

FIRE HISTORY AND WESTERN JUNIPER ENCROACHMENT INTO SAGEBRUSH STEPPE¹

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SUMMARY

The recent expansion of juniper into sagebrush steppe communities throughout the semiarid Intermountain West is most frequently attributed to the reduced role of fire, introduction and overstocking of domestic livestock in the late 1800s, and mild and wet climate conditions around the turn of the century. This statement, however, has limited factual support. Few studies of fire history in the sagebrush steppe have been published, and none that examine the timing of changes in mean fire intervals, introduction of livestock, and coincident climatic conditions with the initiation of postsettlement juniper expansion. This study was undertaken to determine the timing sequence of the postsettlement expansion of juniper, the introduction of domestic livestock, reduction in fire frequency, and optimal climate conditions. We documented the fire history and chronicled western juniper woodlands for a sagebrush steppe in a 5,000 ha watershed in south central Oregon. Records dating the introduction and buildup of livestock during the late 1800s and dates of initial fire suppression were summarized. Western juniper expansion began between 1875 and 1885, with peak expansion rates occurring between 1905 and 1925. The fire record spans 1601 to 1996. Before 1897, mean fire intervals within individual clusters ranged from 12 to 15 years with years between fires varying from 3 to 28. Nearly one-third of the fires in the basin were large and usually preceded by one year of above-average tree-ring growth. Two fire events were recorded in the sparsely vegetated low sagebrush site, 1717 and 1855. The last large fire occurred in the study area in 1870, and the last small fire burned in 1897. The time sequence of wet climatic conditions between 1870 and 1915, introduction of livestock, and the reduced role of fire support the hypothesis that these factors contributed to the postsettlement expansion of western juniper.

INTRODUCTION

A statement we frequently take for granted is: "postsettlement expansion of juniper woodlands in the West is primarily attributed to the introduction and overstocking of livestock, the reduced role of fire, and optimal climatic conditions during the late 1800s". However, only a handful of studies have documented the mean fire intervals in the sagebrush steppe biome, and few, if any, have evaluated the chronosequence of the introduction of livestock, the reduced role of fire, and climatic conditions with the initiation of postsettlement woodland expansion.

Expansion of western juniper (*Juniperus occidentalis*), sagebrush steppe communities in the interior Northwest United States coincides with Euro-American settlement (Burkhardt and Tisdale 1976, Young and Evans 1981, Miller and Rose 1995). Pinyon-juniper woodlands have also expanded during this period in Utah and Nevada (Tausch and West 1988). The current expansion of woodlands is unparalleled to previous expansions, which occurred over the past

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6,000 years (Miller and Wigand 1994). Presettlement expansions occurred during cool wet periods while the current expansion is occurring during a warmer drier period. Current tree densities are also considerably greater than past Holocene expansions based on juniper pollen abundance.

The recent expansion of western juniper began during the late 1800s (Young and Evans 1981, Eddleman 1987, Miller and Rose 1995). The majority of present day woodlands are less than 100 years old (USDI-BLM 1990). Relict *Juniperus* woodlands, historical documents and photographs, pollen and macro fossil data, and the absence of stumps or logs in mountain sagebrush communities indicate presettlement woodlands were considerably less abundant in the West. Old trees are primarily confined to rocky surfaces or ridges with sparse vegetation (West 1984, Miller and Wigand 1994, Miller and Rose 1995). Trees in these locations have the ability to exceed ages of 1,000 years (Miller et al. 1999).

Fire is thought to have played an important role in shaping sagebrush steppe communities and limiting the expansion of juniper in the Intermountain West before Eurasian settlement. In the semiarid region of the Intermountain Northwest, presettlement mean fire intervals between 15 to 25 years have been reported for the mountain big sagebrush community type (Houston 1973, Burkhardt and Tisdale 1976, Martin and Johnson 1979). However, during the last 100 years, the role of fire has greatly declined in these ecosystems. The decline in fire has been attributed to reduced fine fuels through heavy livestock grazing in the late 1800s and to reduced anthropogenic set fires during the nineteenth century (Burkhardt and Tisdale 1976, Miller et al. 1994).

Optimal climatic conditions during the late 1800s and early 1900s may have also interacted with the reduced role of fire and overgrazing by domestic herbivores to accelerate the rate of western juniper expansion into shrub-steppe communities. During this period, winters became more mild, and precipitation increased above the current long-term average conditions (Antevs 1938, Graumlich 1987), which promotes vigorous growth in western juniper.

This study was designed to 1) chronicle western juniper establishment, 2) document pre- and postsettlement mean fire intervals in a mountain big sagebrush community type and 3) determine the proportion of large-to-small fires and evaluate their relationship to growing conditions in years preceding fires. We hypothesized that postsettlement expansion of western juniper woodland was synchronous with the introduction and overstocking of domestic livestock, changes in mean fire intervals, and optimal climate conditions for plant growth.

METHODS AND STUDY AREA

Study Area

The study area was located within the Fremont National Forest in the upper Chewaucan River Basin, 8 km south of Paisley, Oregon. The study unit encompassed 12,000 acres. Vegetation on moderate to moderately deep soils was characterized by mountain big sagebrush with Idaho fescue dominating the north aspects and Thurber needlegrass dominating the south aspects. The low sagebrush/Sandberg bluegrass community type occupied the shallow heavy

clay soils. Associated with these plant communities were juniper trees in varying levels of density. The long-term average precipitation was approximately 15 inches.

Introduction of livestock occurred in the late 1860s in the Chewaucan River Basin (Oliphant 1968). By November of 1873, approximately 4,000 cattle were reported in the lower river basin with several thousand sheep moving in the following year. During the next five years, livestock numbers increased rapidly and peaked at the end of the nineteenth-century. Since 1915 sheep have declined on the forest from nearly 400,000 AUM's (animal unit months) to less than 1,000, while cattle numbers have declined about 30 percent. The USDA Forest Service office in Paisley was established in 1908, which marked the beginning of fire suppression in the study area.

Plant community measurements

Two hundred and fifty points were randomly selected and surveyed in the study area. The major community type (dominant shrub and perennial grass), percent slope, aspect, elevation, stage of transition (Table 1, see page 14), presence or absence of presettlement juniper, old stumps, and logs were recorded. Thirty-two plots were chosen for intensive measurement through a selected random sample to represent the two major community types, low sagebrush and mountain big sagebrush, in various stages of woodland transition.

In 32-circular plots, the juniper density, height, and canopy cover were measured with a radius of 66 ft in mountain big sagebrush and 99 ft in low sagebrush communities. All juniper trees were counted and recorded in 1m height classes. Presettlement trees were also recorded. Tree canopy cover was estimated and all trees were cored or cross-sectioned within each plot to determine aging. The number of standing dead, stumps, and logs were also recorded for each plot.

Fire History

A limited number of small clusters of presettlement ponderosa pine trees were scattered across the study area. Four of these sites contained fire-scarred ponderosa pine trees. Fire history was documented by collecting partial cross sections from three scarred trees within three sites: I, III, and IV, and one cross section from site II. Fire-scarred ponderosa pine trees ranged in age from 275 to 590 years. Cross sections were cross-dated to assign accurate dates to each fire occurrence. Seasonality of fires was estimated from the relative position of the fire scar within the annual ring. We also attempted to determine the occurrence of fire events in the fuel limited low sagebrush / Sandberg bluegrass community. Datable cross-sections from twelve burned western juniper stumps and logs were collected in a general search across the Ennis Butte basin. Tree-ring indices 2 years before and during the year of fire occurrence were compared to evaluate growing conditions preceding and during the year of fire.

Definitions (derived from W. Romme 1980)

Mean fire interval - average time between fires for a designated area during a designated time period; the size of the area and the time period must be specified.

Fire occurrence - one fire event within a designated area during a designated time.

Fire frequency - the number of fires per unit of time in a designated area; the size of the area must be specified.

Fire chronology - a chronological listing of the total fires documented for a designated area, the dates being corrected by cross-dating.

Cross-dating - correcting the chronology determined from an individual tree-ring sample by comparing it with a master tree-ring chronology developed for the area.

RESULTS

Juniper Expansion

Western juniper began expanding between 1875 and 1885 in the Chewaucan River Basin. Tree establishment increased rapidly during the following decades. In the mountain big sagebrush community type, rate of expansion peaked between 1905 and 1915 with generally constant establishment in the open stands through 1995, with the exception of 1935-1945 (Fig. 1). The decline in tree establishment during this period may have been the result of the severe drought conditions during the 1930s. Mean age of trees across the study area was 68 years. Presettlement trees (>130 years) across the study area accounted for less than 1 percent of the total population. The absence of old stumps, logs, and charcoal suggested that presettlement trees have not occupied this community type in the recent past. Woody material may persist in this environment for over 130 years. In the low sagebrush community type, approximately 1.5 percent of the juniper trees measured were greater than 130 years old with several trees sampled exceeding 500 years.

Tree density and canopy cover in closed stands were 4-times and 8-times greater, respectively, than the open juniper shrub steppe stands (Table 2). Saplings were fairly common in open stands but absent in closed stands. Expansion of juniper in open and closed stands across community types began during the same period. However, age-class distributions were different between the closed stands in the mountain big sagebrush types and the open mountain big sagebrush and low sagebrush community types (Fig. 2). Juniper establishment in the closed stands peaked during 1905 to 1915, with 78 percent of the trees establishing between 1885 and 1925 (Fig. 2).

Fire History

Age of sampled, fire-scarred ponderosa pine trees ranged between 275 to 590 years. The fire record we analyzed spanned the period from 1601 to 1996 (Fig. 3). All scars occurred near or at the termination of tree-ring width development, indicating late summer and fall fires. Season of fire events was evenly proportioned during late summer and fall. Before 1871, a fire event occurred somewhere in the study area on an average of every 7.7 years. The number of years between two fire events occurring somewhere in the study area varied between 1 and 19. The maximum hazard function was 45 years (100 percent probability that a fire would occur

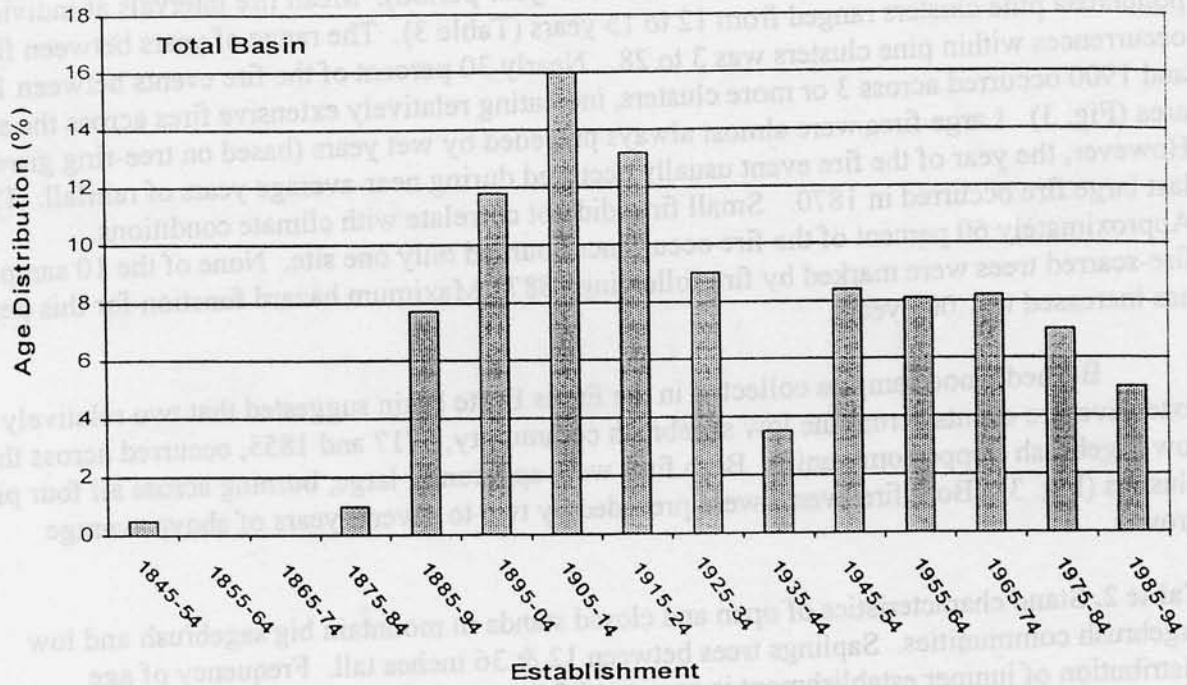


Figure 1. Age structure of western juniper trees by decade across the 32 plots (n=510) within the Chewaucan River basin.

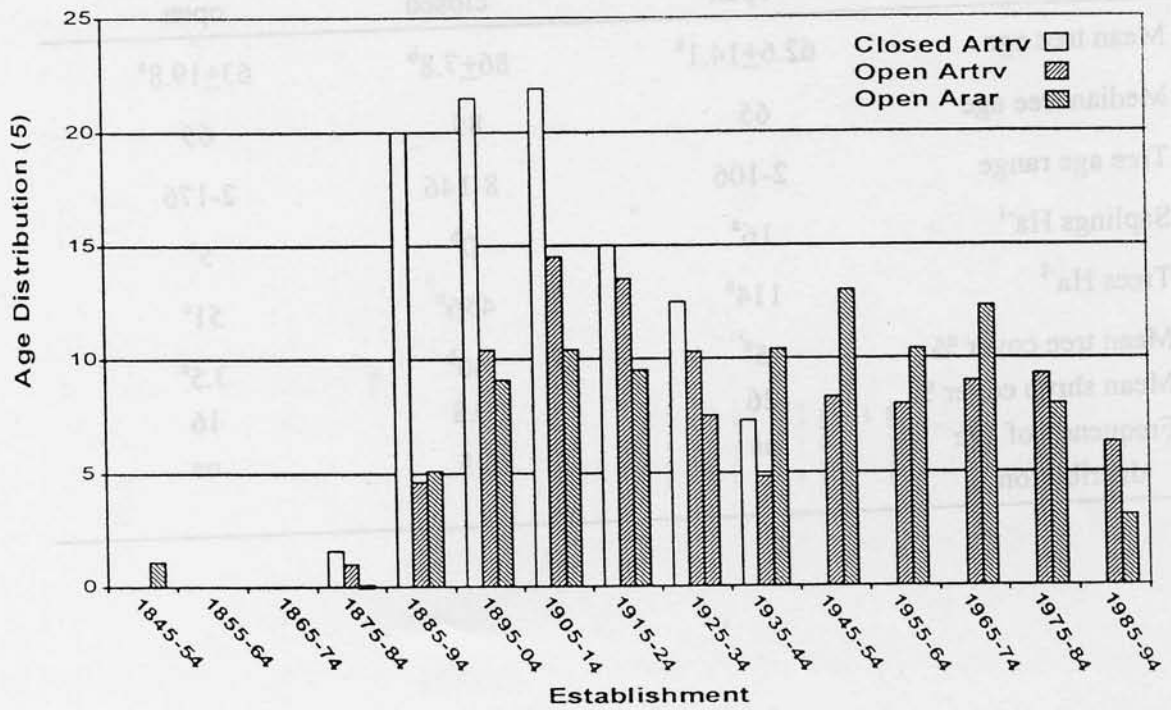


Figure 2. Age distribution (%) of western juniper trees by decade for open low sagebrush (ARAR) (n=88), and open and closed mountain big sagebrush (ARTRV) (n=422).

somewhere inside the study area in less than a 45-year period). Mean fire intervals at individual ponderosa pine clusters ranged from 12 to 15 years (Table 3). The range of years between fire occurrences within pine clusters was 3 to 28. Nearly 30 percent of the fire events between 1693 and 1900 occurred across 3 or more clusters, indicating relatively extensive fires across the study area (Fig. 3). Large fires were almost always preceded by wet years (based on tree-ring growth). However, the year of the fire event usually occurred during near-average years of rainfall. The last large fire occurred in 1870. Small fires did not correlate with climate conditions. Approximately 60 percent of the fire occurrences burned only one site. None of the 10 sampled, fire-scarred trees were marked by fire following 1887. Maximum hazard function for this period has increased to 1,000 years.

Burned wood samples collected in the Ennis Butte basin suggested that two relatively extensive fire events across the low sagebrush community, 1717 and 1855, occurred across the low sagebrush steppe community. Both fires were apparently large, burning across all four pine-clusters (Fig. 3). Both fire events were preceded by two to several years of above average growth.

Table 2. Stand characteristics of open and closed stands in mountain big sagebrush and low sagebrush communities. Saplings trees between 12 & 36 inches tall. Frequency of age distribution of juniper establishment is computed for decades from 1885 through 1995. Rows followed by a different letter are significantly different at the P=0.05.

	Mountain big sagebrush		Low sagebrush
	open	closed	open
Mean tree age	62.6±14.1 ^a	86±7.8 ^b	63±19.8 ^a
Median tree age	65	85	65
Tree age range	2-106	8-146	2-176
Saplings Ha ⁻¹	16 ^a	0 ^b	5 ^c
Trees Ha ⁻¹	114 ^a	456 ^b	51 ^c
Mean tree cover %	5 ^a	40 ^b	3.5 ^a
Mean shrub cover %	26	0.8	16
Frequency of age distribution	ns	s	ns

Table 3. Presettlement mean fire interval computed for the fire period in each cluster where sample size is ≥ 2 (except for site II, $n=1$). The minimum and maximum number of years between two fire events within a cluster are presented as the fire interval range. The mean fire interval and range for the study area indicates a fire occurred somewhere in the study area at a minimum mean fire interval of 7.7 years with years between fires varying between 1 and 19.

Site and Fire Period	Fire Interval	
	Mean	Range
I 1783-1870	12	3-23
II 1654-1870	27	12-54
III 1693-1870	12	4-28
IV 1601-1870	15	6-28
Study Area 1654 - 1870	7.7	1-19

CONCLUSIONS

Western juniper chronicled in the Chewaucan River basin clearly showed major structural change across sagebrush steppe communities since 1875. The most rapid period of establishment in mountain big sagebrush steppe occurred between 1885 and 1925, a period of wetter than average conditions, few fires, and intensive livestock grazing. The start of woodland expansion and its pattern of establishment do not support the hypothesis that rising levels of CO₂ was a primary factor driving 20th century succession of juniper woodland in the northern portion of the Great Basin. Before 1880, fire probably played a major role in limiting western juniper encroachment into these sagebrush communities. Mean fire intervals of less than 15 years were adequate to inhibit western juniper encroachment and probably limit sagebrush cover, allowing the herbaceous layer to dominate the landscape. The co-occurrence of wet climatic conditions, introduction of livestock, and the reduced role of fire do support the hypothesis that all of these factors contributed to the postsettlement expansion of juniper in the West.

Study Area

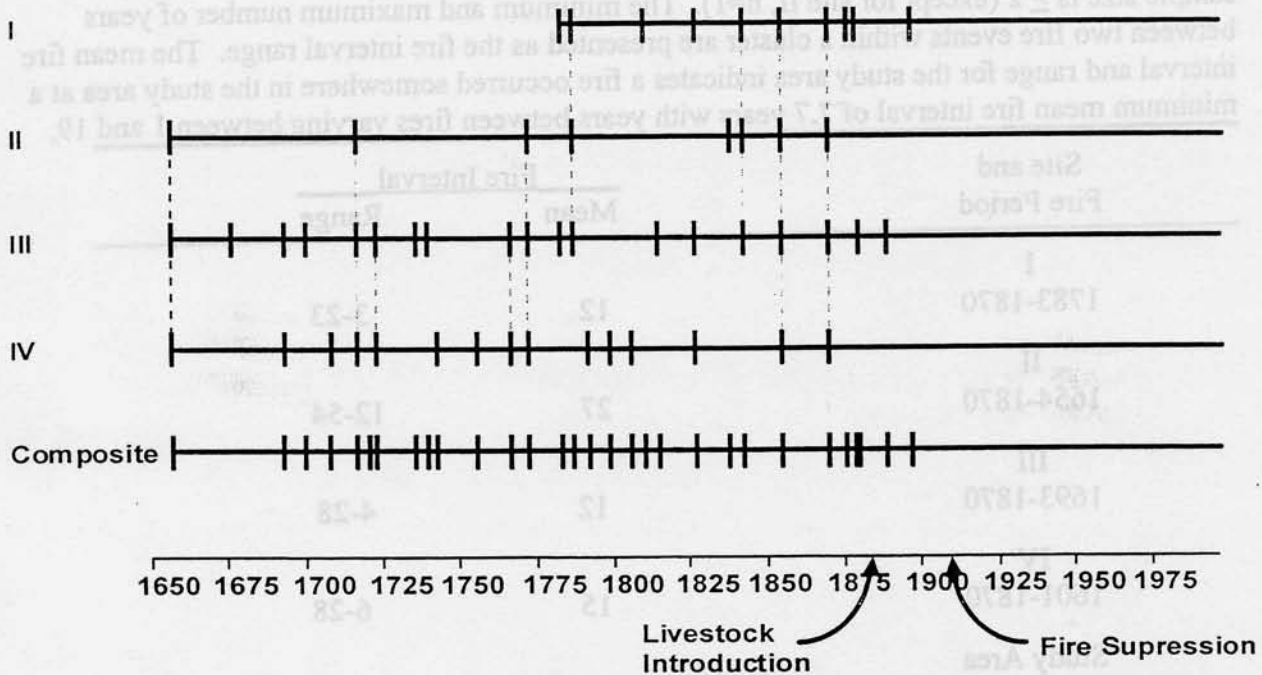


Figure 3. Master fire chronology for the mountain big sagebrush steppe community in the upper Chewaucan River basin. Fire history extends from 1601 to 1996. Each horizontal line represents a sample composite for each collection site with the bottom line being a composite for all fire scar samples across the four sites. Each vertical line designates a fire occurrence. Dashed lines connect collection sites where fires occurred across two or more sites in the same year.

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