Great Basin Naturalist

Volume 46 | Number 1 Article 22

1-31-1986

Tree densities on pinyon-juniper woodland sites in Nevada and California

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TREE DENSITIES ON PINYON-JUNIPER WOODLAND SITES IN NEVADA AND CALIFORNIA

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ABSTRACT.— The densities of singleleaf pinyon and Utah juniper trees in four diameter classes (1–9, 10–19, 20–29, and ≥ 30 cm) were measured on 522 plots of 1/10 ha each throughout the Great Basin. Density distribution patterns of pinyon and juniper varied with aspect, elevation, and eastern (EGB) versus western Great Basin (WGB) locations. On most locations north and, to a lesser extent, west slopes supported higher densities of pinyon than south and east slopes, with high relative densities of small diameter trees on north slopes and large diameter trees on west slopes. Pinyon densities were higher on EGB than on WGB sites and on higher elevation than on lower elevation sites. Juniper densities were higher on EGB than on WGB sites and on lower elevation than on higher elevation sites. Juniper densities on low-elevation WGB sites were higher on south and west aspects than on north and east, with higher relative densities in the 20–29 cm diameter class than in other diameter classes. On low elevation EGB sites, east and south slopes supported higher juniper densities than did north and west slopes, with comparatively higher relative densities in the 10–19 cm diameter class. Differences in relative densities between diameter classes were not significant among aspects on high elevation sites.

Singleleaf pinyon-Utah juniper (*Pinus monophylla* and *Juniperus osteosperma*) woodlands occupy about 7.1 million ha within the Great Basin (Tueller et al. 1979). These woodlands are most prevalent on mountain slopes above sagebrush-dominated (primarily *Artemisia tridentata tridentata*) communities of the valley bottoms. The woodlands may extend to the mountain tops or to the lower edge of high-elevation sagebrush (primarily *Artemisia tridentata vaseyana*) communities. Few studies have recorded the effect of aspect and elevation on tree distribution in mature pinyon-juniper woodlands (West et al. 1978, Tueller et al. 1979, Cooper et al. 1980, Tausch et al. 1981). This paper reports on variations in tree densities by diameter class over four aspects, two elevation classes, and two sections of the Great Basin.

FIELDS METHODS AND DATA ANALYSIS

In 1981 and 1982, the densities of pinyon and juniper trees in four diameter classes (1–9, 10–19, 20–29, and ≥ 30 cm) were determined on 522 plots of 1/10 ha each, on 20 areas in Nevada and California (Fig. 1). Tree diameters were estimated at stump height. Densities were obtained on plots selected for another study in which vegetation on wildfires of various ages and adjacent unburned sites were recorded. Data from 112 unburned woodland sites were combined with data from 410 wildfire sites for analysis. On wildfire sites the number of remnant tree skeletons was recorded to reflect tree densities. The smallest diameter class may be underestimated on burned sites. All wildfire sites were burned within the last 30 years, with 76% of those sites burned within the last 15 years. We sampled only those sites in which pinyon was or had been the dominant species and the understory had been or was assumed to have been (by extrapolation from conditions on adjacent sites) substantially reduced by tree competition. Each plot contained a minimum of 10 trees, 5 with diameter ≥ 20 cm. In each of the 20 areas, tree cores were taken from a minimum of 3 mature dominant pinyon trees on the unburned sites for a total of 91 cores. Plot elevations ranged from 1,585 to 2,280 m, and average slope for each area ranged from 16% to 64%. Estimated annual precipitation for each area ranged from 20 to 33 cm.

Following Cronquist et al. (1972), the sampled areas were divided into three groups—the Reno (or western) section containing 10 sampled areas and 313 plots, the central Great

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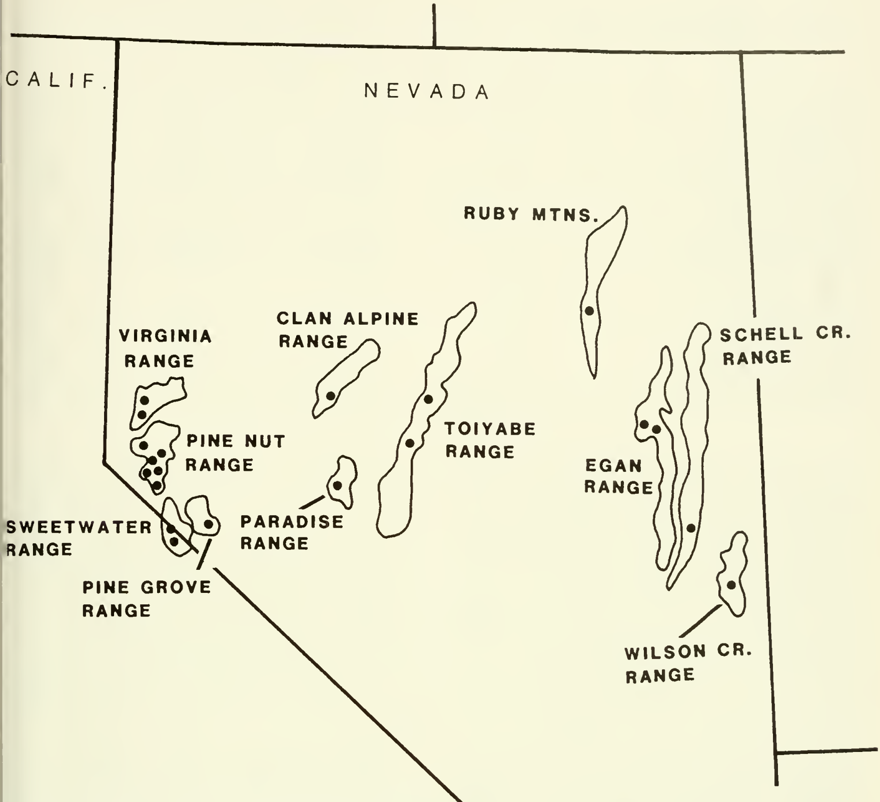


Fig. 1. Location of 20 study sites in Nevada and California.

Basin and Tonapah sections (or central section) containing 5 sampled areas and 117 plots, and the Calcareous Mountain (or eastern Great Basin) section containing 5 sampled areas and 92 plots. Similarity of tree distribution between aspects in the western and central sections on both high- and low-elevation sites justified combining the data from these two sections for analyses (collectively designated as the western Great Basin section).

One-way and two-way analyses of variance were used to compare the number of trees per plot (density) and the percent of the total tree density in each diameter class (relative density) on eastern and western Great Basin sites; on north, south, east, and west aspects; and at high and low elevations. In the eastern Great Basin (EGB), the point selected to differentiate between high and low elevations was 2,160 m compared to 2,040 m in the western Great Basin (WGB). The difference in elevational division reflects sectional differences in woodland belt width and elevational range. The lowest site measured in the eastern section was 2,030 m compared to 1,585 m in the western section.

Results and Discussion

The average age of the pinyon trees in each area sampled ranged from 72 to 159 years. The median age of all pinyon trees sampled was 96 years, with 51% of the trees sampled falling within the 70–110-year age group. Age differ-

TABLE 1. Comparison of tree densities (number of trees per 1/10 ha) between eastern and western Great Basin sites, high and low elevations, and four aspects.

Location	Aspect			
	North	East	South	West
Total tree density:				
Eastern (high elevation)	28.0[abc1]	33.2[a]	29.0[abc]	29.8[ab]
Eastern (low elevation)	30.2[ab]	28.0[abc]	30.7[a]	27.5[abc]
Western (high elevation)	23.6[bc]	17.6[e]	17.2[de]	19.7[de]
Western (low elevation)	22.2[cd]	17.0[e]	18.5[de]	19.8[de]
Pinyon tree density:				
Eastern (high elevation)	24.4[abc]	27.4[a]	22.6[abc]	24.7[ab]
Eastern (low elevation)	25.0[ab]	16.5[bcd]	19.3[abcd]	20.5[abcd]
Western (high elevation)	23.1[ab]	17.2[cd]	16.9[cd]	19.3[bcd]
Western (low elevation)	21.4[ab]	16.4[cd]	15.2[d]	17.3[cd]
Juniper tree density:				
Eastern (high elevation)	3.6[cd]	4.8[bcd]	6.4[bc]	5.1[bcd]
Eastern (low elevation)	5.2[bcd]	11.5[a]	10.5[a]	6.9[b]
Western (high elevation)	0.5[e]	0.4[e]	0.4[e]	0.4[e]
Western (low elevation)	1.0[e]	0.8[e]	3.3[d]	2.5[d]

[1]Means followed by the same letters a, b, c, d, or e do not differ significantly at $P < 0.05$. Each block is a separate analysis.

ences were not apparent between EGB and WGB. Most stands appeared to have established in the mid- to late 1800s or early 1900s (Tausch et al. 1981). During this period pinyon-juniper woodlands were heavily harvested to supply fuel and charcoal for the mining industry. Subsequent regrowth, concurrent with limited harvesting and intensive fire control, has tended to create large woodland areas dominated by trees of roughly equal age (Lanner 1980, Young and Budy 1979). Intensive livestock grazing, which reduced competition from herbaceous and shrubby plant species, may also have contributed to the increase in tree density and dominance during this period (Blackburn and Tueller 1970). Unburned stands exhibited few signs of major disturbance from this period until the present, suggesting that the burned areas may also have been relatively undisturbed until wildfire occurred.

Tree densities on all aspects for both high- and low-elevation classes were higher on EGB sites than on WGB sites, with differences being smallest among north aspects (Table 1). Tree densities were not different between aspects or between elevation classes on EGB sites nor between high- and low-elevation WGB sites of the same aspect. In the WGB, tree densities were higher on north slopes than on other aspects for both high and low elevations.

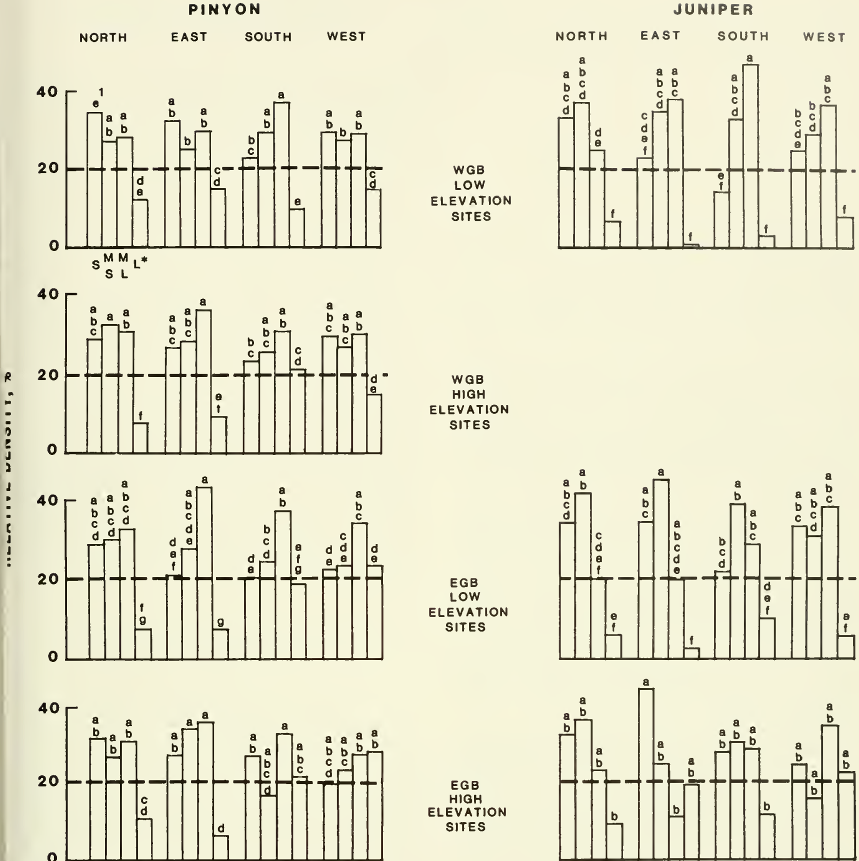
Pinyon Densities

Pinyon densities were generally highest on high-elevation sites and north aspects (Table 1). Cooler, moister environments and longer periods of snow cover were characteristic of these sites. Pinyon densities were also higher in the EGB than WGB, corresponding to higher average annual precipitation and lower average annual temperatures in the EGB (NOAA 1983). Pinyon dominance, contrary to total tree density, was greatest in the WGB, where summer precipitation is at a minimum. In both EGB and WGB the second highest pinyon densities were consistently found on west aspects.

High-elevation EGB sites, unlike other locations, supported higher pinyon densities on east aspects than on north aspects. This may be related to the higher number of storms from the east in the EGB than in the WGB. However, the same relationship is not evident at lower elevations.

Juniper Densities

The density of Utah juniper was greatest in the EGB, on low-elevation sites, and on south slopes (Table 1). The frequency distribution patterns indicate that juniper dominance is positively correlated to higher summer precipitation and greater diurnal fluctuation of soil moisture and temperature. There was some evidence that the higher incidence of paleozoic sedimentary soil parent material in the EGB may be related to higher densities of juniper, but more comprehensive study is required to clarify the relationship. Higher an-



[1] Within each block of 16 bars, bars with the same letters a,b,c,d,e,f, or g do not differ significantly at P< 0.05.

*Diameter classes : S = 1–9 cm, MS = 10–19 cm, ML = 20–29 cm, L = ≥ 30 cm.
This sequence is repeated for every group of four bars.

Fig. 2. Variation in pinyon and juniper relative densities among four diameter classes, four aspects, two elevations, and two locations (WGB = western Great Basin; EGB = eastern Great Basin).

nual precipitation on EGB sites compared to WGB sites probably was not directly related to higher juniper densities, since greater juniper densities were not also evident on generally moister sites at high elevations.

Relatively high juniper densities on low-elevation west-facing slopes in the WGB and on low-elevation east-facing slopes in the EGB may be related to differences in prevailing summer weather patterns (Houghton 1969, Presley 1978). In the WGB summer storms are infrequent and primarily originate in the west and southwest. In the EGB summer storms occur frequently, often originating in the southeast. Influence of aspect on juniper densities was less at high elevations, resulting in approximately equal tree densities on all aspects.

Relative Densities According to Diameter Classes—Pinyon

On north aspects, differences between relative densities (percentage of total tree density in each diameter class) of pinyon in the 1–9, 10–19, and 20–29 cm diameter classes were small except on low-elevation WGB sites (Fig. 2). On these sites a higher proportion of pinyon trees were in the 1–9 cm class. Relative densities in the ≥ 30 cm class were significantly lower than those in the other diameter classes. North slopes, compared to other aspects, tended to have higher proportion of pinyon trees in the 1–9 and 10–19 cm diameter classes.

On east aspects the highest pinyon relative densities were generally in the 20–29 cm diameter class and the lowest in the ≥ 30 cm class. Low-elevation WGB sites deviated from this pattern with high relative densities in the 1–9 cm class. Compared to other aspects, east-facing slopes tended to have higher proportions of pinyon trees in the 20–29 cm classes.

South aspects, like east slopes, had higher proportions of pinyon trees in the 20–29 cm diameter class than in the other classes for all locations. Unlike the distribution of pinyon on east aspects, south aspects also supported relatively high pinyon densities in the ≥ 30 cm diameter class at most locations. South slopes rivaled east slopes for highest relative densities in the 20–29 cm class and west slopes for highest relative density in the ≥ 30 cm class.

On west aspects, pinyon distribution differed substantially between WGB and EGB sites. On WGB sites relative densities in the 1–9, 10–19, and 20–29 cm diameter classes were not significantly different, and those in the ≥ 30 cm class were significantly lower. On EGB sites pinyon relative densities tended to be highest in the 20–29 and ≥ 30 cm classes and lowest on the 1–9 and 10–19 cm classes. Compared to other aspects, west-facing slopes consistently supported high proportions of trees in the ≥ 30 cm diameter class.

Relative Densities According to Diameter Class—Juniper

Because juniper densities were very low on high-elevation WGB sites, these data were deleted from the analysis and discussion of density distribution patterns among diameter classes. Juniper relative densities in the ≥ 30 cm diameter class were lower than in the other classes for all locations except high-elevation EGB east and west slopes. On north slopes juniper relative densities were consistently higher in the 1–9 and 10–19 cm diameter classes than in the 20–29 cm class. On west aspects juniper relative densities were consistently higher in the 20–29 cm class than in the other classes. Distribution of juniper among the three smaller diameter classes on east and south aspects exhibited no consistent patterns. Relative densities in the two smalle classes tended to be higher on north and eas slopes than on other aspects. South and wes aspects frequently supported higher junipe relative densities in the 20–29 and ≥ 30 cm class than did north and east aspects.

Elevational and Sectional Effects on Distribution Patterns

The basic patterns of pinyon and junipe distribution among diameter classes wer similar between high and low elevation (Fig 2). Several trends were apparent, but the were generally not significant. On WGB site variation in relative densities between eleva tion classes was not consistent between as pects. On EGB sites all aspects generally ex hibited an increase in pinyon in the 1–9 and ≥ 30 cm diameter classes with increasing eleva tion, whereas middiameter class relative den sities decreased. Juniper relative densities i the ≥ 30 cm diameter class also tended t increase at higher elevations on EGB sites accompanied by a decrease in the 10–19 cm class. Consistently larger trees at high eleva tion EGB sites may indicate older stands o better growing conditions at these elevations

Distribution patterns of pinyon and junipe among diameter classes were similar betwee EGB and WGB sites (Table 2). For bot pinyon and juniper, distribution patterns o north aspects were almost identical betwee EGB and WGB sites. On other aspects there

TABLE 2. Comparison of pinyon and juniper relative densities on eastern (EGB) and western Great Basin (WGB) sites among four aspects and four diameter classes.

Aspect	Diameter class and location										
	1–9 cm		10–19 cm		20–29 cm			≥ 30 cm			
	WGB	EGB	WGB	EGB	WGB		EGB	WGB		EGB	
Pinyon											
North	32.8	30.5	28.9	28.8	28.9		31.7	10.7		10.1	
East	30.3	24.8	26.0	31.6	32.1		38.1	13.6		6.1	
South	23.4	23.0	28.1	22.2	34.4		35.0	14.0		19.6	
West	29.7	21.3	26.6	23.3	29.2		30.9	15.5	*	24.4	
Juniper											
North	32.7	33.4	38.5	39.3	24.4		20.9	5.0		6.4	
East	21.2	39.9	42.3	33.9	33.9		14.4	0.0	*	11.8	
South	15.1	24.4	28.1	36.3	54.8	*	28.6	2.1	*	10.8	
West	28.4	27.2	29.3	21.2	36.0		36.9	6.8		14.7	

*Pairs denoted by an asterisk (*) are significantly different at $P < 0.05$.

was wider variation; however, few of these differences were significant. WGB south slopes supported significantly greater juniper relative densities in the 20–29 cm diameter class than did EGB south slopes. Pinyon relative densities on west-facing sites and juniper relative densities on south-facing and east-facing sites were significantly higher in the ≥ 30 cm class on EGB sites than on WGB sites. The consistently higher proportion of trees in the ≥ 30 cm class on EGB sites than on WGB sites may indicate better growing conditions or an earlier onset of stand establishment.

Major Distribution Patterns Among Diameter Classes

Sites with the highest total juniper densities (i.e., low elevation south and east EGB sites and low elevation south and west WGB sites) displayed different distribution patterns among diameter classes (Fig. 2). In the WGB, regeneration appeared to have been greatest in the early tree stage of the successional cycle, after the first generation of trees had reached seed-bearing age. Subsequent regeneration may have been limited by competitive interaction for water, nutrients, and space, or by infrequent environmental conditions conducive to seed germination and seedling survival. In the EGB the highest tree establishment rates apparently occurred later in the successional cycle than they did in the WGB. This may have been because environmental conditions were favorable during this period, producing an unusually high regeneration rate. Or perhaps the natural accretion of trees into seed-bearing age, the continued capability of the sites to support new trees, and climate favorable to tree establishment may have yielded progressively higher proportions of small diameter trees, diminishing only in recent years when either adverse environmental conditions or competition limited regeneration. Interspecific competition may also have affected density distribution among diameter classes. For example, high proportions of pinyon in the larger diameter classes on low-elevation EGB sites may indicate early domination by pinyon and subsequent delayed establishment of juniper.

Sites with the highest pinyon densities, north and high-elevation EGB east aspects, displayed similar distribution patterns among diameter classes. Pinyon regeneration on these sites remained high after tree establishment and had not decreased substantially in recent years. The relatively low proportions of trees in the ≥ 30 cm diameter class on these sites may indicate either that competition between large numbers of small-diameter trees restricted or delayed the number of trees attaining substantial girth or that stand establishment occurred later on these sites than on other sites. Historically, north and east slopes may have been exposed to a greater frequency and severity of wildfires than have other aspects because of the generally higher biomass to carry fire. Fire suppression policies in the early 1900s allowed the invasion of many sites previously dominated by shrub disclimax communities. Stand establishment on invaded shrub areas would occur slower than stand establishment after tree harvesting because cut-over areas generally retain numerous small diameter trees. Greater competition from perennial species (Koniak 1985) on these slopes may also delay tree establishment. Neither the tree competition nor the late stand establishment hypotheses are clearly supported by tree diameter and age data in this study or in the literature (Meeuwig 1979, Cooper et al. 1980). More comprehensive study is needed to clarify the underlying processes.

Of the four aspects, west slopes consistently supported the second highest pinyon densities at all locations. Less competition or earlier stand development with less disturbance or both may explain the disproportionately high number of trees in the ≥ 30 cm diameter class on west slopes. EGB west slopes supported higher proportions of pinyon trees in the ≥ 30 cm diameter class than WGB west slopes at both high and low elevations. In the WGB tree establishment has remained high on west slopes. On EGB west slopes competition from large-diameter trees may have restricted regeneration, limiting the proportion of pinyon trees in the smaller diameter classes.

Distribution of pinyon and juniper over aspect, elevation, and eastern versus western Great Basin locations tended to be negatively correlated. However, variations in relative density distribution between diameter classes were often similar. For both pinyon and juniper, north and, to a lesser extent, east aspects tended to support high relative densities of small-diameter trees, whereas south and west aspects tended to support high relative densities of large-diameter trees. Of the diameter classes, relative pinyon and juniper densities were generally lowest in the ≥ 30 cm class. For both pinyon and juniper, relative densities in the ≥ 30 cm class tended to increase with elevation, especially on south and west aspects. One striking difference in the diameter class distribution is the consistently lower proportion of juniper trees in the ≥ 30 cm classes compared to pinyon trees. Juniper appear to be more sensitive to competition than pinyon (Meeuwig 1979) and may be slower to establish in communities where both species are represented.

Most stands sampled had a substantial proportion (20%–35%) of both pinyon and juniper trees in the 1–9 cm diameter class, indicating these woodlands are still in the formative stages of stand renewal (Meeuwig and Cooper 1981). At what point equilibrium with the natural environment will be reached, and the nature of the stand at that time, are largely matters of conjecture. Recording the process, however, will have value in our understanding the dynamics of this system.

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