J. Range Manage.
50:507–512

Browsing and tree size influences on Ashe juniper understory

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Abstract

Ashe juniper (*Juniperus ashei*, Buckholz) is increasing on most sites across the Edwards Plateau of Texas. It is the purpose of this investigation 1) to document the influence of Ashe juniper tree size on understory vegetation and 2) to evaluate how the interaction between tree size and browsing by domestic goats and white-tailed deer modifies overstory/understory relationships. Trees were randomly selected from 2 long-term treatments (browsed and unbrowsed) and analyzed with univariate analysis of covariance and multivariate repeated-measures analysis. Without browsing, Ashe juniper is more abundant and its individual influence increases as the size of the tree increases; trees with a canopy diameter < 6.0 m expressed minimal influence on understory vegetation compared to larger trees. When browsers are present at sufficient stocking rates to create a browse line on large trees, encroachment of Ashe juniper is slowed, rate of increase of all woody species is reduced, and large trees cause a shift in species composition directly under the canopy, however cover of all herbaceous species is not reduced. Immediately under the canopy of small browsed trees, herbaceous cover is lower than for unbrowsed trees. Environmental variables responsible for these patterns were litter depth and light penetrating the canopy when the sun is at an angle (during the winter). The increased cover of several herbaceous species under the canopy of large browsed trees and at the canopy edge of browsed and unbrowsed trees, indicates the importance of the interaction between canopy cover and the presence of a browse line. Browse lines on large trees enhance growth and production of cool season species, such as Texas wintergrass (*Stipa leucotricha* Trin. & Rupr.) and reduce negative influences (low light, thick leaf litter, etc.) on other herbaceous species. At this level of browsing many other palatable species could be reduced or lost from the plant community.

Key Words: *Juniperus ashei*, herbivory, goats, Edwards Plateau, grazing

Ashe juniper (*Juniperus ashei*, Buckholz) is a fire-sensitive, non-sprouting, evergreen small tree or shrub found primarily on the Edwards Plateau of Texas, but with populations in the Arbuckle Mountains of Oklahoma, the Ozark Mountains of Missouri and Arkansas, and the Sierra del Carmen Mountains of Mexico (Johnsen and Alexander 1974). On the semi-arid western divide portion of the Edwards Plateau, this species occurs on shallow, rocky limestone derived soils in a *Quercus/Juniperus* savannah/parkland. The Edwards Plateau is an important sheep and goat production region, it provides habitat for several endangered plant and animal species, as well as game species, it is a growing recreational and second home area, and its rangelands are sources of water for several urban areas (Armstrong 1980, Kroll 1980, Huston et al. 1994, Taylor and Smeins 1994, Thurow and Carlson 1994). The relative proportion of the landscape occupied by Ashe juniper is controlled by fire frequency, intensity, and season of occurrence, degree of soil/geologic heterogeneity, weather/climatic variability, and kind and intensity of herbivory (Smeins and Merrill 1988, Archer 1994, Fuhlendorf et al. 1996).

Understory relationships of other juniper species indicate an inverse relationship between juniper cover and herbaceous species diversity and production (Jameson 1967, Engle et al. 1987, Armentrout and Pieper 1988, McPherson and Wright 1990, Pieper 1990). However, the significance of these community changes for juniper species in western North America have been questioned (Belsky 1996), which suggests that more data is needed to understand the influences of juniper. For example, browsing animals can alter stem density, canopy cover, foliage density, and overall growth habit of juniper plants (Fuhlendorf 1992), which may modify overstory/understory relationships. Age/size relationships have been quantified and are influenced by browsing animals (Fuhlendorf 1992, Smeins et al. 1994) but there has been no attempt to determine the understory relationships of different size/age trees. It is the purpose of this investigation 1) to document the influence of Ashe juniper tree size on understory vegetation and 2) to evaluate how the interaction between tree size and domestic goat and white-tailed deer browsing modifies overstory/understory relationships.

Materials and Methods

This study was conducted on the Texas A&M University Agricultural Research Station which is located on the southwestern edge of the Edwards Plateau about 56 km south of Sonora, Texas. Elevation of the station is approximately 732 m. Average annual precipitation from 1918 to 1994 was approximately 600 mm. The range varied from 156 mm in 1951, to 1,054 mm in 1937 with an annual median of 438 mm. Rainfall is bimodal, with peaks occurring in the spring and fall. Droughts are common. The

Manuscript accepted 3 Nov. 1996.

growing season is about 240 days, with temperatures averaging 30° C in July and 9° C in January (Station records).

Soils are primarily the Tarrant series which are in the thermic family of the Lithic Haplustolls (Thurow et al. 1988). Dominant are Tarrant stony clay soils, which are generally 15 to 30 cm deep. These soils contain 5 to 70% limestone fragments or limestone outcrops. The topography has gentle slopes of 3 to 4%.

Vegetation is a savannah/parkland with individuals or clusters of woody species interspersed within a mid- and shortgrass matrix (Kuchler 1964, Smeins et al. 1976, Smeins and Merrill 1988). Dominant woody plants are live oak (*Quercus virginiana* var. *virginiana* Mill.), Vasey shin oak (*Quercus pungens* var. *vaseyana* Buckholz) and Ashe juniper. Dominant herbaceous species include common curly mesquite (*Hilaria belangeri* Nash), three-awn (*Aristida purpurea* Nutt.), sideoats grama (*Bouteloua curtipendula* var. *curtipendula*), Texas wintergrass (*Stipa leucotricha* Trin. & Rupr.) and Texas cupgrass (*Eriochloa sericea* (Scheele) Munro ex Vasey). Taxonomic nomenclature follows Hatch et al. 1990.

The station was established in 1916 to study animal diseases. In 1948 the primary emphasis was shifted to range management when multiple study units were established to study the influence of stocking rates, kinds and mixtures of animals, and grazing systems on the vegetation. Also in 1948, an attempt was made to remove all junipers on the station by hand cutting. Other woody species were not removed, so many small junipers may have escaped detection. Since 1948, no attempt has been made to manage encroachment of woody species in any of the areas used in this study, except as influenced by herbivores.

Two long-term treatments were selected for this study. The browsed treatment (32 ha) was heavily and continuously browsed by goats only at 5.4 ha/auy from 1948 to 1969, and then moderately grazed by cattle, sheep, and goats (60:20:20) at a stocking rate that has been variable with weather patterns (ca. 9 ha/auy). In 1983, the animal ratio was changed to a 50:25:25 mixture of cattle, sheep, and goats. Cattle and sheep may utilize a significant portion of browse, but overall stocking rate decreases and the reduction of the proportion of goats has reduced the browsing intensity since 1969. Free roaming wildlife, particularly white-tailed deer (*Odocoileus virginianus*) also had access with estimates of 1 deer/5 ha (Kinucan and Smeins 1992). The unbrowsed treatment (16 ha) has had no browsing by livestock or large wildlife since 1948. Both treatments had similar histories of heavy continuous grazing by cattle, sheep, and goats prior to 1948 and are located within 2 km of each other on similar soils and topography.

A line (1,200 and 850 m in the browsed and unbrowsed, respectively) was established through the center of the long axis of each study unit and 12 random points were established along that line. The nearest tree to the point in each of 4 canopy diameter size classes was selected (Table 1). Trees smaller than .76 m were not used since they were typically located in the understory of larger trees and their influence could not be distinguished from the large trees. Also, these small saplings, even when open grown, have limited influence on the understory.

From the stem of each tree a line was established in each cardinal direction. Each cardinal direction was visually classified as open or closed in terms of the cover of adjacent woody species associated with the target tree (closed ≥ 25% woody cover). The canopy radius was divided into 5 equidistant sampling locations from the stem to the edge of the canopy. The line was extended beyond the canopy to twice the distance of the radius which was also divided by 5 to create a total of 10 sampling locations along each line. For trees with a canopy radius of greater than 2.5 m, the distance between locations was limited to 0.5 m to avoid missing transitional zones, and hence the total number of sample locations for these trees exceeded 10 in order to reach twice the canopy radius.

At each sample location, a line was established perpendicular to the radius, and point quadrat measurements were taken at 3 points 5 cm apart on that line, with the first point located directly next to the line. Variables recorded under each point quadrat were litter presence and depth, rock presence, foliar presence of understory species, and height from the ground to the nearest live juniper branch recorded in the following classes: 1 = 0 – 50 cm, 2 = 51 – 100 cm, 3 = 101 – 150 cm, 4 = 151 – 200, 5 > 200 cm. Percent light was measured with a quantum sensor (LI-COR , Inc., Model LI-185B) in the winter (12/10 – 1/15) and summer (6/17 – 7/10) within an hour of midday. Light measurements were only taken for open grown trees and at each sampling location.

For analysis, data were pooled from the 10 or more locations on each cardinal direction line to form 3 zones, the inner zone which contained points nearest the stem and completely under the canopy, the mid zone contained locations at the canopy edge with about 50% under the canopy of the target juniper and 50% outside the canopy, and the outer zone which started approximately 1.5 times the canopy radius away from the target juniper. These zones varied for each tree, but averages were calculated to establish standardized zone limits for each size class (Table 1).

Table 1. Ashe juniper canopy diameter size classes and standardized zones based upon meters from the stem for each size class.

Size class (dia.)	Inner zone	Mid zone	Outer zone
> 6 m	0 – 2.75	2.76 – 4.75	4.76 – 6.00
3.01 – 6.00 m	0 – 1.80	1.81 – 3.00	3.01 – 4.80
1.51 – 3.00 m	0 – 0.70	0.71 – 1.50	1.51 – 2.00
0.76 – 1.50 m	0 – 0.35	0.35 – 0.75	0.75 – 1.00

A factorial design, using an analysis of covariance (SAS Institute 1985), was used to determine the influence of browsing history, location from the stem, and tree size on understory relationships. Percent rock cover was used as the covariate to control variation due to site heterogeneity within each pasture. Since presence of rocks on the surface obviates the absence of understory species, rock cover was used as a covariate. Mean percent rock cover was not significantly different for each browsing history (browsed = 25.3%, unbrowsed = 27.5%).

Percent of full light received at the soil surface for winter and summer, litter depth, and percent foliar cover for total herbaceous, total graminoids, total forbs, total woody, Texas wintergrass, common curly mesquite, sideoats grama, three-awn, and Texas cupgrass were used as dependent variables. The independent variables were size classes, location from the stem (inner, mid, outer), cardinal direction (N, S, E, W), browsing history (browsed, unbrowsed), and several interactions. Type of canopy (open grown or surrounded by other woody plants) was also used as an independent variable without considering its interaction with other variables.

Individual species analyzed separately were highly correlated.

A multivariate repeated-measures analysis (MANOVA; SAS Institute 1985) was used to account for correlation between the dependent variables. The Wilks' lambda test statistic determined the significance of the independent variables on the correlated dependent variables (species) taken collectively, with no inferences on the individual dependent variable response.

Results and Discussion

Understory/overstory patterns of Ashe juniper are best explained by an interaction between browsing history, size of juniper, and distance from the stem (location). This interaction was significant ($p < 0.05$) for total herbaceous cover, total woody plant cover, cover of three-awns, winter light, litter depth, and height to the lowest live branch. Total graminoid cover was moderately significant ($p = 0.064$). Multivariate repeated measures analysis of variance supports the univariate analysis with a moderate Wilks' Lambda statistic p-value of 0.079 for the 3-way interaction. Multivariate analyses accounts for correlation among dependent variables and simultaneously evaluates the responses of the 5 dominant grasses and total forbs.

The significant 3-way interaction is best illustrated by total herbaceous cover, which produced different patterns at the inner location of large and small trees for each browsing history (Fig. 1). For the largest trees, herbaceous cover at inner locations with and without browsing was 38.7 and 9.7%, respectively. Small trees had a reversed pattern where herbaceous cover at the inner location was lowest under browsed trees, though the differences were not significant. With browsing, herbaceous cover at the inner location generally increased with an increase in canopy diameter class. Without browsing, herbaceous cover at the inner location was about the same for the 3 smallest size classes (35%) while cover associated with the largest size class was about 3-fold less (9.7%) at the inner location. When browsing livestock are not present an Ashe juniper tree must approach 6 m in canopy diameter to have a major influence on the herbaceous understory. Total graminoid cover, several individual species (Table 2) and winter light exhibited patterns similar to total herbaceous cover. Patterns of litter depth were inverse to herbaceous cover which suggests that the environmental variables most responsible for the differences in herbaceous cover between large browsed and unbrowsed trees are litter depth and winter light penetration.

Across browsing histories, most variation in herbaceous vegetation occurs at the inner location of large trees (> 6 m canopy diameter). Beneath the canopy of large browsed trees, cover of most herbaceous species was 4 times greater than under large unbrowsed trees (Table 2). These differences are attributed to the browse line created by intense goat utilization of juniper from 1948 to 1969 and associated reductions in litter accumulation (Fig. 2). The largest size class had significantly higher branches under browsing ($p < 0.05$, 60 cm vs. 175 cm). The browse line was also present on some trees with a canopy diameter of 3.01–6.0 m but the differences were not significant. Since 1969 stocking rates of goats have been reduced, however the heavy historical browsing impact is still sufficient to maintain low total cover of all woody plants (Smeins et al. 1994). Limited availability of all woody vegetation due to the past intensive browsing may increase livestock and wildlife utilization of existing juniper

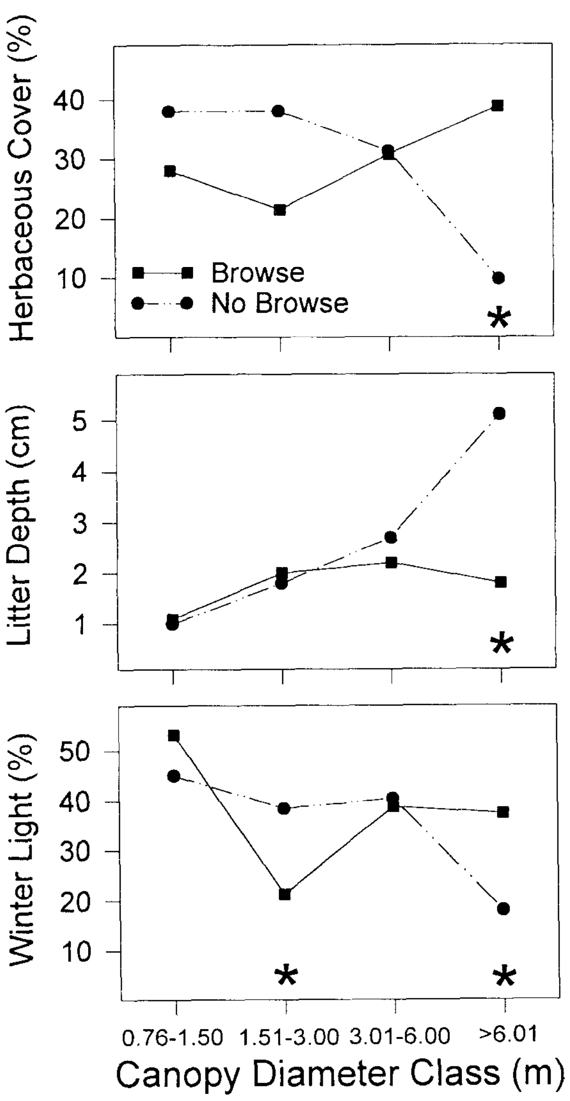

Fig. 1. Herbaceous cover (%), litter depth (cm), and winter light (%) penetrating through the canopy at the inner location of all canopy diameter classes across each browsing history. Significant differences ($p < 0.05$) between browse histories are indicated by *.

trees which continues to maintain the high browse lines even 20 years after reduction in goat stocking rate.

Trees with a browse line had shallower litter depths and more winter light penetration which benefits understory herbaceous species, particularly cool season species such as Texas wintergrass (Table 2). Because less litter accumulates under large trees that are browsed, litter depth did not vary between size classes when browsing occurred (Fig. 1). Shallower litter under large trees with a browse line could be the result of 1) less litter reaching the soil due to animal consumption, 2) incorporation of litter into the mineral soil by trampling and corresponding improved decomposition and nutrient cycling, 3) an improved microenvironment for decomposition, and 4) scattering of litter beyond the canopy by hoof and wind action. Without browsing, litter depth increased with tree size ($p < 0.05$, Fig. 1). Undisturbed Ashe juniper litter forms a hydrophobic layer under large unbrowsed

Table 2. Mean percent foliar cover of total forbs and selected grass species at each location of each Ashe juniper size class in each browsing history on the Texas Agricultural Experiment Station near Sonora, Texas.

		Total Forbs		Texas Wintergrass		Common Curlymesquite		Sideoats Grama		Three-Awns		Texas Cupgrass	
Diameter (m)	Location	No Browse	Browse	No Browse	Browse	No Browse	Browse	No Browse	Browse	No Browse	Browse	No Browse	Browse
		(%)											
> 6	Inner	3.1	5.5	2.6	11.7	0.0	3.9	0.4	1.8	1.3	10.4	0.0	1.5
	Mid	15.5	13.6	2.1	3.7	5.0	8.7	5.7	2.4	5.7	10.2	3.1	0.5
	Outer	17.9	17.2	1.1	1.9	1.4	3.8	9.4	4.3	7.2	12.3	1.1	0.7
	Avg.	12.2	12.1	1.9	5.7	2.2	5.4	5.2	2.9	4.7	11.0	1.4	0.9
3.01 – 6.00	Inner	11.2	4.2	3.2	9.6	2.3	5.9	1.6	1.2	5.9	8.3	4.1	0.5
	Mid	22.7	19.9	2.1	8.1	5.0	10.2	8.3	3.5	12.5	10.0	3.3	0.0
	Outer	25.9	17.4	1.5	3.1	5.1	8.6	6.5	2.7	7.7	10.2	2.6	0.5
	Avg	19.9	13.8	2.3	6.9	4.1	8.2	5.4	2.5	8.7	9.5	3.3	0.4
1.51 – 3.00	Inner	15.5	3.2	5.1	1.6	3.2	3.2	4.6	4.4	6.7	6.0	0.2	0.0
	Mid	19.4	20.0	3.0	1.6	8.5	8.3	9.7	4.9	4.7	19.6	0.0	0.0
	Outer	22.2	17.9	1.9	0.2	3.5	7.5	12.5	2.8	5.8	9.6	1.6	0.0
	Avg	19.1	13.7	3.3	1.1	5.1	6.4	9.0	4.1	5.7	11.8	0.6	0.0
0.76 – 1.50	Inner	12.3	3.9	2.1	4.2	2.1	3.5	4.6	5.6	13.4	6.7	3.2	0.0
	Mid	21.1	9.7	1.0	3.8	6.1	5.7	7.1	3.1	8.7	13.7	4.9	0.0
	Outer	16.1	13.3	2.3	3.3	8.1	4.0	6.4	3.8	8.3	12.0	2.6	0.0
	Avg	16.5	9.0	1.8	3.8	5.4	4.4	6.0	4.1	10.1	10.8	3.6	0.0
Average		16.9	12.2	2.3	4.4	4.2	6.1	6.4	3.4	7.3	10.8	2.2	0.3
Std error		2.6		1.5		1.6		1.9		2.3		1.0	

trees that can physically limit germination and production of herbaceous vegetation (Yager 1993). Litter accumulation by other species limits establishment and production of many grasses (Weaver and Rowland 1952, Jameson 1966, Knapp and Seastedt 1986).

Light penetration was always lower at the inner compared to the mid and outer locations because of the influence of the target tree canopy. Winter light penetration varied as a function of the browsing history, tree size, and location interaction ($p < 0.05$), while summer light was significant for all main effects ($p < 0.05$). For winter light, significant differences between browsing histories were limited to the largest trees and trees with a diameter of 1.50–3.01 m which corresponds with the greatest differences in herbaceous cover. Large browsed trees had greater winter light penetration than unbrowsed trees because the angle of the sun in the winter allows more penetration under the high browse line (Fig. 2).

For trees with a canopy diameter of 1.50–3.01 m, the differences in winter light penetration were inverse to the large trees with the greatest light penetration under unbrowsed trees. For browsed trees, this size class had the least light penetration and herbaceous cover of all other size classes. Browsed trees of this size are nearly twice as old as unbrowsed trees and the foliage is more dense due to a pruning influence caused by browsing (Fuhlendorf 1992). Older trees with more foliage can reduce light penetration and have a longer opportunity to influence the herbaceous understory. Larger browsed (> 3 m diameter) trees had greater winter light penetration and herbaceous cover because of the presence of the browse line. Differences in summer light between browsing histories is primarily due to differences in small trees and associated with the more dense foliage of small, browsed trees caused by continuous pruning (Fuhlendorf 1992). Light was measured at midday for this study. It should be noted, however, that during morning and evening hours, the summer light would be at an angle similar to winter light, so even in the summer, the inner location of large browsed trees probably receives much more light throughout the day than large unbrowsed trees.

Most prior studies have found that herbaceous cover increased with distance from the juniper stem (Engle et al. 1987, Armentrout and Pieper 1988, Pieper 1990, Blomquist 1990). In the current study, however, total percent cover of all herbaceous species, total graminoids, and several individual herbaceous species were greatest at the canopy edge, even though cover of other woody plants was also greatest at the same location (Table 2 and Fig. 3). Higher herbaceous cover at the canopy edge could be the result of increased humidity, decreased wind and temperature, and increased nutrient availability. Redistribution of resources has been shown for other juniper species, with higher levels under the canopy edge than in the open interspaces (Doescher et. al 1987, Padien and Lajtha 1992). Presence of an overstory canopy can increase herbaceous production during a drought (Frost and McDougald 1989) and enhance production of early cool-season species (Clary and Morrison 1973). Texas wintergrass (cool-season grass) cover was most abundant ($p < 0.05$) under the canopy of large trees that had a browse line, less litter, and greater cool-season light levels (Table 2).

The significant 3-way interaction ($p < 0.05$) explained most of the variation in the overstory/understory relationships of Ashe juniper, but differences in vegetation composition between browsing histories were evident (Table 2). The multivariate nature of these data and the significance of the 3-way interaction limits extensive univariate analyses of individual species and main effects but predictable patterns were evident. All woody species that were analyzed separately were significantly less abundant in browsed areas. Texas wintergrass, curly mesquite, and three-awns were most abundant when associated with trees that were exposed to historical goat browsing. Curlymesquite is believed to increase in cover with moderate utilization by livestock (Ralphs et al. 1990, Taylor et al. 1993), while Texas wintergrass, a cool-season grass, apparently benefits from the presence of a large canopy with a browse line and increased winter light.

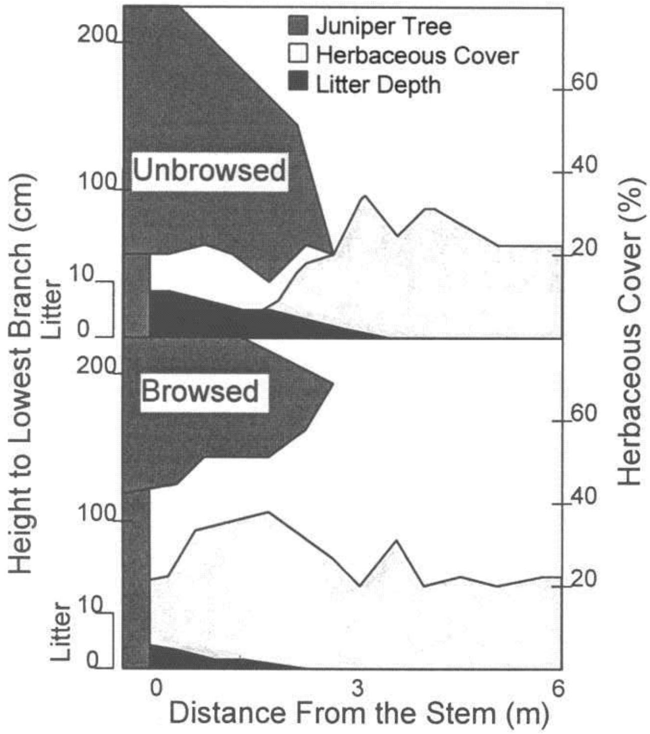

Fig. 2. Schematic drawing of one-half of an Ashe juniper tree from actual data of average graminoid cover, height to the lowest live branch, and litter depth for the largest size class (canopy diameter > 6 m), of both browsing histories, from the stem to twice the canopy radius. Note the y axis on the left accounts for 2 variables. The 0 to 10 region is for litter depth.

Sideoats grama, Texas cupgrass, annual and perennial forbs, and all woody species were more abundant when browsing and grazing were not present. These species are readily utilized by livestock (Ralphs et al. 1990, Taylor et al. 1993) which may result in lower cover in browsed/grazed areas.

Significant differences in woody plants associated with Ashe juniper are explained by the interaction of browsing history, tree size and location from the stem ($p < 0.05$). All dominant woody species were less abundant when browsing occurred ($p < 0.05$). Percent cover of woody species was highest at the mid zone of the largest size class without browsing (62.6%). Cover of woody plants at this location is over twice as much as at any other location, across all other size classes and browsing histories. Under browsing, woody cover never exceeded 20% and for size class 1.51–3.00 m, cover was less than 4% for all locations.

Of woody species associated with the target tree, Ashe juniper was the most abundant, followed by shin oak and live oak, respectively. Juniper adjacent to or under the target tree had a percent canopy cover of 10.1 when unbrowsed compared to 4.5 when browsed. Ashe juniper, live oak, shin oak, Texas persimmon (*Diospyros texana*, Scheele), agarito (*Berberis trifoliolata*, Moric.), sacahuiste, (*Nolina texana*, Wats.) and prickly pear (*Opuntia lindheimeri*, Engelm.) were found in both treatments, while unbrowsed trees were also associated with elbowbush (*Forestiera pubescens*, Nutt.), skunk bush sumac (*Rhus aromatica* var. *flabelliformis*, Ait.), hackberry (*Celtis reticulata*, Torr.), catclaw acacia (*Acacia greggii* var. *greggii*, Benth.), and honey mesquite (*Prosopis glandulosa* var. *glandulosa*, Torr.). Most of these latter species are preferred browse plants for all classes of livestock and white-tailed deer (Armstrong 1980, Smeins and Merrill 1988). Intense browsing has apparently reduced their abundance and/or prevented establishment where browsing has occurred. Juniper contains relatively large amounts of secondary chemicals (Huston et al. 1994) that may discourage browsing by ruminants, so other plant species may be over-utilized prior to the impact of the browsers on juniper.

The abundance and ecological influence of Ashe juniper on the Edwards Plateau of Texas is confounded by the regions diverse topoedaphic sites, variable pre-settlement vegetation, and historic, as well as current management practices (Smeins 1980, Smeins and Merrill 1988, Riskind and Diamond 1988, Van Auken 1988, Gehlbach 1988). As with other juniper species from western North America (Belsky 1996), these confounding influences can contribute to controversy concerning the community influences of these species. Ashe juniper has the potential to produce nearly closed canopy stands on many sites that were previously relatively open savannah communities (Fuhlendorf et al. 1996). With its increase, composition and diversity of native flora and fauna can be greatly altered, as can production and handling of livestock. However, these influences are dependent upon long-term grazing or browsing history and the size of the juniper plants.

Integrated management of livestock and wildlife combinations along with fire and other woody vegetation management tools can produce a mosaic of communities in an area that may be favorable for all, but perhaps not maximal for any single use or

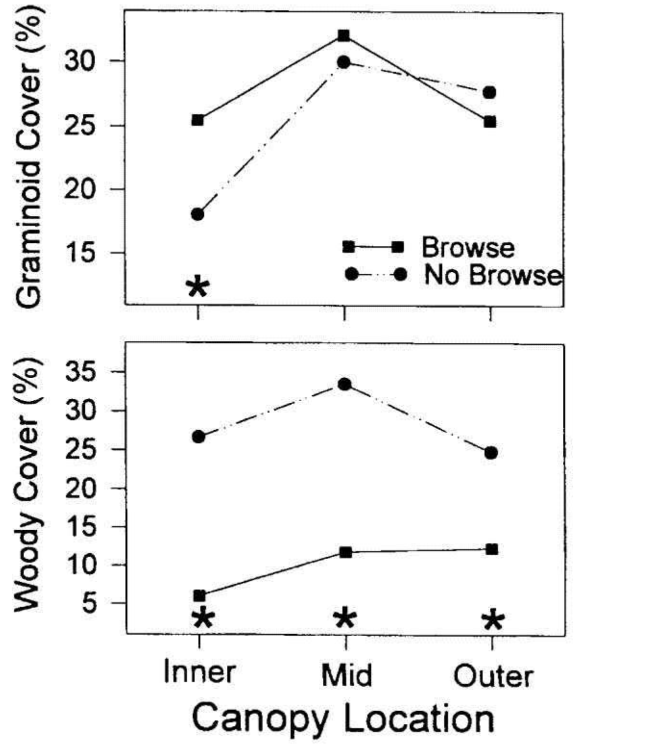

Fig. 3. Graminoid and woody cover (%) at each canopy location for each browsing history. Significant differences ($p < 0.05$) between browse histories are indicated by *.

resource. When grazing and browsing animals are restricted, the primary influence of Ashe juniper is limited to large trees (> 6 m). At high levels of browsing pressure, goat utilization of juniper is sufficient to slow its increase and alter its growth form. This creates a browse line which can reduce some negative impacts on associated species. However, intensity, frequency, and season of forage utilization should be closely monitored since juniper is not highly preferred and other plant species can be over-utilized at high, continuous goat stocking rates. Management of this species to achieve desired amounts can be achieved through monitored browsing and prescribed burning (Wink and Wright 1973, Smeins et al. 1994, Fuhlendorf et al. 1996). This should be done at a landscape level with consideration of site variation, historical land use patterns, and other conservation concerns.

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