly specified. We must use fire rotation instead of median or mean fire interval because that was how the study reported the fire history statistic and there is no direct way to convert fire rotation to other measures of central tendency.*

period, half the existing aspen stands were less than 70 years old and half were older (Romme et al. 1999b).

Seral aspen in the west usually changes to conifer dominated forests if succession is permitted to progress without disturbance (Mueggler 1985). This trend is observed in the mixed conifer on the San Juan. Aspen is dropping out of mixed conifer stands because of the lack of major fire disturbance. Conifers have overtopped the shade tolerant aspen in many stands. Given a long enough time without disturbance, aspen will drop out of the mixed conifer all together. Approximately 62% (180,000 acres) of the San Juan National Forest's aspen stands are seral and considered mature and old.

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