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FIRE HISTORY IN RIPARIAN CANYON PINE-OAK FORESTS AND THE INTERVENING DESERT GRASSLANDS OF THE SOUTHWEST BORDERLANDS: A DENDROECOLOGICAL, HISTORICAL, AND CULTURAL INQUIRY

by

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STATEMENT BY AUTHOR

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ABSTRACT

Dendroecological, documentary, and ethnoecological evidence were combined to provide an integrated understanding of past natural and cultural fires in the Southwest Borderlands. Fire frequency for the desert grasslands was inferred from synchronous intercanyon fire events. Mean fire intervals range between 4-8 years in canyon pine-oak forests, 4-9 years in the intervening desert grasslands, and 5-9 years in the mixed-conifer forests. Riparian canyon pine-oak forests were important corridors for fire spread between the desert grasslands and higher-elevation forests. The decline of post-settlement (>1870s) fires typical of most forests in U.S., is not evident south of the border in Mexico.

Documentary evidence reveals the Apache had detailed knowledge of fire, that burning practices were controlled and limited, and ecosystem enhancement through intentional burning was not suggested. However, the common exception was burning practiced during wartime periods, principally by the Apache but also by the Spanish, Mexicans, and later Americans. Fire reconstructions indicate that wartime-period fires were significantly more frequent than peacetime periods at several canyon-ranchería sites.

CHAPTER 1

1.1 Introduction to Thesis

Known by the Spanish as Apachería, the Southwest Borderlands encompass the international 4-corners region of Arizona, New Mexico, Chihuahua, and Sonora. This basin and range region is renown for isolated mountains with biotic communities stratified across elevational and aspect gradients (Whittaker and Niering 1964, 1965, 1968, 1975). This is the northern range for many Madrean species especially those associated with pine-oak forests (Axelrod 1958, 1975). Although generally temperate, this biome supports both sub-alpine and neotropical flora and fauna (i.e., orchids, palms, milkweeds, coati, thick-billed parrots, and jaguars), and notable species diversity and richness (Felger et al. 1995; Dobson et al. 1997). Climate and fire relations reconstructed from tree rings indicate episodic drought and fires were "keystone" processes that strongly influenced past landscape ecologies in the Southwest Borderlands (Holling 1980; Swetnam and Baisan 1996b; Swetnam and Betancourt 1997).

It is well acknowledged that fires played an important role in most ecosystems of the Southwest Borderlands (Baisan and Swetnam 1990; Swetnam and Baisan 1996a). Also, it is generally accepted that early-settlement landscape fragmentation (post-1870s land-use), and later fire suppression resulted in the extinction of widespread episodic surface fires, and later related vegetation changes (Hastings and Turner 1965; Humphrey 1987; Bahre 1991). Today, in many National Forests of the Southwest U.S., severe biomass accumulation (i.e., about 100 years) has substantially increased the vulnerability of these ecosystems to anomalous stand-replacing fires, that undermine the sustainability and productivity of these forested watersheds (Weaver 1951; Cooper 1960; Covington and Moore 1994). Hazardous fuel buildup and related wildfire problems have reached a critical level in many forests of the Southwest U.S., especially in riparian canyon pine-oak forests of the Southwest Borderlands where resource values are greatest.

This research provides new information on historical fire regimes in ecosystems of the Southwest Borderlands, at a time when fire is being further acknowledged as a necessary ecosystem process, and increasingly used as a tool to restore biological and watershed resources (Allen 1996; Edminster 1996). For example, together the Malpai Borderlands Group and the Coronado National Forest have conducted several extensive prescribed burns over the last several years. The Baker Burn in 1995 was about 2,800 hectares, the Maverick Burn in 1997 was around 5,600 hectares, and the proposed Johnson Peak fire planning area encompasses 12,800 hectares in the western Chiricahua Mountains. Additionally, the Chiricahua National Monument has conducted several smaller burns, and Mexico's forestry agency (SEMARNAP) has allowed recent lightning fires to burn in the Sierra de los Ajos Reserve. This research provides presettlement (pre-1880) fire reconstructions that span centuries for desert grassland, riparian canyon pine-oak forest, and mixed conifer forest communities in this region. Reconstructed fire histories furnish new information that can be applied to long-term fire planning, to better manage fires in an ecological and historical context, across the landscape at ecosystem and watershed scales.

The thesis objective was to provide a better understanding of the historical character, frequency, and connectivity of past fires in the desert grasslands, riparian canyon pine-oak forests, and higher-elevation mixed-conifer forests in the Southwest Borderlands. Additionally, the influence of anthropogenic fires on past fire regimes was investigated using documentary, ethnoecological, and tree-ring fire reconstruction evidence. The background, methods, discussion, findings, and conclusions of both research topics are addressed in two related chapters (Ch. 2 and 3), followed by a summary and conclusions of the thesis in chapter four.

Recent developments in fire management and prescribed burning have fueled interest in the historical role of fires in Madrean ecosystems of the Southwest Borderlands (i.e., Debano et al. 1995; Ffolliott et al. 1996). Past attempts to reconstruct presettlement fire history in the desert grasslands, have been surrounded by uncertainty with wide ranging results, due to limited paleoecological and historical evidence. However, historical and tree-ring evidence suggest many fires spread into and between the canyon forests via the grasslands. Therefore, fire-scarred pine evidence from lower riparian-canyon forests can be used to make reasonable inferences about past fire regimes in the intervening desert grasslands. Chapter two reconstructs fire histories using crossdated fire-scarred pine evidence from six riparian canyon pine-oak forests. Canyon-fire reconstructions are analyzed for synchronous fire events, to infer and reconstruct fire history for the intervening desert grasslands. Finally, desert grassland, riparian canyon pine-oak forest, and higher-elevation mixed-conifer forest fire histories are graphically and statistically analyzed to interpret fire spread between ecosystems and connectivity across the landscape.

The influence of humans on past fire regimes has become a popular research topic (e.g., Williams 1994; AA Society Meeting 1996; Fish 1996; White et al. 1997), in particular with respect to the use of fires in ecosystem management to emulate presettlement fire and ecosystem processes. The controversy is that this region has one of the highest levels of lightning-fire activity in North America, but also, numerous historical accounts have recorded common anthropogenic fires and burning. In chapter three, documentary, ethnoecological, and dendrochronological (tree-ring) evidence are analyzed to infer possible influences of humans on past fire regimes. This multidisciplinary approach explores the historical, cultural, and wartime burning practices that may have influenced past fire histories and ecosystems in the Southwest Borderlands.

CHAPTER TWO

FIRE HISTORY IN RIPARIAN CANYON PINE-OAK FORESTS AND THE INTERVENING DESERT GRASSLANDS OF THE SOUTHWEST BORDERLANDS

2.1 Abstract — Fire-scarred pine samples were crossdated to reconstruct fire histories in riparian canyon pine-oak forests, and to infer the fire frequency of the intervening desert grasslands. Fire chronologies that date back to the 1600s were analyzed for six canyon sites within the Southwest Borderlands. Evidence suggests that in the past extensive fires were common in riparian canyon forests and the desert grasslands. Surface fires in canyon pine-oak forests occurred on average once every 5 to 9 years, and were estimated to have covered an area of at least 50 km^2. Synchronous fires recorded between canyon sites and documentary evidence suggests that the desert grasslands burned approximately every 5 to 10 years. These fires probably ranged between 10 to hundreds of km^2 in size. Wider spread basin-wide fire events were recorded at less commonly about every 7 to 10 years, and ranged between approximately 500 to more than a 1000 hectares. Basin-wide synchronous fire events recorded by three to four of the six fire history sites suggest fires spread between canyons and mountains via the lower grasslands, and through canyons to higher-elevation mixed-conifer forests. Tree-ring and climate evidence suggests that these broader-scale fire patterns were associated with dry years (La Niña, narrow annual rings) when preceded by one or more wet El Niño years.

2.2 Introduction

2.2.1 Background

The Southwest Borderlands is the Basin and Range Province of southern Arizona and New Mexico, and northern Sonora and Chihuahua, Mexico (Fig. 2.1). This "mountain island" region is a biological convergence zone between the temperate Rocky Mountains, and the subtropical Sierra Madres (Gelbach 1981; Wilson 1995; Ffolliott et al. 1996). On the eastern and western boundaries of this semiarid region, the Chihuahua and Sonoran Deserts provide a notable biophysical influence. Episodic patterns of severe drought and associated widespread fires entrain biological processes over this region, both within and across ecosystems (Swetnam and Betancourt 1998).

Vegetation patterns today originate from climate warming that commenced some 11,000 years ago following the last ice age (Martin 1963; Van Devender and Spaulding 1979; Van Devender 1995). Charcoal particles in sediment cores appear in greater abundance after this period, suggesting that climate and vegetation changes had generated conditions conducive for periodic fires (Davis 1994). Packrat midden evidence shows that by at least 4,000 years ago present-day climate patterns and vegetation horizons were well established (Betancourt et al. 1990). Tree-ring reconstructions and historical records indicate that episodic fires were common over the past three to four centuries throughout most ecosystems in this region (excluding the deserts and subalpine forests; Wright and Bailey 1982; Bahre 1991; Swetnam and Baisan 1996b). European-American settlement in the 1880s developed far reaching livestock economies that resulted in an abrupt and widespread extinction of frequent surface fires

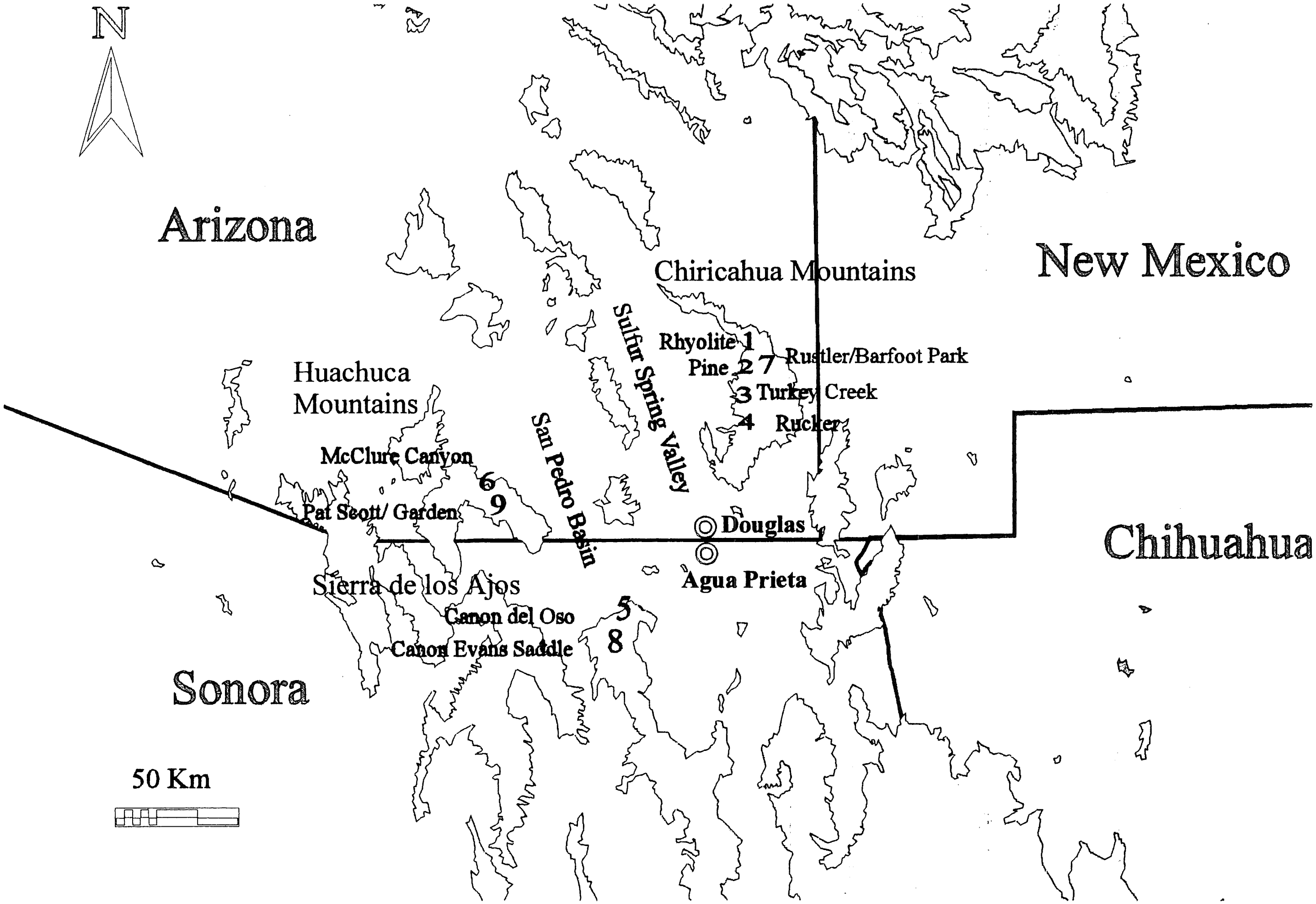

FIGURE 2.1 The Southwest Borderlands fire history reconstruction sites encompassing the lower Sulfur Spring and upper San Pedro Valleys. Canyon pine-oak sites are clockwise from the northwest; Rhyolite (1), Pine (2), Turkey Creek (3), and Rucker (4) Canyons in the western Chiricahua Mountains; Cañon del Oso (5) in the Sierra Ajos, and McClure (6) Canyon in the Huachuca Mountains. Upper-elevation mixed-con forest sites include Barfoot/Rustler Park (7), Cañon Evans Saddle (8), and Sawmill/Pat Scott Peak (9) sites in contiguous mountain ranges.

(Leopold 1924; Marshall 1962; Bahre 1985; Swetnam and Baisan 1996b). Early twentieth century fire suppression became notably more effective after WWII. This ensured that fires were severely limited throughout the borderland ecosystems, producing an unprecedented accumulation of woody fuels that exist today (Wright and Bailey 1982; Bahre 1991).

Widespread vegetation changes and related ecosystem health concerns have led to contemporary land stewardship referred to as ecosystem management or restoration ecology. Watershed managers are now using prescribed fire as a tool to emulate presettlement ecosystem conditions and to restore biological process and watershed resources (USDA 1992, 1993a, 1993b; Dahms and Geils 1997). The historic roles and variability of past fires in borderland ecosystems have been an important consideration for ecosystem management and restoration ecology (Allen 1994; Kaufmann et al. 1994; Morgan et al. 1994; Swanson et al. 1994). This investigation reconstructs and compares the range and variability of past fires in riparian canyon pine-oak forests, desert grasslands, and higher-elevation mixed-conifer forests.

The Southwest Borderlands is a unique region where agrarian culture, rural lifestyles, wide-open spaces, and low-population densities still prevail. The Malpai Borderlands Group of land owners, agencies, and managers are breaking new ground with innovative cooperative range and fire management practices, directed at sustainable grazing and ecosystem stewardship (Fig. 2.2; Klinkenborg 1995; Page 1997). This cooperative land-management affiliation is responsible for over a million acres (400,000 ha) of forest and grassland. A goal of the Malpai Group is to jointly manage livestock

FIGURE 2.2 Animas Valley in the "Malpai Borderlands". Open desert grasslands with pronghorn antelope (*Antilocapra americana*) in the foreground.

grazing and fire in these areas in a historical and ecological context. An underlying objective is to strengthen the regions ecological and socioeconomic viability in order to sustain the wide-open landscapes in the Southwest Borderlands. This is a noteworthy objective when considering demographic trends in other areas of the Southwest U.S. (i.e., Cochise and Santa Cruz Counties, AZ), where large tracts of lands are now rapidly being developed and subdivided. This research will provide presettlement (pre-1880) fire reconstructions that date back to the 1600s encompassing a vegetation gradient from desert grasslands to mixed-conifer forest. This evidence will provide a reference for future long-term ecosystem and fire management in the Southwest Borderlands.

Characteristics of past fire regimes in the desert grasslands have been estimated, but considerable uncertainties have persisted due to the paucity of high-resolution historical and paleoecological evidence. For example, historical records and photographs have been used to assess presettlement fire frequencies (Humphrey 1987; Hastings and Turner 1965; Bahre 1995a, 1991). Also, tree-ring, ecological, and isotopic evidence have been used to estimate past fire frequencies and vegetation changes (e.g., Marshall 1962, 1963; Swetnam et al. 1992; McPherson 1995). Rhyolite Canyon is the only prior canyon pine-oak forest fire reconstruction relative to this investigation. Swetnam and others (1989, 1991, 1992) showed that extensive fires occurred in this canyon forest about once every 10 to 15 years, however, they indicated that flood and debris flows also likely influenced fires at this unique site. In the desert grasslands fire frequencies have been estimated by some investigators to have occurred around every three to seven years, by many at least every 10 years, and by a few, to be infrequent or rare (i.e., Griffiths 1910; Buffington and Herbel 1965; Hastings and Turner 1965; Cable 1973; Humphrey 1984; Bahre 1991; McPherson 1995). However, limited evidence particularly for the grasslands, has resulted in wide disparities in the estimates of past fire frequency. Even less is known about the presettlement temporal variation, spatial extent, and connectivity of past fires in riparian canyon pine-oak forests and the desert grasslands.

The primary goal of this investigation is to provide original evidence to strengthen our understanding of the frequency, dimensions, and ecosystem connectivity regarding past fires in riparian canyon pine-oak forests, the intervening desert grasslands, and higher-elevation mixed-conifer forests. Fire patterns reconstructed from fire-scarred pines back to the mid-1600s provide direct evidence of the range of past fire frequency in canyon pine-oak forests. Desert grassland fire frequency was inferred through graphical and statistical analysis of synchronous fire events recorded between six canyon sites. The spatial extent of past fires were estimated from fire-scarred trees that were located on topographic maps and analyzed within and between sites. Additionally, independent historical evidence from newspapers, journals, and early written accounts were used to help corroborate the character and spatial extent of past fires. Finally, by analyzing synchronous fire patterns between canyon forests and upper-elevation sites, the relation of fire frequency and spread between the desert grasslands, pine-oak forests, and mixed-conifer forests was inferred.

2.2.2 Historical and Cultural Context

Written records in the Southwest Borderlands began in the late 1600s with Spanish colonization and documentary relations from mission and presidio settlements. Known to the Spanish as the Pimería Alta, and later as Apachería, this region experienced many cultural changes around the early historic period. Pima, Sobaipuri, Apache, Spanish, and others forged a new order along the borderlands over centuries of intercultural disputes, war, trade, religion, and marriage. Intrepid Apache raiding and warfare assured that this was one of the last provinces in North America to be permanently settled by Europeans. In 1848, the Treaty of Guadalupe Hidalgo established a new boundary between Mexico and the United States. The present day border established by the Gadsden Purchase in 1854, is closely aligned with the chain of Spanish military presidios along the northern frontier of New Spain (Bancroft 1889; Officer 1987).

European-American colonization of the Southwest Borderlands resulted in unrivaled cultural and ecological changes. By the late 1870s, after centuries of raiding and warfare, most Apache groups were settled on reservations in the Southwest U.S.. American settlement economies were based on mining, sawmills, scattered agriculture, and predominantly ranching (Figs. 2.3 and 2.4; Morrisey 1950; Wagoner 1952, 1961; Bahre 1991). The completion of the transcontinental Southern Pacific Railroad in 1881 marks the beginning of widespread land-use changes in the Southwest U.S.. Tens of thousands of livestock were transported rapidly to feedlots and new markets, from east to west. Homestead cattle, sheep, and goat ranches, and larger more organized ranching companies, endeavored to meet the rising demands for livestock (Hasket 1935, 1936;

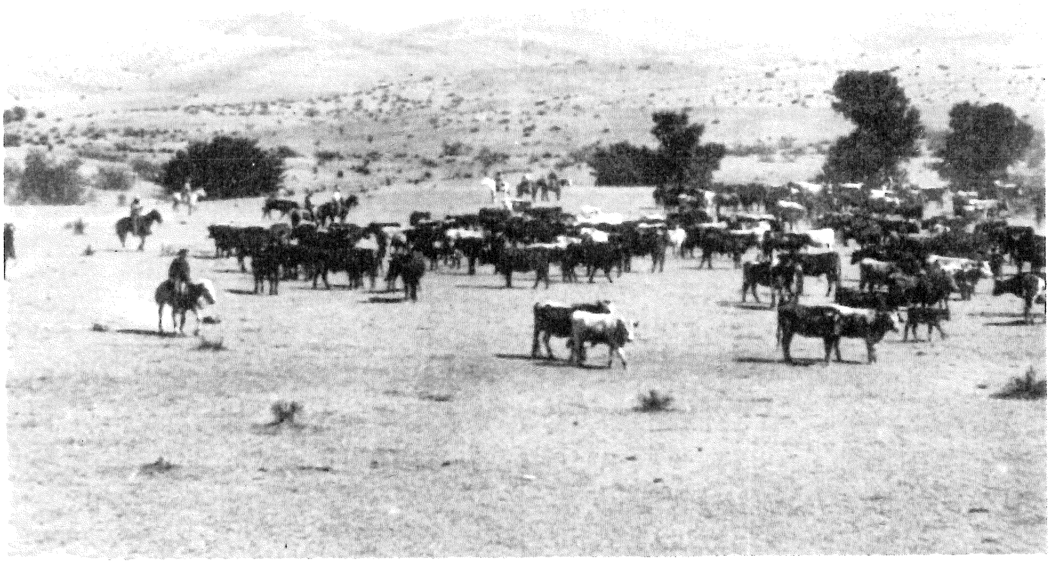

FIGURE 2.3 Sulfur Spring Valley desert grasslands and grazing circa 1880 (Bahre 1991)

FIGURE 2.4 Morse Canyon (Turkey Creek) sawmill circa 1885 (Bahre 1991).

Bailey 1994). In the last decades of the 19th century, massive livestock herds had spread out over the grasslands throughout the Southwest U.S.. This agrarian economy had expanded beyond the capacity of these semiarid lands, removing grasses and forage over extensive areas, soil structure was impaired, fires no longer spread, and vegetation change took root (Glendening1952; Wagoner 1952; Buffington and Herbel 1965; Bahre 1995a, 1995b). Environmental degradation in these overstocked ranges was inescapable and severely compounded by droughts.

By comparison, land-use history in Mexico is less well known. Evidence suggests that land-use intensification and extensification began decades later in the forests of Mexico around the 1940s. Historical records indicate these notable land-use changes in northern Mexico were associated with land tenure reforms in the late 1940s, and strengthened economic ties between the U.S. and Mexico beginning with the Second World War (Sheridan 1988).

2.2.3 Historical Land Use Patterns

Substantial fire and vegetation changes stemming from late-19th century land-use patterns are well documented (Bahre 1991; McPherson et al. 1993; Swetnam and Baisin 1996b; Villanueva 1996). Historical and ecological research indicate that prior to widespread grazing in the late-1880s, desert grasslands were more robust and extensive, with fewer woody species (Hastings and Turner 1965; Cable 1973; Archer 1989, 1994; Bahre and Shelton 1993). More diverse riparian canyon pine-oak forests also experienced astonishing changes, including increased canopy closure, biomass accumulation, and reduced bird, fish, and amphibian diversity (Marshall 1957, 1963; Minkley and Deacon 1991; Rinne 1995; Sredl and Howland 1995). Landscape fragmentation during the settlement period, at the very least contributed to arroyo cutting across the region (Rich 1911; Meinzer et al. 1913; Hastings 1959; Cooke and Reeves 1976). Decades of heavy grazing and later organized fire suppression resulted in the elimination of frequent surface fires. These factors also resulted in increases to unpalatable and fire-intolerant species, further exacerbating vegetation changes (Leopold 1924; Glendening 1952; Smith and Schmutz 1975; Bahre and Bradbury 1978). The regional extermination of prairie dog towns in the early 20th century most likely had a profound influence on the desert grasslands and fires (Weltzin 1990), however, their function in soil nutrient cycling and desert grassland landscape ecology is poorly understood.

2.3 Site Description and Geographical Context

Fire history reconstruction sites were located in mountain canyons of the Sulfur Spring and upper San Pedro watersheds (Table 2.1; See Fig. 2.1). Canyon sites with suitable material for fire history analysis were difficult to find in this region, however, six were located in the lower Chiricahua, Los Ajos, and the Huachuca Mountains. All sites were within riparian canyon pine-oak forests linked by lower adjacent desert grasslands and higher-elevation mixed-conifer forests (Figs. 2.5 and 2.6). Each canyon was sampled for the best fire-scarred pine evidence that could be located using a stratified grid between 1600 and 2400 meters. Existing fire histories from Rhyolite Canyon

Table 2.1. Riparian canyon pine-oak forest and adjacent higher-elevation mixed-conifer forest, fire history reconstruction site information.

Site, (map #; reference)	Elevational Gradient (meters)	Number of Samples	Number of Fire Scars	Inner Ring - Outer Ring Date	Land Management Responsibility
Canyon Pine-Oak Forest Sites					
Western Chiricahua Mountains, North to South					
Rhyolite Canyon (1; Swetnam et al. 1989)	1700-2200	56	96	1460-1987	USDI, Chiricahua N.M.
Pine Canyon (2; Kaib et al. 1996)	1700-2500	27	57	1540-1995	USDA, Coronado N.F
Turkey Creek (3)	1700-2500	26	92	1600-1996	USDA, Coronado N.F
Rucker Canyon (4)	1700-2500	21	84	1550-1996	USDA, Coronado N.F
Sierra de los Ajos					
Canyon Oso and Saddle (5)	1600-2100	19	84	1607-1996	SEMARNAP National Forest Reserve
Fort Huachuca					
McClure Canyon (6)	1700-2400	18	88	1480-1996	Fort Huachuca Military Reserve
Adjacent Upper-Elevation Mixed-Conifer Forest Sites					
Barfoot-Rustler Park (7; Seklecki et al. 1996)	2400-2600	58	74	1460-1995	USDA, Coronado N.F
Sierra de los Ajos, Cañon Evan Saddle, Mexico (8; Dieterich 1983a)	2000-2100	13	127	1438-1996	SEMARNAP National Forest Reserve
Sawmill Canyon / Pat Scott Peak (9; Danzer et al. 1996)	2000-2700	57	150	1499-1994	Fort Huachuca Military Reserve

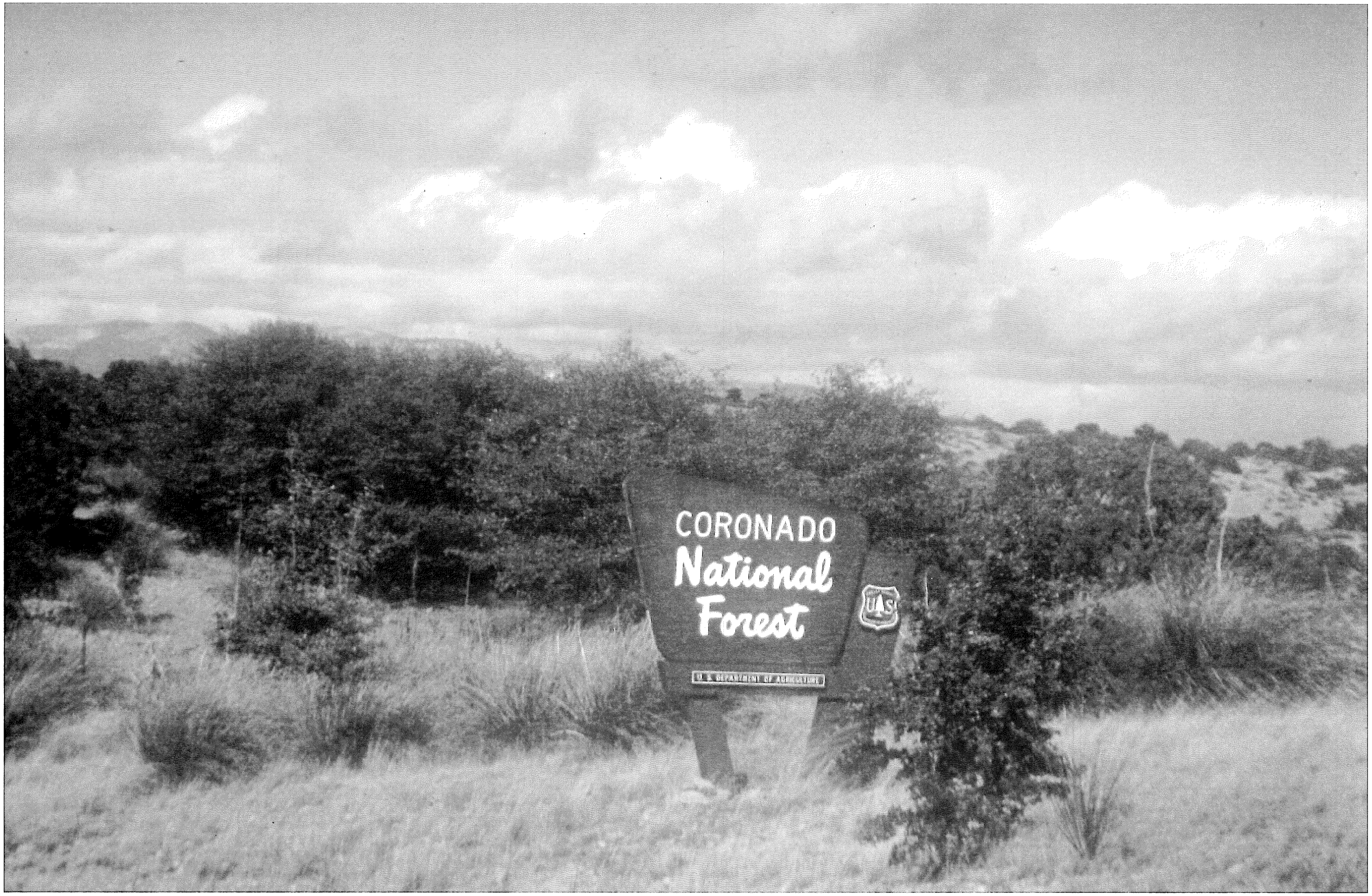

FIGURE 2.5 Desert grasslands and oak woodlands in southeast Arizona.

FIGURE 2.6 Desert grasslands, oak woodlands, and riparian pine-oak forest in the western Chiricahua Mountains

(Swetnam et al. 1989) and higher-elevation mixed-conifer forest sites were also included in this analysis (Dieterich 1983a; Swetnam and Baisan 1996a; Danzer et al. 1996; Seklecki et al. 1996).

Grassland ecosystems (desert, mixed, and plains) provide ground cover and connective fuel that link many ecosystems across the landscape, increasing the probability of fire spreading between areas. Grasslands form a vegetation matrix covering lowland basins, south-facing canyon slopes, and linking canyon forests to higher-elevation forests, across elevations between 1000 to at least 3000 meters (Whittaker and Niering 1964, 1975; Cable 1975; Brown 1982; Brady et al. 1989). Desert grassland biomass production and continuity are also strongly influenced by soil and climate variability, fire regimes, and land-use patterns (Wooten 1916; Wright and Van Dyne 1976).

In the desert grasslands, biomass productivity is the lowest of North American grasslands (Gentry 1957; Herbel et al. 1972; Simms and Singh 1978). Several consecutive seasons or years (i.e., El Niño Years) of above average rainfall favors ignition and spread of fires in these ecosystems due to the greater mass and cover of fine fuels (McLaughlin and Bowers 1982; Rogers and Vint 1987; Swetnam and Betancourt 1990, 1997). Desert grasslands can recover rapidly following a burn or limited grazing, usually within one to three growing seasons depending upon antecedent range conditions and subsequent precipitation patterns (Reynolds and Bohning 1957; Morenno 1968; Bock et al. 1976, 1984; Chew 1982; Robinett 1994).

Desert grasslands of southeast Arizona and the adjacent Mexican Borderlands cover about 40 % of this region and occupy an ecological zone characterized by semiarid climate, sandy-loam soils commonly with caliche horizons, and in the past, recurrent fires (Whitefield and Beutner 1938; Humphrey 1984; McClaran 1995). By comparison, low-elevation riparian canyon pine-oak forests are confined to canyon systems bounded by igneous or sedimentary formations on soils formed from recent alluvium. These forests occupy a topographic niche that affords shelter from the elements, cool-air drainage, increased runoff from higher elevations, and greater productivity (i.e., increased fuels) than neighboring communities (Marshall 1957; Barton and Teeri 1993; Barton 1994; Baker et al. 1995). Community ecotones typically occur at separate geologic formations, alluvial fans, and aspect transitions where the mesic nature of these mountain canyons allow pine-oak forests to "inter-finger" into oak woodlands and lower desert grasslands (See Figs. 2.5 and 2.6).

It is evident that in the past riparian-canyon forests extended further into the lower grasslands. Early accounts describe these "gallery" forests as the most accessible sources of timber for Fort Bowie and Rucker, and later for Bisbee and Tombstone (See Fig. 2.1; Bahre 1985; Wilson 1995). Also, historical records and in some areas remnant stumps indicate that these pine-oak forests once extended further into the desert grasslands (Hayes 1992; Bahre 1995b; Wilson 1995). Additionally, by far the majority of this fire-scarred pine evidence was collected from sawed stumps that typically had outer-ring dates in the late 1800s.

There is a very high floristic diversity within and between vegetation communities in this region (Dobson et al. 1997). These mountain islands have floras with at least 500 to 1000 species (Felger et al. 1995; McLaughlin 1995). Major vegetation communities found dispersed along these canyons include Madrean pine-oak and southwest riparian forests; oak, pinyon, juniper, and mesquite woodlands; interior chaparral; and plains and desert grasslands (Brown and Lowe 1980; Sawyer and Kinraide 1980; Brown 1982; Muldavin et al. 1996). Flora of the Chiricahua Mountains have been described by Reeves (1976) and Bennett and others (1996), the Huachuca Mountains by Wallmo (1955), and the Sierra de los Ajos by Fishbien and others (1995). For this study predominant vegetation types found along selected riparian canyon sites include desert grasslands, oak woodlands, Madrean pine-oak forests, and at higher-elevations mixed-conifer forests.

Precipitation in these areas is extremely variable and only slightly greater than nearby deserts, averaging between 20 to 45 cm annually (Shreve 1915, 1944; Humphrey 1958; Sellers and Hill 1974). The orographic influence of isolated mountains produces more precipitation in the higher elevations than in lower desert grasslands (Shreve 1915; Niering and Lowe 1984; Barton and Teeri 1993; Barton 1994). Annual rainfall has a bimodal distribution with up to 60 % falling during the winter months and the rest falling during the summer monsoons (Douglas et al. 1993; Stensrud et al. 1995). These percentages are reversed to the south in Mexico, where "las aguas" or monsoon rains typically contribute substantially to increase overall annual precipitation (Shreve 1915; 1944; Stensrud et al. 1995). The Southwest Borderlands also has two dry seasons, one in the late spring or early summer, and the other in the fall. However, high levels of lightning coincide only with the late-spring and early-summer dry period, prior to and during the summer monsoon season (Barrows 1978; Gosz et al. 1995).

Although it is possible for fires to burn at almost any time of the year, the peak burning season occurs between May and July when early monsoon storms provide abundant lightning and extremely variable precipitation (Sellers and Hill 1974; Barrows 1978; Baisan and Swetnam 1990). Usually during this time, temperatures are high and the perennial vegetation is dried. Also, many trees and shrubs including several oaks species release their older leaves, a process that is particularly apparent during drought years (Pers. Obs. and Comm. with Fred Shoeffler). According to fire statistics, fires are frequently ignited by "dry" lightning storms that occur with the early monsoons. The position of fire scars within the annual rings, also indicates that the majority of presettlement era fires in this region occurred during the late-spring and early-summer seasons (Swetnam and Baisan 1996b).

Historical and tree-ring research indicates that in the past fires spread across extensive areas throughout the Southwest Borderlands (Bahre 1991; Swetnam and Baisan 1996a). Widespread fire years have been strongly correlated with drought years when preceded by years of above average precipitation and associated fine fuel accumulation (Swetnam 1990; Swetnam and Betancourt 1990). Intense monsoon lightning activity contributes to the majority of fire ignitions in these areas (Jandrey 1975). The National Lightning Detection System and climate data also illustrate that lightning strikes in the summer months are sufficient to support very frequent fire

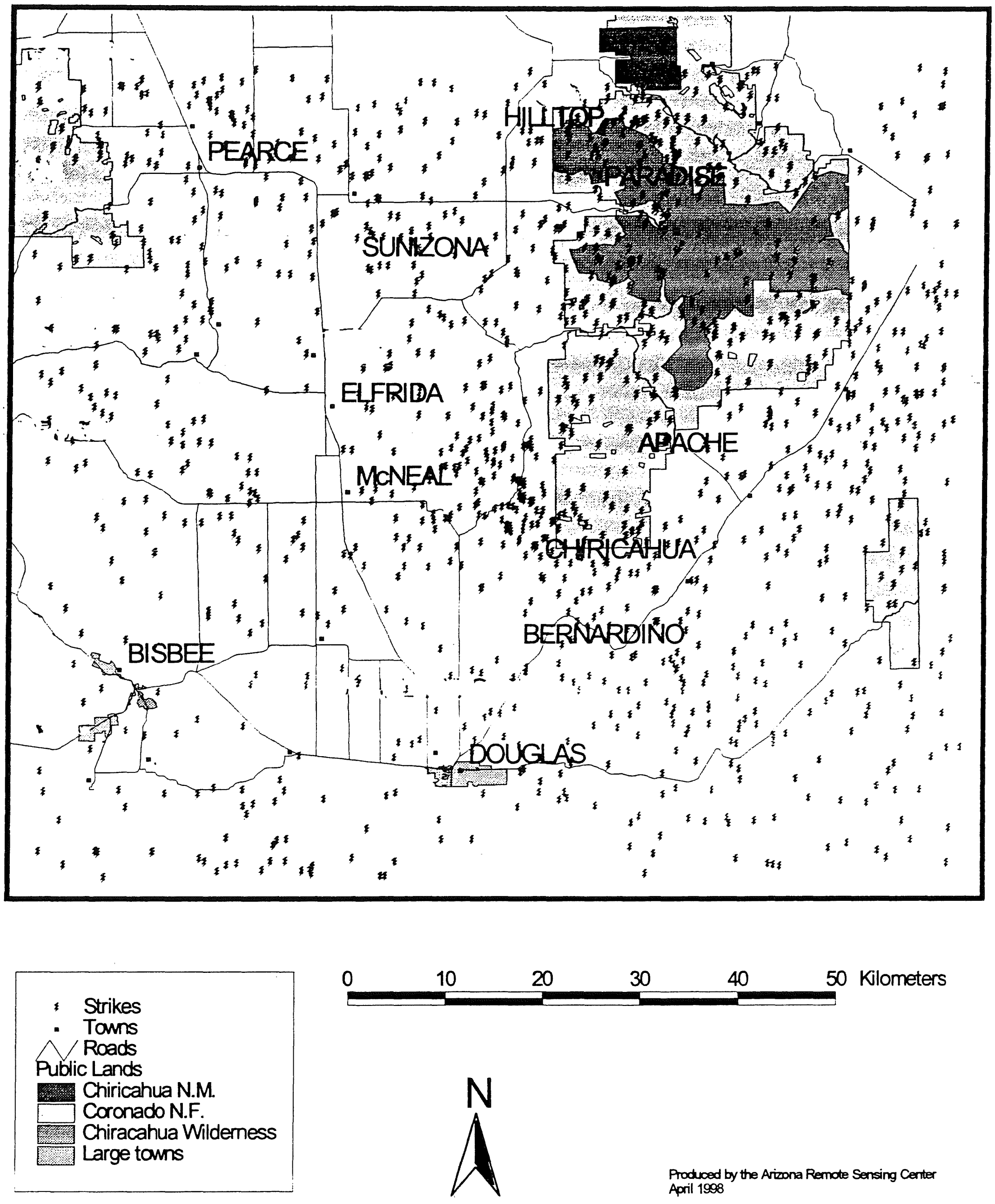

FIGURE 2.7 Lightning strikes in study area for the month of July 1996 (n = 3,016). Data for positive and negative current, cloud to ground lightning, from the National Interagency Fire Center, (NIFC; Boise, Idaho) Lightning Detection System (Krider et al. 1980).

regimes (Fig. 2.7; Barrows 1978; Gosz et al. 1995). In figure 2.7, over 3,000 lightning strikes occurred within the study area surrounding the Chiricahua Mountains during the month of July 1996.

2.4 Methods

2.4.1 Fire History

Five riparian canyon pine-oak forest sites were selected after a thorough reconnaissance of dozens of canyon sites in this region (See Fig. 2.1 and Table 2.1). These canyon sites were chosen for their presence of fire-scarred pine evidence, and proximity and connectivity to the lower desert grasslands. An existing fire history reconstruction from Rhyolite Canyon was added to the analysis (Swetnam et al. 1989, 1992). Fire history evidence was collected from a total of 167 trees at these sites along an elevational gradient between 1700 and 2500 meters. A chain saw was used to obtain partial and full cross sections from fire-scarred Apache pine (*Pinus engelmannii*, Carr.), Arizona pine (*Pinus arizonica*, Engelm.), and ponderosa pine (*Pinus ponderosa*, Dougl. ex Laws) stumps, logs, and snags (Baisan and Swetnam 1990). A limited number of samples were also collected from living trees with non-destructive methods to extend the chronologies to the present decade (Arno and Sneck 1977; Dieterich 1980b; McBride 1983). Fire-scarred cross sections were protected in the field with polyethylene packaging wrap and fiberglass tape for transportation to the laboratory (Brown and Swetnam 1994). At the Laboratory of Tree-Ring Research, fire-scarred pine samples were re-sectioned with a band saw and finely sanded with a belt sander using a series of coarse to fine papers (i.e., 50 to 400 grit). Specimens were crossdated using dendrochronology techniques (Stokes and Smiley 1968; Fritts 1976; Swetnam et al. 1985).

Crossdated fire scars were used to reconstruct fire history from the mid-17th century to the present using compositing and fire interval analysis methods (Dieterich 1980a, 1983b; Dieterich and Swetnam 1984; Grissino-Mayer 1995). Desert grassland fire history and descriptive statistics were inferred and reconstructed from synchronous fire events recorded between canyon sites. Descriptive statistics were also compiled and compared with adjacent higher-elevation mixed-conifer forest sites from prior fire history studies (Dieterich 1983a; Baisan and Swetnam 1995; Danzer et al. 1996; Seklecki et al. 1996).

The relative extent of past fires was inferred from mapped fire-scarred pine samples and the analysis of synchronous fire events within and between collection sites. Fire-event size classes were inferred by analyzing fire chronologies for increasingly greater percentages of trees that recorded specific fire events (Swetnam and Baisan 1996a, Baisan and Swetnam 1990). The finest-scale canyon-fire events were interpreted as those recorded by the fewest numbers of fire-scarred samples (n = 1-3) on a specific year. Fire events recorded by 10 % or more of the samples were interpreted as site-wide fire events that ranged between about five to at least 10 km^2. Fire events recorded by 25% or more samples were interpreted to have extended beyond the sampled area, probably canyon-wide fire events or larger, that ranged between 10 to at least 50 km^2 in extent. The spatial extent of past fires were estimated from fire-event size classes and the distance between fire-scarred trees, canyon sites, canyon and upper-elevation forest sites, and among multiple fire history sites between mountain ranges.

2.4.2 Graphical Analysis of Fire History Reconstructions

Fire history was analyzed for each site using graphical and statistical software (Grissino-Mayer 1994). Graphical analysis was used to interpret the temporal and spatial patterns of historical fires within and between canyon pine-oak forests (i.e., grassland spreading fires) and adjacent mixed-conifer forest sites over the past 300 years. Within sites, fires recorded by fewer trees (i.e., n = 1-3) were inferred to be relatively smaller, patchy fires, while those recorded by a greater proportion of trees (i.e., 10 to 25 %) were interpreted as larger fires that probably spread across the majority or at least the entire site. Likewise, synchronous fire events recorded by adjacent canyon sites were interpreted as more extensive fires that probably spread between sites across intervening desert grasslands. Synchronous fire events were also compared between canyon and upper-elevation fire history sites. The assumptions and limitations of this approach will be explained in the discussion section.

2.4.3 Synchronous Intercanyon Fire Patterns

Synchronous fire events between canyon sites were used to estimate the range of past fire frequency in the intervening desert grasslands. Descriptive statistics were computed for these synchronous intercanyon fire events as proxy fire-interval data for the desert grasslands. Four adjacent western Chiricahua Canyon Sites were analyzed for fires recorded by at least 2, 3, and by all 4 sites. Additionally, sites in the Huachuca and Los Ajos Mountains (upper San Pedro Basin) were analyzed for synchronous-fire events. Finally, synchronous-fire events recorded between at least 2, 3, 4, and 5, of the 6 canyon sites, were analyzed to illustrate the potential range of progressively larger desert grassland fire events.

2.4.4 Statistical Analysis of Fire History Reconstructions

A series of statistical tests were performed on the 6 canyon pine-oak and 3 adjacent mixed-conifer forest sites. A range of descriptive statistics over several time periods were compiled for all sites from the fire interval distributions. These include the mean, median, Weibull median probability interval (WMPI), minimum and maximum fire intervals, and the last 3 recorded fire dates. Fire-interval data commonly have non-normal distributions, and in this case they were all skewed right (i.e., a disproportionate number of short fire intervals). In the case of skewed distributions, the WMPI provides a more robust measure of central tendency, and it also provides a probabilistic framework for interpreting fire interval distributions (Weibull 1951; Johnson and Van Wagner 1985; Johnson and Gutsell 1994; Grissino-Mayer 1995).

All fire chronologies were analyzed for two primary historical periods, 1650 through 1880 and 1700 through 1880. Fire-interval statistics were calculated and analyzed for these two time periods using 3 different criteria: Fire-scar dates recorded at each site by (1) any tree (2) 10 % or more trees, and (3) fires recorded by 25 % or more trees. These criteria were chosen because they span a progressive range of relative fire extent. Smaller patchy fires were interpreted as those recorded by only a few trees at a site, site-wide fires were recorded by 10% or more of the samples, and more extensive fire events were recorded by 25% or more trees at a site, and often by several sites (Swetnam and Baisan 1996a).

Analysis periods and criteria were chosen with consideration of the limited numbers fire-scarred pine specimens and fire scars available in earlier time periods. Due to the natural decay rates of older trees, wood, and fire-scarred samples, less fire history information was available from earlier time periods. Segments of the fire reconstructions from the earliest time periods are probably incomplete, having temporal and spatial gaps in the fire history record. Fire-scar statistics for the earlier analysis period, 1650 to 1880 for example, record longer intervals (means and maxima) than the analysis between 1700 and 1880. The earlier period was still used because of the objective to reconstruct presettlement (pre-1880s) fire regimes over the longest time interval. For these reasons, the reconstructed MFI's are considered conservative. The year 1880 was selected as the ending date for the analysis due to the dramatic changes in fire regimes that began around this decade north of the border. By contrast, very fire-scarred specimens dated prior to the 1760s at the forest sites in Mexico and they recorded fire well into the 20th century. Therefore, the Sierra Ajos sites were analyzed using the same criteria, however, for the period between 1760 and 1970.

2.4.5 Analysis of Spatial Patterns

Fire patterns are strongly influenced by regional climate, creating on any given year interrelated vegetation, fuel, and fire conditions. If climate is the primary factor influencing fire regimes at these sites, then no substantial fire-pattern differences should exist between sites. Additionally, fire spread between canyon sites was probably an important contributing factor for related fire patterns at these sites linked by intervening desert grasslands. However, if differences do exist, they must be explained by other factors besides climate and intersite fire spread. Alternative factors include geomorphic differences and anthropogenic influences. Chi-squared (X^2) tests were used to analyze relative intercanyon fire pattern similarities. The X^2 tests for association were first used by Swetnam and Dieterich (1985) and Swetnam (1993) to test for climate influences, and later by Grissino-Mayer (1995) to investigate climate influences and intersite fire spread. In this study area climate influences and intersite fire spread are mutually inclusive factors. During El Niño wet years, fuel accumulates, and when subsequent La Niña drought years occur, so do extensive fire years (Swetnam and Betancourt 1990). Conversely, the humid conditions of wet years reduce the chances for fire ignitions and spread. Chi-squared tests were used here to analyze the relative differences or strengths of association of fire patterns between all fire history sites.

Chi-squared 2 x 2 and 2 X 1 tests were conducted for all sites to test the relative statistical association or disassociation of fire and non-fire events between sites (Swetnam 1993; Grissino-Mayer 1995). The 2 X 2 test uses binary data to analyze patterns of fire (+) and non-fire years (-) between paired sites (i.e., ++,+-,-+,--). The null hypothesis was that fire patterns are statistically independent or have no association between sites. The null hypothesis was rejected when the 2 X 2 test was statistically significant at a probability level of less than 0.05. A rejected null hypothesis suggests alternatively, fire pattern association between sites due to statistically high numbers of synchronous or asynchronous fire patterns (i.e., due to intercanyon fire spread and climate relations).

The more stringent 2 x 1 X^2 analysis tests only for statistical association of synchronous and asynchronous fire events (++,+-,-+). Synchronous non-fire years (--) are not considered by the 2 X 1 test. Because the 2 X 1 tests only for association of synchronous and asynchronous fire events, it is a more rigorous statistical test than the 2 X 2 analysis (Grissino-Mayer 1995). The null hypothesis states that patterns of fire years are statistically independent or have no association between sites. The 2 x 1 null hypothesis was also rejected at a probability level less than 0.05, and the alternative hypothesis was accepted (HA: fire pattern association exists between sites). Statistical significance for the 2 X 1 may result if the number of observed synchronous (++), or asynchronous fire events (+-,-+), are greater than those expected by chance. Chi-squared tests of association were also used to evaluate the relative association of fire patterns between canyon and higher-elevation mixed-conifer forest sites.

2.4.6 Historical Evidence

Historical fire and land-use information was collected for the study areas and throughout the Southwest Borderlands to evaluate in context with fire history reconstructions. Historical archives and documents from this region provide independent sources of information that illustrate the nature and character of past fires in these areas. Accounts come from a variety of documentary sources including journals, newspapers, and military reports located at the libraries of The University of Arizona. Sources were also collected from library archives at the University of New Mexico in Albuquerque. A larger set of documentary sources were evaluated in the following chapter especially with reference to cultural fire influences. A few historical examples relative to desert grassland fire character and spread were transcribed to illustrate the nature of past fires in the Madrean Borderlands.

2.5 Results

2.5.1 Graphical and Statistical Analysis

Graphical analysis and summary statistics indicate that frequent surface fires occurred in the riparian canyon pine-oak forests at the very least over the 230 year analysis period (Table 2.2). A high degree of fire synchrony between fire history sites suggests that many of these fires were extensive, spreading across desert grasslands, between and through canyon sites, and also to higher elevation forests. Fire history reconstructions for Turkey Creek and McClure Canyons in the Chiricahua and Huachuca Mountains are typical of the canyon forest fire. Graphical reconstructions of fire patterns show that fire events were recorded often by only a few trees along these canyon sites (i.e., solitary vertical fire-scar hatch marks for a given year), suggesting smaller patchy burns reconstructions (Figs. 2.8 and 2.9). For example over the 230 year

TABLE 2.2. Summary of descriptive fire statistics for six riparian canyon pine-oak forest sites, for period between 1650 and 1880, unless otherwise shown. Fire size classes recorded by 10 % or more of the trees are interpreted as site-wide fires, those recorded by 25 % or more are interpreted as canyon-wide fires.

Site n = Trees	n = Fire Intervals	Fire Size Class	Mean	Median	WMPI	Minimum Fire Interval	Maximum Fire Interval	Last 3 Fire Years > 2 trees
Rhyolite Canyon		All Fires	3.52	3	3.01	1	15	1924
56	64	10%	9.38	9	9	1	21	1886
		25%	13.87	14	12.82	1	31	1882
Pine Canyon		All Fires	4.33	4	4.04	1	12	1859
27	57	10%	4.91	4	4.56	1	12	1856
		25%	6.91	6	6.51	3	22	1854
Turkey Creek		All Fires	3.05	2	2.76	1	10	1917
26	73	10%	4.29	4	4.05	1	10	1910
		25%	8.91	7	7.78	3	35	1899
Rucker Canyon		All Fires	3.15	3	2.85	1	12	1890
21	72	10%	3.66	3	3.3	1	12	1886
		25%	7.23	6	6.73	2	16	1877
McClure Canyon		All Fires	3.78	3	3.54	1	10	1946
18	60	10%	4.83	4	4.71	2	10	1918
		25%	6.69	6	6.09	2	21	1911
Canon de Oso		All Fires	4.59	3	3.46	1	38	1972
19	34	10%	5.03	3	3.81	1	38	1964
		25%	7	5	5.62	2	38	1960
Canon de Oso 1760-1970								
19	34	All Fires	3.18	3	2.95	1	10	1972
		10%	3.92	3	3.68	1	10	1964
		25%	5.23	4	4.8	2	18	1960

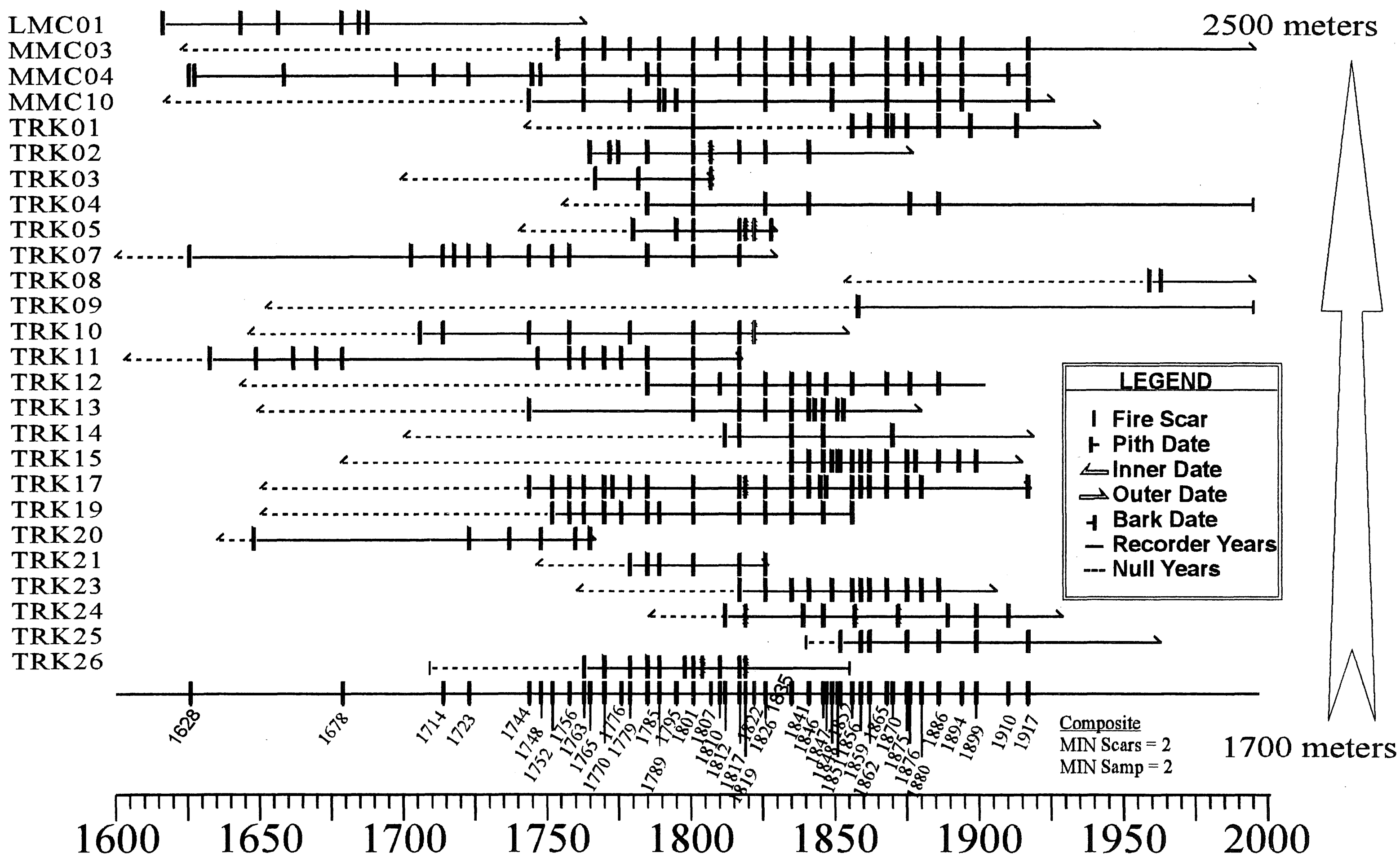

FIGURE 2.8 Fire history reconstruction for Turkey Creek Canyon in the western Chiricahua Mountains. Horizontal lines represent individual fire-scarred tree specimens and vertical hatch marks are dated fire events. The fire composite includes all fires recorded by 2 or more trees.

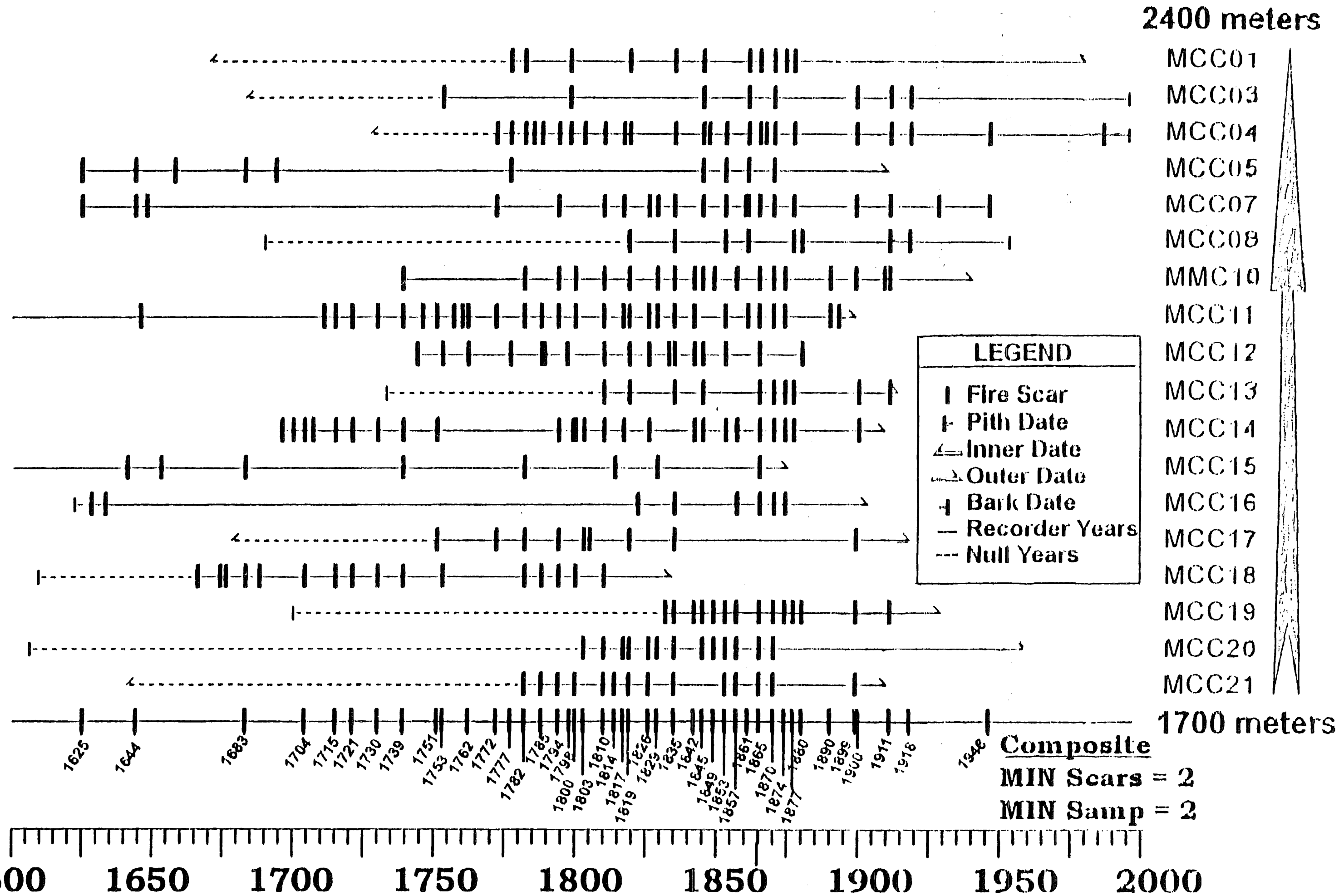

FIGURE 2.9 Fire history reconstruction for McClure Canyon at Fort Huachuca Military Reservation, in the northeastern Huachuca Mountains. Horizontal lines represent individual fire-scarred tree specimens and vertical hatch marks are dated fire events. The fire composite includes all fires recorded by 2 or more trees.

analysis period, 74 total fire events were recorded at Turkey Creek, of which 38 were recorded by at least two trees, while only 23 were recorded by at least three or more trees. McClure recorded 61 total fire events; 35 by at least two trees, while 32 were recorded by at least three or more trees. Additionally, Rucker Canyon recorded 73 total fire events; 48 were recorded by at least two trees, while only 30 were recorded by at least three or more trees.

Five new fire reconstructions were combined with Rhyolite Canyon to provide strong evidence of past fire frequency and variability in these riparian canyon pine-oak forests. In evaluating statistics for all six canyon sites (See Table 2.2) over the 230 year analysis period, finer-scale fire events were recorded by two to three trees on average once every four to five years. Broader-scale fire events occurred about once every seven to nine years. They are illustrated by the graphical fire reconstructions with the alignment of vertical fire-scar hatch marks for several to many trees on certain years (See Figures 2.8 and 2.9).

Fire events reconstructed at Rhyolite suggest less frequent fire occurrence when compared to the other five canyon sites (See Table 2.2). Based on flood-scarred tree evidence, Swetnam and others (1989, 1991) concluded that fire spread at Rhyolite was limited at times by periodic floods and debris flows (i.e., the early 1800s in the middle part of the canyon). However, such gaps in the fire record were not evident at the other canyon sites (See Figs. 2.8 and 2.9). Fire-scar evidence indicates substantial flood and debris flows recognized at Rhyolite, and other canyons at geological-time scales (Wohl and Pearthree 1991), were not common in the other five riparian canyon sites during the same 230 year analysis periods, or that they were not extensive enough to affect canyon-wide fire spread. More importantly, the five new fire histories indicate that frequent canyon site-wide and more extensive fires occurred about every five to nine years within the larger set of riparian canyon pine-oak forest sites.

Fires recorded by at least 10 % of the trees at the canyon pine-oak forest sites, occurred at mean fire intervals (MFIs) ranging between one and 12 years. MFIs recorded by at least 25 % of the trees range between two and 24 years. This wide range between minimum and maximum fire intervals is probably an artifact of an incomplete fire-scar record (especially during the earliest periods), and therefore the maxima should be considered very conservative. Strong synchrony of fire events between adjacent canyon forest sites suggest that fires spread commonly between canyons via the intervening desert and mixed grasslands. Additionally, existing fire histories from mixed-conifer sites show that site-wide and more extensive surface fires also occurred in these adjacent higher-elevation forests, about every five to nine years (Table 2.3; Ahlstrand 1980; Moir 1982; Grissino-Mayer et al. 1995; Swetnam and Baisan 1996b; Seklecki et al. 1996; Danzer et al. 1996).

Almost all fire history reconstructions north of the international boundary show a dramatic decrease in fire activity coinciding with the settlement period in the 1880s. This decline in surface fires was common throughout the Southwest United States and strongly associated with increased livestock grazing and later fire suppression (Swetnam and Baisan 1996a, 1996b). This pattern is clearly evident at Turkey Creek and McClure Canyons. McClure has had slightly more recent 20th century fires when compared to

TABLE 2.3. Summary of descriptive fire statistics for 3 adjacent upper-elevation mixed-conifer forest sites, for the period between 1650 and 1880. Fire-event size classes recorded by 10 % or more of the trees are interpreted as site-wide fires, fire events recorded by 25 % or more are interpreted as canyon-wide or greater, size fires.

n = Trees	n = Fire Intervals	Fire Size Class	Mean	Median	WMPI	Min. Fire Interval	Max. Fire Interval	Last 3 Fire Years; > 2 trees
Rustler and Barfoot Park, Chiricahua Mountains								
58	68	All Fires	3.26	3	2.78	1	16	1994
		10%	3.93	3	3.42	1	16	1892
		25%	4.78	4	4.3	1	16	1886
Ridge and Saddle, Sierra de los Ajos								
25	59	All Fires	3.63	3	3.48	1	9	1972
		10%	4.18	4	4.05	1	9	1964
		25%	9.17	7	8.06	2	33	1960
Sawmill Canyon and Pat Scott Peak, Huachuca Mountains								
57	80	All Fires	2.85	3	2.67	1	9	1977
		10%	4.56	4	4.35	1	11	1914
		25%	9.81	7	8.74	3	26	1902

other canyon sites in the U.S.. Fort Huachuca records show that routine military maneuvers have caused many fires (Biggs 1997; Sheridan Stone Pers. Comm.). The seven fire history reconstruction sites in the U.S., were analyzed through the year 1880, the beginning of widespread European-American settlement and fire regime changes. Also, the fire events recorded nearest to the settlement period (ca. 1880) by 2 or more trees at a site were generally interpreted as the last widespread surface fire, of a similar character to presettlement conditions. Overall, fire records decline earliest at canyon forests when compared to higher-elevation mixed-conifer forest sites. This pattern probably reflects the early influences of grazing, hay harvesting, fuelwood cutting, and logging on these more accessible grasslands and forests (Bahre and Hutchinson 1985; Bahre 1987). For example, widespread fires at three Chiricahua Canyon sites were disrupted earlier than the adjacent mixed-conifer sites at Rustler and Barfoot Park (See Tables 2.2 and 2.3). Pine Canyon showed the earliest fire regime change of all sites, with the number of recorded fire events and samples declining sharply after the 1860's (Kaib et al. 1996b). This is possibly due to early sawmill logging that was corroborated by historical accounts from fort Bowie (Wilson 1995), illustrating how tree-ring and historical accounts can provide evidence of the timing and magnitude of timber harvests at specific sites.

Fire and land-use history in many areas of northern Mexico contrast sharply with nearby sites in Arizona and New Mexico. Fire regime changes in the late 1800s typical of most Southwest U.S. fire histories, did not occur in the Sierra de los Ajos in Sonora, Mexico (Fig. 2.10). At the lowest elevation, the Cañon del Oso site in the Sierra Ajos

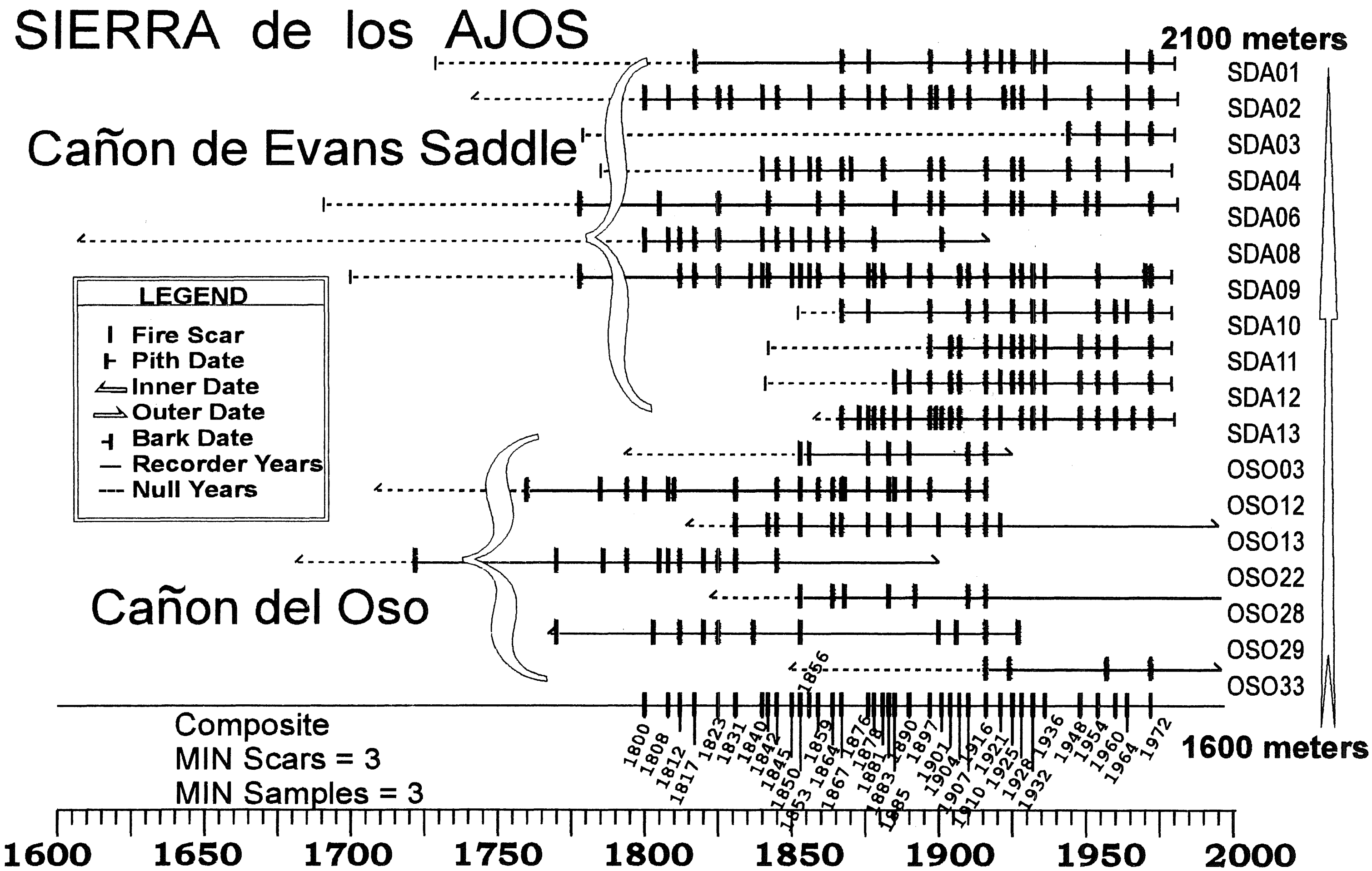

FIGURE 2.10 Fire history reconstruction for the Cañon del Oso and Saddle Sites, in the northern Sierra de los Ajos. Horizontal lines represent individual fire-scarred pine specimens and vertical hatch marks are dated fire events. The fire composite includes all fires recorded by three or more trees.

experienced a decline in fire activity beginning in the 1940s. This pattern may be associated with the establishment of communal *ejído* lands used for livestock production, fuelwood, and timber beginning in the late 1940s. It probably reflects the early influences of intensified land use on the lower grasslands, oak woodlands, and pine-oak forests. By comparison the higher-elevation Sierra Ajos saddle and ridge sites continue to burn with limited influence from land use or fire suppression. The most recent lightning fire in these upper-elevation forests occurred in May of 1997 and burned mostly as a surface fire over approximately 1,400 hectares.

Several other fire history reconstructions in northern Mexico do not experience a decline in surface fires associated with land-use and fire suppression until the late-20th century if at all (Leopold 1937; Minnich 1983; Fule and Covington 1994, 1995, 1996, 1997; Swetnam and Baisan 1996b). Preliminary fire reconstructions from Sierra el Tigre and Sierra Bacadéhuachi, respectively about 100 and 175 kilometers southeast of the Sierra Ajos, show that fire regimes remain unaltered in these more remote forests of Mexico. The last widespread fires in these forested mountains were recorded in the 1990s (Kaib, unpublished data). Fires continue to burn through these Madrean pine-oak forests even after centuries of land-use for local subsistence, and limited grazing. The fact that frequent surface fires continue in these Mexican pine-oak forests alone suggests they are still relatively undisturbed ecosystems, far less altered than neighboring forests in the U.S.. The relatively undisturbed state of these Madrean forests makes them very important for future research on forest ecology, watershed management, and biological conservation in the U.S. and Mexico.

Unharvested forests in Mexico have become almost as rare as in the U.S.. Economic developments (i.e., GATT, NAFTA) have begun to put great pressure on most regions of the Sierra Madres. Mexican and International corporations are extracting large tracts of mineral and timber resources from the Sierra Madres in areas previously inaccessible (i.e., along the newly paved road between Hermosillo and Chihuahua). Sawmills and logging roads are being constructed with modern technology at unprecedented rates (Gingrich 1993). These dramatic land-use changes are reminiscent of early settlement patterns in the Southwest U.S., however, 20th century technology yields more efficient extraction, transportation, and processing. Also the global markets have increased demands for limited resources. The majority of these logging ventures were undertaken with external capitol, limited community participation, little or no environmental planning, and in cases they are subsidized by Mexico and other government organizations (i.e., World Bank). Also these ventures often benefit only a handful of the local populace, sometimes even in places where land-use rights are communally shared (Gingrich 1993). The majority of timber harvesting investments in the northern Sierra Madres are no longer using hatchets, saws, and mules and cables. External markets, new roads, sawmills, and chainsaws are driving this natural resource boom, that is bound to be short lived, and to undermine the long-term sustainability of the future forest and watershed resources. Unfortunately, the rural Native and Mestizo communities who have subsisted off these forest products for centuries will be at greatest risk to long-tern socioeconomic, ecological, and cultural losses. Furthermore, the far-reaching affects of unplanned timber harvesting will also eventually influence the water and energy budget costs of reservoir-dependent population centers in the states of Chihuahua and Sonora.

2.5.2 Intercanyon Fire Synchrony and Desert Grassland Fire Frequency

Intercanyon fire synchrony suggests that extensive fires commonly spread between riparian canyon pine-oak forests across the intervening desert grasslands below. Descriptive statistics of synchronous fire events recorded between the six canyon sites are compiled in Table 2.4 and depicted by Figures 2.11 and 2.12. MFIs of paired fire events recorded between any two to three of the Chiricahua canyon sites, ranged between four to six years. MFIs of paired fire events recorded between any three to four of the Chiricahua canyon sites, ranged between six to eight years. Synchronous fire events recorded between the more distant McClure Canyon and Cañon del Oso (approximately 100 linear km) have MFIs that ranged between six to eight years. These fires were considered as intercanyon to basin-wide spreading fires that probably extended over areas 10 to more than 500 km^2. When considering all six riparian-canyon sites, encompassing an area covering about 1000 square kilometers, MFIs of synchronous fires recorded by any five or more sites, ranged between nine to twelve years. These fires were probably extensive interbasin-wide fires that spread over hundreds and possibly thousands of kilometers across desert grasslands, through canyon forests, and also to higher-elevation forests.

At the Laboratory of Tree-Ring Research, Thomas W. Swetnam and others (Swetnam and Baisan 1996a, 1996b) have gathered extensive evidence from more than

TABLE 2.4. Descriptive statistics of synchronous fire events between riparian canyon pine-oak forest sites, inferred to be desert grassland fires.

Time Period	Fire Size Class	Total Fire Intervals	Mean	Median	WMPI	Min. Fire Interval	Max. Fire Interval
Western Chiricahua Canyon Composite of All 4 Sites							
1650-1880	All Fires	144	1.58	1	1.48	1	6
	2 or more Sites	71	3.17	3	2.89	1	9
	3 or more Sites	32	6.44	6	5.92	1	20
	All 4 Sites	13	8.85	10	8.51	3	16
McClure Canyon and Lower Sierra Ajos; Oso Canon and Saddle sites.							
1700-1880	2 Sites	19	8.95	6	7.06	2	39
1750-1880	2 Sites	13	8.46	7	7.37	2	25
Composite of all 6 Canyon pine-oak forest sites							
1650-1880	All Fires	167	1.36	1	1.3	1	5
1650-1880	2 or more sites	104	2.18	2	2.03	1	7
1700-1880	2 or more sites	89	1.99	2	1.84	1	7
1650-1880	3 or more sites	47	4.47	4	4.1	1	15
1700-1880	3 or more sites	43	4.12	4	3.89	1	9
1700-1880	4 or more sites	27	5.41	5	5.18	2	14
1700-1880	5 or more sites	8	14.3	12.5	12.55	3	30

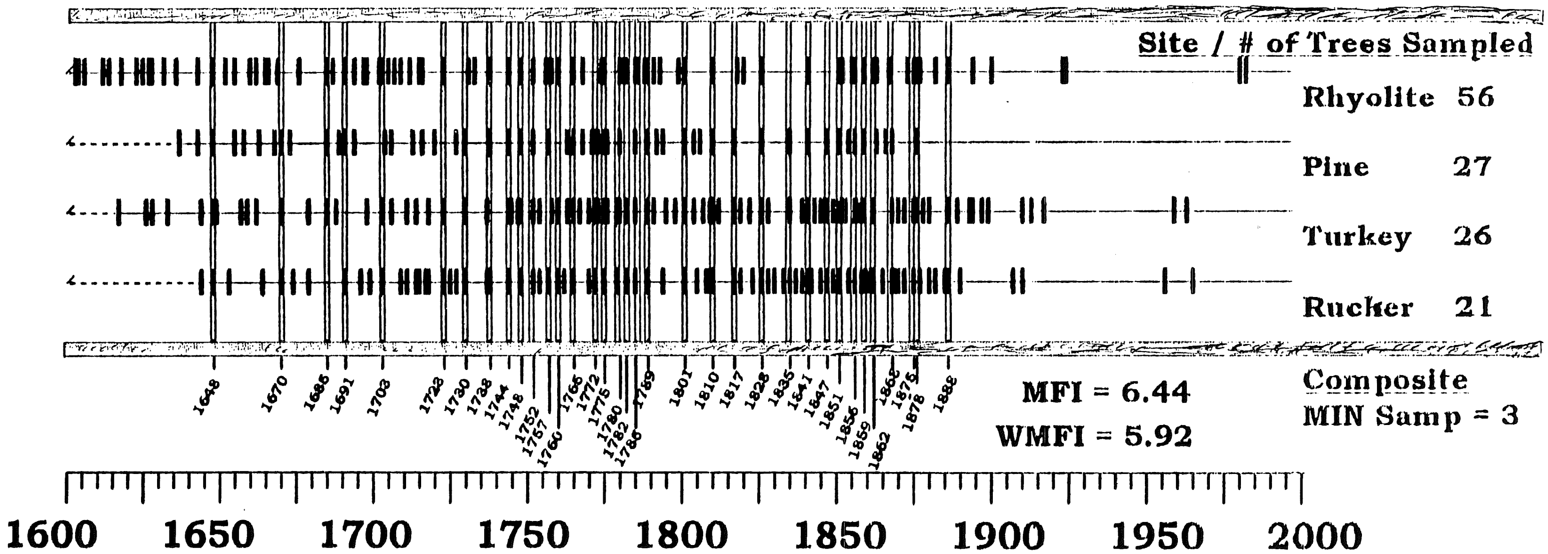

FIGURE 2.11 Master fire chronology for composites of all four Western Chiricahua canyon pine-oak forest sites, for synchronous fires recorded by three or more sites. These fire events are inferred to be desert grassland fires that spread between canyon sites at the lower end of the range of MFIs, probably encompassing areas covering at least 50 km^2.

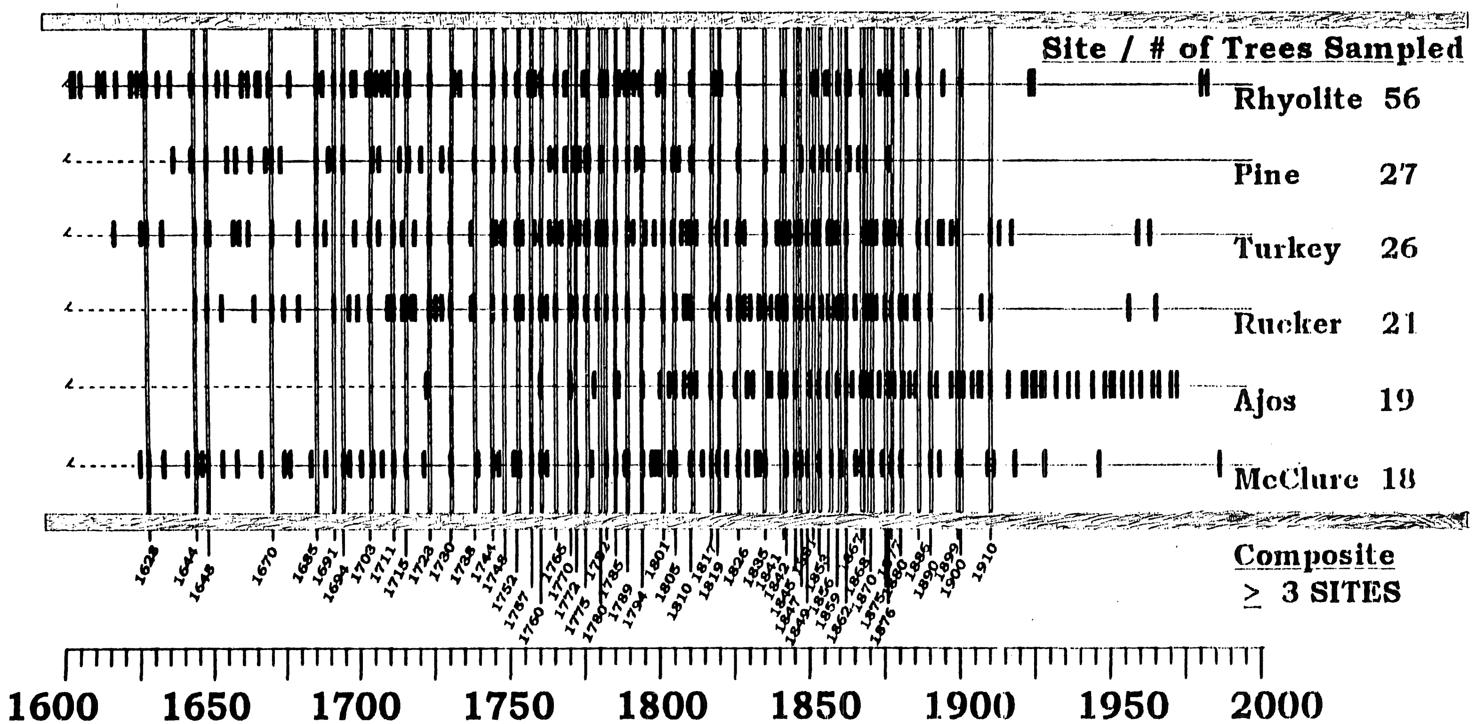

FIGURE 2.12 Master fire chronology for composites of all fires from all six canyon pine-oak forest sites, for synchronous fires recorded by three or more sites. These fire events are inferred to be desert grassland fires that spread between canyon sites, and probably at the more conservative range of MFIs, across entire grassland basins covering distances of approximately 100 km^2.

70 sites in the Southwest U.S., indicating broad-scale climate related fire years occurred in the past at semi-decadal periods. Synchronous fire patterns between all sites in this study also suggest such a climate-fire relation. Uncertainties arise from increasingly larger spatial scales which require more sample data to make inferences with similar confidence. There are also the limitations already mentioned with tree-ring evidence diminishing for the earliest time periods. Therefore, this data indicates that the lower range of synchronous fire intervals recorded between adjacent canyons, may more appropriately reflect the true fire frequency in the desert grasslands. Such desert grassland fires probably covered areas ranging between 10 to hundreds of km^2, and occurred about once every 5 to 9 years.

2.5.3 Fire-Event Size Classes and Inferred Spatial Extent of Past Fires

How large was the fire when it started? (Joke; Pretty Minuscule). Fire-event size classes were inferred by analyzing fire chronologies for increasing percentages of trees that record specific fire events (Table 2.5). The spatial extent of past fires were estimated from fire-event size classes and the distance between fire-scarred trees, canyon sites, canyon and upper-elevation forest sites, and among multiple fire history sites between mountain ranges (See Table 2.5). The finest-scale canyon-fire events (1-3 samples; MFI = 3-4 years) were estimated to range between .01 to five km^2. Site-wide canyon-fire events ($\geq$ 10 % of trees; MFIs = 4-5 years) ranged between about five to at least 10 km^2. Fire events recorded by 25% or more (MFIs = 6-8 years) of the canyon samples were interpreted to have extended beyond the sampled area, probably

TABLE 2.5 Summary of mean fire interval (MFI) distributions and spatial interpretation of fire events for all sites.

Fire-Event Size Classes	Fire Size Description	Average Range of MFIs (Years)	Estimated Fire Size (km2)
Riparian Canyon Pine-Oak Forests			
1-3 trees	Finest-Scale	3-4	.01-5
10% of the Samples	Site-Wide	4-5	5-10
25% of the Samples	Canyon-Wide or Greater	6-8	10-50
Higher-Elevation Mixed-Conifer Forest Reconstructions			
1-3 trees	Finest-Scale	4-5	.01-5
10% of the Samples	Site-Wide	5-6	5-10
25% of the Samples	Extending Beyond the Site	6-9	10-50
Synchronous intercanyon fire event reconstructions inferred to be desert grassland fires.			
2 Sites	Finest-Scale	2-3	5-10
2- 3 Sites	Intercanyon	4-6	10-100
3 to 4 Sites, and McClure-S.Ajos Analysis	Basin-Wide	6-9	100-500
5 or More Sites	Interbasin-Wide, Extensive	9-12	500-1000

canyon-wide fire events or larger, that ranged between 10 to at least 50 km^2 in extent. The limitations and uncertainties concerning spatial inference will be discussed in section 2.7.

For the higher-elevation mixed-conifer sites, the finer-scale fire events were recorded by the fewest trees (n = 1-3) on any given year. These fires occurred about once every five to six years and were estimated to range between .01 to five km^2. Site-wide fires (≥ 10% of samples) occurred around once every six to seven years, and extended between about five to at least 10 km^2. More widespread fire events (≥ 25 % of the samples) were considered to have extended beyond the sampled area. These more extensive fires occurred about every seven to 10 years and extended approximately between 10 to at least 50 km^2.

The synchronous intercanyon fire events inferred to be desert grassland fires occurred less frequently than in the adjacent pine-oak and higher-elevation forests, but probably were more extensive fire events. The finest-scale fire events, recorded between any two canyon sites (Intercanyon MFIs = 2-3 years), encompassed areas ranging between about five to 10 km^2. Synchronous fire events, recorded between any two to three canyon sites (Intercanyon MFIs = 4-6 years), encompassed areas ranging between about 10 to 100 km^2. Synchronous fire events recorded by more widely separated sites, any three to four of the six canyon sites, were interpreted as basin-wide fire events (MFIs = 6-9 years) that extended over areas estimated between 100 to over 500 km^2. The broadest-scale synchronous fire patters were recorded by at least five of the six sites.

These fires were considered to be interbasin-wide fire events (MFIs = 9-12) that spread over extensive areas ranging between hundreds to thousands of km^2.

2.5.4 Analysis of Differences in Fire Patterns between Fire Reconstructions

Chi-squared 2 x 2 and 2 X 1 tests were used to determine intersite association of synchronous-fire, asynchronous-fire, and non-fire events. Each test was conducted between paired chronologies for all 6 canyon sites, for all fire events, and those recorded by at least 10 % of the trees (Tables 2.5 and 2.7). Additionally, composites were analyzed between canyons and nearby upper-elevation mixed-conifer forest sites, for all recorded fire events (Table 2.8). Chi-squared values with probability levels of $p \leq 0.05$ were considered statistically significant. When the chi-squared value was greater than would be expected by chance at this probability level, the null hypothesis was rejected (HO: paired-canyon fire chronologies are not associated). Both X^2 tests provide indications of the relative strength of fire pattern association between canyon forest sites.

All 2 X 2 pair-wise comparisons between Chiricahua canyon sites resulted in significant X^2 values except the two most widely separated canyons, Rhyolite and Rucker (See Tables 2.6 and 2.7). Also the highest degree of fire pattern association was found at Turkey Creek and Rucker, with chi-squared 2 X 2, and 2 X 1 values respectively of 43 and 21 ($p \leq .005$). These two canyon sites are separated by less than 15 kilometers via the lower grasslands and provide the only significant 2 X 1 test with higher numbers of synchronous fire events than predicted by chance. Strong association of fire patterns are also found between Pine Canyon and adjacent Turkey Creek, and

TABLE 2.6. Chi-squared 2 X 2 and 2 X 1 analysis of all fires, for synchronous-fire, asynchronous-fire, and non-fire year events between canyon sites from 1650 to 1880, except where shown. Significant: $p \leq .005$*, $p \leq .01$**, $p \leq .05$*** ; 2 X 1 significance due to statistically high fire synchrony, or fire asynchrony as abbreviated; Not Significant; ns.

Sites	All Fire Years	Rhyolite	Turkey	Rucker	McClure	Pine	Total Significant
Pine	2 X 2	13.19*	17.36*	12.82*	$.21^{ns}$	-----	3
	2 X 1	1.57^{ns}	0.52^{ns}	1.46^{ns}	14.33^{*} (Async)	-----	1
Turkey	2 X 2	5.07**	-----	-----	1.22^{ns}	-----	1
	2 X 1	3.28^{ns}	-----	-----	8.25^{*} (Async)	-----	1
Rucker	2 X 2	2.95^{ns}	42.98*	-----	16.68*	-----	2
	2 X 1	5.16^{**} (Async)	5.34^{**} (Sync)	-----	0.18^{ns}	-----	2
Rhyolite	2 X 2	-----	-----	-----	0.00^{ns}	-----	0
	2 X 1	-----	-----	-----	15.43^{*} (Async)	-----	1
Cañon del Oso, Lower Sierra de los Ajos							
1780-1880	2 X 2	$.46^{ns}$	$.03^{ns}$	$.58^{ns}$	1.05^{ns}	0.0^{ns}	0
	2 X 1	3.68^{ns}	3.39^{ns}	1.97^{ns}	1.85^{ns}	19.5^{*} (Async)	1

TABLE 2.7. Chi-squared 2 X 2 and 2 X 1 analysis of fires, recorded by at least 10 % of the trees at each site, for synchronous-fire, asynchronous-fire, and non-fire years between canyon sites from 1740 to 1880. Significant: $p \leq .005$*, $p \leq .01$**, $p \leq .05$*** ; 2 X 1 significance due to statistically high fire synchrony, or fire asynchronyas abbreviated; Not Significant; ns.

Sites	> 10% scars	Rhyolite	Turkey	Rucker	McClure	Pine	Total Significant
Pine	2 X 2	11.03*	29.18*	18.19*	$.10^{ns}$	-----	3
	2 X 1	2.0^{ns}	1.06^{ns}	$.01^{ns}$	9.66^{*} (Async)	-----	1
Turkey	2 X 2	6.37***	-----	-----	0.16^{ns}	-----	1
	2 X 1	4.55^{***} (Async)	-----	-----	8.68^{*} (Async)	-----	2
Rucker	2 X 2	4.45***	21.12*	-----	9.05*	-----	3
	2 X 1	6.38^{***} (Async)	0.71^{ns}	-----	0.71^{ns}	-----	1
Rhyolite	2 X 2	-----	-----	-----	0.73^{ns}	-----	0
	2 X 1	-----	-----	-----	16.41^{*} (Async)	-----	1
Ajos	2 X 2	0.00^{ns}	0.16^{ns}	0.00^{ns}	1.50^{ns}	1.88^{ns}	0
1780-1880	2 X 1	10.13^{*} (Async)	5.26^{***} (Async)	6.01*** (Async)	2.98^{ns}	3.20^{ns}	3

TABLE 2.8. Chi-squared 2 X 2 and 2 X 1 analysis, of synchronous fire, asynchronous fire, and non-fire years between riparian canyon forests and upper-elevation Madrean forest sites from 1650 to 1880. Significant: $p \leq .01$*; $p \leq .005$** ; 2 X 1 significance due to statistically high fire synchrony, or fire asynchrony as abbreviated; Not Significant; ns. Upper Ajos includes the saddle and ridge sites.

Sites	All Fire Years	Rustler-Barfoot	Lower Ajos	Pat Scott-Sawmill	Sites	Total Significant
Rhyolite	2 X 2	16.19**	-----	20.88**	<== McClure	2
	2 X 1	$.18^{ns}$	-----	$.02^{ns}$		0
Pine	2 X 2	32.13**	-----	-----	-----	1
	2 X 1	$.28^{ns}$	-----	-----	-----	0
Turkey	2 X 2	23.98**	35.18**	<======	Upper Ajos	2
	2 X 1	$.39^{ns}$	7.15* (Sync)	<======	1780-1880	1
Rucker	2 X 2	25.08**	-----	-----	-----	1
	2 X 1	$.48^{ns}$	-----	-----	-----	0

Pine and the more distant Rucker Canyon (about 30 linear km). This high degree of association between adjacent sites suggests that fires spread between nearby canyons through the desert grasslands below. Out of 30 total tests, 13 were significant for the 2 x 2, and 14 out of 30 were significant for the 2 X 1 tests. The high degree of fire synchrony and the X^2 analysis indicates fire pattern association between Chiricahua canyon sites, also suggesting intercanyon fire spread through the intervening desert grasslands, and possible orographic and El Niño climate influences on broader scales.

The more stringent 2 x 1 tests also suggest that some canyon-fire patterns are also associated. Although X^2 tests indicate that fires spread between canyon sites through the lower grasslands, significance due to asynchronous patterns also suggest fires were at times and places limited to single canyon systems and peripheral areas. This pattern may be influenced by the high spatial variability of monsoon precipitation in these areas, which contributes substantially to desert grassland productivity (McClaran 1996). Antecedent-fire events and anthropogenic fire influence are also possible factors affecting intersite association due to asynchronous-fire patterns, especially between sites where 2 X 2 analysis is not significant.

Chi-squared tests between canyon sites and the upper-elevation mixed-conifer forests further suggest intercanyon grassland fire spread (See Tables 2.6, 2.7, and 2.8). Although the tests between Pine Canyon and Rustler-Barfoot Park suggest fire spread through Pine Canyon to higher elevation forests, the weaker degree of association between Rustler-Barfoot Park and the lower canyon sites, and the stronger X^2 association between canyon sites, together suggest that intercanyon grassland fire spread was likely more common in the western Chiricahuas. Only 1 of the 2 X 1 tests were significant between the lower canyon and upper-elevation mixed-conifer forest sites. The 2 X 1 chi-squared tests also show greater fire pattern association between canyon sites than between canyon and upper-elevation Madrean forest sites. These statistical tests suggest that fires spread more commonly between the lower-canyon sites than between canyons and the higher-elevation sites, further supporting the inference that fires commonly spread between canyons through the intervening desert grasslands. Therefore, synchronous fires recorded between canyon sites should provide at the very least conservative estimates of fire frequency in the intervening desert grasslands.

2.5.5 Analysis of Multiple Lines of Evidence

Although the size of historical fires remains uncertain, several lines of evidence indicate that extensive episodic fires occurred in the past. Historical descriptions refer to extensive and vigorous pre-1880 desert grasslands (Bahre 1991; McClaran 1996; McPherson 1996). Hutton (1859) notes in 1859, that in Sulfur Spring Valley;

> "the entire valley and foothills of the mountains (were) covered with a luxuriant growth of gramma and other grasses (Leopold 1951:310)".

The Tombstone Epitaph (Sept. 17, 1881) reports on the abundance of wild hay harvested in the desert grasslands in southern Arizona.

> "The rank crop of grass that has sprung up all over Arizona, as a result of the late rains, opens a fine opportunity to hay makers. There are millions of tons which can be cut by mowers and cured and stacked at a cost not to exceed 4 to 5 dollars a ton. Tens of thousands of acres of mesa land are covered with grass from 2 to 4 feet high (Bahre 1987:70)."

Vegetation maps also delineate a mosaic of extensive grassland coverage encompassing the lowland basins and valleys that link all canyon sites (Brown 1982).

The most distant canyon sites, encompass a area ranging between 50 to more than 100 linear kilometers, all between which synchronous fire events were recorded on a regular basis (See Figs 2.1, 2.11, and 2.12; and Table 2.5). The adjacent canyon sites where synchronous fires are recorded most frequently are separated by about 15 linear kilometers. Of course fires neither spread linearly, rectangle-like, or circular, but irregular and elliptical shapes (i.e., wind-blown, and uphill fire spread) are most common. Synchronous fire events and the X^2 analysis strongly suggest that fires commonly spread between adjacent mountain sites (Approximate MFI s 4-6 years), but not as commonly between more distant mountain ranges or basin-wide events (Approximate MFI 6-9 years). Chi-squared tests and intersite fire synchrony suggests that orographic precipitation strongly influenced fire activity and regimes surrounding isolated mountain sites. Regional El Niño-related climate fire years had extensive multiple fires that spread across and between entire desert grasslands basins. These regional fire years were inferred from synchronous fire events recorded by five of the six canyon sites (MFI = 9 to 12 years), estimated from historical and tree-ring evidence, to range between hundreds to thousands of square kilometers. Documentary sources indicate that in the past fires spread across and between entire grassland valleys, and also into adjacent woodlands and forests. For example *The Arizona Daily Star* reported about fires on April 16th, 1882:

> "Prairie and wood fires have been raging in southern Arizona and western New Mexico recently. The territory burned over is reported to cover forty miles square [408,800 hectares], and the damage done is immense (Bahre1985:192)."

This report also shows the early European-American sentiment concerning the destructive nature and threat of past fires, that brought about fire suppression measures around the turn of the 19th century. Historical records also document the ability of these grasslands to rejuvenate rapidly following fires, and thus their resilience to frequent fires. For example, *The Arizona Daily Star* reports on September 2nd, 1880 (Bahre 1991);

> "the grass over areas that were burned over this season is now knee high and looks as fresh as spring time in this locality (Patagonia, AZ).

In combination, graphical, statistical, and historical evidence suggests that many fires spread throughout and between these riparian canyon pine-oak forest sites. Extensive fire events were recorded by many adjacent sites, and also more distant ones, as illustrated by the graphical comparisons of synchronous fires (See Figs. 2.11 and

2.12). All evidence indicates that past surface fires burned through riparian canyon pine-oak forests on average at least once every five to nine years. Also, evidence suggests the intervening desert grasslands burned almost as frequently, and probably on many of the same years, occurring approximately between every five to 10 years. These findings are within the range of the less conservative estimates by Humphrey (1958, 1963, 1984), who concluded that fires burned in the desert grasslands approximately once every 4 to 7 years. The bulk of the evidence now indicates that at two increasingly broader scales, mountain-wide orographic to interbasin-wide regional climate influenced fire events, occurred at a very minimum once every 10 years in the Southwest Borderlands (Swetnam and Betancourt 1998). These fires probably spread across desert grasslands, through canyon pine-oak forests, and to higher-elevation mixed-conifer forests over many weeks during the dry, summer and fall months. The riparian canyon pine-oak forests furnished corridors for fire connectivity between the lower grasslands and higher-elevation forests. The landscape ecology of these more extensive fire events would have been irregular and broken by a mosaic of finer-scale fire patterns or patches having more frequent fire occurrence.

2.6 Discussion

Tree-ring and documentary evidence indicate that fires in the past were important processes in the riparian pine-oak forests and desert grasslands, burning frequently and sometimes over extensive areas. These historic fires often burned for months at a time, they covered thousands of hectares, and spread throughout many vegetation types, as described by John Bartlett (1854) while on the U.S.-Mexico Boundary Survey.

> On May 29th, 1851, northwest of Bacoachi, Sonora: "The valleys and mountain sides were covered with oaks, while the summits, as far as I could judge, were covered with pines. The whole country during the night had been on fire, including the mountain; so that everything around us was now black and gloomy."

> Seven days later on June 5th northeast of Arizpe, Sonora: "It was nearly dark, and we were in a narrow gorge of the mountains where there was barely room for the wagons to pass. The whole earth had lately been burned over to the very mountain tops, which were even now throwing up columns of flame and smoke; not a blade of grass was to be seen, no water was near, and there was not a level spot to pitch our tents."

> Eight days later on June 13th near Guadalupe Pass, in the Peloncillo Mountains, New Mexico: "A fire has passed over it, destroying all the grass and shrubbery, and turning the green leaves of the sycamores into brown and yellow. The surface of the earth was covered with black ash, and we scarcely recognized it as the enchanting place of our former visit. At first we feared that this devastation had been caused by our own neglect; but on reaching the spot where we had

> encamped, which was separated from the surrounding hills by the rocky bed of the stream, we found the dry grass still around the place, which alone had escaped the fire [Bartlett 1854:274, 287,295-296)."

Bartlett's observations provide important evidence about presettlement fires. They describe an extensive area that was burned over a period of at least two weeks, encompassing a linear distance of more than 200 kilometers. These fires probably covered several thousand hectares. Bartlett also notes from their location in the already burned canyon, that the fire had passed through several vegetation types including grasslands, oak woodlands, and higher-elevation pine forests. The year 1851 was also a regional climate-fire event recorded by sites throughout the Southwest (Swetnam and Baisan 1996a; Swetnam and Betancourt 1998) and by four of the canyon fire history sites (See Fig. 2.12). Note that as Bartlett described, the fire did not burn the grasslands of an earlier encampment. This may have been related to the prior influence of the boundary commission's livestock grazing and general camp use. Three decades later the influence of extensive livestock grazing became more visible.

Livestock provided important economic and subsistence security to migrating settlers in the late-1800s, but intensive grazing soon began to change the landscape ecology of the Southwest. In his journals about Apache campaigns in the 1880s, Captain John Bourke boasts:

> "as for the grasses one has only to say what kind he wants, and lo! It is at his feet-from the course sacaton which is deadly to animals except when it is very green and tender; the dainty mesquite, the bunch, and the white and black grama, succulent and nutritious... I must say, too, that the wild grasses of Arizona always seemed to me to have but slight root in the soil, and my observation is that the presence of herds of cattle soon tears them up and leaves the land bare (Bourke 1891:140)."

Bourke witnessed the early consequences of overstocking the ranges. The influence of overgrazing upon fires was also observed by many in the late 1800s. Early foresters commonly encouraged grazing to prevent wildfires, considered at these times to be detrimental to timber and forage production (Pearce 1899; Leopold 1924).

Unfortunately, the long-term effects of eliminating frequent surface fires were not forecast, and even though Aldo Leopold sounded the warning in 1924, it was not heeded. Many desert grasslands were severely overgrazed during the settlement period and later entrenched with gullies, leaving the watersheds and grassland communities degraded (Meinzer et al. 1913; Leopold 1951). At the time, elimination of periodic fires was considered to be good and of little concern. Prior to the settlement period, episodic low-intensity fires were important ecosystem structuring and nutrient cycling processes. The resulting widespread and varied changes to ecosystems and the overall landscape are associated with the removal of episodic fires. Hazardous fuel loading is now common throughout most Southwestern U.S. oak, pine, and mixed-conifer forests, and high-intensity crown fires have begun to replace the low-intensity surface fires of the past. The opposite is true for desert grasslands, invaded, and in some areas dislodged by increased woody species, to such an extent that these areas can no longer support a surface fire (Humphrey 1987; Bahre 1991; Archer 1994).

One of the many important ecosystem roles of past fires is described inadvertently by Bartlett. While surveying the desert grasslands, Bartlett recorded fire effects on mesquite in his Southwest Borderlands "explorations and incidents". Bartlett notes on several occasions "the scarcity of firewood" in the desert grasslands and, while in these areas, their dependence upon large underground mesquite roots for fuel (Bartlett 1854:75, 186, 344). Bartlett refers to the age-old influence of repeated grassland fires on mesquite, that in the past, severely limited competing woody species.

> "Where the prairies are frequently burned over, the tree is reduced to a shrubby state, a great number of small branches proceeding from one root, which goes on developing and attains a great size... These roots, dug up and dried, are highly prized for fire-wood (Bartlett 1854:75)."

This important process was upset with settlement landscape fragmentation beginning in the late-1800s. In places of the San Simon, Sulfur Spring, and San Pedro Valleys, mesquite and other woody species have now spread over large areas that were once dominated by desert grasslands (Hastings and Turner 1965; Bahre and Bradbury 1978; Bahre and Shelton 1993; Biggs 1997).

Over the last century land use has severely altered the character and function of fire in the borderland ecosystems (Leopold 1924; Marshall 1962). Today's desert grasslands generally have less biomass, and over large areas, woody plants now dominate the landscape. Woodland and forest ecosystems that were once linked by grassland cover and low-intensity surface fires are now connected by multiple layers of accumulating fuel. This dramatic transformation in forest structure (Weaver 1951; Cooper 1960; Marshall 1962), has resulted in a shift from frequent surface fires, toward extraordinary (historically in size and intensity) stand-replacing fires. By contrast, the grasslands have been reduced to such an extent in some areas, from woody species encroachment, that fires of any size are rare. Many Southwestern U.S. forests are now experiencing anomalous stand-replacement burns, that undoubtedly are very different from the fires recorded over centuries in the past (i.e., The Dude and Rattlesnake Fires in Arizona).

Having worked in fire suppression and management in this region for 13 years, I strongly believe as the evidence suggests that the forests in the Southwest U.S. have reached a ecological threshold. Combined with favorable climatic conditions and inevitable lightning-fire ignitions, these human-altered forests will increasingly be threatened by intense stand-replacing fires. Historically anomalous, such fire events certainly affect the socioeconomic attributes, biological conservation efforts, and the long-term sustainability of the watershed and forest resources. Multiple pathway ecological-succession theory (Cattelino et al. 1979; Noble and Slatyer 1980) suggests that these forests can now proceed in at least two plausible trajectories. The pathway with the greatest probability, includes increased stand-replacement wildfires of the most extreme intensity, with high nutrient volatilization and associated soil effects (Medina et al. 1996; i.e., reduced organic matter, acidity, nitrates, sulfates, and porosity, hence, overall more erosion potential). These types of fires are indeed becoming more common as indicated by several recent catastrophic fires in the Southwest U.S.. Such anomalous fires are illustrated by the Chiricahua Mountain Rattlesnake Fire in 1994, and associated watershed degradation (Figs. 2.13 and 2.14). The alternative pathway includes fire planning that begins with less intensive and smaller burns (i.e., Johnson Peak Prescribed Burn Plan). Planning to initially break-up forest homogeneity, reduce hazardous fuel accumulations, designed to successively allow larger burns and lightning fires, to ultimately provide a process once again in these ecosystems. Both alternatives involve humans, however, catastrophic stand-replacing fires and related watershed degradation can only be mitigated through further development of the later.

Compared to the Southwest U.S., the forests of northern Mexico have far less altered fire histories. Fire history sites in the Sierra de los Ajos display uninterrupted fire regimes into the 20th century (See Fig. 2.10). Also in other areas currently being studied in the Sierra Madres fire regimes continue unaltered. Delayed fire-regime changes in Mexico probably result from historically less intensive and extensive land use, limited fire suppression, and land-tenure reforms that began in the 1940s (Marshall 1962; Sheridan 1988; Florintino Garza, Pers. Comm.). The more accessible basin valleys, canyons, and mountain foothills particularly near water sources were affected earliest, as shown by the rapid decline in fire frequency at Cañon del Oso in the 1930s. However, the higher-

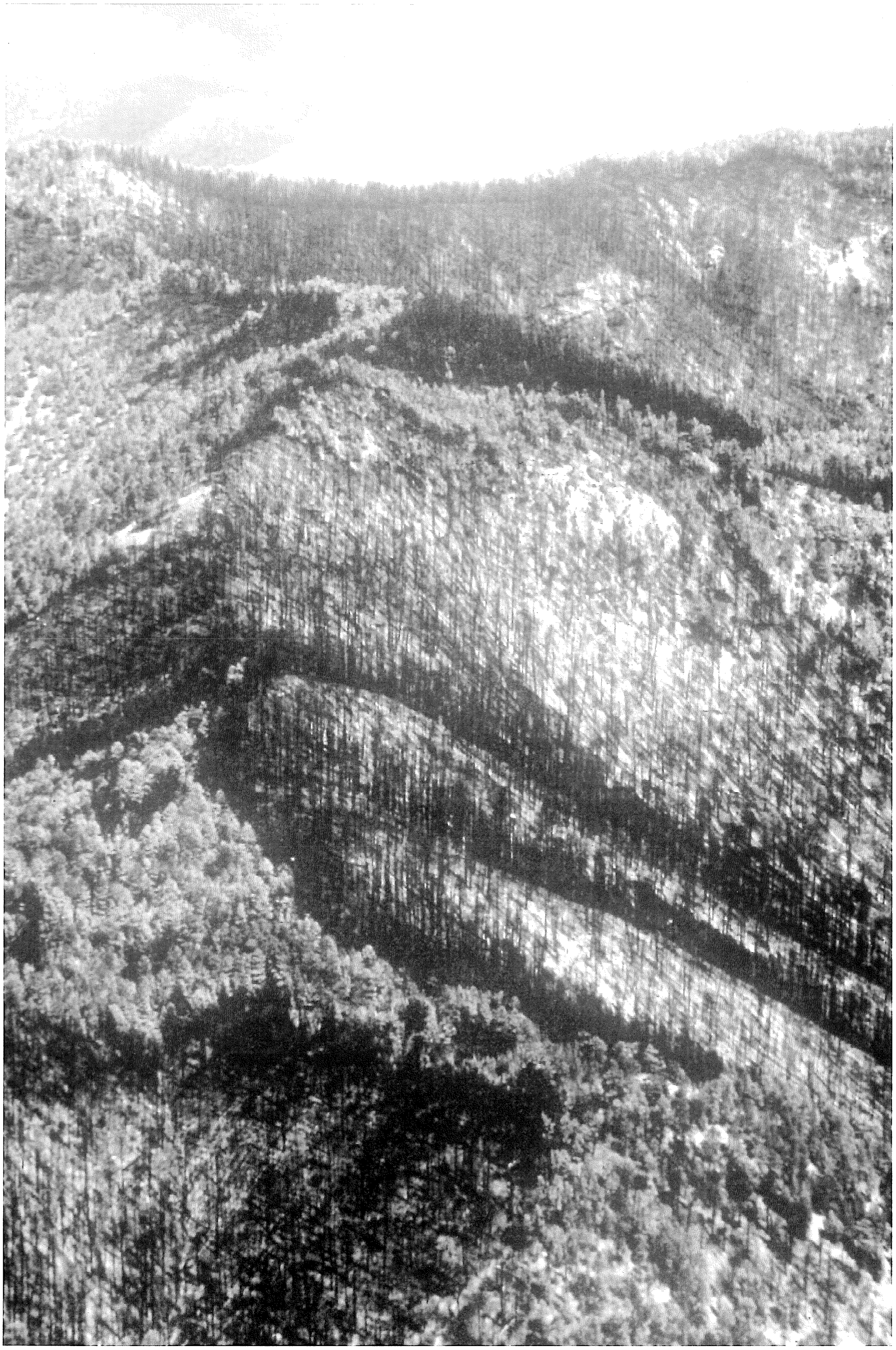

FIGURE 2.13 Bird's eye view of the Rattlesnake Fire in the Chiricahua Mountains. This fire burned mostly as a stand-replacing fire, in areas that had recorded presettlement MFIs ranging between 5 - 9 years (Arizona Daily Star, 1994).

FIGURE 2.14 Upper ward canyon gully erosion associated with the Rattlesnake Fire in the Chiricahua Mountains. This formation was approximately 10 meters deep and 20 meters wide in September 1996, two years after the fire. The lowest exposed strata of sedimentary clay layers were estimated to be tens of thousands of years old (Pearthree Pers. Comm.), suggesting how unusual this fire may be (Photo by Jason Rech).

elevation forest sites in the Sierra Ajos continued to record fires, as do other more remote forests in the northern Sierra Madres.

The less disrupted forests in the northern Sierra Madres and outlying ranges can provide important ecological information applicable to related forests in the Southwest U.S.. These forests in Mexico can be used as a benchmark to evaluate and quantify the magnitude of anthropogenic vegetation changes that plague many forests in the Southwest U.S.. Better documentation of the contrasting land uses and fire histories in the less-disturbed forests in Northern Mexico, will be important for future international forest research, management, and conservation efforts.

2.7 Uncertainties and Limitations of the Evidence

Although several lines of evidence suggest that extensive fires spread between canyon sites through the intervening grasslands, it is also probable that some synchronous fires were the influence of climate and multiple fires, rather than a single widespread fire. Additionally, the statistical association between canyon and mixed-conifer forest sites suggests that some fires did possibly spread "backing" from the higher-elevations, down through canyon areas. It is also possible that some of these fires spread between canyon sites via higher-elevation forests.

There are also some uncertainties with spatial inferences. Adjacent canyon sites are nearest spatially, they have fewer fire-spread barriers, and the highest probability of all sites for intercanyon fire spread via the grasslands. Therefore, synchronous fire events recorded between adjacent canyons have greater meaning, with respect to estimating desert grassland fire intervals, than those recorded between mountain ranges, and across basins. Also, broader-scale inference of interbasin-wide fire events are complex, and due to increased influential factors (i.e., natural fire barriers, vegetation types, multiple ignitions and fires, time for spread, and climatic factors) the certainty of the spatial inference is weakened. Limited numbers of samples and their non-uniform and non-random coverage of the sampled area results in considerable uncertainty with spatial interpretations. For example, finer-scale fire events may have been more extensive due to irregular and patchy burning patterns or because of limited coverage by fire-scar evidence. Some fires could also be much larger than inferred, by extending beyond fire history sites, and at times beyond the larger study area..

After consideration of the many possible limitations of this evidence, it is likely that some fires originated in the higher-elevations, spreading throughout mixed-conifer and adjacent forests. However, regardless of a fires origin, once they spread into the lower grassland communities, they could then potentially spread over much greater distances. Multiple lines of evidence (i.e., a basic law of physics; hot air rises, as do fires and smoke), continue to effectively demonstrate that frequent surface fires (MFI = 4 ≤ 9 years; See Table 2.5) spread between riparian canyon pine-oak forests, through the intervening desert grasslands, and to higher-elevation mixed-conifer forests, regularly from below.

Anthropogenic fire influences suggested by historical and ethnographic evidence, also must be considered, and accordingly, this will be the topic of the following chapter.

2.8 Management Considerations in Restoration Ecology

Fire management policy in the Southwest United States has recently entered a new era. In some forests and grasslands, lightning and prescribed fires, are now being used to manage areas under the ecosystem management mandate (Baker 1992; USDA 1992, 1993b). This approach allows managers to plan for inevitable and essential natural processes, such as fires, to be restored to these landscapes (Allen 1994; Kaufmann et al. 1994; Edminster 1996). Such fire planning has substantially reduced fire management costs, while also reducing threats to firefighters, watershed resources, and biological diversity.

The use of prescribed fires is a direct response to particular dilemmas faced by land managers in the Southwest Borderlands (Kaufmann et al. 1994; Morgan et al. 1994; Swanson et al. 1994). In the past episodic surface fires were common in many different vegetation communities throughout the Southwest Borderlands. Fires provided important processes in fuel and nutrient cycling, and ecosystem structure and function. After over a century in places without fires, numerous forests in the Southwest U.S. now have extreme fuel loading and related health problems. The biological and watershed resources of these forests are also at high risk to volatilization by unusual stand-replacement fires. Historic fire suppression policies have exacerbated and prolonged the situation, costing more while perpetuating greater cumulative risks to life, property, and natural resources. Ecosystem management allows more flexibility to the manager to use natural and prescribed burns to reduce fuel loading, to maintain important ecosystem processes, and to improve ecosystem productivity and overall health.

The biological and economic importance of grassland and forest ecosystems must be considered in light of the current political ecology. Riparian canyon pine-oak forests harbor corridors of high biological diversity and richness that include many endangered species. Additionally these forests provide some of the most sought after real-estate and recreational sites in southern Arizona. At higher-elevations where pine-oak and mixed-conifer forests dominate, a substantial portion of the water budget for the entire watershed, and hence the regions water budget, is amassed (Shreve 1915). Unfortunately, vegetation changes from decades of fire suppression have left these upper-watershed forests, resembling "tinder boxes" or "funeral pyres", at very high risk to intense stand-replacing fires. Decades of accumulated biomass have created an extremely volatile situation that now threatens many canyon and upper-elevation forests. Fires will always be an process in these areas with common lightning occurrence and as long as they are maintained as natural areas. The future of our National Forests is now dependent on ecosystem and fire management, that will only succeed if periodic planned and controlled fires are accepted at ecosystem and landscape scales.

This investigation reconstructed past fire regimes, across a landscape that includes several biotic communities, to help guide future fires management in these areas. The full range of reconstructed fire statistics are provided for desert grasslands, riparian canyon pine-oak forests, and mixed-conifer forests for further interpretation by land managers (See Tables 2.2, 2.3, 2.4, and 2.5). In general across this study area and these ecosystems, recorded presettlement mean fire intervals ranged between every 3 to 9 years. This range of fire intervals can probably be applied to long-term fire planning and prescriptions in more-remote areas with limited resource values. However, in other areas with greater resource values, fires managed conservatively at decadal intervals or less, would still greatly reduce the hazards of fuel buildup, while sustaining watershed and ecosystem resources.

2.9 Conclusions

Canyon-fire reconstructions demonstrate that fires burned commonly between canyon pine-oak forests through the intervening desert grasslands. Paired canyon analyses of 6 sites encompassing the international Sulfur Spring and San Pedro Basins suggest episodic fires were common in the desert grasslands. Fire reconstructions indicate that site-wide fires occurred in the canyon riparian pine-oak forests on the average at least every five to nine years, while the adjacent desert grasslands burned often at the same time but somewhat less frequently around every five to 10 years. It is also probable that many of these same fires spread to higher-elevation mixed-conifer forests where fires occurred on average once every six to 10 years. This is also suggested by how comparable the range of reconstructed fire frequencies are between these three vegetation communities and across the elevational gradient. More extensive climate-related fire events also occurred, spreading across and between entire desert grassland basins, on average at least every 10 to 13 years.

In the past fires have been an important process in these ecosystems with respect to fuel and nutrient cycling, vegetation structure, and spatial diversity. The importance of elevated rainfall interception and evapotranspiration, has hardly been considered with respect to 20th century fuel accumulations. In the past, episodic low-intensity surface fires reduced forest biomass and resulted in greater water infiltration, underground flow, storage, and surface runoff (Baker et al. 1996). Historical records also indicate higher water tables and perennial stream levels, with springs and wet cienega areas being more common (Meinzer et al. 1913; Leopold 1951). As the old saying goes "you cannot squeeze water out of a turnip", nonetheless, by restoring periodic fires within the range of historical fire regimes, related ecosystem processes will also be renewed. At the other extreme, stand-replacing fires can leave extensive areas denuded of vegetation and soil nutrients, influencing mass erosion, and watershed degradation.

Fire is a tool that can be used to restore the sustainability of Southwest Borderland ecosystems. The linkage of ecosystems through fire spread has been greatly underestimated, especially for the riparian canyon pine-oak forests. Although ecosystem connectivity has been disrupted by land use and development in some areas, there are places where fires can still burn from lower grasslands through canyon forests to higher-elevation forests. This research indicates ecosystem connectivity via surface fires was an important process in the past, and therefore such fire prescriptions should be applied to fire planning where possible. Natural and wilderness areas managed without the consideration of fundamental ecosystem processes will eventually become anthropogenic vegetation preserves, far more vulnerable to catastrophic degradation, and unlike the natural landscapes and wilderness areas envisioned by Aldo Leopold (1924) or mandated by the Wilderness Act of 1964. Fires managed in an ecosystem context within the range of presettlement fire regimes will help restore needed biological and physical processes, sustain biological diversity, and overall improve watershed resources for future generations.

CHAPTER THREE

FIRE IN APACHERIA: THE INFLUENCE OF HUMANS ON PAST FIRE REGIMES IN THE SOUTHWEST BORDERLANDS

3.1 Abstract. — The ecological role of fire in the Southwest Borderlands is generally acknowledged, however, the influence of humans upon past fire regimes remains the subject of considerable uncertainty. Multidisciplinary analysis is used to evaluate the influence of cultural fires and burning upon fire regimes and ecosystems in the Southwest Borderlands. Many historical records document the Chiricahua Apache use of canyon-fire reconstruction sites, and extensive use and knowledge of fire. They also indicate close association between cultural burning practices and raiding and wartime periods. These records suggest prevalent fire use in Apache raiding and warfare, and also to a lessor extent by the Spanish, Mexicans, and later Americans. Graphic fire history reconstructions show increased fire activity in relation to wartime periods. The combined evidence suggests that anthropogenic burning altered fire regimes at specific times (wartime periods) and places (*ranchería* campsites within canyon pine-oak forests). Also burning practices commonly documented during wartime periods may have inflated past estimates of the overall importance of Native American burning in this region. Climate, lightning, and fire history evidence suggests that broader-scale fire patterns were probably influenced more by regional climate and vegetation patterns, than by ignition sources.

3.2 Introduction

Uncertainty surrounds the complex interrelation between humans and past fire regimes. Fire environments depend on an ever-changing matrix of vegetation (fuels) and periodic dry climatic conditions that coincide with ignition sources from lightning and humans. North America has at least 15 climate-fire regions with over 75 distinct vegetation communities (Barbour and Billings 1988; Schroeder and Buck 1970). The continent easily also has more than 50 distinct Native American linguistic groups (US Bureau of Ethnology 1891). Some vegetation types burned frequently (e.g., grasslands and pine forests) and others less frequently or rarely (e.g., alpine forests and deserts; Wright and Bailey 1982). Globally, fire environments range from regions where anthropogenic burning contributed to the majority of fires (i.e., California Coastal Environments), while in others where lightning activity accounted for most fires (i.e., Florida Everglades; Steward 1933; Lewis 1973, 1983; Barrett and Arno 1982; Pyne 1995; Williams 1994). Moreover, cultural change and burning patterns are responses to specific environmental conditions. These wide-ranging spatial conditions and temporal scales have often been overlooked by sweeping generalizations that lack specificity to place and time. Intentional and inadvertent Apache fires, and those of other Native Americans, have been suggested to be the prevailing influence on fire regimes and ecosystems throughout this region and beyond (Holsinger 1902; Stewart 1963; Dobyns 1981; Pyne 1982, 1990). Consider the following examples:

"The modification of the American continent by fire at the hands of Indians was the result of repeated, controlled, surface burns on a cycle of one to three years, broken by occasional holocausts from escape fires and periodic conflagrations during times of drought (Pyne 1983:9)."

"Worldwide patterns of aboriginal burning plus repeat photographs and other fire frequency data all indicate that most montane prairies, meadows, and open-forests... were the product, primarily, of aboriginal not lightning fires (Kay and White 1995:123)."

"Since I am convinced by a massive amount of evidence that primitive man with fire as a tool has been the deciding factor in determining the types of vegetation covering about a fourth of the globe, I judge primitive man's role in the ecological equations of utmost importance (Stewart 1963:124)."

The importance of humans in controlling past fire regimes at local and regional scales, has also often been underestimated and under appreciated, especially by ecologists. However, a healthier understanding of the great diversity in fire ecologies and histories is not served by either overstating or over generalizing. Understanding the contribution of humans to past fire regimes is important for many reasons (Barrett and Arno 1982). Extensive areas of Federal Lands are now being managed with fire to restore presettlement ecosystem conditions (pre-1880). For that reason, if in the past, lightning fires were the primary influence driving fire regimes, then managers could plan for lightning ignited fires alone to possibly restore these ecosystems. However, if humans contributed substantially to past fire regimes, then lightning fires alone may not be enough to restore presettlement ecosystems or desired conditions (Barrett and Arno 1982). In any case, the influence of humans on fire histories is important for future planning and management of fires, at ecosystem and landscapes scales. And particularly in the Southwest Borderlands where prescribed burning and ecosystem management are being actively demonstrated.

An objective of this study was to investigate the influence of humans on past fire regimes by analyzing documentary, ethnoecological, and fire history evidence from this region. The goal was to provide a better understanding of cultural burning practices and fire influences on past fire histories in the Southwest Borderlands.

This region provides a unique opportunity to investigate the influence of humans on past fire regimes. Known by the Spanish as Apachería, the Southwest Borderlands region has one of the highest levels of lightning activity in North America, but also Native American burning has commonly been documented by historical records. A fundamental fire history question in this region is: Which ignition source, humans or lightning, dominated past fire regimes, and at what relative scales were these ignition sources important? This paper assesses two fundamental theories; 1) Apache burning was the primary factor controlling past fire regimes in the Southwest Borderlands, and 2) Past fire regimes were elevated by anthropogenic burning associated with historical Apache raiding and wartime periods.

3.3 Nature of the Evidence

Archival documents were searched, read, and compiled into a bibliography of citations with regard to cultural-fire use and knowledge, cultural ecology, wartime periods, and intercultural relations. Ethnohistoric relations about fires come from many unique time periods, and varied cultures and sources. This evidence may be broadly categorized as written accounts, reports, journals, newspapers, letters, and transcribed oral histories. Also included were ethnographic and ethnoecological research based on archival materials and field notes. Chronologies of important events were also compiled to facilitate the evaluation of historical sequence and context. Using these diverse types of evidence, cultural fire patterns were developed from the documentary bibliography of the Southwest Borderlands (Appendix A).

Major ethnobotanical resources of the Apache were compiled along with their specific fire adaptations and resilience, using the USDA Forest Service fire-effects database (www.USDA). Fire resilience was defined as the average time interval necessary for a plant species to recover to a level equal to prefire conditions. Fire resilience intervals (FRIs) were estimated from bibliographic resources found in the Forest Service database. Fire effects and ecology data were used to assess potential plant species and vegetation communities that may have been burned to enhance resource benefits.

High levels of lightning are illustrated in this region by National lightning detection system data (Krider et al. 1980; Gosz et al. 1995). Also U.S. Forest and Park Service records demonstrate an abundance of lightning ignited fires in these areas with reference to general occurrence by vegetation type (Jandrey 1975; Barrows 1978; Baisan and Swetnam 1990).

Because pines are very sensitive to basal scarring by fires once initially injured, fire history reconstructions from tree rings provide the most complete record of past fires for specific locations, including those originating from both lightning and human sources. Some fire history studies have also considered possible anthropogenic influences (i.e., Barrett and Arno 1982; Baisan and Swetnam 1990, 1997; Kaib et al. 1996a; Morino 1996; Seklecki et al. 1996; Wilkinson 1997). When combined with other types of evidence, fire histories can also be tested for the presence of cultural fire patterns.

3.4 Background

3.4.1 Fire Patterns in the Southwest Borderlands

The Southwest Borderlands is a semiarid basin and isolated mountain region of southern Arizona and New Mexico, and northern Sonora and Chihuahua. Considerable anthropological, historical, and ecological investigations have been conducted in this fire endemic region (Hastings and Turner 1965; Gehlbach 198; Wilson 1995). Thus, it provides a suitable locality to analyze the importance of anthropogenic fire in an ecological context. Contemporary data demonstrates this region has one of the highest levels of lightning activity in North America, nonetheless, ethnohistorical records also indicate that many fires were human caused, particularly by the Apache. Therefore, the pertinent fire history questions that this study investigates are: When and where did the Apache and other cultures alter past fire regimes in this region? Can we detect changes or differences in the reconstructed fire histories between places and times, and distinguish between natural (e.g. climatic, lightning) and cultural causes?

3.4.2 History of Cultures and Land-Use

Early Spanish exploration parties led by Cabeza de Vaca, Coronado, Estebán, and Fray Marcos de Niza in the 16th century resulted in the earliest European descriptions of this *Tierra Incognita* (Bancroft 1884, 1889; Bolton 1908, 1949; Officer 1987; Sheridan 1995). By the late-17th century Spanish colonists, missionaries, and military personnel began to record frontier life (Fig. 3.1; Nentvig 1764; Bolton 1919, 1936; Barns et al. 1981). Also written at this time were the first detailed descriptions of the Pima, Sobaipuri, and Apache cultures and of their interrelations, and interactions with the Spanish (Velarde 1716; Spicer 1962; Naylor and Polzer 1986). Through the late-17th and 18th century, Apache raids and wartime periods maintained the borderlands in an unsettled state, hence its renown as "Apachería" (Forbes 1960; Park 1961; 1962; Worcester 1971, 1979; Griffen 1979, 1985). Mexican and American records in the 19th century document similar patterns of Apache raiding and warfare (Basso 1971; Griffen 1988a, 1988b).

Apache groups immigrated into the Southwest Borderlands region by the late 1600s. Comanche and Spanish pressure, all along the Rio Grande Valley, was a driving force behind these southwesterly migrations (John 1975). This was also a time coinciding with Padre Kino's extension of Jesuit missions north (Bolton 1919; Worcester 1941; Forbes 1959a, 1959b). The Apache had long raided Native American villages and

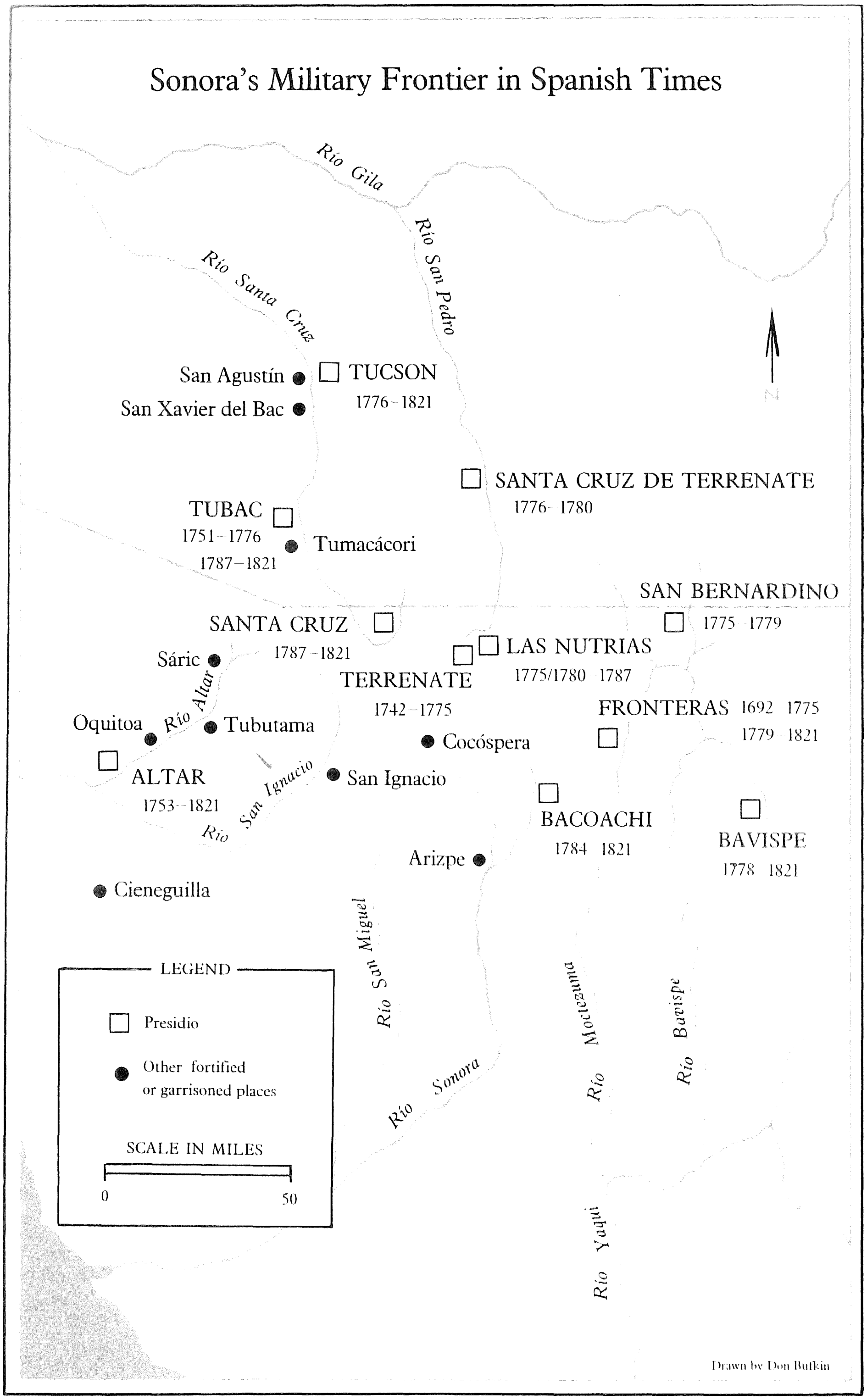

FIGURE 3.1 Map of Spanish presidio establishments in the Southwest Borderlands (Drawn by Don Bufkin; Officer 1987)

Spanish settlements in the Rio Grande region (John 1975), and the borderlands provided new and unlimited raiding opportunities.

The Apache dominated the region for over 2 centuries, living in semi-nomadic clans loosely composed of 10 to 30 extended families (Opler 1983b, 1983c), led by influential chiefs and spiritual leaders. Large gatherings took place at times for reciprocity, social events, hunting and gathering, seasonal migrations, and notably during raiding and warfare activities (Goodwin 1942; Basso 1971). Apache hunting and gathering strategies included horseback raids, to capture livestock wealth and other attractive provisions like alcohol, sugar, chocolate, etc., and occasionally captives (Forbes 1957; 1959a; 1959b). Raiding also provided an important economic and cultural status in Apache society (Basso 1971). Isolated Apache raiding throughout the Southwest Borderlands, resulted in repeated confrontations with the Sobaipuri, Pima, and the Spanish who at times joined forces to defend against the common enemy.

Early Spanish defense was very limited. A line of Spanish military presidios was constructed along the northern frontier beginning in the late 1600s to deal with Apache depredations (Brinkerhoff and Faulk 1965; Moorhead 1968, 1975; Naylor and Polzer 1986). Spanish policy vacillated during specific time periods and places, from aggressive warfare to *establecimientos de paz* or peace establishments. These trappings of peace in the late 1700s provided basic staples to the Apache, and encouraged commerce by allowing peaceful Apache groups, *Apache Mansos*, to encamp near presidio and mission settlements. Spanish peace establishments set the example for later reservation settlements in the Southwest U.S..

Apache groups were extremely independent, and while some made peace treaties, others continued to raid, and some did both. Intermittent raiding resulted in perpetual conflicts, lack of trust on both sides, eventually better organization of Spanish defenses, and recapitulation of several wartime periods that spanned several decades (Forbes 1960; Bannon 1964; Officer 1987; Griffen 1988a, 1988b).

Based on the historical facts, three unique wartime periods (WTP1, WTP2, and WTP3) and two intervening peacetime periods (PTP1, PTP2) were identified. The earliest and lesser known Spanish-Indian wars (WTP1) began in 1680 with the Pueblo and Pima Revolts and declined roughly around 1710 (Spicer 1962; John 1975; Griffen 1979). The early decades of the 18th century between 1710 to the 1740s were relatively calm, so this was the first documented peacetime period (PTP1). The Spanish-Apache wars (WTP2) between 1748 and 1786, and later the Mexican and American, Apache wars (WTP3) between 1831 and 1886 are well documented in history (Bancroft 1884; Bartlett 1954; Bourke 1887-1888; Cole 1988). The intervening peacetime period spanned four decades, roughly from 1787 until 1830 (PTP2). While these wartime and peacetime periods were selected for this analysis, they may be further refined by future research.

The wartime periods commence with written records in the late-17th century, a time when Native Americans began to rebel against brutal Spanish control of lands and resources. Spain reacted by expanding the presidio military network to protect their northern frontier investments (DiPeso 1979). Native American military strategies, tactics, and scouts were gradually adopted by the Spanish, Mexicans, and later

Americans. Through the 18th and 19th centuries Spanish policy involved both aggressive military campaigns and peace establishments. The "carrot and big stick" tactics of the Spanish compelled many Apache groups to pursue peace. However, Independence of Mexico in 1821, led to a breakdown of the peace establishments, and the region was launched into another raiding and wartime period (WTP3).

The present U.S.-Mexico border exists where it does today in part due to the northern frontier presidio line established by the Spanish. With the Treaty of Guadalupe Hidalgo in 1848, partial acquisition of Apachería was negotiated by the United States for a southern travel route. The border was finalized with the 1854 Gadsden Purchase (Bancroft 1889). The combined efforts between Mexican and American troops began to take its toll on the Apache by the late 1800s (Cremony 1877; Howard 1907; Clum 1963). Many Apache bands requested peace and signed reservation treaties by the mid-1870s, and most groups including the Chiricahua, were settled by then on several reservations in the Southwest United States (Lockwood 1938; Cole 1988; Sweeney 1991). Despite these assorted efforts over centuries, the intrepid hit-and-run tactics of several Apache groups continued sporadically in some places until 1886 (possibly later in Mexico), ending with the surrender of Geronimo and Naiche, with the last band of the Chiricahua Apache.

Although the last Apache group did not surrender until the end of WTP3 in 1886, the completion of the transcontinental Southern Pacific Rail Road marks the beginning of European American colonization of the Southwest Borderlands. Mining, logging, fuel-wood cutting, wild hay harvesting, and primarily ranching were land-use activities that spawned the development of this newly colonized territory (Bahre 1985, 1987, 1995a, 1995b; Bahre and Hutchinson 1985). The Railroad brought unprecedented numbers of pioneers and homesteaders, and it provided means for creating wealth through the development of far-reaching livestock economies (Wagoner 1952; 1961). Also free and open ranges were advertised to encourage settlement in Arizona. The railroad epitomizes the beginning of a new era of "extractive" land use in the Southwest U.S. (Sheridan 1995). This dramatic land-use change is strongly associated with the elimination of episodic surface fires (Leopold 1924; Marshall 1962; Swetnam and Baisan 1996a, 1996b), and related to forest and grassland changes documented decades later (Weaver 1951; Marshall 1957; Bahre 1991).

3.5 Site Description

Isolated mountains are scattered across this region which provide strong orographic influence as evidenced by their distinct ecological gradients (Fig. 3.2). Vegetation is coarsely stratified by elevation, aspect, and geomorphic conditions. Lowland basins and alluvial fans are occupied by desert grasslands which extend further upward into oak woodlands and riparian canyon pine-oak forests, mostly on the southern aspects (Marshall 1957; Reeves 1976; Brown 1982). Higher elevations are occupied by Madrean pine-oak and mixed-conifer forests (Whittaker and Niering 1965, 1975; Sawyer and Kinraide 1980).

Impressive habitat diversity can be found along riparian canyon pine-oak forests where water is available most seasons, and ecotones are formed between grasslands,

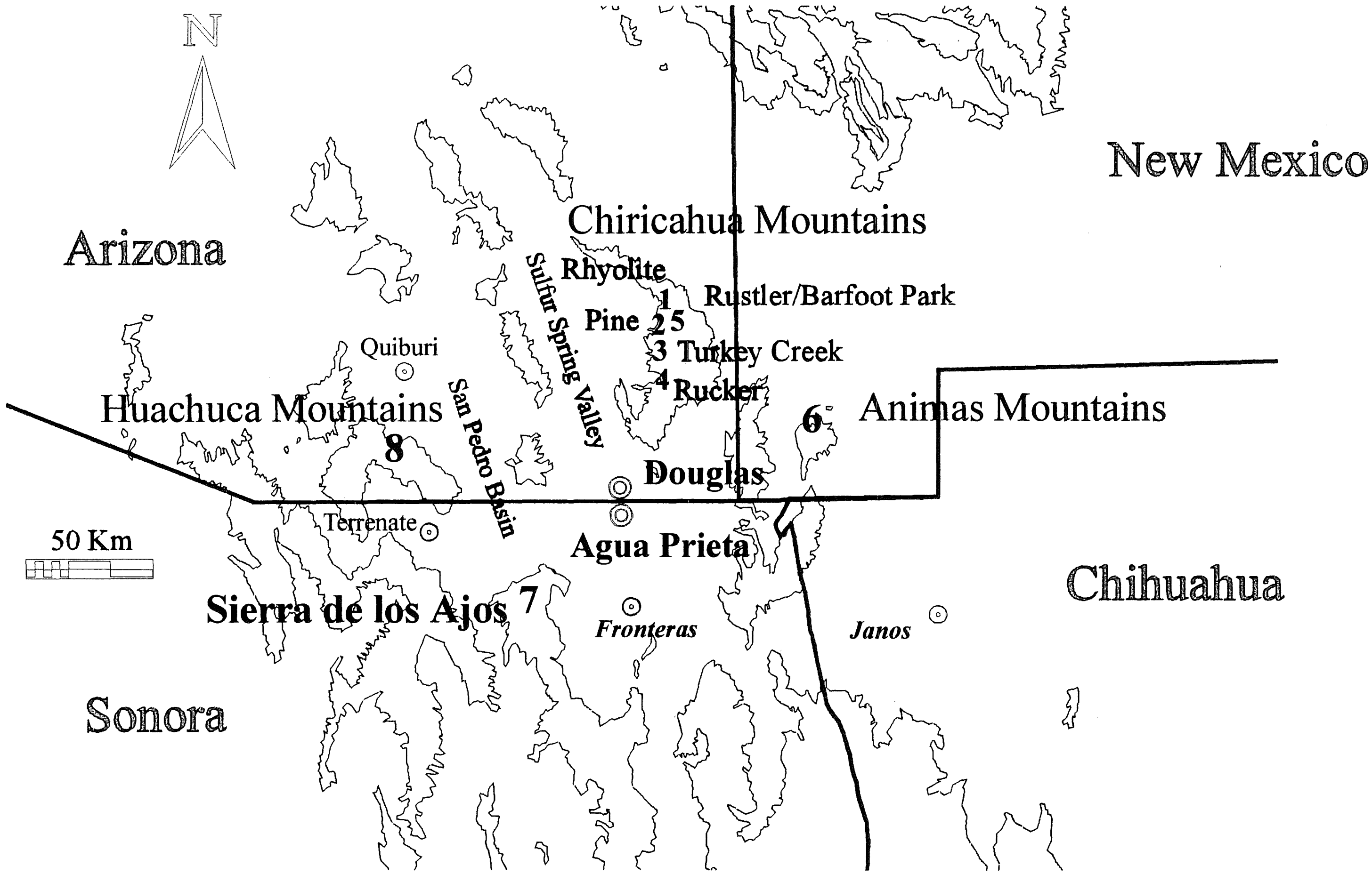

FIGURE 3.2 Fire reconstruction sites in the Southwest Borderlands. Riparian canyon pine-oak forest sites include Rhyolite, Pine, Turkey Creek and Rucker Canyons, the historic Apache ranchería sites. Rustler/Barfoot Park is an adjacent higher-elevation mixed-conifer forest. The sourrounding ranges have fire history collections from both pine-oak and mixed-conifer forests and include the Animas, Sierra Ajos, and Huachuca mountains.

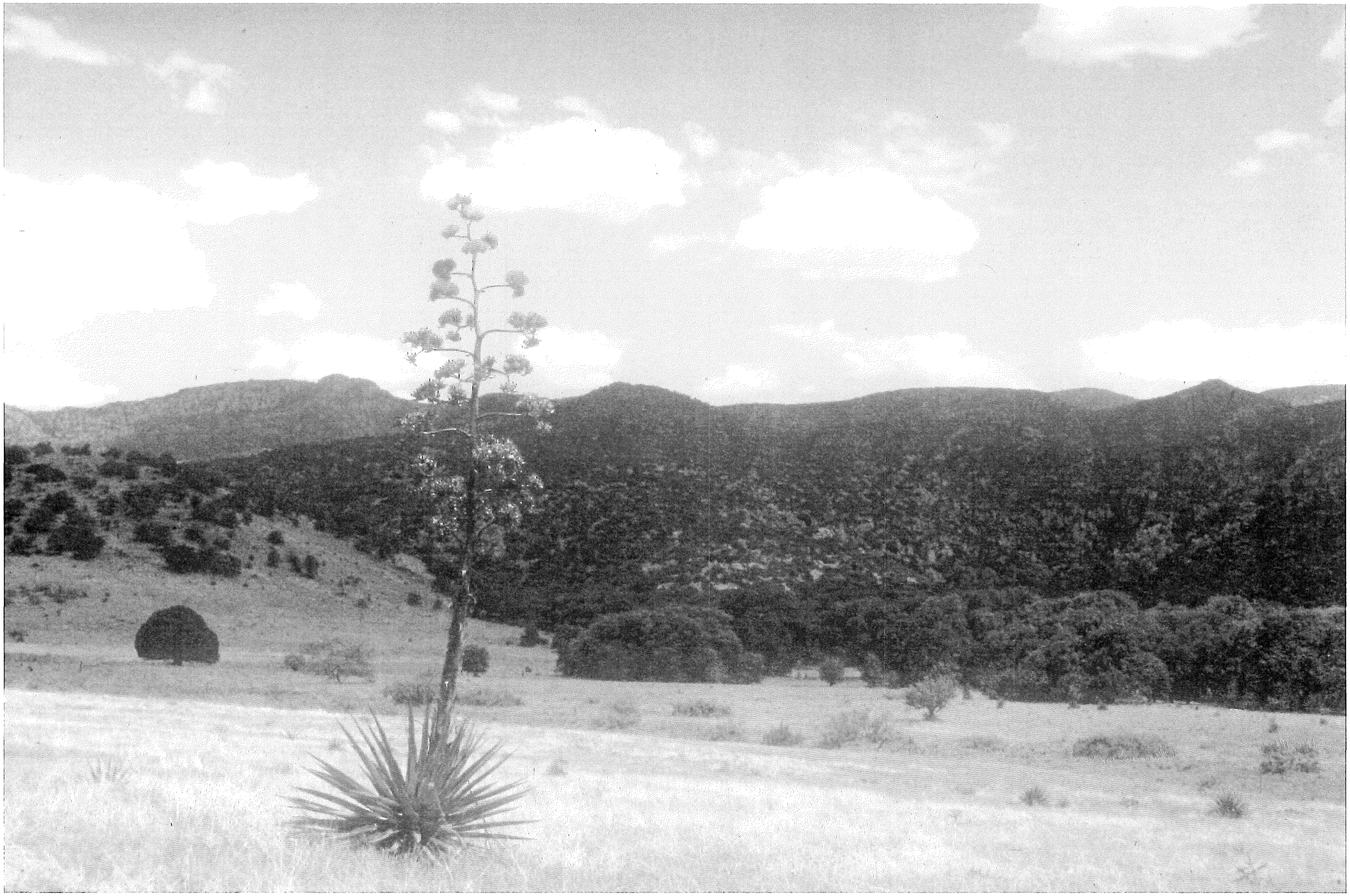

FIGURE 3.3 Desert grasslands looking up into the foothills of Pine Canyon, a riparian pine-oak forest in the western Chiricahua Mountains

FIGURE 3.4 Open Madrean pine-oak forest at Sawmill Canyon, in the northeastern Huachuca Mountains (Photo by C. Baisan).

woodlands, and pine-oak forests (Figs. 3.3 and 3.4). In these areas, geomorphic canyon systems create mesic conditions with perennial water and cold-air drainage. These mountain canyons were common ranchería sites of the Chiricahua Apache for subsistence advantages and the defensive cover they afforded.

A set of fire history sites from several mountain ranges this region are used to analyze cultural fire patterns. The Chiricahua and surrounding mountains are managed by the Coronado National Forest, National Park Service, The Malpai Borderlands Group, The Nature Conservancy, and the Fort Huachuca Military Reserve. The Sierra de los Ajos in Sonora, Mexico are managed by the Secretary of the Environment, Natural Resources, and Fisheries (SEMARNAP).

Fire history data was analyzed from four riparian canyon pine-oak forest sites in the western Chiricahua Mountains (See Fig. 3.2; Swetnam et al. 1989, 1991; Kaib et al. 1996b) and a contiguous higher-elevation mixed-conifer forest site (Seklecki et al. 1996). Additionally, fire histories were analyzed from canyon pine-oak forests and higher-elevation mixed-conifer forest sites in surrounding mountains, including the Animas, the Sierra Ajos, and Huachuca ranges (Dieterich 1983a; Danzer et al. 1996; Swetnam and Baisan 1996a). All fire history sites were sampled, initially to reconstruct fire histories for these particular ecosystems (See Preceding Chapter 2).

Major plant associations dispersed along these mountain foothills and canyons include plains and desert grasslands, oak/pinyon/juniper woodlands, interior chaparral, riparian pine-oak forest, Madrean pine-oak forest, and southwest riparian forest (Marshall 1957; Brown and Lowe 1980; Brown 1982; Muldavin et al. 1996). Riparian pine-oak forests are unique to mesic canyons in the Southwest Borderlands. They represent possibly the most diverse ecosystem in this region, bounded by ecotones and including both Madrean pine-oak and southwest riparian forest species. Common tree species include; ponderosa pine (*Pinus ponderosa*), Arizona pine (*P. arizonica*), Apache pine (*P. englemannii*), Chihuahua pine (*P. leiophylla*), and pinyon pines (*P. discolor and P. edulis*); junipers (*Juniperus deppeana, J monosperma*); oaks (including *Quercus arizonica, Q. emoryi, Q. hypoleucoides, Q. oblongifolia, and Q. rugosa*); and madrone (*Arbutus arizonica*). Common riparian species include the Arizona sycamore (*Platanus wrightii*); cottonwood (*Populus fremontii*); willow (*Salix gooddingii*), and walnut (*Juglans major*). The upper elevation mixed-conifer forest sites are typically less diverse, with ponderosa pine, Arizona pine, and southwestern white pine (*P. strobiformis*), Douglas fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), and Englemann spruce (*Picea englemannii*) as predominant tree species (Sawyer and Kinraide 1980). The flora of the Chiricahua Mountains was described by Bennett et al. (1996.), the Huachuca Mountains by Wallmo (1955), and the Sierra de los Ajos by Fishbien et al. (1995). These mountain islands have very diverse floras ranging between more than 500 to 1,000 species (Felger et al. 1995; McLaughlin 1995).

Rainfall is extremely variable in these areas and only slightly greater than nearby deserts, averaging between 230 and 460 mm annually (Humphrey 1958; Sellars and Hill 1974; McClaran 1995). Orographic influence near mountains produces at the higher elevations almost twice the precipitation when compared to the lower surrounding deserts (Shreve 1915; Nierring and Lowe 1984; Barton 1994). Annual precipitation falls almost equally in two seasons with up to 60 % falling during winter months, and the remainder falling during summer monsoons (Douglas et al. 1993; Stensrud et al. 1995). Percentages are reversed to the south in Mexico where *las aguas*, the monsoon rains, contribute up to sixty % to increase the average annual precipitation (Shreve 1944). Accordingly, this region also has two dry seasons in the early summer and fall. However, high levels of lightning and fire activity coincide only with the period prior to and during the summer monsoon (Barrows 1978; Gosz 1995).

Although fires in the Southwest Borderlands can often ignite and burn from April to November, the peak fire season occurs between May and July when pre-monsoon storms provide sufficient lightning and extremely variable precipitation (Sellers and Hill 1974; Barrows 1978; Baisan and Swetnam 1990). This is a time when perennial vegetation is cured, annuals are stressed from hot-dry weather, and ignition by "dry" lightning precedes the wet monsoon thunderstorms. This region has one of the highest levels of lightning activity in North America, suggesting that ignition sources during the summer-monsoon season were not a factor limiting past fire regimes. Figure 3.5 illustrates the high concentrations of lightning strikes that occur within the study area over short periods during the summer monsoon season. Twentieth century U.S. Forest Service reports show that 73 % of fires in this region originate from lightning (Baisan and Swetnam 1990; Bahre 1991). Chiricahua National Monument fire data over 29 years indicate 83.6 % of fires were caused by lightning (Jandrey 1975). Data from the national lightning detection system also illustrates the seasonal abundance of lightning strikes in this region (See Fig. 3.5; Gosz et al. 1995). The classic study by Barrows

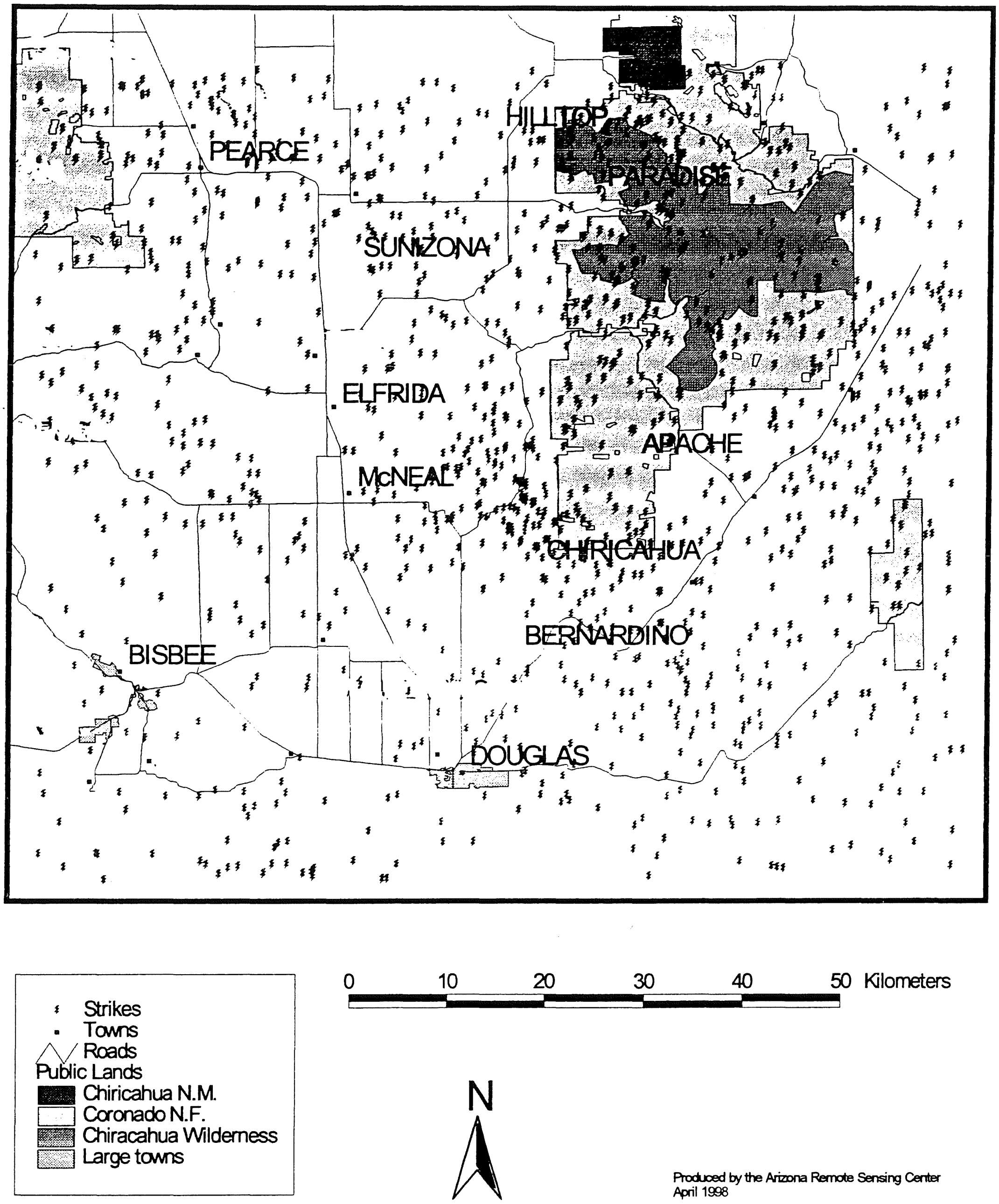

FIGURE 3.5 Lightning strikes in study area for the month of July 1996 (n = 3,016). Data for positive and negative current, cloud to ground lightning, from the National Interagency Fire Center, (NIFC; Boise, Idaho) Lightning Detection System (Krider et al. 1980).

(1978) on 20th century lightning fires in southwestern forests, showed that 48 % of lightning ignitions occurred in ponderosa-pine forest, and 26 % in the lower grassland communities.

Twentieth century records are difficult to interpret due to widespread vegetation changes, however, historical accounts provide independent sources that illustrate the character and origins of presettlement fires. Human-caused fires in the past were commonly documented in these areas by historical accounts (Pyne 1982; Bahre 1985). Past fires often burned for months at a time and covered thousands of hectares (Swetnam 1990; Bahre 1991). Prior to European-American settlement (pre-1880s), throughout the grasslands, woodlands, and pine-oak forests, grasses provided an important component in the fuel matrix (Leopold 1951; Bahre 1996). Thus, relatively few ignitions could result in extensive areas being burned and frequent fires in areas exposed to multiple sources of fire (Swetnam and Baisan 1996a).

3.6 Methods

3.6.1 Documentary Evidence

Documentary evidence was assembled from Spanish, Mexican, Native American, and later American sources, principally on cultural-fire records and information, but also including ethnoecological, wartime, and intercultural relations. Chiricahua Apache residence and use of canyon ranchería sites were also documented (Cole 1988; Sweeney 1991). All documentary evidence, including ethnohistorical and ethnographical reports, were compiled into a bibliography with over 200 citations (Appendix A). Reference to culture, location, and key words preface each bibliographic citation (when available). Fire uses and descriptions were categorized and tabulated from the documentary sources. Warfare and non-warfare uses were two primary categories. All categories of fire use were ranked by the number of times cited, and by the percentage of times a particular culture was cited within the bibliography.

3.6.2 Ethnoecology

Ethnoecological analysis involved compiling major food and fiber resources of the Apache. This data set was developed primarily from the documentary evidence in Appendix A. All plant names were checked with botanical research in these areas (Sawyer and Kinraide 1980; Bennet et al. 1996). A table was compiled of major food and fiber species used by the Apache including trees, shrubs, grasses, and succulents. Additional information was assembled on the fire adaptations and resilience of these ethnobotanical species, using the USDA Forest Service Fire Ecology and Effects Database (www.USDA.Forest Service). A fire resilience interval (FRIs) was defined as the average time interval in years required for a particular plant to recover to prefire conditions following a surface fire. FRIs were estimated from the USFS database using all available ecological, tree-ring, and prescribed fire research. This information was unavailable or qualitative for some species. Apache fire uses were then interpreted in context of the fire ecology and resilience of specific plant species and vegetation types in these areas. My assumption is that if a particular plant responds rapidly after burning (i.e., low FRI), then the greater the chance that manipulation could have occurred via Native American burning.

3.6.3 Fire History

Fire-scarred cross sections were obtained with a chainsaw from logs, stumps, and snags of primarily Apache and Arizona pines but also some ponderosa (Arno and Sneck 1977). Samples were resectioned and finely sanded then crossdated using dendrochronology methods (Douglass 1941, 1946; Stokes and Smiley 1968; Fritts 1976; Swetnam et al. 1985). Multicentury fire histories were reconstructed from fire-scar dates at several sites, and for analysis combined with existing fire history reconstructions in the Southwest Borderlands (Dieterich and Swetnam 1983; Swetnam and Baisan 1996a; Danzer et al. 1996; Seklecki et al. 1996). Although initially these sites were collected for ecological research, the cultural significance of some canyon sites warranted further investigation.

Fire history sites were selected across a hypothesized gradient of human influence that includes four riparian canyon pine-oak forest sites, an adjacent higher-elevation mixed-conifer forest site in the Chiricahua Mountains, and sites within three surrounding mountain ranges. All four of the riparian canyon pine-oak forest sites were documented as historic Apache rancherías or encampments. Fire reconstructions at canyon ranchería sites were compared with an upper-elevation forest site nearby, and also with sites in the surrounding mountains. Fire reconstructions in the surrounding mountains include collections from riparian canyon pine-oak and mixed-conifer forest sites.

The hypothesized gradient of anthropogenic fire influence starts at the canyon ranchería sites in the Chiricahua Mountains, with the adjacent higher-elevation site being intermediate. The surrounding mountain sites, that were on the periphery of the Chiricahua Apache range, possibly may be less influenced from anthropogenic fire influence. The site gradient analysis was chosen for several reasons. Documentary evidence suggests in presettlement times (pre-1880s) common long-term Apache use of the ranchería canyon sites. The higher-elevation sites were used less due to relatively limited resources and prohibitions associated with grizzly and black bears (Castetter and Opler 1936). Additionally, the adjacent mountains are smaller, closer to Spanish military establishments, and therefore offered less protection from enemies. These surrounding mountain sites also have relatively little to no documentation of use as Chiricahua Apache encampments compared to the Chiricahua Canyon strongholds (Opler 1983b). In total, eight fire history reconstructions were graphically and statistically analyzed for cultural fire patterns.

Mean fire intervals were compared between wartime and intervening peacetime periods identified by the documentary evidence. The Student's t-test was used to analyze differences between fire interval distributions. The null hypothesis was that there were no differences between wartime and peacetime mean-fire intervals. Each of the wartime periods (WTP1: 1680-1710, WTP2: 1748-1790, and WTP3: 1831-1886) were tested for differences between intervening peacetime periods (PTP1: 1711-1747, PTP2: 1791-1830). All WTPs were analyzed with the subsequent PTP, except for WTP3, which was tested with the preceding PTP2. This was because following WTP3 in the

1880s the region was settled by European-Americans, Chiricahua Apaches were removed to distant reservations, and extensive grazing eliminated the episodic widespread fires of the past (See Chapter 2).

Assumptions of this analysis include: (1) Data from each wartime period was independent of each peacetime period being tested. (2) The two independent fire-interval sets have normal distributions. (3) Sample sizes were adequate, and (4) Periods chosen were appropriate and valid. The first assumption was accounted for by choosing non-overlapping wartime and peacetime periods. Because fire-interval data are rarely normally distributed, the second assumption was addressed with fire-history software (FHX2) that transforms fire-interval distributions to approximate normality (Grissino-Mayer 1994). Fire-history collections included on average about 30 samples, a sample size shown to be adequate for most Southwestern fire history studies at spatial scales of about 100 to 1000 hectares (Swetnam et al. 1989, 1996a, 1996b). Wartime and peacetime analysis periods were well documented by historical sources. However, there may be some uncertainties about the comparability of peacetime and wartime period interval lengths, that ranged between 30 to 55 years.

Fire reconstructions were assessed for anthropogenic fire influences along both ecological and spatial gradients. Wartime fire patterns were analyzed and compared between canyon, adjacent forest, and surrounding mountain sites, to infer the spatial extent of cultural-fire influences across this area. Finally, wartime burning influences were assessed for desert grassland, riparian canyon pine-oak forest, and mixed-conifer forest ecosystems.

3.7 Results

3.7.1 Raiding and Wartime Periods and Burning Practices

The compilation of documentary evidence suggests that cultural burning patterns were strongly associated with Apache raiding and wartime periods (See Appendix A). A chronology of historical events in the Southwest Borderlands helps to demonstrate the context of wartime (WTP) and peacetime periods (PTP; Table 3.1a, 3.1b, 3.1c). WTP1 (1680 to 1710) was an era of increased Spanish influence in Southwest North America with the first written reports documenting widespread Native American revolts. WTP1 commences with Pima, Pueblo, and Apache Revolts in 1680. The following account illustrates the early Spanish and Pima alliance against Apache raiding.

> In 1693: "The vowed enemies, the Hocomes, Sumas, Mansos, and Apaches, who between great and small numbered about six hundred.....showed their arrogance by attacking the ranchería at daybreak... They killed its captain... and forced them to retreat to their fortification. But the enemy, defending themselves and covering themselves with many buckskins, approach the fortification, climbed upon its roof, destroying it and burning it... They (Apaches) sacked and burned the ranchería... and began to roast and stew meat and beans... But meantime the news reached the neighboring ranchería of Quiburi... its captain, El Cora, came to the rescue of his brave people, together with other Pimas who had come from the west to barter for maize,... Thereupon all the rest of the enemy began to flee, and Pimas followed them through all those woods and hills for

TABLE 3.1a. Southwest Borderlands chronology of late-17th Century historical events.

circa	Historical Events
1680	Pueblo and Pima Revolt
1683	El Paso Presidio Established
1687	Padre Eusebio Kino Establishes Nuestro Senora de los Delores
1688	Pima Uprising in the Upper Santa Cruz Valley
1690	Janos Presidio Established, Pima Uprising
1692	Fronteras Presidio Established
1693	*Compania Volantes* Established at Presidios, Texas Indian Uprising
1694	Pima and Sobaipuri Uprising Suppressed in Huachuca Mountains
1696	Pima Revolt
1697-	Pimas and Sobaipuri Allied Against the Apache to the East
1698	Sobaipuris Abandon San Pedro Valley Due to Apache Raids until 1705

Table 3.1b. Southwest Borderlands chronology of historical events in the 18th Century.

Circa	Historical Events
1700	San Xavier del Bac Founded
1702	Missions Founded at Tumacacori and Guebavi
1702	"Reglemento de los Presidios" Authorizes Pursuit and Annihilation of Hostile Indians
1710	Spanish Regain Tentative Peace with Help of Pima and Sobaipuri Allies
1724	Pedro de Rivera, Begins 4 Year Inspection of Northern Frontier Presidios
1725	Fronteras Attacked by Large Group of Apache with Torches (100-200 Apache)
1729	"*Reglamento of 1729*": Rivera Reports Presidio Inefficiencies and a New Uniform Code
1742	Terrenate Presidio Established on Santa Cruz River
1748	Spanish Viceroy Declares War Against Apaches
1751	Pima Revolt, Tubac Presidio Established
1756	Guevavi and San Xavier Missions, and Tucson Visita Abandoned
1762	Apache Raids Force Sobaipuris to Abandon San Pedro Valley for the Santa Cruz
1766-	Marques de Rubi and Nicolás de Lafora Inspect Presidios of New Spain
1767	Jesuits Expelled from New Spain
1768	Marques de Rubi and Nicolás de Lafora: "*Dictamenes*" Reorganizes Presidios
1768	Franciscans Take Over Missions, San Xavier del Bac Burned by Apaches
1772	"Reglamento de 1772" by Hugo O'Conner, Orders Coordinated Campaigns Against Apaches
1775	San Bernardino and Bacoachi Presidios Established
1776	Tubac Presidio Moved to Tucson, Fronteras to San Bernardino, and Terrenate (Santa Cruz) to Quiburi
1779	Tucson Attacked by About 350 Apaches, Fronteras Re-established Because San Bernardino too Risky
1780	Santa Cruz de Quiburi Presidio and Terrenate Settlement Abandoned
1782	New Spanish Policy of "*Establecimientos de Paz*" later Reinforced by Galvez
1786	Bernardo de Galvez "*Instrucciones*" Decreed Vigorous War on Apaches Not at Peace
1786	Lipan and Mescalero Apaches Establish Peace Treaties with Spanish
1787	Opata Presidio Established at Bavispe
1789	Peace Establishment at Bacoachi, Sonora, Has Over 200 Apaches
1790	Gileno Apache Peace Establishments Commence in Bacoachi, Fronteras, Santa Cruz, and Tucson

Table 3.1c. Southwest Borderlands chronology of historical events in the 19th Century.

circa	Historical Event
1810	Beginning of Mexican Revolution
1820s	Mexican War of Independence, Peace Establishments Begin to Break Down
1821	Mexico Declared Independent from Spain
1830	Peace Establishments Abandoned, Apache Raids and Wartime Period Begins
1831	Mexican Government Sets Bounty on Apache Scalps and Ears
1840	Pima Unrest lasting until 1841 After Several Battles with Mexican Forces
1843	San Rafael Valley Abandoned Due to Apache Depredations
1846-	Mexican-American War
1848	Tubac and Tumacacori Destroyed by Apaches, Treaty of Guadalupe Hidalgo
1851-	U.S. Boundary Commission, Bacoachi Attacked and Houses Burned
1854	Gadsden U.S. Official Purchase of Lower New Mexico (Arizona) Territory
1861-	Bascom Affair Catalyst for Increased Apache Raiding and Warfare
1866	American Civil War Resulted in Neglect and Increased Apache Hostilities
1872	Cochise and General Howard Sign Treaty, Chiricahua Reservation Established
1874	Most Apache Groups Settled on Reservations
1876	Chiricahua Apache moved to San Carlos and Mescalero
1881	Southern Pacific Rail Road Completed Across Southern Arizona

more than four leagues, killing and wounding more than three hundred (Manje1693:249)."

Although early historical records usually only specified losses to property and personal effects, it is probable that many of these fires spread to adjacent lands, when considering the undeveloped nature of early Native American villages. Incidentally, a fire was also recorded in 1693 by several sets of fire-scarred trees in the Huachuca Mountains.

Presidio establishment dates and periods of activity also help illustrate the historical context of these time periods (Table 3.2; See Fig. 3.1). In WTP1, the cultural ecology of Athapascan horseback raiding, general intercultural warfare, and the Spanish reconquest of tribal lands and labor, resonated across the Spanish frontier for subsequent decades. The Spanish reorganized at the northern Presidios, and with assistance from the plains Comanche, they regained control of the Middle Rio Grande around the late 1600s. This encouraged Apache migrations south and west into the mountain "strongholds" of the Southwest Borderlands (Worcester 1941). Farther west, the Spanish had begun mission and presidio settlements along the Rio Sonora, Santa Cruz, and San Pedro river basins. A relatively complacent time period (PTP1: 1710-1747) ensued with the western alliance between the Spanish, Sobaipuri, and Pima, and the strengthened Spanish presence along the Rio Grande to the east. However, in a short time the Apache became established in their canyon strongholds and began to renew their raiding, hence the origin of regions renown as Apachería.

TABLE 3.2. Presidio establishment dates and periods of activity (adapted from Officer 1987)

Tucson	1776-1821
Tubac	1751-1776, 1787-1821
Santa Cruz de Terrenate	1776-1780
Terrenate	1742-1775
San Bernardino	1775-1779
Fronteras	1692-1775, 1779-1821
Bavispe	1778-1821
Bacoachi	1784-1821
Las Nutrias	1775, 1780-1787
Santa Cruz	1787-1821
Altar	1753-1821

The next WTP1 account describes what appears to be a large fire that occurred at a canyon in the western Chiricahua Mountains. The report also suggests that this "heavy smoke" was a signal fire initiated by the Spanish.

> "On September 16, 1695...located in an arroyo of the (western) Chiricahua Mountains. When we saw heavy smoke rising from the canyon at the head of this arroyo, we knew that the thirty-six troops under the command of Lieutenant Antonio de Sólis who had left the night before were in combat, because they had been told to send us a smoke signal (Naylor and Polzer 1986:640)."

Later wartime and peacetime periods were better documented by the general increase in historical materials (See Tables 3.1b and 3.1c; Bolton 1919; Hackett 1926, 1937; Bannon 1974). WTP2 (1748 to 1787) commenced when the Spanish Viceroy declared war against the Apache in 1748, beginning a period of renewed presidio development and wartime hostilities (Forbes 1966). By this time the Spanish had improved relations with the Pima and Sobaipuri, and their combined forces commonly fought off Apache raids. Presidios were at their peak of combat readiness in the mid to late 1700s (See Table 3.2; Griffen 1987). Ethnohistorical research on Apache raiding and warfare political ecology suggests increasingly volatile battles occurred during the mid-18th century wartime period (Griffen 1988a, 1988b). By the end of the 1780s many Apache bands began to request peace, and Spanish peace establishments were promoted and developed, leading to PTP2 (1788-1830) in the Southwest Borderlands.

These following accounts demonstrate the popular Apache practice of burning enemy pasturage. This practice was also recorded by several other documentary sources. Grasslands were essential for the livestock herds that European cavalries required for food and transportation. Apache burning on these occasions were used to control enemy movements by limiting forage in places, particularly around water holes.

> "In the spring (1786) Alferez Vergara, with troops from Fronteras, Bacoachi, and Bavispe, made a reconnaissance from the Chiricahuas (Mountains). He found large swaths of grasslands burned off, apparently to destroy fodder for Spanish horses. He then marched to the Pitaicachi and Embudos Mountains and to Cucuveracchi where he attacked over one hundred Apache warriors who were there with their families making mescal (Griffen 1988a:48)."

> In May, 1788; "Cordero, reinforced by eighty-five men from San Elizario, veered his course to the west into the Las Animas and El Hacha Mountains. His men saw no Apaches but Apaches saw them and burned off the grass around the water holes, thus depriving the Spanish horses of much pasturage (Griffen 1988a:62)."

The following incident documents another Apache practice of burning off grasslands in raiding and warfare. Mr. Fife recalled this encounter with 35 Chiricahua

Apache warriors in Pinery Canyon (on April 13th, 1882 or 1883), decades after it occurred.

> "After a while I saw two Indians down on the floor of the canyon pulling dry grass and piling it in a horseshoe shape around the ridge I was on. They lit the fire, and the smoke was soon billowing up upon me. I dug a hole in the ground and put my head in it. I looked up once to see a breeze coming across the top of the ridge folding the smoke back into the canyon. In a little while, when the fire came close I decided to try to run through it. I did and got to the bottom of the canyon (Tucson Daily Citizen, Mon., November 15, 1933; Bahre 1991)."

This fire more likely occurred in 1882 as documented shortly thereafter by Briggs (1932) and also as recorded by a nearby fire reconstruction in Pine Canyon.

Warfare burning practices were also utilized by European cultures. By the mid-18th century, Spanish presidio troops were better organized and equipped (Griffen 1988a, 1988b). *Compañía volantes* or flying companies pursued the Apache to their rancherías and camps, usually to find the Apache had already retreated (Figs. 3.6 and 3.7). Typically when rancherías were discovered any resources of value were taken or destroyed with fire including the ranchería camps, wigwams, and any human effects. This popular warfare strategy is illustrated in the following reports.

FIGURE 3.6 Geronimo (right horse) and Naiche, the son of Cochise (right horse). Respectively, the war chief and medicine man, leaders of the last group of Chiricahua Apache raiders (Ball 1970).

UNDER ATTACK   BY JACK SCHLICHTING

FIGURE 3.7 *Soldados de Cuera*, 18th century Spanish presidio soldiers in military regalia including a lance, sword, two pistols, and a carbine. The *companías volantes*, or flying companies traveled light in groups of fifty or more, to protect frontier settlements from Apache raids (Brinckerhoff and Faulk 1965).

> "Reglamento de 1772 to all frontier commanders: troops were to take the offensive and wage a relentless war on the Apaches, attacking them at their camp sites and removing all opportunity for the rancherías to unite. All places known to be frequented by the Apaches camps, water holes, and mescal harvesting areas were to be scoured (Griffen 1988a:56)."

> "New reforms culminated in the Royal Regulations of 1772. Troops marched from Sonora to Tejas in massive pincer movements, burning abandoned rancherías and recapturing vast numbers of horses (Moorhead 1975:71-72)."

In the following incident, Texas pioneers attacked and burned an Apache ranchería, near the Huachuca Mountains on July 2, 1849.

> "Indians continually sent up sky-reaching signal smokes, telegraphing our movements. The sun was about to rise when twelve men in front and ten in the rear charged the Indian ranchería, expecting each moment to slay the tenants as they rushed forth. The wigwams of thatched grass were soon ignited. Our approach had been observed. Bucks, squaws, and families had had time to get a mile away, up the steep slope (Possibly at Santa Cruz Peak, Huachuca Mountains) with all their horses except one American mare and thirty-nine cows having Spanish brands, fresh lance marks, and tender feet---proving they had

recently been stolen and driven there (Harris 1849; Dillon (ed.) 1960; cited by Hadley and Sheridan 1995)."

Incidentally, a fire was recorded on the same year by several fire histories in the nearby Huachuca Mountains. Lieutenant Rucker's Cavalry Report dated January 14th, 1877 also provides testimony to the common European military practice of burning Apache rancherías.

> "The hostile camp consisted of 16 lodges containing about 35 warriors. The captured property brought into camp Bowie has been identified as belongings to portions of the Chiricahua Indians who formerly lived on this reservation, forty six horses and mules were captured, also a large quantity of blankets, calico, manta, clothing, camp utensils, and large quantities of dried meat, mescal, & c. (etc.)... All the property which was deemed impractical to be carried off was destroyed by fire (Unpublished U.S. Military Documents cited in Wilson 1995:116, 339)."

The following recollection was made by Will Barnes who in 1880 was on his way to Fort Apache. Note his use of the term "prairie fire" to describe the actions taken by the Apache. Also note that the American forces were well aware of the counter-offensive use of fire in warfare.

> “But the Indians were full of ideas. Ash Creek Flat for miles on every side was covered with a dense growth of wild oats, as dry as tinder and in places waist-high. Smoke began to appear at two or three places "up the wind," and it was realized that the noble red men were going to try a prairie-fire attack for a change. Driven by a stiff breeze, the billows of flame and smoke came rolling down onto the crater which protected our outfit. (Lieut.) Cruse promptly met this attack by back-firing the tall grass. With all hands at work, a wide barrier of burned-over land was created entirely around the location, and all danger from that source was ended. The dense smoke bothered us some, but that was all (Barnes 1941:31).”

In 20th century fire suppression terminology this technique is called “black lining” or the “black line”. It provides a safe method to control grass fires, and apparently an age-old technique used by the Apache, other Native Americans, and Europeans alike.

Another example of tactical warfare burning occurred in the late spring in 1882, this time by the Mexicans.

> “The Mexicans tried all afternoon to dislodge the Indians. After dark they set fire to the grass hoping to burn the Indians out. The latter were now in a serious condition. They were surrounded by a prairie fire, the circle of it growing closer. (The warriors) all crawled through the fire and got away without being seen (Betzinez 1959:74).”

Peace establishments began to break down and Apache raiding escalated soon after the independence of Mexico in 1821. Mexico's sovereignty meant no Spanish support and generally less funding for presidio troops and establishments. WTP3 spanned between 1831 and 1886, and was better documented by substantial historical and tree-ring evidence when compared to earlier time periods. Combined military pressure upon the Apache from American and Mexican troops, superior firearms, and assistance from Apache scouts, also made WTP3 the most bloody wartime period. In the end, after centuries of raiding and warfare, the last Apache raiders were forced to surrender to U.S. reservations in the late 1880s.

Most records of Apache burning come from military reports. Apache raiding and warfare burning practices were well known at the time. In these times, most all fires were believed to have been from Apache sources, regardless of any real proof of their true source. In fact, many of these fires probably originated from lightning given their occurrence during the natural lightning-fire season. However, common historical bias in both the 18th and 19th centuries blamed any and every fire or smoke, on the Apache, as illustrated by the following Cavalry Report from 1871.

> "Cushing and myself (Sergeant John Mott) noticed that the grass was being set on fire and concluded it was done by Indians as a signal to their fellows in the mountains; but I have since learned that when about two miles from the command Mr. Kitchen saw some thirty or more Indians on our trail and burned the grass to warn us (Thrapp 1967)."

The majority of human-caused fire citations were associated with raiding and wartime periods. Regular or non-warfare Apache burning practices were scarcely recorded by the documentary evidence. However, some traditional fire uses have emerged from a closer examination of the ethnographical and documentary sources.

3.7.2 Chiricahua Apache Burning Practices and Fire Use

> "(They) go about with a firebrand, setting fire to the plains and timber so as to drive off the mosquitoes, and also to get lizards and similar things which they eat, to come out of the soil. In the same manner they kill deer, encircling them with fires, and they do it also to deprive the animals of pasture, compelling them to go for food where the Indians want (Bandalier 1905:93)."

This is the earliest known account of Native American burning in this region. It took place in the year 1528, while Cabeza de Vaca was traveling through what is now southeastern Texas. This report provides several early interpretations of Native American burning practices, that were explained in further detail by later documentary sources.

Native American burning practices and fire uses were diverse (Pyne 1995). Fire has occupied a spiritual and mythical domain for most if not all cultures since time immemorial. Castetter and Opler (1936) provide the leading ethnoecological investigation of the Chiricahua Apache. They describe the Apache's healthy respect for thunder and lightning, and their many concerns regarding the influence of summer lightning and monsoon seasons. These beliefs are illustrated by the Apache oral history of the mountain spirit mythology (Fig. 3.8).

> "Life and conscious aims are attributed to natural forces as well. The Apache conception of thunder will serve as an example. Thunder is thought of as people and thunderclaps are the voices and shouting of these people. Lightning is the arrow of the thunder people and these arrows reach the earth as the elongated flints which the apache find throughout their territory... the arrows of the thunder people are reserved for any who act disrespectfully to the thunder people or otherwise disobey the injunctions of Apache life. When lightning flashes, the Apaches says, '*Let it be well, my brother lightning,*' or '*Strike high, my brother*' (so as to not start a fire at or below the ranchería sites). When the lightning hits close the relationship is altered to make the prayer more appealing and the apache says: '*Continue in a good way. Be kind as you go through; Do not frighten these poor people; My grandfather, let it be well; Don't frighten us poor people.*' Space does not permit a full discussion of the restrictions in food, speech, and even in the color of objects displayed during a storm, which are obeyed in order to appease the thunder people (Castetter and Opler 1936:17-18)."

Mountain Spirit Dancer. Watercolor by Allan Houser. (Neg. No. 86228, Courtesy Museum of New Mexico, Santa Fe.)

FIGURE 3.8 The Mountain Spirit Dancer (Allan Houser; John and Wheat 1978), invokes images of the spiritual and physical relations the Apache had with lightning, thunder, and summer fires.

Castetter and Opler (1936) also describe the general fear and apprehension of lightning and thunder, associated fasting, and impending wildfires and losses that occurred during these summer lightning-fire seasons (Opler 1941, 1942).

The following incident depicts the Apache concern for wildfires, implied by the mountain spirit mythology. Jason Betzinez tells of a wildfire that caught his ranchería completely by surprise in the northern Sierra Madres in 1883.

> "I heard my mother calling me. She said a grass fire had started east of the spring and was spreading. I ran rapidly down the slope to where my horse was standing directly in the path of the fire. The flames were roaring now, seemingly thirty or forty feet high and rushing toward us behind a strong wind. By this time the smoke and heat were so intense that I wet my bandanna kerchief in the spring and tied it over my mouth and nose... By the time I got past the line of the blaze I could see people around the camp fighting the fire in an effort to save their tents. This was the most dangerous and exciting fire I ever saw... A great cloud of smoke was billowing high above the Sierra Madres, visible for a hundred miles in all directions... Therefore the base camp was moved to the mountains west of the Huachinera (Mountains; Betzinez 1959:110)."

Figure 3.9 provides ethnographic sketches of Native American fire-making technology. Fire making was a skill known to both Apache men and women and at an early age most could rapidly kindle a fire using the hand-held drill. The traditional fire making kit

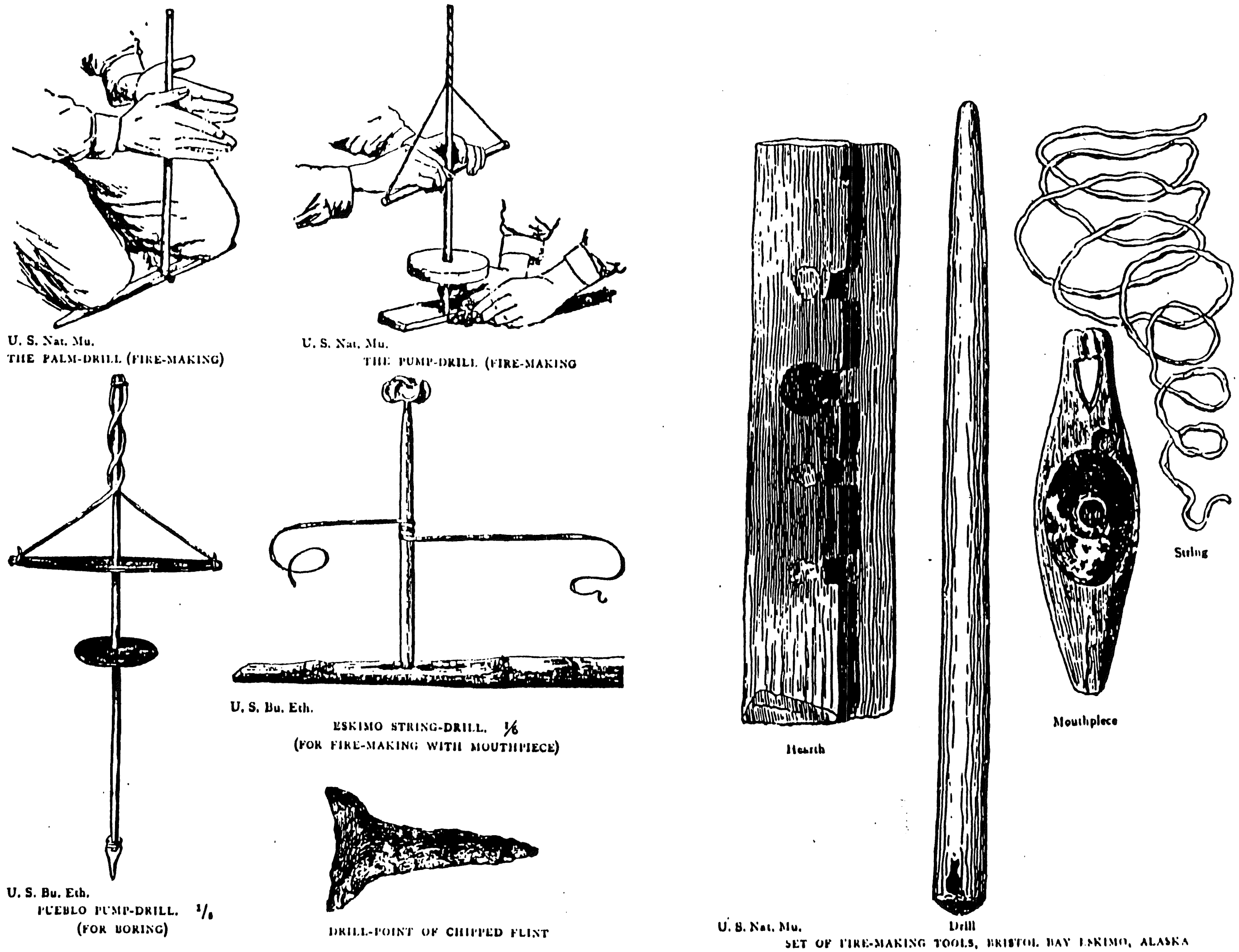

FIGURE 3.9 Native American fire making technologies (Dellenbaugh 1906). The hand drill depicted by the sketches to the upper-left and right, was commonly used by the Apache. Dried flowering stalks of several agave and yucca species were typically used for the drill and hearth (Castetter and Opler 1936).

contained the hand-drill and hearth (both usually made from the flowering stalks of various agave and yucca species), and some very fine kindling (i.e., juniper bark, grasses) to catch the ember (Castetter and Opler 1936). Later when available, flint and steel were also used. Below, Antonio Cordero describes the art of fire making.

> In order not to be delayed in the making of smoke, there is no man or women who does not carry with him the implements necessary to make fire. They prefer flint, steel and tinder when they can get them; but if these are lacking they carry in their place two prepared sticks, one of sotal (*Dasylirion wheeleri*) and the other of lechuguilla (*Agave lechuguilla*), well dried, which they rub with force with both hands like a little hand mill, the point of one against the flat side of the other, and thus they succeed in a moment in setting fire to the shavings or dust of the rubbed part; and this is a process which even children are not ignorant of (Cordero 1796; translated by Matson and Schroeder 1957:348-349)."

Don Antonio Cordero had immense knowledge about the Southern Apache bands including the Chiricahua, from his many reconnaissance and war campaigns between the 1780s and 1790s throughout the Northern Provinces. Cordero had fought with the Apache from youth, he knew their language, and he had a profound understanding of Apache cultural ecology (Matson and Schroeder 1957). Lieutenant Cordero provided important eyewitness accounts of early Apache burning practices. The following report characterizes the fire-drive hunt.

> "At dawn a piece of terrain is encircled, which frequently is five or six leagues in circumference (therefore an area equal to about 30 km^2). The sign to commence the chase, and consequently to close the circle is given by smoke signals. There are men on horseback assigned to this project, which consists in setting fire to the grass and herbage of the whole circumference; and since for this purpose they are already placed ahead of time in their posts with torches ready which they make from dried bark or dried palmilla (*Yucca spp.*), it takes only a moment to see the whole circle flare up. At the same instant the shouts and the noise commence, the animals flee, they find no exit, and finally they fall into the hands of their astute adversaries. This kind of hunt takes place only when the grass and shrubs are dry. In flood season when the fields cannot be set afire they set up their enclosures by rivers and arroyos. The deer and antelope hunt is carried out with the greatest skill by one Indian alone; and due to the great profit which results from it, he always prefers it to the noisy type of chase (fire and game drive), which serves more for the amusement than to provide necessities (Matson and Schroeder 1957:343-344)."

The "flame beaters" who knocked down and controlled the burning perimeter fire as quickly as it was lit, illustrate an important observation. It suggests that the Apache were conscious of the consequences of letting fires get out of their control. This report also indicates this type of hunt was a social event for all including the children and elders, and other methods employed by a single well-equipped hunter were more effective.

Cordero and his accounts were influential in their time as suggested by the apparent reiteration by later authors (Cortés 1799; Velasco 1861). The historical popularity of the fire-drive hunt story may have resulted in it's true importance being misunderstood, and account for the strong emphasis given this hunting technique by others (i.e., Dobyns 1981; Pyne 1982). Nevertheless, this type of hunt is only recorded by a few early known documentary sources from this region.

Cordero probably did not understand or report the full meaning of these observations and burning practices. It is unclear from the scant evidence how common and extensive fire-drive hunting was in presettlement times (pre-1880). The former account suggests the Apache conducted organized and controlled burns that were probably limited spatially by the number of participants. Because there are only a few known early firsthand accounts that refer to fire-drive hunting, the importance of this Apache burning practice may have diminished with time. It is also possible this practice was not very common in these areas in the past, or its use may have been disrupted by raiding and warfare culture. More important, is the early narrative of controlled burning, an age-old Apache skill recorded by many other later accounts. For example, during the boundary survey in the 1850s, alert Apache scouts put to use their fire control skills and saved the camp from fires on at least one occasion (Bartlett 1854).

Although fires did escape on occasions, by design, communication fires and smoke signals were controlled, and lack of control would have usually defeated their purpose. Therefore, most fire and smoke signals used in Apache communication would generally have had limited spatial influence. Below, Cordero describes the use of fire in communication.

> "In spite of the continuous movement in which these people live, and the great deserts of their country, they find each other easily when they desire to communicate... Understanding it is a science; but it is so well known by all of them that they are never mistaken in the meaning of its messages... A smoke signal made on a height, put out immediately, is a sign for all to prepare to resist enemies who are nearby and have already been seen personally or their tracks have been noted. Any camps that detect them give the news to others in the same way. A small smoke made on the slope of a mountain, is a sign that they are hunting their own people whom they desire to meet. Another smoke in reply half way up the sides of an eminence, indicates that there is their habitation, and that they can freely come to it. Two or three small smokes made successively in a plain or canyon pointing in one direction, are an indication of desire to parley with their enemies, and reply is made to this in the same fashion. In this way they have many general signals used in common by all Apache groups. In the same way there are also signals that have been specially agreed upon, which no one can understand without possessing the key. They make use of these frequently when they enter hostile country for the purpose of raiding (Cordero 1796; translated by Matson and Schroeder 1957:348-349)."

Having transcribed the most valuable documentary sources that were located with reference to traditional Apache burning practices, few if any suggest that extensive areas were burned in regular or non-warfare context (See Appendix A). Regular fires were used in cooking, heating, lighting, campfires (aesthetic), communication, spiritual practices, and burial ceremonies. Conversely, burning practices associated with raiding and WTPs had broader-scale influences, and included fires for communication, direct-offensive burning, defensive burning, burning of crops and forage, burning of dwellings, covering trails, hindering enemy pursuit and movements, and also fires that were concealed and at times forbidden. Furthermore, although Castetter and Opler (1936) provide the most thorough ethnoecological investigation, they furnish no evidence of extensive (i.e., > 50 km^2) or regular burning practices beyond the finer-scale influences of general household maintenance (Opler 1941). Perhaps early ethnographers did not ask relevant questions about burning and fires. This does not appear to be the case with Castetter and Opler (1936) who describe numerous burning practices and fire uses in detail. Nonetheless, no known documentation exists of intentional Apache burning to promote ethnobotanical resources in grasslands or forests. However, the common exception was regular and widespread burning associated with raiding and wartime cultural ecology.

Fire use by prehistoric and historic humans has also been described in many cases as careless (Holsinger 1902; Pyne 1982; Bahre 1991). By contrast, most documentary evidence shows the Apache had an astute awareness of fire effects and behavior, and knowledge of the environmental costs and benefits associated with wildfires. Evidence shows that threats from enemy attacks required the Apache to be on constant guard, campfires were habitually kept under control, and burning practices were used with extreme discretion (Madsen 1997). Most evidence indicates that apart from raiding and warfare burning, and associated fires, the Apache were careful with fires, and burning practices were limited to times and places where control was possible, as suggested by the following examples.

> "Through it ran an arroyo deep enough to conceal fires and afford exits in case of attack. Only at midday did she (grandmother) permit fires to be lighted, and then only of very dry wood. Unlike white eyes (Europeans) we never camped at the water's edge, and we never built big fires to frighten game or betray our presence to the enemy (Ball 1970:17)."

> "Occasionally several rancherías, or settlements, are united at the same place, either for the purpose of war or hunting. When they mediate an attack upon their enemies, the tribes contiguous to each other assemble generally in the most inaccessible parts of the mountains, and appoint their bravest warrior as chief, to carry out their plan of operations. In these cases it is forbidden to light a fire, and sentinels of tried vigilance are posted at every point of exposure (Velasco 1861:162)."

Traditional Apache burial customs required burning of the deceased, their belongings, and even entire rancherías in cases of multiple or important deaths, and at times of disease and famine (Opler 1941). Apache funeral pyres were verified by other historical records and ethnographic research (i.e., Bourke 1887-1888; Goodwin 1941; Matson and Schroeder 1957; Basso 1971). Burning practices associated with burials illustrate a holistic and spiritual cleansing approach to deal with death, disease, and epidemics (Castetter and Opler 1936). These types of burning practices may have been elevated from increased European contact and the casualties associated with raiding and wartime periods. The Apache burial traditional is recorded by Captain Bourke.

> "From every peak now curled the ominous smoke signal of the enemy, and no further surprises could be possible. Not all of the smokes were to be taken as signals; many of them might be signs of death, as the Apaches at that time adhered to the old custom of abandoning a village and setting it on fire the moment one of their number died, and as soon as this smoke was seen the adjacent villages would send up answers of sympathy (Bourke 1891:41)."

> "The Apaches had been there to bury their kinsfolk and bewail their loss, and in token of grief and rage had set fire to all the grass for several miles, and consequently it was to the direct benefit of all our command... to keep moving until we might find a better site for a bivouac (Bourke 1891:46)."

FIGURE 3.10 Apache wickiup in southeastern Arizona circa late 1800s (Lockwood 1987). These household structures were constructed from branches covered with grasses, and sometimes mud and hides.

Routine living conditions at Apache rancherías also suggest possible fire concerns. The Apaches lived in extremely flammable thatch huts constructed of bent poles and covered with grasses, mud, and hides (Fig. 3.10; Castetter and Opler 1936; Opler 1983c). In the semiarid environment of the Southwest Borderlands, these structures would have been extremely vulnerable to accidental, lightning, and enemy-set fires. Even with constant attention as demonstrated, fires occasionally escaped control and jeopardized ranchería camps, neighboring Apache groups, and important resources.

Although regular (non-warfare) Apache fire uses and burning practices were generally controlled and spatially confined, those associated with raiding and warfare influenced much broader landscapes. Raiding and warfare burning was usually not controlled or restricted except by environmental conditions. The Chiricahua Apache commonly burned off large tracts of grasslands in raiding and warfare, particularly once they were discovered by enemies there was nothing to lose from indiscriminate burning. Substantial documentary evidence indicates a pattern of increased burning and fire use during the historic wartime periods. Additionally, burial burning customs likely added to the overall fire activity in these areas during wartime periods.

3.7.3 Summary of Findings from Documentary Evidence

Raiding and wartime burning practices, regular (non-warfare) fire use and burning practices, and Apache fire making skills and tools were characterized using the most informative sources of documentary evidence (See Appendix A). Although accidental and escaped fires were recorded, evidence does not suggest careless use of fire. Also, some burning practices were used during both regular, and warfare circumstances (i.e., communication, Apache burial tradition). Overall, the documentary evidence indicates the Apache culture had an intimate understanding of their fire environment. They knew the consequences of unwanted fires, whether from escaped, lightning-ignited, or enemy fires. Therefore they were cautious when burning and using fires (Opler 1942; Madsen 1997).

There are no known primary sources that suggest the Apache burned-off large areas (> 50 km^2) of forest or grassland ecosystems in order to promote or improve resource conditions. The common exception was burning and fires used in raiding and warfare, when extensive areas were burned off. This was particularly common when the Apache were discovered by enemies, pending migrations to other provinces. Apache raiding and warfare burning practices were prevalent and diverse, and on occasions affected extensive grassland and forest areas. By contrast, regular burning practices were more cautious and spatially limited (Fish et al 1996; Madsen 1997) than suggested by prior investigations (e.g., Holsinger 1902; Stewart 1951, 1963; Dobyns 1981; Pyne 1982, 1983).

Documentary evidence demonstrates that burning practices were popular in raiding and warfare, and primarily conducted by the Apache, but also by other Native Americans, the Spanish, Mexicans, and later Americans (Table 3.3). Almost 80 % of the cultural fire citations were associated with raiding and wartime periods (WTP1, WTP2, and WTP3), compared to only about 20 % with regular fire use or non-wartime periods. Also, 78 % of the wartime fire citations refer directly to fires set by the Apache, while 11

TABLE 3.3. Tabulated evidence of historical wartime and peacetime fire records cited in Appendix A.

	Fire Uses	Times Cited	Percentage of Total Citations	Citation bibliographic reference number from Appendix A.
Warfare Fire Citations	Signal/Communication	48	30.57	2,21,26,27,28,33,34,35,39,40,41,42,52,56,57,58,59,69,72 73,77,80,90,95,105,107,110,111,117,124,125,134,139,174 179,180,181,183,184,185,186,188,193,194,198,199,209,210
	Direct-Offensive Fire Attack	16	10.19	13,19,20,36,60,62,70,140,145,168,169,172,178,191,197,200
	Defensive Fire Attack	5	3.18	20, 71,177,190,196
	Destroy Crops/Forage	11	7.01	31,83,84,98,100,114,119,121,126,149,182
	Destroy Inhabitations	26	16.56	1,87,94,96,99,103,104,106,113,115,116,118,119,120 120,141,146,147,148,150,151,169,182,205,206,207
	Cover Trails	3	1.91	48,85,127
	Hidden or Forbidden Fires	8	5.10	14,54,112,123,161,189,195,201
	Escaped Fire	5	3.18	15,22,25,81,160
Total Warfare Fire Citations		**96**		
% Warfare Fire Citations			**77.70 %**	
% Warfare Fire Citations by Cuture		**Apache 78%,**	**American 11%,**	**Spanish 8 %, Mexican 3 %**
Non-Warfare Fire Citations	Cooking, Camp Fire	7	4.46	14,15,29,50,51,141,173
	Burial Practices	9	5.73	11,53,64,65,78,91,102,152,202
	Hunting, Fire Drive	4	2.55	68,76,159,204
	Vegetation/Crop Management	3	1.91	160,162,208
	Cultural/Fire Knowledge	12	7.64	12,30,63,69,79,109,135,136,137,154,155,203
% Non-Warfare Fire Citations			**22.30 %**	
Total Non-Warfare Fire Citations		**35**		
Total Cultural Fire Citations		**131**		
Wartime Political and Cultural Ecology, and Intercultural Relations		44		16,17,18,43,44,45,46,66,67,74,75,82,86,88,89,92,93,97,101,128 129,130,131,132,133,138,142,144,146,153,156,157,158,163,164 165,166,167,170,171,175,176,199,201
	Natural Fire	15		3,4,5,6,7,8,9,10,23,24,32,37,47,49,55
	Fires of Undescribed Sources	6		38,61,84,108,187,192

% refer to Americans, 8 % to the Spanish, and 3 % to Mexicans.

Although numerous fire uses have been described by the documents, few indicate the deliberate setting of large fires except during warfare (Appendix A; See Table 3.3; Cortés 1799; Corral 1959). Early reports of game-hunting drives suggest the broadest-scale effects (roughly around 30 km^2) of traditional burning practices(Matson and Schroeder 1957). However, the few known fire-drive reports suggest this practice was more of a social gathering, and uncommon or very limited in use. Also, the effectiveness and spatial extent of fire drives were limited by the number of participants. The majority of documentary evidence shows that regular burning and fire use by the Apache was controlled and limited temporally and spatially. The exception was burning and fire use in raiding and warfare, when increased fire activity was associated with wartime cultural ecology and tactical fire use by all cultures.

3.7.4 Ethnoecology

Fire ecology and effects were assessed for important Apache ethnobotanical resources. Resilience fire intervals (RFIs; Tables 3.4a and 3.4b) were defined as the average time in years for a particular plant species to recover to pre-fire conditions following a typical fire. RFIs were estimated from fire ecology and effects data (Appendix B). Shorter RFIs indicate greater resilience to fire, or plants favored by higher fire frequency, and hence, plants the Apache potentially could have promoted through burning. Few of the ethnobotanical species used by the Apache have resilience to frequent fires (i.e., MFIs between one to three years). Tables 3.4a and 3.4b show

TABLE 3.4a. The most important ethnobotanical food and fiber species of the Southern Apache. The resileince fire interval (RFI) is the average number of years typically required for a particular species to recover after burning to prefire conditions. This information was extrapolated from the US Forest Service Fire Ecology and Effects Database (WWW.USDA.Forest Service).

Primary Food Sources (XXX)	Species	Common Names	Resilience Fire Intervals (RFI) Average Years
Trees and Shrubs			
	Acer negundo	Boxelder	20
	Arbutus arizonica	Arizona Madrone	10
	Arctostaphylos pungens	Pointed-Leaf Manzanita	6
	Cercocarpus montanus	Mountain Mahogany	10
	Cupressus arizonica	Arizona Cypress	10
	Juglans major	Arizona Walnut	10
	Juniperus deppeana	Alligator Juniper	10
	Juniperous scopulorum	Rocky Mountain Juniper	20
	J. monosperma	One Seed Juniper	20
	Pinus engelmannii	Apache Pine	8
	P. leiophylla var. chih.	Chihuahua Pine	12.5*
	P. arizonica	Arizona Pine	7
XXX	*P. cembroides*	Mexican Pinyon	20
XXX	*P. edulus*	True Pinyon	30
	Plantanus occidentalis	Sycamore	5-8
	Populus fremontii	Cottonwood	15
XXX	*Prosopis glandulosa*	Honey Mesquite	5
	Pseudotsuga menziesii	Douglas-fir	20
	Quercus gambelii	Gambels Oak	17
	Q. arizonica	Arizona White Oak	15
XXX	*Q. emoryi*	Emory Oak	15
	Q. rugosa	Netleaf Oak	15
	Q. oblongifolia	Mexican blue oak	15
	*Rhus trilobata***	Skunkbrush Sumac	2

* RFIs estimated from limited data.

** Species with low RFIs, and better chance for enhanced yields via Apache burning practices.

TABLE 3.4b. The most important ethnobotanical food and fiber species of the Southern Apache. The resileince fire interval (RFI) is the average number of years typically required for a particular species to recover after burning to prefire conditions. This information was extrapolated from the US Forest Service Fire Ecology and Effects Database (WWW.USDA.Forest Service).

Primary Food Sources (XXX)	Species	Common Names	Resilience Fire Intervals (RFI) Average Years
Grasses			
	Bouteloua curtipendula	Side-Oats Grama	3
	Bouteloua eriopoda	Black Grama	3
	Bouteloua gracilis	Blue Grama	3
	Bouteloua hirsuta	Hairy Grama	3
	*Buchloe dactyloides***	Buffalograss	2
	*Eragrostis intermedia***	Plains Lovegrass	2
	Hilaria belangeri	Curly Mesquite	3
	Hilaria mutica	Tobosa	3
	Muhlenbergia montana	Mountain Muhly	3
	Muhlenbergia porteri	Bush Muhly	3
XXX	*Panicum obtusum***	Vine-Mesquite	1
XXX	*Sporobolus airoides*	Alkali Sacaton	3
XXX	*Sporobolus cryptandrus***	Sand DropSeed	2
XXX	*Sporobolus flexuosa*	Mesa DropSeed	3
XXX	*Sporobolus wrightii*	Giant Sacaton	3
	*Digitaria californica***	Arizona Cottontop	1
Succulent, Cacti, and Yucca Species			
XXX	*Agave parryi*	Mescal	7*
XXX	*Agave lechuguilla*	Agave	7
XXX	*Dasylirion wheeleri*	Sotal	4*
	Nolina microcarpa	Beargrass, Sacahuiste	4*
	Yucca glauca	Soapweed Yucca	5
	Y. elata	Soaptree Yucca	5
XXX	*Y. baccata*	Banana Yucca	5
XXX	*Opuntia polyacantha*	Cholla/ Prickly Pear	5*
	Echinocereus spp.	Hedgehog Cacti	5*

* RFIs estimated from limited data.

* * Species with low RFIs, and better chance for enhanced yields via Apache burning practices.

that the majority of Apache food and fiber resources would probably have been adversely affected by increased burning. The high incidence of lightning fires in this region (See Fig 3.5) must also be considered. Anthropogenic burning would have contributed to the already frequent fire regimes recorded by dozens of fire history studies in this region (Baisan and swetnam 1990; Swetnam and Baisan 1996a, 1996b). Furthermore, fuels may be the most limiting factor in this semiarid region having ecosystems with low productivity and high-ignitions rates, these areas may not have responded to increased ignitions beyond a certain level.

Relatively short RFIs for many grass species suggests the potential to improve these and associated resources through burning. Certain grasses and grassland areas provided important food and fiber resources, and fodder for the semi-pastoral economies of the Apache. It is conceivable that controlled burning was utilized in some grassland areas, likely around riparian canyon pine-oak forests, particularly ones documented as Apache rancherías. These grasslands were important local resources with relatively high productivity and low RFIs, hence their ability to respond rapidly following a burn. In these areas burning may have been used to improve grassland extent, productivity, and to induced earlier green-up (Pyne 1982; Wright and Bailey 1982). However, grasslands and grasses in these canyon areas were probably not a limited resource that required manipulation via fire or other means.

Another potential burning practice was fire proofing of ranchería camps (i.e., reduce fine-fuel accumulation) from escaped, lightning, and enemy fires. Given the common lightning fires and documented wartime burning in this fire-prone region, it is possible that the Apache used burning around rancherías to reduce the threats from these fire sources. Unfortunately, thus far none of these hypothetical burning practices have been verified by first-hand documentary evidence or ethnoecological research.

Aside from the grasses, only one (*Rhus spp.*) out of the 30 evaluated species had high resilience to fires. Also, the annual tobaccos (i.e., *Nicotiana attenuata, N. trigonophylla*) may have been promoted through burning as done in other regions (Steward 1933; Lewis 1973). Nevertheless, the primary ethnobotanical resources of the Apache (i.e., many oak, pine, pinyon, mesquite, agave, and yucca species; See Tables 3.4a and 3.4b) would probably have been limited spatially and in productivity from increased burning. Particularly the succulent agave and yucca species which provided a substantial part of annual subsistence requirements for the Apache (Castetter and Opler 1936). Wildlife resources were an important part of Apache subsistence, and potential burning and fire effects on specific types of game animals need further research.

The Apache as all pre-industrial societies relied heavily upon fuelwood for campfires, ceremonial occasions, heating, and cooking. Fuelwood was also an important resource that would have been severely limited by indiscriminate or widespread burning (Fish et al. 1996). Additionally, climate influences would have made fire control very difficult at times (i.e., fuel accumulation during wet years, followed by a dry-summer favored extensive fires), and threats to inhabitations and resources would probably have discouraged widespread and unintentional burning. Also in this region, high climate variability and unpredictable precipitation would have reduced the chances of obtaining benefits from burning. Overall, the documentary and ethnoecological evidence suggests that neither widespread nor local burning practices were used to promote forest or grassland resources. Nevertheless, the opposite was true in raiding and warfare, when common and indiscriminate burning of extensive areas was commonly documented.

In summary, documentary and ethnoecological evidence suggests; (1) Non-warfare Apache burning practices were more restricted and cautious than previously suggested. (2) Non-warfare burning practices were also more likely controlled spatially and limited in use because of (a) enemy detection, (b) inherent problems with fire control, (c) threats to life and property. And (d) because increasing fire frequencies beyond the normal fire regimes would probably have been detrimental to the majority of important ethnobotanical resources including fuelwood. (4) Common and indiscriminate burning practices that influenced extensive areas, were associated with documented raiding and wartime periods.

3.7.5 Fire History Analysis

Fire histories reconstructed from tree-rings were selected and analyzed for several canyons proven to be historic Apache ranchería sites, and also for other nearby forest areas in the Southwest Borderlands (Table 3.5). Widespread synchrony of presettlement (pre-1880) fire years throughout this region indicate important climate control of broad-scale fire patterns, and intersite fire spread over extensive areas (See prior chapter; Swetnam 1990; Swetnam and Betancourt 1997). Fire histories show a precipitous decline in episodic surface fires in the 1880s associated with early European-American settlement. Early settlement patterns caused landscape fragmentation that disrupted the

TABLE 3.5. Fire history reconstruction sites in the Southwest Borderlands used in the analysis of anthropogenic fire patterns.

Site (Map #), Reference	Elevational Gradient (Meters)	N = Tree Samples	N = Fire Scars	Inner-Outer Ring Date	Land Steward
Western Chiricahua Mountain Riparian Canyon Pine-Oak Forests, North to South					
Rhyolite Canyon (1), Swetnam et al. 1989	1700-2500	56	96	1466-1987	USDI,Chiricahua N.M.
Pine Canyon (2), Kaib et al. 1996	1700-2500	27	57	1540-1995	USDA, Coronado N.F
Turkey Creek (3)	1700-2500	26	92	1600-1996	USDA, Coronado N.F
Rucker Canyon (4)	1700-2500	21	83	1550-1996	USDA, Coronado N.F
Adjacent Chiricahua Mountain Upper-Elevation Mixed-Conifer Forest					
Barfoot-Rustler Park (5), Seklecki et al. 1996	2500-3000	58	74	1460-1995	USDA, Coronado N.F
Sourrounding Mountains, Riparian Canyon Pine-Oak and Mixed-Conifer Forest Sites					
Animas (6), Swetnam and Baisan 1995	2300-2600	74	92	1445-1992	Malpai Borderlands Group
Huachuca, McClure and Garden (8)	1829-2590	75	150	1499-1996	Fort Huachuca Military Reserve
Sierra Ajos Mexico; Canon Oso and Canon Evans Saddle (7) Dieterich 1983a	1800-2100	32	127	1438-1996	SEMARNAP National Forest Reserve

continuity and quantity of fine fuels, necessary for widespread surface fires (Savage and Swetnam 1990; Touchan et al. 1995; Swetnam and Baisan 1996b; Baisan and Swetnam 1997). This regional fire pattern is typical of fire histories in the Southwest U.S., and illustrated by the fire history reconstruction for Turkey Creek Canyon (Fig. 3.11).

By contrast, episodic surface fires continue to be recorded in forests of northern Mexico. In the Sierra de los Ajos near Cananea Sonora, surface fires continue to burn (Fig. 3.12), even after the Apache had been settled on U.S. reservations for decades. Additionally, preliminary fire history reconstructions from Sierra el Tigre and Sierra Bacadéhuachi, show that fire regimes remained unaltered in these forests, with the last one recorded in the 1990s (Kaib, unpublished data). Therefore, fire events at these sites in Mexico, which occurred after the 1880s, cannot be attributed to Apache burning (Swetnam and Baisan 1996a).

Although Mexican ranchers and loggers did utilize the Ajos in the late-19th and during the 20th century, their influence on fires was not discernible from the fire history evidence until after the 1940s. Mexican land reforms began to take place in these areas in the late 1930s and 1940s (Sheridan 1988). While higher-elevation fire histories appear to have not been affected by grazing or logging during this century, the lower-elevation fire history at Cañon del Oso (See Fig. 3.12) shows a decline in fire activity around the 1940s. This fire decline is probably associated with communal grazing of ejído lands. Additionally, interviews with over a dozen Mexican ejídatarians (communal land owners) indicated that burning practices and fires were discouraged in these areas, because of competition with livestock for grasses and forage. Therefore it is unlikely that the

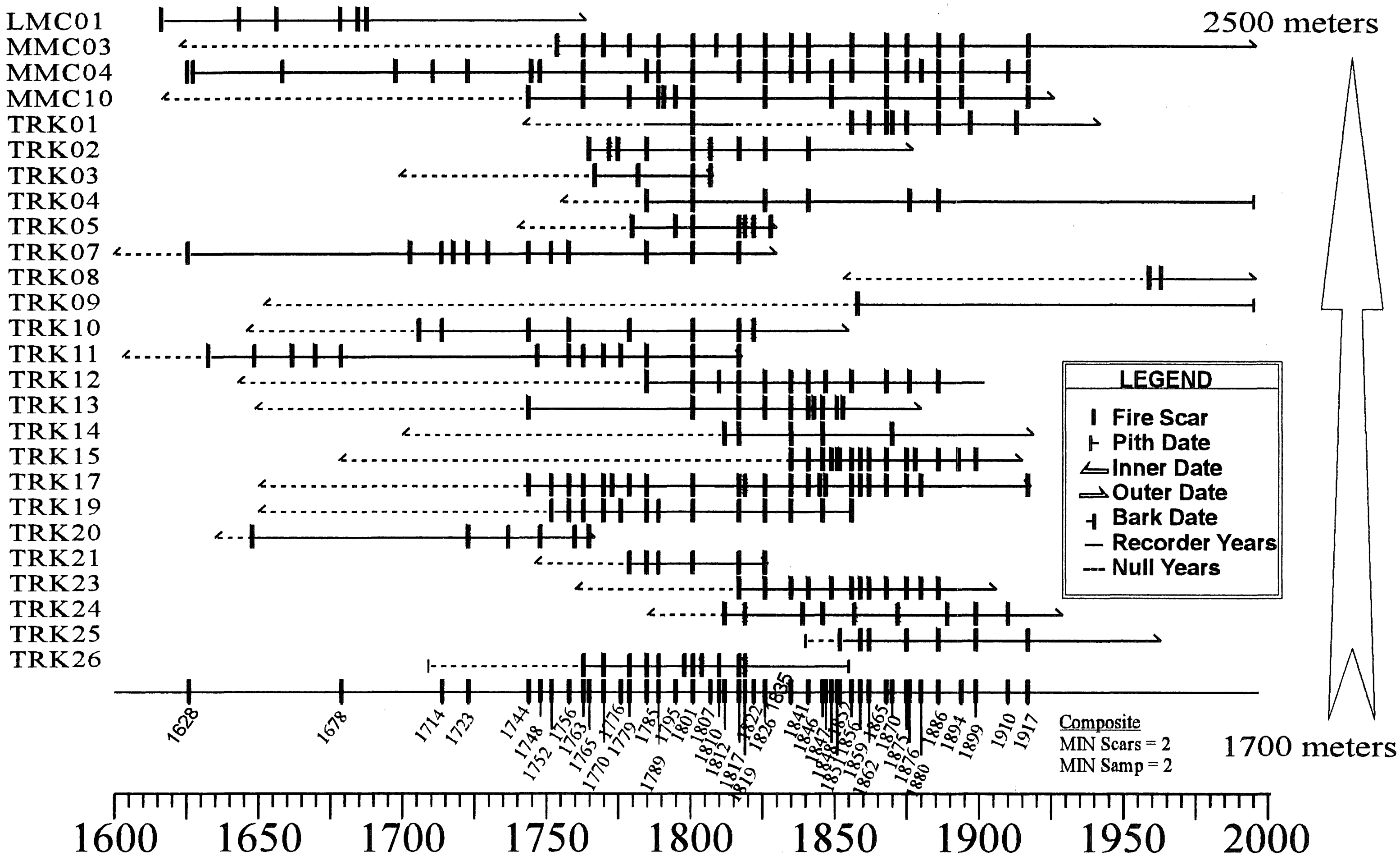

FIGURE 3.11 Turkey Creek Canyon fire history reconstruction. Horizontal lines represent single trees, vertical hatch marks are dated fire scars or fire events. The fire composite shows fire events recorded by two or more trees.

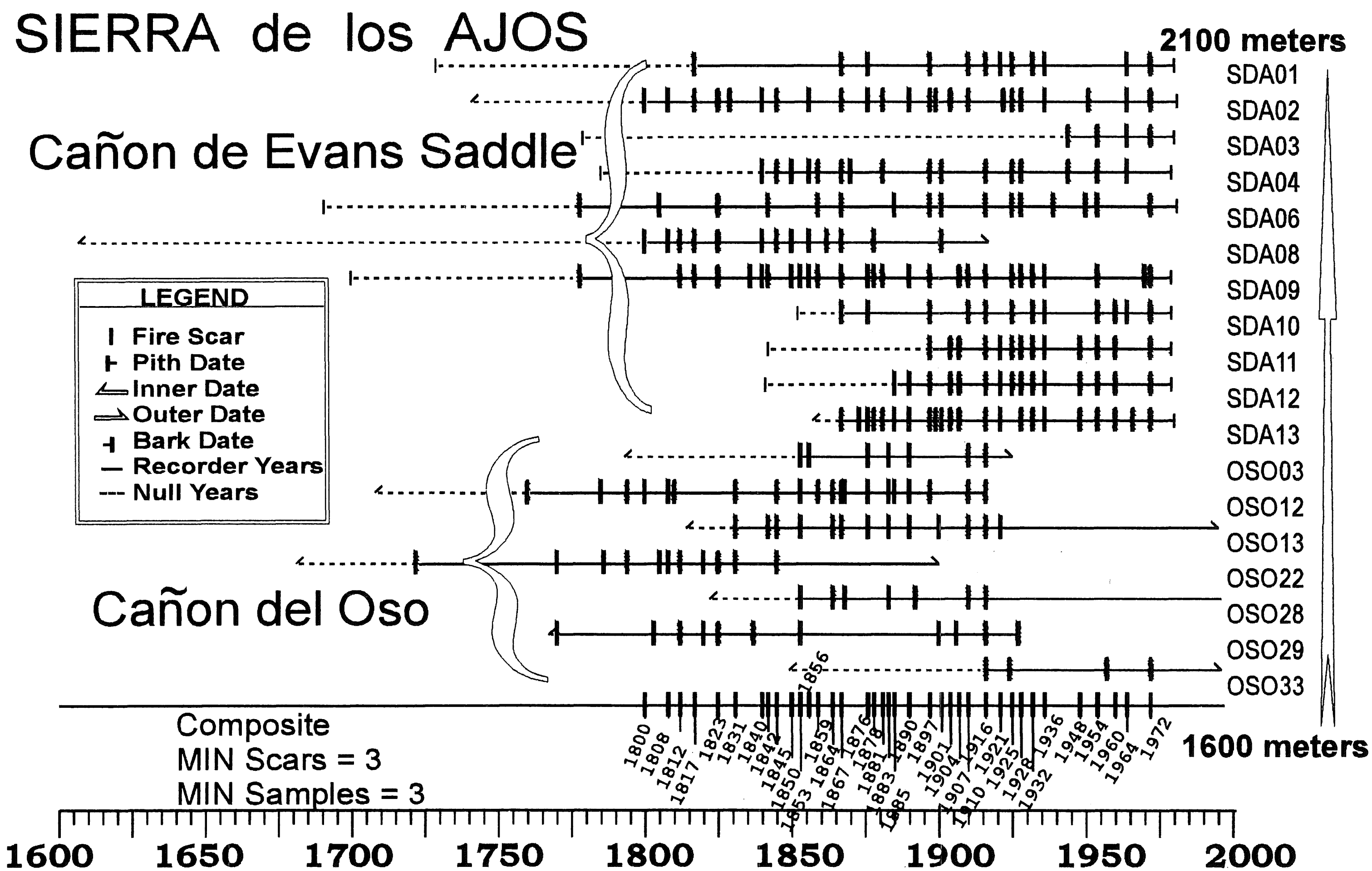

FIGURE 3.12 Sierra de los Ajos fire history reconstruction, northeastern Sonora, Mexico. Horizontal lines represent individual fire-scarred tree specimens and vertical hatch marks are dated fire events. The fire composite includes all fires recorded by three or more trees.

Mexicans did much burning in these areas. Also, fire suppression in these areas has not been supported in the past by any level of government, and so has only been conducted with limited success on private and communal lands. This evidence further suggests that the undisrupted 20th century fire histories in Mexico, and thus fires regimes during prior centuries, were influenced primarily by lightning ignitions.

However, prior to the 1880s, Chiricahua Mountain fire histories show distinct multidecadal intervals of increased fire frequency. In context with documentary and ethnographic evidence, these anomalous fire patterns suggest possible anthropogenic influences. Intervals of high fire frequency graphically correspond with the three historic wartime periods, as illustrated by fire history composites from all five sites in the Chiricahua Mountains (Fig. 3.13). These five fire history composites include four riparian canyon pine-oak forest sites and one higher-elevation mixed-conifer forest site. Differences between wartime and peacetime fire frequencies are also illustrated in Figure 3.14, showing the 10, 25, and 50 year running-mean fire intervals for the same five Chiricahua composites. The canyons of the Chiricahua Mountains were central to the Chiricahua Apache territory and range, as a result they were named by the Spanish for the "Chiguicagui" Apache (Bolton 1908; Griffen 1986b). Therefore if any Apache burning occurred in the Southwest Borderlands, the local pines around the Chiricahua Mountains would have likely provided a fire-scar record. Graphically, figures 3.13 and 3.14 indicate that intervals of elevated fire frequencies may be associated with the three documented historic wartime periods. Statistical analysis was used test for differences in

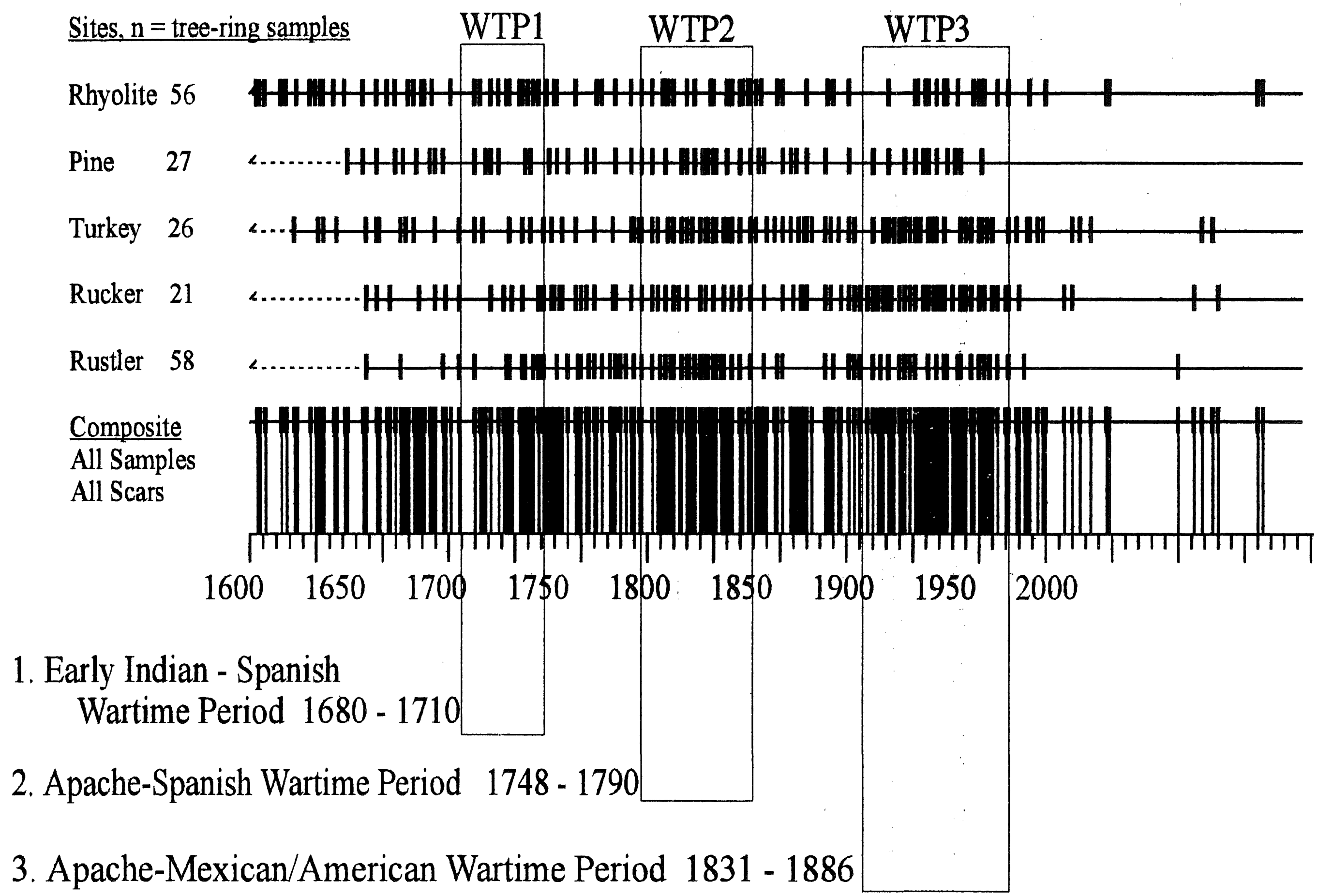

FIGURE 3.13 Composite of five sites in the Chiricahua Mountains illustrating fire frequency changes over wartime and peacetime periods.

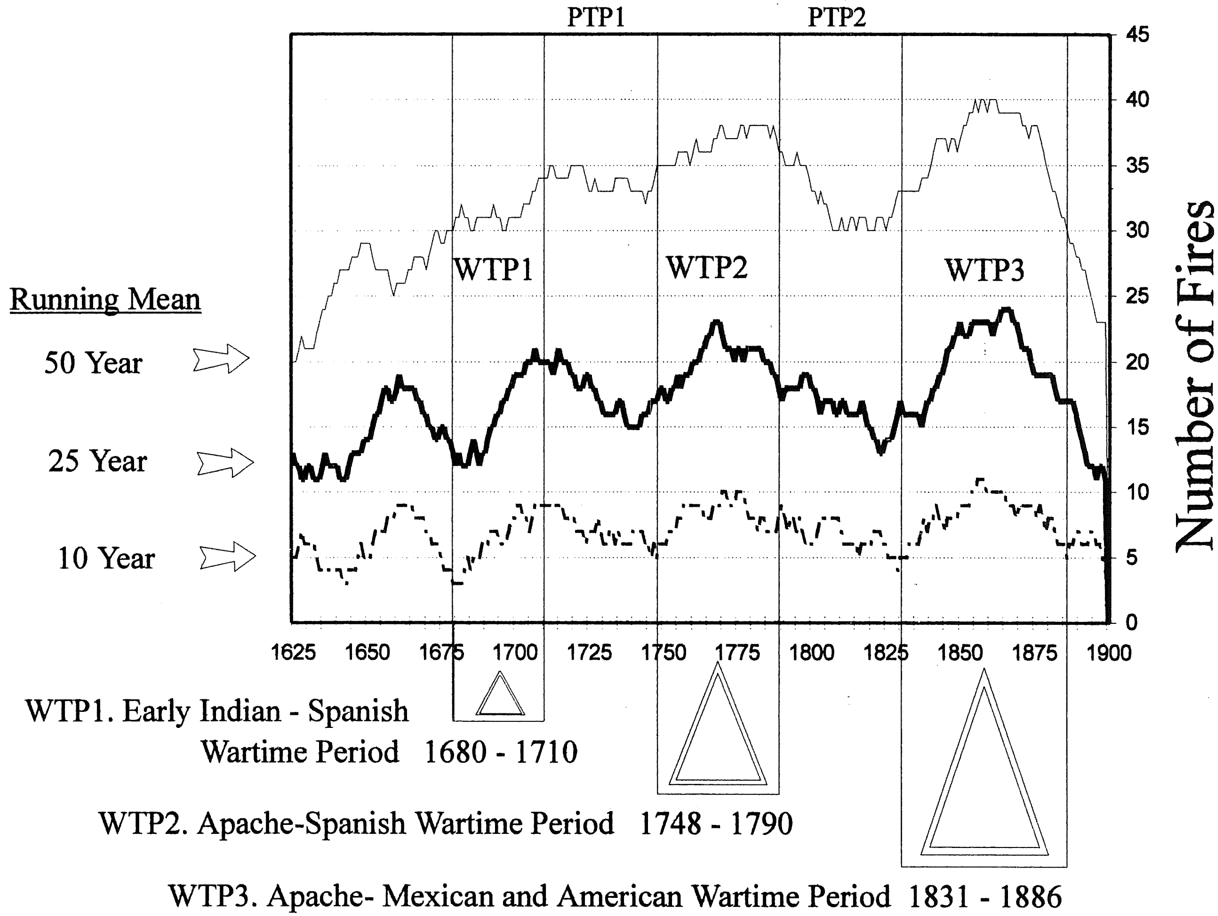

FIGURE 3.14 Running 10, 25, and 50 year, mean fire frequencies for composite fire reconstruction of five sites in the Chiricahua Mountains illustrating fire frequency changes over wartime and peacetime periods.

Table 3.6. Testing differences in mean fire intervals between wartime periods (1680-1710, 1748-1790, 1831-1886) and intervening peacetime periods (1711-1747, 1791-1830) by site. Student's t-test analyzed for differences in mean fire intervals. Statistically significant (p ≤ .10 *, p ≤ .05**). t-test results assume unequal variance. Sample size in parenthesis.

Sites Test	Rhyolite Canyon	Pine Canyon	Turkey Creek	Rucker Canyon	Rustler/ Barfoot	Sierra Ajos 32	Huachuca Mountains	Animas Mountains	Total Sites w/ Pattern
Mean:									
1680-1710	2.4 (10)	4.20 (5)	5.25 (4)	4.50 (4)	4.00 (6)	4.14 (7)	2.45 (11)	6.50 (4)	1
1711-1747	4.57 (7)	5.17 (6)	4.50 (8)	3.0 (11)	2.83 (12)	3.44 (9)	2.19 (16)	4.25 (8)	
|t|-value	-1.69	-0.88	0.47	2.00*	0.24	0.84	0.29	1.67	
p value (>t)	0.13	0.41	0.65	0.07	0.82	0.41	0.77	0.13	
Mean:									
1748-1790	2.56 (16)	3.15 (13)	2.41 (17)	3.15 (13)	2.05 (20)	3.73 (11)	1.86 (22)	3.09 (11)	2
1791-1830	5.0 (7)	4.86 (7)	2.85 (13)	3.27 (11)	5.14 (7)	3.18 (11)	2.11 (18)	5.80 (5)	
|t|-value	-2.22**	-1.49	-1.15	0.49	-2.11*	0.48	-0.88	-1.46	
p value (>t)	0.05	0.13	0.25	0.63	0.07	0.63	0.38	0.18	
Mean:									
1831-1886	3.21 (14)	4.10 (10)	2.22 (23)	1.96 (27)	2.83 (18)	2.35 (23)	1.90 (29)	2.39 (18)	5
1791-1830	5.00 (7)	4.86 (7)	2.85 (13)	3.27 (11)	5.14 (7)	3.18 (11)	2.11 (18)	5.8 (5)	
|t|-value	-1.56*	-0.45	-2.05**	-1.89*	-1.22	-1.54*	-0.88	-2.27*	
p value (>t)	0.10	0.66	0.05	0.08	0.26	0.10	0.38	0.07	

mean fire intervals (MFIs) between the wartime and intervening peacetime periods (Table 3.6). Results of the Student's t-test suggest there were statistically significant differences ($p \leq .10$) for some sites and WTPs, however not by the majority of sites. A total of eight out of 24 sites had significantly different MFIs during the three WTPs. Four of the five sites in the Chiricahua Mountains had at least one WTP with significantly higher fire frequencies. Significantly more frequent fires were recorded for WTP2 at two Chiricahua Mountain sites, Rhyolite Canyon and Rustler-Barfoot Park (See Table 3.6). The majority of tested fire history sites had significantly lower MFIs during the later WTP, with three of the four Chiricahua canyon sites recording significantly lower MFIs during WTP3. This analysis of the Chiricahua Mountain and nearby fire history sites suggests some sites recorded significantly more fires during WTPs when compared to the intervening PTPs. This was particularly evident for WTP3, between 1831 and 1886, when five of the eight sites recorded more frequent fire regimes. These more robust analysis may be accounted for by the greater historical sources and tree rings evidence available for these later periods.

The spatial relation of anthropogenic WTP fire patterns was also inferred. WTP3 fire intervals were significantly lower at three out of five sites in the Chiricahua Mountains, the Animas Mountains to the east, and the Sierra Ajos to the south. The major canyons in these three ranges and the Dragoon Mountains, were primary ranchería sites of the Chiricahua Apache (Castetter and Opler 1936; Cole 1988; Sweeney 1991). Additionally, there were no significantly different MFIs detected for the Huachuca fire history sites. The Huachuca Mountains and the adjacent San Pedro River were historically the location of Sobaipuri settlements, and the site of several later Spanish presidios and forts. Therefore, the lack of WTP fire patterns in the Huachuca Mountains may have been influenced by the long-term presence of Sabaipuri and Spanish populations. Overall, the fire history analysis suggests that elevated WTP fire patterns were most prominent at the Chiricahua Canyon sites during WTP3.

Overall, the documentary, ethnoecological, and tree-ring evidence indicate that raiding and wartime burning practices may have elevated the fire frequencies at some fire history sites in the Southwest Borderlands. Reconstructed fire patterns at sites across the study area suggest cultural burning was primarily limited to major canyon sites within the central range of the Chiricahua Apache, including the Chiricahua, the Animas, and the Ajos mountains notably during the 19th century wartime period. Anthropogenic enhanced fire regimes in these areas probably mainly influenced the grassland ecotones along these canyon-ranchería sites. Finally, elevated fire frequencies were due to burning practices associated with the cultural ecology of raiding and wartime periods.

3.8 Discussion

We know from numerous documentary relations that fire was used in warfare commonly by the Apache and also by other Native Americans and Europeans. In such a dry, fire-prone environment, fires could easily be set in the grassland areas where they would rapidly spread with the wind or uphill into the canyons and mountains. WTP burning practices of the Europeans were designed to inflict the most damage upon the Apache and their resources, with the fewest risks. These fires probably forced the

Apache to migrate on occasions to new areas. Apache burning practices included fires used as decoys in raids, to cover trails, to injure their adversaries, to destroy pasture (i.e., especially around water holes), to control enemy movements, and for various forms of communication. Extensive grassland areas were burned off by the Apache especially when detected by their enemies, pending migration to new ranges.

In the Southwest Borderlands, wet years resulted in widespread accumulation of fine fuels and when followed by a relatively dry summer, extensive fire events were usually generated (Swetnam and Baisan 1996a, Swetnam and Betancourt 1997). Ultimately then, if regional climate and vegetation conditions were not conducive for widespread burning (i.e., presence of adequate cover and quantity of fine fuels), then increased human ignitions may have had limited influence on broader-scale fire patterns. Conversely, if climate and vegetation conditions were favorable for burning, then relatively few ignitions (whether from lightning or humans) may have been sufficient to account for most fire patterns. Additionally, climate and fine-fuel conditioned fire years would have multiplied the threats from escaped, enemy, and lightning fires, and consequently regular fire use during these times may have been very cautious. An alternative situation is possible when fuel conditions are favorable for burning, but monsoon weather patterns are weak and atmospheric lightning or ignition conditions are unsatisfactory. For example the year 1989, when abundant fuels coincided with a drought period, but typical monsoon cumulonimbus lightning development was weak. In this scenario, the influence from anthropogenic ignition sources may have provided a substantial contribution to the fire regimes on a given year. Nevertheless, fire histories, and climate and lightning records suggest such conditions were historically rare, and that past lightning patterns were probably sufficient, to at the very least sustain semidecadal fire regimes (Barrows 1978; Swetnam and Betancourt 1997).

If all Student t-tests are considered, then only eight out of 24 tests showed significantly ($p \leq .10$) different MFIs between wartime and peacetime periods, suggesting inconclusive results. However, if only numerical differences are considered then 17 out of the 24 sites had lower MFIs for the three WTPs, including all eight sites for WTP3 (See Table 3.6). Furthermore, if only WTP3 is considered, then the majority of sites record significantly lower MFIs (i.e., five out of eight). It may very well be that anthropogenic enhanced fire regimes were of some ecological importance but statistically insignificant, because, they only slightly increased the already frequent fire regimes in these areas. Fine fuels are probably the most limiting factor in these semiarid lands, with relatively low productivity and high ignitions rates, these ecosystems may not be very responsive to increased ignitions beyond a certain point.

In presettlement times, it is probable that anthropogenic burning practices contributed to the fire regimes at specific sites during at least some wartime periods. The average MFIs differences between WTPs and PTPs for the eight significant tests was about 2 years. Therefore, the WTP fires occurred about every three years rather than every five years. Although, anomalous WTP fire patterns have not been encountered at dozens of other fire history sites in this region (Swetnam and Baisan 1996a, 1996b), this research brings together the first set of fire reconstructions from riparian canyon pine-oak forests. Cultural ignition sources and burning practices were probably limited to areas that were repeatedly inhabited and traveled through, population and cultural centers, and adjacent vegetation communities, as found by related research on anthropogenic ecosystem influences (Barret and Arno 1982; Swetnam 1984; Betancourt et al. 1986). In the Southwest Borderlands these areas are the major riparian canyon pine-oak forests within isolated mountain ranges. They are relatively the most productive and biologically diverse ecosystems in these areas and also the places documented as historical Apache rancherías.

Elevated wartime fire frequencies recorded at these ranchería sites, may have at times also influenced the adjacent desert grasslands and higher-elevation forests. This is suggested by significantly more frequent fires recorded for WTP2 between Rhyollite Canyon and the adjacent mixed-conifer forest site at Rustler-Barfoot Park. However, this pattern does not show up during the other wartime periods, particularly the better documented WTP3, suggesting that anthropogenic fire patterns are associated more consistently with the canyon forests. Because the tested fire histories from surrounding mountains include both lower-canyon and higher-elevation forests, ecosystem-specific human influences cannot be separated. Inferred desert grassland fire reconstructions suggest that the lower grasslands burned on many of the same years as adjacent canyons but less frequently (See prior chapter). This evidence suggests that desert grasslands were probably influenced by anthropogenic fires in close association with the canyon-ranchería sites and fire sources. A more thorough analysis of fire histories and documentary evidence in this region is necessary for a better assessment of specific ecosystem influences and relative spatial effects of anthropogenic fires.

The influence of climate variation upon subsistence, warfare, and burning strategies also needs further examination. Wartime periods and elevated WTP fire frequencies may be associated with increased climate variability, and related droughts, famines, and epidemics as suggested by ethnohistorical literature (Spicer 1962; John 1975; Dobyns 1981) and climate research (Grisinno-Mayer and Swetnam 1997; Swetnam and Betancourt 1997). Tree-ring reconstructions show that the driest time interval in the 18th century occurred between 1730 and 1750, the period leading into WTP2 (Swetnam and Beatancourt 1997). Additionally, the year 1748 was one of the severest drought and fire years recorded by trees and fire history sites throughout the Southwest Borderlands (Swetnam and Baisan 1996b). Incidentally this was also the year when war was officially declared upon the Apache by the Spanish Viceroy, a response to the increased raids of preceding decades. Between the 1750s and 1770s, the Borderlands had reached an unequaled pinnacle of Apache-Spanish hostilities and armed battles (Griffen 1988a, 1988b).

The possible relation between increased climate variability and droughts, resource scarcity, raiding and warfare, and burning cultural ecology in the Southwest Borderlands has not been investigated. Basic anthropology theory suggests that at times of increased drought, food and water resource scarcity become critical, and regular subsistence strategies require modification (Netting 1977; Moran 1979; Park 1993). For the Apache, this may have meant that isolated canyons and mountains which typically provided subsistence, did not adequately meet Apache needs during these drought periods. Therefore, some possible Apache drought coping strategies were migrations to distant mountain ranges, augmentation of food provisions through raiding, and the utilization of Spanish peace establishment food rations (Castetter and Opler 1936; Opler 1941; Basso 1971; Griffen 1988a, 1988b).

Tree-ring width chronologies from conifer species in this region suggest these three coping strategies may have occurred in succession relative to drought severity. Swetnam and Betancourt (1997) illustrate that multidecadal periods of increased climate variability are closely associated with the mid-18th and Mid-19th century wartime periods. Additionally, below-average tree-ring width indices (i.e., dry years) occurred during the two peacetime periods, while above-average indices (wet years) were recorded in the early part of the later WTPs (Swetnam and Betancourt 1997). Decades of erratic precipitation with increased droughts likely encouraged the Apache to enhance subsistence thorough raiding up to a point. However, when high climate variability, and related raiding and warfare periods were prolonged over decades, this may have forced the Apache beyond raiding, to seek subsistence at Spanish *Establecimientos de Paz*. Below average tree-ring indices during the PTPs suggest relatively limited food and water resource abundance corresponded with Apache subsistence at *Establecimientos de Paz* and limited raiding. Future multidisciplinary research based on dendrochronology and historical evidence, may shed light on these hypothetical relations between climate variability and subsistence, and peace and warfare.

Analysis of multiple lines of evidence suggests that anthropogenic enhanced fire regimes occurred in some riparian canyon pine-oak forests and associated grasslands, during the raiding and WTPs in the Southwest Borderlands, and particularly those documented as historical Apache rancherías. Overall however, this evidence indicates that it is unclear and even unlikely that such finer-scale fire patterns were very important ecologically, when considering broader-scale climate and fire relations, and related landscape vegetation patterns (Swetnam and Betancourt 1997).

3.9 Limitations, Uncertainties, and Strengths of Data Sources

3.9.1 Documentary Evidence

Of more than 200 documentary citations, less than half contain eyewitness or primary accounts with respect to cultural burning. The more general citations include some less reliable reports and second-hand accounts, but overall, they contribute to a larger data set, and strengthen the categories of cultural burning. Less credible sources can also be compared, and sometimes proven or refuted by more reliable accounts (See Table 3.3). Because historical sources like tree-rings, become scarcer as one precedes back in time, the majority of the documentary evidence comes from the 18th and 19th centuries. Also for this reason, the earliest historical analysis periods (i.e., WTP1 and PTP1) are the least well known and documented.

Documentary relations were often the subject of historical bias. Almost all the fires that were reported were blamed on the Apache, regardless of any knowledge of their true source. Many presumed Apache-set fires could have easily been lightning fires, particularly those that occurred during the normal lightning-fire season. For this reason the total number of Apache burning records are probably slightly overstated. Documentary evidence of cultural burning may also be biased towards wartime periods, because of the increase in European-military activity and associated written reports. Although these historical biases surface on several occasions, the majority of evidence continues to suggest that burning patterns and fire frequencies were elevated during raiding and wartime periods.

3.9.2 Ethnoecological Evidence

By the time ethnographers studied the Apache, much of their traditional knowledge and oral histories had been seriously limited or discouraged by European culture. Fortunately, research on the Apache commenced in the early decades of this century when traditional knowledge was still retained by some Apache elders. Nevertheless, the Apache carried strong suspicion and sometimes hatred for "white man", after many years of deceit most did not freely share their cultural knowledge. So even though the Apache were studied extensively, the information that was recorded was limited in many ways, and it is even possible that some Apache burning practices may be lost or unknown.

Additionally, an inherent problem with ethnographic studies and oral histories is that informants usually only respond to the questions they are asked. Therefore, if Castetter and Opler (1936), Goodwin (1942), and others did not ask their informants explicitly about various burning practices, then this information may have been overlooked. Despite these limitations, the many detailed ethnographic studies and the compilation of documentary evidence suggests that the majority if not all cultural burning practices used historically by the Apache, were recorded in some detail.

The ethnobotanicals selected for the fire effects analysis represent the primary subsistence resources of the Apache. Even so, this list is by no means an exhaustive inventory of plants used by the Apache. Additionally, wildlife including insects, birds, rodents, herbivores, and predators, at times made up a substantial part of daily and annual Apache subsistence requirements, but were not adequately considered. A more systematic approach of fire effects on all important Apache botanical and wildlife resources may be warranted.

3.9.3 Fire History

Fire history reconstructions provide the most consistent and unbiased sources of data on presettlement fire occurrence. Reconstructions typically span centuries while still providing precise annual and often seasonal resolution. Limitations include the lack of evidence for treeless vegetation communities and diminishing evidence with earlier time periods. Natural organic matter decay rates generally produce less robust data and analysis for the earliest sections of any tree-ring record. For this reason most fire reconstruction analyses began at the earliest in 1650, because of too few samples and fire scars preceding that date. Fewer tree-ring samples and documentary sources were available for the early analysis periods (i.e., WTP1 and PTP1), therefore, their test results are less meaningful. Also these early periods were scarcely recognized and poorly documented. However, the later-18th and 19th century analysis periods (i.e., WTP2, PTP2, and WTP3) contain more substantial documentary and tree-ring evidence, and therefore, they provide a more robust analysis and significant results.

Additionally, it is possible that anthropogenic fires may have been of such a low intensity that they were left unrecorded by many trees. Conifer species fire-scarring processes suggest this was not likely the case. Because high amounts of pine resins and volatile oils produced by prior fire scarring provide a fuel source that is susceptible to any fires within contact, and even fires of very low intensity (Weaver 1951; Lewis 1980; Barrett and Arno 1982; Dieterich and Swetnam 1984).

There are some uncertainties with spatial inference from fire history reconstructions. Mapped fire-scarred samples are used to infer fire spread between sampled trees and sites. However, because fire-scar samples are distributed and collected non-uniformly and non-randomly across the landscape, some recorded fires probably spread beyond the sampled areas, while others may not have spread completely throughout the entire site, and it is also possible that still some other fire events went unrecorded by the trees sampled. Each fire history reconstruction contains between 20 to 50 trees encompassing a 10 to 100 hectare sample area. An extensive fire-history database suggests that most fire events were recorded with comparable sample sets and site areas, and that relatively few fire dates were added when additional samples were collected (Swetnam and Baisan 1996a, 1996b). Nevertheless, estimates of fire frequency are still probably conservative because of the natural sample decay, and the limited numbers of samples that were preserved in these canyons, and able to be collected and crossdated.

3.10 Conclusions

Analysis of documentary, ethnoecological, and tree-ring evidence was used to isolate cultural and natural fire patterns from fire histories in the Southwest Borderlands. Evidence indicates cautious Apache fire use and an understanding of fire control, and the costs of escaped and wildfires. Oral histories describe apprehension of resource scarcity and increased risk associated with summer lightning-fire seasons (e.g., the mountain spirit mythology). The benefits of burning in these semiarid ecosystem would have been very difficult to predict with the extremely variable precipitation. Furthermore, wildfires were difficult to control, and escaped, lightning-ignited, and enemy fires threatened rancherías and nearby resources. Fire effects and ecology research suggests that human-enhanced fire regimes may have been detrimental to the majority of the Apache ethnobotanical resources, especially fuelwood and their primary subsistence foods (i.e., agave, yucca, mesquite, and pine species). Although undocumented by historical or ethnographical research, high fire resilience suggests grassland areas could potentially have been burned to improved this fairly important Apache resource (i.e., food, fiber, and livestock fodder). The common exception to cautious fire use and controlled burning was during raiding and wartime periods.

Anthropogenic wartime fire patterns are graphically demonstrated with documentary evidence and fire history composites. Wartime burning practices were primarily used by the Apache, but also by Europeans, and other Native Americans. Fire history reconstructions were graphically analyzed for elevated wartime fire activity, suggested by documentary evidence. Also fire reconstructions were tested for differences in MFIs between wartime (WTP) and peacetime periods (PTP). WTP mean fire intervals (MFIs) were numerically lower for 17 out of 24 sites, but statistically significantly ($p \leq .10$) for only eight out of 24 sites. Anthropogenic fire influences were strongly suggested by all evidence for the Chiricahua Canyon sites during WTP3 (1831-1886), when all sites had recorded numerically more frequent fires, and five out of eight sites had significantly ($p \leq .10$) more frequent fires. Therefore WTP burning patterns probably had some influence on the riparian canyon pine-oak forests and associated grasslands in the Southwest Borderlands, particularly those which were best documented as historic Apache rancherías (i.e., Rhyollite, Pinery, Turkey Creek, and Rucker).

Together the evidence suggests that although anthropogenic fires may have influenced finer-scale fire history patterns, they do not indicate broader-scale influences on ecosystem and landscape structure. It is possible that human-elevated fire regimes may have influenced ecosystem structure within some riparian canyon pine-oak forests, particularly around the grassland-ecotone boundaries. However, considerable climate and lightning-fire evidence indicates that broader-scale fire and landscape ecologies, were primarily influenced by regional climate variation (Swetnam and Betancourt 1997). When wet atmospheric conditions produced widespread fine-fuel accumulations, a subsequent dry summer almost guaranteed that extensive fires spread across the landscape in most ecosystems. Fire histories indicate these conditions occurred episodically at decadal intervals or less.

CHAPTER FOUR

THESIS SUMMARY AND CONCLUSIONS

Fire reconstructions demonstrate that surface fires spread frequently through riparian canyon pine-oak forests, and often on the same years through the intervening desert grasslands and higher-elevation mixed-conifer forests. Fires recorded by 25 % or more of the samples at six canyon sites, occurred at least once every four to eight years over the 230 year analysis period (1650-1880). Canyon forests sustained more frequent fire activity than previously thought, and also more fires than the desert grasslands and mixed-conifer forests. Fire histories from higher-elevation mixed-conifer forests indicate extensive surface fires were recorded on many of the same years as the canyon and inferred grassland fire events, at MFIs ranging between five to nine years. The repeated patterns of synchronous fires between many and sometimes all sites, suggests the importance of ecosystem and landscape connectivity via grassland-fire spread.

Canyon forests have relatively high productivity and historically more robust connectivity via lower grassland communities, while they are separated by precipitous rock formations in the intervening upper-canyon areas. Historical reports and fire-scarred pines also indicate that past fires burned through extensive areas of grasslands, woodlands, and forests, easily encompassing thousands of hectares. Although fires originated in both higher-elevation forests and lower desert grasslands, on certain years regardless of their origin, once fires entered contiguous grassland communities they were able to spread over great distances. Synchronous fires were recorded often on the same years between adjacent (i.e., 15 km^2) and basin-wide (i.e., ≥ 100 km^2) canyon sites, suggesting extensive fires commonly spread between these canyon forests through the intervening desert grasslands. Therefore, synchronous intercanyon fire events were inferred to be desert grassland fires. Synchronous fire events recorded between any two to three of the six canyon sites, suggest the adjacent desert grasslands burned about every five to seven years. Wider-spreading grassland fire events, recorded by three to four of the six canyon sites, had MFIs ranging between six to nine years. More extensive climate related interbasin-fire events occurred at less common intervals, with MFIs ranging between 9 to 12 years. Due to the spatial and temporal limitations of tree-ring evidence, these fire frequency estimates are considered conservative and the lower range of the mean fire intervals may better reflect true fire frequencies in these areas.

The spatial extent of fire events was inferred from the relative distance between tree-ring samples and collection sites. Fire events that spread canyon-wide or larger (MFI = 4-8 years) were inferred to have ranged between five to more than 50 km^2. Fires that spread between any two to three canyon sites (MFI = 4-6 years) were estimated to have covered areas between around 10 to over 100 km^2. Basin-wide fires (MFI = 6-9 years) recorded by at least three to four of the canyon sites, spread over extensive areas of desert grasslands and higher-elevation forests, and probably extended over hundreds of square kilometers. Broader-scale, interbasin-wide or regional fire events (MFI = 9-12 years) occurred less commonly at decadal intervals and ranged over hundreds to thousands of square kilometers in extent for specific fire years. Regional fire years were typically marked by a relatively dry summer-fall when preceded by wet El Niño years and related widespread fine-fuel accumulation (Swetnam and Betancourt 1990, 1997).

The historical importance of episodic surface-fire spread between ecosystems, and landscape connectivity via grassland fires, has not been sufficiently recognized, especially the integral role of riparian canyon pine-oak forests. Lightning evidence suggests ignition sources were not limited in these areas. Also, fire records reveal that lightning ignitions occurred commonly in both the desert grasslands and higher-elevation forests (Barrows 1978; Jandrey 1975). Wet-climate and fine-fuel cycles were probably the most important factor controlling synchronous fire patterns across the elevation and vegetation gradients that encompass broader landscapes. Wet years primed the regions ecosystems with an abundance of fine fuels that favored widespread fires that were carried predominantly by grassland communities. Fire adapted grassland communities linked past desert grassland, pine-oak forest, and mixed-conifer forest ecosystems via fire spread. In this respect, riparian canyon pine-oak forests were essential biogeographical corridors for fire spread between the desert grasslands and higher-elevation forests.

The majority of the fire history reconstructions in the Southwest U.S. show a rapid decline in fire activity following European-American settlement in the 1870s. This fire pattern "signature" was strongly associated with early settlement landscape fragmentation, particularly livestock grazing and later fire suppression (Swetnam and Baisan 1996a, 1996b). A related fire pattern illustrated by the canyon-fire reconstructions suggests fire activity declined earliest in lower-canyon forests when compared to higher-elevation mixed-conifer forest sites. This pattern probably reflects the earliest influences of grazing and logging in the more accessible desert grasslands and riparian-canyon areas, with water and timber sources.

Southwest U.S. fire histories contrast sharply with those from nearby forests in northern Sonora, Mexico. In the Sierra de los Ajos and in other forests in Sonora Mexico (i.e., Sierra el Tigre and Sierra Bacadéhuachi), episodic surface fires continue to be recorded as undisturbed ecosystem processes. In these Mexican forests surface-fire regimes are relatively undisturbed in spite of limited grazing, logging, and subsistence agriculture. Although fire activity in the lower Sierra Ajos began to decline in Cañon del Oso by the 1940s and 50s, the higher-elevation fire regimes remained unaltered. The lower-elevation fire decline was probably related to communal land developments in the 1940s (i.e., *ejídos*). However, fire histories in northern Mexico show relatively limited changes overall when compared to related forests in the Southwest U.S.. The striking contrast between the Mexican and American fire histories, suggests the magnitude of differences and timing of past land-use patterns. Unfortunately, the northern Sierra Madres are rapidly loosing these more pristine undisturbed forests. The effects of more recent economic developments (i.e., NAFTA; GATT) and related increases in timber harvesting operations need further investigation. Before these forests and the important ecological information they hold is lost.

The influence of humans on past fire regimes is an important question for most fire history research. Particularly with respect to ecosystem and fire management, in areas where lightning-ignited fires alone, could be used to emulate and manage for presettlement fire frequencies and patterns. Because the forests in Mexico continued to record fires unchanged even after the Apache had been settled on reservations in the U.S. for over a century, fires recorded after the 1880s cannot be attributed to Apache burning. Mexican fire reconstructions, lightning data, and fire records suggest the importance of lightning ignitions in sustaining the majority of past fire regimes (Barrows 1978; Swetnam and Baisan 1996a).

Some canyon sites in presettlement times however, recorded anomalous intervals of high fire frequency that in context with documentary evidence, suggest anthropogenic fire influences. Documentary and ethnoecological evidence demonstrate the common use of Chiricahua canyon-ranchería sites, Apache burning practices, and detailed fire use and knowledge. Evidence indicates cautious Apache fire use, and an oral history that describes resource scarcity and increased risks associated with monsoon lightning-fire seasons. Burning practices in these semiarid lands were labor intensive, with uncertain advantages given the regions high climate variability and relative abundance of lightning fires. Also wildfires were difficult to control, so careless fire use and uncontrolled burning sometimes threatened ranchería camps and nearby resources. Furthermore, fire ecology and effects data suggest that increased burning would likely have been detrimental to the majority of Apache ethnobotanical resources including fuelwood, and notably their primary food and fiber sources (i.e., agave, mesquite, oak, and pine species).

Documentary and ethnoecological evidence suggests that neither widespread or controlled burning practices were utilized by the Apache to promote resources in forest or grassland areas. However, the analysis of documentary evidence demonstrates that

Apache raiding and warfare burning practices were prevalent and uncontrolled, as related during the three documented wartime periods (WTP1: 1680-1710, WTP2: 1748-1790, and WTP3: 1831-1886). Almost 80 % of the cultural fire citations were associated with these wartime periods, while only about 20 % come from non-wartime sources or regular-fire use. Wartime burning was also recorded to a lessor degree by other Native Americans, the Spanish, Mexicans, and later Americans. Almost 80 % of the wartime-fire citations refer directly to the Apache, while only 11 % to Americans, 8 % to the Spanish, and 3 % to Mexicans. The majority of documentary evidence suggests that extensive and uncontrolled burning practices were customarily used by the Apache during raiding and wartime periods.

Statistical analysis was used test fire histories for differences in mean fire intervals between wartime and peacetime periods (PTPs). Five of the eight sites tested had significantly ($p \leq .10$) shorter MFIs for the later WTP between 1831 and 1886. Numerical and significant fire-interval differences were also recorded for earlier WTPs and other fire history sites. The canyon sites of the Western Chiricahua Mountains had the most robust numerical and statistical tests indicating lower WTP fire intervals. Multidisciplinary evidence suggests that anthropogenic WTP burning influences were limited to areas that were commonly inhabited, traveled through, and population or cultural centers. Evidence further suggests these areas were the riparian canyon pine-oak forests documented as historic ranchería sites and by fire histories. Anthropogenic fires probably influences these canyon ecosystems particularly around the surrounding grassland, woodland, and forest ecotones. The greatest MFI differences between WTPs and PTPs averaged about 2 years for the eight significant tests. Therefore, anthropogenic fire influences may have elevated fire frequencies in these areas from once every five, to once every three years, during the WTPs. Because these fire patterns were limited to certain mountain ranges and canyons during the later two WTPs, it is unclear and even questionable whether such differences in fire frequencies were very important ecologically across broader landscapes. More extensive regional fire patterns were most likely primarily influenced by wet climate conditions and fine-fuel cycles. On these occasions when weather and fuel conditions were favorable, monsoon lightning probably furnished sufficient ignitions to sustain semidecadal MFIs across the majority of Madrean Ecosystems.

It is now widely acknowledged that fires were important processes in most Southwest Borderland ecosystems. In the past, episodic surface fires provided fundamental ecosystem structuring and nutrient cycling processes. The elimination of frequent surface fires throughout many National Forests in the Southwest U.S., has resulted in far-reaching ecological, economic, and social implications. Federal and non-government land management groups have a great opportunity to finally restore fire processes and ecosystems in some of these areas. It is also the responsibility of these agencies as public land stewards, to manage fires in these fire-adapted ecosystems, in efforts that reduce the hazards of more destructive fires, while sustaining the natural values and the diversity of watershed resources. Appropriately, these organizations have recently demonstrated that large prescribed and natural fires can be managed in these areas to restore ecosystem and watershed processes. Ecosystem and fire management will in the long run diminish the threats of stand-replacing fires to forest and watershed resources, and be far less expensive than completely suppressing all fires.

National forests, grasslands, and wilderness areas that continue to be managed without consideration of necessary fire processes will eventually be overwhelmed with hazardous fuel accumulation, vegetation changes, increased stand-replacing fires, and associated watershed degradation. This land management related trend has been verified by recent anomalous stand-replacing forest fires in the Tonto and Coronado National Forests. Public lands and natural areas in the U.S. have become far different from the wild places known and described by Aldo Leopold (1924, 1936) and Joe Marshall (1957, 1963), or even those conditions designated by the Wilderness Act of 1964. Fortunately, under current ecosystem and fire management, it may not be too late for fires, to once again spread across grassland and forest landscapes in the Southwest Borderlands.

APPENDIX A: CULTURAL FIRE CITATIONS IN THE SOUTHWEST BORDERLANDS, INCLUDING REFERENCES TO WARTIME PERIODS, CULTURAL ECOLOGY, AND INTERCULTURAL RELATIONS

1. Alamada, Francisco, R. 1952. Diccionario de Historia, Geografica y Biografia Sonorenses. Ruiz Sandoval, P. 75. Bacoachi, Sonora. *"En enero de 1851 los Apaches, en el Pueblo de Bacoachi, saquearon y robaron cuanto pudieron, prendieron fuego a las casa y se llevaran cautivos a los ninos y algunos mujeres."*
2. Altshuler, Constance, W. 1984. Arizona in 1861: A Contemporary Account by Samuel Robinson. Journal of Arizona History 25(1): 21-76:26. Northwest of the Santa Rita Mountains. "Agua Caliente" springs, southeastern Arizona. "After a long and weary march we gained the top of a high hill a little after dark, completely tired out. The soldiers were set to work gathering up what little brush and sticks they could find to build a signal fire."
3. Altshuler, Ibid, 1984:37. Santa Rita Mountains, southeastern Arizona. "There is a large fire in the mountains tonight, among the pine trees on the ridge between the two high peaks."
4. Altshuler, Ibid, 1984:43.1984. Santa Rita Mountains and southeast Arizona, February 24, 1997. "The grass has been on fire a mile and a half east of this yesterday and today. Also a larger [fire] beyond the Santa Rita in the Pinery."
5. Arizona Daily Star, April 16, 1882. Cited in Bahre, Conrad J., 1985, Wildfire in Southeast Arizona Between 1859 and 1890. Desert Plants 7(4): 190-194:192. Southern Arizona, western New Mexico. "Prairie and wood fires have been raging in southern Arizona and western New Mexico recently. The territory burned over is reported to cover forty miles square [1,022,000 acres], and the damage done is immense. The origin of the fire is attributed to the Indians."
6. Arizona Daily Star, June 14, 1887. Bahre Ibid, 1985:192. Patagonia Mountains, between the town of Patagonia and the Huachuca Mountains, southeastern Arizona. "The Patagonia mountains are on fire and the country between the Patagonia and the Huachucas, a distance of twenty miles, is covered with smoke. The tall grass and the pine timber is burning furiously, the noise being like a rushing storm. The heat is so great that one cannot approach within a distance of it. An area of country about five miles square [16,000 acres] is now burning. It was set on fire by the Indians, the day they murdered poor Grace."
7. Arizona Daily Star, June 15, 1887. Bahre, Ibid, 1985:193. Southeastern Arizona. "Every mountain over which the Indians have recently passed has been fired. There is method in this business."
8. Arizona Daily Star, June 9, 1887. Bahre, Ibid, 1985:193. Crest of the Santa Catalina Mountains, north of Tucson, Arizona. "Last night the crest of the Santa Catalina Mountains was observed on fire in different places, probably fired by the Apache."
9. Arizona Daily Star, March 24, 1882. Bahre, Ibid, 1985:193. Upper Gila River, between Fort Cummings, New Mexico, and the San Carlos Indian Reservation.

"On the 11th of the present month three companies of Indian scouts on their way from Fort Cummings, New Mexico to the San Carlos Indian Reservation when passing through the stock ranges of the upper Gila... set fire to the grass... thereby doing great damage to the stock raisers."

10. Arizona Daily Star, May 21, 1882. Bahre, Ibid, 1985:192. Southern Arizona, western New Mexico. "Immense forest fires are still prevailing in some parts of western New Mexico and southern Arizona. They are believed to have been set out by Indians. Next to the pleasures of killing, burning appears to be the favorite amusement of the savages."
11. Aschmann, Homer. 1970. Athapaskan expansion in the west. Association of Pacific Coast Geographers 32:79-97:96. Apache Culture. "The Apache abhorrence and avoidance of the dead results in property destruction and loss through burning of the deceased's residence and effects and sometimes killing his livestock that is indeed uneconomic and tends to increase poverty. This death avoidance, coupled with a dispersed settlement pattern, however, would tend to restrict the spread of epidemic diseases."
12. Ball, Eve. 1970. In the Days of Victorio: Recollections of a Warm Springs Apache. Tucson, AZ: The University of Arizona Press. 222:144. Southeastern Arizona. "Word was passed to leave the arroyo. The Mexicans anticipated this move and attempted to prevent it by setting fire to the vegetation. Flames crept toward the ditch."
13. Ball, Ibid, 1970:17. Southern New Mexico, northern Sonora/Chihuahua, April 23, 1996. "Through it ran an arroyo deep enough to conceal fires and afford exits in case of attack. Only at midday did she [Grandmother] permit fires to be lighted, and then only of very dry wood. Unlike White Eyes [Anglos] we never camped at the water's edge, and we never built big fires to frighten game or betray our presence to the enemy."
14. Ball, Ibid, 1970:13. Southern New Mexico, northern Sonora/Chihuahua. "I've often wondered why so much has been written about smoke signals. As far as I know they were not much used."
15. Ball, Eve. 1980. Indeh: An Apache Odyssey. Provo: Brigham Young University Press. 334 pp. P. 93. Near Cook's Peak, Black Range, southern New Mexico. "Cooking mescal is a three-day job at best, and the pit must be watched night and day to prevent the escape of steam and heat. We took turns keeping watch, and during my watch on the third day I fell asleep. Awakened at Frank's urging I saw that the whole forest was on fire! Without even getting our blankets we ran for higher ground. It was lucky for us that the wind was blowing the fire away from us."
16. Bannon, John Francis. 1970. The Spanish Borderlands Frontier 1513-1821. Holt, Rinehart and Winston, New York, 308:90-91. Spanish Borderlands. In 1696 the Indians sought to put on a repeat performance of the 1680. June 4, this time, was their D-Day. Five friars, along with 21 Spaniards, settlers, and soldiers, fell victims to the new Indian fury. There was widespread burning and rapine. Only five of the Pueblos remained completely faithful and unaffected.

17. Bannon, Ibid, 1970:67-70. Spanish Borderlands. Exploring and mapping the Pimería, the Papaguería, and beyond were among his many contributions. Padre Kino has become known as the "padre on horseback." He and his Indians at Dolores were remarkable ranch men. After he had founded San Xavier del Bac, in 1700, 1400 head of cattle were soon on the trail thither. Though not successful in the long run, Kino did what he could to build the Indians of his Pimería into the guardians of the northwestern frontier against the increasing pressures of the hostile raiders from the northeast. The Apache menace was developing, and the Jocome and the Jano were learning fast, too fast. After he was gone, the folk of Sonora came to recognize his power and his influence.
18. Bannon, Ibid, 1970:176, 177. Spanish Borderlands. The two northern presidios in Sonora were next visited, Fronteras and Terrenate... the Marqués noted that in proceeding from Fronteras to Terrenate his party had passed four pueblos that had been abandoned because of constant Apache raids (176). However, the mine strike at Arizonac, in the upper Altar Valley, had brought many unscrupulous fortune hunters into the area and their coming had precipitated unrest and revolt among the Pima in the early 1750s, which had exacted a toll of over 100 Spanish lives, including two Jesuit Padres. Subsequent to the Pima revolt two new presidios had been founded: one at Altar, in the valley of that name, and the second in Tubac, to the south of San Xavier del Bac.
19. Bannon, Ibid, 1970:172, 174. Spanish Borderlands. In 1765 Charles III made two appointments, each in its own way designed to step up the reform program in New Spain. José de Gálvez .. visitador general and orders to direct a thorough overhaul of the administration and economic machinery of the viceroyalty. The second appointee was Cayetano María Pignatelli Rubí Corbera y San Climent..known as the Marqués de Rubí. Rubí spent the better part of the two years 1766 and 1767 on the frontier, gathering the materials for his extensive report and his subsequent recommendations. His report was largely the work of his constant companion, the highly intelligent and keenly observant Nicolás de Lafora, Captain of the Royal Engineers. Rubí's inspection of the frontier was not wholly unique. Forty years before, between 1724 and 1728, Pedro Rivera had gone north on a similar mission. The map of Nicolás de Lafora which came out of this tour of the frontier inspection was one of the most comprehensive surveys of the northern New Spain in colonial times. Lafora completed it and submitted it in 1771.
20. Barnes, Will C. 1941. Apaches and Longhorns. Los Angeles, CA: Ward Ritchie and Company. 214:59. Fort Apache, Arizona. "At two or three different points were solitary smokes or merely Indian camp-fires."
21. Barnes, Ibid, 1941:31. Ash Creek Flat, north of old Camp Thomas, between Fort Grant and Fort Apache, in southern central Arizona. "But the Indians were full of ideas. Ash Creek Flat for miles on every side was covered with a dense growth of wild oats, as dry as tinder and in places waist-high. Smoke began to appear at two or three places "up the wind," and it was realized that the noble red men were going to try a prairie-fire attack for a change. Driven by a stiff breeze, the

billows of flame and smoke came rolling down onto the crater which protected our outfit. [Lieut.] Cruse promptly met this attack by back-firing the tall grass. With all hands at work, a wide barrier of burned-over land was created entirely around the location, and all danger from that source was ended. The dense smoke bothered us some, but that was all."

22. Bartlett, J. R. 1854. Personal Narrative of Explorations and Incidents in Texas, New Mexico, California, Sonora, and Chihuahua. 2 Vols. D. Appleton and Co. New York. Pp. 88-89. Near Animas/ San Bernardino Valley. Boundary Commission Report 1851. " One of the cooks contrary to my express orders, built his fire near the dry grass without digging a hole. The grass took fire, spreading on all sides, and advanced with fearful rapidity towards the wagons... All hands (particularly Apache Scouts) ran to the rescue with blankets and cloths to beat down the fire...During the late war with Mexico, several wagons were burned by the grass taking fire."
23. Bartlett, Ibid, 1854:295-296. Guadalupe Mountains, southern New Mexico and extreme western Texas. "A fire has passed over it, destroying all the grass and shrubbery, and turning the green leaves of the sycamores into brown and yellow. The surface of the earth was covered with black ash, and we scarcely recognized it as the enchanting place of our former visit. At first we feared that this devastation had been caused by our own neglect; but on reaching the spot where we had encamped, which was separated from the surrounding hills by the rocky bed of the stream, we found the dry grass still around the place, which alone had escaped the fire. A little further on we came to a camp of two hundred Mexican soldiers, a portion of the brigade of General Carrasco [from Fronteras].. It was evident now how the fire which I have mentioned originated. A portion of the brigade had passed the canon a few days after us [June 1851]; and their twenty or thirty camp fires had, no doubt, communicated the flames to the grass, which had afterwards extended over the whole mountain."
24. Bartlett, Ibid, 1854:287. June 5th, 1851, Guadalupe Mountains, Southwest Borderlands, Agua Prieta to Arispe, Bacuachi. "It was nearly dark, and we were in a narrow gorge of the mountains where there was barely room for the wagons to pass. The whole earth had lately been burned over to the very mountain tops, which were even now throwing up columns of flame and smoke; not a blade of grass was to be seen, no water was near, and there was not a level spot to pitch our tents."
25. Bartlett, Ibid, 1854:274. May 29th, 185, Guadalupe Mountains, Southwest Borderlands, Agua Prieta to Arispe, Bacuachi. "The valleys and mountain sides were covered with oaks, while the summits, as far as I could judge, were covered with pines. The whole country during the night had been on fire, including the mountain; so that every thing around us was now black and gloomy."
26. Basso, Keith H. 1971. Western Apache Raiding and Warfare: From the Notes of Grenville Goodwin. The University of Arizona Press, Tucson. 330 Pp. P. 115. Northern Sonora, Mexico, 1880s. "Later on she went on up the mountain. From

here she could see the fire and smoke signals that the Mexicans were making to tell of her escape."

27. Basso, Ibid, 1971:133. Little Hatchita Mountain, probably the Little Hatchet Mountains in extreme southwest New Mexico, as this was on the road to Janos, Mexico, 1880s. "Twelve of us scouts got permission to go and hunt deer over near Little Hatchita Mountain. The officer told us if we twelve were needed back because of trouble, a big fire would be built to signal us to come. .. That night we watched for a signal fire. The next morning we could see lots of smoke but we waited for a while to see what would happen."
28. Basso, Ibid, 1971:152. Sierra de Media, perhaps in northern Sonora or Chihuahua, and perhaps close to the Sierra Madre, Mexico, 1880s. "The way we used to do when we were traveling was to make lots of fire before sundown so there would be plenty of coals. The after sundown we would have no flames, only a big heap of coals."
29. Basso, Ibid, 1971:100. From Blue River on the way to Goodwin Springs, east-central Arizona, 1880s.. "So this chief, whom the Whites called Diablo, started out for Goodwin Springs. As he traveled along with some other people, he kept burning the brush along the trail and making lots of smoke. As long as we [John Rope and others back in camp] could see this smoke, our people would know that things were going all right and that there was no danger. But it the smoke stopped, we would know that this party had got into trouble with the White men."
30. Basso, Ibid, 1971:98. Goodwin Springs, Gila River. "There our man met us and told us what he had seen. Somebody found some little sticks with red points on their ends. These were matches, but we had never seen them before and did not know what they were. They had been dropped there by the White men. They caught fire and that was when we first knew matches."
31. Bell, W.A. 1870. New Tracks in North America. 2nd Edition, 2 Volumes. London, Chapman & Hall Publishers. "The Apaches also have a very destructive habit amongst their long catalogue of vices of firing the forests of their enemies."
32. Betzinez, Jason. 1959. I Fought With Geronimo. Harrisburg, PA: Stackpole Company. 214 Pp. P. 13. Just northeast of Safford, Arizona, at foothills of the Mogollon Mountains. "Dilchthe got up and looked around for materials with which to build a smoke signal.. The Apaches used smoke on mountain tops mainly as signals of distress. The smoke meant, "There is some kind of trouble here. Come and investigate." The investigating party would approach carefully, and keeping under cover. They always suspected a trick. Today, we see cartoons telling how Indians carry on a regular conversation by means of smoke signals. From my experience that is all nonsense. I never saw signal fires or smokes that conveyed more than the simple message I have indicated. I am always surprised at the absurdities written and played on the screen concerning Indians, especially when the truth is so easy to learn and just as interesting as what is invented."

33. Betzinez, Ibid, 1959:110. Sierra Madres, northern Sonora, Mexico. "I heard my mother calling me. She said a grass fire had started east of the spring and was spreading. I ran rapidly down the slope to where my horse was standing directly in the path of the fire. The flames were roaring now, seemingly thirty or forty feet high and rushing toward us behind a strong wind. By this time the smoke and heat were so intense that I wet my bandana kerchief in the spring and tied it over my mouth and nose.. By the time I got past the line of the blaze I could see people around the camp fighting the fire in an effort to save their tents. This was the most dangerous and exciting fire I ever saw.. A great cloud of smoke was billowing high above the Sierra Madres, visible for a hundred miles in all directions.. Therefore the base camp was moved to the mountains west of the Huachinera [Mountains]."
34. Betzinez, Ibid, 1959:63. Stein's Peak, at Arizona/New Mexico border, near old railroad town of Steins. "At this time a party of U.S. Indian Scouts moving ahead of the some troops were looking for our band. Instead of finding us our reconnoitering party located them and at once attacked, killing one of the scouts. The latter though badly outnumbered put up a good fight. They set fire to the grass to tell their main body that they had met the hostile Indians."
35. Betzinez, Ibid, 1959:13. Just northeast of Safford, Arizona, at foothills of the Mogollon Mountains. "This is how Indians who did not have matches or flint and steel make a fire: they cut.. a round, hard stick of wood which they twirl between their palms, the rounded end bearing in a little cup-shaped hollow made in a flat, softer piece of wood. The trick is in cutting a little notch in the end of the round stick, so that the friction quickly generates heat to cause the soft piece to smolder. The little wood shavings then glow, and when blown upon burst into flame. Of course the Indian has already prepared a little heap of dry materials to which the flame is applied. In this manner a fire can be started in a few moments."
36. Betzinez, Ibid, 1959:74. A few miles west of the town of Janos, in extreme northwestern Chihuahua, on the Rio de Janos. "The Mexicans tried all afternoon to dislodge the Indians. After dark they set fire to the grass hoping to burn the Indians out. The latter were now in a serious condition. They were surrounded by a prairie fire, the circle of it growing closer. [The warriors] all crawled through the fire and got away without being seen."
37. Bigelow, John. 1958. On the Bloody Trail of Geronimo. Los Angeles: Westernlore Press. 237 Pp. P. 22. Somewhere in Sonora, northern Mexico, across from Patagonia Mountains in Santa Cruz County in southern Arizona. "Last night, between ten and eleven o'clock, I was waked up by the sentinel coming to tell the captain that there was a signal fire visible from his lookout. He located it about where we saw the first fire over in Mexico, four days ago. He has watched it for about an hour, more or less, before it went out and had seen it go down and come up again a half dozen times. Shortly after breakfast the captain set out with ten of our men and three Indian scouts to ascertain what truth there was in the different reports in regard to signal fires, especially those in the Mowry Pass."

38. Bigelow, Ibid, 1958:79. On the Gila River, about 12 miles from Clifton, "in the mountains about the Metcalf mines," October 5, 1885. "We had made about a half day's march when two men on ponies came galloping up to us, and reported that Indian fires had been seen about twelve miles from Clifton, in the mountains about the Metcalf mines.. I doubted whether the fires were anything more than signals made by runners from the reservation, on the lookout for friends returning from Mexico."
39. Bigelow, Ibid, 1958:82. Sheldon, southeastern Arizona, just north of present-day Duncan, on the Gila River in Greenlee County. "Immediately after dark I had a fire made on an elevation back of the camp, for the guidance of my two dismounted men."
40. Bigelow, Ibid, 1958:21. Mowry Pass, near the Mowry Mine, south of Patagonia, Santa Cruz County, north end of the Patagonia Mountains, southern Arizona. "One of the men who was sent to McCullough's ranch to-day to get some provisions for the mess brought back information that, night before last, a signal fire was seen in the Mowry Pass, about five miles below our camp [the camp being located at the Tempest Mine].."
41. Bigelow, Ibid, 1958:202. Rincon Mountains, southeastern Arizona. "The captain received this morning from the Acting Adjutant-General in Wilcox, the following copy of a dispatch from Fort Lowell: 'Signal fires have been seen in Rincon Mountains the last two nights. A party of eight Indians was seen in San Pedro valley last night.. These Indians have evidently been in the Rincon Mountains for the last two weeks.' These signal fires are doubtless the burning woods that have been observable to us ever since we came here [on May 24, 1886]."
42. Bigelow, Ibid, 1958:149. Somewhere in Sonora, northern Mexico, across from Patagonia Mountains in Santa Cruz County in southern Arizona. "While upon the lookout this afternoon, I watched for sometime a great volume of faintly colored smoke rising from a mountain range over in Mexico, which I judged to be about sixty miles from here. It was too large for camp or signal fires and probably came from burning grass or timber. If caused by Indian deviltry, we shall probably soon know about it."
43. Bolton Hubert, E. 1908. Spanish Exploration in the Southwest 1542 - 1706. Barnes and Noble, New York. 486 Pp. . Pp. 451-452. 1690-1710, Southwest Borderlands. "For many years this province of Sonora has suffered very much from its avowed enemies, the Hocomes, Janos, and Apaches, through continual thefts of horses and cattle, and murders of Christian Indians and Spaniards, etc., injuries which in many years not even the two expensive presidios, that of Janos and that of this province in Sonora, have been able to remedy completely, for still these enemies continue to infest, as always, all this province of Sonora... a great restraint can be placed upon these enemies, who are accustomed to live in the neighboring sierras Chiguicagui; and by fortifying for said Captain Cora his great ranchería for a new pueblo, as shortly, God willing, we shall fortify him for the protection of Santa María Baseraca, he will continue better his accustomed expeditions against these enemies; and he will be able to chastise them, as he is

accustomed to do, winning very good victories, as always, and even greater, for the total relief of Sonora, just as when a few years ago (1698) he killed at one blow more than two hundred of those enemies, and as four months ago, in the expedition which he made in pursuit of those who were carrying off cattle and horses from the Real de Bacanuche, he killed fifteen adult enemies and carried off ten little prisoners."

44. Bolton, H.E. 1917. The Mission as a Frontier Institution in the Spanish American Colonies. American Historical Review 22: 42-61. Pages 49-65, Reprinted in New Spain's Far Northern Frontier: Essays on Spain in the American West, 1540-1821, Weber, D.J. (Ed.), Southern Methodist University Press, Dallas. P. 57. 1758, New Spain. It is significant, too, in this connection, that the Real Hacienda, or Royal Fisc, charged the expenses for presidios and missions both to the same account, the Ramo de Guerra, or "War Fund." In a report for New Spain made in 1758 a treasury official casually remarked, " Presidios are erected and missions founded in tierra firme whenever it is necessary to defend conquered districts from the hostilities and invasions of warlike, barbarian tribes, and to plant and extend our Holy Faith, for which purposes juntas de guerra y haciendas are held."
45. Bolton, H.E. 1919. Kino's Historical Memoir of Pimeria Alta. 2 Vols. Aurthur H. Clark, Cleveland. . Pp. 1919: Vol. 1:170-171. Upper San Pedro Valley. Captain Juan Mateo Manje, Pimería Alta, 1697. "A league below was Quiburi, home of Captain Cora, head Pima chief. In great villages they raised by irrigation large quantities of maize, frijoles, and cotton, the last of which they used for clothing."
46. Bolton, H.E. 1936. Rim of Christendom: A Biography of Eusebio Francisco Kino, Pacific Coast Pioneer. The University of Arizona Press, Tucson. Pp. 1936:358-367. Southwest Borderlands. Padre Francisco Eusebio Kino, Pablo de Quiburi, November 7, 1697 "dancing over the scalps and spoils of fifteen enemies, jacomes, and janos, whom they killed a few days before."
47. Bourke, John G. 1886. An Apache Campaign in the Sierra Madre. New York, Charles Scribner's Sons. 112 Pp. P. 26. "If they want to make a little fire, they kindle one with matches, if they happen to have them; if not, a rapid twirl, between the palms, of a hard round stick fitting into a circular hole in another stick of softer fiber, will bring fire in from eight to forty-five seconds."
48. Bourke, Ibid, 1886:105. Sierra Madre, northern Sonora, Mexico. "we crossed the main divide of the Sierra Madre at an altitude of something over 8,000 feet. The pine timber was large and dense, and much of it on fire, the smoke and heat parching our throats, and blackening our faces."
49. Bourke, Ibid, 1886:28. "These Indians, with scarcely an exception, sleep with their feet pointed towards little fires, which, they claim, are warm, while the big ones built by the American soldiers, are so hot that they drive people away from them, and, besides, attract the attention of a lurking enemy."
50. Bourke, Ibid, 1886:106-108. The valley containing the town of Janos, coming from the Sierra Madre, Mexico. "The command was threatened by a great prairie fire on coming down into the broad grassy valley of the Janos. Under the impetus of

a fierce wind the flames were rushing upon camp. There was not a moment to be lost. The conflagration had already seized the hill-crest nearest our position; brownish and gray clouds poured skyward in compact masses; at their feet a long line of scarlet flame flashed and leaped high in the air. It was a grand, terrible sight: in front was smiling nature, behind, ruin and desolation. The heat created a vacuum, and the air, pouring in, made whirlwinds, which sent the black funnels of soot winding and twisting with the symmetry of hour-glasses almost to the zenith. For one moment the line of fire paused.. Our people stood bravely up to their work, and the swish! swish! swish! of willow brooms proved that camp was not to be surrendered without a struggle.. We won the day.. but over a vast surface of territory the ruthless flames swept, mantling the land with soot and an opaque pall of mist and smoke through which the sun's rays could not penetrate.. For two or three nights afterwards the horizon was gloriously lighted with lines of fire creeping over the higher ridges."

51. Bourke, Ibid, 1886: 58, 61, 66. Sierra Madre, northern Sonora, Mexico. P. 58: "No fires were allowed.." P. 61: "Fires were allowed only in rare cases, and impositions affording absolute concealment." P. 66: "No fires were allowed at night, and all cooking was done at midday."
52. Bourke, Ibid, 1886:80-81. Sierra Madre, northern Sonora, Mexico. "The command moved out from this place, going to another and better location a few miles south-east. The first lofty ridge had been scaled, when we descried on the summit of a prominent knoll directly in our front a thin curl of smoke wreathing upwards. This was immediately answered by the scouts, who heaped up pine-cones and cedar branches, which, in a second after ignition, shot a bold, black, resinous signal above the tops of the loftiest pines.. The Apache scouts sent up a second smoke signal, promptly responded to from a neighboring butte."
53. Bourke, Ibid,1886:73. Near Bavispe River, northern Sonora, near Sierra Madre, Mexico. "On May 15, 1883, we climbed and marched ten or twelve miles to the south-east, crossing a piece of country recently burned over, the air, filled with soot and hot dust, blackening and blistering our faces."
54. Bourke, J. G. 1891.On the Border with Crook. New York, Charles Scribner's Sons. 491 Pp. P. 45. "From every peak now curled the ominous smoke signal of the enemy, and no further surprises could be possible. Not all of the smokes were to be taken as signals; many of them might be signs of death, as the Apaches at that time adhered to the old custom of abandoning a village and setting it on fire the moment one of their number died, and as soon as this smoke was seen the adjacent villages would send up answers of sympathy."
55. Bourke, Ibid,1891:46. A spring at the base of the Pinal Mountains, central Arizona. "The Apaches had been there to bury their kinsfolk and bewail their loss, and in token of grief and rage had set fire to all the grass for several miles, and consequently it was to the direct benefit of all our command.. to keep moving until we might find a better site for a bivouac."

56. Bourke, Ibid, 1891:106. Bear Springs, base of Whetstone Mountains, southern Arizona. "charred to a crisp in the flames which the savage had ignited in the grass to conceal their line of retreat."

57. Briggs, L. Vernon. 1932. Arizona and New Mexico 1882, California 1886, Mexico 1891. New York: Argonaut Press, Ltd. 282 Pp. P. 58. Pinery Canyon, Chiricahua Mountains, southeastern Arizona. "We are told that four men have come in from Morse's sawmill in the Chiricahua Mountains with another terrible report: On Wednesday last, James Fife started up Pinery Canyon after a load of bagging. They had not gone far when they came upon a band of Indians, upon whom they fired, killing one. The Indians returned the fire, killing two of the men with Fife and wounding him in the breast and arm. He ran down the canyon and hid himself in the thick undergrowth. The Indians set fire to the brush, but Fife managed to crawl along until he got out of range, when he ran down the Canyon to his father's house, near the valley, where he now lies in a very critical condition."

58. Briggs, Ibid, 1932:59. Mountains around White River, in southeastern Arizona. "When they left camp they saw big fires in the mountains, supposed to be the work of hostiles, and they passed one band of ten Indians at a distance and "saw many signs."

59. Briggs, Ibid, 1932:44. Mountain ranges except the Chiricahua Mountains in southeastern Arizona. "Later reports by the runners are that the hostiles have reached the Chiricahuas, and a report from Bowie states that signal fires are burning on the mountain ranges except the Chiricahuas."

60. Briggs, Ibid, 1932:48. Mountains north and south of Wilcox, likely the Pinaleno or Galiuro Mountains and the Chiricahua Mountains of southeastern Arizona. "Signal fires were reported to be seen in the mountains from Wilcox last night, both north and south. It is thought that the squaws belonging to the bucks now on the warpath were signaling back and forth. About a dozen squaws, loaded with packs, left Wilcox to-day."

61. Briggs, Ibid, 1932:48. Mountains north and south of Wilcox, likely the Pinaleno or Galiuro Mountains and the Chiricahua Mountains of southeastern Arizona. "Signal fires were reported to be seen in the mountains from Wilcox last night, both north and south. It is thought that the squaws belonging to the bucks now on the warpath were signaling back and forth. About a dozen squaws, loaded with packs, left Wilcox to-day."

62. Browne, John Ross. 1871. Adventures in the Apache Country: A Tour Through Arizona and Sonora, with Notes on the Silver Regions of Nevada. Pp. 218, 220. Along the Santa Cruz River in northern Sonora, December, 1863. Pg 218: "Meantime the Indians had come out of their ambush and set fire to the grass, which was tall and dry. The flames swept down upon the wagons so rapidly that it was found necessary to abandon the shelter of the tree, and make for a rise of ground about 200 yards distant.. Just as they reached this point, the Indians shouting and yelling all around them, the grass was again fired to windward, and the flames swept down toward them with fearful rapidity." Pg 220: "The Indians

set fire to the grass again, and the flames swept toward him with fearful rapidity, compelling him to climb the tree for security, and even then burning part of the legs off his pantaloons."

63. Castetter, Edward, F. and Morris. E. Opler. 1936. The Ethnobiology of the Chiricahua and Mescalero Apache. University of New Mexico Bulletin No. 297, Biological Service, Ethnobiological Studies in the American Southwest. 63 Pp. . P. 33. Chiricahua Apache. "Like all other Southern Athabascans, the Chiricahua and Mescalero showed the most acute dread of anything connected with death. The corpse was buried as quickly as possible and the place of burial never revisited. The possessions of the deceased were destroyed, and the family at once abandoned the camp at which the death occurred." "Those who prepared the body for burial burned or discarded the clothes worn on the occasion."

64. Castetter and Opler, Ibid, 1936:17-18. Chiricahua Apache. "Life and conscious aims are attributed to natural forces as well. The Apache conception of thunder will serve as an example. Thunder is thought of as people and thunderclaps are the voices and shouting of these people. Lightning is the arrow of the thunder people and these arrows reach the earth as the elongated flints which the apache find throughout their territory. At one time the thunder people hunted for the Apache and slew deer for them with these arrows. But those days are past and now the arrows of the thunder people are reserved for any who act d disrespectfully to the thunder people or otherwise disobey the injunctions of Apache life. When lightning flashes, the Apaches says, "Let it be well, my brother lightning," or "Strike high, my brother." When the lightning hits close the relationship is altered to make the prayer more appealing and the apache says: "Continue in a good way. Be kind as you go through; Do not frighten these poor people; My grandfather, let it be well; Don't frighten us poor people." Space does not permit a full discussion of the restrictions in food, speech, and even in the color of objects displayed during a storm, which are obeyed in order to appease the thunder people."

65. Cole, D.C. 1988. The Chiricahua Apache 1846-1876: From War to Reservation. University of New Mexico Press, Albuquerque, New Mexico. 219 Pp. . P. 87. Chiricahua Apaches. "While there were no stories relating to an epidemic disease at the time, there were a number of cultural changes which originated during the period of population decline. Consumable property of the deceased person, including the dwelling, was burned as was the corpse of a person dying suddenly of disease."

66. Cordero, Colonel Don, Antonio. 1796. Matson, Daniel S., and Schroeder, Albert H. 1957. Cordero's Description of the Apache - 1796. New Mexico Historical Review 32: 335-356. . Pp. 338-339. Northern Chihuahua and Sonora, Mexico, El Paso. " So far as the game is concerned, it is the burro (bura), deer, antelope, bear, wild pig (jabali), panther (leopardo --possibly the mountain lion), and the porcupine. The common fruits are the tuna, the datil, the pitaya, the acorn, and the pinon; but their principal delicacies are the mescal. There are various kinds taken from the hearts of the maguey, sotol, palmilla and lechuguilla; and it is used

by cooking it with a slow fire in a subterranean fireplace, until it acquires a certain degree of sweetness and piquancy. They likewise make a sort of grits or pinal of the seed of hay or grass which they reap with much care in its season, although in small quantities (since they are not by nature farmers); they likewise raise some little corn, squash, beans, and tobacco, which the land produces more on account of its fertility than for the work which is expended in its cultivation."

67. Cordero, Ibid, 1796. Matson and Schroeder (Trans). 1957:343-344. Northern Chihuahua and Sonora, Mexico. "At dawn a piece of terrain is encircled, which frequently is five or six leagues [15 to 18 miles] in circumference [therefore about 4.5 to 5.5 miles in diameter]. The sign to commence the chase, and consequently to close the circle is given by smoke signals. There are men on horseback assigned to this project, which consists in setting fire to the grass and herbage of the whole circumference; and since for this purpose they are already placed ahead of time in their posts with torches ready which they make from dried bark or dried palmilla [soap yucca], it takes only a moment to see the whole circle flare up. At the same instant the shouts and the noise commence, the animals flee, they find no exit, and finally they fall into the hands of their astute adversaries. This kind of hunt takes place only when the grass and shrubs are dry. In flood season when the fields cannot be set afire they set up their enclosures by rivers and arroyos. The deer and antelope hunt is carried out with the greatest skill by one indian alone; and due to the great profit which results from it, he always prefers it to the noisy type of chase, which serves more for the amusement than to provide necessities."

68. Cordero, Ibid, 1796. Matson and Schroeder (Trans). 1957:339. Northern Chihuahua and Sonora, Mexico, El Paso. " In general they choose for dwelling places the most rugged and mountainous ranges. In these they find water and wood in abundance, the wild produce necessary, and natural fortifications where they can defend themselves from their enemies. Their hovels and huts are circular, made of branches of trees, covered with skins of horses, cows, or bison, and many likewise use tents of this type. In the canyons of these mountain ranges the men seek large and small game, going as far as the contiguous plains; and when they have obtained what was necessary, they bring it to their camp, where it is the work of the women, not only to prepare the foods, but also to tan the skins which are then used for various purposes, particularly for their clothing."

69. Cordero, Ibid, 1796. Matson and Schroeder (Trans). 1957:348-349. Northern Chihuahua and Sonora, Mexico. "In spite of the continuous movement in which these people live, and the great deserts of their country, they find each other as easily when they desire to communicate... Understanding it is a science; but it is so well known by all of them that they are never mistaken in the meaning of its messages... "A smoke signal made on a height, put out immediately, is a sign for all to prepare to resist enemies who are near by and have already been seen personally or their tracks have been noted. Any camps that detect them give the news to others in the same way. A small smoke made on the slope of a mountain, is a sign that they are hunting their own people whom they desire to

meet. Another smoke in reply half way up the sides of an eminence, indicates that there is their habitation, and that they can freely come to it. Two or three small smokes made successively in a plain or canyon pointing in one direction, are an indication of desire to parley with their enemies, and reply is made to this in the same fashion. In this way they have many general signals used in common by all Apache groups. In the same way there are also signals that have been specially agreed upon, which no one can understand without processing the key. They make use of these frequently when they enter hostile country for the purpose of raiding. In order not to be delayed in the making of smoke, there is no man or women who does not carry with him the implements necessary to make fire. They prefer flint, steel and tinder when they can get them; but if 5hese are lacking they carry in their place two prepared sticks, one of sotal and the other of lechuguilla, well dried, which they rub with force with both hands like a little hand mill, the point of one against the flat side of the other, and thus they succeed in a moment in setting fire to the shavings or dust of the rubbed part; and this is a process which even children are not ignorant of."

70. Corral, Ramon. 1959. *Obras Historicas: Resena Historica del Estado de Sonora*, 1856 - 1877, Biografia de Jose Maria Leyva Cajeme, Las Razas Indigenas de Sonora. Biblioteca Sonorense de Geografia y Historia, Hermosila, Sonora. 260 Pp. . P. 247. 1856-1877, Apache Culture. *"Cuando andan en campana emplean us sistema de senales para reconocerse a muy largas distancias, haciendo grandes humaredas por medio de las cuales se indican los lugares en donde se encuentran; los rumbos que deben seguir para reunirse y otras varias circunstancias cuyo conocimiento aprovechan maravillosamente."*

71. Corral, Ibid, 1959:230. Bacadehuachi. 18th of April 1883: *"Los coroneles Garcia y Torres dieron un ataque vigoroso que resistieron los Indios en sus posiciones, haciendo un fuego nutrido (Substatial Fire) sobre nuestros soldados. El primero de los expresados, al rendir al parte de este acción, dijo que despues de tres horas de combate lograron desalojar al enemigo de los rocas donde se había parapetado, dispersandolo completamente."*

72. Corral, Ibid, 1959:234. Nacori Chico, July 21, 1883: *Después de una defensa encarnizada y herido el sargento Benito Garrobo, comenzaron a hacer fuego en retirada (*retreating*) dirigiéndose a la población.*

73. Cortes, Jose, 1799. John, E.A. (ed.), and J. Wheat (translated). 1978. Views from the Apache Frontier; Report on The Provinces of New Spain, University of Oklahoma Press, Norman. 163 pp. P. 75. 1799, Northern provinces of Mexico, such as Sonora, Coahuila, and Chihuahua, Mexico. "So as not to delay the aforesaid smoke signals, no man or woman fails to carry with them what they need to make fires. They prefer flint, steel, and tinder when they manage to acquire these tools, but if they lack these they carry two prepared and well-dried sticks, one of sotol and the other of lechugilla. Rubbing vigorously with both hands, with the point of one placed on the flat side of the other in the manner of a small hand grinder, they manage in a moment to light the shavings or sawdust from the rubbed part."

74. Cortes, Ibid, 1799. 1978:58. Northern provinces of Mexico, Janos, Chihuahua, Mexico. " The foods with which they sustain themselves include meats, provided by their constant hunting and cattle stealing carried out in the territory of their enemies. Their common sustenance also includes wild fruits that grow in their respective areas. Thus, the later, as well as types of game, will vary according to where they are living. But there are some that are common to every place Among the game are the desert mule deer, white-tailed deer, pronghorn, bears, javalinas, mountain lions, and porcupines. Fruits generally abundant everywhere are the tuna, the datil, the pitahaya, the acorn, and the pine nut. One of their favorite treats is also the mescal, which comes from several varieties because it is extracted from the heart of the maguey, the sotol, the pamilla, and the lechuguilla. It is processed by being cooked slowly underground until it achieves a certain degree of sweetness and potency. They also make a kind of porridge from the seed and the hay or grass which they collect in great quantities."

75. Cortes, Ibid, 1799. 1978:68. Northern Provinces; Sonora and Chihuahua, Mexico. "The signal to begin beating and close in is given by smoke signals, to which the task riders are assigned. The operation begins by their setting fire to the grass and vegetation all around a circle. Since they are all in their respective positions for this purpose, with torches from dried palmilla bark at the ready, it is the only moment before one sees in flames the entire circle that is to be beaten. At the same moment they begin to yell and make noise. The game flees but finds no escape, and finally falls into the hands of such clever adversaries. This type of hunt is done only when the hay and grass are dry. In the rainy season, when they cannot burn the vegetation, they set up their encirclements next to rivers and arroyos... A lone Indian will also hunt deer and pronghorns with the greatest skill. They especially like this type of hunt for its total efficiency, which is not the case in the noisy scheme of beating, which provides more entertainment than it does efficiency. ."

76. Cortes, Ibid, 1799. 1978:74-75. Northern provinces of Mexico, such as Sonora, Coahuila, and Chihuahua, Mexico. "smoke signals are their surest mail system, by means of which they communicate with one another. There is no doubt that understanding the smokes is a science, but one so well known to them all that they never mistake the contents of their signals. A smoke made from a height and then stokes higher is a warning for everyone to prepare to contain enemies who are close and have been directly sighted or discovered from their tracks. Then all the rancherías that see it respond with another in the same manner. A small smoke made on a slope of a mountain means they are seeking their own people with whom they wish to communicate. Another in reply made from midslope of a peak means that their people are there and that they can approach freely. Two or three small puffs made in succession in the same direction from a plain or canyon express a request to parley with their enemies, to which a reply is made with similar signals. They have established many general signals of this tenor which are commonly accepted by all Apache groups. On the other hand,

there are also prearranged signals that no one can know without having the code to them, and they use these often when they invade enemy territory on raids."

77. Cortes, Ibid, 1799. 1978:65. Northern Provinces; Sonora and Chihuahua, Mexico. "Thus gathered, the rancherías always occupy the steepest canyons in the mountains, surrounded by the most difficult passes for approaching the site where they are located. That last site chosen, as a general rule, adjacent to the greatest heights in order to command the surrounding valleys and plains."
78. Cortes, Ibid, 1799. 1978:78. Northern provinces of Mexico, Janos, Chihuahua, Mexico. " An indian apparently thirty to thirty-five years of age suffered an illness which, by its severity and its symptoms, those attending him recognized as fatal. Finally toward the end of his prostration, or thinking him near death, they removed him from his hut, laid him upon a large pile of cottonwood branches, and covered him with more branches, leaving only his eyes exposed. Everyone came from his ranchería with their arrows and placed them in a circle around the dead mans body. They did the same with their lances, sticking them into the ground not far from the object of their sorrow. At this point a woman appeared--who I learned afterward was the mother-in-law of the dying man--carrying a burning stick in her hand and fixing her gaze on the eyes of the son-in-law. When she saw that one of them had closed, the social life of the infidel was considered finished, and she lit the woodpile that was serving as his resting place and covering him. Other women who were also carrying burning sticks set fire at the same time to all the huts in that ranchería, except that of the deceased, which they brought in so that it might burn alongside him, as well as his weapons, saddle, his wife's hair, skirts, and other skins that he wore."
79. Cortes, Ibid, 1799. 1978:75. Northern Provinces; Sonora and Chihuahua, Mexico. "So as not to delay in making the aforesaid smoke signals, no man or woman fails to carry with them what they need to make fires. They prefer flint, steel, and tinder when they manage to acquire these tools, but if they lack these they carry two prepared and well dried sticks, one of sotal and the other of lechuguilla. Rubbing vigorously with both hands, with the point of one placed on the flat side of the other in the manner of a small hand grinder, they manage in a moment to light the shavings or sawdust from the rubbed part. This operation is known even to the children."
80. Cremony, John C. 1868. Life Among the Apaches. San Francisco, CA: A. Roman and Company, Publishers. 322 Pp. Pp. 183-184. Southern Arizona or southern New Mexico. "Smokes are of various kinds, each one significant of a particular object. A sudden puff, rising into a graceful column from the mountain heights, and almost as suddenly losing its identity by dissolving into the rarefied atmosphere at those heights, simply indicates the presence of a strange party upon the plains below; but if these columns are rapidly multiplied and repeated, they serve as a warning to show that the travelers are well armed and numerous. If a steady smoke is maintained for some time, the object is to collect the scattered bands of savages at some designated point, with hostile intention, should it be practicable. These signals are made at night, in the same order, by the

use of fires, which being kindled, are either alternately exposed and shrouded from view, or suffered to burn steadily, as occasion may require."

81. DeVoto, Bernard. 1961. The Year of Decision: 1846. Boston, Houghlin Mifflin and Co. Pp. 408-409. Ojo Caliente, Sierra Madre, northern Sonora, Mexico. "Beyond the hot springs [Ojo Caliente] they made a fifty-five mile jornada and, on the other side, got themselves into a prairie fire. One of Gilpin's campfires spread through the mountains, where it burned beside them throughout a day's march... that night they had to run, when a gale drove the flames down to their camp. There was a wild half hour when the army set backfires, galloped the horses and wagons about, and swore at one another in pyrotechnic light till the show was over."

82. DiPeso, C.C. 1953. The Sobaipuri Indians of the Upper San Pedro River Valley, Southeastern Arizona. No. 6, The Amerind Foundation, Dragoon, AZ. 285 Pp. . Pp. 233, 40-41. Sonora, Padre Pfefferkorn. "(stock raising) was attended by such success that not only among the Spaniards and Missionaries, but also among the Indians, there were so many who had sizable herds of all kinds of animals. Because of there numbers the animals were so inexpensive that a fine mule sold for 2 silver marks, an excellent horse for 1 mark, a fat cow for half a mark, a fat ox for six silver lots, a whether for 2 silver lots, a sheep for 1 and a half silver lots."

83. Dobyns H.F. 1981. From Fire to Flood: Historic Human Destruction of Sonoran Riverine Oases. Ballena Press, Socorro, New Mexico, 222 Pp. . Pp. 20-22. Arivaipa Creek. May 28th 1830: Around 8 that night I halted in the mouth of said canyon where I encountered the infantry that went to reconnoiter. Having learned that the Indians caused a large fire that had been burning for five days, and that there were some thick pieces of wood still burning, I continued to march toward the north. May 19th: This Indian escaped very badly wounded with one broken arm and a [lance] thrust through the lung, from which I doubt he will survive. The other who came burning the pasturage fled through the Sierras after hearing the shots.

84. Dobyns, Ibid, 1981:32. Southwest Borderlands. Some environmentalists have in the enthusiasm of the moment attributed to Indoamerican respect for nature (really the presence of imminent power in animate and inanimate things) a minimal Indoamerican impact upon natural environments. Actually the degree of the Indoamerican impact on the environment stemmed from technological capability rather than high valuation for any given natural environment unmodified by Indoamerican man. Fire constituted the principal technology that Indoamericans possessed for modifying natural environments in order to augment their food supplies.

85. Faulk, Odie, B.1969. The Geronimo Campaign. New York: Oxford University Press. 245 Pp. P. 105. South of Nogales, Sonora, Mexico. "That afternoon the fleeing renegades set fire to the country over which they had passed to hide their trail, forcing the soldiers to ride through forest fires."

86. Faulk, Odie B., and Sidney B. Brinckerhoff. 1966. Soldering at the End of the World. The American West. 3:28-37. Pp. 36-37. Southwest Borderlands, New Mexico, Arizona. Finally in 1786 the new viceroy, Bernardo de Galvez, who had seen service on the northern frontier, and had later governed Louisiana, put a new plan into effect. He decreed a vigorous war on those Indians not at peace with Spain. Once the savages asked for peace, he ordered that they be settled in villages in the shadow of a presidio where they would be given presents, inferior firearms, and alcoholic beverages... The Galvez policy worked sufficiently well to bring about a period of relative peace from 1787 to 1818.

87. Faulk and Brinckerhoff, Ibid, 1966:30. Southwest Borderlands, New Mexico, Arizona. "The lordly Comanches and the fierce Apaches did not take to sedentary mission life; they would not give up the warpath for the plow. Even among normally peaceful tribes in this region there were occasional rebellions. In 1751, for example, the Pimas of Arizona staged a bloody uprising, as had New Mexican natives in 1680, and the Texas Indians in 1693."

88. Faulk and Brinckerhoff, Ibid, 1966:35-36. Southwest Borderlands, New Mexico, Arizona. The trooper who served out his ten year enlistment was often a veteran of dozens of campaigns made against the Indians who raided in the vicinity... On long expeditions the soldados de cuera took along six or seven extra horses apiece, plus pack mules with supplies. Heavily burdened with equipment and a large remuda, the column generally traveled no more than twenty miles a day. The Indians, if they had not fled into their wilderness hideouts, watched from high ground as the conspicuous column proceeded after them, or if and opportunity presented itself they would strike quickly and suddenly at the remount herd, driving off most of the horses and thus forcing the column to turn back. Another favorite trick of the enemy was to double back and attack the unprotected settlement near the presidio. When these Spanish columns did penetrate the Indian country far enough to find a native village, it was usually abandoned, and little could be accomplished except the destruction of the site (with fire, my emphasis).

89. Forbes, Jack, D. 1960. Apache Navajo and Spaniard. University of Oklahoma Press, Norman. 304 Pp. Pp. 304:200-224. Sonora, Southwest Borderlands. "This massive outbreak, the Great Northern Revolt, ravaged almost the entire northern frontier of New Spain — from the Gulf of California coast in Sonora to the Big Bend country in Texas. Almost every Indian tribe which had been brought to terms and many of those which had been reduced to mission life rose up against the Spanish occupation during those eighteen years (1680-1699)."

90. Gatewood, Charles B. 1986. The Surrender of Geronimo. In C.L. Sonnichsen, Ed., Geronimo and the End of the Apache Wars. Lincoln, The University of Nebraska Press: 53-70. P. 60. Bavispe River, at its northernmost extent in northern Sonora, where it curves back down to join the Rio Yaqui, Mexico. "We adjoined to the place designated in the river bottom after passing signals (smoke & shots) signifying that all was well."

91. Goodwin, Grenville. 1942. The Social Organization of the Western Apache. The University of Chicago Press, Illinois. 701 Pp. P. 83. Southern Apaches. "The White Mountain, being nearest, generally understood the distinction between the three Chiricahua bands and knew their names, though not making frequent use of them: tcí-hé ('Red Clay People') directly to the east, t'cókánén' about the Dragoon and Chiricahua Mountains, and n'dé-ndá-í ('Enemy or Renegade People') in the region of the Sierra Espuela, Sonora, and the present international border just north of it."

92. Goodwin, Ibid, 1942:520. Apache Culture. "If a person is married, and dies, then it is the mate of the dead one who sets fire to the wickiup, but if the dead one is single, it will be some close kin of his who is the same clan.. If a man is killed at war way down in Mexico, he has to be buried there of course;.. Also his wickiup and property are burned, and his wife and children move away."

93. Goodwin, Ibid, 1942:93. Apache Culture. "Apache horses, mules, burros, cattle, cloth, clothing, blankets, metal to be made into spear heads, arrow points, or knives, occasionally firearms, saddles, bridles, leather, cowhide for moccasin soles, and anything else light and useful which could be brought home.. The raids to Mexico became an integral part of the culture."

94. Governor Juan Francisco Trevino translated by Elizabeth, A. John. 1975. Storms Brewed in Other Men's Worlds; the Confrontation of Indians, Spanish, and French in the Southwest, 1540-1795. Texas A & M University Press, College Station. 805 Pp. . P. 94. Pueblos of the Upper Rio Grande; Zuni, Acoma, Taos, Jemez.. "Governor Juan Francisco Trevino, who dispatched soldiers to seize the leaders, confiscate their religious paraphernalia, and burn their kivas."

95. Griffen, William, B. 1988a. Apaches at War and Peace: The Janos Presidio, 1750-1858. University of New Mexico Press, Albuquerque. 300 pp. P. 38. New Mexico, Chihuahua. "From 1777 into 1781 Apaches identified as Gilenos kept up depredations in the south from Chihuahua City to Valle de San Bartolomé (today valle de Allende). Spaniards kept military pressure on the Apaches and destroyed (with fire, our emphasis) rancherías that were found warring."

96. Griffen, Ibid, 1988a:8. Apache Burial Culture. "Apaches interred selected personal belongings with the deceased's body, including a man's favorite war horse; but other articles and the house where the death occurred were burned, the camp abandoned, and the spot avoided for a considerable period afterward."

97. Griffen, Ibid, 1988a:46. New Mexico, Chihuahua. "Reglamento de 1772 to all frontier commanders: troops were to take the offensive and wage a relentless war on the Apaches, attacking them at their camp sites and removing all opportunity for the rancherías to unite. All places known to be frequented by the Apaches (camps, water holes, and mescal harvesting areas) were to be scoured."

98. Griffen, Ibid, 1988a:48. Chiricahua Mountains; Fronteras; Bacoachi; Bavispe. "On January 30 (1786) a horde of Apaches fell on the remaining animals and carried off 225 in the ensuing stampede. Slightly before this Captain Manuel de Azuela from Fronteras had reconnoitered the Chiricahua Mountains south to the Sierra de las Espuelas, northwest of Janos. There he discovered such a large gathering

of Apaches that he was afraid to attack with his mere 114 troops. These were probably the same Apaches who stormed Janos a short while later. In the spring Alferez Vergara, with troops from Fronteras, Bacoachi, and Bavispe, made a reconnaissance from the Chiricahuas. He found large swaths of grasslands burned off, apparently to destroy fodder for Spanish horses. He then marched to the Pitaicachi and Embudos mountains and to Cucuveráchi where he attacked over one hundred Apache warriors who were there with their families making mescal."

99. Griffen, Ibid, 1988a:62. Las Animas and El Hacha Mountains. " Cordero, reinforced by eighty-five men from San Elizario, veered his course to the west into the Las Animas and El Hacha mountains. His men saw no Apaches but Apaches saw them and burned off the grass around the water holes, thus depriving the Spanish horses of much pasturage."

100. Griffen, Ibid, 1988a:63. Bacoachi, Sonora. "Nonetheless, by late 1789 the Chiricagui population at Bacoachi in Sonora had reached over two hundred souls, and some Gilenos and Sierra Blanca Mescaleros had made peace in New Mexico."

101. Griffen, Ibid, 1988a:168. Santa Rita del Cobre, Southern New Mexico. " Following these events, Santa Ritans could see a great flurry of activity among the Apaches who sent up huge smoke signals and did other things that made it look as if many people were coming into the area."

102. Griffen, William B. 1988b. Utmost Good Faith Patterns of Apache-Mexican Hostilities in Northern Chihuahua Border Warfare, 1821-1848. University of New Mexico Press, Albuquerque. 337 Pp. . P. 59. Carrizal Presidio, Chihuahua. May 8th 1840: "They killed six warriors, captured seven women and six children, and took twenty-one horses and mules, six barrels (four with liquor), and a few other odds and ends. Before leaving, they burned ten Apache huts."

103. Hadley D. and T.E. Sheridan. 1995. Land Use History of the San Rafael Valley, Arizona (1540-1960). Rocky Mountain Forest and Range Experiment Station. General Technical Report, RM-GTR-269. 279 Pp. . P. 66. San Rafael Valley. "Forty-niners attributed abandoned settlements and mining sites to Apache raiding. San Lazaro, where extensive mining and smelting activity had taken place, had been abandoned a few years earlier after a particular intense Apache attack in which over 1,000 head of cattle were stolen and many buildings burned" (Hunter 1849:114).

104. Hadley and Sheridan. Ibid, 1995:68. San Rafael Valley. "In April 1866, Chiricahua warriors again attacked the San Rafael Ranch, forcing owner Rafael Saavedra and his servants into the main house. When the Apaches set the buildings on fire..."

105. Harris, Benjamin Butler. 1960. The Gila Trail: The Texas Argonauts and the California Gold Rush. Norman: University of Oklahoma Press. 175 Pp. P. 73. 1849, Between Agua Prieta, northern Sonora, and the Santa Cruz Valley, southeastern Arizona. "As we passed, tall ranges of timbered, table-top mountains loomed as a distant wall on the right, from which streams ran Pacific

wards and from whose distant summits Indians continually sent up sky-reaching signal smokes, telegraphing our movements."

106. Harris, Ibid, 1960: 73-75. 1849, Southeastern Arizona, Huachuca Mountain Foothills. "Indians continually sent up sky-reaching signal smokes, telegraphing our movements. The sun was about to rise when twelve men in front and ten in the rear charged the Indian ranchería, expecting each moment to slay the tenants as they rushed forth. The wigwams of thatched grass were soon ignited. Our approach had been observed. Bucks, squaws, and families had had time to get a mile away, up the steep slope (Santa Cruz Peak ?) with all their horses except one American mare and thirty-nine cows having Spanish brands, fresh lance marks. And tender feet---proven they had recently been stolen and driven there."

107. Hayes, Alden C. 1992. Cochise Quarterly 21(4): 8-27. P. 20. Cathedral Rock, east side of Chiricahua Mountains, southeastern Arizona. "As soon as we moved they commenced building signal fires along the cliffs in the direction we were going.. The signal fires convinced me there were more Indians in the direction we were going, and I was anxious to get going as speedily as possible."

108. Holsinger, S.J. 1902. The Boundary Line Between Desert and Forest. Forestry and Irrigation 8: 21-27. Pp. 23-25. Pg 23: "These prehistoric aborigines must have exerted a marked influence upon the vegetation of the country. Their fires, and those of the historic races, unquestionably account for the open condition of the forest, to which reference has been made." Pg 23-24: "The most potent and powerful weapon in the hands of these aborigines was the firebrand. It was used alike to capture the deer, the elk and the antelope, and to vanquish the enemy. It cleared the mountain trail and destroyed the cover in which their quarry took refuge." Pg 24: "Were it not for the long Indian occupancy and the ravages of fire incident to their habitancy, vast territories now barren desert wastes might be covered with a forest growth." Pg 25: "The forests within their domain, where they have not seen fit to apply the torch in accord with their well-grounded superstition that forest fires cause rain, show a regrowth gradating into many past decades."

109. Hough, Walter. 1901. Apache and Navajo Fire-Making. American Anthropologist 3(3): 585-586. Pp. 585-586. Central Arizona. "While among the White Mountain Apache last summer the writer had opportunity to collect interesting details with regard to fire-making. Having procured dried flower stalks of *Yucca bacata*, and Apache visitor to our camp was asked to make fire with them. Without leaving his squatting-place on the ground, he took the sticks, selected the tapering upper portion of one of the stalks for a drill, polished off the inequalities formed by the leaf scars, and rounded the lower end by means of a sandstone picked up at his feet. The thicker portion of the stalk was chosen for a hearth. Another small stone, also picked up from the ground, having a rounded corner about the size of the end of the first finger, was ground against the hearth and soon reamed a cavity suitable for the reception of the end of the drill. A moment's search on the ground within a foot or so brought to light a bit of flint, which was used to saw the groove leading from the cavity down the side of the stick. Then he sank a

stone to the level of the ground in order to insure stability for the hearth, set the hearth with the cavity over the stone, took the drill between his palms, and twirled out fire in the shape of a glowing coal held in the groove of the hearth. Reaching out, he picked up a piece of dry dung, broke it in two, knocked the coal between the pieces, blew it a moment, and the fire was assured. No attempt at speed was made, but the Indian maintained that with sticks of his selection he could have a blaze started in the time necessary for a match to burn out. As the 'Alligator' match, a slow but sure sulphur variety used in this part of the world, will probably last for three quarters of a minute, the statement by the Apache seems plausible. The late Captain John G. Bourke stated that the Apache can grind out fire in ten seconds. The operation of fire-getting as noted here is refreshingly primitive, being carried on as though the white man had never existed.. When given a match to light their cigarettes, Apache women preserve fire against exigencies by igniting a little bunch of grass or leaves near where they sit."

110. Howard, Oliver O. 1907. My Life and Times Among Our Hostile Indians. Hartford, CT: A.T. Worthington & Co. 570 Pp. P. 199. Dragoon Mountains, s southeastern Arizona,. "All the day, under Ponce's direction, we were setting five fires in circular order. This meant peace and five comers. We watched in vain for a responsive smoke."
111. Howard, Ibid, 1907:193-194. Peloncillo Mountains, southeastern edge of Arizona, on way to Apache Pass and the Dragoon Mountains. "There were no trees of any size, but here and there were some resinous shoots, straight and tall, having glade-like leaves, with the firmness of a cornstalk. Chie set eight of these, ranging in a large circuit, - then to eight more, and repeated the operation; the fire would shoot up quickly and leave a peculiar little cloud of black smoke. I asked: "What does he do that for?" Ponce answered: "Paz, humo paz," that is, peace, peace smoke."
112. John, Elizabeth, A. 1975. Storms Brewed in Other Men's Worlds; the Confrontation of Indians, Spanish, and French in the Southwest, 1540-1795. Texas A & M University Press, College Station. 805 Pp. P. 94. Northern New Mexico Puebloans. "Governor Juan Francisco Trevino (1675-1677), who dispatched soldiers to seize the leaders, confiscate their religious paraphernalia, and burn their kivas."
113. John, Ibid, 1975:86. New Mexico. "Raiders swept New Mexico in 1640, burning an estimated 50,000 bushels of corn, essentially wiping out the provincial stores."
114. John, Elizabeth, A. 1984. A Cautionary Exercise in Apache Historiography. Journal of Arizona History 27:301-315. P. 306. Northern Frontier, Provincias Internas. "From these heights they command and inspect the plains, to which they do not descend without careful reconnaissance, making no fire by day because of the smoke, nor by night because of the light, avoiding movement in groups in order not to raise dust nor mark the trail ."
115. Kroeber, Clifton B., and Bernard, L. Fontana. 1986. Massacre on the Gila: An Account of the Last Major Battle Between American Indians, with Reflections on

the Origin of War. Tucson: The University of Arizona Press. 232 Pp. Pp. 6-8. Maricopa Wells, near present-day Sacaton, south-central Arizona, near the confluence of the Gila and Santa Cruz Rivers. "Below the place he [Isaiah Woods] was sitting, a short way to the north, he noticed a bonfire. Then another, and still another. The burning grass and limbs poured thick white smoke into the morning sky. Signal fires, he thought. But signaling what.. Still more bonfires blazed, each a hundred yards or more from the others. The sound of shouting voices came from the direction of the fires.. people could be seen running. Then it became clear. The flames were leaping from the Maricopa's dome-shaped brush houses that had been set to the torch. The Maricopa's villages had been attacked by other Indians and a battle was taking place!"

116. Lieutenant Rucker Cavalry Report Jan. 14th 1877. Cited in Wilson, J. P. 1987. Merchants, Guns, and Money: The Story of Lincoln County and Its Wars. Santa Fe, Museum of New Mexico Press. . Chiricahua Mountains. "The hostile camp consisted of 16 lodges containing about 35 warriors. The captured property brought into camp Bowie has been identified as belongings to portions of the Chiricahua Indians who formerly lived on this reservation, forty six horses and mules were captured, also a large quantity of blankets, calico, manta, clothing, camp utensils, and large quantities of dried meat, mescal, & c. (etc.). All the property which was deemed impractical to be carried off was destroyed by fire."

117. Lockwood, Frank C. 1938. The Apache Indians. New York, Macmillan & Co. 348 Pp. Pp. 60-61. Southeastern Arizona. "He [the Apache] had his own sign language, too, and his highly effective telegraph system.. He had perfected a system of smoke signaling over wide spaces that was swift and most effective. Both Cremony and White give details concerning the war craft of the Apache in trailing and communicating by smoke signals."

118. Manje, Captian Juan, Mateo. 1693-1721. Unknown Arizona and Sonora 1693-1721, from the Francisco Fernandez del Castillo Version of "Luz de Tierra Incognita. Translated by Harry J. Karns, 1954, Tucson, Arizona. 303 Pp. P. 65. Pimeria Alta. He had been placed on the hill. He did not see the father and the soldiers leave town, but he saw the flames of fire, so he crossed the mountain and ran the distance of 10 leagues to the mission of Dolores. While Father Kino and I were eating, the Indian arrived with his hair disheveled, crying and saying that the enemy, the Pimas, had burnt Father Agustin and the squad of soldiers alive, burnt the house and everything."

119. Manje, Ibid, 1954:126. Cocospera, Sonora. "On the 13th we went south. After 16 leagues we camped at the pueblo of Cocospera, where in 1698 the Apaches attacked and burnt the town. Father Pedro Ruiz and the Indians defended it valiantly as long as they could, but the enemy having set fire to the house, his reverence and the Indians were obliged to flee for their lives."

120. Manje, Ibid, 1954:66. Pimeria Alta. "Generala Don Juan Fernadez de la Fuente and Don Domingo Teran de los Rios arrived with troops under their command and entered the rebellious nation of the Pimeria. The three companies together

destroyed all the fields (with fire, my emphasis) and supplies, thus punishing some of the accomplices."

121. Manje, Ibid, 1954:97. Cocospera, Sonora. "On March 30, of this same year, 1698, about 500 enemy Indians came back to destroy and burn the settlement of Santa Cruz de Jaybanipitca de Pimas. Taking the people by surprise early in the morning, they took away all their corn and small jewelry, hiding their loot in the mountains. The enemy burned all the houses."
122. Manje, Ibid, 1954: 249. On March 30, 1698, Santa Cruz de Gaybanipitea. "The vowed enemies, the Hocomes, Sumas, Mansos, and Apaches, who between great and small numbered about six hundred.. showed their arrogance by attacking the ranchería at daybreak. They killed its captain. nd forced them to retreat to their fortification. But the enemy, defending themselves and covering themselves with many buckskins, approach the fortification, climbed upon its roof, destroying it and burning it. They (Apaches) sacked and burned the ranchería. nd began to roast and stew meat and beans. In the meantime the news reached the neighboring ranchería of Quiburi. its captain, El Cora, came to the rescue of his brave people, together with other Pimas who had come from the west to barter for maize. Thereupon (after a 10 Pima against 10 Apaches staged battle of warriors game) all the rest of the enemy began to flee, and Pimas followed them through all those woods and hills for more than four leagues, killing and wounding more than three hundred."
123. Miles, Nelson A. 1896. Personal Recollections and Observations of General Nelson A. Miles: Volume 2. Lincoln: University of Nebraska Press. 591 Pp. P. 452. Near Nocasari, Sierra Madres, northern Sonora, Mexico. "By day small fires were built of dry wood to avoid smoke, and at night they were made in hidden places so as to be invisible."
124. Miles, Ibid, 1896: 491-492. South of the Patagonia Mountains of southeastern Arizona, in the Sierra Madre. Exact location not given. "Most of the country had been burned over leaving no grass, and water was so scarce that the troops frequently suffered intensely."
125. Miles, Ibid, 1896: 467. About ten miles south of the border on the San Bernardino River in northern Sonora, Mexico. "I was ordered to return, February 5, to Mexico and look out for the hostiles, who had agreed to signal their return. I camped about ten miles south of the line on the San Bernardino River, and remained there until the 15th of March, when a signal was observed on a high point about twenty miles south."
126. Miles, Ibid, 1896: 517. None given, but occurred in northern Sonora, Mexico, at base of Sierra Madres. "At other times they [the Apaches] would set fire to the grass and bushes."
127. Miles, Ibid, 1896: 480-481. A general statement, hence southeastern Arizona and northern Mexico. "they could signal from one mountain range to another.. As to their being able to signal by the use of fire and smoke and the flashes of some bright piece of metal for a short distance, I thought we could not only equal, but far surpass them in a short time.."

128. Moorhead, Max, L. 1968. The Apache Frontier: Jacobe Ugarte and Spanish-Indian Relations in Northern New Spain 1769-1791. 309 Pp. P. 104. Northern New Spain. "Reglemento de 1772, which required that the troops wage an incessant war on the hostiles (Apache Indians) attacking them whenever possible in their own camps."

129. Moorhead, Max, L. 1969. The Soldado de Cuera: Stalwart of the Spanish Borderlands. Journal of the West. 8:38-55. P. 46. Northern New Spain, Borderlands. "Until 1729 it was customary for each trooper to maintain a string of ten horses. Then the first reglamento specified six horses and one mule, and the new Reglamento in 1772 required the same plus an additional colt. Even with this number, owing to losses suffered from fatigue, heavy snows, severe droughts, stampedes, and especially theft by the Indians, the armored trooper needed at least three horses a year for replacements."

130. Moorhead, Ibid, 1969:52. Northern New Spain, Borderlands. "The grand expedition directed by Commandant inspector Hugo O'Conner in 1775 involved approximately 1,300 troops and lasted four months. It killed 130 enemy warriors, captured 104, (mostly women and children), and recovered 1,966 head of stolen livestock, all with the loss of only one soldier. On the other hand, a smaller-scale campaign undertaken in 1782 by Colonel Ugalde with 240 men and lasting 112 days killed only five of the enemy and captured only thirty-seven. However, it also released six of the enemy's captives and recovered approximately 500 horses and mules. In a single engagement in 1788, Lieutenant Jose Manuel Carrasco with a contingent of eighty-five troops fired a total of 1,761 rounds at a hostile band of Apaches four times his own strength in rugged-mountain terrain. Although the lieutenant was able to report that he had wounded a "large number" of the enemy, he could claim only five killed."

131. Moorhead, Ibid, 1969:47. Northern New Spain, Borderlands. "Those presidios which formed the outer (northern) line of defense against Indian invasions were most often situated in desolate terrain. They were remote not only from convivial town life but also from essential supplies. In 1780, when harvests throughout Sonora were drastically reduced by drought, the men of some presidios had to go out like Indians in search of wild fruits. Grain had to be brought in from such distances that the freight cost more than the commodity itself, and some of the troops and their families at Santa Cruz de Terrenate and Fronteras actually died from hunger."

132. Moorhead, Ibid, 1969:39. Northern New Spain, Borderlands. "Each company (sodados de cuera) was responsible for maintaining a daily patrol of one-half of the terrain between its garrison (presidio) and that of its nearest neighbor on either side, often fifty or more miles in each direction. When this operation failed to prevent an attack on an interior settlement, the company had to dispatch a special force to intercept the marauders, punish them, and recover the booty. It also had to furnish its quota of troops for general campaigns into enemy territory. These were launched every year and lasted about four months each until the 1780's, when they were stepped up to one every month for a shorter duration."

133. Moorhead, Max, L. 1975. The Presidio, Bastion of the Spanish Borderlands. University of Oklahoma Press, Norman. 288 Pp. P. 46. "In effect, the Reglamento of 1729 did little more than call attention to the loose practices of the past and adopt, in principle, a uniform code for the presidios."

134. Opler, Morris, Edward. 1941. An Apache Life-Way: The Economic, Social, and Religious Institutions of the Chiricahua Indians. The University of Chicago Press, Illinois. 500 Pp. P. 347. Chiricahua Apache Range. "If a group agrees that when they get to a certain place they will make a smoke signal, the others watch for it. None is made except on agreement. It has to be used during the daytime. Sotal is used to make these smoke signals. For signal smoke a fire is built, and damp wood and grass are put on; this makes a smoke that can be seen for great distances. Whenever the Chiricahua see smoke from a long distance, they know something is happening. The smoke always means something, usually there are enemies or that there is an epidemic. If it means the first the smoke is from a mountaintop. If it means sickness, it comes from camp in a valley. If one party of men sees another in the distance, it lights a fire to the right of it and sends up one column of smoke. This means, "Who are you?" If the other group builds a fire to its right and send up one column of smoke it means we are Chiricahua and friends."

135. Opler, Ibid, 1941:358. Chiricahua Apache Range "Onions are eaten raw or boiled with other vegetables and meat. Later (Late summer) at least two other kinds are gathered. In the early part of the growing season, too, especially when other food is scarce, the woman strips off the bark of the Western yellow pine, scrapes its inner surface, and heaps together the soft sweet material."

136. Opler, Ibid, 1941:355. Chiricahua Apache Culture. "Besides the four seasons, six time periods, beginning with the first signs of spring, divide the year. There names, in order are: 'Little Eagles,' 'Many Leaves,' 'Large Leaves,' 'Large Fruit,' 'Earth is Reddish Brown,' and 'Ghost Face.' By late fall the hills assume a color for which the term, 'Earth is Reddish Brown' seems appropriate."

137. Opler, Ibid, 1941: 394. Chiricahua Apache Ethnoecology. "We take a little stick of wood about eight or ten inches long. It has to be good solid wood and dry. It might be juniper or sotal. It is shaved thin--to about the thickness of a pencil. It does not come to a real point at the lower end but is rather blunt there." "We have a flat piece of wood made of sotal stalk or yucca. It is thin. When it is used for the hearth, it has to be about eight to ten inches long. The one who is going to work the drill make a little hole or notch in which to put it at the start, so it won't slip around. This little whole can be at the center or at the edge. If the drill goes right through the hearth without a fire being made, the person can start a new notch. We go to a juniper tree and get the bark, and get some dry grass too. We keep these tied to the set and keep the whole thing dry. When using the drill, we put the grass or shredded bark around the hole, and some of it in the hole too. If we can't get a fire quickly, we put just a pinch of dirt or sand in the hole. As a man twirls the drill between his hands, the smoke comes up. Sometimes the tinder blazes up. If it doesn't blaze but you see that you have a

good spark, you take the stick out of the hole, push the grass close together, and blow on it until you get your fire." "All you need is two sticks and your tender. These two sticks are wrapped together and carried around, for these are the matches of the Chiricahua, you know. They are carried in a bag tied to the belt or in the quiver when the men are on a journey. Dry manure is used to catch the spark sometimes. Some men can get fire in a very few turns, but some blister their hands trying to do it and give up."

138. Naylor, Thomas H., and Polzer. 1986. The Presidio and Militia on the Northern Frontier of New Spain; a Documentary History, Volume One: 1570-1700. The University of Arizona Press, Tucson. 756 Pp. P. 543. Southwest Borderlands, Chiricahua Mountains. Captain Ramirez de Salazar, El Paso, April 12th, 1685 "The apostates and their allies then fled toward the Rio del Norte (Grande). His lordship ordered the rancherías and all the Indians' belongings burned" pp. 543

139. Naylor and Polzer, Ibid, 1986:543. Southwest Borderlands, Chiricahua Mountains. Captain Roque Madrid, El Paso, Janos, April 13, 1685, in response to Suma revolt of 1684: "during the campaign all the Indian rancherías, camps, and watering places were scoured."

140. Naylor and Polzer, Ibid, 1986:640. Southwest Borderlands, Chiricahua Mountains. Captain Juan Mateo Manje (1693-1721), April 6, 1694 "the soldiers of the compania volante set out on an expedition to punish the pride and the continuous thefts of horses by the common enemies, the Apache, Jacomes, (and) Janos."

141. Naylor and Polzer, Ibid, 1986:585. Southwest Borderlands, Chiricahua Mountains. Domingo Terán de los Ríos, Domingo Jironza Petriz, Juan Fernández de la Fuente, Order dated May, 9, 1695 "during the past eight months concerning the destruction, thefts, killings, and ambushes of the enemy in the different pueblos of the province of Sonora and the war of fire and blood they have waged on all the frontiers. We have seen how the Janos, Jocomes, Mansos, Sumas, Chinarras, and Apaches have united."

142. Naylor and Polzer, Ibid, 1986:651. Southwest Borderlands, Chiricahua Mountains. "On September 28, 1695, we were still at this watering place of the Springs of San Simón. The corporals told us they had searched all the springs, entrances, and canyons of both sierras (Chiricahua and San Bartolomé Mountains) neglecting nothing. In the canyon were the enemy had made peace with us last July, they saw the crosses we had set up as a sign that the peace was secure. They kept the peace only as long as our weapons were present. For these reasons we felt that war should be made against them with fire and blood, just as they do and have been doing for the last fourteen years."

143. Naylor and Polzer, Ibid, 1986:640. Southwest Borderlands, Chiricahua Mountains. Generals Don Domingo Jironez Petriz and Teran de Rios in the Chiricahua Mountains Sept. 16th, 1695. " We saw heavy smoke rising from the canyon at the head of this arroyo, we knew that the thirty-six troops under the command of lieutenant Antonio de Solis who had left the night before were in combat, because they had been told to send us a smoke signals."

144. Naylor and Polzer, Ibid, 1986:542. Southwest Borderlands, Chiricahua Mountains. Captain Ramirez de Salazar, 1680s "In conformity with his orders, the witness attacked the enemies in their rugged stronghold. The battle was fierce and waged with fire and blood"

145. Naylor and Polzer, Ibid, 1986:592. Southwest Borderlands, Chiricahua Mountains. "On the 29th of June, 1695,...were located at the Chupaderos de las Lágrimas de San Pedro (thought to be dripping springs, eastern Chiricahuas). ...we found more than forty separate ash mounds with beds of grass around each one. Since the tracks and hot ashes were very fresh we asked the Indian captive when the enemy had been there.... "

146. Nentvig, Juan, S.J. (1713 -1768), 1764. Rudo Ensayo: A Description of Sonora and Arizona in 1764. Translated by A.F Pradeau, and R.R Rasmussen. The University of Arizona Press, Tucson. 144 Pp. P. 124, 92-93. Fronteras, Sonora. "We shall start with the presidio at Fronteras, also known as Santa Rosa de Corodéhuachi, 32 degrees, 10 minutes latitude, 265 degrees, 46 minutes longitude. It was the first and only presidio in Sonora from 1690 to 1740. The Jocomes, Sumas, Janos, and Apaches rose in revolt in 1686 and attacked Santa Rosa, an Opata village eight leagues north of Cuquiárachi, on May 10, 1688, and Cuquiárachi itself on June 11, 1689, forcing Opata populations to withdraw to Corodéhuachi. The missions of Cuquiárachi, established in 1660, Santa Rosa and Cuchuta, both established in 1686, and the dependent mission of Teras were more and more frequently the victims of the incursions of the four tribes mentioned for nearly ninety years. The fifteen soldiers from the presidio of Sinaloa who had been stationed at Teuricachi for three years were moved to the beautiful site of Corodéhuachi. in 1690 or 1691.""Cocóspera is a dependent mission of Soamca twelve leagues southwest of Terrenate....attacked by Apaches on February 16, 1746, and its church burned down." "Also, it would be well to repeople the Santa Rosa de Corodéhuachi Mission in the vicinity of the royal presidio of Fronteras. If these two places were populated, it would impede the Apache incursions into the province of Sonora from the east as well as the west." (Santa Rosa de Corodéhuachi Valley gave its name to the mission which was abandoned about 1752 and the fort, more commonly referred to as fronteras). The most warlike of all the Pima are those we call the Sobaipuris, for they are born and reared on the border of the Apaches; but they have become tired of living in constant warfare, and have, during the present year of 1762, abandoned their beautiful and fertile valley..."

147. Officer, James E. 1987. Hispanic Arizona, 1536-1856. The University of Arizona Press. 462 Pp. P. 119. Calabasas. "In January, 1830, the hostile Indians attacked Calabazas, where they burned buildings and raided the San Pedro Ranch, stealing large numbers of livestock."

148. Officer, Ibid, 1987:249-250. Tucson. "They killed another civilian on the north side and gravely wounded a second, while driving off the livestock: cattle, horses, mules, and oxen. They (Apaches) burned a sack of wheat and plundered a nearby ranch house."

149. Officer, Ibid, 1987:36. Santa María Soamca. In November, 1751: "The rebels (Pimas) caused extensive damage at San Xavier and Guevavi, burned the church and the priest's home at Tubac, and killed eleven Spaniards and some friendly Natives in the Arivaca area."

150. Officer, Ibid, 1987:149. Canoa Ranch, Tubac. "The Ortiz family apparently did not actually live on their Canoa grant after the 1830s, although they continued to run cattle there.. Later, the Apaches also burned the house they occupied within the Presidio (Tubac)."

151. Officer, Ibid, 1987:47. Santa María Soamca. November, 1768. "The following month, the Apaches besieged and burned the mission of Santa María Soamca."

152. Ogle, Ralph H. 1939. Federal Control of the Western Apaches, 1848-1886. New Mexico Historical Review. XIV: 309-365. P. 328. San Carlos Apaches. "The Apache practice of burning the property and wickiup (frequently a village) of a tribesman who died, although done for superstitious reasons, was an excellent health measure."

153. Ogle, Ibid, 1939:363. Chiricahua Apaches and Mountains, October, 1865. "A strong command in October successfully defended the Verde settlements against two hundred raiders and killed five of them. Almost simultaneously Cochise's band was struck in the Chiricahua Mountains and rendered hors de combat for the rest of the winter."

154. Opler, Morris, E. 1969. Apache Odyssey: A Journal Between Two Worlds. Case Studies in Cultural Anthropology. Holt, Rinehart and Winston, New York, New York. 301 Pp. P. 20. Apache Culture. "However, game was usually hunted by men, singly, in pairs, or in small groups, who depended mainly on a knowledge of the habits of the animals and a familiarity with their haunts and watering places."

155. Opler, Ibid, 1969 :214. Apache Lightning Culture. "Sickness is said to occur when lightning strikes too close. Here the shaman is attributing the anger of lightning to the use of ceremony by the sick boy's father at an inappropriate time. The Mescalero stop work, stop eating, and pray respectfully during a violent lightning storm."

156. Padre Luis Velarde. 1716. Padre Luis Velarde's Relacion of Pimeria Alto, 1716. R.K. Wyllys (Ed.). New Mexico Historical Review. April, 1931. 7:111-157. P. 138-139. Pimería Alta, Chiricahua Mountains. "Informer years, before there were padres here and when all were gentiles, the Sabaipuris had the last communication with the Apaches of the Sierra of Chiguacaqui (Chiricahuas), and much later since then, the Captain Ramiriz (Zevallos) in good style and without bloodshed separated them. The Pimas are valiant and daring, as is proven by the wars which the Sobaípuris and the rest of the Northern tribes have maintained against the Apaches... Their arms are clubs, bow and arrow....when they go on a campaign... Killing a good number by following them into the hills, or in campaigns accompanying the mounted soldiers of the presidio of this province. Although the Pimas wish to return to peace and communication, they have not.... for the Apaches have occupied the pass on the Rio Gila where the road is"

157. Park, Joseph, F. 1962. Spanish Indian Policy in Northern Mexico, 1765-1810. Arizona and the West 4:325-44. P. 230, 231. Southern New Mexico, Santa Fe, Gila. "General Ugalde led an army of four hundred soldiers and Apache scouts on a six-month campaign into the Pecos River region, and in 1787 concluded treaties with the Lipan and Mescalero Apaches. Spanish troops drove scattered bands into the region west of Santa Fe, where in 1787 General Ugarte struck the Apaches in their rancherías. To induce his soldiers to greater exertions, he offered a bonus for each pair of Apache ears they took during battle or while on patrol. This practice later led to the offering of scalp bounties by the civil and military authorities in Chihuahua and Sonora. By 1790 the principal Gileno groups had agreed to settle near the Spanish presidios. From 1790 to 1810, frontier towns experienced new life, churches were built, and prospectors began exploring for precious metal."

158. Park, Joseph, F. 1961. The Apaches in Mexican-American Relations, 1848-1861: A Footnote to the Gadsden Treaty. Arizona and the West 4:129-344. P. 130. Upper Rio Grande; Fronteras, Sonora. "For example, following the Pueblo uprising of 1680 along the upper Rio Grande, Captain General Jironza Petriz de Cruzate marched against the eastern Apaches who had resisted the missionizing influence and who had agitated the Pueblos to revolt. He destroyed their corn fields and rancherías and drove the majority of the hostile bands into the mountains of eastern Arizona, only to see them begin raids into Sonora. Jironza was transferred to the Valley of the Turicachi to command the Compania Volante de Sonora in Corodéhuachi (Fronteras), and from this point he forced the marauders north to southeastern Arizona. There, these restless bands stirred the Pimas and other tribes to the west to rebellion, forcing the Spaniards in 1694 to send expeditions to the Huachuca Mountains to prevent a general uprising."

159. Pfefferkorn, Ignaz. 1949. Sonora, a Description of the Province. Translated and Edited by Theodore E. Treutlein. Vol. XII. Albuquerque, University of New Mexico Press. P. 198. Most likely northern Sonora, Apache and Seri country, but Hastings and Turner say these are Pimas. "In various places in Sonora there are large areas covered with [sacaton]. This thick brush is infested with large numbers of rats and mice which the Sonorans sometimes hunt. Twenty or thirty and sometimes more Sonorans assemble and surround a given circle of brush. They start fires, setting the dry brush ablaze in a circle, and the animals hidden therein are forced to take flight. As the fire advances, the animals retreat more and more to the center and the Indians in turn close the circle on them."

160. Pfefferkorn, Ibid, 1949: 39-40. Most likely northern Sonora, Apache and Seri country, but Hastings and Turner (1965) say these are Pimas. "It is the custom at this season [June and July] to burn the dried-out straw which remains lying on the field after the threshing. It often happens also that on their expeditions through the country the Apaches and Series, as well as the herdsmen, light fires on the mountains to roast their meat. Because these are not extinguished before their departure, the fires spread easily and without resistance in the high grass, which is generally dried out by the heat of the sun at this time of year [June and

July], seize on trees which standing the way, and often cause a frightful conflagration. One thing and another fills the air with fiery vapors and increases the heat, which is great enough without this."

161. Salmon, Roberto Mario. 1979. No Hope of Victory: Pineda's 1791 Report of the Apache Frontier. Journal of Arizona History 20(3): 269-282. P. 274. Generally northern Mexico. "They [Apaches] build no fires by day because of smoke, nor by night because of light emitted."
162. Simpson, Lesley B. 1952. Exploitation of Land in Central Mexico in the Sixteenth Century. Berkeley, University of California Press. P. 3. Between Mexico City and Guadalajara, Mexico. "the savannas and pastures along the road had been fired, which is done so that new grass will come up for the sheep as soon as it rains, and for almost all the two and half leagues the Father Commissary was beset by smoke from both sides of the road."
163. Smith, F.J. 1993. Captain of the Phantom Presidio: A History of the Presidio of Fronteras, Sonora, New Spain 1686-1735, Including the Inspection by Brigadier Pedro de Rivera, 1726. The Arthur H. Clark CO. Spokane, Washington. 217 Pp. P. 86. Fronteras, Southwest Borderlands. "My dear sir: On January 24, 1725, God was served in taking out the bodies which were in pieces which caused compassion. It is the providence of the Lord that those escaped who did, because not only were there 100 Indians, but more than 200 by the torches and rancherías they had about a shot's distance from the road; fourteen or fifteen men had gone back for provisions or there would have been more deaths. Fronteras, January 26, 1725, Your faithful servant who kisses your hand, Juan Antonio Durán (Signed)."
164. Smith, Ibid, 1993:91. Fronteras, Southwest Borderlands. "Bandera (Alcalde Mayor Don Miguel Alvarez de Bandera) looked at Lázaro's (Domingo) wounds on the left side below the hip bone. They were undoubtedly made by an arrow. Lázaro said he was in Huerta's house about nine o'clock Saturday night, September 29 [1725]. He was unable to say who wounded him, for flaming arrows were shot through the window which had no bars or anything to stop them. One of them hit him. He alleviated the pain somewhat by pulling the arrow out. Then he stayed inside to put out the fire which was raging everywhere, when the wooden roof covered with mud and straw and fell in. The attackers had thrown a torch on top of it, and he was afraid of the smoke and fire."
165. Smith, Ibid, 1993:113. Fronteras, Southwest Borderlands. "Only occasionally did their superiors order them to follow the enemy Apaches to retrieve stolen horses. During the eighteen years the captain had served he led campaigns only three times. On these three occasions they owed the good results to their friends, the Pimas, for helping them in the rugged mountains."
166. Smith, Ibid, 1993:132-133. Fronteras, Southwest Borderlands. "To keep the enemy from penetrating the frontiers, Rivera ordered the army to patrol constantly the passes and areas where hostile Indians entered. He ordered patrols to be distributed among the soldiers proportionately and equally so that permanent watchfulness would not be burdensome. He added that in making forays against

the enemy the captain and officials must use forethought in furnishing sufficient provisions, arms and horses. Rivera urged the greatest caution in passing through the places the enemy frequented. In addition to continuous vigilance the sentinels should search the fields before moving the horses from one pasture to another. The all-knowing, ever-present Apaches always took advantage of the least movement of the soldiers. On occasion, because of carelessness, some Spaniards had been surprised and killed. When the enemy Indians were found in the interior, Rivera urged the new captain of Fronteras to advise the captain of Janos immediately and to enlist his aid. Likewise, he ordered full cooperation with the other presidios in similar situations. Rivera's emphasis was on holding the present frontier line rather than in making campaigns into the Apache strongholds."

167. Smith, Ibid, 1993:115. Fronteras, Southwest Borderlands. Although they went out on campaigns against the Apaches they couldn't sustain their pace and engage in action, for they needed food. Thus their efforts were failures; in eleven years Joseph had seen their captain leave on two campaigns only, although there were urgent occasions which he ignored.

168. Smith, Ibid, 1993:131. Fronteras, Southwest Borderlands. "Because the enemy Indians used long lances, longer than the three-foot Spanish dagger, Rivere concluded the natives had a greater advantage. Therefore, he ordered the soldiers to use and practice with the lances longer than those of the enemy. He warned, however, that the lances should not be so long that the impeded the handling of the horses. Rivera also recommended a short, wide sword instead of a long, narrow dagger now in use because of greater ease of use on horseback. One of the most important clauses in the revised regulations directed that each soldier must have six horses in good condition at all times, ready for sallies and engagements with the enemy, which called for strength and vigor."

169. Smith, Ibid, 1993:115. Fronteras, Southwest Borderlands. "Although they went out on campaigns against the Apaches they couldn't sustain their pace and engage in action, for they needed food. Thus their efforts were failures; in eleven years Joseph had seen their captain leave on two campaigns only, although there were urgent occasions which he ignored."

170. Smith, Ralph, A. 1962. Apache Plunder Trails Southward, 1831-1840. New Mexico Historical Review 37:20-42. P. 31, 32. Sonora, Chihuahua. " The failure of the Mexicans to provide allowances and rations led to frequent Apache raids from 1833 through 1835." "In despair Sonora returned to the old Spanish policy of buying Indian scalps and ears on September 7, 1835."

171. Stevens, Robert, C. 1964. The Apache Menace in Sonora 1831-1849. Arizona and the West. 6: 211-222. P. 219. Sonora. "By 1835 numerous haciendas and rancherías in northern Sonora had been abandoned. It was reported by one Sonoran official that some 5,000 persons had lost there lives in the early 1830s because of the raids. If this figures is accurate, it means that from five to ten per cent of the Sonoran population were casualties during these years."

172. Sweeney, E. R. 1991. Sweeney, E. R. Cochise: Chiricahua Apache Chief. University of Oklahoma Press, Norman, Oklahoma. 501 Pp. P. 214. Chiricahua Mountains, July 24th, 1863. "About two weeks later a detachment of California Volunteers commanded by Second Lieutenant John Lambert left Las Cruses and entered Cook's Canyon at 5 a.m. on July 24th. The allied Chiricahuas were ready and opened fire, wounding a sergeant and killing a private. After driving the Indians back, Lambert circled his wagons, which probably saved lives because the Apaches, estimates at between 150 and 250 warriors, were concealed in ambush. After five hours of skirmishing the Indians tried to set fire to the grass, which failed to ignite."

173. Sweeney, Ibid, 1991:90. Chiricahua Mountains, March 22, 1852. "The next morning, the Mexicans moved along the foothills of the western side of the Chiricahua Mountains, took a short siesta, and continued on to Bonita Canyon in the Chiricahua Mountains, where they camped. That evening they noticed Indian fires above the canyon. Consequently, Escalante sent out a small scouting force, who reported that the slopes were crawling with Apaches. At dawn the next morning , March 22, 1852, three hundred to four hundred Chiricahua warrior attacked the Mexican force at Bonito Canyon."

174. The Weekly Arizonan, May 15th, 1869. The Weekly Arizonan. Between Camp Grant and Tucson. "The sergeant in charge seeing that it would be utter madness to contend further against a party of Indians whose number had now increased to over three hundred. Ere the escaping party lost site of the Indians in the distance, they discovered the flames and smoke rising from the burning wagons and freight."

175. Thomas, Alfred B. 1932. Forgotten Frontiers: A Study of the Spanish Indian Policy of Don Juan Bautista de Anza, Governor of New Mexico 1777-1787. The University of Oklahoma Press, Norman. P. 254. Sierra la Florida. "According to the news which may be reported by the detachments mentioned, either by fires which the pagans commonly make when they are attacked or discover our troops in their lands.

176. Thomas, Ibid, 1932:209. San Simon, Chiricahua Mountains. "About nine, Lieutenant Don Pablo Romero turned up, explaining that he had encountered no Indians nor any signs of them on his whole march, but had found a cave which they had walled. He ordered it opened, revealing in it various things for the use of the Apaches, hides, leather, mescal, maize, and seeds which they steal. Both soldiers and Indians took procession as much as they could, leaving what they could not carry."

177. Thomas, Ibid, 1932:237. Moqui, Gualpi, and Oraibe Pueblos. " The causes which have contributed to the extermination of these pueblos or provinces, all its natives agree, have been hunger and pestilence, the first because it has not rained since the year (17) 77, and from that has resulted the second. To this may be added the war which the Utes and Navajos make upon them cruelly."

178. Thomas, Ibid, 1932:37. Rio Grande, Southern New Mexico. "The journey there was without incident, aside from heavy snowstorms and the discovery of some indian fires in the foothills, signals from one band to another.

179. Thomas, Ibid, 1932:283. Southwestern New Mexico; Unknown, but along the route to "El Cobre" in 1785. "I came out of the sierra when it was already night and halted without water. From there I noticed many fires in the Sierra de Las Burras. During the morning I continued keeping near the slopes of this sierra the route to el Cobre. I discovered on arriving at one of the canyons a considerable number of Indians discharging muskets from above. Having already without doubt learned of the other detachment from the many smokes and trails that had come from those directions they had entered this sierra with horseherds and stock."

180. Thomas, Ibid, 1932:288. El Picacho (Cooke's Peak), Las Burras Mountains, likely in northern Sonora. "But noting at midday a smoke which was raised on the Sierra of Las Burras, I set out on the road with forty men including Lieutenant Don Manuel Rengel and Ensign Don Juan Juarez. He reported to me that a large smoke having been sent up on El Picacho of Las Mimbres [Cooke's Peak], those of Las Burras were communicating with others, the ones I had seen."

181. Thomas, Ibid, 1932:274. Southwestern New Mexico, Sierra la Florida, Sierra Burros, Mimbres, and Cobre. "The division was discovered by the Apaches from the Sierra de la Florida. They showed themselves various times in the sierras of El " Cobre, Mimbres, Burras, and others, but in lands so advantageous that the command would have been exposed in any attempt to sally out upon the rocks and rough heights where they were. For this reason, because they had already given warnings with fires that the troop was marching in their countries and because of the weak condition of the horse, Martínez undertook his retreat, suffering on it a violent snow storm which took great toll of the animals."

182. Thomas, Ibid, 1932:198. 51 leagues south of Santa Fe along the Rio Grande on the Camino Real. "From ten in the morning until the end of the afternoon, a cloud of smoke was observed five leagues distance along the way we were traveling. It was inferred from the smoke that the fire was made by our common enemies, to advise each other, as they are always accustomed, that we were along this road."

183. Thomas, Alfred, B. 1941. Teodoro de Croix and the Northern Frontier of New Spain, 1776- 1783. University of Oklahoma Press, Norman. 273 Pp. P. 31-32. Santa Cruz. In 1777 Teodoro de Croix received a report from the presidio troops stationed in Santa Cruz, still located on the San Pedro River: "the captain of Santa Cruz presidio reported its crops burned, the settlers' houses fired, and the settlers scattered."

184. Thrapp, Dan, L. 1967. The Conquest of Apacheria. Norman, University of Oklahoma Press. 405 Pp. P. 132. Baby Canyon [perhaps Little Squaw Creek near Gilette], near Agua Fria, near the Bradshaw Mountains. "On January 19 [1873], to the northwest, [Sergeant William L.] Day, again in command of a small unit, ignored signal smokes that said the hostiles knew of his presence."

185. Thrapp, Ibid, 1967:135. Bloody Basin, perhaps near the Bradshaws or the Mazatzals in central Arizona. "Randall became very discreet in his movements, moving his column after night, and watching during the day while the best of his scouts slipped through the tangled brush.. here, however it was dangerous, for the [mules] fell into the hands of the hostiles, who excitedly sent up signal smokes, alerting bands for scores of miles."
186. Thrapp, Ibid, 1967:67. Valley just northeast of Pinal Mountains, south-central Arizona. "From it [Signal Peak, highest point in the Pinal Mountains], the command on the evening of June 4 [1870] saw a smoke rising like a dust-devil from a valley to the northeast. The Indians had apparently believed they had thrown off pursuit."
187. Thrapp, Ibid, 1967:137. Near Camp Verde, and the Tonto Basin, central Arizona. "In the first week of April a deputation from the hostile bands reached Camp Verde, and expressed a desire to make peace; they were told to return for the head chiefs, with whom General Crook would talk at that point. Signal fires were at once set on all the hills, scouts sent to all places where they would be likely to meet.."
188. Thrapp, Ibid, 1967:244. East Doubtful Canyon, near Stein's Peak at the southern Arizona, New Mexico border. "Forsyth moved his men toward the enemy, who fired the grass and brush, creating an enormous smoke cloud as screen to their movements. major Wirt Davis opened the attack, charging through the blazing grass and brushes, and rounding up a number of the hostiles' ponies."
189. Thrapp, Ibid, 1967:49, 51. Walapais Valley, Arizona. "He and his men hid in a ravine that night, careful to light no fire, keep the animals quiet and the men equally so. Sleep was out of the question; besides a cold north wind was blowing a gale, and the little party dare not kindle a fire."
190. Thrapp, Ibid, 1967:268. Somewhere between the Swisshelm Mountains and Tombstone. "Leslie, about a half mile from camp [near Swisshelms], barely beat the Indians in [to Tombstone], he and [Captain Charles] Young standing off a siege at the ranch house all afternoon. The raiders fired the grass, hoping to burn them out, but without success."
191. Thrapp, Ibid, 1967: 73-76. Santa Cruz Mountains, southern Arizona and northern Sonora. "May 1st [1871].. About an hour after Mr. Kitchen left Lieut. Cushing and myself noticed that the grass was being set on fire and concluded it was done by Indians as a signal to their fellows in the mountains; but I have since learned that when about two miles from the command Mr. Kitchen saw some thirty or more Indians on our trail and burned the grass to warn us.. May 4th left camp, marching over a broken and rocky country.. grass very scarce owing to the country around having burned for several days.. May 5th.. arrived at old Camp Wallen, A.T., at which place Lieut. Cushing intended to camp, but finding the grass all burned off and still burning, concluded to march to Bear Springs, Whetstone Mountains."

192. Thrapp, Ibid, 1967:281. Oputo, northern Mexico. "Betzinez says that the fight took place near Oputo, and was brought about by a furious grass fire that poured a towering column of smoke that served as a beacon. This brought the Mexicans."
193. Thrapp, Dan, L. 1974. Victorio and the Mimbres Apaches. Norman, OK: The University of Oklahoma Press. 393 Pp. P. 72. Apache Pass, Dos Cabezas Mountains, southeastern Arizona. "the occupants [of the stage] reported that in a narrow canon they found the road obstructed with a large quantity of hay, probably placed there to be fired on the approach of the coach to stop it an afford light to enable then to shoot the occupants."
194. Thrapp, Ibid, 1974:241. General statement for southern Arizona and New Mexico. "As Crook pointed out, one might frequently engage in "battles" with the Apaches and never see one, only the puffs of smoke revealing their location."
195. Thrapp, Ibid, 1974:174. Southern New Mexico. "Information of the Chiricahua disturbance had promptly reached Victorio's people, of course, and "many of them have left," Shaw reported a week later. Earlier he had demanded more troops as a precautionary measure, and these provoked "great fright and fires at once blazed on all the mountain tops and caused great alarm."
196. Thrapp, Ibid, 1974:291. South of Ft. Craig, located on the Rio Grande, south of the Magdalena Mountains and east of the San Mateo Mountains, central New Mexico. "Parting with Maney, Crawford rode south, loosing smoke signals from hilltops, hoping to catch the eye of the band we were hunting, hoping that the signs would be returned. They were not."
197. Thrapp, Ibid, 1974:242. Near Cuchillo Negro, south of Canada Alamosa, directly south of the San Mateo Mountains, central New Mexico, west of the Rio Grande. "Gatewood graphically describes the hard scouting necessary to find and keep the hostiles' trail.. daring to build only tiny fires lest smoke or glow warn the enemy."
198. Thrapp, Ibid, 1974:13. Southern New Mexico. "Relatives and older men told him what to take, how to conduct himself.. to travel only by night unless in the mountains.. and the proper use of smoke signals. These intriguing devices were not, as some would have it, a primitive semaphore, but rather an announcement of some fact such as one's location or the location of friends, or an order to bring in comrades or, with other related signs, to muster strength."
199. Thrapp, Ibid, 1974:302. Tres Castillos, in Chihuahua, northern Mexico. "At about 10:00 P.M., some leagues to the south, a sudden blaze flared up while the entrapped Indians gathered brush, the only combustible material on the mountain, and kindled a response."
200. Tidball, Captain. 1877. Cited in Wilson, J. P. 1987. Merchants ,Guns, and Money: The Story of Lincoln County and Its Wars. Santa Fe, Museum of New Mexico Press. Chiricahua Mountains, 1877 military reconnaissance by Captain Tidball. "Five months before this American expedition, a rather large military party of Mexicans from Sonora surprised an Apache camp in the Chiricahuas, probably in Turkey creek, killing several men, women and children. All great cañons through which we passed between this point (Potrero) and Apache Pass, were formerly

favorite resorts of the Indians (Apache), as their numerous old "peels" indicate; A mescal pit was found within four hundred yards of my camp, from which the roasted mescal had been drawn. It was a mere chance that we saw any of these Indians at all, as the heavy rains...prevented their mescal fires from being seen. As soon as we moved they commenced building signal fires along the cliffs in the direction we were going. Here I found several huts which had been occupied within a few weeks by a small party of Indians."

201. Tucson Daily Citizen, November 15, 1933. Pp. 1. Chiricahua Mountains, southeastern Arizona, Pinery Canyon on April 13th, 1883 "After a while, I saw two Indians down on the floor of the canyon, pulling dry grass and piling it in a horseshoe shape around the ridge I was on. They lit the fire, and the smoke was soon billowing up upon me. In a little while, when the fires came close I decided to run through it."

202. Velasco, Francisco, D. 1861. Sonora: Its Extent, Population, Natural Productions, Indian Tribes, Mines, Mineral Lands, Etc., Etc. Translated by W.M. Nye. H. and H. Bancroft and Company, San Francisco. 173 Pp. P. 163. Sonora. " They burn the bodies of their dead."

203. Velasco, Ibid, 1861:172. Sonora. " At Bacanuche they (Apaches)..drove all the livestock belonging to the place; at Tetuachi they burned all the buildings...At Tucson they drove off all the cattle in sight of the inhabitants."

204. Velasco, Ibid, 1861:162. Sonora. "Occasionally several rancherías, or settlements, are united at the same place, either for the purpose of war or hunting. When they mediate an attack upon their enemies, the tribes contiguous to each other assemble generally in the most inaccessible parts of the mountains, and appoint their bravest warrior as chief, to carry out their plan of operations. In these cases it is forbidden to light a fire, and sentinels of tried vigilance are posted at every point of exposure."

205. Velasco, Ibid, 1861:167. Sonora. "Their hunting parties are often large---men, women and children attending them. Their plan is to encircle a tract of land four to six leagues in circumference, and then set fire to the grass: frightened animals fly in all directions, and fall an easy prey to the expectant hunters."

206. Velasco, Ibid, 1861:165. Sonora. "They obtain fire from two kinds of wood, called sosole and lechugilla."

207. Velasco, Ibid, 1861:168. Sonora. "On the 19th of March, 1846 the Apaches murdered thirteen persons, and burned the houses in both places (Rancho de Metatitos and Bamuri), carrying off four hundred and fifty horses, some of them of great value."

208. Wheeler, G.M. 1878. Report Upon United States Geographical Surveys West of the 100th Meridian. Vol. 1. Topography. Washington, DC, Government Printing Office. Little Colorado River, central Arizona. "For a little less than 2 miles the grass is of the old crop, then begins the new and juicy growth of the year subsequent to the burning over by fires set by Indians."

209. Worcester, Donald E. 1979. The Apaches: Eagles of the Southwest. Norman: The University of Oklahoma Press. 389 Pp. P. 138. Base of the Dragoon Mountains,

southeastern Arizona. "They crossed the Chiricahua Mountains and the San Simon Valley to the foothills of the Dragoons. Several times during the day Chie and Ponce built five fires in a circle, to indicate that five men came in peace."

210. Worcester, Ibid, 1979:31. General statement relevant to the southern portion of the Southwest. "A smoke signal on the slope of a mountain meant that Apaches were hunting their own people. A signal made on a high place and immediately put out meant for all to prepare to resist approaching enemies. There were many universal signals known to all bands, but some bands had, in addition, special signals of their own. Apaches always carried flint and steel or two prepared sticks for making fire, so they could send messages quickly at any time. They could relay messages two or three hundred miles in a few hours; this made it possible to assemble their scattered camps."

Appendix B:

The most important ethnobotanical food and fiber species of the Southern Apache (Trees and Shrubs).
Post-fire regeneration strategies and fire adaptations obtained from the U.S. Forest Service Fire Ecology and Effects Database (WWW.USDA.Forest Service).

Vegetation Form / Species	Common Names	Post-Fire Regeneration, Fire Adaptations
Tree and Shrub Species		
Acer negundo	Boxelder	Adventitious-Bud Root Crown, Root Suckers, Off-Site Colonizer
Arbutus arizonica	Arizona Madrone	Resprouter, OffSite Seed
Arctostaphylos pungens	Pointed-Leaf Manzanita	Obligate Seeder, Heat Scarified
Cercocarpus montanus	Mountain Mahogany	Adventitious-Bud Root Crown, Seed
Cupressus arizonica	Arizona Cypress	Serotinous Cones
Juglans major	Arizona Walnut	Off-Site Seed
Juniperus deppeana	Alligator Juniper	Resprouter, OffSite/OnSite Seed
Juniperous scopulorum	Rocky Mountain Juniper	Off-Site Colonizer, Off-Site Seed, Secondary Colinizer
J. monosperma	OneSeed Juniper	Secondary Colinizer, Off-Site Seed
Pinus engelmannii	Apache Pine	Fire Tolerant When > 8yrs, On-Site Initial Community, Off-Site Seed
P. leiophylla var. chih.	Chihuahua Pine	Adventitious-Bud Root Crown, Resprouter, On-Site/Off-Site Seed
P. arizonica	Arizona Pine	Fire Tolerant When > 8yrs, On-Site Initial Community, Off-Site Seed
P. cembroides	Mexican Pinyon	Off-Site initial colonizer, Off-Site Seed
P. edulus	True Pinyon	Secondary colonizer, Off-Site Seed
Plantanus occidentalis	Sycamore	Adventitious-Bud Root Crown, Root Suckers, Off-Site Seed
Populus fremontii	Cottonwood	Survivor, Resprouter, Off-Site Colonizer
Prosopis glandulosa	Honey Mesquite	Susceptible < 2.5 Years, Resprouter, Initial Off-Site Colonizer
Pseudotsuga menziesii	Douglas-fir	Off-Site, Secondary Colonizer
Quercus gambelii	Oak Species	Adventitious-Bud Root Crown, Root Suckers
Q. arizonica	Arizona White Oak	Adventitious-Bud Root Crown, Root Suckers, Off-Site Seed
Q. emoryi	Emory Oak	Adventitious-Bud Root Crown, Initial Off-Site Seed
Q. rugosa	Netleaf Oak	Adventitious-Bud Root Crown, Secondary Off-Site Seed
Q. oblongifolia	Mexican blue oak	Adventitious-Bud Root Crown, Secondary Off-Site Seed
Rhus trilobata	Skunkbrush Sumac	Adventitious-Bud Root Crown, Rhizomatous
Grasses		
Bouteloua curtipendula	Side-Oats Grama	Seed and/or Rhizomes
Bouteloua eriopoda	Black Grama	Stolons and Less Often Seed
Bouteloua gracilis	Blue Grama	Rhizomes and/or Seed
Bouteloua hirsuta	Hairy Grama	Rhizomes and/or Seed
Buchloe dactyloides	Buffalograss	Caudex, Heat Tolerant Seed
Eragrostis intermedia	Plains Lovegrass	Basal Sprouts
Hilaria belangeri	Curly Mesquite	Stoloniferous/Seed
Hilaria mutica	Tobosa	Rhizomes and Basal Sprouts
Muhlenbergia montana	Mountain Muhly	OnSite Seed Soil Storage, Basal Sprouts
Muhlenbergia porteri	Bush Muhly	OnSite Seed Soil Storage
Panicum obtusum	Vine-Mesquite	Stoloniferous (Long)
Sporobolus airoides	Alkali Sacaton	OnSite Seed Soil Storage
Sporobolus cryptandrus	Sand DropSeed	OnSite Seed Soil Storage
Sporobolus flexuosa	Mesa DropSeed	OnSite Seed Soil Storage
Sporobolus wrightii	Giant Sacaton	Basal Sprouts
Digitaria californica	Arizona Cottontop	Basal Sprouts, OnSite Seed Soil Storage
Succulent, Cacti, and Yucca Species		
Agave parryi	Mescal	Rhizomatous Offsets, Seed
Agave lechuguilla	Agave	Rhizomatous Offsets, Seed
Dasylirion wheeleri	Sotal	Survivor, Caudex Sprouter
Nolina microcarpa	Beargrass, Sacahuiste	Survivor, Respouter Root Crown or Caudex
Yucca glauca	Soapweed Yucca	Survivor, Rhizomatous Sprouter, Off-Site Seed Colinizer
Y. elata	Soaptree Yucca	Survivor, Rhizomatous Sprouter,
Y. baccata	Banana Yucca	Survivor, Rhizomatous Sprouter,
Opuntia polyacantha	Cholla/ Prickly Pear	Survivor, Secondary Colonizer, Off-Site Seed
Echinocereus spp.	Hedgehog Cacti	High Susceptibility

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