THE IMPACTS OF JUNIPER ENCROACHMENT ON UNDERSTORY COVER AND DIVERSITY[2]

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SUMMARY

Western juniper (*Juniperus occidentalis*) has been actively invading shrub steppe communities in the Pacific Northwest during the past 120 years. The majority of these stands are still in a state of transition from shrub steppe to juniper woodland. In addition to different stages of stand development, juniper expansion occurs in different plant communities occupying different soils and topographic positions. Despite this high degree of variability, juniper woodlands are frequently treated generically in resource inventories, management, and wildlife habitat assessments. The goal of this study was to evaluate the influence of juniper dominance on plant community dynamics across several plant communities commonly impacted by western juniper encroachment in southeastern Oregon and northeastern California. The increase in juniper dominance had little impact on low sagebrush and an inconsistent affect on bitterbrush. However, as juniper dominance increased to about 50% of maximum canopy cover, mountain big sagebrush declined by nearly 80% of its maximum potential. Aspen also significantly declined as juniper dominance increased. Herbaceous cover and species diversity declined, and bareground increased with increasing juniper dominance in the mountain big sagebrush/Thurber needlegrass community. However, herbaceous cover on the deeper soils characterized by Idaho fescue and Columbia needlegrass did not decrease with increasing juniper dominance.

INTRODUCTION

In the Intermountain West the conversion of shrub steppe communities to juniper woodlands has been an actively ongoing process during the past 120 years. Over ninety percent of the 8 million acres of western juniper woodlands have developed in the last 100 years. Before settlement, juniper was primarily confined to rocky ridges or surfaces with sparse vegetation. However, newly formed juniper woodlands now occupy more productive sites with deep well-drained soils (Burkhardt and Tisdale 1969, Miller and Rose 1995). The replacement of shrub steppe communities with juniper woodland has been largely attributed to reduced fire frequency (Burkhardt and Tisdale 1976, Miller and Rose 1999). Heavy livestock grazing between 1880 and 1930 removed fine fuels (herbaceous biomass) which, previously had carried the fires.

Western juniper woodlands influence a large land area and occupy a broad array of environments. Despite the heterogeneity of the landscape occupied by juniper and the various stages of woodland development occupying these landscapes, juniper woodlands are frequently treated generically in resource management, inventories, and wildlife

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habitat assessments. In addition, the classification of plant communities have frequently ignored woodland succession. Given the diverse landscapes occupied by western juniper, it is very likely that stand development and understory/overstory relations will be strongly influenced by soils, aspect, elevation, etc. The stage of woodland development will also affect composition and structure of the understory.

The objective of this study was to evaluate the influence of juniper dominance on plant community dynamics across several major communities common throughout the range of western juniper. Our specific objectives were to 1) evaluate the impacts of juniper on understory structure and composition across different plant communities common in the sagebrush steppe and 2) measure tree density and cover at full woodland development among different plant communities.

METHODS

The study area was located in southeastern Oregon and northeastern California. A combination of basin and range and weathered mountains of volcanic origin characterize the topography. The climate is cool and semiarid, characteristic of the northern Intermountain Region. Mean annual precipitation in the juniper zone across the study area typically varies between 12 and 16 in. (Taylor 1993). Three rangeland cover types were studied: low sagebrush, mountain big sagebrush, and aspen (Table 1). Aspen stands evaluated were associated with shrub steppe communities in the Steens Mountain and the south Warner Mountains below 7,000 ft. Study sites spanned from aspen on deep loamy soils to low sagebrush on shallow heavy clay soils, thus providing a variety of soils, landforms, and topographic positions. Elevation of study plots varied from 4750 to 6900 ft. One hundred and eight stands were measured across the study area. To evaluate the impacts of western juniper on understory composition and structure, we selected sites where disturbance (grazing, roads, etc.) appeared to have had minimal affect on community dynamics. We also selected sites where fire had been absent at least during the last 50 years.

Plant communities measured are reported in Table 1. Stages of woodland development were categorized into one of four successional stages: early, mid, late, and closed, based on annual tree growth and stand structural characteristics (Table 2). Two tree growth characteristics were used: annual lateral and terminal leader growth on sapling and full size trees. Stand structure characteristics used were tree cover, tree height, and proportion of live to dead shrub canopy. The key characteristic for stand closure was limited sapling leader growth, typically less than ½ in. We attempted to locate plots within each community in the four different phases of woodland development.

Tree and shrub cover and density as well as herbaceous and bareground cover were measured. Diversity and richness of plant species were also evaluated. Aspect, slope, and elevation were recorded for each stand and soils were described. Rill and gullies were noted if present on a site because they provided indirect evidence of soil movement.

Table 1: Plant community types included in this study.

Community Type	Sample size	Elevation (ft) Range (mean)	General Aspect	% Slope	Soils A & B Horizons
Low sagebrush / Sandberg bluegrass	12	4860-5980 (5333)		<2	A: Shallow clay loam to clay B: clay
Mountain big sagebrush / Thurber needlegrass	15	5166-6525 (5698)	Southerly	8-22	A: Sandy clay loam to clay loam B: Sandy clay loam to silty clay loam
Bluebunch wheatgrass	5	5068-6199 (5625)	South to West	8-26	A: Sandy to clay loam B: Clay loam to clay
Idaho fescue	49	5000-6580 (5650)	Northwest to Southeast	0-45	A: Loam to clay loam B: Clay loam to clay
-Mountain snowberry/ Columbia needlegrass	12	5115-6900 (6050)	Northwest to Northeast	10-25	A&B: Loam
Quaking aspen	15	5840-6710 (6250)	North to East	8-35	A&B: Loam

Table 2. Juniper woodland successional stages in mountain big sagebrush sites.

Characteristics (Post Settlement Stands)	Early	Mid	Late	Closed
Tree Canopy	Open, actively expanding, cover ≤ 5%	Actively expanding, cover 6 to 20%	Canopy expansion greatly reduced, cover 21-30%	Canopy expansion stabilized, over > 30%
Leader Growth (Dominant Trees)	Good terminal & lateral growth	Good terminal & lateral growth	Good terminal growth, reduced lateral growth	Reduced terminal growth, lateral growth absent
Crown Lift[3] (Dominant Trees)	Absent	Absent	Lower limbs beginning to die where tree canopy > 40%	Present where tree canopy > 40%
Potential Berry production	Low	Moderate to high	Low to moderate	Low to near absent
Tree Recruitment	Active	Active	Reduced, limited primarily to beneath trees	Absent
Leader Growth (Understory Trees)	Good terminal & lateral growth	Good terminal & lateral growth	Reduced terminal & lateral growth; reduced ring growth	Absent, some mortality; reduced ring growth
Shrub Layer	Intact	Nearly intact to some mortality around dominant trees	≥ 40% dead	≥ 85% dead

[3] Crown lift is the mortality of lower tree limbs usually due to shading from neighboring trees.

RESULTS

Juniper Cover and Density in Fully Developed Woodlands

Tree cover and density in fully developed juniper woodlands varied widely across different plant communities (Table 3). Woodland canopy cover of closed stands ranged from 19% in the low sagebrush/Sandberg bluegrass community to a high of 90% in aspen community. Tree density in closed juniper stands also varied widely across communities ranging between 26 and 700 trees/ac in closed stands. As woodland development approached stand closure, maximum density of young trees (less than 10 ft tall) declined (Fig. 1).

Table 3. Mean and range of juniper cover and density (trees > 10 ft tall) in closed stands for six community types. Means followed by different letters were significantly different ($p \leq 0.0001$) for cover or density between community types.

Community Type	% Cover (range)	Trees/Ha (range)
Low sagebrush/Sandberg bluegrass (n=4)	21[a] (19-24)	34[a] (26-45)
Mountain big sagebrush/ Thurber needlegrass (n=6)	34[b] (25-41)	140[b] (90-195)
Mountain big sagebrush/ bluebunch wheatgrass (n=2)[4]	43 (35-47)	140 (105-180)
Mountain big sagebrush/ Idaho fescue (n=15)	48[c] (34-58)	194 (100-290)
Mountain big sagebrush-snowberry/Columbia needlegrass (n=1)[4]	63	360
Quaking aspen (n=3)	84[d] (78-90)	535 (366-700)

Shrub and Aspen Canopy in Response to Juniper

Increasing juniper density had little affect on low sagebrush cover. This may partially be due to the open nature of these stands. However, there was a strong relationship between juniper and mountain big sagebrush canopy cover (Fig. 2). The shrub layer declined by nearly 80% of maximum potential in the mountain big sagebrush/Thurber needlegrass, mountain big sagebrush/Idaho fescue, and mountain big sagebrush-snowberry/Columbia needlegrass communities when juniper canopies reached 50% of maximum woodland cover. The response

[4] Not included in analysis because n<3.

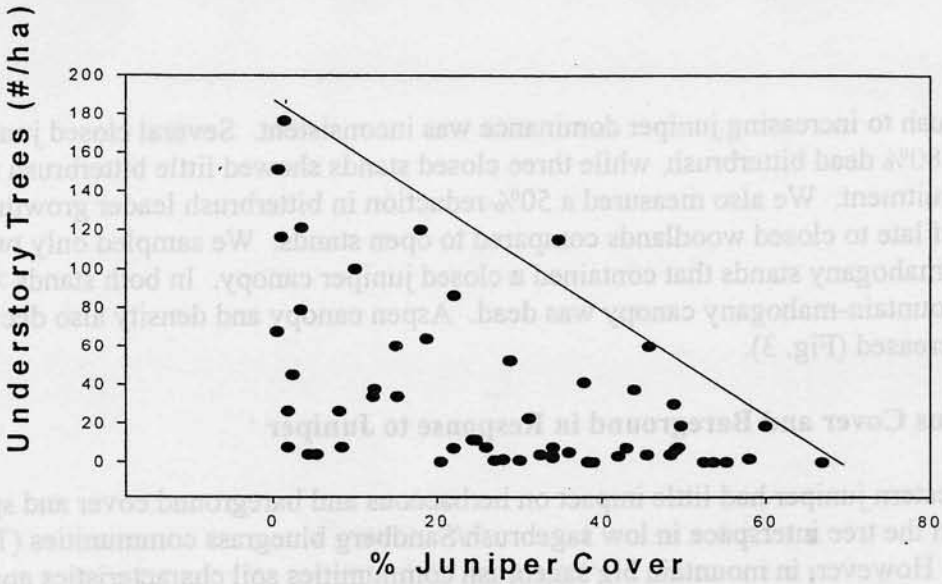

Figure 1. The relationship between understory juniper tree density (trees <3m tall) and mature overstory tree canopy cover for mountain big sagebrush communities. The line represents a boundary layer of maximum juvenile juniper trees occurring with varying juniper overstory canopy cover.

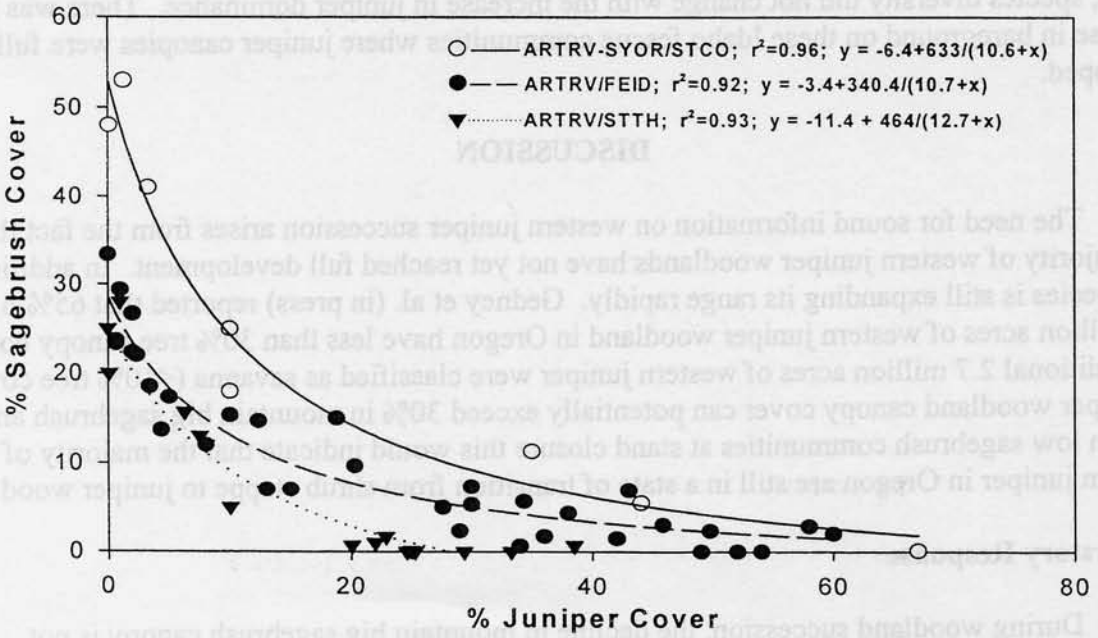

Figure 2. The relationship between juniper and mountain big sagebrush cover for the mountain big sagebrush/Thurber needlegrass (ARTRV/STTH), mountain big sagebrush/ Idaho fescue (ARTRV/FEID), and mountain big sagebrush-snow berry/Columbia needlegrass (ARTRV-SYOR/STCO) communities.

of bitterbrush to increasing juniper dominance was inconsistent. Several closed juniper stands contained 80% dead bitterbrush, while three closed stands showed little bitterbrush mortality and active recruitment. We also measured a 50% reduction in bitterbrush leader growth across the majority of late to closed woodlands compared to open stands. We sampled only two curlleaf mountain-mahogany stands that contained a closed juniper canopy. In both stands > 90% of the curlleaf mountain-mahogany canopy was dead. Aspen canopy and density also declined as juniper increased (Fig. 3).

Herbaceous Cover and Baregound in Response to Juniper

Western juniper had little impact on herbaceous and bareground cover and species diversity in the tree interspace in low sagebrush/Sandberg bluegrass communities (Table 4, 5, & 6; Fig. 4). However, in mountain big sagebrush communities soil characteristics appeared to determine the affects on juniper on understory vegetation. In the drier mountain big sagebrush communities characterized by shallow soils (often underlain by a hardpan between 12 and 24 inches below the surface) juniper significantly increased the amount of bareground (Table 5) as well as decreased plant herbaceous cover (Table 4 & Figure 5) and species diversity (Table 6). The dominant grass on these sites was often Thurber needlegrass. On deeper well drained soils characterized by an understory of Idaho fescue, increasing juniper had little affect on herbaceous cover. However, the affects juniper had on plant diversity varied across stands measured in the mountain big sagebrush/Idaho fescue community. In some stands a decline in species diversity as juniper increased was primarily due to a decline in the abundance of forbs. However, in other stands, species diversity did not change with the increase in juniper dominance. There was no increase in bareground on these Idaho fescue communities where juniper canopies were fully developed.

DISCUSSION

The need for sound information on western juniper succession arises from the fact that the majority of western juniper woodlands have not yet reached full development. In addition, this species is still expanding its range rapidly. Gedney et al. (in press) reported that 65% of the 2.2 million acres of western juniper woodland in Oregon have less than 30% tree canopy cover. An additional 2.7 million acres of western juniper were classified as savanna (<10% tree cover). If juniper woodland canopy cover can potentially exceed 30% in mountain big sagebrush and 20% in low sagebrush communities at stand closure this would indicate that the majority of western juniper in Oregon are still in a state of transition from shrub steppe to juniper woodland.

Understory Response

During woodland succession, the decline in mountain big sagebrush canopy is not proportional to the increase in juniper canopy. As juniper approaches 50% of maximum potential canopy cover in mountain big sagebrush communities, mountain big sagebrush

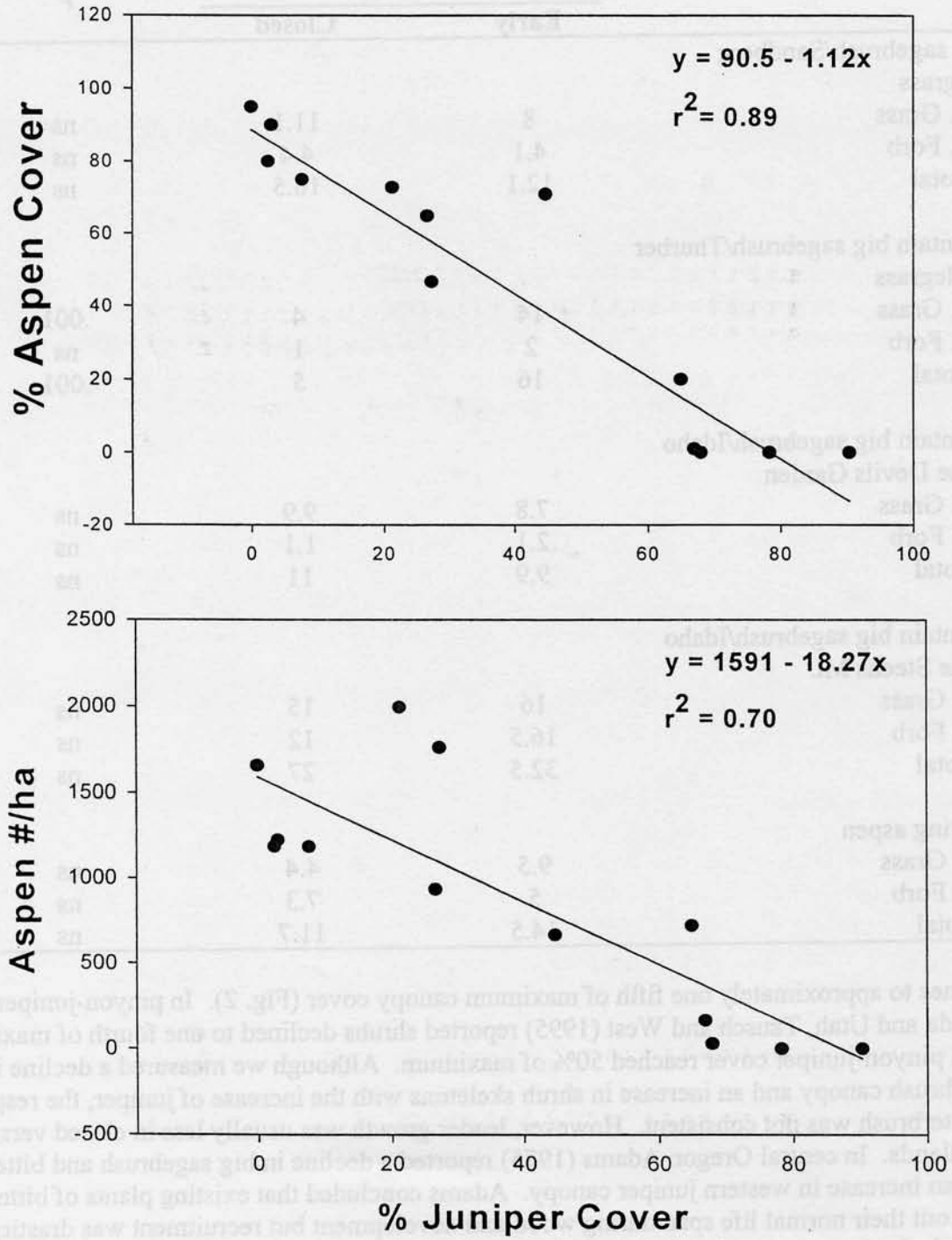

Figure 3. The relationship between juniper canopy cover and aspen canopy cover ($p \leq 0.0001$) and density ($p \leq 0.003$)

Table 4. Perennial grass and forb cover (%) for early and closed stages of woodland development across different plant communities (ns = not significantly different).

Community Type	% Cover		*p*
	Early	Closed	
Low sagebrush/Sandberg bluegrass			
P. Grass	8	11.1	ns
P. Forb	4.1	4.4	ns
Total	12.1	16.5	ns
Mountain big sagebrush/Thurber needlegrass			
P. Grass	14	4	.001
P. Forb	2	1	ns
Total	16	5	.001
Mountain big sagebrush/Idaho fescue Devils Garden			
P. Grass	7.8	9.9	ns
P. Forb	2.1	1.1	ns
Total	9.9	11	ns
Mountain big sagebrush/Idaho fescue Steens Mt.			
P. Grass	16	15	ns
P. Forb	16.5	12	ns
Total	32.5	27	ns
Quaking aspen			
P. Grass	9.5	4.4	ns
P. Forb	5	7.3	ns
Total	14.5	11.7	ns

declines to approximately one fifth of maximum canopy cover (Fig. 2). In pinyon-juniper in Nevada and Utah, Tausch and West (1995) reported shrubs declined to one fourth of maximum when pinyon-juniper cover reached 50% of maximum. Although we measured a decline in bitterbrush canopy and an increase in shrub skeletons with the increase of juniper, the response of bitterbrush was not consistent. However, leader growth was usually less in closed versus open woodlands. In central Oregon Adams (1975) reported a decline in big sagebrush and bitterbrush with an increase in western juniper canopy. Adams concluded that existing plants of bitterbrush lived out their normal life span during woodland development but recruitment was drastically limited. Juniper also readily invaded aspen stands. Both aspen density and cover declined as juniper canopy cover increased. In the absence of fire, juniper will likely continue to invade and replace aspen stands. Grazing by both domestic and wild large herbivores is also a major factor influencing aspen recruitment.

Table 5. Percent bareground in the tree interspace for five community types.

Community Type	% Cover				
	Open	n	Closed	n	Prob
Low sagebrush/Sandberg bluegrass	56	5	54	4	ns
Mountain big sagebrush/ Thurber needlegrass	55	5	90	7	.001
Mountain big sagebrush/ Idaho fescue (Devils Garden)	34	6	32.4	9	ns
Mountain big sagebrush/ Idaho fescue (Steens)	16	9	18	6	ns
Quaking aspen	5	8	3.8	3	ns

Table 6. Mean plant diversity indices within community types for early and closed juniper woodlands. Hills diversity numbers: N0 = species number; N1 = Shannon's index, the number of abundant species; N2 = Simpson's index, the number of very abundant species. Neither mountain big sagebrush nor juniper cover were included in diversity indices.

Community Type	N0	N1	N2
Low sagebrush/Sandberg bluegrass			
open (n=5)	35	8.4	5.9
closed (n=4)	37	9.5	6.4
Mountain big sagebrush/ Thurber needlegrass			
open (n=5)	45	10.6	7.2
closed (n=6)	39	2.5	1.6
Idaho fescue (Devils Garden)			
open (n=6)	33	9.2	6.3
closed (n=9)	38	4.0	2.4
Idaho fescue (Steens Mt)			
open (n=9)	43	10.7	6.2
closed (n=6)	41	10.3	6.6
Quaking aspen			
open (9)	35	8.8	5.7
closed (4)	35	8.9	5.7

The response of herbaceous species to increasing juniper dominance did not always fit the common belief that as western juniper increases the herb layer declines. Across southeastern Oregon and northeastern California the response of herbaceous plant cover in mountain big sagebrush/Thurber needlegrass communities consistently declined as western juniper increased. The majority of these soils had a restrictive layer between 12 and 20 in. deep. We observed a very high density of juniper roots in the soil layer above the hardpan in our soil pits. In this same community, Bates et al. (1999) reported a 3 fold increase in herbaceous cover during the second

growing season following western juniper removal. However, in the mountain big sagebrush/Idaho fescue community there was no significant difference in herbaceous cover between early and closed woodlands. These sites occupied deeper soils underlain by fractured bedrock. In the soil pits we observed a lower concentration of juniper roots in the upper 20 inches.

The amount of bareground in the tree interspace was greater in closed stands compared to earlier stages of development only in the mountain big sagebrush/Thurber needlegrass community. Although juniper cover averaged 34% in closed stands, little plant or litter cover protected the interspace, which accounted for 66% of the total area. We observed considerably more surface soil movement on this community than any other community.

However, the relationship of juniper cover and understory changes under poor grazing practices, where perennial herbaceous cover will significantly decline in juniper woodlands. We have observed significant increases in bareground across all juniper woodlands where past grazing practices have been abusive.

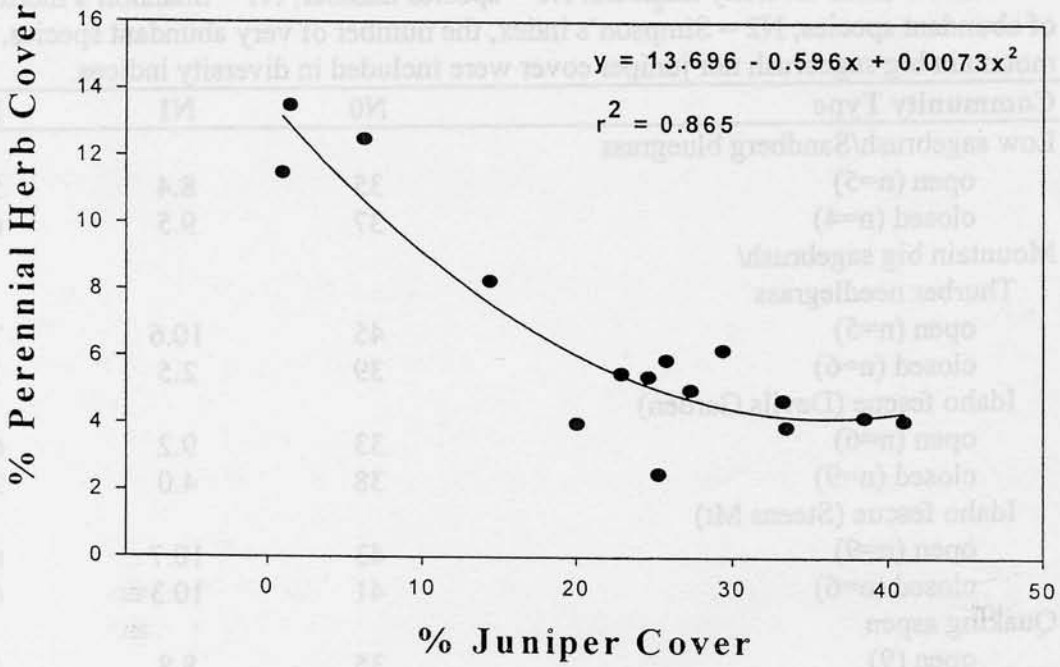

Figure 4. The relationship between perennial herb and juniper cover in the mountain big sagebrush Thurber needlegrass community.

Floristics and Diversity

We encountered 335 vascular plant species across the 105 stands we measured. The contribution of perennial forbs was highly variable among and within communities. Mean forb cover ranged between 1 and 16.5% among communities. On Steens Mountain, forbs accounted for a significant portion of the understory vegetation, while contributing ≤2% of the ground cover in northern California.

MANAGEMENT IMPLICATIONS

The identification of woodland successional stage and site variability in western juniper woodlands is extremely important when evaluating potential resource problems, assessing wildlife habitat values, and developing management plans. As shrub steppe communities are converted to juniper woodlands, community structure, composition, function, processes, and wildlife habitat suitability are altered. The conceptual model presented in Figure 5 (derived from Archer 1989) illustrates the conversion of a mountain big sagebrush steppe community to juniper woodlands in the absence of fire. During the early phases of woodland development, transition is easily reversible with fire. Juniper establishment during the early seral stages of shrub steppe is limited by a low density of shrubs. By the mid- to late stages of transition, a threshold is crossed when the natural reversal to shrub steppe communities by fire is unlikely. As shrubs decline the probability of a fire event intense enough to kill large juniper trees rapidly decreases. Juniper establishment declines with woodland maturity because of a decrease in safe seedling establishment sites provided by the shrubs. On-site seed input also declines because of the loss of the fruit crop through increasing tree competition. As juniper woodlands close and mast crops (Miller and Rose 1995) and shrubs are lost, fauna dependent on berries or shrubs also decline.

As community structure changes during woodland development, management options, wildlife habitat suitability, and important ecological variables such as hydrologic, nutrient, and energy cycles also change. Crossing ecological thresholds not only results in a significant reduction in the role of fire, but depending on the site may result in the loss of native plant species and loss of soils. Proper identification of the community and soils will indicate the effects of stand closure on a given site. The state of woodland transition can be identified by structural characteristics described in Table 1. Tree canopy cover and density alone are only of value if the range within a community has been defined. To improve interpretation, the spatial and temporal heterogeneity of a site or landscape in question must be identified when conducting inventories, designing research, or in developing management plans and classification schemes.

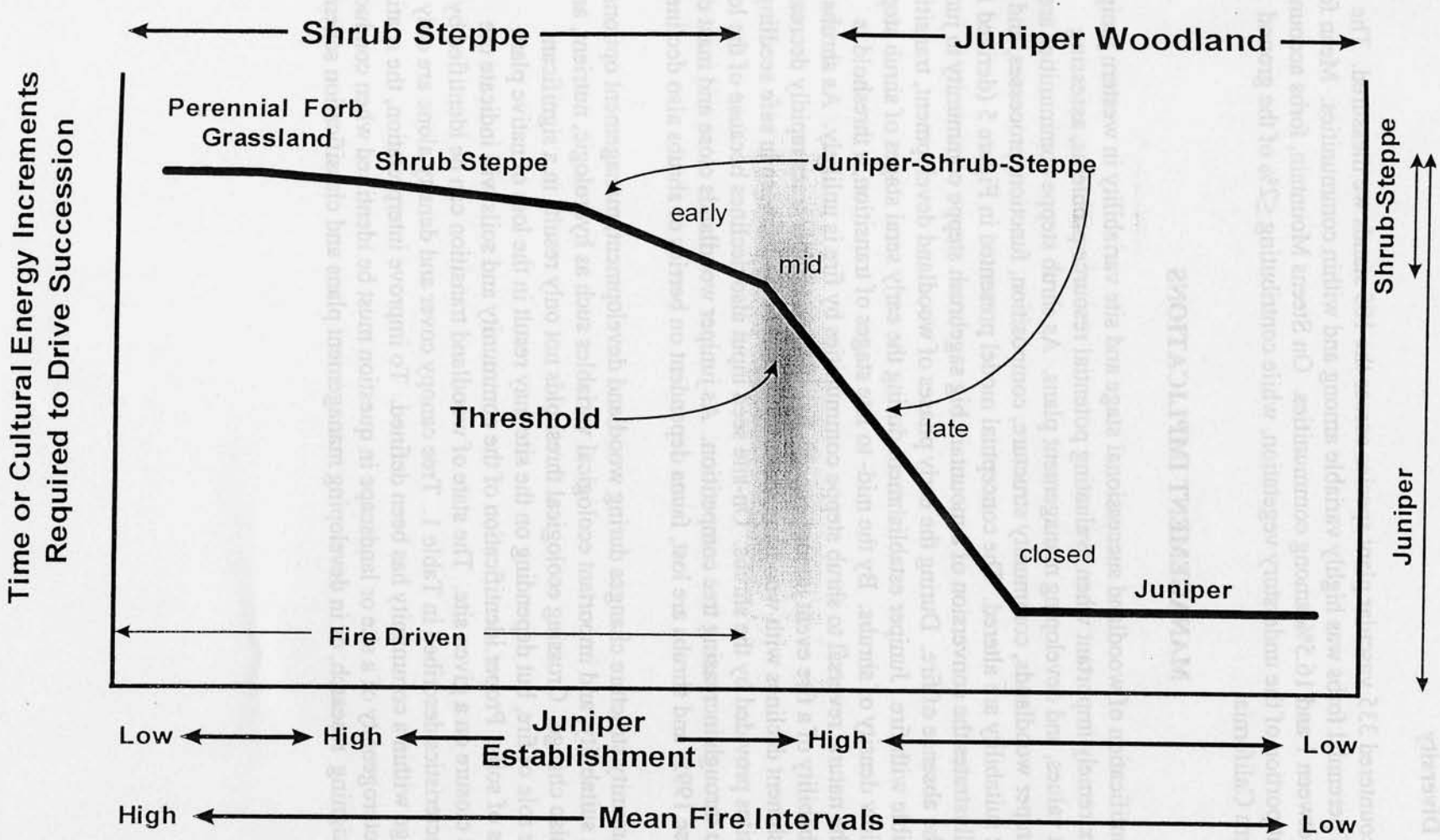

Figure 5. Conceptual diagram of changes in a shrub steppe community in the absence of fire (modeled after Archer 1989). In the absence of fire the abundance of shrubs decline as juniper trees gain dominance. A threshold has been crossed when understory fuels drop to a level where fire is unlikely to carry through the stand or generate enough heat to kill trees > 3m tall. The probability of the woodland crossing the threshold and reverting back to shrub steppe is very low in the absence of a major disturbance or very costly inputs. Tree establishment declines due to a decrease in seed input and safe sites provided by shrubs.

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