Historical and Modern Roles of Fire in Pinyon-Juniper

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Abstract—Fire history investigations were carried out in three widely separated Great Basin pinyon-juniper woodlands in east-central Nevada, southeastern Oregon and northwestern Nevada, and western Nevada. Study results suggested frequent fires on deep soils that produced an abundance of fine fuels and infrequent fires on shallow soils and rocky sites where fuels were sparse. Decades of intensive livestock grazing and successful fire suppression in pinyon-juniper woodlands have resulted in a shift from low intensity fires to high intensity fires. This shift has been the result of large increases in woody fuels and introduction of exotic grasses. Considering the extent of fuel buildup, severe wildfires in the Great Basin will continue and perhaps become more frequent.

Charred wood and tree stems bearing fire scars indicate that historically fire influenced succession in pinyon-juniper woodlands. Researchers investigating pinyon-juniper ecology have noted the importance of fire as a historic disturbance agent (Arnold and others 1964; Humphrey and Mehrhoff 1958; Miller and Rose 1995; West 1988;). Past fires can be dated by study of fire scars on tree rings. However, in contrast to mixed conifer forests where fire-scarred ponderosa pine (*Pinus ponderosa*) or Jeffrey pine (*P. jeffreyi*) are common; the relatively low number of fire scars in pinyon-juniper woodlands and their restriction to sites that did not readily burn, limits our ability to accurately determine fire history (Gruell 1997a). The few fire history studies carried out in pinyon-juniper woodlands show variations in fire frequency. Young and Evans (1981) concluded that between 1600 and 1850, there were periods of up to 90 years that western juniper (*Juniperus occidentalis*) growing on low sagebrush (*Artemisia arbuscula*) sites of northeastern California showed no evidence of fire scars. Burkhardt and Tisdale (1976) reported average fire intervals of less than 20 years in climax western juniper on the Owyhee Plateau of southwestern Oregon. Chappel (1997) reports a mean fire interval of 50 years for four pinyon-juniper sites on Monroe Mountain south of Richfield, Utah and she considered this to be a conservative estimate of the fire interval.

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Study Areas and Methods

Between 1990 and 1997, I investigated fire frequency in pinyon-juniper woodlands at three widely separated localities of the Great Basin. They included Great Basin National Park in east-central Nevada, Hart Mountain-Sheldon Refuge complex in southeastern Oregon and northwestern Nevada, and the Walker River Watershed Project area in western Nevada. Fire-scarred pinyon (*P. monophylla*), Utah juniper (*J. osteosperma*) and western juniper were cut with a chainsaw following careful search of study areas. Surfaces of cross-sections were later sanded smooth and annual rings were counted under magnification to determine the approximate year of scarring. This procedure did not include dendrochronological cross-dating as described by Stokes and Smiley (1968). The fortuitous presence of ponderosa or Jeffrey pine provided a unique opportunity to collect more definitive data in each of the study areas. Ponderosa and Jeffrey pine are excellent recorders of fire since they are long-lived, fire resistant, have clear annual growth rings, and occupy sites that were fire susceptible.

Great Basin National Park

This study entailed removal of fire scars from 23 pinyon and three juniper in four locations representative of variations in pinyon-juniper woodlands in Great Basin National Park (GBNP), a 30,840 ha (77,100 acre) portion of the South Snake Range in east-central Nevada (Gruell and others 1994). Increment coring of 73 pinyon was also carried out to determine the approximate ages of post-fire regeneration.

Intact fire scars were found on or near 16 of 20 macroplots that had previously been established for purposes of classifying Potential Native Plant Communities (Eddleman and Jaindl 1994). Although singleleaf pinyon, Utah juniper, and curlleaf mountain-mahogany (*Cercocarpus ledifolius*) all showed scarring, pinyon yielded the best scar samples. The probability of locating sound fire scars was low because: (1) a majority of trees in the study area were too young to bear scars of pre-1900 fires, (2) most trees old enough to bear fire scars were growing in the protection of boulders or on sites where fuels were sparse (areas unlikely to burn), and (3) some fire scars had been destroyed by carpenter ant excavations.

Hart Mountain and Sheldon Refuges

The historic influence of fire on plant succession, plant communities, and wildlife habitat was studied during 1994-95 at Hart Mountain National Antelope Refuge (HMNAR), Oregon and Sheldon National Wildlife Refuge (SNWR), Nevada (Gruell 1995). These refuges are situated in the volcanic plateau region of the Great Basin. Vegetation composition in this shrub steppe community is dominated by mountain big sagebrush (*A. tridentata* subsp. *vaseyana*). Western juniper covers less than 4 percent of the area. Field studies included aging of curlleaf mountain-mahogany and western juniper, collection of fire scars from trees, and repeat photography.

The opportunity to evaluate historic fire frequency on HMNAR and SNWR was severely limited by the scarcity of trees that survived and recorded past fires by scarring. Analysis of 36 multiple scarred aspen provided no definitive information on fire return intervals. Only nine trees were old enough to have recorded fire before 1880. Of these, two were scarred. Six trees were scarred in the 1890's, apparently by causes other than fire.

Insight on the frequency of historic fires was made possible by the presence of scarred ponderosa pine in a 12 ha (30 acre) stand growing in association with western juniper at Blue Sky on the lower east slope of Hart Mountain. No other ponderosa pine occur on the refuges excepting scattered individuals at high elevations at HMNAR and several trees in an isolated stand growing on bare mineral soil at SNWR. The Blue Sky stand is almost entirely composed of second-growth (Simonson 1975) that regenerated following cutting of nearly all trees in 1866-67 by the U.S. Cavalry for construction material and fuel at Fort Warner (Shaver and others 1905). A few large pines were not cut, including a "catfaced" tree with multiple scar wounds. A cross-section was removed from this tree and from a stump that contained multiple fire scars.

Walker River Watershed Project Area

This study was conducted in the Walker River Watershed Project (WRWP), an area encompassing 157,100 ha (392,750 acres) inclusive of the east slope of the Sweetwater Mountains, the Pine Grove Hills, and the west slope of the Bodie Hills (Gruell 1997b). Pinyon dominates the landscape. Scattered juniper is intermixed with pinyon, being primarily found on south slopes and dry sites at lower elevations.

A collection of fire scars from 22 pinyon and Jeffrey pine was made during June-July 1997 in the Little Frying Pan and Desert Creek drainages of the Sweetwater Mountains, Nye Canyon and a nameless canyon on the northeast side of Bald Mountain in the Pine Grove Hills, and the Masonic Gulch area in the Bodie Hills. Random searches were made until three or more trees bearing fire scars were located. The size of the search area varied according to fire scar availability. Few fire-scarred pinyons were found in areas where the trees were young (less than 130 years of age). Those bearing fire scars were widely distributed on fire resistant sites. Except for two trees in isolated stands in the Pine Grove and Bodie Hills, fire-scarred Jeffrey pine were confined to the Little Frying Pan drainage where scattered stands grew on sites susceptible to fire. Trees with well-developed scars were sampled by removing a cross-section from each with a chain saw. Between four and nine samples were collected from each area.

Emphasis was placed in the Little Frying Pan area because the Jeffrey pine intermixed with pinyon and juniper exhibited a high complement of fire scars. Although Jeffrey pine grows in association with pinyon-juniper on the lower east slope of the Sierra Nevada, they are not normally present in Great Basin woodlands. Six fire-scarred Jeffrey pine (four live trees and two stumps) and three pinyon were sampled. Although the cambial ring year of the stumps was unknown, historical accounts (Kerston 1964; Paher 1970) suggest these trees were cut in the 1860's. An 1868 cutting date was assigned to the stumps after synchronizing their most recent fire scars with those on nearby live trees (Arno and Sneck 1977).

A master fire chronology was developed for the Little Frying Pan area according to the geographical position of sample trees. Questionable fire years were adjusted with those considered to be the most probable years of scarring (Arno and Sneck 1977). The probability of false rings, missing rings, and the deteriorated state of counting surfaces reduced the accuracy of ring counts on portions of some samples.

Thus, the fire history statistics are considered reasonably accurate, but no exact. A master fire chronology was not prepared for the Desert Creek, Bald Mountain and Masonic areas because of the minimal number of fire scars on the samples collected.

Three historical photographs taken during the period 1899-1906 were rephotographed in the Bodie Hills and the east slope of the Sweetwater Mountains. These scenes aided interpretations of plant succession by providing visual evidence of composition and structure during early stages of EuroAmerican settlement (Gruell 1997b).

Results

Great Basin National Park

Data and field observations demonstrated that fire played a major ecological role in pinyon-juniper woodlands of GBNP over the past several hundred years. Insight into fire frequency in the 1800's and 1700's within four macroplot complexes was provided by fire scar samples. These data showed a complex and variable fire history that largely took place before 1860. Pooling of 35 datable fire scars revealed that 3 percent of the fires occurred in the 1900's, 76 percent in the 1800's, and 21 percent in the 1700's or earlier. Pre-1900 fire frequencies varied considerably depending on aspect, topography, and ignition source. Apparently fires occurred at close intervals on north-facing slopes, in canyon bottoms, and in other localities where fine fuels were sufficient to carry fire. Quantitative evidence suggested that north-facing slopes in the Snake Creek and Strawberry Creek drainages burned on the order of 15-20 years (Gruell and others 1994). This figure may be conservative considering the low number of scars in the sample.

Close fire intervals were apparently the product of lightning and Indian ignitions. Indians intentionally set fire to vegetation for a variety of reasons including production of grass seed and other food plants, stimulation of willow (*Salix* spp.) shoots used in basket-making, immobilizing crickets and grasshoppers, driving jackrabbits (*Lepus* spp.), clearing campsites, and signaling between bands (Cooper 1961; Gruell 1985; Lewis 1985; Moore 1972; Stewart 1963).

Intentional or escaped fires could have spread from the valley or canyon bottoms to adjacent slopes wherever fuel continuity allowed.

Contrastingly, on rocky landscapes containing localized patches of flammable fuels, it appeared that fires of any appreciable size occurred infrequently. The limited fire scar evidence suggests that fire return intervals were 50 to 100 years or longer. These areas included the drier south-facing slopes and some west-facing slopes on the west and south end of the Snake Range. Under extreme conditions, fire apparently spotted into available fuels, thereby creating a mosaic of burned and unburned landscape.

By design, fire scar sampling was confined to pinyon and juniper trees at previously established macroplots which did not support ponderosa pine. Ponderosa pine was present, however, in some localities at higher elevations where they are associated with pinyon and juniper. Because of ponderosa pine's proclivity to scar, a sample was taken from a stump at about 2,500 m (8,200 ft) on the Lehman Creek Scenic Highway west of Baker, Nevada. This tree had been scarred 8 times in a 124-year period for a mean fire return interval of 18 years. The longest interval was 29 years, while the shortest was 8 years. The locality in which the stump was located had burned periodically as evidenced by charred wood and multiple fire-scarred trees and stumps. These data are consistent with the fire-scarred pinyon, which suggest vegetation occupying deep soils on GBNP burned frequently before settlement by EuroAmericans.

Fire has not been a significant factor in the Snake Range since EuroAmerican settlement. As recalled by Wayne Gonder, a local rancher, the largest fire in the South Snake Range in modern times took place between 1908-1910 covering an area of 80-120 ha (200-300 acres). U.S. Department of Agriculture, Forest Service fire reports during the 29 year period between 1959-1988, show an average of less than 3 fires a year (total 83) suppressed in the Snake Range. Nearly all fires were less than 1 ha, excepting three that were between 4 and 24 ha (10 and 60 acres). Lightning ignited nearly 90 percent of all fires. Although significant fires have not occurred in this century, these woodlands have the potential to fuel high intensity fires during periods of hot temperatures and strong winds.

Hart Mountain and Sheldon Refuges

Collectively, samples cut for purposes of aging included 48 mountain-mahogany, 43 western juniper and six ponderosa pine. Thirty-eight mahoganies at HMNAR averaged 81 years old and ranged between 54 and 109 years. This suggested that current stands were composed mainly of trees that established after 1880. Ten cross-sections removed from varying diameter mahogany growing on deep soils on Badger Mountain (SNWR), showed an average age of 89 years (range 55-137). A previous study that included aging of mahogany on Badger Mountain suggested that tree age ranged from 30-145 years (Tiedemann and Furniss 1985).

Collectively, 94 percent of the juniper associated with mountain big sagebrush were of post-1900 origin. These trees averaged 82 years old (range 59-110). Junipers associated with low sagebrush exhibited a greater average age (143 years) and greater variance in age (range 63-289 years) compared to juniper associated with mountain big sagebrush. These data suggest that fuels on the more productive big sagebrush sites supported a fire regime that burned more often than that in low sagebrush where fuels were light and discontinuous. Hence, tree encroachment of big sagebrush communities was inhibited, while on low sagebrush sites that burned infrequently and at low intensity, trees were able to persist.

Analysis of the scar data from Blue Sky showed that the two sample trees had recorded a total of 9 fires within an area of less than 20 ha (50 acres) during the 101-year period 1760-1861. This suggested a composite mean fire-return interval of 13 years (Arno and Sneck 1977). Fire intervals ranged from 3 to 32 years. This record appears conservative considering the limited number of old pine (greater than 200 years of age) that had potential to record fire before EuroAmerican settlement. It was also likely that the two trees sampled did not unerringly record every fire because of variations in fuel loading. Furthermore, the cross-section from the scarred stump did not contain a complete record of the original fire scars due to rot.

The short mean fire interval indicated by the Blue-Sky data suggested grass dominance on deep soils. Recent prescribed fires in the vicinity of Blue Sky demonstrate the potential for dominance of a grass sere following fire in the shrub steppe. Abundant grass fuels would have been receptive to recurrent burning upon being ignited by lightning or Indians. Further evidence of frequent fires in the shrub steppe is indicated by the expansion of woody vegetation since the late 1800's. There is almost a complete absence of snags, stumps, and charred wood within existing stands of pine, juniper, and mahogany growing on deep soils. Had woody vegetation comprised significant cover historically, residual material would be very apparent in these tree stands today. Substantial increases of juniper and mahogany on HMNAR and SNWR was also documented by retake of five historical photographs (Gruell 1995).

Modern wildfire was not a significant disturbance factor on SNWR until 1988 when 840 ha (2,100 acres) burned on Bald Mountain. Between 1945 and 1967, 9 of 10 fires suppressed burned less than 1 acre. One fire in sagebrush reached 40 ha (100 acres). During this era heavy utilization of fine fuels by livestock had essentially removed the potential of fires to spread. Fire occurrence at HMNAR has followed the same trend except that three fires ranging in size from 2,400 ha (6,000 acres) to 6,400 ha (16,000 acres) (the later being an escaped prescribed fire) occurred between 1954 and 1985. A decline in livestock grazing, followed by recent removal of livestock from both refuges has increased the potential for large wildfires. Despite a major suppression effort, 3,000 ha (7,500 acres) of sagebrush and mountain-mahogany burned on Badger Mountain in 1994.

Walker River Watershed Project

The samples from the six Jeffrey pine and three pinyon pine in the Little Frying Pan area produced a 208-year master fire chronology dating from 1687 to 1895. A total of 51 fire scars formed on the nine trees during this period. At least 27 different fire years are represented. Sample trees recorded from 1 to 5 fire scars during each of these 27 fire years. This suggests that fires burned somewhere within the less than 40 ha (100 acre) study area every 8 years. Fire scars on five of the six Jeffrey pine samples suggested extensive burning in 1857. Extensive burning is also indicated in 1864, 1844, 1801, and 1785 when three trees were scarred in each of these years. Fires were particularly frequent during the 1840's, 1850's, and 1860's when 17 of the 51 scars formed.

Fire scarred pinyons in the Little Frying Pan area verified fire occurrence, but were not a reliable indicator of fire frequency. The three pinyon sampled had been scarred one time ea~h, while the six Jeffrey pine carried between 3 and 12 fire scars each (total 48). This marked contrast in fire frequency reflects major differences in fuel loading on sites occupied by pinyon compared to those occupied by Jeffrey pine. The fire scarred pinyons were able to persist in microsites where fuels were sparse, and as a result they seldom were exposed to lethal heat. In contrast the Jeffrey pine grew on productive microsites that supported fine fuels of sufficient volume to carry fire. Moreover, pinyon needle litter is not as combustible as the long-needle litter of Jeffrey pine.

Ten of the 14 pinyon collected in the four sample areas were over 300 years of age, while three exceeded 400 years. Excepting one, these trees recorded only one fire each; this demonstrates an extremely low susceptibility to scarring. A low susceptibility to scarring was also indicated by the length of time since the last fire (range 82-248 years).

The repeat of three photographs taken between 1899-1906 indicated substantial increases in the density of pinyon-juniper in the Walker River Watershed Project (Gruell 1997b). However, they are not considered representative of pre-European settlement conditions. As suggested by the fire history data, the absence of fire for 2 to 4 decades or longer had probably allowed an increase in tree cover by the turn of the century when the original photos were taken.

Pre-settlement fire intervals averaging only 8 years in the less than 40 ha (100 acre) Little Frying Pan study area provide strong evidence that low intensity spreading fires ignited by lighting and Indians were a common occurrence within the WRWP prior to EuroAmerican settlement. The high frequency and apparent low intensity of these fires suggested that they were fueled by abundant perennial grass, the remnants of which are present today. Sites capable of producing contiguous surface fuels, including north slopes, canyon bottoms, and gentle topography were particularly susceptible to frequent fire. The relatively young age of trees and low incidence of charred wood (fragments), the presence of which required burning of heavy fuels, provide further evidence of frequent low intensity fires on these sites. Tree establishment would have been inhibited since trees less than 50 years old are very susceptible to being killed by fire (Young and Evans 1981). Infertile shallow soils and rocky sites seldom burned since they did not produce sufficient fuel to allow fire spread. Thus, the prevailing presettlement fire regime maintained a savanna-like landscape composed of groups and single trees interspersed by large openings with grass being the primary ground cover.

Judging from the presence of down tree trunks, localized stand replacement fires apparently occurred during extreme conditions. These fires appear to have been uncommon, however, because concentrations of down tree trunks are lacking in these woodlands. Fire scar records indicate that pinyon-juniper woodlands of the WRWP were fire maintained until the beginning of EuroAmerican settlement. Soon afterwards fire became infrequent, probably due to removal of light fuels by livestock, and later by aggressive fire suppression.

By the 1930's, fire suppression strategy placed emphasis on aggressive attack of all fires. Since 1960, 266 wildfires have been suppressed in the Walker River Watershed Project area. Ninety percent of these fires have been held under one-quarter acre. Only five of these have been over 40 ha (100 acres). The largest, 360 ha (900 acres), occurred in 1996.

Modern Fire in the Great Basin

USDA Forest Service, Intermountain Region fire reports covering Nevada, Utah, southern Idaho and western Wyoming show an apparent trend. During the 58 year period 1930-1978 there were two years when 40,000 ha (100,000 acres) or more burned in the Intermountain Region. In contrast, in 9 of the past 18 years 100,000 or more acres burn in the Intermountain Region. In 1988 and again in 1994 over 200,000 ha (500,000 acres) burned. Although these data reflect a wide range of fuel types, they show a significant increase in the occurrence of wildfire in the Intermountain Region over the past 76 years.

Fire reports at the Boise Interagency Fire Center, show that many Intermountain Region wildfires have occurred in pinyon-juniper woodlands. In the 15 year period 1970-1985 suppression action was taken on 1,744 of these fires. Twenty-eight reached 40 ha (100 acres) or more. The largest of these was 14,000 ha (35,000 acres). The fire report record for the 1986-96 fire seasons is incomplete. This was a period of many high intensity wildfires. In 1995 and 1996 alone, 24 fires reached or exceeded 40 ha (100 acres). Some of these were between 2,000 ha (5,000 acres) and 6,400 ha (16,000 acres). Fire reports covering suppression actions in a larger area of pinyon-juniper woodlands administered by USDI Bureau of Land Management (BLM) were not available. Wildfire occurrence on BLM lands has paralleled that on lands administered by the Forest Service. Over 100,000 ha (250,000 acres) burned in western Utah in 1996. A majority of these lands are administered by the BLM and include considerable acreage in pinyon and juniper.

Management Implications

The results of fire history studies summarized in this paper suggest that in the presettlement era, fires were common in pinyon-juniper woodlands of the Great Basin. Fire frequency varied greatly because of marked differences in fuel continuity. Fire scar evidence suggests that fire was frequent on soils that supported sufficient fuels to allow fire spread. It was infrequent and did not readily spread on thin soils or rocky sites where fuels were sparse or absent. Considering these variables, it appears that fire burned in irregular patterns, producing a mosaic of burned and unburned landscape. This fire regime was severely altered by EuroAmericans. Many decades of heavy livestock grazing and fire suppression in the Great Basin allowed an enormous increase in density and crown cover of pinyon-juniper (Christensen and Johnson 1964; Cottam and Stewart 1940; Eddleman and Jaindl 1994; Tausch and others 1981; West 1984). Buildup of woody fuels and increase in fine fuels coincident with marked reductions in livestock grazing has resulted in a shift from low intensity fires to high intensity fires. Considering the enormity of fuel buildup, it is evident that high intensity wildfires will continue and perhaps increase. This presents a major resource management challenge.

Fire has played a major role in the ecology of pinyon-juniper woodlands. The challenge facing society is one of deciding whether to treat fire as an essential disturbance agent or as a destructive force that should be suppressed. The ultimate outcome will be decided on the reliability of information that reaches the public. It is likely that a knowledgeable public would support a program that emphasizes fuel reduction by harvesting excess trees and application of prescribed fire in priority areas. Considering long-term costs and resource values, it is abundantly evident that this would be highly beneficial to future generations, both environmentally and economically.

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